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IOR/EOR Practices for Enhanced Efficiency in the Evolving Carbon-Conscious Environment

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Natural Fluid Tracer Application for IOR/EOR iWAG Surveillance and Monitoring

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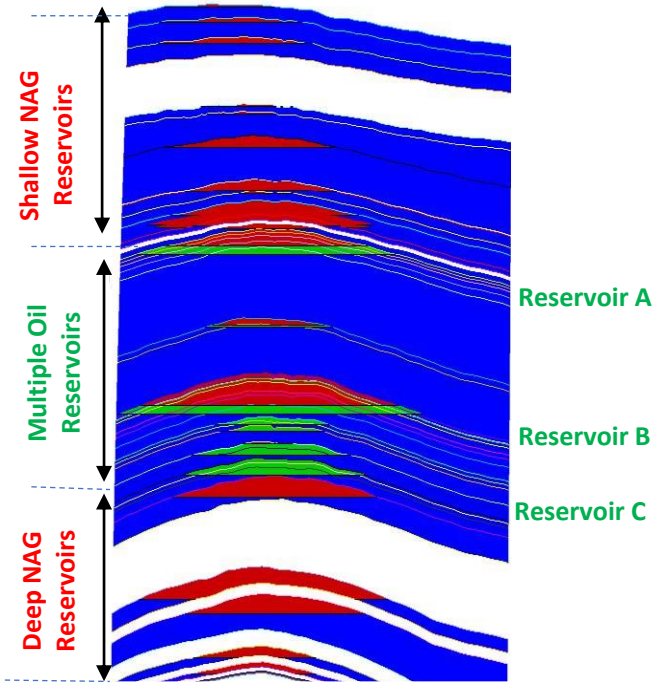
Presentation Outline

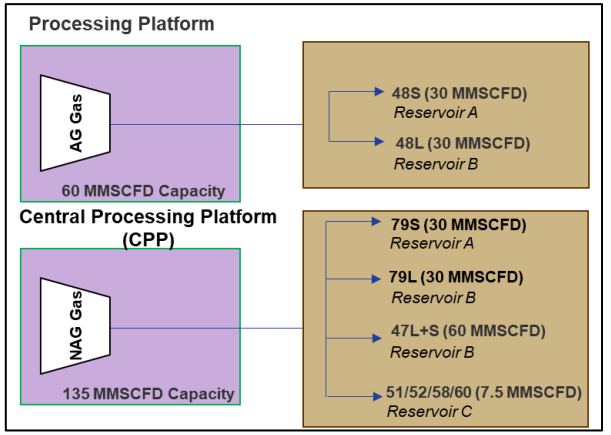
- Field Background
- Natural Fluid Tracer
- Screening Study
- Candidate Selection and Results
- Benefits and Improvement

Introduction

- Field Echo field is located 40km offshore Sarawak, with first production in 1972.
- Comprises of non associated gas and oil reservoirs.
- Major reservoir A,B and C embarked on secondary recovery after 20 years production and since then has achieved >30% recovery.
- Field redevelopment started in 2019 on IOR/EOR recovery with crestal gas and flank water injection at reservoir A and B and iWAG injection at reservoir C to further improve recovery.
- It is crucial to monitor injection flood front and oil rim movement to ensure IOR/EOR success.
- Shallower and deep NAG reservoir are produced as additional gas injection supply for IOR/EOR phases.



Gas Injection System



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Drive Mechanism

Primary

Secondary

IOR/EOR

Reservoir A

Oil rim satured reservoir with gas cap expansion (m=1.1) and strong aquifer drive

