

The Avenue former Coking Works Remediation and Regeneration Project (1999-2015+)

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Scope of Presentation

- Project Overview
- Remediation Strategy and Techniques
- CW CSM
- CW Assessments/DQRA
- Post Completion landform and CSM

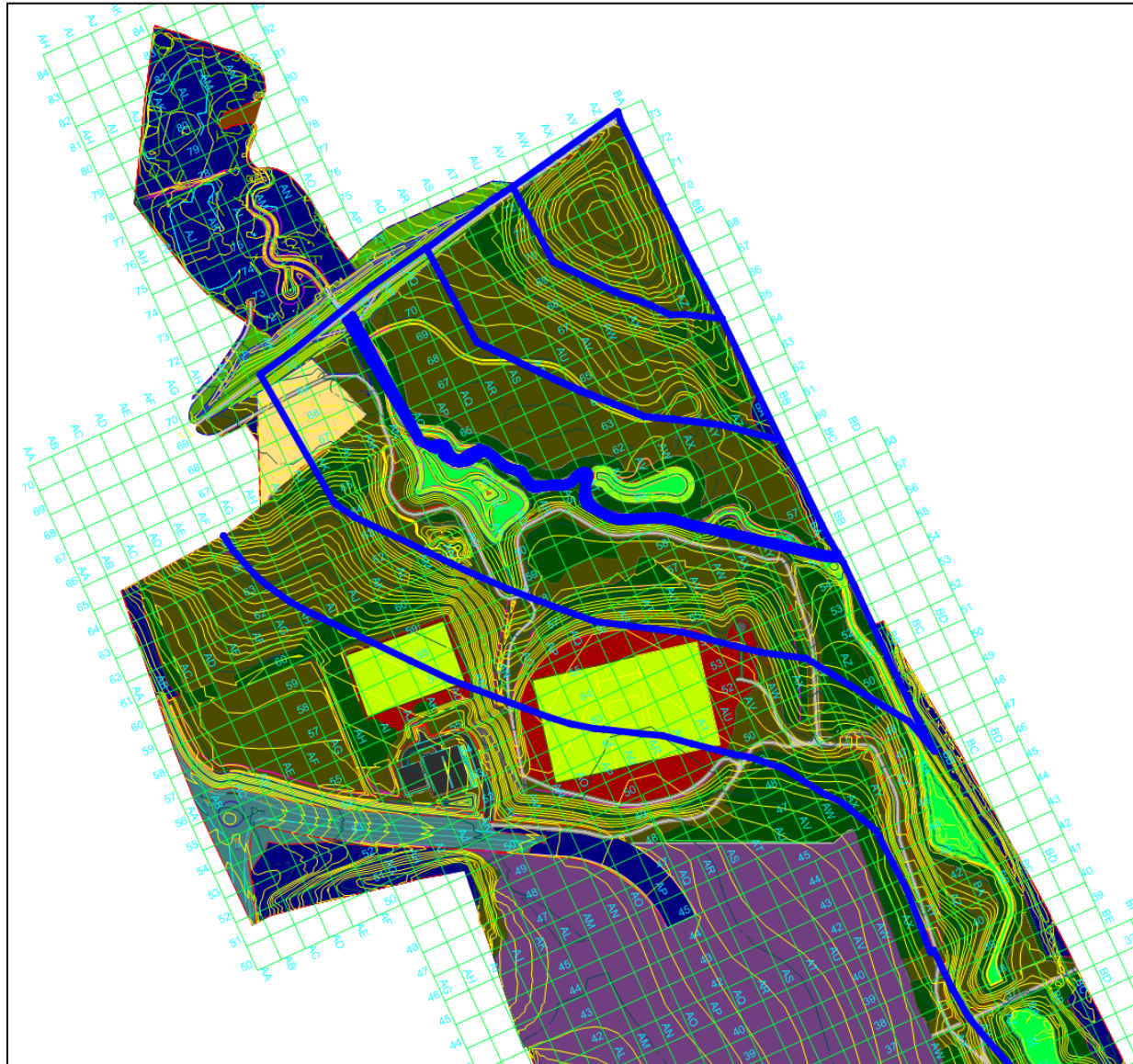
Project Objectives and Overview

- To discharge HCA's legal obligations: source contamination, cleaning up the River Rother/ shallow groundwater
- Prepare the site for the planned redevelopment in accordance with the planning consent for the project
- Planning Permission CW4/0507/39 remediation of the site via on-site treatment of contaminated soils and sediments, with landform reinstatement to a variety of end-uses, including public open space, formal and informal leisure areas, nature conservation areas and a development platform
- Incorporate flood protection measures and SUDs (of which the Environment Agency is the promoter)
- Voluntary remediation to avoid any regulatory action under Part IIA of the Environmental Protection Act
- Between 1991 and 2007: 22 Phases of investigation: 415 Boreholes/750 Trial Pits
- Environmental Monitoring Programmes (Ground gas, Vapour, Air Quality, Surface Water, Groundwater, leachate)
- Source characterisation: Identified Contaminants of Concern : PAHs (Poly Aromatic Hydrocarbons), Phenols, DROs (Diesel Range Organics), PROs (Petrol Range Organics), BTEX (Benzene, Toluene, Ethylene, Xylene), Cyanide, Thiocyanate, Ammonia, Heavy Metals (Arsenic, Nickel, Cadmium, Chromium), Asbestos
- Geological / Geotechnical / Hydrogeological Characterisation
- Maximise re-use of site won material with treatment / and minimise off-site disposal

