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Open Hole Gravel Packing: New Trends and What We are Doing to Overcome the Challenges

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Petrobras

Society of Petroleum Engineers
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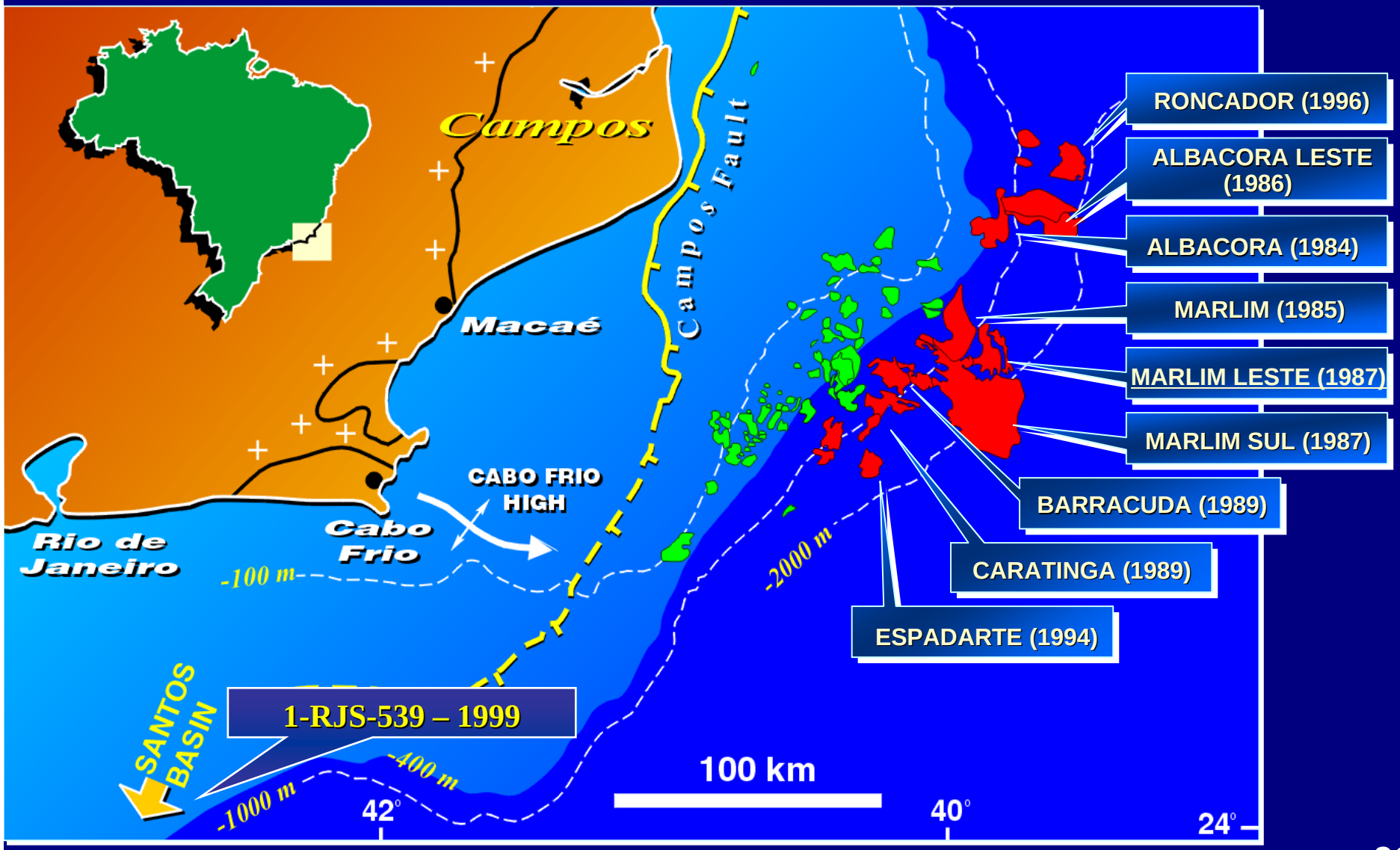
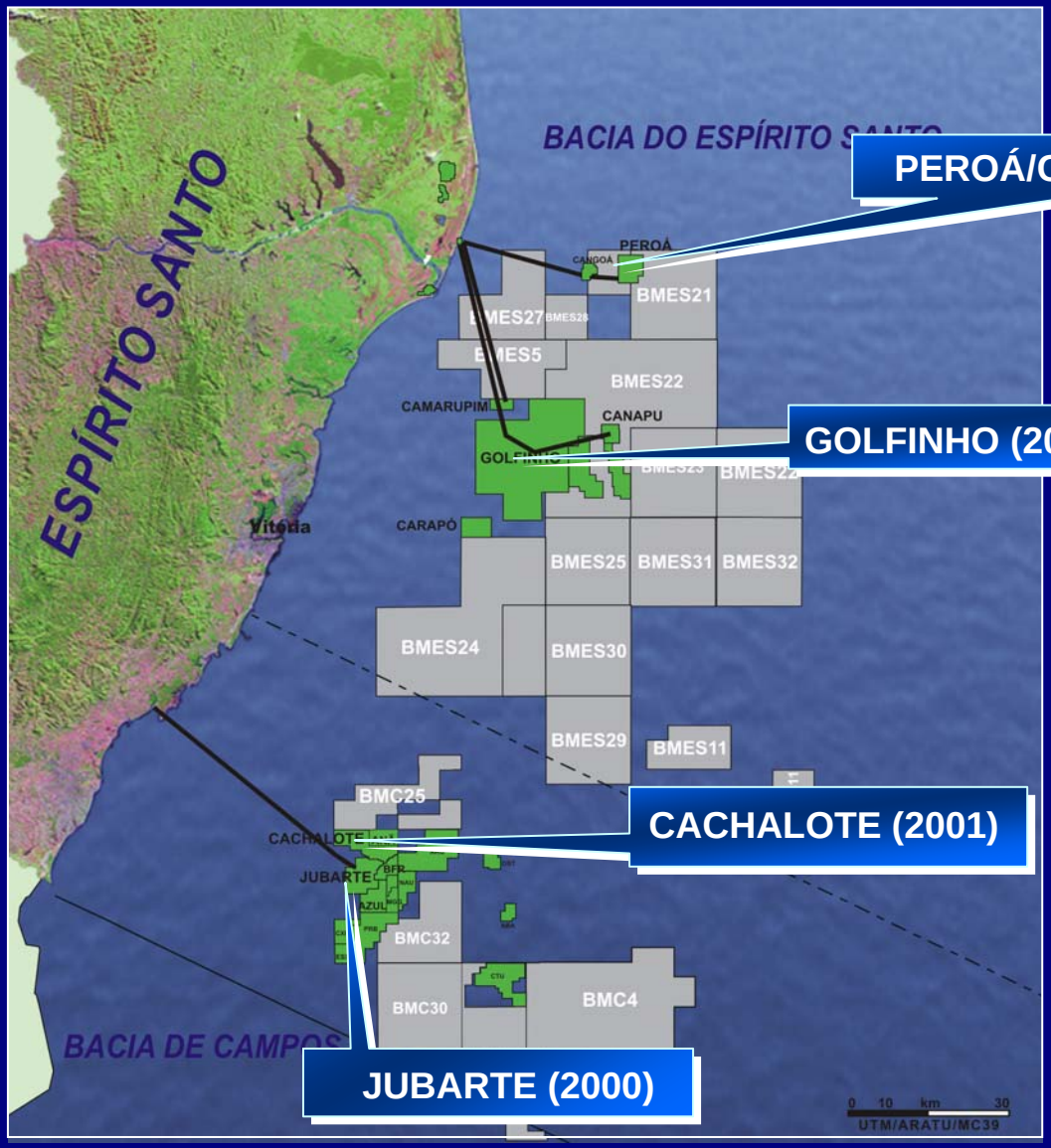
Outline

- Main unconsolidated sandstone reservoirs in Brazil
- Review of the current Horizontal Open Hole Gravel Pack Technology – evaluation
- New trends and challenges in Open Hole Gravel Pack
- Conclusions

Main unconsolidated sandstone reservoirs in Brazil – Campos Basin



Main unconsolidated sandstone reservoirs in Brazil – Espirito Santo Basin



Review of the current Open Hole Gravel Pack (OHGP) technology

- **Offshore reservoirs:**

  Unconsolidated Sandstones

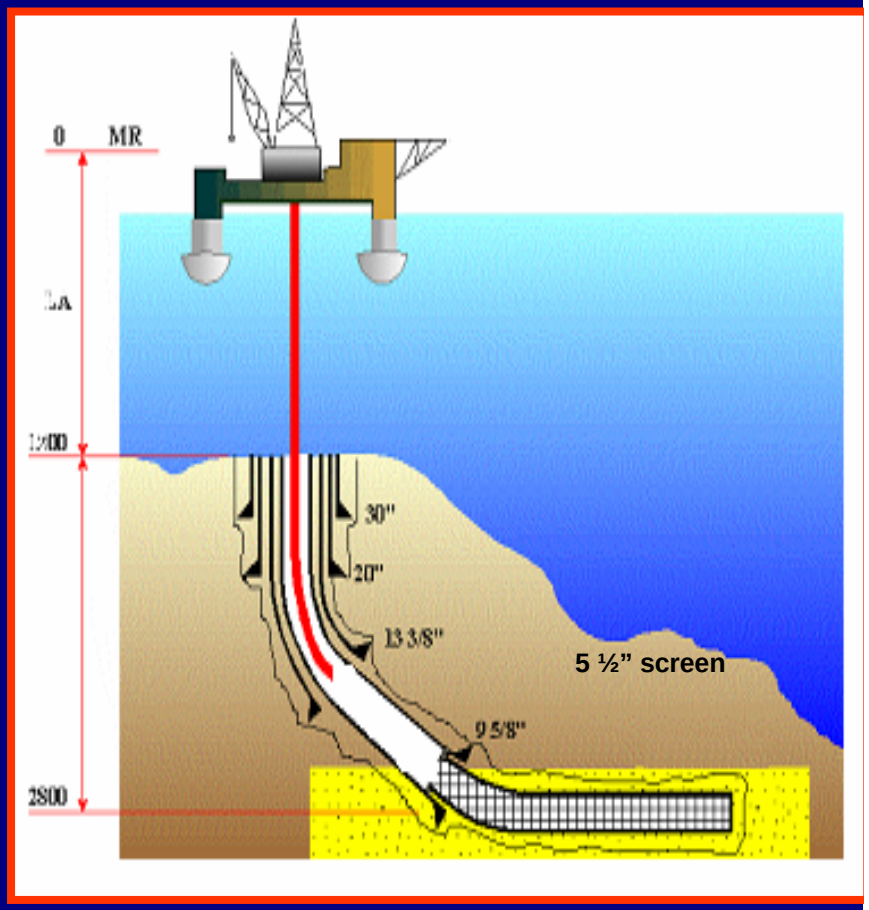
  ↑ Ø ↑ K

- **OHGP → Good solution**

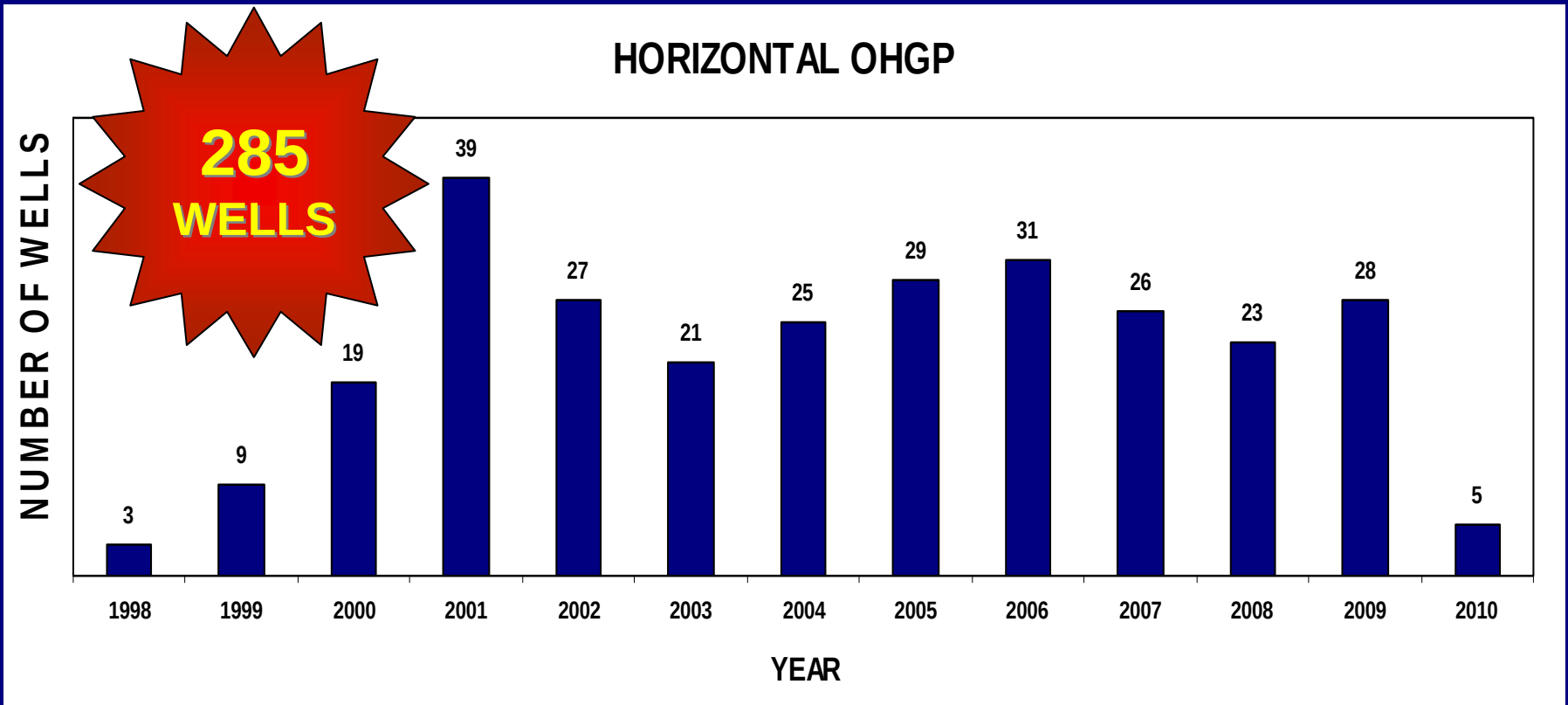
  for sand control

- **Horizontal Wells:**

  High Productivities

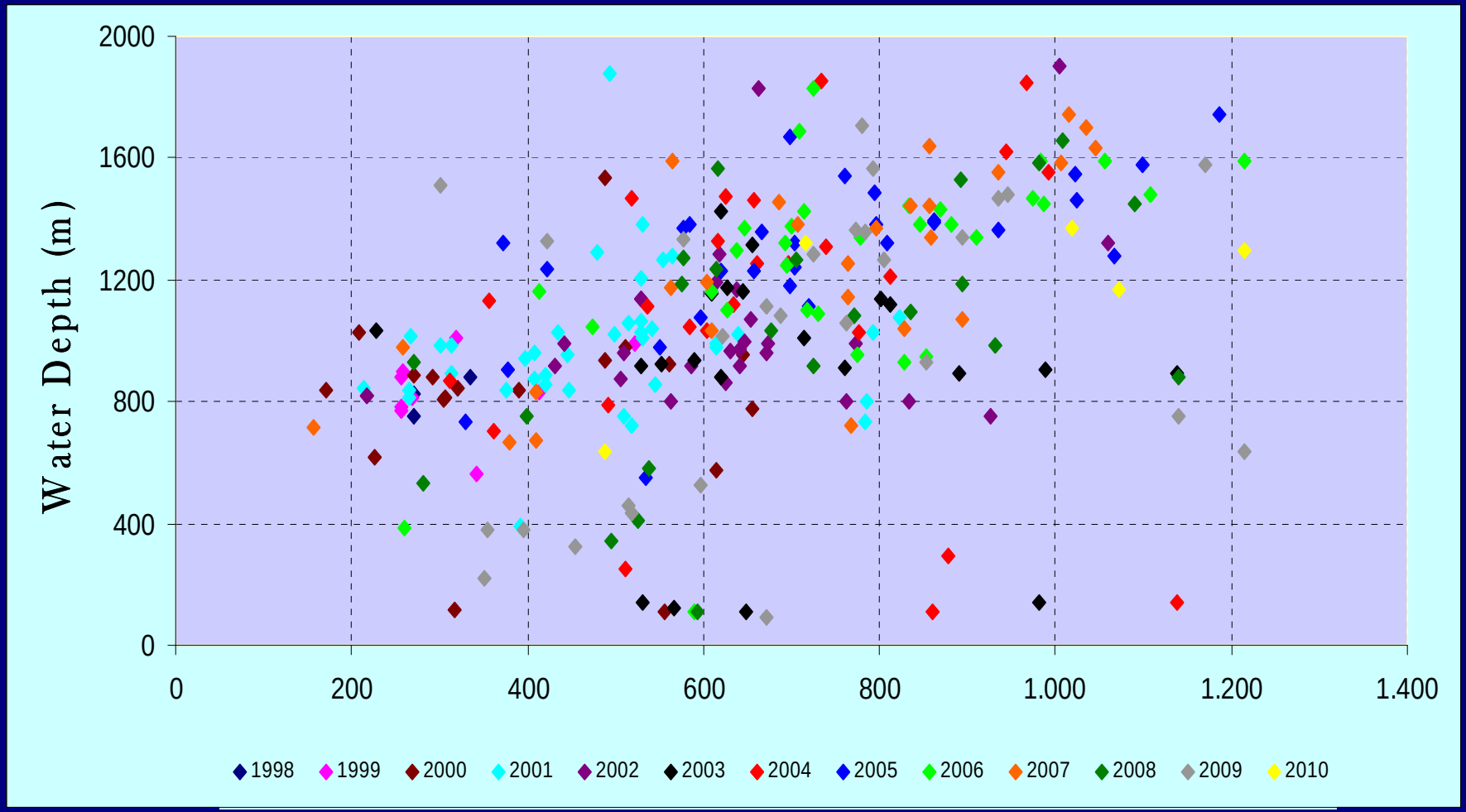


Review OHGP



285 wells - No sand control failure (sand production)

