Housekeeping…

Please stay on mute

Turn camera off if you don't want to appear in the recording

Ask a question in the chat

Want to ask a question during Q&A?
Type 'Hand up' in the chat

Experts in Continuous Monitoring

TB18 - Using multiple 'lines of evidence' to move gas risk assessment beyond GSV

Matt Askin

Scottish Contaminated Land Forum
20th May 2021

Please do ask questions

Type your questions as they occur in the Q&A box (bottom of screen menu)

I'll go through these at the end.

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Loscoe 1986

Importance of the Source-Pathway-Receptor Model
and
Key driver mechanisms

Loscoe 1986

Importance of the Source-Pathway-Receptor Model
and
Key driver mechanisms

Cranbourne, Melbourne 2010

Landfill gas is a serious hazard and the site specific geology affects its migration, over long distances

Gorebridge 2013

Changing the ground-conditions will change the ground-gas risk

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Development of guidance & standards

2007 ⇨ 2012 ⇨ 2013 ⇨ 2018 ⇨ 2019

Development of guidance & standards


CIRIA C665 London, 2007

Assessing risks posed by hazardous ground gases to buildings

S Wilson	EPG Ltd
S Oliver	Millard Consulting
H Mallett	Buro Happold
H Hutchings	Enviros Consulting Ltd
G Card	Card Geotechnics Ltd

CIRIA sharing knowledge • building best practice
Classic House, 174–180 Old Street, London EC1V 9BP
TELEPHONE 020 7549 3300 FAX 020 7253 0523
EMAIL enquiries@ciria.org
WEBSITE www.ciria.org

2007 → 2012 → 2013 → 2018 → 2019

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Development of guidance & standards

2007 → 2012 → 2013 → 2018 → 2019

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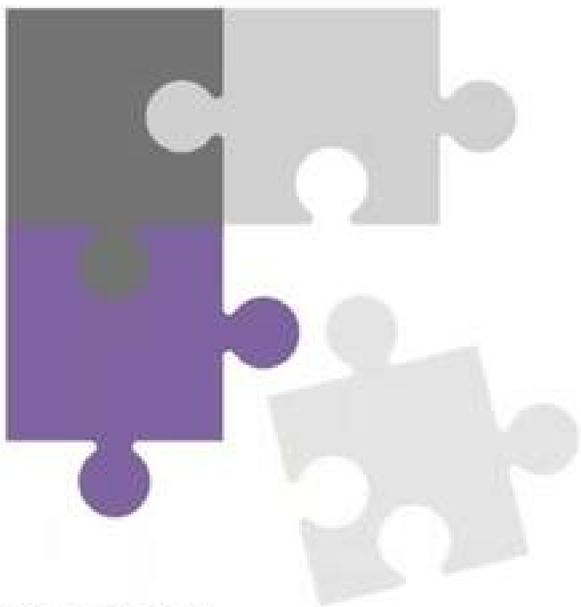
Gas Screening Value (GSV)

GSV – What is it?

A single, calculated value based on periodic monitoring results, implying a characteristic risk situation.

How is it calculated?

Max observed concentration (CH_4% & CO_2%) x Worst case borehole flow (L/hr)



So, simple right?

In ("professional") practice, probably too simple.

What's the problem?

Ground gas behaviour is seldom stable or predictable
Concentration (out of context) is not necessarily a driver of risk
Measured flow can be influenced many things....some material, some irrelevant.

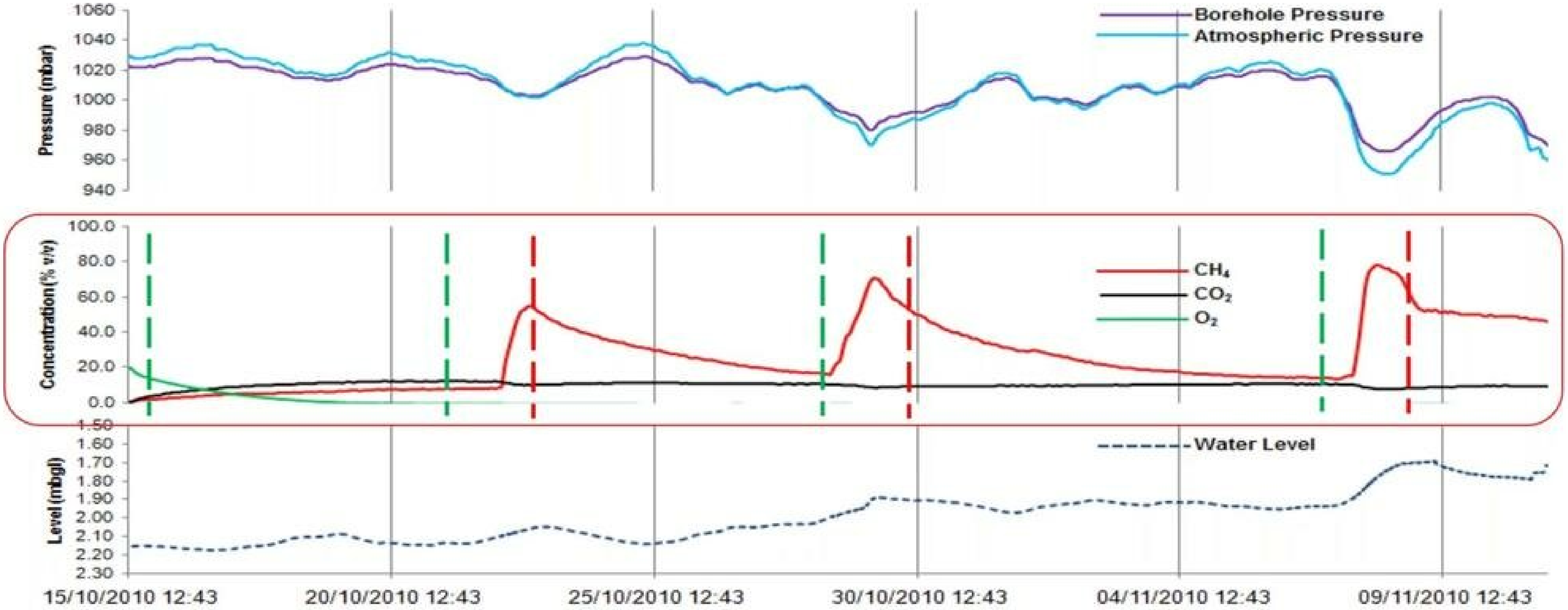
Very often overlooked but.....GSV was intended as a *Guideline value, not an absolute threshold.*

So, beyond GSV? Yes, but not how you might expect.

GSV is a recognised and accepted metric, but it's real value is as part of a detailed CSM and when **informed by** and **consistent with** all lines of evidence.

Ground gas behaviour & variability

Ground gas behaviour & variability



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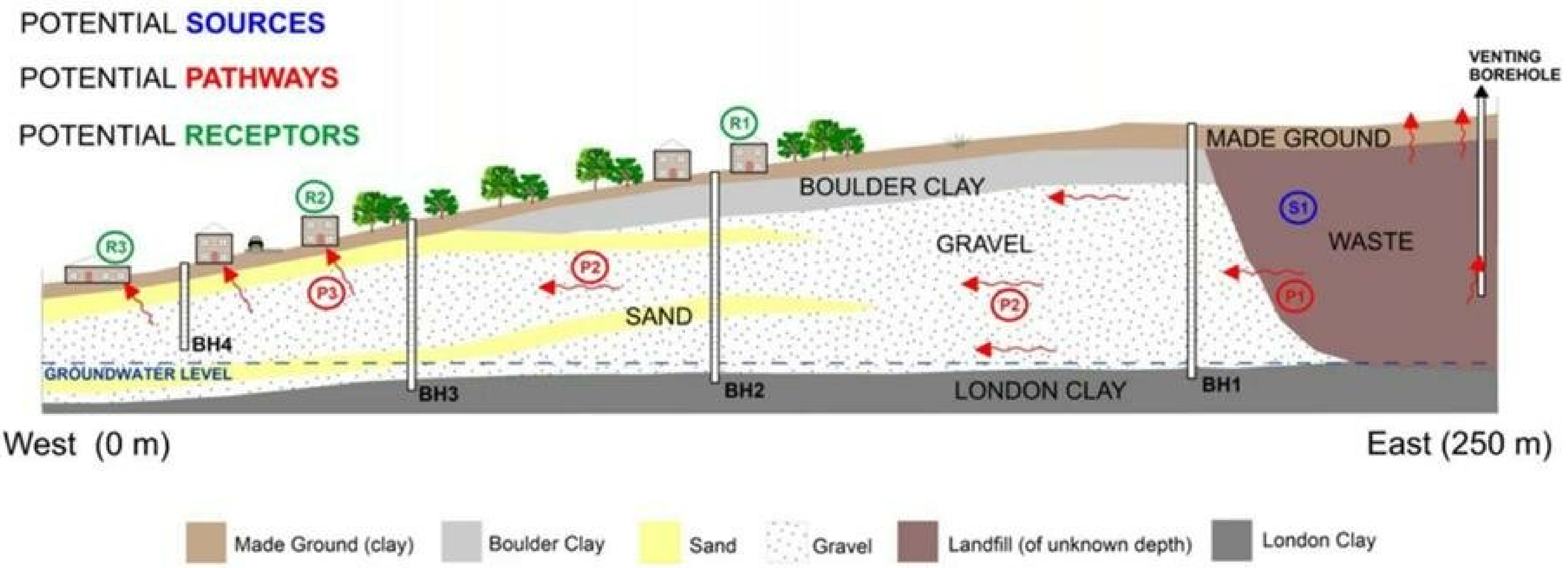
Importance of the Conceptual Site Model (CSM)



Risk Assessment

Tier 1 – Is there a potential pollutant linkage?

Tier 2 - Generic risk assessment (inc. GSV)

Tier 3 – Detailed risk assessment (inc. LoE)

Multiple Lines of Evidence

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Desk Study Data Sets

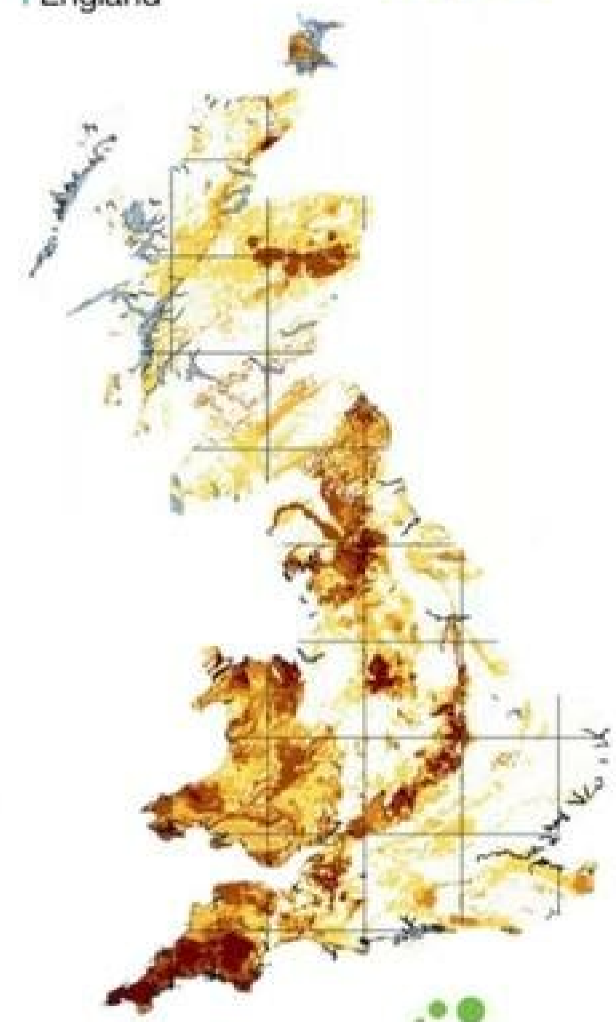
British Geological Survey

The Coal Authority

BMJ

Public Health England

bre



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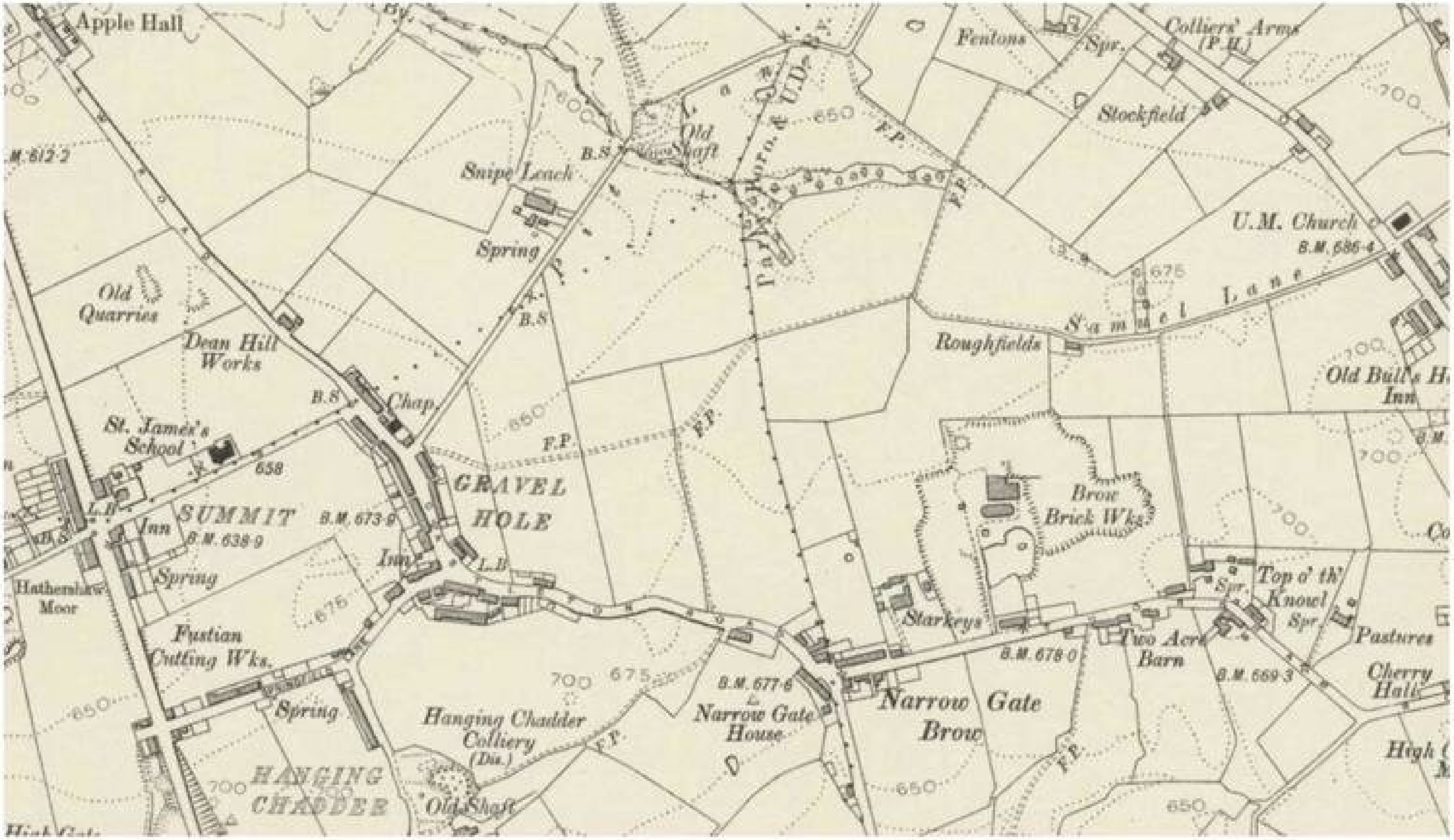
Historical Maps



