REMEDIATION & ENABLING WORKS STRATEGY

Former Stagecoach Bus Depot
Land off Bowes Street
Manchester

Prepared for:

Rowlinson Construction

E3P Report: 11-813-r1-RevA

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EXECUTIVE SUMMARY	
Site Address	Former Stagecoach Depot, Bowes Street, Manchester, M14 7JQ
National Grid Reference	E383996, N395006
Site Area	~2.2Ha
Background	E3P has been instructed by Rowlinson Construction to develop a Remediation and Enabling Works Strategy for the proposed residential development at a parcel of derelict land off Bowes Street in Manchester. The E3P Remediation & Enabling works strategy has been produced in due consideration of the Geo-Environmental Site Investigation and Contaminated Land Assessments previously undertaken by Capita. It has been noted that there are other various stages of investigation reports (primarily by Curtins Consulting) completed during the site's construction as a Stagecoach depot. The reports haven't been provided however their findings have been summarised within the Capita reports and will therefore also be a consideration as part of the development of this Remediation Strategy. Furthermore, a phase of remediation was undertaken on the site by GB-Building Solutions, validated by Beech Remediation in 2012 (prior to the Capita investigations) with details included within the aforementioned Validation Report, albeit subsequent investigations confirmed remediation was not wholly successful and a secondary phase will be required.
Contaminated Land Assessment	
Human Health Risk Assessment	The Tier I Human Health risk assessment identified the presence of elevated concentrations inorganic heavy metals, PAH compounds and hydrocarbons within shallow Made Ground deposits. The shallow made ground is therefore not suitable for use within proposed 'soft' areas where a direct exposure pathway exists. In the case of Heavy Metals, non-volatile PAH and TPH compounds the viable exposure pathway is associated direct contact, inhalation of particulates, consumption of home grown vegetables and ingestion of soil. The proposed development of the site will include hard cover and the importation of certified sub-soil and topsoil soil in areas of private gardens and landscaping, thus removing this pathway. With regards to the elevated naphthalene and volatile TPHs, these compounds present potential volatilisation to indoor air risk. Following the review of the existing information and E3P assessment the remediation issues, potentially volatile hydrocarbon contamination has been confirmed to be widespread in the shallow Made Ground strata associated with petroleum and diesel range impact which has spread by a plume across the eastern sector. Considering the widespread nature of the elevated TPHs and naphthalene across the eastern and southern sectors, delineation and hotspot validation works will not be possible for much of the impact. One remediation option would be to undertake a reduced level dig of the impacted Made Ground with subsequent excavation and ex-situ treatment, however this is unlikely to be viable given the scale of the 'smear zone' contaminant impact. It is therefore intended for the Made Ground soils to be retained on the site with the identified risk to the proposed dwellings to be mitigated by the installation of hydrocarbon resistant membranes to mitigate the potential for any vapour volatilisation to indoor air.

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	Within the locality of TP214 in the northern sector of the site, hydrocarbon impact has been identified to significant depth migrating to substratum and thus in direct contact with the bedrock geology. Considering the migration and depth, it is likely this hydrocarbon impact is due to the position of underground storage tanks in the area (now removed) which have leaked in the past, allowing petroleum and diesel to enter the soils. As this hydrocarbon impact is present at depth and at significantly greater concentrations than in other areas of the site, this localised area will require delineation, excavation and chemical validation to remove the impacted hydrocarbon soils in their entirety. Investigation has confirmed that overlying soils may be retained for use within the development (pending chemical validation) however it is likely that the hydrocarbon impacted soils will require disposal off-site due to the concentrations recorded. Chemical analysis of the natural clay drift deposits has identified that the majority of the natural soils on the site are chemically suitable however there are locations where the natural soils are elevated in hydrocarbons (albeit this will be removed during a hotspot validation). If site natural soils are intended to be utilised for the subsoil element of the cover system, supplementary validation analysis is required in order to confirm chemical suitability and ensure concentrations hydrocarbons within these soils are not elevated when considering protection to human health in a residential setting. There is no suitable topsoil source on site, therefore all topsoil deposits for the garden areas will require importation of chemically validated material.
Controlled Waters Risk Assessment	The primary area of hydrocarbon impact within soils and groundwater identified as being in the vicinity of TP214 where hydrocarbon impact is confirmed to depth (~4.00m bgl) and in direct contact with the bedrock. This area is considered to pose a potentially significant risk to the underlying aquifer in its current situation, therefore a phase of remediation by delineation, excavation and validation will be required to remove all impacted soils prior to their treatment and disposal. These works will ensure the complete removal of any soils that represent a significant and unacceptable degree of risk to the underlying aquifer. Following a review of the Capita reports, as an evolving Remediation Strategy, E3P considered it prudent to undertake a detailed controlled waters risk assessment utilising the EA RTM methodology to generate site specific screening criteria to use within the remediation of this localised area to ensure there is no unacceptable risk to the controlled water receptors from the remaining soils across the wider area. This will be considered as Source Area 1. Following review of the information, E3P considered that further assessment was required if soils where hydrocarbon compounds capable of entering the dissolved phase (at any concentration) are to be retained in-situ. The shallow Made Ground soils that occupy the southern and eastern sectors of the site are impacted by hydrocarbon compounds and naphthalene. Whilst investigation has identified no evidence of vertical migration of these contaminants towards the underlying aquifer, no quantitative assessment of future migration potential is made within the Capita Report. Whilst E3P would consider the soils to be suitable for retention in their current location where they will pose no unacceptable risk to human health (subject to the installation of a cover system and hydrocarbon membranes within all proposed dwellings), it was considered essential to undertake a Tier 2 controlled waters risk assessment to confirm the existing soils will present no undue risk to the underlying Principal Aquifer and generate further SSRTs which may be utilised should any localised hotspot remediation be required. This will be considered as Source Area 2.

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Tier 2 Controlled Waters Assessment	A Tier 2 controlled waters assessment has been undertaken to generate SSRTs for the remediation of Source Area 1 and confirm the absence of significant risk of associated with residual soluble phase hydrocarbon impact within shallow Made Ground soils to be retained in situ in the eastern sector of the site. Validation leachate analysis will need to be undertaken of these Made Ground soils to confirm they will present no significant risk of migration to the underlying aquifer, compared to the SSRTs generated for Source Area 2.
Ground Gas	The ground gas assessment as completed by Capita has identified the site to be classed as Characteristic Situation 2 / Amber 1 therefore proposed plots will require low level gas protection measures to be installed within proposed plots. Due to the presence of hydrocarbon vapours within the Made Ground, all plots will also require the installation of a hydrocarbon resistant membrane.
Coal Mining & Historical Workings	The site is not considered to be at risk from mining or quarrying related issues.
Invasive Plants	Invasive species have not been identified on site during works carried out by Capita.
Geotechnical Considerations	The remediation and enabling works will be delivered in a manner that will seek to ensure: - *Extensive relict sub-structures, infrastructure and materials deemed geotechnically deleterious are identified;* - *Protection of the sub-grade to minimise disturbance and promote sustainable infrastructure construction;* - *Where shallow stratum suitable of supporting a shallow spread foundation, care should be taken to protect to minimise the disturbance to natural drift deposits;* - *Where deep Made Ground is present (>1.50m) the stratum should be prepared in a manner that will facilitate re-engineering using a pre-cast concrete pile;* - *Engineer all up-filled materials beneath highways to sub-grade in accordance with the requirements of this specification to ensure a CBR >5% in the sub-grade.* Continued….

EXECUTIVE SUMMARY	
Summary of Site Remediation & Enabling Works	The site Remediation / Enabling Works Strategy provides a comprehensive specification for the regeneration of the land to negate identified pollutant linkages and construct a development platform that will be geotechnically suitable for the proposed end use. The salient features of the Remediation & Enabling Works Strategy are summarised below: • Implement all works in strict accordance with UK Environmental Permitting and Local Planning Authority Requirements. • Controlled removal of all trees and vegetation; • Removal and treatment of all invasive plant species (as required) in accordance with specialist contractor method statement, validation and independent certification; • Delineation and removal of hydrocarbon impacted soil in vicinity of TP214, validation testing of material that remains and removal of all unsuitable soils; • Validation leachate analysis to be undertaken of Made Ground soils in eastern sector with hotspot delineation and excavation where and if necessary; • Removal of all structures, relict foundations and buried features in their entirety; • Removal of all materials considered geotechnically deleterious; • Excavation and processing of Made Ground in a controlled manner with the sorting, processing and segregation of identified deleterious materials to geotechnical specification; • Validation sampling and leachate testing to confirm material retained on-site pose no unacceptable risk to the residential end users, controlled waters or wider environ; • Importation of suitable material (if required) to achieve the required development levels; and, • Replacement of material in accordance with the E3P enabling specification & engineering requirements.
Summary of Build Phase Mitigation Requirements	The developer's works will also include the completion of the following additional elements: • Provision of a 600mm cover system using certified material with appropriate validation within proposed garden areas, comprising 450mm subsoil (potentially site won natural drift deposits) overlain by 150mm topsoil; and, • Provision of a 300mm cover system using certified material with appropriate validation within proposed areas of Public Open Space and soft landscaping. • Installation of hydrocarbon resistant membranes within proposed plots. • Construction of specific dwellings with appropriate gas mitigation to be compliant with CS2 / Amber 1 for elevated CO2 in isolated area; and, • Construction of appropriate potable water supply infrastructure.

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Appendix I Limitations
Appendix II Glossary
Appendix III Drawings

Drawing No 11-813-001 – Site Location Plan
Drawing No 11-813-002 – Proposed Development Layout
Drawing No 11-813-003 – Historical Features Plan
Drawing No 11-813-004 – Exploratory Hole Location Plan
Drawing No 11-813-005 – Remediation Issues Plan
Drawing No 11-813-006 – Controlled Waters Risk Assessment Plan

Appendix IV E3P Remediation / Validation Criteria
Appendix V E3P Material Import Criteria
Appendix VI EA RTM Sheets
Appendix VII Contractor Completion Document

1. INTRODUCTION

1.1 Background

E3P has been instructed by Rowlinson Construction to develop the Remediation and Enabling Works Strategy for the proposed residential development at a parcel of derelict land off Bowes Street in Manchester.

The site has been previously subject to various phases of intrusive investigation and assessment by Capita, of which E3P has been provided with and are forming the basis of the Remediation Strategy proposals.

1.2 Report Objectives

The objectives of this report are to:

- Prepare overview of Contaminated Land Remediation requirements;
- Evaluate feasible remedial technologies;
- Generate site specific screening values using the EA RTM sheets;
- Assess the most appropriate earthworks solution to ensure the delivery of the optimum development platform;
- Define validation criteria to demonstrate the successful implementation of a site Remediation & Enabling works plan;
- Specify Geotechnical Engineering Performance Requirements; and,
- Ensure the safe, cost effective and regulatory compliant redevelopment of the site.

1.3 Scope of Works

The development of the risk management strategy for the subject site includes the following tasks:

- Identification the relevant pollutant linkages;
- Review of site characteristics;
- Identification of geotechnical constraints;
- Completion of a DQRA utilising the EA P20 RTM model;
- Development of remedial objectives;
- Selection of appropriate remedial technology; and,
- Development of remedial strategy.

1.4 Previous Works

The following phases of Geo-Environmental investigations have previously been carried out at the site:

Beech Group – *Validation Works, Northern Area.* Report Reference: BC/1702/691/R14, dated July 2012.

Capita – *Phase 1 Geo-Environmental Desk Study, Bowes Street, Manchester.* Report Reference: CS/088198-P1DS, dated August 2016.

Capita – *Phase 2 Ground Investigation & Assessment, Bowes Street, Manchester.* Report Reference: CS/088198-GIA, dated March 2017.

Capita – *Remediation Strategy, Bowes Street, Manchester.* Report Reference: CS/088198-RS, dated March 2017.

It has been noted that there are other various stages of investigation reports (primarily by Curtins Consulting) completed during the site's construction as a Stagecoach depot. The reports haven't been provided however their findings have been summarised within the Capita reports and will therefore also be a consideration as part of the development of this Remediation Strategy.

Furthermore, a phase of partial remediation was undertaken on the site by GB-Building Solutions, validated by Beech Remediation in 2012 (prior to the Capita investigations) with details included within the aforementioned Validation Report, but was only intended to remove slabs, foundations and below ground storage tanks. Subsequent investigation in these localities identified that below ground storage tanks may have leaked historically and a degree of soil remediation will be required.

To inform the assessment of the potential risk to contaminated land within the context of the proposed residential development and to inform the preparation of the Remediation Strategy the pertinent points from the above reports are summarised within Section 2.0.

For the avoidance of any doubt, the E3P Geo-Environmental Site Investigation Report should be read both as a precursor and in conjunction with this document.

1.5 Redevelopment Plan

Rowlinson Construction propose to redevelop the site for low rise residential end use comprising a series of dwellings with gardens, access roads, driveways and adopted drainage infrastructure.

The proposed development layout is included as Drawing 11-813-002 (Appendix III) and a snapshot is indicated in Figure 1.1 below:

Figure 1.1 Proposed Development

1.6 Summary of Parties Involved

FUNCTION / INTEREST	NAME OF PARTY
Local Planning Authority	Manchester City Council
Developer	Rowlinson Construction
Geo-Environmental Consultant	E3P
Main Contractor	Rowlinson Construction
Remediation / Enabling Works Contractor	TBC
Human Health Regulator	Manchester City Council
Controlled Waters & Waste Regulator	Environment Agency

1.7 Regulatory Correspondence

Rowlinson Construction are in the process of submitting an application to discharge conditions on their approved detailed Planning Application to the Local Planning Authority for the proposed redevelopment of the site for low rise residential housing with associated adopted estate roads and infrastructure.

It is presumed that as part of the planning approval process, the Planning Authority will undertake consultation with the pertinent statutory consultees which will include:

- Environmental Health / Contaminated Land Officer at the Local Authority (or external advisor); and,
- Environment Agency Planning Liaison.

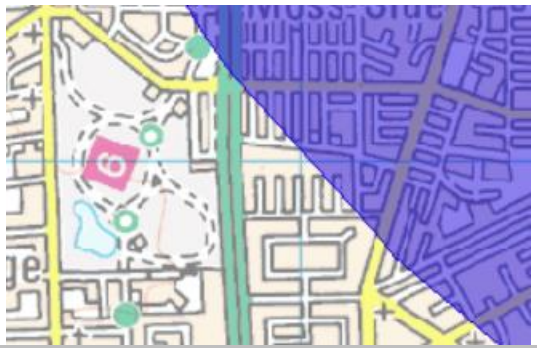
1.8 Site Details

Site Address	Former Stagecoach Depot, Bowes Street, Manchester, M14 7JQ
National Grid Reference	E383996, N395006
Site Area	~2.2Ha

All acronyms used within this report are defined in the Glossary presented in Appendix II.

A site location map is presented in Appendix III as Drawing 11-813-001.

1.9 Site Summary

SITE DESCRIPTION & SETTING		
Occupancy/use	The site is currently derelict apart from a substation on the northern boundary with Bowes Street roughly opposite Caythorpe Street. The site has been in its current condition since demolition of the former bus station and primary school in November 2011 and subsequent ground remediation works during 2012. The perimeter of the site is defined by mesh fencing. Gated vehicular and pedestrian access onto the site can be gained from the western end of Bowes Street.	
Environmental Setting	*Drift Geology*	Glacial Till - Clay with granular Sand & Gravels.
	Bedrock Geology	Chester Pebble Beds Formation - Sandstone.
	Hydrogeology	Secondary (undifferentiated) Aquifer (Drift) over Principal Aquifer (Bedrock). One groundwater abstraction located within 1km of the site at 845m north at the Brewery in Moss Side. The eastern portion of the site lies within a Groundwater Source Protection Zone 3 (Total Catchment) as indicated below. 
	Hydrology	The closest surface watercourse is Platt Brook located circa 1km to the south east and is not considered to be in hydraulic continuity with the site. A surface water culvert is also located to the north west of the site running under Princess Road.
	Flood Risk	The site is not located within a fluvial flood risk zone.
	Subsidence Hazard	No hazard identified in data searches.
Site History	The site was unoccupied land in the earliest mapping of 1849 with a small pond on the northern boundary of the site, infilled by 1892. By 1916 the site is labelled as Princess Road Car Shed with tramlines entering the site then by 1933 the site is labelled as a bus depot which occupies the entire site. The electricity substation was constructed by 1950 along the northern boundary. The site has been cleared in recent years.	
Landfill Sites & Ground Gases	No landfill sites have been identified within 250m.	
Coal Mining	The site is not located within an area affected by shallow coal mining therefore no further assessment is required.	
Radon	Unaffected – no special precautions required.	

1.10 Summary of Reported Ground Conditions

E3P has reviewed the previous Capita reports and a summary of the reported ground conditions is summarised below:

SUMMARY OF GROUND CONDITIONS	
Made Ground	Made Ground comprised both granular and cohesive material and was encountered in all of the exploratory holes. The Made Ground was variable comprising silty SAND, silty gravelly SAND, clayey sandy GRAVEL, silty sandy GRAVEL, sandy gravelly COBBLES, slightly sandy slightly gravelly CLAY, sandy slightly gravelly CLAY and slightly sandy gravelly CLAY. Gravel typically comprised fragments of brick, metal, concrete, Victorian concrete, sandstone, mudstone, siltstone, coal, clinker, slag, coal, plastic, timber, glass, ceramic and slate. Frequent cobbles were recorded across the subject site, and generally consisted of brick, concrete, Victorian concrete and sandstone.
Topsoil	No topsoil that would be deemed suitable for re-use has been identified within any of the exploratory hole locations.
Drift	Glacial Till deposits were encountered in a number of exploratory holes which bottomed out the Made Ground at depths of between 0.40m and 2.20mbgl. Glacial Till deposits comprised both cohesive and granular strata. Cohesive Till deposits comprised firm to very stiff brown mottled grey slightly sandy slightly gravelly CLAY, firm silty CLAY and stiff sandy slightly gravelly CLAY. Granular strata was encountered within a single locality and comprised silty SAND & GRAVEL. Cobbles were noted at various locations around the subject site, within cohesive Glacial Till deposits.
Bedrock	Bedrock of Chester Pebble Beds Formation was encountered within all exploratory boreholes and a number of trial pit locations primarily to the west of the subject site. The stratum appears to lie at greater depths to the east of the site. Bedrock was found to underlie Made Ground and Glacial Till deposits at depths of between 1.60m and 6.45mbgl. The strata comprised very weak to medium strength weathered reddish brown Sandstone. The uppermost weathered deposits were recovered as reddish brown silty fine to coarse SAND.
Visual & Olfactory Evidence of Contamination	A significant amount of palpable visual and olfactory evidence of hydrocarbon contamination was noted across the subject site, and was recorded by the Capita engineer as diesel, phenol and hydrocarbon odours. The impact was primarily located along the north western boundary along Bowes Street, Princess Parkway to the west of the site and to the southeast of the site in close proximity to Laurel Avenue. The impact was noted within granular and cohesive Made Ground deposits, Granular Glacial Till and within the underlying bedrock of the Chester Pebble Beds.
Groundwater	Groundwater entries were recorded during exploratory hole formation at depths of between 0.35-3.00mbgl. The majority of the groundwater seepages/strikes were recorded within Made Ground and are not thought to be representative of the true groundwater level, but are perched waters within Made Ground deposits, predominantly sitting atop impermeable cohesive Glacial Till deposits. During subsequent monitoring, rest water levels were recorded in the standpipes at depths of between 0.62 and 2.45mbgl. The rest groundwater levels in BH301 and BH302 between 3.62-4.66mbgl are considered to be representative of the true groundwater within the bedrock aquifer beneath the site.

2. CONTAMINATION RISK ASSESSMENT

2.1 Background

E3P has undertaken a review of the available investigation reports to determine the overall risk to human health, controlled waters and the wider environ. The assessments are documented in full within the individual Capita reports however for clarity the details are summarised below.

E3P has been provided with information within the Beech Consultants Ltd Validation Report (Ref: BC/1702/691/R14) dated July 2012, to suggest the site has been previously remediated (albeit the report only includes details of the remediation of the northern sector). Information can be taken from this report as to the decommission and removal of below ground storage tanks however further investigation undertaken by Capita would suggest that the associated soils have not undergone a sufficient degree of remediation to render the site suitable for residential development.

The site may be considered to be free of obstructions however following the phase of remediation and enabling works and it is likely that all below ground structures and tanks have been removed and it is only soils that remain that will require remediation.

2.2 Human Health Risk Summary

The Capita intrusive investigation along with their most recent delineation investigations and Tier 1 assessment identified concentrations of the following determinants at or above the screening criteria for the assessment of no unacceptable degree of risk to human health.

- Arsenic
- Lead
- Copper
- TPH Aliphatic C8-C10
- TPH Aromatic C8-C10, C12-C16, C16-C21 & C21-C35
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Chrysene
- Naphthalene
- Indeno(123-cd)pyrene
- Dibenz(ah)anthracene
- Benzene
- Ethylbenzene
- Xylenes

Analysis of asbestos within 27 No. samples resulted in no positive results.

Furthermore, PCB analysis (PCB EC7 and PCB WHO12 congeners) in the vicinity of the substation did not identify the presence of any PCBs above the limit of detection.

In the case of Heavy Metals, non-volatile PAH and TPH compounds the viable exposure pathway is associated direct contact, inhalation of particulates, consumption of home grown vegetables and ingestion of soil. The proposed development of the site will include hard cover and the importation of certified sub-soil and topsoil soil in areas of private gardens and landscaping, thus removing this pathway.

The specific design and installation process for the appropriate cover systems will be clearly defined within the Site remediation & Enabling Works Strategy, however industry best practice (as outlined within BRE 465) will require the following minimum depths of certified clean cover:

- Private Gardens where home-grown vegetables can be cultivated – **600mm**
- Landscaped areas within private dwellings – **300mm**
- Public Open Space – **300mm**

With regards to the elevated naphthalene and volatile TPHs, these present potential volatilisation to indoor air risk. Following the review of the information and production of the remediation issues drawing (Ref: 11-813-005, Appendix III), the identified hydrocarbon contamination has been identified to be widespread in the shallow Made Ground strata, particularly in the south east sector. Considering the widespread nature of the elevated TPHs and naphthalene across the eastern and southern sectors, delineation and hotspot validation works will not be possible.

