


SUPPLEMENTARY GROUNDWATER MONITORING AND RISK ASSESSMENT

POL19, Heyford Park

For

Paragon Fleet Solutions

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Borehole Location Plan

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1 INTRODUCTION

Pick Everard have previously undertaken a ground investigation at POL19, a below ground fuel installation at Heyford Park currently used by Paragon Fleet Solutions. The installation is a relic of the former Upper Heyford airbase and is the only such facility that remains in operation at the site. It is understood that the tanks are to be decommissioned and replaced by an above ground facility.

1.1 Background

The site lies within the boundary of a planning application for a mixed use development which covers a large part of the former airbase. The investigation was undertaken to establish the presence of any liabilities relating to hydrocarbon contamination (particularly with reference to controlled waters) and any associated implications for the wider planning application site.

The findings of the investigation are presented in the following report;

- ‘Ground Investigation, POL19, Heyford Park’, Pick Everard, Report No. 110799/R002, 18th May 2012.

Following discussions with the Environment Agency and in light of the findings of other investigation works on nearby parts of the application site, it was considered that a second round sampling and analysis of groundwater would be beneficial to supplement that undertaken as part of the original investigation.

The investigation comprised the drilling of six boreholes (the locations of which are presented in Figure 1), the installation of monitoring standpipes and the sampling and analysis of groundwater from each location. The investigation recorded hydrocarbons in three locations (all with the central ‘island’ close to the tanks, at a maximum total concentration of 3mg/l. Groundwater flow is understood to be to the south / south-east, and no hydrocarbons were recorded at locations between the central island and the southern boundary of POL19. Based on these findings, and the assumed presence of an aquiclude protecting the underlying Principal Aquifer from the contaminated shallow groundwater, there were not considered to be any significant risks to controlled waters. However, a second round of sampling and analysis was considered necessary to provide an appropriate level of confidence in the results.

1.2 Scope of work

The scope of the additional phase of sampling, analysis and assessment comprised the following elements;

- Retrieval of samples of groundwater from the 6 existing standpipes;
- Laboratory analysis of samples for petroleum hydrocarbons (Full TPHCWG Aliphatic / Aromatic spilt) at an UKAS / MCERTS accredited laboratory;
- Interpretation of results and risk assessment, including quantitative modelling using the Environment Agency’s Remedial Targets Methodology.

Samples were taken on 6th September 2012.

2 RESULTS

2.1 Groundwater Levels

The following table presents the measured groundwater levels recorded during each monitoring visit.

Monitoring Standpipe	Groundwater Level (m.bgl)	
	11/4/12	6/9/12
BH1	1.78	1.53
BH2	1.82	1.50
BH3	1.71	1.45
BH4	1.49	1.19
BH5	1.70	1.33
BH6	1.92	1.67

Table 1 – Groundwater Levels

2.2 Chemical Analytical Results

The following table presents the results of hydrocarbon analysis undertaken on samples retrieved during the two monitoring visits.

Hydrocarbon Fraction	Concentration on 11/4/12 (µg/l)					
	BH1	BH2	BH3	BH4	BH5	BH6
Aliphatic >C5-6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C6-8	<0.1	<0.1	2300	<0.1	<0.1	<0.1
Aliphatic >C8-10	<0.1	<0.1	420	<0.1	<0.1	<0.1
Aliphatic >C10-12	<0.1	<0.1	60	<0.1	<0.1	<0.1
Aliphatic >C12-16	<0.1	<0.1	4.5	<0.1	<0.1	<0.1
Aliphatic >C16-21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aromatic >C5-7	<0.1	<0.1	95	130	<0.1	250
Aromatic >C7-8	<0.1	<0.1	54	200	<0.1	220
Aromatic >C8-10	<0.1	<0.1	57	130	<0.1	68
Aromatic >C10-12	<0.1	<0.1	39	39	<0.1	11
Aromatic >C12-16	<0.1	<0.1	4.1	<0.1	<0.1	<0.1
Aromatic >C16-21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total	<10	<10	3000	500	<10	550

