Learnings from a Long-Term Petroleum Plume Monitoring Case Study

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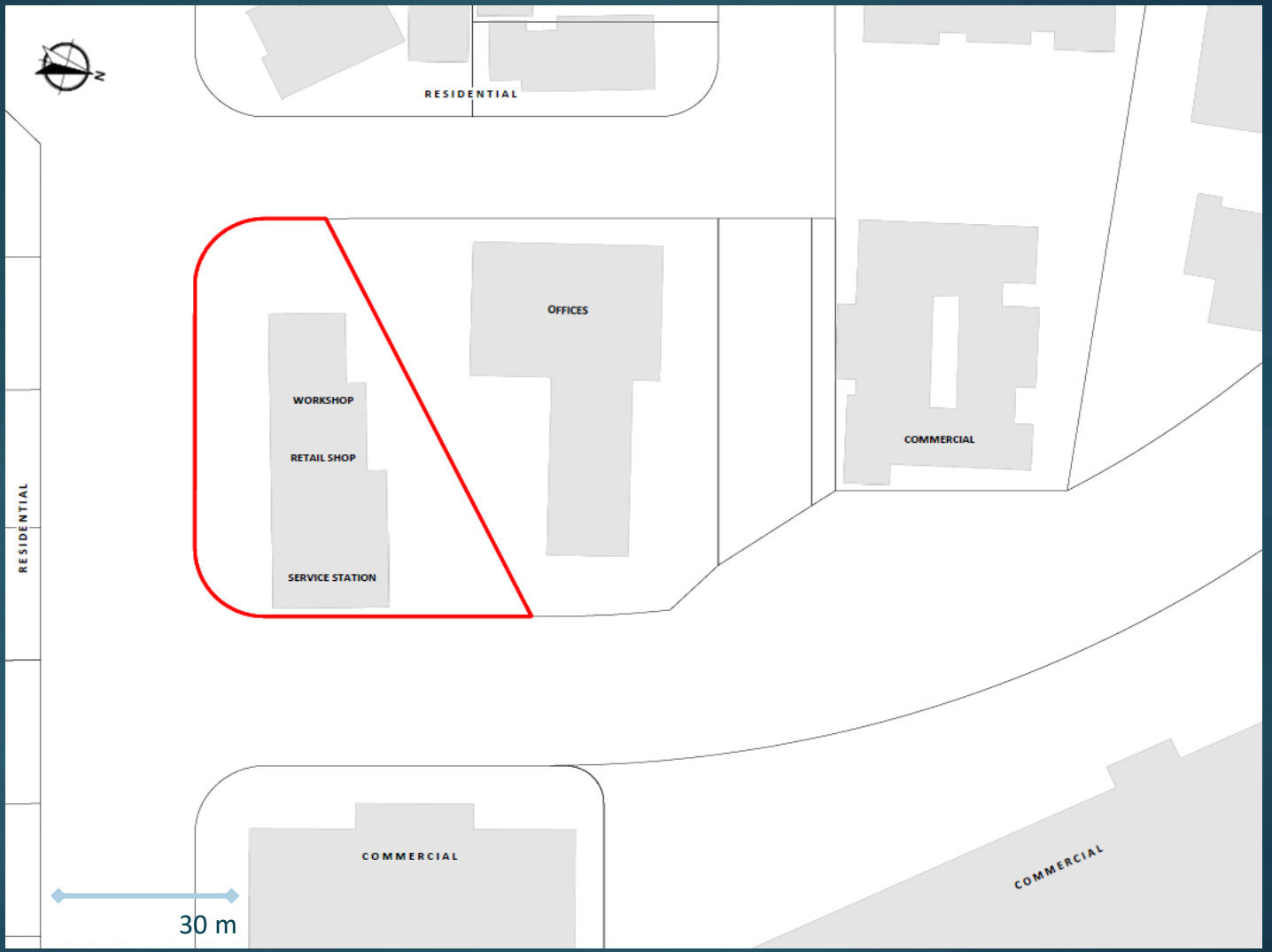
Outline

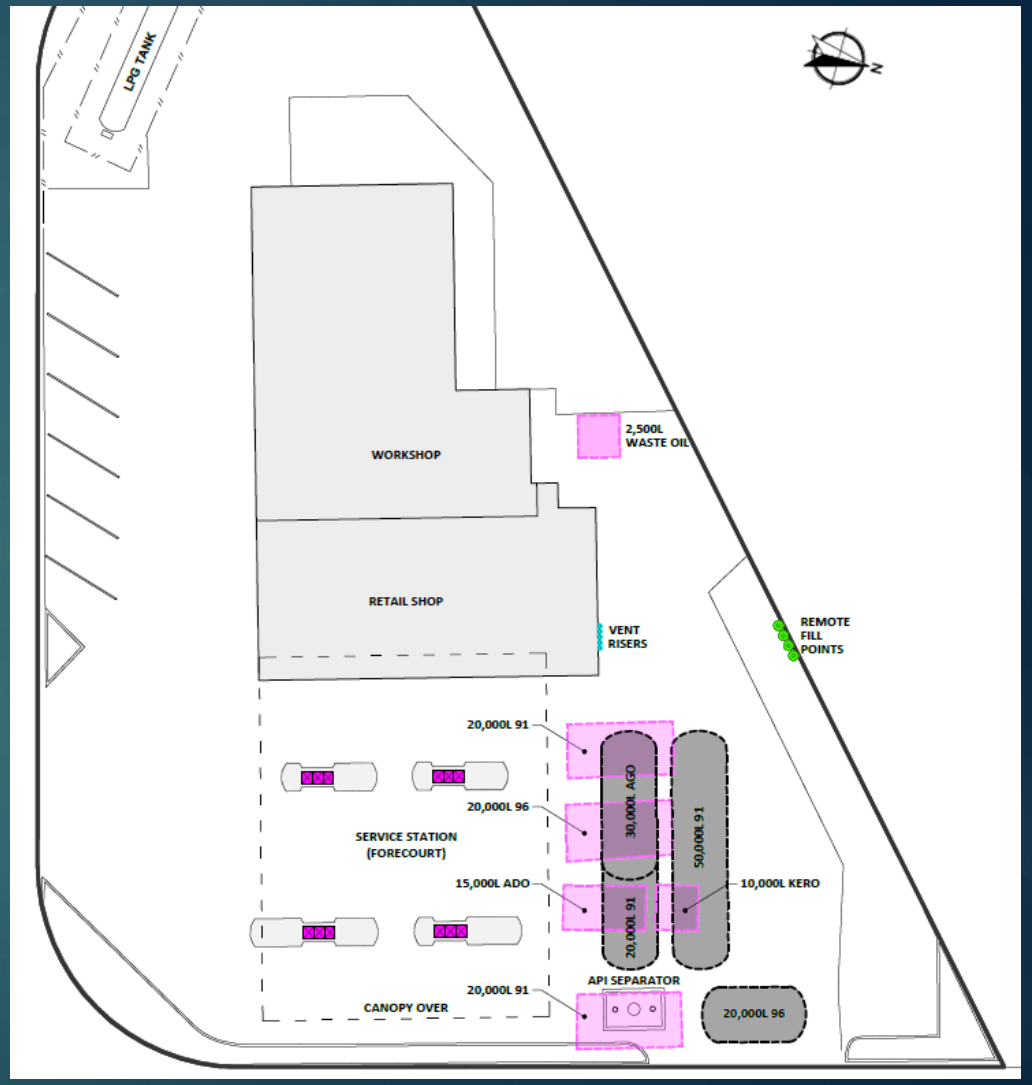
- Site Background
- Environmental Investigations
- Conceptual Site Model
- Petroleum Hydrocarbon Trends
- Monitoring and Management
- MNA Checklist
- Summary and Learnings

Background - Site Setting

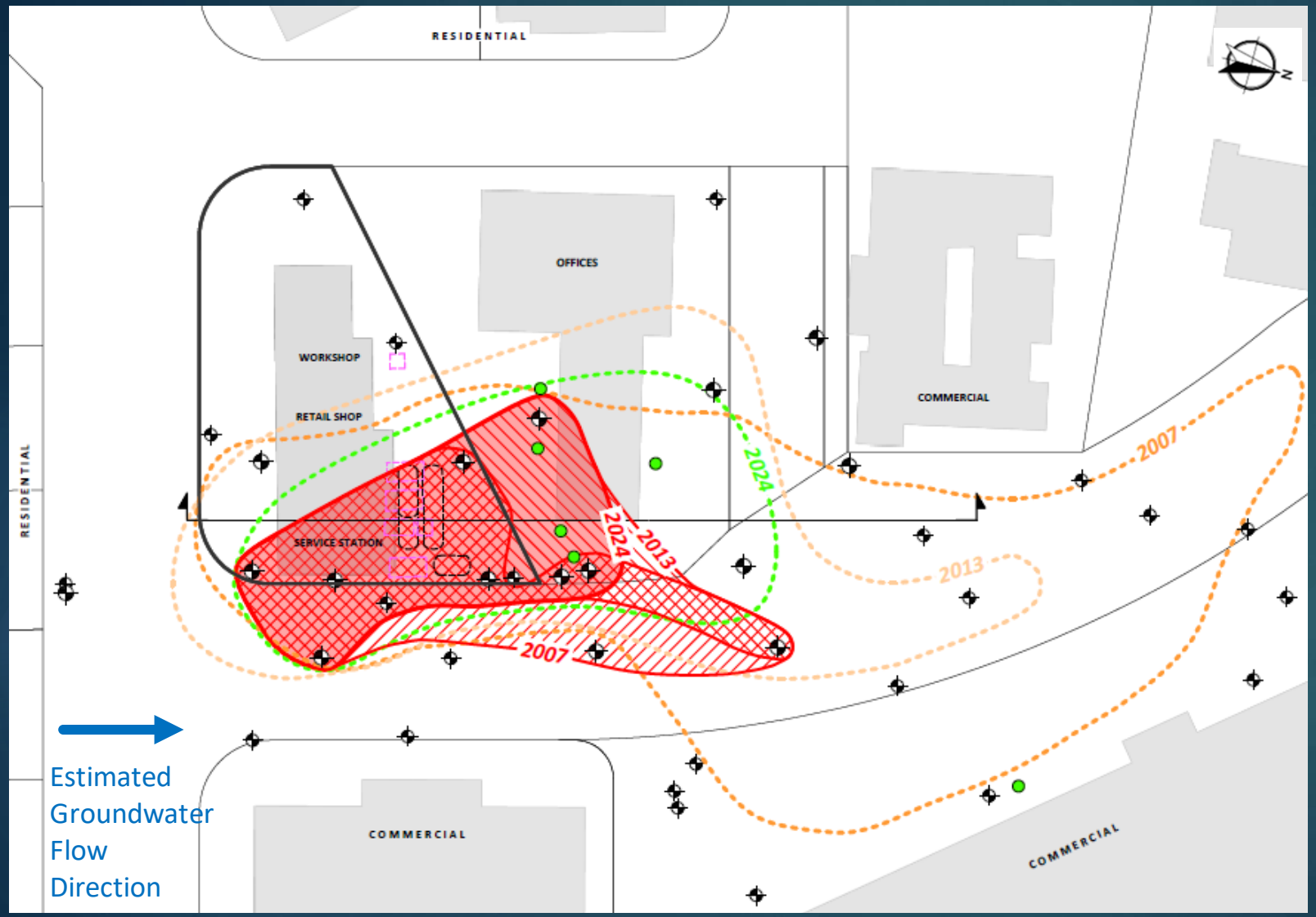


Background – Site History

- Service station since early 1970s and last upgraded in 2004.
- History of multiple fuel leakage from the UPSS.
- Approximately 417 tonnes of petroleum impacted soil removed from the site during the UPSS upgrade.
- LNAPL (petrol) was identified to have migrated off-site beneath the roadway and the neighbouring property.
- Remedial system operated between November 2005 and 2008 which involved interconnecting conduit below ground between monitoring wells
- Approx. 3,000 L of product recovered.



