Numerical Simulation of Horizontal Alternate Steam Drive (HASD) for Heavy Oil Fields in the Marañon Basin*

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Abstract

The Heavy oil reservoirs in Marañon Basin in Peru have been exploited for more than 40 years under primary recovery techniques using mainly deviated and horizontal wells with ESP pumps. "Cold production techniques" only accounted for a recovery factor ranging in between 12% and 15 % with a vast potential of remained oil. What is more, high viscosities and heterogeneities affect well productivity, which creates the perfect scenario for the implementation of different thermal recovery methods.

Innovative techniques are highly required in the oil and gas industry to meet the future demand of the hydrocarbon fuels; as a consequence, significant efforts have been deployed on the development of new innovative technologies to increase the oil recovery; Horizontal wells and steam injection are becoming a very important component in the thermal recovery of heavy oil reservoirs; Steam Assisted Gravity Segregation (SAGD) and Cyclic Steam Stimulation (CSS) are two of the most successful technologies worldwide.

Horizontal Alternate Steam Drive (HASD) is a repetitive pattern that uses horizontal wells with equal depth which alternate as producers and steam injectors; the main recovery process is horizontal steam flooding between consecutive wells and is more efficient than the traditional cyclic steam injection to achieve an effective sweep in the vicinity of the producers while decreasing oil viscosity and improving oil drainage.

A conceptual simulation model was built to evaluate production performance and estimate a recovery factor of SAGD and HASD processes in a heavy oil field of Marañon Basin (as compared with cold production); a local-grid-refined sector was used to model the heat transfer process, as well as, oil drainage. Deliverables of the study include a matrix with recovery factors of each development scenario, as well as, some recommendations towards its implementation.

The HASD process looks very promising for a feasibility study with an expected recovery factor between 30 – 40%; this project aims to bridge the gap that Peru has in Thermal Recovery and EOR processes.

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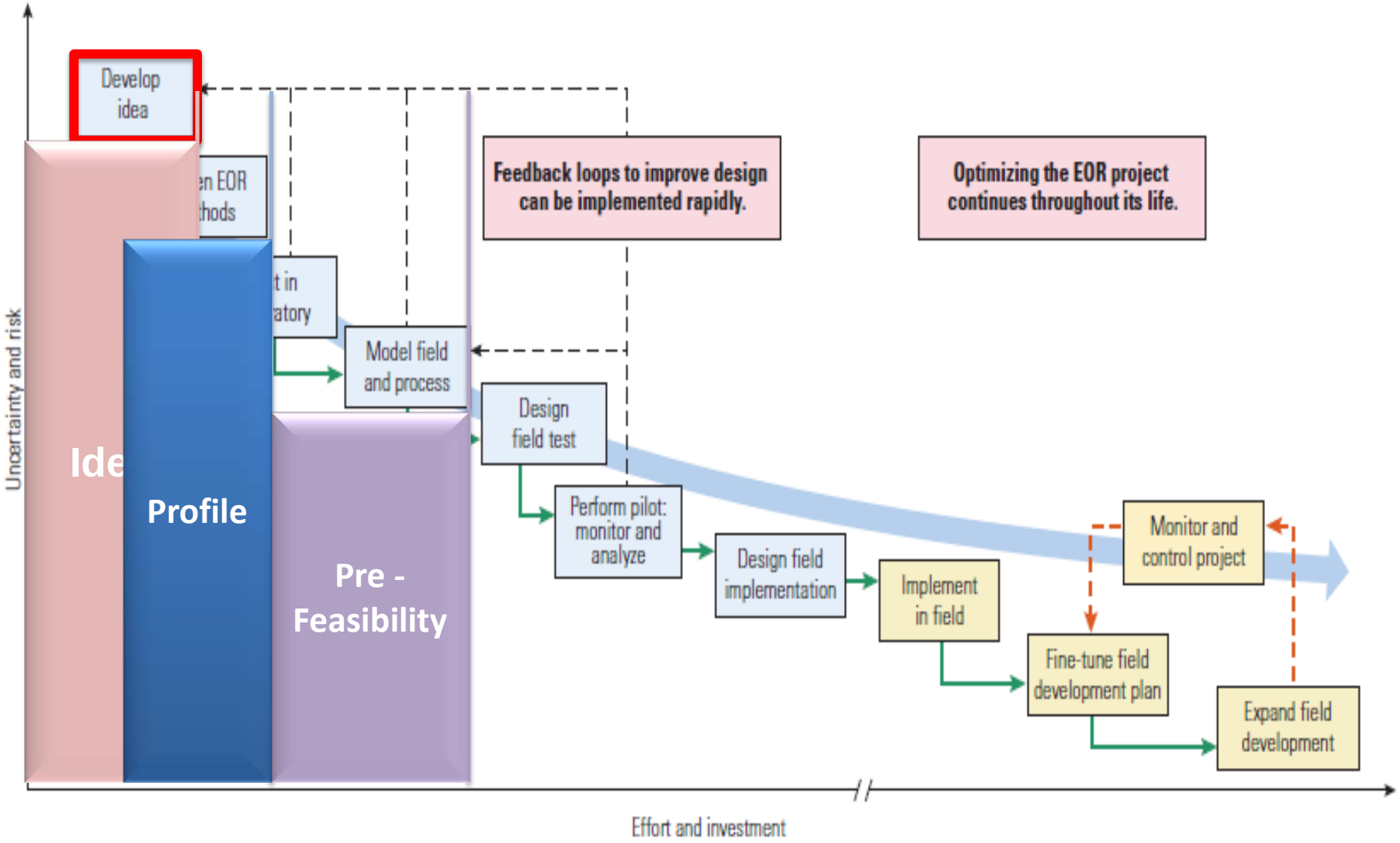
OUTLINE

- Background
- Reservoir Characterization
- Screening Criteria
- Reservoir Model
- Conclusions & Future

