

Oil Reserves Associated with IOR Projects: Recommendations for the Design of Pilot Tests

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GCA is “a small integrated oil company, with no oil ...”
Peter Gaffney



Bentley Office



*Founders:
Ben Cline and Peter Gaffney*

Partial Listing of Diverse Client Base

Oil & Gas Companies



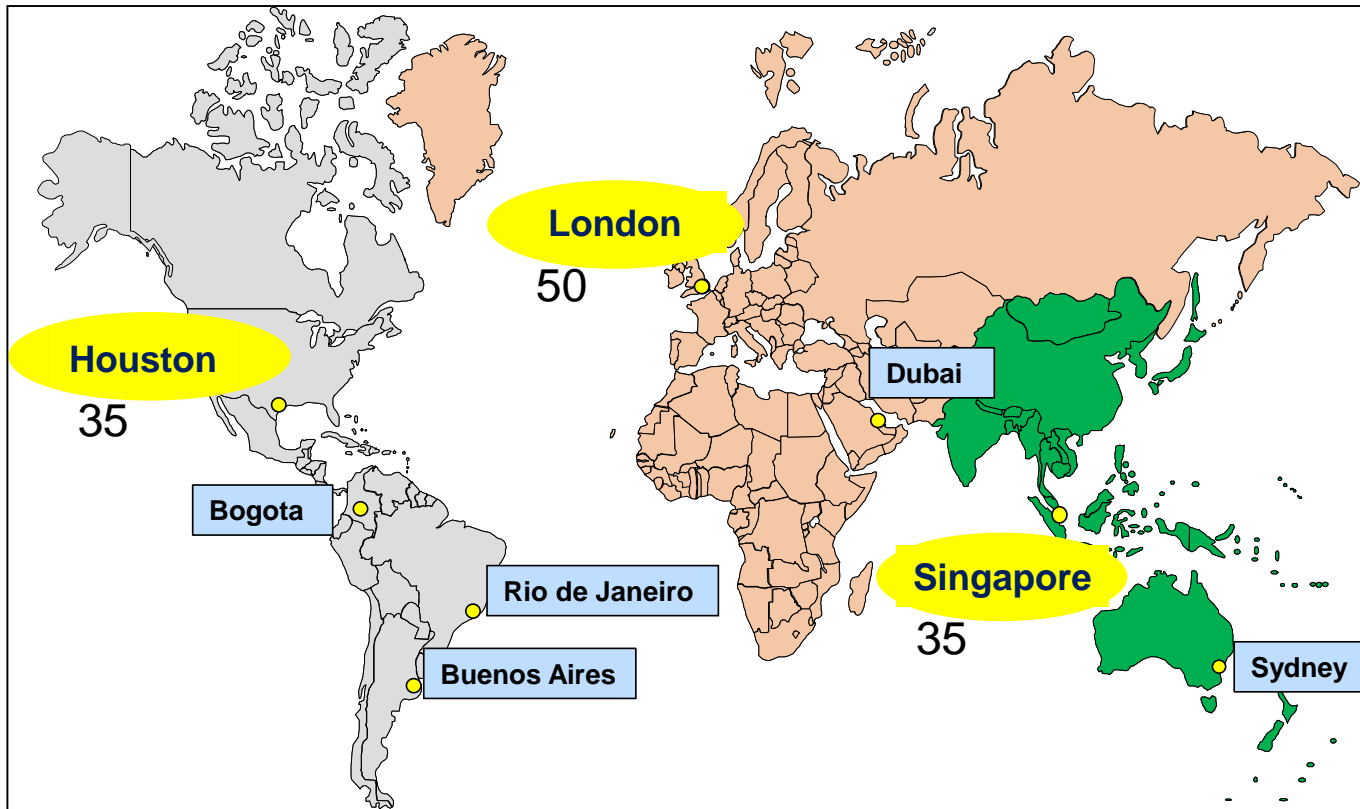
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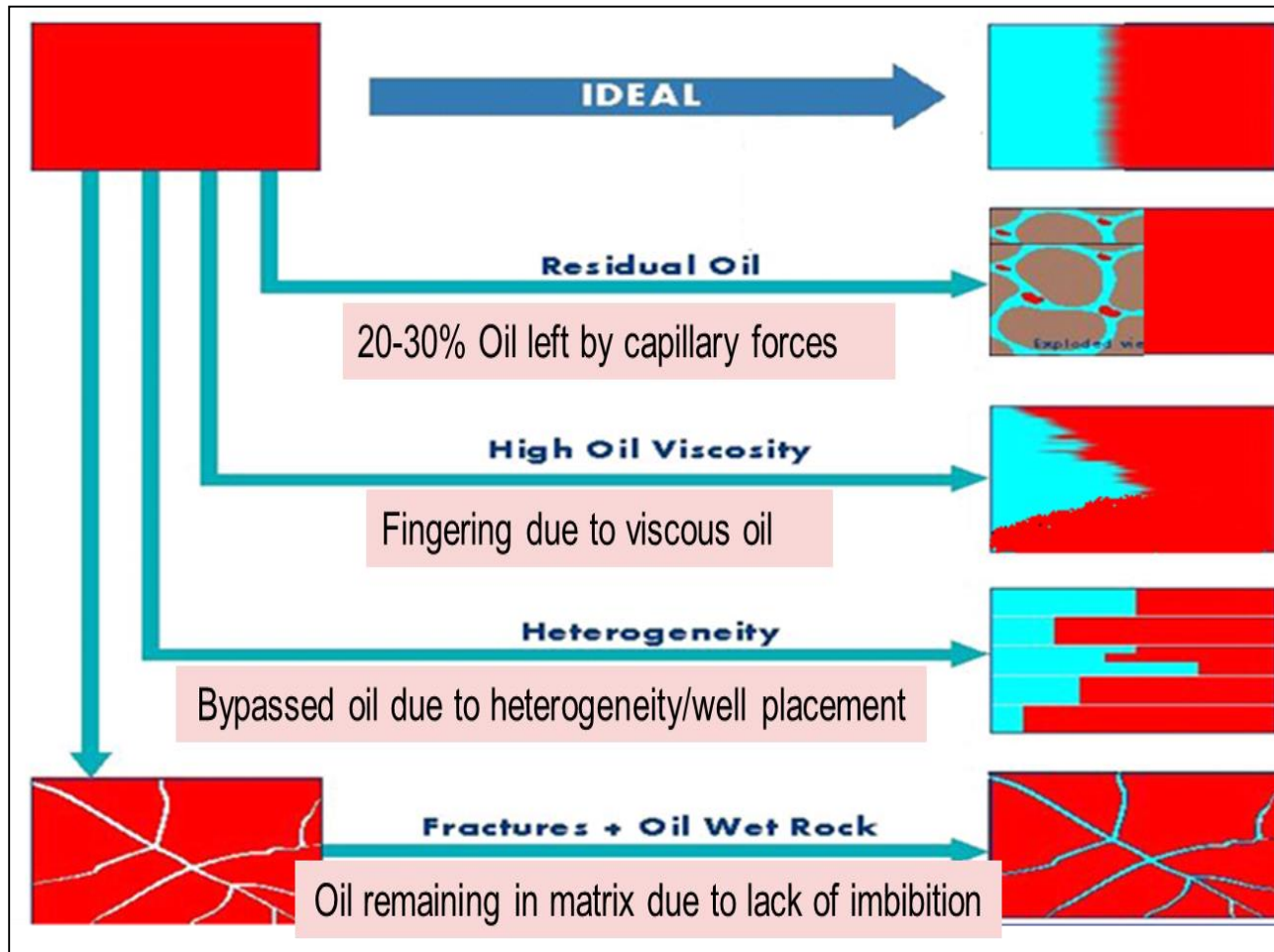


Commercial Services and Advice

Summary

- As the "easy oil" disappears, options for future production will be based on "Unconventional Reservoirs" (Tight/Shale Oil), on the implementation of best management practices and application of Improved Oil Recovery processes (IOR) predominantly on Heavy, Extra Heavy Oil and Tar Sands
- This presentation has been focused on the nature of IOR projects, identifying reasons why insufficient attention is paid in the design of IOR pilots, reducing the potential of booking additional reserves, leading the industry to come up short in the contribution that this activity could bring

