

BTEX IN THE SAND RIVER AQUIFER: Evidence of Natural Anoxic Decomposition of Plant Matter

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Overview



- SAGD Facility Located in Northeast Alberta
- Groundwater Monitoring as part of the Thermal Directive
- Hydrocarbons in the Sand River Aquifer
- Investigating the Source???



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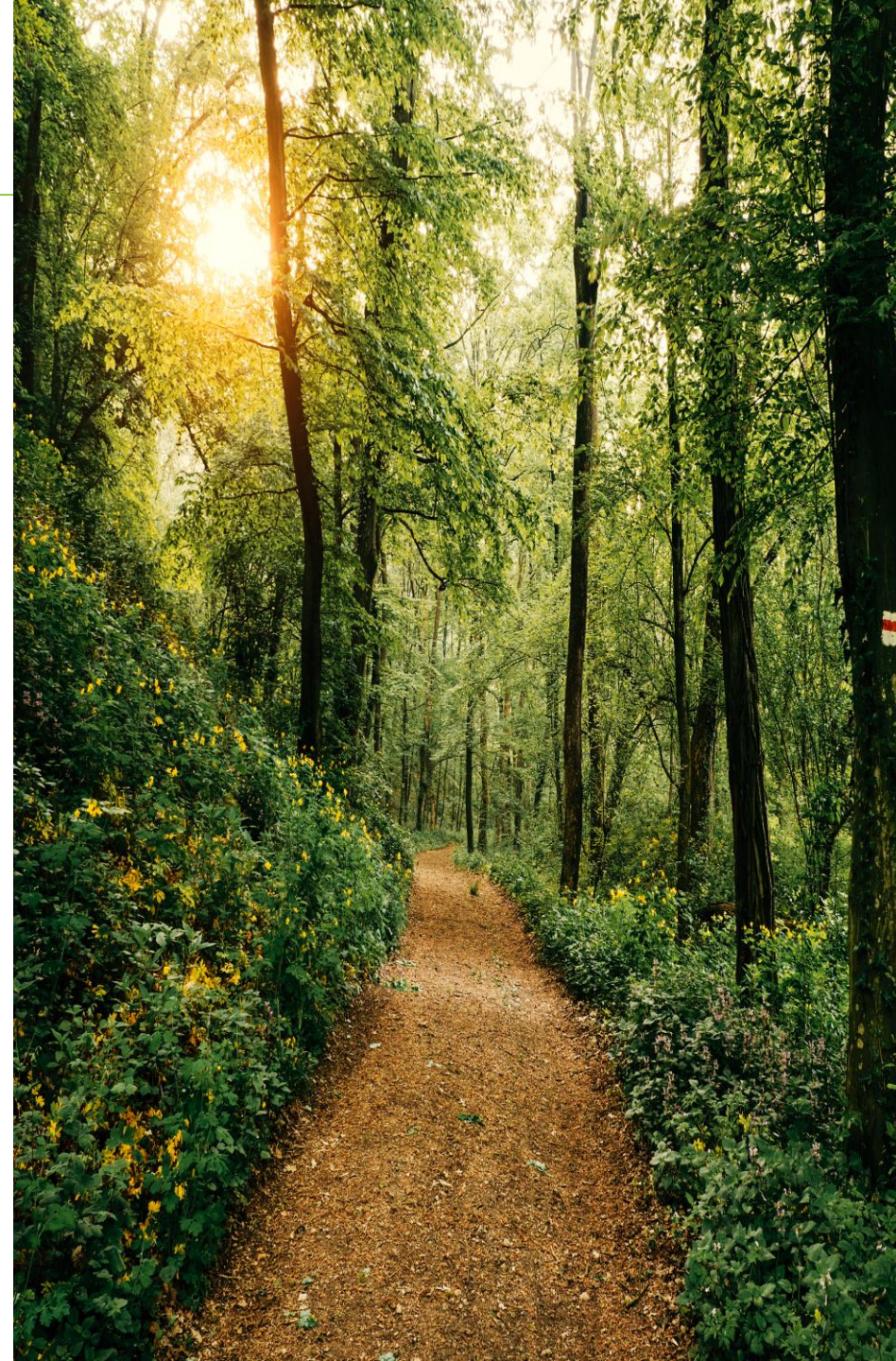
Senior Hydrogeologist

Introduction to the Project Team



Outline

- Background: Site Setting and Thermal Groundwater Monitoring
- Hydrocarbon Investigations: Forensic Chemistry Analysis & Experiment
- Present Day Results & Conclusion