The Petroleum Hydrocarbon Plume



- LNAPL plume extending approximately 30-40 m northeast & 5-10 m east of the service station.
- Dissolved phase plume (benzene isopleth map to 0.95 mg/L) approximately 80 m north of the site and a further 50 m north of the LNAPL plume.

Environmental Investigations Summary

Investigation Type	Date	Comments
Soil Validation Investigation – UPSS upgrade	2004	▪ Elevated petroleum hydrocarbon concentrations detected in backfill, walls and base of the former USTs (between 3.5 m - 3.7 m depth), pumps and remote fills. ▪ Soils exceeding maintenance/excavation, inhalation and PAH surrogate pathway criteria and protection of GW quality.
Monitoring well installation	2004 – 2009	▪ Total of 42 GW monitoring wells installed. ▪ Moderate to strong petroleum hydrocarbon impacts in soils (4 - 7 mbgl). Highest concentrations noted in soils closest to the site. ▪ Soils exceeding maintenance/excavation, and inhalation pathway criteria.
Permeability Tests	2005 - 2009	▪ Slug tests on seven selected monitoring wells. ▪ Moderate to high hydraulic conductivities (10^{-3} – 10^{-6} m/s) typical of silty sand and sand soil types.
Product Analysis	2005 & 2022	▪ Weathered petrol indicated. Possible losses prior to 2003.

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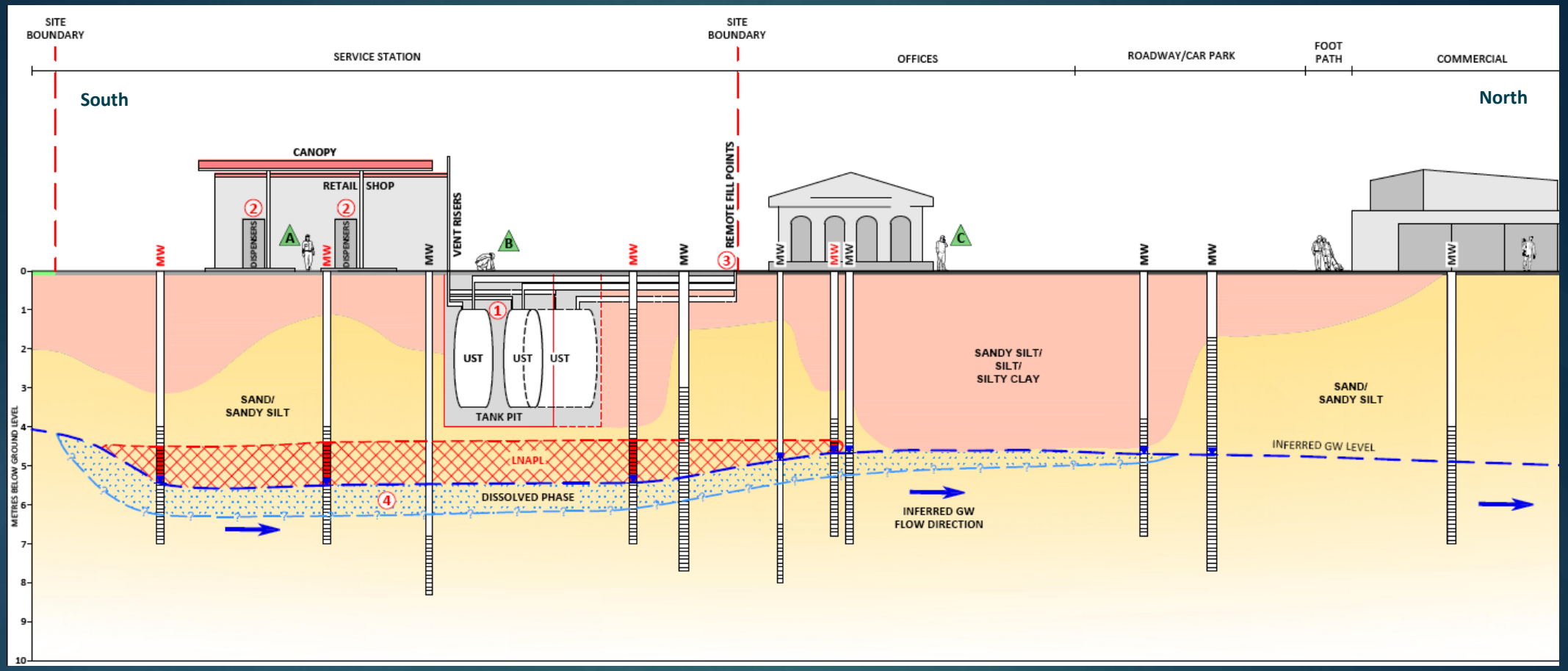
Environmental Investigations Summary – Cont.

Investigation Type	Date	Comments
Product Bail Down Tests	2005 & 2006	▪ Variable transmissivity indicated based on heterogeneity in soils.
Soil Gas Sampling	2004 - 2009	▪ Six nested soil gas points installed. ▪ Low to non-detect BTEX concentrations reported via. summa canister sampling.
Ambient Air Monitoring	2005 - 2009	▪ Indoor and outdoor monitoring conducted at neighbouring property using thermal desorption tubes and passive badges. ▪ Trace to non-detect BTEX concentrations reported.
SW and SS Network PID Survey	2005 – 2018	▪ High PID readings recorded in sewer network in 2005. ▪ Generally low PID levels recorded in stormwater and sewer network post 2005.
Groundwater Monitoring	On-going	▪ TPH and BTEX monitored. PAH and heavy metals analysed initially – low to non-detect. Geochemical data collected. ▪ Current monitoring requirements: Biennial monitoring events, sampling 14 monitoring wells for BTEX analysis and gauging selected wells.

Conceptual Site Model



KEY :

POTENTIAL SOURCES

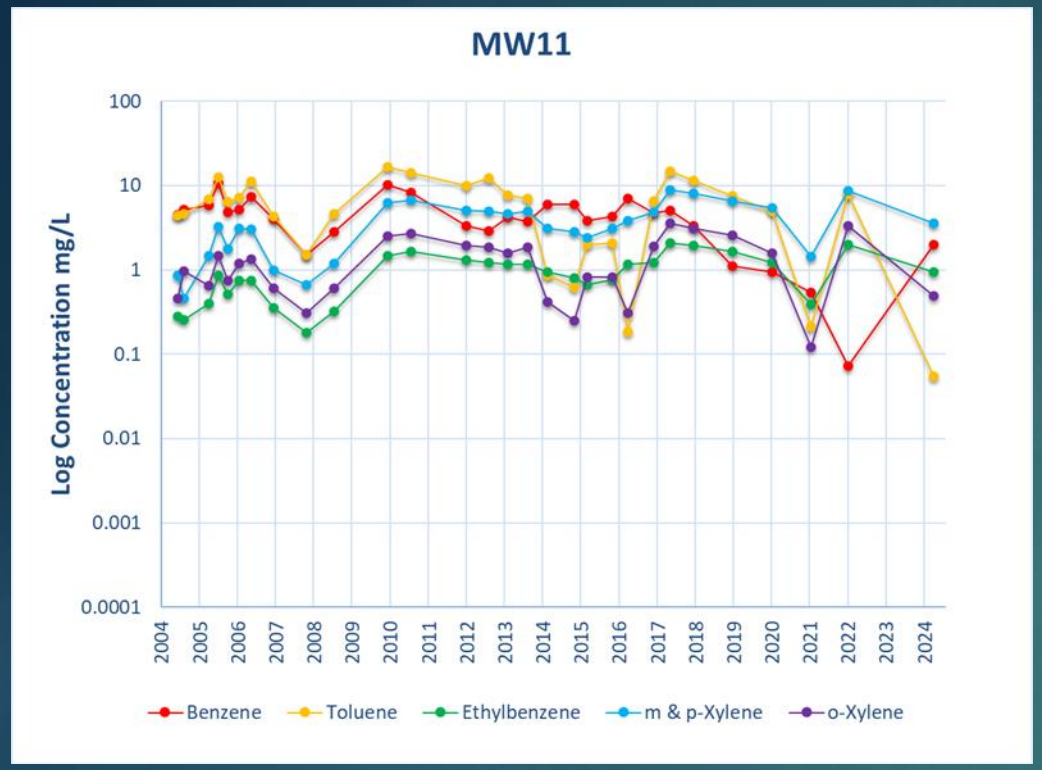
1. FORMER/CURRENT UNDERGROUND STORAGE TANK AREA
2. FUEL DISPENSING PUMPS
3. FILL POINTS & FILL LINES
4. DISSOLVED PHASE HYDROCARBON IMPACT