BACKGROUND

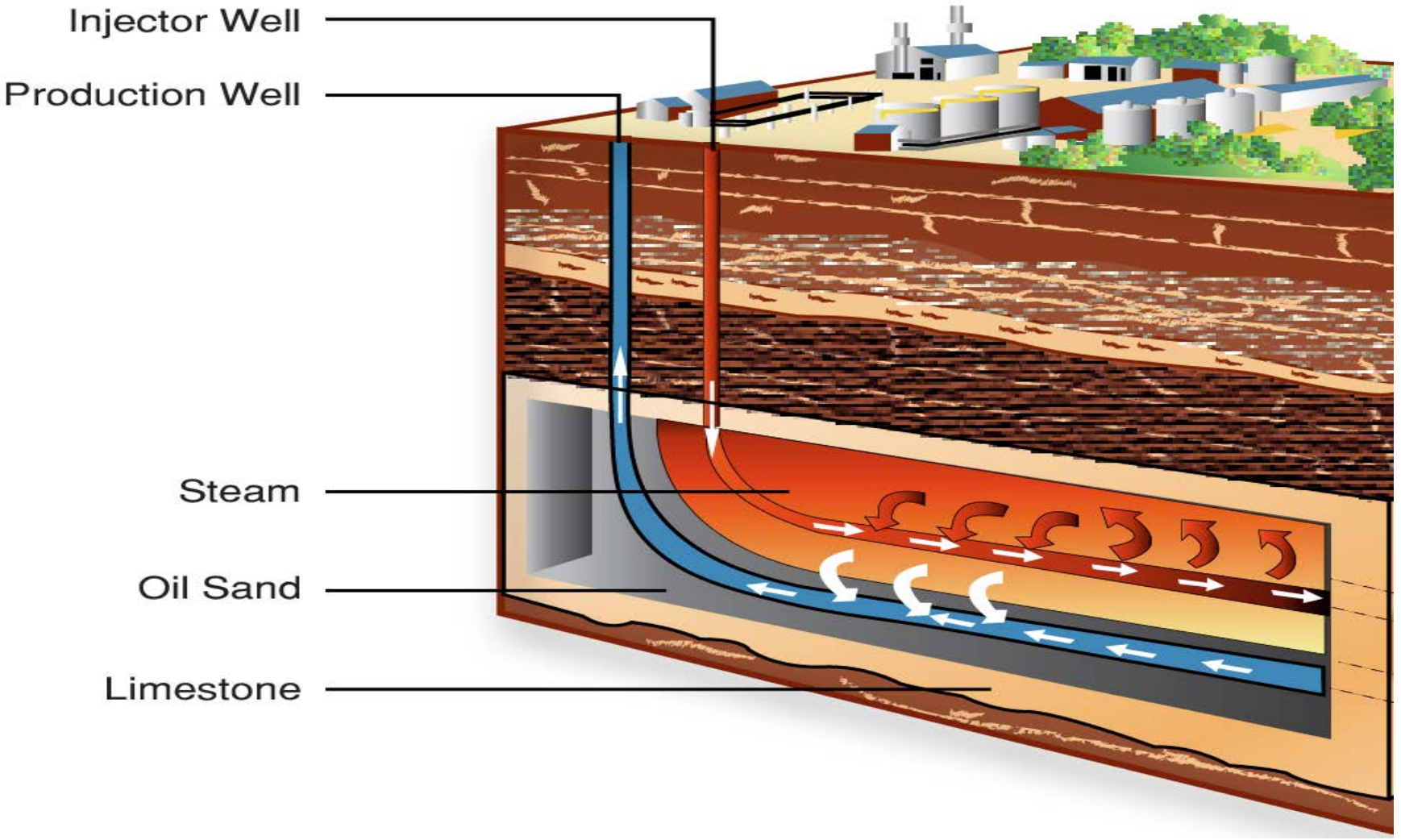
- Heavy oil fields were discovered in 1974.
- Heavy Oil Recovery factor of 14% have been achieved.
- Undeveloped reserves around 1400 MMBO with an API average grade of 13° .
- Deviated and horizontal wells with ESP pumps, workover.
- Improve recovery techniques show us an opportunity to produce it.

WORKFLOW - EOR PROJECT



Source: "Has the time come for EOR?", Schlumberger

HASD PROCESS



HASD

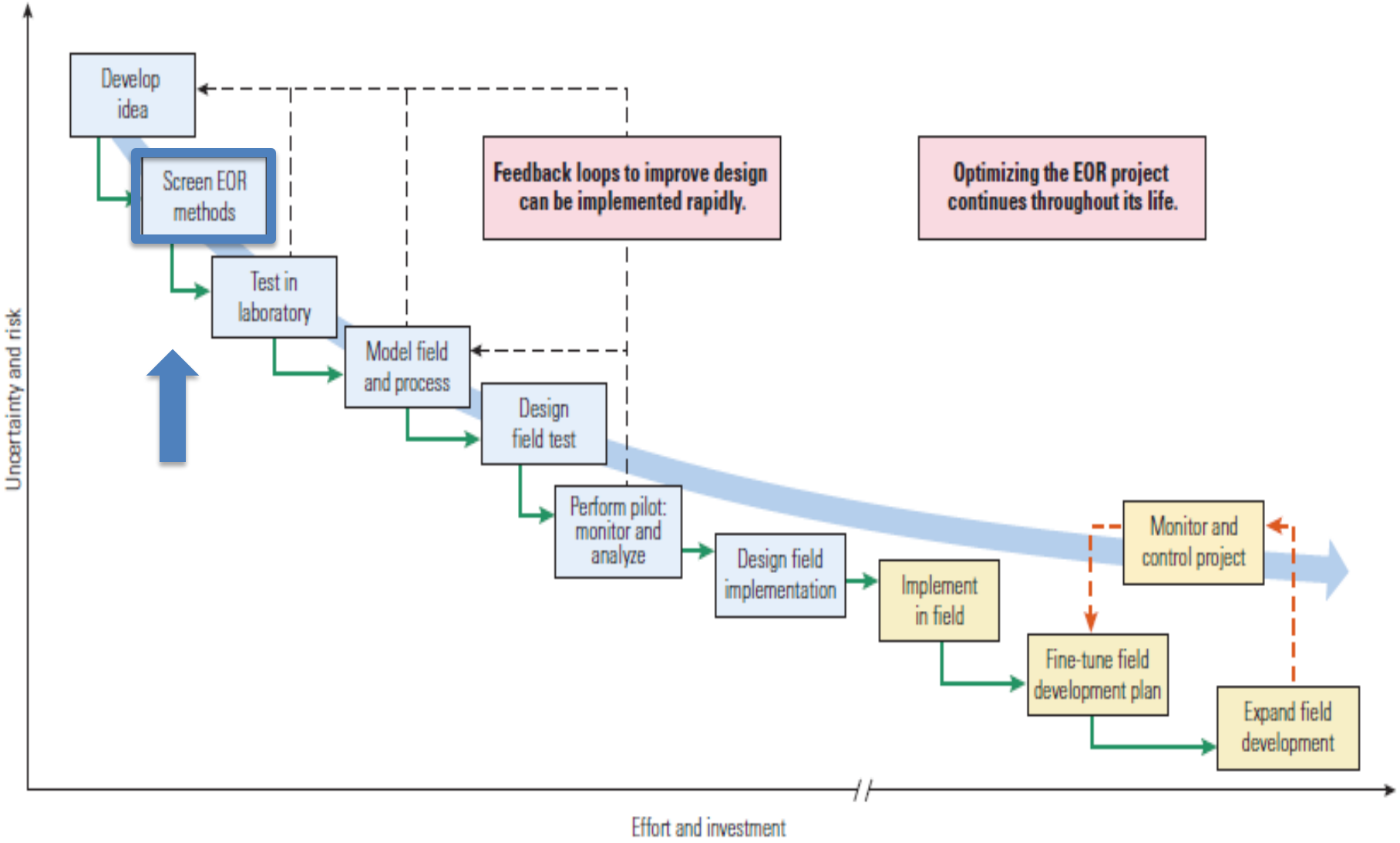
Advantages

- Increasing of drainage area.
- Better manage of thin oil formations of great lateral continuity.
- Better sweep efficiency, reduction of the steam canalization processes.
- Override elimination.
- Reduces water coning.
- Greater crude-oil mobility.