One option would be to undertake a reduced level dig of the impacted Made Ground however this is unlikely to be viable, therefore it would be intended for the Made Ground soils to be retained on the site and for proposed dwellings to be installed with a hydrocarbon resistant membrane to mitigate the potential for any vapour volatilisation to indoor air.

That being said, in the locality of TP214 in the northern sector of the site, hydrocarbon impact has been identified to significant depth where it is coming into contact with the bedrock geology. Considering the depth, it is likely this hydrocarbon impact is due to the position of underground storage tanks in the area (now removed) which may have leaked in the past, entering the soils. As this hydrocarbon impact is present at depth and is present at a greater concentration than in other areas of the site, this localised area will require delineation, excavation and chemical validation to remove the impacted hydrocarbon soils in their entirety. Investigation has confirmed that overlying soils may be retained for use within the development (pending chemical validation) however it is likely that the hydrocarbon impacted soils will require disposal off-site due to the concentrations recorded.

Chemical analysis of the natural clay drift deposits has identified that the majority of the natural soils on the site are chemically suitable however there are locations where the natural soils are elevated in hydrocarbons (however this will be removed during a hotspot validation). If site natural soils are intended to be utilised for the subsoil element of the cover system, supplementary validation analysis is required in order to confirm chemical suitability and ensure concentrations hydrocarbons within these soils are not elevated when considering protection to human health in a residential setting.

There is no suitable topsoil source on site, therefore all topsoil deposits for the garden areas will require importation.

2.3 Controlled Waters Contamination Risk Summary

The site sensitivity with respect to controlled waters is summarised within Table 2.1

Table 2.1 Summary of Controlled Water Sensitivity

Risk Profile	Discussion	Sensitivity Rating & Rationale
Groundwater Source Protection Zone or Drinking Water Safeguard Zone	Yes	**High –** Groundwater SPZ 3 across eastern sector of the site.
Distance to the closest groundwater abstraction point.	845m	**Moderate -** One groundwater abstraction located within 1km of the site at 845m north at the Brewery in Moss Side.
Aquifer Classification in Superficial Drift Deposits.	Secondary (undifferentiated)	**Low** – The site is underlain by low permeability sandy gravelly clays to depths in excess of circa 4.00m which may reduce the potential for mobile phase contaminants to migrate towards a viable receptor.
Aquifer classification in Bedrock.	Principal	**High –** The underlying bedrock is classified as a principal aquifer.
Viability for Anthropogenic soil in direct contact with aquifer (drift or bedrock).	Yes	**Low –** Variable Made Ground with heavy metal, PAH and hydrocarbon impact is present in the near surface with areas of deeper contamination.
Is the site underlain by low permeability Drift to depths in excess of 10.0m?	No	**No –** Bedrock was found to underlie Made Ground and Glacial Till deposits at depths of between 1.60m and 6.45mbgl.
Is the site located within 50m of a surface watercourse?	No	**No –** The risk to a surface water is negligible given the absence of a viable receptor within influencing distance of the site. The closest surface watercourse is Platt Brook located circa 1km to the south east.
Summary The ICSM developed within the context of the site setting has identified the most sensitive receptor to be the underlying Principal Aquifer with the potential for mobile contamination to migrate towards the aquifer. In order to assess the potential risks to controlled water, E3P has assessed a viable pollutant risk associated with the downward migration of potentially mobile phase soluble contaminants towards the underlying Principal Aquifer.		

In due consideration of the identified pollutant linkage, a Tier 1 controlled water risk assessment has been completed by Capita as part of their investigation, the findings which are summarised below.

Groundwater samples obtained from boreholes identified the presence of heavy metals and PAHs which were identified to no present an unacceptable risk to controlled waters due to the low level concentrations. However, hydrocarbon compounds were identified within several boreholes, associated with the hydrocarbon contamination within the shallow Made Ground.

The main area of hydrocarbon impact within soils and groundwater has been identified as being in the vicinity of TP214 where hydrocarbon impact has been noted to be present to depth (4.00m bgl) and coming into contact with the bedrock. This area is considered to pose

a significant risk to the underlying aquifer as currently present and as discussed in Section 2.1, a phase of delineation, excavation and validation will be required to remove all impacted soils and dispose off-site, to ensure the complete removal of any soils that may impact the underlying aquifer. This area has been identified on Drawing 11-813-006, Appendix III.

Although not discussed within the Capita reports, E3P would consider it prudent to undertake a detailed controlled waters risk assessment utilising the EA RTM sheets to generate site specific screening criteria to use within the remediation of this localised area to ensure there is no unacceptable risk to the controlled water receptors from the remaining soils. This will be considered as Source Area 1.

Capita following their controlled waters risk assessment (with the exception of the locality of TP214 discussed above) identified the site to present no unacceptable risk to controlled waters, however following review of the information, E3P would consider that further assessment is required if soils are to be retained on site. The shallow Made Ground soils that occupy the southern and eastern sectors of the site are impacted by hydrocarbon compounds and naphthalene. Whilst investigation has identified no evidence of vertical migration of these contaminants towards the underlying aquifer, no real consideration to this potential has been made. Whilst E3P would consider the soils to be suitable for retention in their current location where they will pose no unacceptable risk to human health (subject to the installation of a cover system and hydrocarbon membranes within all proposed dwellings), it will be essential to undertake a Tier 2 controlled waters risk assessment to confirm the existing soils will present no undue risk to the underlying Principal Aquifer and generate further SSRTs which may be utilised should any localised hotspot remediation be required. This will be considered as Source Area 2.

Based on the above, it will be necessary to develop Site Specific Remediation Targets (SSRT's) utilising the EA Remedial Targets Methodology (RTM P20) to determine the permissible concentrations of hydrocarbons in the soil and groundwater that would ensure an adequate degree of protection to the underlying aquifer, modelled for both individual source areas.

With the above in mind, it is considered that following a phase of remediation and enabling works, there will be no unacceptable risk to the controlled water receptors. However, as part of this remediation strategy, a series of site specific Remedial Target Values have been developed in order to ensure residual soils will pose no unacceptable risk to the underlying aquifer, detailed within Section 3.0 of this report.

Furthermore, whilst there has been no evidence of vertical migration from the general shallow Made Ground soils, during the remediation and enabling works, it may be prudent for a series of leachate validation samples to be obtained during the course of the remediation works to confirm there is no leachate risk from these Made Ground soils.

2.4 Ground Gas

British Standard BS8485 (2015) provides two types of residential property that require assessment. These building types are:

- **Type A building:** private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.

- **Type B building:** private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small to medium size rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.

Based on the ground gas risk assessment undertaken by Capita and the proposed Type A Building, it is envisaged that a point score of 3.5 will be required for the proposed development site where the calculated CSV for CO2 exceeds the action criteria as summarised in Table 2.2.

Table 2.2 BS8485 (2015) Points Required for Type A and B Building

CHARACTERISTIC SITUATION	NHBC TRAFFIC LIGHT SYSTEM	MINIMUM GAS PROTECTION SCORE (POINTS)	
		High Sensitivity	
		Type A building	Type B building
1	Green	0	0
2	Amber 1	3.5	3.5
3	Amber 2	4.5	4
4	Red	6.5	5.5
5	N/A	—	6.5
6	N/A	—	—

3.5 points must be achieved by installation of a suitable combination of measures detailed Table 2.3 within plots across the site. Furthermore, considering the presence of hydrocarbon impacted Made Ground soils across the site, all proposed dwellings will require the installation of hydrocarbon resistant membranes.

Table 2.2 BS8485 (2015) Point Score Summary

GAS PROTECTION SCORES FOR THE STRUCTURAL BARRIER	SCORE
a) **Floor and substructure design**	
Precast suspended segmental subfloor (i.e. beam and block).	0
Cast in situ ground bearing floor slab (with only nominal mesh reinforcement.	0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations.	1 or 1.5
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing.	2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing.	2.5

PROTECTION ELEMENT SYSTEM		SCORE	COMMENTS
Gas protection scores for ventilation protection measures			
(a) Pressure relief pathway (usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building)		0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measures systems. If the layer has a low permeability and / or is not terminated in a venting trench (or similar), then the score is zero.
(b) Passive sub floor dispersal layer: Media used to provide the dispersal layer are: • *Clear void* • *Polystyrene void former blanket* • *Geocomposite void former blanket* • *No-fines gravel layer with gas drains* • *No-fines gravel layer*	Very good performance	2.5	The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing and type and the thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B of BS8485:2015. Passive ventilation should be designed to meet at least "good performance".
	Good performance	1.5	
(c) Active dispersal layer, usually comprising fans with active abstraction (suction) from a sub floor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers.		1.5 to 2.5	This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure the continued maintenance of the system, including pumps and vents. Active ventilation should always be designed to meet at least "good performance".
(d) Active positive pressurization by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket.		1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park)		4	Assumes that the car park is vented to deal with car exhaust fumes, designed to *Buildings Regulations 2000, Approved Document F [9].*
Gas protection score for the gas resistant membrane			
Gas resistant membrane meeting all of the following criteria: • *Sufficiently impervious to the gases with a methane gas transmission rate <40.0 ml/day/m^2/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method_;*		2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. For example, a minimum 0.40mm thickness (equivalent to 370g/m^2 for polyethylene) reinforced membrane

Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; *Sufficiently strong to withstand in-service stresses (eg settlement if placed below a floor slab);* *Sufficiently strong to withstand the installation process and following trades until covered (eg penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools etc);* *Capable, after installation, of providing a complete barrier to the entry of the relevant gas; and,* *Verified in accordance with CIRIA C735.*		(virgin polymer) meets the performance criteria opposite. If a membrane is installed that does not meet all the criteria opposite then the score is zero.

It is concluded that the site will be suitable for the proposed residential end use subject to the completion of the afore mentioned supplementary assessments and the following build phase mitigation items:

- Completion of localised remediation works to remove all hydrocarbon impacted soils in the locality of TP214 that may currently present an unacceptable risk to human health and controlled waters;
- Completion of a Tier 2 controlled waters risk assessment to confirm the shallow Made Ground soils impacted by hydrocarbon compounds will present no unacceptable risk to the underlying aquifer;
- Completion of a detailed vapour risk assessment following the completion of the site remediation and enabling works;
- Installation of hydrocarbon resistant membranes within all proposed plots;
- Use of potable water supply infrastructure that will be compliant with UKWIR assessment criteria;
- Construction of selected dwellings with ground gas mitigation measures that conform to CS2 / Amber 1 requirements of BS8485; and,
- Construction of a 600mm clean cover system to all areas of private garden in accordance with the detailed methodologies herein.

3. DETAILED QUANTITATIVE CONTROLLED WATER RISK ASSESSMENT

3.1 Background

The Tier 1 risk assessment for controlled waters as completed by Capita and reviewed / amended by E3P, has identified two contaminant source areas on the subject site which are considered to present a potential risk to controlled waters as follows:

- **Source Area 1 –** The locality of TP214 has been identified as containing elevated hydrocarbon compounds, mainly aromatics and naphthalene within the soil and groundwater to a depth of 4.00m bgl directly overlying the bedrock. This area has therefore been identified as posing an unacceptable risk to the underlying Principal Aquifer if soils were to be retained in situ, therefore soils will require removal in their entirety and disposed off-site. Soils (and groundwater if present) will be validated against site specific screening values generated by the EA RTM within this section.

- **Source Area 2 –** This area covers much of the eastern portion of the site and relates to the shallow Made Ground strata where elevated hydrocarbon compounds and naphthalene have been identified (in significantly lower concentrations than within Source Area 1). These materials have been determined to be suitable for retention in their current location subject to the installation of a cover system within soft landscaping and installation of hydrocarbon resistant membranes within proposed plots, however further assessment needs to be undertaken to confirm the absence of risk to the underlying Principal Aquifer. The EA RTM will in this case be undertaken to confirm that these soils are suitable for retention and identify any areas where soils may require localised removal should they exceed the site specific screening criteria for Source Area 2.

The source areas are indicated on Drawing 11-813-005 (Appendix III).

Based on the above, a detailed controlled waters risk assessment has been undertaken for the following organic contaminants:

- *Naphthalene;*
- *TPH Aliphatic C12-C16;*
- *TPH Aliphatic C16-C35;*
- *TPH Aromatic C10-C12;*
- *TPH Aromatic C12-C16; and,*
- *TPH Aromatic C16-C35.*

The DQRA has been undertaken based on the two identified sources, performing two purposes: confirmation that the identified elevated TPHs will present no unacceptable risk to the underlying aquifer in addition to the calculation of Remedial Target Values for soil and groundwater which will be used to ensure that soil and groundwater encountered on site will pose no unacceptable risk to the controlled water receptors.

3.2 Discussion of Physical Parameters

Groundwater modelling has been undertaken on the site as part of the E3P review works, utilising the Capita groundwater monitoring data, identifying a general groundwater flow from the west to the east, presumably influenced by the topographical variances (albeit only slight). Drawing 11-813-006 (Appendix III) identifies the generalised groundwater flow along with the average groundwater levels in m AOD.

One main receptor has been identified which would be the underlying Principal Aquifer within the bedrock, which has been identified as being present at a shallow depth beneath the site, overlain by predominantly low permeability Glacial strata. The depth of bedrock has been identified at varying depths across the site, at circa 4.00m in the locality of TP214 (Source Area 1) and dropping off to 7.50m bgl at BH302 (Source Area 2). Based on the exploratory hole logs by Capita, the bedrock geology appears to be deeper in the eastern sector (where contaminated soils are present) and shallowing towards the west.

The main objective of this assessment is to generate site specific remedial targets for the remediation of hydrocarbon impacted soils and confirmation that remaining soils may be retained, for the protection of the underlying Principal Aquifer. Therefore based on the depth of bedrock and the depth of water strikes within the bedrock geology within nearby BGS boreholes, conservative compliance points of 20m have been used to demonstrate a theoretical monitoring point into the Principal Aquifer down-hydrualic gradient of the source areas.

The hydraulic gradient of the site has been calculated using site levelling data of 0.007. E3P has also utilised an arbitrary value for a clay soil of 0.001% for the Fraction of Organic Carbon (FOC), which has been utilised within the DQRA.

Additionally, E3P has reviewed the annual rainfall data on the Met Office for the area and taking into account evapotranspiration, it has been determined that a conservative annual rainfall value would be 600mm/year which returns an infiltration rate of 0.00164m/d, which has been used in the DQRA model.

Further details regarding the various physical and chemical inputs required for the DQRA are included within Tables 3.1 and 3.2 (overleaf).

Table 3.1 DQRA Physical Input Parameters

PARAMETER	VALUE	SOURCE	JUSTIFICATION
Method of calculating partition co-efficient	Non-polar Organic Chemicals		
Analytical Solution	Ogata Banks		
Degradation Conditions (aerobic / anaerobic)	Assumed anaerobic conditions to remain conservative		
Level Three - Groundwater			
Pathway Aquifer	N/A	N/A	Migration is assumed to be via the natural clays with sand lenses to the underlying Principal Aquifer (Receptor).
Saturated aquifer thickness (m)	10m	Estimate from deep borehole data	Approximation based on site ground conditions and information from the nearby BGS borehole.
Bulk density of aquifer materials (g/cm^3)	1.20	SR3	Taken from the value for sandy clay loam within the Updated Technical Background CLEA-SR3.
Air filled porosity (cm^3/cm^3)	0.16	SR3	Taken from the value for sandy clay loam within the Updated Technical Background CLEA-SR3.
Water filled porosity (cm^3/cm^3)	0.37	SR3	Taken from the value for sandy clay loam within the Updated Technical Background CLEA-SR3.
Effective porosity of the aquifer (cm^3/cm^3)	0.53	SR3	Taken from the value for sandy clay loam within the Updated Technical Background CLEA-SR3.
Hydraulic gradient	0.007	Site Data	Calculated using site levelling data.
Hydraulic conductivity of the aquifer (m/d)	2.04	SR3	Taken from the value for sandy clay loam within the Updated Technical Background CLEA-SR3.
Distance to compliance point (m)	20m	Site Compliance Point	The compliance point is believed to be the Principal Aquifer underlying the site (sandstone) – hypothetical borehole downstream.
Assumed groundwater flow direction	E	Site Data	Based on site data and groundwater modelling.
Fraction Organic Carbon in aquifer (FOC)	0.001	Site Data	Based on site soil samples.
Source Area 1 – TP214			
Width of plume in aquifer at source (m)	24	Site Data	Based on site data
Length of plume in aquifer at source (m)	39	Site Data	Based on site data
Plume thickness at source (m)	1.97	Calculated within RTM	This value is calculated from the mixing thickness within the Level 2 soils in the RTM model
Source Area 2 – Eastern Sector			
Width of plume in aquifer at source (m)	55	Site Data	Based on site data
Length of plume in aquifer at source (m)	186	Site Data	Based on site data
Plume thickness at source (m)	10	Calculated within RTM	This value is calculated from the mixing thickness within the Level 2 soils in the RTM model

Table 3.2 General DQRA Chemical Input Parameters

CONTAMINANT	KOC (L/KG)	SOURCE	ANAEROBIC DEG. HALF-LIFE (D)		SOURCE	HENRY'S LAW	SOURCE
			SOIL	WATER			
Naphthalene	2511.8864	LQM-CIEH	25	20	Howard et al – Naphthalene	0.0722	LQM-CIEH
TPH Aliphatic C12-C16	5370317.964	LQM-CIEH	3650	3650	Conservative Estimate	171	LQM-CIEH
TPH Aliphatic C16-C35	5754399373	LQM-CIEH	8560	8560	Conservative Estimate	1070	LQM-CIEH
TPH Aromatic C10-C12	2511.8864	LQM-CIEH	25	20	Howard et al – Naphthalene	0.0722	LQM-CIEH
TPH Aromatic C12-C16	5011.872	LQM-CIEH	200	50	Howard et al - Anthracene	0.00126	LQM-CIEH
TPH Aromatic C16-C21	14125.375	LQM-CIEH	900	210	Howard et al – Pyrene	0.000695	LQM-CIEH
TPH Aromatic C21-C35	125892.541	LQM-CIEH	228	57	Howard et al – Benzo(a)Pyrene	0.0000248	LQM-CIEH

Table 3.3 Maximum Site Concentrations– Vertical Migration to Principal Aquifer

CONTAMINANT	MAX CONC IN SOIL (MG/KG)	SITE SOURCE	MAX CONC IN WATER (MG/L)	SITE SOURCE
Source Area 1				
Naphthalene	9.1	TP214 4.20m	0.00011	BH301
TPH Aliphatic C12-C16	38	TP214 4.20m	<0.01	BH301
TPH Aliphatic C16-C35	98	TP214 4.20m	0.07	BH301
TPH Aromatic C10-C12	30	TP214 4.20m	0.04	BH301
TPH Aromatic C12-C16	250	TP214 4.20m	0.17	BH301
TPH Aromatic C16-C21	980	TP214 4.20m	0.57	BH301
TPH Aromatic C21-C35	1000	TP214 4.20m	0.08	BH301
Source Area 2				
Naphthalene	26	BH206 1.40m	0.00002	BH302
TPH Aliphatic C12-C16	10	TP308 0.60m	0.02	BH302
TPH Aliphatic C16-C35	217	TP308 0.60m	0.04	BH302
TPH Aromatic C10-C12	10	TP308 0.60m	0.02	BH302
TPH Aromatic C12-C16	420	TP308 0.60m	0.02	BH302
TPH Aromatic C16-C21	2700	TP308 0.60m	0.02	BH302
TPH Aromatic C21-C35	2900	TP308 0.60m	0.02	BH302

3.3 Results

The results of the detailed risk assessment are summarised within Table 3.4 below. The results provide remediation target concentrations for the Made Ground soils which may be used for validation purposes following the remediation of localised impacted soils. The results also demonstrate whether any elevated contaminant concentrations present within the existing soils may vertically migrate towards the underlying Principal Aquifer thus posing an unacceptable risk to controlled waters.

Table 3.4 Results

CONTAMINANT	UNITS	SOURCE CONCENTRATION IN RTM MODEL	LEVEL 3 REMEDIAL TARGET CONCENTRATION
Source Area 1			
Naphthalene	mg/kg	9.1	175
	mg/l	0.00011	18800
TPH Aliphatic C12-C16	mg/kg	38	161
	mg/l	<0.01	0.0125
TPH Aliphatic C16-C35	mg/kg	98	163000
	mg/l	0.07	0.115
TPH Aromatic C10-C12	mg/kg	30	404
	mg/l	0.04	4340
TPH Aromatic C12-C16	mg/kg	250	**7.85**
	mg/l	0.17	77.5
TPH Aromatic C16-C21	mg/kg	980	**2.79**
	mg/l	0.57	**0.415**
TPH Aromatic C21-C35	mg/kg	1000	**61.2**
	mg/l	0.08	16.8
Source Area 2			
Naphthalene	mg/kg	26	49.6
	mg/l	0.00002	18800
TPH Aliphatic C12-C16	mg/kg	10	82.8
	mg/l	0.02	0.0125
TPH Aliphatic C16-C35	mg/kg	217	86100
	mg/l	0.04	0.0115
TPH Aromatic C10-C12	mg/kg	10	11.6
	mg/l	0.02	4340
TPH Aromatic C12-C16	mg/kg	420	**2.18**
	mg/l	0.02	77.5
TPH Aromatic C16-C21	mg/kg	2700	**1.27**
	mg/l	0.02	0.415
TPH Aromatic C21-C35	mg/kg	2900	**18.2**
	mg/l	0.02	16.8

Source Area 1

The results summarised in Table 3.4 above indicate that if the hydrocarbon impacts soils in the vicinity of TP214 were to be retained in situ, particularly as these impacted soils are directly overlying the bedrock, they would present a significant risk to the Principal Aquifer, therefore remediation works will be required to excavate the impacted soils in their entirety. Remediation Target Concentrations have been produced from the RTM which may be utilised to compare validation samples of the soils during the excavation, delineation and remediation of these impacted soils, to confirm there will be no long term risk to the controlled water receptors.