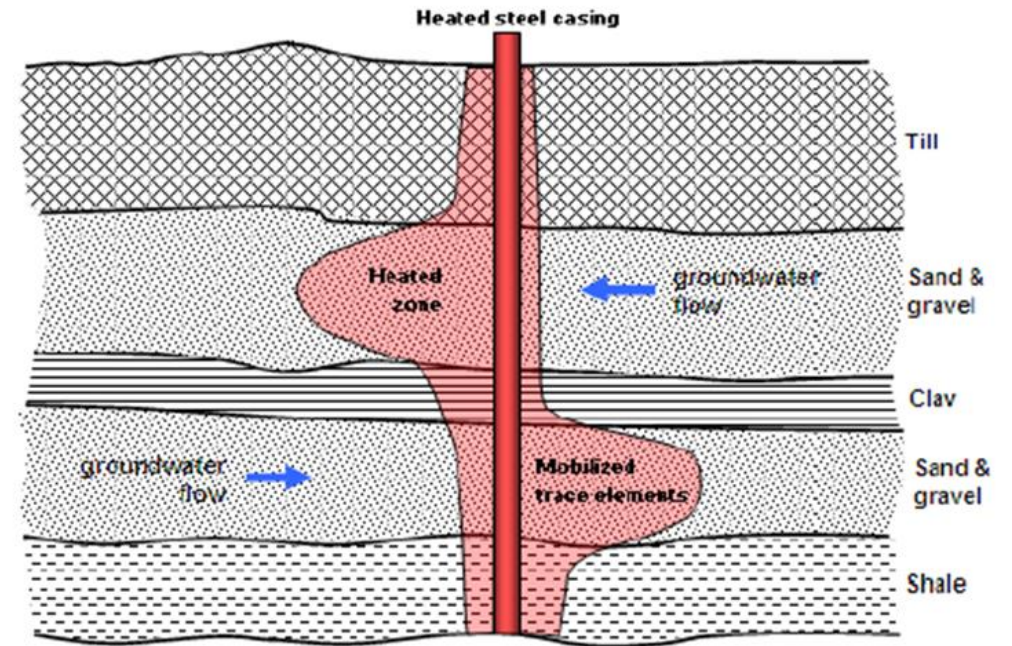


Background

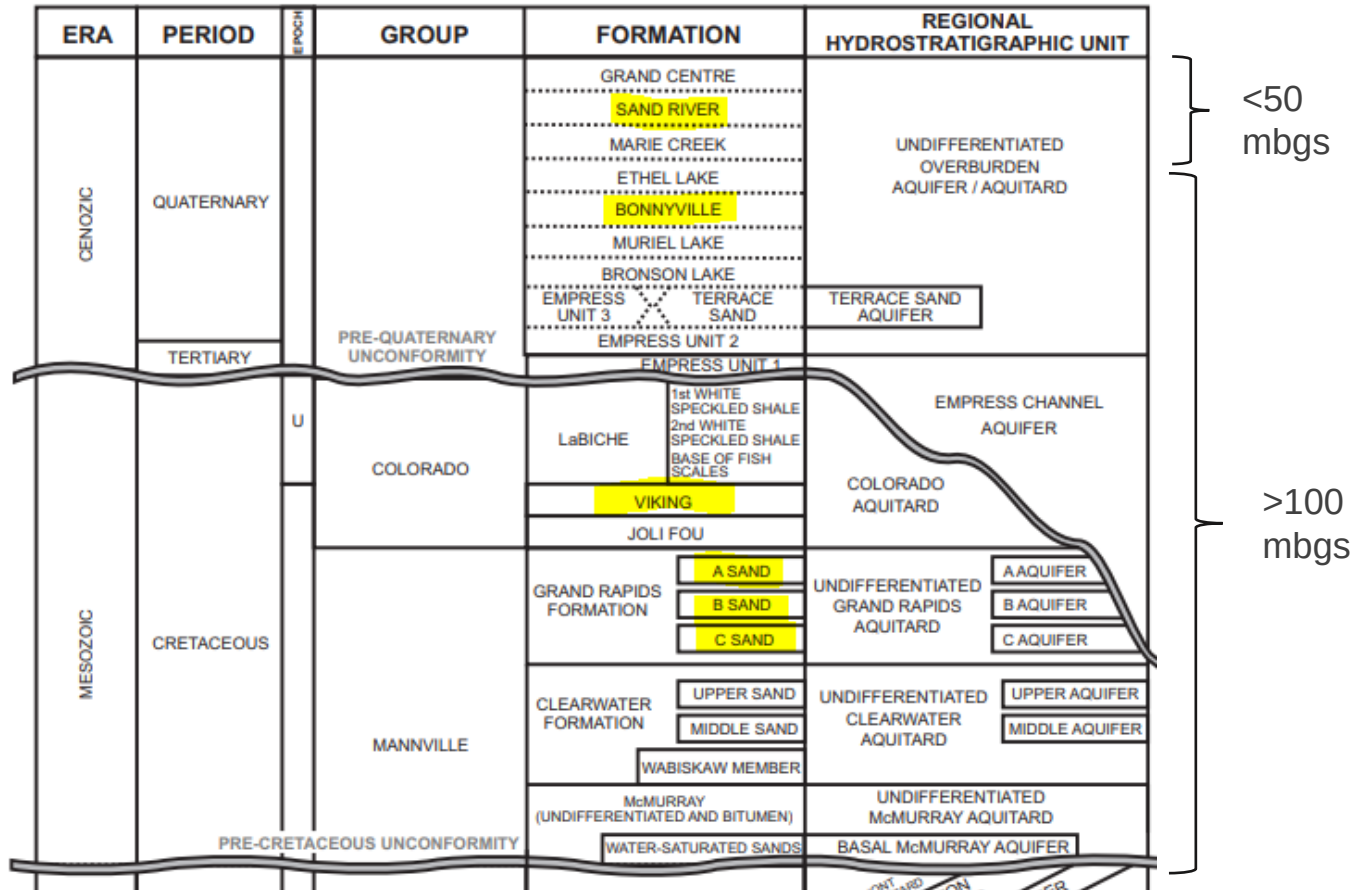


Thermal Directive (2018)

- Objective is to protect impacts to regional groundwater and surface water bodies from chemical constituents mobilized by thermal in-situ operations.
- SAGD Operators must manage potential thermal impacts through thermal groundwater monitoring programs at highest risk pads



Hydrostratigraphy at the SAGD Facility



- 6 regionally extensive aquifers underlying the facility
- Sand River only aquifer less than 50 mbgs and has potential to be connected to surface water receptors.
- Only aquifer classified as an Aquifer Management Unit (AMU) under Thermal Directive
- AMU - Non-saline aquifer that has identified risks associated with it and has been selected for thermal monitoring

Heat Source Well 1, SAGD Well Pad (2019)



- Heat Source monitoring well (HSW) must be located downgradient of heat source (within 50 m)
- Where thermal effects are anticipated to be observed (Thermal Directive 2018)

Initial Thermal Groundwater Sampling (2019)



Hydrocarbons below
detection limits

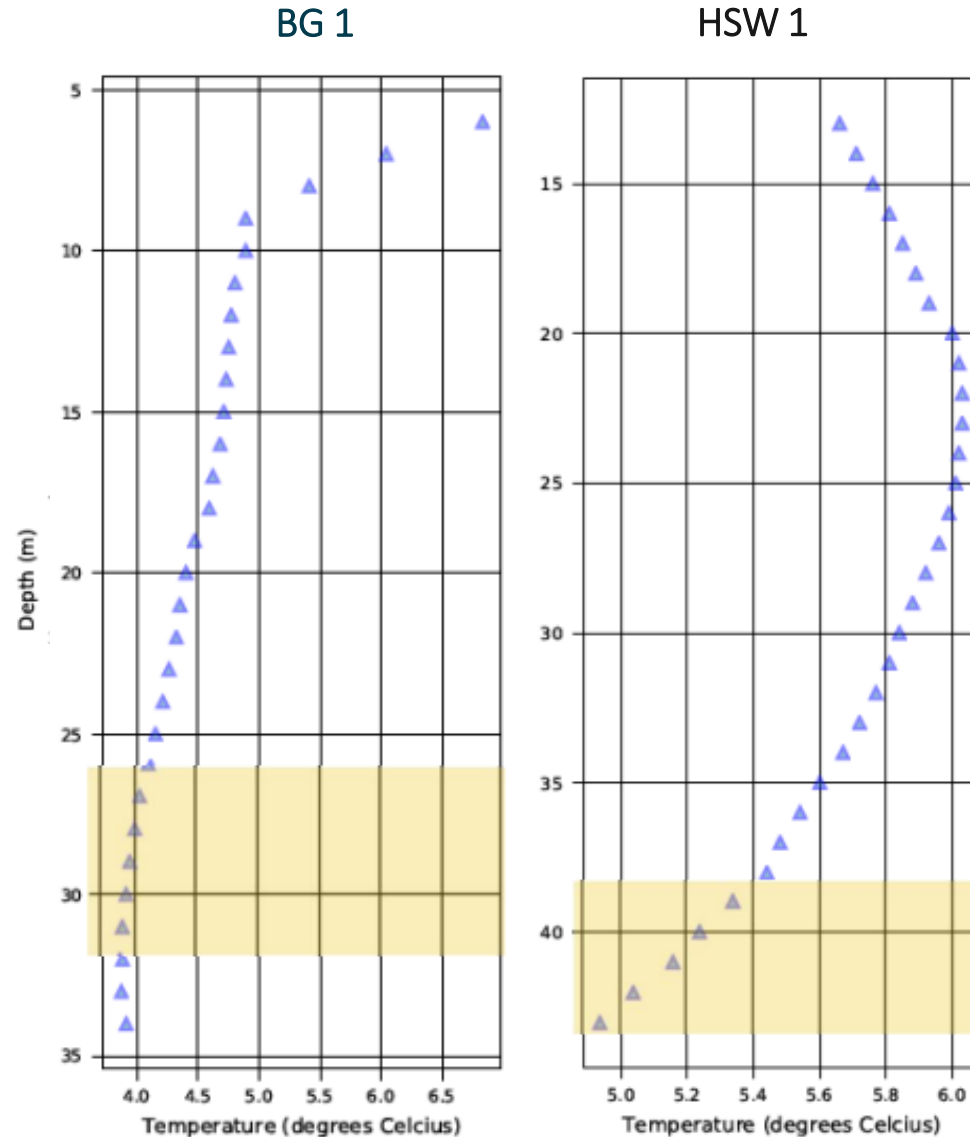
Hydrocarbons above Tier
1 Guidelines

HSW 1 Groundwater Quality Results - Hydrocarbons

Sample Date	Benzene mg/L	Toluene mg/L	Ethylbenzene mg/L	Xylenes mg/L	F1 mg/L	F2 mg/L
01-Aug-19	0.002	0.0016	<0.0010	<0.001	<0.1	<0.1
25-Oct-19	0.012	0.023	0.0005	0.00096	<0.1	<0.10
23-Oct-20	0.044	0.042	0.0026	0.0058	0.17	0.18
25-Jun-21	0.028	0.029	0.0019	0.004	0.14	<0.10
14-Oct-21	0.029	0.034	0.0028	0.0059	0.15	<0.10
19-May-22	0.024	0.033	0.0029	0.0065	0.14	0.16
20-Oct-22	0.028	0.034	0.0033	0.0076	<0.1	0.2
07-Jun-23	0.029	0.029	0.0029	0.0065	0.17	0.19
19-Oct-23	0.031	0.029	0.0028	0.0062	0.1	0.15
	0.0050 ^{P,MAC}	0.021 ^A	0.0016 ^{P,AO}	0.020 ^{P,AO}	2.2 ^P	1.1 ^P