Four Key Issues to Resolve to Maximize Oil Recovery



Improved Oil Recovery

Definition and Importance

Improved Oil Recovery Defined

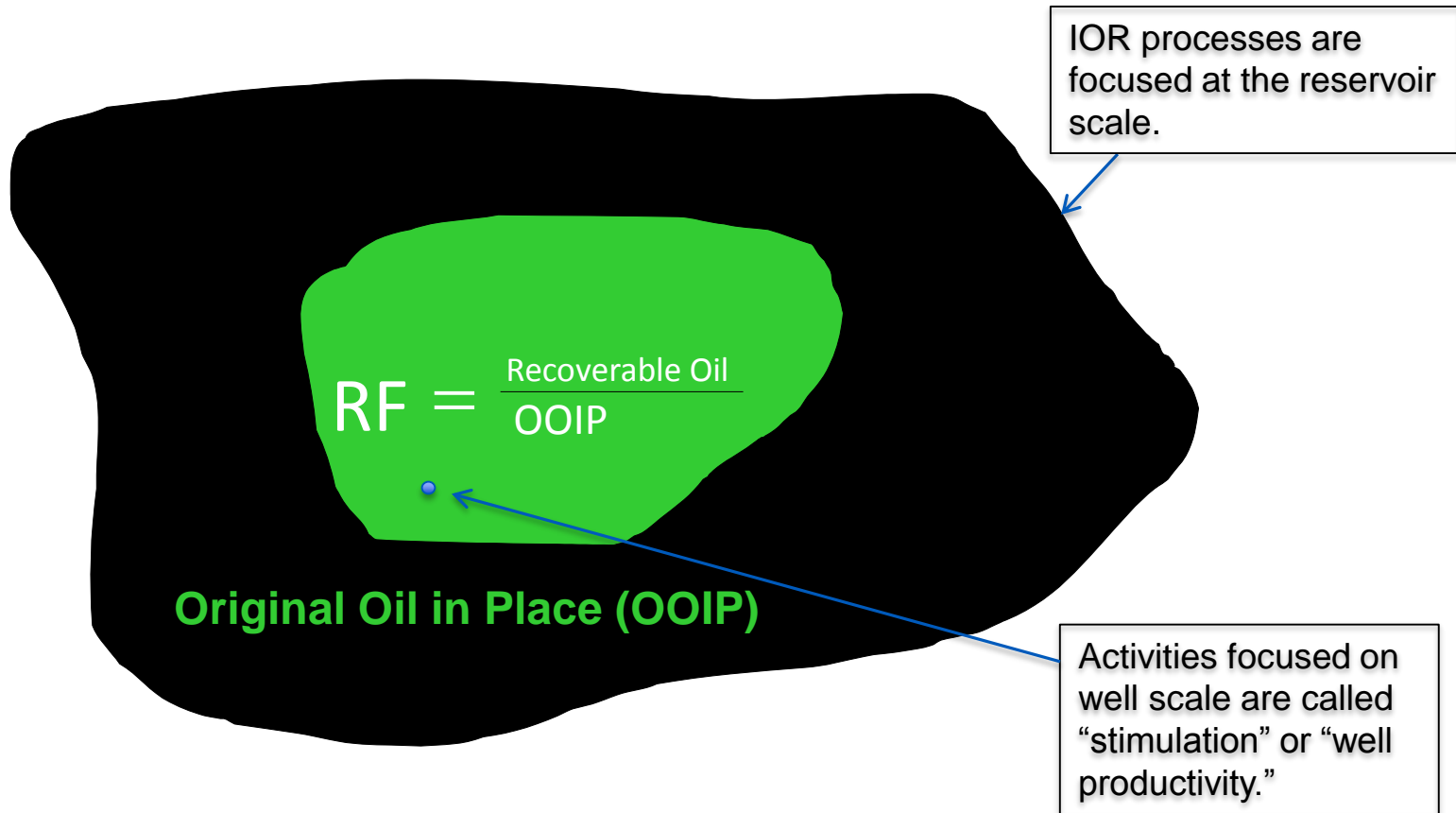
Improved Oil Recovery (IOR) refers to any practice oriented to increase oil production by injection of fluids and energy into the reservoir

This practice has to be economically and technically viable:

- Near-wellbore conformance control (injector wells)
- Immiscible gas injection (dry gas, CO₂, nitrogen, alternating injection with water)
- Miscible flooding (CO₂, nitrogen, hydrocarbon, solvent)
- Water injection
- Chemical flooding
- Thermal recovery
- Well stimulation
- Microbial

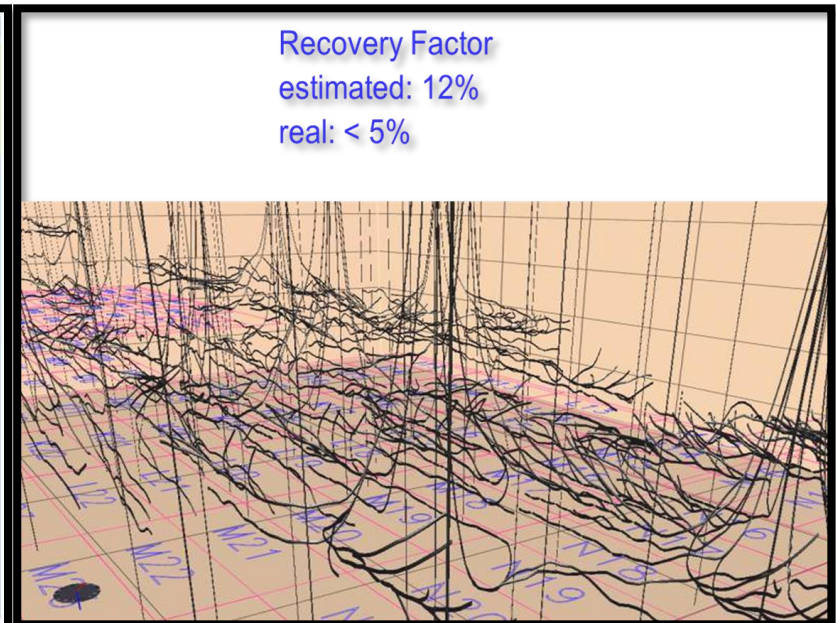
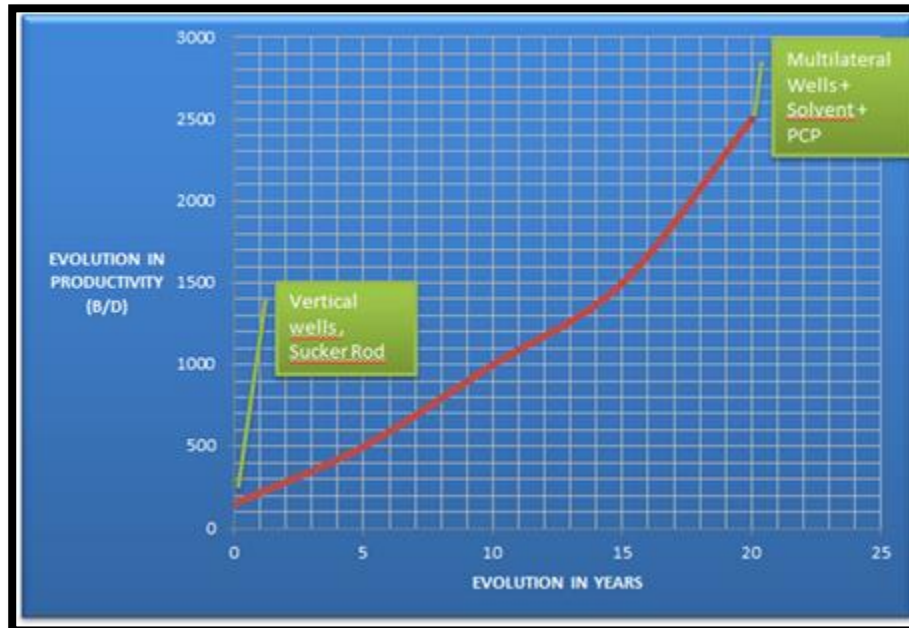
These practices could be supported by additional technologies/activities oriented to well productivity improvement, such as horizontal wells, infill drilling, artificial lift, fracking, etc.