Site Zones

98 Hectares

Type	Narrative
Former Uses	Zone 1A to 5B which broadly correspond to the primary historical contaminative land-use areas.
Grid Cells	In order to manage the earthworks the site up into over 2000 grid cells
Material Reuse Zones	3x re-use zone denoted from the distance from the River Rother in the final alignment (0-100m, 100-200m and >200m).
Structural Performance Zones	range of zones associated with structural performance of placed fill material.



The Problems

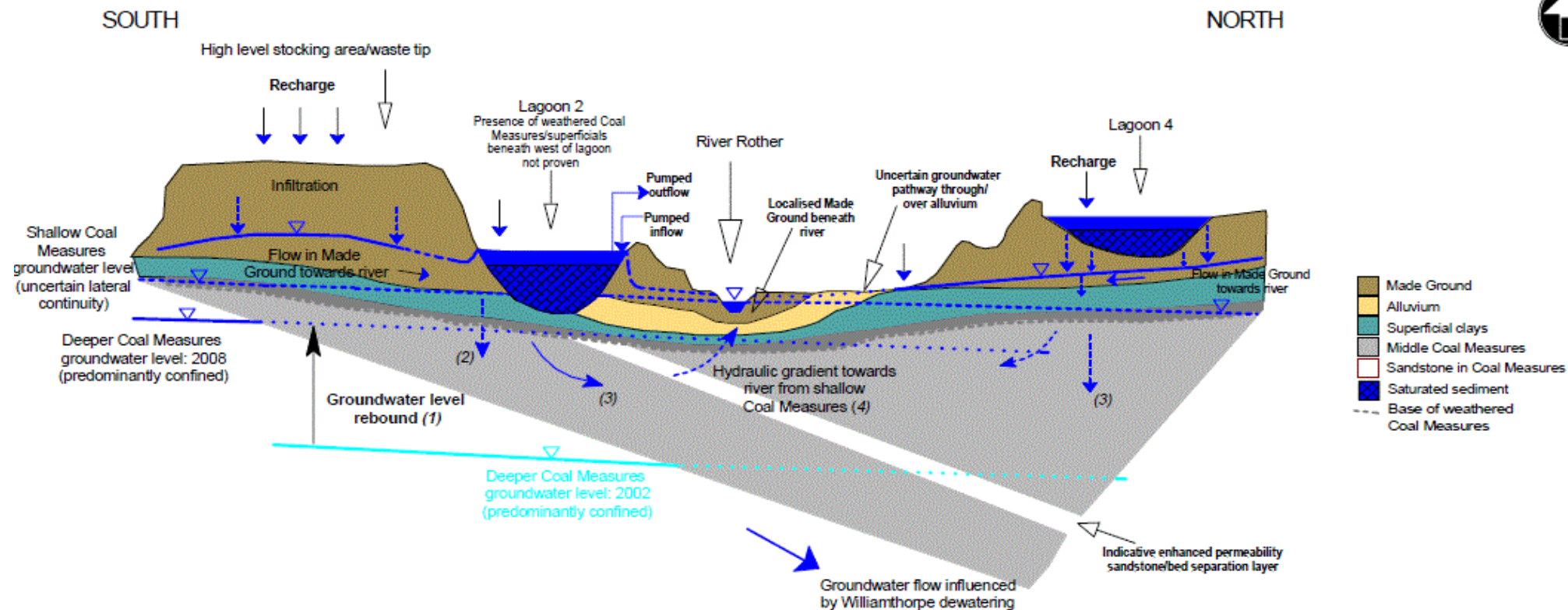


Predicted/Final Treatment Volumes Remediation Techniques

Technique	Designs Volume	Final / Forecast
Treatment (m³)		
Thermal desorption	270,300	257,266
Soil screening /sorting	237,600	203,485
Bioremediation	74,000	181,206
Total	581,900	641,497
Off-Site Disposal (Tonnes)		
Asbestos	2352	913
Metal	3000	550
Other waste	4600	2470
Recovered Timber	1450	10,000
Tar	0	19,000
Total	11, 402	32,020
All Earthworks (m³)		
Total Material volume (cut)	1,883,377	2,244,989
Total Material volume (Fill)	1,934,896	2,178,20
Total	3,818,273	4,423,189
Material Import to Create Landform	0	80,000
Groundwater and Surface Water Treated	??	635,654



