# The Design and Application of a Polymer EOR Trial on Barrow Island

**John Scott – Subsurface Operations Team Leader**

Wisnu Widjanarko, Lina Hartanto, Daniel León, Paul Welton, Alistair Fletcher, Paul Costelloe

APPEA Conference & Exhibition / 16-19 May 2010

# Agenda

- Project Scope
- Barrow Island Introduction
- Reservoir Challenges and Pattern Selection Criteria
- Screening EOR Methods
- In-Depth Flow Diversion (IFD) Process
- Operation
- Surveillance & Monitoring
- Results to Date
- Achievements
- Summary

# Project Scope

## What are we doing?

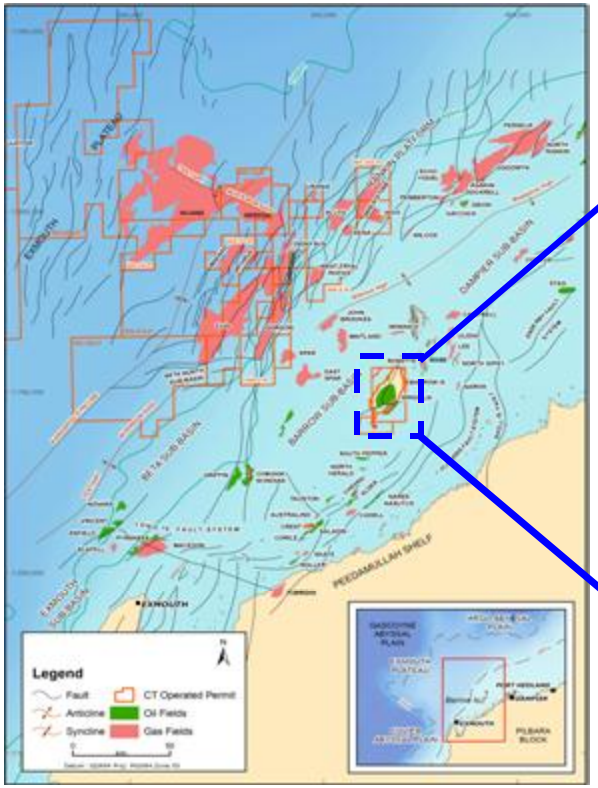
Studying the applicability of Chemical EOR technology and conducting a trial on selected patterns within BWI Windalia reservoir

## Why are we doing it?

To determine whether incremental oil resources may be commercially recovered using EOR techniques, and future broader application to increase ultimate recovery beyond current estimates

# Barrow Island Introduction

- Located 56 km off NW Coast of WA
- Class "A" Nature Reserve
- L1H Permit currently 2nd (L1H R2) renewal phase expires 2030
- Chevron (4/7) operates BWI on behalf of Santos (2/7) and ExxonMobil (1/7)




# Barrow Island Introduction

- Australia's biggest onshore oilfield with over 1 billion STB
- Primary producing reservoir - Windalia sandstone
- Currently under secondary recovery – 147 waterflood patterns
- 43 years production history – 469 producers , 231 injectors
- High porosity, low permeability – average 23% and 5 mD
- Light and sweet oil – 36° API and 0.65 cP
- Average depth ~600 meters
- Temperature 65°C

# Reservoir Challenges

- Large waterflood patterns (10 MMbbl at 20 acre well spacing)
- Injection above the formation fracture gradient
- Permeability contrast – 5 mD average, with higher 20-150 mD streaks exhibiting water cycling
- Complex mineralogy - high in glauconite with layered facies and carbonate cemented streaks
- Formation water salinity (30,000 ppm of TDS) and hardness (1,000 ppm of Ca+Mg)

**Pattern Selection Criteria**

- Water cycling
  - Considerable volumes of unswept oil remaining
- Continuity of pattern injection
  - Uninterrupted injection for baseline (historical VRR > 1)
- Ring fenced waterflood infrastructure for volume control

# Screening EOR Methods

- Miscible injection (hydrocarbon, nitrogen or $CO_2$) not feasible due to reservoir depth (shallowness)
- Thermal methods (combustion, steam flooding) not applicable because of low viscosity crude
- Only feasible approach - chemical flooding
- Low reservoir permeability pushing the envelope (applied and proven for >10 md)

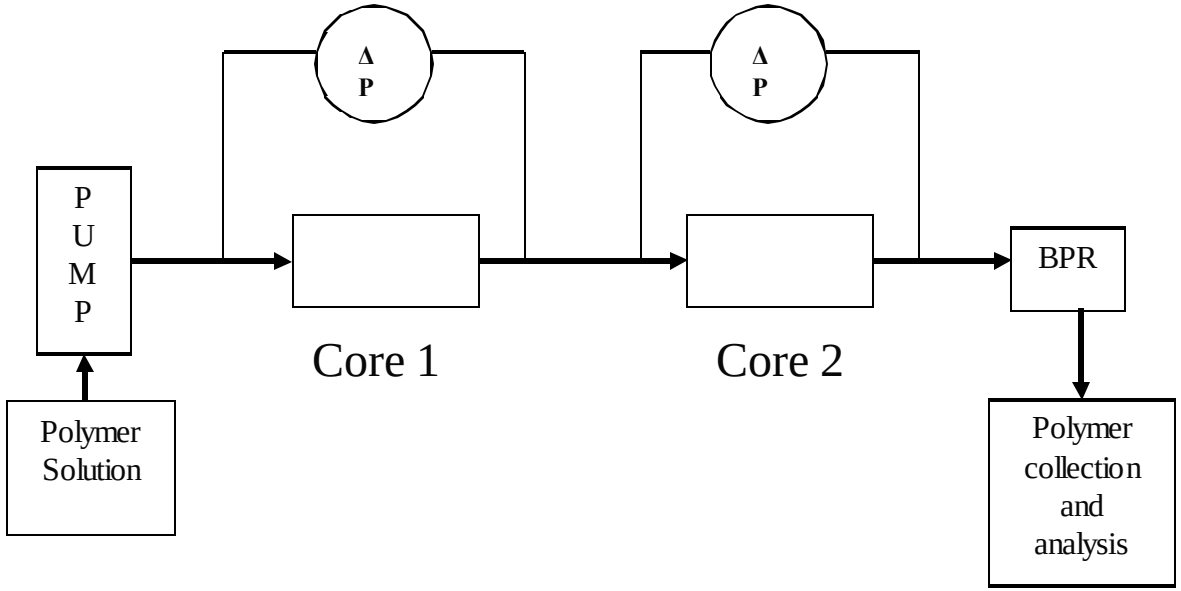
# Screening EOR Methods

| | Oil Properties | | Reservoir Characteristics | |
|---|---|---|---|---|
| | **Viscosity** | **Composition** | **Avg Perm** | **Depth (ft)** |
| **Windalia Reservoir Properties** | 0.65 cp | No organic acids | 4-5 mD | ~2000 ft |
| **Gas Injection Methods/Miscible** | | | | |
| **Hydrocarbon** | <3 | High % of C2-C7 | N.C. | **>4000** |
| **Nitrogen (& Flue Gas)** | **<0.4** | High % of C1-C7 | N.C. | **>6000** |
| **$CO_2$** | <10 | High % of C5-C12 | N.C. | **>2500** |
| **Chemical Flooding** | | | | |
| **Micellar/-Polymer; Alkaline/-Polymer (ASP); and Alkaline Flooding** | <35 | **Light Intermediate.** ***Some organic acids for Alkaline floods*** *(surfactant required)* | >10mD | <9000 |
| **Polymer** | <150 | Not Critical | >10mD (as low as 3 mD in some cases) | <9000 |
| **Thermal** | | | | |
| **Combustion** | <5000 | Some asphaltic components | **>50** | <11,500 |
| **Steam flooding** | <200,000 | Not Critical | **>200** | <4500 |

***Reference: SPE 12069 (1983) & SPE 35385 (1996) (Taber,J.J, Martin,F.D., Seright,R.S.) and SPE Textbook Vol.6 (Henry Doherty series ) EOR , 1998***

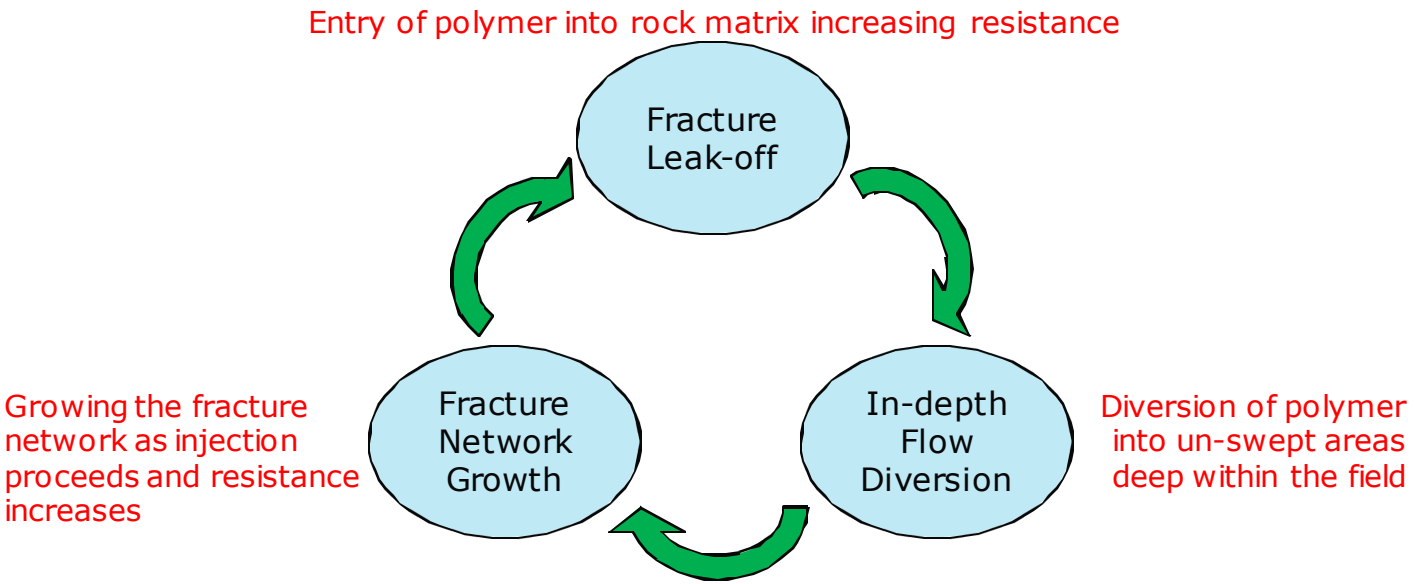
# Polymer Selection – Corefloods

- Low permeability of Windalia is a critical issue due to the possible impact of the polymer on well injectivity
- Engaged specialist EOR vendor (+40 years experience)
- Coreflood experiments conducted with multiple polymers at different concentrations to test for blockage and propagation of polymer through core stages
- Low molecular weight polymer selected at conservative concentration to mitigate against blockage issues



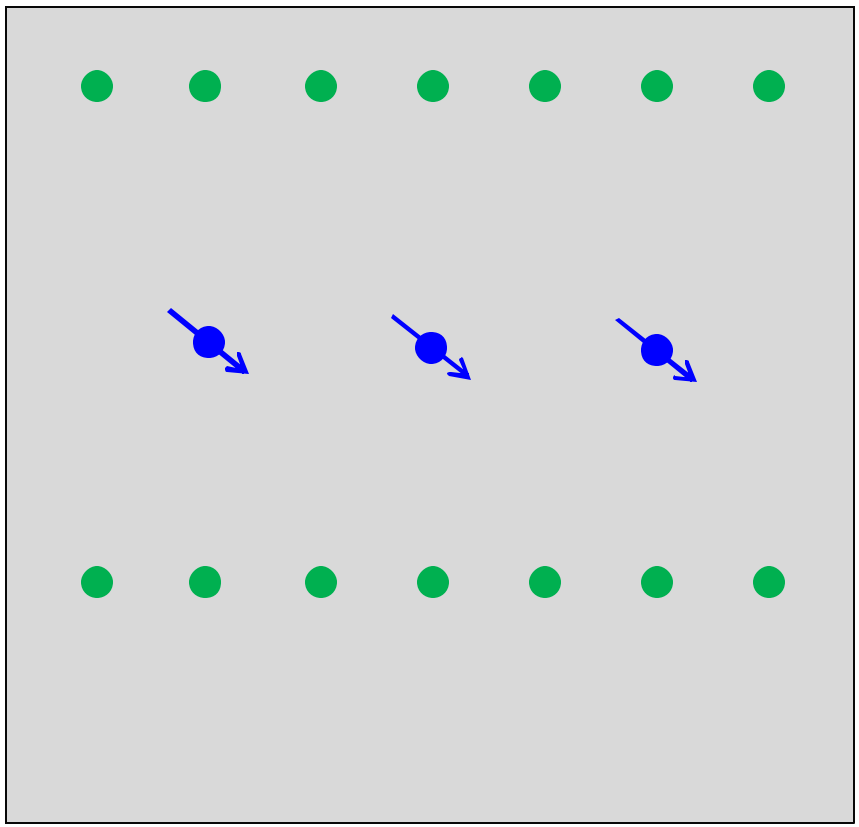
# In-Depth Flow Diversion (IFD) Process

- Polymer adsorbs to rock grains coating fracture walls increasing resistance to flow
- Higher resistance causes pressure to increase, initiating fracture growth
- New un-swept oil zones are accessed by growing fracture network
- Post polymer injection, injected water continues to be diverted to un-swept zones



# Operation

- Equipment installed and operations commenced mid May 2009
- Low molecular weight polymer (500 ppm) is injected into pilot pattern injectors (3) for 2–3 years
- 14 offset producers are being monitored
- A back-up pattern has also been identified (contingency)



# Surveillance and Monitoring

**Well Testing**

- Detect & quantify incremental oil uplift in the range of 2 to 50 bopd
- 14 producers tested every month

**Sampling and Lab Analysis**

- Measure polymer concentration at each injector **(avg 412 ppm)** and detect breakthrough at the producers **(none to date)**
- 17 wells sampled every week

**Pressure Monitoring**

- Measure increase in resistance to flow and fracture growth behaviour at injectors
- Pressure Fall Off surveys acquired prior to start-up and on annual basis
- Pressure Build Up surveys acquired to update simulation model

# Results to Date

- The pilot is operating incident and injury free (IIF)
- All project metrics achieved (except reliability)

**PTD Scorecard**

| | Target | Actual | |
|---|---|---|---|
| Days Away from Work | 0 | 0 | |
| Total Recordable Incidents | 0 | 0 | |
| Recordable Spills (bbl/MMbbl) | < 1.07 | 0 | |
| Surveillance & Monitoring* | > 90% | 96.0% | |
| Water Injection Rate (bwipd) | 1890 - 2554 | 2174 | |
| EOR Installation Uptime | > 95% | 77.5% | |
| Producers Uptime | 95.2% | 95.6% | |
| Injectors Uptime | 95.2% | 100% | |
| Production Uplift (bopd) | 0 | 0 | |
| OPEX ($MM) | 1.460 | 1.330 | |

*Surveillance compliance calculated as the sum of all monthly activities

- Unit reliability poor (23% down time) mainly due to foreign sourced equipment and spares availability
- Reliability lookback conducted Dec-09. Identified major issues and actions required to improve uptime during 2010

# Achievements

## Current

- Polymer can be injected into Windalia reservoir
- Well head injection pressure has increased as a result of increased resistance to flow
- No early polymer breakthrough detected at pilot producers (14)
- Surveillance and monitoring compliance

## Future

- Achieve high installation reliability during 2010
- Quantify fracture growth at injectors (PFO analysis)
- Detect and quantify reduction in water-oil ratio and subsequent increase in oil production

# Summary

- Chemical EOR technology being trialed on Barrow Island (Windalia reservoir)
- Low reservoir permeability, induced injection fractures and water cycling are key parameters in EOR method selected
- Coreflood experiments used to select polymer type and concentration to mitigate negative risks to reservoir
- In-depth flow diversion (IFD) is the proposed methodology
- Low molecular weight polymer (500 ppm) injected continuously for 2-3 years
- Surveillance and monitoring compliant and remains a focus area
- An exponential decline baseline chosen to quantify oil uplift
- Building on current safety performance and maintaining IIF operations continue to be key focus items

# Thank You

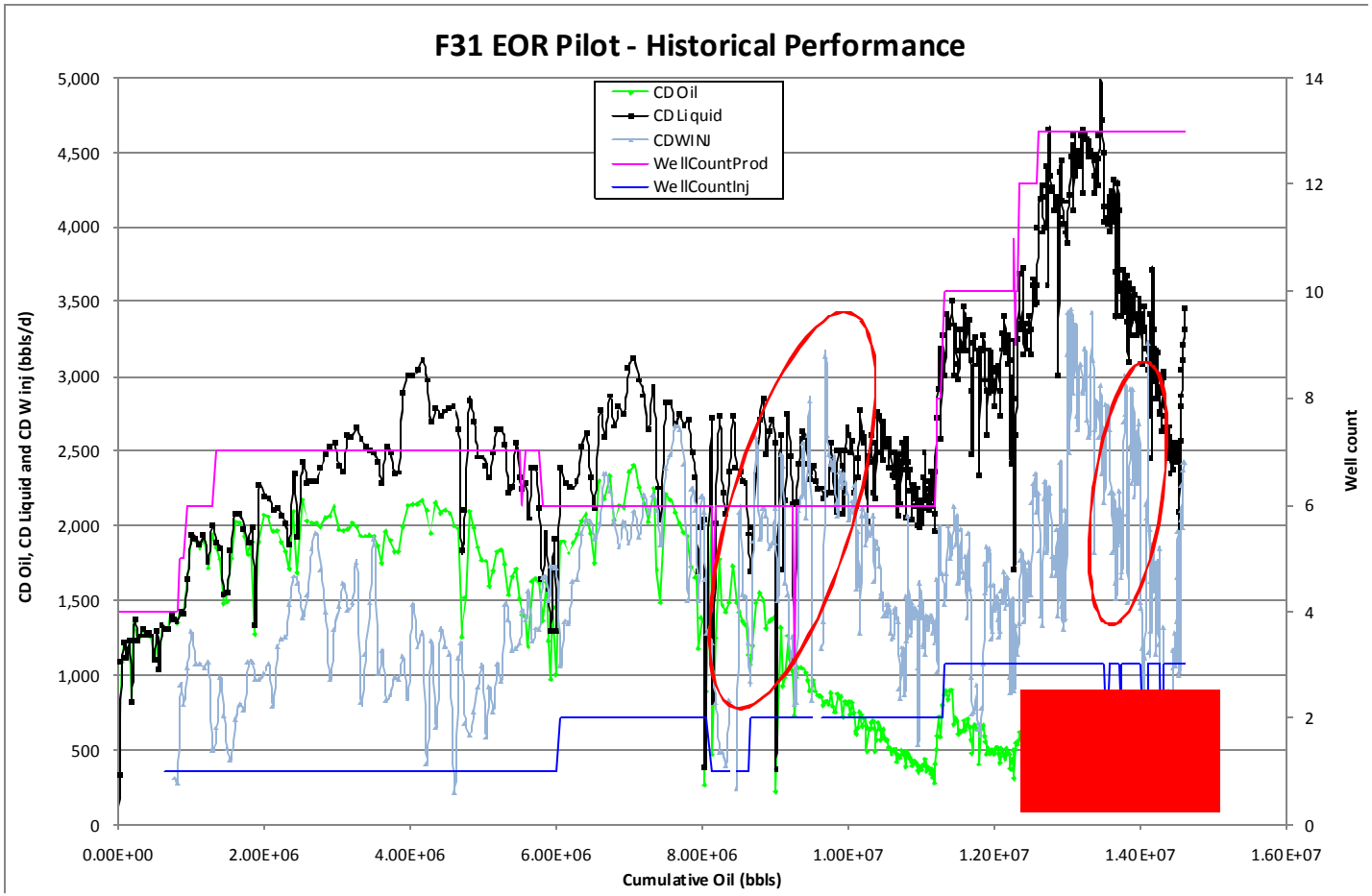
# See you next year with "EOR Part II – The Results"

# Questions

# Back Up Slides

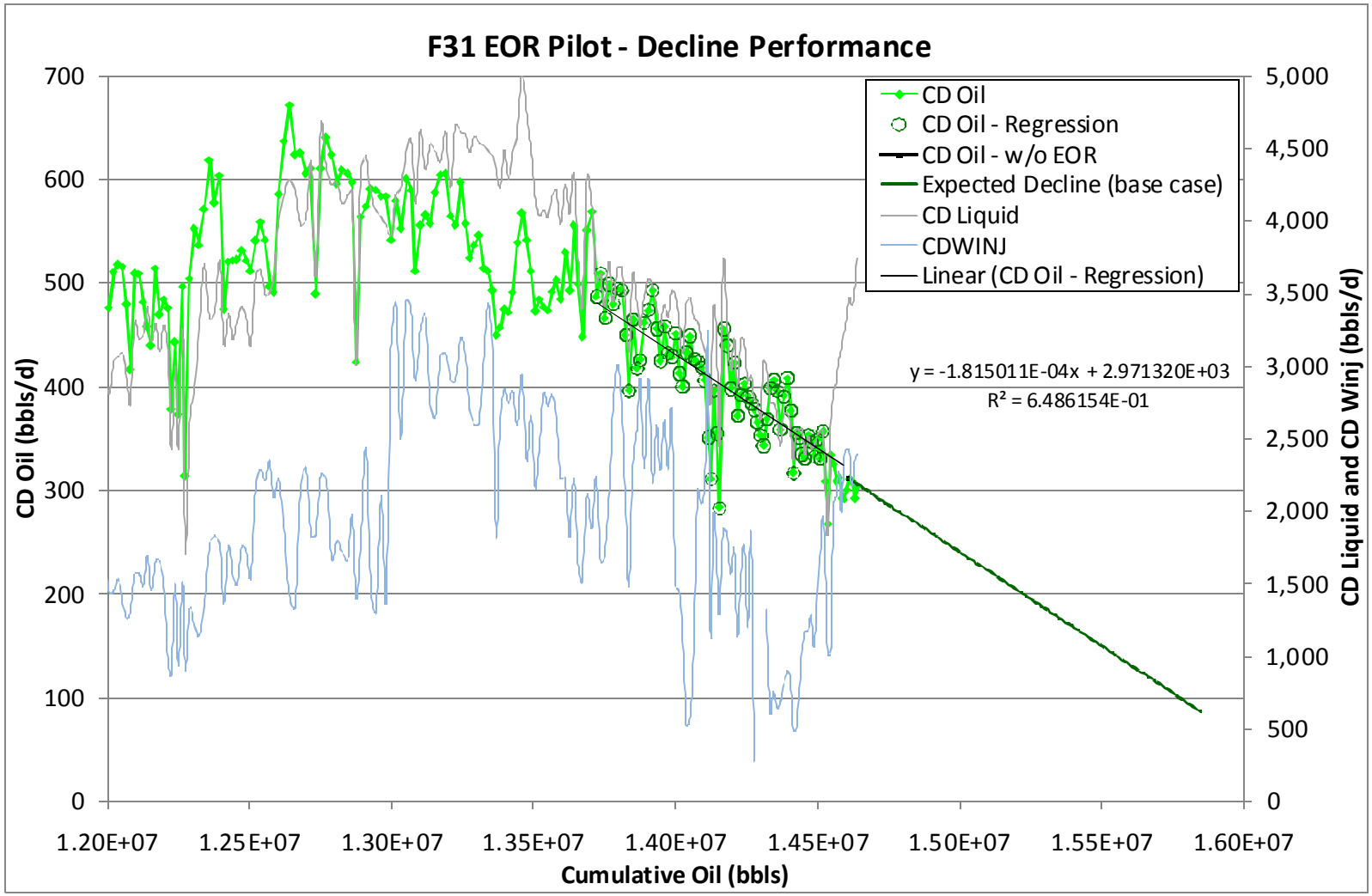
# Historical Performance

- The F31 pattern was identified because it exhibits severe water cycling and had relatively uninterrupted injection (VRR > 1)
- A period where 13 offset wells were online was chosen



# Baseline Production

- Exponential decline fitted during 2003-09 corresponds to an average decline rate of 6.6% p.a. Decline extrapolated from 31-Oct-09



# Expected Oil Production Uplift

- First response expected mid 2010, peak incremental in Q4- 2011, and total incremental oil of 116 Mstb by 2021