



Santos

# Big Lake Infill Pad Pilot

## DrillWell Adelaide 2010

**Gas Exploitation:** R. Shrivastava, S. Cheong, A. Carey, C. Oviawe, S. Chipperfield

**Drilling:** G. Cernev, M. Gilmour, Mahbub Hoq

**Completions:** S. Brooks, M. Howard E. Samari, M. Satyagraha

**Flowlines:** A. Masullo

**Lease Build / Remediation:** K. Batchelor, A. Ward

# The Power of Teamwork...



Janmashtami Festival, India

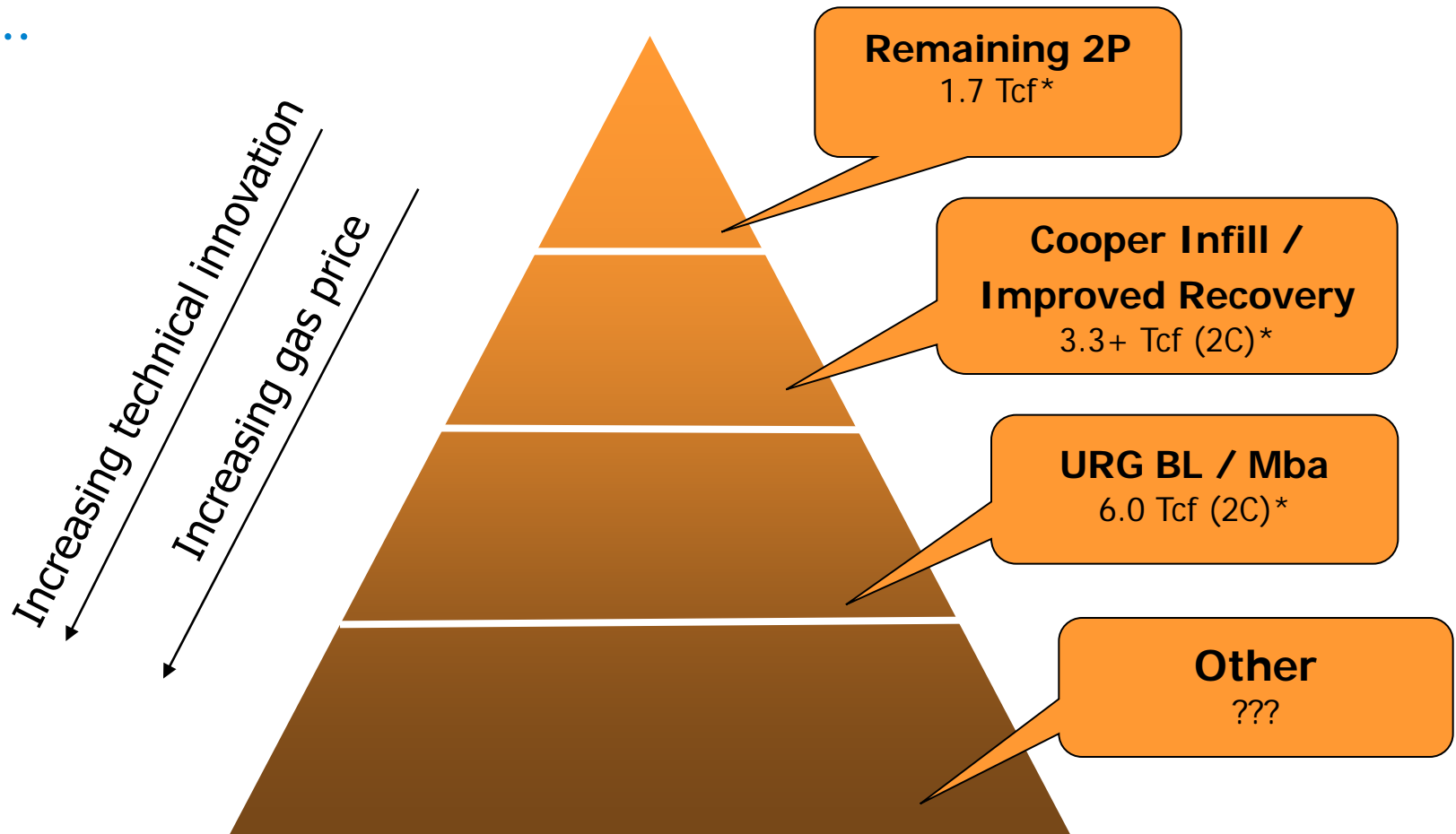
**“The whole is greater than the sum of the parts.”**

Anonymous

**Santos**  
We have the energy.

# Cooper Gas – Reserve Potential

Significant potential left within the Cooper Basin with ongoing focus...