Table 2 – Hydrocarbon concentrations 11/4/12

Hydrocarbon Fraction	Concentration on 11/4/12 ($\mu\text{g/l}$)					
	BH1	BH2	BH3	BH4	BH5	BH6
Aliphatic >C5-6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C6-8	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C8-10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C10-12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C12-16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aliphatic >C16-21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aromatic >C5-7	<0.1	<0.1	720	<0.1	<0.1	800
Aromatic >C7-8	<0.1	<0.1	990	<0.1	<0.1	710
Aromatic >C8-10	<0.1	<0.1	380	<0.1	<0.1	330
Aromatic >C10-12	<0.1	<0.1	71	<0.1	<0.1	61
Aromatic >C12-16	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Aromatic >C16-21	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total	<10	<10	2200	<10	<10	1900

Table 3 – Hydrocarbon concentrations 6/9/12

3 DISCUSSION AND RISK ASSESSMENT

3.1 General

On each occasion only the boreholes closest to the tanks have recorded the presence of hydrocarbons, with BH3 displaying the highest concentrations. None have been recorded in BH1 or BH2 which are located down hydraulic gradient of the tanks. There is no evidence to indicate that significantly contaminated groundwater is leaving POL19.

The recorded contamination is almost entirely within the light aromatic fractions. An exception is recorded at BH3, where aliphatic hydrocarbons dominated in April, but by September only aromatic hydrocarbons were recorded. The reasons for this are not known. Predominantly aromatic hydrocarbons are common in groundwater, particularly in the dissolved phase, due to their greater solubility. The contamination is generally indicative of petrol range hydrocarbons.

In order to provide greater confidence that the recorded contamination does present a significant risk to controlled waters, an assessment using the Environment Agency's Remedial Targets Methodology has been undertaken. The assessment has used common water quality standards to estimate a source concentration, below which there are not expected to be any significant risks to controlled waters.

3.2 Remedial Targets Inputs

Given the nature of the available information (i.e. contamination concentrations in groundwater, rather than soil) a 'Level 3 Groundwater' assessment has been undertaken for each hydrocarbon fraction of concern, using the excel spreadsheet which supports the Remedial Targets Methodology. The fractions modelled are Aromatic >C5-7, C7-8, C8-10 and C10-12.

Table 4 presents the key input parameters used for each fraction

Parameter	Units	Aromatic Hydrocarbon Fraction			
		>C5-7	>C7-8	>C8-10	>C10-12
Degradation Half-Life	Days	2500	2280	17000	17000
Width of plume at source	m	10 (estimated from site observations)			
Plume thickness at source	m	2 (estimated from site observations)			
Saturated aquifer thickness	m	2.1(estimated from site observations)			
Bulk density of aquifer materials	g/cm3	2.5 (estimate for limestone)			
Effective porosity of aquifer	fraction	0.14 (estimated mean for limestone)			
Hydraulic gradient	fraction	0.007 (from waterman report)			
Hydraulic conductivity of aquifer	m/d	0.7 (Max in shallow groundwater in new settlement area – from Waterman report)			
Distance to compliance point	m	400 (distance to Camp Road)			
Fraction of organic carbon in aquifer	fraction	0.005			
Organic carbon partition coefficient	l/kg	68	252	1590	2510

Table 4 – Remedial Targets Worksheet Inputs

Degradation half lives are based on literature values of degradation in groundwater for indicator compounds from each fraction, these being benzene (>C5-7), ethylbenzene (>C7-8) and naphthalene (>C8-10 & >C10-12). A factor of 10 has been applied to each value for reasons of conservatism. Organic carbon partition co-efficients are based on TPHCWG values for the specific fractions.

The calculations of remedial targets are based on a target concentration for each fraction of 0.01mg/l at the compliance point, which is taken as the site boundary to the south. The target concentration represents an Environmental Quality Standard (EQS) for benzene, and the former UK Drinking Water Standard (DWS) for total hydrocarbons, and is considered conservative for groundwater.

3.3 Remedial Targets Results

The following table presents the modelled remedial targets for groundwater and compares them with the measured concentrations on site. Copies of the worksheets are presented in Appendix 1.