http://www.archiuk.com/

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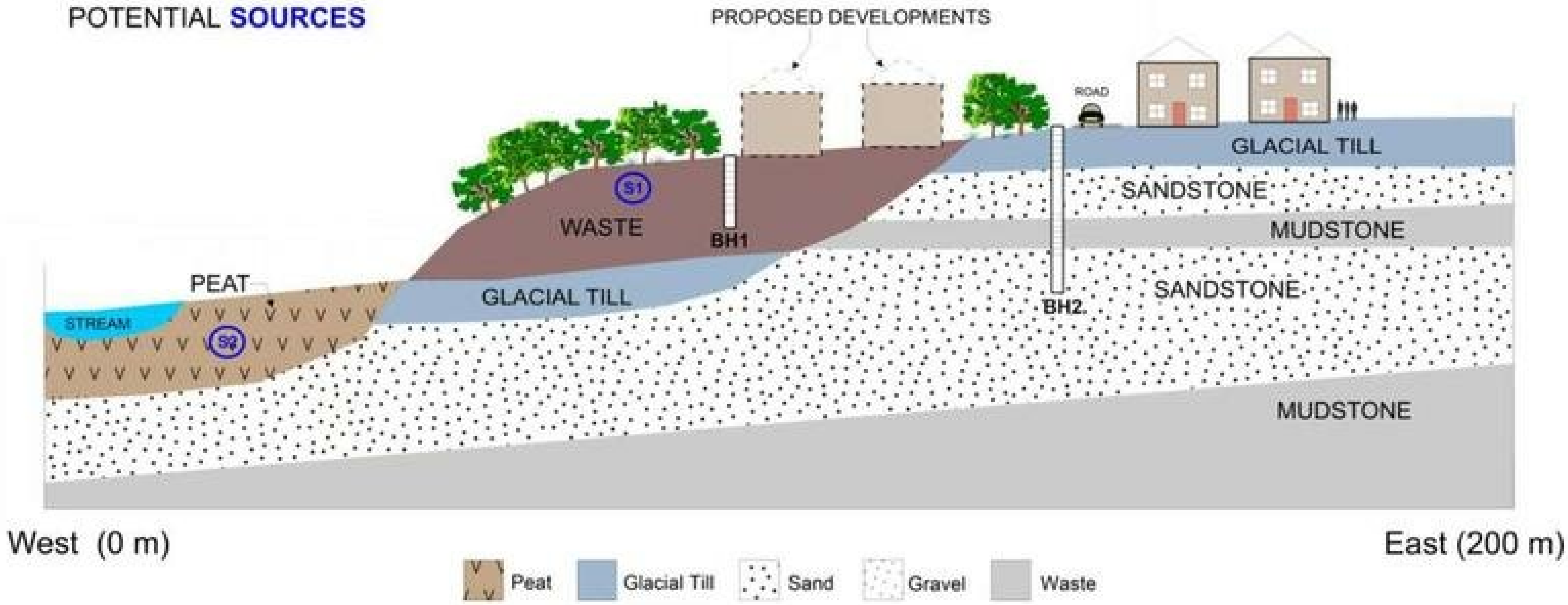
Preliminary Conceptual Site Model



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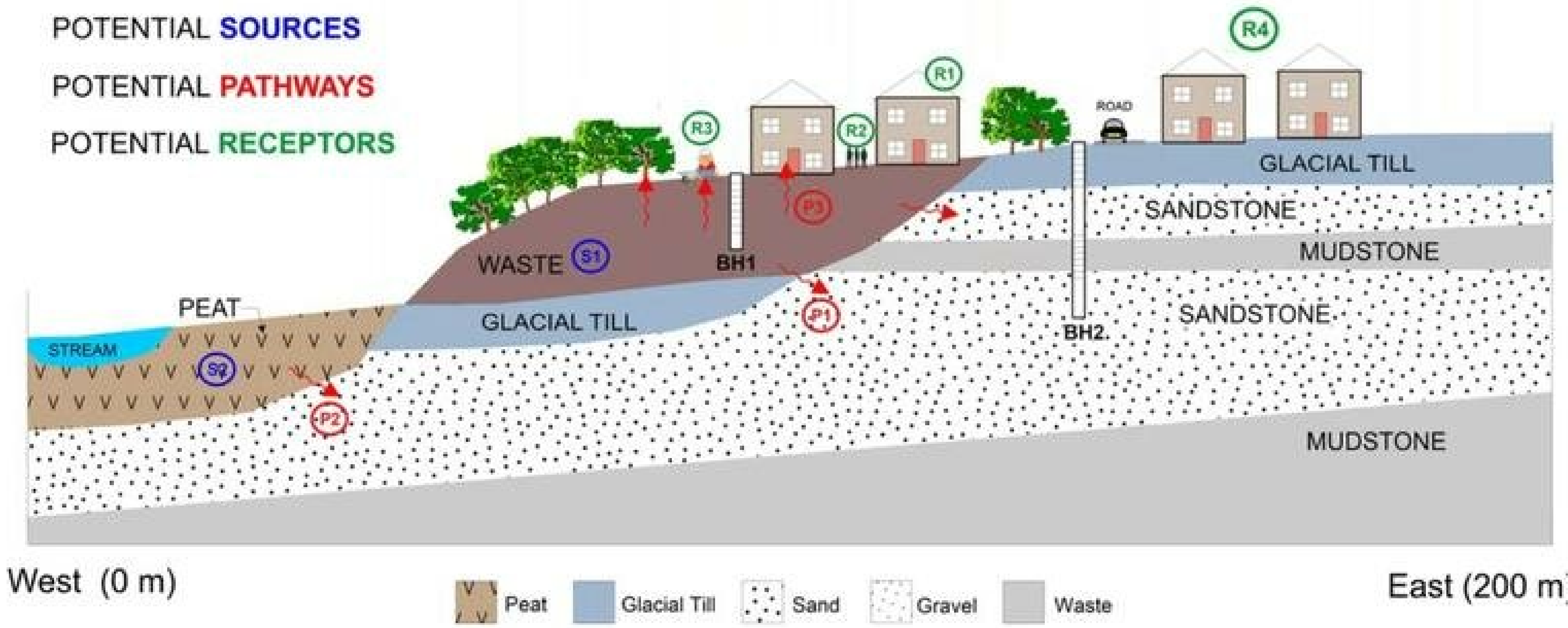
Preliminary Conceptual Site Model



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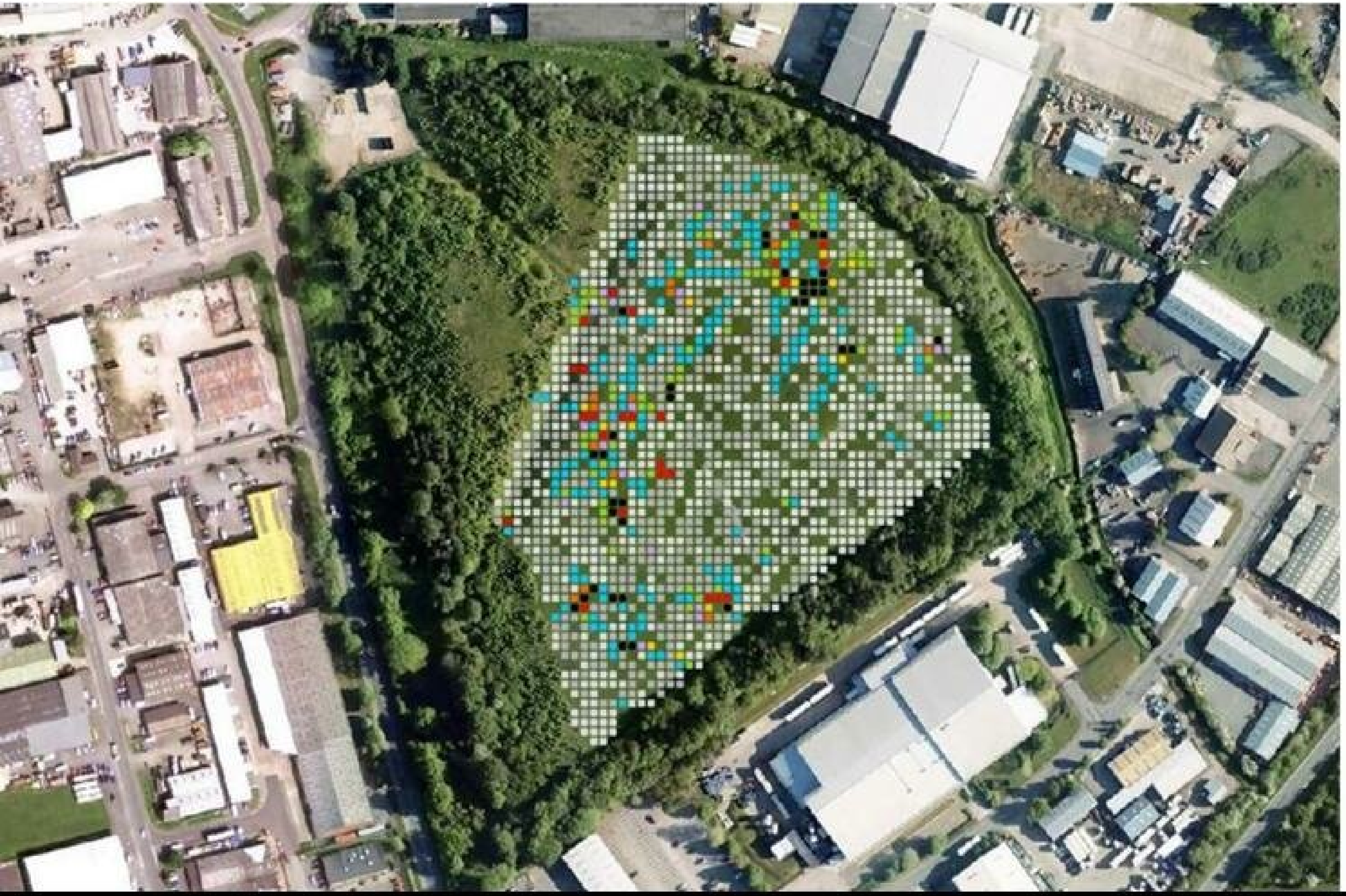
Surface Emission Surveys



Legend

Methane concentration (ppmv)

- < 2.5
- 2.5 - 4.9
- 5.0 - 9.9
- 10.0 - 24.9
- 25.0 - 49.9
- 50.0 - 99.9
- 100.0 - 999.9
- 1000.0 - 9999.9

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Trial Pitting

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Trial Pit	1.5x5.0x0.7m	175.16	Ground Gas Solutions	
	Location	**Dates**	**Project Contractor**	**Sheet**
		21/09/2018		1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				174.86	(0.30) 0.30	MADE GROUND: Grass over dark brown slightly gravelly sandy CLAY with occasional rootlets (topsoil). Sand is fine to medium. Gravel is fine to medium and subrounded comprising sandstone and mudstone.		
				174.71	(0.15) 0.45	MADE GROUND: Yellowish brown sandy GRAVEL (MOT layer). Sand is fine to medium. Gravel is fine to medium and subangular to subrounded comprising sandstone.		
				174.46	(0.25) 0.70	MADE GROUND: Blackish brown gravelly sandy CLAY with frequent ash, clinker, glass bottles, glass fragments, occasional pottery fragments, brick fragments, plastic and rare newspaper and bone. Sand is fine to medium. Gravel is fine to coarse and subangular to subrounded comprising sandstone and mudstone. Wet grey clayey SAND layer at base of trial trench.		
						Complete at 0.70m		

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Empirical approach using TOC

CLAIRE

RB 17

research bulletin

A Pragmatic Approach to Ground Gas Risk Assessment

ABSTRACT

1. INTRODUCTION

A Pragmatic Approach to Ground Gas Risk Assessment"

CL:AIRE research bulletin RB 17, 2012

- Only to be used for very low to moderate onsite gas hazard
- Requires carefully planned and executed investigation
- Uses TOC analysis and forensic logging

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Empirical approach using TOC

A Pragmatic Approach to Ground Gas Risk Assessment"