The results included within Table 3.4 also indicate that the groundwater beneath the site will pose no unacceptable risk to the aquifer as no analysis results exceeded the site specific screening criteria (with the exception of TPH C16-C21 very marginally), however during remediation, if any visual or olfactory evidence of hydrocarbon impacted is identified within any groundwater encountered, the Remedial Target Concentrations for groundwater will be utilised by way of validation.

It is therefore considered that once this localised area is excavated, delineated and chemically validated using the site specific remedial target values, there will remain no unacceptable risk to the Principal Aquifer from Source Area 1.

Source Area 2

The results summarised in Table 3.4 indicate that for Source Area 2 there are a number of hydrocarbon concentrations which are present within the shallow Made Ground soils which present a theoretical risk to the underlying aquifer.

It should be noted at this point that there are greater concentrations of heavy end TPHs present within the shallow soils than are present within the locality of TP214, however it is important to distinguish the difference between these elevated compounds in the shallow granular strata with no separate phase apparent and no evidence of migration, and those present at depth directly overlying the aquifer in the location of TP214 where a degree of separate phase and visual / olfactory evidence of hydrocarbon impact was noted during the site investigation.

Intrusive investigation and analysis has identified no vertical migration of the elevated contaminants and no elevated contaminants were noted within groundwater samples, suggesting that any elevated contaminants are remaining within Made Ground strata and will not present an unacceptable risk to the underlying aquifer. That being said, it should be noted that no leachate analysis of the Made Ground soils has thus far been undertaken and for soils to remain in situ, E3P would consider it essential for leachate analysis to be undertaken of the upper 1m of Made Ground soils on a grid system (circa 1 sample per 500m^3) in order to confirm the absence of any leachate risk to the underlying aquifer. Leachate samples will be compared to the site specific screening criteria and where any samples identify a potential leachate risk and thus a risk to the aquifer, this will be considered a hotspot and the appropriate delineation, excavation and chemical validation will be undertaken to remove the impacted soils.

It is considered that following this process of leachate analysis and hotspot removal if required, the shallow Made Ground soils in the eastern portion of the site will present no unacceptable risk to the underlying aquifer.

4. SITE REMEDIATION & ENABLING WORKS

4.1 REMEDIATION TECHNOLOGY

Taking into account the site-specific conditions including the nature of the identified impacts, the geology and the objectives of the remediation, the most appropriate soil remedial technologies are considered to be:

- Delineation, excavation and chemical validation using the SSRTs of soils in the locality of TP214;
- Leachate validation of soils across the eastern sector of the site to show all residual soil concentrations are below the SSRT's for the protection of human health, controlled waters and the wider environ;
- Localised hotspot validation of any soils where required across the eastern sector (following leachate validation);
- Construction of a suitable cover system to mitigate the risk associated with non-volatile / insoluble compounds;
- Characteristic Situation 2 ground gas mitigation measures within all proposed plots to ensure compliance with BS8485 (2015) with independent validation of each unit; and,
- Installation of hydrocarbon resistant membrane within proposed plots.

It is considered that these technologies and methodologies will address the identified active pollutant linkages in the following manner:

4.2 Overview of Works

Prior to the commencement of works on-site, the contractor must establish all necessary plant, equipment and site welfare facilities as is necessary to complete the contract within the agreed timescales to the rationale as outlined in Table 4.1 (below).

Table 4.1 Enabling Works Schedule

RE-1	**Pre-Commencement Regulatory Compliance** Prior to commencement of any works on-site, all reports relating to the assessment of risk to contaminated land should be submitted to the regulatory authorities to gain written approval. All relevant Standard Rules Permits should be registered with the EA. The LAPC Part B Notification for deployment of mobile crushing plant should be implemented prior to the establishment of equipment on-site. If the proposed volume of soils to be re-used (excluding crushed materials) exceeds the parameters of the Standard Rules Permit, a CL:AIRE MMP Qualified Declaration should be made by the contractor having obtained full written approval for the Remediation Strategy from the LPA and Environment Agency. It is not anticipated that there will be any requirement to treat any materials on-site (such as hydrocarbon impact soil or groundwater), however should any previously unidentified contractor must either notify the EA of their intention to complete a minor works operation or arrange for the deployment of the appropriate Environmental Permit for the specified operation.

RE-2	**Environment & Nuisance Control** Management of all works so as to ensure that no environmental nuisance is created through dust emissions, noise or vibration levels. Ensure that all works are completed in a manner so as not to create any structural risk to the adjacent highways. Implement all temporary works as necessary to support excavations throughout the duration of the works. In the event that a complaint is made in respect of dust emissions, noise or vibration levels, remedial measures and a programme of ongoing monitoring should be agreed with the local authority and implemented on site.
RE-3	**Risk to Infrastructure** Site works should be completed in a manner that ensures no risk of disturbance to the adjacent infrastructure. This includes during the excavation of the impacted soils in the locality of TP214 which is adjacent to the pavement and highway on the northern boundary, as the excavation will be circa 4.00m in depth, therefore shoring will be required in order to support the adjacent highway.
RE-4	**Identification, Isolation and Treatment of Invasive Plants** At this time no invasive plant species have been identified, however the contractor must satisfy themselves with respect to the absence of any species deemed invasive prior to the commencement of works on-site. The contractor shall employ a suitably qualified expert to investigate the presence of invasive plant species on or adjacent to the site. If invasive plant species are identified, these will be treated in strict accordance with an approved method statement. If invasive plant species are identified at the site boundary, a suitable barrier shall be installed to prevent any future re-infestation of the subject site. If any invasive species are treated, a validation report should be prepared documenting all identified invasive plant species, their location and the treatment methodology. Where materials are removed from site all Waste Transfer Notes / Duty of Care certificates should be included within the validation statement.
RE-5	**Site Clearance Operations** General site clearance & provision of welfare, offices and site security as per the contract requirements. The site is currently overgrown with self-seeded vegetation; this material should be removed in a controlled manner with full compliance with any ecological mitigation measures that are required for the works. Any such measures are outside the scope of this report. All vegetation should either be stockpiled at a pre-agreed location or alternatively removed from site in accordance with Waste Permitting Regulations. All root networks are to be removed in accordance with the requirements of the NHBC / LABC**.**

RE-6	**Delineation, Excavation, Validation and Disposal of Impacted Materials at TP214** The soils in the locality of TP214 have been identified, if retained in situ, to present a significant risk to the underlying Principal Aquifer due to the concentrations of hydrocarbon impact in close proximity to the bedrock geology. This area has apparently undergone previous remediation with the removal of tanks however investigation determined that whilst tanks may have been removed, the surrounding soils which are likely to have become impacted from the leakage of these tanks, did not undergo remediation and have been left in place. Investigation would suggest that near surface soils are suitable for future re-use on the site, therefore a reduced level dig of these soils should be undertaken across Source Area 1 (Drawing 11-813-005), with these near surface soils placed to the side on visqueen pending chemical validation utilising SSRTs for the protection of human health, controlled waters and the wider environ to determine suitability for re-use. Material deemed to be impacted through either visual or olfactory observations or as a result of notable PID readings (>50ppm) will be excavated and stockpiled on an impermeable membrane. The membrane will be placed upon a clay containment bund and covered to negate the risk of soils leaching and dispersal of any odours and/or vapours. An E3P engineer will regularly monitor the stockpiled material with a PID to determine the need for boundary monitoring (albeit not anticipated). This material will then be subject to detailed laboratory analysis to determine the suitability for re-use or the requirements for off-site disposal. Following these works, the significantly hydrocarbon impacted soils will require excavation and disposal off-site as they will be chemically unsuitable for re-use within the context of a residential development. Upon completion of the delineation and excavation, the sides and base of the resulting void(s) will be chemically validated to confirm no impacted materials remain in situ. Validation samples will be collected at 10 linear meter centres from the side and base of the excavation. The results of this validation testing will be directly compared to the Site Specific Remediation Targets (as defined within Appendix IV of this report) to demonstrate that no unacceptable level of risk to human health, controlled waters or the wider environment remains. The resulting excavation will be backfilled using geotechnically suitable (and chemically suitable) materials to prepare this area for residential development. As mentioned within RE-3, extreme care must be undertaken during these works to not disturb the adjacent footpath and highway.

RE-7	**Validation Leachate Analysis of Shallow Made Ground Soils in Eastern Sector** As discussed within Section 3.0, shallow Made Ground soils in the eastern sector contain widespread concentrations of TPHs and naphthalene. The DQRA with respect to controlled waters has identified that the elevated heavy end TPHs present a theoretical risk to the underlying aquifer, however intrusive investigation and analysis has confirmed there is no vertical migration of these elevated contaminants and there has been no elevated concentrations present within groundwater samples. With this in mind, it has been determined that the shallow Made Ground soils may be retained in situ (subject to the installation of cover systems and hydrocarbon membranes) however a phase of validation leachate analysis will also be required of the upper 1m of Made Ground (circa 1 sample per 500m^3), which will be compared to the SSRTs generated for Source Area 2, and confirm the absence of any long term risk to the underlying aquifer. Should validation analysis identify the presence of elevated soils which exceed the SSRTs, these localised soils will require excavation, delineation and chemical validation to remove soils which may impact the underlying aquifer. Following this localised removal, validation samples will be collected from the sides and base of the resulting excavation.
RE-8	**Excavation, Breaking and Processing of All Above & Below Ground Structures** Obstructions, relict foundations and infrastructure (apart from live services) are to be removed from the areas of proposed residential development to include plot footprints, rear gardens, private driveways, adopted highway and utilities infrastructure (road box) in their entirety. It is understood that the site has previously undergone a phase of remediation, albeit this appears to have only involved the excavation (and decommissioning) of below ground storage tanks and relic foundations and obstructions. With this in mind, it is anticipated that any remaining obstructions will be minimal, if present. Artificially hard materials should be broken out and crushed. Stockpiles will be made, validation testing undertaken, and site won material reused on site where required. Materials will be processed as per the E3P chemical and geotechnical specification using licensed plant. The E3P drawings denote the extent of known historic features with obstructions, however it will be the contractor's responsibility to remove all obstructions. Obstructions encountered within the near surface soils will be chased to their full depth and removed; if not possible, the obstruction must be surveyed with the location communicated to E3P, the client and the developer. Where natural soils are present at a relatively shallow depth (northern sector), extreme care should be taken to ensure that the natural cohesive deposits remain undisturbed with a full reduced level survey to be completed to map the depth of filled / processed material.
RE-9	**Cut & Filling of Made Ground to Development Levels** The Made Ground is noted to be present to substantial depth in some areas of the site (>2.0m), is considered that it will be possible to utilise a pre-cast concrete pile in these areas. Where the proposed enabling works levels require the current landform to be cut, extreme care should be taken so as not to disturb the underlying stratum prior to the placement of the appropriate platform in compliance with the E3P Geotechnical Specification.

	Where the development levels require material to be filled, site derived Made Ground must be sorted in a controlled manner prior to replacement in accordance with the requirements of this specification for the intended land use. The maximum dry density must be determined in laboratory conditions utilising UKAS accredited testing prior to the commencement of filling and compaction works. In-situ density testing us required to demonstrate compliance with the E3P Geotechnical Performance Specification.
RE-10	**Construction of Temporary Working Platform** Where plots are to be prepared in a manner that will facilitate a pre-cast concrete pile, a Temporary Working Platform will be constructed. The specific design for such a platform should be obtained from E3P, however as a minimum this will comprise: Proof rolling of the sub-grade to ensure a CBR >5%; Placement of 300mm of certified 6F2 to be rolled and compacted to ensure a CBR >15%.
RE-11	**Replacement of Materials Geotechnical Engineering Requirements** Material is to be backfilled in strict compliance with the E3P Geotechnical Engineering Specification as presented in detail within Section 6 of this report which generally requires the following reinstatement and compaction criteria: Unless specific instruction is issued from the client, plots should be prepared for a strip foundation where the target founding stratum is identified to be present at a depth of 1.50m below FFL. Consideration is to be given to the need to construct a strip foundation ~200-400mm into the natural stratum and the contractor remediation elevations:

LAND USE	CONSTRUCTION REQUIREMENT	REQUIREMENT
Footprint of proposed structure (2.0m on all elevations).	Pile Foundation	Backfill using general Method Compaction to CBR of 5%
	Traditional Spread Foundation	Ensure no disturbance of natural soil at shallow depth.
Highways	Adopted Estate Road / Drainage	Method Compaction using DOT ensure CBR >5% in sub-grade (engineered fill)
Driveways	Private Drives & Car Parking	Method Compaction to CBR >5%
Gardens & POS	N/A	Method Compaction to ensure no settlement.

RE-12	**Importation of Bulk Fill** Where there is a net shortfall of material required to achieve the proposed ground levels, it will be necessary to import natural inert soils and aggregate as per the engineering requirements (Section 6). Imported material must be certified as suitable for use in strict accordance with the E3P chemical and geotechnical performance criteria in conjunction with the required duty of care notes and waste transfer exemption. If recycled aggregates are imported laboratory testing should be completed to demonstrate compliance with the WRAP Protocol. Where inert soils are imported laboratory testing should be completed in accordance with the requirements of the pertinent Environmental Permit (i.e. U1 Standard Rules) or CL:AIRE MMP for the re-use of clean naturally occurring soils.
RE-13	**Preparation of Garden for Cover System** As part of the land remediation works, garden areas will be prepared in a manner that will facilitate the placement of the clean cover system during the development phase of the woks. The preparation of the areas requiring clean cover is critical in ensuring delivery of the site in a manner that will ensure no risk to the proposed end users. Where Made Ground is deemed unsuitable for retention in a garden, the area will be subject to a reduced level dig to remove unsuitable material to a minimum depth of 600mm below finished garden level or verified natural stratum (whichever is the shallower). Excavated soil will be stockpiled pending the results of the appropriate validation testing (to be completed in accordance with this specification) prior to re-use in an area of no sensitivity or where necessary, this material will be removed from site in accordance with UK Waste Management Legislation. The placement of certified sub-soil and topsoil will be completed as part of the developer works / build phase mitigation plan. All garden areas where a cover system is required will be subject to plot specific independent validation.
RE-14	**Provision of Subsoil** The shallow natural drift deposits (predominantly cohesive soils) are deemed suitable for use within the upper 600mm of clean cover to residential gardens and areas of soft landscaping. It is therefore deemed viable to re-use and materials that are cut as part of the wider earthworks or through a soil inversion (regulated by an MMP) to generate the requited volumes of material. The garden and landscaped areas will require depth validation to satisfy the requirement of the Council Mortgage Lenders (CML) in order to demonstrate that the appropriate thickness has been provided as a growing medium.
RE-15	**Provision of Topsoil** No material that would be deemed suitable for use as topsoil is present on-site and as such there will be requirement to import suitable material for use within the proposed development. Topsoil will require testing in line with the schedule present within Section 4.4 and Table 4.2. The garden and landscaped areas will require depth validation to satisfy the requirement of CML in order to demonstrate that the appropriate thickness has been provided.

RE-16	**Independent Validation – Watching Brief** Given the site history and potential contamination sources identified within the ICSM, a degree of uncertainty remains with regard to the potential for as yet unidentified contamination impact within the near surface soils and groundwater. It will therefore be necessary to instigate the site wide Remediation & Enabling works under the supervision of a suitably qualified and independent specialist. The specialist is required to attend site as and when appropriate to monitor works, record ground conditions and fully investigate all potential sources of as yet unidentified contamination.
RE-17	**Post-Remediation Detailed Vapour Risk Assessment** Shallow Made Ground soils present in the eastern sector of the site will be retained in situ (subject to confirmatory validation analysis to confirm absence of risk to the underlying aquifer). The proposed development will be installed with a 600mm cover system and proposed plots will be installed with a hydrocarbon resistant membrane to mitigate exposure to these soils, however it would be prudent to undertake a detailed vapour risk assessment following completion of the works in the eastern sector to confirm these soils will pose no vapour risk to the future residents. This assessment will only be required if remediation and validation works deem it to be a necessity.
RE-18	**Remedial Verification Report** Collation of information relating to site clearance, chemical testing, remedial works, remedial verification, material movements and waste transfer documentation where appropriate. Complete remedial validation reported in line with regulatory guidance. This will include a detailed risk assessment. The report will be submitted to the Local Authority for approval following completion.

For the avoidance of any doubt, the proposed operations as set out herein document the required performance objectives and validation sampling protocols, however the specific methods of work deployed to ensure the remediation objectives are achieved in a compliant manner on-site will be the responsibility of the appointed contractor.

4.3 Second Phase Mitigation & Management – Build Phase

A second post Remediation & Enabling phase of works will be required to ensure the proposed development is constructed in a manner that incorporates the required mitigation measures to ensure the development is compliant with UK Building Regulations and the Local Authority Planning requirements.

Once the ground has been stabilised and rendered suitable for development, the builder will be required to undertake a second phase of remediation works to mitigate the identified theoretical risk to human health.

- Provision of a 600mm cover system over made ground encountered across the site, using certified material with appropriate validation within proposed garden areas. Natural drift deposits encountered within the upper 600mm of finished ground levels can be directly overlain with a suitable cover (minimum 150mm topsoil).
- Provision of 300mm certified cover system to all areas of soft landscaping and POS.
- Provision of appropriately assessed water supply pipes.
- Construction of all dwellings with the appropriate ground gas mitigation measures and

corresponding independent validation.

- Installation of hydrocarbon resistant membrane within proposed plots.

4.4 Materials Management & Legislative Compliance

The processing of recycled aggregates will be completed using LAPC Part B Licensed Plant with the appropriate deployment notification to the Local Authority prior to commencement of works. All materials that are recovered as recycled aggregate will be compliant with the requirements of the WRAP protocol and the E3P validation testing requirements and as such would not be deemed to be a waste material.

A U1 Standard Rules Permit will be registered for the site which allows the re-use of up to 3000m3 of material within construction with up to 12,500m3 of material permissible to be re-used in the construction of roads.

A T5 Standard Rules permit allows the screening and recovery of up to 3000m3 of material for sub-sequent re-use in construction will also be registered.

All materials that are recovered under the WRAP Protocol, U1 or T5 exemptions must be analysed to demonstrate that they are both chemically and structurally suitable for use within the context of the development.

The relevant LAPC, U1, T5 and WRAP Licenses, Exemption and Protocols provides the legislative framework for material compliance during the site remediation and enabling works to be completed by the specialist contractor under the supervision or E3P.

Where necessary operations as outlined in detailed within the Remediation Enabling Works Rationale summarised above may be subject to regulation using the appropriate Environmental Permit, Standard Rules Exemption and 'Materials Management Plan' (MMP) to be created in accordance with Version 2 of the CL:AIRE Definition of Waste - Industry Code of Practice.

If required, the MMP will be created with due consideration to all proposed remediation and enabling works operations prescribed within this document and will be undertaken by a Qualified Person and a signed declaration submitted to the EA prior to re-use of materials on the site.

The importation of material for use within the proposed construction of a development platform will be subject to the compliance with the E3P Protocol for the importation of materials as set out within the specification for material import included within the Appendix of this report.

4.5 Validation Sampling Protocol

In accordance with the current requirements of the regulatory authorities, validation samples will be collected from all materials that are to be subject to movement under the protocols outlined within this Remediation Strategy, or for materials to be imported onto site to facilitate the proposed residential development.

Soil samples destined for chemical analysis will be collected at regular intervals in appropriate sampling containers. All samples will subsequently be stored in cooled boxes prior to submission to a UKAS / MCERTS accredited laboratory.

All samples will be collected using appropriate PPE and sampling equipment that will be cleaned at each sampling location. A detailed copy of E3P Ltd sampling methodology, QA procedures and laboratory chain of custody forms will be documented within the site records and presented within the final validation report for the site.

Where material is found to contain concentrations of potential contaminants at levels in excess of the site specific screening criteria (as detailed within Appendix IV), E3P will undertake further assessment and recommendations on the appropriate use for the material in question, which may involve the disposal of such materials off-site to a suitable waste management facility.

The sampling frequency for materials to be managed under the Remediation Strategy is presented within Table 4.2.

Table 4.2 Specification of Chemical Validation Laboratory Analysis

MATERIAL USE	TESTING FREQUENCY	SUITE OF ANALYSIS
Site Generated		
Site Generated 6F2	1 Sample Per 1000m^3	A / B / C / D
Site Won Made Ground General Backfill	1 Sample Per 250m^3	G
Site Won Made Ground General Backfill (Eastern Sector)	1 Sample Per 500m^3	H
Site Won Natural Backfill	1 Sample Per 2000m^3	A / B / C / D
Site generated Sub-Soil *(450mm garden cover)*	1 Sample Per 250m^3	A / B / C / D
Hydrocarbon Impacted Materials Validation Samples	1 Sample per 10m of linear excavation to base and sidewall.	J / G
	1 Sample per 10m of linear excavation to base and sidewall.	E / G
	1 Sample per 250m^3 of stockpiled excavated materials.	J / G
	1 Sample per 500m^3 of stockpiled excavated materials.	J / G / H
Imported		
6F2	1 Sample Per 1000m^3	A / B / C / D
Subsoil Greenfield Source *(450mm garden cover)*	1 Sample per 200m^3	A / B / C / D
Subsoil Brownfield Source *(450mm garden cover)*	1 Sample per 50m^3	A / B / C / D
Topsoil Greenfield Source *(150mm garden cover)*	1 Sample per 200m^3	A / B / C / D
Topsoil Brownfield Source *(150mm garden cover)*	1 Sample per 50m^3	A / B / C / D
General Engineering Fill (Class 1 & 2 Soil)	1 Sample Per 1000m^3	A / B / C / D

Notes
Suites of Analysis
A) Speciated PAH
B) Speciated TPH (C5-C35)
C) Asbestos (ID)
D) CLEA Inorganic Heavy Metals
E) Speciated PAH, Banded TPH
F) SVOC / Speciated TPH
G) On-site screening for VOC using calibrated PID
H) Leachate 2:1 TPH CWG
I) Leachate analysis of Inorganic heavy metals, TPH, sulphate and PAH.
J) Banded TPH

All analysis prescribed above to be completed by UKAS accredited laboratory.

