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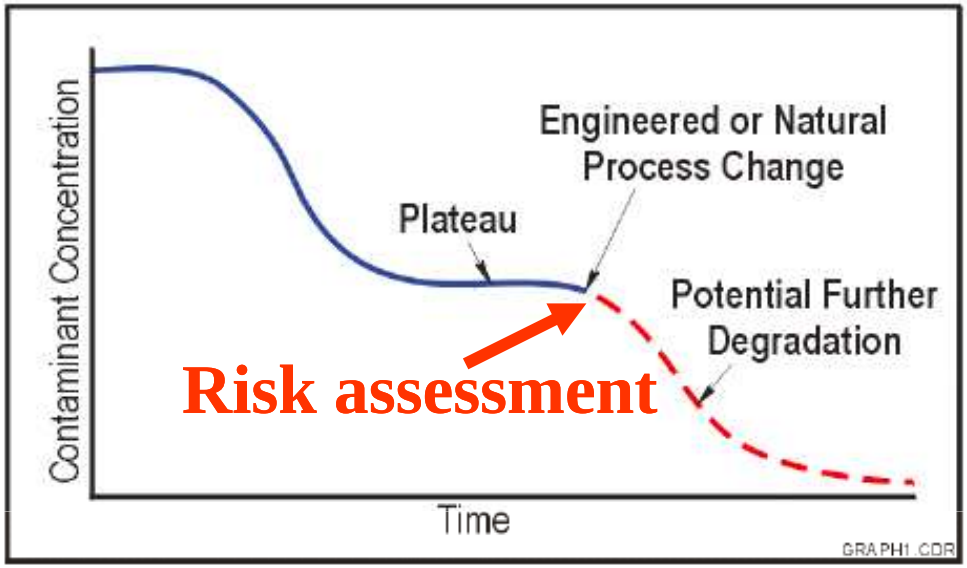
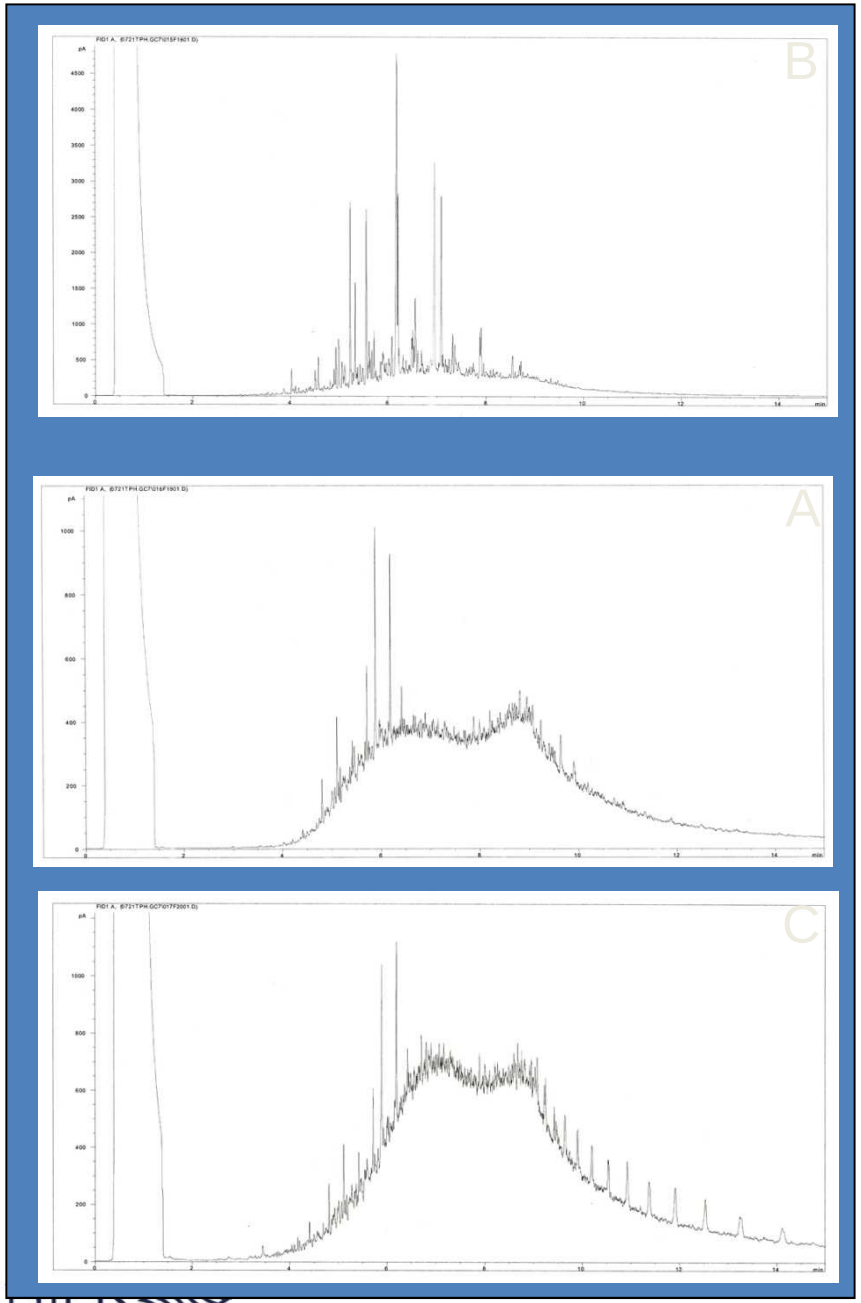
Fractionating Hydrocarbons For Hazard and Risk Assessment; Chemical and Biological Analysis

Why do this?

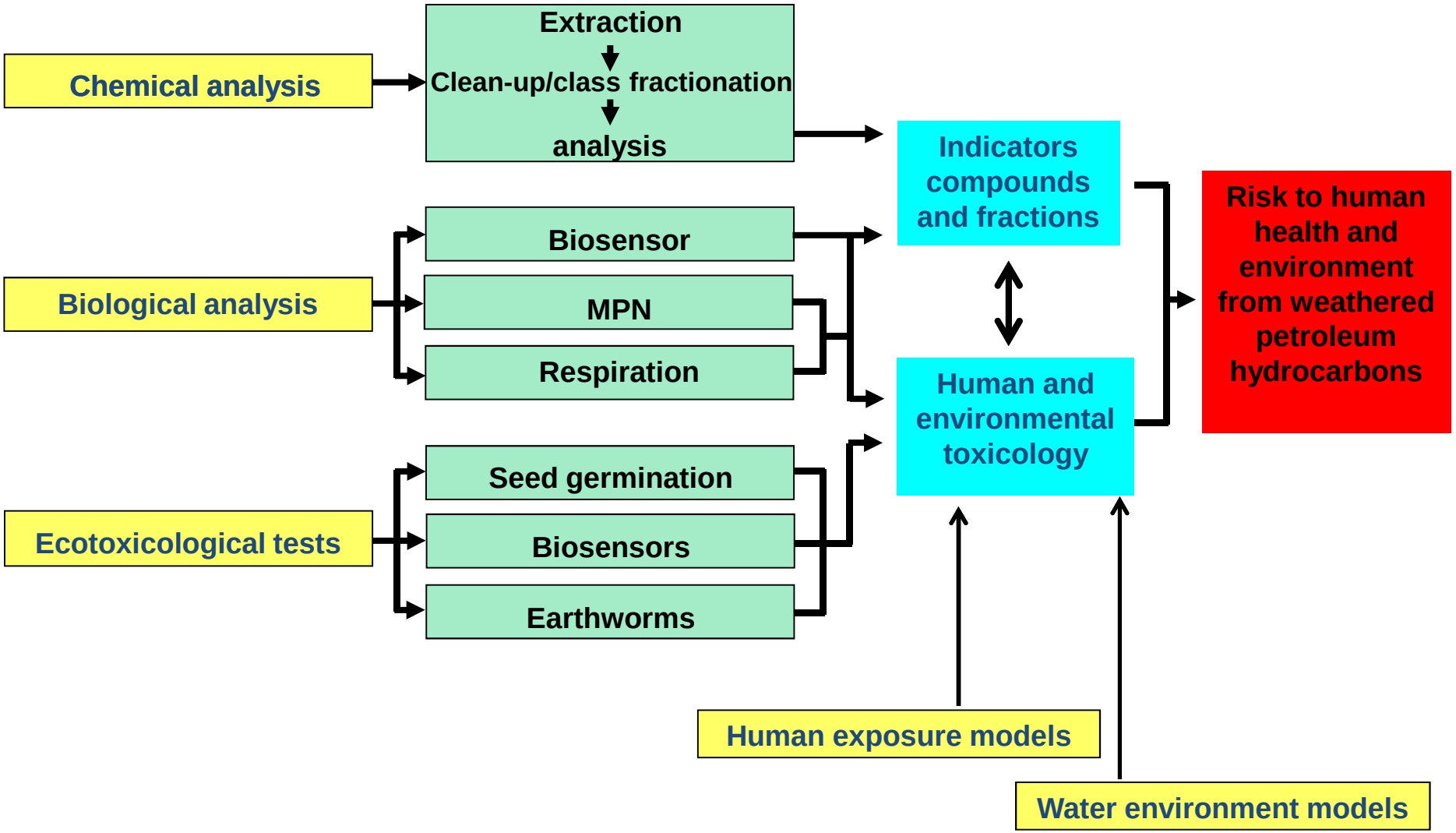


- Risk management is the language of business and regulation
- Showing we can manage risk instils confidence

- Confidence builds trust in stakeholders
- Trust supports legitimacy and community buy-in into regeneration – a critical 'quality of life' endpoint for sustainable communities



- B – oil extracted from a oil-contaminated clay soil prior to remediation.
- A – residual oil remaining after windrow treatment.
- C – oil extracted from heavily contaminated peaty soil from a decommissioned oil refinery.


Chemical analysis
Extraction
Clean-up/class fractionation
analysis
Biological analysis
Biosensor
MPN
Respiration
Ecotoxicological tests
Seed germination
Biosensors
Earthworms
Indicators compounds and fractions
Human and environmental toxicology
Risk to human health and environment from weathered petroleum hydrocarbons
Human exposure models
Water environment models

SECOND LINK BIOREMEDIATION PROGRAMME

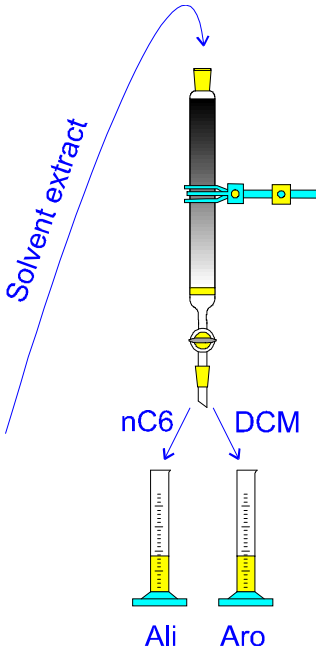
BIOREM 35

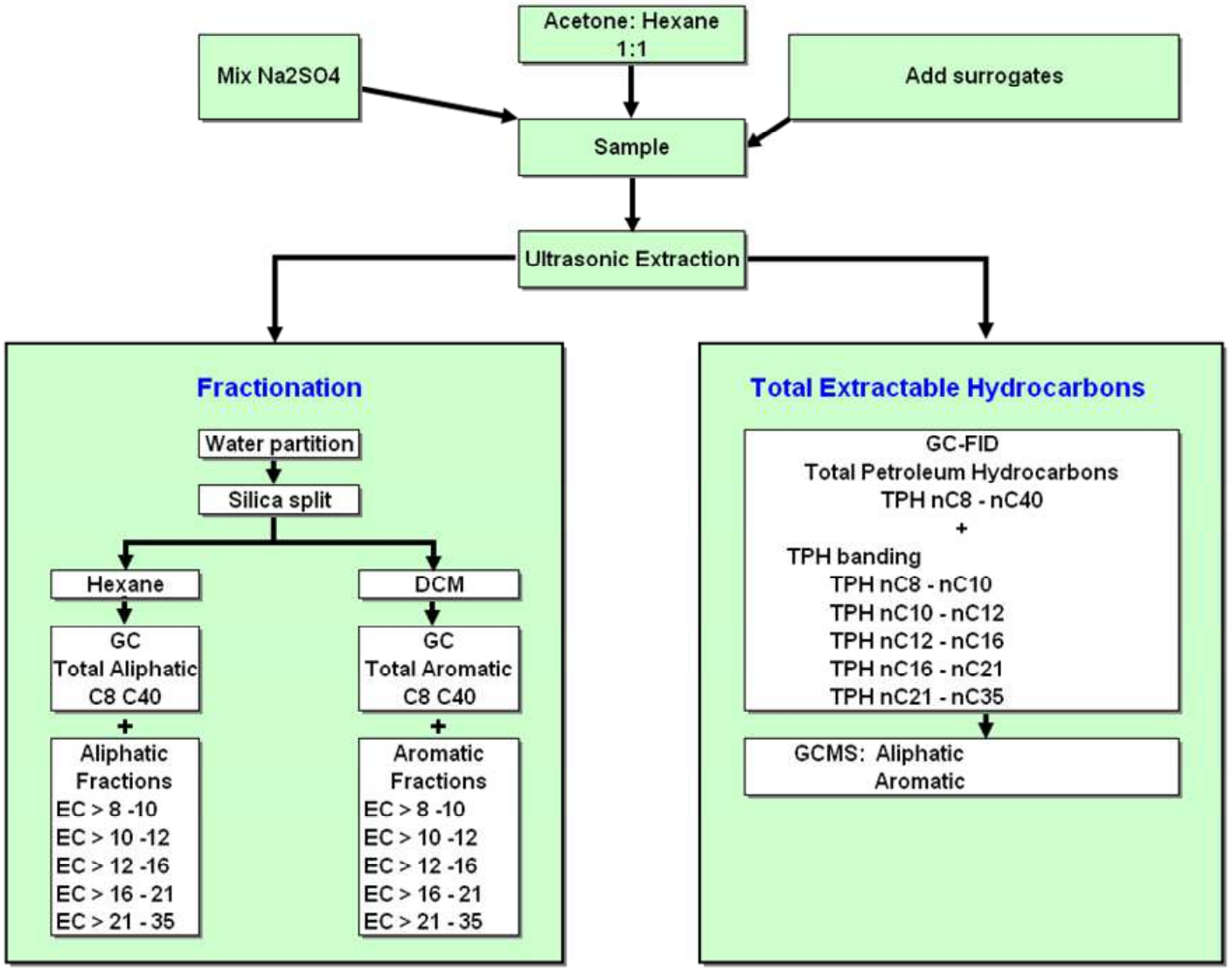
Optimising biopile processes for weathered hydrocarbons within a risk management framework - PROMISE

S. Pollard, F. Coulon, G. Paton, J. Bellarby,
K. Semple, G. Risdon, B. Bone, K. Brassington and
S. Mitchell.

Chemical analysis

Figure 6
Analytical schematic recommended for analysing soil contaminated with weathered hydrocarbons.