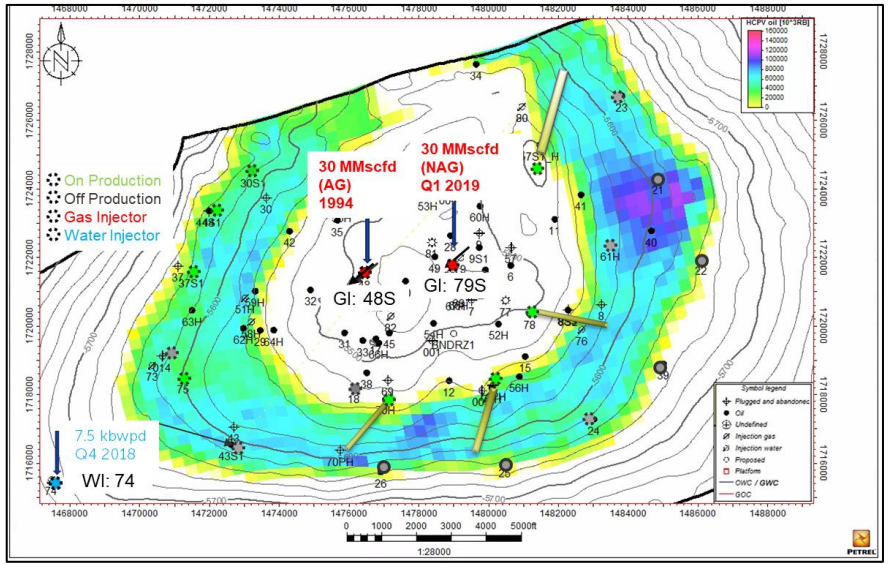
Gas Re-injection

1994 : 1 crestal gas injector to support gas cap expansion and pressure maintenance with Gi/Gp of 0.4.

Oil Rim Management

2019 : - Additional gas injector inject towards eastern area and prevent further oil rim shrinking with Gi/Gp of 1

- 1 water injector at west to complement strong east aquifer



Reservoir C

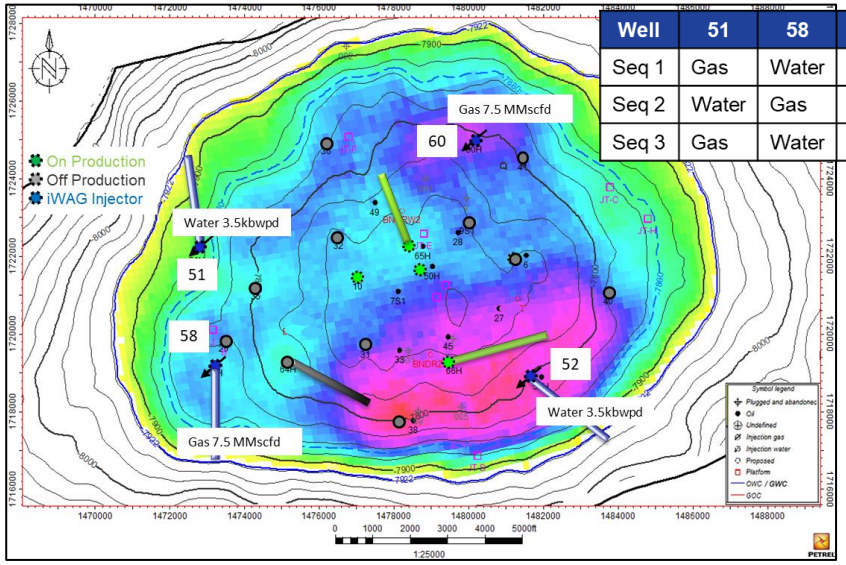
Under-saturated reservoir with weak aquifer

Water Injection

1994 : Peripheral water injection via 4 horizontal injector to maintain reservoir pressure with VRR of 1

Immiscible Water Alternating Gas

2019 : 4 WI conversion to iWAG to increase sweep efficiency and Sor reduction. Alternate water & gas injection with 90days cycle



Well	51	58	52	60
Seq 1	Gas	Water	Gas	Water
Seq 2	Water	Gas	Water	Gas
Seq 3	Gas	Water	Gas	Water

Fluid Natural Tracer

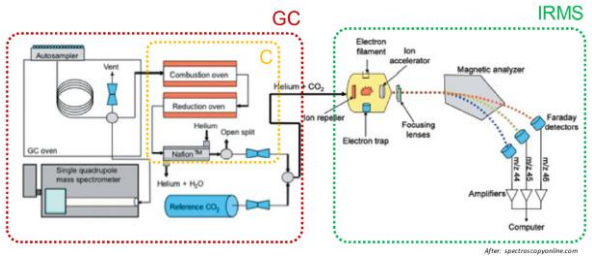
- Identification markers of any compound, elements, or properties of a fluid that distinguishes it from another fluid without addition of artificial substance.
- Isotopes of fluid element (Carbon, Hydrogen, etc) used as tracers as stable isotopes has no tendency to undergo decay, degradation.
- Fluid samples undergoes Compound Specific Isotope Analysis (CSIA) via Gas Chromatography Combustion Isotope Ratio Mass Spectrometry (GC-C-IRMS) to detect variation of isotope signature that show contrast between fluids.
- Water samples also undergo full water 12+ ion compositions via Inductively Coupled Plasma Mass spectrometer (ICP-MS) to show contrast in composition.