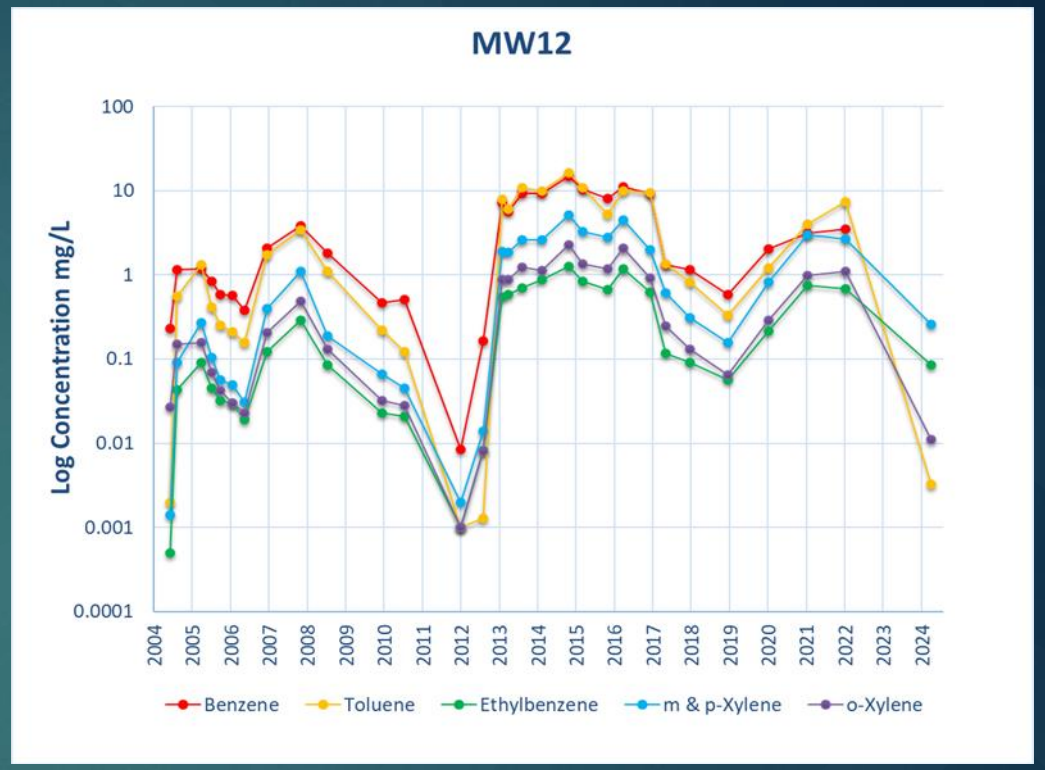
POTENTIAL RECEPTORS & PATHWAYS

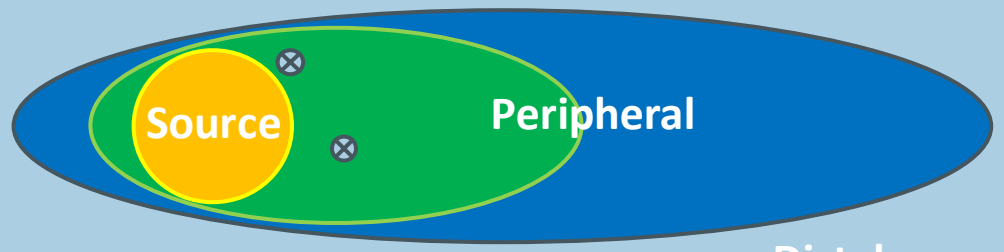
- A ONSITE SITE USERS/OCCUPIERS
- B MAINTENANCE/EXCAVATION WORKERS
- C OFFSITE SITE USERS/OCCUPIERS

- COMPLETE EXPOSURE PATHWAY
- INCOMPLETE EXPOSURE PATHWAY

BTEX Trends – Near Source



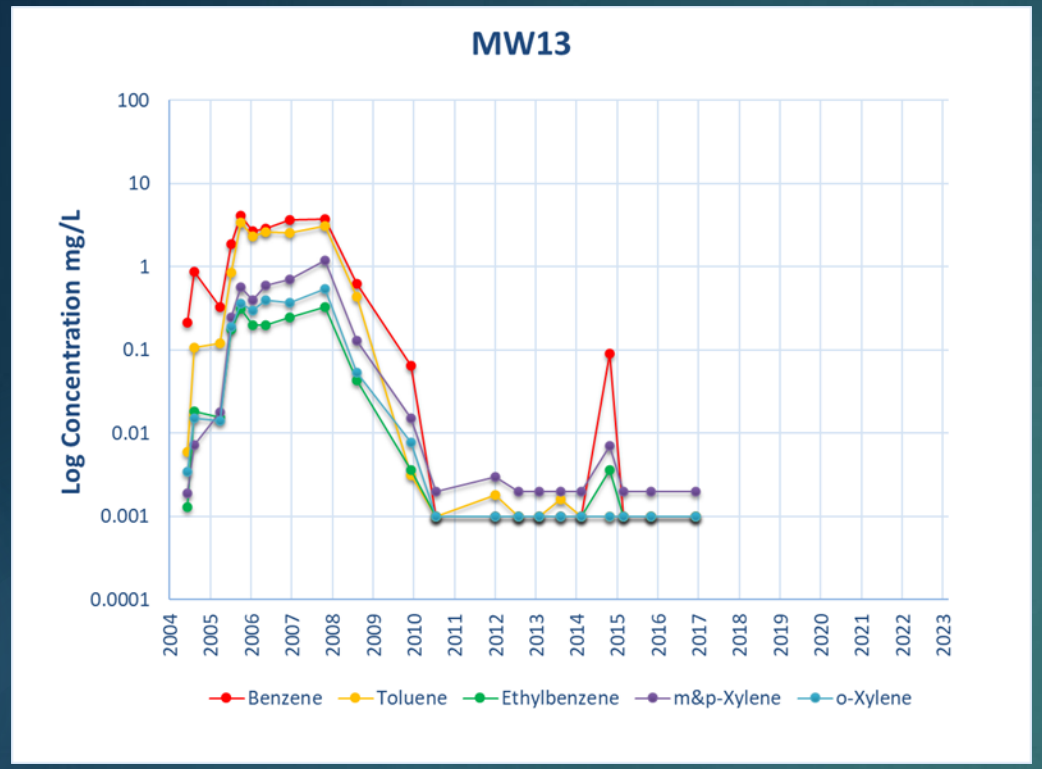


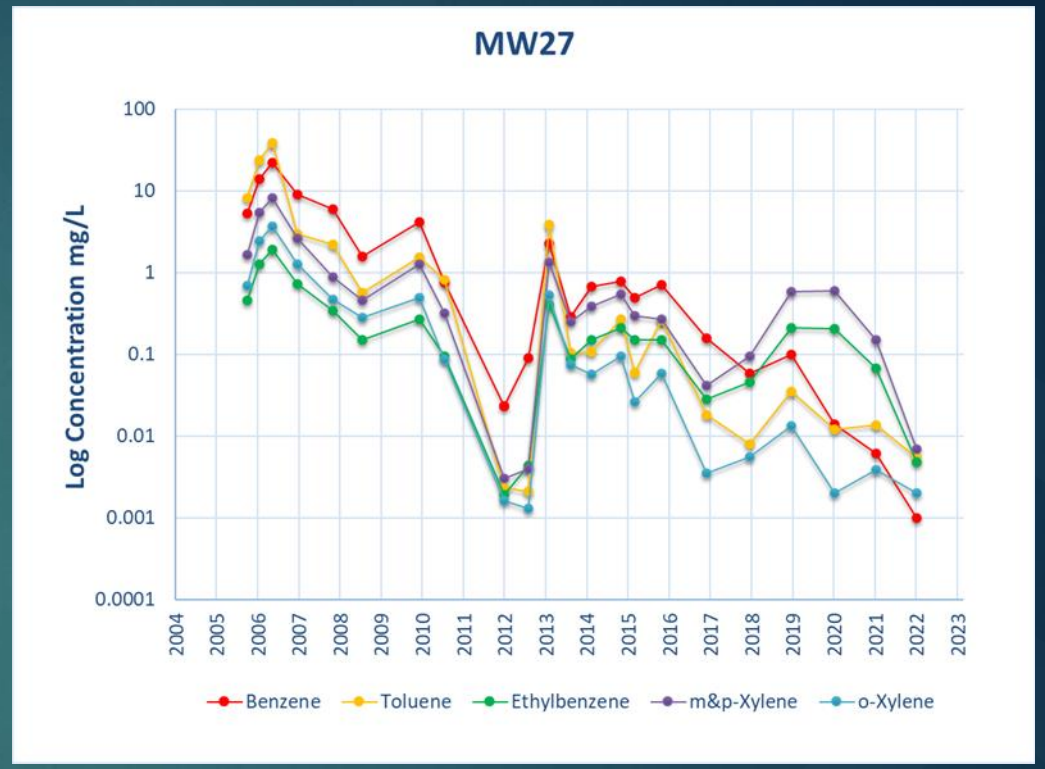


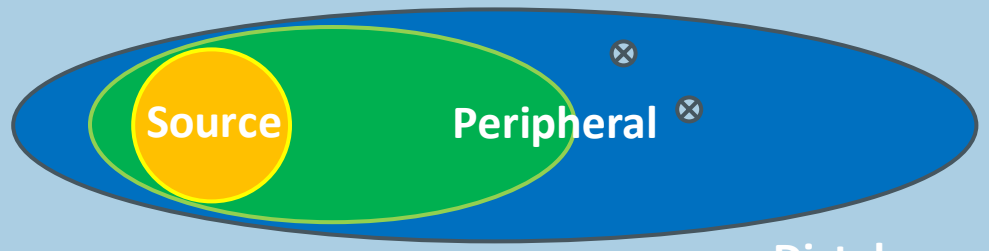
Groundwater Flow Direction

(NOT TO SCALE)