Alberta Tier 1 - Coarse-grained Soils - Natural Areas*

Vertical Thermal Profiling (2019)

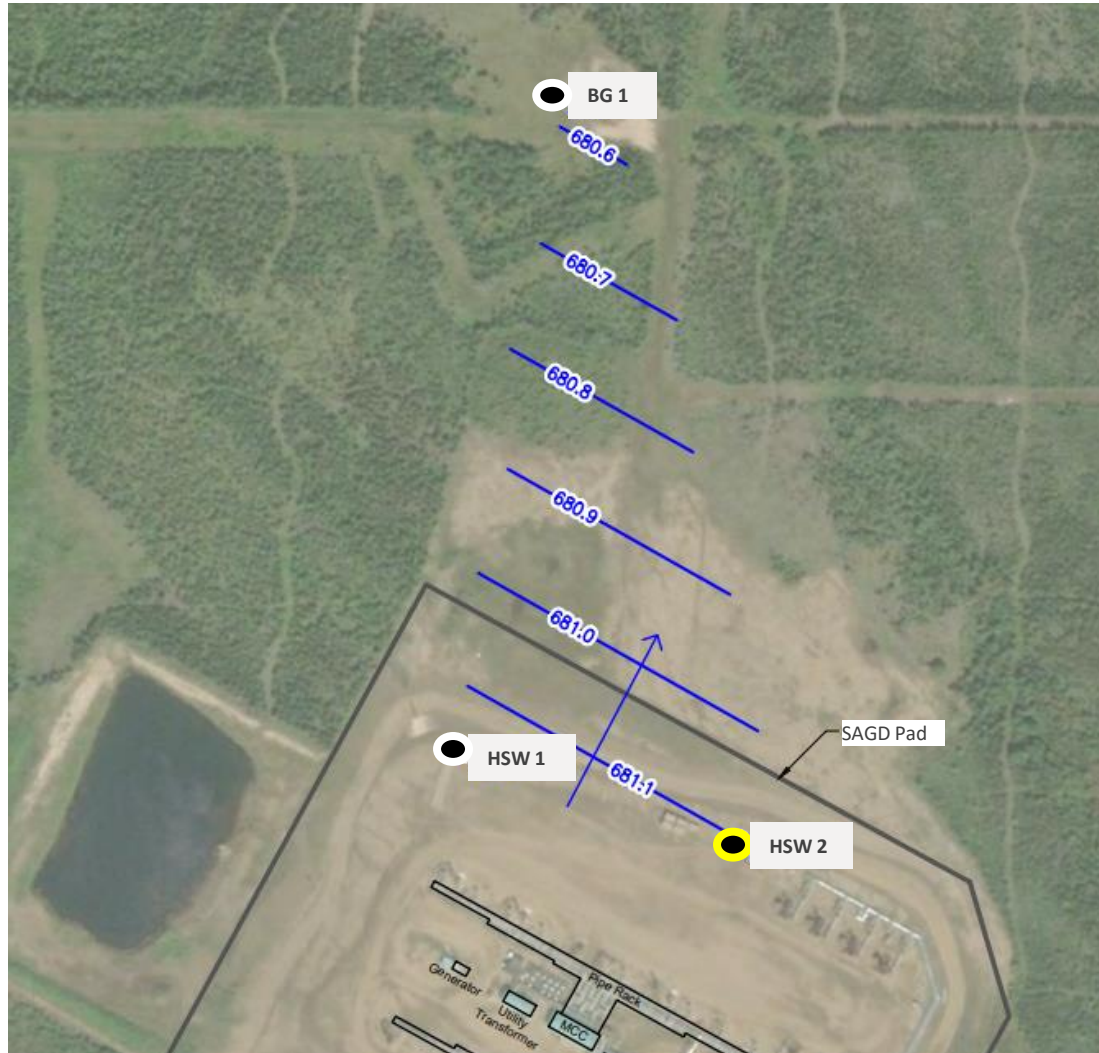


Average Temperatures

- BG 1: 3.8 ° C
- HSW 1: 5.2° C

Sand River Aquifer Interval

Heat Source Well 2 (2021)



GW flow was interpreted to be to the north based on regional data, however, minimal thermal effects at HSW 1 suggested it was not directly downgradient