4.6 Remediation Contractors Site Management & Responsibility

The appointed Remediation Contractor will take full and overarching responsibility for all methods of work required to complete the site remediation and enabling operations to ensure the delivery of the site and the completion of the objectives a safe, legislative compliant manner that ensures no pollution to the subject site or the wider environs.

For individual remediation operations as set out within this performance specification, the contractor will provide site specific methods of work for individual operations pertaining to the removal and treatment of contaminated liquids and soils. For each and every operation as set out herein the contractor will provide a written methodology of works to be supplied to the supervising geo-environmental engineering prior to the instigation of operations on-site.

The site manager will be responsible for documentation of each day's activities with a full recorded schedule of works completed and corresponding site specific method statements that have been utilised to ensure the completion of the task to the required standard.

5. ENVIRONMENTAL MONITORING AND VALIDATION

5.1 Site Management

The tracking of materials will be based on the following hierarchy:

- The Principal Contractor will have the responsibility for setting out areas of the site on the basis of the contract specification;
- Operatives will have instructions only to excavate and to emplace materials in specified areas as assigned by the Site Manager / Foreman;
- The Site Manager (employed by the Principal Contractor) will issue daily instructions to drivers regarding the placement of materials sourced from specific stockpiles or areas, ensuring that appropriate documentary evidence is collected that details which materials are going where and why;
- The strategy for each day's work will be agreed with the E3P Consultant, who will be in attendance as required, prior to the commencement of the works. E3P will:
    - Inspect the excavation areas and certify that the correct materials are being excavated;
    - Conduct spot checks on loaded vehicles to ensure compliance with this Remediation Strategy;
    - Ensure that any loads which fail visual, olfactory or spot checks either remain on the vehicle or if unloaded are excavated and set aside. This material will be treated according to the recommendations of the E3P site engineer.
- All material imported and removed from site will have Duty of Care / Consignment Notes, copies of which will be retained on-site by the Site Manager; and,
- Materials directly reusable will be incorporated into the earthworks, subject to operational conditions and phasing of excavations, in which case they will be stockpiled prior to final placement.

5.2 Completion

Following the completion of the remediation works a report will be compiled by the Environmental Consultant detailing all site enabling works undertaken, waste consignment notes, and all site investigations, laboratory test certificates, and validation testing undertaken.

A certificate of completion of earthworks should be included within the report which should then be issued to The Local Authority for their approval.

E3P considers that with the adoption of the above best practices the site can be safely redeveloped. The site enabling works process and presence of any residual contamination (if this is the case) should be recorded for future reference by landowners /occupiers. Future development at the site where this may result in penetration of new areas of hard-standing should be subject to no less stringent measures with respect to assessment, and, where appropriate, monitoring than those set out above.

6. GEOTECHNICAL ENGINEERING SPECIFICATION

6.1 E3P Geotechnical Engineering Specification

The overarching philosophy of the site enabling works will be the delivery of the following:

- Preparation of plot footprint (+2.0m on all elevation) to be suitable for a pre-cast concrete pile where depth of stiff clay / medium dense sands exceeds 1.50m from proposed Finished Floor Level;
- Preparation of plots to be suitable for construction with shallow spread foundation where firm to stiff clay and medium dense sands are present at a depth <1.50m from proposed FFL across the complete plot; and,
- Engineer all areas of proposed adopted road and private drive to be complaint with the E3P Geotechnical Specification with CBR and elevation defined by the client.

In the event that it is not possible to prepare the site in a manner that will achieve the required foundation solution, the Supervising Engineer and Client should be contacted at the first available opportunity.

The contractor should employ a suitably experienced engineer to be present on site during these earthwork operations to ensure soil suitability, placement, compaction and testing is undertaken in accordance with this specification and to ensure that any unforeseen circumstances, such as adverse weather, do not compromise the earthworks process.

Works should be halted during periods of intermittent or prolonged rainfall to ensure the materials are not placed in a manner that would result in softening of either the formation or the newly placed material. It will be the contractor's responsibility to determine appropriate weather conditions and determine the suitability of works.

Particular attention must be given to variable weather conditions when re-engineering clay soils as a moisture content fluctuation (2%+/-) of the tolerable limit will result in unacceptable degree of compaction loss.

6.2 Locally Won Fill Material

It is proposed to up-fill and level the site with material won from the development area. From the site specific investigations undertaken to date, it is expected that the majority of the soils won from the processing of demolition material will be granular and cohesive soil matrixes.

Due to climatic weather conditions and variance in long term differential settlement associated with even well compacted granular soils it is essential that the cut and fill process is well controlled and materials are placed /. Compacted in accordance with this specification.

Where site won materials are to be used as fill to achieve the required development platform, they must be compacted to ensure in-situ densities that are in excess of 95% of the Maximum Dry Density as determined using a 4.5KG laboratory Procter Test.

Materials should only be compacted when the actual moisture content is within 2% (+/-) of the optimum for the soil matrices as determined by laboratory bench testing.

6.3 Classification of Fill Material

This Specification should be read in conjunction with the following:

- The Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works, Series 600, Earthworks as amended in November 2005; and,
- Soils for Civil Engineering Purposes, BS1377, 1999.

6.3.1 General Classification

The contractor should ensure that all earthworks materials comply with Clause 601 of the Specification for Highway Works and shall fall into one of the other of the following general classifications as defined in Table 6/1 of the Specification for Highway Works.

- General granular fill (Class 1),
- General cohesive fill (Class 2), excluding class 2A and 2E,
- Selected granular fill (Class 6).

Table 6.1 Specification for Backfill Compaction

E3P EARTHWORKS GEOTECHNICAL COMPACTION SPECIFICATION					
SOIL / MATERIAL TYPE	**CLASS**	**DESCRIPTION**	**COMPACTION EQUIPMENT**	**LAYER THICKNESS**	**ROLLER PASSES**
Granular Fill (**Sand** & gravel Matrices)	**1 A**	Sandy Gravel with some cobbles	>5000kg Vibrating Roller	225mm	4
	1 B	Sand or Gravel of same grading size	>5000kg Vibrating Roller	250mm	10
	1 C	Coarse gravels with many cobbles	>5000kg Vibrating Roller	400mm	5
Cohesive Fill (**Clay** with minor sand and gravel component)	**2 A**	Wet Clays	>100kg Metric Ton Vibrating Tamping Roller **(Sheep Foot ONLY)**	100-225mm	3
	2 B	Dry Clay	>5000kg Vibrating Roller or 1400kg Tamping (Trench Roller)	225mm or 125mm	4 or 12
	2 C	Gravelly Clay	>5000kg Vibrating Roller or 1400kg Tamping (Trench Roller)	225mm or 125mm	4 or 12
	2 D	Silty / sandy Clay	>5000kg Vibrating Roller or 1400kg Tamping (Trench Roller)	225mm or 125mm	4 or 12
Recycled Aggregate Crush. (<125mm Well Graded)	**6F2**	Any combination of inert hard materials other colliery spoil or rock with substantial amounts of clay like component.	>5000kg Vibrating Roller	250mm	6

6.3.2 Use of Fill Materials

In addition to any grading requirement the maximum particle size of any fill material shall be no more than two-thirds of the compacted layer thickness except that cobbles having an equivalent diameter of more than 150mm shall not be deposited within the restored surface level unless directed otherwise by the Engineer. Un-burnt colliery spoil, pulverised fuel ash or furnace bottom ash shall not be used as a fill material.

6.4 General Requirements

The contractor shall employ only plant and working methods which are suited to the materials to be handled and traversed. He shall be responsible for maintaining the nature of the acceptable material so that when it is placed and compacted it remains acceptable in accordance with the Contract.

For the purposes of this contract, the proposed earthworks requirements have been split into distinct end use categories with the corresponding requirements for the earthworks specification assigned to individual areas.

Table 6.2 Compaction / Backfill Requirements

LAND USE	COMPACTION METHODOLOGY & GENRAL PERFORMANCE CRITERIA
Traditional Spread Foundation	Ensure no disturbance of natural soil at shallow depth.
Piled Foundation	All plot footprint (+2.0m) must be free of any deleterious elements, tree roots and obstructions >150mm. Where upfill is proposed, material to be placed using method Compaction Specification to achieve CBR as required by developer for piling mat construction. Piling mat to be placed and constructed in accordance with approved geotechnical engineer's temporary works design.
Adopted Highways (+2.0m from back of footpath).	Method Compaction – Highways Design Manual Series 600 with in-situ Validation Testing to meet requirement of adoptions authority. CBR >5% at sub-grade formation (prior to placement of Capping).
Estate Roads	Method Compaction – Highways Design Manual Series 600 with CBR >5%.
Gardens, POS & Other External Areas	Material is to be placed in layers not exceeding 300mm and must be rolled using dedicated plant (no earth moving equipment) and in general compliance with the requirements of Highways Design Manual Series 600.

Acceptability shall be determined in accordance with Table 6/1 of the Highway Specification.

Laboratory testing for the purposes of determining acceptability and compaction requirements will be conducted by the Engineer.

Haulage of material to embankments or other areas of fill shall proceed only when sufficient spreading and compaction. Plant is operating at the place of deposition to ensure compliance with Clause 612 of the Highways specification.

No excavated acceptable material or unacceptable material required to be processed, other than surplus to the requirements of the Contract, shall be removed from the site.

Where the excavation reveals a combination of acceptable and unacceptable materials the Contractor shall carry out the excavation in such a manner that the acceptable materials are excavated separately for use in the Permanent Works without contamination by the unacceptable materials. Unless otherwise described in the Contract classes of fill material required to be deposited separately shall be excavated separately without contamination by other classes of material.

The Contractor shall make his own arrangements for stockpiling of acceptable material, and unacceptable material to be processed, and for the provision of site for purpose.

The Contractor shall ensure that he does not adversely affect the stability of excavations or fills by his methods of stockpiling materials, use of plant or sitting of temporary buildings or structures.

Topsoil shall wherever practicable be used immediately after its stripping and if not shall be stored in stockpiles of heights not exceeding 2.0m; topsoil shall not be stockpiled for more than two years. Topsoil shall not be unnecessarily trafficked either before stripping or when in a stockpile. Stockpiles shall not be surcharged or otherwise loaded and multiple handling shall be kept to a minimum.

Excavations requiring backfilling shall remain open only for the minimum period necessary.

The Contractor shall keep earthworks free of water including:

(i) Arranging the rapid removal of water:
  (a) shed on to the earthworks
  (b) entering the earthworks from any source

(ii) Provide where necessary temporary watercourses, drains, pumping and the like:

(iii) Discharge accumulated water and groundwater into the permanent outfalls of the drainage system where practicable

(iv) Provide adequate means for trapping silt on temporary systems discharging into permanent drainage systems.

The Contractor shall carry out and maintain and groundwater lowering or other treatment required.

Where materials are designated either Class U1B or Class U2 (according to the Highways Specification), the Contractor shall carry out any special requirements for their handling. Where such materials are encountered during the progress of the Works, the Contractor shall make all necessary arrangements for their safe handling and disposal after consultation with the appropriate environmental authority.

6.4.1 Construction of Fills – Highways

All fills shall be constructed:

(i) In the locations as shown in the contract drawings to the lines and levels stated therein;

(ii) Of classes of material complying with this specification;

(iii) By deposition, as soon as practicable after excavation, in layers to meet the compaction requirements as required for each Class of material as specified.

(iv) To the requirements of this clause and any other requirements for fill in this Specification.

Before commencing work on any area of fill the Contractor shall ensure that:

(i) The base is sound and stable by excavating and removing any topsoil as soft subsoil.

(ii) Base layers are not exposed until the fill layer is ready for placement.

(iii) Un-compacted material on the side slopes of previously backfilled zones shall be removed and benches of between 1.0m and 1.5m height cut in compacted fill

immediately prior to deposition of the new fill to ensure that the new backfill placed against the slope is properly integrated.

Whenever fill is to be placed on surfaces inclined at 1 vertical to 7 horizontal or steeper, the surface shall be benched immediately prior to deposition of the fill in order to achieve horizontal basal surfaces. The benches shall be between 1.0m and 1.5m in height.

Areas of fill shall, unless otherwise permitted by the Engineer, be constructed evenly over their fullest possible extent and the Contractor shall carefully control and direct construction plant and other vehicular traffic uniformly over the area of compacted fill. The minimum plan dimensions of any one panel of backfilling shall be properly integrated with areas of previous backfilling. Damage by construction plant and other vehicular traffic shall be made good by the Contractor with material having the same characteristics and strength as the material had before it was damaged.

Temporary slopes within compacted and un-compacted backfill shall be formed at gradients which ensure stability.

6.4.2 Construction of Fills – Adopted Highways, Estate Roads & Car Park

The Contractor shall carry out compaction upon the materials which require to be compacted, as soon as practicable after deposition.

Compaction shall be either method as required for the classes of fill in Table 6/1 which requires to be compacted.

The Contractor shall obtain permission from the Overseeing Organisation before carrying out compaction requirements as listed in Table 6/1 for the Class of material being compacted.

Method compaction shall be undertaken using the plant and methods appropriate to the compaction requirements as listed in Table 6/1 for the Class of material being compacted.

Earthmoving plant shall not be accepted as compaction equipment nor shall the use of a lighter category of plant to provide any preliminary compaction to assist the use of heavier plant to be taken into account when assessing the amount of compaction required for any layer.

If more than one class of material is being used in such a way that it is not practicable to define the areas in which each class occurs, the Contractor shall compact with plant operating as if only the material which required the greater compaction effort is being compacted.

If the results of field tests show densities which indicate the state of the compaction to be inadequate, if this is due to failure on the Contractor to comply with requirements of the Contract, the Contractor shall carry out such further work as is required to comply with the contract.

Refer to Clause 612/10 of the Highway specification for definition of plant to be used in accordance with this specified works.

The Contractor will be responsible for assessing the Class of Fill in accordance with Table 6/1 of the Highways Specification. Table 6/4 of the Highways Specification should then be employed to assess the method of compaction to be employed. The test results and method statements shall be submitted to the Consulting Engineers for approval.

6.5 Earthworks Material Tests

Prior testing of the potential sources of fill shall be undertaken by the Contractor and submitted to the Consulting Engineers for approval. This testing shall include, but not necessarily be limited to the compaction and backfill requirements detailed in Table 5.3.

Table 6.3 Compaction / Backfill Requirements

<table>
<tr><th>LAND USE</th><th>COMPACTION METHODOLOGY & GENERAL PERFORMANCE CRITERIA</th></tr>
<tr><td>Liquid and plastic limits</td><td>BS1377: Part 2</td></tr>
<tr><td>Grading</td><td>BS1377: Part 2</td></tr>
<tr><td>Uniformity Co-efficient</td><td>Calculated from grading curve</td></tr>
<tr><td>Moisture content</td><td>BS1377: Part 2</td></tr>
<tr><td>Organic Matter (maximum 2.5% total organic content)</td><td>BS1377: Part 3</td></tr>
<tr><td>Water soluble sulphate</td><td>TRL Report 447 test No 1</td></tr>
<tr><td>Total sulphate content</td><td>TRL Report 447 Test No 4</td></tr>
<tr><td>Earthwork In-situ Tests
Subsequent to the filling and compaction of the material a series of in-situ tests shall be undertaken to confirm the success of the compaction process. This testing shall include but necessarily be limited to, the following:
<table>
<tr><th>TEST</th><th>TEST METHOD</th></tr>
<tr><td>Plate load tests (equivalent CBR of 5%)</td><td>BS1377: Part 9</td></tr>
</table>
Disposal of Materials
The contractor shall be responsible for the safe disposal of any excess of unsuitable material found on the Site.
Multi Point Moisture Condition Value (MCV) (to assess optimum moisture content)</td><td>Clause 632 (BS1377: Part 4)</td></tr>
<tr><td>Proctor compaction testing</td><td>BS1377: Part 4</td></tr>
</table>

7. RECORD KEEPING & VERIFICATION

7.1 Record Keeping

During the course of the remediation and site enabling works, the on-site E3P Consultant will undertake the following record keeping protocols:

- Detailed daily site diary including material movements;
- Sampling register, testing results, photographs, details of locations of hydrocarbon impacted soils (drawings), details of hotspot removals, details of consignment notes of any hydrocarbon impacted material that is required to be disposed of off-site; and,
- Detailed surveys (volumes).

Record keeping on site, in particular movements and analysis of specific material types, will be in the form of site diaries and a remediation excavation record. This record will remain on site and will be completed by the E3P on-site engineer during the course of the remediation and site enabling works.

7.2 Verification

The records listed above will then be compiled into a Validation Report produced by E3P on completion of the remediation and site enabling works, clearly referencing the origin of the materials used and testing carried out to confirm its suitability for use, where required. E3P will also prepare an as built development drawing clearly detailing the materials present on-site to be cross referenced with the supporting validation documentation.

The Validation Report will include the following:

- Remediation Strategy (including copies of confirmation from regulatory authorities agreeing criteria);
- Detailed surveys of all excavations and production of ‘as built’ drawings for the earthworks;
- Copy of Consignment Notes relating to the movement of wastes to a licensed waste management facility;
- Detailed drawings showing all sampling locations for both chemical and geotechnical testing;
- Chemical test results;
- Geotechnical test results;
- Details of Qualified Persons signed declaration; and,
- Monitoring results if undertaken (i.e. asbestos in air, gas water etc.)

8. CONTINGENCY PLAN

8.1 Previously Unidentified Contaminants

Should significantly impacted material be encountered during the development, then it will be excavated and stockpiled on an impermeable material and sampled and tested for an appropriate range of determinants.

Once the laboratory analysis of the material is available an assessment will be undertaken to determine whether it can be retained on-site as part of the Material Management Plan or whether it should be disposed off-site.

Depending on the nature of any such impact it may be necessary to undertake validation testing of the excavation faces in order to demonstrate that no such materials are left in-situ.

END OF REPORT

APPENDIX I
LIMITATIONS

1. This report and its findings should be considered in relation to the terms of reference and objectives agreed between E3P and the Client as indicated in Section 1.2.

2. For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information it has been assumed it is correct. No attempt has been made to verify the information.

3. This report has been produced in accordance with current UK policy and legislative requirements for land and groundwater contamination which are enforced by the local authority and the Environment Agency. Liabilities associated with land contamination are complex and requires advice from legal professionals.

4. During the site walkover reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover no attempt has been made to enter areas of the site that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not be made known or accessible.

5. Access considerations, the presence of services and the activities being carried out on the site limited the locations where sampling locations could be installed and the techniques that could be used.

6. Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.

7. Where mention has been made to the identification of Japanese Knotweed and other invasive plant species and asbestos or asbestos-containing materials this is for indicative purposes only and do not constitute or replace full and proper surveys.

8. The executive summary, conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the report in full.

9. E3P cannot be held responsible for any use of the report or its contents for any purpose other than that for which it was prepared. The copyright in this report and other plans and documents prepared by E3P is owned by them and no such plans or documents may be reproduced, published or adapted without written consent. Complete copies of this may, however, be made and distributed by the client as is expected in dealing with matters related to its commission. Should the client pass copies of the report to other parties for information, the whole report should be copied, but no professional liability or warranties shall be extended to other parties by E3P in this connection without their explicit written agreement there to by E3P.

10. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole or in part.