OHGP Operations: Water Depth x Horizontal Lenght



Total Screen length – Open Hole Gravel Pack

OHGP – Evaluation (141 wells – 50%)

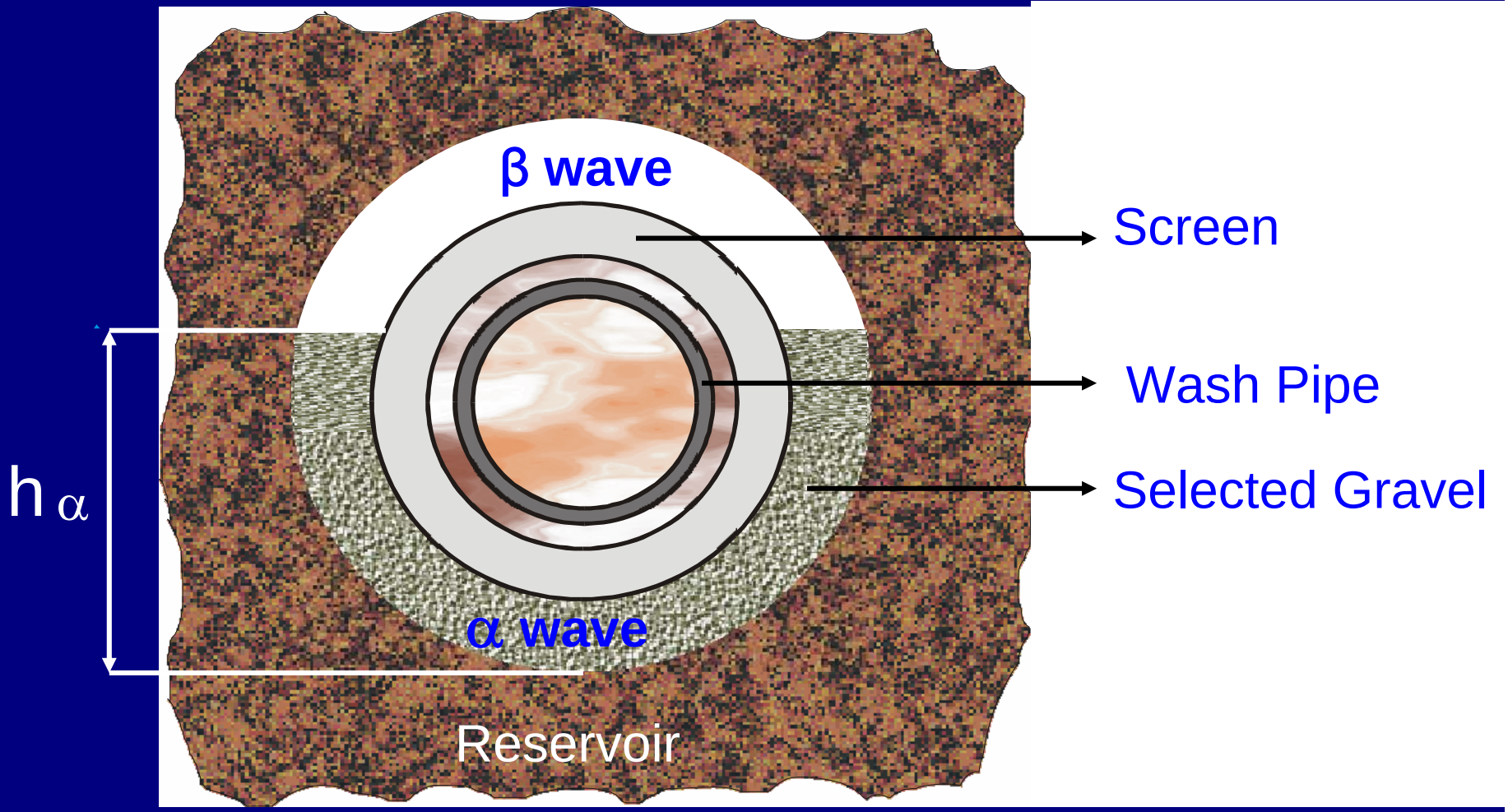
Average completion efficiency: 86 %

C.E. (Completion Efficiency) = 1/DR x 100

$$DR = \frac{P_e - P_{wf}}{P_e - P_{wf} - \Delta P_{skin}}$$

Review of the current Open Hole Gravel Pack

Alpha and Beta Wave Technology – Water Pack



Cross section well with Open Hole Gravel Pack

Review of the current Open Hole Gravel Pack

The method “Alpha and Beta Wave Technology” – Water Pack

Alpha and Beta Wave Technology – Water Pack
(High Leakoff or Formation Fracture – Result Incomplete Pack)

Deep Water Challenges for OHGP Operations

Deep and ultra deepwaters

Short sediment layers

Rocks w/ low fracture resistance

High productivity

Long horizontal sections

High friction losses during GP op.

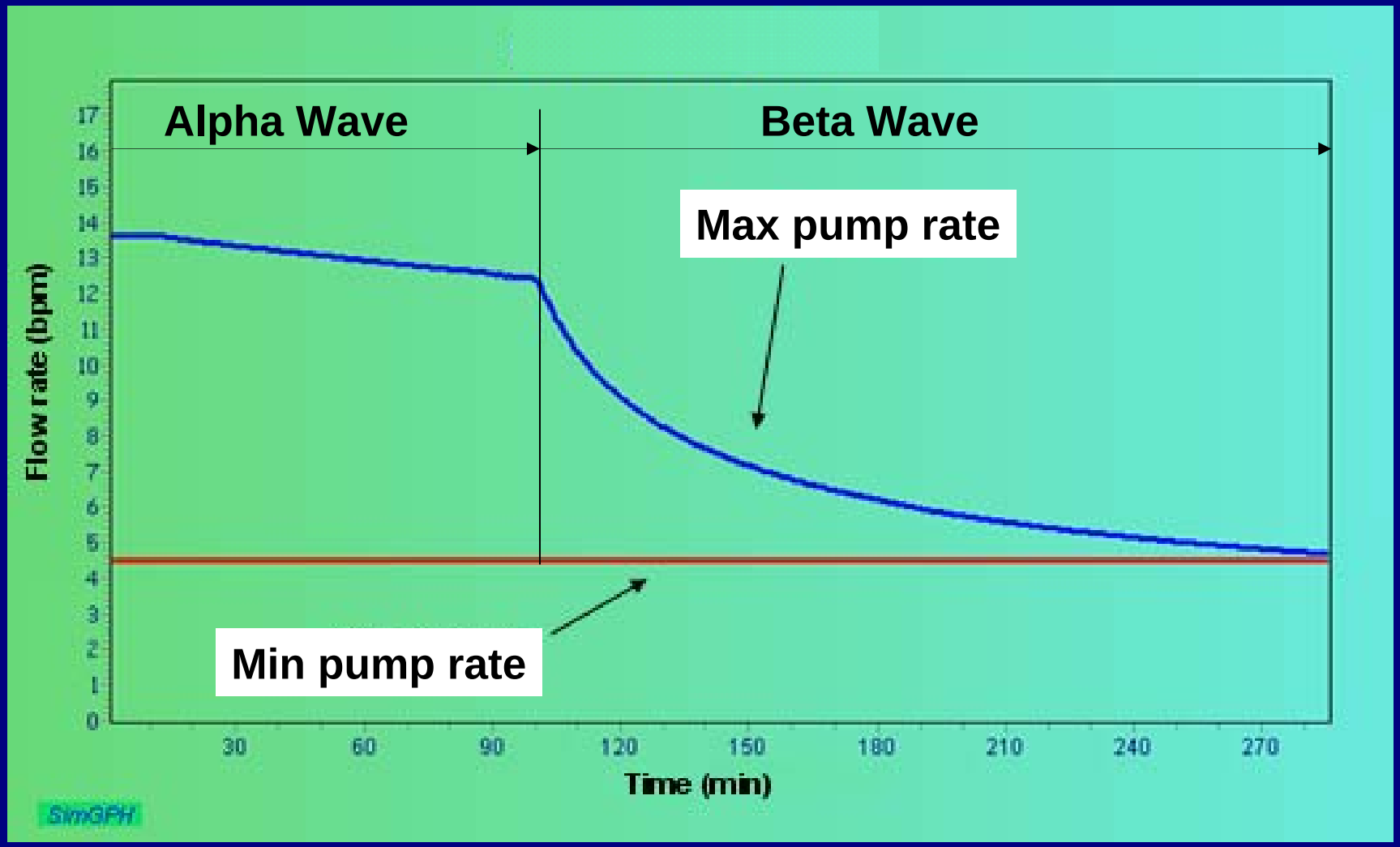
Narrow operational window for OHGP operations

Hydraulic Limits Definition

Upper Limit: High pump rates → pay zone fracture
→premature screen out

Minimum pump rates → premature screen out in the rat hole

Simulator - Variable flow rate design



Hydraulic limits extension - OHGP

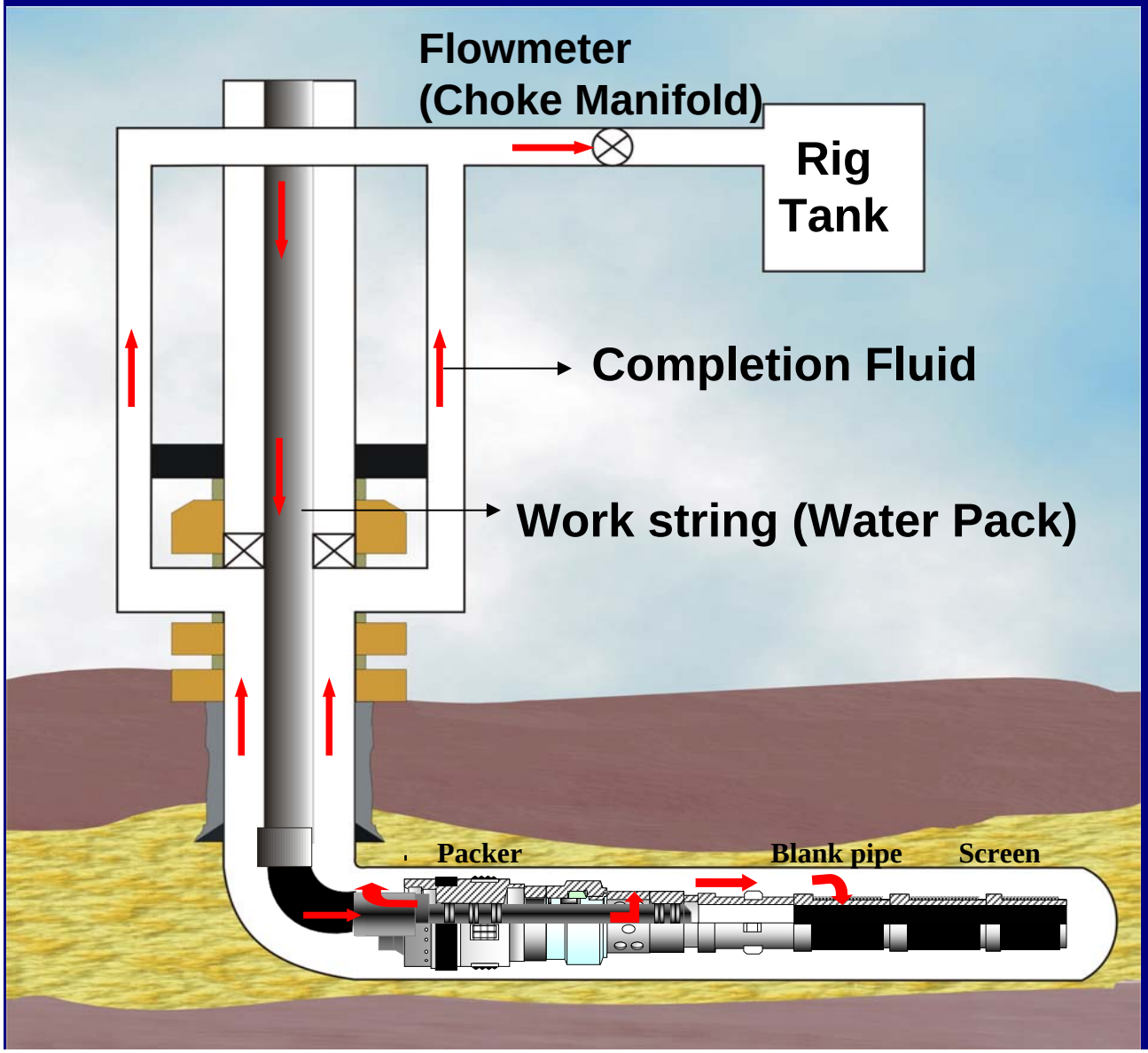
Narrow operational window

↓

Some strategies to overcome the limits

- Open BOP configuration
- Reducing the fluid weight
- Use of lightweight proppants
- Zero rat hole configuration
- Flow divergence valves
- Large diameter well
- Friction reducer