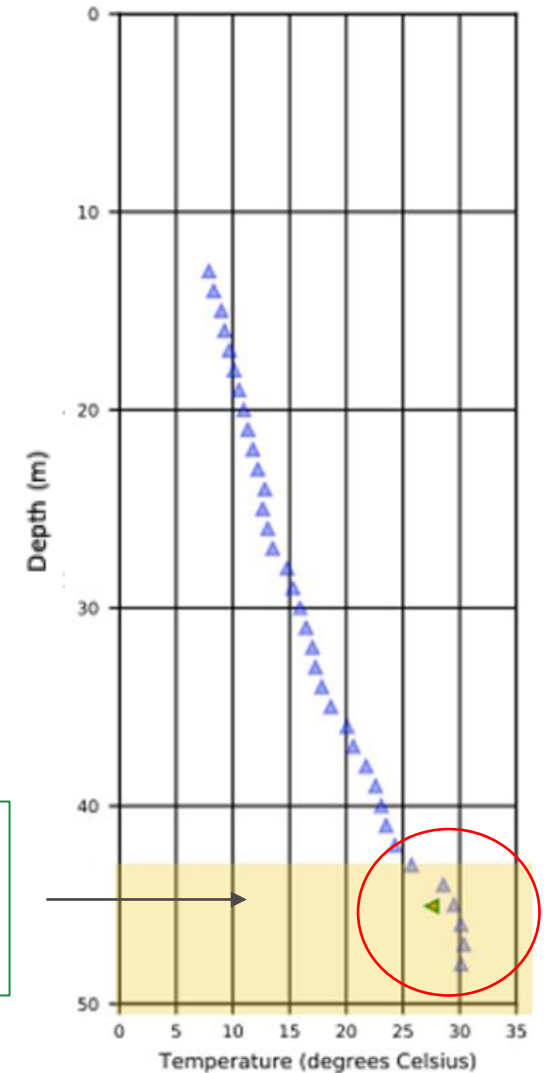
Heat Source Well 2 - Results

HSW 2 Groundwater Quality Results - Hydrocarbons

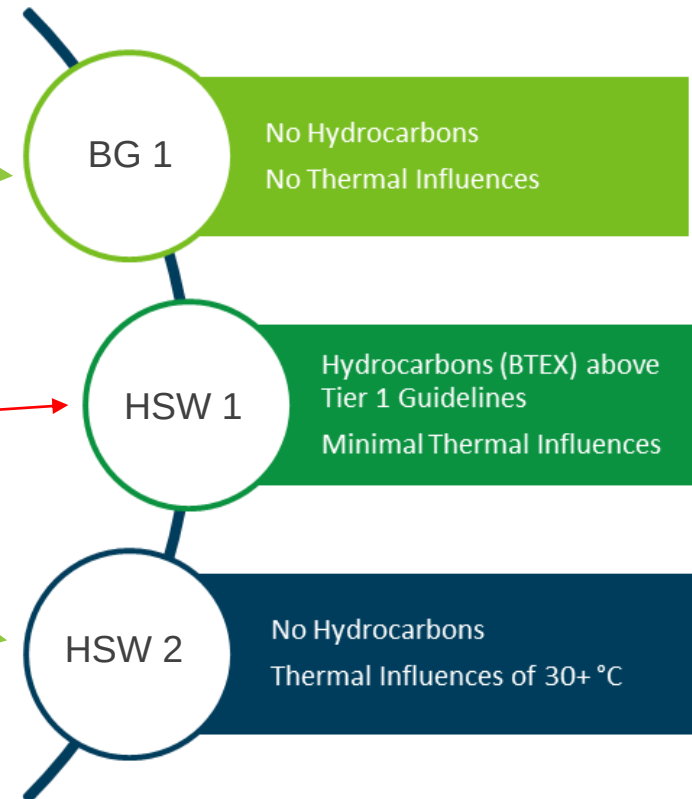
Sample Date	Benzene mg/L	Toluene mg/L	Ethylbenzene mg/L	Xylenes mg/L	F1 mg/L	F2 mg/L
14-Oct-21	<0.00040	<0.00040	<0.00040	<0.00089	<0.1	<0.10
19-May-22	<0.00040	<0.00040	<0.00040	<0.00089	<0.1	<0.10
20-Oct-22	<0.00040	<0.00040	<0.00040	<0.00089	<0.1	<0.10
07-Jun-23	<0.00040	<0.00040	<0.00040	<0.00089	<0.1	<0.10
19-Oct-23	<0.00040	0.00054	<0.00040	<0.00089	<0.1	<0.10
	0.0050 ^{P,MAC}	0.021 ^A	0.0016 ^{P,AO}	0.020 ^{P,AO}	2.2 ^P	1.1 ^P

Average Temperature

- HSW 2: 30.5° C



Groundwater Quality Summary (2021)



Hydrocarbon Source Investigations and Forensic Chemistry



Potential Hydrocarbon Sources (2022-2023)

Casing Leak

- Abnormal
- Produced
- No
- surface casing vent flow testing

Emulsion Sample

- Collected from production well on pad
- **Contains BTEX - Potential source**

Disposal Fluid Sample

- Collected from disposal well on pad (historical steam injection well)
- **Contains BTEX - Potential source**

Steam

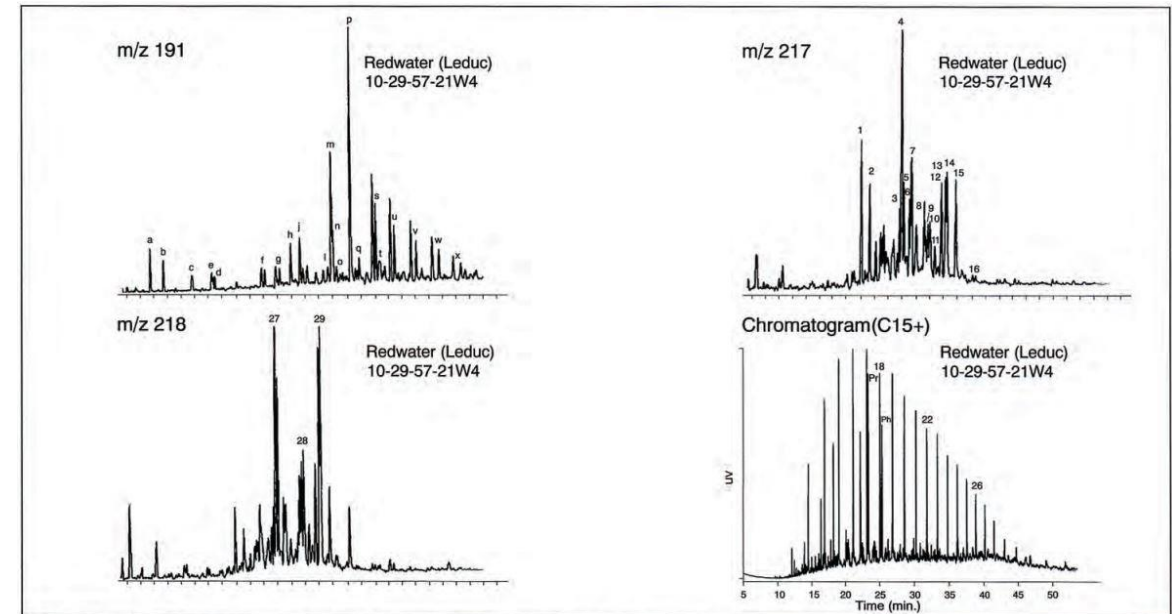
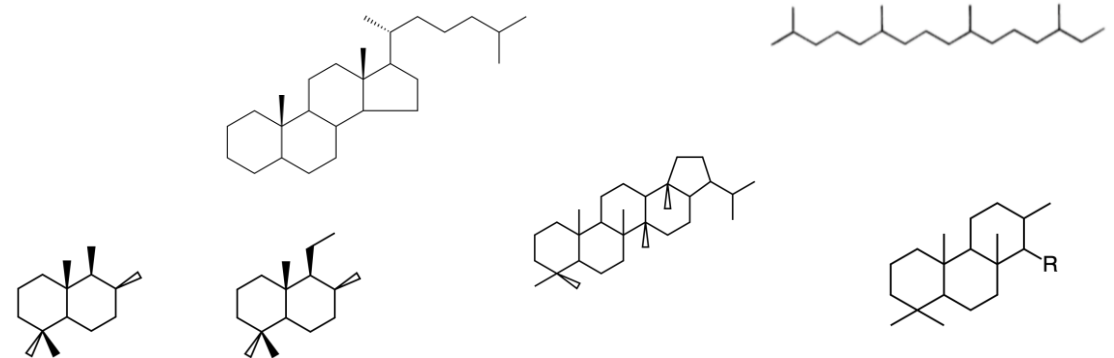
- Collected from
- some wells
- were below detection limits

Forensic Chemistry

Characteristic chemistry features to distinguish potential sources.

For petroleum hydrocarbons there are lots of good forensic chemistry options.