Disadvantages

- High steam quantities, particularly for thin and low-quality oil fields.
- Needs an enormous source of fresh water.
- Limited by oil-well depths, as imposed by steam's critical pressure.

WORKFLOW - EOR PROJECT



Source: "Has the time come for EOR?", Schlumberger

SCREENING CRITERIA

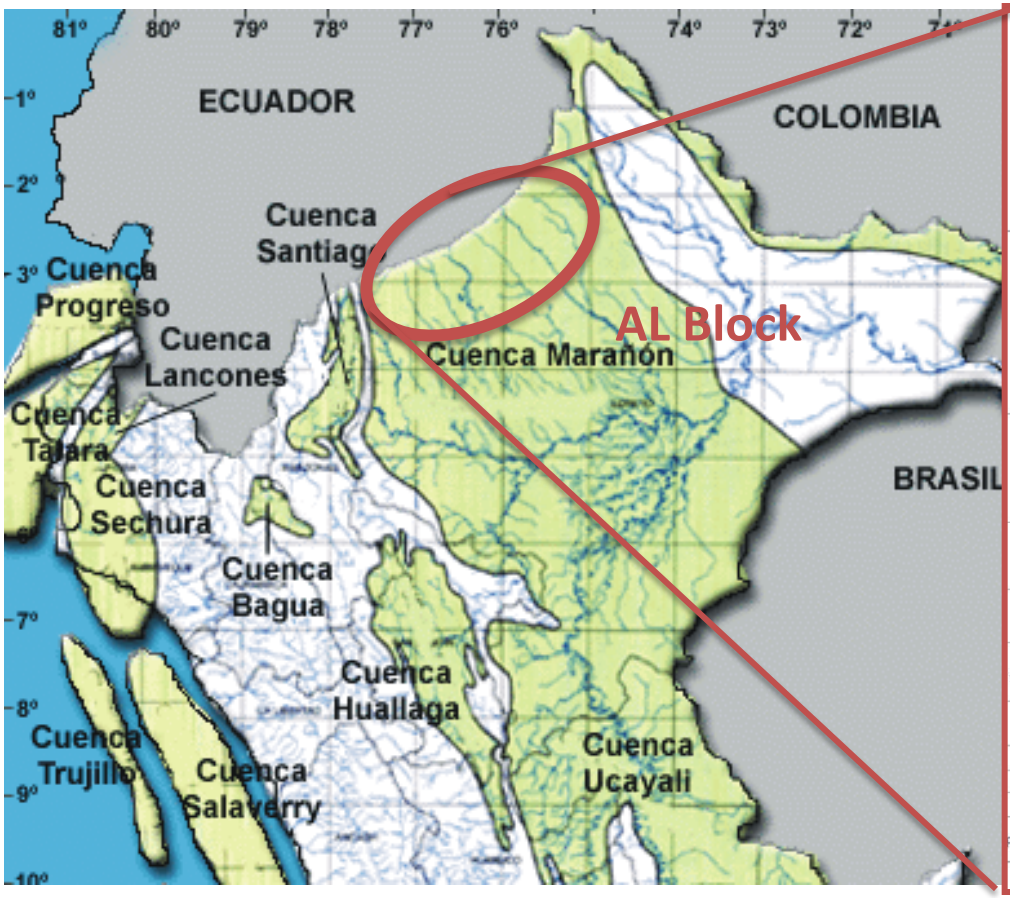
To realize the screening criteria applied to Marañon Basin, the following topics were included:

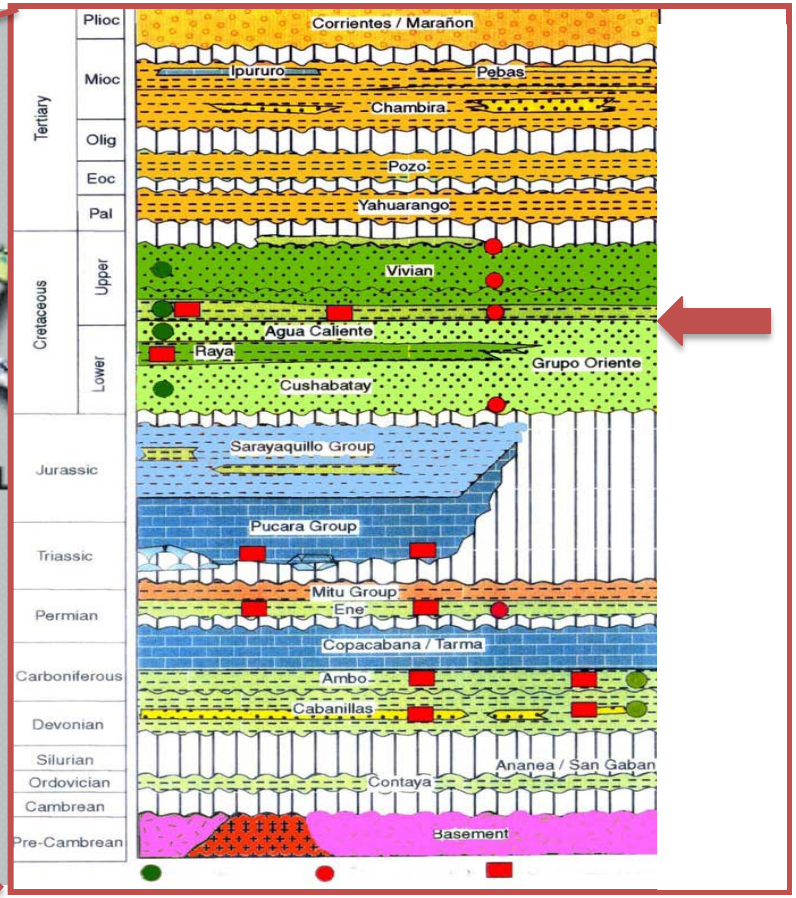
- Reserves.
- Fluid properties
- Reservoir continuity.
- Reservoir quality.
- Surface facilities.
- Expected recovery factors and production rates.
- Environmental sensitivity.

As a result of this complete analysis a matrix was prepared.

METHOD	BASIC CHARACTERISTICS	MAIN SCREENING CRITERIA	TYPICAL RECOVERY FACTORS	WELL
Cold Production	Long horizontal wells and multilaterals, minimal sand produced.	No H_2O. K > 2 D for 1000 cP. K > 0.5 D for 100-300 cP. h > 10 m.	Recovery factor: < 5% μ > 1000 cP, K < 1 D. Recovery factor: 10% - 20% High K reservoirs. Recovery factor : 25% High K, low μ.	Long horizontal wells, high K, little clay, 10-15 years, peak 2000-3500 bbl/d. Low K, short horizontal well, 3-6 years life, 200 bbl/d as maximum.
HASD	A three-stage process. Long horizontal producers, injectors.	Sands low consolidated API < 15; μ > 100 cp -25000 cp; ϕ > 20%; Kv/Kh > 0.6; h > 30 ft; K > 2 D; Z < 5000 ft.	Recovery Factor :50% - 70%. Heterogeneity.	500-3000 bbl/d peak rates, vertical section of the wells with spacing 13 ft - 23 ft between them until 3280 ft of horizontal displacement.