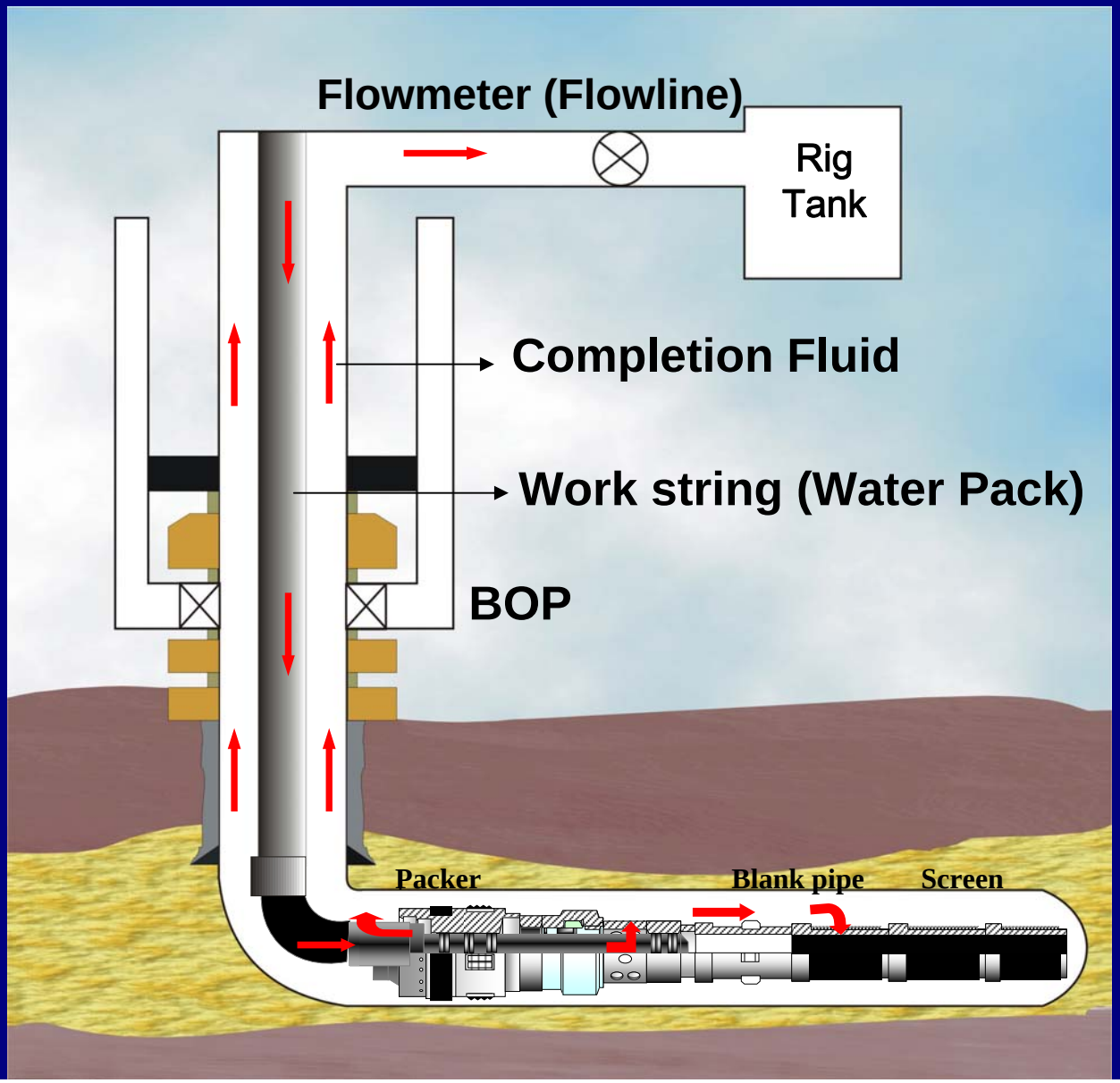
Hydraulic limits extension - OHGP



- Closed BOP configuration

BOP – Blow Out Preventer

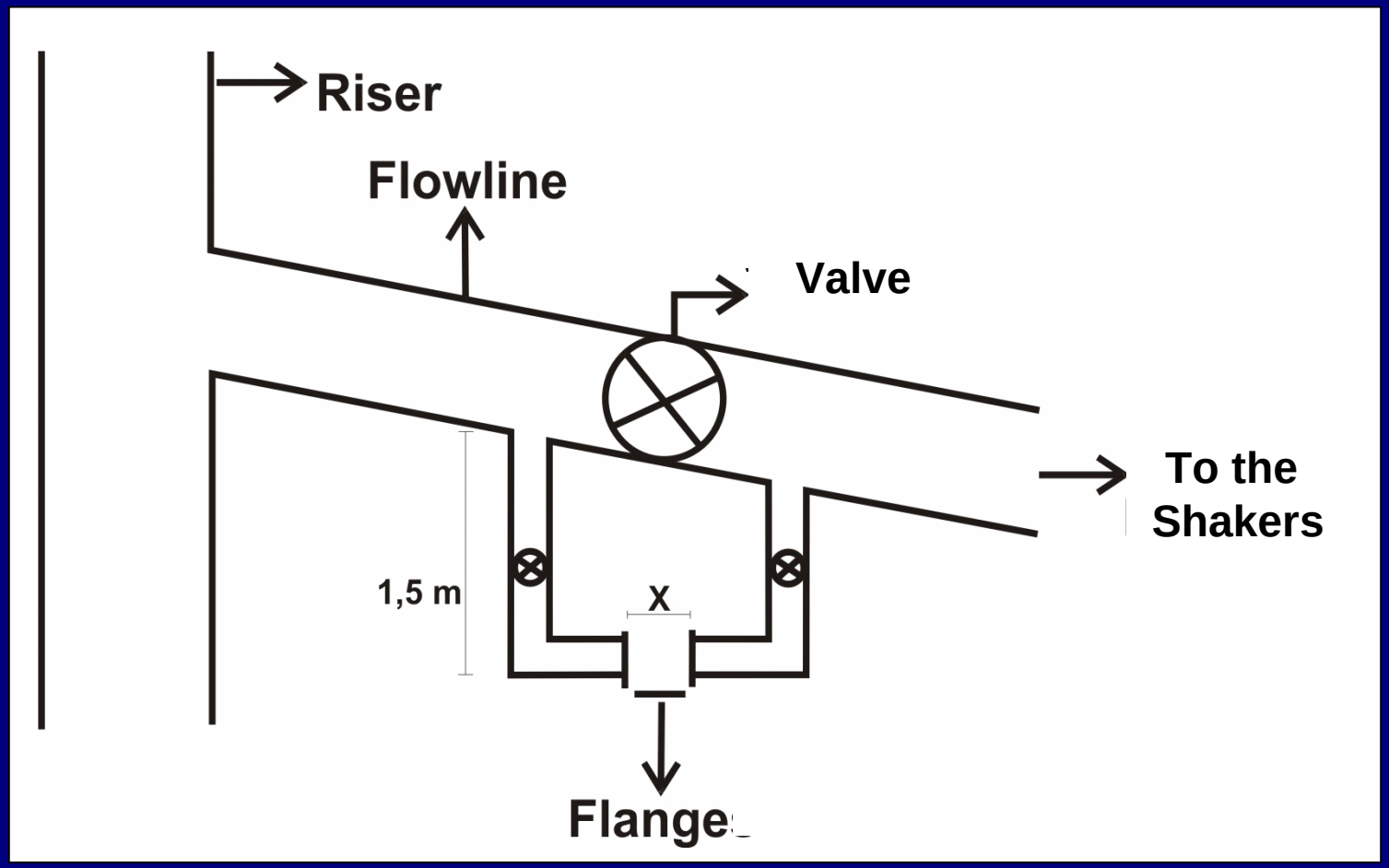
Hydraulic limits extension - OHGP



- Open BOP configuration

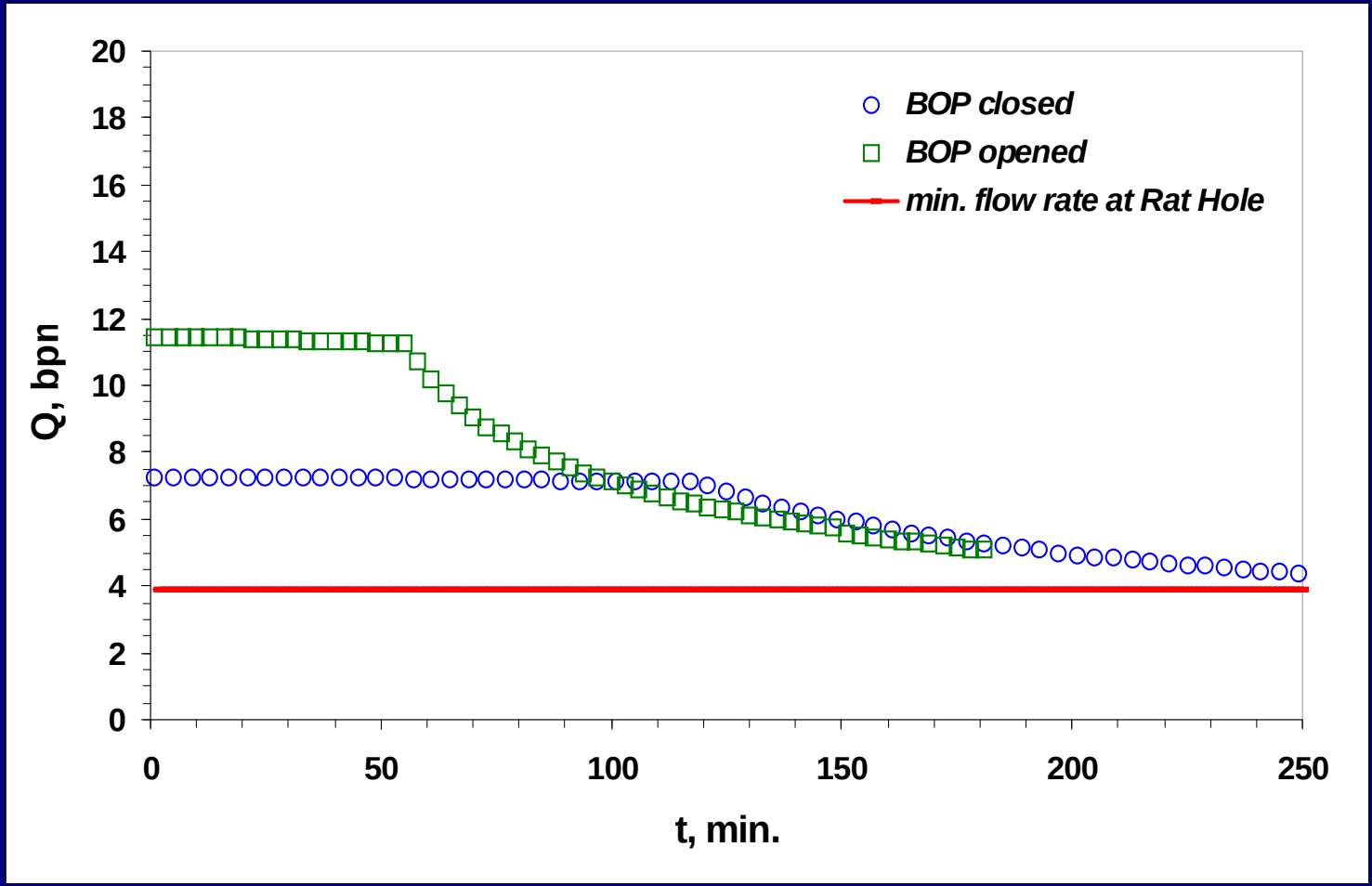
Hydraulic limits extension - OHGP

- Open BOP configuration – Flowmeter in the Flowline



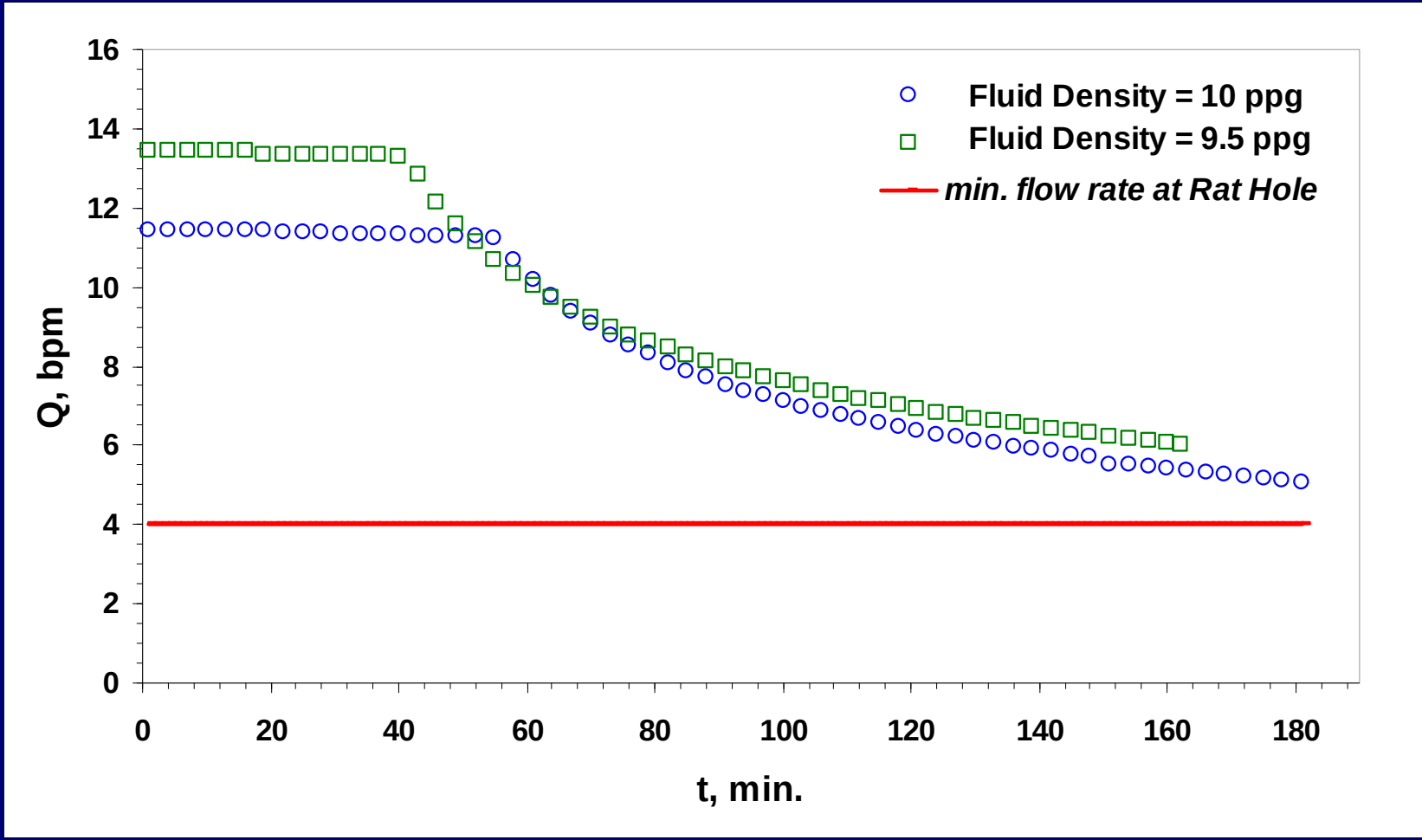
Hydraulic limits extension - OHGP

- Open BOP configuration



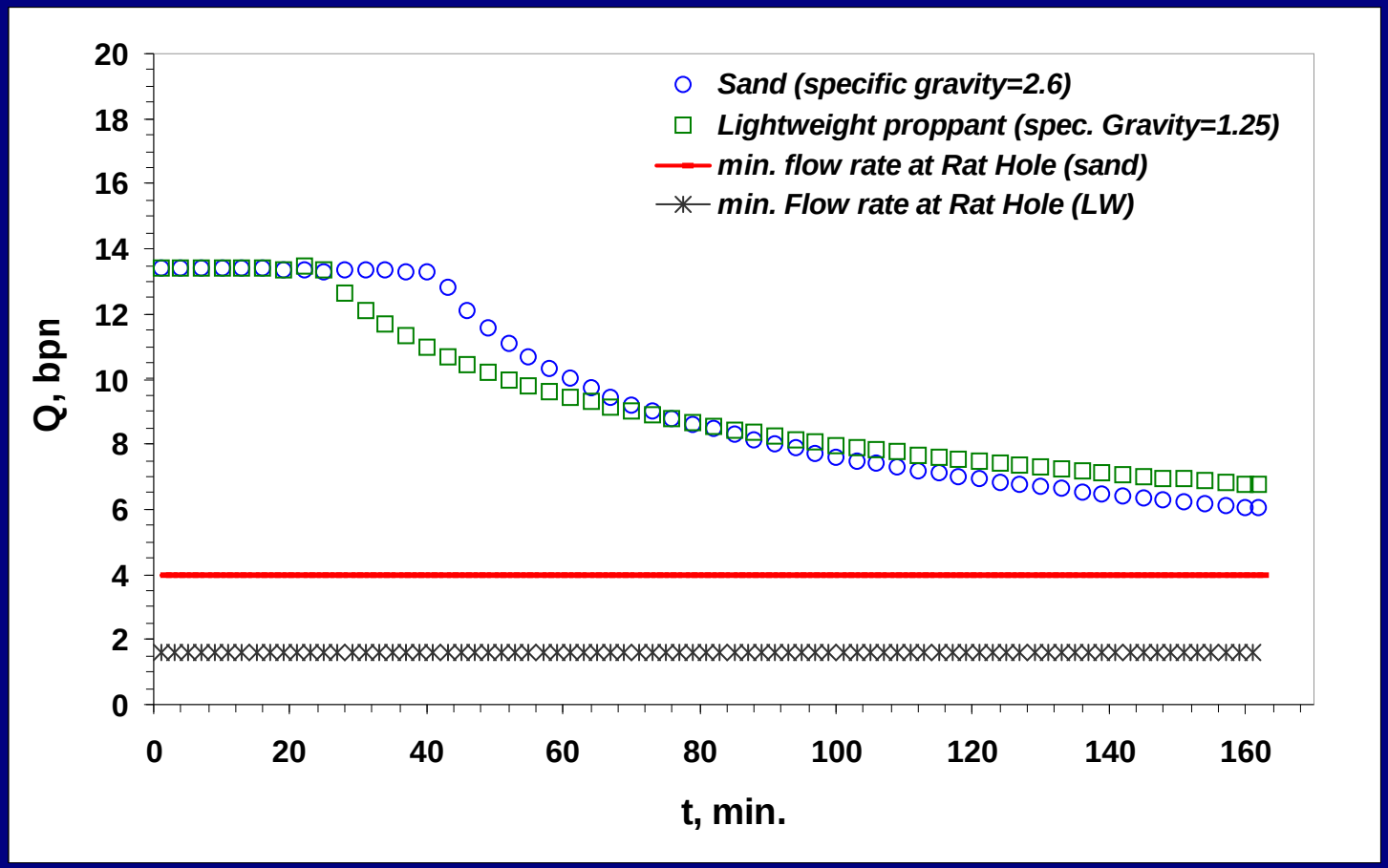
Hydraulic limits extension - OHGP

- Reducing the fluid weight (Gravel pack carrier fluid)



