# TEC 304
# World First All-Electric Intelligent Completion System With Permanent Monitoring to Evaluate Injection Performance in a Mature Injector Well

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XIX CONGRESO REGIONAL COLOMBIANO DE PETRÓLEO, GAS Y ENERGÍA 2022
Sostenibilidad y Coexistencia Energética: el futuro de Colombia

# PRESENTATION OVERVIEW

- Introduction
- Background
- Conventional Completion Vs. Intelligent Completion
- Objectives of the Project
- Well and Technology Selection
- Real Time Monitoring
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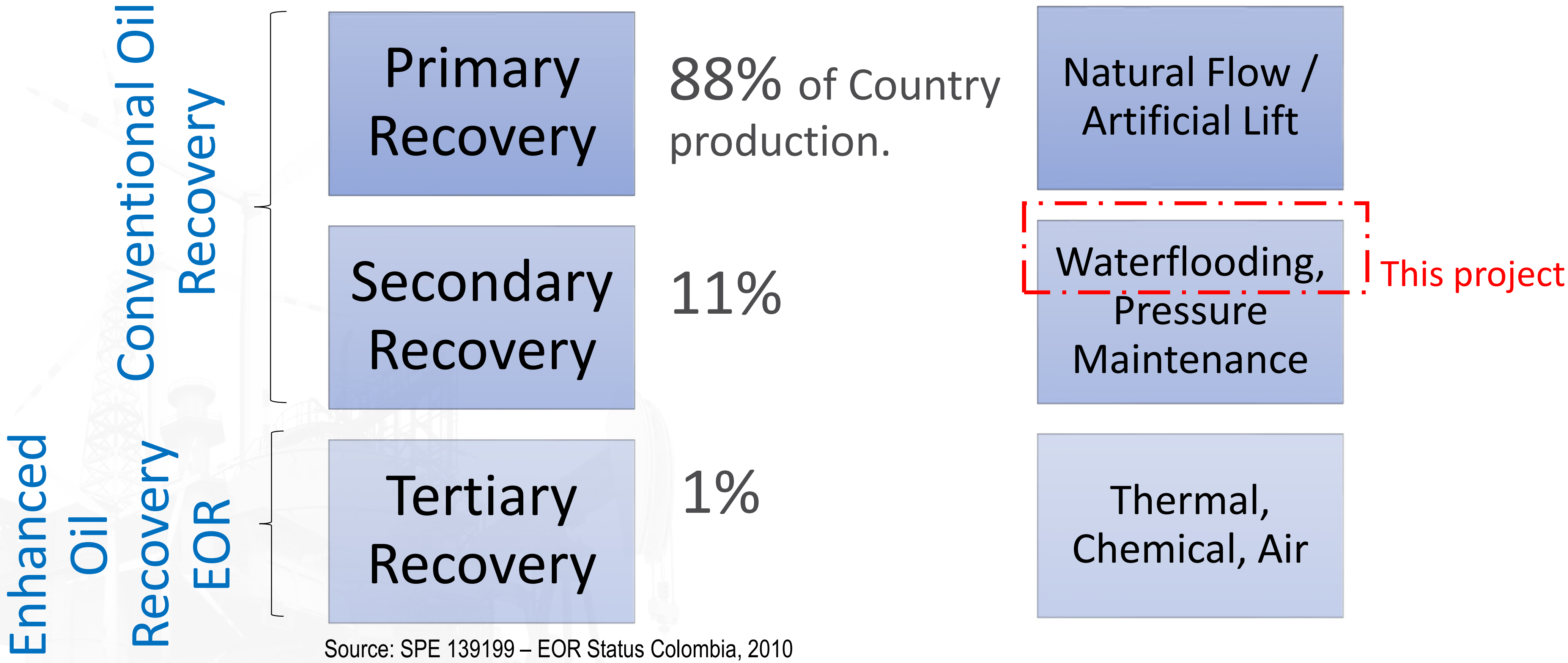
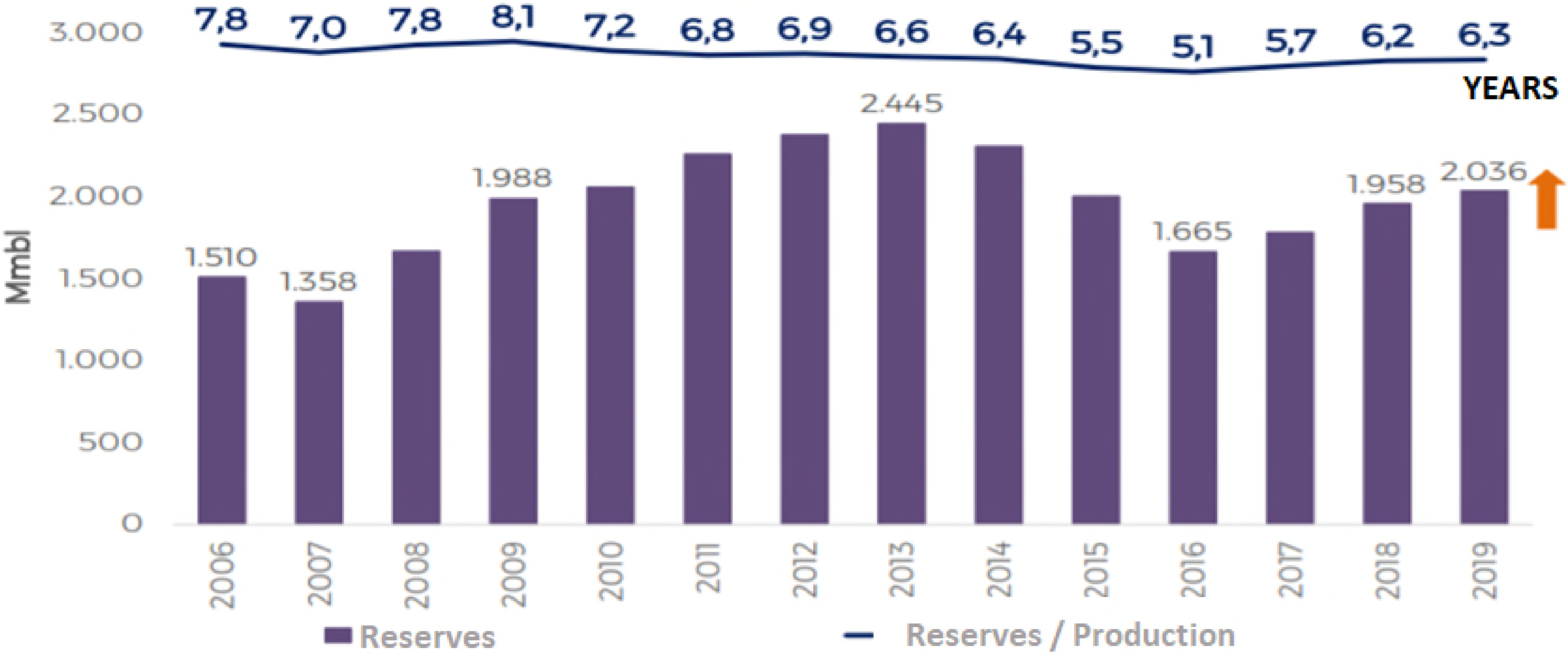
# 88% Colombian Oil Production come from Primary Recovery (@2010 –SPE 139199)