Pre-Remediation Conceptual Site Model (Controlled Waters)



DQRA Model / Assumptions

- EA agreed risk to groundwater need not be considered on the basis of cost benefit and therefore the River Rother =Receptor
- Free phase excluded (Visible Free Product (VFP) requires treatment mandatory)
- Upward flow from coal measures (artesian /rising groundwater) excluded as aquitard reinstated
- Conceptual agreement that COCs above the Coal measures will migrate to river /no GW water + COC loss to the aquifer
- Base of excavation derived to excavate and treat all contaminated material above coal measures
- In-situ biodegradation not included -conservative
- Retardation allowed for (KOC)
- Plume concentration diluted by a factor of 175 (low flow river DF) + 1/10th EQS
- Limited suite of COCs given TDU/cost (50,000+ soil samples) + COCs co-exist i.e. destroy one, destroy them all

Numerous iterations to reach final RTs

- COC physical/chemical properties: retained in all DQRA
- Source: Material volumes, placement zones +depth, composition -varies as scheme evolves
- Pathway: Hydrogeological Parameterisation-constant review as scheme evolves
- Receptor : River final location-varies as scheme evolves

Determinand	Units	Reuse within 100m of River Rother	Reuse between 100m and 200m of River Rother	Reuse more than 200m from the River Rother
Ammoniacal Nitrogen (NH ₄)	mg/l	2.5	n/a	n/a
Benzene	mg/l	0.03	1.75	8.75
Cyanide (CN)	mg/l	0.05	175	175
Naphthalene	mg/l	0.01	n/a	n/a
Phenol	mg/l	0.03	0.7	1.75
Diesel Range Organics (DRO)	mg/l	0.3	n/a	n/a
Thiocyanate (SCN)	mg/l	1	17.5	17.5

Controlled Water Risk Assessment and Remedial Targets

Phases of CW modelling and risk assessment:

2002: Consim v1.06

Source : fill material zones (X, Y, Z) / single value RT (benzene/ phenol / cyanide / thiocyanate) through an iterative process of varying leachate concentrations until no theoretical impact was observed at **receptor**

Pathway: GW above coal measures discharges to river/low flow river dilution factor applied (DF=50)

2004: Derivation of Leachable Soil RT: Consim v1.07

Source: fill material zones and material volumes changed (Areas 1,2,3) / derive RT (single value) (ammonical nitrogen/ benzene/ phenol / cyanide / thiocyanate/DRO) - iterative process of varying leachate concentrations / background SW/GW quality not included /100 year time frame

Pathways: GW above coal measures (drift/fill) discharges to river (DF=170).

Other inputs best estimates (bulk density, unsaturated zone thickness/hydraulic conductivity/porosity/aquifer properties/ hydraulic gradient)

2008: Derivation of Leachable Soil RT : Consim v1.?

Value engineering/l££/landform changes/river location changes/ 3x zones created / 0-100m zone RT =EQS

2012: Post Remediation Fill Verification Forecast to completion (ConSim 2.5-multiple source areas+ As built data available)

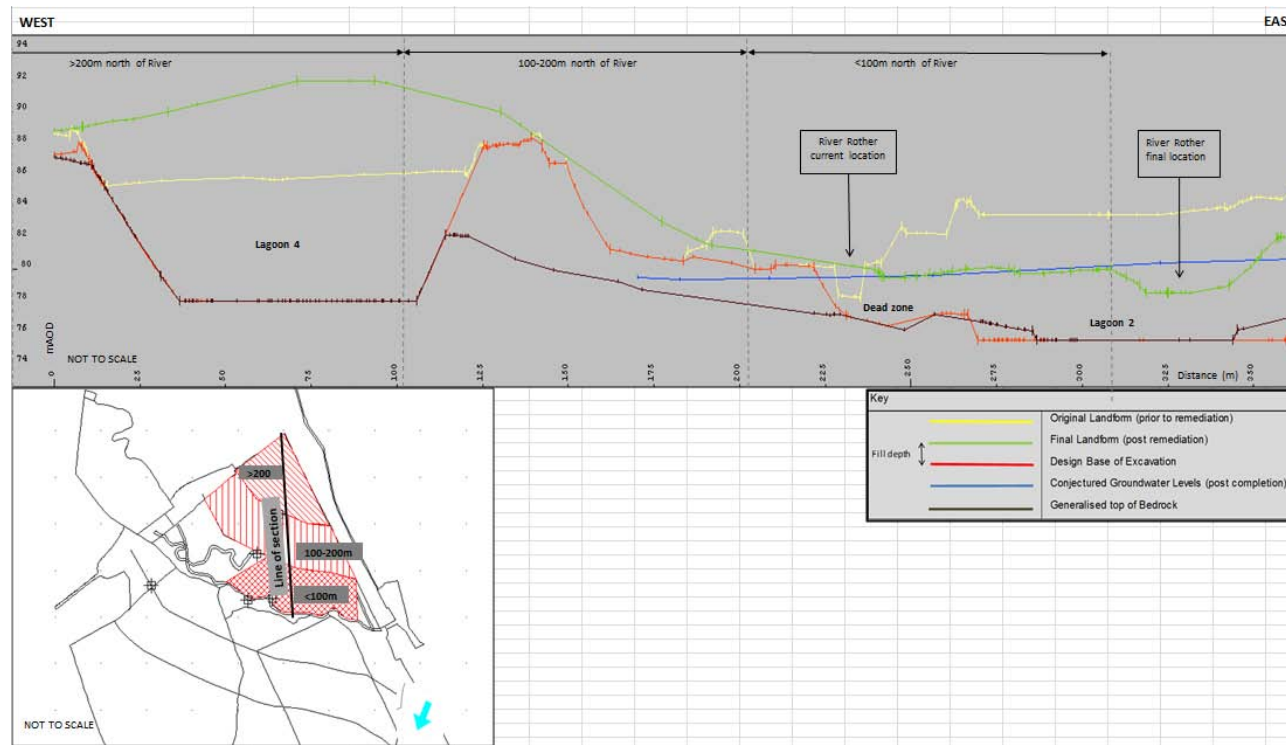
20012-2015: Numerous QRAs to evaluative Local Conditions / unforeseen / value engineering (ConSim/EA RTM)