Fraction	Remedial Target (mg/l)	Maximum Measured Concentration (mg/l)
>C5-7	6.66	0.72
>C7-8	8.73	0.99
>C8-10	0.54	0.38
>C10-12	0.54	0.07

Table 5 – Calculated Remedial Targets

The calculated remedial targets shown in Table 5 are all above the maximum measured concentrations in the groundwater. This indicates that the recorded contaminant concentrations should not result in an exceedence of the EQS / DWS at the compliance point.

4 CONCLUSIONS

This assessment has not identified a significant risk to controlled waters from the recorded contaminant concentrations in the shallow groundwater at POL19. Although the site lies above a Principal Aquifer, information from previous investigations indicates that this is protected by an aquiclude between the shallow and deeper groundwater, and the overall quality of the deeper groundwater is understood to be good. The investigation works at POL19 did not penetrate the aquiclude in order to avoid creating potential pathways via which contaminated groundwater could migrate downwards.

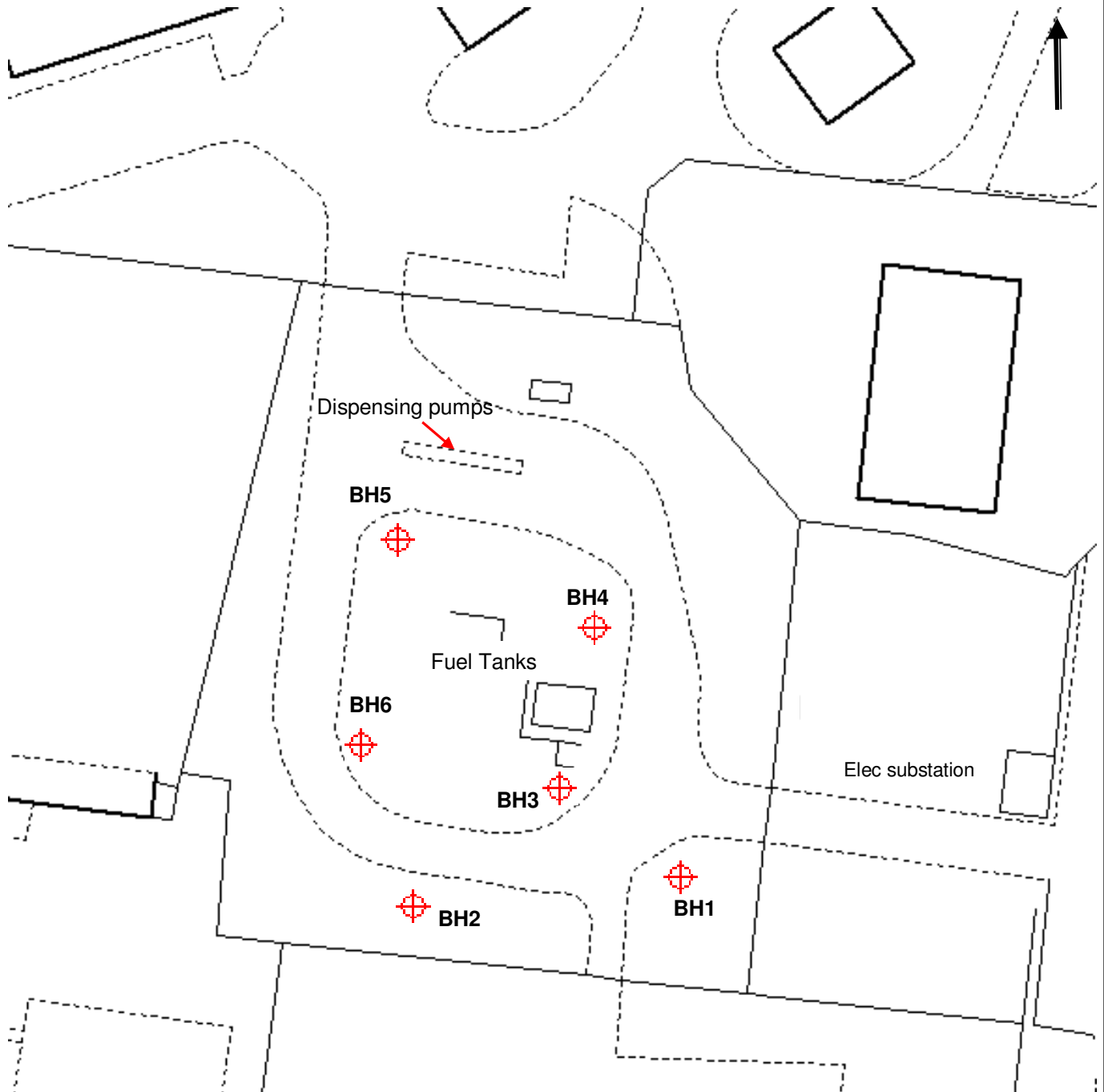
Based on the risk assessment using the Environment Agency's Remedial Targets Methodology, the target concentrations would not be exceeded at the compliance point, taken as Camp Road 400m south of POL19. In reality, hydrocarbon concentrations have not been recorded above detection limits in groundwater 20m south of tanks, which suggests the risks are considerably lower than the Remedial Targets risk assessment suggests.