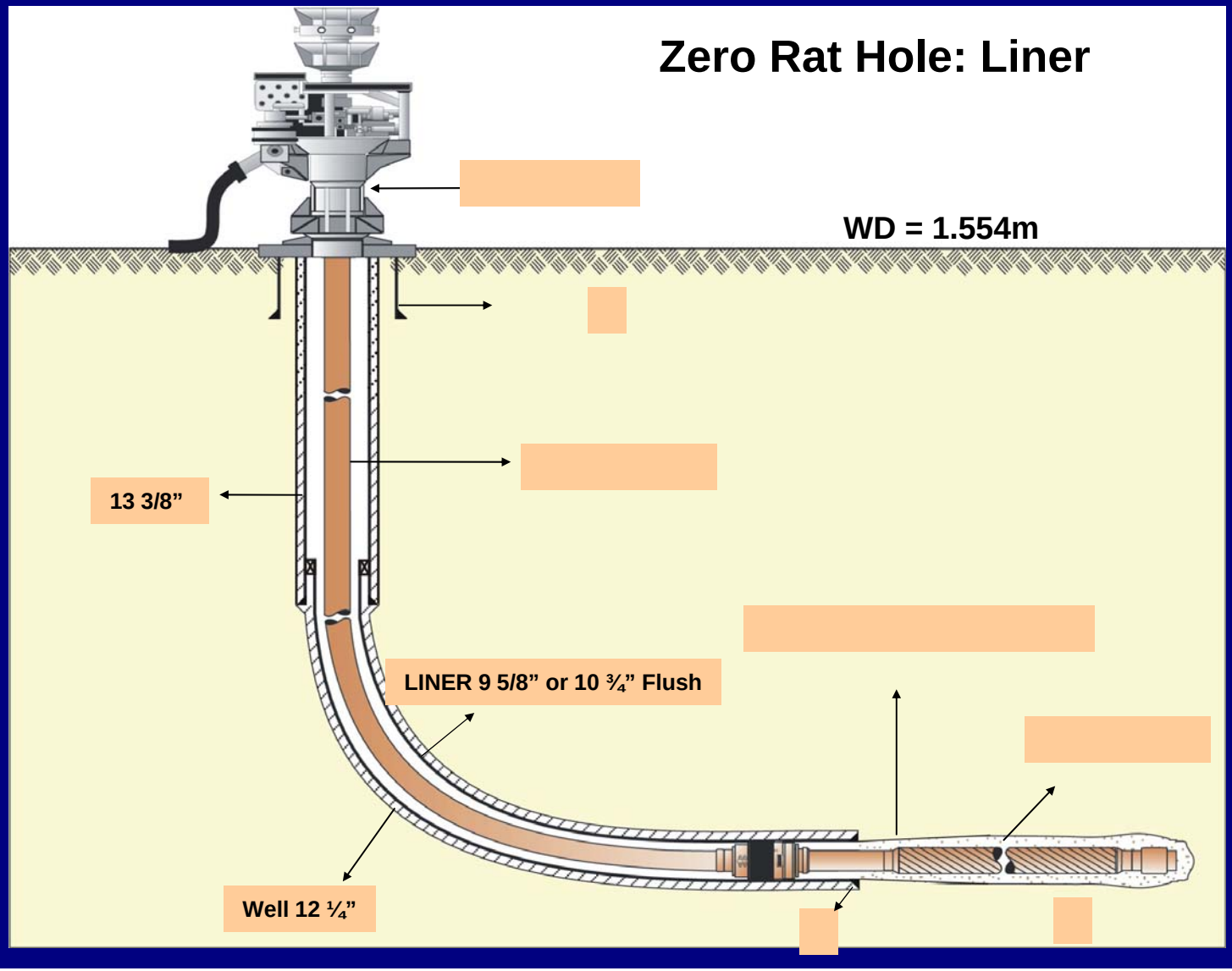
Hydraulic limits extension - OHGP

- Use of lightweight proppants



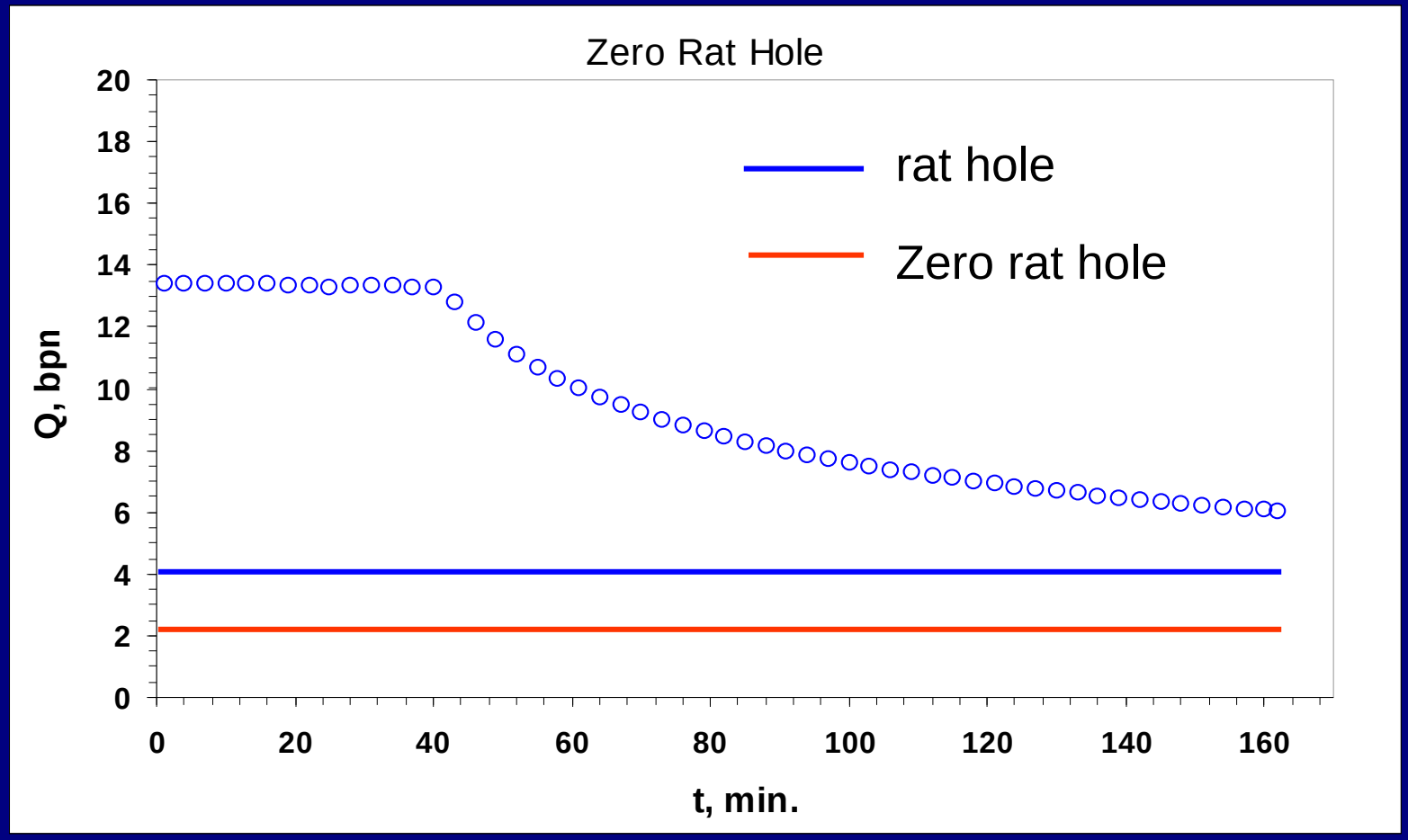
Hydraulic limits extension - OHGP

- Zero Rat Hole Configuration



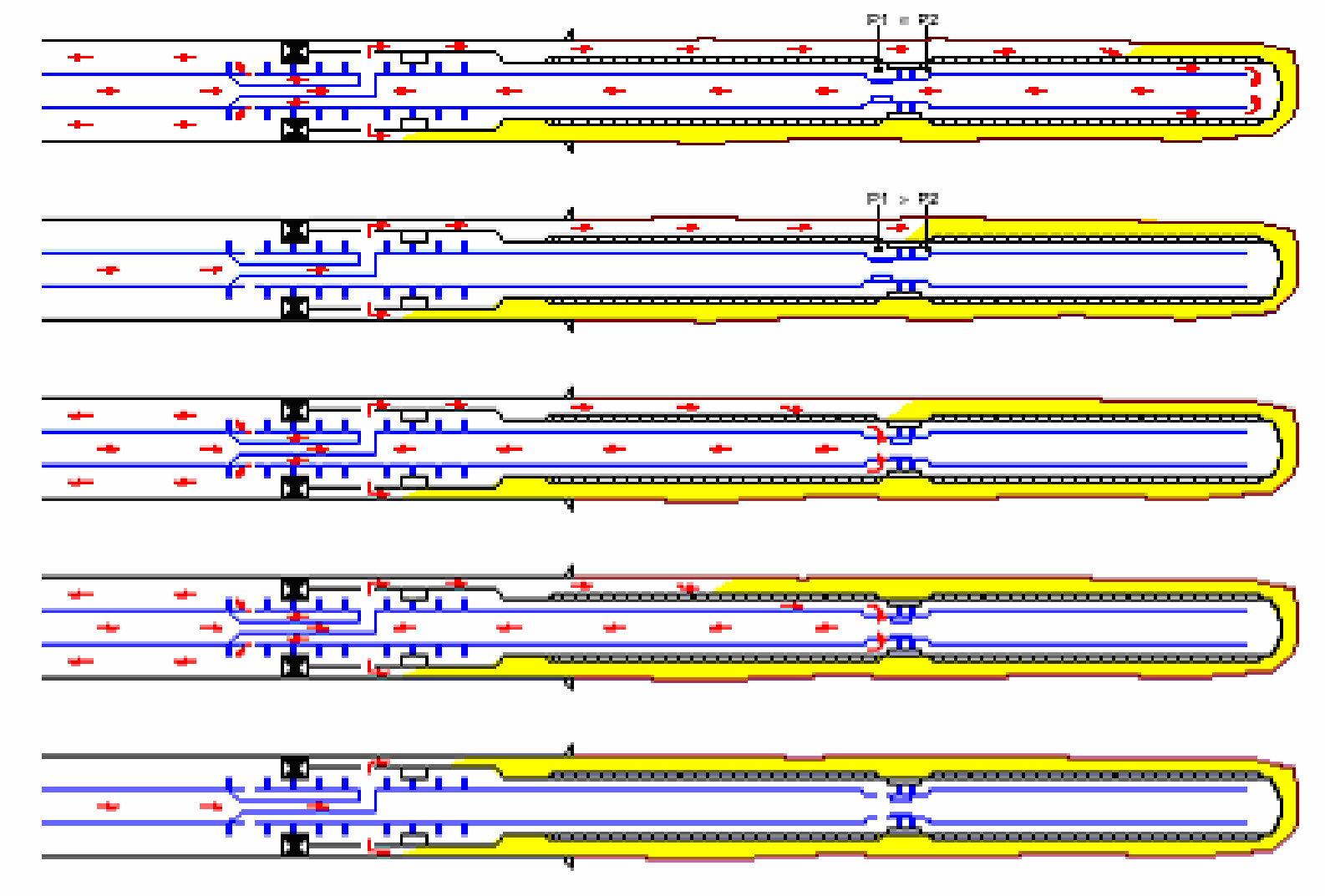
Hydraulic limits extension - OHGP

- Zero rat hole configuration



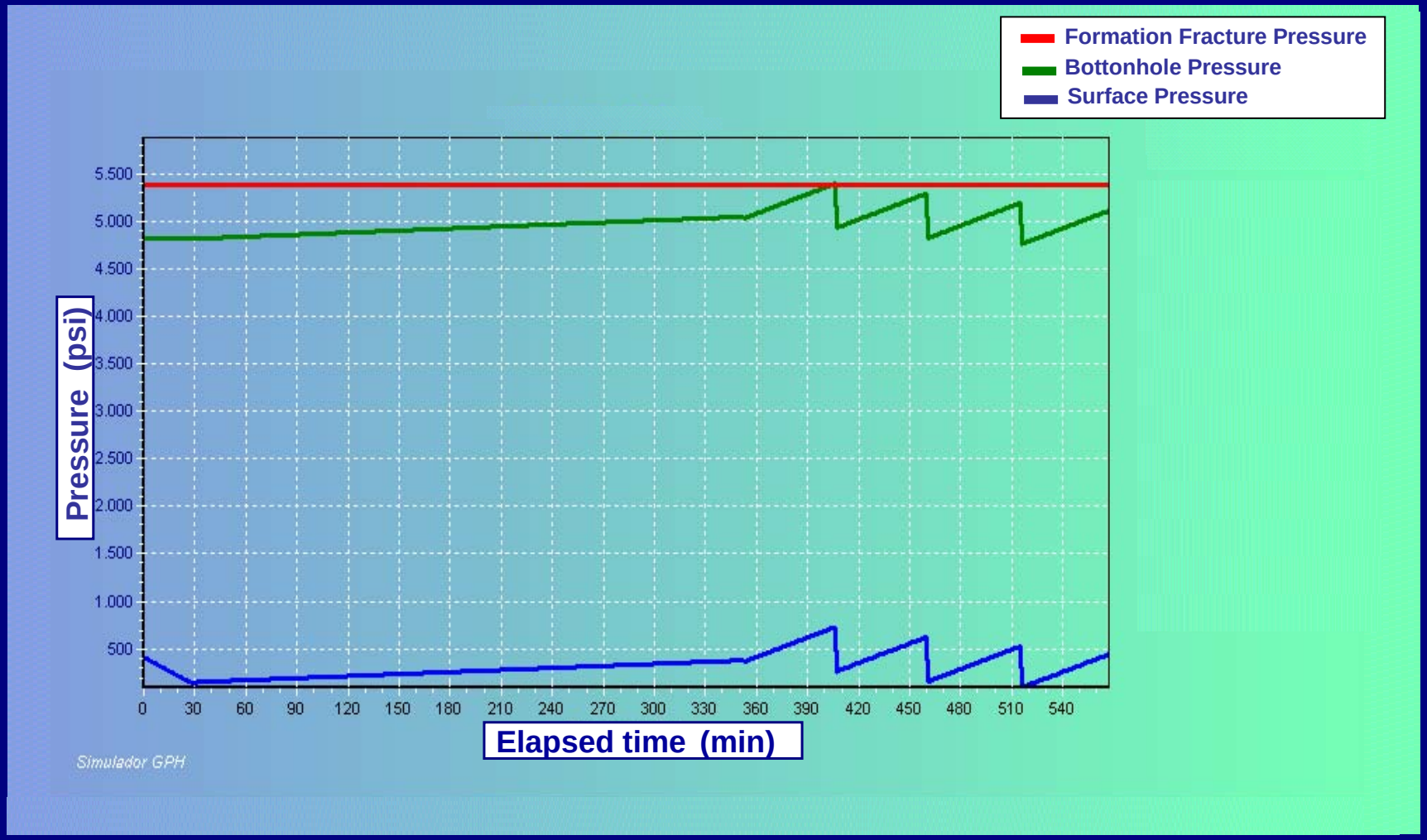
Hydraulic limits extension - OHGP

➢Flow Divergence Valves



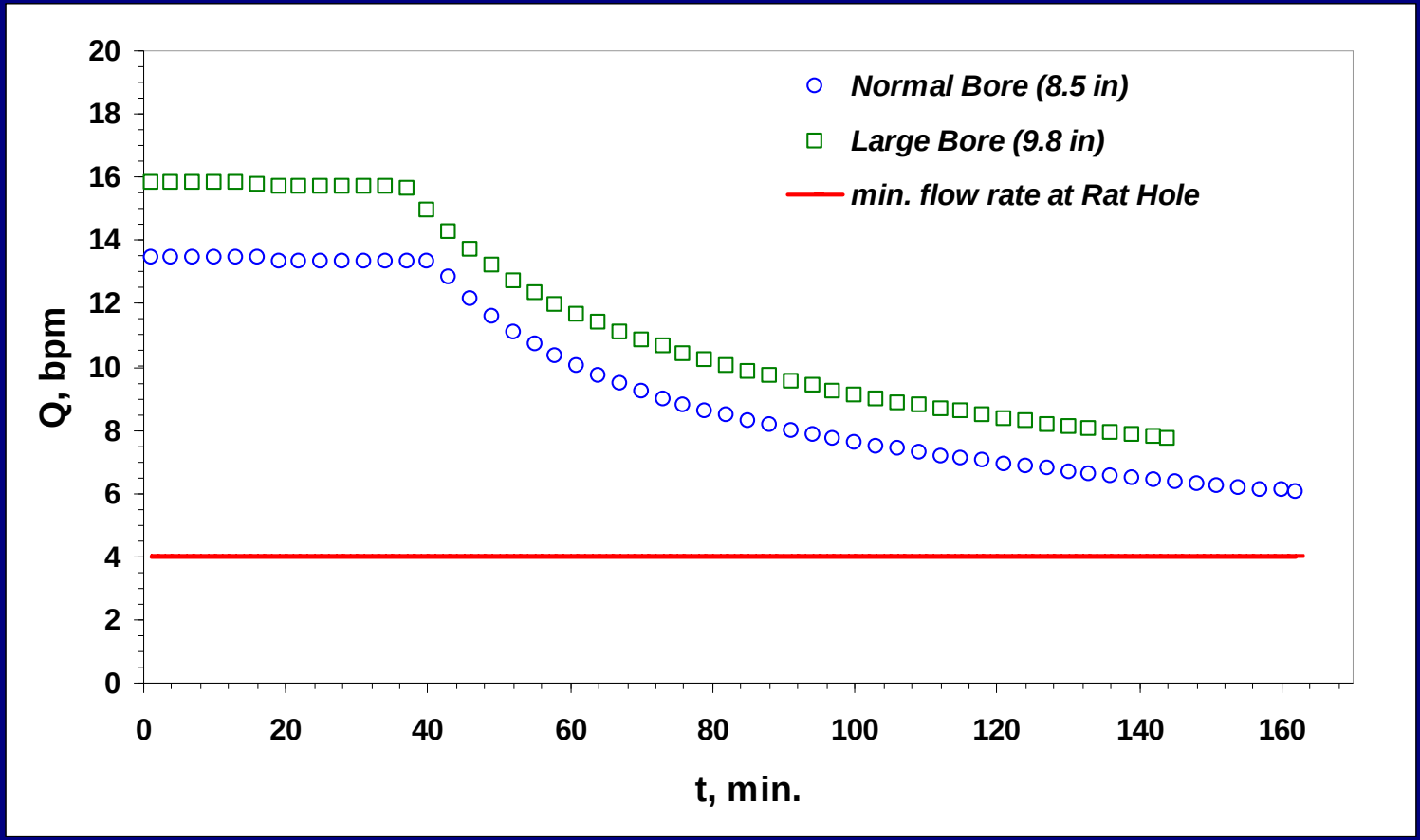
Hydraulic limits extension - OHGP

- Flow divergence valves



Hydraulic limits extension - OHGP

- Large diameter well



Hydraulic limits extension - OHGP

- Case Study using 3 Strategies: Open BOP configuration / Duo density Proppants / Reducing the fluid weight (Gravel pack carrier fluid)

Well data (Golfinho Field):

Horizontal Extension: 1150m

Water Depth: 1581m

Fluid weight: 9.6 ppg

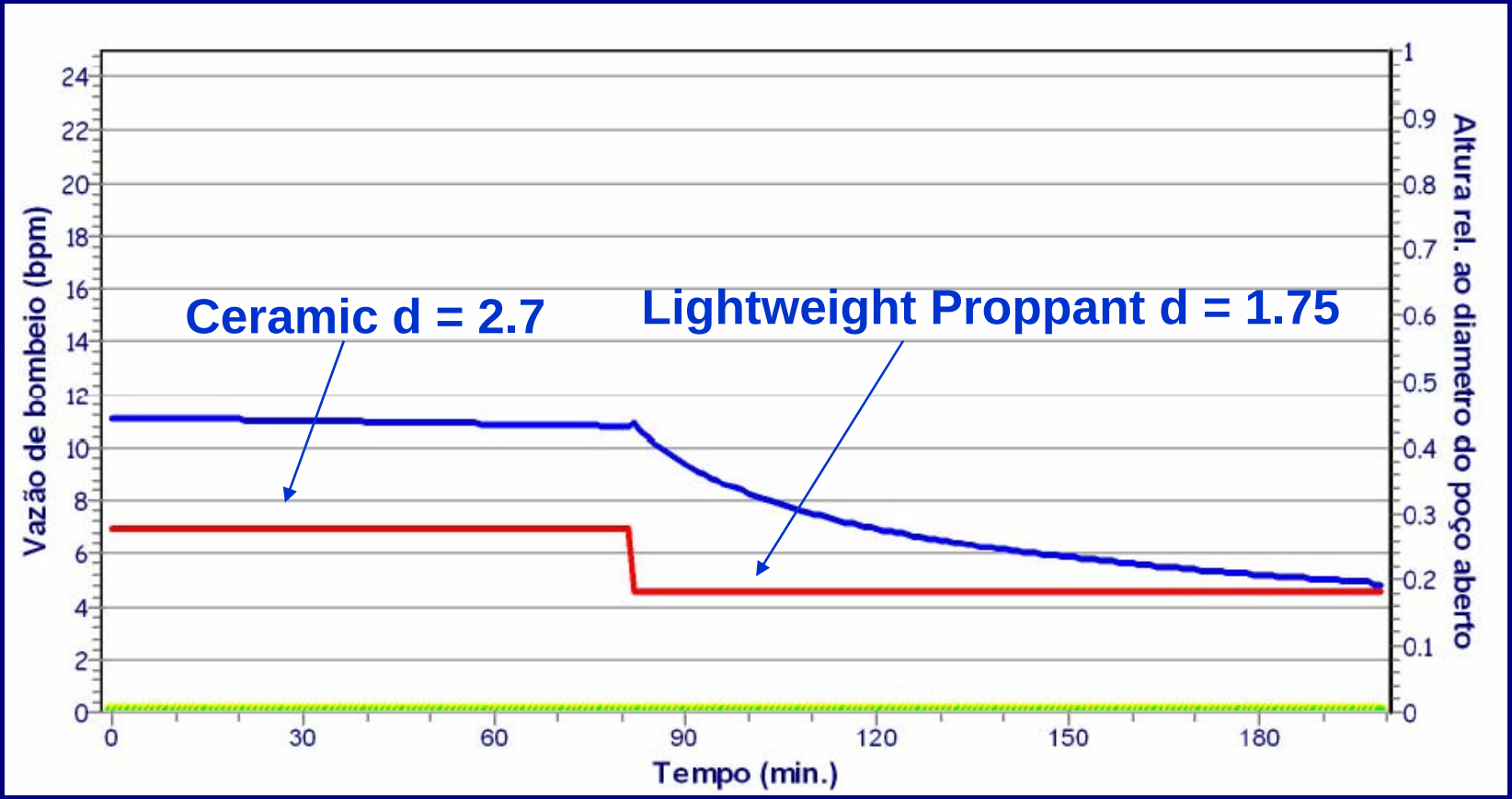
Gravel Pack Carrier fluid: 9.1 ppg

Frac Gradient: 0.56 psi/ft

Rat Hole: 14.75”