Alluvial deposits in 0-100m zone / TDU output material , tar etc.

2016: Final DQRA and 2 year monitoring programme - to be completed

2012: Post Remediation Fill Verification Forecast to completion

- Forward Mode to check predicted impacts at river (in final alignment)
- Real as-built data (Soil chemistry and properties after treatment and placement) Inc. 0-100m zone
- As built geology /geometry /parametrisation
- Still some assumptions about groundwater / hydrogeology /flow/head/gradient
- 3 Source areas to account for one direction flow in Consim
- Predicted “Raw Concentration” from 3 models combined and diluted by DF for river concentration
- Model run for 1000 years
- All new as built parameters reviewed against original parameters (sensitivity analysis)

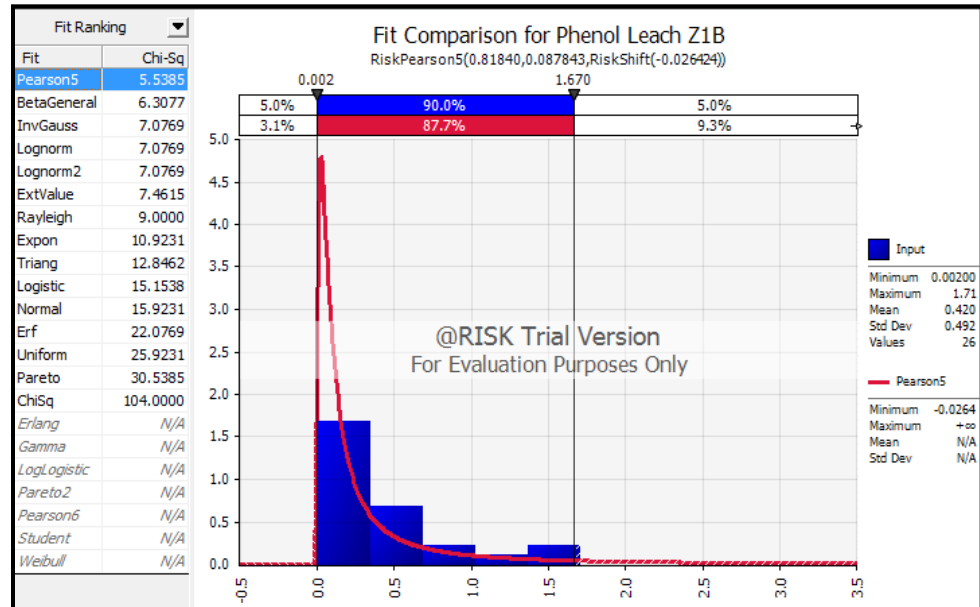
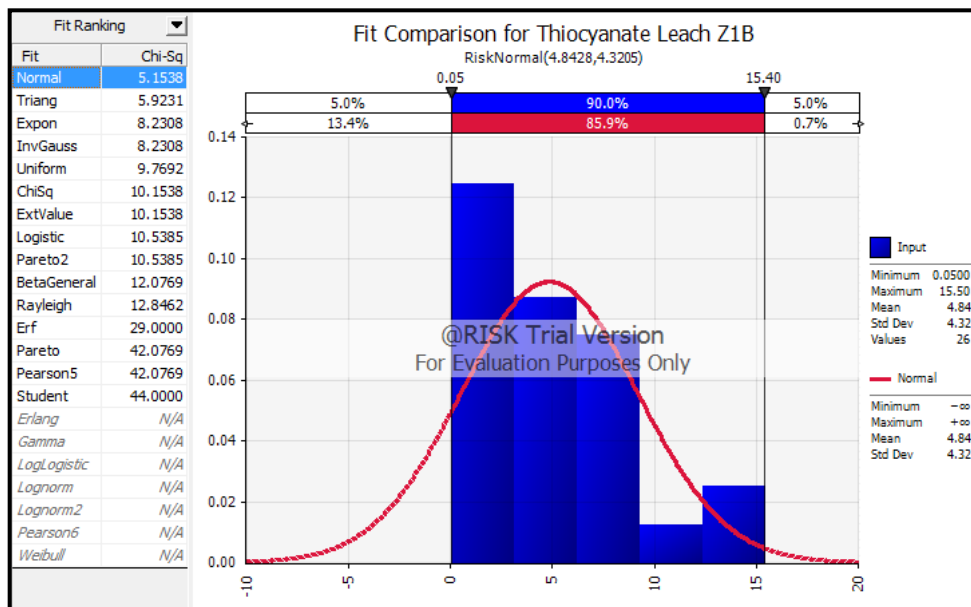