Recovery Factor

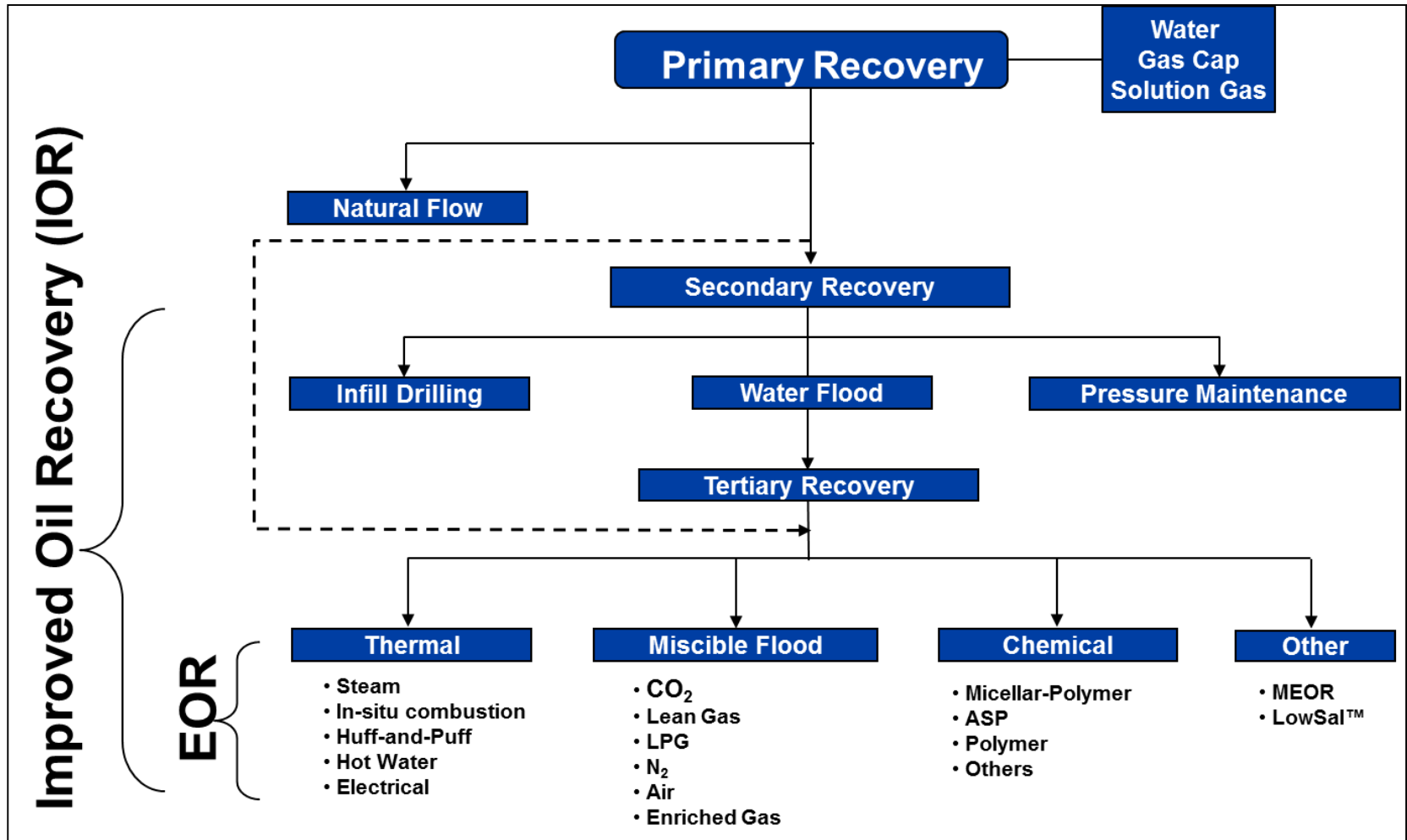


IOR vs. Oil Productivity

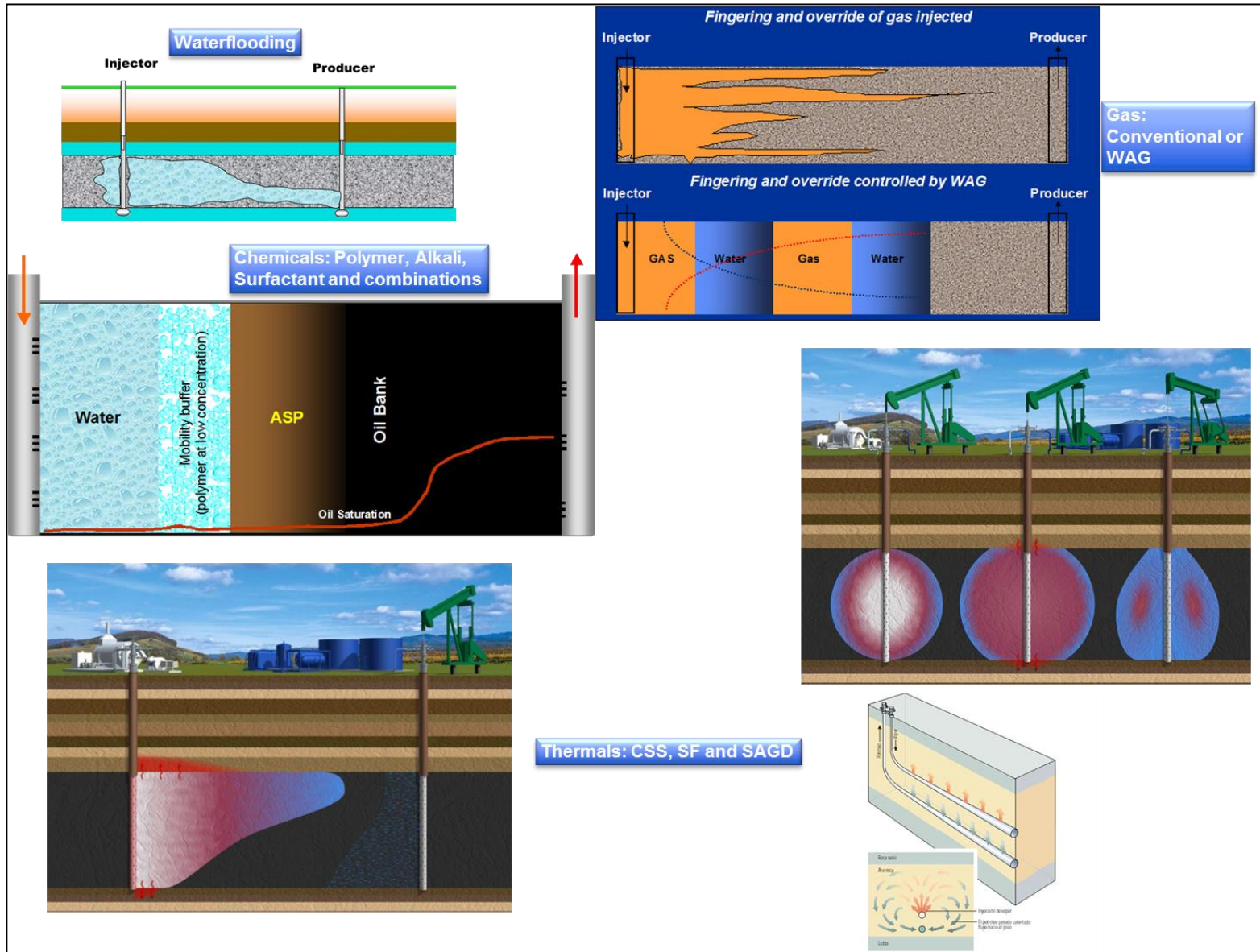
- IOR processes mean a **higher recovery factor (RF)**; however, it does **not** always mean **higher oil rates**
 - There are many cases when high oil rates are reached with a final RF that is very low
- In this example, the well architecture and lifting systems allowed high oil rates in an extra heavy oil reservoir, but the final RF was lower than expected