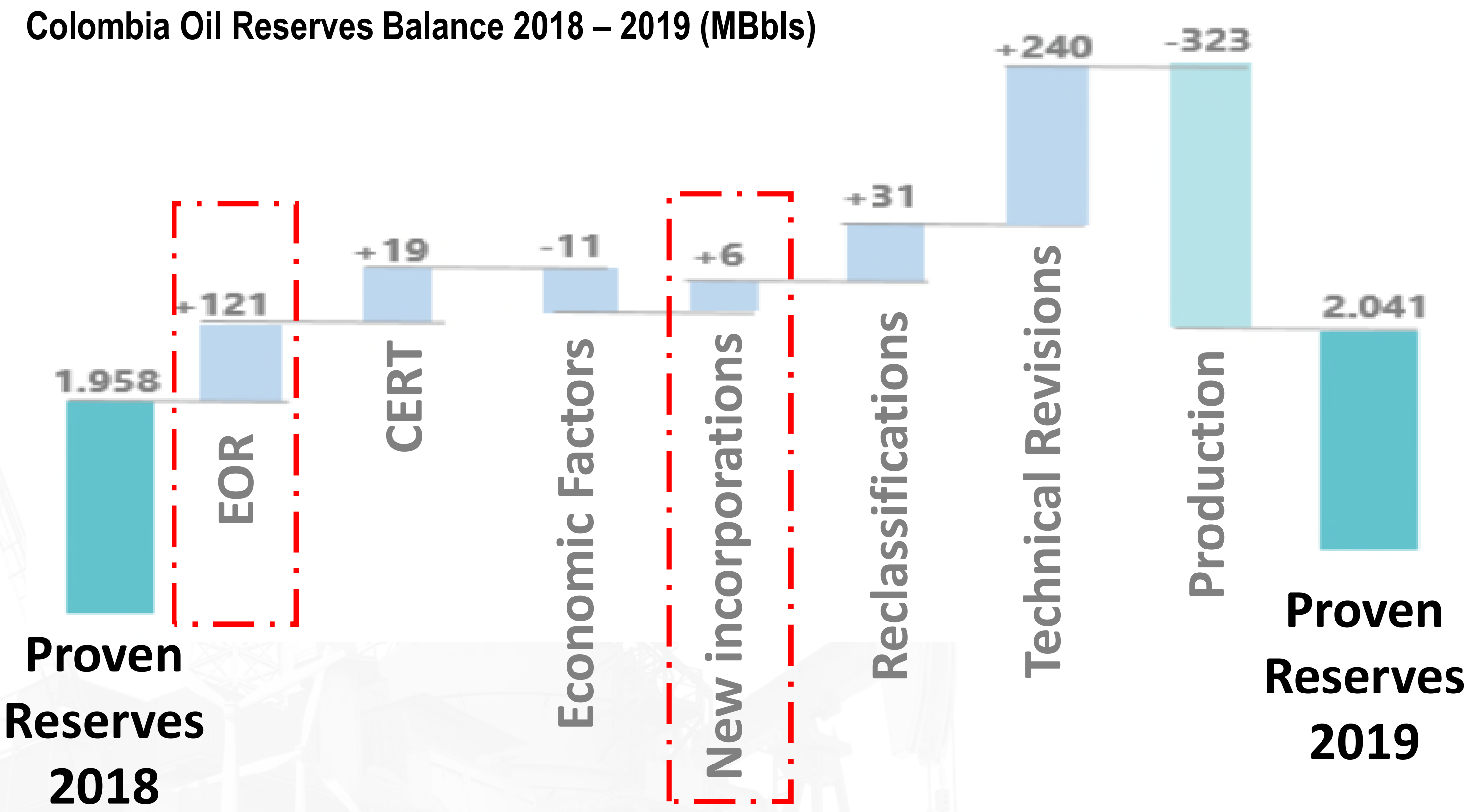

Source: SPE 139199 – EOR Status Colombia, 2010

# Colombian Petroleum Self-Sufficiency is on average: 6 years.




Source: Ecopetrol Media and Diario la República 2021

# +30% of Colombian Incorporated Reserves come from EOR




Source: Agencia Nacional de Hidrocarburos, Colombia

- EOR: 121 MBbl. Total incorporated reserves: 406 MBls.
- New incorporations are only 1,5% of total incorporated reserves during 2019.