Overall, there are not considered to be any significant risks to controlled waters based on the available information.

FIGURE 1

Borehole Location Plan

NO DIMENSIONS TO BE SCALED FROM THIS DRAWING



Approximate location of boreholes

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Drawing Title Borehole Locations	Status Final	
	Scale - unless otherwise stated NTS	
	Drawing Number D001MNS - 110799	Rev

APPENDIX 1

Remedial Targets Worksheets

R&D Publication 20 Remedial Targets Worksheet, Release 3.1



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Aromatic 5-7 (Benzene)	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
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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

Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C ₀ 7.20E-01	mg/l	
Half life for degradation of contaminant in water	t _{1/2} 2.50E+03	days	Conservative Estimate based on literature
Calculated decay rate	λ 2.77E-04	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz 1.00E+01	m	
Plume thickness at source	Sy 2.00E+00	m	
Saturated aquifer thickness	da 2.10E+00	m	
Bulk density of aquifer materials	ρ 2.50E+00	g/cm ³	Estimated for limestone
Effective porosity of aquifer	n 1.40E-01	fraction	Estimated mean for limestone
Hydraulic gradient	i 7.00E-03	fraction	From Waterman report - for shallow GW in the south
Hydraulic conductivity of aquifer	K 7.00E-01	m/d	From waterman report - Max in shallow aquifer
Distance to compliance point	x 4.00E+02	m	Distance to Camp Road
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
Partition coefficient	Kd 3.40E-01	l/kg	see options
Longitudinal dispersivity	ax 8.35E+00	m	see options
Transverse dispersivity	az 8.35E-01	m	see options
Vertical dispersivity	ay 8.35E-02	m	see options

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

Calculate for non-polar organic chemicals

Soil water partition coefficient	Kd	3.40E-01	l/kg
Fraction of organic carbon in aquifer	foc	5.00E-03	fraction
Organic carbon partition coefficient	Koc	6.80E+01	l/kg
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	3.40E-01	l/kg

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

Dispersivity based on Xu & Eckstein (1995)

Variable	Enter value	Calc value	Xu & Eckstein	Unit
Longitudinal dispersivity	ax 3.00E+01	4.00E+01	8.35E+00	m
Transverse dispersivity	az 3.00E+00	4.00E+00	8.35E-01	m
Vertical dispersivity	ay 1.00E-03	4.00E-01	8.35E-02	m

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(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

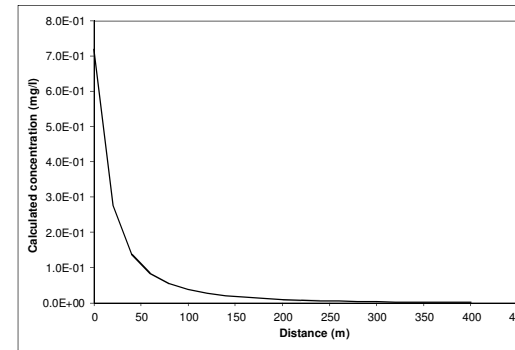
Calculated Parameters

Groundwater flow velocity	v	3.50E-02	m/d
Retardation factor	Rf	7.07E+00	fraction
Decay rate used	λ	3.92E-05	d ⁻¹
Rate of contaminant flow due to retardation	u	4.95E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	1.08E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	6.66E+02	

Remedial Targets

Remedial Target	6.66E+00	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	400	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀ 1.08E-03	mg/l	Ogata Banks
	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.