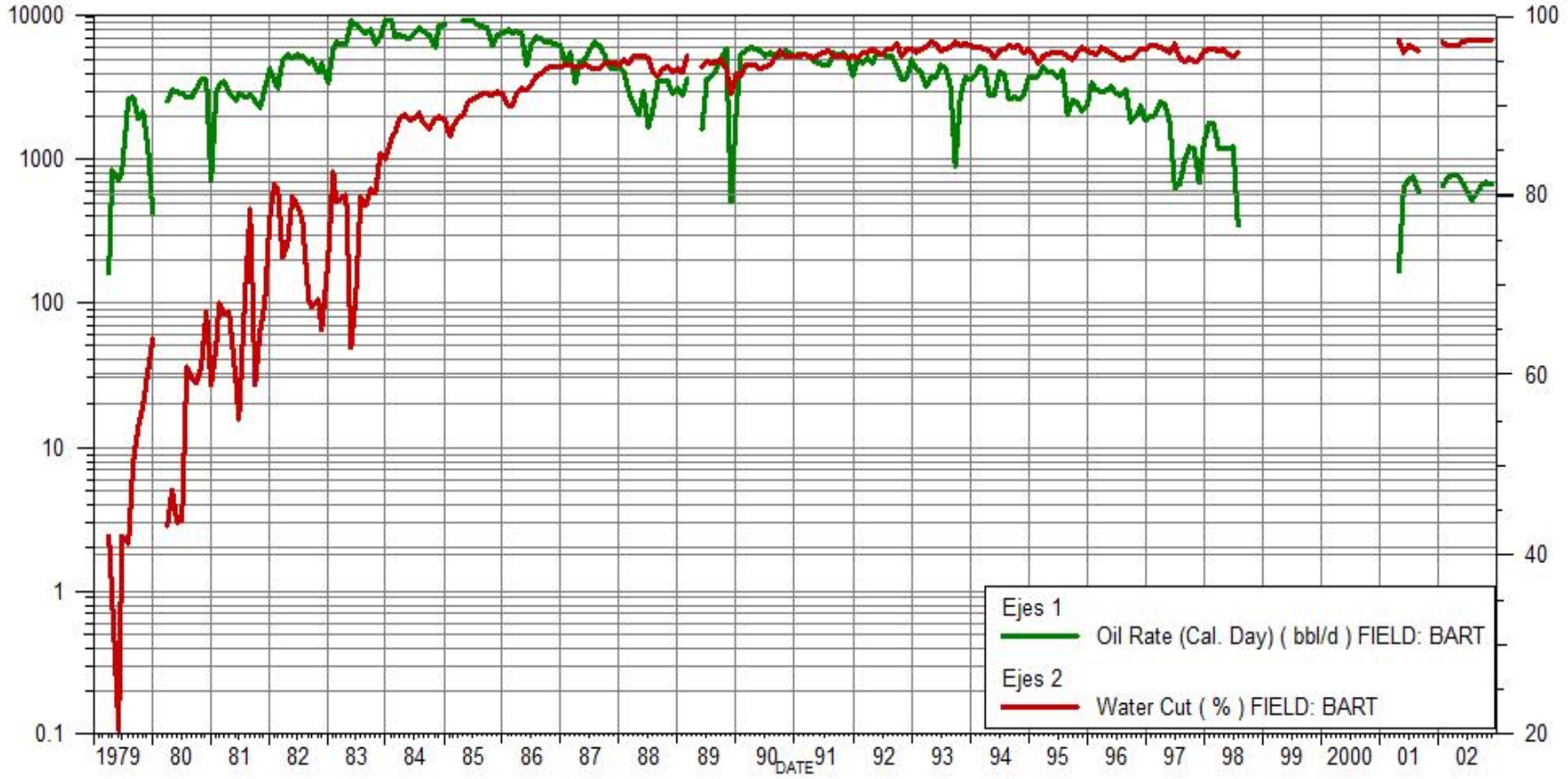
RESERVOIR CHARACTERIZATION



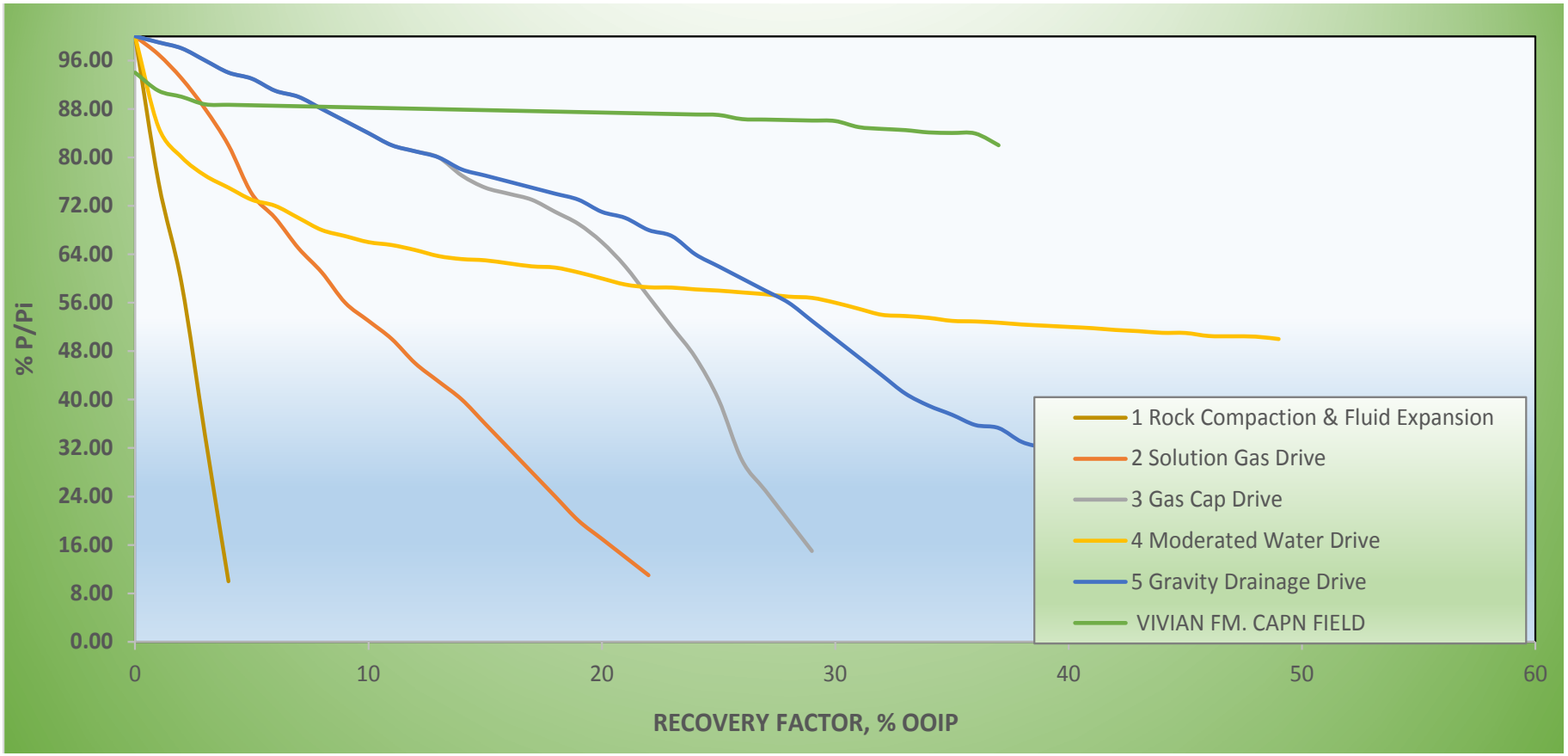


CAMPO	FORMACIÓN	K (mD)	u (cp)	API°	OOIP MMBBO	RF%
YANAYACU	Vivian	500-2000	7.2	19	60.4	**36.5%**
JIBARITO	Vivian	4000	66	10.5	315.4	**20.7%**
JIBARO	Vivian	2000	67	10.5	214.6	**12.1%**
TIGRE	B. Terciario	2500	85	11	25.4	**0.0%**
BARTRA	B. Terciario	3000	78	11.5	84.1	**17.8%**
BARTRA	Vivian	3000	75	11.5	154.3	**10.0%**