REMEDIOS
INTELLIGENT SOLUTIONS

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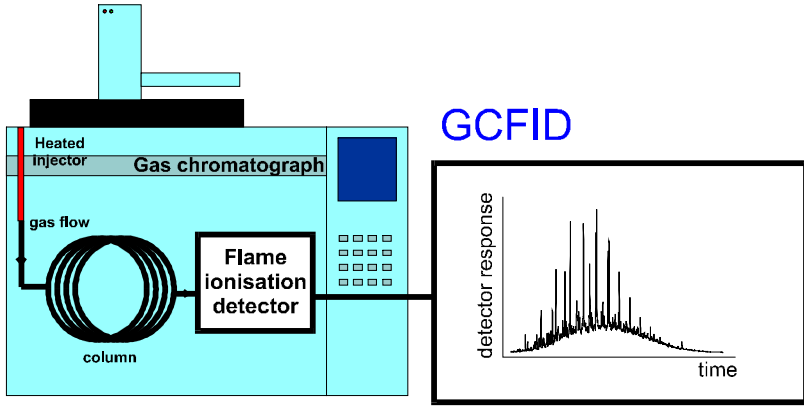
Table 4

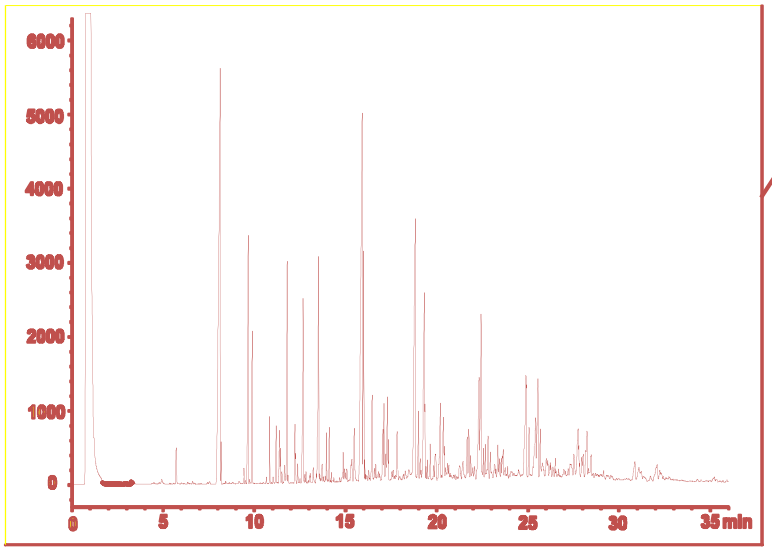
Mean concentration, precision & bias for duplicate samples extraction from each soil matrix

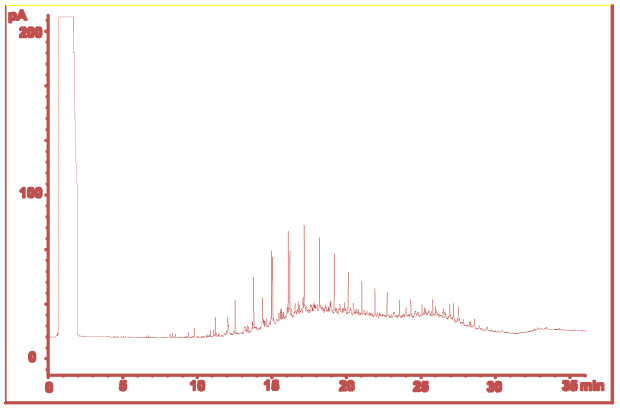
Matrix	Spike concentration mg kg^{-1}	Mean concentration mg kg^{-1}	Precision mg kg^{-1}	Precision % RSD	Bias mg kg-1	Bias %
Silty soil	0	65	6.8	10.5		
	10000	9988	301	3	-77	-0.8
	30000	29280	800	2.7	-785	-2.6
Clay soil	0	81	22.6	27.9		
	10000	10142	680	6.7	61	0.6
	30000	30104	2171	7.2	23	0.1
Sandy soil	0	9.4	5.8	61.7		
	10000	9727	377	3.9	-282.4	2.8
	30000	28759	611	2.1	-1250.4	4.2
Made ground'	0	286	63.5	22.2		
	10000	10802	320	3	516	5
	30000	31166	1497	4.8	880	2.9

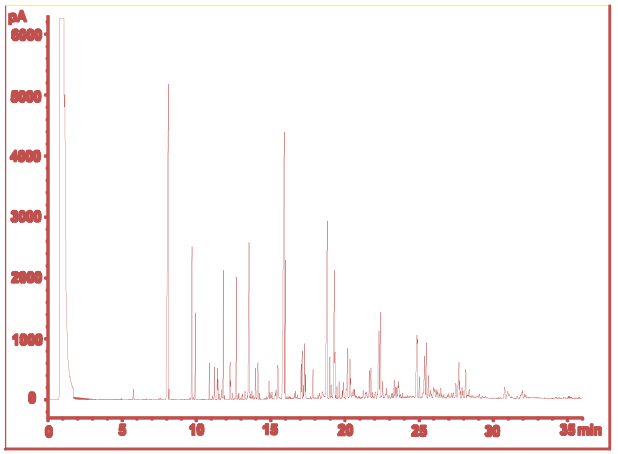
	Certified value mg kg-1	Mean concentration mg kg^{-1}	Precision mg kg^{-1}	Precision % RSD	Bias mg kg-1	Bias %
RTC CRMPR	9510	11124	374	3.4	1614	17

Speciation of oil extract (class fractioning)

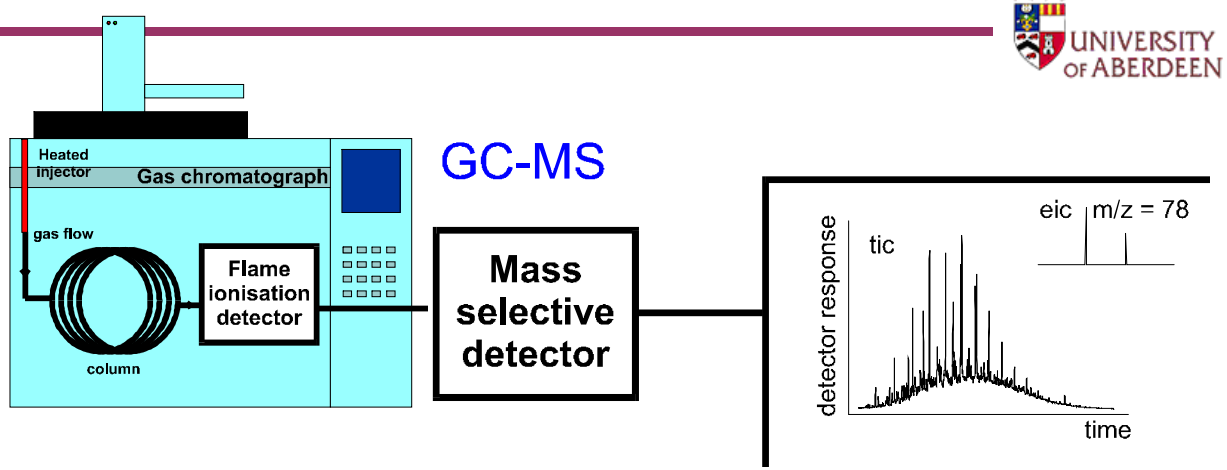


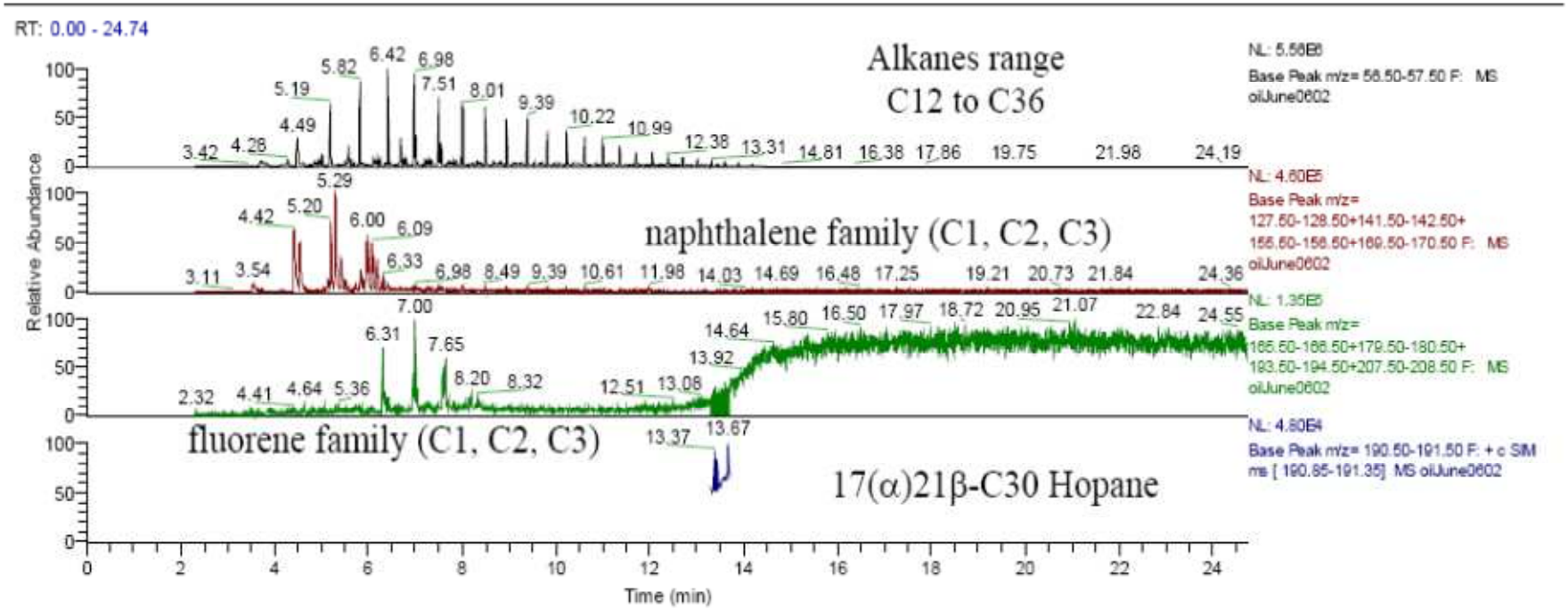






Identification of oil target compounds



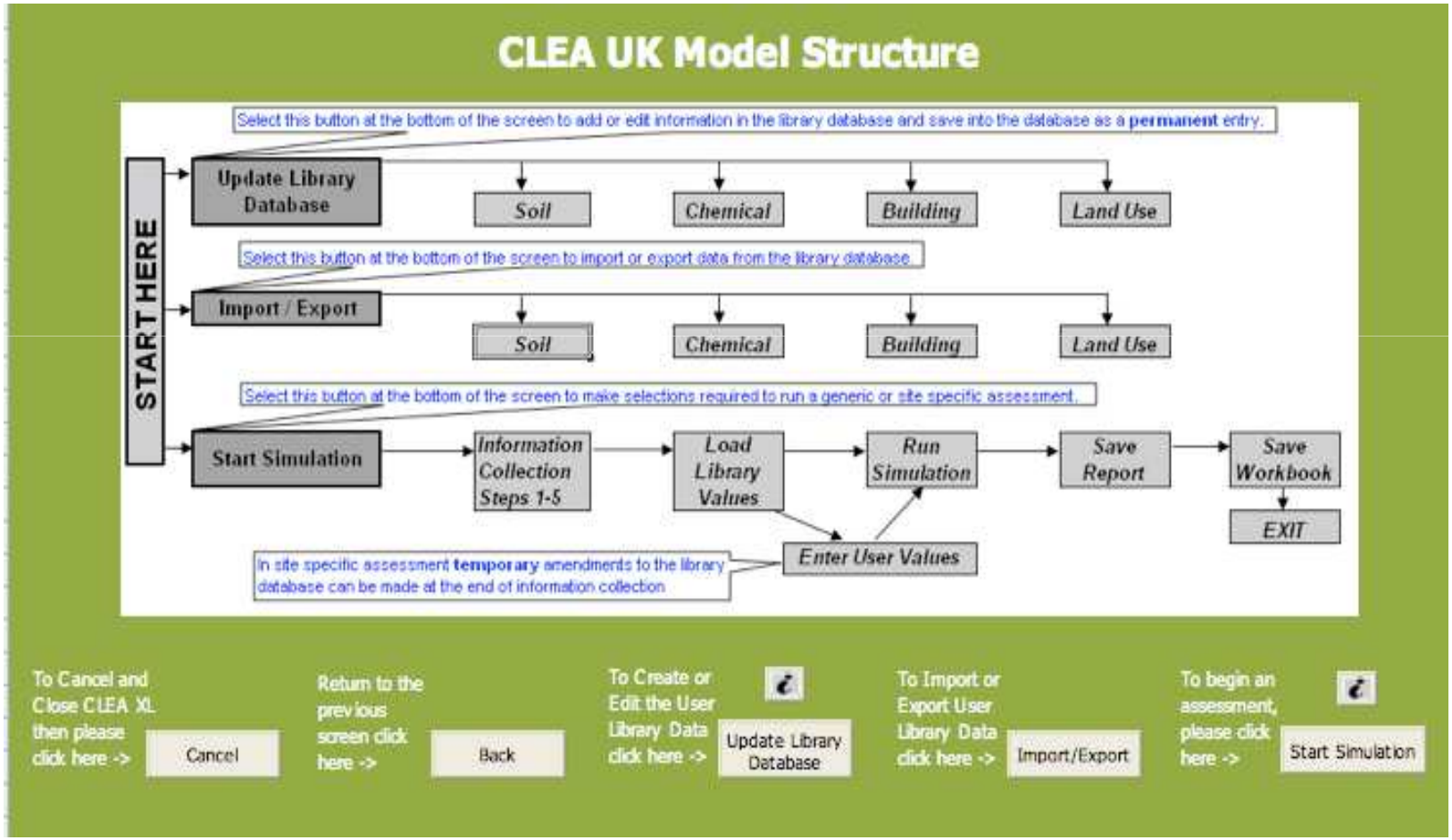


Chemical analysis

- **Develop a robust analytical procedure for diagnostic tool kit**
  - » Complete recovery (low bias)
  - » Good precision (within and between batch)
  - » Conform to Environment Agency *mCERTs* performance targets (30% bias, 15% precision)
  - » Compatible with UK risk framework (Carbon banding convention(s) and Class fractionation)

- **Outputs:**
  - » Move to ultrasonic sequential solvent extraction with Acetone and hexane
  - » Generate high throughput and fast process.
  - » scalable
  - » Remove evaporative steps
  - » Solvent exchange via water partitioning prior to class fractionation

Exposure Assessment



Tolerable daily intake

Hydrocarbon fractions	TDI_{oral} ($\mu g\ kg^{-1}\ bw\ day^{-1}$)			$TDI_{Inhalation}$ ($\mu g\ kg^{-1}\ bw\ day^{-1}$)			Target organs/systems or effects
	EA (2006)	MADEP (2002)	TPHCWG (1997)	EA (2006)	MADEP (2002)	TPHCWG (1997)	
Aliphatic fractions							
>C5-C6	60	40	5000	200	60	5250	Neurological
>C6-C8	2000	40	5000	770	60	5250	
>C8-C10	100	100	100	60	60	285	Liver, blood
>C10-C12	100	100	100	60	60	285	
>C12-C16	100	100	100	60	60	285	
>C16-C35	2000	2000	2000	-	-	-	Liver
>C35-C44	6000	-	20000	-	-	-	
Aromatic fractions							
>C5-C7	-	-	2	-	-	9	Liver, neurological
>C7-C8	200	-	200	74	-	115	
>C8-C10	100	30	40	63	15	60	Body weight
>C10-C12	40	30	40	15	15	60	
>C12-C16	40	30	40	15	15	60	
>C16-C21	30	30	30	NA	15	-	Kidney
>C21-C35	12.5	30	30	NA	-	-	
>C35-C44	12.5	-	30	NA		-	
Combined Aliphatic and aromatic fractions							
>C44-C70	12.5		30	NA		-	

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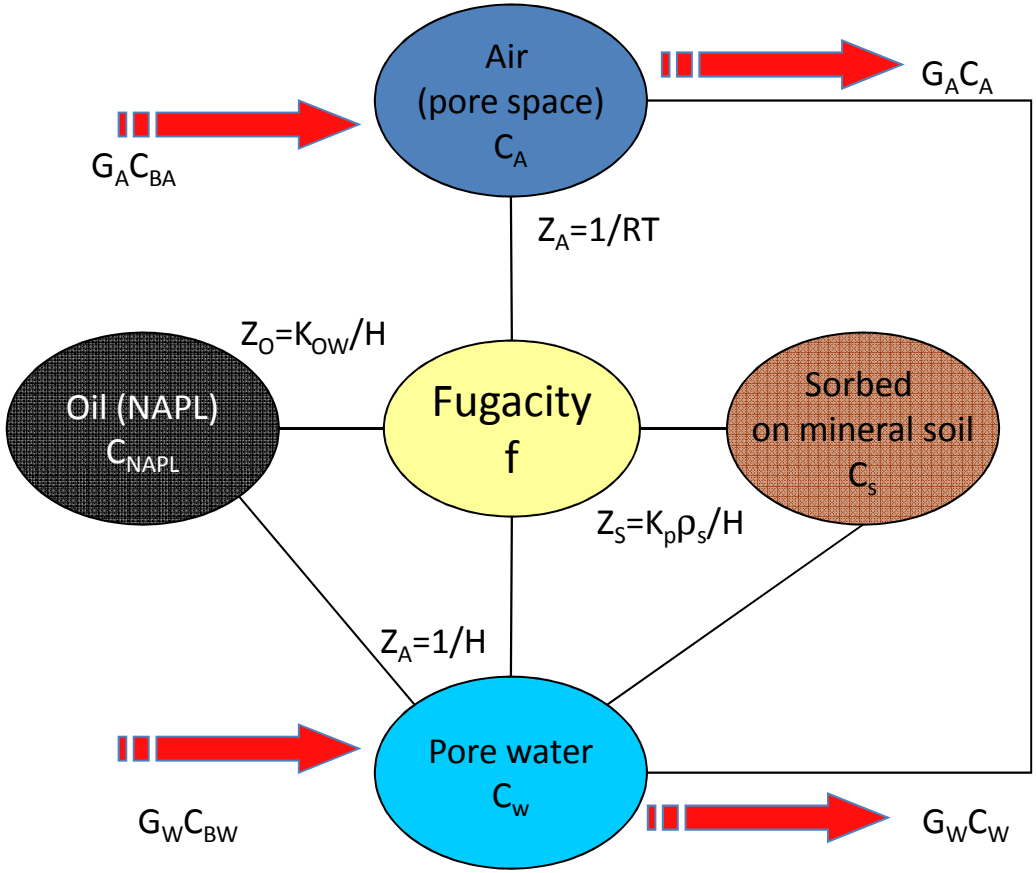
Typical targets values in petroleum hydrocarbon-contaminated soils