Calculated concentrations for distance-concentration graph

Distance	Concentration
0	7.2E-01
20.0	2.76E-01
40.0	1.38E-01
60.0	8.32E-02
80.0	5.52E-02
100.0	3.86E-02
120.0	2.80E-02
140.0	2.08E-02
160.0	1.58E-02
180.0	1.22E-02
200.0	9.46E-03
220.0	7.43E-03
240.0	5.88E-03
260.0	4.68E-03
280.0	3.75E-03
300.0	3.02E-03
320.0	2.44E-03
340.0	1.98E-03
360.0	1.62E-03
380.0	1.32E-03
400.0	1.08E-03

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 described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

Site being assessed:	POL19
Completed by:	CMH
Date:	#####
Version:	x.xx

R&D Publication 20 Remedial Targets Worksheet, Release 3.1



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Aromatic 7-8	from Level 1
Target Concentration	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
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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

Initial contaminant concentration in groundwater at plume core	C ₀	9.90E-01	mg/l	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	2.28E+03	days	Conservative Estimate based on literature
Calculated decay rate	λ	3.04E-04	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m	
Plume thickness at source	Sy	2.00E+00	m	
Saturated aquifer thickness	da	2.10E+00	m	
Bulk density of aquifer materials	ρ	2.50E+00	g/cm ³	Estimated for Limestone
Effective porosity of aquifer	n	1.40E-01	fraction	Estimated mean for limestone
Hydraulic gradient	i	7.00E-03	fraction	From Waterman report - for shallow GW in the south
Hydraulic conductivity of aquifer	K	7.00E-01	m/d	From waterman report - Max in shallow aquifer
Distance (lateral) to compliance point	x	4.00E+02	m	Distance to Camp road
Distance (depth) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Time since pollutant entered groundwater	t	1.00E+100	days	time variant options only
Partition coefficient	Kd	1.26E+00	l/kg	see options
Longitudinal dispersivity	ax	8.35E+00	m	see options
Transverse dispersivity	az	8.35E-01	m	see options
Vertical dispersivity	ay	8.35E-02	m	see options

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

Calculate for non-polar organic chemicals

Soil water partition coefficient	Kd	1.26E+00	l/kg
Fraction of organic carbon in aquifer	foc	5.00E-03	fraction
Organic carbon partition coefficient	Koc	2.52E+02	l/kg
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+00	l/kg

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

Dispersivity based on Xu & Eckstein (1995)

Longitudinal dispersivity	ax	0.00E+00	4.00E+01	8.35E+00	m
Transverse dispersivity	az	0.00E+00	4.00E+00	8.35E-01	m
Vertical dispersivity	ay	0.00E+00	4.00E-01	8.35E-02	m

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(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

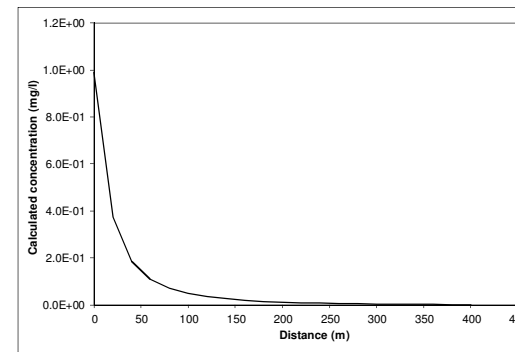
Calculated Parameters

Groundwater flow velocity	v	3.50E-02	m/d
Retardation factor	Rf	2.35E+01	fraction
Decay rate used	λ	1.29E-05	d ⁻¹
Rate of contaminant flow due to retardation	u	1.49E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	1.13E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	8.73E+02	

Remedial Targets

Remedial Target	8.73E+00	mg/l	For comparison with measured groundwater concentration.
Distance to compliance point	400	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀	1.13E-03	mg/l
		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.