Parameterisation: North of River Model (Source Area 3)

	Parameters		Units	Input*	Reference and Justification
North of River >200m	Source Zone				
	Dry Bulk Density		g/cm3	Uniform (1.6,2,2)	Based on Jacobs Babbie 2004 (Consim values) and refined based on data from fill placed (site geotechnical data base)
	Thickness		m	Triangular (0.5, 9, 14)	Likely depth of fill proposed within the Lagoon 4 area is based on the earthworks and Mass Haul (VSD 2011) (also see Figure 3.3).
	Source Inventory				
	SSAC Leachate concentrations (User defined)	Benzene	mg/l	Exponential (1.32)	Leachate concentration of placed fill materials (and taken to be an accurate forecast of future material) based on the Mass Haul (VSD 2011). Fill is proposed to be comprised of bi-mediated sediment, timber, made ground, TDU output. A review of data was carried out within Tables 4.12a and b.
		Cyanide (Total)	mg/l	Exponential (3.39)	
		Phenol	mg/l	LogNormal (0.42, 0.049)	
		Thiocyanate	mg/l	Normal (4.84, 4.32)	
	Unsaturated Zone - Superficials/Weathered Coal Measures				
	Thickness		m	Single (1)	Conservative estimate based on Mass Haul (VSD 2011) and source thickness in Lagoon 4.
	Dry Bulk Density		g/cm3	Uniform (1.6,3,2)	Based on Jacobs Babbie 2004 (Consim values)
	Vertical Dispersivity		m	Single (0.1)	10% of unsaturated zone thickness (Recommended in Consim)(Jacobs Babbie 2004).
	FOC		%	LogTriangular (0.27, 2.348,14.8)	Site specific data review of (clean) strata north of the river.
	Water filled porosity		fraction	Triangular (0.011, 0.179, 0.375)	Site specific data (Jacobs Babbie 2004).
	Unsaturated Conductivity		m/s	LogTriangular (1.19e-08,9.7e-07, 1.51e-05)	Site specific data (Jacobs Babbie 2004), refined to more accurately reflect the strata in this area.
North of River 100-200m	Source Zone				
	Dry Bulk Density		g/cm3	Uniform (1.6,2,2)	Based on Jacobs Babbie 2004 (Consim values) and refined based on data from fill placed (site geotechnical data base)
	Thickness		m	Triangular (0.5, 2.5, 4.5)	Likely depth of fill within area based on the earthworks and Mass Haul (VSD 2011) (also see Figure 3.3).
	Source Inventory				
	SSAC Leachate concentrations (User defined)	Benzene	mg/l	Normal (0.00572, 0.036)	Leachate concentrations from verification data of fill placed to date and TDU output suitable for 100-200m from the river. A review of data was carried out within Tables 4.10a and b.
		Cyanide (Total)	mg/l	Normal (0.00529, 0.0256)	
		Phenol	mg/l	Normal (0.0204, 0.0462)	
		Thiocyanate	mg/l	Normal (0.0736, 0.116)	
	Unsaturated Zone - Superficials/Weathered Coal Measures				
	Thickness		m	Triangular (0.5,1.5,2)	Conservative estimate based on Mass Haul (VSD 2011) (also see Figure 3.3).
	Dry Bulk Density		g/cm3	Uniform (1, 3, 2)	Consim values to account for all potential strata, (clay, till, sandstone, siltstone, shale) Jacobs Babbie 2004.
	Vertical Dispersivity		m	Triangular (0.05,0.15,0.2)	10% of unsaturated zone thickness (Recommended in Consim)(Jacobs Babbie 2004).
	FOC		%	LogTriangular (0.27,2.348,14.8)	Site specific data review of (clean) strata north of the river.
	Water filled porosity		fraction	Triangular (0.011, 0.179, 0.375)	Site specific data (Jacobs Babbie 2004).
	Unsaturated Conductivity		m/s	LogTriangular (1.19e-08,9.7e-07, 1.51e-05)	Site specific data (Jacobs Babbie 2004), refined to more accurately reflect the strata in this area.
North of River <100m	Source Zone				