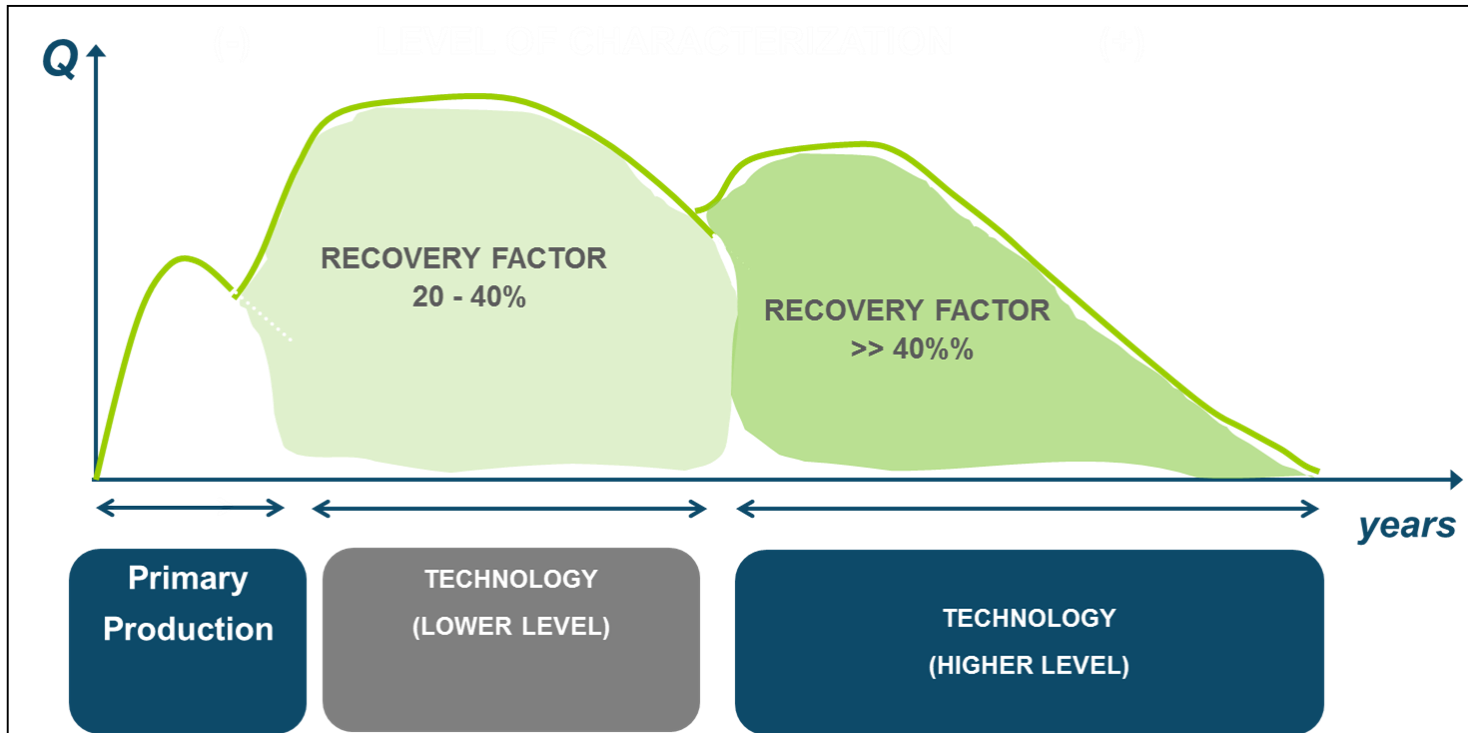
What is Meant by Enhanced Oil Recovery (EOR)?



Principal Mature IOR Technologies

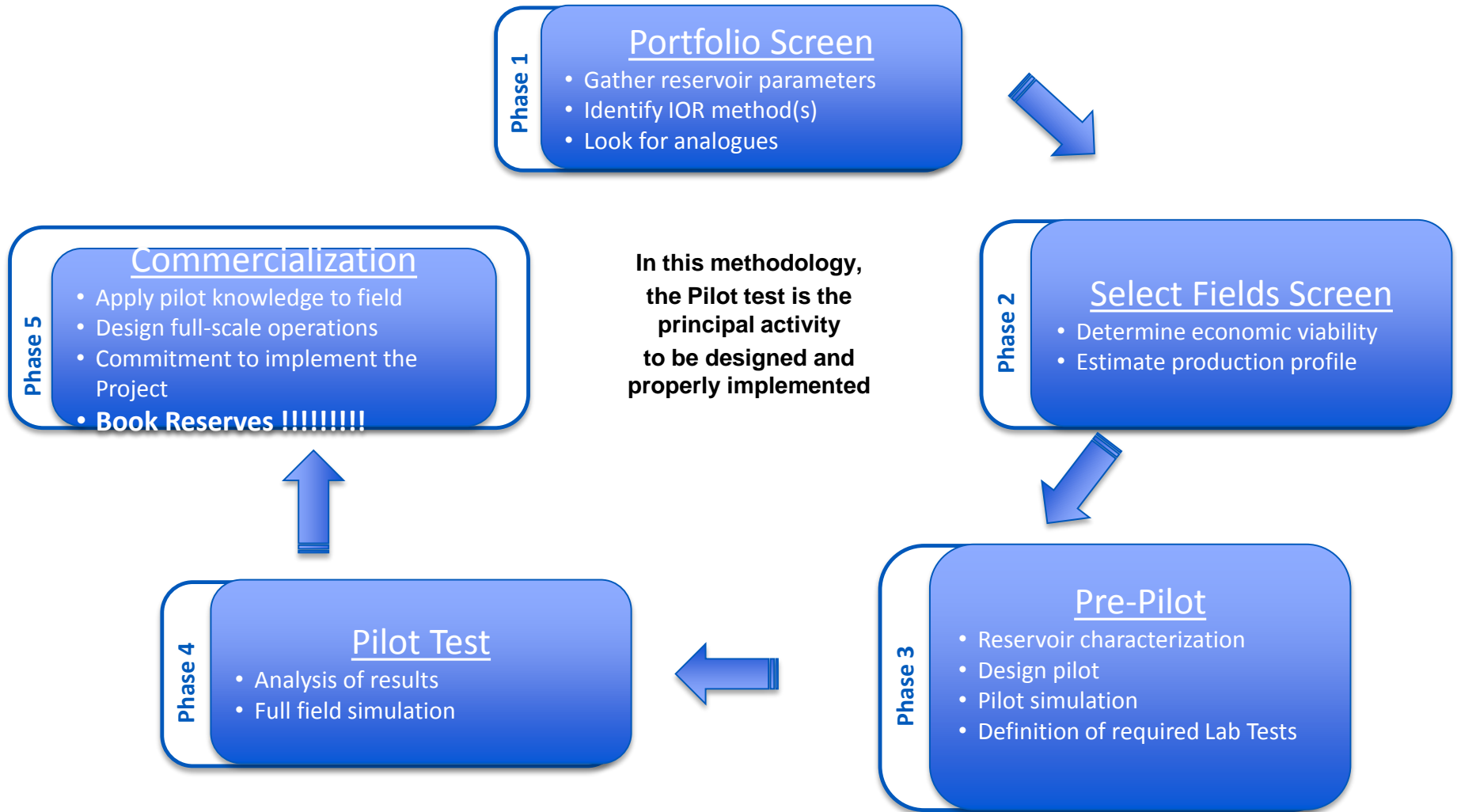


Stages of Exploitation and Recovery Processes



More than “any practice after primary recovery,” IOR means the sequential strategic and systematic combination of secondary and tertiary processes to maximize the economic life and RF of the oil reservoirs

General Methodology for IOR Evaluation and Implementation



Relevance of the Pilot Test

- The PRMS¹ clearly specifies in section 2.3.4, Improved Recovery, the importance of the pilot test for classification of resources into reserves volumes: **"The judgment on commerciality is based on pilot testing within the subject reservoir or by comparison to a reservoir with analogous rock and fluid properties and where a similar established improved recovery project has been successfully applied"**
- It is more specific in the following paragraph: **"Incremental recoveries through improved recovery methods that have yet to be established through routine, commercially successful applications are included as Reserves only after a favorable production response from the subject reservoir from either (a) a representative pilot or (b) an installed program, where the response provides support for the analysis on which the project is based"**

Pilot Test

- A pilot test is a field experiment in which the control and monitoring of input variables is less than in a laboratory scale test, but more than a conventional operation. Most IOR projects are the result of a field-scaled expansion of the pilot test
- Because the PRMS is a set of principles, it does not provide any specific guidance for the design of pilots. Similarly, while the application guidelines document discusses the uses of pilots, there are no details on the criteria to be considered when designing and implementing a pilot
- There are many instances in which pilots fail to achieve their stated goals because of poor design

General Recommendations for Pilot Test Design and Implementation

General Recommendations for Pilot Test Design and Implementation

- 1. Definition of Objectives**
- 2. Characterization of Pilot Area**
- 3. Location of Pilot Area**
- 4. Observation Wells**
- 5. Operating Condition of Wells**
- 6. Baseline Establishment**
- 7. Data Gathering**
- 8. Analysis of Results and Scaling**
- 9. Economic Analysis**
- 10. Reserves**