Input

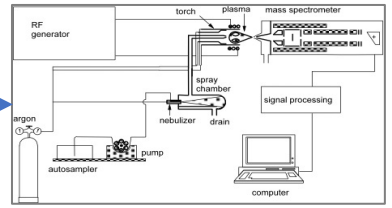
Gas Sample

Water Sample

Analysis



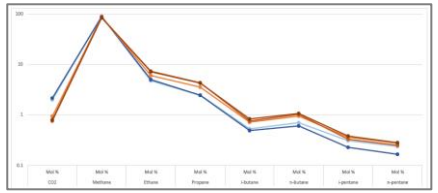
Schematic of Gas Chromatography Combustion Isotope Ratio Mass Spectrometry



Schematics of ICP - MS

Output

Gas: Carbon Isotope Ratio



Water: Hydrogen Isotope Ratio

Samples	Hydrogen	Oxygen
	δ2HVSMOW (‰	δ18OVSMOW (‰
Produced Water W65	-10.26	0.15
Produced Water W65	-8.19	0.74
Seawater WI	-0.65	-0.42
Seawater WI	-0.29	-0.44

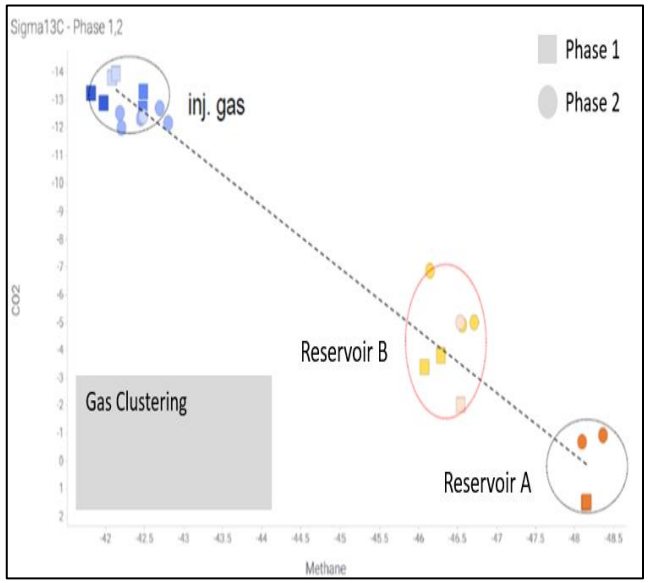
Water Composition – Ion Contrast

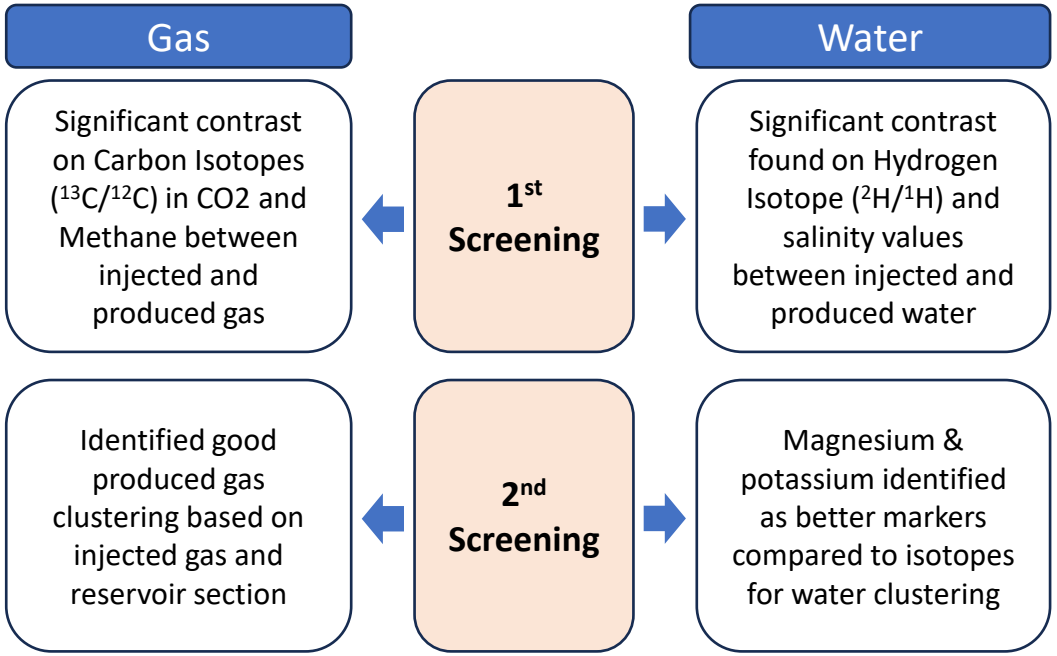
Seawater W65 produced

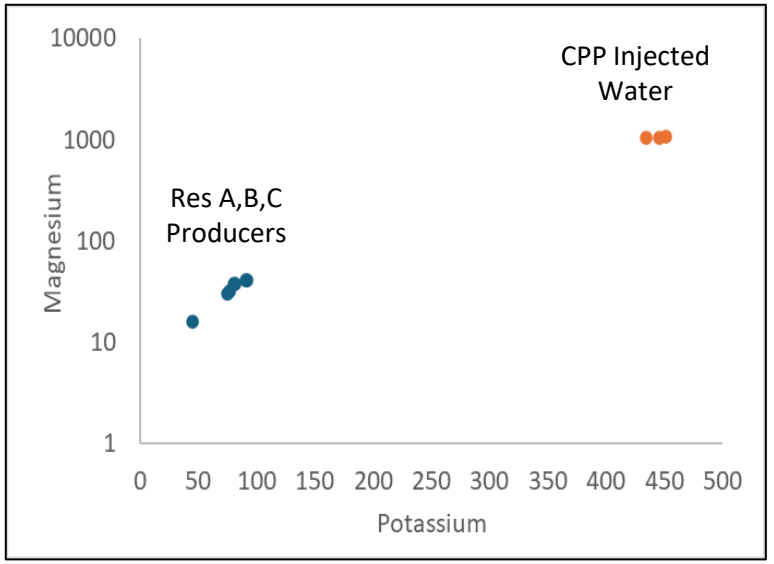
Test Parameters	Results	Results	Test Method
Salinity	33	20	APHA 2520 B
(ii) Anionic	**mg/L**	**mg/L**	
Chloride (Cl^-)	18600	10800	APHA 4500 Cl- D
Sulphate (SO_4^{2-})	2850	115	APHA 4110 B
Bicarbonate measured, HCO3	198	4442	APHA 2320 B
Carbonate, CO3	Absent	Absent	APHA 2320 B
Hydroxyl Ion, OH	Absent	Absent	APHA 2320 B
Total Anions			
(ii) Cationic	**mg/L**	**mg/L**	
Sodium	9660	8780	APHA 3030 F & APHA 3120 B
Potassium	434	81.8	APHA 3030 F & APHA 3120 B
Calcium	320	131	APHA 3030 F & APHA 3120 B
Magnesium	1050	37.1	APHA 3030 F & APHA 3120 B
Strontium	5.87	11.2	APHA 3030 F & APHA 3120 B
Barium	0.05	2.63	APHA 3030 F & APHA 3120 B
Iron	0.28	0.99	APHA 3030 F & APHA 3120 B
Total Cations			

Methodology / Screening Study

- Tracer screening is conducted to identify if produced fluid has distinguished isotope signature from injected fluid.
- 2 stage screening was conducted using different wells from each reservoirs and injection fluid to increase data confidence.
- Better identification of candidate wells to monitor IOR/EOR performance through natural tracer application.