	Dry Bulk Density		g/cm3	Uniform (1.6,2,2)	Based on Jacobs Babbie 2004 (Consim values) and refined based on data from fill placed (site geotechnical data base)
	Thickness		m	Triangular(0.2,5,8)	Likely depth of fill proposed including Lagoon 2 based on the earthworks and Mass Haul (VSD 2011) (also see Figure 3.3).
	Source Inventory				
	SSAC Leachate concentrations (User defined)	Benzene	mg/l	Normal(0.00235, 0.00858)	Leachate concentrations anticipated based on proposed fill materials, i.e TDU output suitable for <100m from river. A review of data was carried out within Tables 4.11a and b.
		Cyanide (Total)	mg/l	Single(0.025)	
		Phenol	mg/l	Normal(0.0652,0.00827)	
		Thiocyanate	mg/l	Normal(0.0602,0.0393)	
	Unsaturated Zone - Superficials/Weathered Coal Measures				
	Thickness		m	Triangular (0.5,1.5,2)	Conservative estimate based on Mass Haul (VSD 2011) (also see Figure 3.3).
	Dry Bulk Density		g/cm3	Uniform (1, 3, 2)	Consim values to account for all potential strata, (clay, till, sandstone, siltstone, shale) Jacobs Babbie 2004
	Vertical Dispersivity		m	Triangular (0.05,0.15,0.2)	10% of unsaturated zone thickness (Recommended in Consim)(Jacobs Babbie 2004).
	FOC		%	LogTriangular (0.27,2.348,14.8)	Site specific data review of (clean) strata north of the river.
	Water filled porosity		fraction	Triangular (0.011, 0.179, 0.375)	Site specific data (Jacobs Babbie 2004).
	Unsaturated Conductivity		m/s	LogTriangular (1.19e-08,9.7e-07, 1.51e-05)	Site specific data (Jacobs Babbie 2004), refined to more accurately reflect the strata in this area.
Aquifer Pathway	Thickness		m	Triangular (20,40,60)	Jacobs Babbie 2004. Although the Coal Measures extend for hundreds of metres beneath the site the thickness of the aquifer has been assigned a most likely depth of 40m. This has been undertaken to allow for vertical water loss in the complex horizontal bedded water regime.
	Dry Bulk Density		g/cm3	Triangular (1,1.75, 3.2)	Consim values to account for all potential strata, (clay, till, sandstone, siltstone, shale). Adapted from Jacobs Babbie (2004) to account for a significant proportion of TDU output material which is to be placed in the footprint of lagoon2 in the final location of the river
	FOC		%	LogTriangular (0.27,2.348,14.8)	Review of all FOC data for (clean) strata north of the river.
	Mixing Zone Thickness		m	Calculated	Calculated within the model.(Jacobs Babbie 2004).
	Hydraulic Conductivity		m/s	LogTriangular (1.19e-08,9.7e-07, 1.51e-05)	Site specific data (Jacobs Babbie 2004), refined to more accurately reflect the strata in this area.
	Effective Porosity		fraction	Triangular(0.01,0.3,0.5)	Jacobs Babbie (2004) values published within the minor aquifer properties manual, adapted to include the TDU output material porosity data and the most likely value representing porosity of the most likely strata/porosity expected.
	Hydraulic Gradient		-	Single (0.03)	Calculated based on site monitoring data north of the River.
	Groundwater Flow Direction		degrees	203	Anticipated direction of flow based on site knowledge and receptor location.
	Longitudinal Dispersivity		m	Uniform (0, 1,35)	10% of pathway length. Pathway length is taken as a minimum of 1m from the River to a maximum of 325m at the northern corner of Lagoon 4.
	Lateral Dispersivity		m	Uniform (0.03, 10.5)	Taken to be 30% of Longitudinal dispersivity (recommended in Consim).