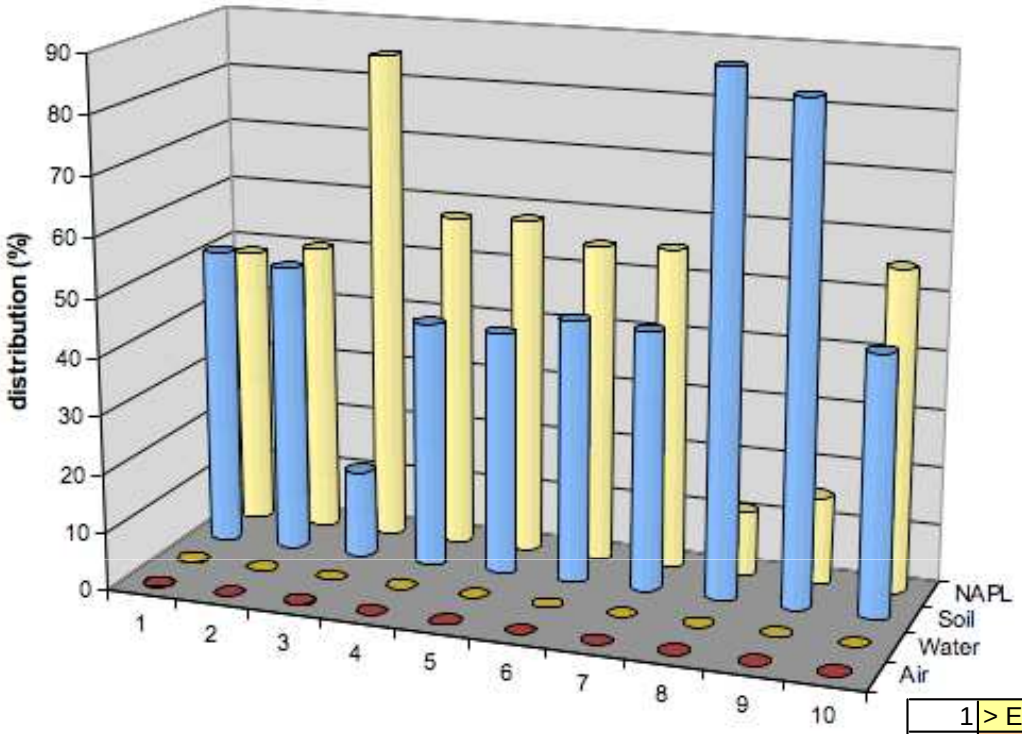
Petroleum Hydrocarbon fractions		GAC[a] (mg kg^{-1}) UK		SSAC[b] (mg kg^{-1}) UK		Targets organs/ systems or effects
		Residential without plant uptake	Industrial/ commercial	Residential without plant uptake	Industrial	
Aliphatic fractions	>C5-C6	2.11	95.3	8.79	397	Neurological
	>C6-C8	5.37	242	17.20	69000	
	>C8-C10	1.46	65.9	3.53	11300	Liver, blood
	>C10-C12	8.6	29900	17.49	15700	
	>C12-C16	42.1	29900	4888	16800	
	>C16-C35	27600	617000	137957	n.d	Liver
	>C35-C44	27600	617000	414509	n.d	
Aromatic fractions	>C5-C7	0.613	26.9	1.85	84	Liver, neurological
	>C7-C8	0.694	30.4	4.12	186	
	>C8-C10	2.39	107	5.54	250	Body weight
	>C10-C12	14.2	625	29.5	45021	
	>C12-C16	72.7	12200	148	60650	
	>C16-C21	291	9190	1825	46430	Kidney
	>C21-C35	417	9250	2074	46553	
	>C35-C44	417	9250	2074	46553	
	>C44-C70	417	9250	2073	46553	

Fugacity approach: Level I and II



- fate drives analysis, exposure and performance
- log $K_{oil\text{-}soil}$ coefficients
- weathering increases PAH log $K_{oil\text{-}soil}$
- risk = f (availability and toxic response)
- Combination of advective processes and degrading reactions
- Determination of compounds persistence or residence time

Partitioning behaviour: Fugacity level I



General partitioning behaviour and preferential partitioning in a constructed biopile

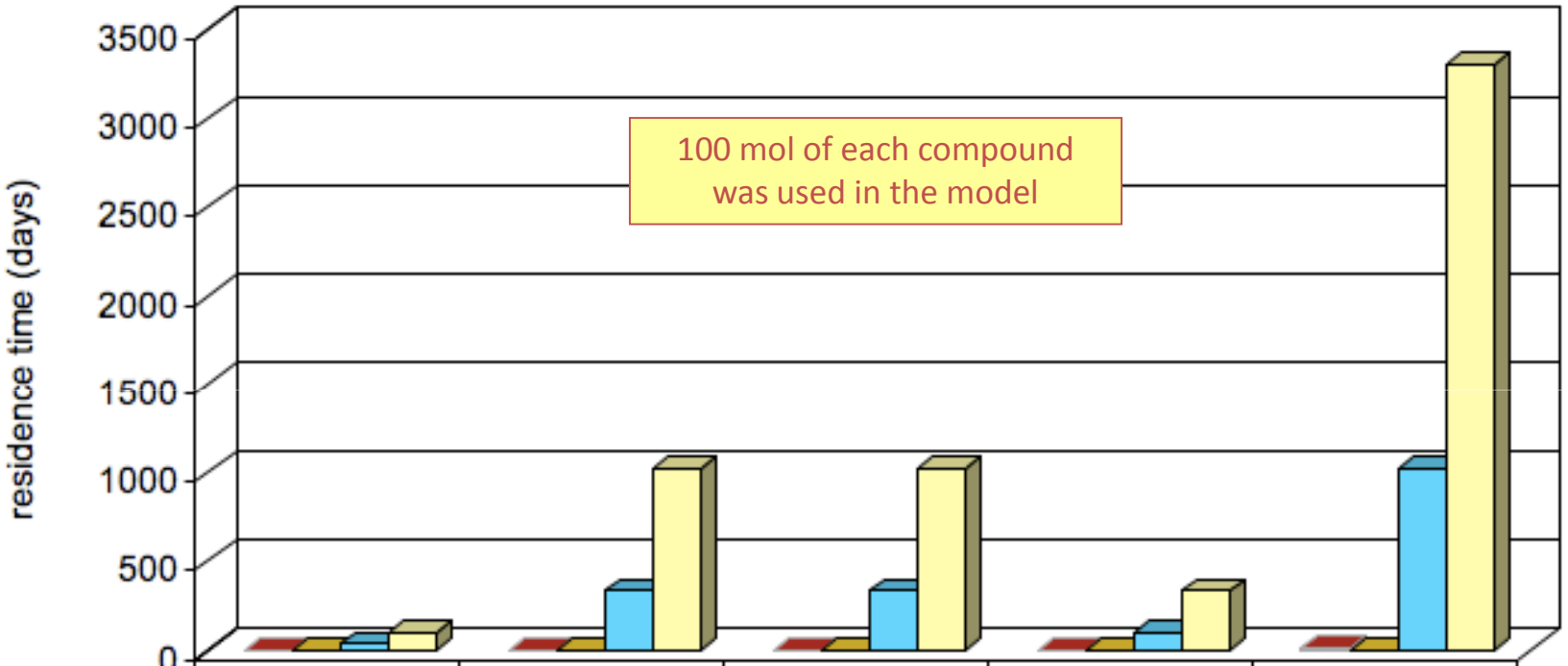
Fugacity calculator for subsurface environments. Available at

http://www.infoclearinghouse.com/files/FugacityEXCEL.xls

			Air	Water	Soil	NAPL
1	> EC10-EC12	Naphthalene	0.0	0.2	51.5	48.4
2	> EC12-EC16	Acenaphthene	0.0	0.0	49.8	50.2
3		1-methylphenanthrene	0.2	0.0	15.1	84.7
4	> EC16-EC21	Anthracene	0.0	0.0	42.4	57.6
5		Phenanthrene	0.0	0.0	41.8	58.2
6		Pyrene	0.0	0.0	45.2	54.8
7	> EC21-EC35	Chrysene	0.0	0.0	44.7	55.3
8		Benzo(a)pyrene	0.0	0.0	88.7	11.3
9		Benzo(a)anthracene	0.0	0.0	84.8	15.2
10		Benzo(ghi)perylene	0.0	0.0	44.7	55.3

Residence time: Fugacity level II

Distribution of 5 chemicals modelled in soil microcosms where advection and degradation reaction were combined



	benzene	anthracene	phenanthrene	methylphenanthrene	benzo(a)pyrene
AIR	1	3	3	1	6
WATER	0	0	0	0	0
SOIL	33	331	331	102	1022
NAPL	102	1022	1022	331	3306

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.

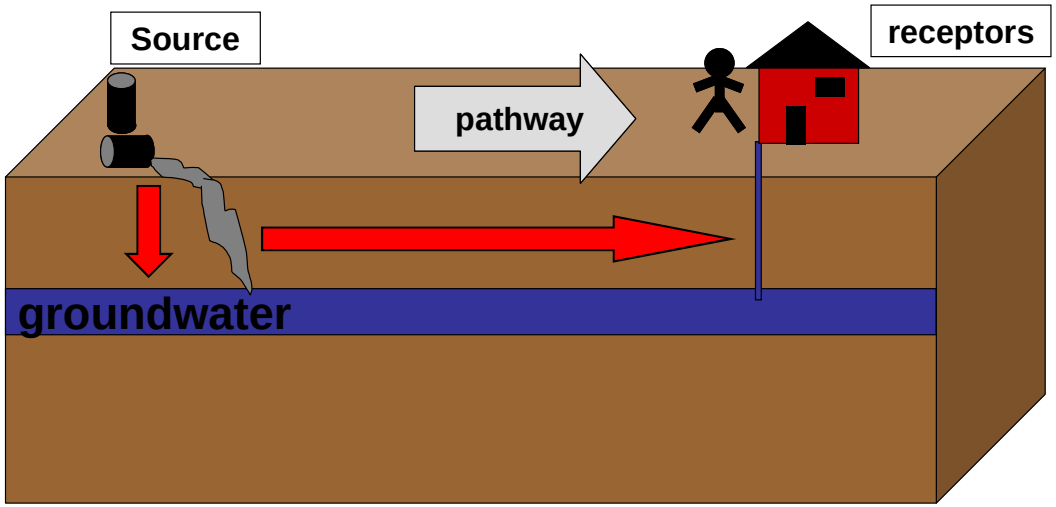
IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA

Details to be completed for each assessment				
Site Name:	TCE site			
Site Address:	Aberdeen			
Completed by:	LM			
Date:	14-Feb-13		Version:	x.xx
Contaminant	TCE			
Target Concentration (C_T)	0.01	mg/l	Origin of C_T:	Specify basis for target concentration

RISK-INTEGRATED
RISC
SOFTWARE FOR CLEAN-UPS

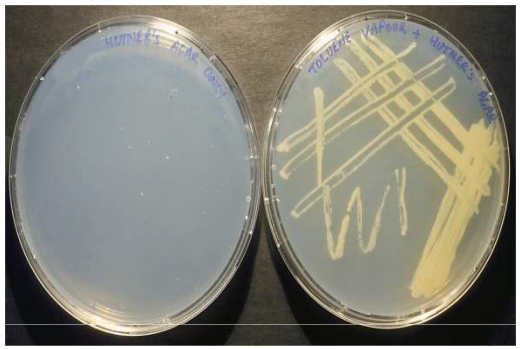
Environmental Standards and DWS values

COC	EQS/DWS (µg/l)
Phenols Monohydric	30
Benzene	10
Toluene	10
Ethyl benzene	10
m & p Xylene	10
o Xylene	10
Aliphatics C5-C6	10
Aliphatics >C6-C8	10
Aliphatics >C8-C10	10
Aliphatics >C10-C12	10
Aliphatics >C12-C16	10
Aliphatics >C16-C21	10
Aliphatics >C21-C35	10
Aromatics C6-C7	10
Aromatics >C7-C8	10
Aromatics >EC8-EC10	10
Aromatics >EC10-EC12	10
Aromatics >EC12-EC16	10
Aromatics >EC16-EC21	10
Aromatics >EC21-EC35	10
Naphthalene	10
Benzo(b)fluoranthene	0.10
Benzo(k)fluoranthene	0.10
Benzo(a)pyrene	0.01
Indeno(123cd)pyrene	0.10
Benzo(ghi)perylene	0.10



Bioassays

Microbial



Biomass

Respiration

Nitrification

Enzyme assays

lux-based bacteria

Earthworms

Lethal and Sub-lethal

Eisenia fetida

Lumbricus terrestris

Plants

Seed Germination

Mustard

Rye grass

Pea

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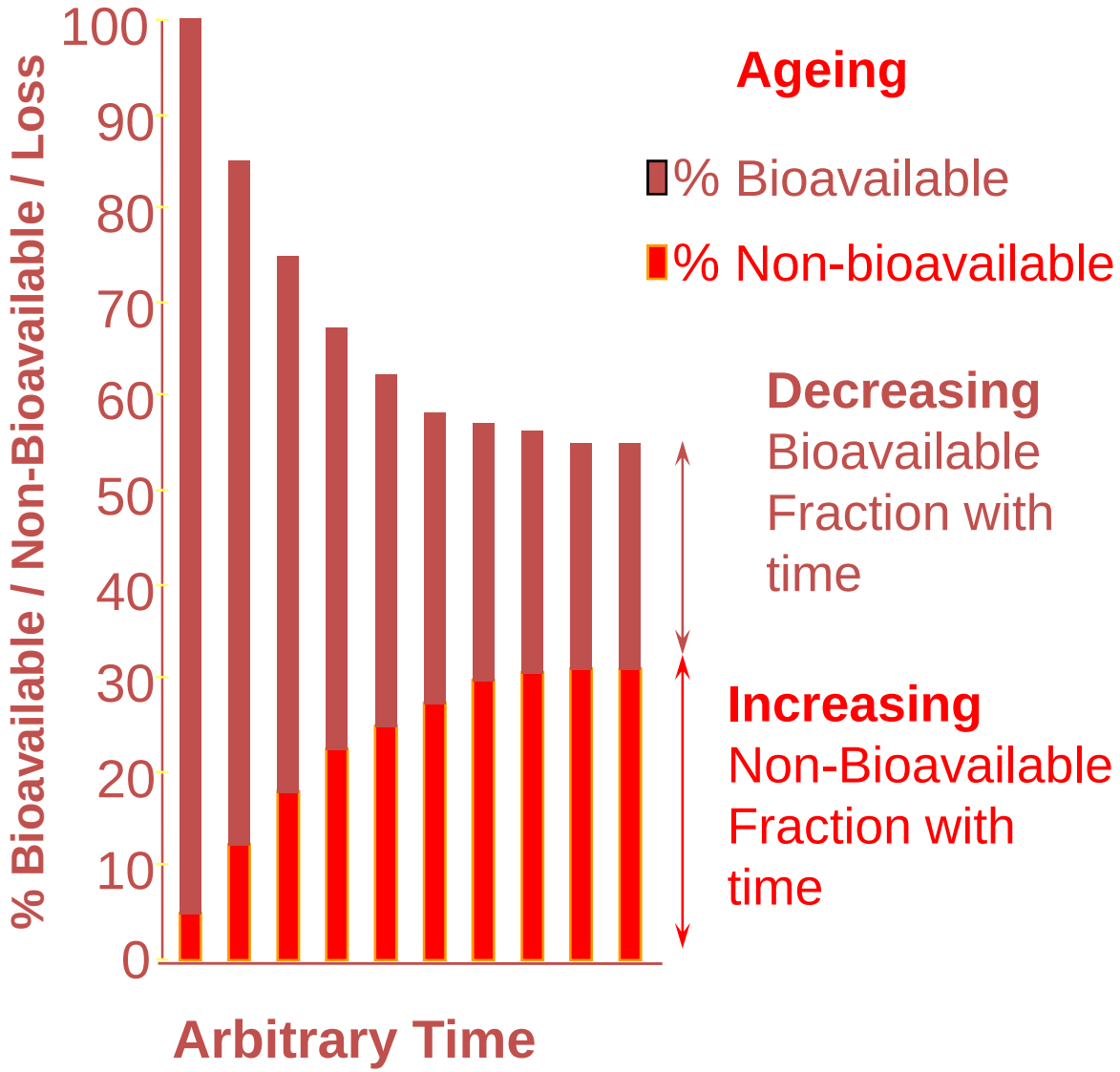
What do we expect to happen

- The hydrocarbons will age and the bioavailability (as a function of degradation and toxicity) will change
- Toxicity may increase and then decrease in association with biodegradation
- Field scale validation may respond in parallel