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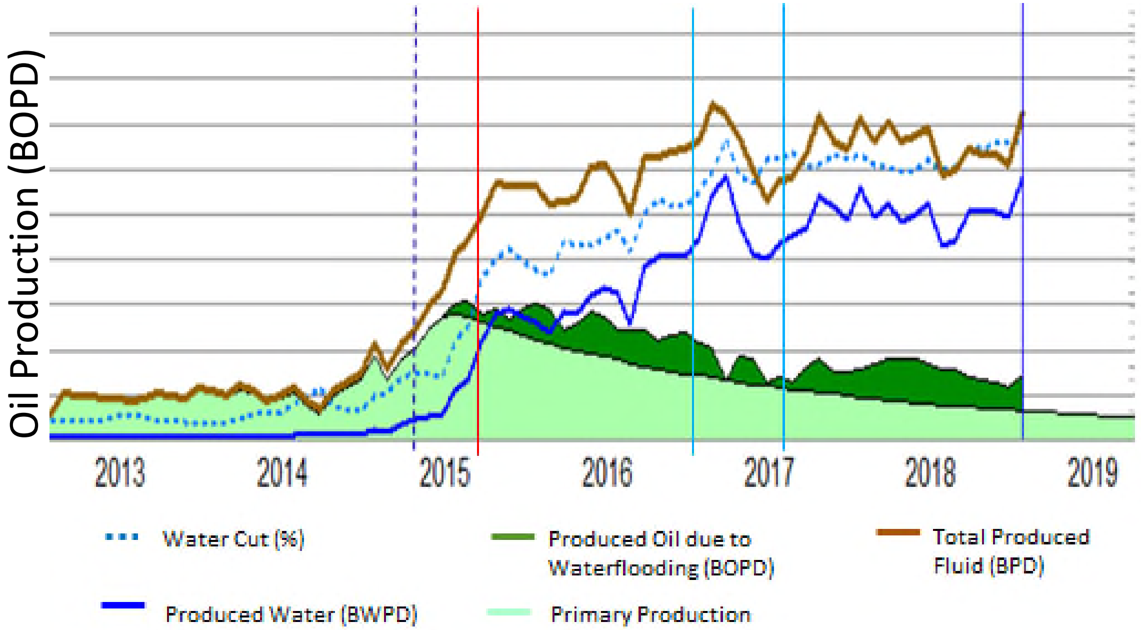
# Chichimene Field: Declining oil production is one of the field most difficult challenges

- Location: Colombian Llanos Basin.
- Type of production: Heavy Oil.
- Waterflooding Pilot start date: 2014.