CL:AIRE research bulletin RB 17, 2012

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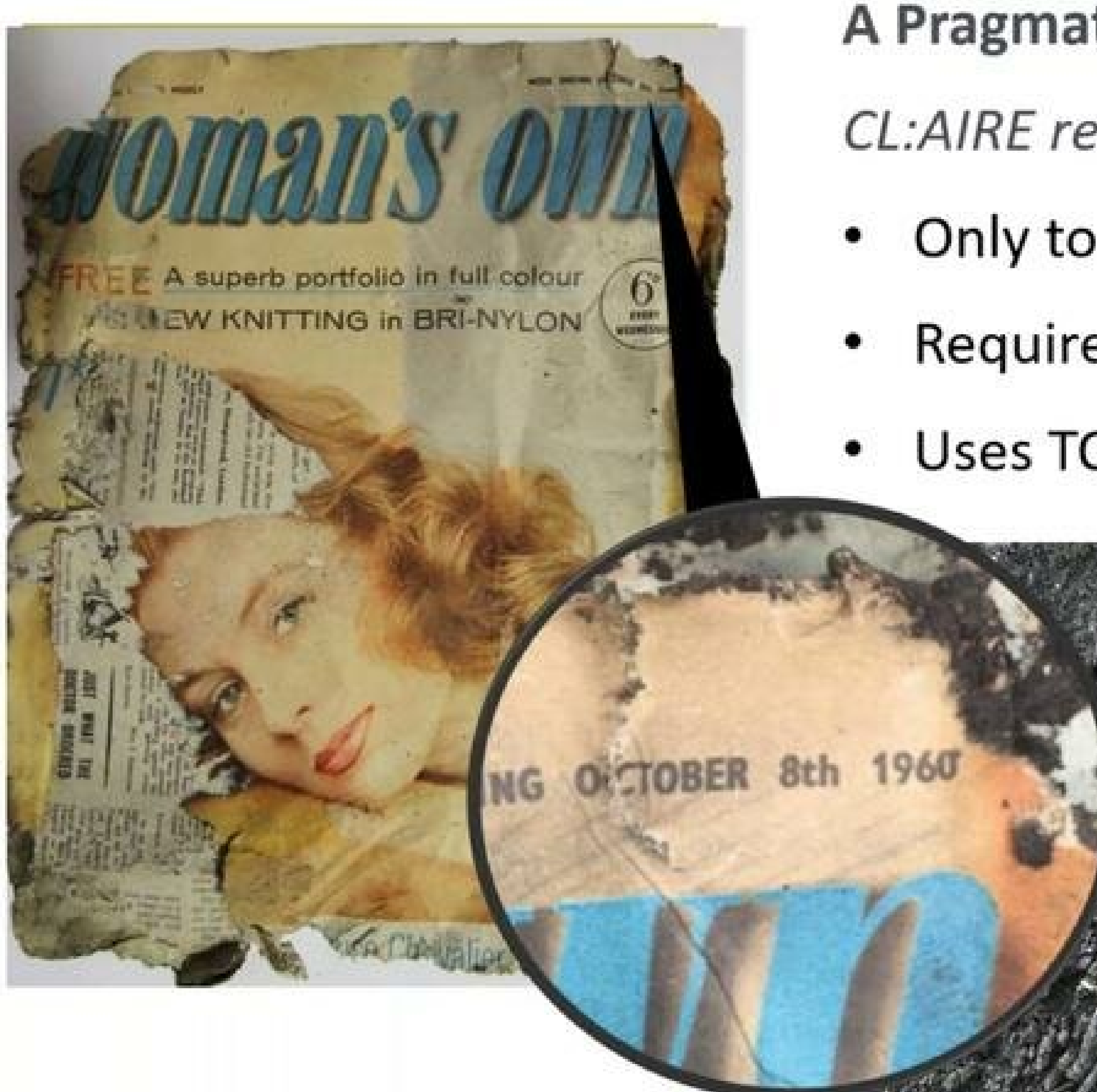

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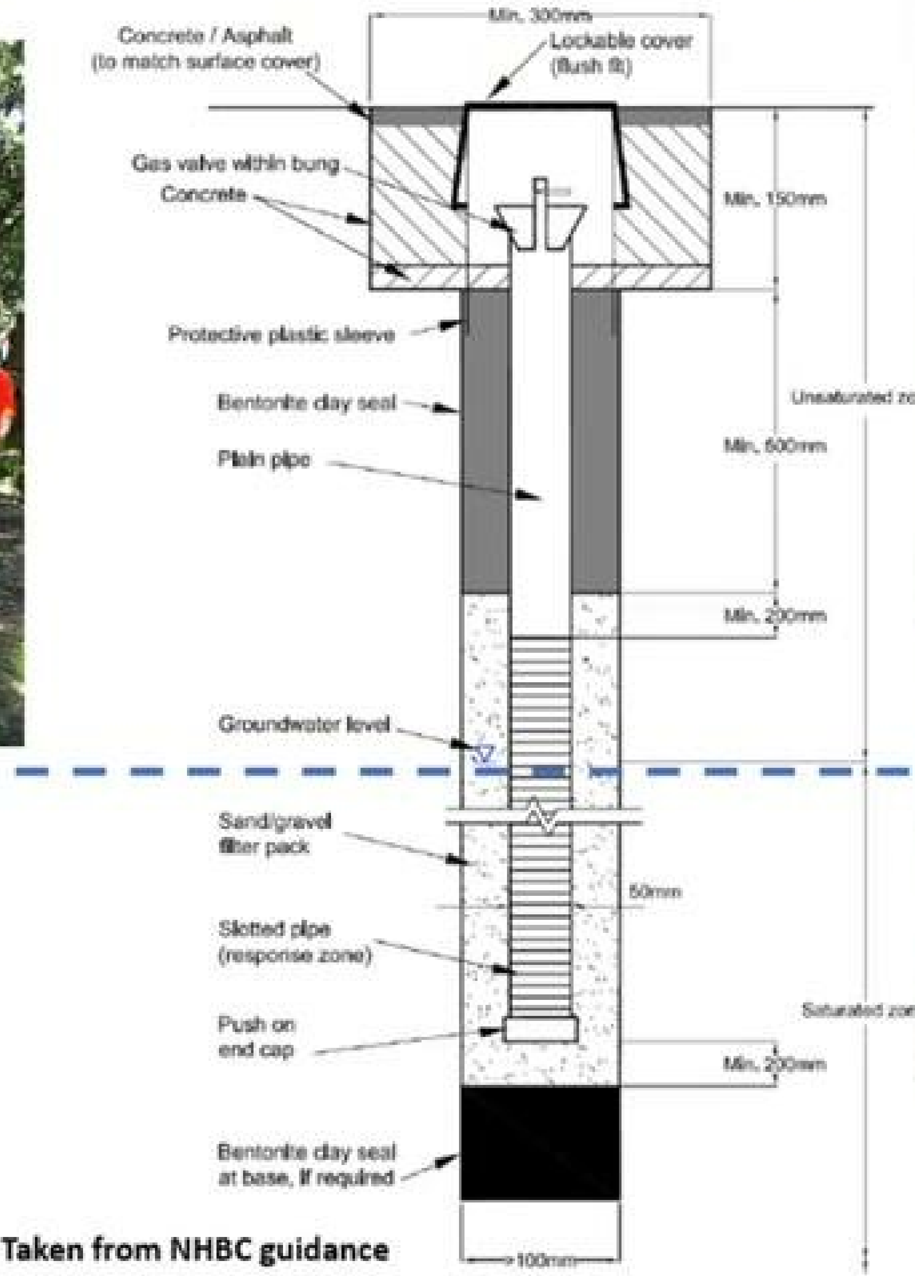
Boreholes and Monitoring Wells



Taken from NHBC guidance

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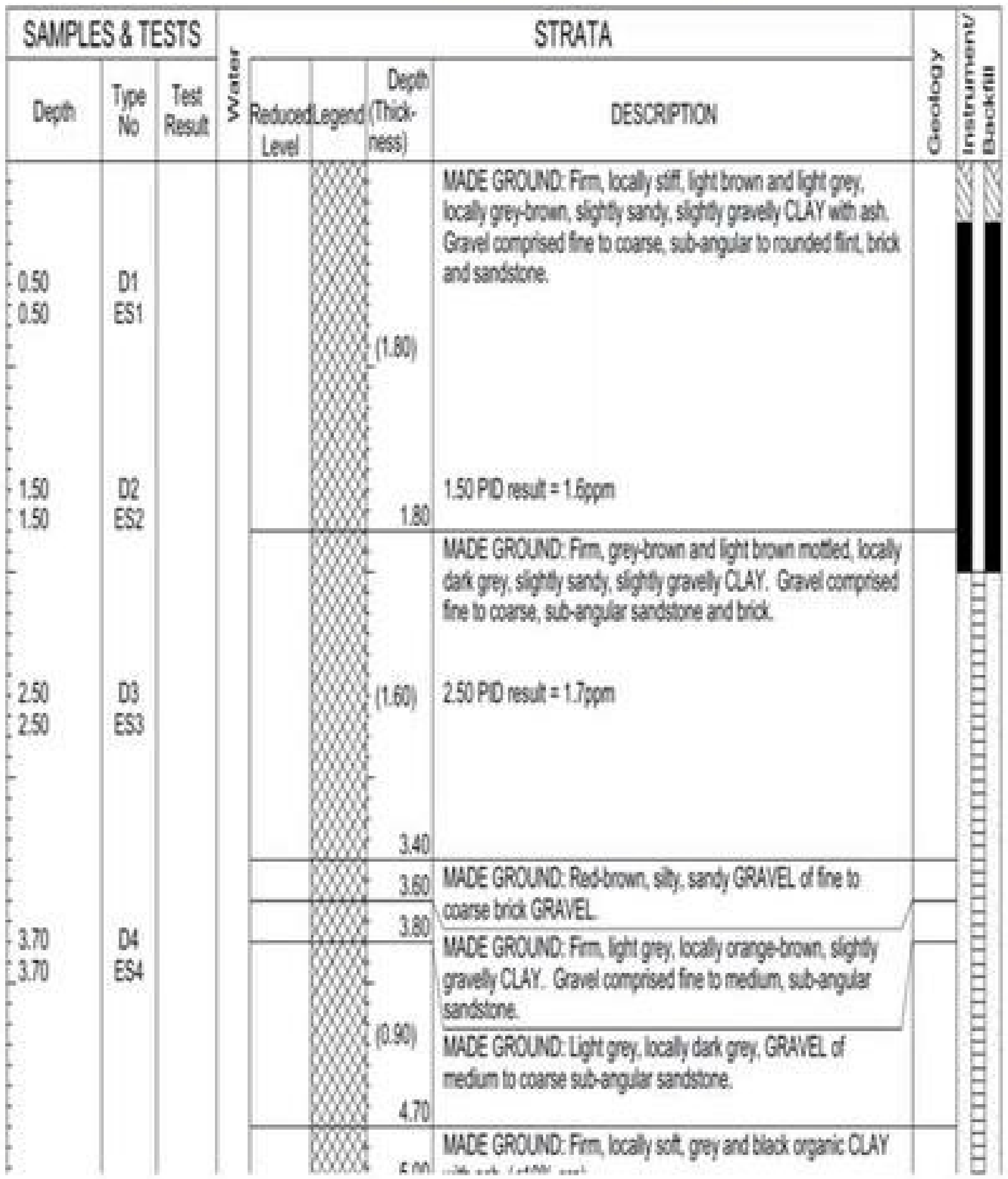
Boreholes and Monitoring Wells



Valuable data source – treat them like a scientific instrument

- Supervise their drilling and installation
- Provide as much description as possible in line with BS5930 and BS10175 within the logs and add further forensic descriptions
- Take downhole (profile) gas readings and soil samples
- Carefully select the appropriate screening horizon
- Don't forget to seal both below and above the response zone with appropriately hydrated bentonite

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Boreholes and Monitoring Wells

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Periodic Monitoring

PROJECT ID:

SITE:

DATE:

SPECIALIST:

Doc Ref: QMS-SGMF

Issue:v1.8

EQUIPMENT		WEATHER CONDITIONS	GROUND CONDITIONS / GENERAL COMMENTS
Model	**Serial Number**	Clear sky, dry, moderate wind, 18° C.	Ground dry, cracked in places. Little to no vegetation throughout Parcel 2, with shell fragments along the south and south west part of the parcel. San
GasData GFM 430	10356	Start Pressure (mb): 1021 End Pressure (mb): 1018	
PhoCheck Tiger	105553		
Dip Meter	N/A		

BH ID	Time	Barometric Pressure (mb)	Line Test	External Flow (ltr/hr)			TVOC (ppmv)	Steady CH_4 (% v/v)	Peak CH_4 (% v/v)	Steady CO_2 (% v/v)	Peak CO_2 (% v/v)	O_2 (% v/v)	CO (ppmv)	H_2S (ppmv)	SWL (mbgl)	Base Dip (mbgl)	Con
			OK?	Initial	Duration	Steady											
Fresh Air	12:33	1021	OK	NM	N/A	NM	0.0	0.0	0.0	0.0	0.0	20.6	0	0	N/A	N/A	
WS5_5	14:50	1017	OK	17.9	>1 min	17.9	0.8	0.0	0.0	1.6	1.6	17.4	0	0	Dry	5.95	
WS5_6	14:40	1018	OK	18.4	>1 min	18.4	0.2	0.0	0.0	3.4	3.4	12.2	0	0	Dry	6.00	
WS5_10	13:30	1020	OK	0	N/A	0	1.0	0.0	0.0	0.4	0.4	18.1	0	0	Dry	5.97	
WS5_13	12:40	1021	OK	0	N/A	0	0.2	0.0	0.0	0.0	0.0	19.5	0	0	Dry	5.80	
WS5_14	13:00	1021	OK	0	N/A	0	1.1	0.0	0.0	30.4	30.4	5.8	0	0	Dry	5.77	
BH5_3S	14:20	1019	OK	1.9	>1 min	1.9	0.4	0.0	0.0	4.2	4.2	14.7	0	0	Dry	2.96	