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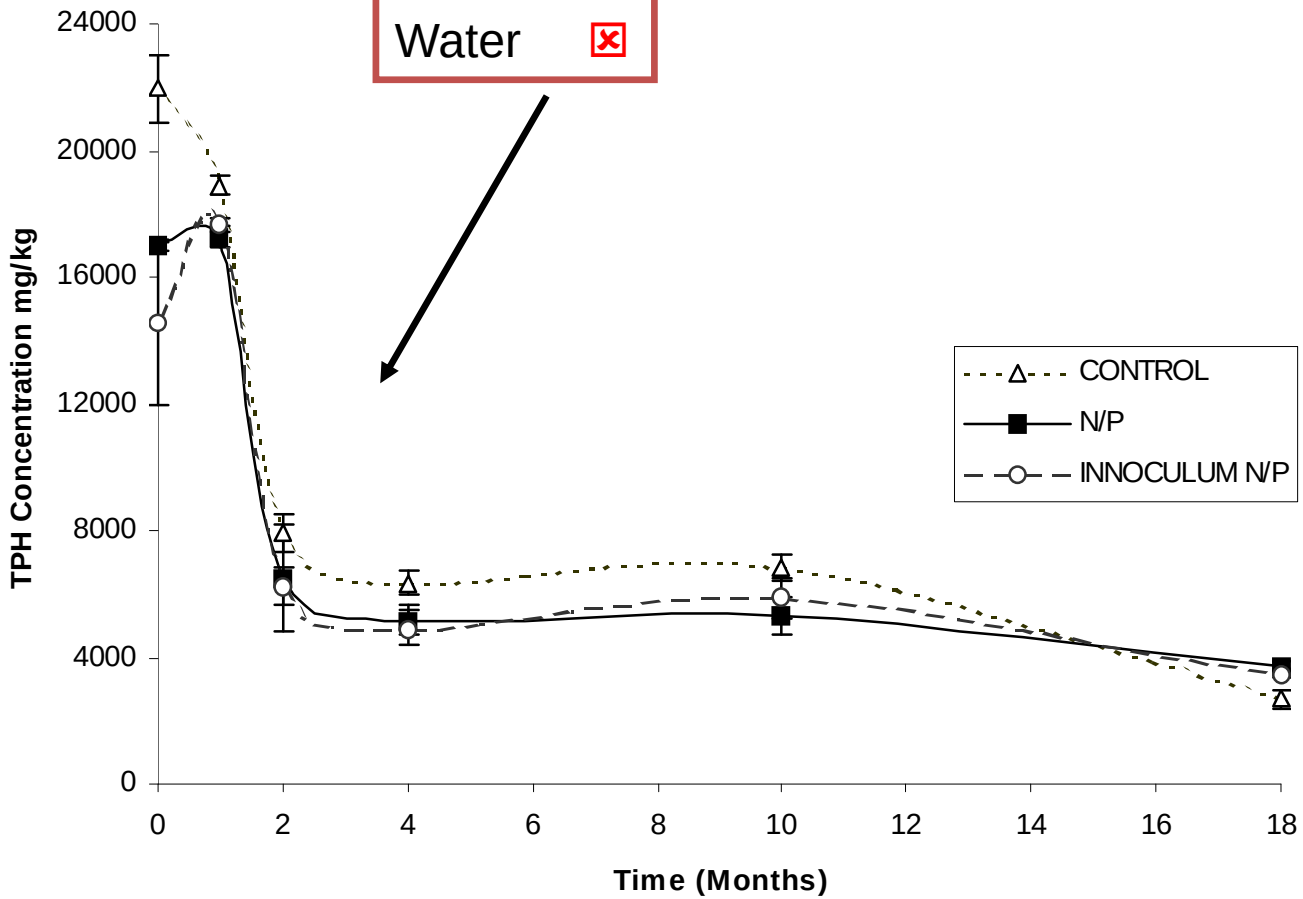
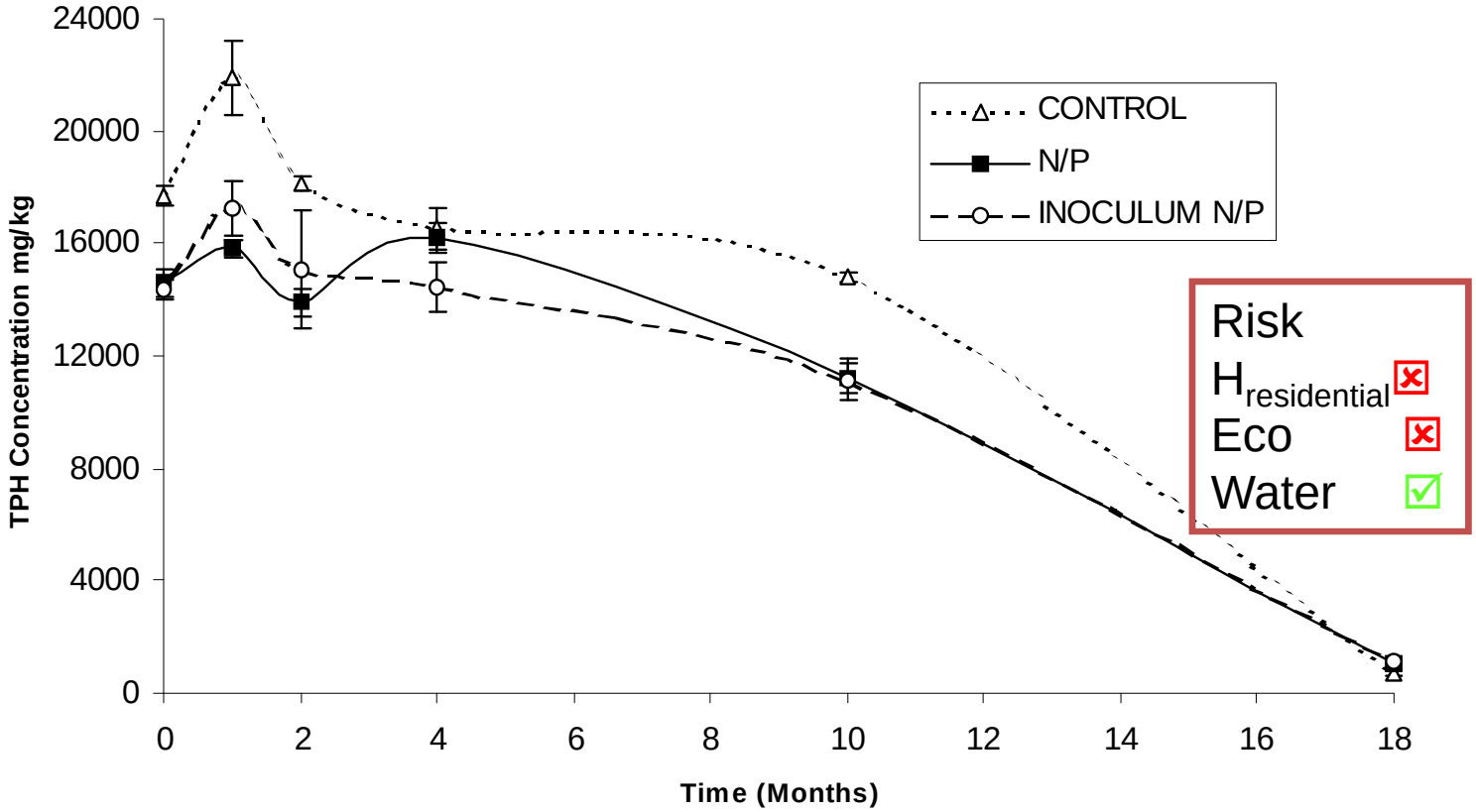
Soil B

Risk
$H_{residential}$ ☑
Eco ☒
Water ☒



Promise

Soil C



Promise

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Pre-mixing

Inoculum

Windrow Turning

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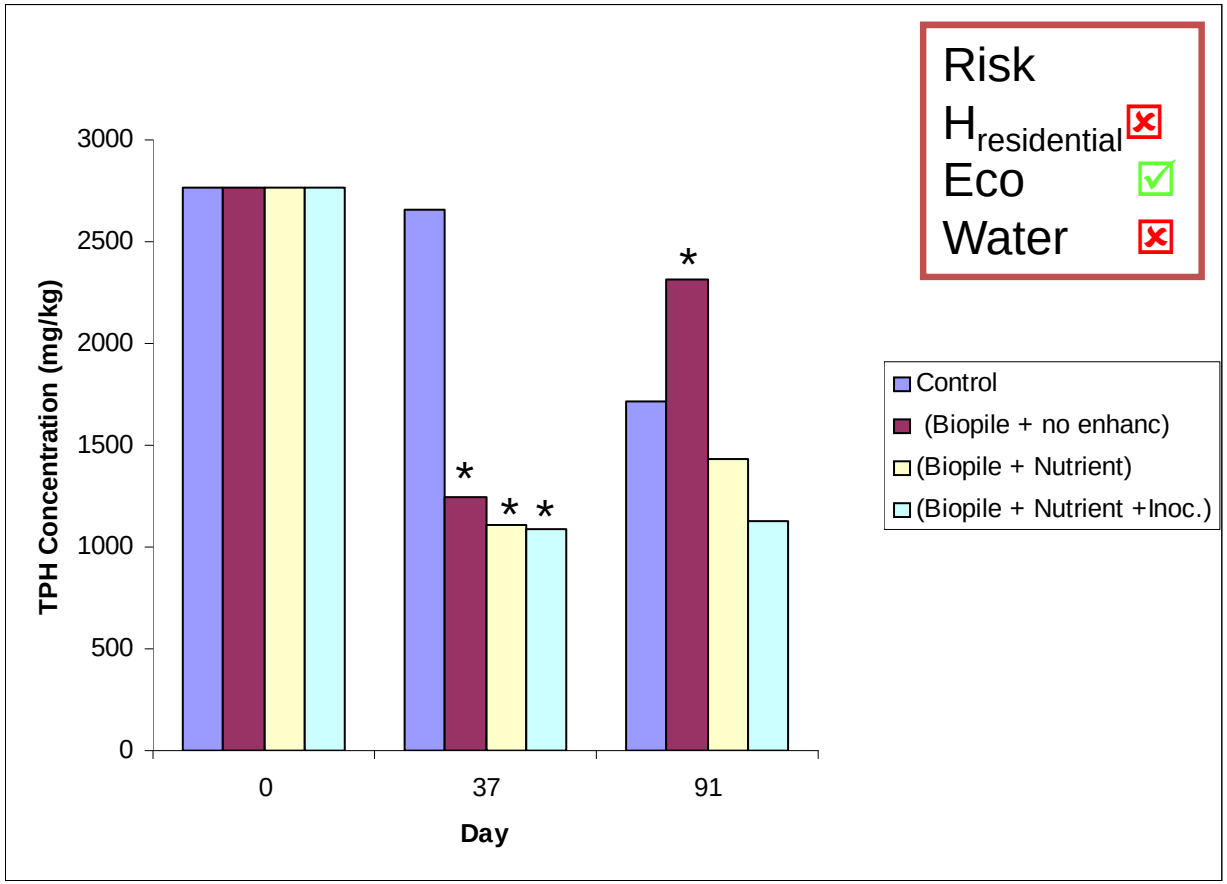
Windrow Turning

Importance of Irrigation

Routine Monitoring Continues

TPH Degradation- Biopiles



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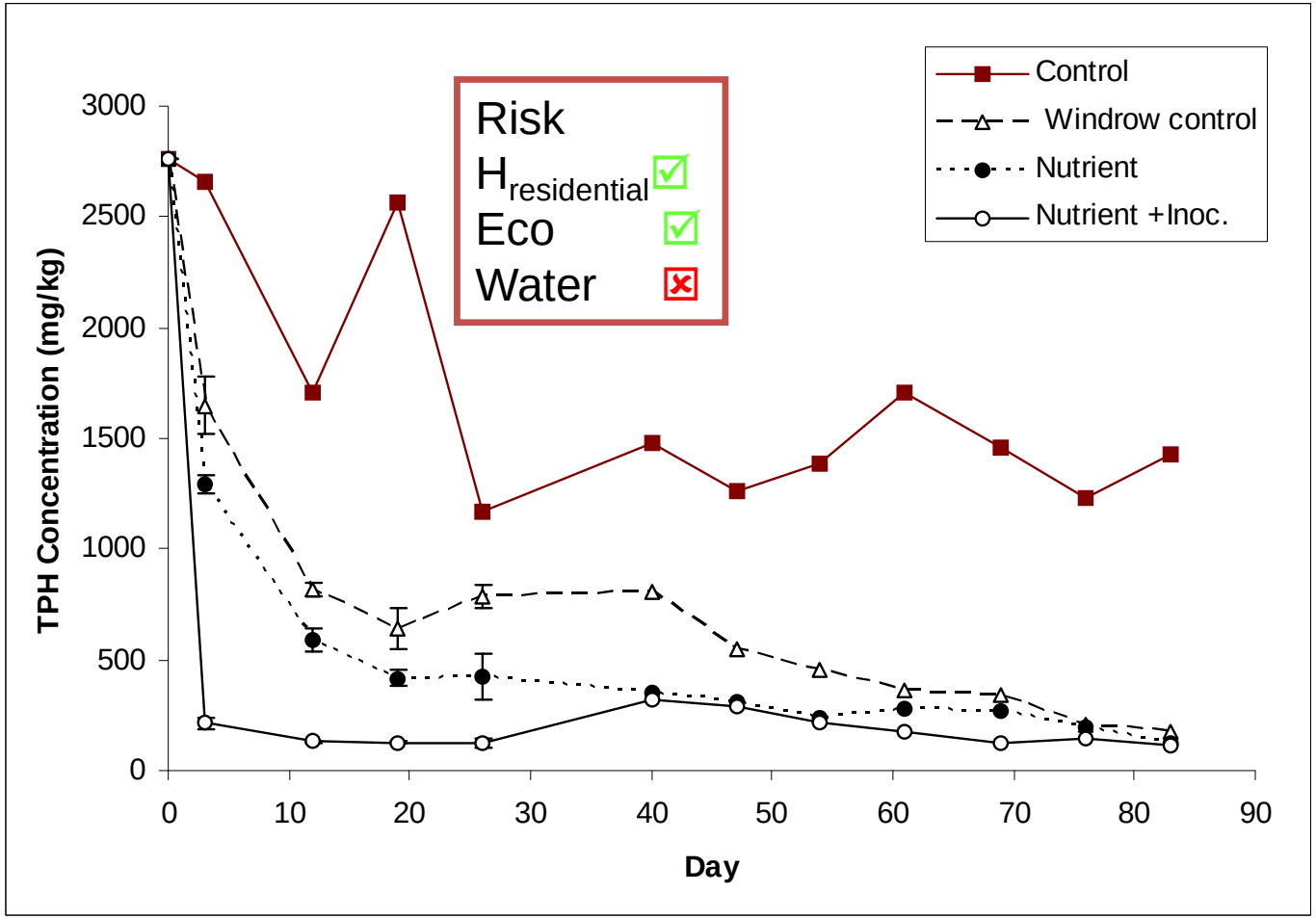
TPH Degradation- Windrows



Promise

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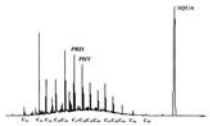
Remediation Decision Support Tool

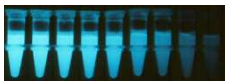
- Developed support tool based on 3 tiers, designed to reduce uncertainty in technology selection
- Road tested on genuine scenarios
- The tool assists in the decision making process of remediation technologies:
  - Enabling transparent justification of selection
  - Gives focussed and streamlined support for targeting best options.
  - Interfaces with web to enable continual updating as practices become established and lessons are learned

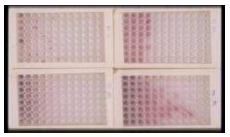
Predicting Hydrocarbon Remediation?