APPENDIX II
GLOSSARY

TERMS

AST	Above Ground Storage Tank	**SGV**	Soil Guideline Value
BGS	British Geological Survey	**SPH**	Separate Phase Hydrocarbon
BSI	British Standards Institute	**TPH CWG**	Total Petroleum Hydrocarbon (Criteria Working Group)
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes	**SPT**	Standard Penetration Test
CIEH	Chartered Institute of Environmental Health	**SVOC**	Semi Volatile Organic Compound
CIRIA	Construction Industry Research Association	**UST**	Underground Storage Tank
CLEA	Contaminated Land Exposure Assessment	**VCCs**	Vibro Concrete Columns
CSM	Conceptual Site Model	**VOC**	Volatile Organic Compound
DNAPL	Dense Non-Aqueous Phase Liquid (chlorinated solvents, PCB)	**WTE**	Water Table Elevation
DWS	Drinking Water Standard	**m**	Metres
EA	Environment Agency	**km**	Kilometres
EQS	Environmental Quality Standard	**%**	Percent
GAC	General Assessment Criteria	**%v/v**	Percent volume in air
GL	Ground Level	**mb**	Milli Bars (atmospheric pressure)
GSV	Gas Screening Value	**l/hr**	Litres per hour
HCV	Health Criteria Value	**µg/l**	Micrograms per Litre (parts per billion)
ICSM	Initial Conceptual Site Model	**ppb**	Parts Per Billion
LNAPL	Light Non-Aqueous Phase Liquid (petrol, diesel, kerosene)	**mg/kg**	Milligrams per kilogram (parts per million)
ND	Not Detected	**ppm**	Parts Per Million
LMRL	Lower Method Reporting Limit	**mg/m^3**	Milligram per metre cubed
NR	Not Recorded	**m bgl**	Metres Below Ground Level
PAH	Polycyclic Aromatic Hydrocarbon	**m bcl**	Metre Below Cover Level
PCB	Poly-Chlorinated Biphenyl	**mAOD**	Metres Above Ordnance Datum (sea level)
PID	Photo Ionisation Detector	**kN/m^2**	Kilo Newtons per metre squared
QA	Quality Assurance	**µm**	Micro metre
SGV	Soil Guideline Value		

APPENDIX III
DRAWINGS

Key:

Notes:

Phase	Revision	Date	Issue	Drawn	Authorised
P1	-	02.02.2018	DRAFT	CB	MD

Client: Rowlinson Construction	Job No: 11-813	Date: 02.02.2018
	Drawing No: 002	Scale: NTS @ A3
Job Title: Bowes Street, Manchester	Drawing Title: Proposed Development Plan	

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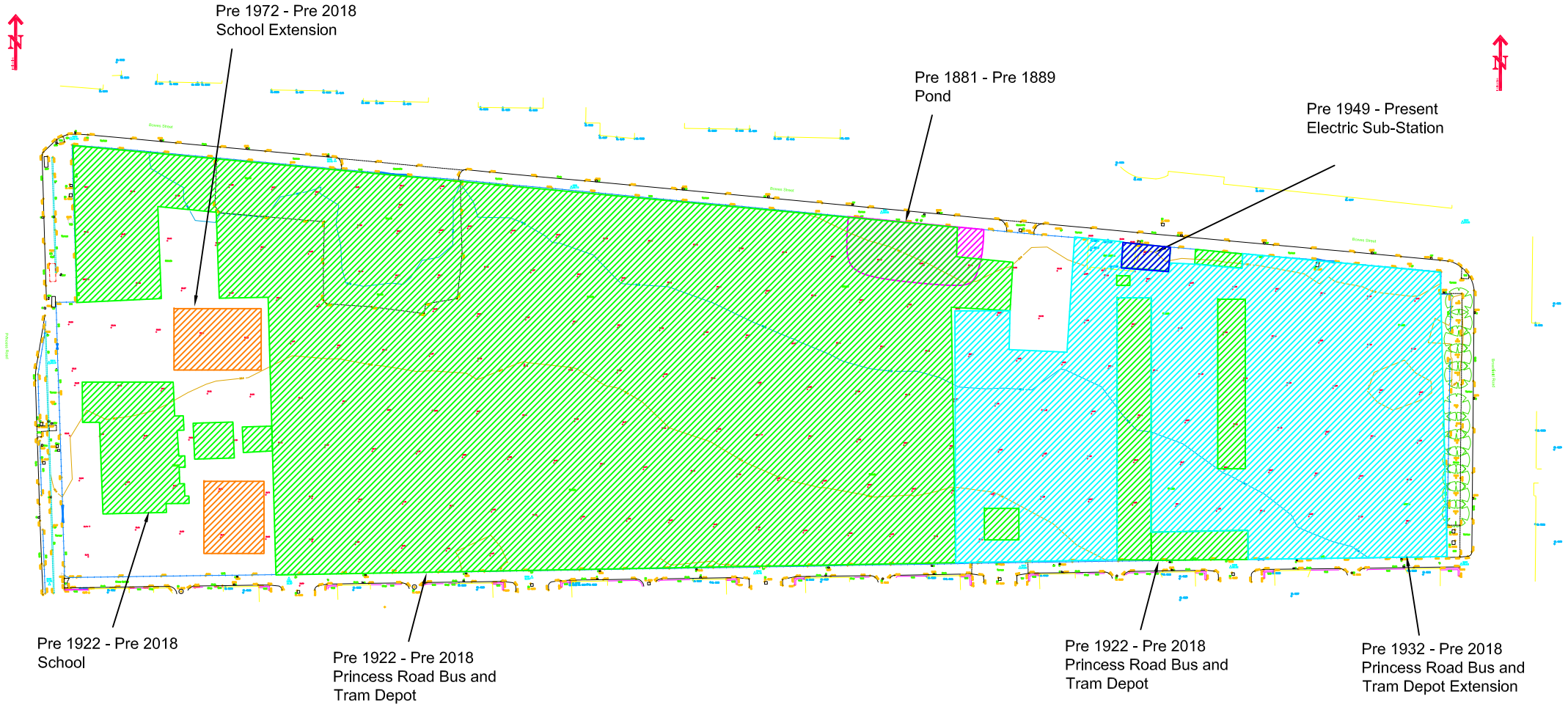

Key:

Historical Features

- Pre 1881 (Pond)
- Pre 1922 (School, Princess Road Bus and Tram Depot)
- Pre 1932 (Depot Extension)
- Pre 1949 (Electric Sub-Station)
- Pre 1972 (School Extension)

Notes:

Phase	Revision	Date	Issue	Drawn	Authorised
P1	-	02.02.2018	DRAFT	CB	MD

Client: Rowlinson Construction

Job No: 11-813

Date: 02.02.2018

Drawing No: 003

Scale: 1:1250 @ A3

Job Title: Bowes Street, Manchester

Drawing Title: Historical Features Plan

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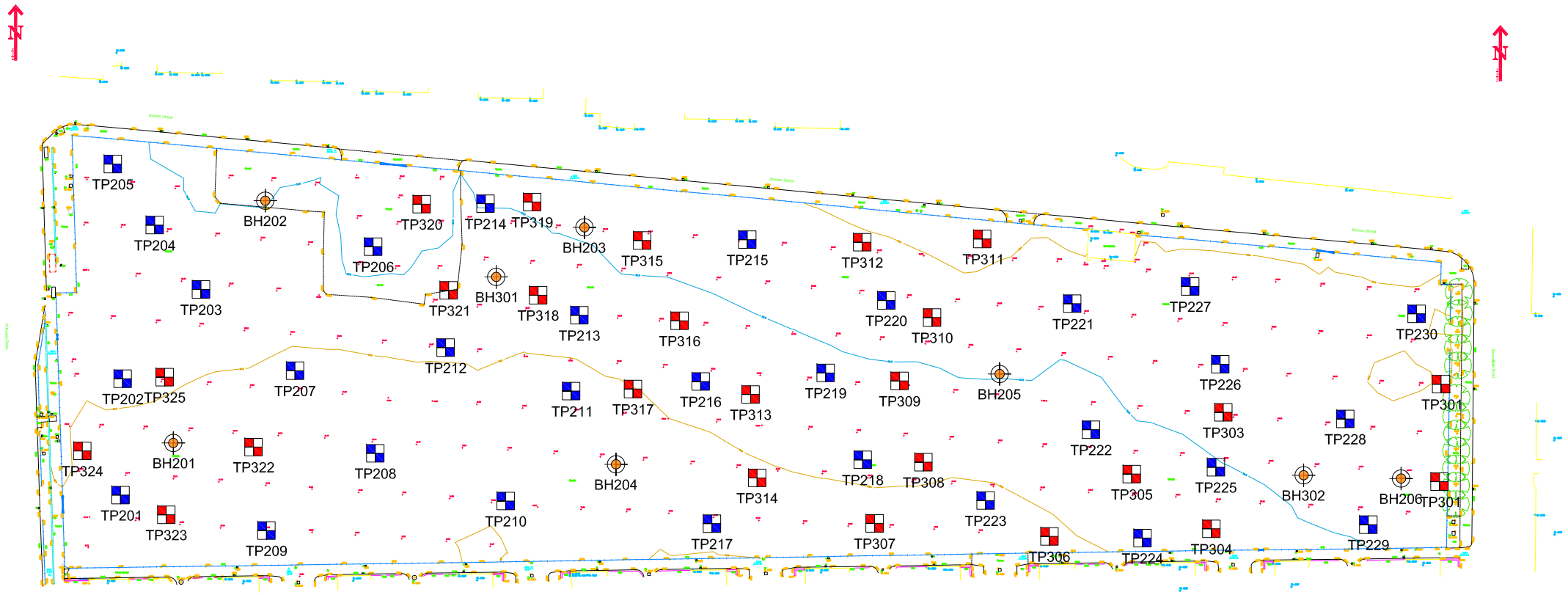

Key:

Location Symbols

TP201 Approximate Trial Pit Location (Capita Location)

TP301 Approximate Trial Pit Location (Capita Location)

BH101 Approximate Borehole Location (Capita Location)

Notes:

Phase	Revision	Date	Issue	Drawn	Authorised
P1	-	02.02.2018	DRAFT	CB	MD

Client: Rowlinson Construction

Job No: 11-813

Date: 02.02.2018

Drawing No: 004

Scale: 1:1250 @ A3

Job Title: Bowes Street, Manchester

Drawing Title: Exploratory Hole Location Plan

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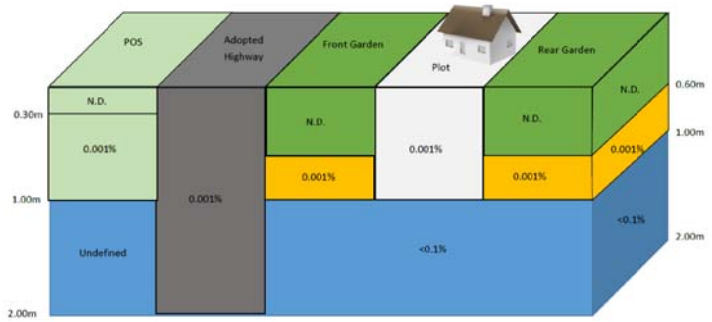
Asbestos in Soils Conceptual Site Model
Notes:

N.D - None Detected

0.001% - Soils may contain <0.001% asbestos using composite testing to ensure there is no potential risk to human health. This value is present within areas where there may be short term low level exposure of soils containing trace asbestos fibres by construction workers where an appropriate level of asbestos management is employed (dust suppression).

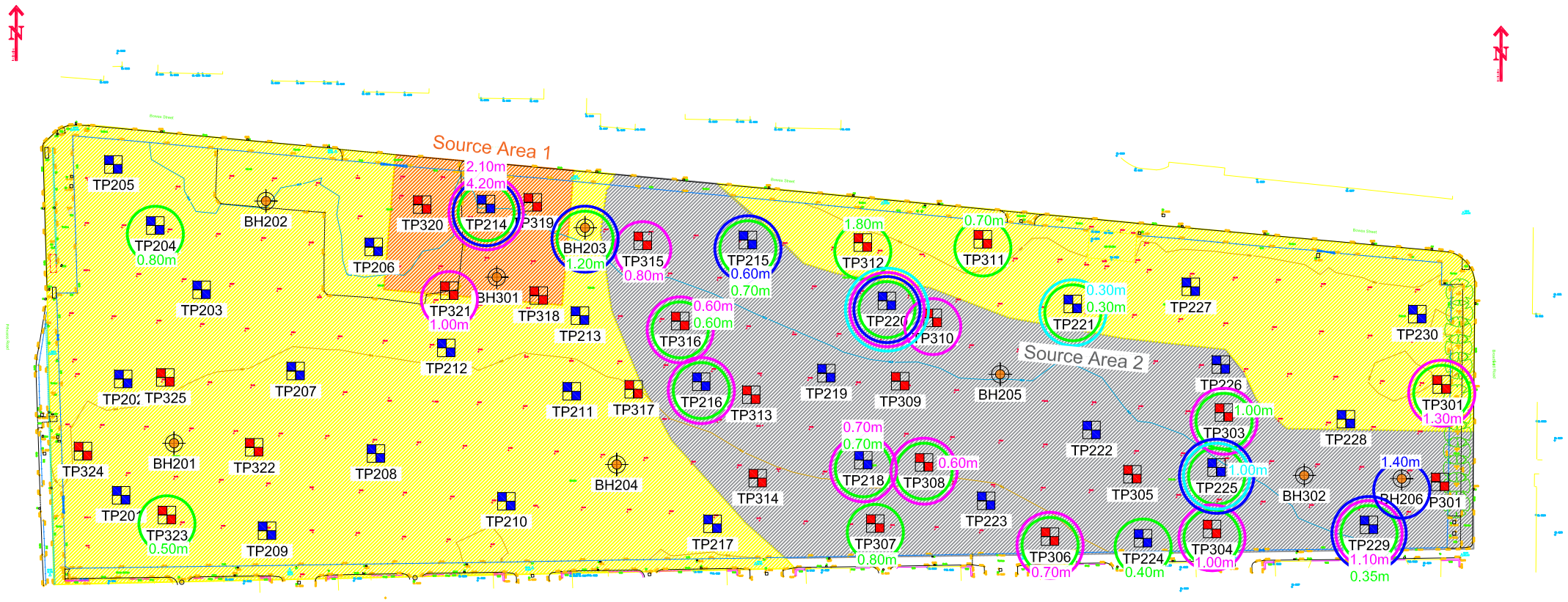
Undefined - This will be dependent upon soils encountered during the earthworks, which may be placed at these depths to ensure no potential risk to human health.



Key:

Location Symbols

- TP201 — Approximate Trial Pit Location (Capita Location)
- TP301 — Approximate Trial Pit Location (Capita Location)
- BH101 — Approximate Borehole Location (Capita Location)
- Area of hydrocarbon contamination in surface of bedrock and within groundwater. Detailed assessment required to generate SSRTS, with excavation, delineation and chemical validation to remove impacted soils.
- Remainder of site suitable for residential development with installation of 600mm cover system in gardens and landscaping.
- Area where hydrocarbon contamination identified within near surface soils. Confirmed no vertical delineation and soils to be retained in soils if houses include installation of hydrocarbon membranes, however DQRA for controlled waters required to confirm they will present no undue risk to underlying principle aquifer.
- Elevated heavy metals 600mm chemically suitable cover system will be installed within all gardens to mitigate
- PAHs 600mm chemically suitable cover system will be installed within all gardens to mitigate
- Elevated TPHs and BTEX hotspot delineation and remediation will be required to remove volatilisation pathway or houses will require installation of hydrocarbon membranes
- Elevated napthalene hotspot delineation and remediation will be required to remove volatilisation pathway



Remediation Issues

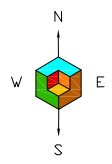
Item	Plot Number	Active
Garden Cover System	-	-
Hotspot Treatment	-	-
CO_2 Membrane	-	-
CH_4 Membrane	-	-
Hydrocarbon Membrane	-	-
Hazardous Material Storage	-	-

Notes:

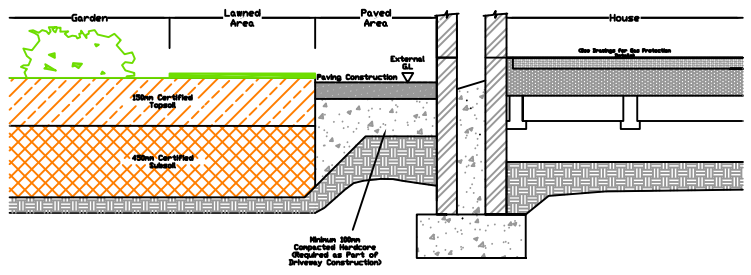
N.B: *All areas of identified contamination impact to soil and groundwater are estimated using best endeavors from historic and current intrusive investigation. However, the contractor must satisfy themselves of the potential extent of remediation works. The identified impact must be spatially delineated in accordance with the E3P Remediation strategy. The entire development site will require a 600mm chemically suitable cover system comprising of 150mm topsoil & 450mm subsoil with underlying orange 'no dig' geotextile membrane installed in all proposed garden areas to mitigate the elevated contaminant concentrations.*

Phase	Revision	Date	Issue	Drawn	Authorised
P1	-	02-02-2018	DRAFT	CB	MD

Client: Rowlinson Construction		Job No: 11-813	Date: 02-02-2018
		Drawing No: 005	Scale: 1:1250 @ A3
Job Title: Bowes Street, Manchester		Drawing Title: Remediation Issues Plan	



Indicative Construction for Garden Cover



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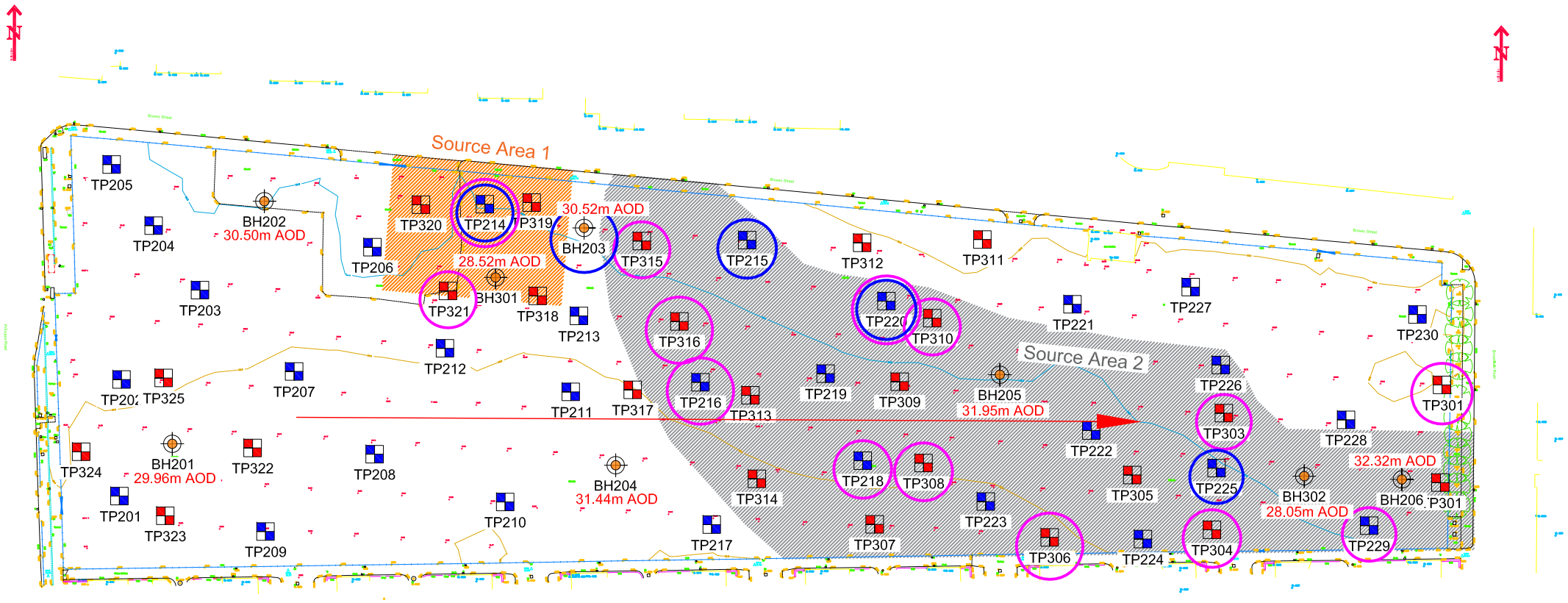

Key:

Location Symbols

TP201 — Approximate Trial Pit Location (Capita Location)

TP301 — Approximate Trial Pit Location (Capita Location)

BH101 — Approximate Borehole Location (Capita Location)

Area of hydrocarbon contamination in surface of bedrock and within groundwater. Detailed assessment required to generate SSRTS, with excavation, delineation and chemical validation to remove impacted soils.

Area where hydrocarbon contamination identified within near surface soils. Confirmed no vertical delineation and soils to be retained in soils if houses include installation of hydrocarbon membranes, however DQRA for controlled waters required to confirm they will present no undue risk to underlying principle aquifer.