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Periodic Monitoring

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WEATHER CONDITIONS	GENERAL COMMENTS / H&S NOTES
Sunny Strong easterly breeze	4 open sludge lagoons, and sludge cake deposits on site

GROUND CONDITIONS	MONITORING WELL COMMENTS
Site is mostly dry, with some pooling water	Old raised headwork, heavily rusted and cover rusted open. Flooded 50mm standpipe. Rubber bung with single valve fitted (closed) Water sucked into monitoring tube - quickly disconnected

PROJECT DETAILS			
Project ID		Date	13/08/2019
Site		Time	12:45
Specialist	JN		

EQUIPMENT	
Model	Serial Number
GA 5000	G504460
Geotech Dip Meter	201162

BOREHOLE DETAILS		
Borehole ID	BH 112	
Groundwater Level (mbgl)	0.68	
Depth to base (mbgl)	6.18	
Atmospheric Temp (°C)	@ 16	
	Start	End
Atmosphere pressure (mb)	1010	1010
Borehole Pressure (mb)	nm	nm

KEY: 0.0 = Below instrument limit of detection, NM = Not Measured, N/A = Not Applicable, %v/v = Percentage volume by volume, ppmv = parts per million by volume, mb = millibar, ltr/hr = litres per hour, mbgl = metres below ground level, OS = off scale of instrument

IMS Ref. GMPM Version: 2.1

TIME	Gas Flow	Gas Readings						
(seconds)	Litres/hour	CH_4 (% v/v)	CO_2 (% v/v)	O_2 (% v/v)	BAL	CO (ppmv)	H_2S (ppmv)	TVOC (ppmv)
Fresh Air	0.0	0.0	0.0	20.9	79.1	0	0	0
Initial	9.4	87.0	0.5	0.4	12.1	0	0	0
30	8.2	87.6	0.5	0.3	11.6	0	0	0
60	7.6	87.6	0.5	0.3	11.6	0	0	0
90	6.1	87.6	0.5	0.3	11.6	0	0	0
120	5.1	87.6	0.5	0.3	11.6	0	0	0
150	3.1	87.6	0.5	0.3	11.6	0	0	0
180	2.3							
240	1.2							
300	0.0							

STEADY STATE FINAL RESULTS								
	Flow (l/hr)	CH_4 (%)	CO_2 (%)	O_2 (% v/v)	BAL	CO (ppm)	H_2S (ppm)	TVOC (ppm)
Steady state time (s)	<30	<30	<30	<30	<30	0	<30	0.0
Steady state value	1.2	87.6	0.5	0.3	11.6	0	0	0.0
Peak Value (O_2 Low)	9.4	87.6	0.5	0.3	12.1	0	0	0

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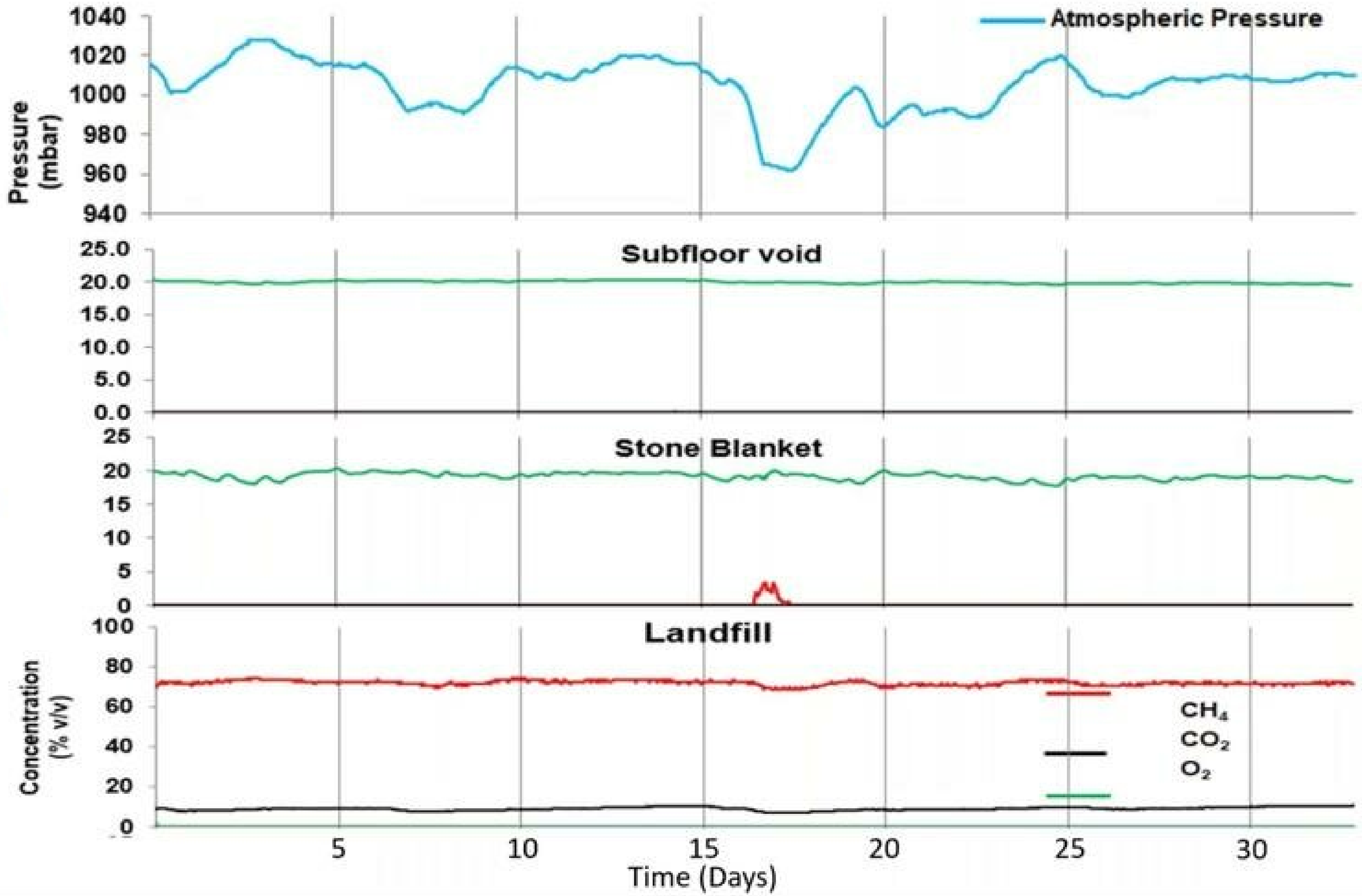
S-P-R Monitoring

RECEPTOR

PATHWAY

SOURCE



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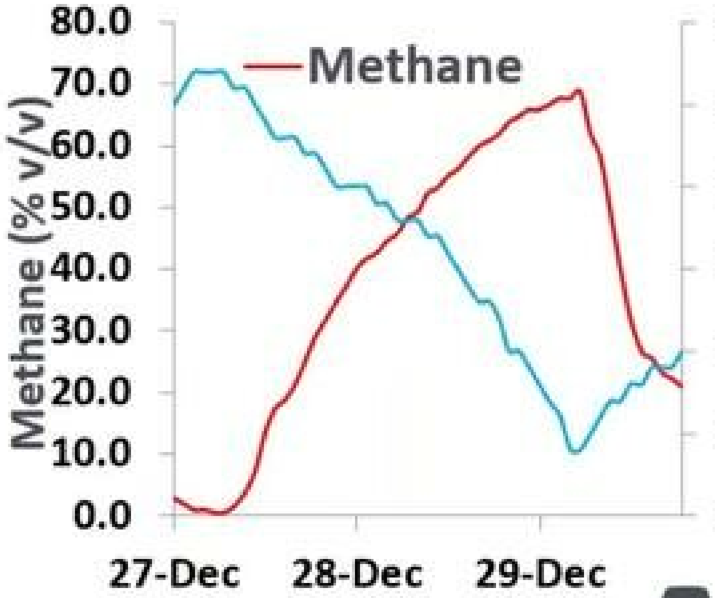
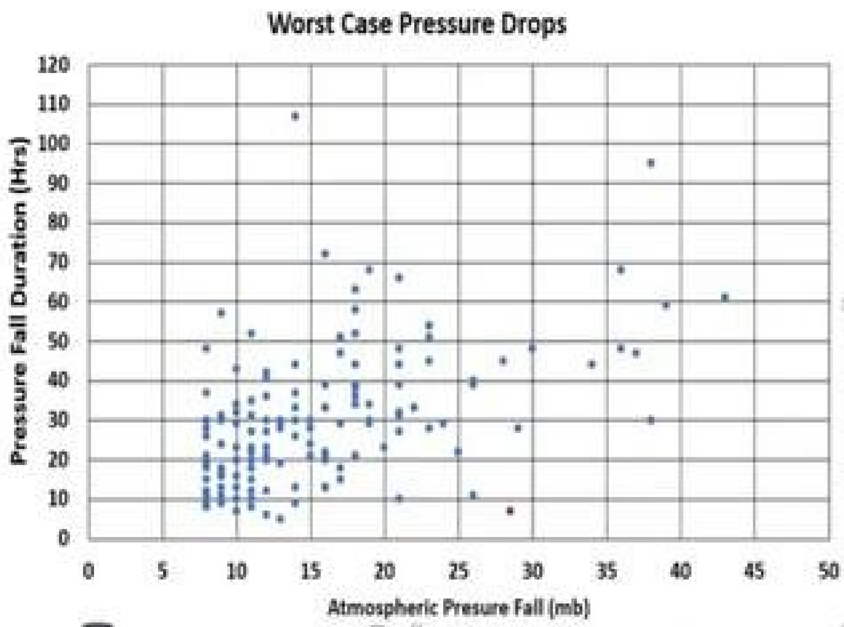
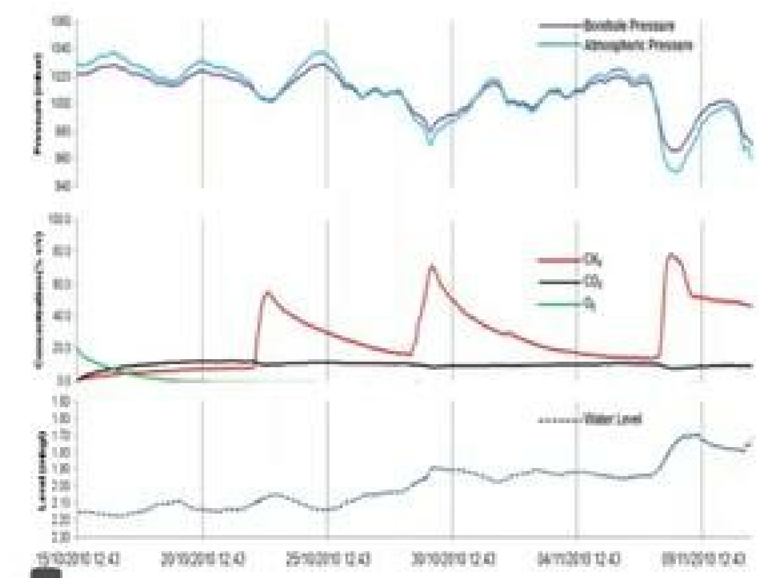
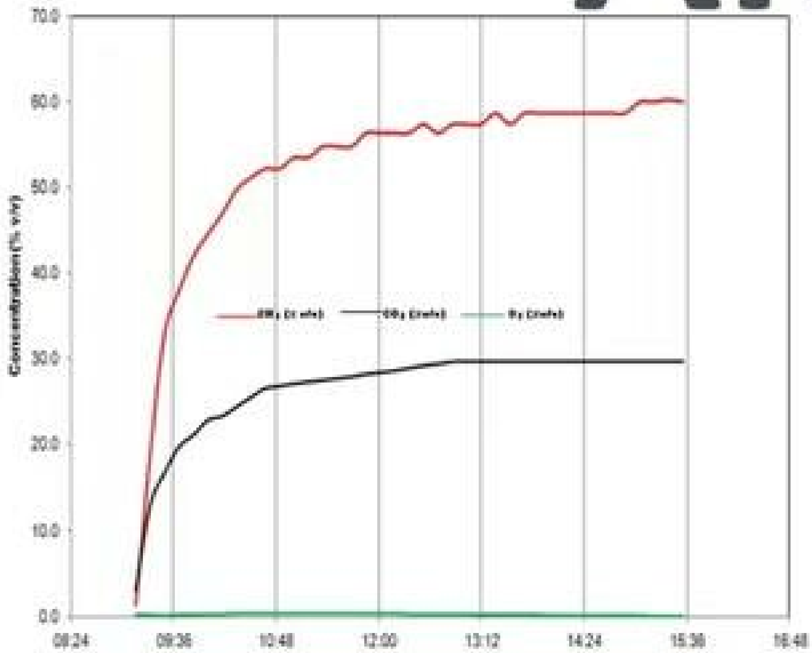
Receptor Monitoring

