Tracers and Pressure Transient Analysis Used to Better Understand Reservoir Connectivity, Wara - Greater Burgan, Kuwait*

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Abstract

The Wara reservoir in Greater Burgan Field has been on production since 1948. The pressure has declined below bubble point pressure in several parts of the reservoir prompting the need for a pressure maintenance program. A Pilot scale water injection program and associated tracer application was initiated in 2010 to understand the waterflood response and gather information to design a full field scale waterflood. This article highlights the results of the application of tracer and Pressure transient analysis (PTA) in mitigating the uncertainties and to develop improved waterflood strategies in the Wara reservoir. The highly heterogeneous nature of the Wara reservoir poses major challenges in managing the waterflood and improving its effectiveness. Complex depositional reservoir geometry coupled with the presence of faults/flow barriers and variation of fluid properties results in a complicated plumbing system in the Wara reservoir. Pressure transient studies provide insight to reservoir connectivity and presence of fault/baffles. Understanding the injector-producer connectivity is crucial in managing the waterflood effectively to optimize the volumetric sweep efficiency. The pilot tracer program offers insight to injector-producer connectivity, and water movement within the reservoir. The combination of PTA and tracer injection in the Wara reservoir has been extremely helpful in the following: (1) Understanding the injector-producer connectivity, (2) building a better subsurface description for development planning and reservoir simulation, (3) optimizing well spacing, (4) volumetric sweep and strategy for improvement, and (5) identifying development opportunities.

An extensive tracer monitoring program in the pilot water injection area has provided valuable information in understanding the flood front movement in this area. In the Wara waterflood area, tracer breakthrough times vary between 1 and 7 years of injection. This is an indication of the complex nature of the reservoir connectivity and fluid movement within the reservoir. Integration of PTA and the application of tracer injection in a complex and heterogeneous reservoir has provided valuable insights to waterflood behavior and enabled modifications to the development strategy to optimize sweep efficiency, well spacing and pattern development in where reservoir connectivity relatively low.

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Overview

This presentation highlights how the application of Tracer and Pressure transient analysis (PTA) helped in

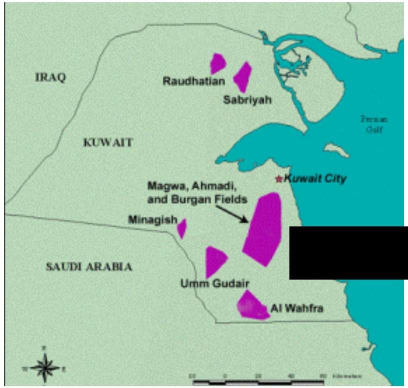
- Mitigating the uncertainties
- to have improved waterflood strategies

in Wara reservoir in Burgan field which is currently under waterflood.

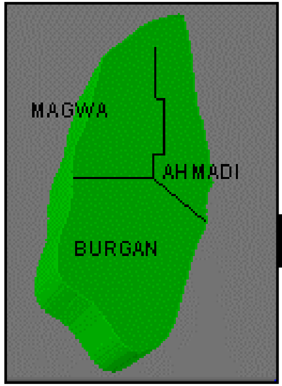
Outline

- Geological Introduction
- Interference study, PBU and PFO
- Tracer application
- Integration of PTA and Tracer
- Summary and conclusion