Elevated TPHs and BTEX hotspot delineation and remediation will be required to remove volatilisation pathway or houses will require installation of hydrocarbon membranes

Elevated napthalene hotspot delineation and remediation will be required to remove volatilisation pathway

30.50m AOD — Average Groundwater Levels in M AOD

Assumed Groundwater Flow

Notes:

Phase	Revision	Date	Issue	Drawn	Authorised
P1	-	02.02.2018	DRAFT	CB	MD

Client: Rowlinson Construction	Job No: 11-813	Date: 02.02.2018
	Drawing No: 006	Scale: 1:1250 @ A3
Job Title: Bowes Street, Manchester	Drawing Title: Controlled Waters Risk Assessment Plan	

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APPENDIX IV
E3P REMEDIATION
&
VALIDATION CRITERIA

Human Health Remediation Targets – Low Rise Residential End Use

Determinand	Units	Within 600mm Cover System (Garden)	Hard Standing and >600mm of cover system	Public Open Space 300mm Cover	Public Open Space >300mm	Pathway
Arsenic	mg/kg	**37**(i)	**40**(ii)	**79**(iii)	**640**(iv)	1
Cadmium	mg/kg	**11**(i)	**85**(ii)	**120**(iii)	**532**(iv)	1
Chromium (Hexavalent)	mg/kg	**6**(i)	**6**(ii)	**7.7**(iii)	**220**(iv)	1
Lead	mg/kg	**210**(vi)	**330**(vii)	**760**(viii)	**760**(viii)	1
Elemental Mercury	mg/kg	**1.2**(i)	**1.2**(ii)	**16**(iii)	**30**(iv)	2
Nickel	mg/kg	**180**(i)	**180**(ii)	**230**(iii)	**3400**(iv)	1
Selenium	mg/kg	**250**(i)	**430**(ii)	**1100**(iii)	**1800**(iv)	1
Copper	mg/kg	**2400**(i)	**7100**(ii)	**12000**(iii)	**44000**(iv)	1
Zinc	mg/kg	**3700**(i)	**40000**(ii)	**81000**(iii)	**170000**(iv)	1
Phenol	mg/kg	**280**(i)(xi)	**280**(xiv)(xi)	**760**(iii)(xi)	**760**(iv)(xi)	2
Naphthalene	mg/kg	**2.3**(i)(xi)	**2.3**(xiv)(xi)	**1200**(iv)(xi)	**1200**(iv)(xi)	2
Acenaphthylene	mg/kg	**170**(i)(xi)	**500**(v)	**15000**(iii)(xi)	**29000**(iv)(xi)	3
Acenaphthene	mg/kg	**210**(i)(xi)	**500**(v)	**15000**(iii)(xi)	**29000**(iv)(xi)	1
Fluorene	mg/kg	**170**(i)(xi)	**500**(v)	**9900**(iii)(xi)	**20000**(iv)(xi)	1
Phenanthrene	mg/kg	**95**(i)(xi)	**500**(v)	**3100**(iii)(xi)	**6200**(iv)(xi)	3
Anthracene	mg/kg	**500**(i)(xi)	**500**(v)	**74000**(iii)(xi)	**150000**(iv)(xi)	3
Fluoranthene	mg/kg	**280**(i)(xi)	**500**(v)	**3100**(iii)(xi)	**6300**(iv)(xi)	3
Pyrene	mg/kg	**500**(i)(xi)	**500**(v)	**7400**(iii)(xi)	**15000**(iv)(xi)	3
Benzo(a)Anthracene(	mg/kg	**7.2**(i)(xi)	**11**(ii)(xi)	**29**(iii)(xi)	**49**(iv)(xi)	3
Chrysene	mg/kg	**15**(i)(xi)	**30**(ii)(xi)	**57**(iii)(xi)	**93**(iv)(xi)	3
Benzo(b)Fluoranthene (iii)	mg/kg	**2.6**(i)(xi)	**3.9**(ii)(xi)	**7.1**(iii)(xi)	**13**(iv)(xi)	3
Benzo(k)Fluoranthene (iii	mg/kg	**77**(i)(xi)	**110**(ii)(xi)	**190**(iii)(xi)	**370**(iv)(xi)	3
Benzo(a)Pyrene (vii)	mg/kg	**2.2**(i)(xi)	**3.2**(ii)(xi)	**5.7**(iii)(xi)	**11**(iv)(xi)	3
Indeno(123-cd)Pyrene	mg/kg	**27**(i)(xi)	**45**(ii)(xi)	**82**(iii)(xi)	**150**(iv)(xi)	3
Dibenzo(a,h)Anthracene	mg/kg	**0.24**(i)(xi)	**0.31**(ii)(xi)	**0.57**(iii)(xi)	**1.1**(iv)(xi)	3
Benzo(ghi)Perylene	mg/kg	**320**(i)(xi)	**360**(ii)(xi)	**640**(iii)(xi)	**1400**(iv)(xi)	3
TPH C_5-C_6 (aliphatic)	mg/kg	**42**(i)(xi)	**42**(ii)(xi)	**42**(ii)(xi)	**10000**(xiv)(xi)	2
TPH C_6-C_8 (aliphatic)	mg/kg	**100**(i)(xi)	**100**(ii)(xi)	**100**(ii)(xi)	**10000**(xiv)(xi)	2
TPH C_8-C_{10} (aliphatic)	mg/kg	**27**(i)(xi)	**27**(ii)(xi)	**27**(ii)(xi)	**10000**(xiv)(xi)	2
TPH C_{10}-C_{12} (aliphatic)	mg/kg	**130**(i)(xi)	**130**(ii)(xi)	**130**(ii)(xi)	**10000**(xiv)(xi)	2
TPH C_{12}-C_{16} (aliphatic)	mg/kg	**1000**(xiv)(xi)	**1000**(xiv)(xi)	**1000**(xiv)(xi)	**10000**(xiv)(xi)	1
TPH C_{16}-C_{21} (aliphatic)	mg/kg	**500**(xiv)(xi)	**500**(xiv)(xi)	**500**(xiv)(xi)	**10000**(xiv)(xi)	1
TPH C_{21}-C_{35} (aliphatic)	mg/kg					1
TPH C_5-C_7 (aromatic)	mg/kg	**70**(i)(xi)	**70**(xiii)(xi)	**70**(xiii)(xi)	**10000**(xiv)(xi)	2
TPH C_7-C_8 (aromatic)	mg/kg	**130**(i)(xi)	**130**(xiii)(xi)	**130**(xiii)(xi)	**10000**(xiv)(xi)	2
TPH C_8-C_{10} (aromatic)	mg/kg	**34**(i)(xi)	**34**(xiii)(xi)	**34**(xiii)(xi)	**10000**(xiv)(xi)	2
TPH C_{10}-C_{12} (aromatic)	mg/kg	**74**(i)(xi)	**74**(xiii)(xi)	**74**(xiii)(xi)	**10000**(xiv)(xi)	2
TPH C_{12}-C_{16} (aromatic)	mg/kg	**140**(i)(xi)	**140**(xiii)(xi)	**140**(xiii)(xi)	**10000**(xiv)(xi)	1
TPH C_{16}-C_{21} (aromatic)	mg/kg	**260**(i)(xi)	**260**(xiii)(xi)	**260**(xiii)(xi)	**10000**(xiv)(xi)	1
TPH C_{21}-C_{35} (aromatic)	mg/kg	**1000**(xiv)(xi)	**1000**(xiv)(xi)	**1000**(xiv)(xi)	**10000**(xiv)(xi)	1

Notes 1

Asbestos will be screened visually on-site by a qualified environmental consultant and where potential ACM is identified representative samples will be subject to quantitative analysis of 5&volume by weight. Should any ACM be identified within the soil matrices, further detailed % assessment would be required when the reported laboratory result exceeds the limit of detection for the analytical method at 0.01% by volume (weight).

Notes 2

Excludes matrices where free product is observed;
Commercial Tier 1 GAC modelled to assume no exposure pathway; and,
No viable exposure pathway beneath hard standing and cover system.

Notes 3

Main Exposure Pathways: 1 = Soil Ingestion, 2 = Vapour Inhalation (indoor), 3 = Dermal Contact & Ingestion, 4 = Dust Inhalation.
Abbreviations: GAC = General Assessment Criteria, n = number of samples, MC = Maximum Concentration; NA – Not Applicable (no exceedance of assessment criteria); Loc of MC = Location of Exceedances

(i) Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use **with** plant uptake.
(ii) Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use **without** plant uptake – these levels used below 600mm cover system within residential gardens as soils will be present within a residential setting yet soils will not be disturbed and garden plants will not reach these soils.
(iii) Value derived from LQM Suitable 4 Use Levels (S4ULs) for Public open Space (POS) residential.
(iv) Value derived from LQM Suitable 4 Use Levels (S4ULs) for Public Open Space (POS) park – these levels used below 300mm POS cover system as soils will not be disturbed by any future site users and exposure to these soils will be similar to a park end use.
(v) Value derived from LQM Suitable 4 Use Levels (S4ULs) alongside assessment with WM3 to ensure that materials remaining on site do not exceed the WM3 toxicity criteria for hazardous waste.
(vi) Value derived from Category 4 Screening Levels (C4SL) for residential land use **with** homegrown produce.
(vii) Value derived from Category 4 Screening Levels (C4SL) for residential land use **without** homegrown produce.
(viii) Value derived from Category 4 Screening Levels (C4SL) for Public open Space (POS) residential.
(ix) Value derived from Category 4 Screening Levels (C4SL) for Public Open Space (POS) park.
(x) Mercury – Based on elemental Mercury.
(xi) PAH and TPH levels used are for 1% SOM.
(xii) Xylenes based on p-xylene (o-xylene 2600mg/kg, m-xylene 3500mg/kg) and is capped by its solubility.
(xiii) Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use **with** plant uptake due to the volatilisation risk.
(xiv) BTEX is not SOM related due to inhalation pathway.

Site Specific Remedial Targets for the Protection of Controlled Waters

CONTAMINANT	UNITS	SOURCE CONCENTRATION IN RTM MODEL	LEVEL 3 REMEDIAL TARGET CONCENTRATION
Source Area 1			
Naphthalene	mg/kg	9.1	175
	mg/l	0.00011	18800
TPH Aliphatic C12-C16	mg/kg	38	161
	mg/l	<0.01	0.0125
TPH Aliphatic C16-C35	mg/kg	98	163000
	mg/l	0.07	0.115
TPH Aromatic C10-C12	mg/kg	30	404
	mg/l	0.04	4340
TPH Aromatic C12-C16	mg/kg	250	**7.85**
	mg/l	0.17	77.5
TPH Aromatic C16-C21	mg/kg	980	**2.79**
	mg/l	0.57	**0.415**
TPH Aromatic C21-C35	mg/kg	1000	**61.2**
	mg/l	0.08	16.8
Source Area 2			
Naphthalene	mg/kg	26	49.6
	mg/l	0.00002	18800
TPH Aliphatic C12-C16	mg/kg	10	82.8
	mg/l	0.02	0.0125
TPH Aliphatic C16-C35	mg/kg	217	86100
	mg/l	0.04	0.0115
TPH Aromatic C10-C12	mg/kg	10	11.6
	mg/l	0.02	4340
TPH Aromatic C12-C16	mg/kg	420	**2.18**
	mg/l	0.02	77.5
TPH Aromatic C16-C21	mg/kg	2700	**1.27**
	mg/l	0.02	0.415
TPH Aromatic C21-C35	mg/kg	2900	**18.2**
	mg/l	0.02	16.8

Remediation Targets – Comparison of Leachate Analysis with Tier 1 Screening Levels

DETERMINAND	UNITS	SCREENING VALUE
Arsenic	µg/l	50[1]
Cadmium	µg/l	5[2]
Chromium	µg/l	2[1]
Copper	µg/l	5[1,3]
Total Cyanide	µg/l	1[1]
Lead	µg/l	4[1]
Mercury	µg/l	1[2]
Nickel	µg/l	50[1]
Selenium	µg/l	100[4]
Zinc	µg/l	10[5]
pH	-	6-9
Naphthalene	µg/l	10[1]
Benzo(a)pyrene	µg/l	0.05[7]
benzo[b/k]fluoranthene benzo[g,h,i]perylene & indeno(1,2,3-cd]pyrene	µg/l	0.10[6]
TPH C5-C6 (benzene)	µg/l	30[1]
TPH C6-C8 (toluene)	µg/l	50[1]
TPH C8-C10 (ethyl Benzene)	µg/l	20[1]
TPH C10-C12 (xylene)	µg/l	30[1]
TPH C12-C16 (naphthalene)	µg/l	10#[1]
TPH C16-C35	µg/l	50#

Notes

Solubility <0.01µg/l

1. Council Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (Dangerous Substances Directive) - List II substances
2. Council Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (Dangerous Substances Directive) - List I substances
3. Surface Waters (River Ecosystem) (Classification) Regulations 1994
4. WHO Guidelines for Drinking Water Quality. Third edition (2004)
5. Council Directive on the quality of fresh waters needing protection or improvement in order to support fish life (Freshwater Fish Directive)
6. Council Directive on the quality of water intended for human consumption (Drinking Water Directive)
7. Directive establishing a framework for Community action in the field of water policy (Water Framework Directive)

APPENDIX V
E3P REMEDIATION MATERIAL IMPORT CONTROL

Material Import Quality Control Procedure

SITE OF IMPORTATION ADDRESS		E3P HELIPORT BUSINESS PARK LIVERPOOL ROAD ECCLES MANCHESTER M30 7RU *0161 707 9612*
Client		
Main Contractor		
Earthworks Contractor		
Haulier		
Date of Planned Import		

Overview of Planned Material Import	
Material Source (site of origin) & Postcode	
Site Investigation report	***Report Title & Reference:*** ***Date:*** ***Information supplied by:***
Reason for generation of excess material at site of origin	
Chemical Test Results for Stockpile at site of origin	***Date:*** ***Laboratory Certificate ref:*** ***Organisation responsible for stockpile sampling:***
Geotechnical Material Classification & Testing	***Delete as appropriate:*** Class 1 / Class 2 / Class 6 / Topsoil
Pictures of Material Stockpile Pending Transportation	***Delete as appropriate:*** Yes / No
Person or organisation responsible for ensuring Quality Control at site of origin.	
Quantity of material to be imported (m3).	
Proposed area of deposition (site of re-use)	
Waste Exemption / Permit or CL:AIRE MMP	***Delete as appropriate:*** U1 Standard Rules / CL:AIRE MMP (Direct Transfer) / Bespoke

APPENDIX VI
EA RTM SHEETS

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**Naphthalene**			
Target Concentration (C_T)	**0.13**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Naphthalene**		
Target concentration	C_T	**0.13**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	7.22E-02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	2.51E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.51E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**3.68E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.13	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**Naphthalene**		from Level 1
Target concentration	C_T	**0.13**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**1.91E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		5.40E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	0.13	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		26	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.50E+01	days	*Howard et al*
Calculated decay rate	λ	2.77E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	4.15E-03	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	1.26E-02	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	1.09E-02	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**9.18E+01**	**fraction**
Calculated soil leachate concentration	Co	9.19E+00	mg/l

Remedial Targets

Level 3 Remedial Target		**1.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.96E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**1.09E-02**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

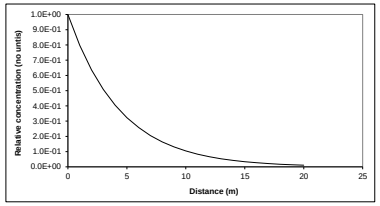
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	6.26E+00
1.0	7.98E-01	4.99E+00
2.0	6.36E-01	3.98E+00
3.0	5.08E-01	3.18E+00
4.0	4.05E-01	2.53E+00
5.0	3.23E-01	2.02E+00
6.0	2.58E-01	1.61E+00
7.0	2.06E-01	1.29E+00
8.0	1.64E-01	1.03E+00
9.0	1.31E-01	8.19E-01
10.0	1.04E-01	6.53E-01
11.0	8.33E-02	5.21E-01
12.0	6.64E-02	4.16E-01
13.0	5.30E-02	3.32E-01
14.0	4.23E-02	2.64E-01
15.0	3.37E-02	2.11E-01
16.0	2.69E-02	1.68E-01
17.0	2.15E-02	1.34E-01
18.0	1.71E-02	1.07E-01
19.0	1.37E-02	8.54E-02
20.0	1.09E-02	6.82E-02

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	1.30E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-05	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+01	days	*Howard et al*
Calculated decay rate	λ	3.47E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	5.18E-03	d^{-1}
Rate of contaminant flow due to retardation	u	4.03E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.38E-10	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.45E+05**	

Remedial Targets

Remedial Target		**1.88E+04**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.38E-10**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

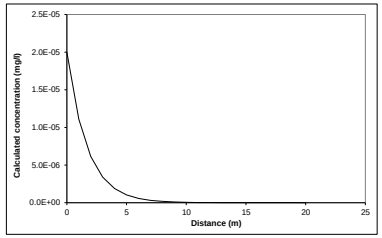
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-05
1.0	1.11E-05
2.0	6.15E-06
3.0	3.41E-06
4.0	1.89E-06
5.0	1.05E-06
6.0	5.79E-07
7.0	3.21E-07
8.0	1.77E-07
9.0	9.80E-08
10.0	5.41E-08
11.0	2.98E-08
12.0	1.64E-08
13.0	9.06E-09
14.0	4.99E-09
15.0	2.75E-09
16.0	1.51E-09
17.0	8.32E-10
18.0	4.58E-10
19.0	2.52E-10
20.0	1.38E-10

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aliphatic C10-C12**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aliphatic C10-C12**		
Target concentration	C_T	**0.01**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.71E+02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.37E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.39E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aliphatic C10-C12**		from Level 1
Target concentration	C_T	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**2.73E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.47E+02	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C10-C12		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		38	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	3.65E+03	days	*Howard et al*
Calculated decay rate	λ	1.90E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.37E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	1.22E+04	fraction
Decay rate used	λ	1.56E-08	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	3.50E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.15E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.09E+00**	**fraction**
Calculated soil leachate concentration	Co	7.05E-03	mg/l

Remedial Targets

Level 3 Remedial Target		**2.98E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.61E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.15E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.37E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

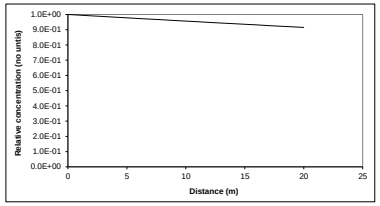
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.58E-03
1.0	9.96E-01	2.57E-03
2.0	9.91E-01	2.56E-03
3.0	9.87E-01	2.55E-03
4.0	9.82E-01	2.54E-03
5.0	9.78E-01	2.53E-03
6.0	9.74E-01	2.52E-03
7.0	9.69E-01	2.50E-03
8.0	9.65E-01	2.49E-03
9.0	9.61E-01	2.48E-03
10.0	9.57E-01	2.47E-03
11.0	9.52E-01	2.46E-03
12.0	9.48E-01	2.45E-03
13.0	9.44E-01	2.44E-03
14.0	9.40E-01	2.43E-03
15.0	9.36E-01	2.42E-03
16.0	9.32E-01	2.41E-03
17.0	9.28E-01	2.40E-03
18.0	9.23E-01	2.39E-03
19.0	9.19E-01	2.37E-03
20.0	9.15E-01	2.36E-03

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C10-C12		from Level 1
Target Concentration	C_T	1.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.00E-02	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	3.65E+03	days	*Howard et al*
Calculated decay rate	λ	1.90E-04	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Time since pollutant entered groundwater	y	0.00E+00	m	
Parameters values determined from options	t	1.00E+100	days	*time variant options only*
Partition coefficient	Kd	5.37E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.22E+04	fraction
Decay rate used	λ	1.56E-08	d^{-1}
Rate of contaminant flow due to retardation	u	2.22E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	8.03E-03	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.25E+00**	

Remedial Targets

Remedial Target		**1.25E-02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**8.03E-03**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

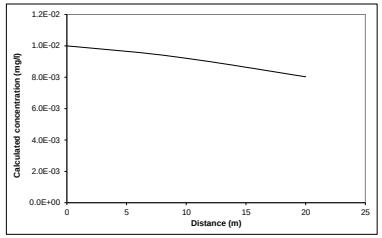
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\ n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\ i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.37E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value Xu & Eckstein		
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E-02
1.0	9.93E-03
2.0	9.86E-03
3.0	9.79E-03
4.0	9.73E-03
5.0	9.65E-03
6.0	9.58E-03
7.0	9.50E-03
8.0	9.41E-03
9.0	9.31E-03
10.0	9.21E-03
11.0	9.11E-03
12.0	8.99E-03
13.0	8.88E-03
14.0	8.76E-03
15.0	8.64E-03
16.0	8.52E-03
17.0	8.40E-03
18.0	8.27E-03
19.0	8.15E-03
20.0	8.03E-03

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aliphatic C16-C35**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aliphatic C16-C35**	
Target concentration	C_T	**0.01**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.07E+03	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.75E+09	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.75E+06**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.75E+04**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aliphatic C16-C35**		from Level 1
Target concentration	C_T	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**2.73E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.57E+05	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C16-C35		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		98	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	8.56E+03	days	*Howard et al*
Calculated decay rate	λ	8.10E-05	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.75E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	1.30E+04	fraction
Decay rate used	λ	6.22E-09	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	3.27E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.63E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.04E+00**	**fraction**
Calculated soil leachate concentration	Co	1.70E-05	mg/l

Remedial Targets

Level 3 Remedial Target		**2.83E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.63E+05	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.63E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd [redacted] l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+06	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg
pH value	pH	[redacted]	
Acid dissociation constant	pKa	[redacted]	
Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Soil water partition coefficient	Kd	5.75E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

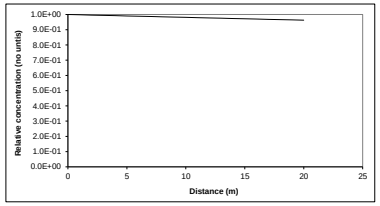
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	6.24E-06
1.0	9.98E-01	6.23E-06
2.0	9.96E-01	6.22E-06
3.0	9.94E-01	6.21E-06
4.0	9.92E-01	6.20E-06
5.0	9.91E-01	6.18E-06
6.0	9.89E-01	6.17E-06
7.0	9.87E-01	6.16E-06
8.0	9.85E-01	6.15E-06
9.0	9.83E-01	6.14E-06
10.0	9.81E-01	6.13E-06
11.0	9.79E-01	6.11E-06
12.0	9.78E-01	6.10E-06
13.0	9.76E-01	6.09E-06
14.0	9.74E-01	6.08E-06
15.0	9.72E-01	6.07E-06
16.0	9.70E-01	6.06E-06
17.0	9.68E-01	6.05E-06
18.0	9.66E-01	6.03E-06
19.0	9.65E-01	6.02E-06
20.0	9.63E-01	6.01E-06

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C16-C35		from Level 1
Target Concentration	C_T	1.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	7.00E-02	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	8.56E+03	days	*Howard et al*
Calculated decay rate	λ	8.10E-05	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.75E+06	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.30E+07	fraction
Decay rate used	λ	6.22E-12	d^{-1}
Rate of contaminant flow due to retardation	u	2.07E-09	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	6.09E-02	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.15E+00**	

Remedial Targets

Remedial Target		**1.15E-02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**6.09E-02**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

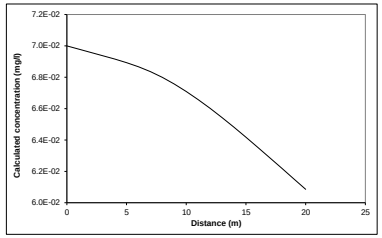
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+09	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.75E+06	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value Xu & Eckstein		
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	7.0E-02
1.0	6.98E-02
2.0	6.96E-02
3.0	6.94E-02
4.0	6.92E-02
5.0	6.89E-02
6.0	6.87E-02
7.0	6.84E-02
8.0	6.80E-02
9.0	6.76E-02
10.0	6.71E-02
11.0	6.66E-02
12.0	6.60E-02
13.0	6.54E-02
14.0	6.48E-02
15.0	6.42E-02
16.0	6.35E-02
17.0	6.29E-02
18.0	6.22E-02
19.0	6.15E-02
20.0	6.09E-02

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C10-C12**			
Target Concentration (C_T)	**0.03**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C10-C12**	
Target concentration	C_T	**0.03**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	7.22E-02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	2.51E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.51E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**8.49E-02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.03	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C10-C12**		from Level 1
Target concentration	C_T	**0.03**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**8.18E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		2.32E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C10-C12		from Level 1
Target Concentration	C_T	0.03	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		30	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.50E+01	days	*Howard et al*
Calculated decay rate	λ	2.77E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	4.15E-03	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	6.36E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	5.73E-04	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.74E+03**	**fraction**
Calculated soil leachate concentration	Co	1.06E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.43E+02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.04E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**5.73E-04**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd [redacted] l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg
pH value	pH	[redacted]	
Acid dissociation constant	pKa	[redacted]	
Fraction of organic carbon in aquifer	foc	[redacted]	fraction