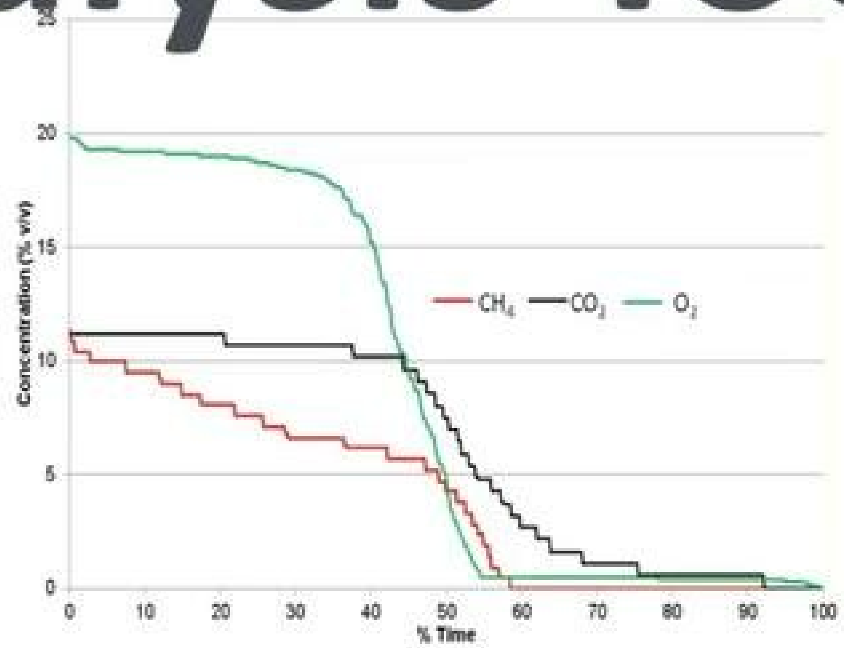


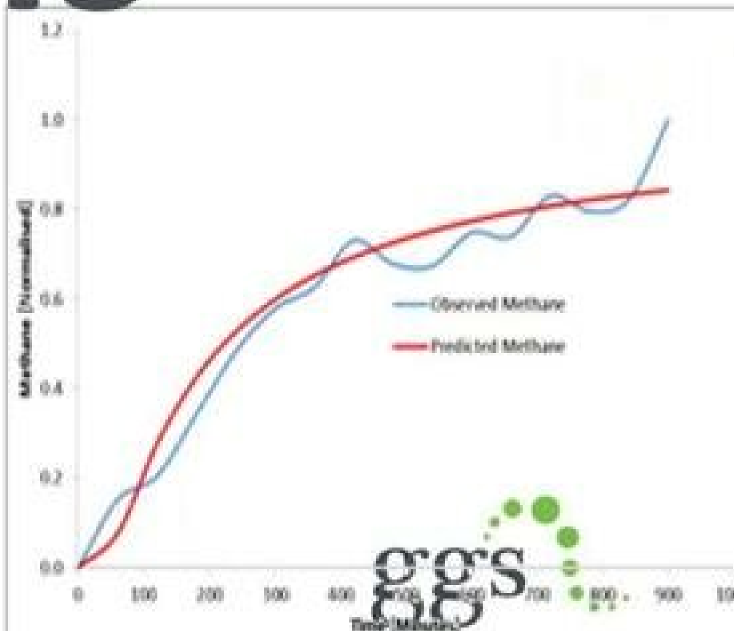




Analysis Tools







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Environmental Correlations

Multi-parameter continuous data allows correlations to be drawn between environmental parameters and ground-gas concentration, to identify ground-gas drivers

Ground-gas drivers include:

- Atmospheric pressure
- Borehole pressure
- Temperature
- Ground-water levels

Variables showing no correlation with ground-gas concentration may be eliminated

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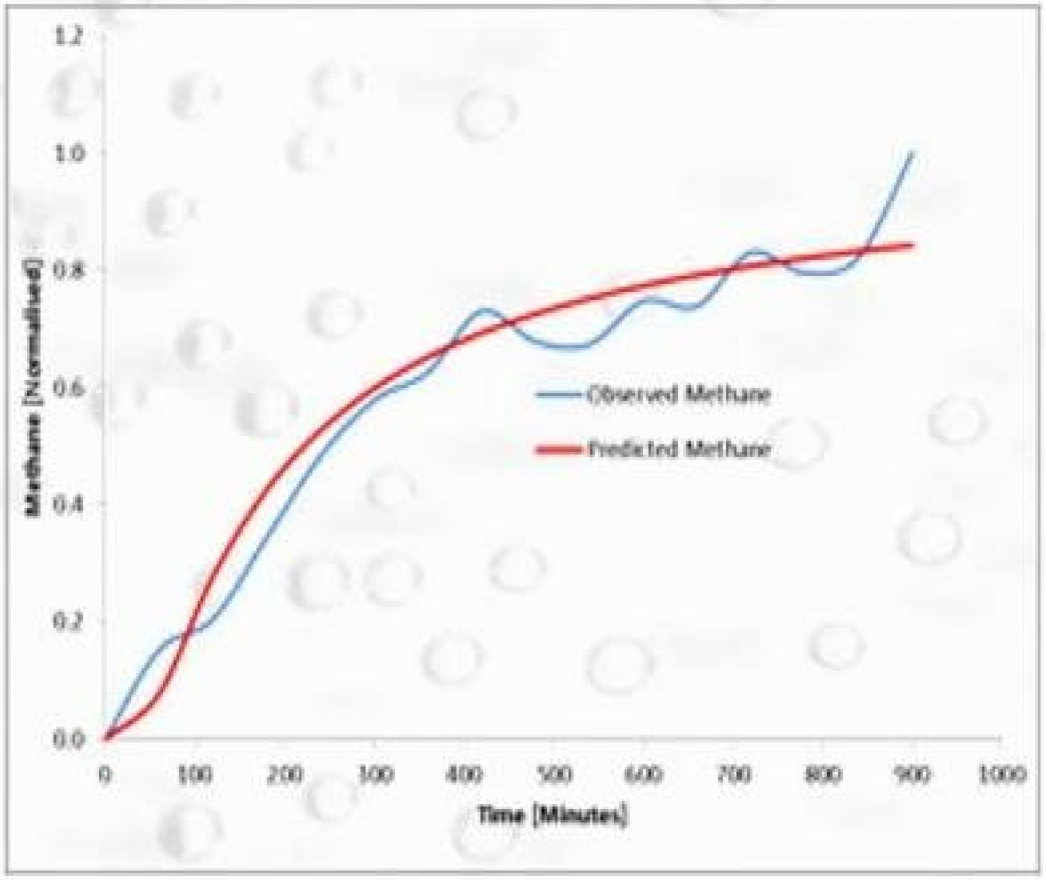
Dissolved Gases



- Dissolved gases behave differently than free gas and need a different approach
- Typically gas will partition out of solution via diffusion until it reaches equilibrium
- Where there is a trapped headspace of limited volume, gas concentrations can be highly elevated
- Be careful with deeper or pressurised sources

if just 1.6mg/l of dissolved methane were to completely degas then it could give rise to approximately 5% v/v in a borehole

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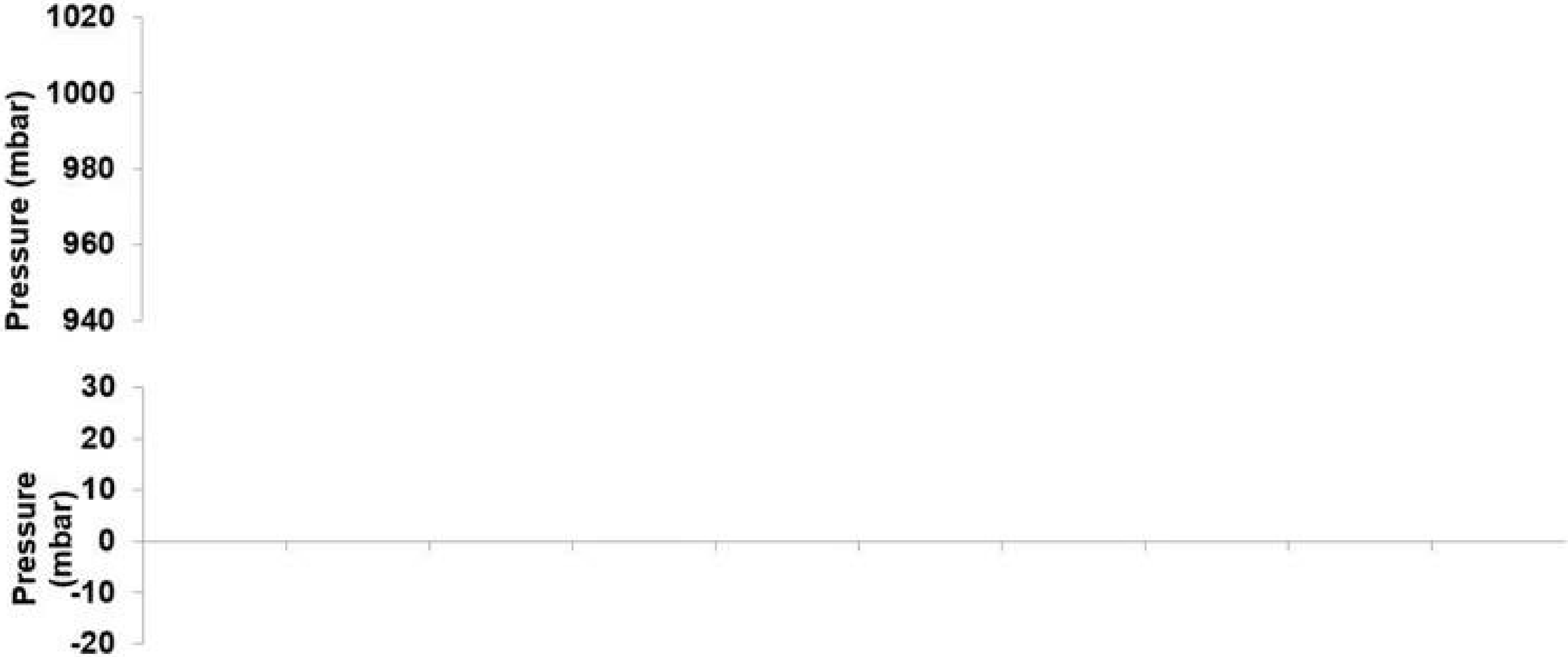
Differential (Static) Pressure Assessment



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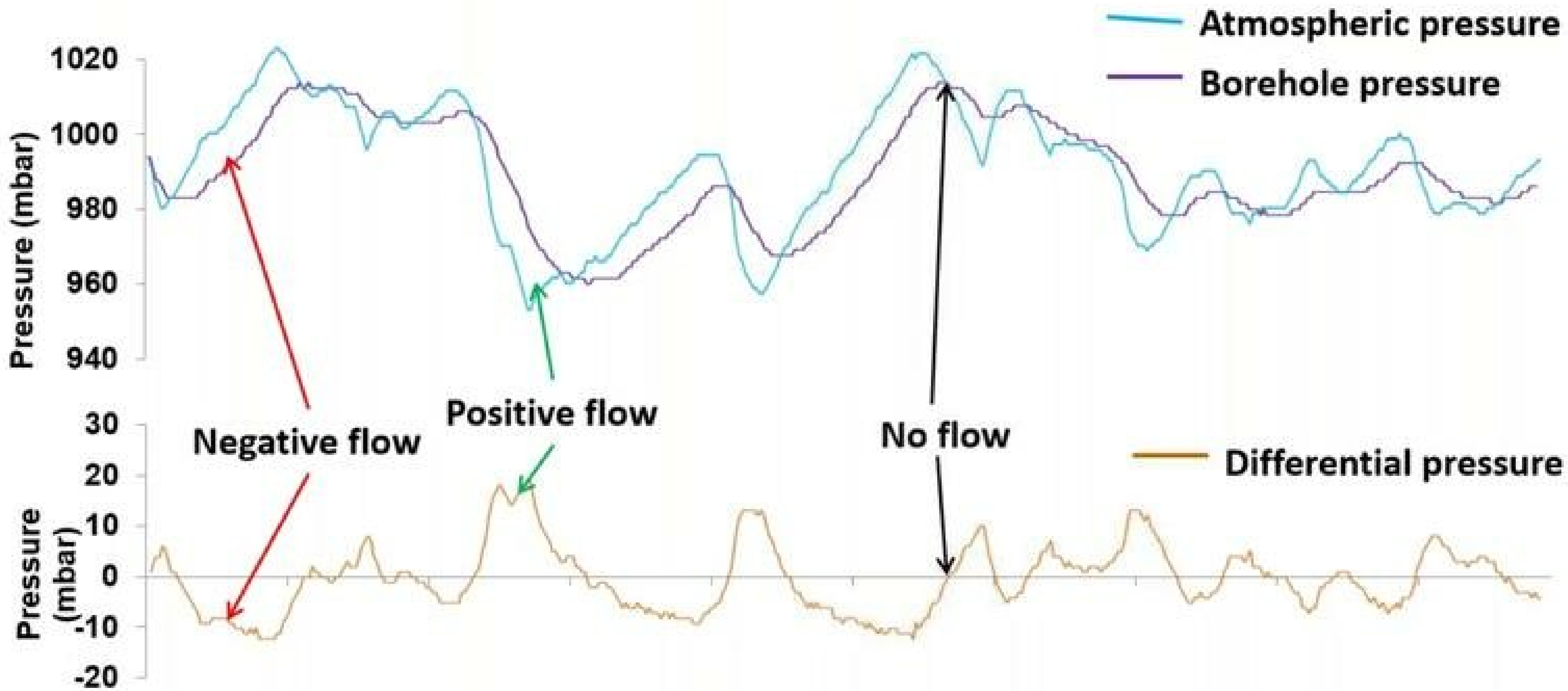
Differential (Static) Pressure Assessment