Calculated concentrations for distance-concentration graph

Ogata Banks	
From calculation sheet	
Distance	Concentration
	mg/l
0	9.9E-01
20.0	3.75E-01
40.0	1.84E-01
60.0	1.10E-01
80.0	7.19E-02
100.0	4.96E-02
120.0	3.55E-02
140.0	2.61E-02
160.0	1.95E-02
180.0	1.48E-02
200.0	1.14E-02
220.0	8.80E-03
240.0	6.87E-03
260.0	5.40E-03
280.0	4.27E-03
300.0	3.39E-03
320.0	2.71E-03
340.0	2.17E-03
360.0	1.74E-03
380.0	1.40E-03
400.0	1.13E-03

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 described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

Site being assessed:	POL19
Completed by:	CMH
Date:	#####
Version:	x.xx

R&D Publication 20 Remedial Targets Worksheet, Release 3.1



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Aromatic 8-10	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
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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

Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C ₀ 3.80E-01	mg/l	
Half life for degradation of contaminant in water	t _{1/2} 1.70E+04	days	Conservative Estimate based on literature
Calculated decay rate	λ 4.08E-05	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz 1.00E+01	m	
Plume thickness at source	Sy 2.00E+00	m	
Saturated aquifer thickness	da 2.10E+00	m	
Bulk density of aquifer materials	ρ 2.50E+00	g/cm ³	Estimated for Limestone
Effective porosity of aquifer	n 1.40E-01	fraction	Estimated mean for limestone
Hydraulic gradient	i 7.00E-03	fraction	From Waterman report - for shallow GW in the south
Hydraulic conductivity of aquifer	K 7.00E-01	m/d	From waterman report - Max in shallow aquifer
Distance (lateral) to compliance point	x 4.00E+02	m	Distance to Camp road
Distance (depth) to compliance point perpendicular to flow direction	z 0.00E+00	m	
Time since pollutant entered groundwater	t 1.00E+100	days	time variant options only
Partition coefficient	Kd 7.93E+00	l/kg	see options
Longitudinal dispersivity	ax 8.35E+00	m	see options
Transverse dispersivity	az 8.35E-01	m	see options
Vertical dispersivity	ay 8.35E-02	m	see options

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

Calculate for non-polar organic chemicals

Soil water partition coefficient	Kd	7.93E+00	l/kg
Fraction of organic carbon in aquifer	foc	5.00E-03	fraction
Organic carbon partition coefficient	Koc	1.59E+03	l/kg
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	7.93E+00	l/kg

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

Dispersivity based on Xu & Eckstein (1995)

Variable	Enter value	Calc value	Xu & Eckstein	Unit
Longitudinal dispersivity	ax 0.00E+00	4.00E+01	8.35E+00	m
Transverse dispersivity	az 0.00E+00	4.00E+00	8.35E-01	m
Vertical dispersivity	ay 0.00E+00	4.00E-01	8.35E-02	m

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(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

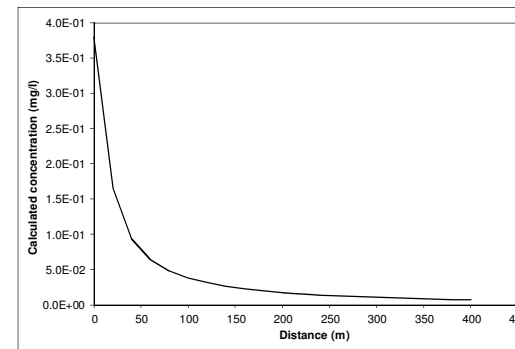
Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v 3.50E-02	m/d
Retardation factor	Rf 1.43E+02	fraction
Decay rate used	λ 2.86E-07	d ⁻¹
Rate of contaminant flow due to retardation	u 2.46E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED} 7.10E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF 5.35E+01	

Remedial Targets

Remedial Target	Value	Unit	Notes
Ogata Banks	5.35E-01	mg/l	For comparison with measured groundwater concentration.
Distance to compliance point	400	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀ 7.10E-03	mg/l	Ogata Banks
	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.