Soil water partition coefficient Kd 2.51E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

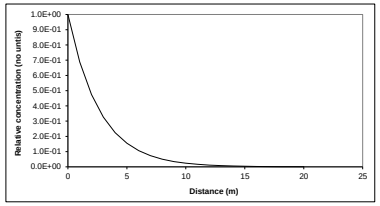
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	3.89E+00
1.0	6.89E-01	2.68E+00
2.0	4.74E-01	1.84E+00
3.0	3.26E-01	1.27E+00
4.0	2.25E-01	8.74E-01
5.0	1.55E-01	6.01E-01
6.0	1.07E-01	4.14E-01
7.0	7.34E-02	2.85E-01
8.0	5.05E-02	1.96E-01
9.0	3.48E-02	1.35E-01
10.0	2.39E-02	9.31E-02
11.0	1.65E-02	6.41E-02
12.0	1.14E-02	4.41E-02
13.0	7.82E-03	3.04E-02
14.0	5.38E-03	2.09E-02
15.0	3.71E-03	1.44E-02
16.0	2.55E-03	9.92E-03
17.0	1.76E-03	6.83E-03
18.0	1.21E-03	4.70E-03
19.0	8.33E-04	3.24E-03
20.0	5.73E-04	2.23E-03

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C10-C12		from Level 1
Target Concentration	C_T	3.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.00E-02	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+01	days	*Howard et al*
Calculated decay rate	λ	3.47E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	5.18E-03	d^{-1}
Rate of contaminant flow due to retardation	u	4.03E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.77E-07	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**1.45E+05**	

Remedial Targets

Remedial Target		**4.34E+03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**2.77E-07**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

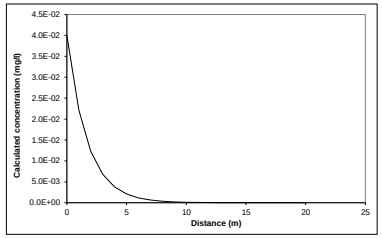
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	4.0E-02
1.0	2.22E-02
2.0	1.23E-02
3.0	6.81E-03
4.0	3.78E-03
5.0	2.09E-03
6.0	1.16E-03
7.0	6.41E-04
8.0	3.55E-04
9.0	1.96E-04
10.0	1.08E-04
11.0	5.97E-05
12.0	3.29E-05
13.0	1.81E-05
14.0	9.98E-06
15.0	5.50E-06
16.0	3.02E-06
17.0	1.66E-06
18.0	9.15E-07
19.0	5.03E-07
20.0	2.77E-07

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C12-C16**			
Target Concentration (C_T)	**0.13**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C12-C16**		
Target concentration	C_T	**0.13**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.26E-03	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.01E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.01E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**6.92E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.13	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C12-C16**		from Level 1
Target concentration	C_T	**0.13**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**3.55E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.89E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C12-C16		from Level 1
Target Concentration	C_T	0.13	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		250	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+02	days	*Howard et al*
Calculated decay rate	λ	3.47E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.01E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	1.23E+01	fraction
Decay rate used	λ	2.91E-04	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	3.45E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.40E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**4.16E+00**	**fraction**
Calculated soil leachate concentration	Co	4.70E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.48E+00**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		7.85E+00	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**2.40E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.01E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

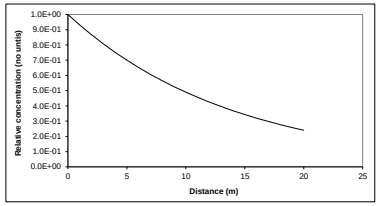
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.72E+01
1.0	9.31E-01	1.60E+01
2.0	8.67E-01	1.49E+01
3.0	8.07E-01	1.39E+01
4.0	7.52E-01	1.30E+01
5.0	7.00E-01	1.21E+01
6.0	6.52E-01	1.12E+01
7.0	6.07E-01	1.05E+01
8.0	5.65E-01	9.74E+00
9.0	5.26E-01	9.07E+00
10.0	4.90E-01	8.44E+00
11.0	4.56E-01	7.86E+00
12.0	4.25E-01	7.32E+00
13.0	3.96E-01	6.82E+00
14.0	3.69E-01	6.35E+00
15.0	3.43E-01	5.91E+00
16.0	3.20E-01	5.51E+00
17.0	2.98E-01	5.13E+00
18.0	2.77E-01	4.77E+00
19.0	2.58E-01	4.44E+00
20.0	2.40E-01	4.14E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C12-C16		from Level 1
Target Concentration	C_T	1.30E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	1.70E-01	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	5.00E+01	days	*Howard et al*
Calculated decay rate	λ	1.39E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.01E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.23E+01	fraction
Decay rate used	λ	1.12E-03	d^{-1}
Rate of contaminant flow due to retardation	u	2.18E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.85E-04	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**5.96E+02**	

Remedial Targets

Remedial Target		**7.75E+01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**2.85E-04**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

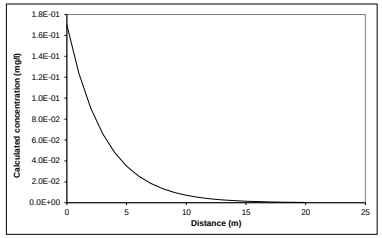
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.01E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.7E-01
1.0	1.24E-01
2.0	9.05E-02
3.0	6.60E-02
4.0	4.81E-02
5.0	3.51E-02
6.0	2.56E-02
7.0	1.86E-02
8.0	1.36E-02
9.0	9.86E-03
10.0	7.16E-03
11.0	5.20E-03
12.0	3.77E-03
13.0	2.73E-03
14.0	1.98E-03
15.0	1.44E-03
16.0	1.04E-03
17.0	7.53E-04
18.0	5.45E-04
19.0	3.94E-04
20.0	2.85E-04

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C16-C21**			
Target Concentration (C_T)	**0.05**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C16-C21**	
Target concentration	C_T	**0.05**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	6.95E-04	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.41E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**7.22E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.05	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C16-C21**		from Level 1
Target concentration	C_T	**0.05**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**1.36E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.97E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C16-C21		from Level 1
Target Concentration	C_T	0.05	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		980	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+02	days	*Howard et al*
Calculated decay rate	λ	7.70E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.41E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	3.30E+01	fraction
Decay rate used	λ	2.34E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	1.29E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	7.05E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.42E+00**	**fraction**
Calculated soil leachate concentration	Co	6.79E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.94E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.79E+00	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**7.05E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction

Soil water partition coefficient — Kd — 1.41E+01 — l/kg

Define dispersivity (click brown cell and use pull down list)

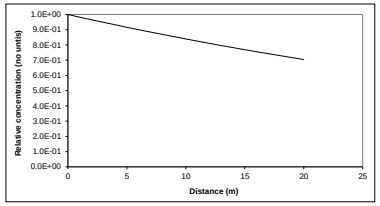
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.49E+01
1.0	9.83E-01	2.45E+01
2.0	9.66E-01	2.40E+01
3.0	9.49E-01	2.36E+01
4.0	9.32E-01	2.32E+01
5.0	9.16E-01	2.28E+01
6.0	9.00E-01	2.24E+01
7.0	8.85E-01	2.20E+01
8.0	8.69E-01	2.16E+01
9.0	8.54E-01	2.13E+01
10.0	8.40E-01	2.09E+01
11.0	8.25E-01	2.05E+01
12.0	8.11E-01	2.02E+01
13.0	7.97E-01	1.98E+01
14.0	7.83E-01	1.95E+01
15.0	7.69E-01	1.91E+01
16.0	7.56E-01	1.88E+01
17.0	7.43E-01	1.85E+01
18.0	7.30E-01	1.82E+01
19.0	7.17E-01	1.79E+01
20.0	7.05E-01	1.75E+01

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C16-C21		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	5.70E-01	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	2.10E+02	days	*Howard et al*
Calculated decay rate	λ	3.30E-03	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.41E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	3.30E+01	fraction
Decay rate used	λ	1.00E-04	d^{-1}
Rate of contaminant flow due to retardation	u	8.17E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	6.87E-02	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**8.30E+00**	

Remedial Targets

Remedial Target		**4.15E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**6.87E-02**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

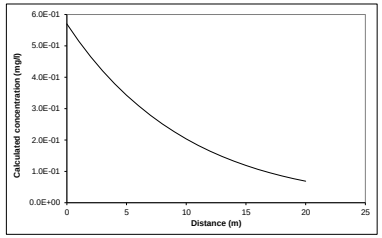
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\ n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\ i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.41E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value Xu & Eckstein		
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	5.7E-01
1.0	5.15E-01
2.0	4.65E-01
3.0	4.20E-01
4.0	3.79E-01
5.0	3.43E-01
6.0	3.09E-01
7.0	2.79E-01
8.0	2.51E-01
9.0	2.26E-01
10.0	2.03E-01
11.0	1.83E-01
12.0	1.64E-01
13.0	1.47E-01
14.0	1.32E-01
15.0	1.19E-01
16.0	1.06E-01
17.0	9.54E-02
18.0	8.55E-02
19.0	7.67E-02
20.0	6.87E-02

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aliphatic C12-C16**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aliphatic C12-C16**	
Target concentration	C_T	**0.01**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.71E+02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.37E+06	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.37E+03**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.39E+01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aliphatic C12-C16**		from Level 1
Target concentration	C_T	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**1.47E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		7.92E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C12-C16		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		10	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	3.65E+03	days	*Howard et al*
Calculated decay rate	λ	1.90E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.37E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	1.22E+04	fraction
Decay rate used	λ	1.56E-08	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	6.95E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.56E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.05E+00**	**fraction**
Calculated soil leachate concentration	Co	1.85E-03	mg/l

Remedial Targets

Level 3 Remedial Target	**1.54E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks	**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
	8.28E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point	**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0 9.56E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd [redacted] l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg
pH value	pH	[redacted]	
Acid dissociation constant	pKa	[redacted]	
Fraction of organic carbon in aquifer	foc	[redacted]	fraction

Soil water partition coefficient Kd 5.37E+03 l/kg

Define dispersivity (click brown cell and use pull down list)

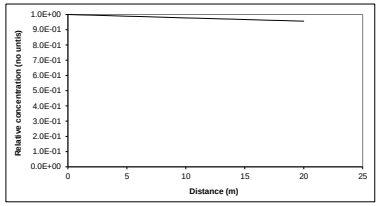
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.26E-03
1.0	9.98E-01	1.26E-03
2.0	9.96E-01	1.26E-03
3.0	9.93E-01	1.25E-03
4.0	9.91E-01	1.25E-03
5.0	9.89E-01	1.25E-03
6.0	9.87E-01	1.25E-03
7.0	9.84E-01	1.24E-03
8.0	9.82E-01	1.24E-03
9.0	9.80E-01	1.24E-03
10.0	9.78E-01	1.23E-03
11.0	9.76E-01	1.23E-03
12.0	9.74E-01	1.23E-03
13.0	9.71E-01	1.23E-03
14.0	9.69E-01	1.22E-03
15.0	9.67E-01	1.22E-03
16.0	9.65E-01	1.22E-03
17.0	9.63E-01	1.22E-03
18.0	9.61E-01	1.21E-03
19.0	9.58E-01	1.21E-03
20.0	9.56E-01	1.21E-03

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C12-C16		from Level 1
Target Concentration	C_T	1.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	3.65E+03	days	*Howard et al*
Calculated decay rate	λ	1.90E-04	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.37E+03	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.22E+04	fraction
Decay rate used	λ	1.56E-08	d^{-1}
Rate of contaminant flow due to retardation	u	2.22E-06	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.61E-02	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.25E+00**	

Remedial Targets

Remedial Target		**1.25E-02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.61E-02**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

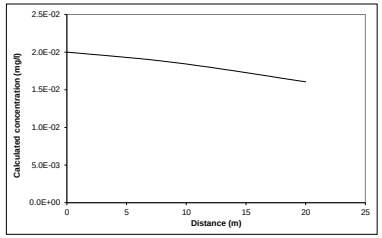
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.37E+06	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.37E+03	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-02
1.0	1.99E-02
2.0	1.97E-02
3.0	1.96E-02
4.0	1.95E-02
5.0	1.93E-02
6.0	1.92E-02
7.0	1.90E-02
8.0	1.88E-02
9.0	1.86E-02
10.0	1.84E-02
11.0	1.82E-02
12.0	1.80E-02
13.0	1.78E-02
14.0	1.75E-02
15.0	1.73E-02
16.0	1.70E-02
17.0	1.68E-02
18.0	1.65E-02
19.0	1.63E-02
20.0	1.61E-02

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C21-C35**			
Target Concentration (C_T)	**0.05**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C21-C35**	
Target concentration	C_T	**0.05**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	2.48E-05	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	1.26E+05	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.26E+02**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**6.31E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.05	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C21-C35**		from Level 1
Target concentration	C_T	**0.05**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	9.36E+02	m^2	**39m x 24m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.90E+01	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	2.40E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	7.74E+00	m		

Calculated Parameters

Dilution Factor	**DF**	**2.73E+00**		
Level 2 Remedial Target		**1.36E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.72E+01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C21-C35		from Level 1
Target Concentration	C_T	0.05	mg/l	from Level 1
Dilution Factor	DF	2.73E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		1000	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.28E+02	days	*Howard et al*
Calculated decay rate	λ	3.04E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.40E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	7.74E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	1.11E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.26E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	4.25E-02	m/d
Retardation factor	Rf	2.86E+02	fraction
Decay rate used	λ	1.06E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	1.11E-02	fraction
Rate of contaminant flow due to retardation	u	1.49E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	2.81E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**3.56E+00**	**fraction**
Calculated soil leachate concentration	Co	7.92E+00	mg/l

Remedial Targets

Level 3 Remedial Target		**4.85E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		6.12E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**2.81E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.26E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

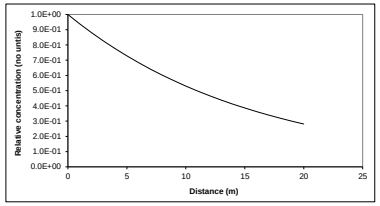
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.91E+00
1.0	9.39E-01	2.73E+00
2.0	8.81E-01	2.56E+00
3.0	8.27E-01	2.40E+00
4.0	7.76E-01	2.25E+00
5.0	7.28E-01	2.12E+00
6.0	6.84E-01	1.99E+00
7.0	6.41E-01	1.86E+00
8.0	6.02E-01	1.75E+00
9.0	5.65E-01	1.64E+00
10.0	5.30E-01	1.54E+00
11.0	4.98E-01	1.45E+00
12.0	4.67E-01	1.36E+00
13.0	4.38E-01	1.27E+00
14.0	4.12E-01	1.20E+00
15.0	3.86E-01	1.12E+00
16.0	3.62E-01	1.05E+00
17.0	3.40E-01	9.88E-01
18.0	3.19E-01	9.28E-01
19.0	3.00E-01	8.71E-01
20.0	2.81E-01	8.17E-01

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C21-C35		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	8.00E-02	mg/l	*BH301*
Half life for degradation of contaminant in water	$t_{1/2}$	5.70E+01	days	*Howard et al*
Calculated decay rate	λ	1.22E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	7.74E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Time since pollutant entered groundwater	y	0.00E+00	m	
Parameters values determined from options	t	1.00E+100	days	*time variant options only*
Partition coefficient	Kd	1.26E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	2.86E+02	fraction
Decay rate used	λ	4.25E-05	d^{-1}
Rate of contaminant flow due to retardation	u	9.42E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.38E-04	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**3.36E+02**	

Remedial Targets

Remedial Target		**1.68E+01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**2.38E-04**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

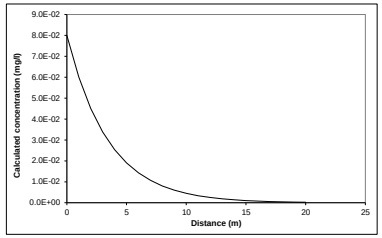
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.26E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	8.0E-02
1.0	6.01E-02
2.0	4.51E-02
3.0	3.38E-02
4.0	2.54E-02
5.0	1.91E-02
6.0	1.43E-02
7.0	1.07E-02
8.0	8.02E-03
9.0	6.00E-03
10.0	4.49E-03
11.0	3.35E-03
12.0	2.50E-03
13.0	1.87E-03
14.0	1.39E-03
15.0	1.04E-03
16.0	7.74E-04
17.0	5.77E-04
18.0	4.29E-04
19.0	3.20E-04
20.0	2.38E-04

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aliphatic C16-C35**			
Target Concentration (C_T)	**0.01**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aliphatic C16-C35**	
Target concentration	C_T	**0.01**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.07E+03	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.75E+09	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.75E+06**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**5.75E+04**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.01	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aliphatic C16-C35**		from Level 1
Target concentration	C_T	**0.01**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**1.47E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		8.45E+04	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C16-C35		from Level 1
Target Concentration	C_T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		217	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	8.56E+03	days	*Howard et al*
Calculated decay rate	λ	8.10E-05	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.75E+06	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	1.30E+07	fraction
Decay rate used	λ	6.22E-12	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	6.49E-09	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	9.81E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.02E+00**	**fraction**
Calculated soil leachate concentration	Co	3.77E-05	mg/l

Remedial Targets

Level 3 Remedial Target		**1.50E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		8.61E+04	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**9.81E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd [redacted] l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+09	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	[redacted]	l/kg
pH value	pH	[redacted]	
Acid dissociation constant	pKa	[redacted]	
Fraction of organic carbon in aquifer	foc	[redacted]	fraction

Soil water partition coefficient Kd 5.75E+06 l/kg

Define dispersivity (click brown cell and use pull down list)

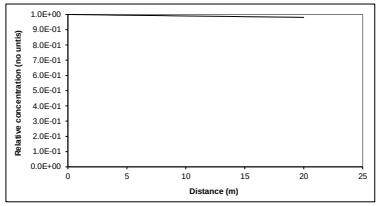
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.57E-05
1.0	9.99E-01	2.57E-05
2.0	9.98E-01	2.56E-05
3.0	9.97E-01	2.56E-05
4.0	9.96E-01	2.56E-05
5.0	9.95E-01	2.56E-05
6.0	9.94E-01	2.55E-05
7.0	9.93E-01	2.55E-05
8.0	9.92E-01	2.55E-05
9.0	9.91E-01	2.55E-05
10.0	9.90E-01	2.54E-05
11.0	9.90E-01	2.54E-05
12.0	9.89E-01	2.54E-05
13.0	9.88E-01	2.54E-05
14.0	9.87E-01	2.53E-05
15.0	9.86E-01	2.53E-05
16.0	9.85E-01	2.53E-05
17.0	9.84E-01	2.53E-05
18.0	9.83E-01	2.52E-05
19.0	9.82E-01	2.52E-05
20.0	9.81E-01	2.52E-05

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aliphatic C16-C35		from Level 1
Target Concentration	C_T	1.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	8.56E+03	days	*Howard et al*
Calculated decay rate	λ	8.10E-05	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Time since pollutant entered groundwater	y	0.00E+00	m	
Parameters values determined from options	t	1.00E+100	days	*time variant options only*
Partition coefficient	Kd	5.75E+06	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.30E+07	fraction
Decay rate used	λ	6.22E-12	d^{-1}
Rate of contaminant flow due to retardation	u	2.07E-09	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	3.48E-02	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.15E+00**	

Remedial Targets

Remedial Target		**1.15E-02**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**3.48E-02**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.75E+09	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.75E+06	l/kg

Define dispersivity (click brown cell and use pull down list)

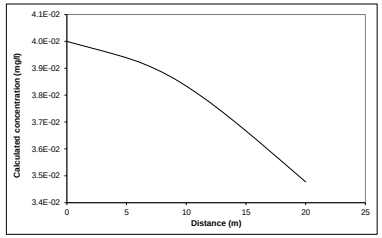
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	4.0E-02
1.0	3.99E-02
2.0	3.98E-02
3.0	3.96E-02
4.0	3.95E-02
5.0	3.94E-02
6.0	3.92E-02
7.0	3.91E-02
8.0	3.89E-02
9.0	3.86E-02
10.0	3.83E-02
11.0	3.80E-02
12.0	3.77E-02
13.0	3.74E-02
14.0	3.70E-02
15.0	3.67E-02
16.0	3.63E-02
17.0	3.59E-02
18.0	3.55E-02
19.0	3.52E-02
20.0	3.48E-02

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C10-C12**			
Target Concentration (C_T)	**0.03**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C10-C12**	
Target concentration	C_T	**0.03**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	7.22E-02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	2.55E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.55E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**8.61E-02**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.03	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C10-C12**		from Level 1
Target concentration	C_T	**0.03**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**4.40E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.26E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C10-C12		from Level 1
Target Concentration	C_T	0.03	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		10	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.50E+01	days	*Howard et al*
Calculated decay rate	λ	2.77E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	4.15E-03	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	1.26E-02	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	1.09E-02	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**9.18E+01**	**fraction**
Calculated soil leachate concentration	Co	3.48E+00	mg/l

Remedial Targets

Level 3 Remedial Target		**4.04E+00**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.16E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**1.09E-02**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

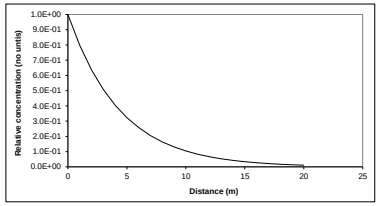
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.37E+00
1.0	7.98E-01	1.89E+00
2.0	6.36E-01	1.51E+00
3.0	5.08E-01	1.20E+00
4.0	4.05E-01	9.61E-01
5.0	3.23E-01	7.67E-01
6.0	2.58E-01	6.12E-01
7.0	2.06E-01	4.88E-01
8.0	1.64E-01	3.89E-01
9.0	1.31E-01	3.11E-01
10.0	1.04E-01	2.48E-01
11.0	8.33E-02	1.98E-01
12.0	6.64E-02	1.58E-01
13.0	5.30E-02	1.26E-01
14.0	4.23E-02	1.00E-01
15.0	3.37E-02	8.00E-02
16.0	2.69E-02	6.38E-02
17.0	2.15E-02	5.09E-02
18.0	1.71E-02	4.06E-02
19.0	1.37E-02	3.24E-02
20.0	1.09E-02	2.59E-02