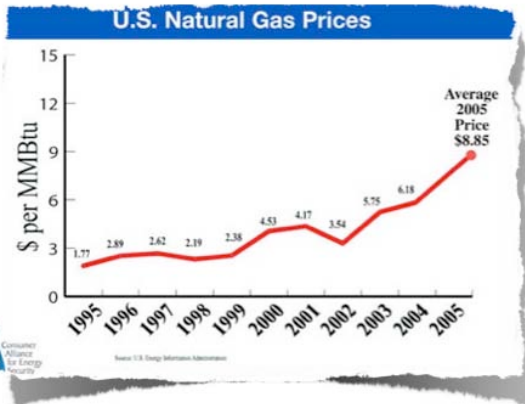


\* Sales Gas Gross

...to define gas price and tech contingencies

# Three Critical Factors for Infill Success

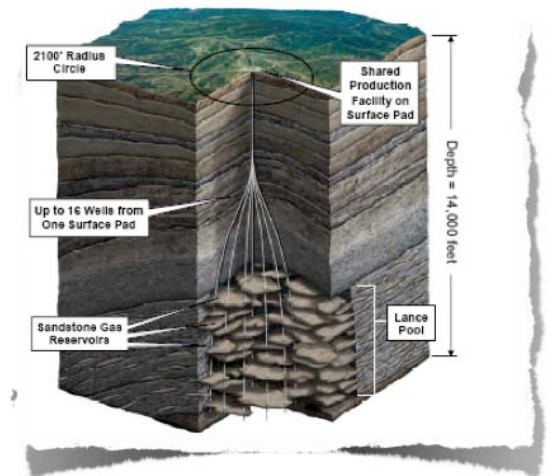
## Infill Potential



Economics



Geology



Well Cost

# North American Pad Drilling Benefits

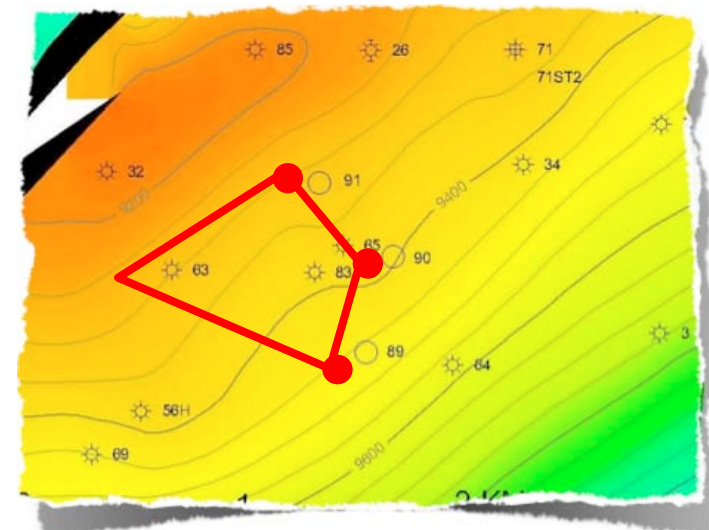
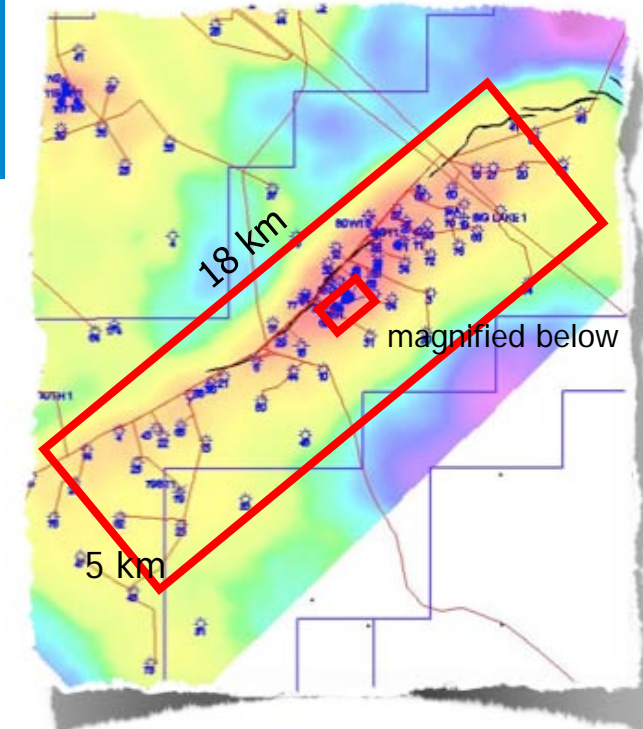
- **Cost and Efficiency**
  - More efficient drilling (Fit For Purpose equipt)
  - Faster rig moves (5 days down to 4 hours)
  - Facilitates SIMOPS operations
  - Cost reduction of 30% total well construction
- **Field Logistics**
  - 70% less roads
  - 75% reduction in heavy traffic
  - Centralized water usage
- **Environmental**
  - 50% reduction in surface disturbance
- **Safety**
  - Reduced exposure: rig-up/rig-down, driving
    - Rig moves were cut by as much as 75%
    - Vehicle traffic reduced by 40 to 90%
- **Predicated on large committed program**