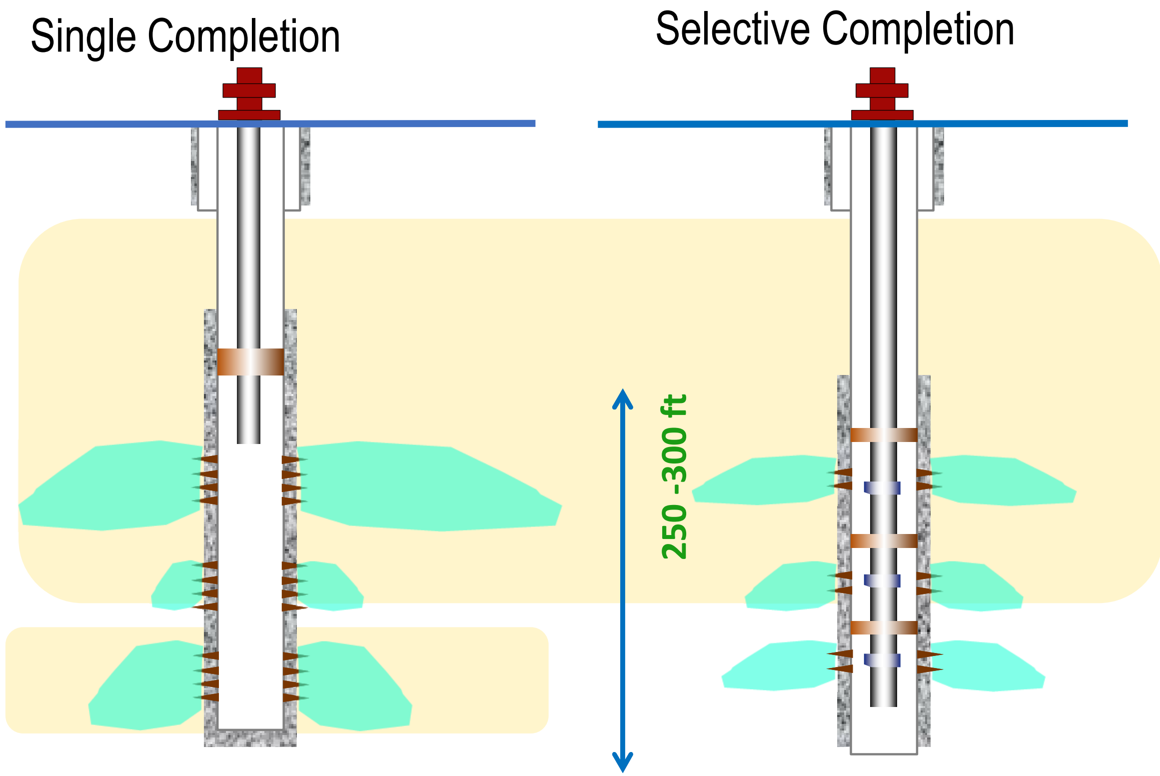

Source: Ecopetrol. Chichimene Field, historical production

## Field Challenges:

- High Net-Pay (+250 ft).
- High differences in vertical permeability. (5D – 5mD in few ft).
- Distribution of existing Wells.
- Operational complexity in existing Wells.

# The Chichimene Waterflooding Pilot finished in 2019 with 37 injector Wells.

- **2014** – Waterflooding pilot. 13 patterns (3 new wells and 10 converted to injector)
  - Single completion increased in 3% the Recovery Factor (RF).
  - Selective Completion increased 10% RF.
- **2018** – Technology expansion.
- **2021** - Total 37 injector wells with Good results in production and reserves.




Source: Solorzano, 2018 – SPE-191170-MS

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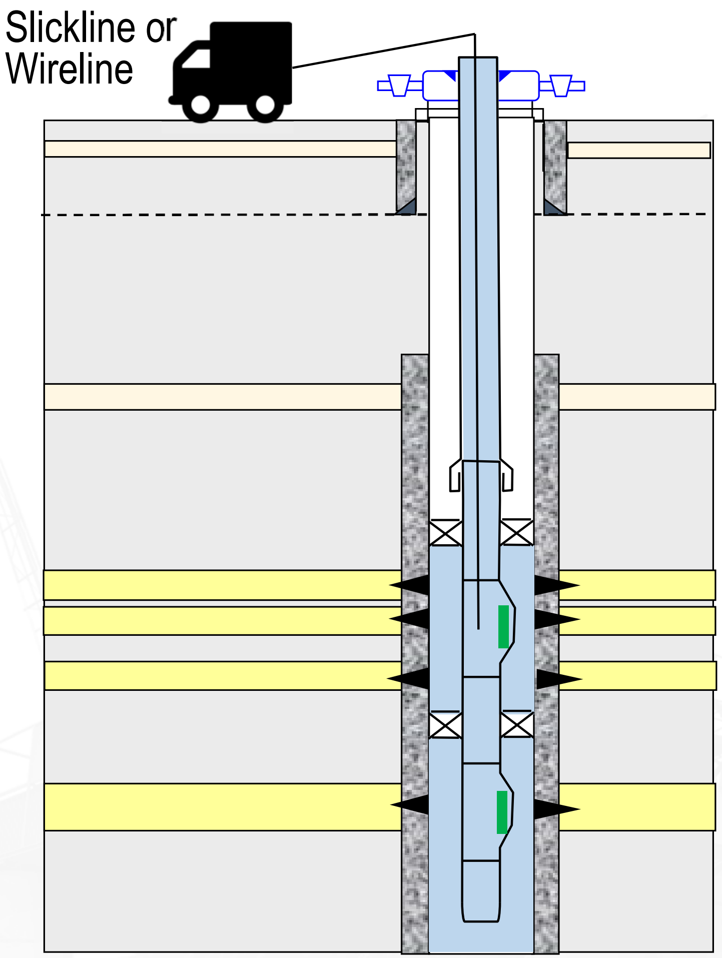
# Between 4-6 Weeks to Reach the Injection Targets Rates per Zone with Conventional Completion




**Completion Design:**

- Hydraulic packers.
- Injection mandrels and dummies.
- Flow Regulator Valves. FRV.

**Well Monitoring (SL, WL, CT):**

- FRVs and Dummies with Slickline.
- Injection Log Tests (ILT) with Wireline + Fiber Optics.
- **Repeat, Repeat, Repeat.**

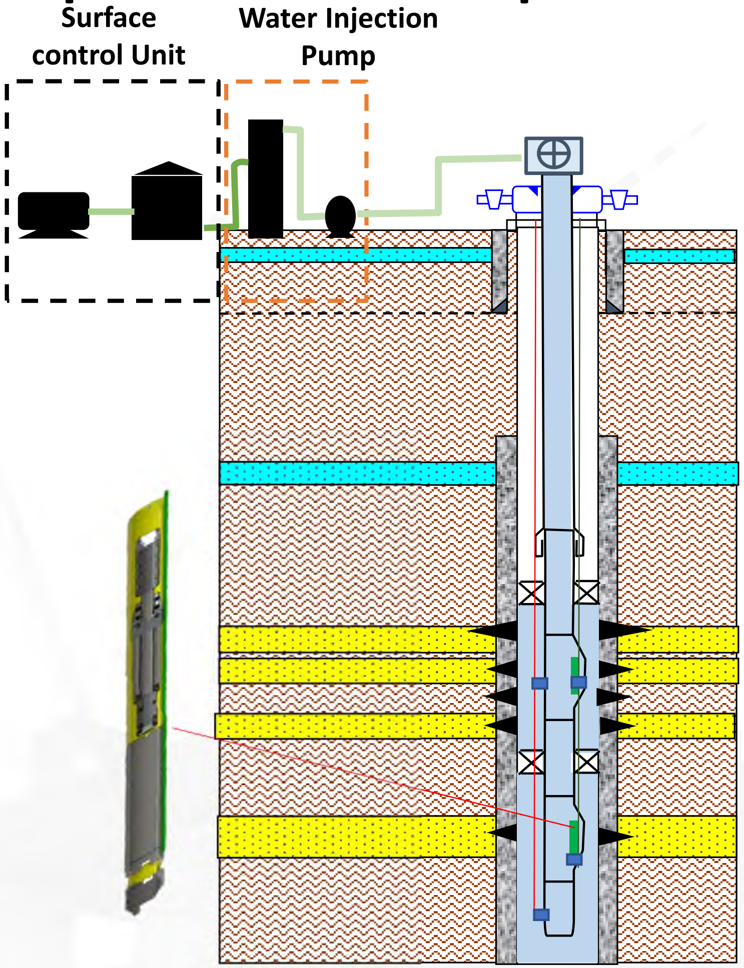
**Time to Reach injection Targets**:

- 4-6 Weeks.
- 2-3 FRV changes and ILTs.

**With manual calibration and monitoring**:

- Canalizations.
- Lack of data on time.
- Low injection swapping efficiency
- Operational incidents during Rig-less operations with.
- FRV Plugging.

# Intelligent completion reduced calibration times, increased production, reduced Opex and CO2 Footprint

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**Completion Design:**

- Feedthrough Hydraulic packers.
- 4 Electric Intelligent control valves ICV

**Well Monitoring (SL, WL, CT):**

- Permanent Fiber Optics with DAS* and DTS**.
- Remote Valve actuation

**Time to Reach injection Targets**:

- Less than 6 hours
- 1 ICV actuation

*DAS: Distributed Acoustic Sensing
**DTS: Distributed Temperature Sensing

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# Three Strategic Objectives were defined

## Objectives of the Project

Prove that an intelligent well completion:

1. Works for mature Wells with heavy oil.
2. Can optimize the Water Flow regulation and effectively monitor the injection.
3. Prove the Cycle Water Injection Technique to improve the swapping efficiency in the injection pattern.

## Some Key Performance Indicators

- Difference between target flow per zone vs actual flow injected Target **(Target flow/Actual Flow. %)**
- Difference between FO Calculation versus ILTs. (**ILT Flow calculation / FO Flow Calculation. %)**

**Others:**

- % Increase in production.

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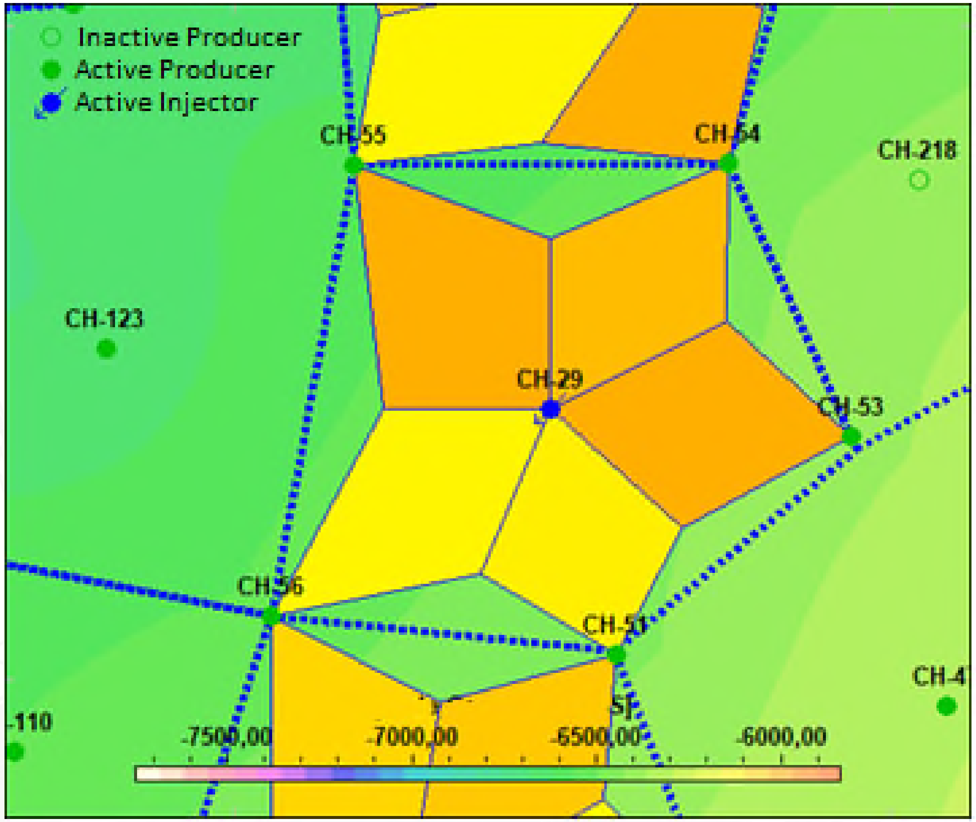
# CH29 Well was Selected among 10 Wells based on 6 key parameters

## Chichimene-29 Injection Pattern




1. Existing Well.
2. Solid Injection baseline and performance.
3. Good reservoir connectivity.
4. Good pattern production.
5. Well Integrity.
6. Well Geometry and construction.