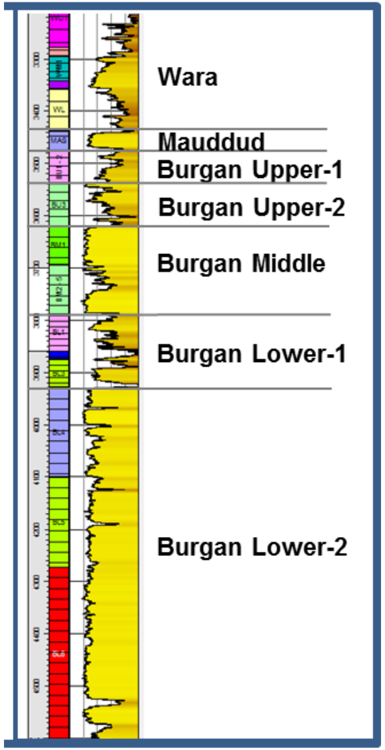
Introduction



Burgan

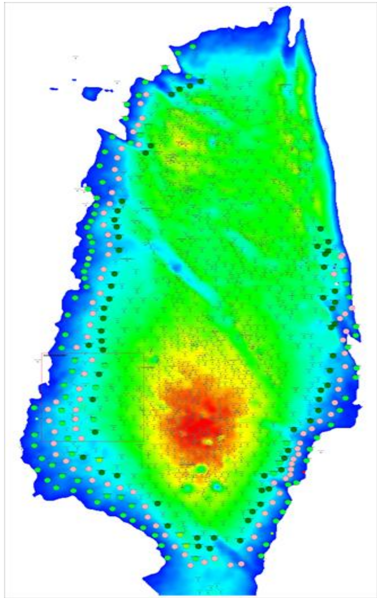


Major Reservoirs



Type Log

- Complex depositional environment
- Tidally dominated deltaic system

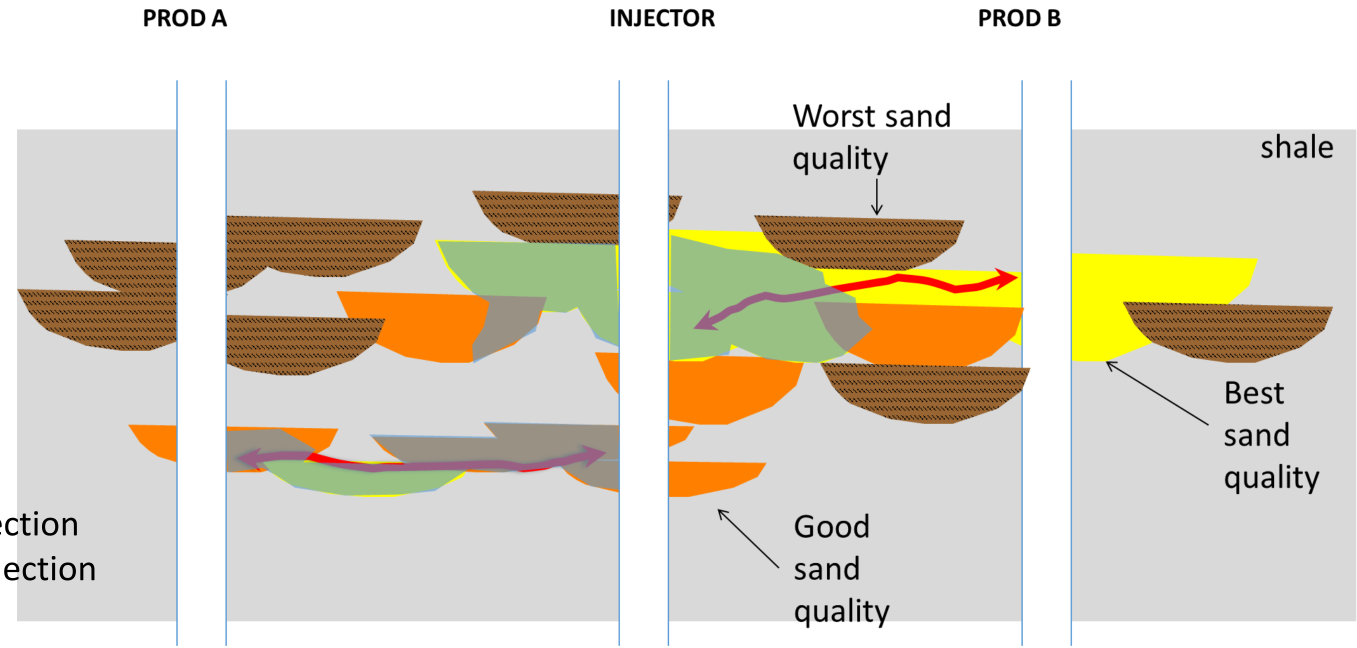


- WARA is one of the main producing reservoir
- Long production history, Limited aquifer support leading to accelerated pressure depletion
- Step-in peripheral water injection was identified as the best Pressure Maintenance Project for Wara, known as WPMP