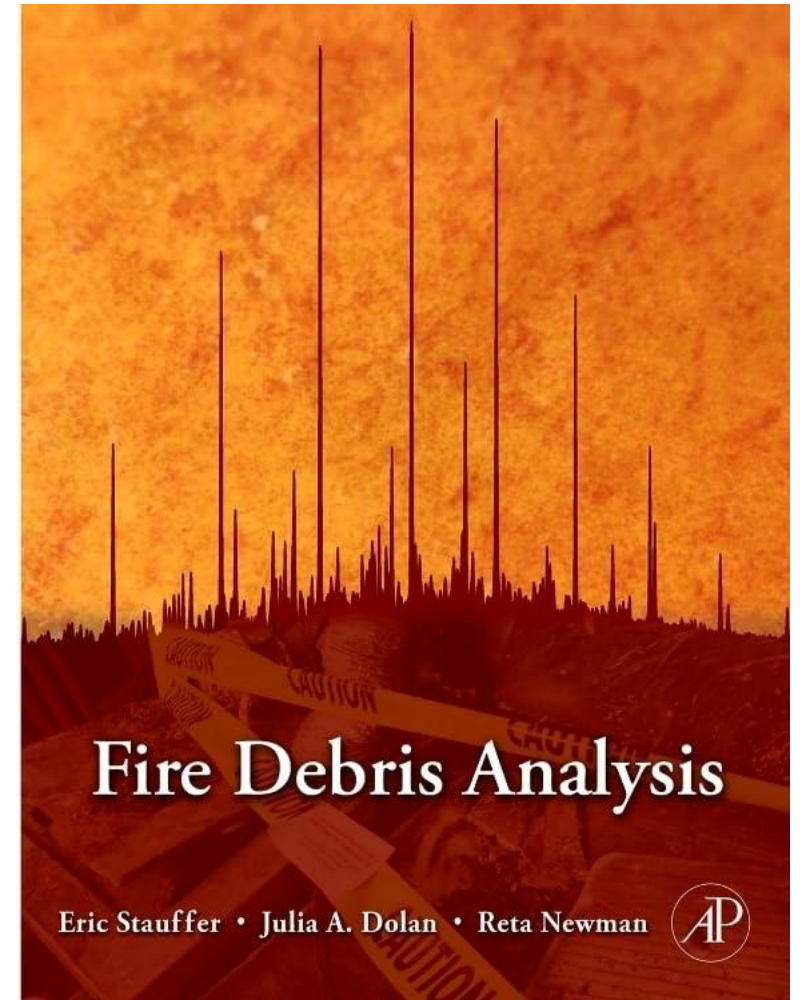
For BTEX this is more difficult...



Example from Geological Atlas of the Western Canada Sedimentary Basin

Detailed Volatile Hydrocarbon Analysis

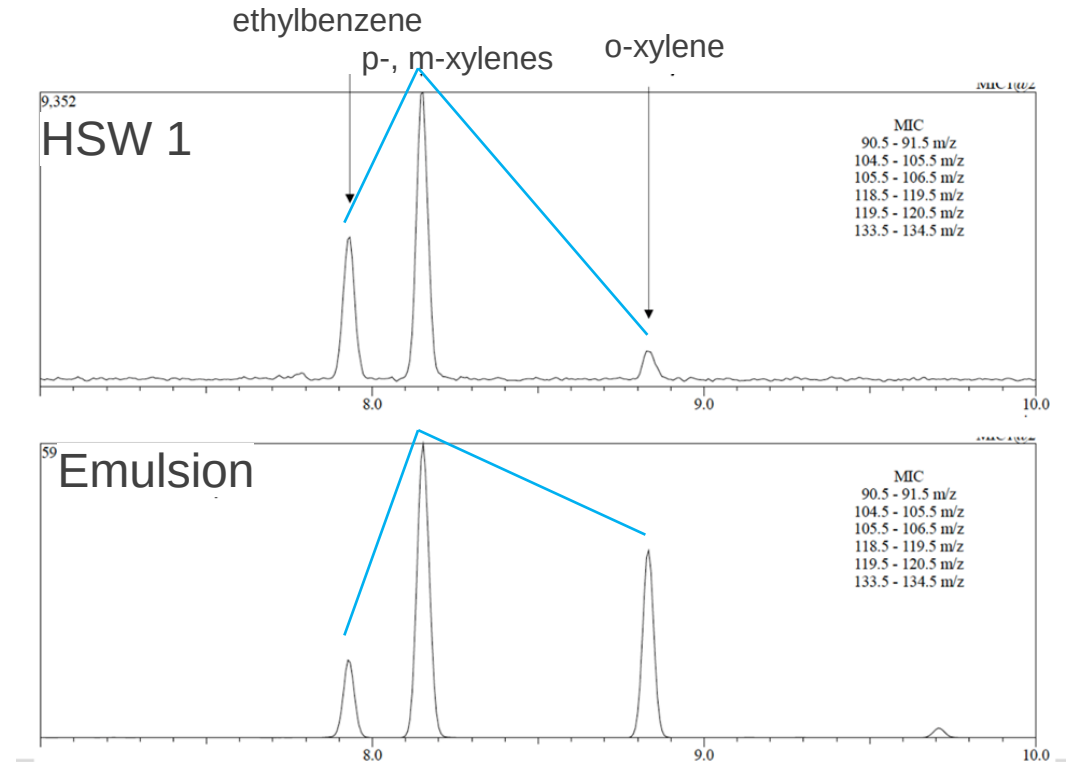
- Developed for arson investigations...
- Follows an ASTM protocol.
- Robust methodology for legal scrutiny.
- Typically gasoline.
- Volatile hydrocarbons including BTEX and related alkylated benzenes, and other characteristic hydrocarbon groups.



Detailed Volatile Hydrocarbon Analysis

Identified key features in groundwater from HSW 1.

Characteristic profile that is not present in emulsion or disposal fluid samples.



Potential Hydrocarbon Sources (2022-2023)

Casing Leak

- No abnormal air pressure or pressure spikes
- No evidence of surface casing vent flow testing

Emulsion Sample

- Collected from production well on production
- Results compared to groundwater results at HSW 1