- CH29
  - Drilled in 2008.
  - 9-5/8” Casing y 7” liner .
  - 3 zones Injector Well.
  - Target formation @ 8570 ft.

# CH29 HAD ADDITIONAL CHALLENGES

- **Short distance between injection zones**
  - As short as 30ft between packers, resulting in a rigid assembly to install.
- **Existing perforations**
  - Zones with 8ft space to set packers, which could cause integrity issues.
- **Low formation Pressure**
  - High differential pressure (1,200 psi) during completion installation and valves operation compromised completion operation
- **Well Integrity**
  - Higher risk than other candidates.
  - 11 years since drilled
  - 29 well services (13 WO and 16 Rig-less).
- **Operational Risks**
  - Returns and circulation @ +10 BPM.

# 6 KEY PARAMETERS WERE DEFINED FOR THE PROJECT

## Ranking of parameters for the project

| Item | Parameter | Category | Score |
|---|---|---|---|
| 1 | Technology Readiness level (TRL) and associated risks during completion installation and well life | Technology | 10 |
| 2 | Compliance with operating parameters such as injection flow per zone and total injection flow. Ability to respond to changes in parameters in the future. | Completion equipment | 8 |
| 3 | Quality and precision of the information delivered by the intelligent injection control monitoring system (Temperature, Rate, Injection profile per perforation). | Information | 7 |
| 4 | Manufacturing and delivery time of the technology | Time and cost | 6 |
| 5 | Initial investment cost (CAPEX) and operating costs (OPEX) | Time and cost | 3 |
| 6 | Time to receive the information of the calculated injection flows by zone and the time to actuate the valves. | Completion equipment | 2 |

# OPERATIONAL REQUIREMENTS WERE COMPARED TO AVAILABLE TECHNOLOGIES

## Technology Screening

| Item | Equipment | Operational Parameters | Available Technologies |
|---|---|---|---|
| 1 | Packers | **Required**<br>• Withstand tubing loads @ 2K psi and 6K BWPD and stimulation @ 3K psi and 0.5 BPM.<br>• Have a feed-through feature to pass the cables | 1. Permanent hydraulic.<br>2. Semi-permanent hydraulic (cut to release or shift to release).<br>3. Tension Release Hydraulic |
| 2 | Intelligent Valves | **Required**<br>• Ranges between 200 BWPD and 6K BWPD.<br>• Unloading pressure greater than downhole pressure differentials.<br>Desired<br>Have the fewest cables for actuation | 1. Hydraulically actuated.<br>2. Electrically actuated.<br>3. Electro-hydraulic. |
| 3 | Valve regulation system (Chokes) | **Required**<br>Enough positions to meet operating pressure and flow ranges.<br>Desired<br>Allow the least tortuosity and pressure losses | 1. Sliding sleeve type choke<br>2. Helical type choke<br>3. Flow Regulation valve actuated from surface. |
| 4 | Flow calculation system by zone | **Required**<br>Allow the calculation of flow per zone in real time (without stopping the injection) with an accuracy of 90%.<br>Allow calculation of injected fluid per perforate. | 1. Flowmeter with direct downhole flow measurement.<br>2. Pressure and temperature gauges.<br>3. Permanent fiber optic - Distributed Temperature Sensing (DTS) and Distributed Acoustic Sensing (DAS). |

# The Selected Configuration Was: 100% Electric Valves and Permanent Fiber Optics Monitoring for Flow Calculation

## Ranking and Selection of Technology Options

| | Option | PR #1 | PR #2 | PR #3 | PR #4 | PR #5 | PR #6 | Score | Ranking | Result |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Electric valves and permanent fiber optics (DTS & DAS) for flow calculation | 3 | 3 | 3 | 2 | 2 | 3 | 2.71 | 1 | Selected |
| 2 | Hydraulic valves with pressure and temperature (P/T) gauges for flow calculation | 3 | 3 | 1 | 3 | 2 | 2 | 2.69 | 2 | Optional |
| 3 | Electric valves with pressure and temperature gauges (P/T) for flow calculation | 3 | 3 | 1 | 3 | 2 | 2 | 2.69 | 3 | Optional |
| 4 | Hydraulic valves and permanent fiber optics for flow calculation | 3 | 3 | 3 | 2 | 2 | 2 | 2.66 | 4 | Discard |

**Some advantages:**

- Electric Valves - 1 single cable.
- Helicoidal choke.
- Calculation of Rates per zone with DAS and rates por perforation with DTS.