- Empirical data from thirty sites have been generated & applied to appraise and validate.

$$BF = \left(\frac{Resp}{(I \times [TPH]} \right) \times \left(\frac{[TPH]}{\log (MPN)} \right) \times Inhibition$$

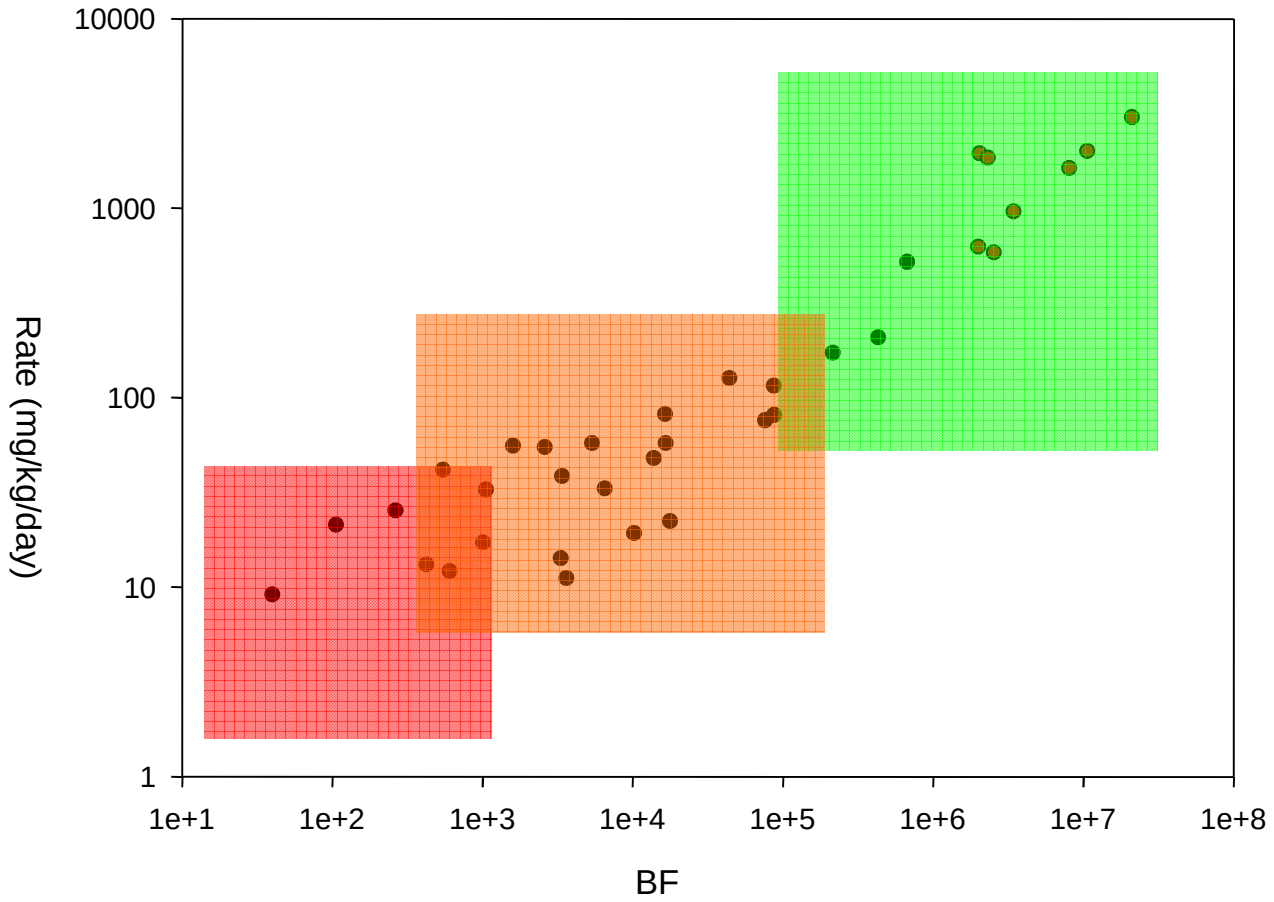






BF = bioremediation function
I = induction
[TPH] =TPH concentration
MPN = most probable number
Resp = respiration

BF & Rate of Degradation



Hydrocarbon Validation

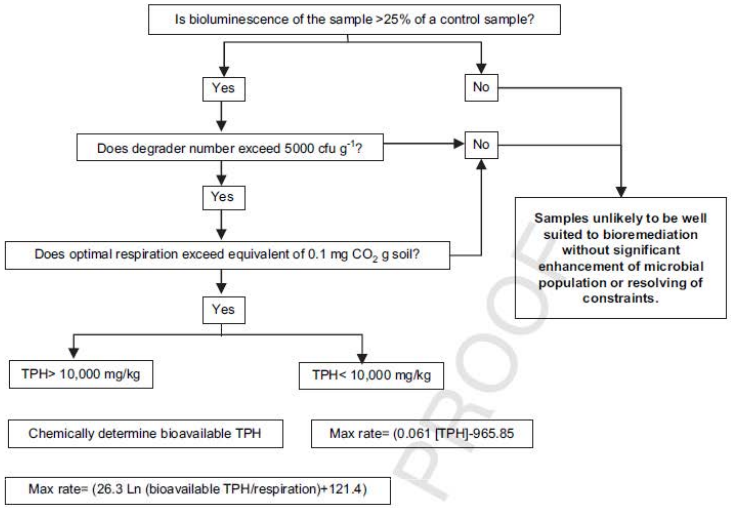


Fig. 3. Decision support tree to make use of derived equations in the assessment of suitability of materials for bioremediation.

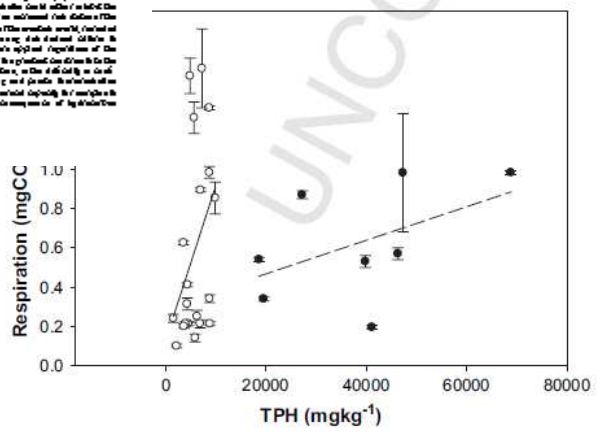


Fig. 2. Total measured petroleum hydrocarbon concentration plotted against the maximum measured rate of respiration ((○) >10,000 mg kg^{-1} (●) <10,000 mg kg^{-1}).

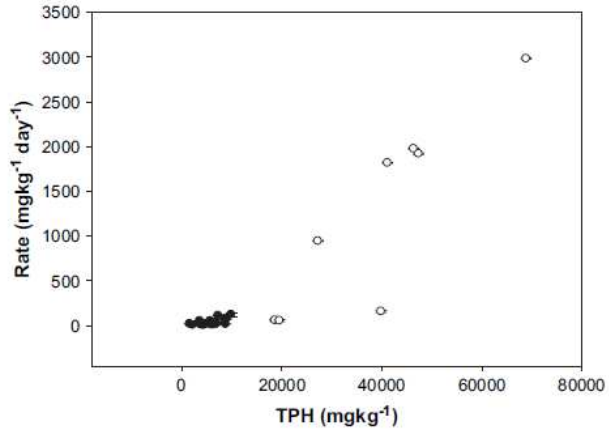
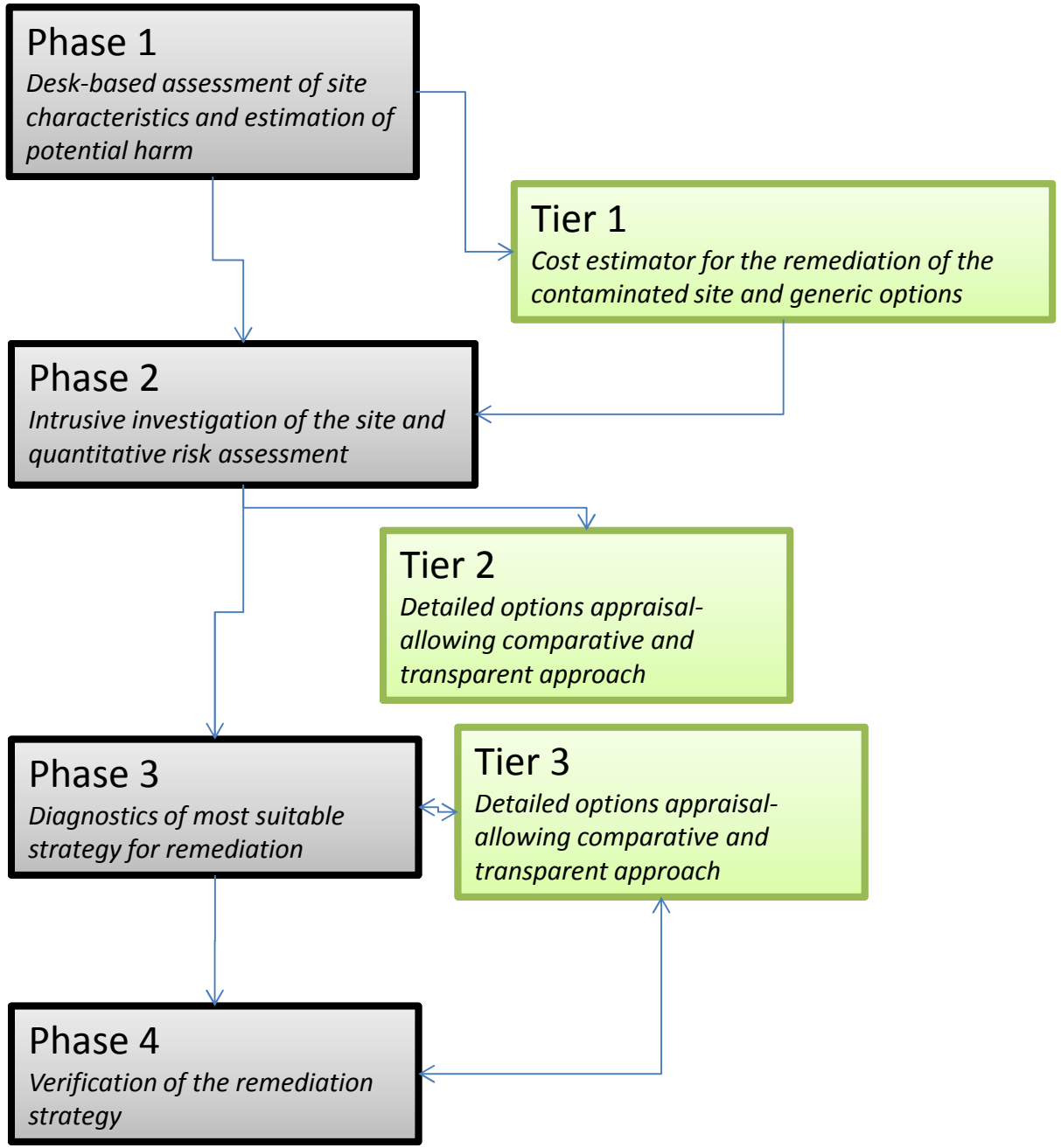


Fig. 1. Total measured petroleum hydrocarbon concentration plotted against the maximum rate of measured hydrocarbon degradation ((○) >10,000 mg kg^{-1} (●) <10,000 mg kg^{-1}).

OVERVIEW- *ORGANISING A SUITABLE MATRIX*


Phase 1
Desk-based assessment of site characteristics and estimation of potential harm
Tier 1
Cost estimator for the remediation of the contaminated site and generic options
Phase 2
Intrusive investigation of the site and quantitative risk assessment
Tier 2
Detailed options appraisal- allowing comparative and transparent approach
Phase 3
Diagnostics of most suitable strategy for remediation
Tier 3
Detailed options appraisal- allowing comparative and transparent approach
Phase 4
Verification of the remediation strategy

TIER 1- *RAPID OVERVIEW WITH LIMITED DATA*

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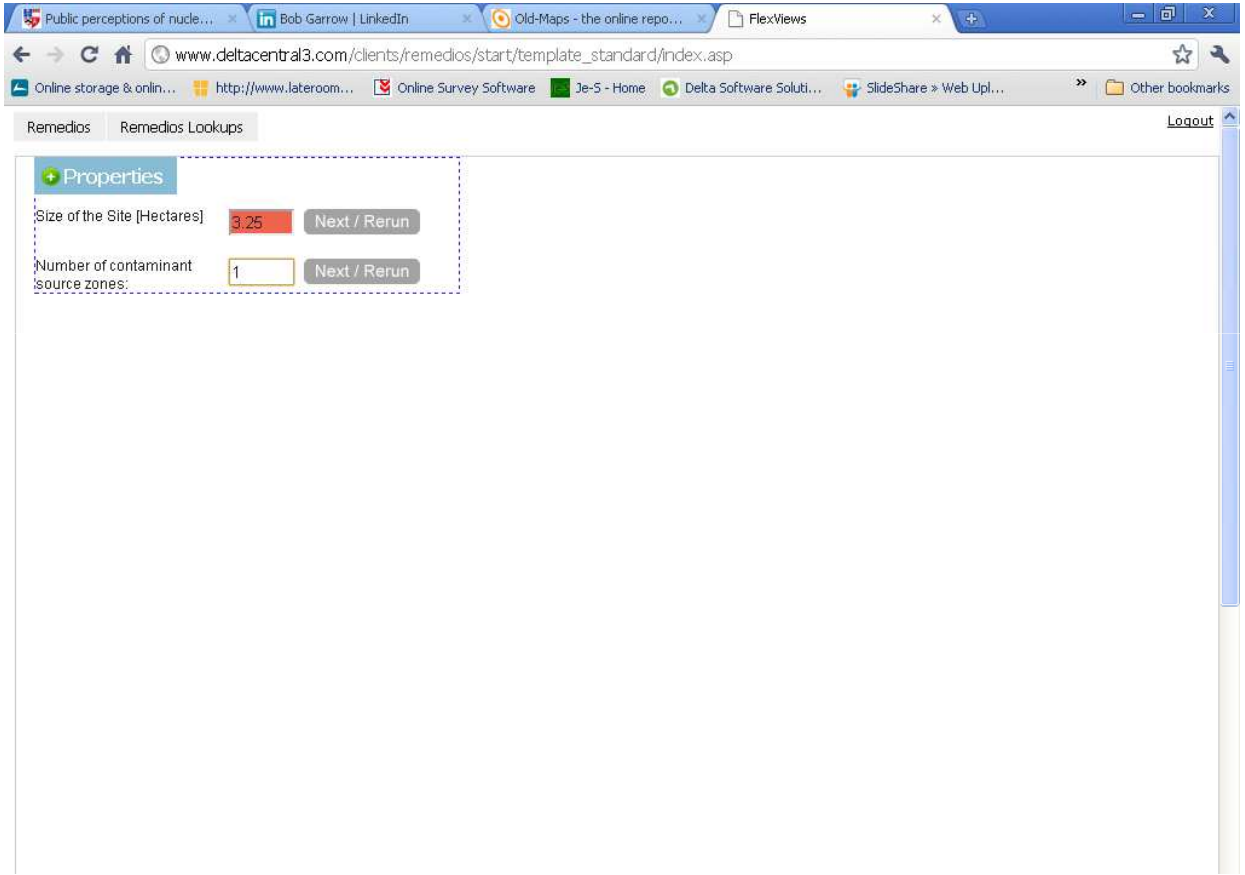
Probability/ Consequence Matrix

		Consequence			
		Severe	Medium	Mild	Minor
Probability	V. Likely	V High Risk	High Risk	Moderate Risk	Moderate/ low risk
	Likely	High Risk	Moderate Risk	Moderate/ Low Risk	Low risk
	Low Likely	Moderate Risk	Moderate/ Low risk	Low Risk	Very low risk
	Unlikely	Moderate/ Low Risk	Low risk	Very low risk	Very low risk