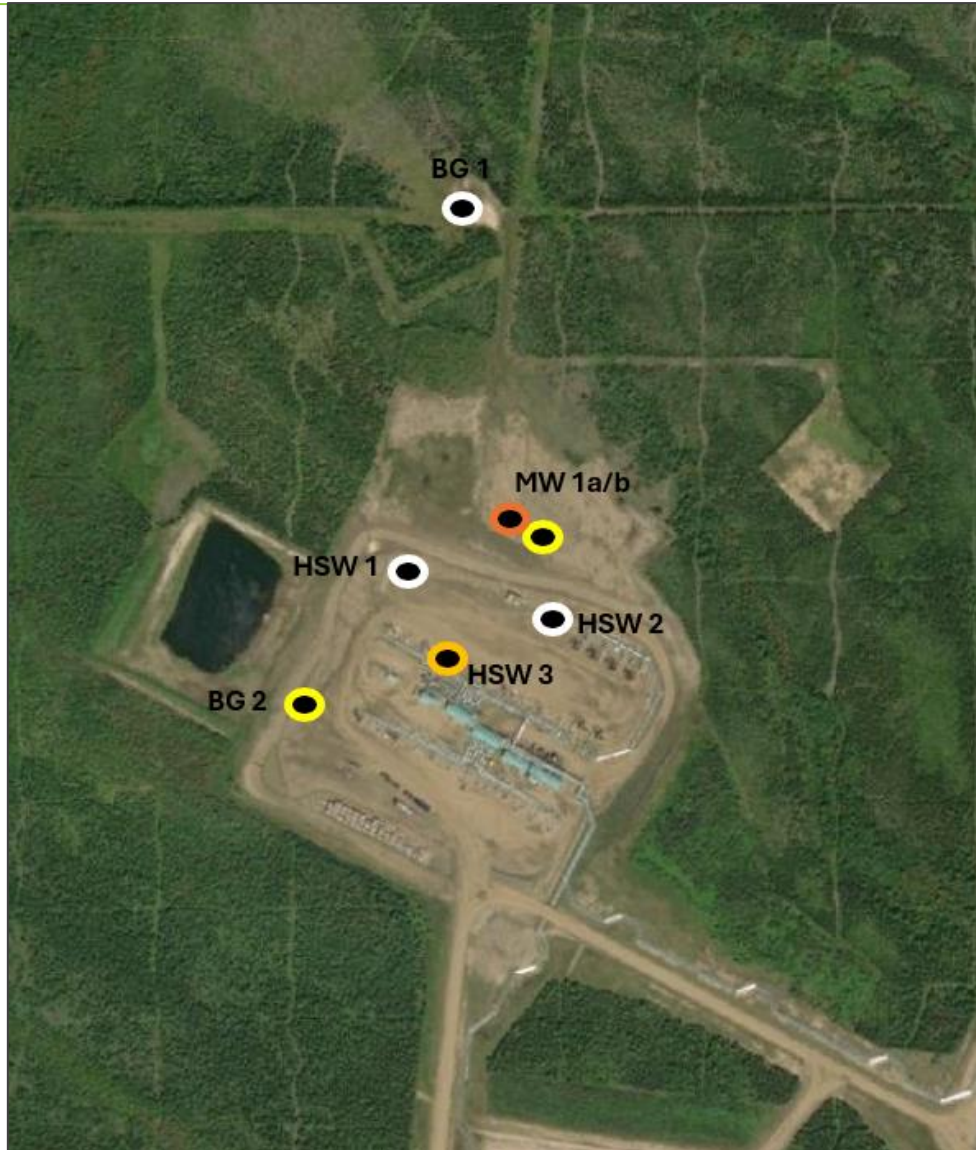
Disposal Fluid Sample

- Collected from disposal well on production
- Results compared to groundwater results at HSW 1

Steam

- Collected from steam wells
- Results compared to groundwater results at HSW 1

Additional Wells Installed (2023)



- BG 2 – True Background (upgradient)
- HSW3 – Close to Heat Source
- MW1a/b – Nested (downgradient)
- MW1a – Shallow Groundwater Unit



Thermal Well Drilling Program (2023)

Collected samples at each location for the following parameters:

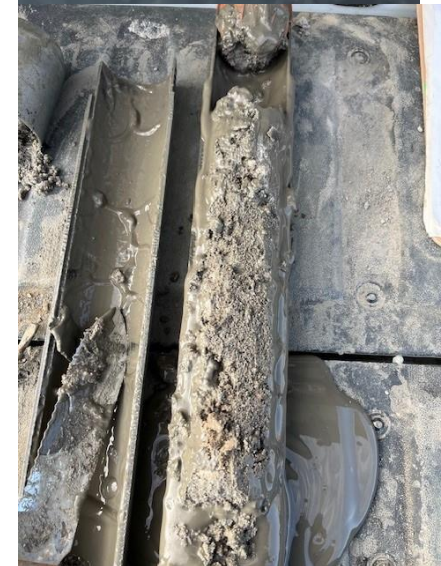
- BTEX, F1-F4
- Polycyclic aromatic hydrocarbons (PAHs)
- Metals
- Detailed salinity
- Particle size



Results

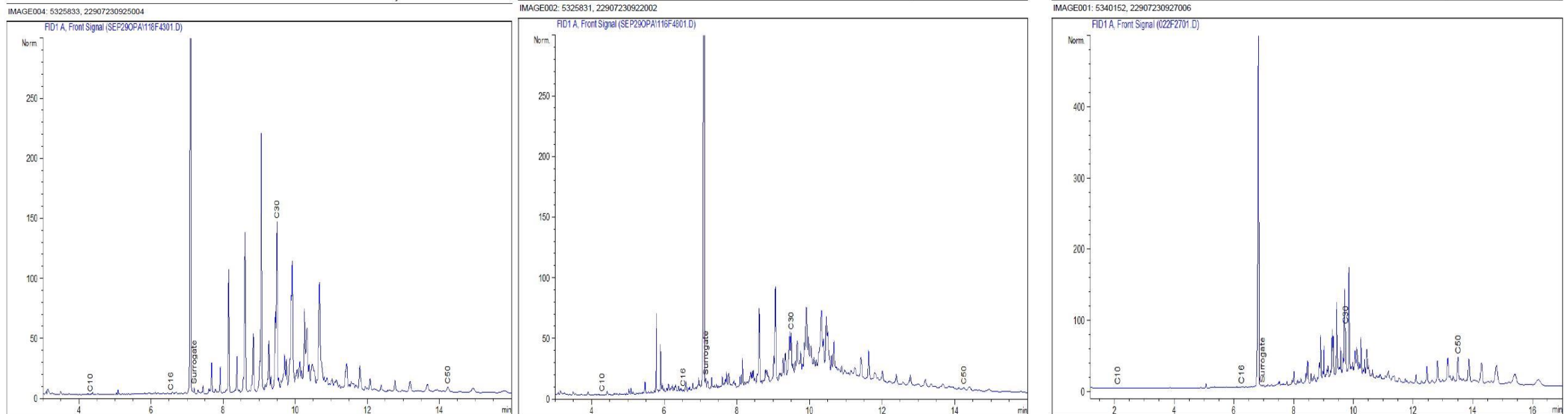
Sample Point	Start Depth m	End Depth m	Benzene mg/kg	Toluene mg/kg	Ethylbenzene mg/kg	Xylenes mg/kg	F1 C ₆ -C ₁₀ - BTEX mg/kg	F2 C _{>10} -C ₁₆ mg/kg	F3 C _{>16} -C ₃₄ mg/kg	F4 C _{>34} mg/kg
HSW 3	23.16	23.62	<0.005	<0.05	<0.01	<0.05	<10	<10	125	59
HSW 3	40.50	41.00	<0.005	<0.05	<0.01	<0.05	<10	<10	286	109
HSW 3	43.59	44.05	<0.005	<0.05	<0.01	<0.05	<10	<10	28	15
BG 2	29.70	30.18	<0.005	<0.05	<0.01	<0.05	<10	<10	126	59
BG 2	49.10	49.30	<0.005	<0.05	<0.01	<0.05	<10	34	463	243
MW 1a	11.28	11.74	<0.005	<0.05	<0.010	<0.05	<10	13	114	57
MW 1b	38.41	38.87	<0.005	<0.05	<0.010	<0.05	<10	18	586	7590
MW 1b	39.93	40.39	<0.005	<0.05	<0.010	<0.05	<10	<10	24	16
MW 1b	46.94	47.40	<0.005	0.05	<0.010	<0.05	<10	<10	40	20

- Detected PHCs, mostly heavier fractions
- Odours noted during drilling program
- Observed dark organic material near the top of the Sand River Aquifer



PHC chromatograms

Assessment of chromatograms for source information...



Plant hydrocarbons – differing degrees of degradation observed.

Plant material in the aquifer (40 m bgs), odours, black material... BTEX...?