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C10-C12		from Level 1
Target Concentration	C_T	3.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+01	days	*Howard et al*
Calculated decay rate	λ	3.47E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	5.18E-03	d^{-1}
Rate of contaminant flow due to retardation	u	4.03E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.38E-07	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.45E+05**	

Remedial Targets

Remedial Target		**4.34E+03**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.38E-07**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

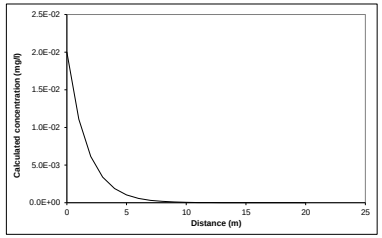
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-02
1.0	1.11E-02
2.0	6.15E-03
3.0	3.41E-03
4.0	1.89E-03
5.0	1.05E-03
6.0	5.79E-04
7.0	3.21E-04
8.0	1.77E-04
9.0	9.80E-05
10.0	5.41E-05
11.0	2.98E-05
12.0	1.64E-05
13.0	9.06E-06
14.0	4.99E-06
15.0	2.75E-06
16.0	1.51E-06
17.0	8.32E-07
18.0	4.58E-07
19.0	2.52E-07
20.0	1.38E-07

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C12-C16**			
Target Concentration (C_T)	**0.13**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C12-C16**	
Target concentration	C_T	**0.13**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	1.26E-03	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	5.01E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**5.01E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**6.92E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.13	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C12-C16**		from Level 1
Target concentration	C_T	**0.13**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**1.91E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.02E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C12-C16		from Level 1
Target Concentration	C_T	0.13	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		420	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+02	days	*Howard et al*
Calculated decay rate	λ	3.47E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.01E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	1.23E+01	fraction
Decay rate used	λ	2.91E-04	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	6.84E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	4.67E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**2.14E+00**	**fraction**
Calculated soil leachate concentration	Co	7.89E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**4.09E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		2.18E+00	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**4.67E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.01E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

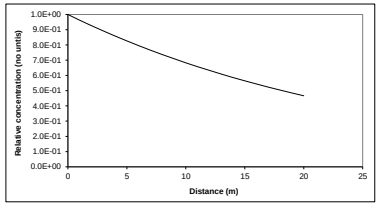
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	5.38E+01
1.0	9.63E-01	5.18E+01
2.0	9.27E-01	4.98E+01
3.0	8.92E-01	4.80E+01
4.0	8.59E-01	4.62E+01
5.0	8.27E-01	4.44E+01
6.0	7.96E-01	4.28E+01
7.0	7.66E-01	4.12E+01
8.0	7.37E-01	3.96E+01
9.0	7.10E-01	3.82E+01
10.0	6.83E-01	3.67E+01
11.0	6.58E-01	3.54E+01
12.0	6.33E-01	3.40E+01
13.0	6.09E-01	3.28E+01
14.0	5.87E-01	3.15E+01
15.0	5.65E-01	3.04E+01
16.0	5.43E-01	2.92E+01
17.0	5.23E-01	2.81E+01
18.0	5.04E-01	2.71E+01
19.0	4.85E-01	2.61E+01
20.0	4.67E-01	2.51E+01

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C12-C16		from Level 1
Target Concentration	C_T	1.30E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	5.00E+01	days	*Howard et al*
Calculated decay rate	λ	1.39E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance (lateral) to compliance point perpendicular to flow direction	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	5.01E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	1.23E+01	fraction
Decay rate used	λ	1.12E-03	d^{-1}
Rate of contaminant flow due to retardation	u	2.18E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	3.36E-05	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**5.96E+02**	

Remedial Targets

Remedial Target		**7.75E+01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**3.36E-05**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

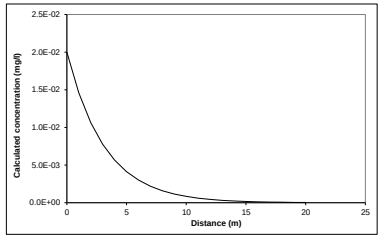
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	5.01E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.01E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value Xu & Eckstein		
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-02
1.0	1.46E-02
2.0	1.06E-02
3.0	7.76E-03
4.0	5.66E-03
5.0	4.13E-03
6.0	3.01E-03
7.0	2.19E-03
8.0	1.59E-03
9.0	1.16E-03
10.0	8.42E-04
11.0	6.11E-04
12.0	4.44E-04
13.0	3.22E-04
14.0	2.33E-04
15.0	1.69E-04
16.0	1.22E-04
17.0	8.85E-05
18.0	6.41E-05
19.0	4.64E-05
20.0	3.36E-05

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C16-C21**			
Target Concentration (C_T)	**0.05**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C16-C21**		
Target concentration	C_T	**0.05**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	6.95E-04	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	1.41E+04	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.41E+01**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**7.22E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.05	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C16-C21**		from Level 1
Target concentration	C_T	**0.05**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**7.34E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		1.06E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Environment Agency

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C16-C21		from Level 1
Target Concentration	C_T	0.05	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — **Equations in HRA publication**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		2700	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+02	days	*Howard et al*
Calculated decay rate	λ	7.70E-04	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.41E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.41E+01	l/kg

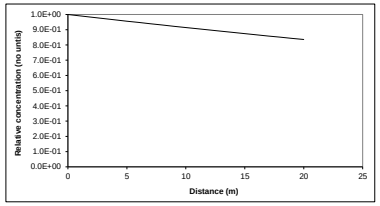
Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	az	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	ay	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.27E+02
1.0	9.91E-01	1.26E+02
2.0	9.82E-01	1.25E+02
3.0	9.73E-01	1.24E+02
4.0	9.65E-01	1.23E+02
5.0	9.56E-01	1.22E+02
6.0	9.48E-01	1.21E+02
7.0	9.39E-01	1.20E+02
8.0	9.31E-01	1.19E+02
9.0	9.23E-01	1.18E+02
10.0	9.14E-01	1.17E+02
11.0	9.06E-01	1.15E+02
12.0	8.98E-01	1.14E+02
13.0	8.90E-01	1.13E+02
14.0	8.82E-01	1.12E+02
15.0	8.74E-01	1.11E+02
16.0	8.67E-01	1.10E+02
17.0	8.59E-01	1.09E+02
18.0	8.51E-01	1.08E+02
19.0	8.44E-01	1.07E+02
20.0	8.36E-01	1.07E+02

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	3.30E+01	fraction
Decay rate used	λ	2.34E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	2.56E-03	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	8.36E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.20E+00**	**fraction**
Calculated soil leachate concentration	Co	1.87E+02	mg/l

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Remedial Targets

Level 3 Remedial Target		**8.78E-02**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.27E+00	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**8.36E-01**	**fraction**	Ogata Banks

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C16-C21		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	2.10E+02	days	*Howard et al*
Calculated decay rate	λ	3.30E-03	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.41E+01	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	3.30E+01	fraction
Decay rate used	λ	1.00E-04	d^{-1}
Rate of contaminant flow due to retardation	u	8.17E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.41E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**8.30E+00**	

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.41E+04	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.41E+01	l/kg

Define dispersivity (click brown cell and use pull down list)

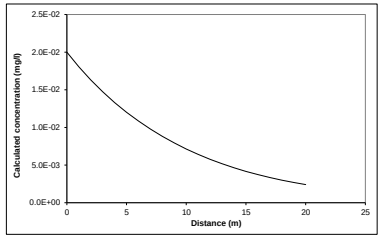
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-02
1.0	1.81E-02
2.0	1.63E-02
3.0	1.47E-02
4.0	1.33E-02
5.0	1.20E-02
6.0	1.08E-02
7.0	9.78E-03
8.0	8.81E-03
9.0	7.93E-03
10.0	7.14E-03
11.0	6.42E-03
12.0	5.76E-03
13.0	5.17E-03
14.0	4.64E-03
15.0	4.17E-03
16.0	3.74E-03
17.0	3.35E-03
18.0	3.00E-03
19.0	2.69E-03
20.0	2.41E-03

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Remedial Targets

Remedial Target		**4.15E-01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**2.41E-03**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**TPH Aromatic C21-C35**			
Target Concentration (C_T)	**0.05**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Environment Agency

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**TPH Aromatic C21-C35**	
Target concentration	C_T	**0.05**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	2.48E-05	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	1.26E+05	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**1.26E+02**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**6.31E+00**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.05	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**TPH Aromatic C21-C35**		from Level 1
Target concentration	C_T	**0.05**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**7.34E-02**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		9.26E+00	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C21-C35		from Level 1
Target Concentration	C_T	0.05	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		2900	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.28E+02	days	*Howard et al*
Calculated decay rate	λ	3.04E-03	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.26E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	2.86E+02	fraction
Decay rate used	λ	1.06E-05	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	2.95E-04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	5.10E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**1.96E+00**	**fraction**
Calculated soil leachate concentration	Co	2.30E+01	mg/l

Remedial Targets

Level 3 Remedial Target		**1.44E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		1.82E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**5.10E-01**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction

Soil water partition coefficient — Kd — 1.26E+02 — l/kg

Define dispersivity (click brown cell and use pull down list)

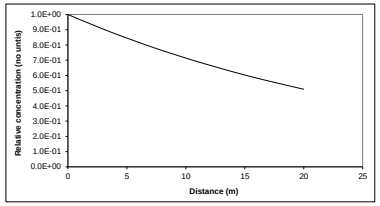
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.57E+01
1.0	9.67E-01	1.51E+01
2.0	9.35E-01	1.46E+01
3.0	9.04E-01	1.41E+01
4.0	8.74E-01	1.37E+01
5.0	8.45E-01	1.32E+01
6.0	8.17E-01	1.28E+01
7.0	7.90E-01	1.24E+01
8.0	7.64E-01	1.20E+01
9.0	7.38E-01	1.16E+01
10.0	7.14E-01	1.12E+01
11.0	6.90E-01	1.08E+01
12.0	6.67E-01	1.04E+01
13.0	6.45E-01	1.01E+01
14.0	6.24E-01	9.76E+00
15.0	6.03E-01	9.44E+00
16.0	5.83E-01	9.13E+00
17.0	5.64E-01	8.83E+00
18.0	5.45E-01	8.53E+00
19.0	5.27E-01	8.25E+00
20.0	5.10E-01	7.98E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		TPH Aromatic C21-C35		from Level 1
Target Concentration	C_T	5.00E-02	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-02	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	5.70E+01	days	*Howard et al*
Calculated decay rate	λ	1.22E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.26E+02	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	2.86E+02	fraction
Decay rate used	λ	4.25E-05	d^{-1}
Rate of contaminant flow due to retardation	u	9.42E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	5.96E-05	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	**3.36E+02**	

Remedial Targets

Remedial Target		**1.68E+01**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**5.96E-05**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

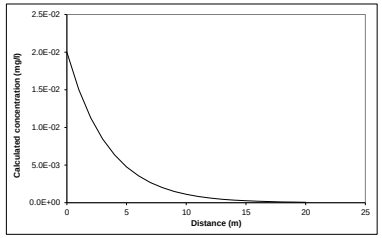
Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	1.26E+05	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.26E+02	l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0
For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-02
1.0	1.50E-02
2.0	1.13E-02
3.0	8.46E-03
4.0	6.35E-03
5.0	4.76E-03
6.0	3.57E-03
7.0	2.68E-03
8.0	2.01E-03
9.0	1.50E-03
10.0	1.12E-03
11.0	8.38E-04
12.0	6.26E-04
13.0	4.67E-04
14.0	3.48E-04
15.0	2.60E-04
16.0	1.93E-04
17.0	1.44E-04
18.0	1.07E-04
19.0	8.00E-05
20.0	5.96E-05

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: October 2006

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions)

Details to be completed for each assessment

Site Name:	**Former Stagecoach Depot**			
Site Address:	**Bowes Street, Manchester**			
Completed by:	**Stephanie Cox**			
Date:	**26-Jan-18**		**Version:**	**1**
Contaminant	**Naphthalene**			
Target Concentration (C_T)	**0.13**	**mg/l**	**Origin of C_T:**	**EQS**

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
Data carried forward from an earlier worksheet are identified by a light green background
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.1

Level 1 - Soil

Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant		**Naphthalene**		
Target concentration	C_T	**0.13**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	3.70E-01	fraction	SR3 sandy clay
Air filled soil porosity	θa	1.60E-01	fraction	SR3 sandy clay
Bulk density of soil zone material	ρ	1.20E+00	g/cm^3	SR3 sandy clay
Henry's Law constant	H	7.22E-02	dimensionless	*LQM - CIEH*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd		l/kg	
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc	1.00E-03	fraction	Arbitrary value for clay soil
Organic carbon partition coefficient	Koc	2.51E+03	l/kg	*LQM - CIEH*
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Fraction of organic carbon (in soil)	foc		fraction	
Soil water partition coefficient used in Level Assessment	**Kd**	**2.51E+00**	**l/kg**	*Calculated value*

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Level 1 Remedial Target

Level 1 Remedial Target	**3.68E-01**	**mg/kg**	**(for comparison with soil analyses)**
	or		
	0.13	**mg/l**	**(for comparison with leachate test results)**

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 2 - Soil

Contaminant		**Naphthalene**		from Level 1
Target concentration	C_T	**0.13**	**mg/l**	from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamiantion' (Environment Agency 2006)

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	1.64E-03	m/d	**assume 600mm/yr with transpiration**	
Area of contaminant source	A	1.02E+04	m^2	**186m x 55m**	Not used in calculation
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	1.86E+02	m		
Saturated aquifer thickness	da	1.00E+01	m	**Based on nearby BGS borehole data**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	2.04E+00	m/d	**SR3 sandy clay**	
Hydraulic gradient of water table	i	7.00E-03	fraction	**Site data**	
Width of contaminant source perpendicular to groundwater flow	w	5.50E+01	m	**estimate based on borehole data**	Not used in calculation
Background concentration of contaminant in groundwater beneath site	Cu	0.00E+00	mg/l		
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone thickness	Mz		m		
Calculated mixing zone thickness	Mz	1.00E+01	m		

Calculated Parameters

Dilution Factor	**DF**	**1.47E+00**		
Level 2 Remedial Target		**1.91E-01**	**mg/l**	**For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentra**
		or		
		5.40E-01	**mg/kg**	**For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water**

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	CP10
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	0

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26-Jan-18
Version:	1

Remedial Targets Worksheet , Release 3.1

Level 3 - Soil

See Note

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	0.13	mg/l	from Level 1
Dilution Factor	DF	1.47E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil concentration as mg/kg		
Enter soil concentration		26	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	2.50E+01	days	*Howard et al*
Calculated decay rate	λ	2.77E-02	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	5.50E+01	m	from Level 2
Plume thickness in aquifer at source	Sy	1.00E+01	m	from Level 2
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	2.20E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.04E+00	m/d	from Level 2
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z		m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.000	m	*see options*
Transverse dispersivity	az	0.200	m	*see options*
Vertical dispersivity	ay	0.020	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	8.45E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	4.15E-03	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	2.20E-02	fraction
Rate of contaminant flow due to retardation	u	1.26E-02	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	1.09E-02	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**9.18E+01**	**fraction**
Calculated soil leachate concentration	Co	9.19E+00	mg/l

Remedial Targets

Level 3 Remedial Target		**1.75E+01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		4.96E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**20**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**1.09E-02**	**fraction**	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	$K_{oc,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

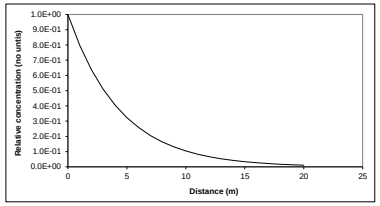
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	26/01/2018
Version:	1

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	6.26E+00
1.0	7.98E-01	4.99E+00
2.0	6.36E-01	3.98E+00
3.0	5.08E-01	3.18E+00
4.0	4.05E-01	2.53E+00
5.0	3.23E-01	2.02E+00
6.0	2.58E-01	1.61E+00
7.0	2.06E-01	1.29E+00
8.0	1.64E-01	1.03E+00
9.0	1.31E-01	8.19E-01
10.0	1.04E-01	6.53E-01
11.0	8.33E-02	5.21E-01
12.0	6.64E-02	4.16E-01
13.0	5.30E-02	3.32E-01
14.0	4.23E-02	2.64E-01
15.0	3.37E-02	2.11E-01
16.0	2.69E-02	1.68E-01
17.0	2.15E-02	1.34E-01
18.0	1.71E-02	1.07E-01
19.0	1.37E-02	8.54E-02
20.0	1.09E-02	6.82E-02

R&D Publication 20 Remedial Targets Worksheet, Release 3.1

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C_T	1.30E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in HRA publication

Approach for simulating vertical dispersion: **Simulate vertical dispersion in 1 direction**

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: **Apply degradation rate to dissolved pollutants only**

				Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	2.00E-05	mg/l	*BH302*
Half life for degradation of contaminant in water	$t_{1/2}$	2.00E+01	days	*Howard et al*
Calculated decay rate	λ	3.47E-02	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	*estimate based on site data*
Plume thickness at source	Sy	9.00E+00	m	*From Level 2*
Saturated aquifer thickness	da	1.00E+01	m	*based on deep BGS borehole*
Bulk density of aquifer materials	ρ	1.20E+00	g/cm^3	*SR3 sandy clay*
Effective porosity of aquifer	n	5.30E-01	fraction	*SR3 sandy clay*
Hydraulic gradient	i	7.00E-03	fraction	*Site levelling data*
Hydraulic conductivity of aquifer	K	2.04E+00	m/d	*SR3 sandy clay*
Distance to compliance point	x	2.00E+01	m	*Contaminant source to underlying aquifer*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	2.51E+00	l/kg	*see options*
Longitudinal dispersivity	ax	2.00E+00	m	*see options*
Transverse dispersivity	az	2.00E-01	m	*see options*
Vertical dispersivity	ay	2.00E-02	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.69E-02	m/d
Retardation factor	Rf	6.69E+00	fraction
Decay rate used	λ	5.18E-03	d^{-1}
Rate of contaminant flow due to retardation	u	4.03E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	1.38E-10	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.45E+05**	

Remedial Targets

Remedial Target		**1.88E+04**	**mg/l**	For comparison with measured groundwater concentration.
Ogata Banks				
Distance to compliance point		**20**	**m**	
Concentration of contaminant at compliance point	C_{ED}/C_0	**1.38E-10**	**mg/l**	Ogata Banks
after		**1.0E+100**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd		l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	1.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc\,n}$		l/kg
Sorption coefficient for ionised species	$K_{oc\,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	2.51E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

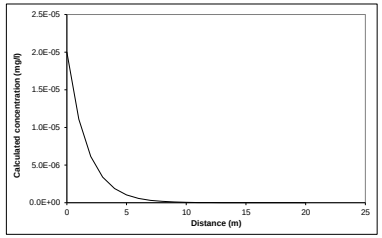
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00E+00	2.00E+00	1.57E+00	m
Transverse dispersivity	**az**	0.00E+00	2.00E-01	1.57E-01	m
Vertical dispersivity	**ay**	0.00E+00	2.00E-02	1.57E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.
Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	2.0E-05
1.0	1.11E-05
2.0	6.15E-06
3.0	3.41E-06
4.0	1.89E-06
5.0	1.05E-06
6.0	5.79E-07
7.0	3.21E-07
8.0	1.77E-07
9.0	9.80E-08
10.0	5.41E-08
11.0	2.98E-08
12.0	1.64E-08
13.0	9.06E-09
14.0	4.99E-09
15.0	2.75E-09
16.0	1.51E-09
17.0	8.32E-10
18.0	4.58E-10
19.0	2.52E-10
20.0	1.38E-10

Site being assessed:	Former Stagecoach Depot
Completed by:	Stephanie Cox
Date:	#######
Version:	1

APPENDIX VII CONTRACTORS COMPLETION DOCUMENT

«AddressBlock»

Manchester / London / Edinburgh
0161 707 9612

info@E3P.co.uk
«Website»

Geotechnical Enabling Works Completion Form

Upon completion of all site remediation and enabling works, this form will be completed by E3P in the presence of the appointed contractor to ensure that all pertinent geotechnical enabling works activities are complete or where a deviation from the specification has occurred, all future limitations and issues are documented for the clients record.

Activity	***Complete***			***Signature (initial)***
	Yes	*No*	*N/A*	
Eradication of all invasive plant species;				
Removal of all vegetation				
Removal of all root bulbs and root networks				
Stockpiling of topsoil and certification of suitability for re-use				
Stockpiling of subsoil and certification of suitability for re-use				
Stockpile all recycled aggregate with geotechnical and chemical validation testing.				
Removal of all relict foundations and infrastructure in their entirety				
Decommission of all redundant drainage infrastructure.				
Decommission of all former interceptors				
Decommission of all former above and below ground tanks				
Removal of all waste materials to a licensed facility				
Removal of all asbestos to a licensed facility				
Engineering of all plots for Shallow Spread Foundation in accordance with E3P Geotechnical Specification.				
Engineering of all plots for VSC in accordance with E3P Geotechnical Specification.				
Engineering of all plots for Pile Foundation in accordance with E3P Geotechnical Specification.				
Engineering of all plots for Raft Foundation in accordance with E3P Geotechnical Specification.				
Engineering of highways bulk upfill in accordance with E3P Specification with compliant validation testing				
Engineering of highways sub-grade in accordance with E3P Specification with compliant validation testing				
Engineering of highways capping in accordance with E3P Specification with compliant validation testing				
Cut and fill the development site to clients required elevation with 'as built' survey.				

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Post Remediation & Enabling Limitations

All and every deviation from the approved specification for works should be documented by the Remediation & Enabling Works Contractor below: