

Cerro Dragón: History and Future Challenges for an Integrally Managed Field*

Javier Gomez¹

Search and Discovery Article #20313 (2015)**
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Abstract

The Cerro Dragón Field, covering 860,000 acres, was acquired in 1958 from Amoco and produces oil and gas using primary and secondary water injection. The waterflood was started in 1969, and since 2008 there were about 200 wells drilled per year, with a current total of 3190 producers and 647 injection wells.

Production is from Middle to Late Cretaceous fluvial and alluvial (braided stream) sandstones with an average of 20% porosity and 10-50 mD. Individual reservoirs of 3-15 feet thick are stacked to 600 to 1200 feet vertically, each having different fluid contacts. Due to the high clay content, the reservoir is sensitive to formation damage. The trap is combination structural (tilted horst blocks and faulted anticlines) and stratigraphic (pinchouts). Formation water is low salinity (<4000 ppm), and oil is 20-30 API with high viscosity (20 cp).

Summary

- Pan American Energy has made a significant investment effort in exploration, development, infrastructure and technology. Cerro Dragon is today one of the most productive areas in Argentina with more than 1 billion barrels of accumulated oil.
- Cerro Dragon is a mature field, discovering new opportunities based on studies and technology application.
- Waterflooding is one of the key drivers for production increase and reserves replacement.
- 75% of Cerro Dragon is under waterflooding. Injection volumes exceed 170 Mm³/d (1 MMbbl/d). All produced water is treated and re-injected.
- The challenge is to continue developing water flood projects and to increase recovery factors through studies and new technology application, managing complexity and uncertainties.

References Cited

Barredo, S., and L. Stinco, 2010, Geodinámica de las cuencas sedimentarias: su importancia en la localización de sistemas petroleros en Argentina: Petrotecnia. Instituto Argentino del Petróleo y del Gas, Argentina, v. 2, p. 48-68.

Galloway, William E., and David K. Hobday, 1996, Terrigenous Clastic Depositional Systems: Applications to Fossil Fuel and Groundwater Resources: Springer-Verlag, 489 p.



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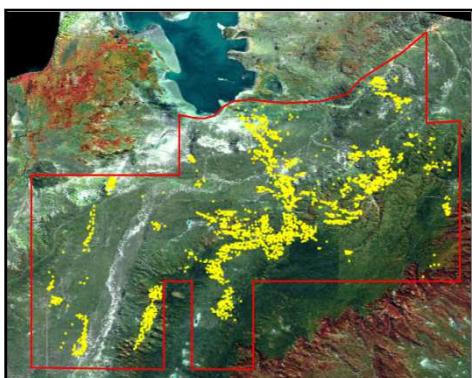
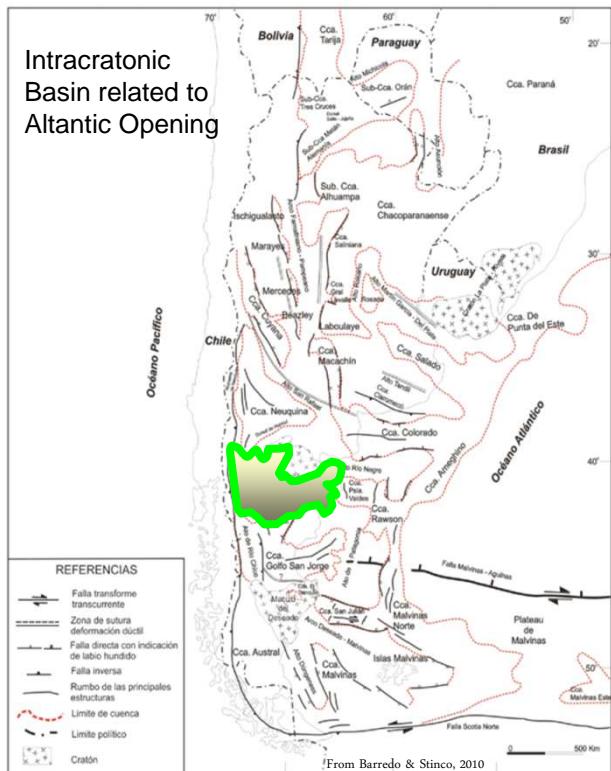


Cerro Dragón

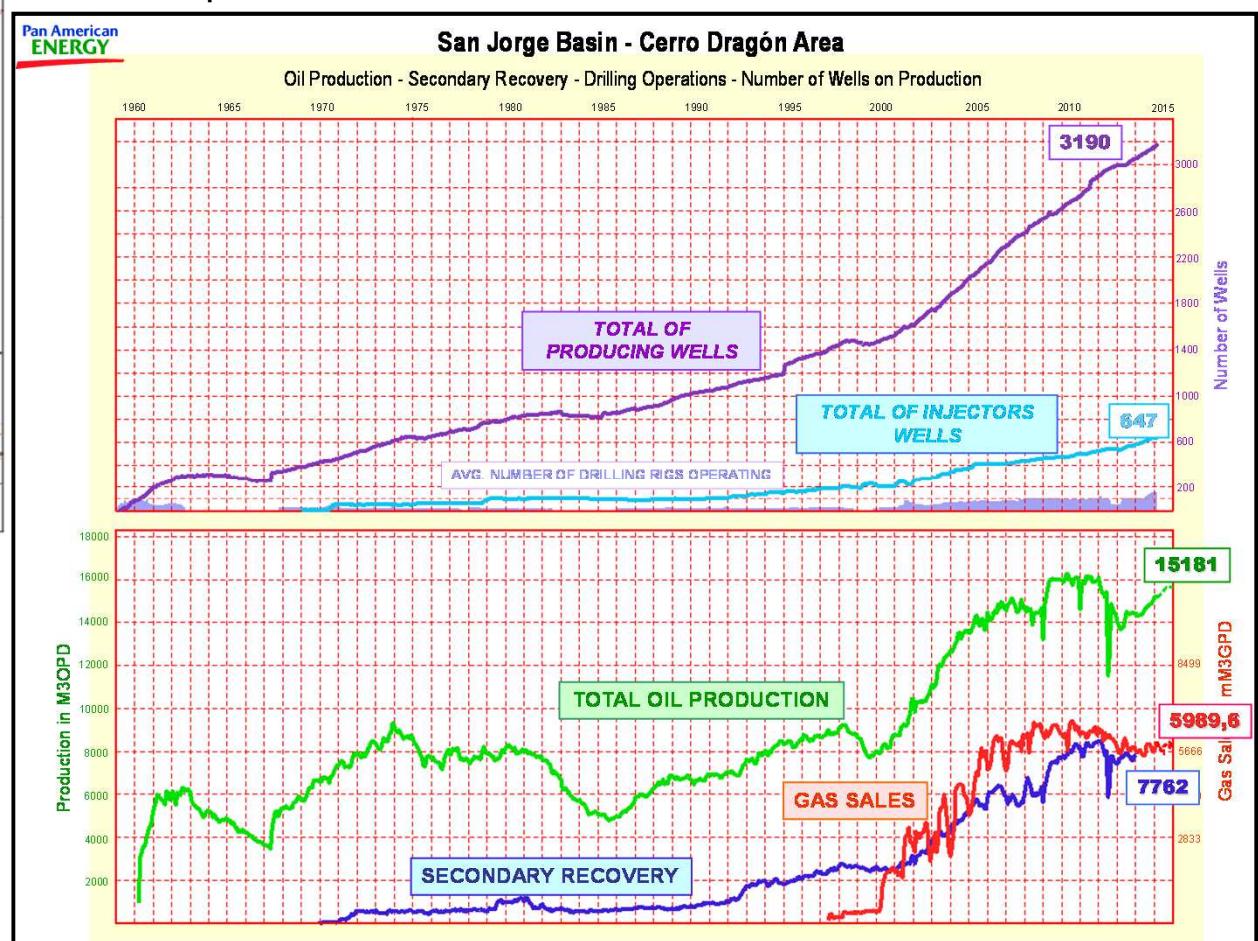
History and Future Challenges for an Integrally Managed Field

Javier E. Gómez (Pan American Energy LLC)

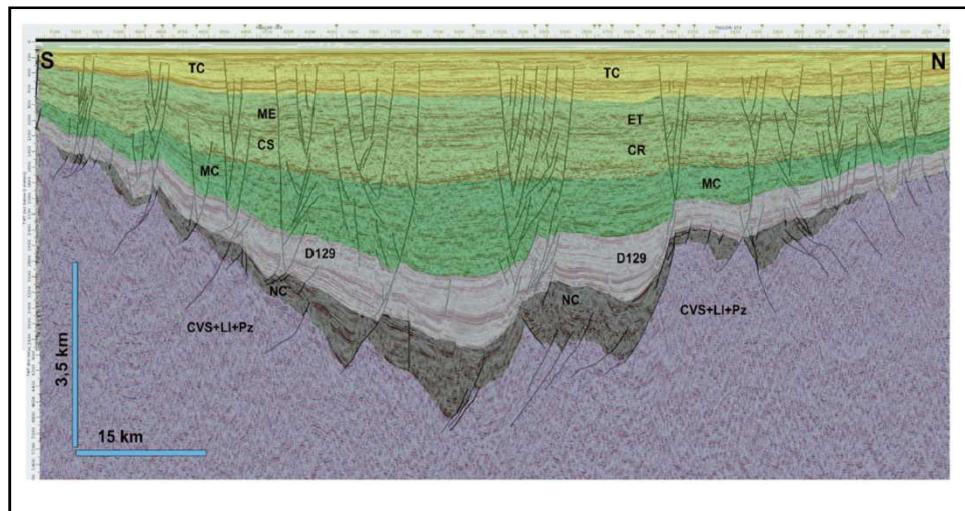
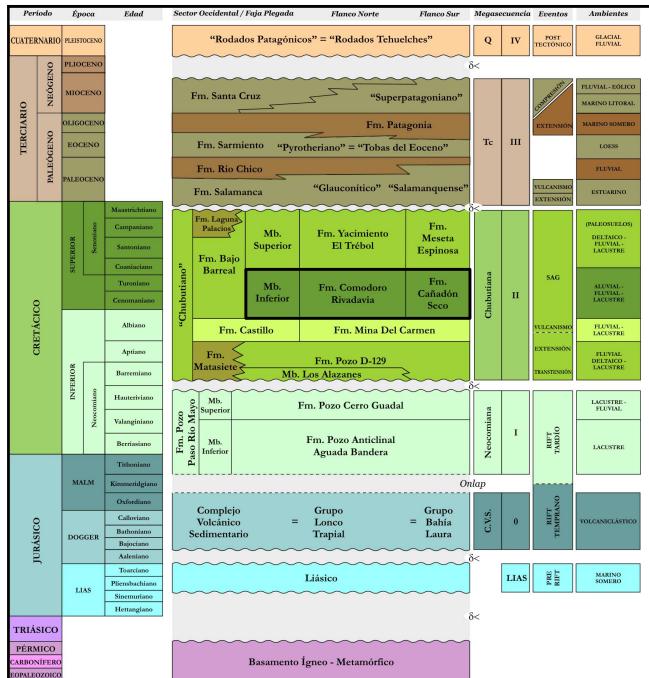
General Description



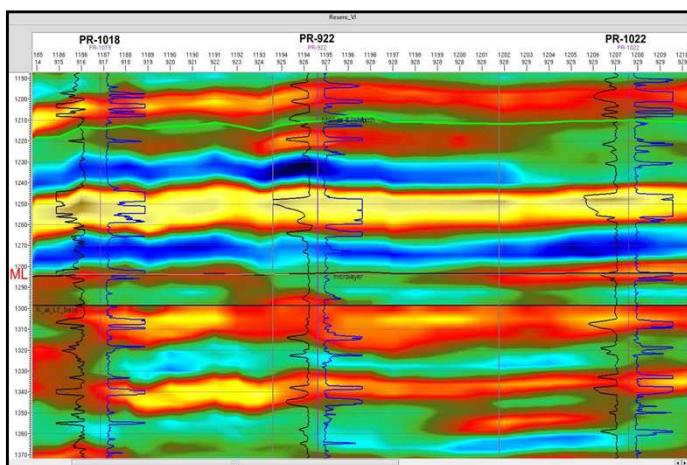
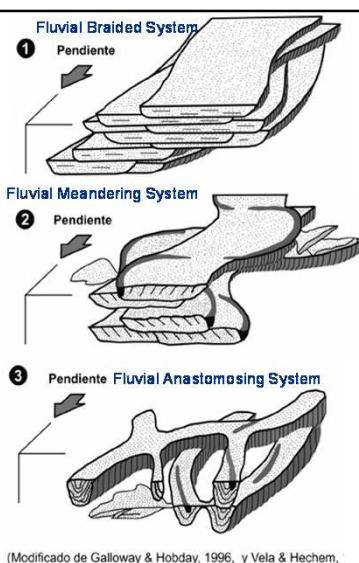
- Acquisition Date: 1958 (Amoco)
- Area: 860,000 acres
- Produces by primary and secondary (water injection)
- Gas production
- WF started in 1969
- 3190 prod & 647 inj
- Two hundred wells (200) per year have been drilled since 2008



General Description



Reservoir: Mid to late Cretaceous sandstones. Average 20 % porosity, 10-50 md permeability. High clay, lithic content sensitive to formation damage, Environment of Deposition: Fluvial and alluvial braided stream. Migration through faults.

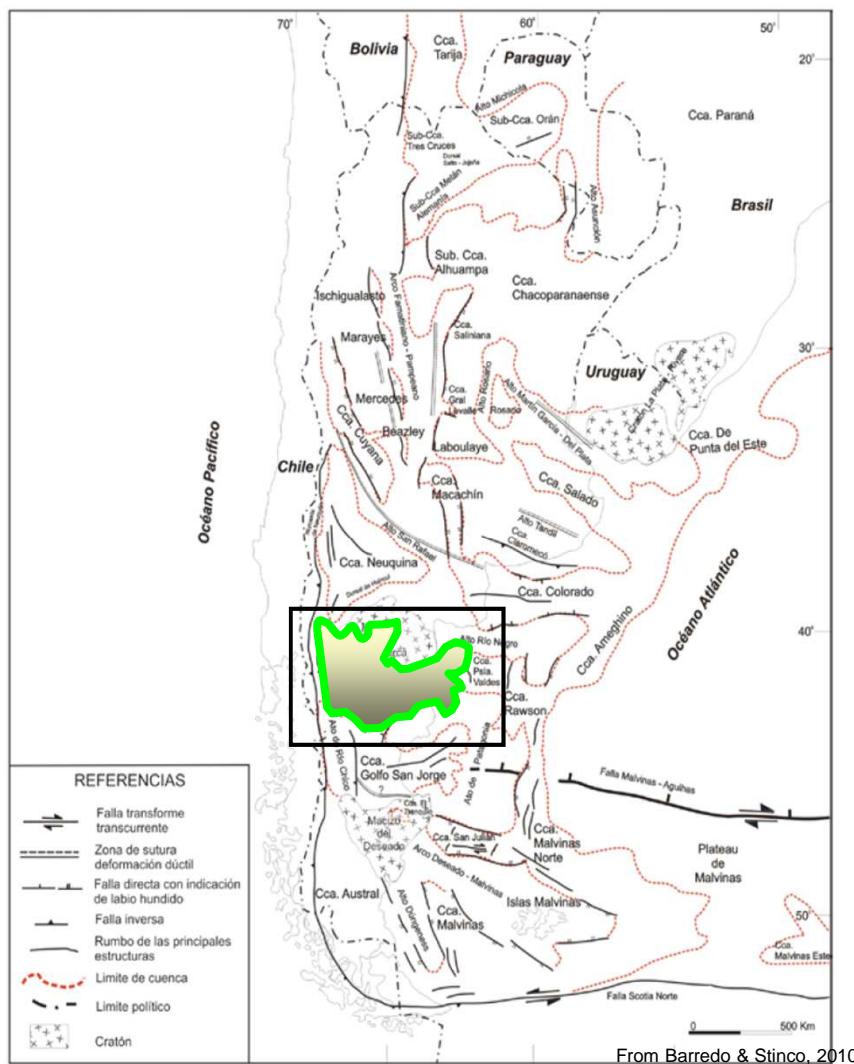


Trap: Tilted horst blocks, faulted anticlines, combination structural/stratigraphic, stratigraphic pinchouts.

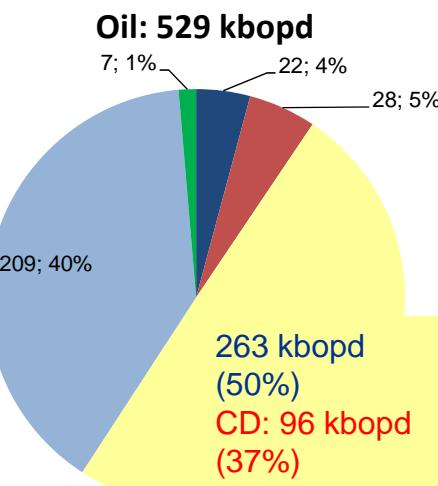
Pay Distribution: 600' to 1200' stacked individual reservoirs 3' to 15' thick, each with different fluid contacts. Wells require stimulation to break past formation damage caused during drilling and testing.

Fluid: low salinity (<4,000 ppm) fm water, 20-30 API, high viscosity 20 cp

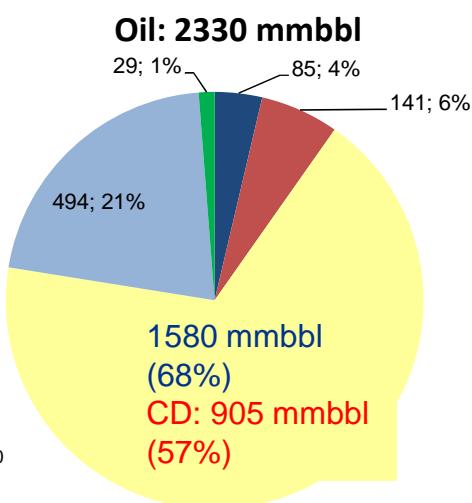
Production & Reserves



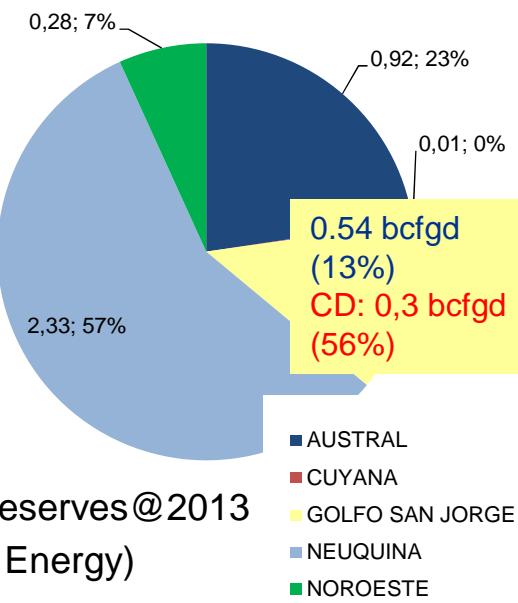
Argentina Daily Production
(Feb 2015)



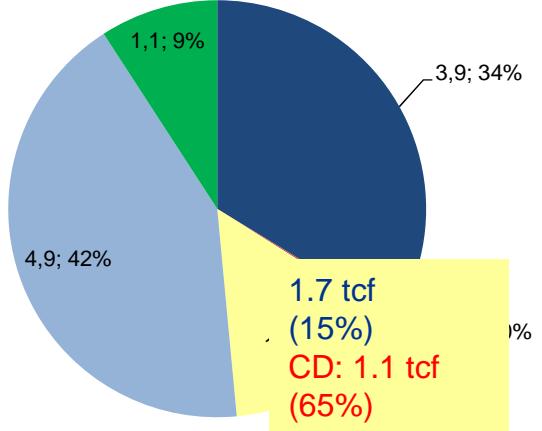
Argentina Proved Reserves@2013
(Nat. Sec. of Energy)



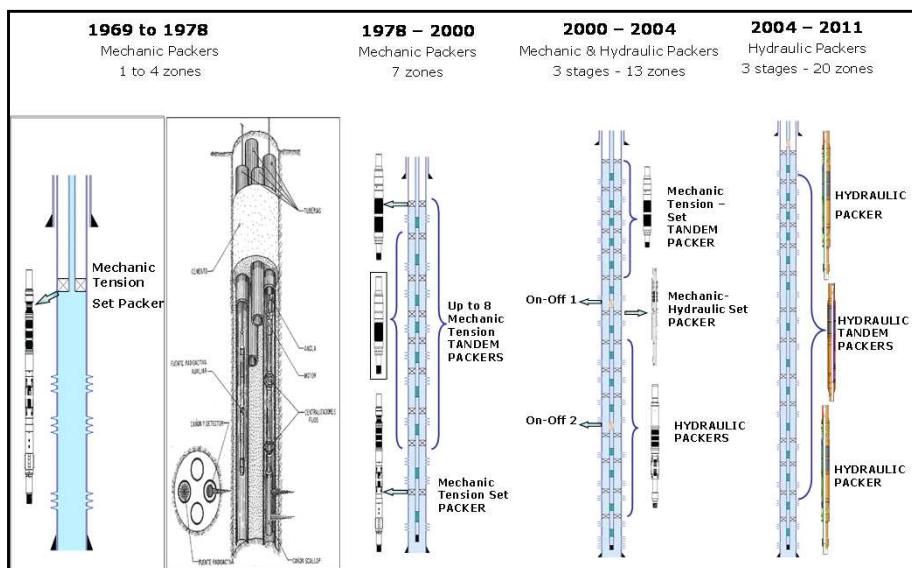
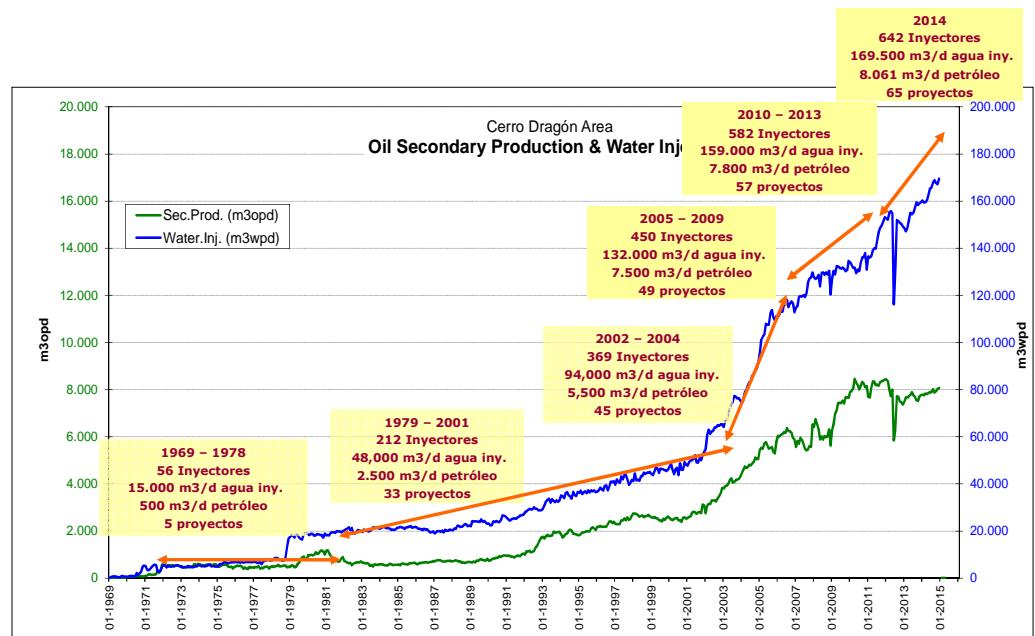
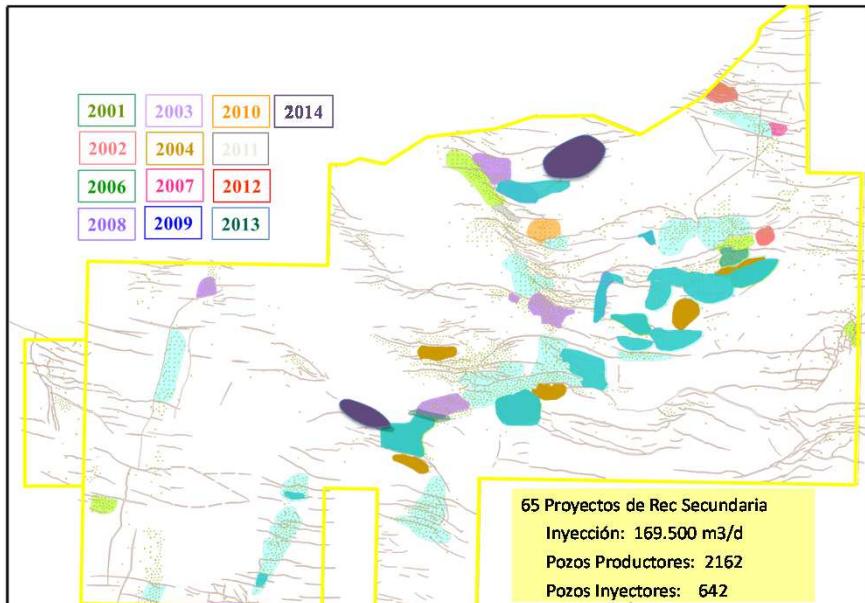
Gas: 4,07 bcfgd



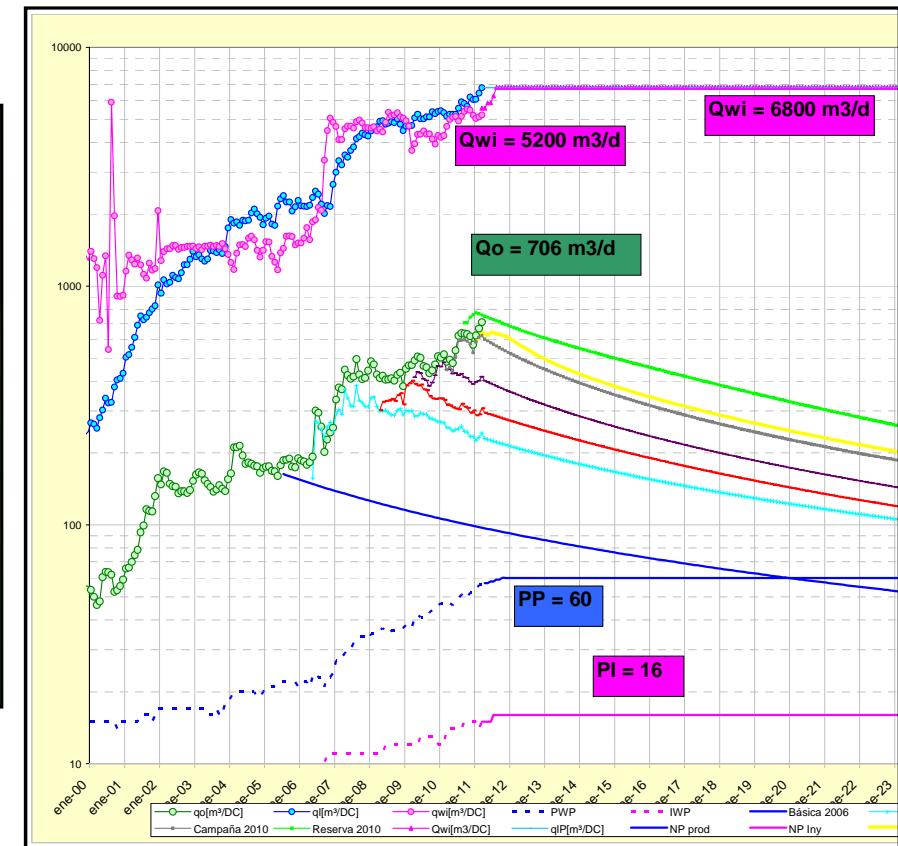
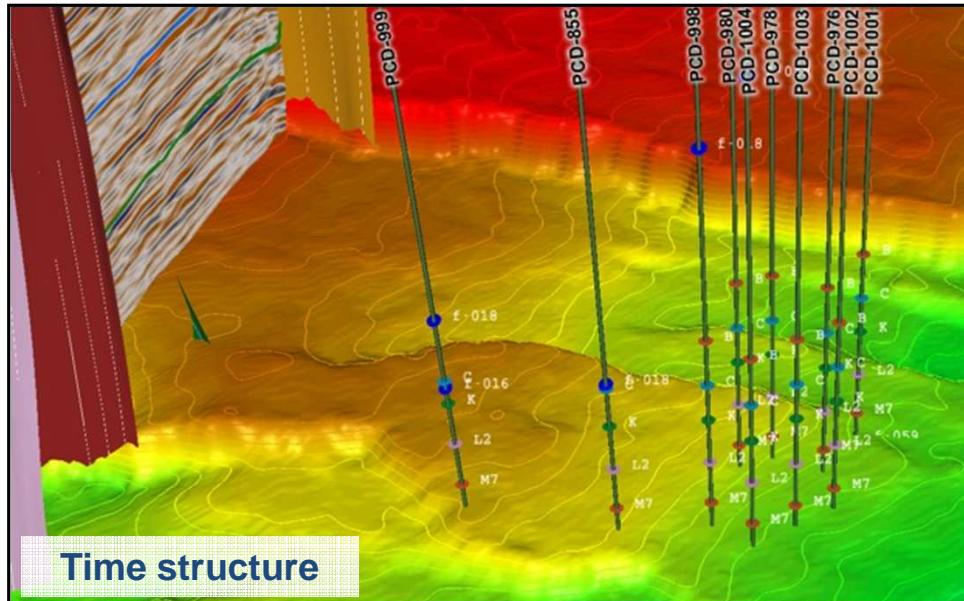
Gas: 11,6 tcf



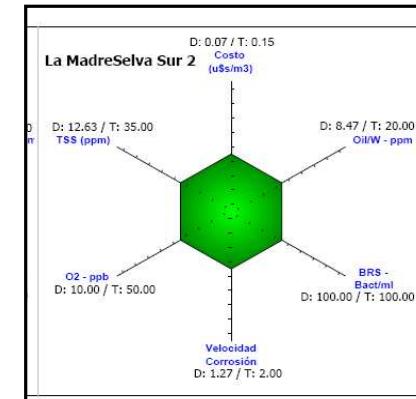
Waterflooding Progression



Injection Evolution



- Selective injection (up to 20 mandrels per well)
- Well head pressure measurement
- Injection rate measurement by layer
- Water quality control



Injection Conformance

¿What does Conformance mean?

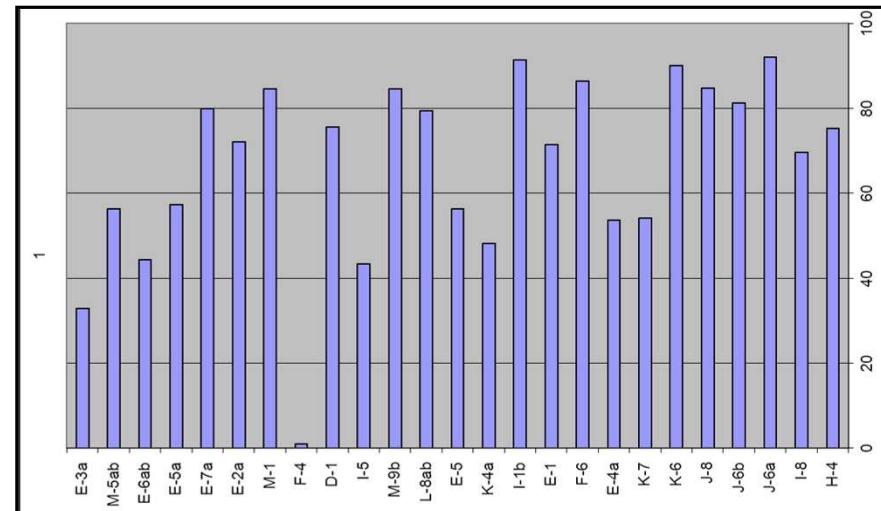
It is said that water injection is *on conformance* when it is injected the defined rate in the corresponding layer.

Injection rate comes from the simulation study.

¿Why we consider it important?

Conformance computation and monitoring is an important surveillance tool to detect deviations, assure a good waterflooding management and an efficient swept.

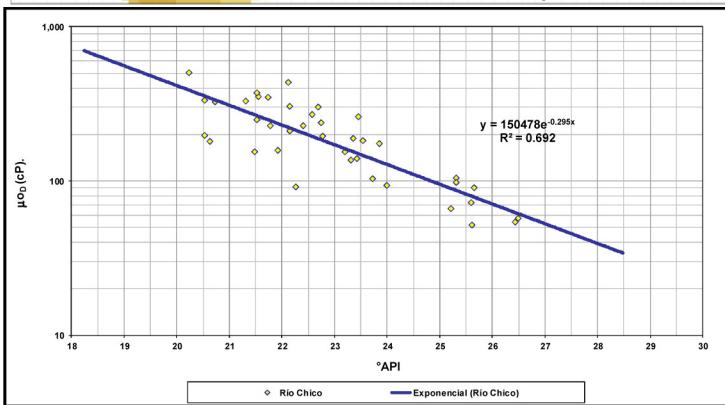
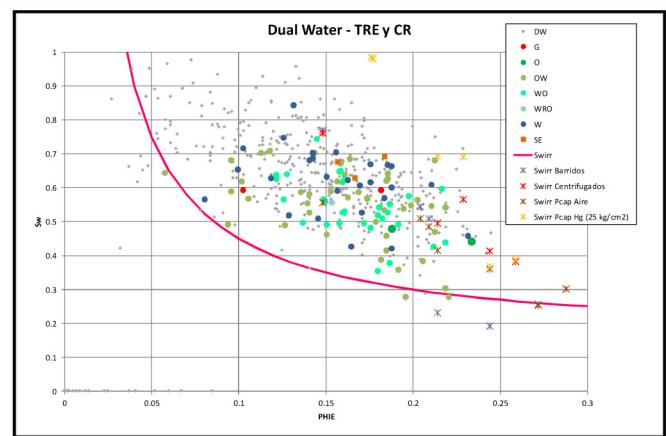
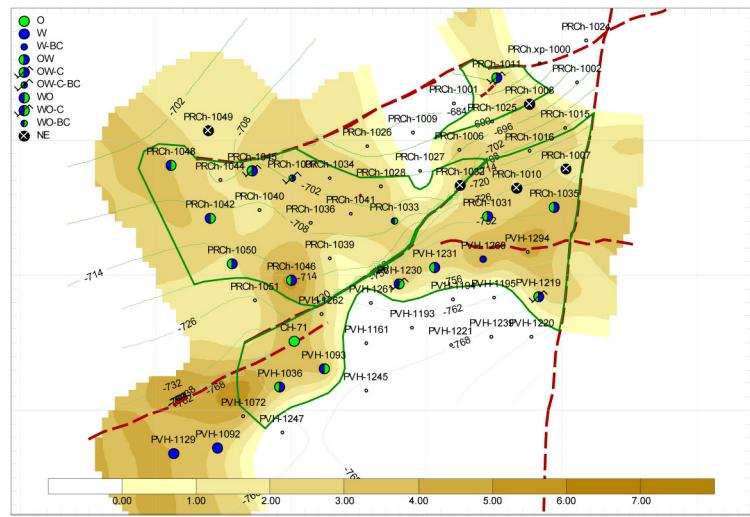
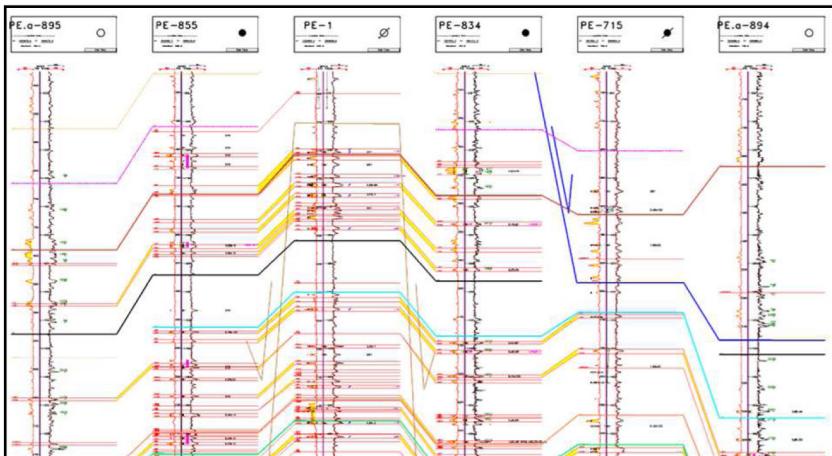
Conformance Computation -> Layer -> Well -> Project



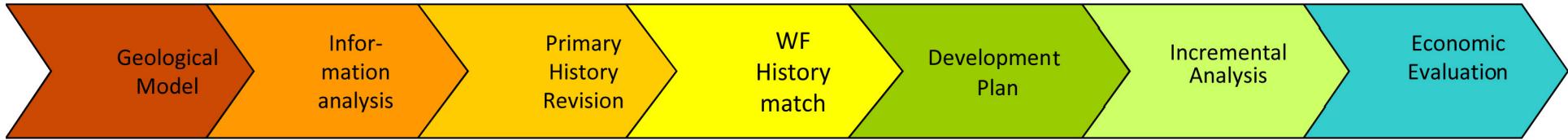
Conformance Proyecto % 68					
Pozo	Qiny real [m ³ /d]	Qiny Teórico [m ³ /d]	Diferencia [m ³ /d]	Qiny PC [m ³ /d]	Conformance (%)
PZ-101	106	195	89	195	16%
PZ-104	324	390	66	390	74%
PZ-1106	365	325	-40	325	62%
PZ-117	489	440	-49	440	59%
PZ-120	366	395	29	395	52%
PZ-122	633	530	-103	530	57%
PZ-1224	442	445	3	445	79%
PZ-126	153	210	57	210	73%
PZ-38	-	-	-	-	-
PZ-706	432	425	-7	365	77%
PZ-711	257	275	18	275	70%
PZ-720	185	200	15	200	60%
PZ-898	129	170	41	170	71%
PZ-987	221	185	-36	185	59%
PZ-99	323	335	12	335	77%
PZ-997	498	510	12	510	72%
PZ-1223	337	395	58	395	76%
PZ-1055	434	470	36	470	87%
PZ-1225	403	420	17	420	70%
PZ-1014	276	260	-16	260	72%
PZ-707	355	420	65	420	58%
PZ-709	209	230	21	230	87%

Waterflooding Studies

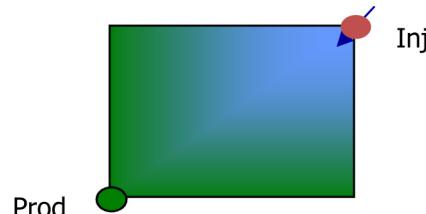
Through a WF Common Value Process, using an Analytical Simulation



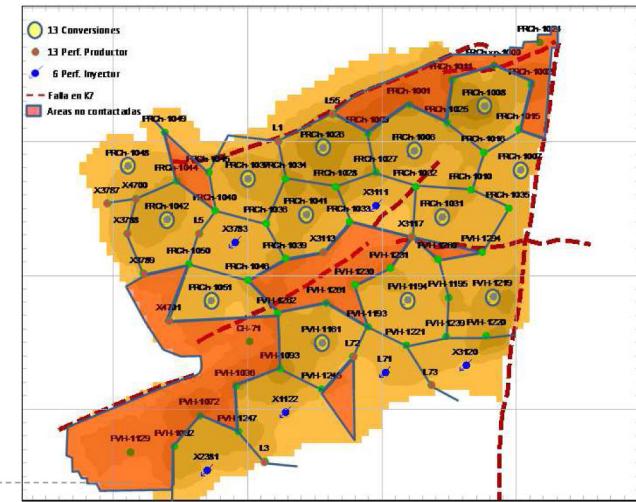
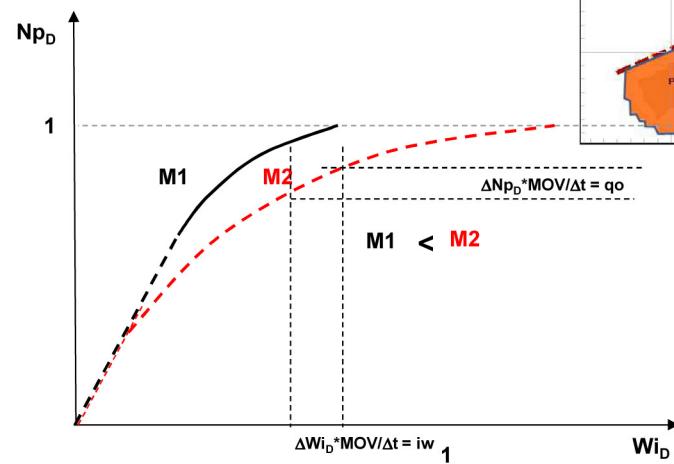
Waterflooding Studies



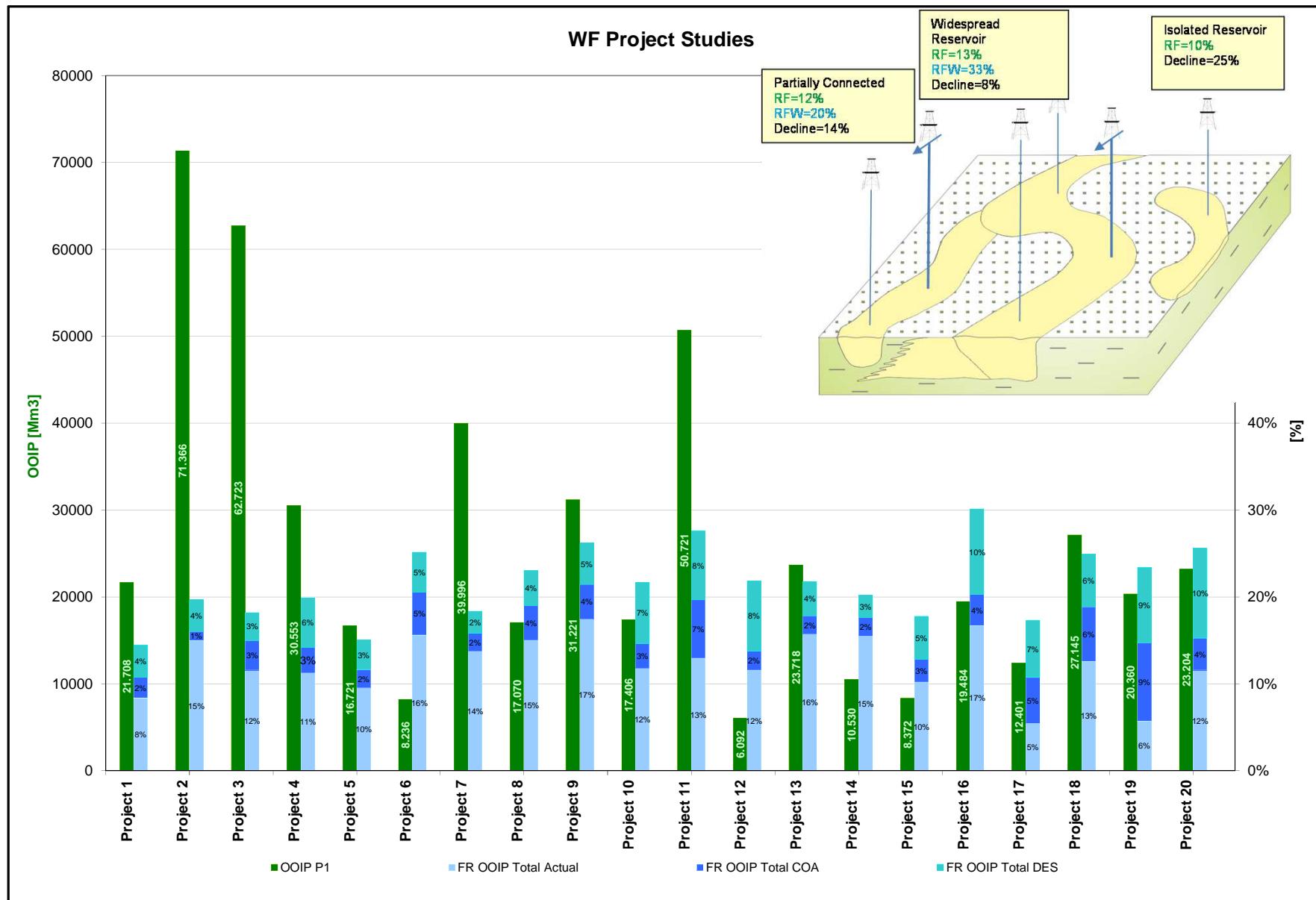
- Handles incompressible fluid displacement, therefore contemplates no transients pressure changes.
 - Oil saturation of each reservoir depends on its evolution and past production mechanism.
 - Saturation is considered homogeneous inside flow element and it evolves inside the element during the WF development.
 - Delayed response by the presence of an initial gas saturation is modeled by empirical filling curve that depends on the initial saturation of gas.



$\text{VP}_1, \text{Swa}_1, \text{Sor}1, \text{M}_1, \text{C}_{\text{D}1}$



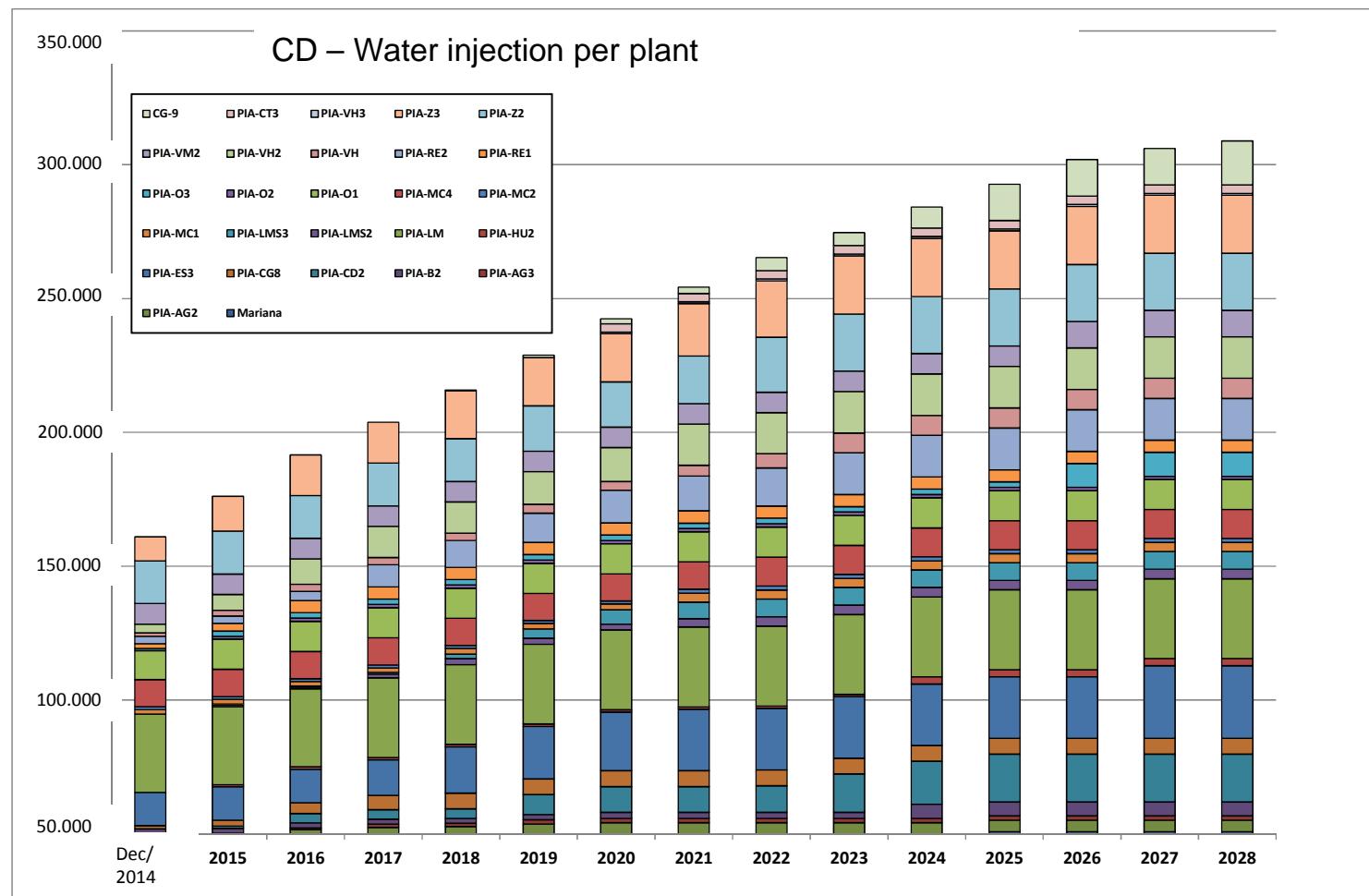
WF Studies Results



Water Injection Growth Plan

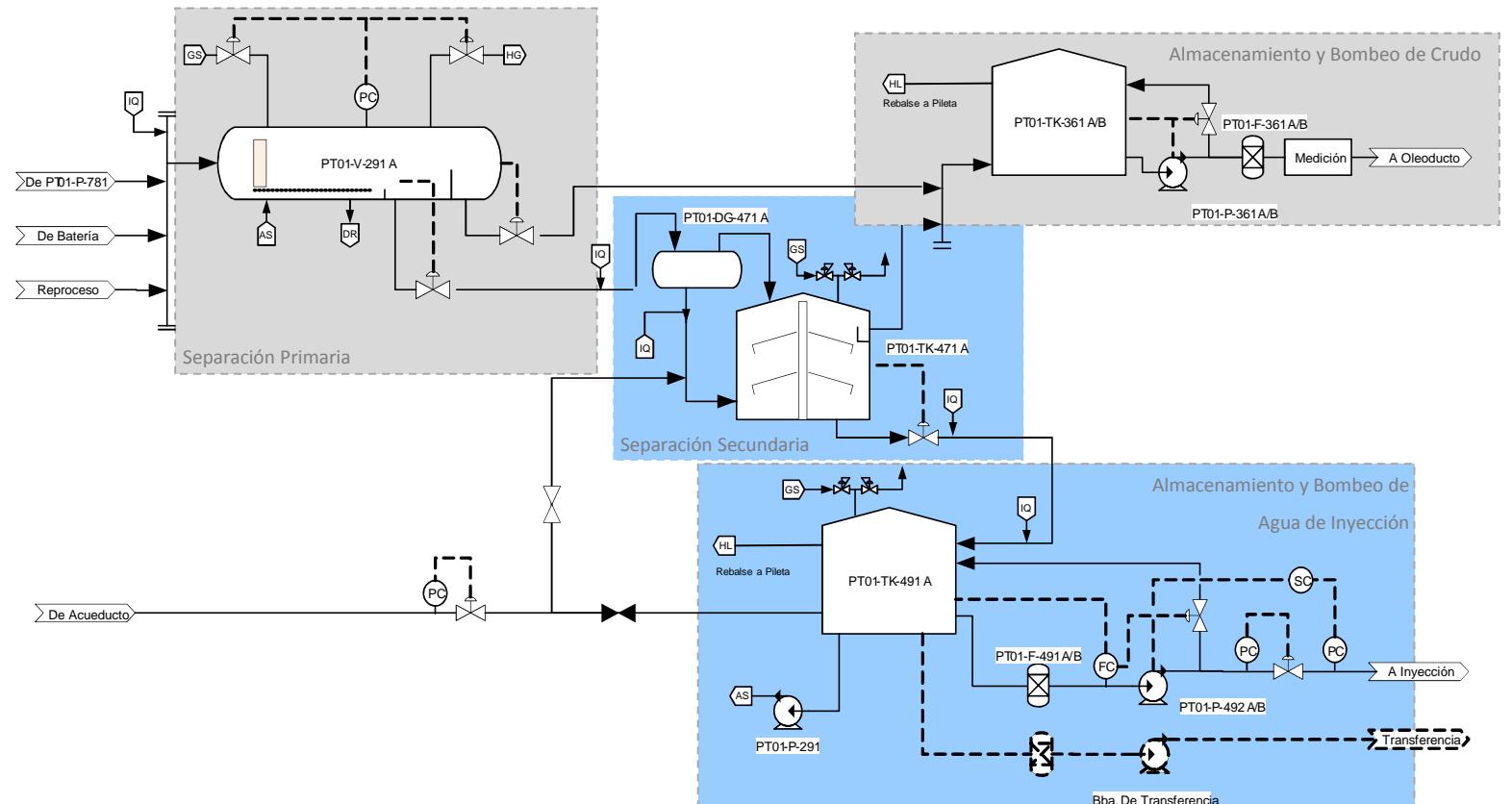
Average WI Growth 13000 m³/d per year

New Facilities: Water Injection Plants and Batteries



Water Injection Facilities

Injection Plant is designed for full capacity, but it is constructed by stages (8000 m³/d wi each) according to waterflooding projects expansion



PT01-V-291 A
Free Water Knock
Out

PT01-DG-471 A
Tanque
Desgasificador

PT01-TK-471 A
Tanque Skimmer

PT01-TK-491 A
Tanque Stock de
Aqua

PT01-P-291
Bomba de
Desarenado

PT01-F-491 A/B
Filtros Tipo
Canasto

PT01-P-492 A/B
Bombas de
Inyección

PT01-TK-361 A/B
Tanques de
Transferencia

PT01-P-361 A/B
Bombas de
Transferencia

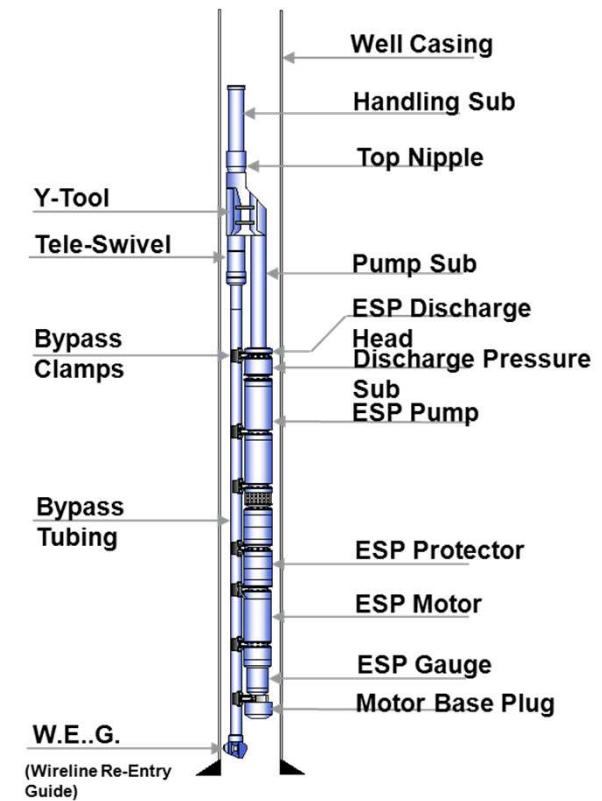
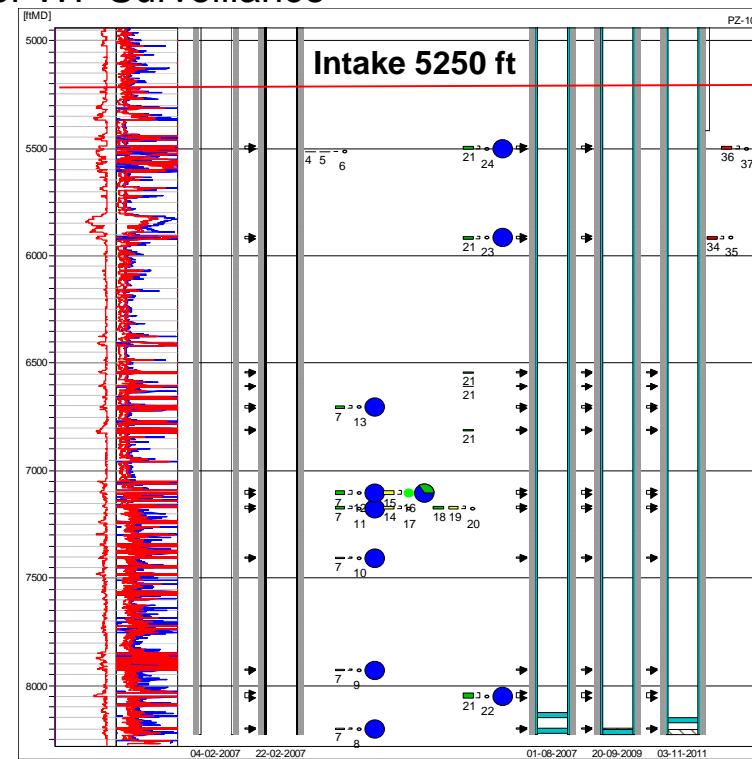
PT01-F-361 A/B
Filtros Canasto

TargeT Logging

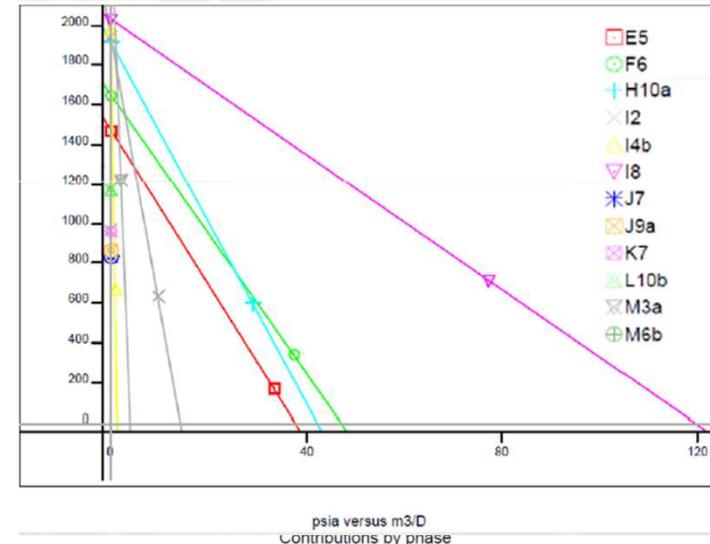
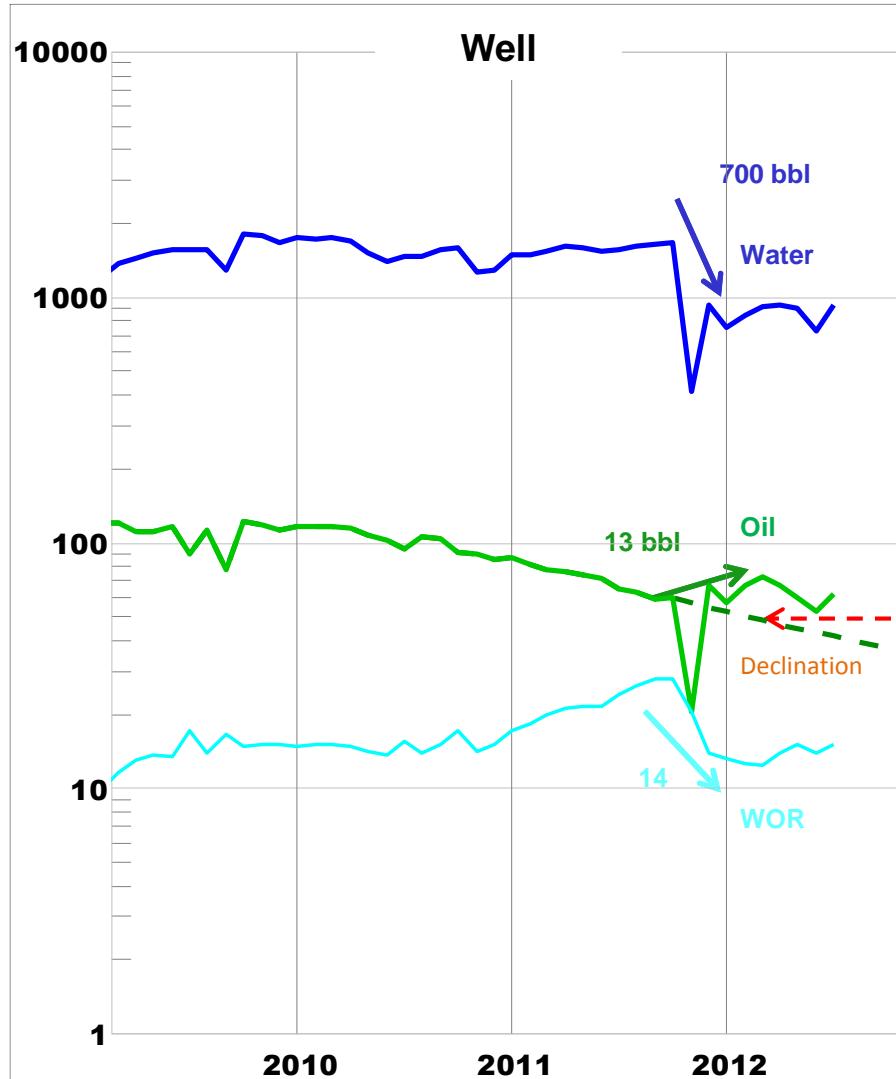
- Define the reservoir dynamic behavior producing all together
- Identify the layers with high WOR
- Evaluate the production of perforated layer without test, evolution of stimulated zones and detect possible future stimulations
- Identify cross flow in static/dynamic conditions
- Determinate if the cemented layers are still hermetic
- Obtain information for WF Surveillance

- 12-18 perforated zones
- Water Cut > 95%
- Each zone placed on production test

This is the 1st time PLT Data can be recorded in wells that don't flow naturally in 5 ½" casings



TargeT Logging



psia versus m^3/D
Contributions by phase

Zones m	Qw res. m^3/D	Qo res. m^3/D	Qg res. m^3/D	W O G
E5(1674.0-1677.0)	27.54	0.47	2.21	1.84
F6(1801.0-1805.0)	40.35	0.49	0.41	0.41
H10a(1992.5-1996.0)	29.09	-0.66	-	-
I2(2013.0-2014.5)	7.85	5.07E-2	9.14E-2	0.00
I4b(2041.5-2044.5)	2.72	-0.22	-1.30E-2	0.00
I8(2074.0-2077.0)	74.74	3.89	1.61	0.00
M3a(2448.0-2455.0)	2.34	0.00	0.00	0.00
M6b(2497.5-2499.5)	-1.74	0.00	0.00	0.00

Pulsating Injection

PPT produces a pulsing injection that dilates the matrix pore space through an elastic response. It causes not only the current pore network to increase in porosity and permeability but also opens up additional pore spaces to liquid flow.

Therefore, Pressure Pulses can enhance the water conformance, reduce the front instabilities and overcome capillary.

Injection range from 40 to 1600 m³/d.

Setting in the tool in front of the layer with connection cable up to the surface (WO operation).

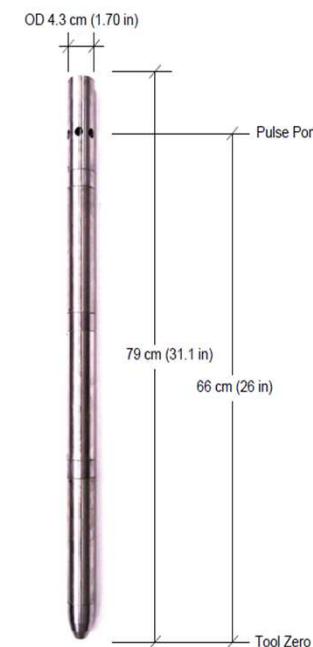
Frequency adjustment from the Surface Panel from 10 to 20 pulse/min.

Pressure range from 250 to 1500 psi.

Electric Model



Mechanic Model



Injection range from 40 m³/d to 240 m³/d.

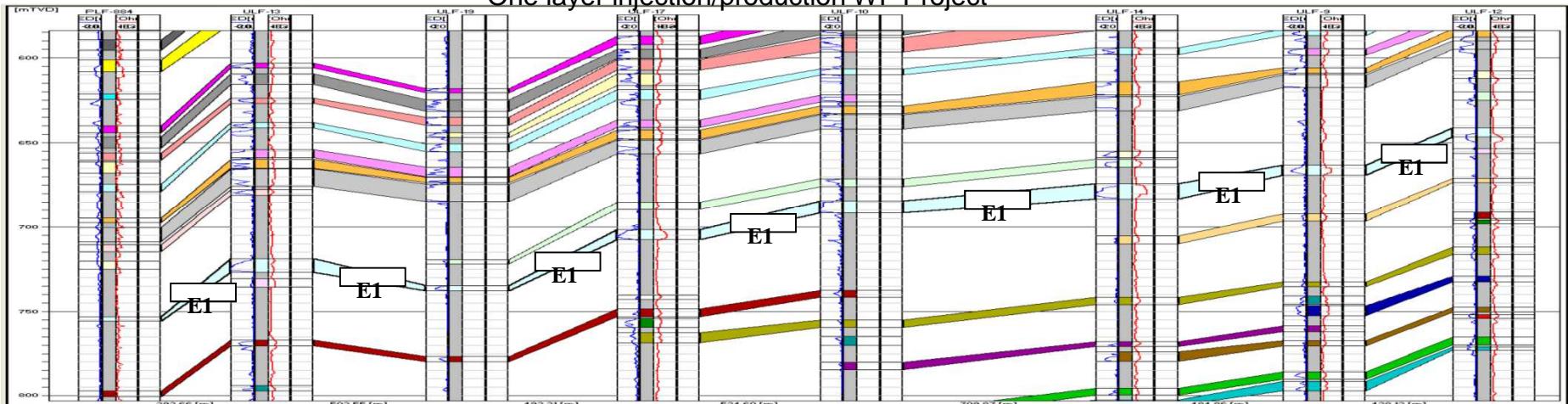
Setting in the tool in front of the layer, hung on the tubing nipple (WL operation)

The operation frequency auto-adjusts in relation with the pressure difference between the reservoir pressure and WHBP

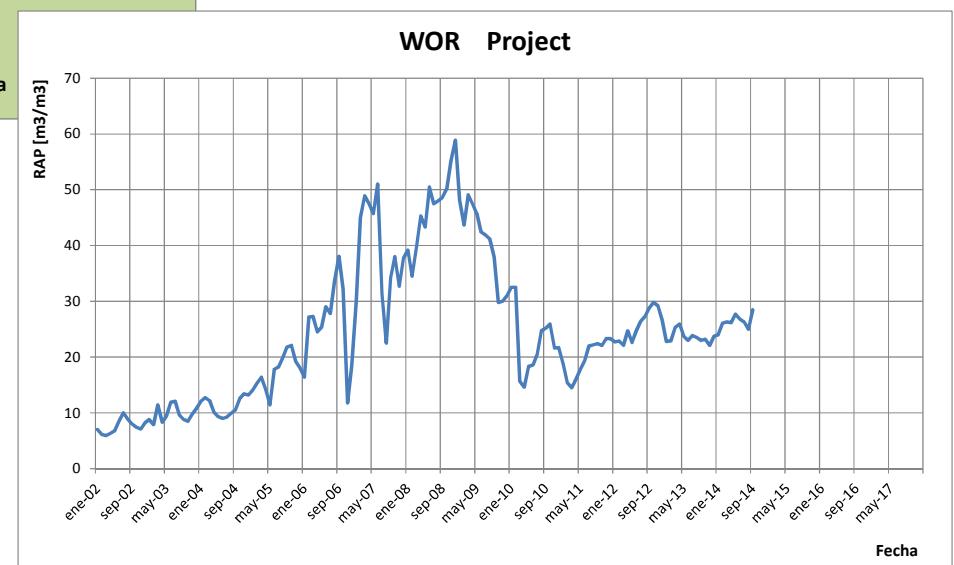
Pulsating Injection

- The layer E1 has individual injection.
 - E1 has the best cumulative oil and cumulative water injection in the zone.
 - So 57 %.
 - Good connectivity producers – injectors, without barriers or faults.
 - Low current Recovery Factor= 7.5 % (prim + sec).
 - Isolated geological block .
 - Individual oil test without fracture job.
 - Low pressure water admission (200 psi).
 - 30 days Tracer Transit Time (between injector and producer)