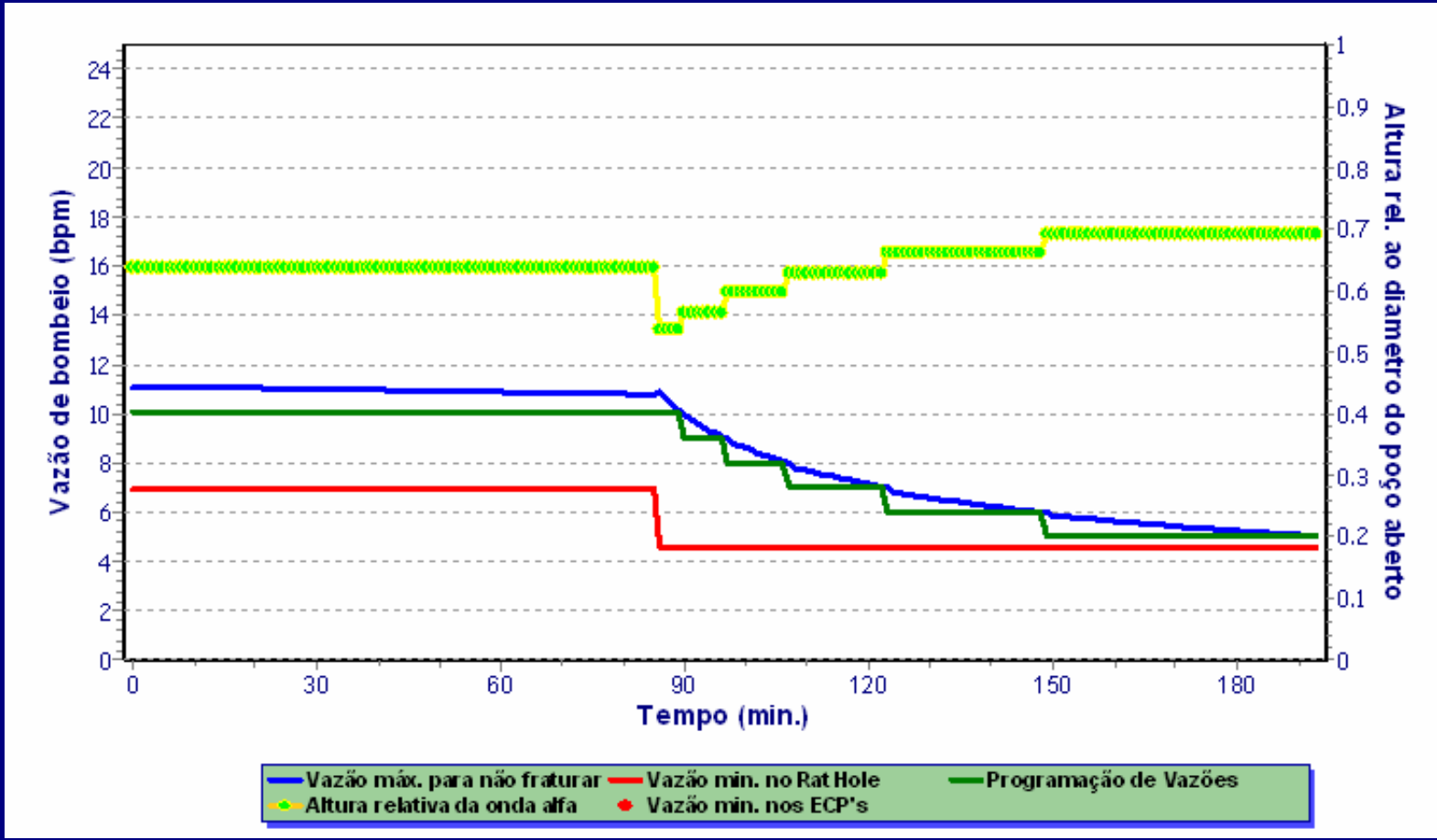
Hydraulic limits extension - OHGP

- **Output of Simulator**



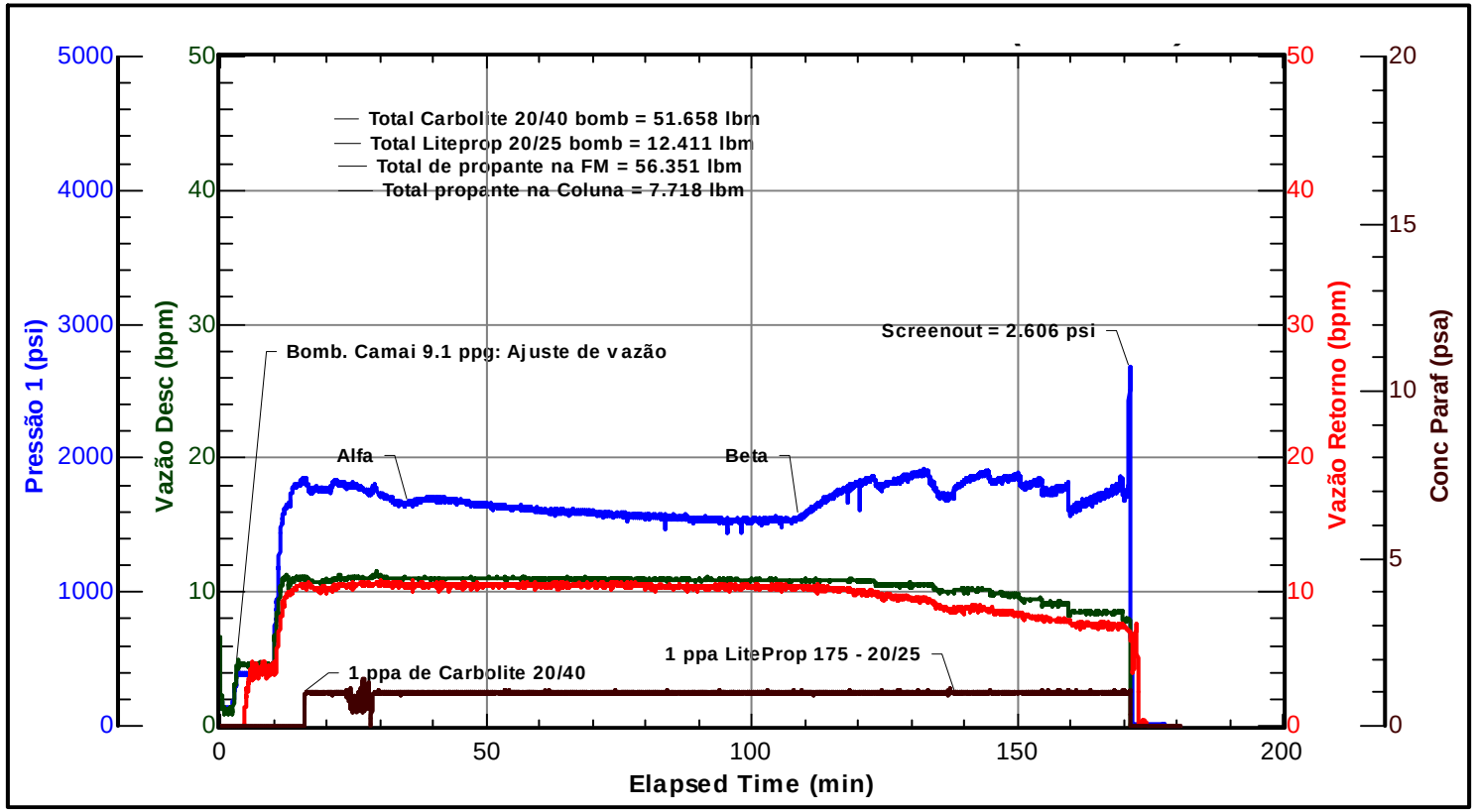
Hydraulic limits extension - OHGP

- Output of Simulator



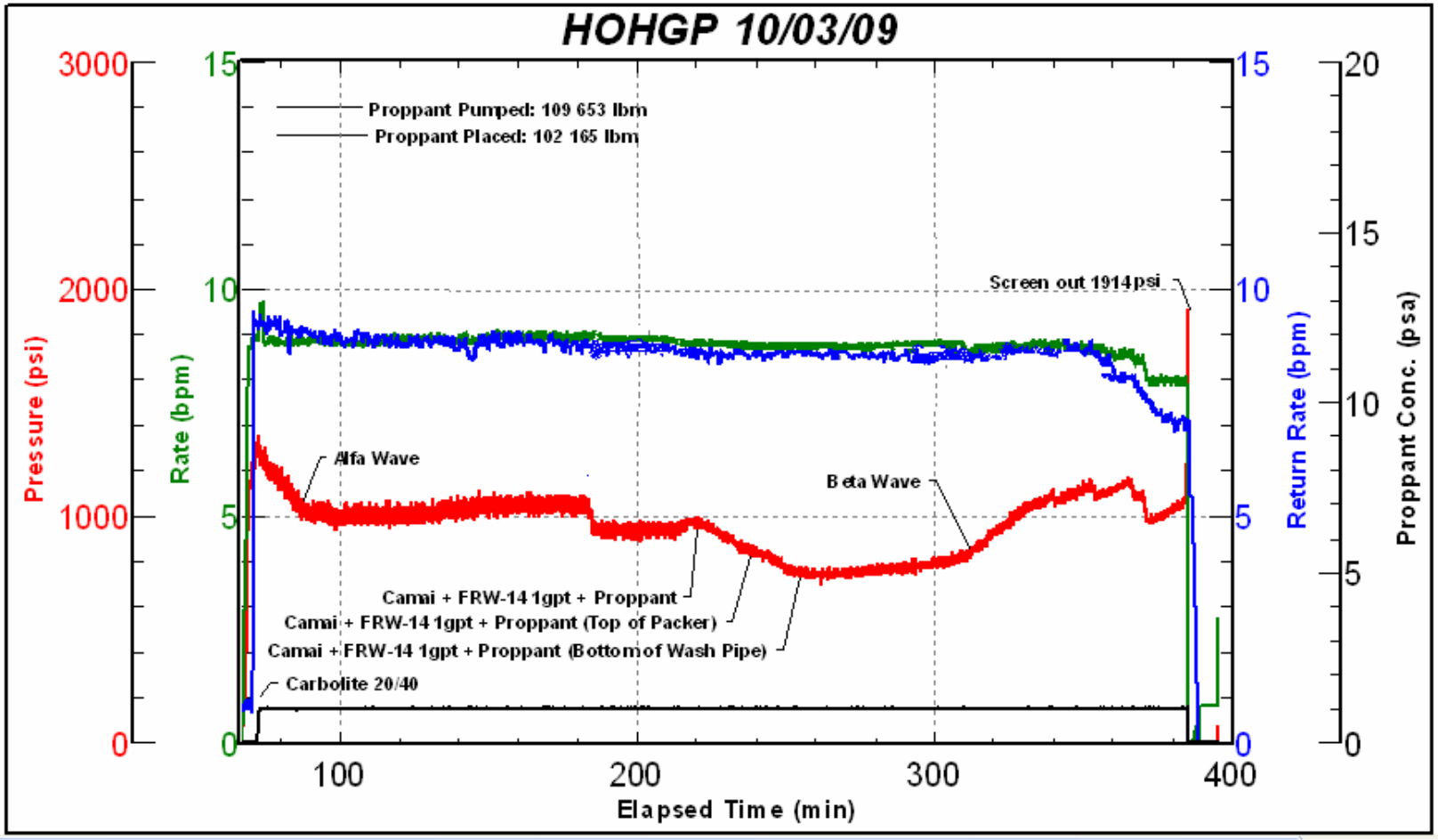
Hydraulic limits extension - OHGP

➢**Golfinho Field:** Open BOP configuration / Duo density Proppants / Reducing the fluid weight (Gravel pack carrier fluid)