Challenges and Uncertainties in Wara

There are several challenges involved in WARA waterflood

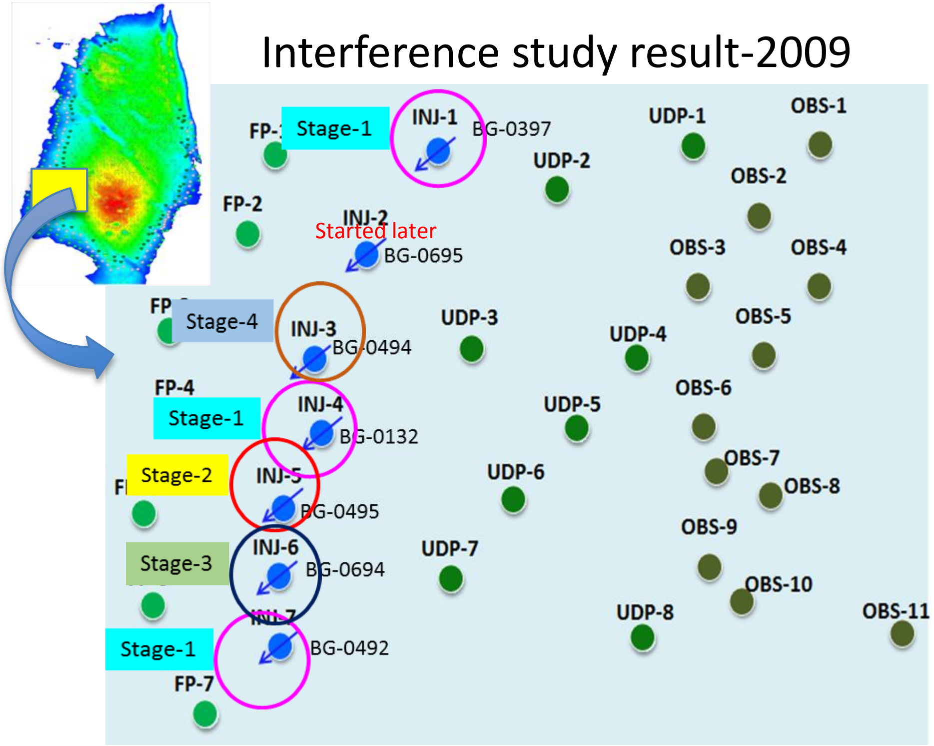
- Giant size, vertical and lateral heterogeneities
- Uncertainties in
  - Reservoir quality
  - Sand continuity



PRD A and INJ, say 200mD connection
PRD B and INJ, say 1000mD connection

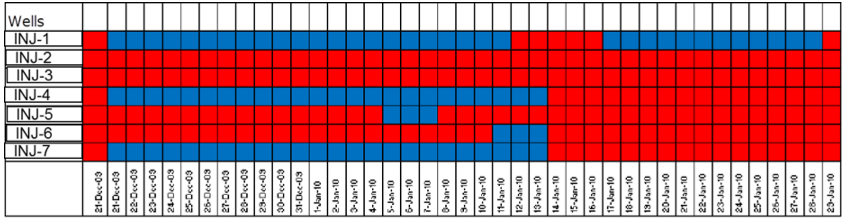
INTERFERENCE STUDY DURING INJECTION START-UP

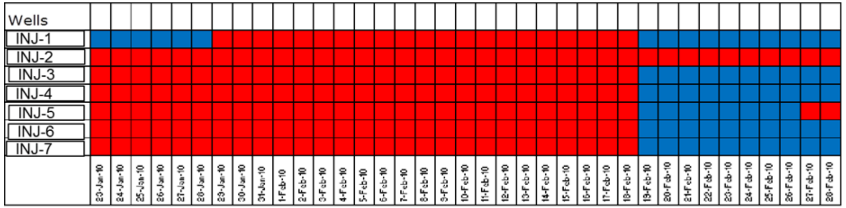
Interference study result-2009



Interference study Sequence

- Gauges lowered in Injectors and producers one week in advance.
- Injection started in 5 stages