**Jonah field**  
(>18 wells / pad at 5 acres)

# Big Lake Field

- Legacy Asset
  - 20km SE of Moomba Plant
  - 1Tcf+ produced since 1972
  - Current Capacity: 2000 E3M3/D
  - Broad well spacing ~200 acres
- Low recovery - large reserve potential
  - Patchawarra 10% & 2P OGIP: 1 Tcf
  - Tirrawarra 44% & 2P OGIP: 600 Bcf
- Big Lake Pad pilot objectives
  - Assess incremental reserves at 50 acres
  - Test cost reduction capability of Pad Drilling & SIMOPS
  - Deliver rate & reserve to Development Program

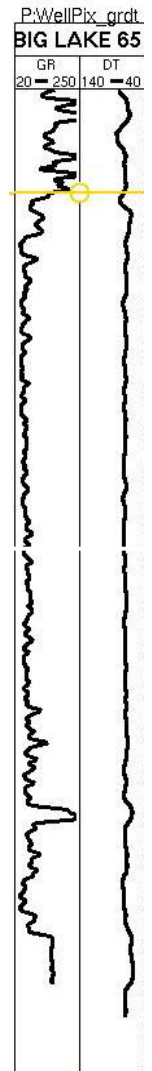
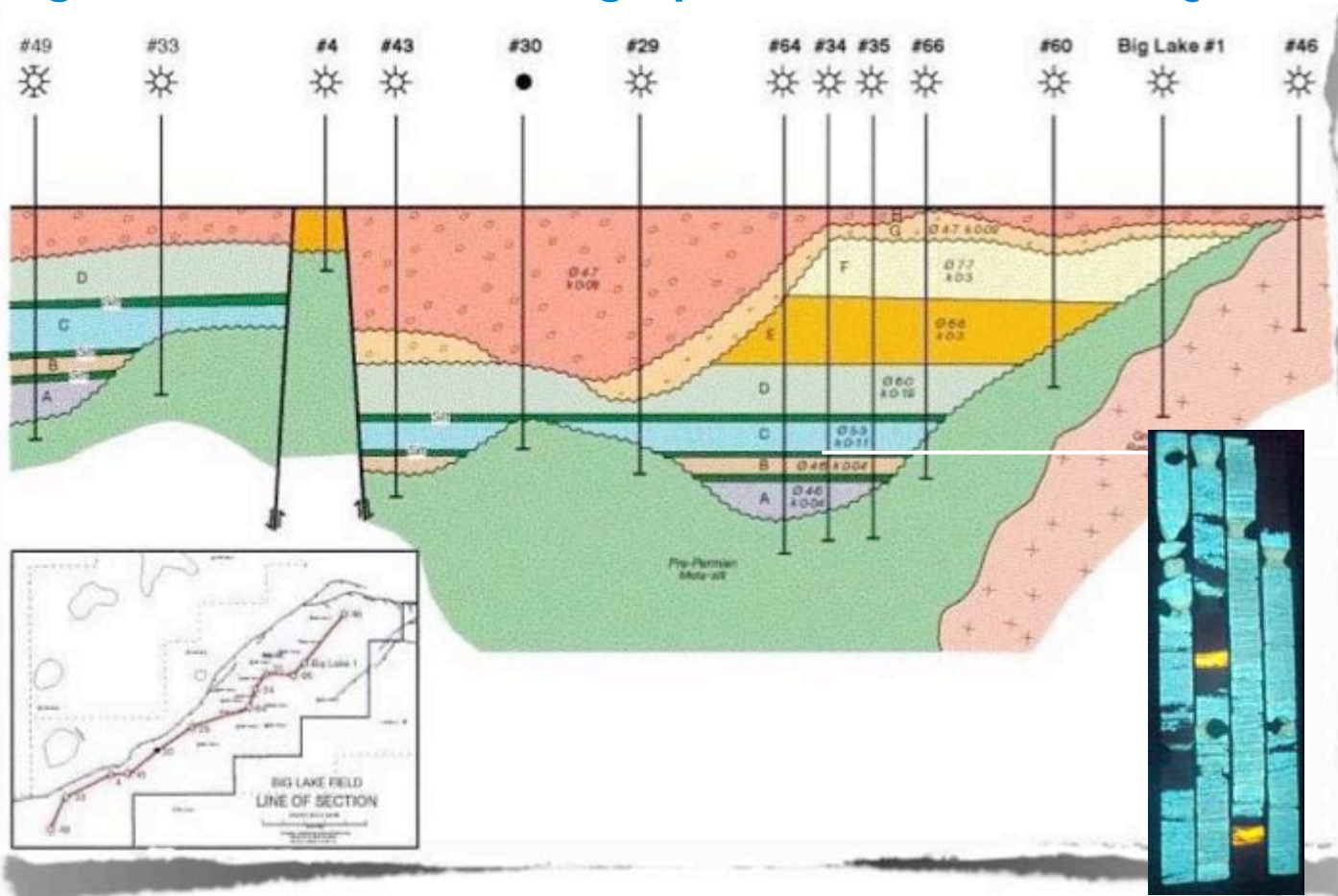