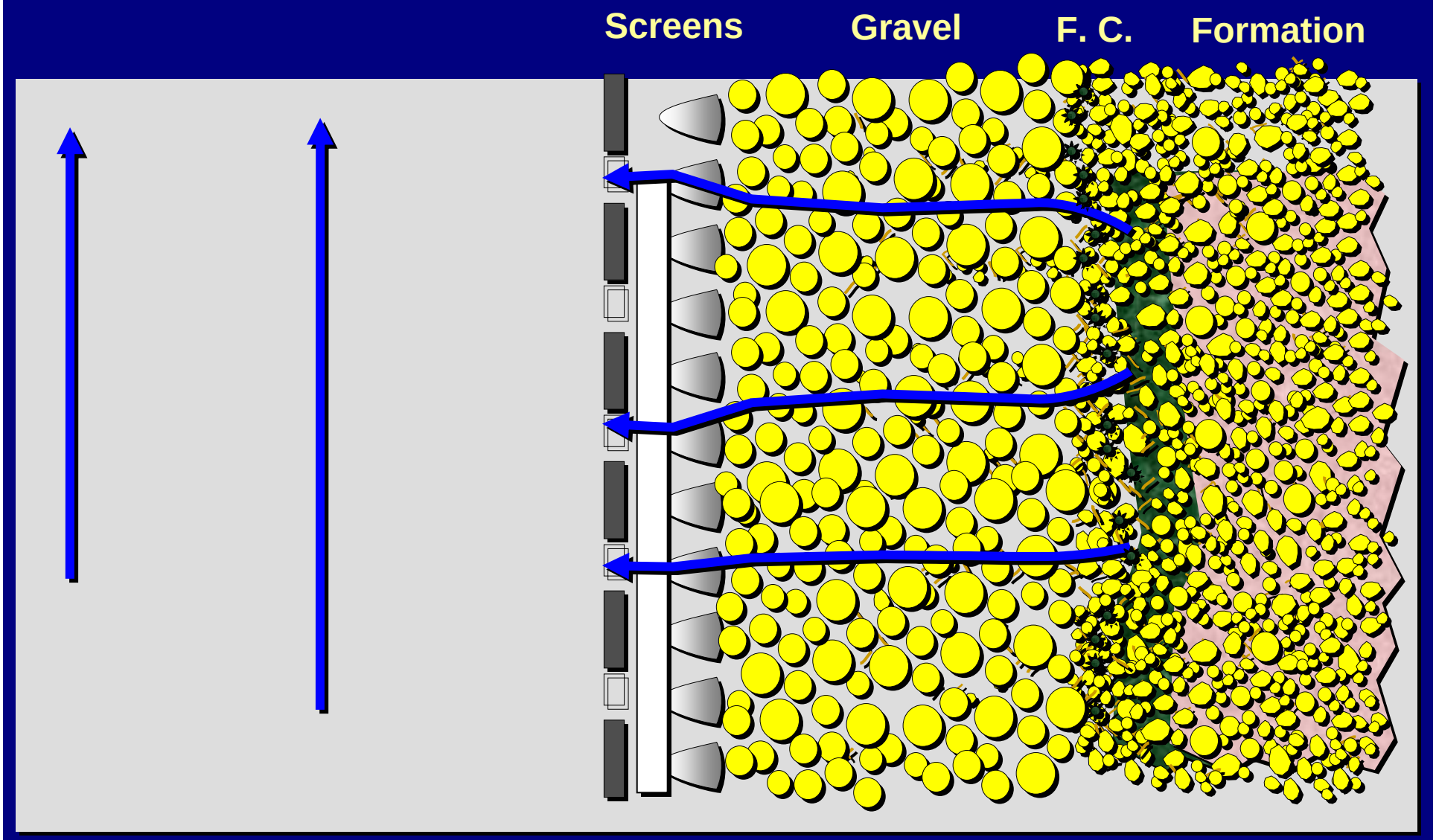


Hydraulic limits extension - OHGP

Test with friction reducer



Filter Cake Removal - The Producer Well

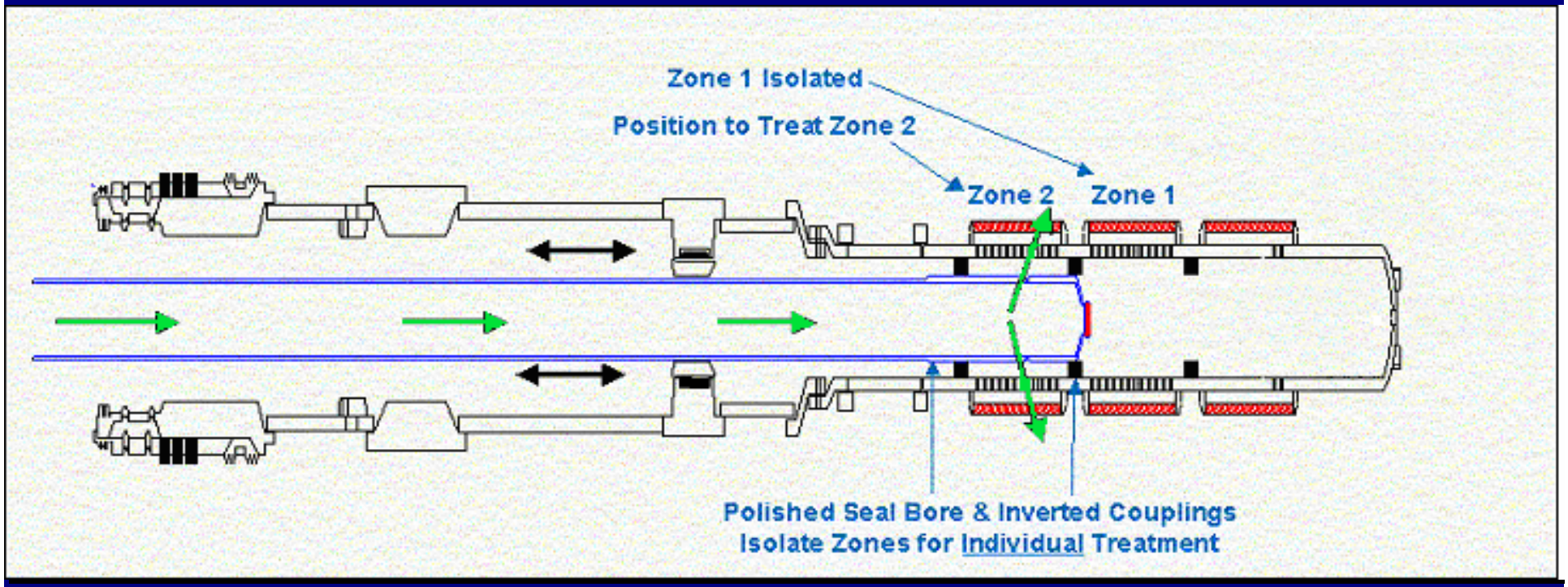


The Injector's Problem

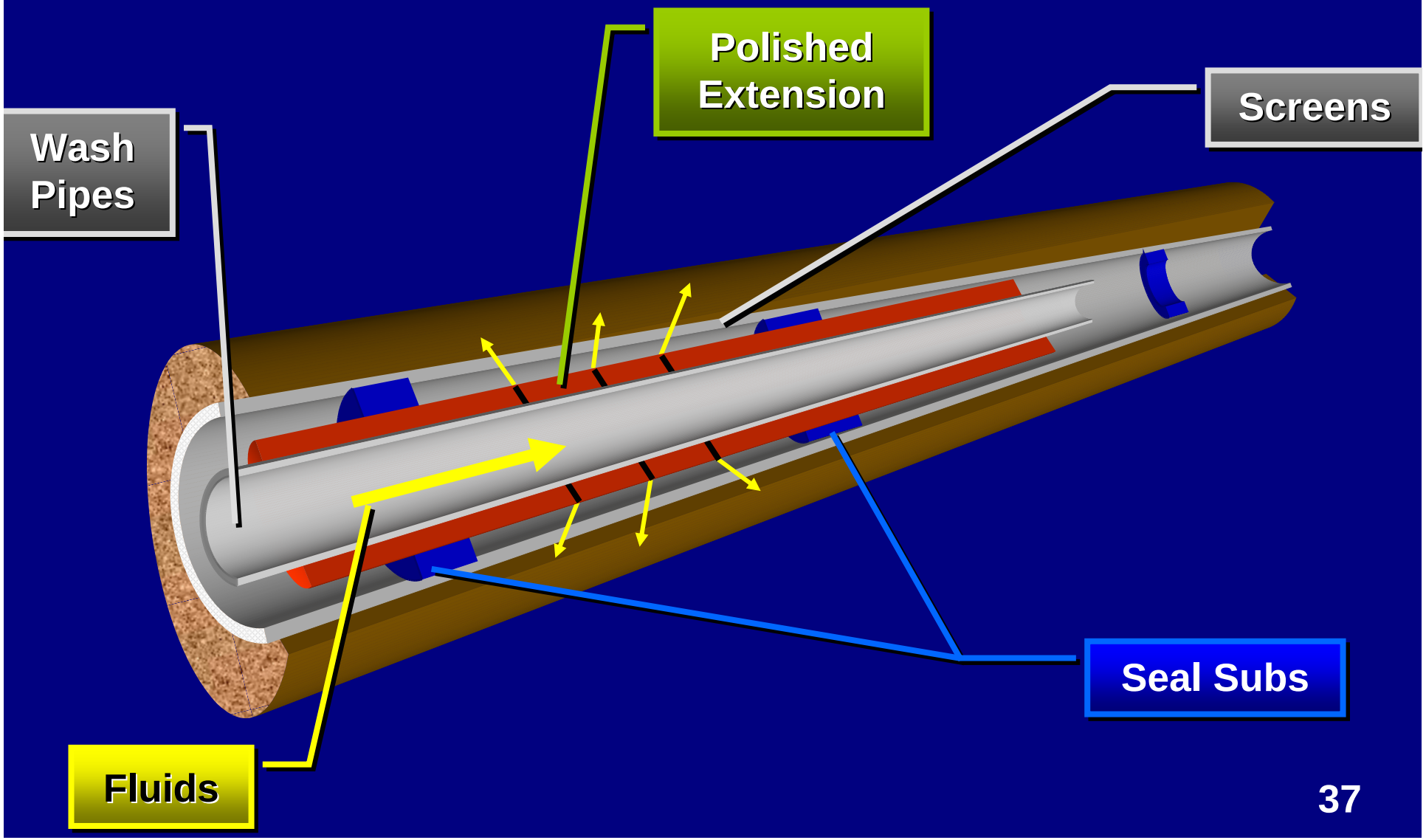
- No mechanical filter cake removal mechanism
- Injection impairment
- Costs: clean up (flow back) vs acidizing
- Poor results without treatments
- Always treated → Mud acid → Drill solids

Dedicated Acidizing Tool

- **Tool schematic**



Field Application - Dedicated Acidizing Tool

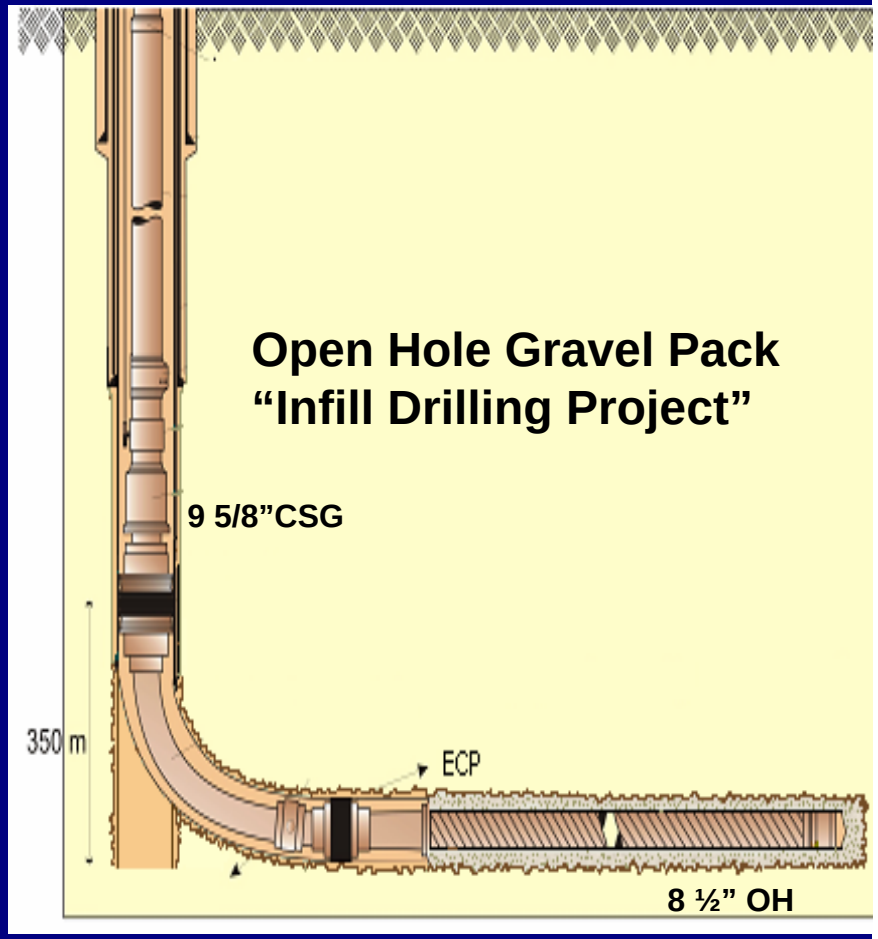


New Trends and Challenges in OHGP

Non-aqueous fluid for OHGP - alfa and beta wave mode

In 2007

- **Drilled horizontal section with SBM and OHGP with non-aqueous fluid (alpha and beta wave mode)**



New trends and challenges in OHGP

Non aqueous fluid for OHGP – Newtonian behavior

- **Focus**

  - **Make the formulation of inverted solids-free emulsion with carrier fluid for horizontal gravel pack operations feasible**

  - **Evaluate if the alpha and beta waves occur**

  - **Keep the use of regular premium screens without any kind of extra paths**

Physical testing simulation - results

- After fluid development: Physical simulation (flow loop): 3 kind of proppants (sand, ceramic and bauxite) and new gravel pack carrier fluid

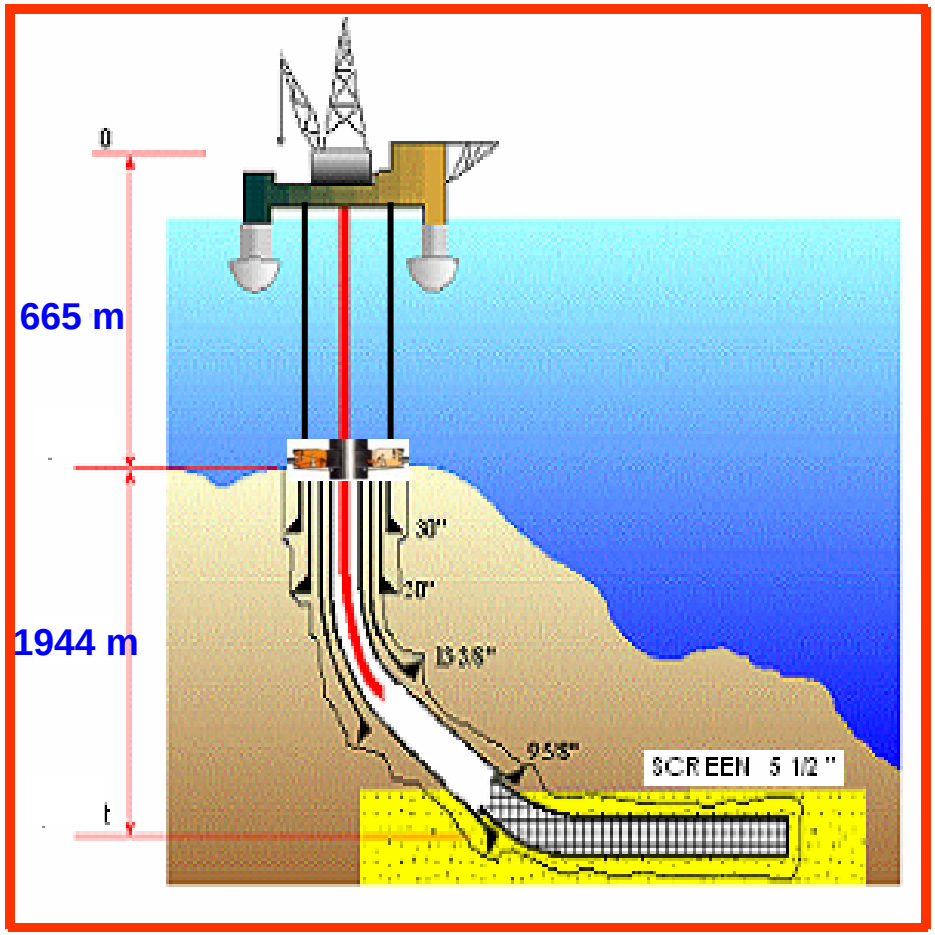
- Alpha and Beta wave was detected with all proppants

- Excellent packing

SPE 102295

Non aqueous fluid for OHGP - alfa and beta wave

1st STEP – Field application – Marlim
SPE 110440

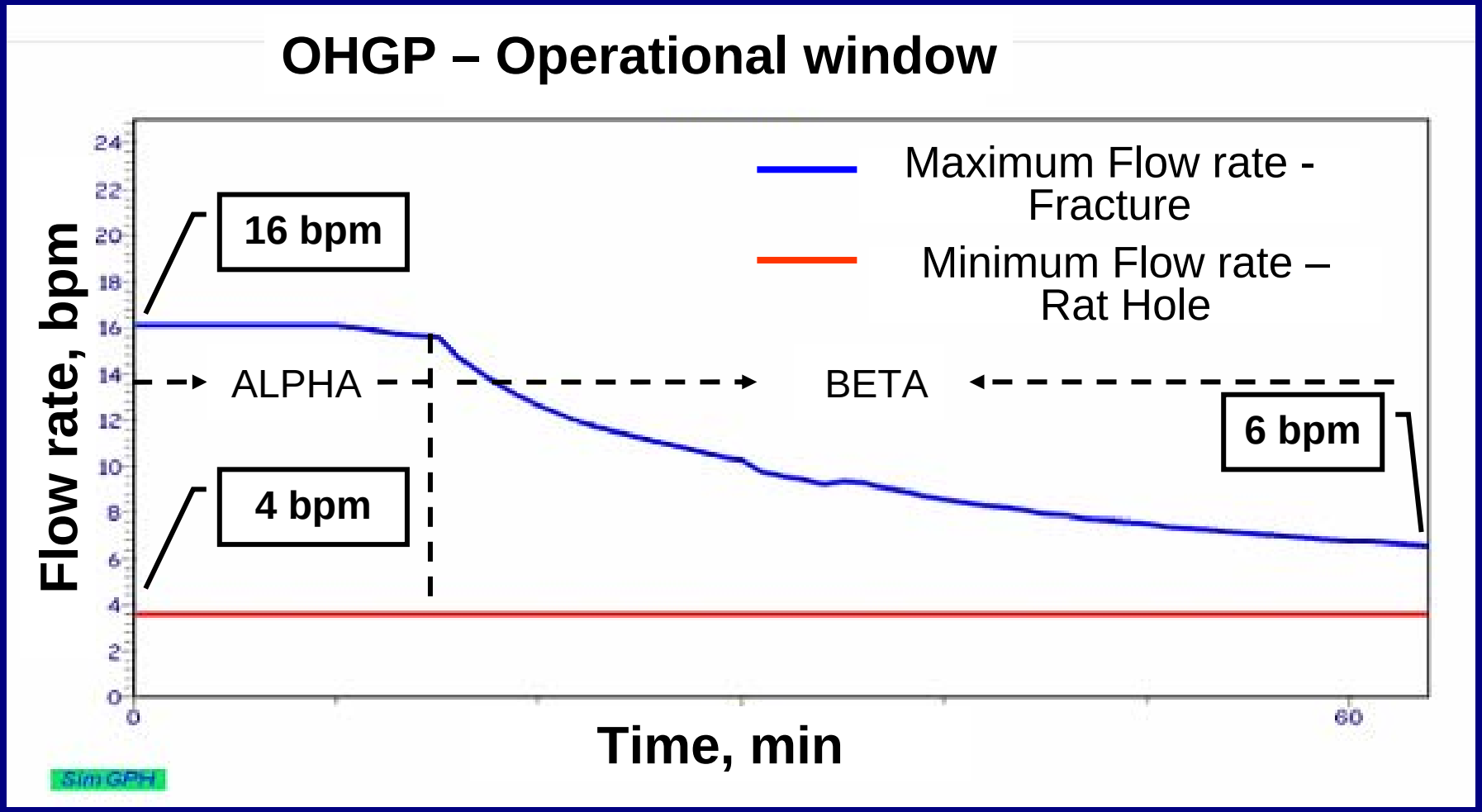


Well Design

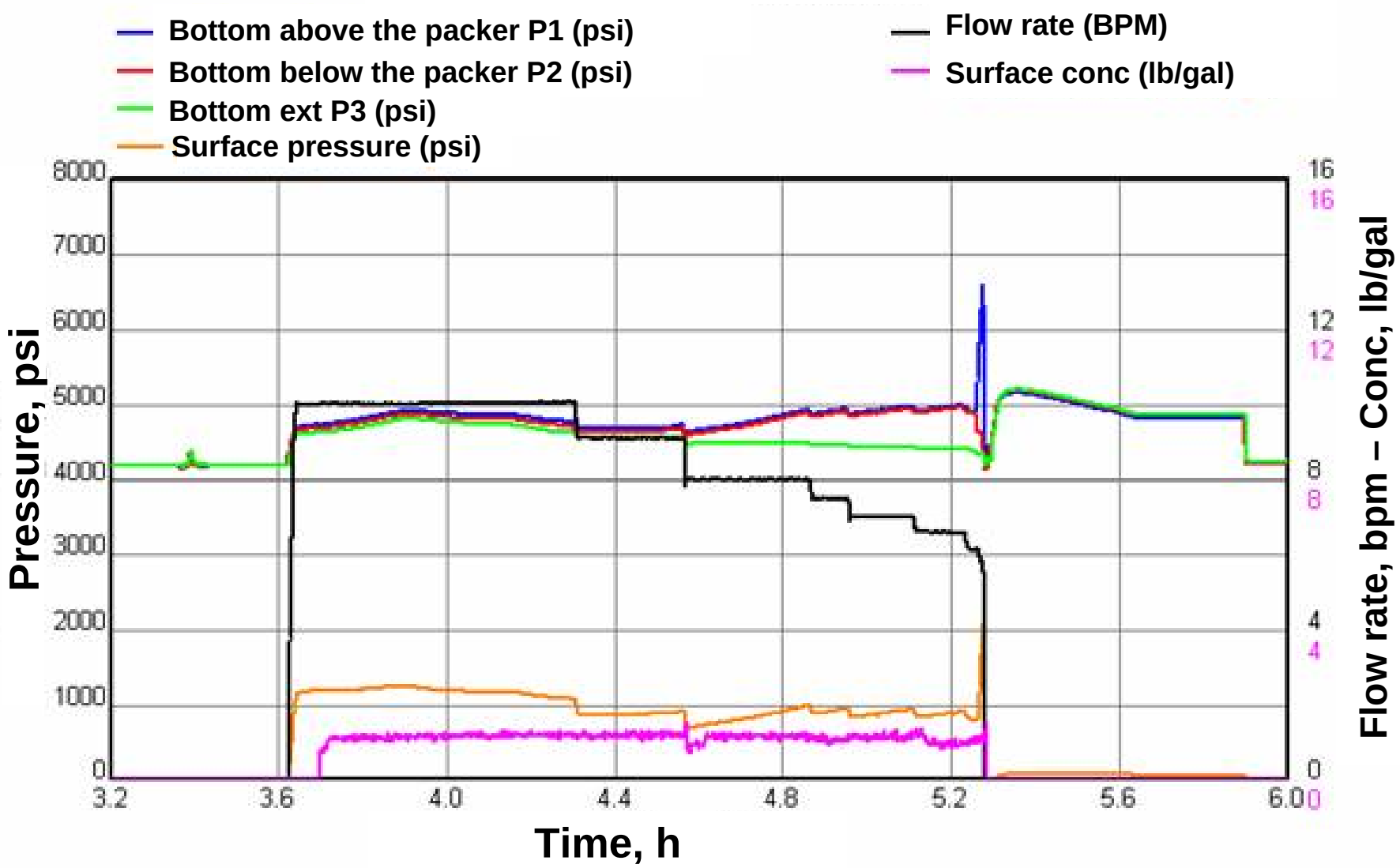
Basic Data:

- Water depth: 665m
- Horizontal Section: 380m
- 8 ½” Well ; 5 ½” 250 µ screen
- Proppant: 16/20 mesh (Ceramic)
- Frac gradient = 0.60 psi/ft

Field application – OHGP design



Gravel pack execution – Marlim field

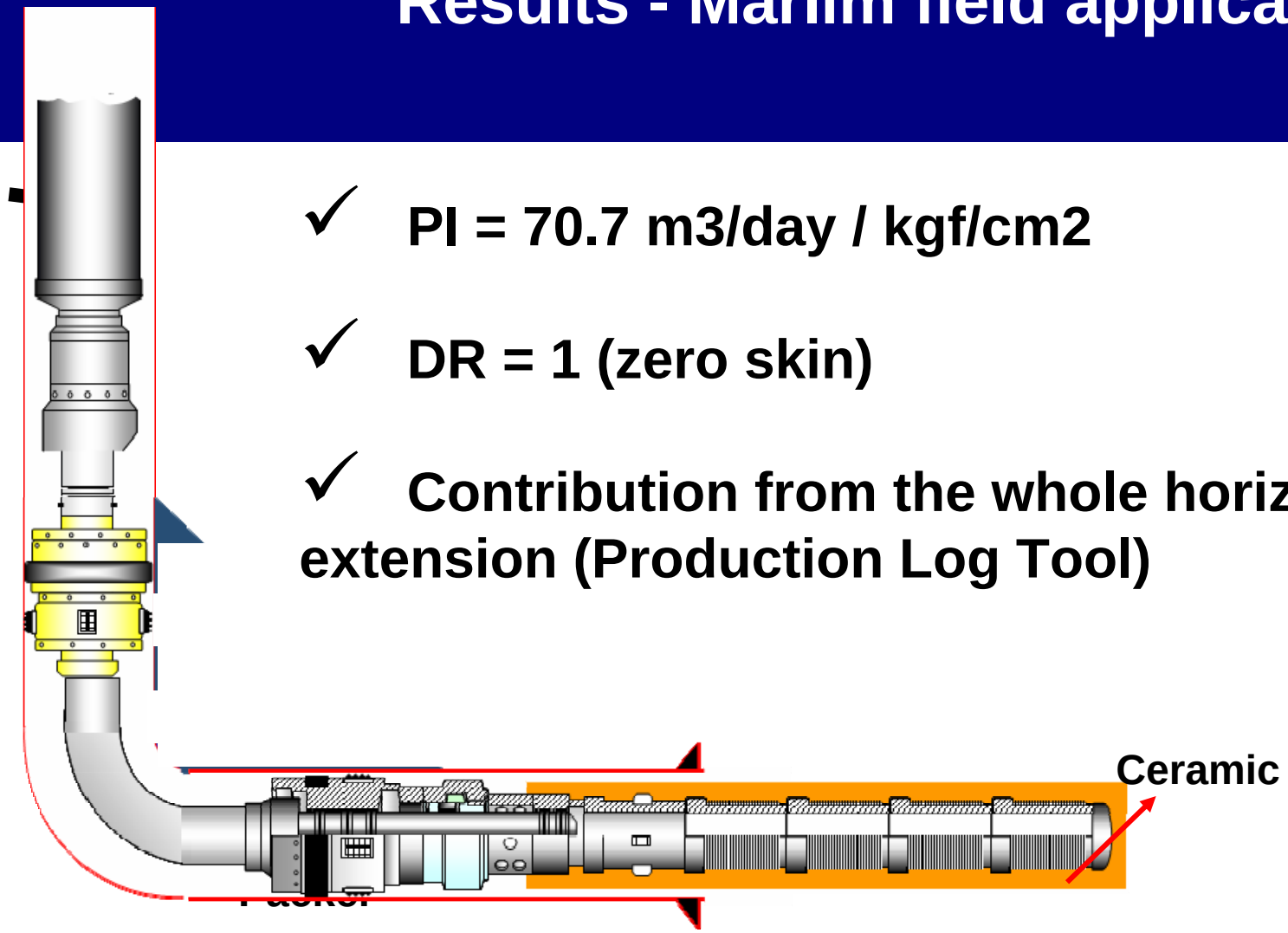


Gravel pack execution – Marlim field

Relevant observations – Marlim field application

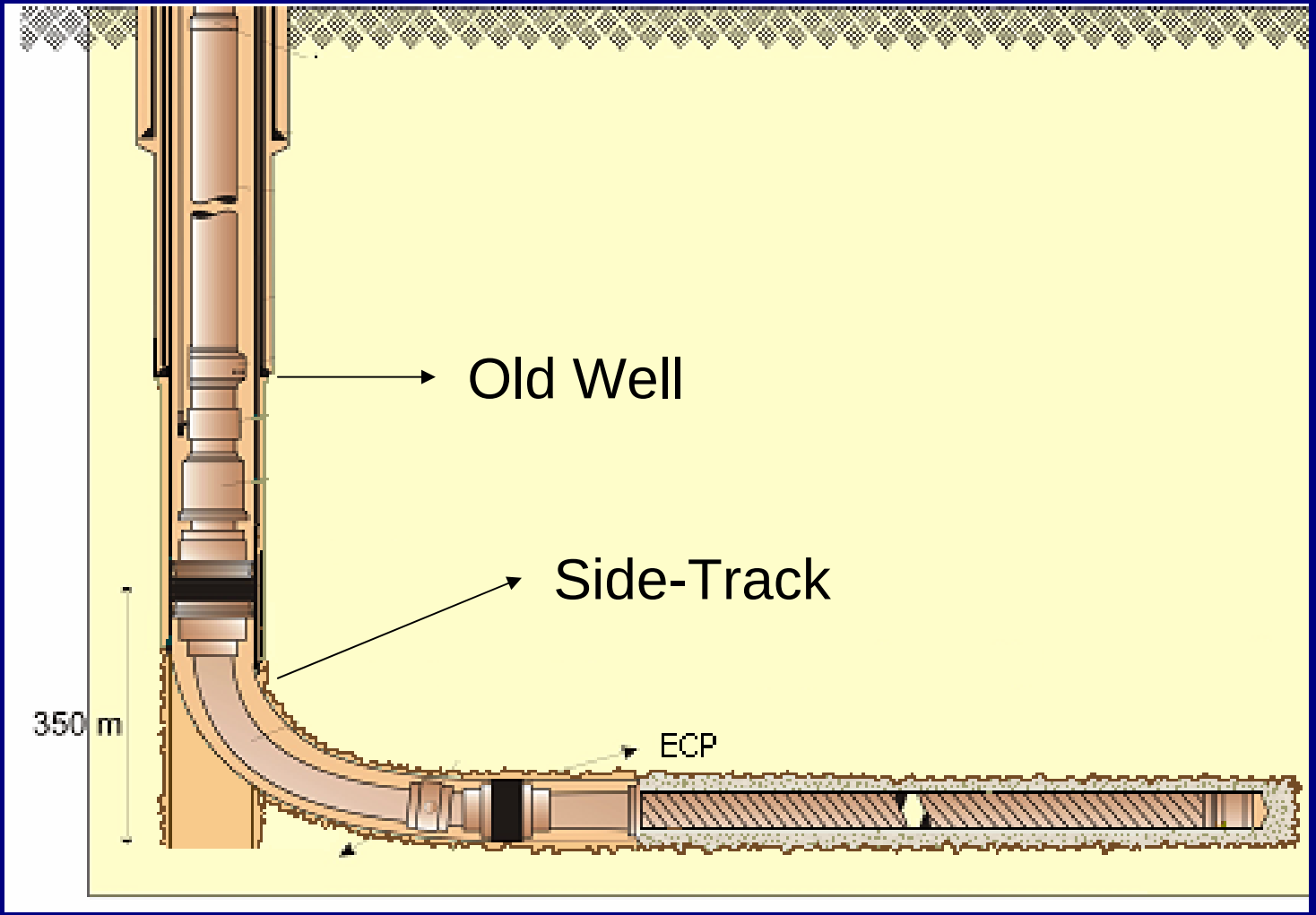
- Low contamination of GP carrier fluid with DIF
- Effective mud cake DIF x GP carrier fluid – no losses
- The measured and the simulated pressures were found similar
- Excellent ceramic packing (> 100%)
- Proper filter cake clean up with production flow

Results - Marlim field application



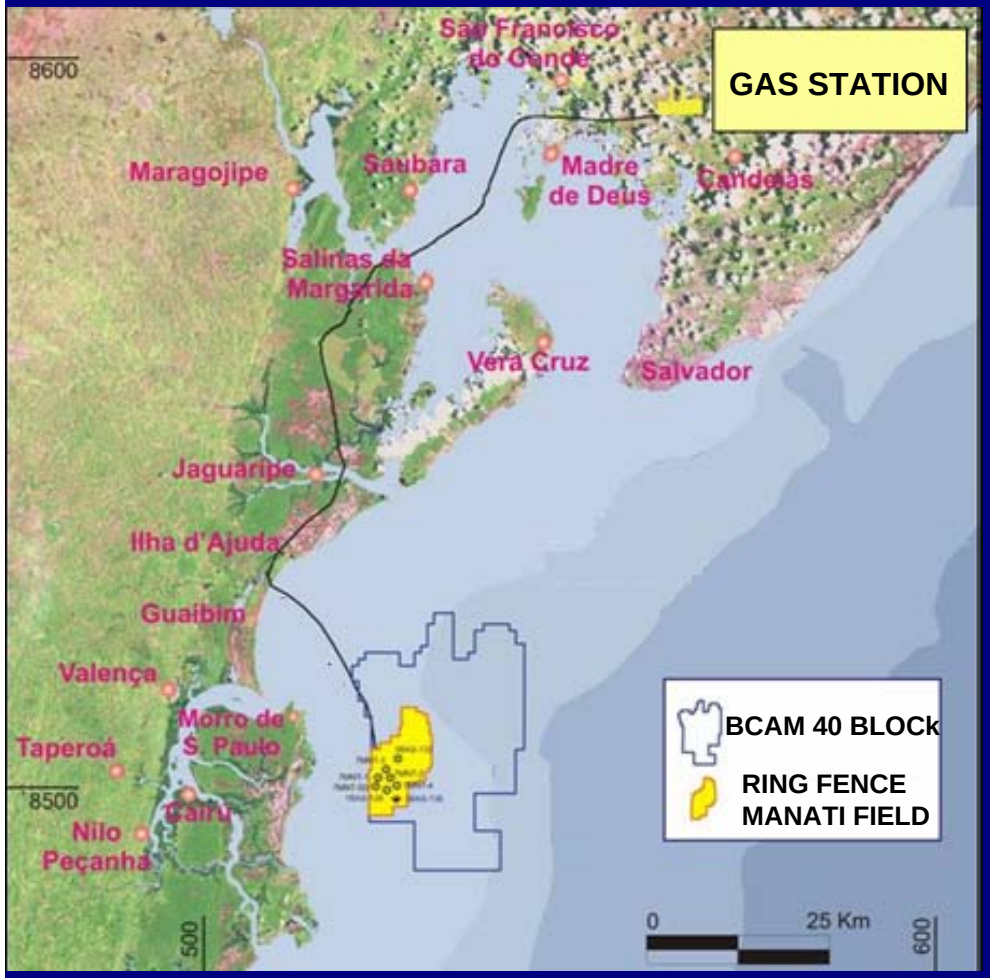
- ✓ PI = 70.7 m3/day / kgf/cm2
- ✓ DR = 1 (zero skin)
- ✓ Contribution from the whole horizontal extension (Production Log Tool)

Next Step → Infill drilling project (2010)



New trends and challenges in OHGP

Manati Field – Northeast of Brazil



Block - BCAM 40

Water depth < 50m

9 Km from the coast

Environmental sensitive area (zero discharge)

Manati field – northeast of Brazil

Discovered - oct/2000, well 1-BAS-128

Gas Reservoir – Low vertical depth (1400m)

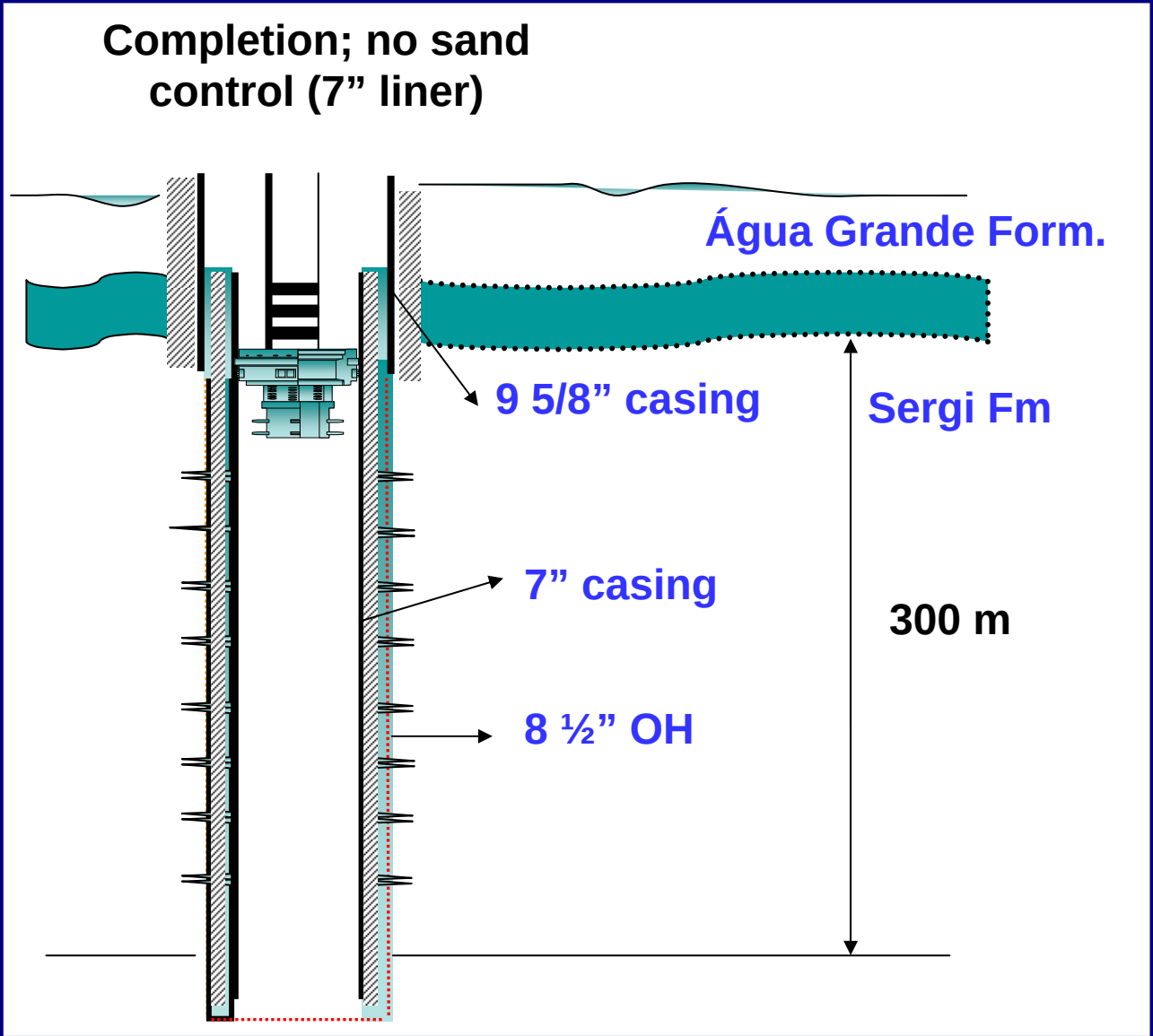
Thick reservoir - (100m to 350m)

High permeabilities (200 mD – 500 mD) and high porosities (21%)