1. Definition of Objectives

Before beginning the design of the pilot, the objectives should be clearly defined. A pilot test should be designed to fulfill the purpose of gathering information about parameters or key variables that are considered important for understanding and modelling the process mechanisms. Some such factors are mentioned below:

- Microscopic displacement efficiency (ability to reduce residual oil saturation)
- Volumetric displacement efficiency (capacity for the displacing fluids to contact and mobilize the oil towards production wells)
- Interactions between the displacing fluid and the rock and reservoir fluids
- Ratio of injected to produced fluids
- Injectivity into the formation
- Recovery factor
- Operational issues
- Potential risks for full field implementation
- OPEX and CAPEX

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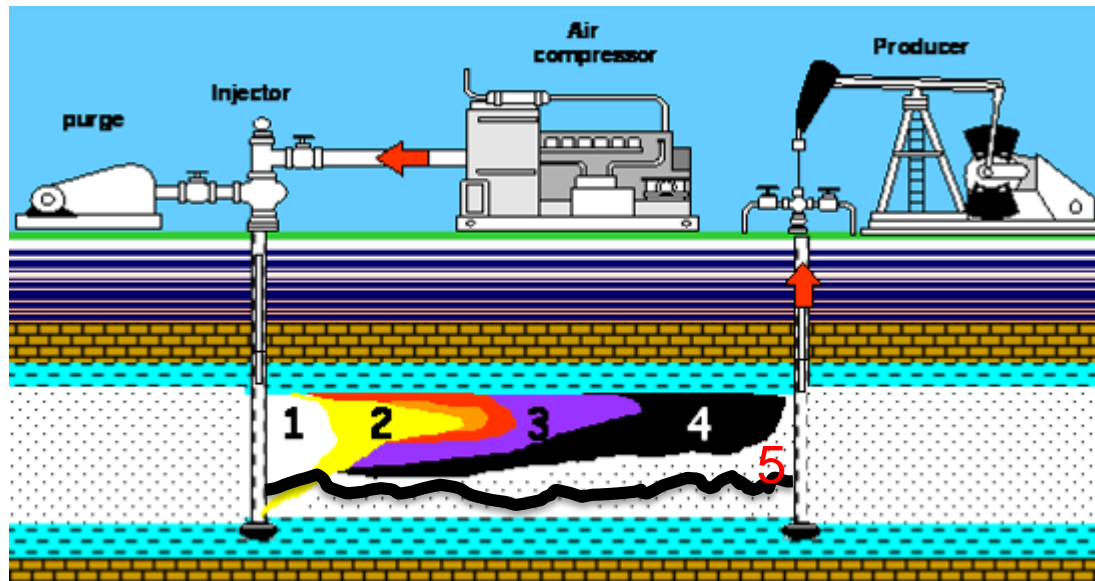
2. Characterization of Pilot Area

- Many times the failure of an IOR/EOR process implementation has been ascribed to the technology, but a deeper analysis shows that the main cause has been a misunderstanding of the geological and petrophysical complexities of the reservoir
- Special attention should be given to a proper geo-technical description of the pilot area in order to build an accurate geological and fluid-dynamic model of the actual condition of reservoir to be evaluated

An Anecdote ... from somewhere in the World ...

A pilot test of a fire flood was started in 1964 (with one injector), and operated successfully for 8 years ...

... later, another operator tried to expand the project in a sector towards the west of the pilot area without a previous formal reservoir study. Air was injected in one well, the fire front (number 2 in the figure) hit a fault (number 5 in figure) erupting in a producer well. There is no written report about this incident ... but it is believed the well is still in orbit around the earth ...



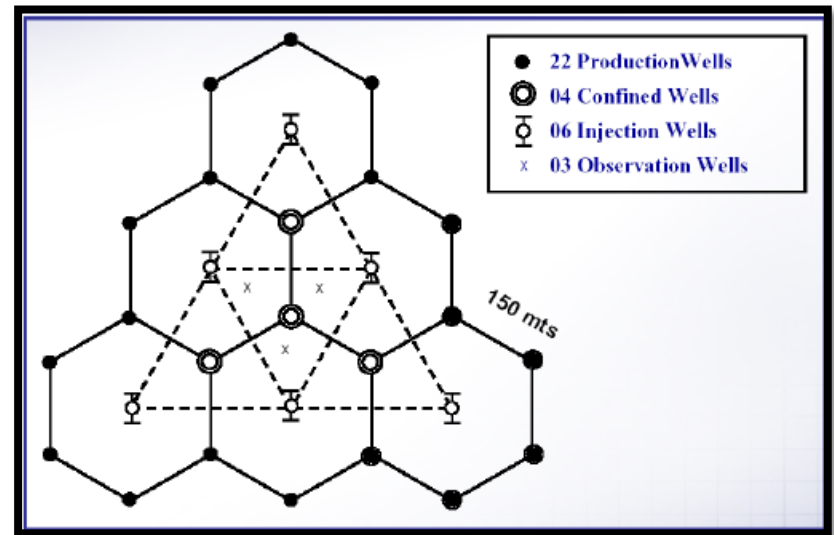
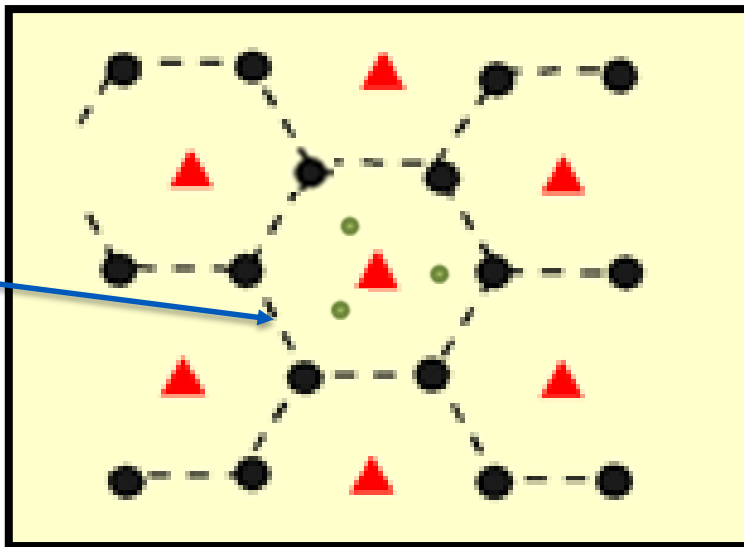
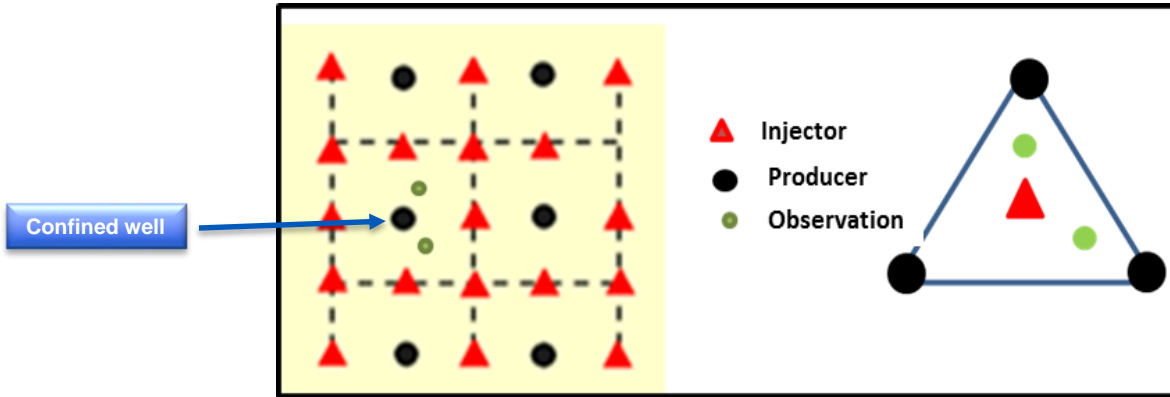
3. Location of Pilot Area

- The pilot area should be “representative of the field¹”, implying a compromise between those more prolific and less favored areas, the first giving too optimistic results and the second potentially leading to failure of the process
- General guidance is that “reservoir properties must, in the aggregate, be no more favorable in the analog than in the reservoir of interest”
- It is common practice to use pattern architecture “to confine” wells or patterns in order to insulate from external “noises” the area under study