Literature

2002 EUB report describes results from drilling within the study area:

- Hydrocarbons of both biogenic (plant) and petrogenic (bitumen) origin.
- Roots similar to peat or lignite
- Hydrocarbon odours
- 'rotten egg' odour

Hydrocarbons present within the sediment
Anoxic conditions



Geo-Note 2002-01

**Observations of Naturally
Occurring Hydrocarbons
(Bitumen) in Quaternary
Sediments, Athabasca Oil
Sands Area and Areas West,
Alberta**

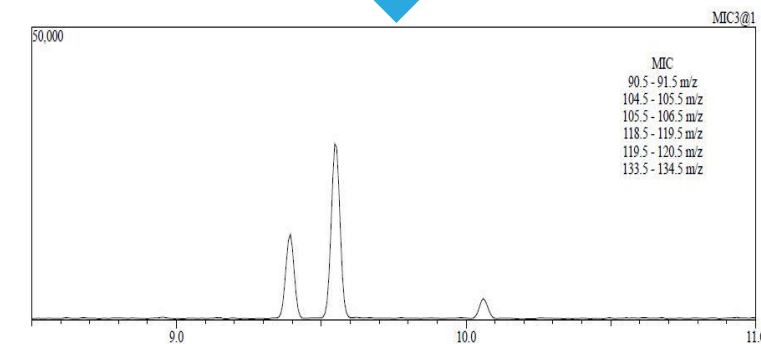
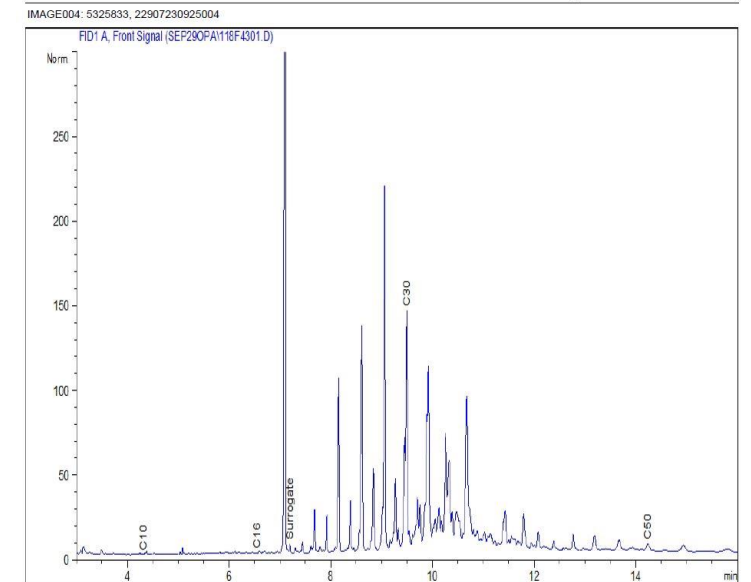


Experimental Design!

Can natural degradation of plant hydrocarbons under anoxic conditions produce BTEX?

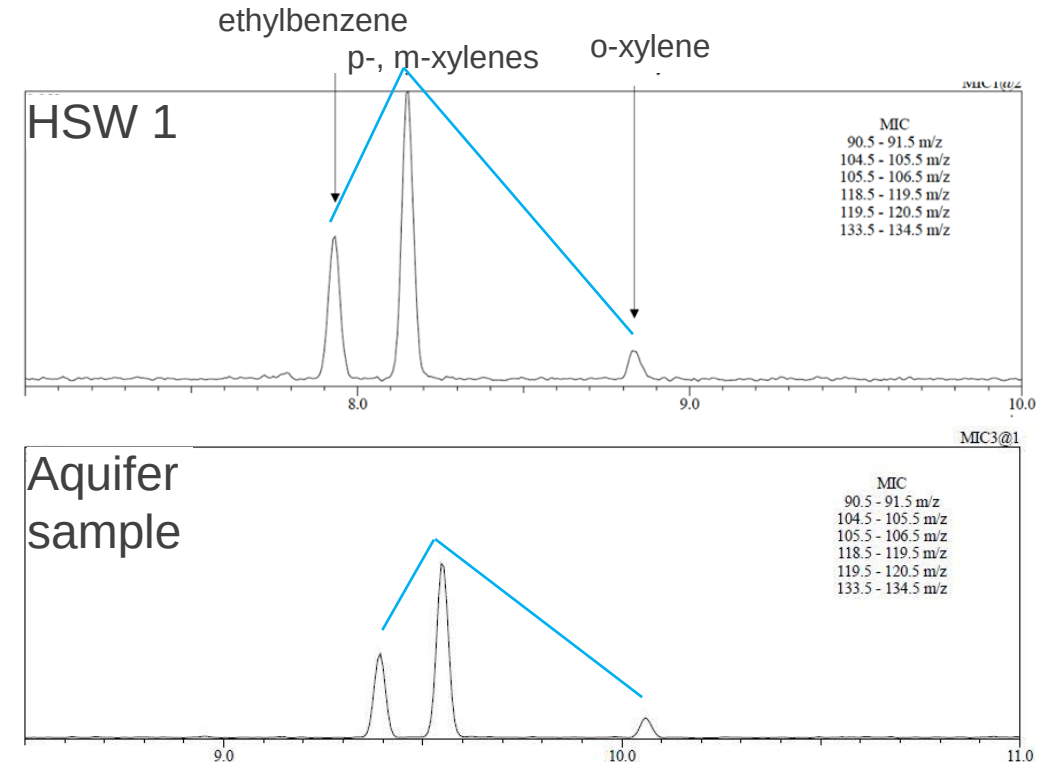
Cannot represent subsurface conditions in lab setting. Attempt to stimulate breakdown of hydrocarbons in aquifer sediment on a conceptual basis:

- Sub-samples of sediment that include evidence of plant material,
- Enclose within vials with the exclusion of air,
- Explore different temperatures – from no heat applied, to 150°C,
- Analyze using the Detailed Volatile Hydrocarbon Analysis method,