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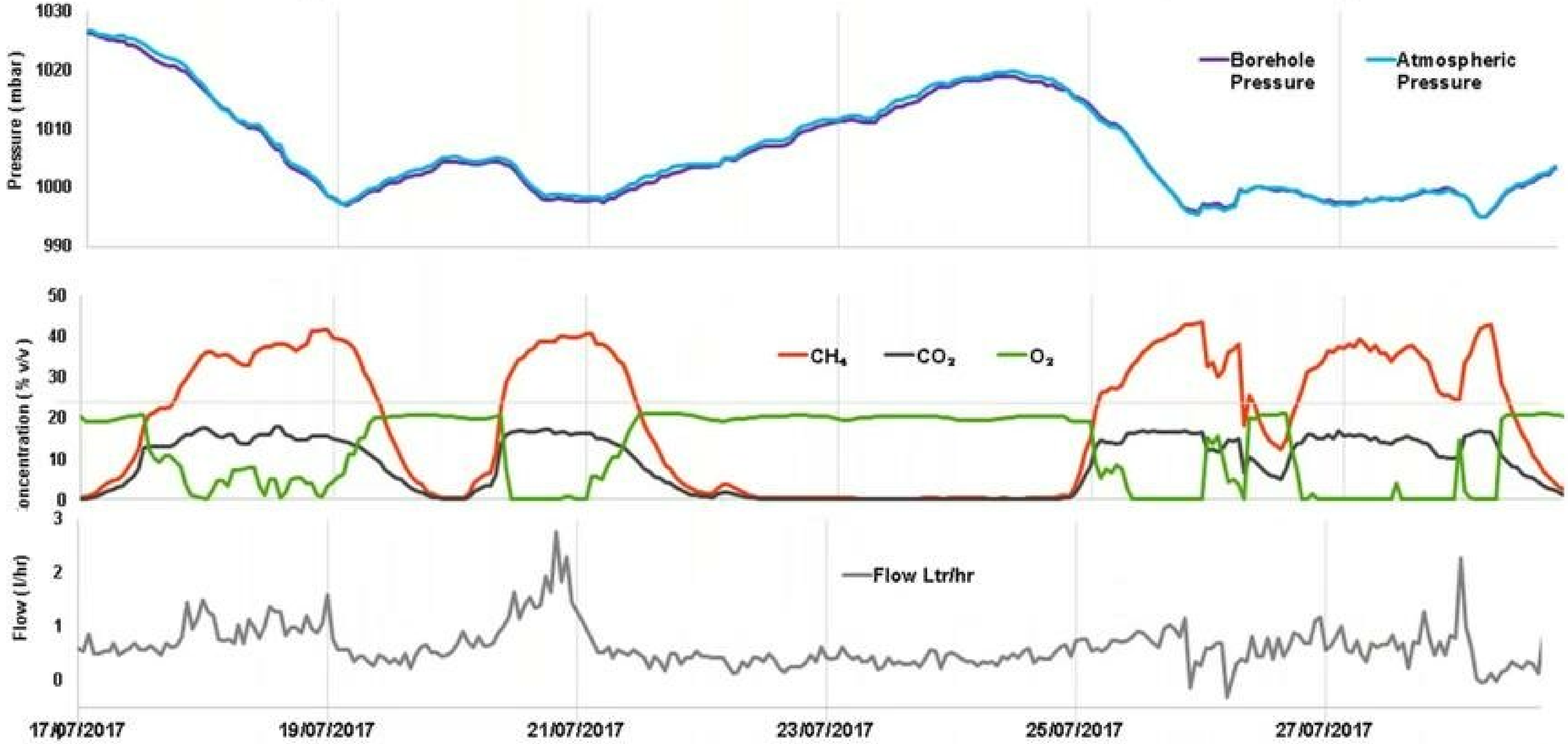
Dynamic Pressure Assessment (Flow!)



GGS GasSentinel® Time Series

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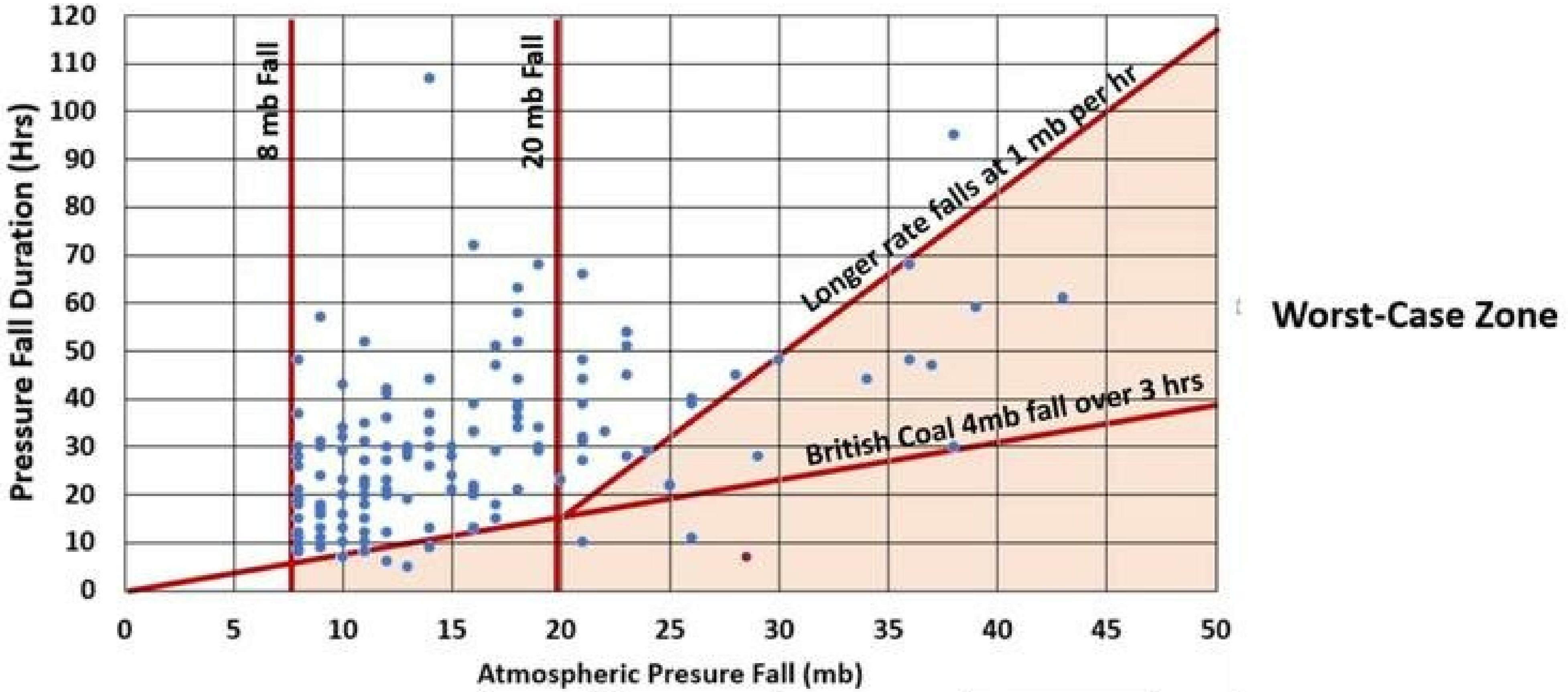
Worst Case Pressure Drops



	Pressure Fall (mb)	Time (Hrs)	Rate of Fall (mb/Hrs)
n	138	138	138
Max	43	107	2.60
Min	8	5	0.13
Mean	15.8	30.6	0.64
Median	14	28.5	0.53
St Dev	7.6	17.5	0.40
95th	34.3	61.3	1.28
90th	25.3	52	1.08
80th	21	44	0.82
75th	19	39	0.76

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Modelling

- Simple spreadsheet based calculations to quiet sophisticated commercial modelling packages
- 1D modelling using basic principles: Boyles Law, Darcy's Law, Fick's Law (and others)
- Concentration modelling 2D surface and 3D plots with time dimension
- CLEA, USEPA J&E v6, GasSim2.5 (and others)
- Unfortunately it is very easy to get sucked into the numbers and forget reality!
  - Is the model based on sound scientific principles?
  - Is the model appropriate for the site specific circumstances?
  - Have you got realistic numbers for physical parameters?
  - Have you done sensitivity analysis and what factors of safety are you considering?

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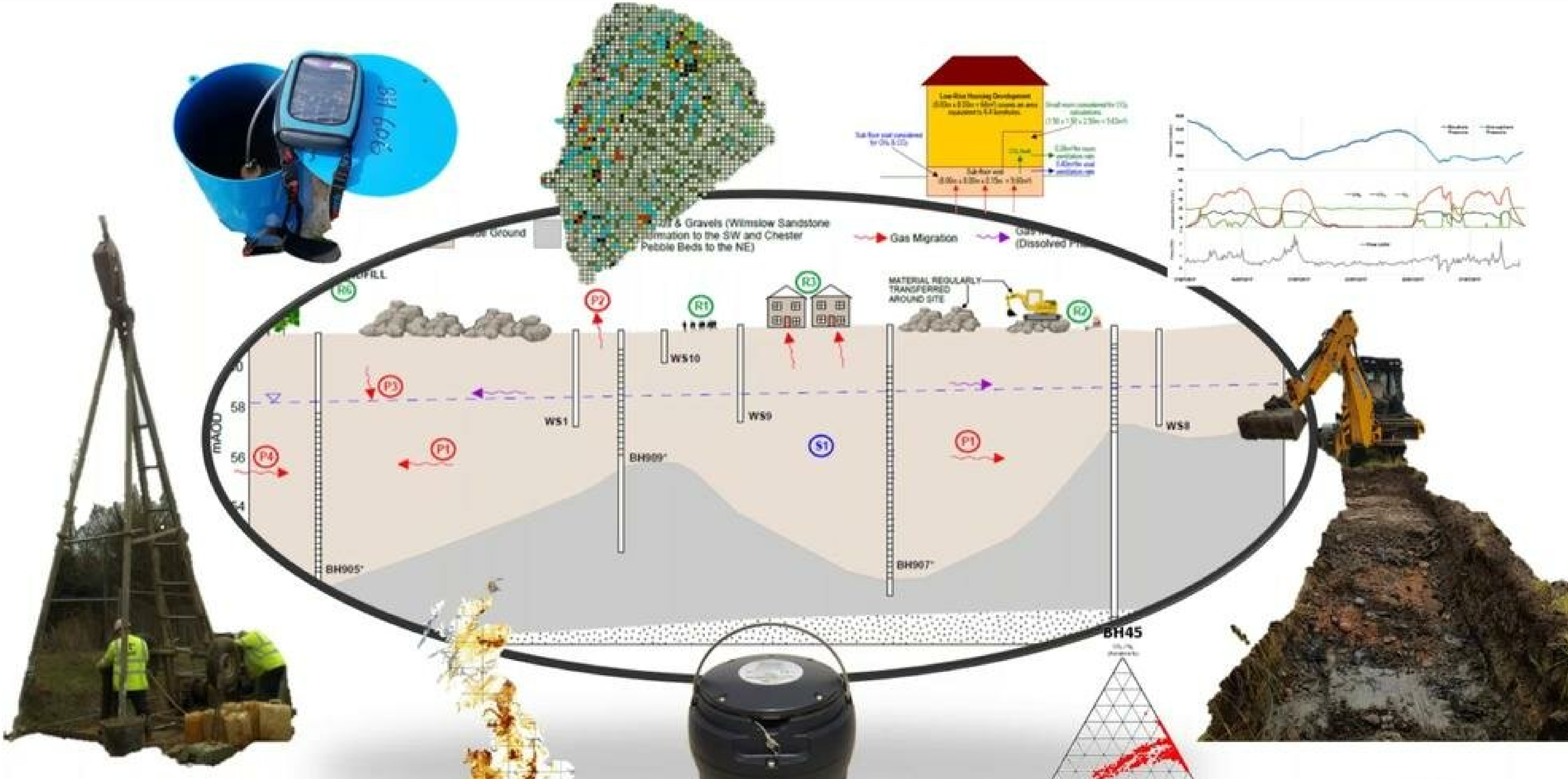
Fault Tree and Event Tree Analysis

These methods are used to analyse a failure mechanism, looking at a series of failures that lead to an unwanted event

- Fault tree analysis is a 'top down' approach starting with the unwanted event and then looks at individual failures that get you to that event
- Event tree analysis is 'bottom up', starting with an initiating event and follows ever branching time order sequences until you end up with your unwanted event

You can attribute numerical probabilities to the events that provides an estimate of the annual frequency of which such events will occur (F)



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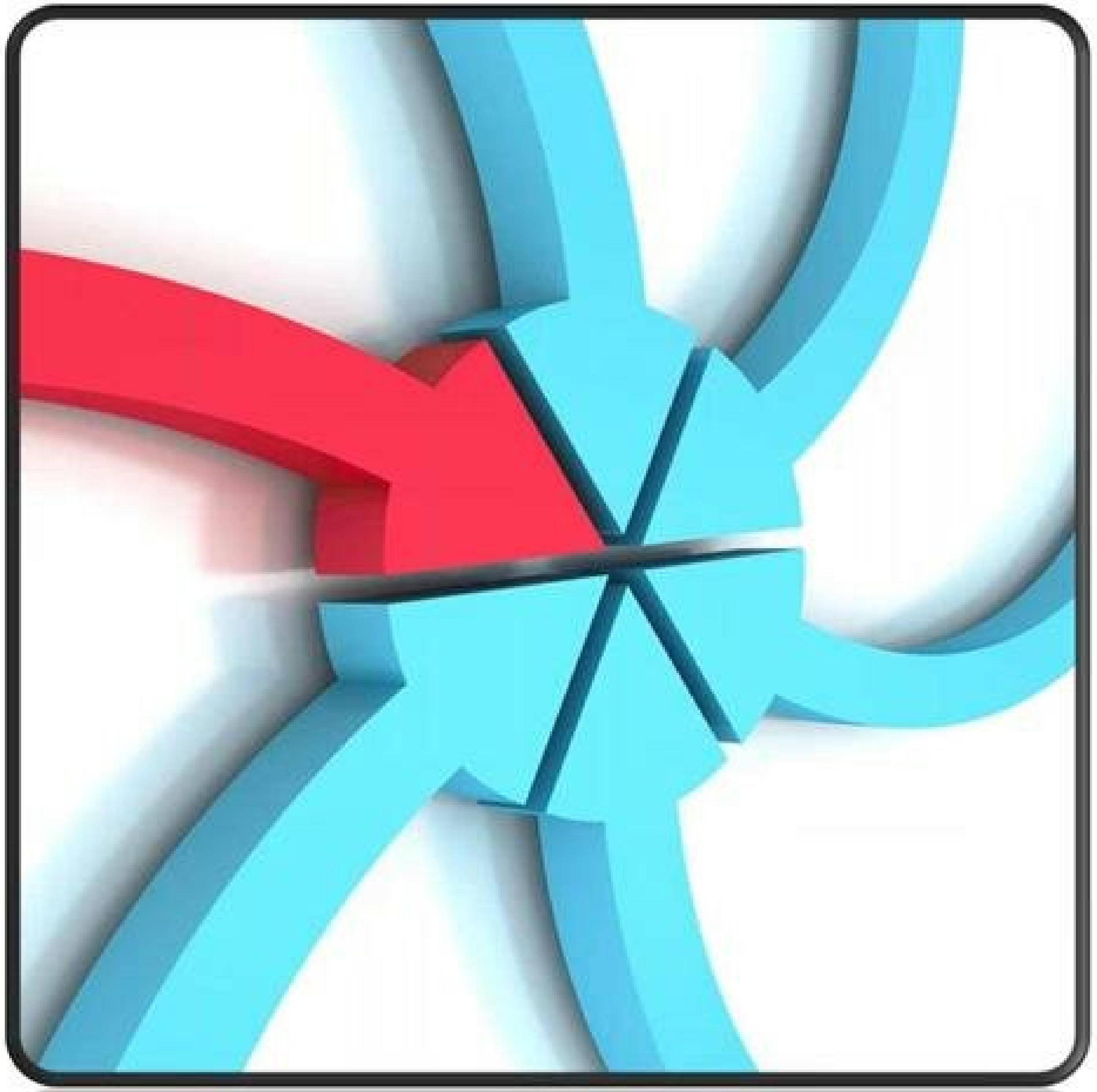
Lines of Evidence for Ground Gas Risk Assessment