SAN JACINTO	Vivian	2000	71	11.5	495.8	**8.3%**
SAN JACINTO	Bs. Chonta	2000	81	14.5	93.6	**0.2%**

TYPICAL PRODUCTION CURVE - MARAÑON BASIN



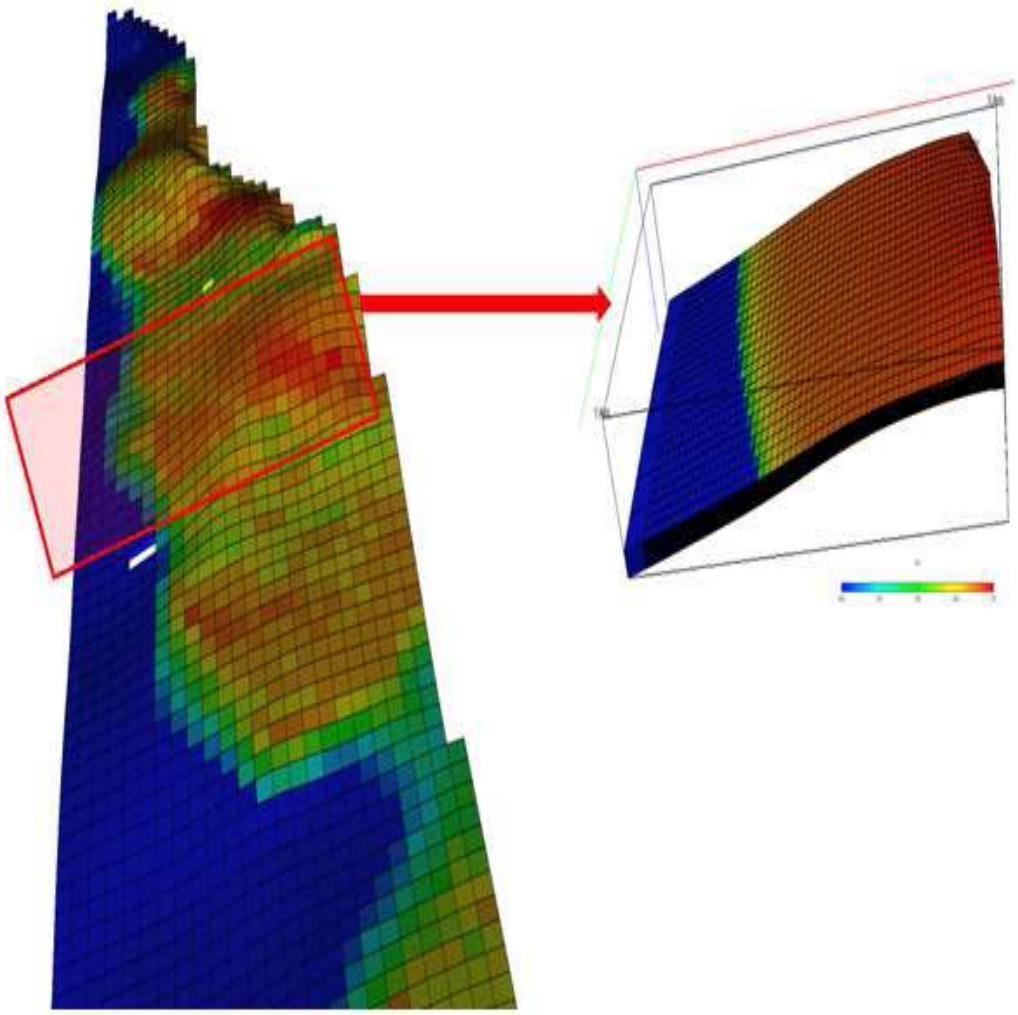
STRONG WATER DRIVE MECHANISM - MARAÑON BASIN



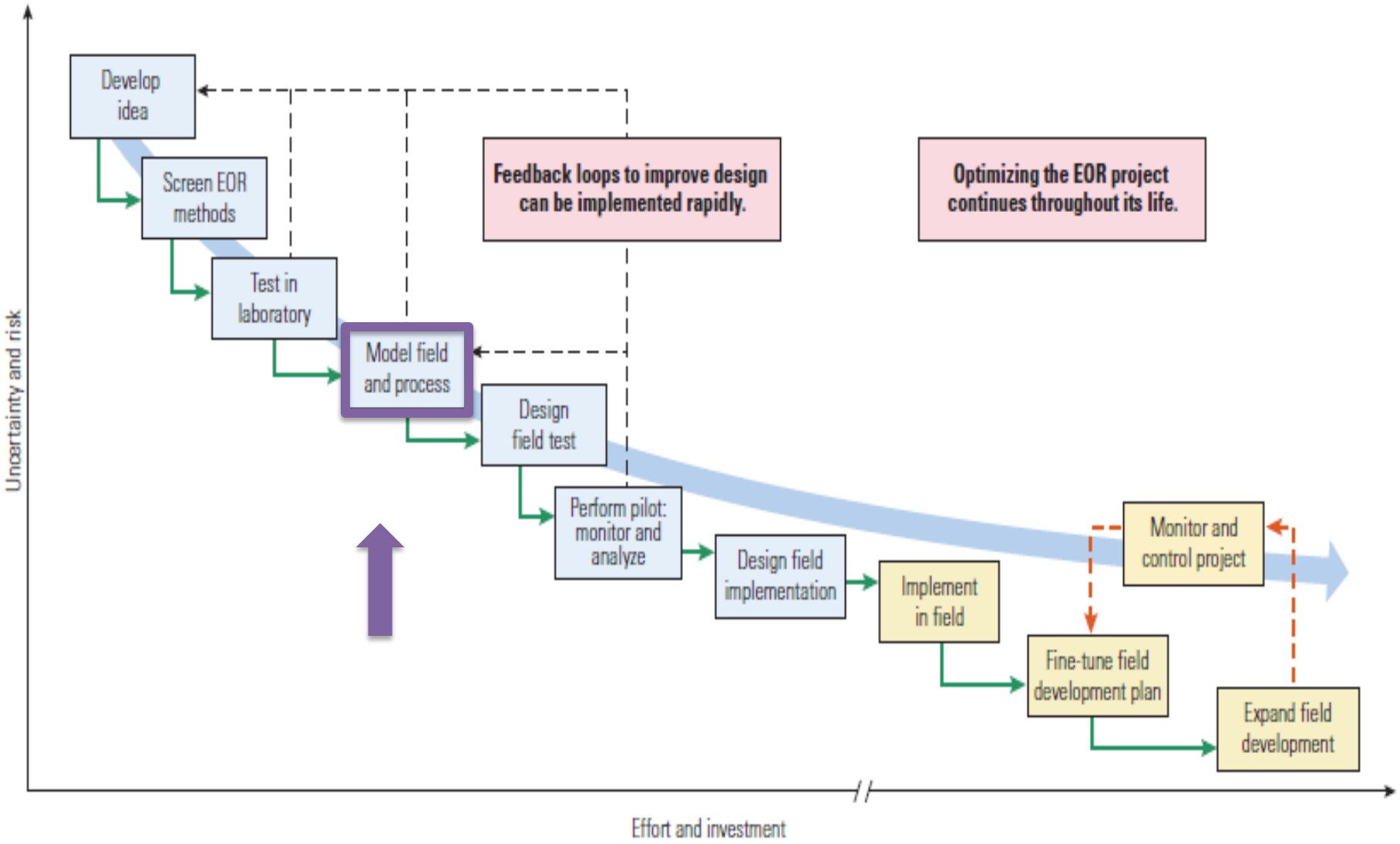
Two kind of strong water drive mechanisms have been identified; flank water encroachment is predominant over bottom drive.