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# 6 TEST WERE PERFORMED TO CHECK DAS PERFORMANCE

## Comparison Between DAS and ILT

| Test Number | Date | Choque position | ILT (Allocation) | ILT (BWPD) | DAS (Allocation) | DAS (BPD) | DAS vs ILT (%) |
|---|---|---|---|---|---|---|---|
| 1 | 6/08/2019 | Valve Zone 4 | 0% | 0 | 5% | 266 | -5% |
| | | Valve Zone 3 | 20% | 1190 | 11% | 631 | 9% |
| | | Valve Zone 2 | 71% | 4262 | 68% | 3994 | 3% |
| | | Valve Zone 1 | 9% | 548 | 17% | 1009 | -8% |
| 2 | 23/08/2019 | Valve Zone 4 | 0% | 0 | 11% | 599 | -11% |
| | | Valve Zone 3 | 30% | 1598 | 20% | 1055 | 10% |
| | | Valve Zone 2 | 59% | 3117 | 40% | 2136 | 19% |
| | | Valve Zone 1 | 11% | 585 | 28% | 1505 | -17% |
| 3 | 29/08/2019 | Valve Zone 4 | 0% | 0 | 9% | 509 | -9% |
| | | Valve Zone 3 | 31% | 1629 | 24% | 1277 | 7% |
| | | Valve Zone 2 | 54% | 2859 | 55% | 2970 | -1% |
| | | Valve Zone 1 | 15% | 813 | 12% | 655 | 3% |
| 4 | 30/08/2019 | Valve Zone 4 | 0% | 0 | 12% | 518 | -12% |
| | | Valve Zone 3 | 30% | 1359 | 25% | 1125 | 5% |
| | | Valve Zone 2 | 52% | 2334 | 48% | 2151 | 4% |
| | | Valve Zone 1 | 18% | 807 | 16% | 702 | 2% |
| 5 | 30/08/2019 | Valve Zone 4 | 0% | 0 | 11% | 572 | -11% |
| | | Valve Zone 3 | 36% | 1944 | 24% | 1296 | 12% |
| | | Valve Zone 2 | 43% | 2322 | 53% | 2862 | -10% |
| | | Valve Zone 1 | 21% | 1134 | 13% | 675 | 9% |
| 6 | 30/08/2019 | Valve Zone 4 | 0% | 0 | 11% | 605 | -11% |
| | | Valve Zone 3 | 36% | 1947 | 26% | 1377 | 11% |
| | | Valve Zone 2 | 52% | 2831 | 50% | 2689 | 3% |
| | | Valve Zone 1 | 12% | 622 | 14% | 7229 | -2% |

## Comparison Between DAS and Target Rates per Zone

| Calculated DAS Allocation | Calculated DAS Rate (BWPD) | Target Allocation | Target rate (BWPD) | Allocation Diference (DAS vs Target) |
|---|---|---|---|---|
| 5% | 266 | 12% | 781 | -8% |
| 11% | 631 | 23% | 1491 | -13% |
| 68% | 3994 | 50% | 3168 | 18% |
| 17% | 1009 | 15% | 954 | 2% |
| 11% | 599 | 12% | 781 | -1% |
| 20% | 1055 | 23% | 1491 | -3% |
| 40% | 2136 | 50% | 3168 | -9% |
| 28% | 1505 | 15% | 954 | 13% |
| 9% | 509 | 12% | 781 | -3% |
| 24% | 1277 | 23% | 1491 | 0% |
| 55% | 2970 | 50% | 3168 | 5% |
| 12% | 655 | 15% | 954 | -3% |
| 12% | 518 | 12% | 781 | -1% |
| 25% | 1125 | 23% | 1491 | 2% |
| 48% | 2151 | 50% | 3168 | -2% |
| 16% | 702 | 15% | 954 | 1% |
| 11% | 572 | 12% | 781 | -2% |
| 24% | 1296 | 23% | 1491 | 1% |
| 53% | 2862 | 50% | 3168 | 3% |
| 13% | 675 | 15% | 954 | -2% |
| 11% | 605 | 12% | 781 | -1% |
| 26% | 1377 | 23% | 1491 | 2% |
| 50% | 2689 | 50% | 3168 | 0% |
| 14% | 7229 | 15% | 954 | -1% |

# The System delivers 1 datum per day (Compared to 1 datum each 3 months with conventional completion)

## Measure and Control Surface System

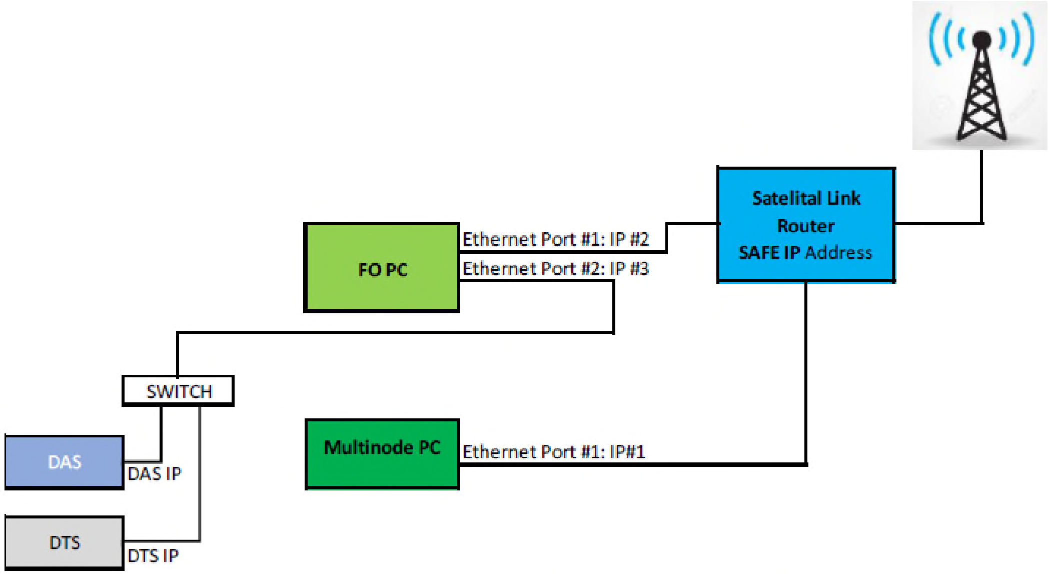


Figure 10 - Schematic of Surface Control and Surveillance Systems.