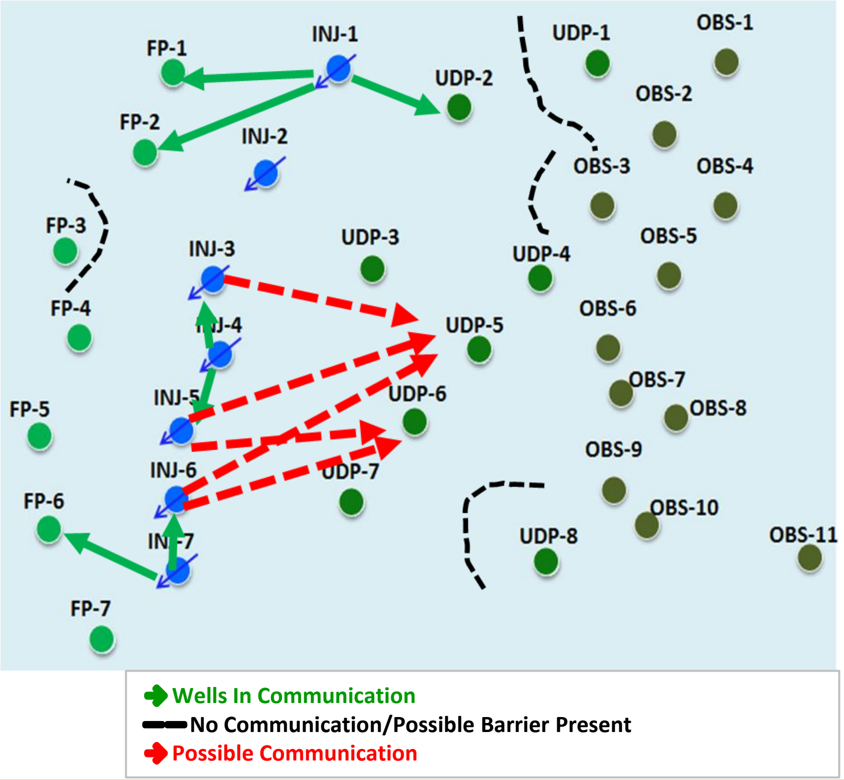




All Injectors – Except **INJ-2** Start on 19-Feb

Injection
No Injection

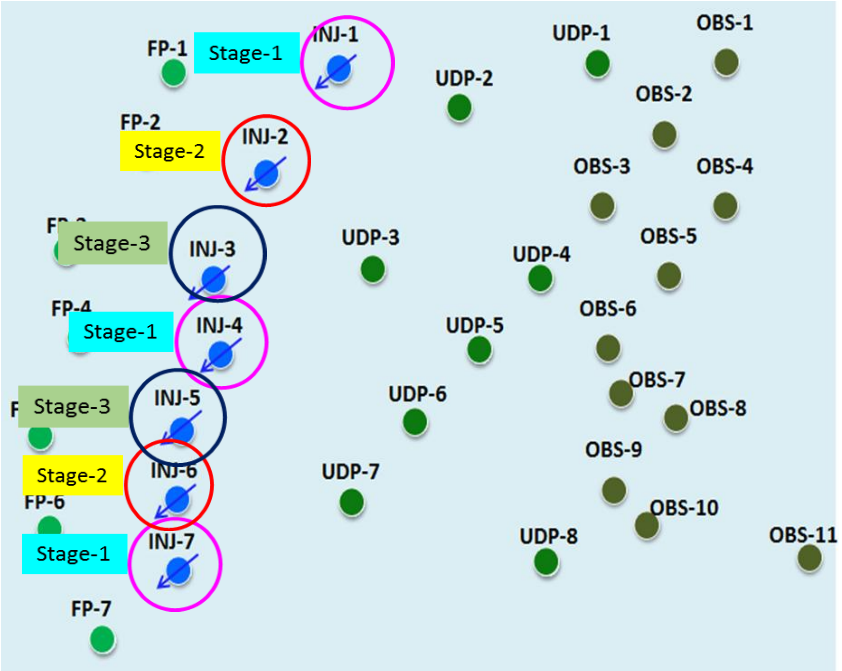
Interference study result-2009



Reservoir Evaluation Summary

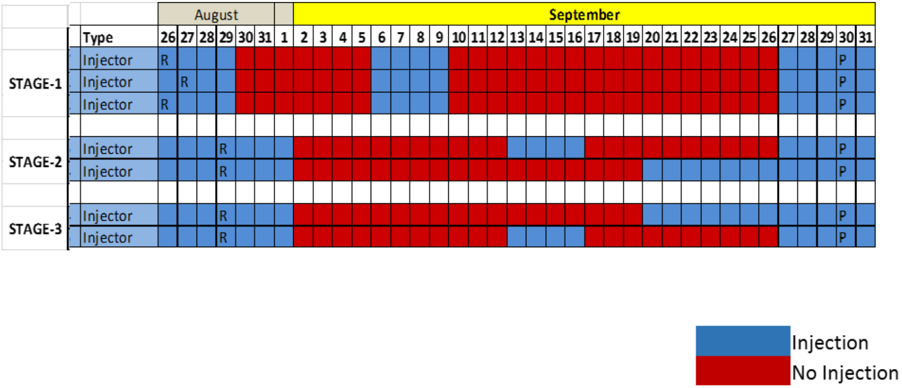
- **Average Reservoir Permeability** ≈ 420 mD (using average thickness 46 ft)
- **Communication exists** between **INJ-1** and **3** **Producers.**
- **Communication exists** between **INJ-4** and **2** **Injectors.**
- **Communication exists** between **INJ-7** and **1** **Injector and 1 Producer.**