Results

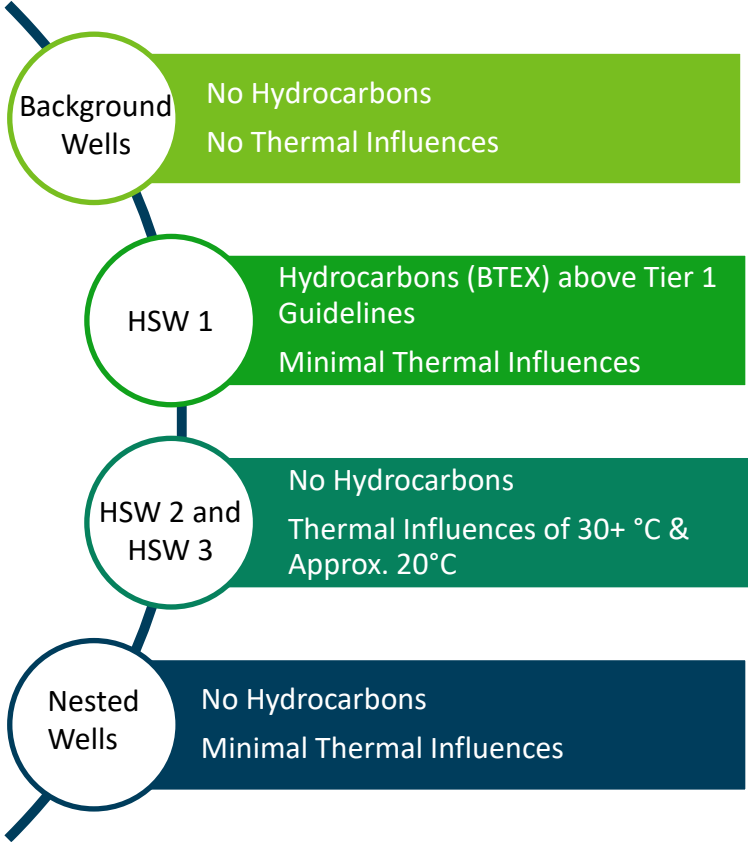
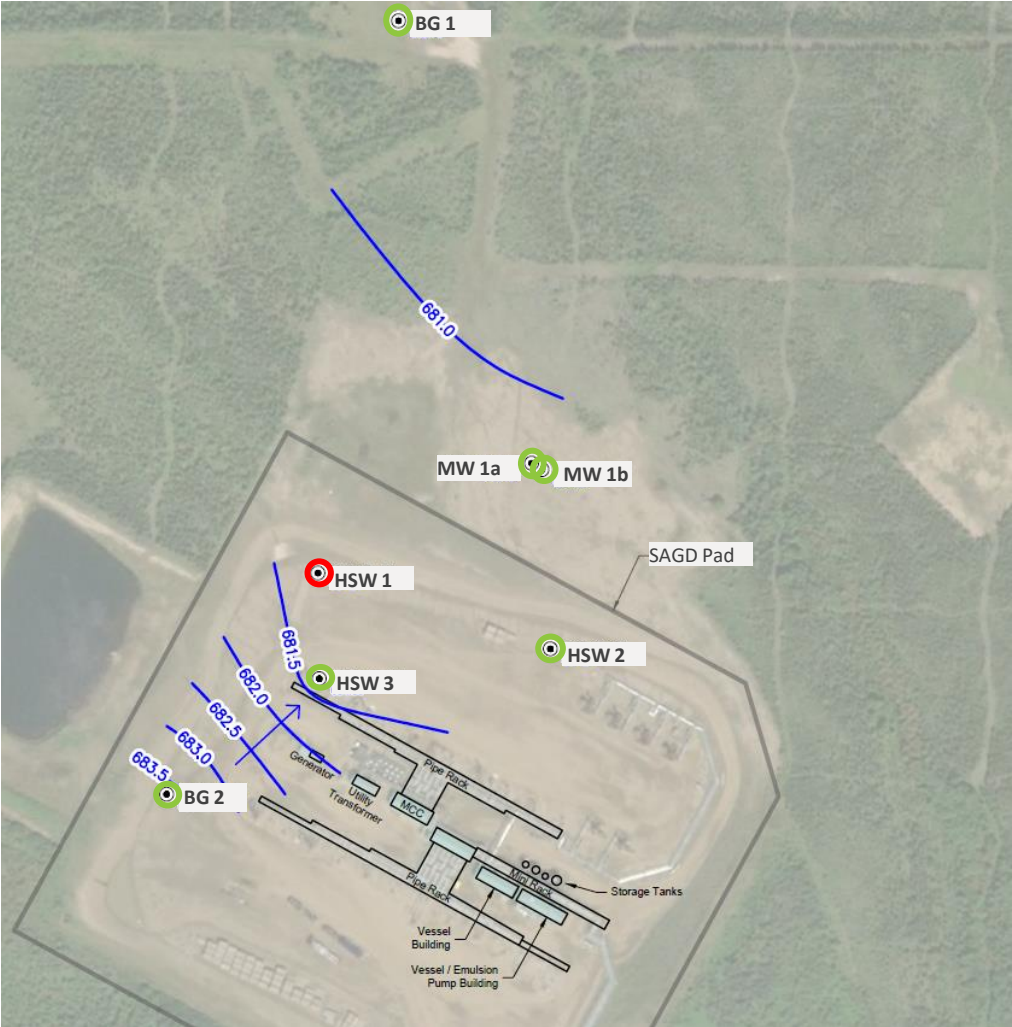
- One sample containing biogenic (plant) hydrocarbons was able to produce BTEX in high concentration.
- The BTEX has a characteristic profile comparable with the HSW 1 water sample.
- Notable concentration of linear alkylbenzenes (nPr-Bz, nBu-Bz etc)
- **This occurred within an enclosed vessel at room temperature (no heating).**



Present Day Results & Conclusion



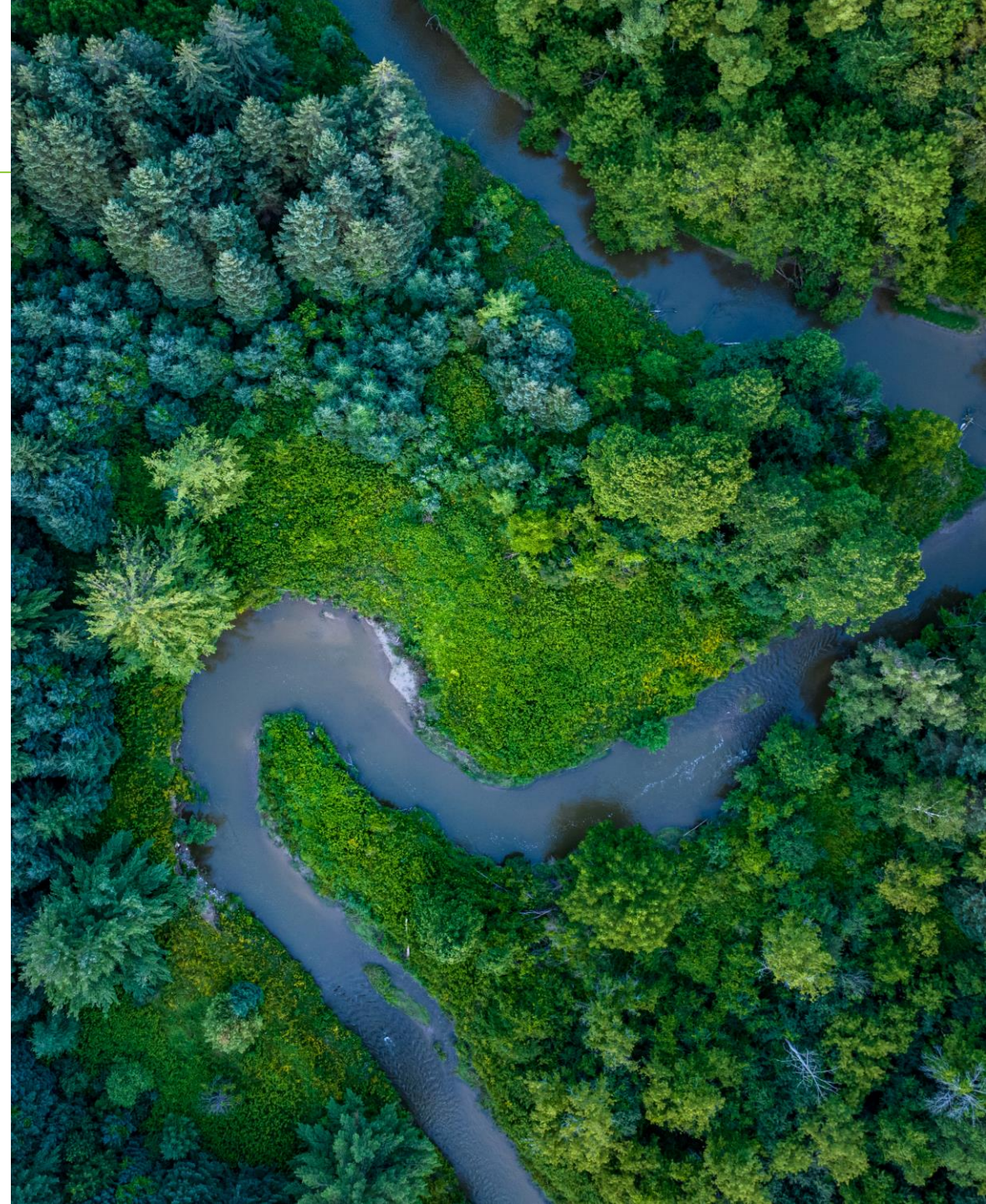
Groundwater Quality Summary: Additional Wells (2025)



Conclusion

BTEX concentrations in the Sand River Aquifer at HSW 1 are not related to SAGD operations:

- Findings suggest that hydrocarbons at HSW 1 are naturally occurring in the Sand River Aquifer and not primarily influenced by temperature
- The hydrocarbons at HSW 1 remain isolated and are delineated
- Other heat source wells influenced by thermal effects have reported hydrocarbons below guidelines
- The Thermal Directive requirements are not applicable in this case
- Unique redox chemistry at HSW1
 - (phenols, pH, Fe+Mn, sulphate)



Contact Us

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