RESERVOIR CHARACTERIZATION

Reservoir Formation	Vivian
Depth	4500 ft
Permeability	5.6 D
Net Pay	38 ft
Porosity	18 % - 20 %
Reservoir Pressure	2400 psia
Temperature	195 F°
API @ 60 F°	13.2
Oil viscosity @ P_{res}	121 cp



WORKFLOW - EOR PROJECT



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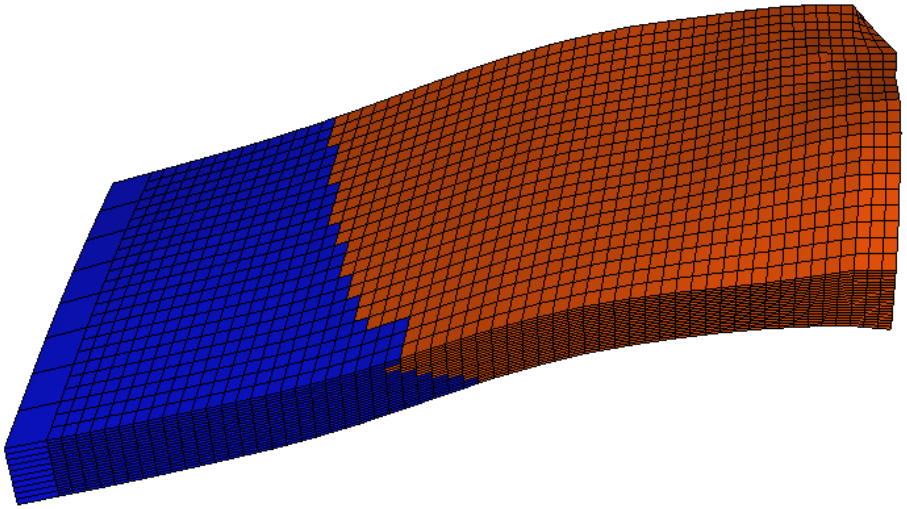
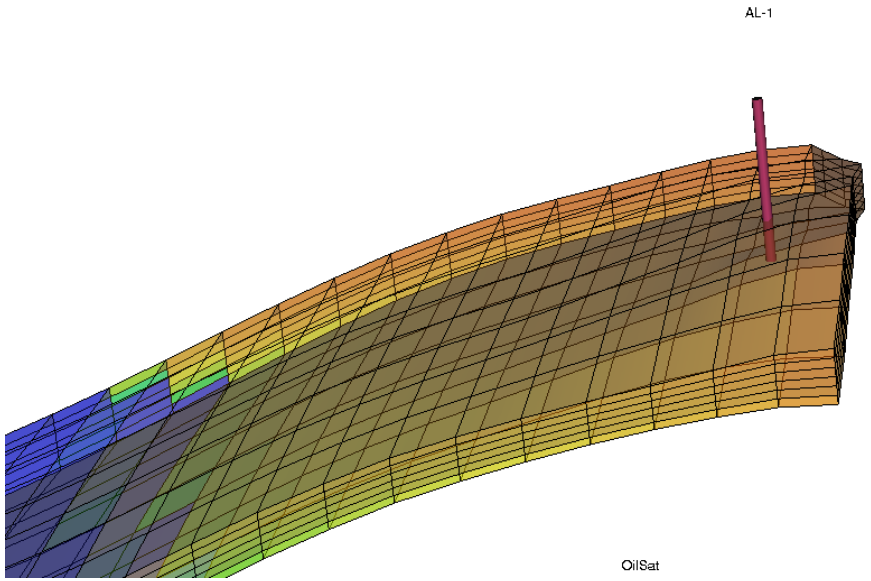
RESERVOIR MODEL

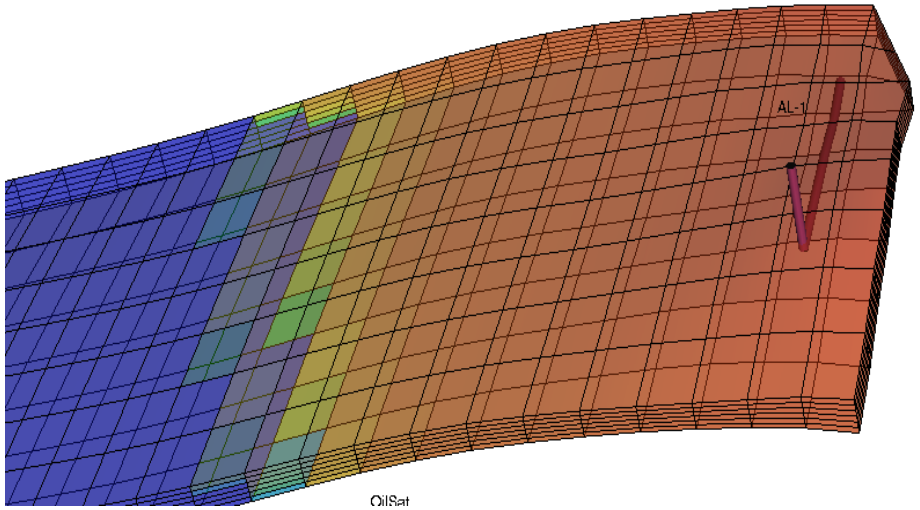
PARAMETER	MODEL CHARACTERISTIC
GRID	20 x 8 x 10 - Refining of 3 to 1 over the main area
PVT	One Region for Vivian
CORE DATA	Three saturation functions, initial water saturation, permeability, porosity and Kv/Kh were taken from core data.
AQUIFER	Carter-Tracy, porosity of 25%, permeability of 4 Darcy, depth of 4700 ft.
MAIN CONSTRAINS	Steam Quality of 70%., Maximum Oil Rate 1200 STB/D, Minimum Oil Rate 50 STB/D, Maximum Liquid 4500 STB/D, Maximum Water Cut 98%, Years of simulation: 20 years