- Each line of evidence is initially considered separately
- When considered together for a potential pollutant linkage, do they make sense (Converge)
- What weighting are we going to assign
- Confidence (uncertainty) in our evidence
- Used to inform and justify the Conceptual Site Model

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Uncertainty (Confidence)

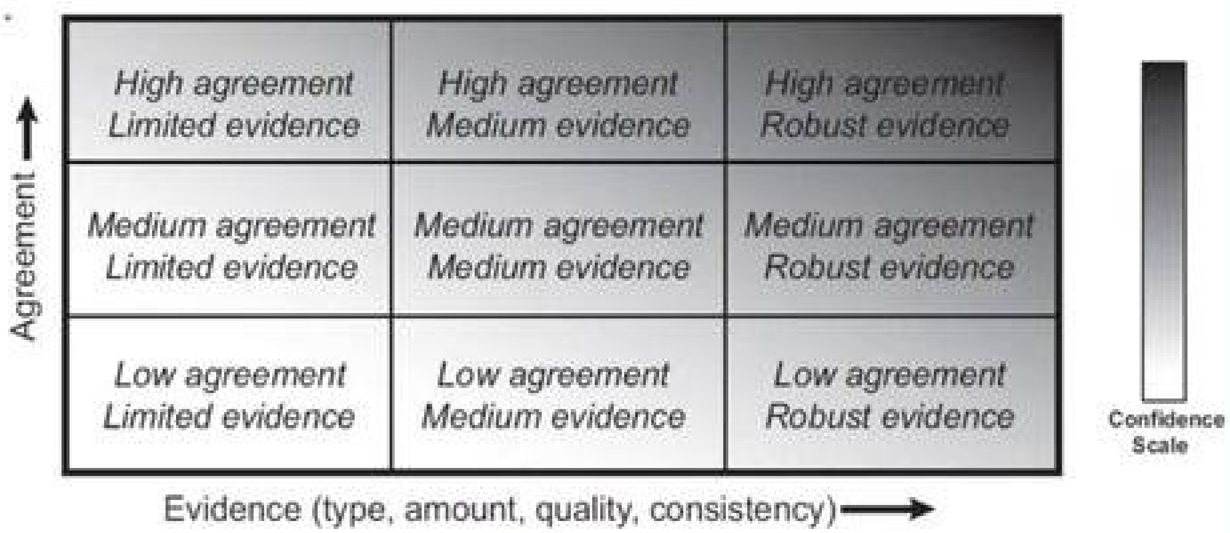
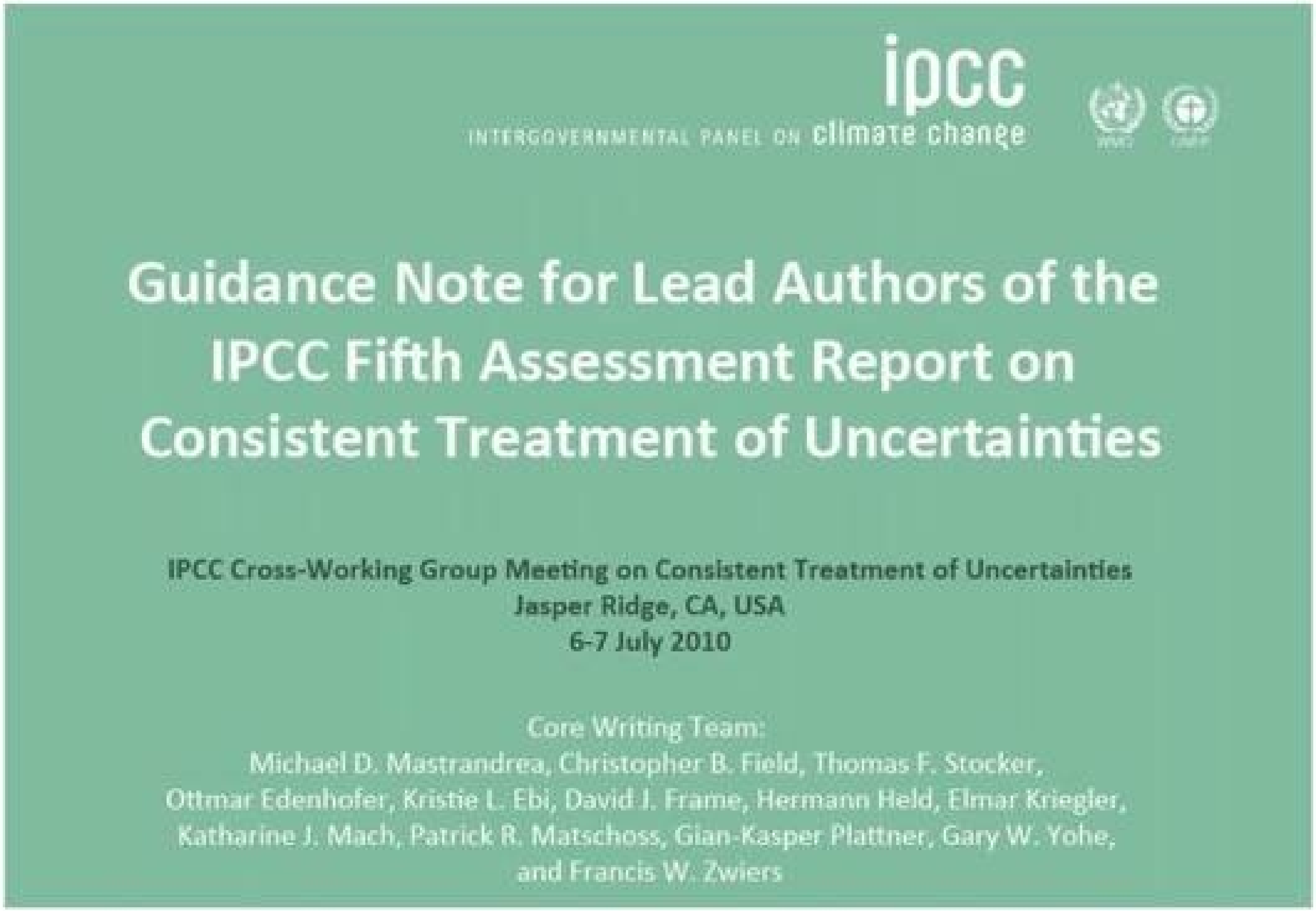


Figure 1 of the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties 2010



ipcc

INTERGOVERNMENTAL PANEL ON climate change

Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties

IPCC Cross-Working Group Meeting on Consistent Treatment of Uncertainties
Jasper Ridge, CA, USA
6-7 July 2010

Core Writing Team:
Michael D. Mastrandrea, Christopher B. Field, Thomas F. Stocker, Ottmar Edenhofer, Kristie L. Ebi, David J. Frame, Hermann Held, Elmar Kriegler, Katharine J. Mach, Patrick R. Matschoss, Gian-Kasper Plattner, Gary W. Yohe, and Francis W. Zwiers

Uncertainty (Confidence)

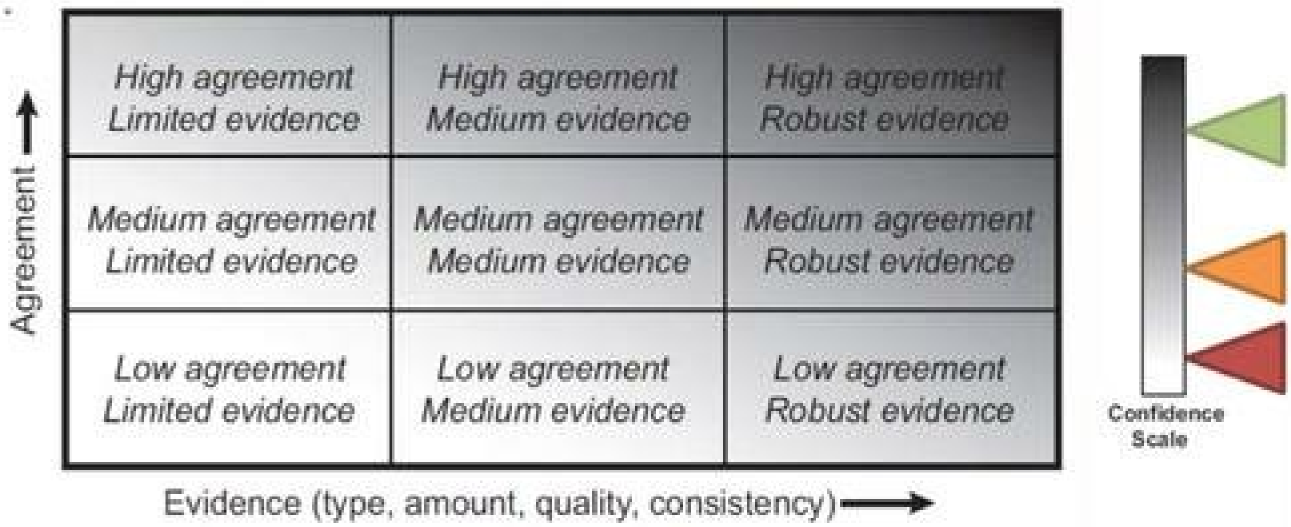


Figure 1 of the Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties 2010

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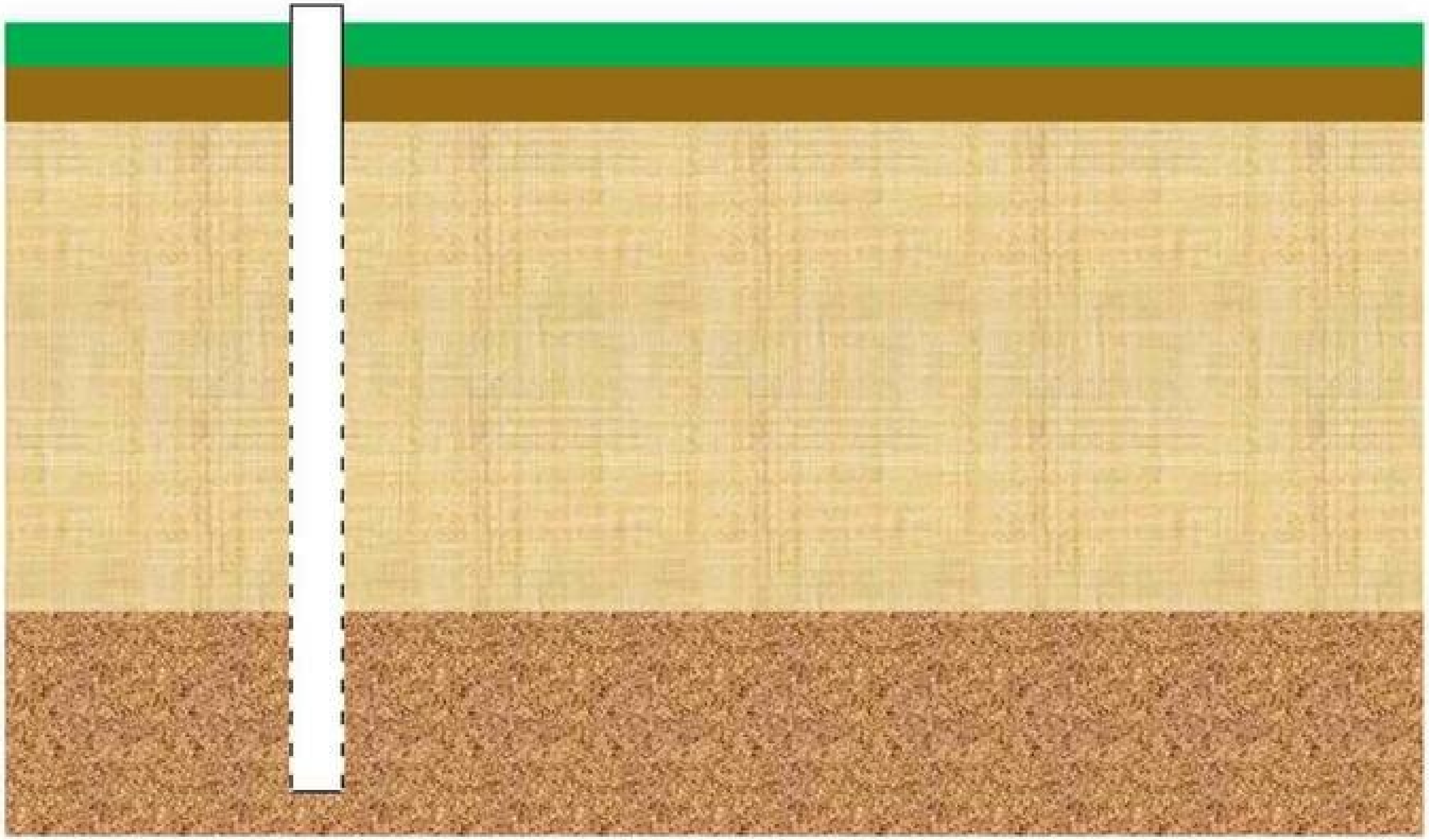
The Unexpected Reading



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The Unexpected Reading

Visit No.	CH4 (%v/v)	CO2 (%v/v)	O2 (%v/v)
1	0	0.2	21.0
2	0	0.5	19.9
3	0	0.3	20.1
4	82.3	6.1	0.5
5	0	0.1	20.6
6	0	0.2	20.2

What factors might effect GSV?