Data Input from Phase 1



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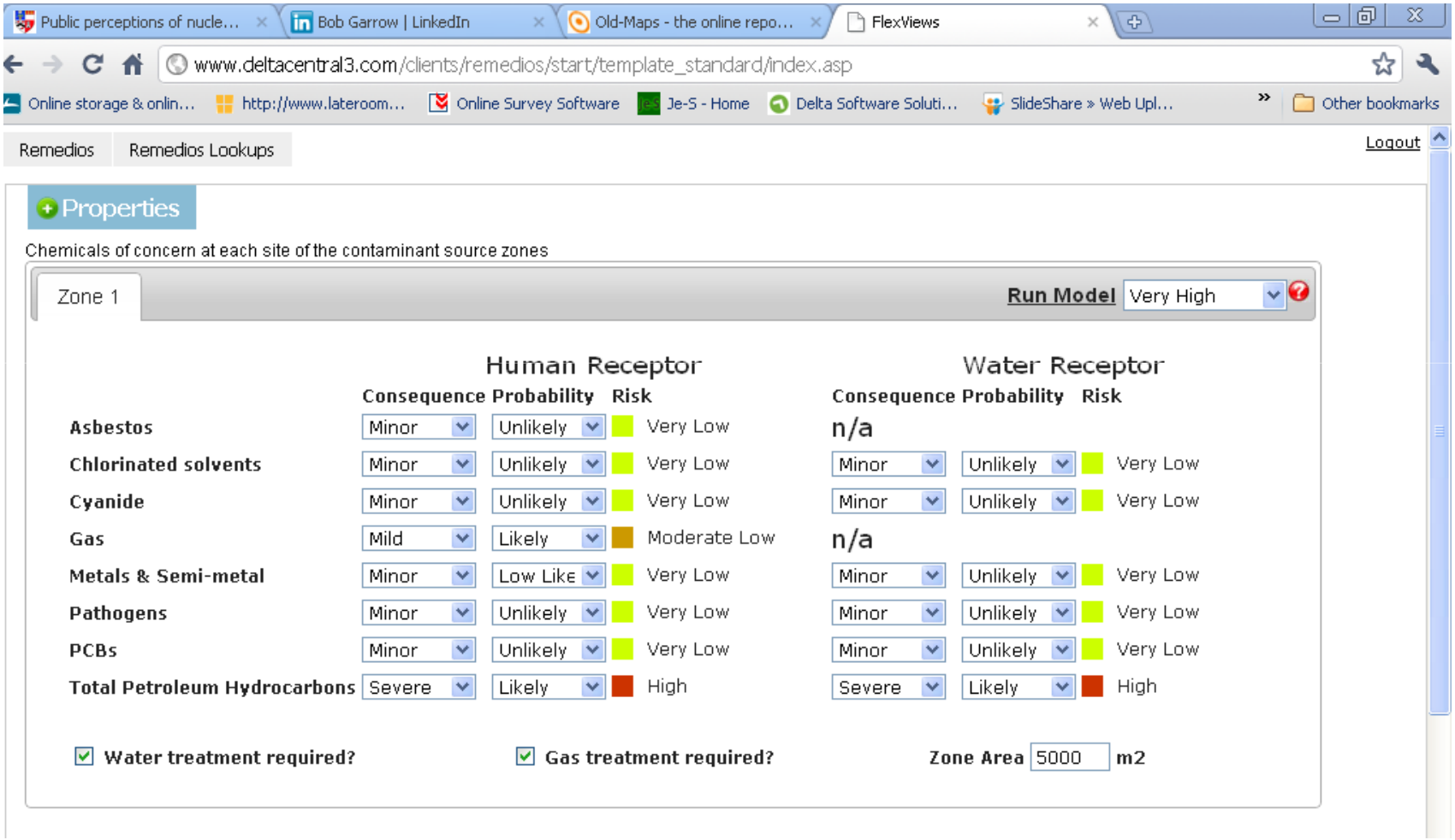
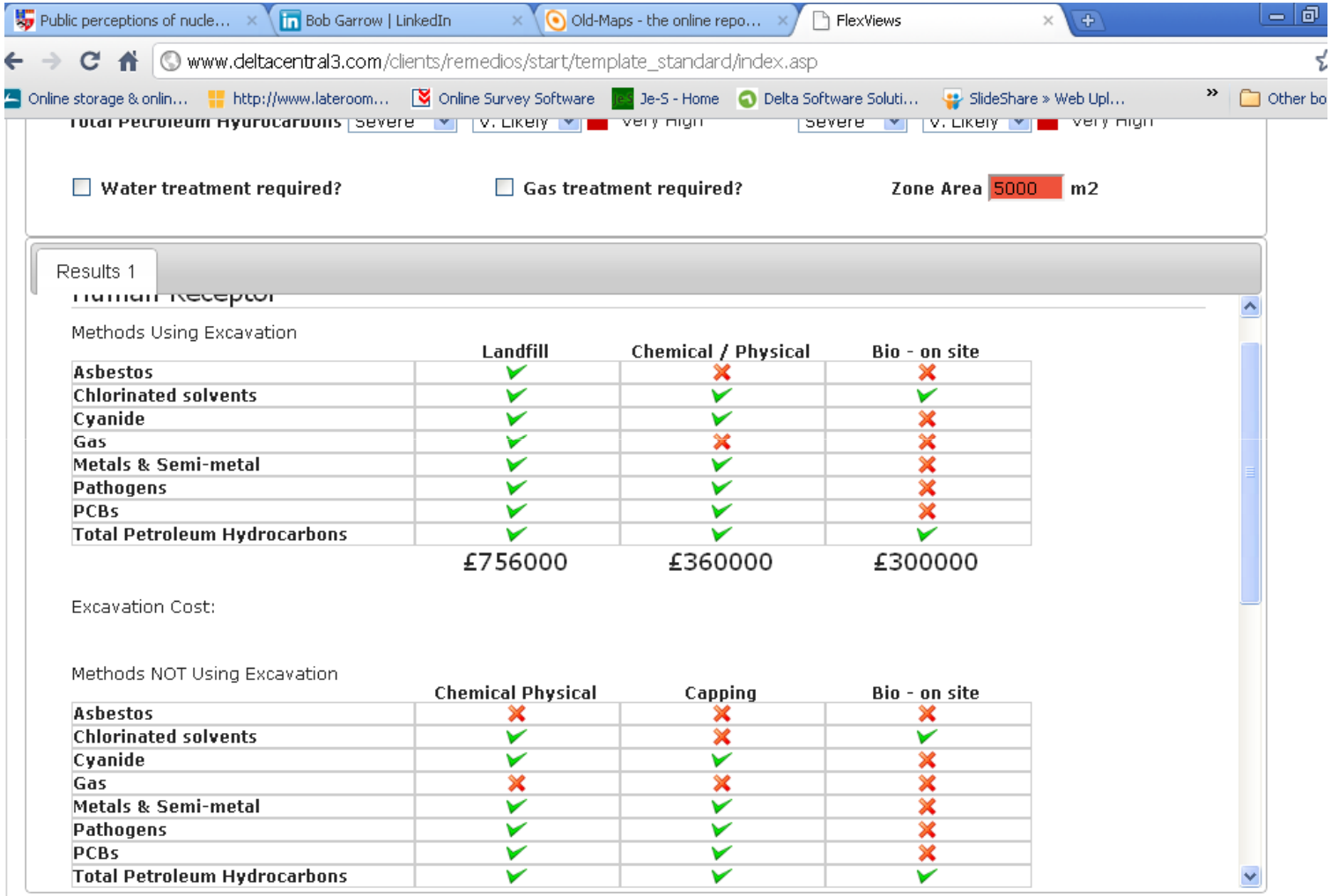
Data Input from Tier 1

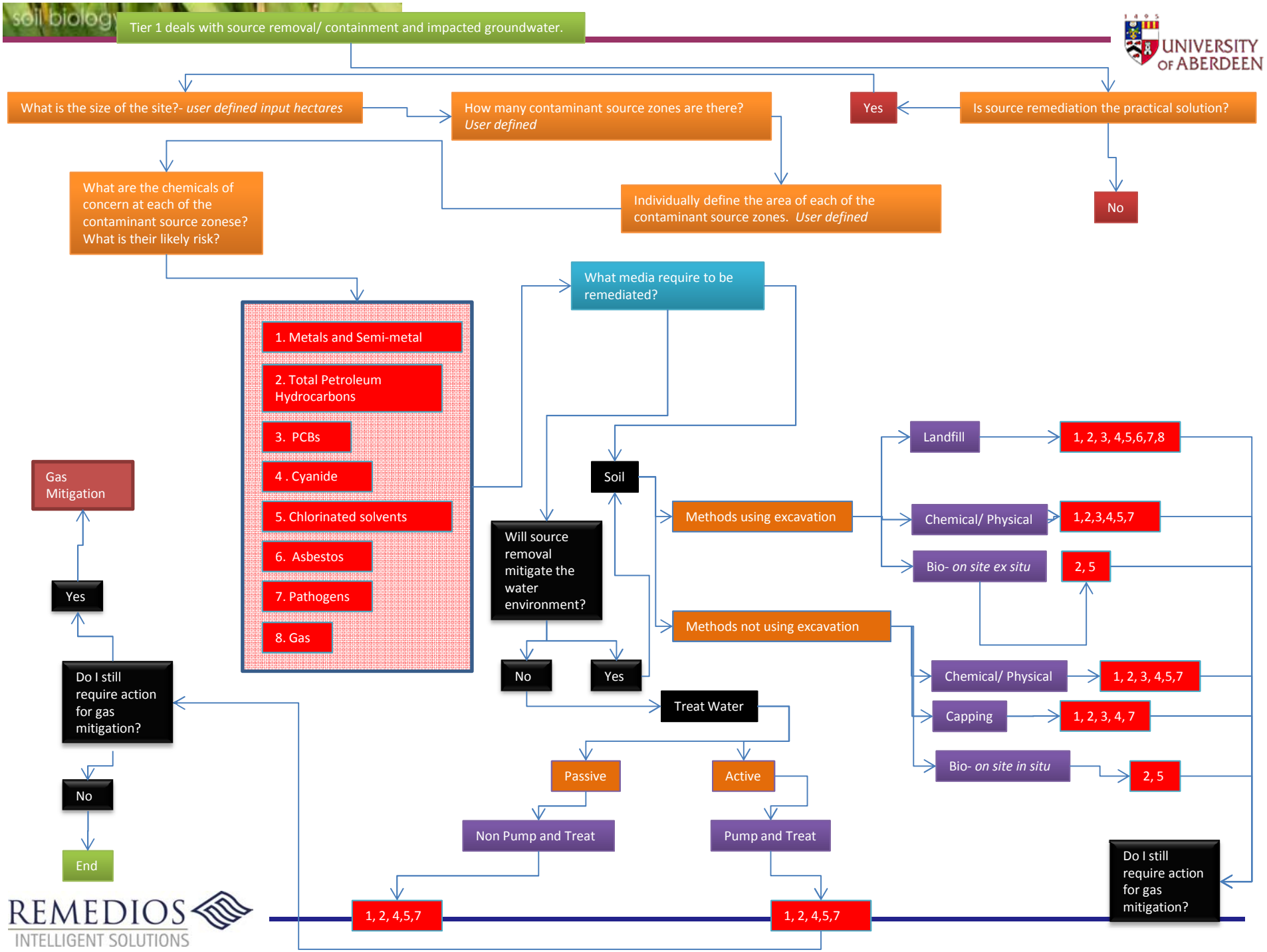


REMEDIOS
INTELLIGENT SOLUTIONS

Output


Public perceptions of nucle...
Bob Garrow | LinkedIn
Old-Maps - the online repo...
FlexViews
www.deltacentral3.com/clients/remedios/start/template_standard/index.asp
Online storage & onlin...
http://www.lateroom...
Online Survey Software
Je-S - Home
Delta Software Soluti...
SlideShare » Web Upl...
Other bo
Severe
V. Likely
Very High
Water treatment required?
Gas treatment required?
Zone Area 5000 m2
Results 1
Methods Using Excavation
Landfill
Chemical / Physical
Bio - on site
Asbestos
Chlorinated solvents
Cyanide
Gas
Metals & Semi-metal
Pathogens
PCBs
Total Petroleum Hydrocarbons
£756000
£360000
£300000
Excavation Cost:
Methods NOT Using Excavation
Chemical Physical
Capping
Bio - on site
Asbestos
Chlorinated solvents
Cyanide
Gas
Metals & Semi-metal
Pathogens
PCBs
Total Petroleum Hydrocarbons

TIER 2- *SITE SPECIFIC MATCHING OF TECHNIQUES*


soil biology
Tier 1 deals with source removal/ containment and impacted groundwater.
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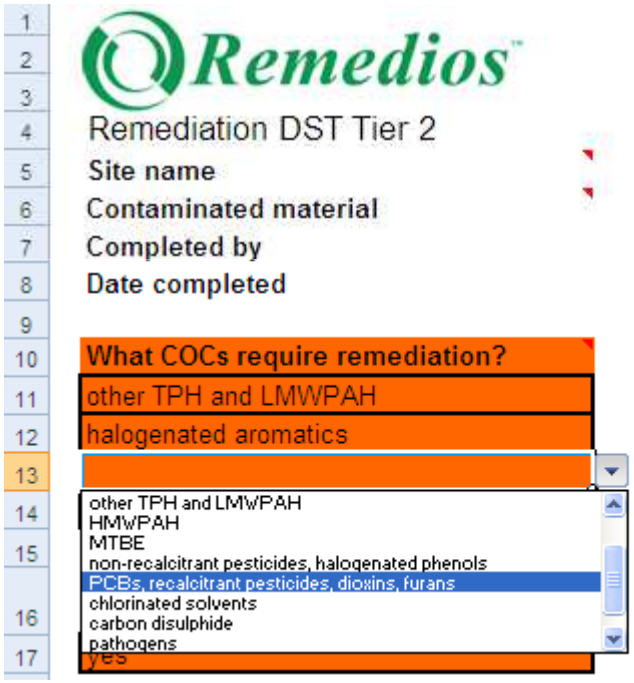
What is the size of the site?- user defined input hectares
How many contaminant source zones are there? User defined
Yes
Is source remediation the practical solution?
No
Individually define the area of each of the contaminant source zones. User defined
What are the chemicals of concern at each of the contaminant source zonese? What is their likely risk?
What media require to be remediated?
1. Metals and Semi-metal
2. Total Petroleum Hydrocarbons
3. PCBs
4 . Cyanide
5. Chlorinated solvents
6. Asbestos
7. Pathogens
8. Gas
Soil
Will source removal mitigate the water environment?
No
Yes
Treat Water
Passive
Active
Non Pump and Treat
Pump and Treat
1, 2, 4,5,7
1, 2, 4,5,7
Methods using excavation
Landfill
1, 2, 3, 4,5,6,7,8
Chemical/ Physical
1,2,3,4,5,7
Bio- on site ex situ
2, 5
Methods not using excavation
Chemical/ Physical
1, 2, 3, 4,5,7
Capping
1, 2, 3, 4, 7
Bio- on site in situ
2, 5
Do I still require action for gas mitigation?
Gas Mitigation
Yes
Do I still require action for gas mitigation?
No
End
REMEDIOS
INTELLIGENT SOLUTIONS

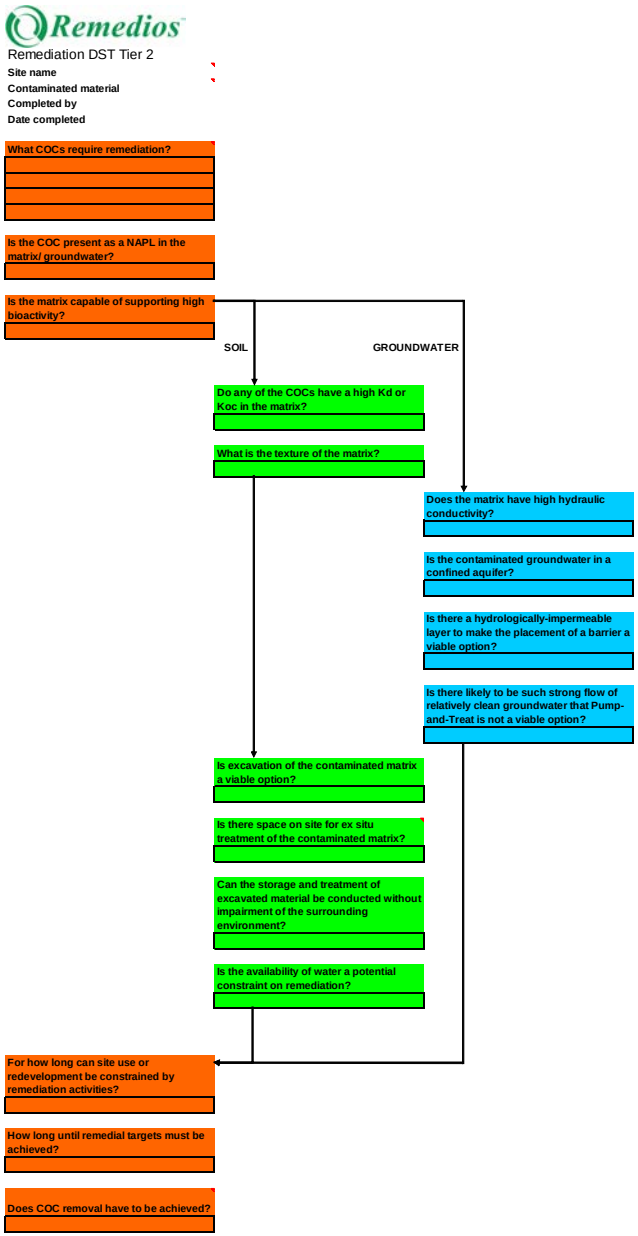
Which does what?

Row	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
3				soil																	groundwater											
4				in situ										ex situ																		
5				MNA	bioventing	enhanced bioremediation	phytoremediation	chemical oxidation and reduction	electrokinetic separation	soil flushing	SVE	solidification/stabilization	thermal treatment	bioremediation	chemical oxidation, reduction & dehalogenation	soil washing/separation	solidification/stabilization	incineration	thermal desorption	off-site disposal	MNA	enhanced bioremediation	phytoremediation	bioslurping	air sparging	chemical oxidation	dual phase extraction	thermal treatment	in-well air stripping	passive/reactive treatment walls	physical/chemical (pump & treat)	physical barriers
6–7		**CHEMICALS OF CONCERN Questions that define the suitability of the technique to the site**																														
8																																
9	COCQ1	What is/are the CoCs that require remediation?																														
10			metals/semi-metals	y	n	y	y	n	y	y	n	y	n	n	n	y	y	n	n	y	y	y	y	n	n	n	n	n	n	y	y	y
11			mono aromatics, substituted aromatics and halogenated aromatics	y	y	y	y	y	n	y	y	n	y	y	y	y	n	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
12			other TPH and LMWPAH	y	y	y	y	y	n	y	y	n	y	y	y	y	n	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
13			HMWPAH	n	n	n	y	y	n	n	n	n	n	n	n	y	n	y	y	y	n	n	y	n	n	y	n	y	n	y	y	y
14			MTBE	y	y	y	y	y	n	y	n	n	n	y	y	n	n	y	y	y	y	y	y	n	n	y	n	y	n	y	y	y
15			non-recalcitrant pesticides, halogenated phenols	y	y	y	y	y	n	y	n	n	y	y	y	y	n	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
16			PCBs, recalcitrant pesticides, dioxins, furans	n	n	n	y	n	n	n	n	n	n	n	y	n	n	y	y	y	n	n	y	n	n	y	n	n	n	y	y	y
17			chlorinated solvents	y	n	y	y	y	n	n	y	n	y	y	y	y	n	y	y	y	y	y	y	n	y	y	n	y	y	y	y	y
18			carbon disulphide	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	n	n	n	n	n	n	n	n	y	n	n
19			pathogens	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	y	n	n	n	n	n	n	n	n	n	n	n	n
20			asbestos (Soil only)	n	n	n	n	n	n	n	n	y	n	n	n	n	y	n	n	y	[redacted]											
21																																
22	COCQ2	Is the CoC present as a NAPL in the matrix/ groundwater?																														
23			yes	n	n	n	n	y	n	n	y	n	y	n	y	y	n	y	n	y	n	n	n	y	n	y	y	n	y	n	y	n
24			no	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
25																																
26–27		**MATRIX Terms that define the site-specific matrix and relate this to the appropriateness of the**																														
28																																
29	MQ1	Is the matrix capable of supporting high bioactivity?																														
30			yes	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
31			no	y	n	n	n	y	y	y	y	y	y	n	y	y	y	y	y	y	y	n	n	n	y	y	y	y	y	y	y	y
32			unknown (same as no)																													
33																																
34	MQ2	Soil only: Do any of the CoCs have a high Kd or Koc in the matrix?																														
35			yes	y	n	n	n	y	y	y	y	y	y	n	y	y	y	y	y	y	[redacted]											
36			no	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y												
37																																
38	MQ3	Soil only: Define the texture(s) of the matrix.																														