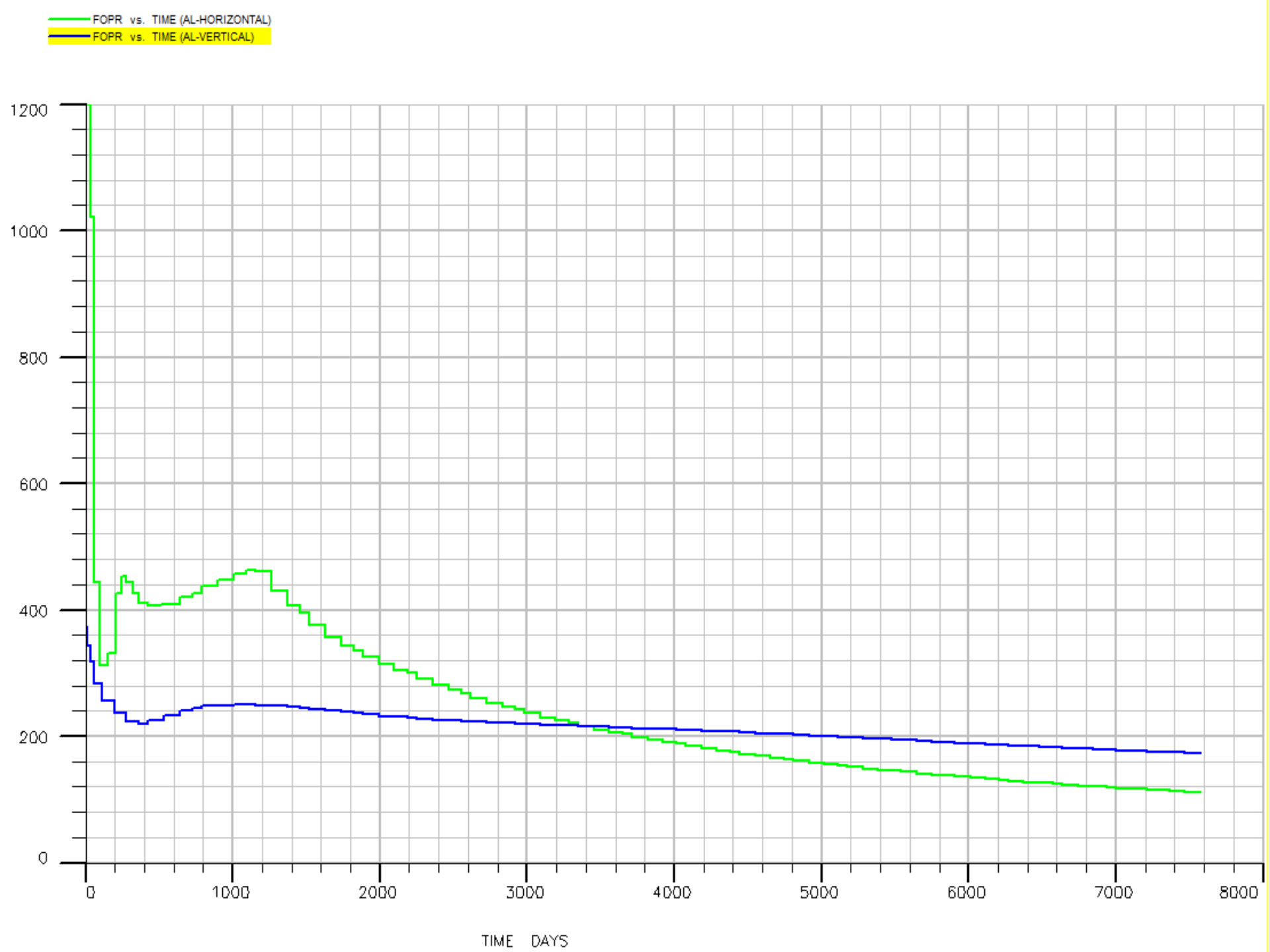


SENSITIVITY ANALYSIS

CASE	COMMENTS
VERT	26 ft Perforated
HORIZONT	Length 1200 ft

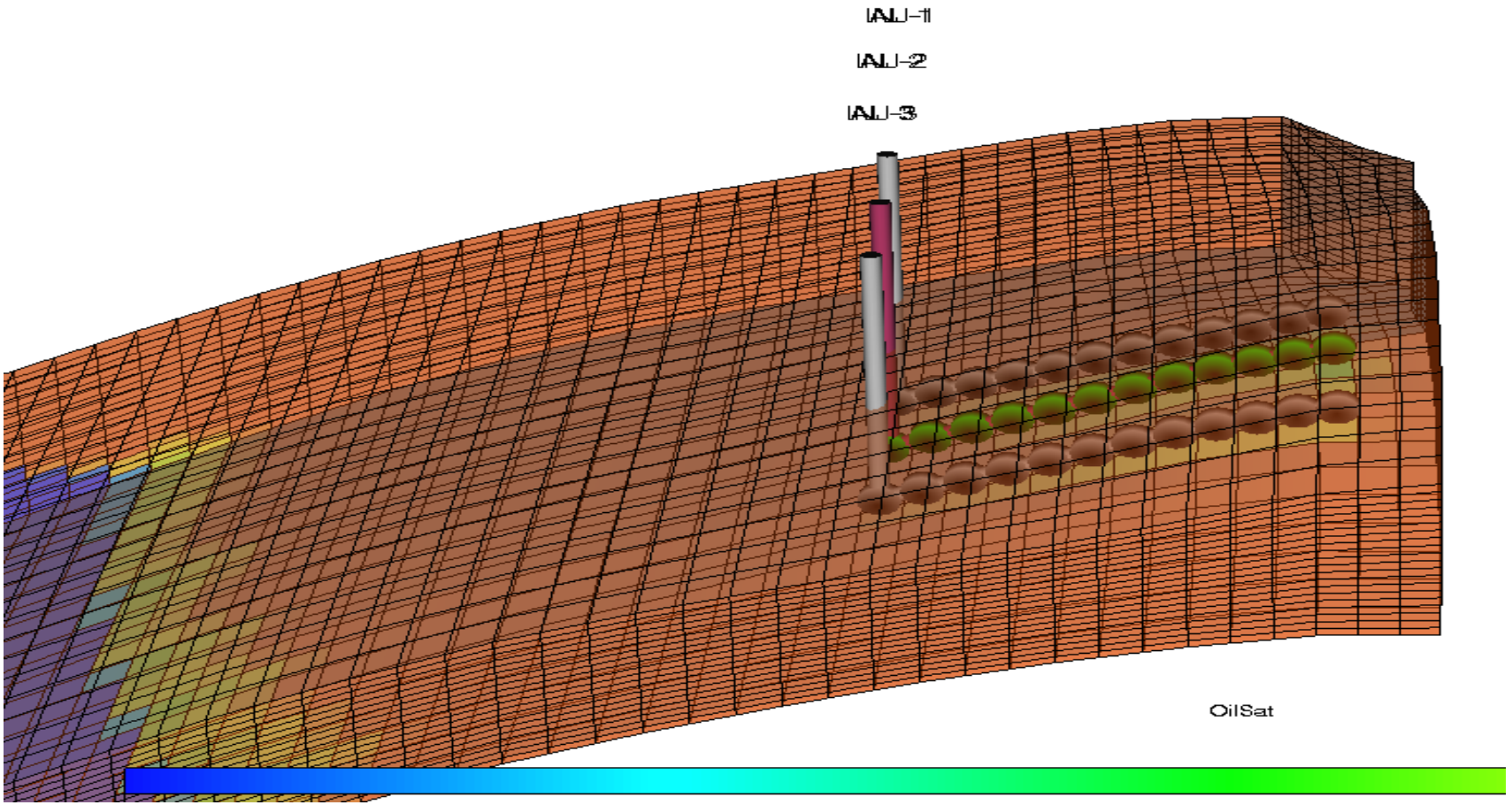


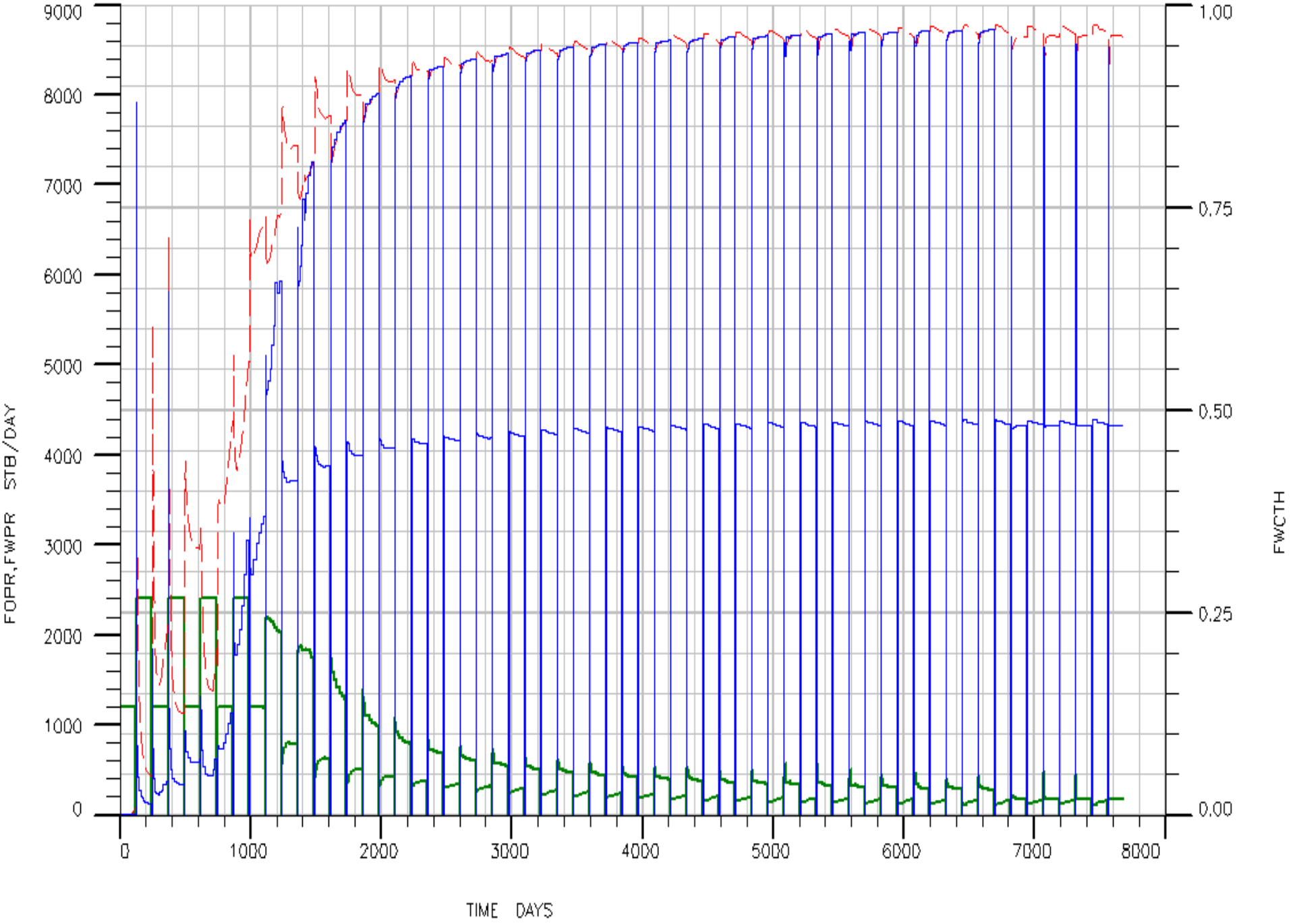



FOPR vs. TIME (AL-HORIZONTAL)
FOPR vs. TIME (AL-VERTICAL)
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
8000
TIME DAYS

SENSITIVITY ANALYSIS

CASE	TEMPERATURE (F°)	INJECTION RATE (BLS/D)	COMMENTS
HASD-3	760	400	Two Horizontal Producer well - One Horizontal Injection well / Alternate, Length 1200 ft




9000
8000
7000
6000
5000
4000
3000
2000
1000
0
FOPR,FWPR STB/DAY
1.00
0.75
0.50
0.25
0.00
FWCTH
0
1000
2000
3000
4000
5000
6000
7000
8000
TIME DAYS

RECOVERY ANALYSIS

CASE	PARAMETERS	FOPT (MSTB)	FWPR (MSTB)	FWCT	INCREMENTAL (%)
VERT	Cold Production	1.1	10.48	0.8676	-
HORI	Cold Production	2.4	27.30	0.9182	118%
HASD 3	Thermal Production	4.55	39.24	0.9606	314%

CONCLUSIONS & FUTURE

- As it was expected according to screening criteria matrix, HAGD appears to be a good alternative to develop heavy oil resources of Block AL.

- Wells located at the top of structure can be selected for this technology while others located at the flank may be used for watering out.

- A further detailed feasibility study should be recommended for an integrated development plan.

- Downhole steam generators, ICD could improve the performance of the project..

CONCLUSIONS & FUTURE

- Heavy Oil represent a complex problem, higher cost, but necessary
- Long-term investment/good planning.
- Different economic models
  - ✓ Better incentives/ low royalties
  - ✓ Long-term commitment
  - ✓ Multiple investors

HEAVY OIL

Should NOT be taken lightly !!!

THANK YOU

QUESTIONS?