Standpipe and valve diameter

Geology

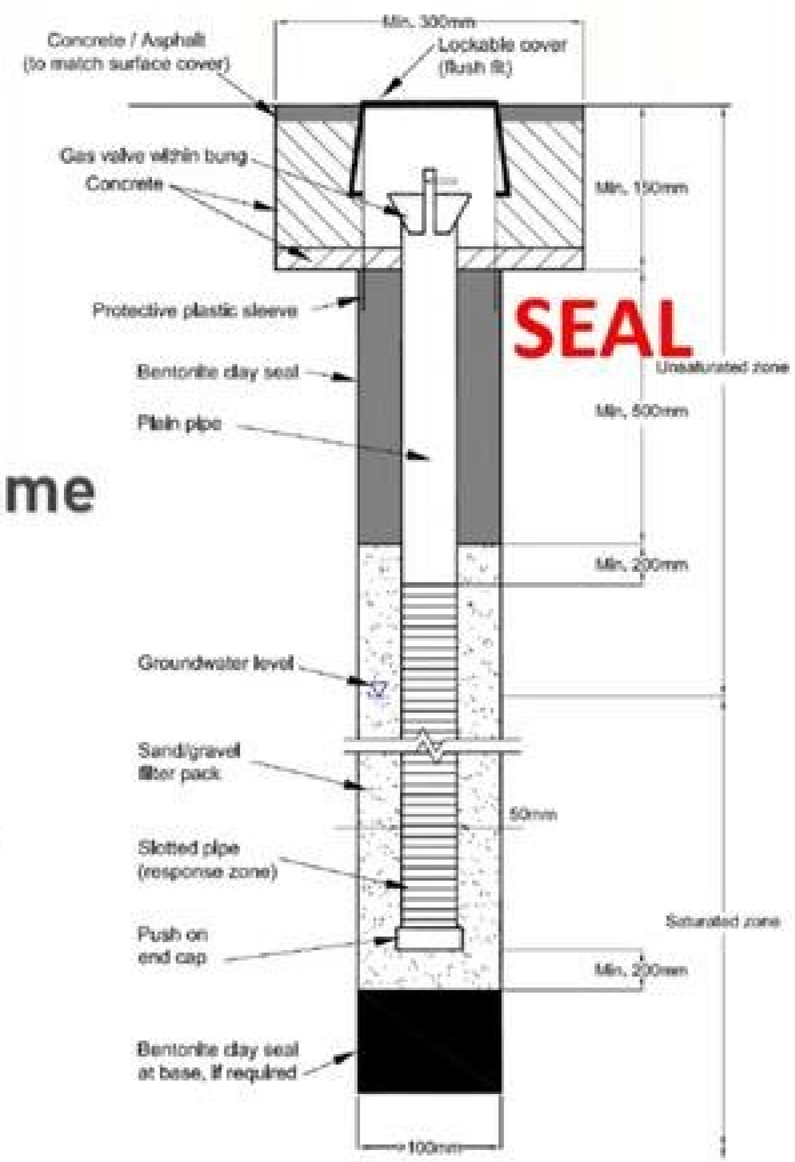
Gas Reservoir Volume

Biology

Gas Modification

Geochemistry

Gas Generation



Monitoring Well
(a unique scientific instrument)

Weather Conditions

Sampling Equipment

Sampling Methodology

Soil permeability

Response Zone Location

Groundwater

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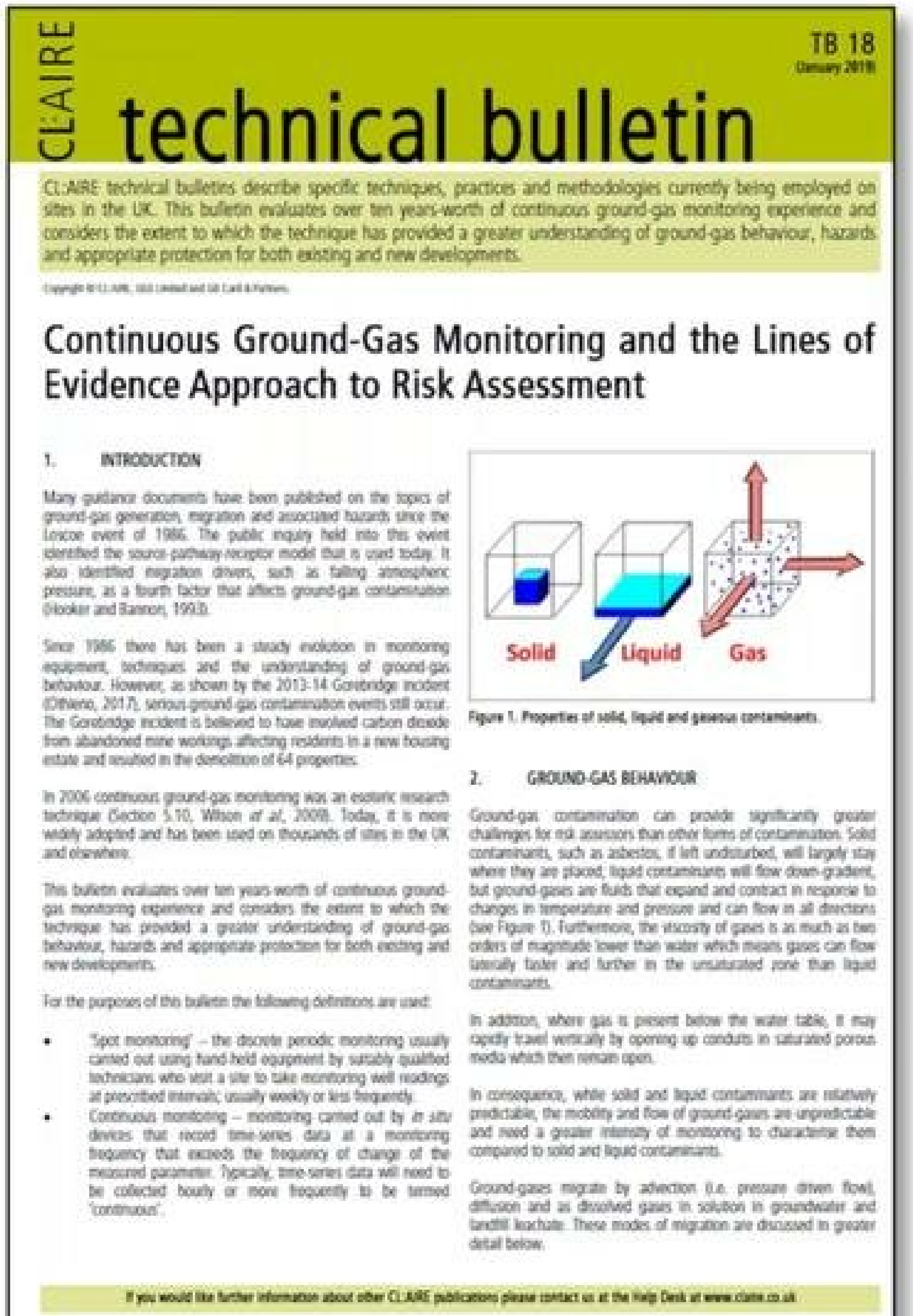
CL:AIRE TB18 - Jan 2019


CL:AIRE

TB 18
(January 2019)

technical bulletin

CL:AIRE technical bulletins describe specific techniques, practices and methodologies currently being employed on sites in the UK. This bulletin evaluates over ten years-worth of continuous ground-gas monitoring experience and considers the extent to which the technique has provided a greater understanding of ground-gas behaviour, hazards and appropriate protection for both existing and new developments.

Continuous Ground-Gas Monitoring and the Lines of Evidence Approach to Risk Assessment

1. INTRODUCTION

Many guidance documents have been published on the topics of ground-gas generation, migration and associated hazards since the Loscoe event of 1986. The public inquiry held into this event identified the source-pathway-receptor model that is used today. It also identified migration drivers, such as falling atmospheric pressure, as a fourth factor that affects ground-gas contamination (Hooker and Bannon, 1993).

Since 1986 there has been a steady evolution in monitoring equipment, techniques and the understanding of ground-gas behaviour. However, as shown by the 2013-14 Gorebridge incident (Othieno, 2017), serious ground-gas contamination events still occur. The Gorebridge incident is believed to have involved carbon dioxide from abandoned mine workings affecting residents in a new housing estate and resulted in the demolition of 64 properties.

In 2006 continuous ground-gas monitoring was an esoteric research technique (Section 5.10, Wilson *et al*, 2009). Today, it is more widely adopted and has been used on thousands of sites in the UK and elsewhere.

This bulletin evaluates over ten years-worth of continuous ground-gas monitoring experience and considers the extent to which the technique has provided a greater understanding of ground-gas behaviour, hazards and appropriate protection for both existing and new developments.

For the purposes of this bulletin the following definitions are used:

- 'Spot monitoring' – the discrete periodic monitoring usually carried out using hand-held equipment by suitably qualified technicians who visit a site to take monitoring well readings at prescribed intervals; usually weekly or less frequently.
- Continuous monitoring – monitoring carried out by *in situ* devices that record time-series data at a monitoring frequency that exceeds the frequency of change of the measured parameter. Typically, time-series data will need to be collected hourly or more frequently to be termed 'continuous'.

Solid Liquid Gas

Figure 1. Properties of solid, liquid and gaseous contaminants.

2. GROUND-GAS BEHAVIOUR

Ground-gas contamination can provide significantly greater challenges for risk assessors than other forms of contamination. Solid contaminants, such as asbestos, if left undisturbed, will largely stay where they are placed; liquid contaminants will flow down-gradient, but ground-gases are fluids that expand and contract in response to changes in temperature and pressure and can flow in all directions (see Figure 1). Furthermore, the viscosity of gases is as much as two orders of magnitude lower than water which means gases can flow laterally faster and further in the unsaturated zone than liquid contaminants.

In addition, where gas is present below the water table, it may rapidly travel vertically by opening up conduits in saturated porous media which then remain open.

In consequence, while solid and liquid contaminants are relatively predictable, the mobility and flow of ground-gases are unpredictable and need a greater intensity of monitoring to characterise them compared to solid and liquid contaminants.

Ground-gases migrate by advection (i.e. pressure driven flow), diffusion and as dissolved gases in solution in groundwater and landfill leachate. These modes of migration are discussed in greater detail below.

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- Built on over 12 years experience of continuous monitoring
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- Ground-gas properties and behaviour
- Best practice in collecting continuous data
- Gas behaviour within the Source-Pathway-Receptor
- Lines of evidence approach to risk assessment

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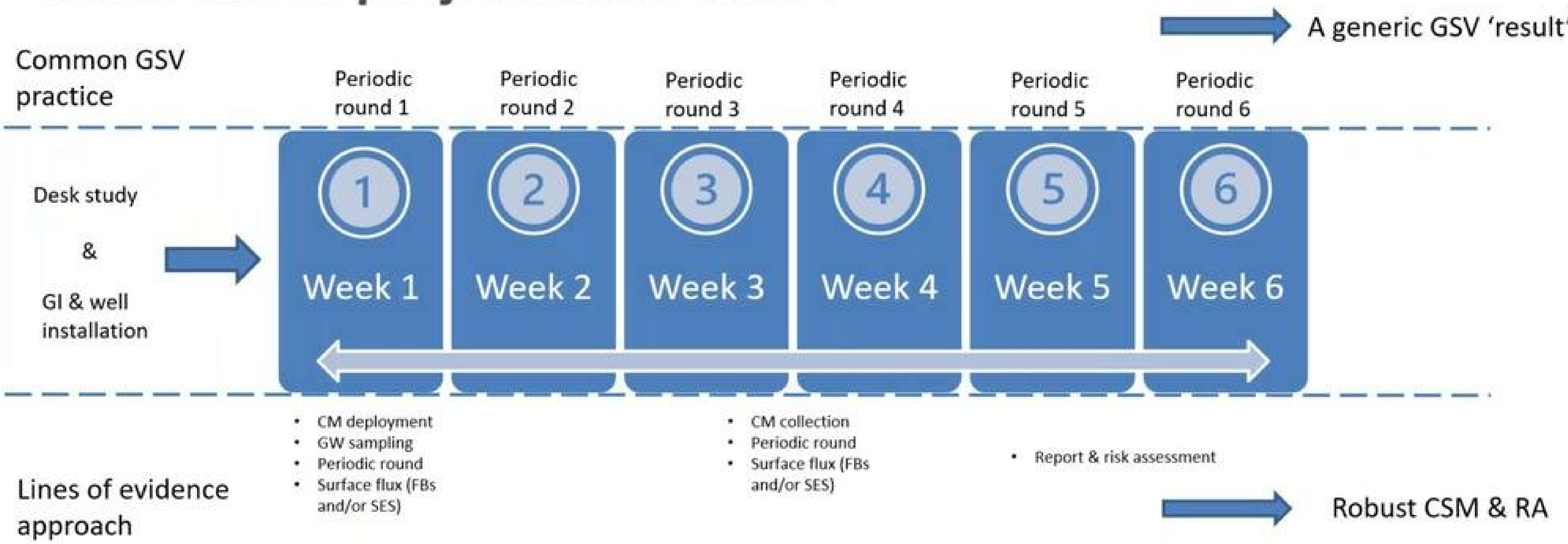
What about project timescales?



What about project costs?

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Thank You

Any questions?

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