Duration | Updated and revamped techniques

Chemicals of Concern

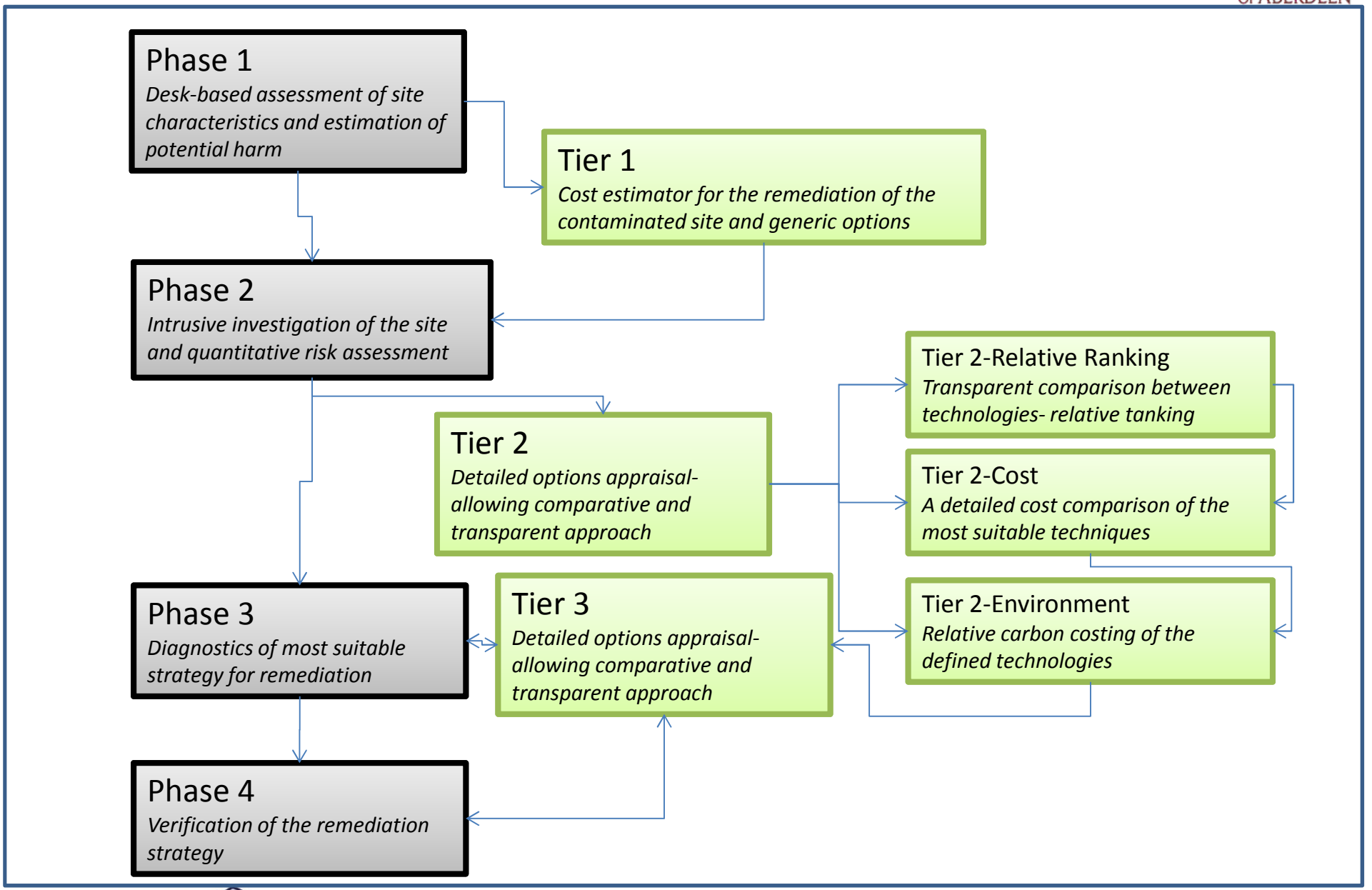




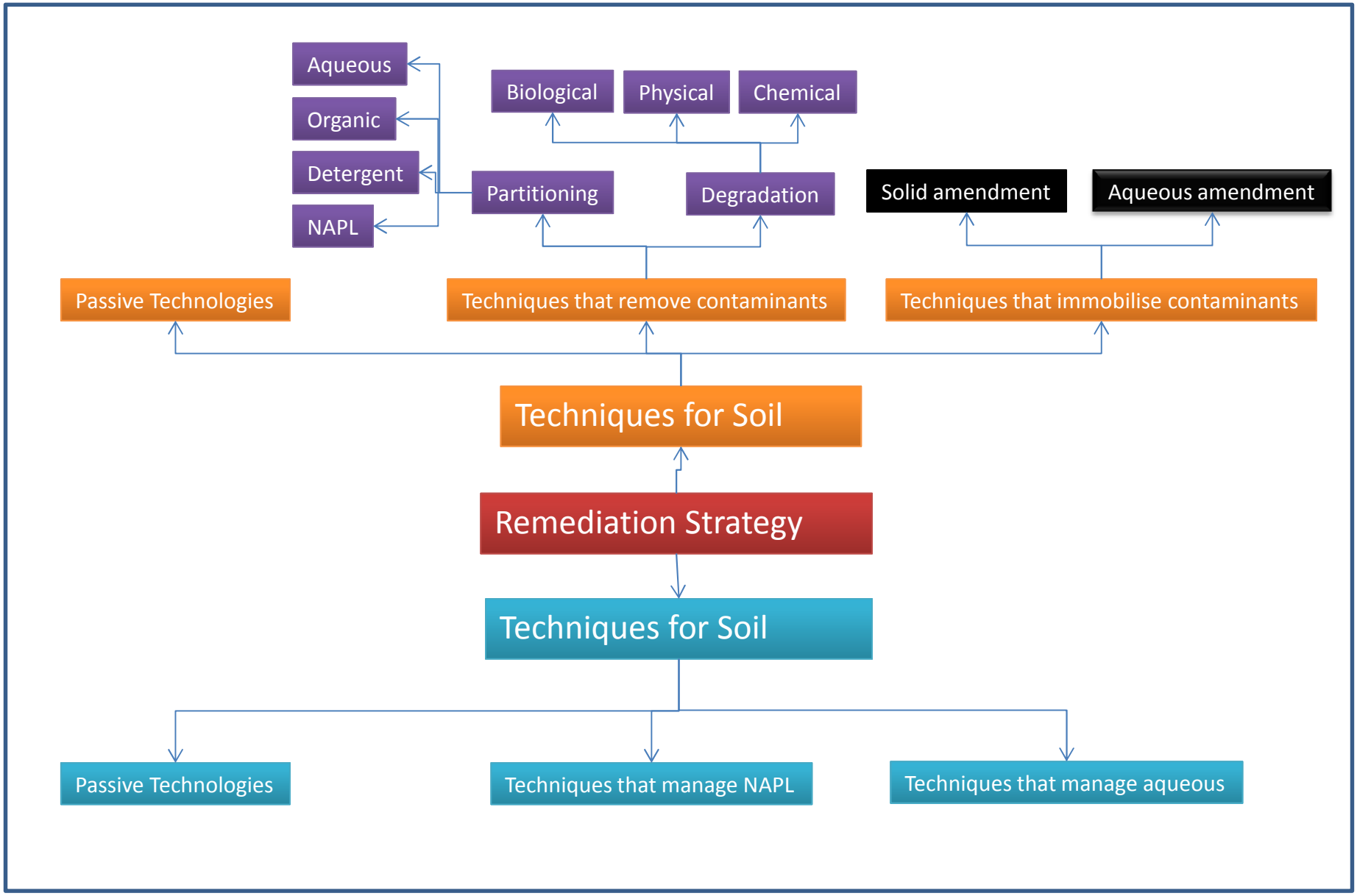
- Visual basic interface
- Multi-pollutant credible
- Considers major processes
- Links to a ranked output

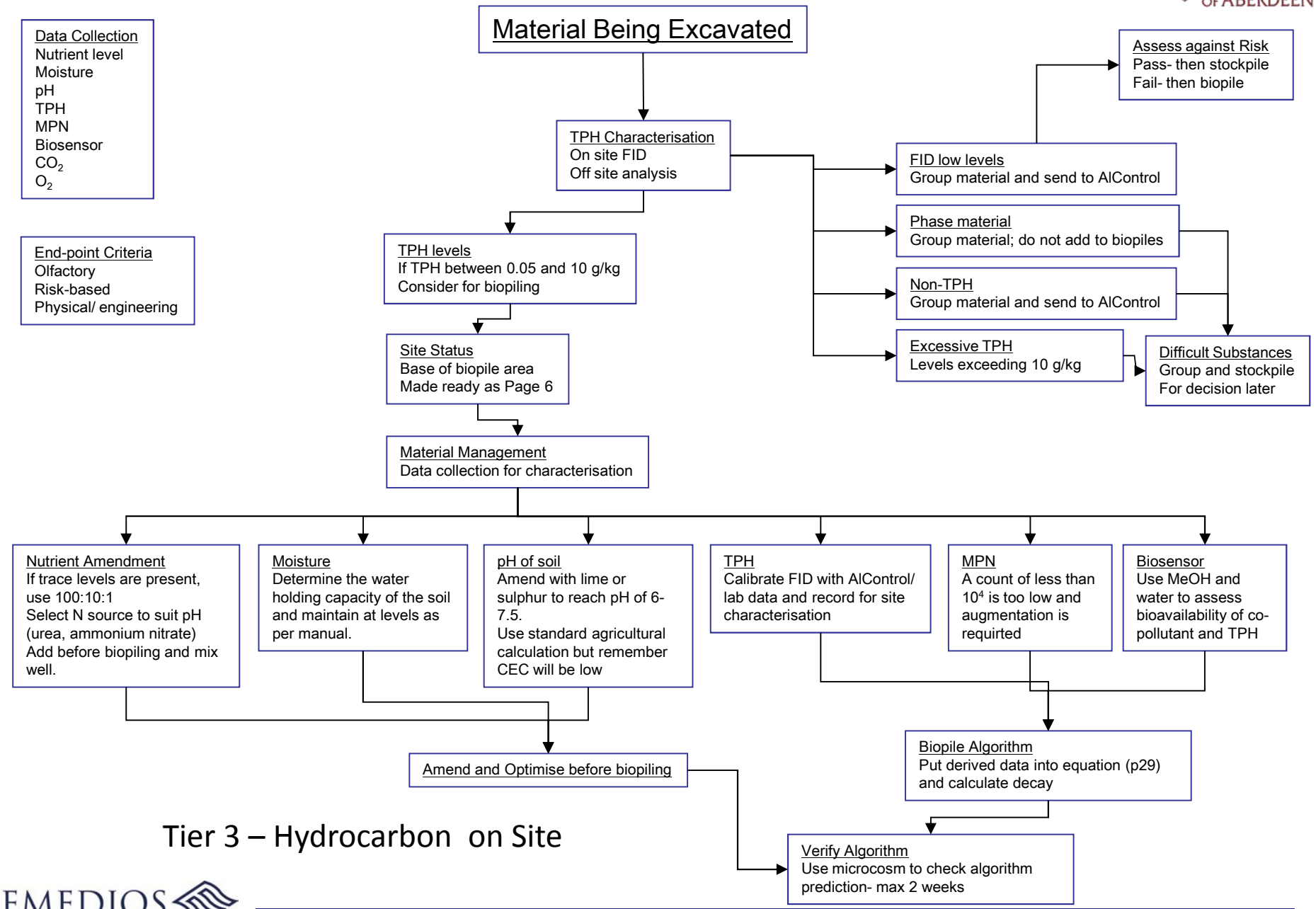
		Technique	Site Specific Applicability	Permisibility	Certainty	Capital Costs	O and M Costs	Market Constraints	Remediation Duration	Environmental Credits	Weighted Score	Rank
Soil, Sediment, Bedrock and Sludge Treatment Technologies	Priority Techniques from Stage 1	Do nothing	7	6	5	10	10	10	3	5	77.00	3
		Monitor	9	8	5	8	8	10	5	10	96.00	1
		Chemical oxidation	4	8	5	3	8	8	7	4	57.00	9
		Solidification/ Stabilisation (in situ)	4	9	9	5	8	7	7	8	79.50	2
		Biopiles	0	8	6	6	6	9	5	8	60.50	7
		Windrowing	0	8	6	6	6	9	5	8	60.50	7
		Separartion	4	8	9	4	7	9	6	7	74.50	5
		Soil washing	3	7	10	3	8	8	7	4	63.00	6
		Solidification/ Stabilisation (ex situ)	6	8	8	4	6	8	6	7	77.00	3
		Landfill cap	0	8	10	2	4	10	8	3	48.00	11
		Excavation and off site	2	8	10	2	4	10	8	3	54.00	10

		Technique	Site Specific Applicability	Permisibility	Certainty	Capital Costs	O and M Costs	Market Constraints	Remediation Duration	Environmental Credits	Weighted Score	Rank
Groundwater, Surface Water and Leachate Treatment Technologies	Priority Techniques from Stage 1	Do nothing	6	6	5	10	10	10	3	5	74.00	8
		Monitor	9	8	5	8	8	10	5	10	96.00	2
		Monitored Natural Attenuation	9	8	5	8	8	10	5	10	96.00	2
		Bioslurping	6	8	7	6	5	9	6	7	76.50	6
		Chemical oxidation	6	6	8	6	6	9	8	6	74.50	7
		Passive/ Reactive Walls	8	8	10	6	8	8	8	8	94.00	4
		Groundwater Pump and Treat	9	9	7	5	6	8	7	7	86.00	5
		Physical Barriers	9	8	10	5	9	9	9	8	97.50	1
		Membrane Separation	4	7	6	4	5	5	7	6	60.50	10
		Oxidation	4	7	6	4	6	6	7	6	62.00	9


Phase 1
Desk-based assessment of site characteristics and estimation of potential harm
Tier 1
Cost estimator for the remediation of the contaminated site and generic options
Phase 2
Intrusive investigation of the site and quantitative risk assessment
Tier 2-Relative Ranking
Transparent comparison between technologies- relative tanking
Tier 2
Detailed options appraisal- allowing comparative and transparent approach
Tier 2-Cost
A detailed cost comparison of the most suitable techniques
Phase 3
Diagnostics of most suitable strategy for remediation
Tier 3
Detailed options appraisal- allowing comparative and transparent approach
Tier 2-Environment
Relative carbon costing of the defined technologies
Phase 4
Verification of the remediation strategy

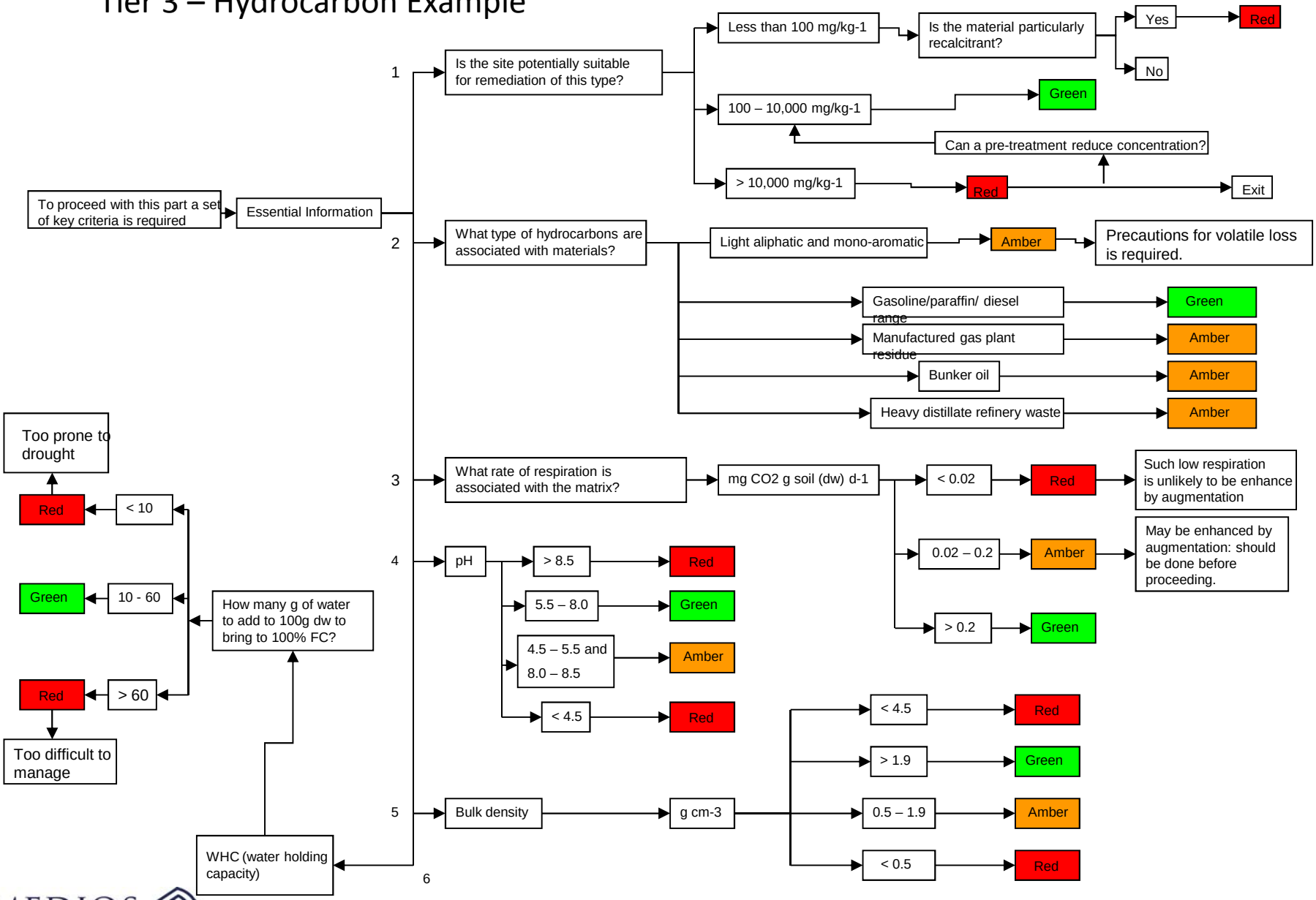
TIER 3- *SITE SPECIFIC PROCEDURES WITH REGULATORY ENGAGEMENT*


Aqueous
Organic
Detergent
NAPL
Partitioning
Biological
Physical
Chemical
Degradation
Solid amendment
Aqueous amendment
Passive Technologies
Techniques that remove contaminants
Techniques that immobilise contaminants
Techniques for Soil
Remediation Strategy
Techniques for Soil
Passive Technologies
Techniques that manage NAPL
Techniques that manage aqueous