INTERFERENCE STUDY 2012

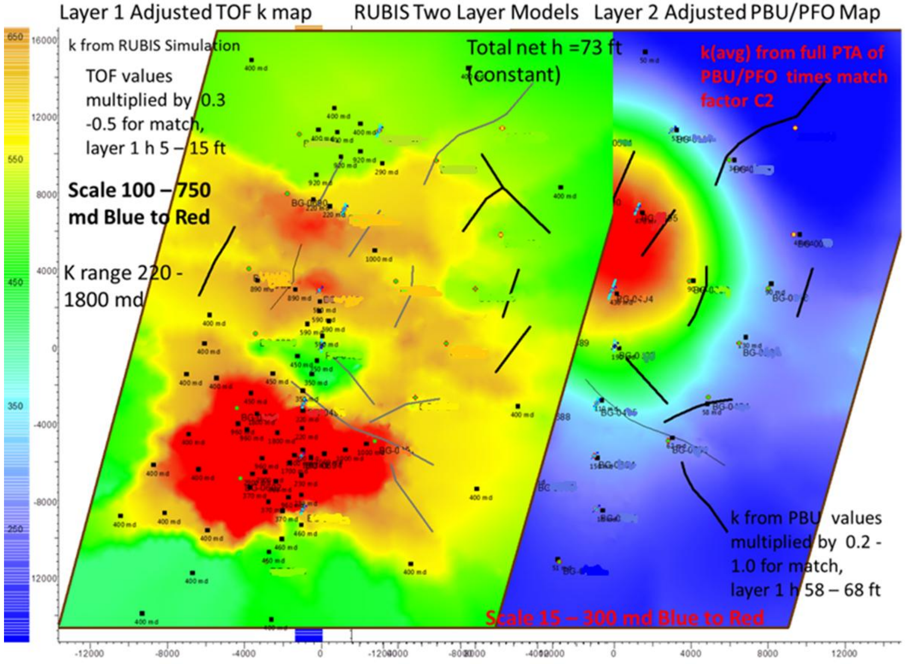


Interference study Sequence

- Gauges lowered in Injectors and producers before the test.
- Interference test conducted in stages



Map : Interference Results and PTA Results

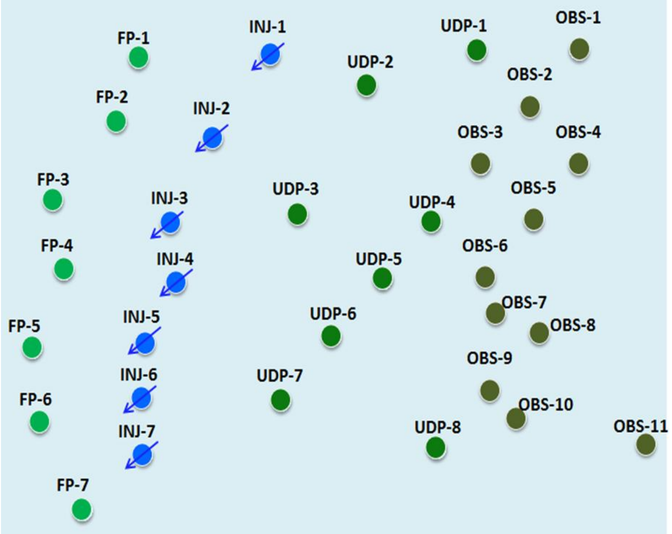


RUBIS Two-Layer Model:

- Thin High-perm based on Interference.