## Visualization

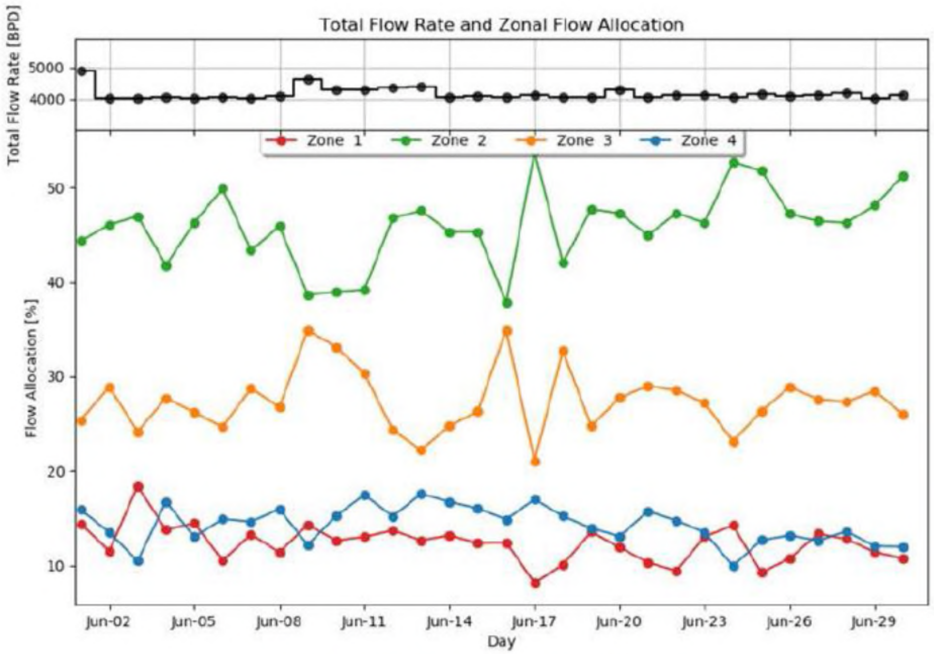


Figure 11 – Zonal Flow Allocation for one month

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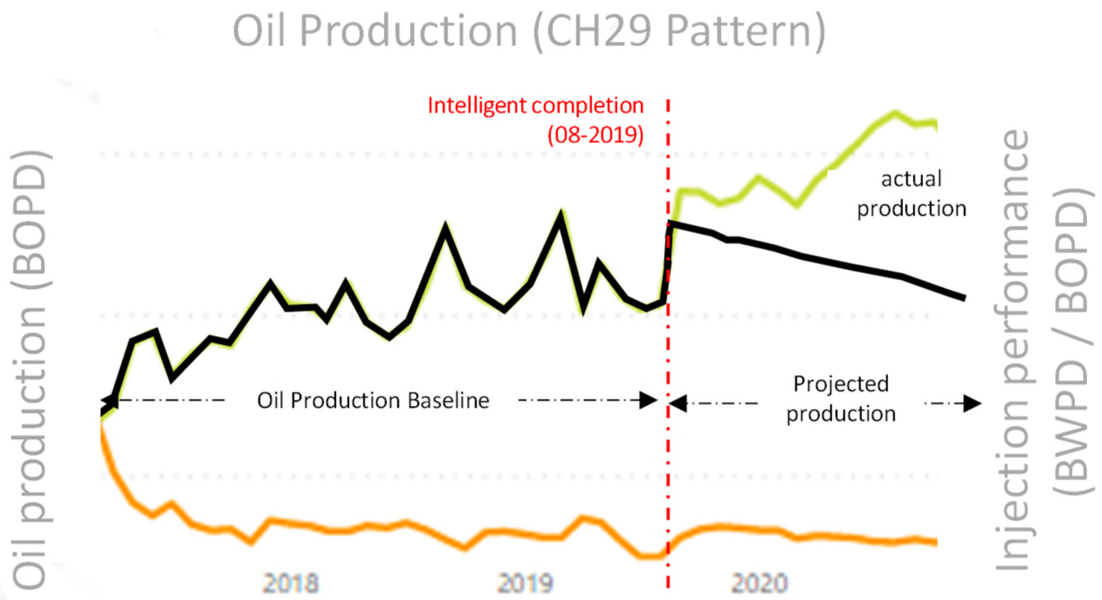
# The system Increased the Oil Production +60%




Actual production with Intelligent Completion(BOPD)

Injection performance (BWPD/BOPD)

Projected production before Intelligent Completion (BOPD)

**60 %** — **Increase of pattern production**

Compared with the baseline production before completion

**22 Months** — **After Installation**

100% reliability in valve actuation and well integrity

**30%** — **Savings in Opex/year**

Compared with the cost of interventions in 2017.

**80%** — **Reduction in Carbon Footprint**

Elimination of well interventions.

# Conclusions

- Real-time monitoring and remote well actuation systems brings valuable benefits in terms of production, injection performance, and reduction of operational costs. This consequently accelerates the return on investment and optimize enhanced oil recovery processes.

- An intelligent completion can operate adequately in conditions of variable permeability and mobility, heavy oil, and high reservoir thicknesses. Such a system can also improve the sweeping efficiency and the recovery factor.

- DAS fiber optics delivered enough information to make on-time decisions for this project. DAS results provided an accuracy of 90% in the flow calculation per zone. If a greater accuracy is required, other technologies must be evaluated.

- The process of selecting the well and identifying the appropriate technology for this application, allowed the completion to be installed without complications in a complex injector well and to maintain its reliability and integrity to date.

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