Tier 3 – Hydrocarbon on Site

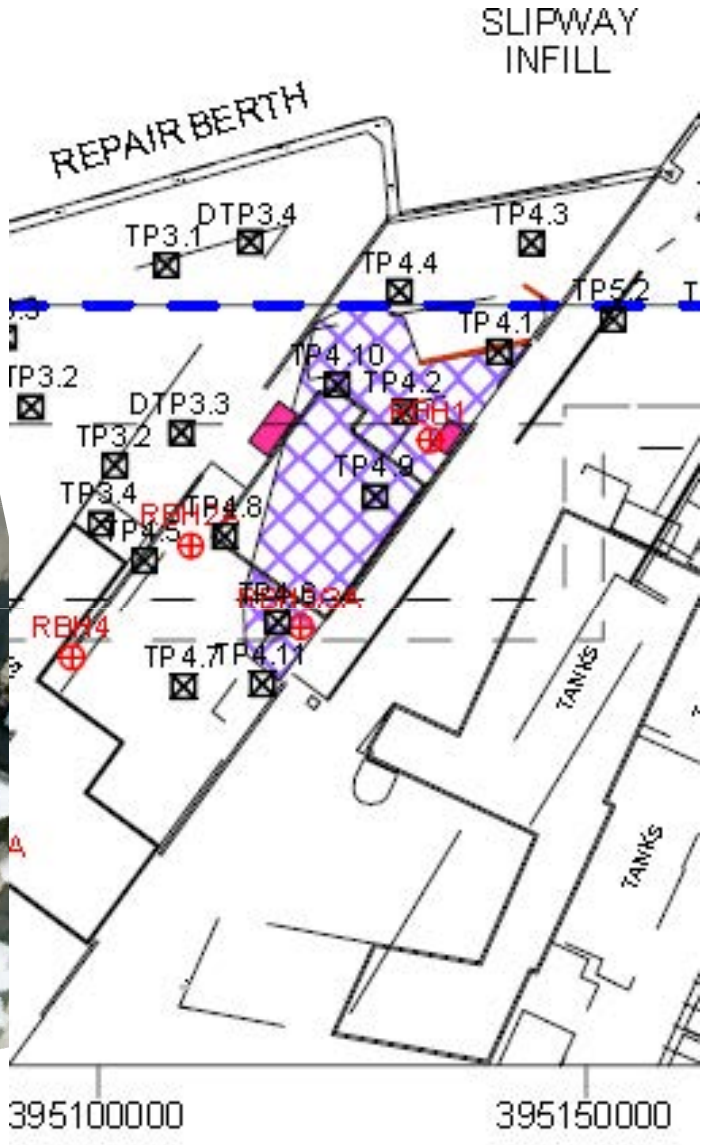
Tier 3 – Hydrocarbon Example



Integration of Tiers

- Information in tiers integrated together to form more manageable and aesthetically pleasing interface……the Remediation DST support tool.

CASE STUDIES


SLIPWAY
INFILL
REPAIR BERTH
TP3.1
DTP3.4
TP4.3
TP4.4
TP4.1
TP4.10
TP4.2
TP3.2
DTP3.3
TP3.2
TP3.4
TP4.9
TP4.8
TP4.5
RBH4
TP4.7
TP4.11
TANKS
TANKS
395100000
395150000

What we know and what we need to know

- ✓ The slipway area is impacted with hydrocarbons
- ✓ Contamination starts from 2 m bgl
- ✓ The area is tidal
- ✓ The contamination is within a defined zone
- ✓ Limited ability to excavate
- ✓ Over 2000 tonnes of soil has been removed
- ✓ Over 1700 tonnes of water has been treated
- ✓ Phase has been effectively managed

- Biodegradation and partitioning work is well underway
- Unlikely that neighbouring sites contribute to contamination source

		Technique	Site Specific Applicability	Permisibility	Certainty	Capital Costs	O and M Costs	Market Constraints	Remediation Duration	Environmental Credits	Weighted Score	Rank
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		Chemical oxidation	4	8	5	3	8	8	7	4	57.00	9
		Solidification/ Stabilisation (in situ)	4	9	9	5	8	7	7	8	79.50	2
		Biopiles	0	8	6	6	6	9	5	8	60.50	7
		Windrowing	0	8	6	6	6	9	5	8	60.50	7
		Separartion	4	8	9	4	7	9	6	7	74.50	5
		Soil washing	3	7	10	3	8	8	7	4	63.00	6
		Solidification/ Stabilisation (ex situ)	6	8	8	4	6	8	6	7	77.00	3
		Landfill cap	0	8	10	2	4	10	8	3	48.00	11
		Excavation and off site	2	8	10	2	4	10	8	3	54.00	10

		Technique	Site Specific Applicability	Permisibility	Certainty	Capital Costs	O and M Costs	Market Constraints	Remediation Duration	Environmental Credits	Weighted Score	Rank
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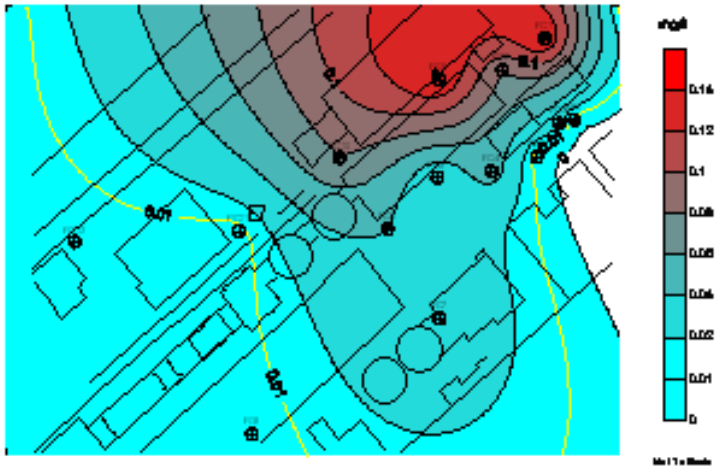
		Monitor	9	8	5	8	8	10	5	10	96.00	2
		Monitored Natural Attenuation	9	8	5	8	8	10	5	10	96.00	2
		Bioslurping	6	8	7	6	5	9	6	7	76.50	6
		Chemical oxidation	6	6	8	6	6	9	8	6	74.50	7
		Passive/ Reactive Walls	8	8	10	6	8	8	8	8	94.00	4
		Groundwater Pump and Treat	9	9	7	5	6	8	7	7	86.00	5
		Physical Barriers	9	8	10	5	9	9	9	8	97.50	1
		Membrane Separation	4	7	6	4	5	5	7	6	60.50	10
		Oxidation	4	7	6	4	6	6	7	6	62.00	9

Case Studies DST – Application to Genuine Environment

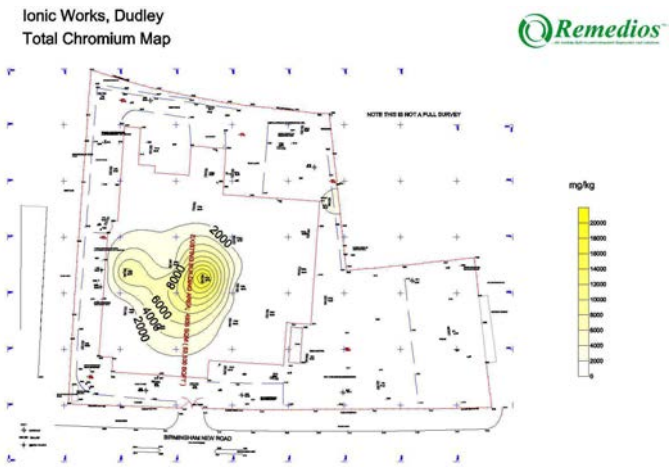
- A former railway yard, contaminated with an excess of heavy and mid-range hydrocarbons
- DST proposed action: windrow/ biopiling or landfarm
- Actual action: as DST suggested, biopiling was evaluated

- Cement and aggregate provider concerned about the environmental liability associated with a landfill site
- DST proposed action: MNA, windrow/biopile or landfill
- Actual action: as DST suggested, MNA was evaluated.



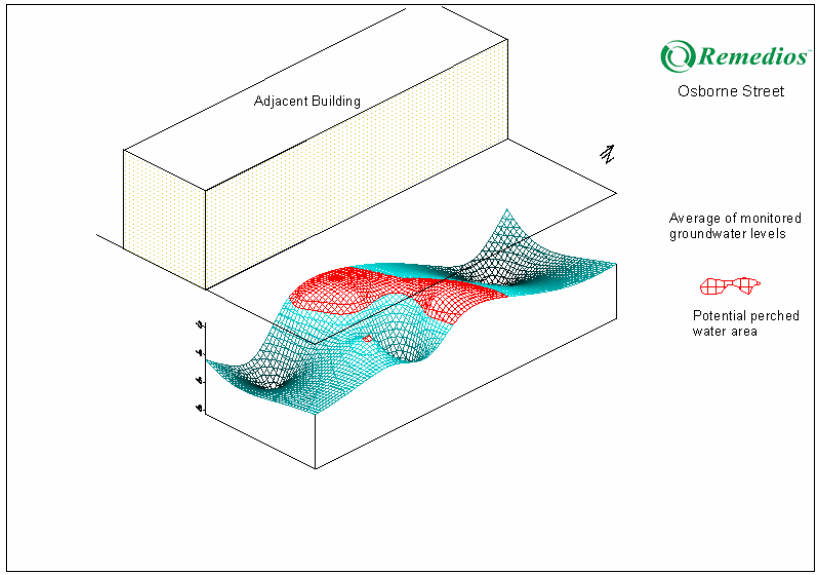
Case Studies DST – Application to Genuine Environment

- A former metal works facility to be re-used for light industry
- DST proposed action: excavation and some complexation agents
- Actual action: as DST suggested
- Cement factory with significant contamination issues and need for "greening"
- DST proposed wide range of actions and these are being systematically developed and applied

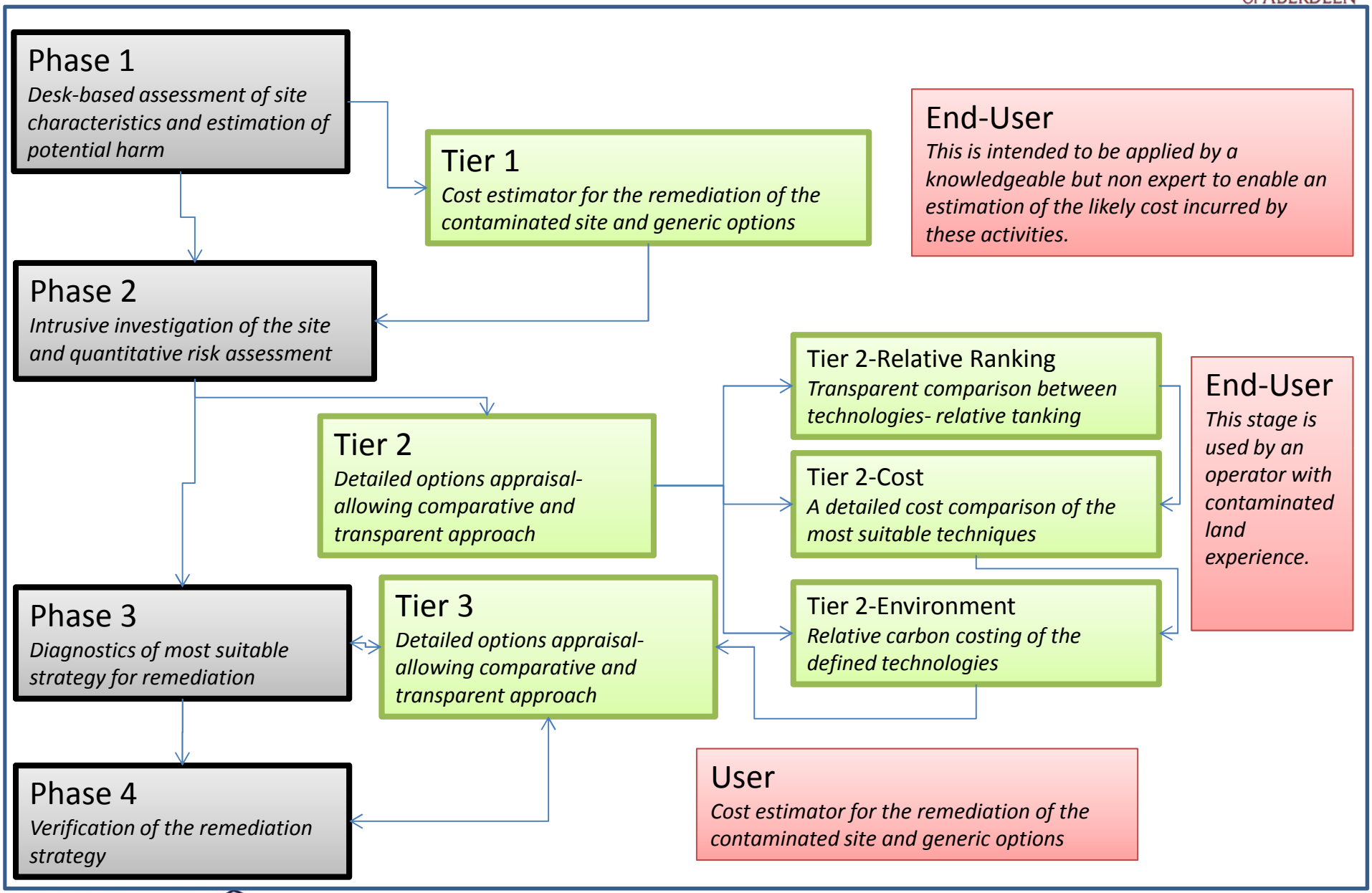


Case Studies DST – Application to Genuine Environment

- A impacted plume in an urban setting
- DST proposed action: pump and treat through a range of processes
- Actual action as DST



- Former goods yard was grossly hydrocarbon impacted
- DST proposed action: barrier and bioremediation
- Actual action: as DST suggested, MNA was also evaluated.


Phase 1
Desk-based assessment of site characteristics and estimation of potential harm
Tier 1
Cost estimator for the remediation of the contaminated site and generic options
End-User
This is intended to be applied by a knowledgeable but non expert to enable an estimation of the likely cost incurred by these activities.
Phase 2
Intrusive investigation of the site and quantitative risk assessment
Tier 2-Relative Ranking
Transparent comparison between technologies- relative tanking
Tier 2
Detailed options appraisal- allowing comparative and transparent approach
Tier 2-Cost
A detailed cost comparison of the most suitable techniques
End-User
This stage is used by an operator with contaminated land experience.
Phase 3
Diagnostics of most suitable strategy for remediation
Tier 3
Detailed options appraisal- allowing comparative and transparent approach
Tier 2-Environment
Relative carbon costing of the defined technologies
Phase 4
Verification of the remediation strategy
User
Cost estimator for the remediation of the contaminated site and generic options

Thank you for your attention

REMEDIOS INTELLIGENT SOLUTIONS
CL:AIRE
CLARRC RESEARCH THAT MEANS BUSINESS
bbsrc biotechnology and biological sciences research council
NATURAL ENVIRONMENT RESEARCH COUNCIL
EPSRC Engineering and Physical Sciences Research Council