BTEX Trends – Peripheral Plume



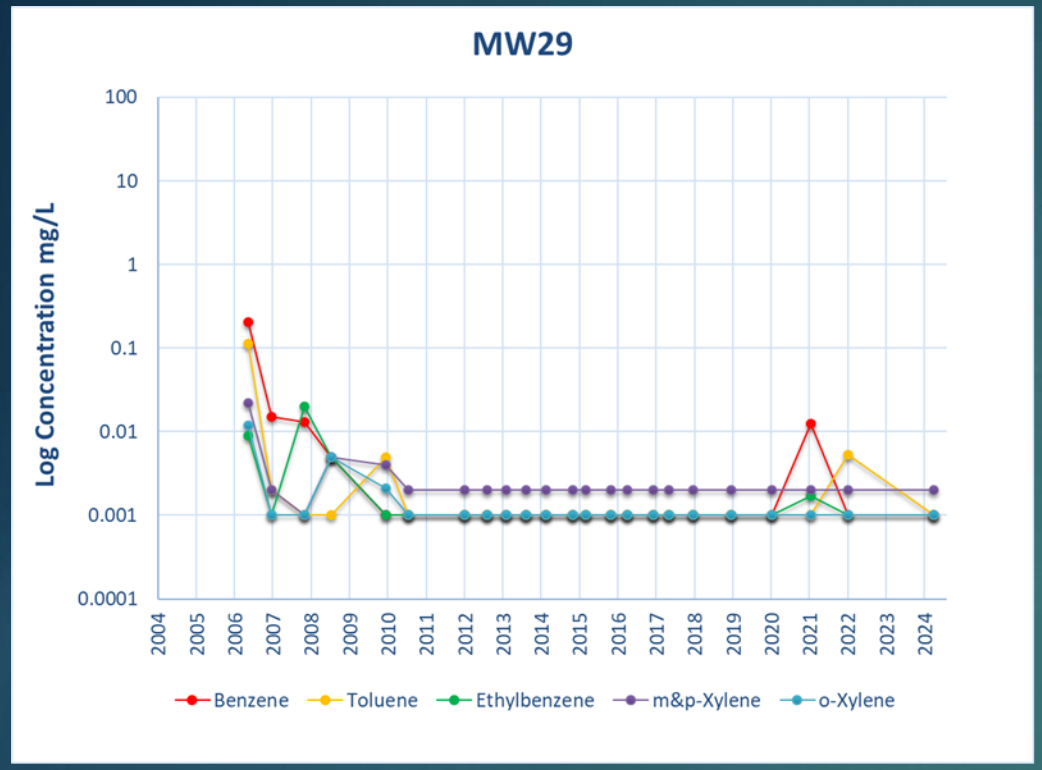


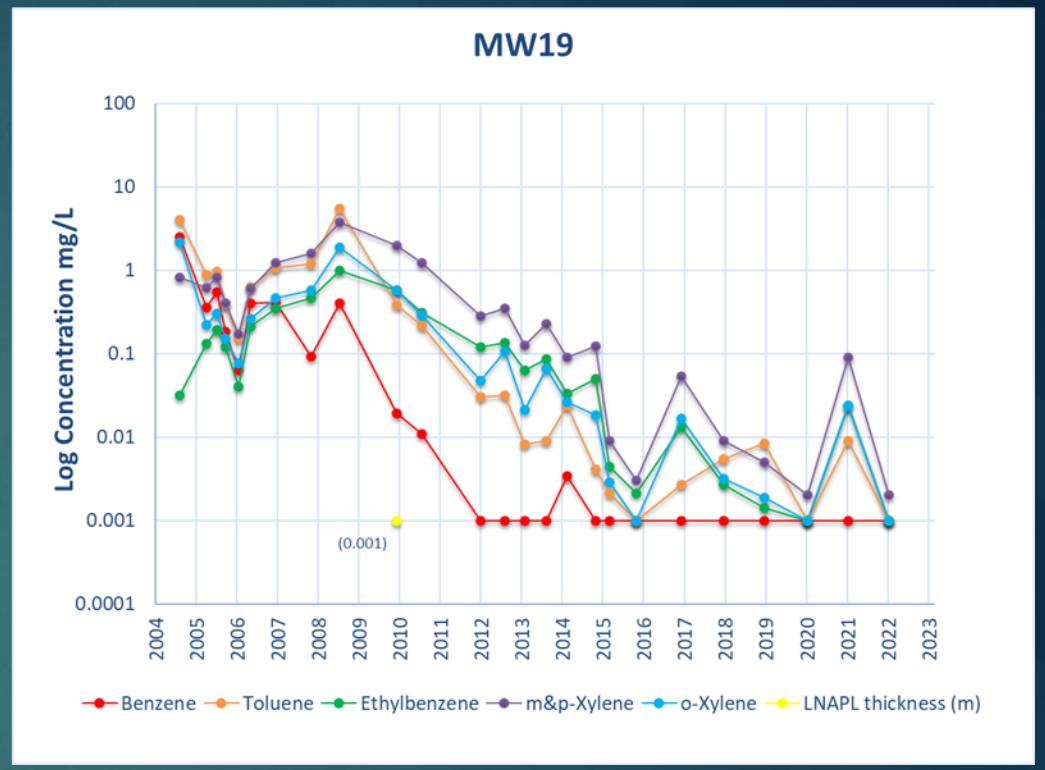


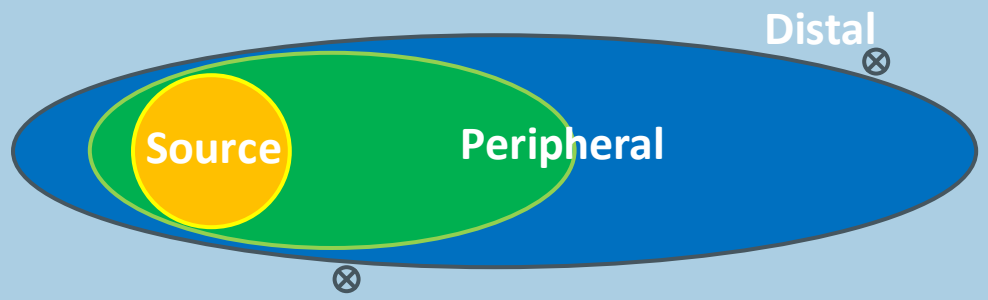
Groundwater Flow Direction

(NOT TO SCALE)

BTEX Trends – Distal Wells





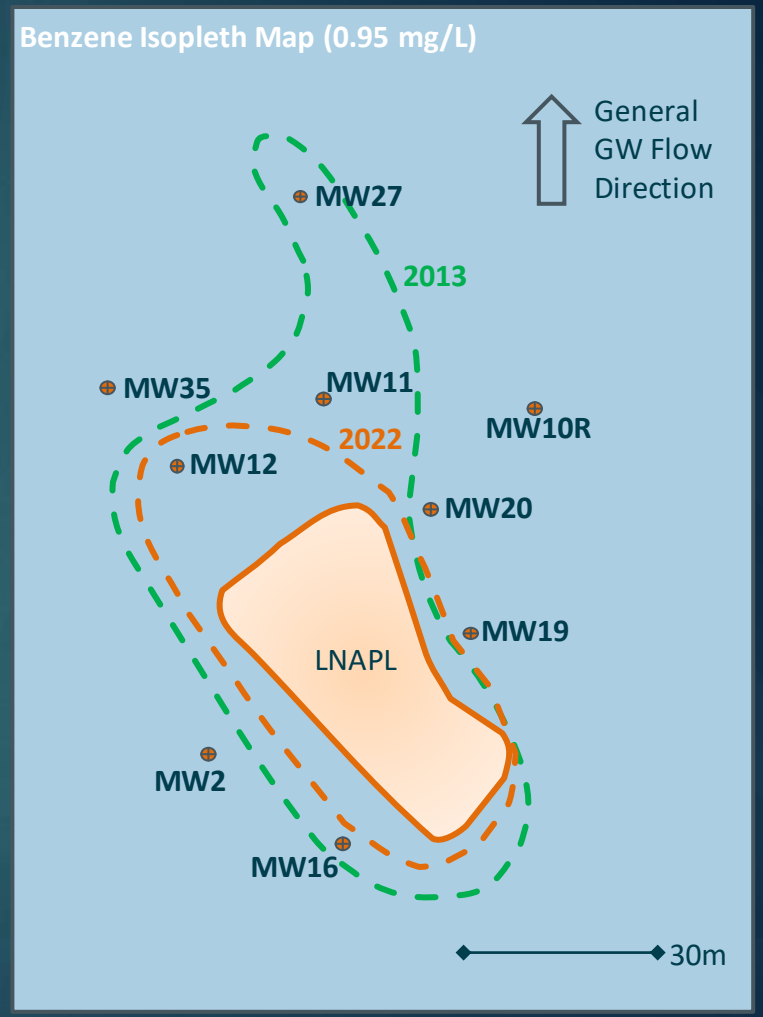


Groundwater Flow Direction

(NOT TO SCALE)

Geochemical Analytical Results

Well	MNA Parameter	Relative Indicator	Anaerobic Biodegradation
MW11 MW12 MW20 MW16	CH_4	Higher	Methanogenesis - Yes
	Mn, Fe	Higher	
	NO_3, SO_4, ORP, DO	Lower	Denitrification and Anaerobic Conditions - Yes
MW2 MW10R MW19 MW35	CH_4	Lower	Methanogenesis - No
	Mn, Fe	Lower	
	NO_3, SO_4, ORP, DO	Higher (apart from MW35)	Denitrification and Anaerobic Conditions - No
MW27	CH_4	Slightly higher	Methanogenesis - Yes
	Mn, Fe	Lower	
	NO_3, SO_4, ORP, DO	Higher	Denitrification and Anaerobic Conditions - No



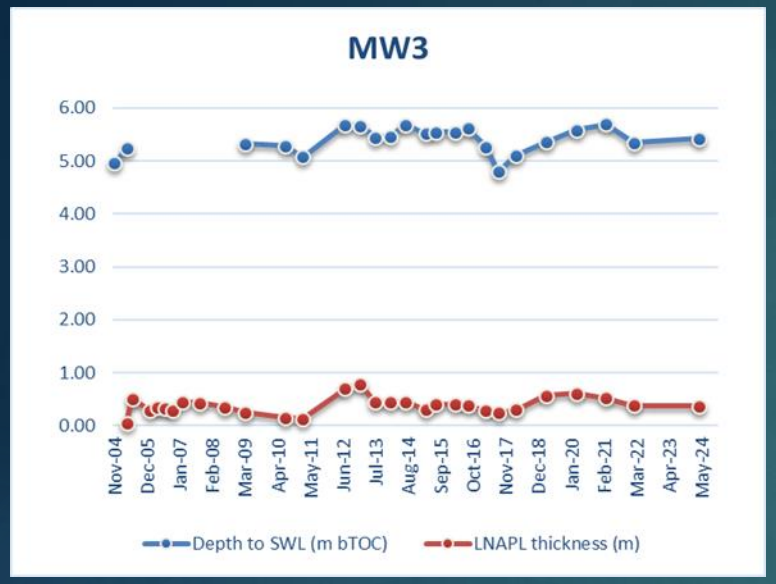
Product Composition

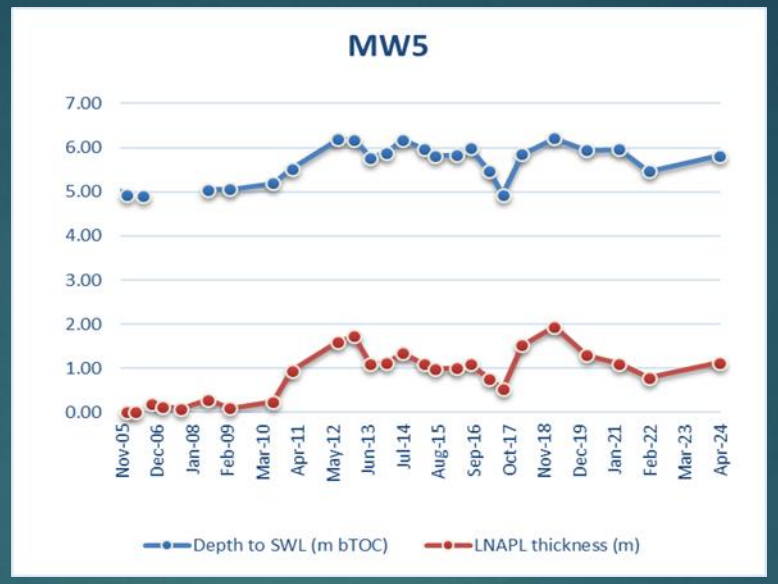
2022				
Analyte (%wt)	**Fresh Petrol**	**MW3**	**MW5**	**MW7**
TPH ($\leq C_6$)	36	7.7	38	28
TPH (C_7 - C_9)	58	72	56	64
TPH (C_{10} - C_{14})	6	20	5.8	7.1
TPH ($\geq C_{15}$)	ND	ND	ND	ND
Benzene	0.6	0.6	≤0.02	0.05
Toluene	11.2	6.8	1.9	4.7
Ethylbenzene	2.6	3.3	2.3	2.2
m&p-Xylene	5.0	16	11	13
o-Xylene	3.1	5.3	3	4