Calculated concentrations for distance-concentration graph

Distance	Concentration
0	3.8E-01
20.0	1.65E-01
40.0	9.35E-02
60.0	6.41E-02
80.0	4.82E-02
100.0	3.83E-02
120.0	3.15E-02
140.0	2.66E-02
160.0	2.29E-02
180.0	2.00E-02
200.0	1.76E-02
220.0	1.57E-02
240.0	1.41E-02
260.0	1.27E-02
280.0	1.16E-02
300.0	1.06E-02
320.0	9.70E-03
340.0	8.93E-03
360.0	8.25E-03
380.0	7.65E-03
400.0	7.10E-03

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 described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

Site being assessed:	POL19
Completed by:	CMH
Date:	#####
Version:	x.xx

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	Aromatic 10-12		mg/l	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
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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

Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C ₀	7.00E-02	mg/l
Half life for degradation of contaminant in water	t _{1/2}	1.70E+04	days
Calculated decay rate	λ	4.08E-05	days ⁻¹
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+01	m
Plume thickness at source	Sy	2.00E+00	m
Saturated aquifer thickness	da	2.10E+00	m
Bulk density of aquifer materials	ρ	2.50E+00	g/cm ³
Effective porosity of aquifer	n	1.40E-01	fraction
Hydraulic gradient	i	7.00E-03	fraction
Hydraulic conductivity of aquifer	K	7.00E-01	m/d
Distance to compliance point	x	4.00E+02	m
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
Partition coefficient	Kd	1.26E+01	l/kg
Longitudinal dispersivity	ax	8.35E+00	m
Transverse dispersivity	az	8.35E-01	m
Vertical dispersivity	ay	8.35E-02	m

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

Calculate for non-polar organic chemicals

Soil water partition coefficient	Kd	1.26E+01	l/kg
Fraction of organic carbon in aquifer	foc	5.00E-03	fraction
Organic carbon partition coefficient	Koc	2.51E+03	l/kg
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

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

Dispersivity based on Xu & Eckstein (1995)

Variable	Enter value	Calc value	Xu & Eckstein	Unit
Longitudinal dispersivity	ax	8.35E+00	8.35E+00	m
Transverse dispersivity	az	8.35E-01	8.35E-01	m
Vertical dispersivity	ay	8.35E-02	8.35E-02	m

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(log₁₀x)^{2.414}; az = ax/10, ay = ax/100 are assumed

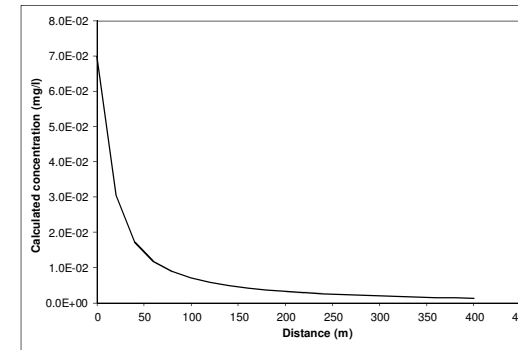
Calculated Parameters Variable

Groundwater flow velocity	v	3.50E-02	m/d
Retardation factor	Rf	2.25E+02	fraction
Decay rate used	λ	1.81E-07	d ⁻¹
Rate of contaminant flow due to retardation	u	1.55E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	1.31E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	5.35E+01	

Remedial Targets

Remedial Target	5.35E-01	mg/l	For comparison with measured groundwater concentration.
Distance to compliance point	400	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀	1.31E-03	mg/l
		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.



Calculated concentrations for distance-concentration graph

Distance	Concentration
0	7.0E-02
20.0	3.05E-02
40.0	1.72E-02
60.0	1.18E-02
80.0	8.88E-03
100.0	7.05E-03
120.0	5.80E-03
140.0	4.90E-03
160.0	4.21E-03
180.0	3.68E-03
200.0	3.24E-03
220.0	2.89E-03
240.0	2.60E-03
260.0	2.35E-03
280.0	2.13E-03
300.0	1.95E-03
320.0	1.79E-03
340.0	1.65E-03
360.0	1.52E-03
380.0	1.41E-03
400.0	1.31E-03

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.

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