One layer injection/production WF Project

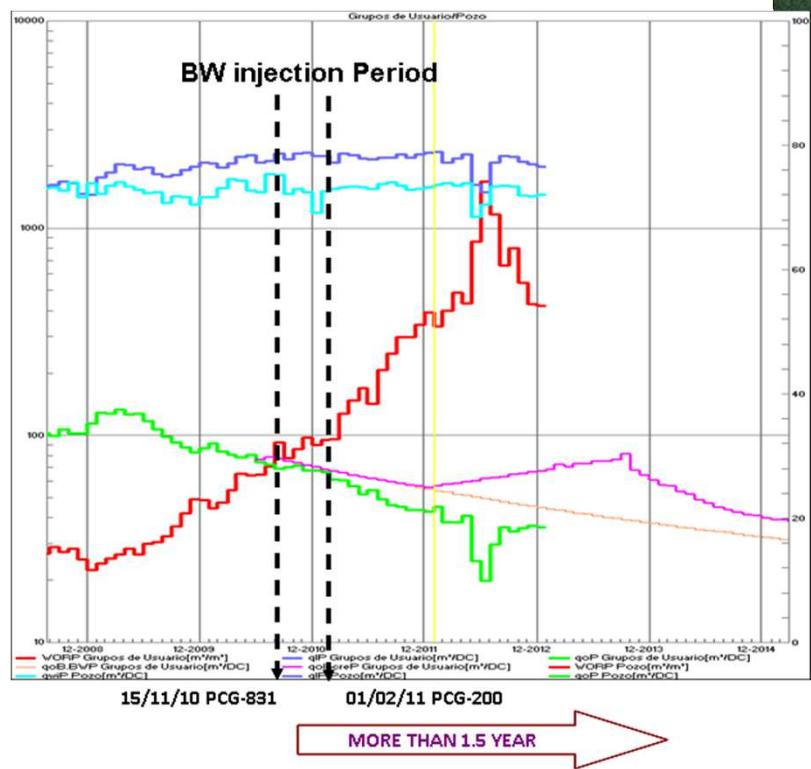
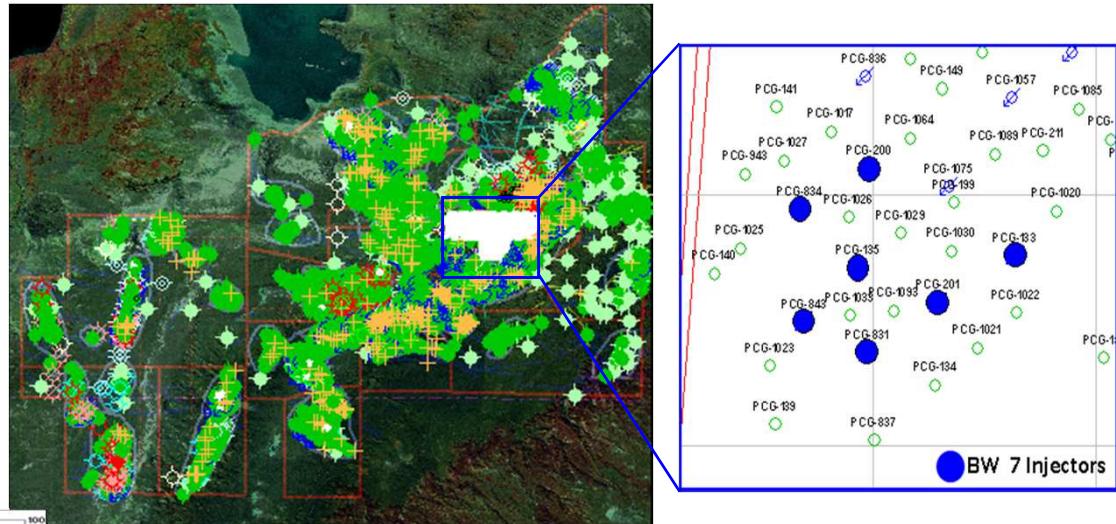


Pulsating Injection Pilot Results



EOR

- Bright Water gel treatment in 7 injection wells
- 15 associated producers inside the patterns
- 24 layers treated

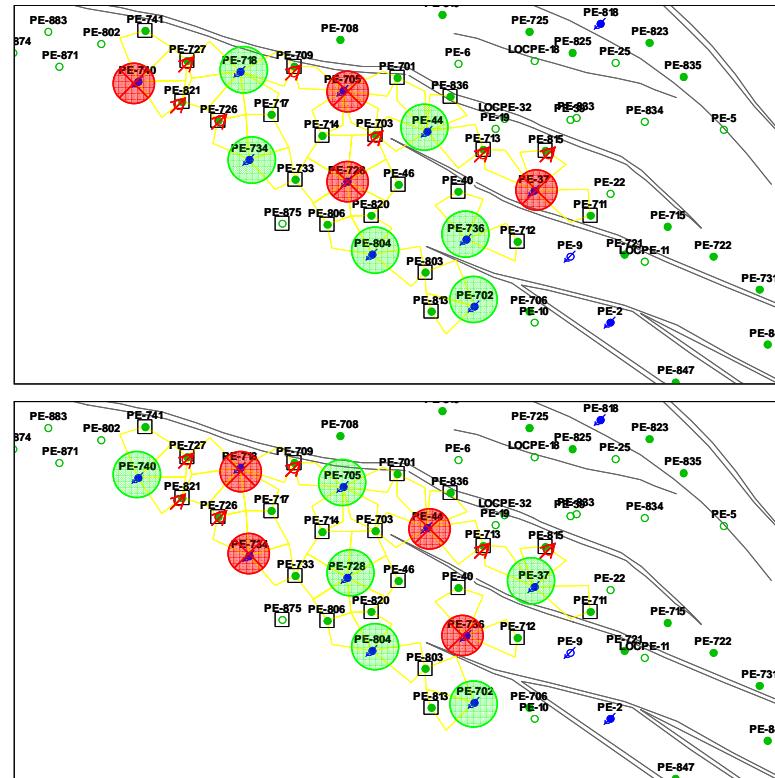


- Production response underperformance (after 18 months)
- BW treatment volume could be less than the needed
- Only one fall off test showed some change un flow path after treatment
- Some mechanical problems impacted injection
- Opportunities: Better static and dynamic characterization, BW volume estimation, economic feasibility

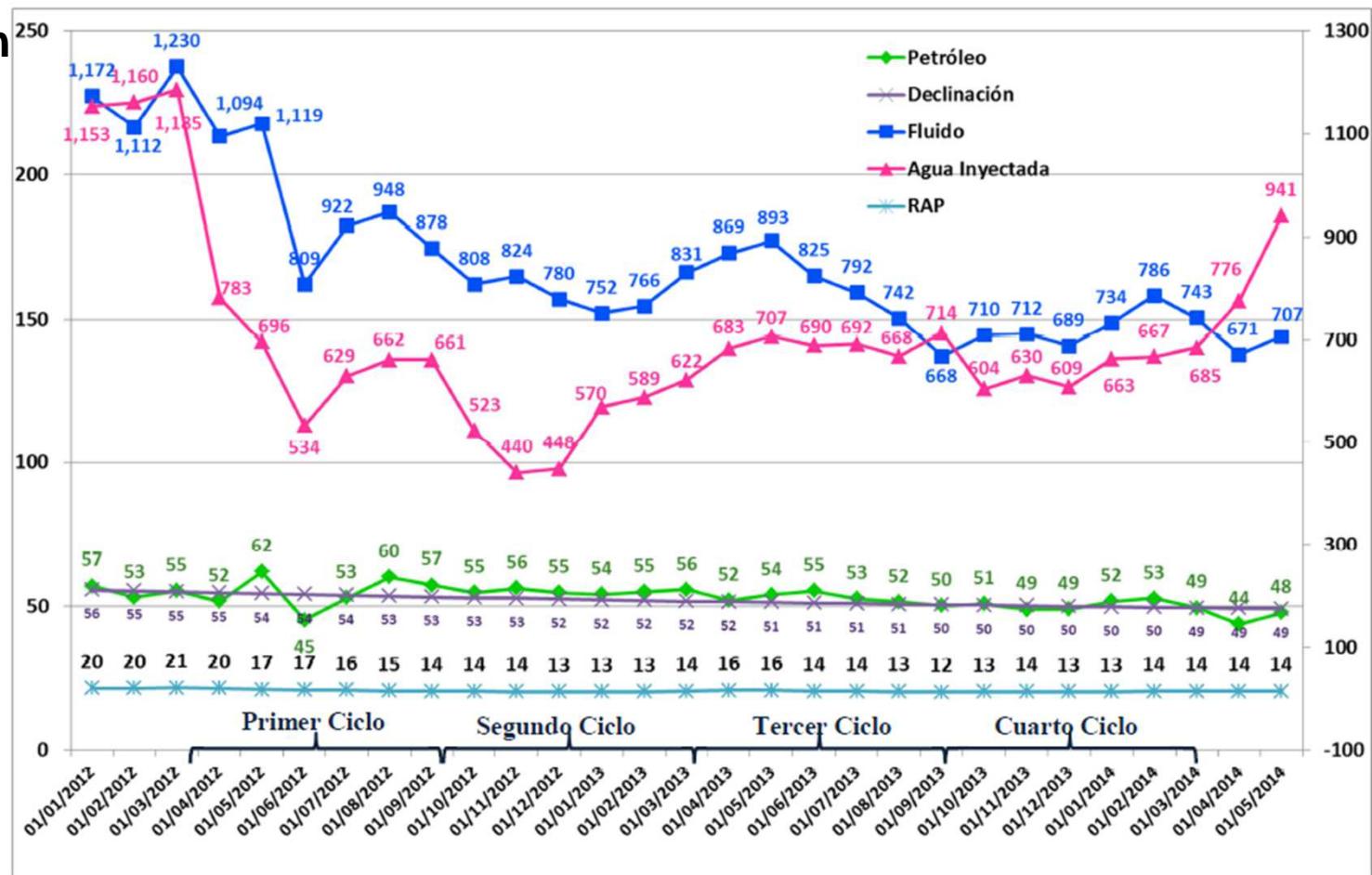
Cyclic Injection

- The methodology pretends to take advantage, through a secondary recovery process, of viscous as well as capillary drives
 - Improve production efficiency, reducing WOR
 - Reduce the volume of injected water for the development of the plan
 - Improve the final recovery factor
 - 10 injector wells
 - 22 producer wells
 - Average WOR before project: 20 (Wcut: 95%)
 - Annual oil decline: 7%.
 - Injection started in 1992.

Project	
Pore Volume of the block (thousand barrels)	29,514
Initial Oil Saturation	0,43
Initial Water Saturation	0,57
Residual Oil Saturation	0,27
Mobile Oil Saturation	0,16
Mobile Oil (reservoir thousand barrels)	4,724
Injected Water to Date (thousand barrels)	59,529
Injected Water to Date in PV	2
Injected Water to Date in MOVs	12,6



Cyclic Injection



- Results show that it is possible to take advantage of capillary forces, without giving up the benefits of viscous drive
 - Cyclic Injection reduces to a great extent the power consumption, by managing much smaller volumes of injected water and with less produced fluid. Volumes of water not injected in the closure cycle can be used for flooding new reservoirs in the same project or in neighboring zones

Summary

- Pan American Energy has made a significant investment effort in exploration, development, infrastructure and technology. Cerro Dragon is today one of the most productive areas in Argentina with more than 1 billion barrels of oil accumulated.
- Cerro Dragon is a mature field, discovering new opportunities based on studies and technology application.
- Waterflooding is one of the key drivers for production increase and reserves replacement.
- 75% of Cerro Dragon is under waterflooding. Injection volumes exceed 170 Mm³/d (1 MMbbld). All produced water is treated and injected.
- The challenge is to continue developing WF projects and to increase RF through studies and new technology application, managing complexity and uncertainties.



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Thank you!!