4. Observation Wells

- Execution of a pilot test is a compromise between the need for information in the shortest possible time and the representativeness of the results.
- Observation wells provide important information in a relatively short time (months rather than years) and sometimes continuously (monitoring temperature, pressure or other parameters in real time), so they are commonly used in pilot testing of improved and enhanced recovery processes.
- They are usually positioned around 30% to 50% of the injector–producer distance for vertical wells in order to capture information on the movement of the front of the injected fluid

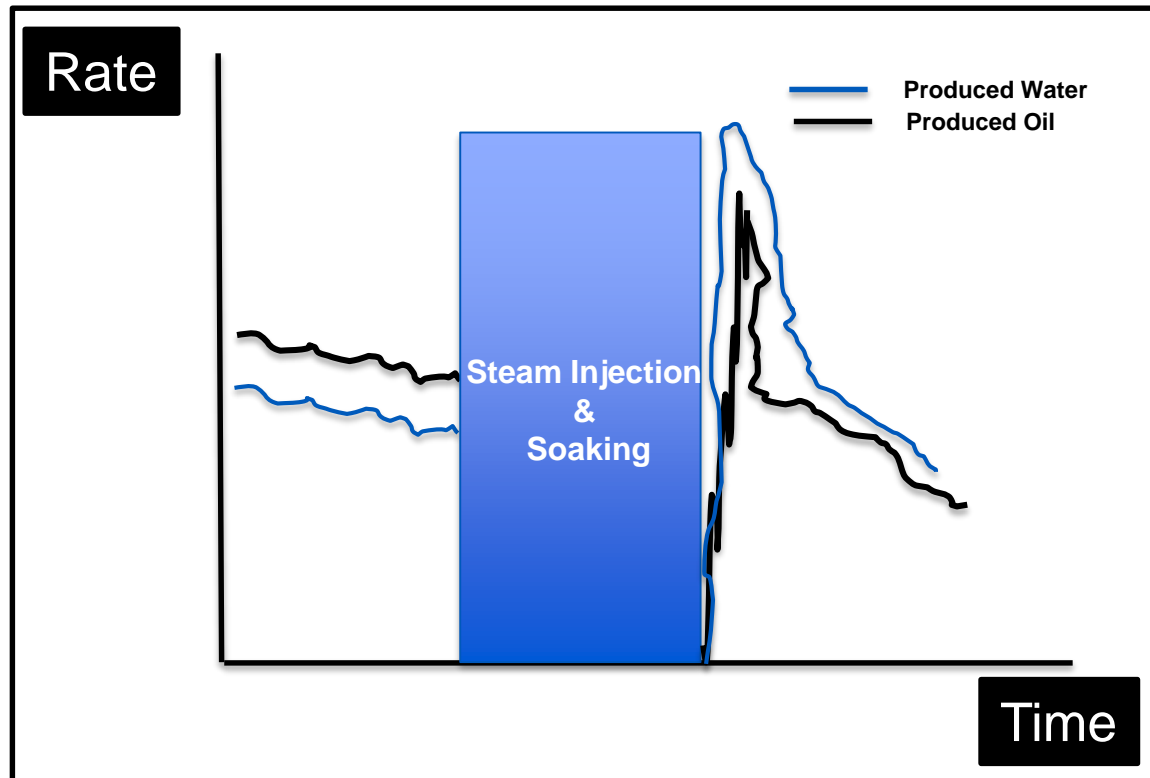
4. Observation Wells (cont.)



5. Operating Condition of Wells

A defective producing well can have disastrous consequences on the rate of recovery. A defective injector well could yield an erroneous interpretation of injectivity and/or result in failure of the pilot test. For these reasons it is crucial to ensure proper operating condition of each of the wells before starting the pilot

Pilot test of CSS (Cyclic Steam Stimulation) in one well:
The steam injectivity was insufficient due to operational problems in well and facilities, no response in production was observed, the pilot failed and reserves could not be allocated



Source: GCA recreation of a real case

6. Baseline Establishment

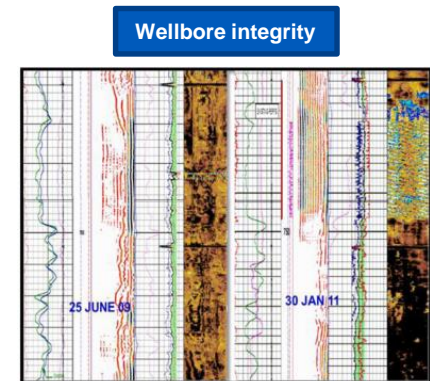
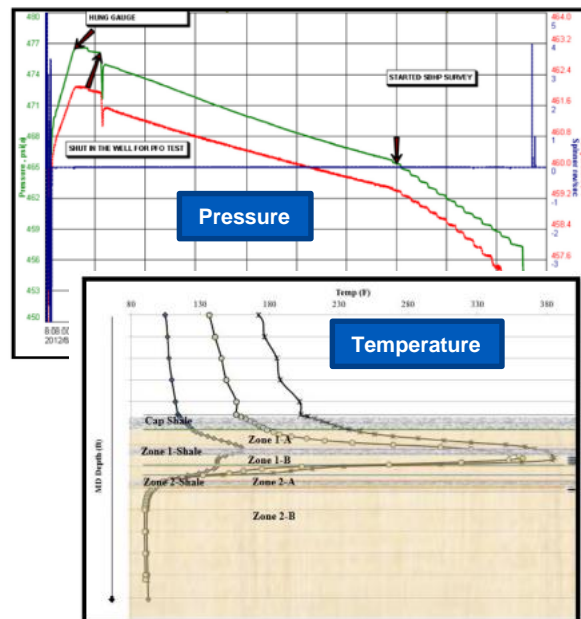
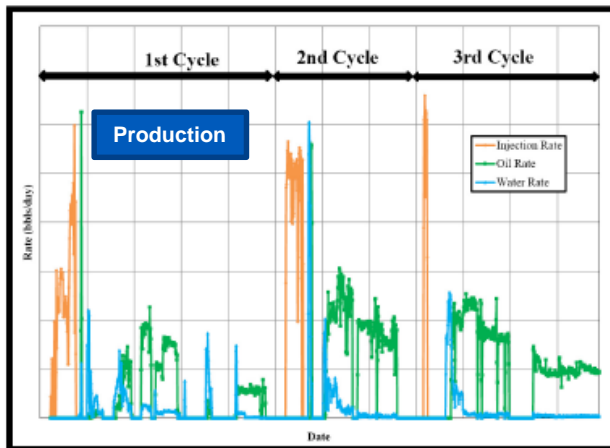
It is imperative to establish with sufficient clarity a production base line before starting the process implementation in order to permit the subsequent interpretation of the test (many pilot tests fail in this point). Some items to consider are:

- Rates of production / injection
- Artificial lift systems
- Workovers or any other intervention in the wells under study
- Operational condition of surface facilities such as compressors, pumps, valves, etc.

In general, any alteration in the steady state of the system means complications in the eventual interpretation of pilot results

7. Data Gathering

- The operator should pay careful attention to the collection and analysis of all necessary data, as this is the ultimate goal of the test.
- The paper prepared by the Kuwait Oil Company and published by the SPE in 2016¹ is a good reference. The work describes the surveillance of the main parameters like temperature, pressure, saturation etc., for a Cyclic Steam Stimulation process (CSS) pilot in a heavy oil reservoir in Kuwait



1. Source: Shaikha Al-Ballam, et al, Kuwait Oil Company (KOC). "Well Surveillance Operation and Data Analysis in Thermal Viscous Crude Project in Kuwait-A Case Study. SPE-179058-MS, 2016

8. Analysis of Results and Scaling

- To facilitate the interpretation and analysis of the results, the construction of a numerical simulation model of the pilot area is recommended. The model will be used to design the test and then must be adjusted according to the results for designing the field scale process
- In addition, numerical simulation could not be enough to predict with accuracy complex scenarios, detailed analysis with multidisciplinary groups that integrate information from all sources is required

8. Analysis of Results and Scaling (cont.)

Finally, the design of a pilot test should provide some measure of "result scalability". This is feasible if certain conditions from the pilot test are met by the commercial scale project:

- The fluid and reservoir properties and the values of the main variables are reasonably similar
- The behavior of production and fundamental variables during the pilot test should not differ significantly from those expected or predetermined