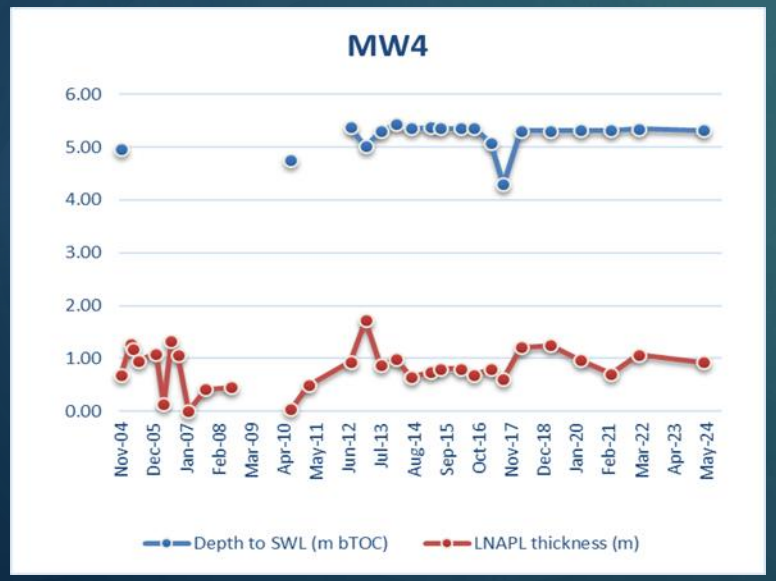
2007			
Analyte (%wt)	**MW1**	**MW3**	**MW7**
Benzene	1.58	0.99	1.22

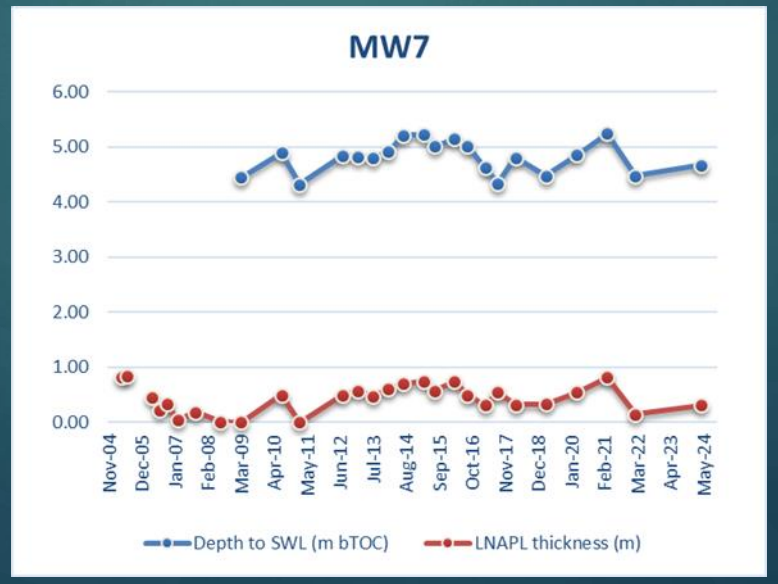
- 2022 benzene concentrations reduced in wells MW5, MW7 compared to MW3 (located closest to the former and current USTs).
- 2007 benzene concentrations are higher than recent reported levels.
- Original source of petrol pre-dates 2003 when fuel contained higher benzene concentrations (up to 3 % v/v).