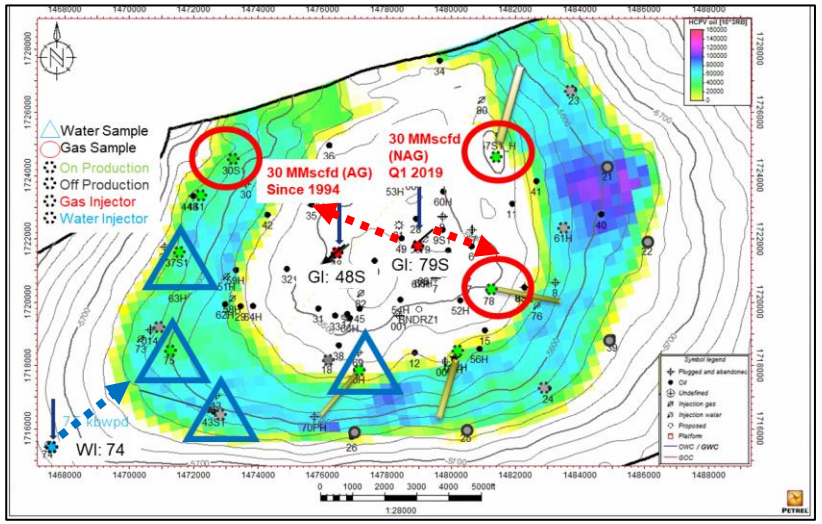




Reservoir A – Tracer screening and results

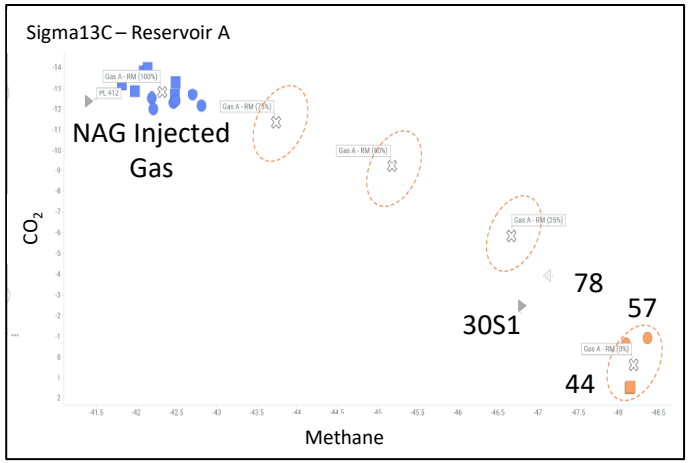
Objective

- To monitor new gas injection effectiveness towards eastern area to combat strong eastern aquifer
- To monitor water breakthrough at western flank



Observation (Gas)

- 44S1 & 57S1 displays original produced gas
- 30S1 & 78 showed 15-20% mixing of NAG injected gas

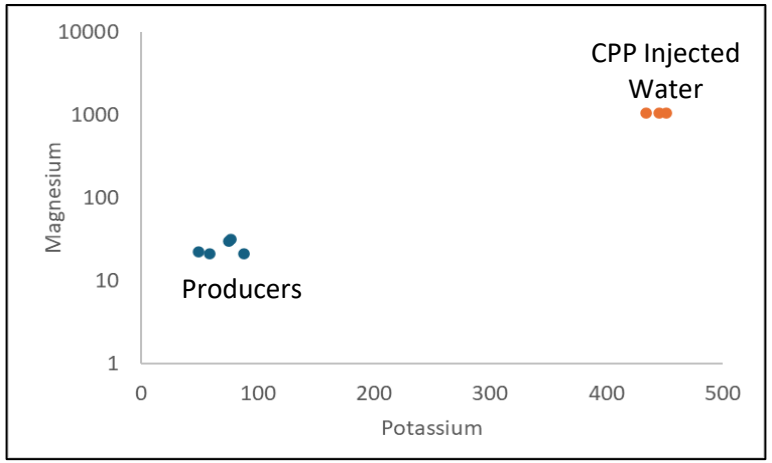


Result

- Some injected gas from 79S distributed towards north west area.
- Requires increase production withdrawal to redirect gas to eastern area

Observation (Water)

- Produced water sample has distinct signature from injected water
- All water sample 37S, 57, 75, 78 showed formation water



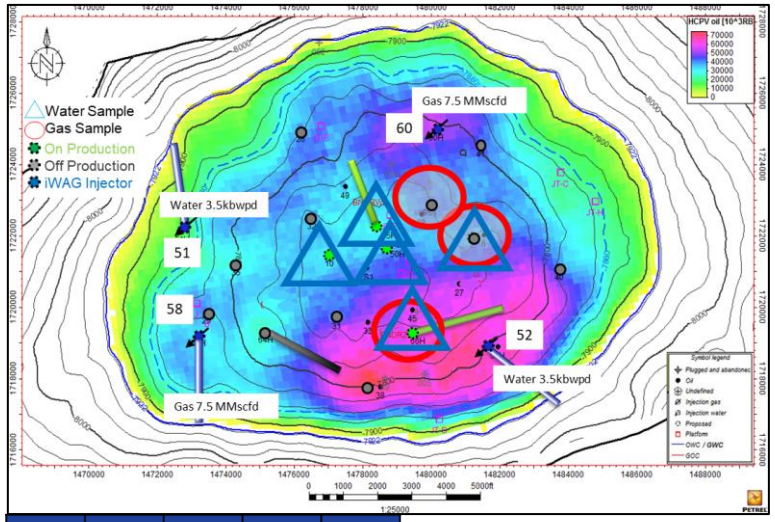
Result

- High watercut observed are due to OWC movement up.
- WI 74 water injection has yet to breakthrough producer 75.