  Thick lower perm to equal PBU -k

Tracer Injection Program



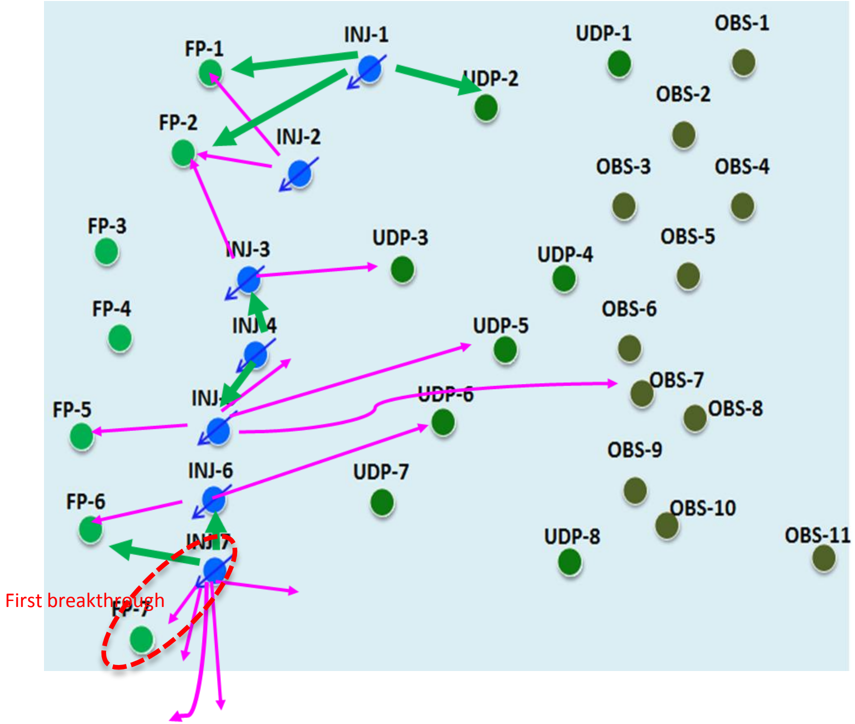
Well	Tracer Type recommended	Quantity Required (Kg)
INJ-1	T-190c	165
INJ-2	T-190b	65
INJ-3	T-190a	135
INJ-4	T-158c	160
INJ-5	T-140a	250
INJ-6	T-140c	175
INJ-7	T-158a	150

- Quantify injection water flowing from one injector to a specific Producer using percentage of tracer produced.
- Identify source of produced water
- Calibration of simulation models using first tracer breakthrough time.
- Calculate Volumetric sweep efficiency using average tracer transit time from each injector to producer wells.
- Test communication through Fault block/channel.
- Fault transmissibility: If fault block communication occurs tracer will enable quantification of fault block flow.
- Determine high permeable channel fingering between injector and producers from the shape of the tracer concentration versus time curves.

Initial plan:

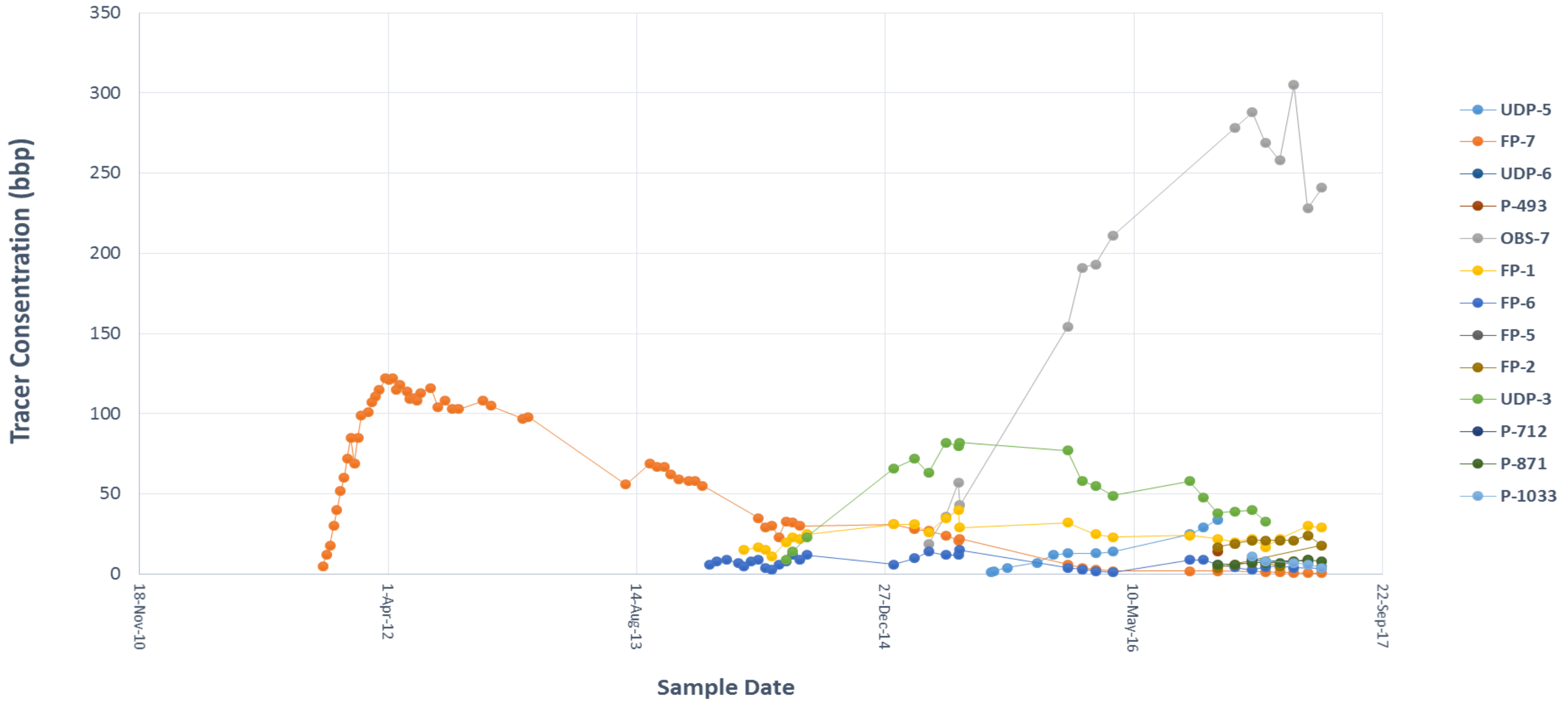
1. Weekly sampling in first line wells
2. One sample per month for second line wells.
3. Analyze every third sample from a well.