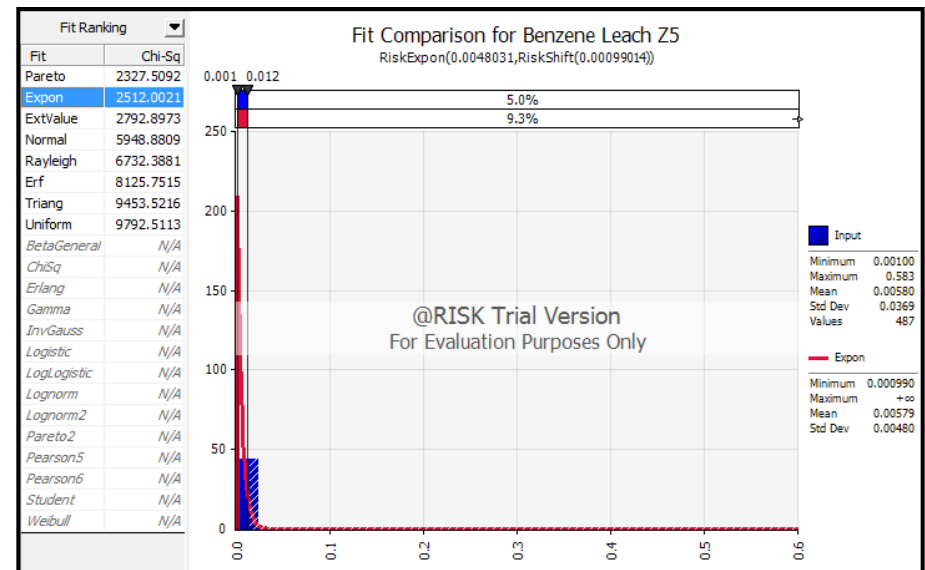
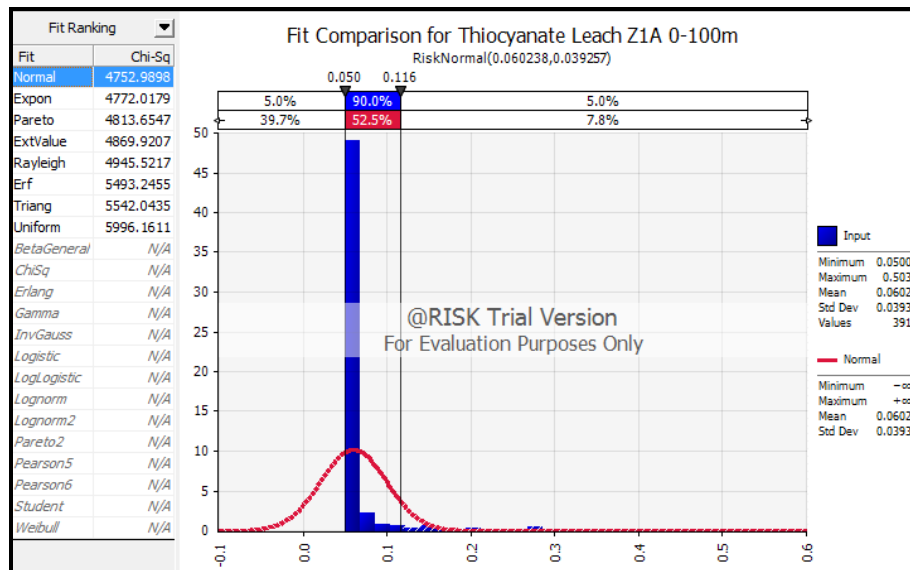
Soil Test Results North of River Model (>200m)

Benzene	Benzo(a) pyrene	Naphthalene	Phenol	Ammoniacal Nitrogen	Benzene	Cyanide	Naphthalene	Phenol	DRO	Thiocyanate	
mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
35	292	2610	6	25.8	5.17	31.1	5.15	1.71	24.9	15.5	MAX
0.773	0.027	0.381	0.471	0.2	0.001	0.05	0.0001	0.002	0.046	0.05	MIN
11.031	91.28	1173.29	3.001	13.033	1.32	3.394	2.561	0.420	11.872	4.843	AVERAGE
n/a	n/a	n/a	n/a	n/a	8.75	175	n/a	1.75	n/a	17.5	Remedial Targets >200m



Soil Test Results North of River Model (0-100m)

Benzene	Benzo(a)pyrene	Naphthalene	Phenol	Ammoniacal Nitrogen	Benzene	Cyanide	Naphthalene	Phenol	DRO	Thiocyanate	
mg/kg	mg/kg	mg/kg	mg/kg	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	
19	4.68	155	1.85	1.52	0.13	0.05	0.0052	0.030	0.090	0.29	MAX
0.009	0.015	0.009	0.01	0.2	0.001	0.05	0.0001	0.002	0.046	0.05	MIN
1.0558	0.1169	2.2606	0.1410	0.228	0.0022	0.05	0.0002	0.0065	0.0462	0.0583	AVERAGE
n/a	n/a	n/a	n/a	2.5	1.75	0.05	0.01	0.03	0.3	1	Remedial Targets <100m



Predicted /Actual GW/SW Water Results

Table 4.14 - Consim 2.5 Results (2012)