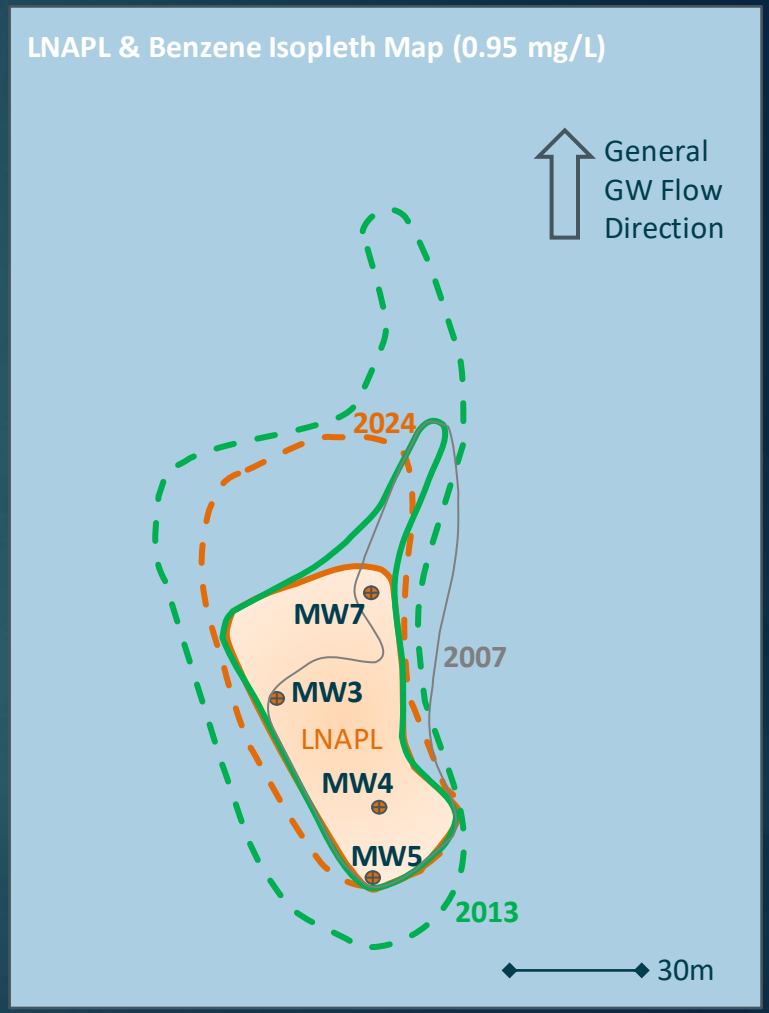
Historical GW Levels & LNAPL



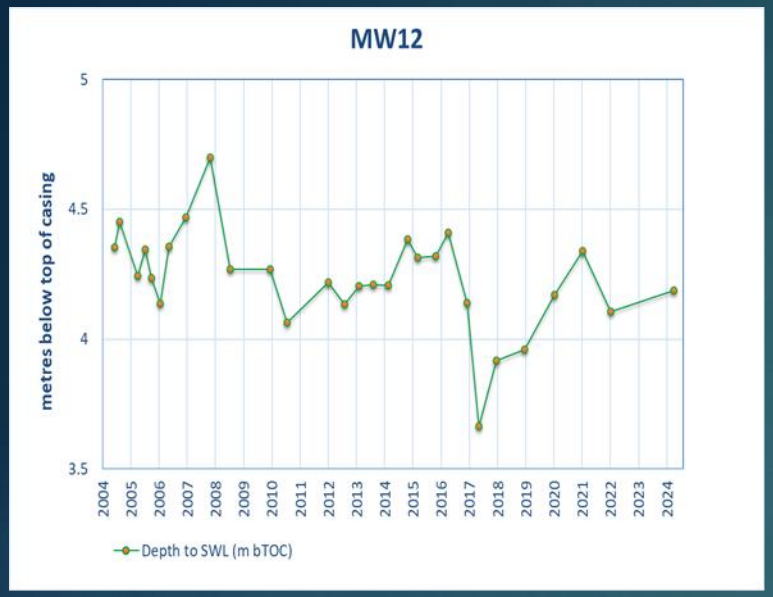


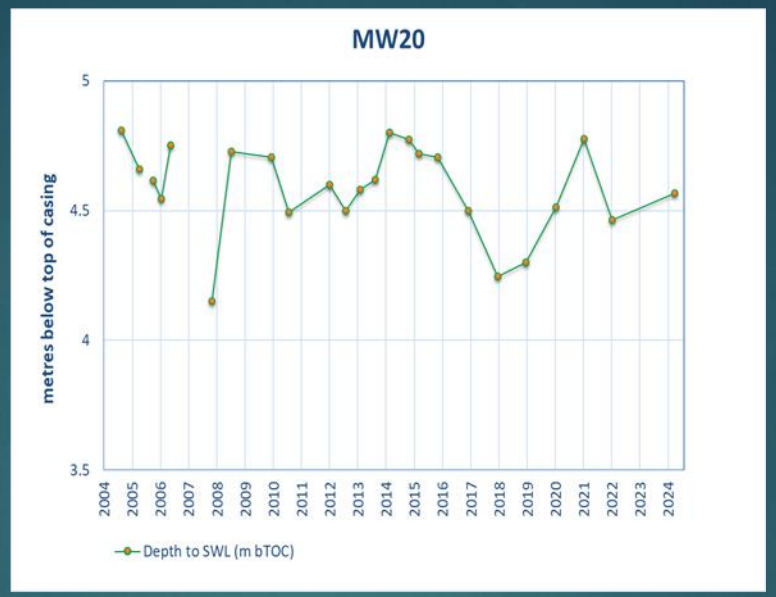


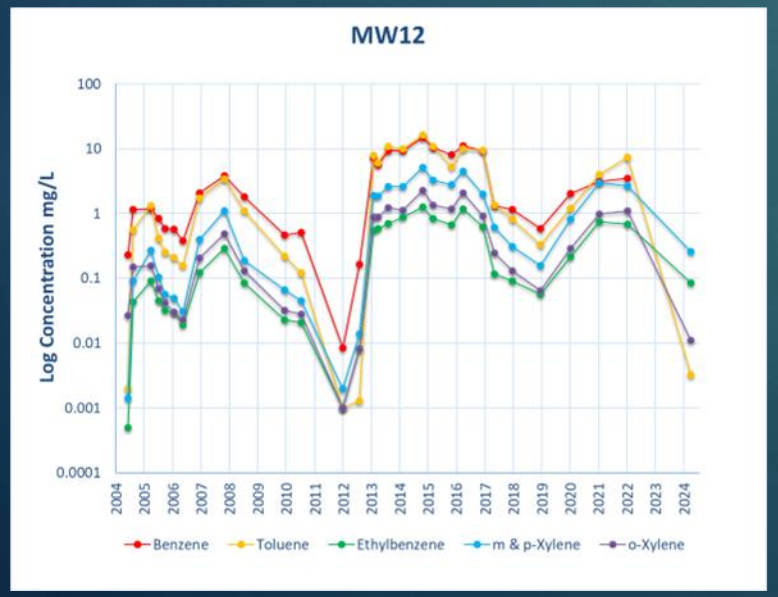


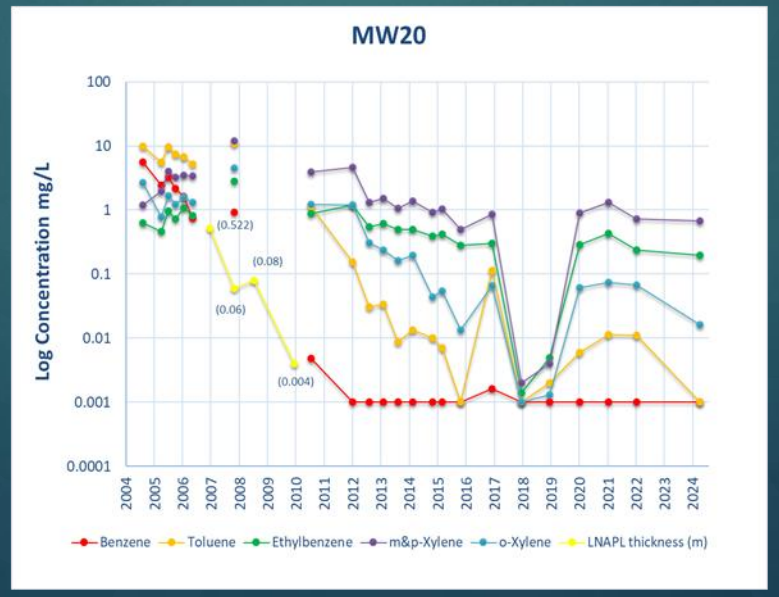


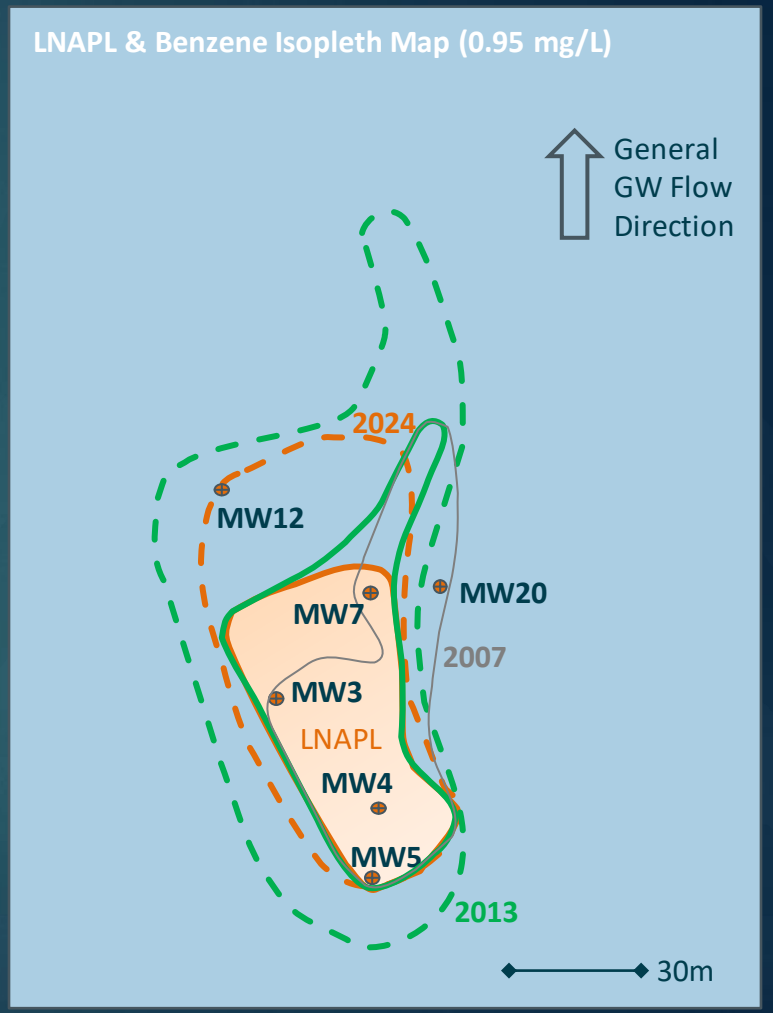
Historical GW Levels & Dissolved Phase











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Challenges

- Liaising with multiple affected parties: landowner, site operator, local transport authority, and immediate neighbouring commercial properties.
- Effective product recovery challenging owing to heterogeneous nature of the underlying soils and variable LNAPL saturations. Bail-down tests indicating that product transmissivities are variable at the site.
- Established infrastructure within commercial area.
- Traffic management – working at night to undertake monitoring.
- Potential loss of background data and knowledge via. regulatory authority and consultants with changes in site ownership.
- Renewing consent for continued monitoring.

https://www.parallaxx.co.nz/temporary-traffic-management/becoming-an-expert-in-the-ttm-industry/

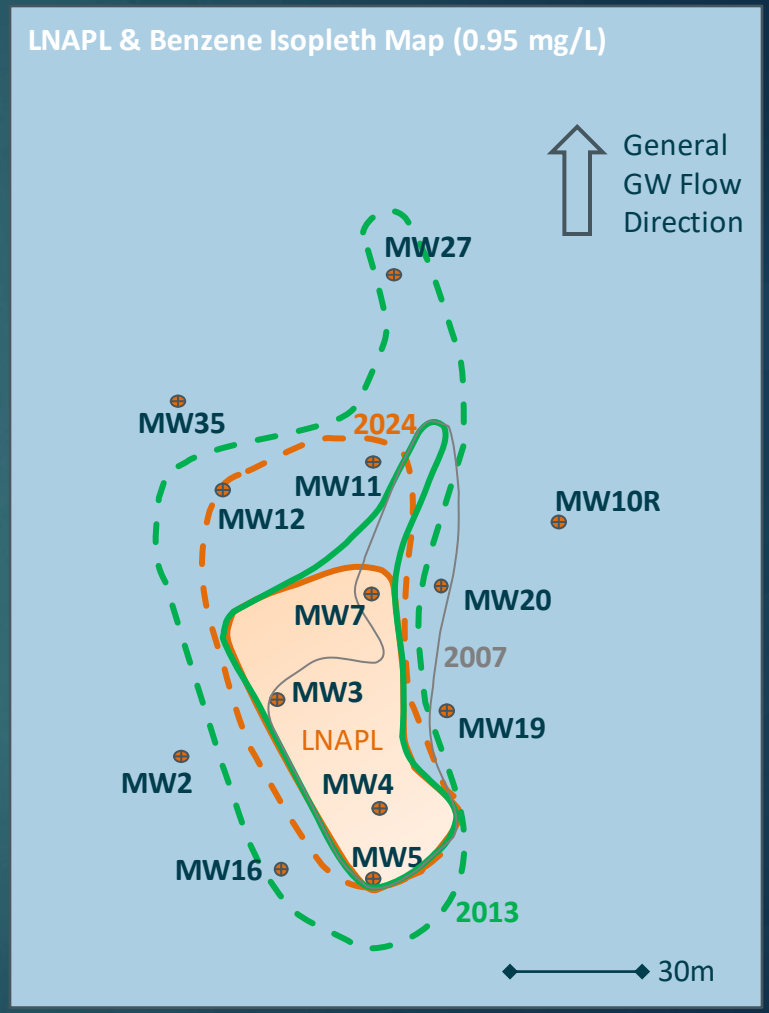
Long Term Monitoring and Management

- Managed by LTMMP and SMP as part of passive discharge consent.
- Verify the CSM and protect potential receptors.
- Remedial options assessment.
- Safety, cost and sustainability considerations.
- Also providing information to B4UDig to manage potential residual petroleum hydrocarbons in the road reserve.
- Continual revisions to monitoring or management measures may be required.

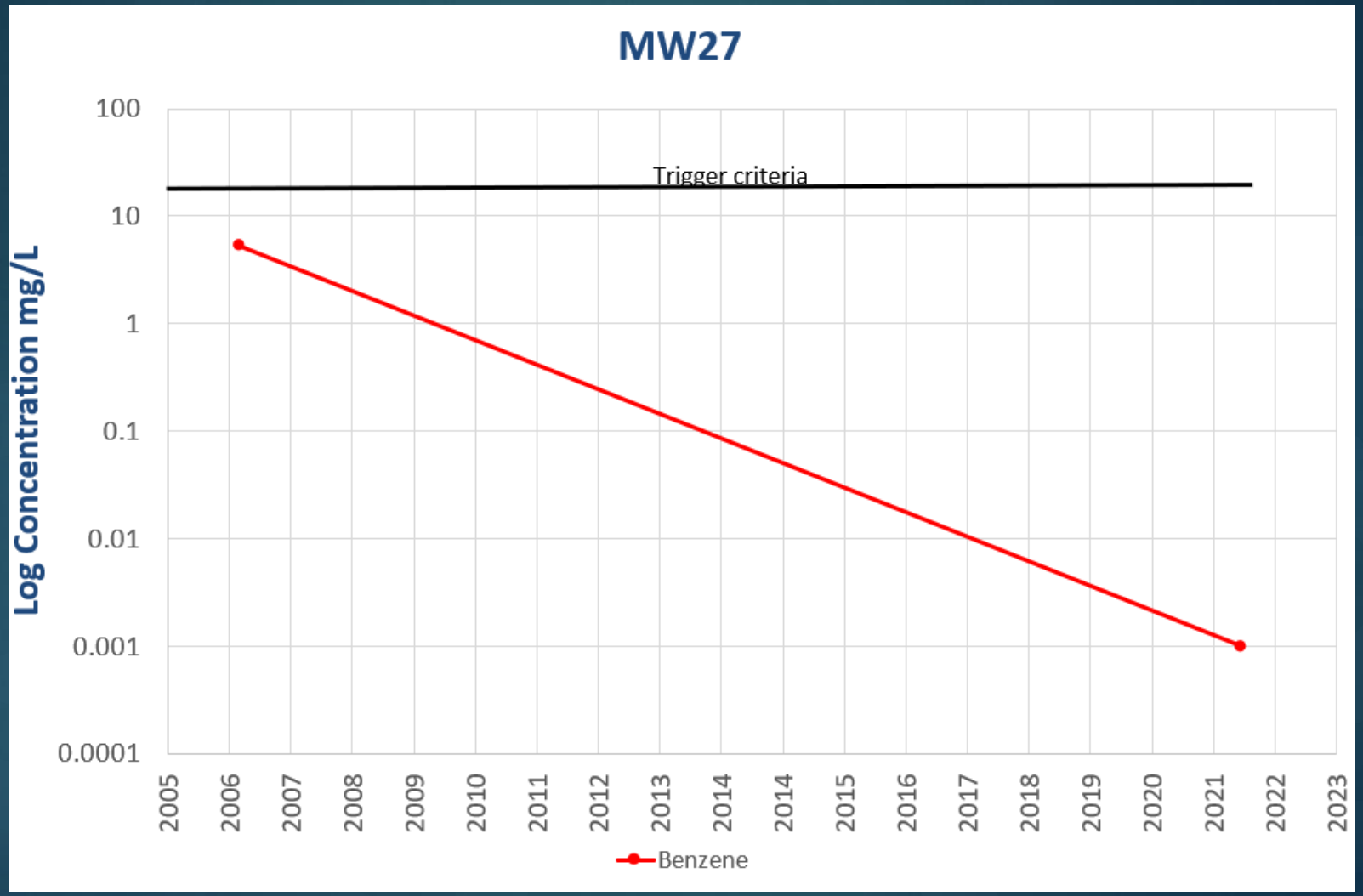
- Evidence from numerous plumes (in many different hydrogeological settings) is that natural attenuation is ubiquitous.
- OIEWG Practice Note in development.

I Shrink Therefore I am…(Attenuating)

- What monitoring is required to demonstrate ongoing attenuation?