Tracer Breakthrough

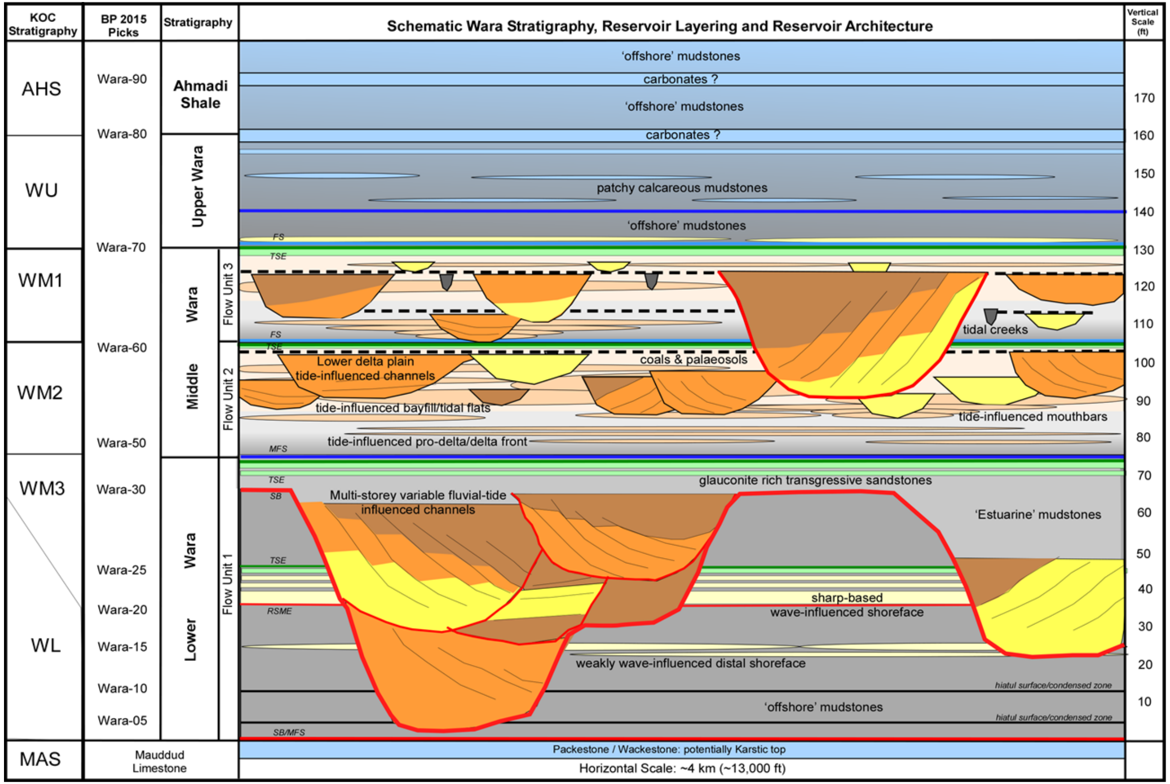


Distance, kms	Breakthrough time, days	Order of occurrence
1.00	349	1
1.00	1181	2
1.32	1250	3
1.20	1334	4
3.32	1621	5
2.42	1747	6
1.40	1992	7
1.26	2202	7
1.40	2202	7
1.58	2202	8
0.89	2202	9
1.67	2203	10
1.80	2272	11
1.00	2412	11
2.00	2412	12

Tracer Breakthrough

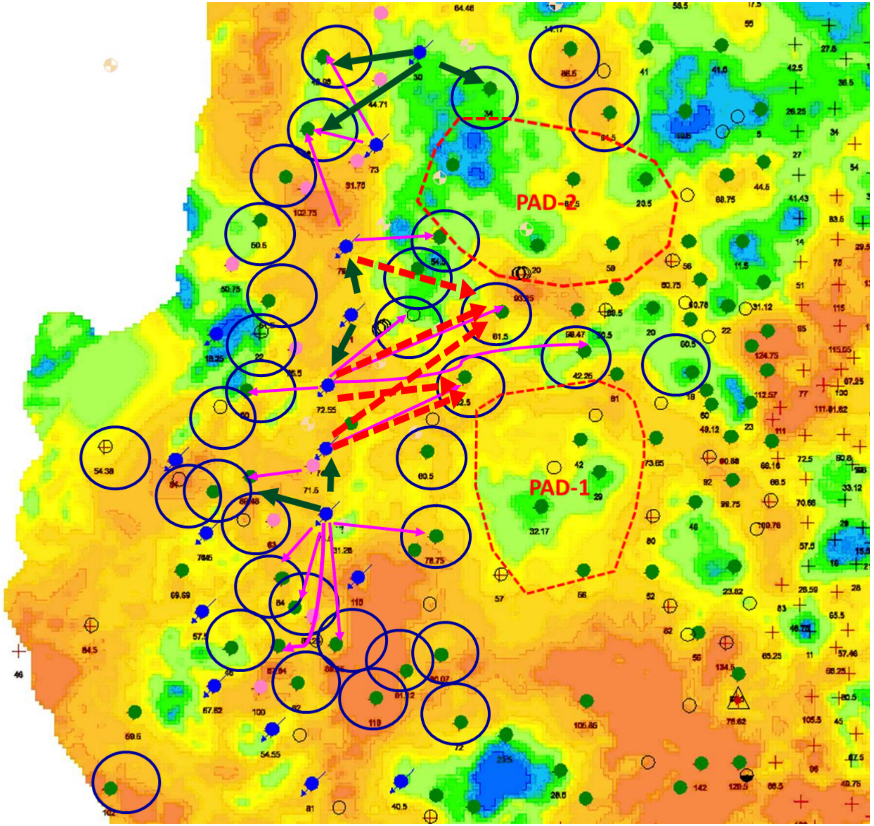


Use of Tracer data in Integrated Sub-surface Model



- Tracer breakthrough data is used to validate the reservoir layering model and connectivity.
- Tracer breakthrough data recognize tortuous flow-paths in parts of the Wara Formation are common .
- The new understanding of reservoir flow units and reservoir architecture help to frame production-injection strategies, completion options and surveillance plans.

Integration of PTA and Tracer breakthrough data



Interference

- Identify reservoir connectivity
- Recognize possible communication

Tracer

- Inject in all injectors
- Water sample from all producers
- Identify flooded area
- Identify area need more injection

ISD

- Integrate both PTA data and Tracer breakthrough data
- Identify potential development area
- Propose additional wells

Summary and Conclusion

Integration of Tracer and PTA data helped the following

- to identify potential development areas to improve waterflood performance.
- Revision of well spacing
- Modification of Injection pattern from line drive to 5 spot
- Calibration of simulation model
- Improve sub-surface understanding of the reservoir