Reservoir C – Tracer screening and results

Objective

- To identify iWAG flood front movement (gas and water)
- To confirm historical waterflood performance

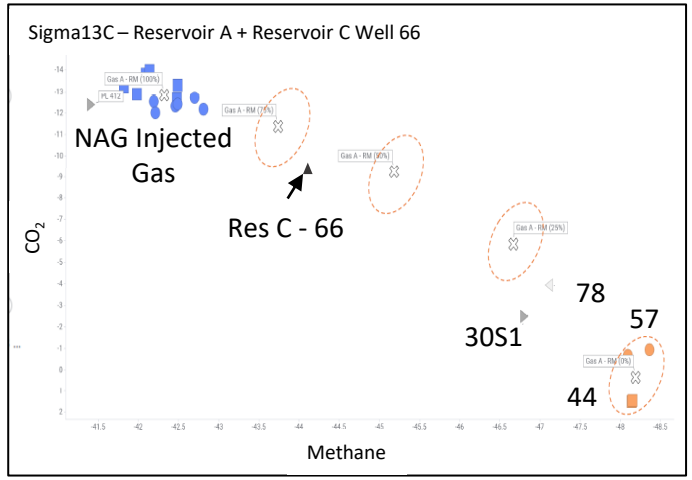


Well	51	58	52	60
Seq 1	Gas	Water	Gas	Water
Seq 2	Water	Gas	Water	Gas
Seq 3	Gas	Water	Gas	Water

Observation (Gas)

**Limited sample obtained from Res C*

- Sample 66 showed close isotope properties with NAG injected gas

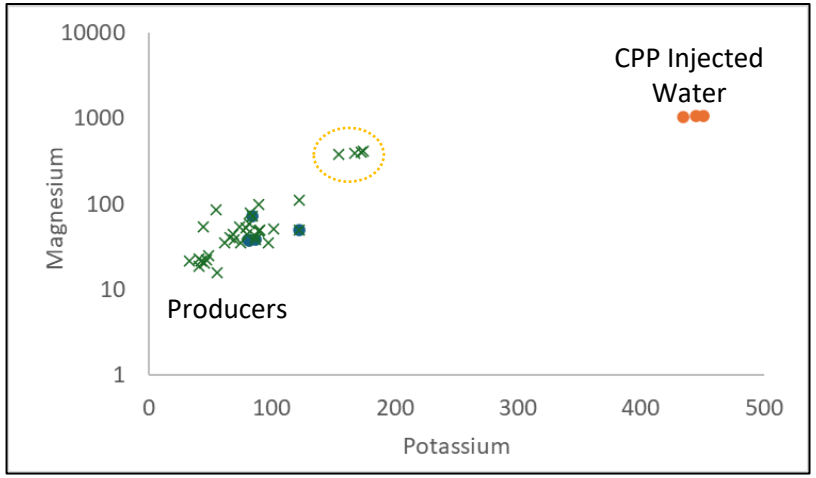


Result

- Due to limited baseline, sample 66 result is not conclusive
- More samples required for baseline

Observation (Water)

- Data are combined routine samples monitoring
- Historical water sample 64L showed mixture with injected water



Result

- Well 64L shown to have injector water breakthrough, and well is close in due to high watercut
- Other wells showed formation water even after 20 years water injection

Benefits and Improvement

Benefits

Natural Source
Does not require artificial chemical injection

No expiry
Sample can be collected and analysed even anytime when injection starts

Cost & Operational Viable
Compared to chemical/artificial tracer method

Practical for WI Surveillance
Continued at 6-monthly monitoring

Future Improvement

Long TAT for Isotope Analysis
No O&G laboratory capability and expertise in Asia

Limited applicability
Required comprehensive screening test to confirm viability

Limited streamline study
Unable to differentiate injectors preferential flow path

Thank You / Questions

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