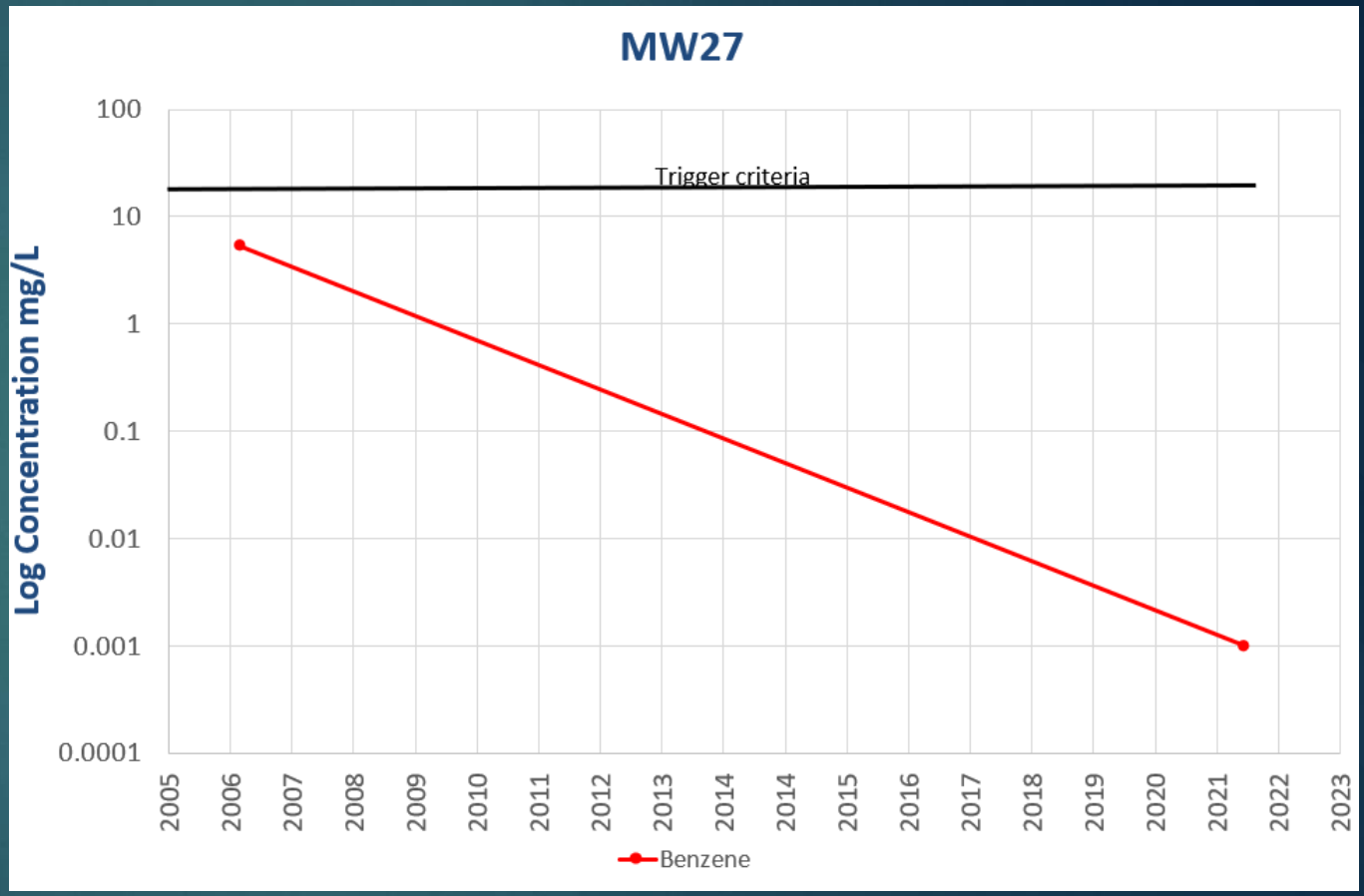


Two data points

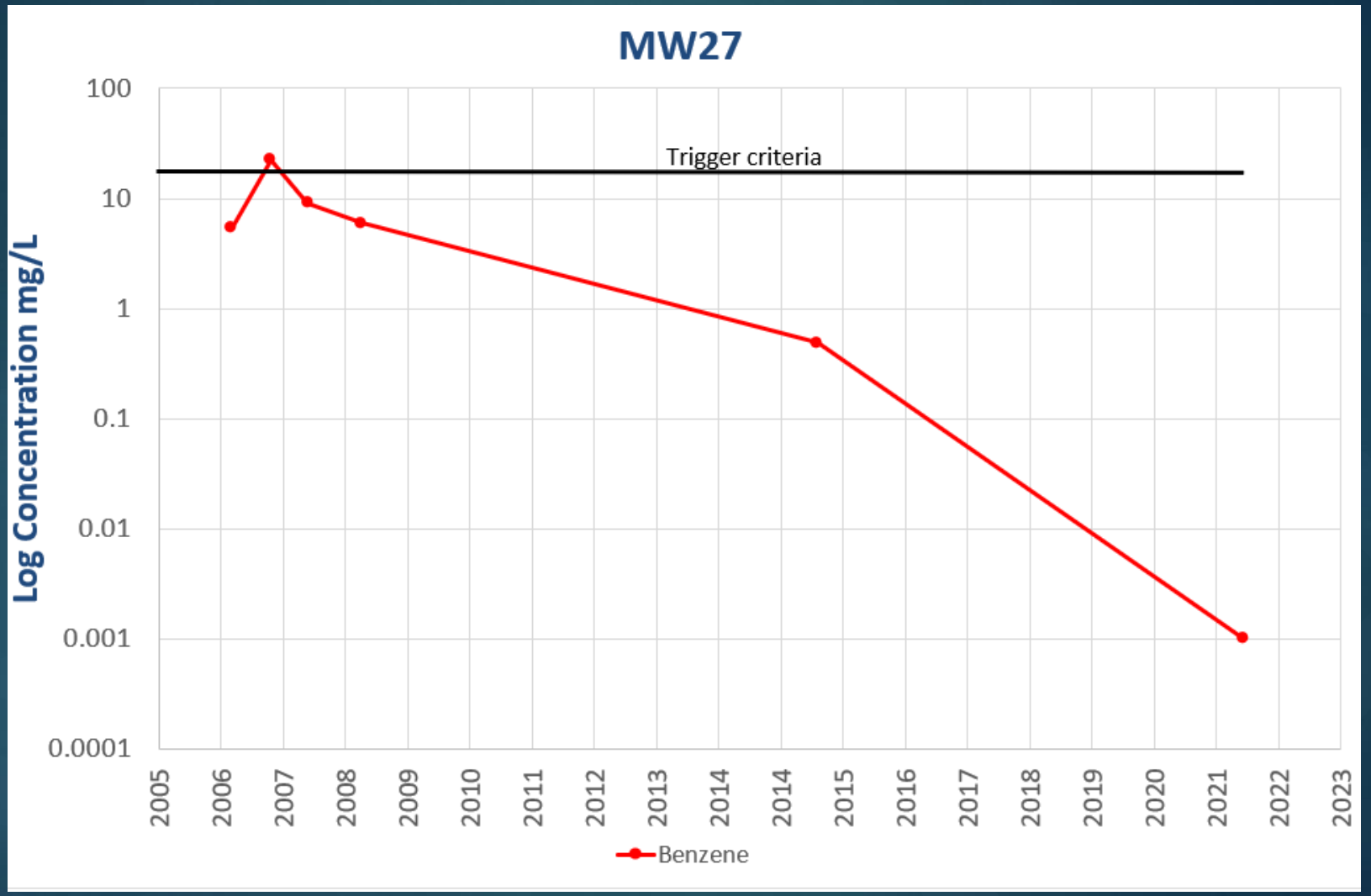


Two data points

- Misses possible peak – does it matter?
- Peripheral well this is the long-term trend – experience tells us it will not vary significantly from this.
- Unacceptable indoor air risk requires long-term exposure (20 years @ Guideline Value).