9. Economic Analysis

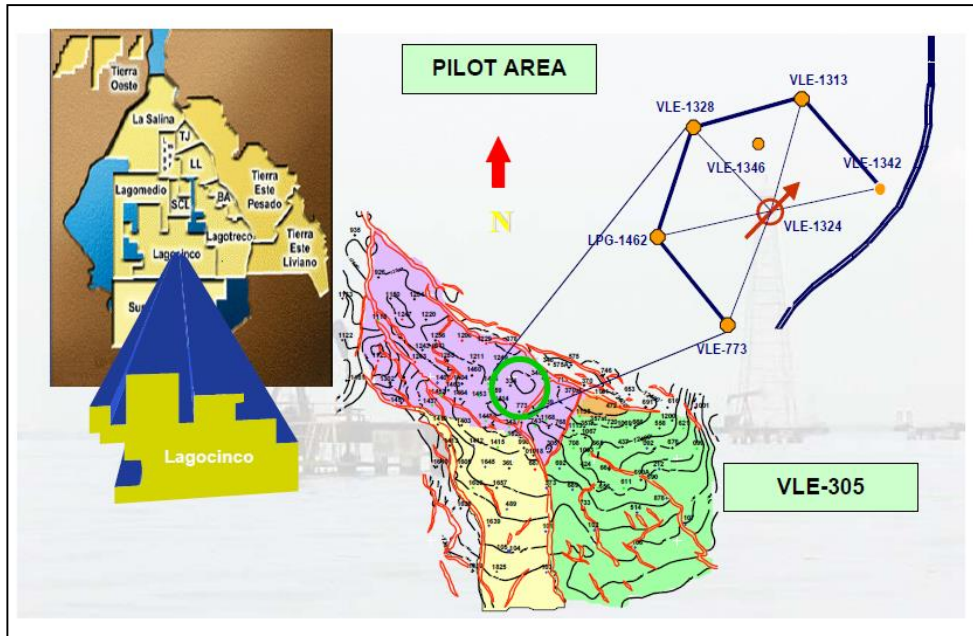
Economic analysis is critical for determining the commercial feasibility of the process under evaluation. It is necessary to identify the critical technical parameters that govern the profitability

A pilot test could end with the conclusion that, while the process can produce more oil, it will result in a negative cash flow

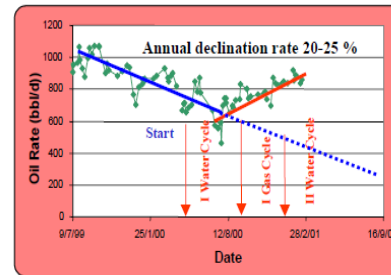
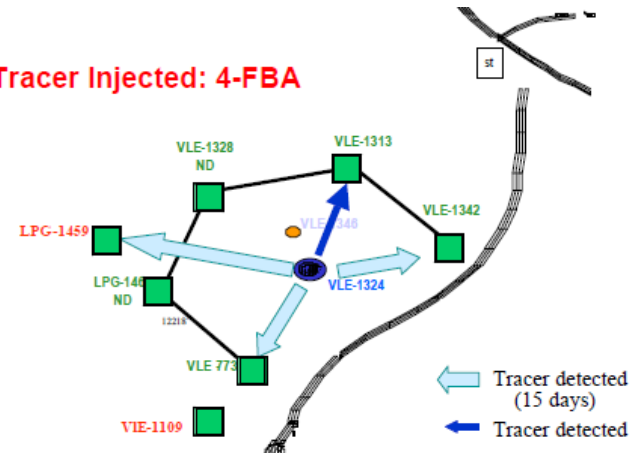
In that case the operator will avoid an expensive investment in the expansion of the process and will have the opportunity to look for other alternatives for increasing the production and hydrocarbon reserves

Example of a Pilot Test

Water-Alternating-Gas Injection (WAG)

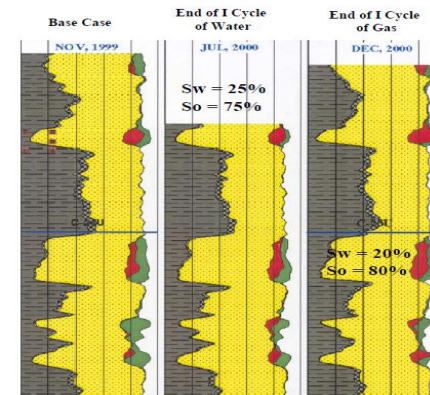


Tracer Injected: 4-FBA



WAG pilot at Lagocinco, Maracaibo Lake Venezuela; fluid, saturations, and production were monitored before and after the application

After the analysis of this pilot test, the operator realized that the process was technically feasible, but the amount of gas required for full field implementation was greater than the availability in the area. It was not possible to assign additional reserves



10. Reserves

Upon completion of the pilot test, most of the questions in relation to the technical and economic feasibility of the IOR process should have been addressed. Volumes associated with the commercial project can be classified from resources to reserves when the appropriate requirements have been satisfied, as noted in the PRMS in section 2.3.4¹:

“Improved oil recovery projects must meet the same reserves commerciality criteria as primary recovery projects. There should be an expectation that the project will be economic and that the entity has committed to implement the project in a reasonable time frame (generally within 5 years; further delay should be clearly justified”.

10. Reserves (cont.)

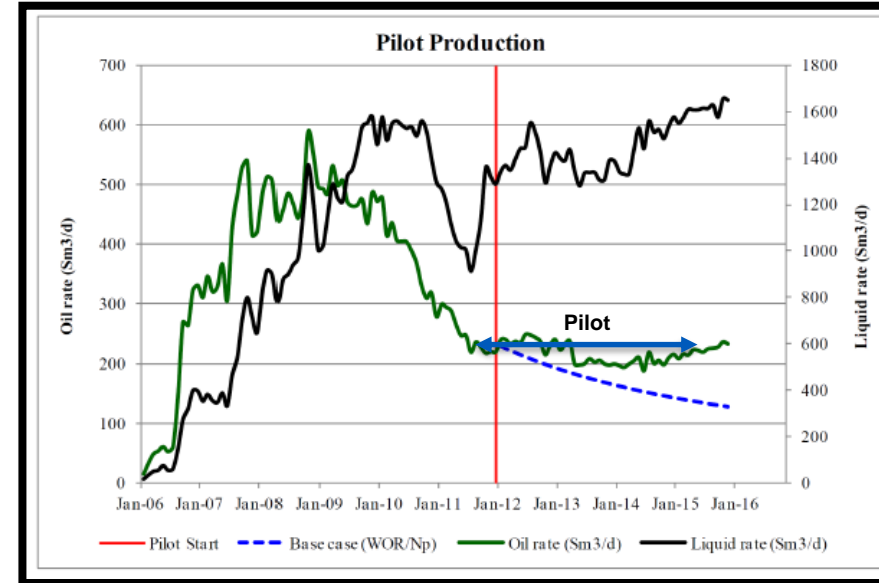
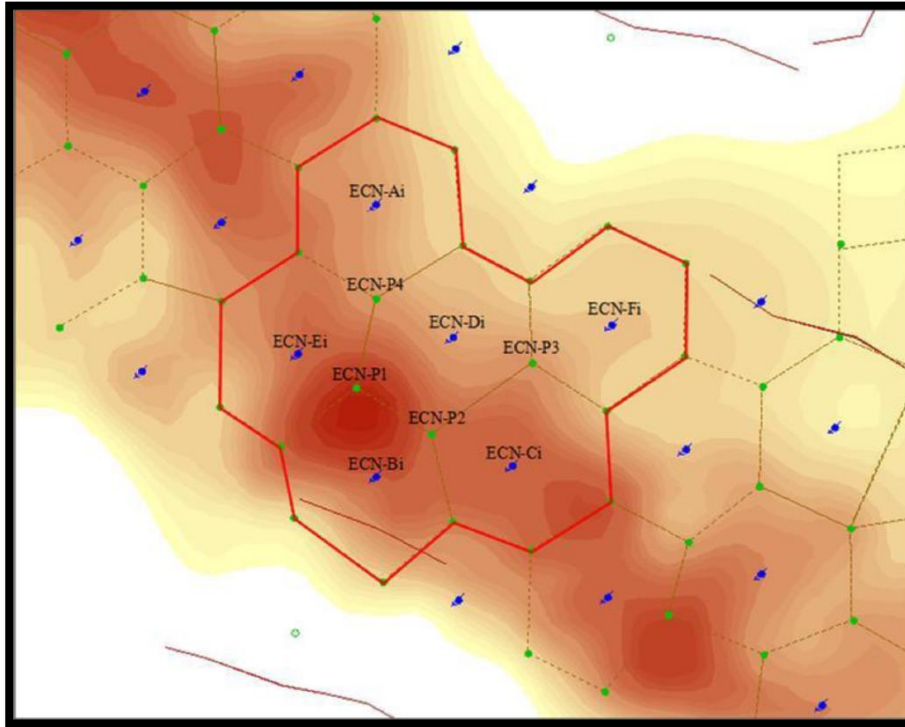
Later in the same section:

“These incremental recoveries in commercial projects are categorized into Proved, Probable, and Possible Reserves based on certainty derived from engineering analysis and analogous application in similar reservoirs”

The pilot test becomes the analog for the rest of the field. However, since the parameters of the field will often differ from those in the pilot area, it is usually appropriate to assign a reasonably certain volume to Proved Reserves with some portion of the projected recovery being assigned to Probable and/or Possible Reserves

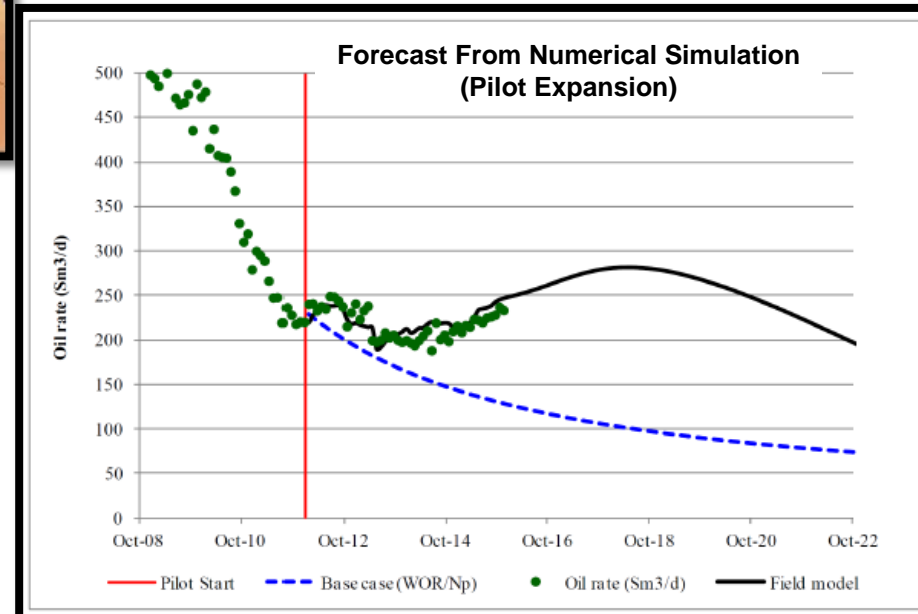
Example of a Pilot Test

Polymer Injection



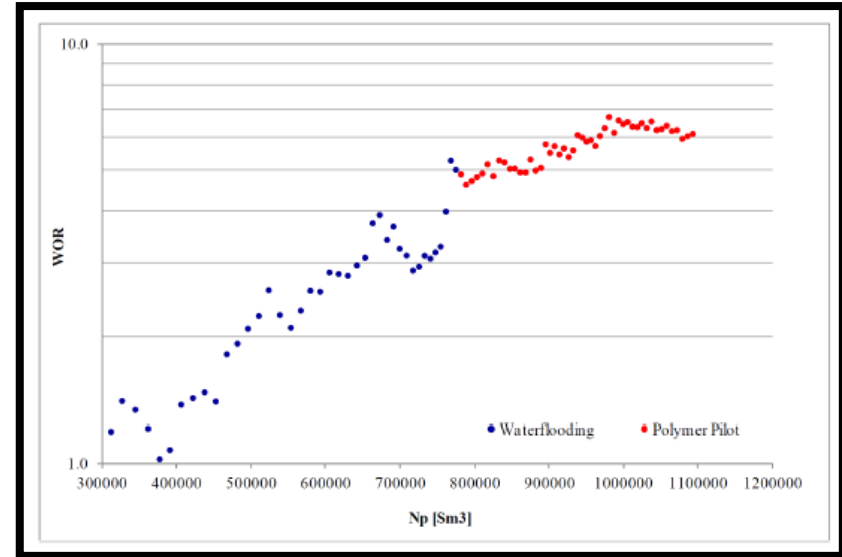
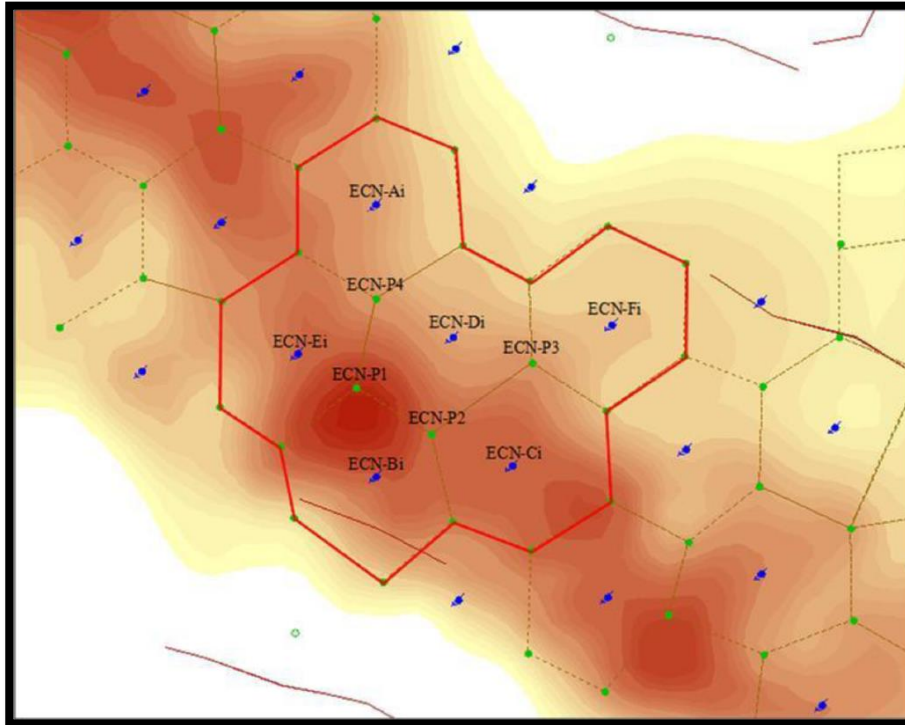
Polymer pilot test in El Corcobo Field, Neuquén Basin, Argentina

The pilot started in 2012; the evaluation finished in 2016

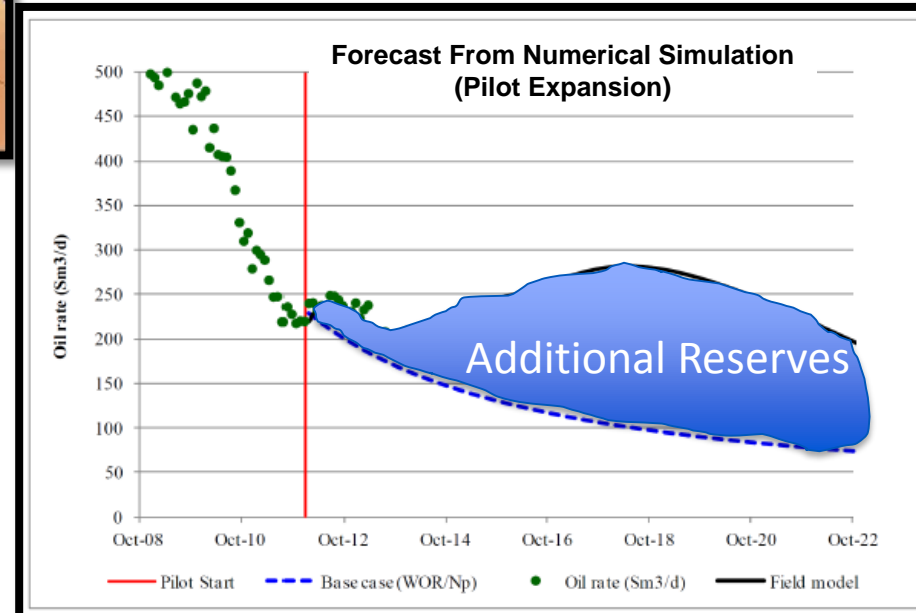


Example of a Pilot Test

Polymer Injection



Thanks to the good designing, operation and monitoring of this field test, the Operator could build a full field development plan with polymer injection, booking a considerable volume of additional reserves



Thank You / Questions?

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