High Productivity Index

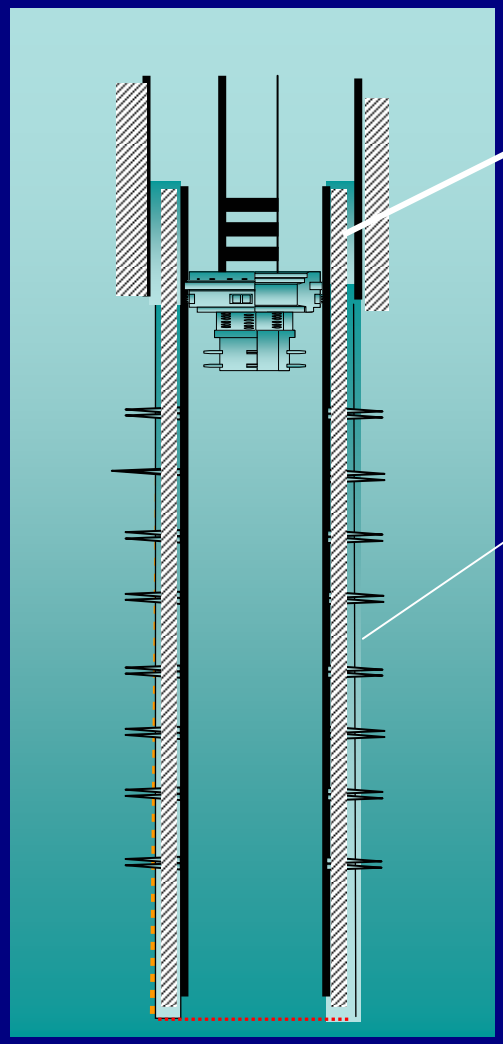
High fluid density (up to 12.5 ppg)

Manati field – Initial well project (no sand control)



Initial well project (no sand control)

Main restrictions observed during well completions:



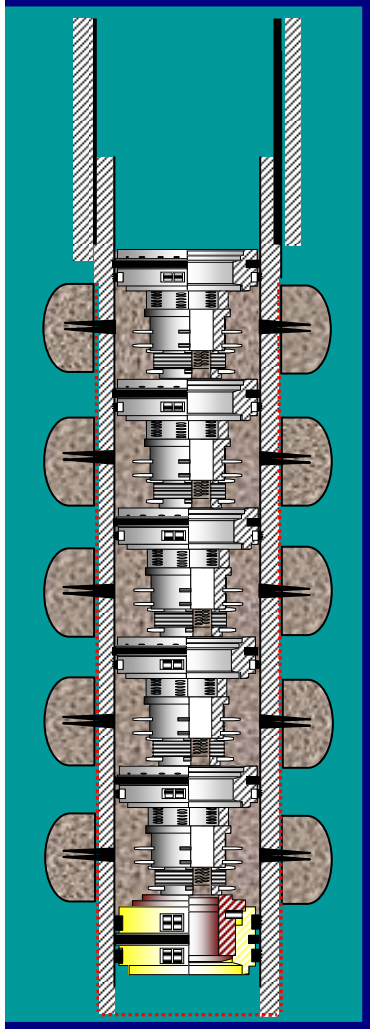
Liner top isolation (dry-test) – 52 hours / well

300m perforation (high costs)

- **During well completions, new requirements (50% increase in flow rates)**
- **R&D Center (CENPES) → Sand production risks → Sand control requirement**

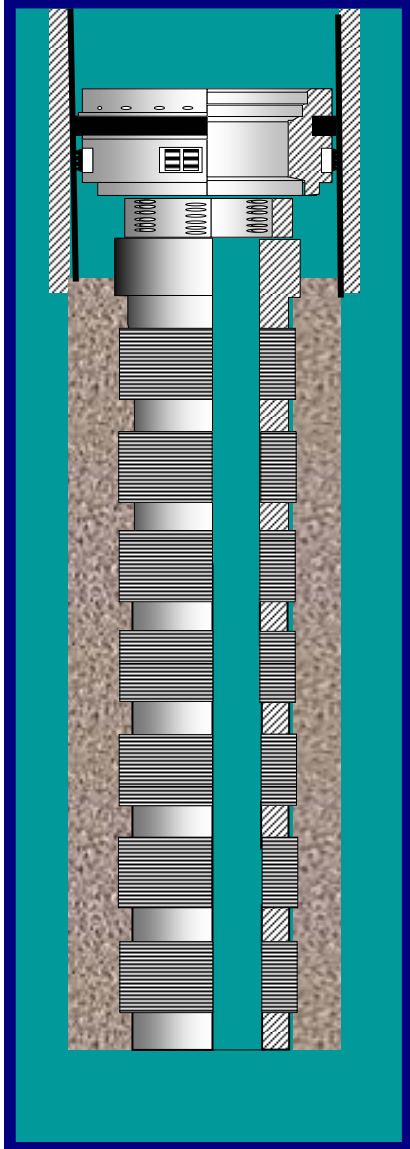
Sand control options for Manati field

Main limitations for cased hole sand control (Fracpack) – Manati field:



- Liner top isolation (rig time and leak risks)
- Long perforation intervals
- Smaller screen diameter - 3 ½”
- Injection of high fluid volumes - calibration tests and fracpack (minimum 10000 bbl estimated)
- Longer rig time to flow back the well and environmental restrictions (zero discharge).
- High water volumes injection in gas reservoirs are not recommended
- Fracpack require stimulation boat: high power, pressures, gel and higher costs

Sand control with OHGP for Manati field:

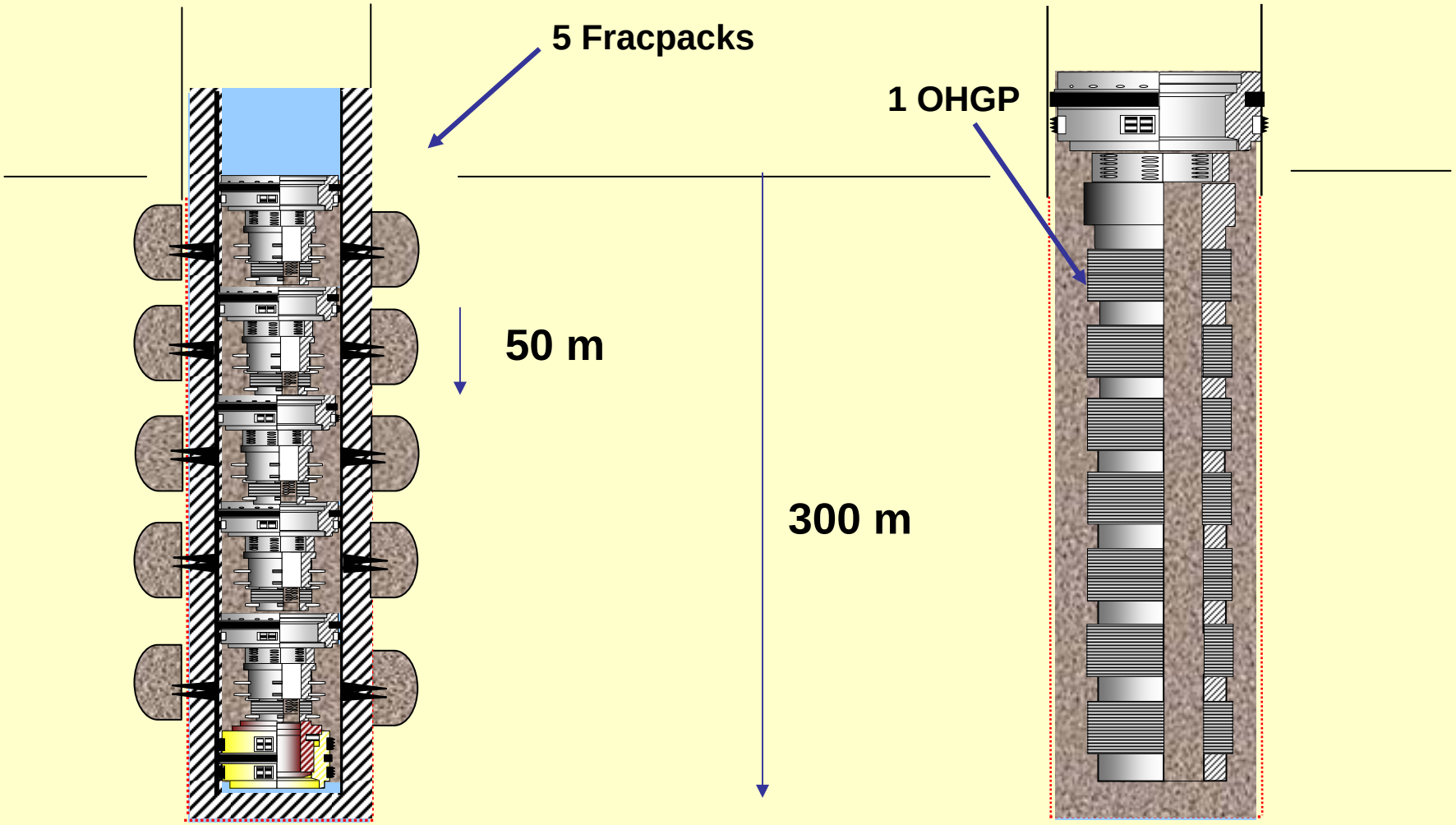


- No liner, cement operations, logs for cement evaluation, dry-test.
- No guns and rig time
- No fluid injection and related problems with flow back, separation, environmental restrictions. The evaluation is fast;
- OHGP with low pump rate and pressure, low power, no gel, lower costs and risks.
- One operation for OHGP and up to 5 fracpack operations, for 300m thickness
- OHGP requires 5 ½” screen (8 1/2” OH) and fracpack 3 ½” screen (7” CSG).

Options for sand control – Manati field

Fracpack

OHGP Selected

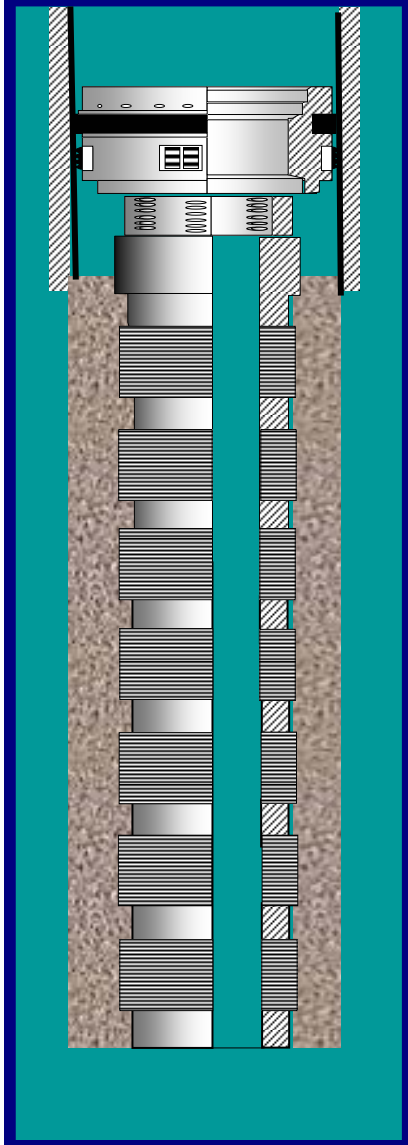


Main challenges for OHGP in Manati field

- Higher pore pressure than the conventional OHGP;
- Drill in fluid requirements:
- Completion fluid → Same weight D.I.F and compatible;
- Usual D.I.F. (NaCl base)→ More than 10 ppg ($CaCl_2$) is usual, but is incompatible with polymers
- Drill in Fluid (sodium formate) and completion fluid (sodium formate and potassium formate) →

Good results (All requirements): Mud cake thickness (< 1mm), Break out pressure (< 10 psi), K return (90 %)

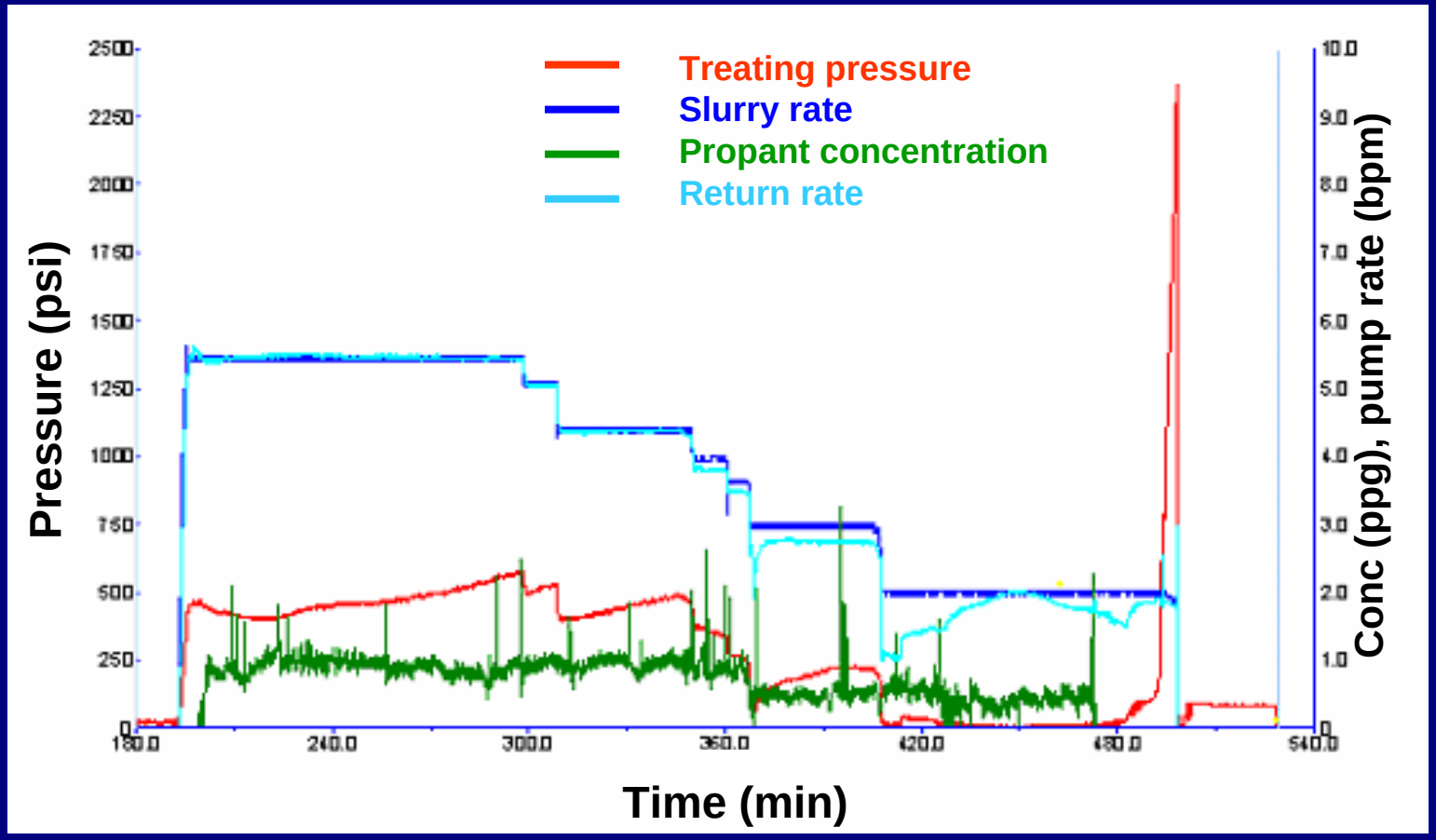
OHGP in Manati field: wells number 5 and 6



- These 2 wells were drilled with water base D.I.F (Sodium Formate base)
- The D.I.F. was displaced by filtered completion Fluid (Sodium Formate and Potassium Formate).
- The premium screens was RIH and the OHGP performed

OHGP execution – Manati field (2 Wells)

OHGP Chart - Well 5 (100% packed)



Well tests evaluation Manati field:

PAPER
IPTC 12364

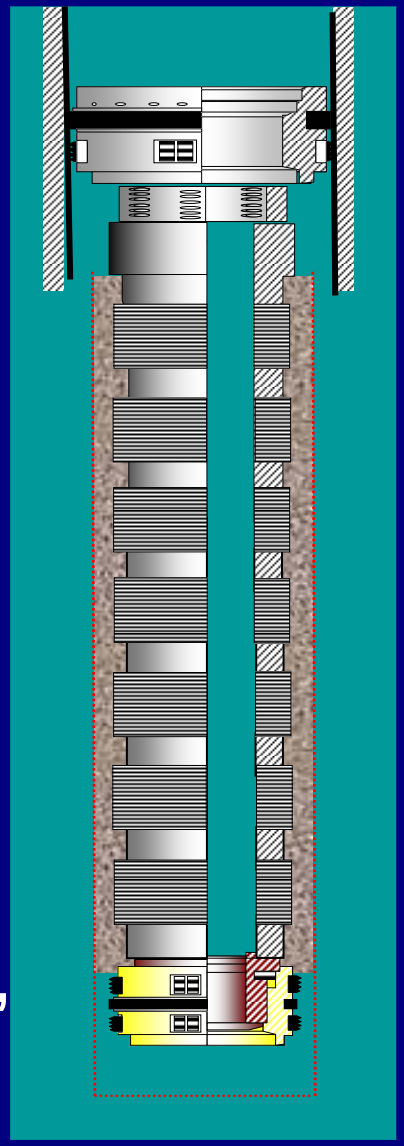
Wells	Sand Control (Y/N)	Net Pay (m)	AOF (million m3/day)	K (mD)
Well-03	N	191	12.6	305
Well-04	N	194	11.5	295
Well-05	**Y**	**243**	**15.8**	**220**
Well-06	**Y**	**142**	**19.7**	**482**

(OHGP) Higher productivity than without sand control

The best productivity result in Manati field is OHGP (compared with wells without Sand Control)

Conclusions

- ✓ OHGP: Productivity and reliability;
- ✓ The oil base system as a gravel pack carrier fluid: sensitive reservoirs and mature fields;
- ✓ For higher pore pressure reservoirs → formates;
- ✓ OHGP is a good option for high permeability reservoirs (gas or oil): simplicity, productivity and economic advantages



Thank you !

Questions ?

Distinguished Lecturer Program

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Acknowledgments:

- SPE

- Petrobras

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