JACOBS BABTIE								
Predicted 95%ile Concentration at the Receptor at 300 years- mg/l								
Benzene		Cyanide		Phenol		Thiocyanate		
0.03	0.003	0.05	0.005	0.03	0.003	1	0.1	
Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	
Groundwater Source Model 3 North of River	0.8003	0.0046	0.0331	0.00019	0.2883	0.0016	7.1227	0.0407
Groundwater Source Model 2 South of River	0.0285	0.0002	0.7376	0.00422	0.1534	0.0009	8.3372	0.0476
Groundwater Source Model 1 Zones 4 and 5	0.0063	0.00004	0.0032	0.00002	0.0484	0.0002763	0.1636	0.0009348
Total concentration at River Rother	0.8351	0.004772	0.7740	0.004	0.4901	0.0028	15.6236	0.09
Applied Dilution factor	175							
Predicted 95%ile Concentration at the Receptor at 500 years- mg/l								
Benzene		Cyanide		Phenol		Thiocyanate		
0.03	0.003	0.05	0.005	0.03	0.003	1	0.1	
Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	
Groundwater Source Model 3 North of River	1.1830	0.0067601	0.3630	0.0021	0.3365	0.0019	7.1227	0.0407
Groundwater Source Model 2 South of River	0.0555	0.0003174	2.5126	0.0144	0.2155	0.0012	8.3372	0.0476
Groundwater Source Model 1 Zones 4 and 5	0.0126	0.0000720	0.0541	0.0003089	0.0683	0.0003901	0.1636	0.0009349
Total concentration at River Rother	1.2512	0.007	2.9296	0.017	0.6202	0.0035	15.6236	0.089
Applied Dilution factor	175							
Predicted 95%ile Concentration at the Receptor at 1000 years- mg/l								
Benzene		Cyanide		Phenol		Thiocyanate		
0.03	0.003	0.05	0.005	0.03	0.003	1	0.1	
Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	Raw concentration	Diluted concentration	
Groundwater Source Model 3 North of River	1.5569	0.0088966	1.2769	0.0073	0.3722	0.0021	7.1227	0.0407
Groundwater Source Model 2 South of River	0.0944	0.0003394	7.3306	0.0419	0.2747	0.0016	8.3372	0.0476
Groundwater Source Model 1 Zones 4 and 5	0.0224	0.0001281	0.2576	0.0014722	0.0926	0.0005282	0.1636	0.0009349
Total concentration at River Rother	1.6737	0.0095	8.8731	0.0507	0.7395	0.004	15.6236	0.089
Applied Dilution factor	175							
Key								
Exceedance								
Marginal Exceedance								
No exceedance								

	Measured GW Concentration	Concnatio in Surface Water 170 (DF)
General Water Quality		
Conductivity @ 20 deg.C	mS/cm	15.8
pH	pH Units	10.3
Sulphate	mg/l	8790
Chloride	mg/l	4130
Thiocyanate	mg/l	1.17
Ammoniacal Nitrogen as NH3	mg/l	0.259
COD, unfiltered	mg/l	885
BOD, unfiltered	mg/l	476
Nitrate as N	mg/l	0.0677
Cyanide, Free	mg/l	0.05
Organic Compounds		
GRO >C5-C12	µg/l	50
Benzene	µg/l	7
Toluene	µg/l	6
Ethylbenzene	µg/l	5
m,p-Xylene	µg/l	8
o-Xylene	µg/l	3
Total Aliphatics >C12-C35 (aq)	µg/l	10
Total Aromatics >EC12-EC35 (aq)	µg/l	15
Total Aliphatics & Aromatics >C5-35 (aq)	µg/l	35
PAH, Total Detected	µg/l	6.9
Phenol	mg/l	0.002
Metals		
Iron, Ferric (+3)	mg/l	0.05
Iron (diss.filt)	mg/l	0.195
Iron, Ferrous (+2)	mg/l	35.5
Iron	mg/l	19
Mercury	µg/l	0.105
Cadmium	µg/l	1.07
Chromium	µg/l	19.6
Copper	µg/l	29.6
Nickel	µg/l	26.9
Lead	µg/l	184
Zinc	µg/l	109

Masterplan – Post Completed Landform

- 28 hectares of residential led mixed use development
- Flood alleviation scheme (Dam and Reservoir)
- Realigned River Rother and Backwater
- 65 hectares of public open space & nature reserve
- Sports Facilities
- Sustainable Urban Drainage (SUDS)
- Access Road and Car Park



Conclusions (H and H)

- ☐ CSM evolve – gather data; test hypothesis; revise the CSM
- ☐ Early contractor involvement
- ☐ Scientific advancement
- ☐ Changing RTs in contract
- ☐ Contingency in RT (unforeseen)
- ☐ Care with VE
- ☐ Mass Haul Changes
- ☐ Regulatory engagement and agreement is vital.

Thank you for your attention. Any questions?