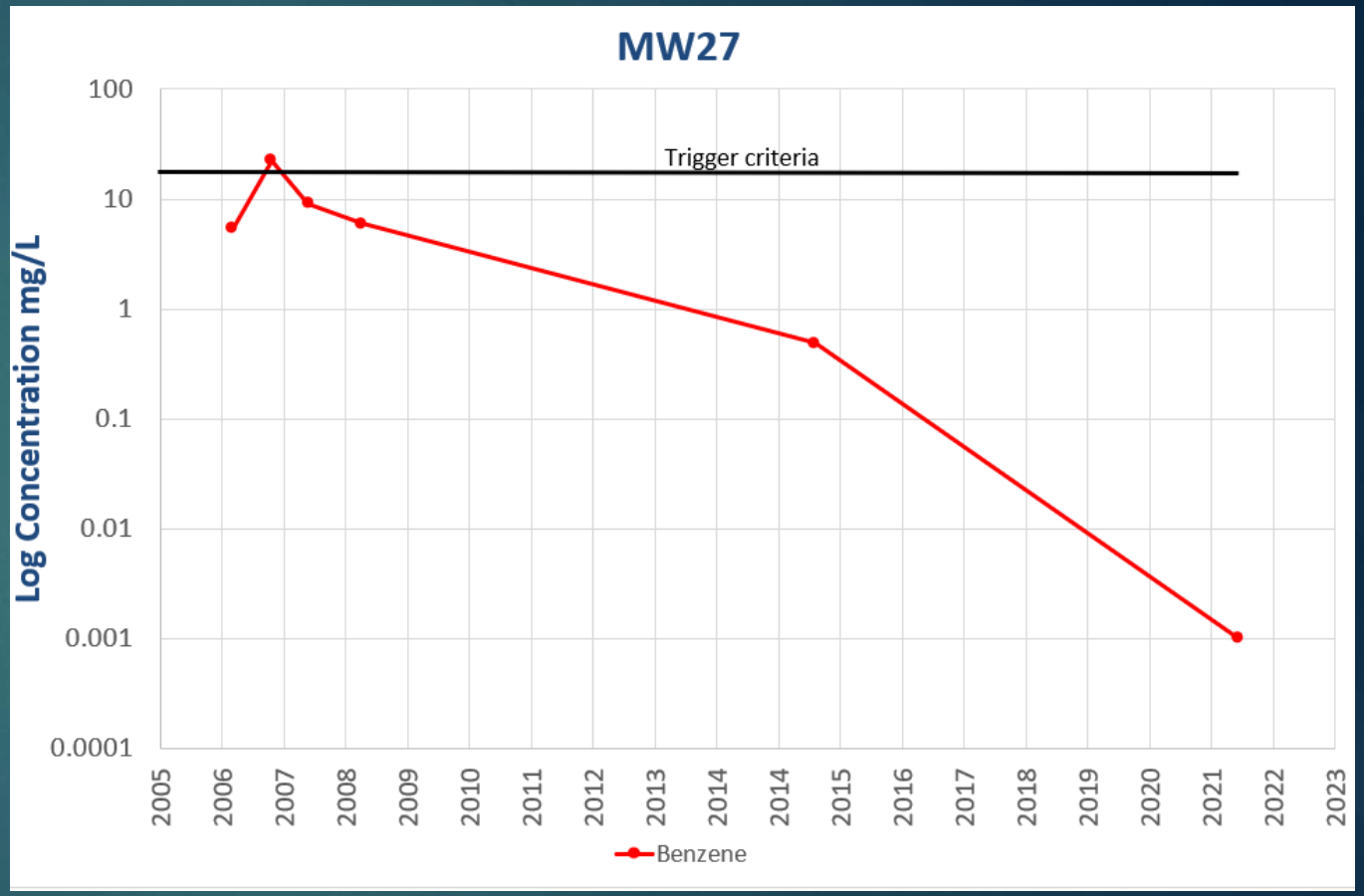


Establish peak and trend, then at 5 and 10 years



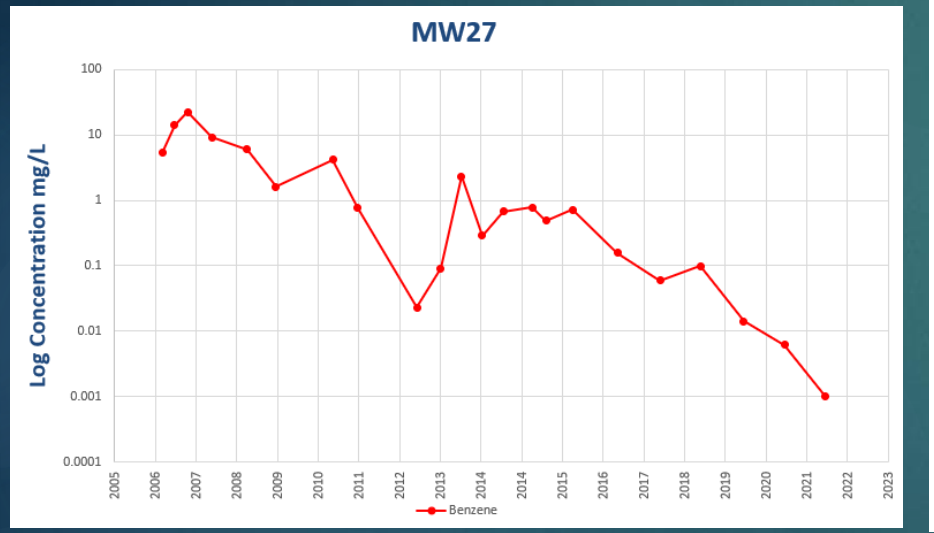
Establish peak and trend, then at 5 years

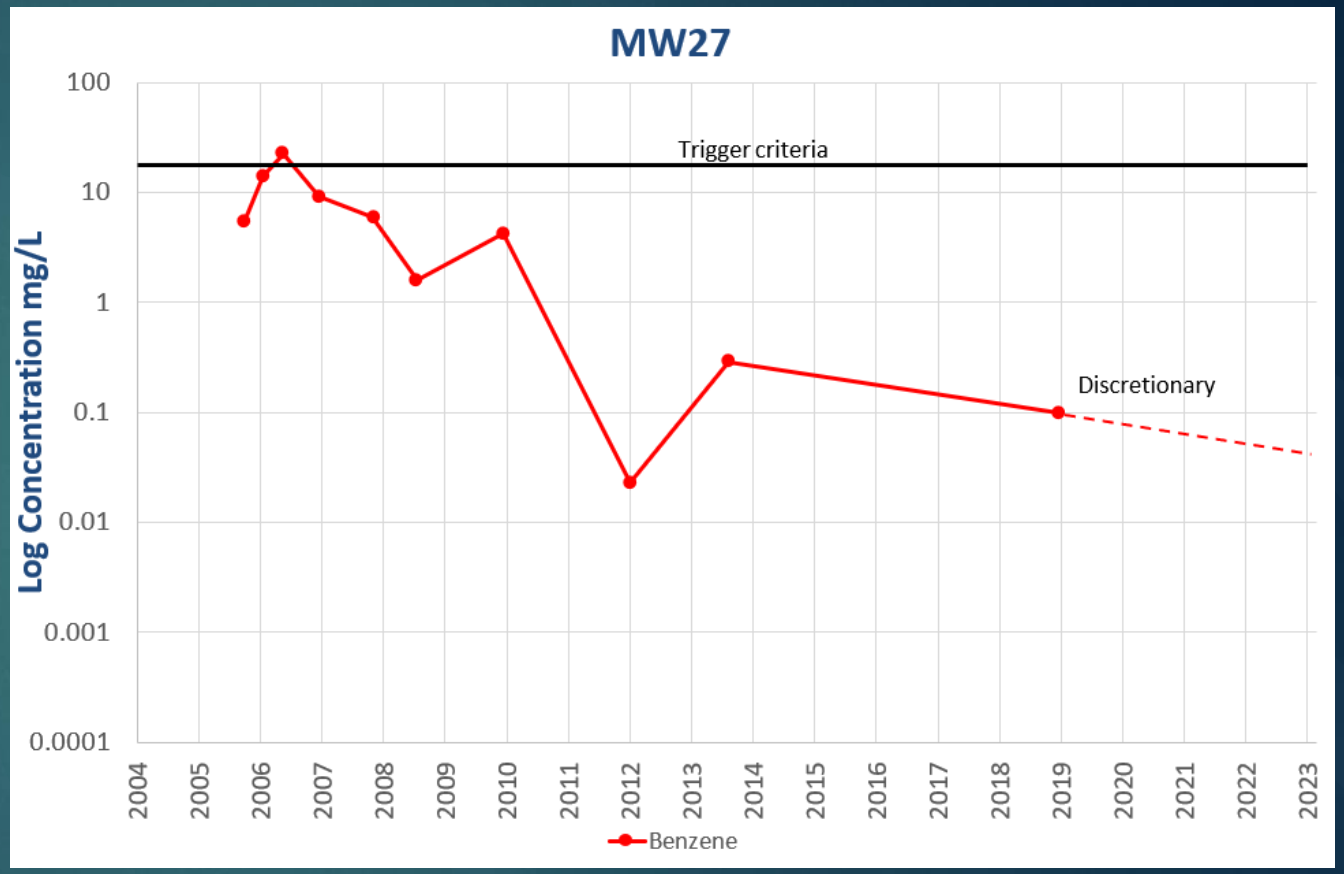
- Detects the peak concentration (aka ‘peak risk’).
- Briefly exceeds risk-based trigger.
- Line represents a conservative trigger for further investigation (Tier 2).
- Indoor air surveys of adjacent buildings at peak concentration, showed no unacceptable risk.
- Due to ongoing presence of LNAPL a further 5 year-round may be warranted in some wells.



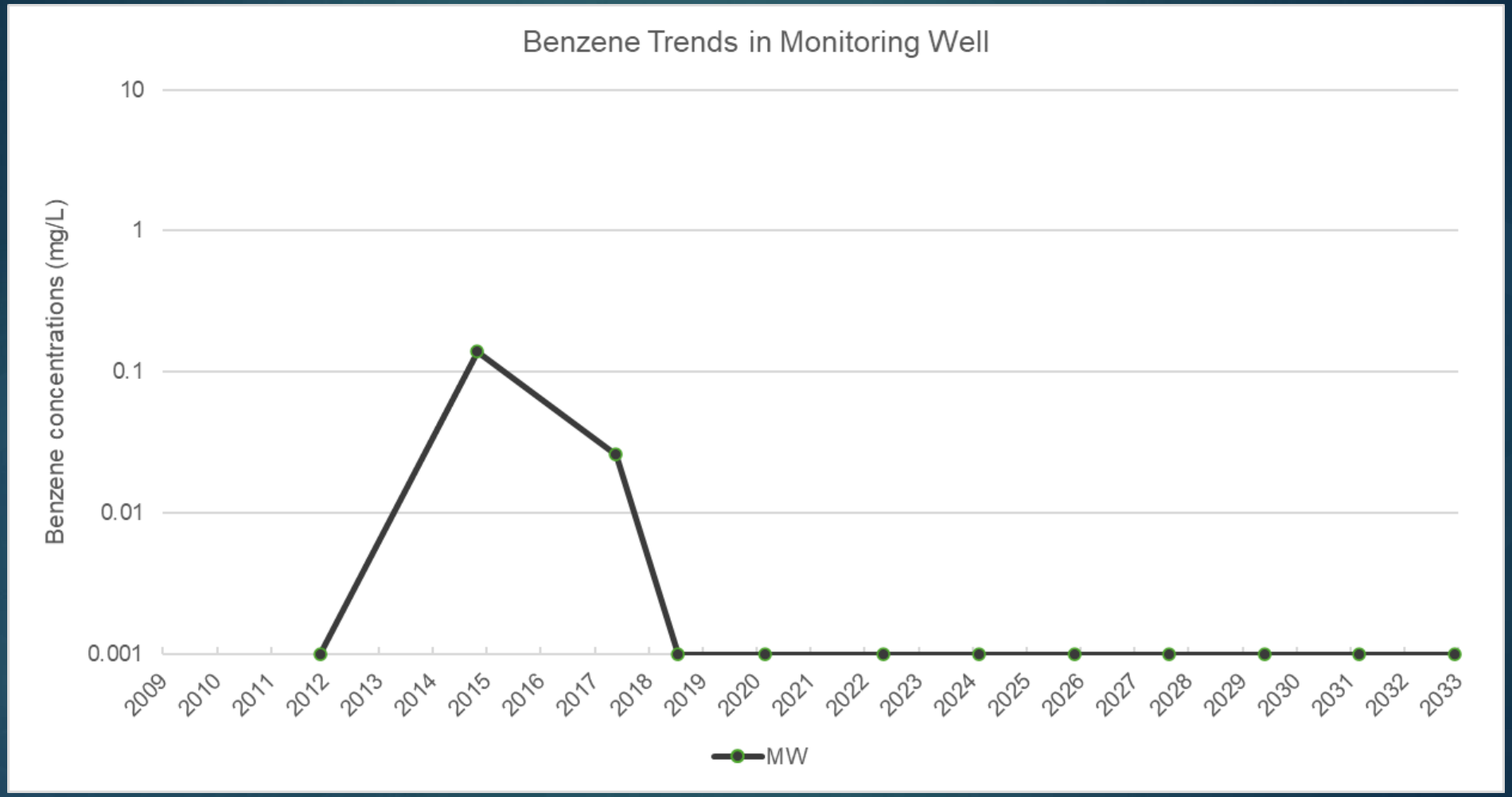
Recommended – decreasing frequency

- Detects the peak, confirms the trend, avoids the ‘noise’.





Sentinel Well Example (not case study site)



MNA Checklist

- To determine applicability of MNA as a management approach.
- MNA may be appropriate if there is no unacceptable risk to environmental or human health receptors.
- Discharge of contaminants from primary source has ceased.
- Remediation considerations.
- Information to be shared with regulatory authority.
- Helps to establish that a robust CSM has been developed.
- Characterisation of the shape and extent of the hydrocarbon plume.
- Establish appropriate monitoring well coverage.
- Consideration of appropriate trigger levels.

Summary and Learnings

- Seasonal variation is unlikely to change the level of risk posed by groundwater concentrations.
- Hydrocarbon concentrations vary however this is around an overall decreasing trend.
- Typical pattern of the hydrocarbon plume rapidly expanding during a loss, then quite quickly reaches a quasi-steady state before the plume begins to shrink over time.
- Short term fluctuations do not impact on long term risk. If the risk is acceptable at the peak concentration and the plume is shrinking, monitoring can be infrequent.
- Management of hydrocarbon plumes needs to take into consideration the sensitivity of the receiving environment, field worker safety, costs and sustainability.