Big Lake Field

Big Lake Infill Area

# Tirrawarra Geology

## Big Lake Tirrawarra Stratigraphic X-Section (showing sub-units)

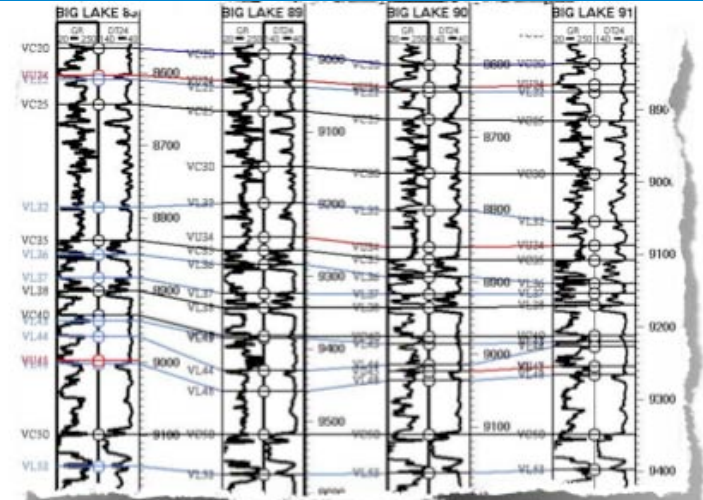
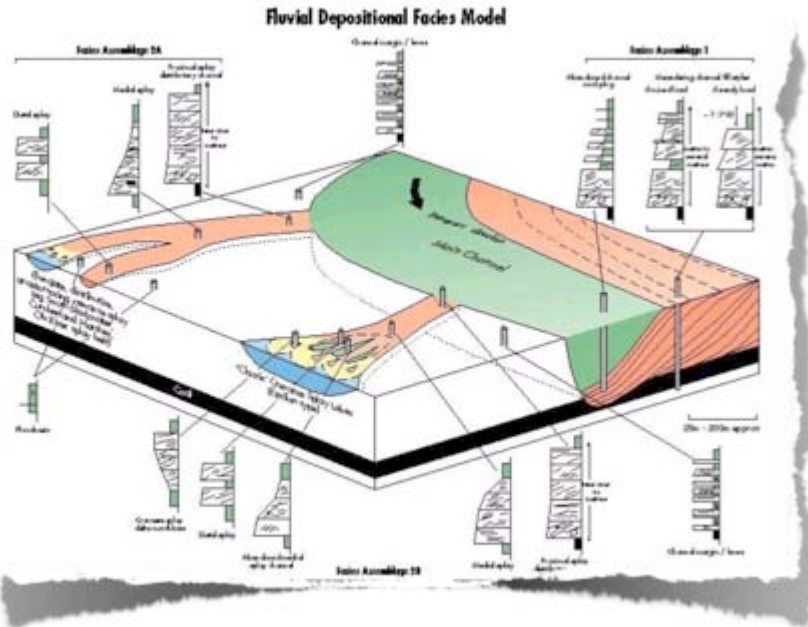


Tirrawarra Type-log

Tirrawarra Field  
Tirrawarra Formation  
Oil Fluorescence\*

\*Courtesy Nick Lemon

# Patchawarra Geology



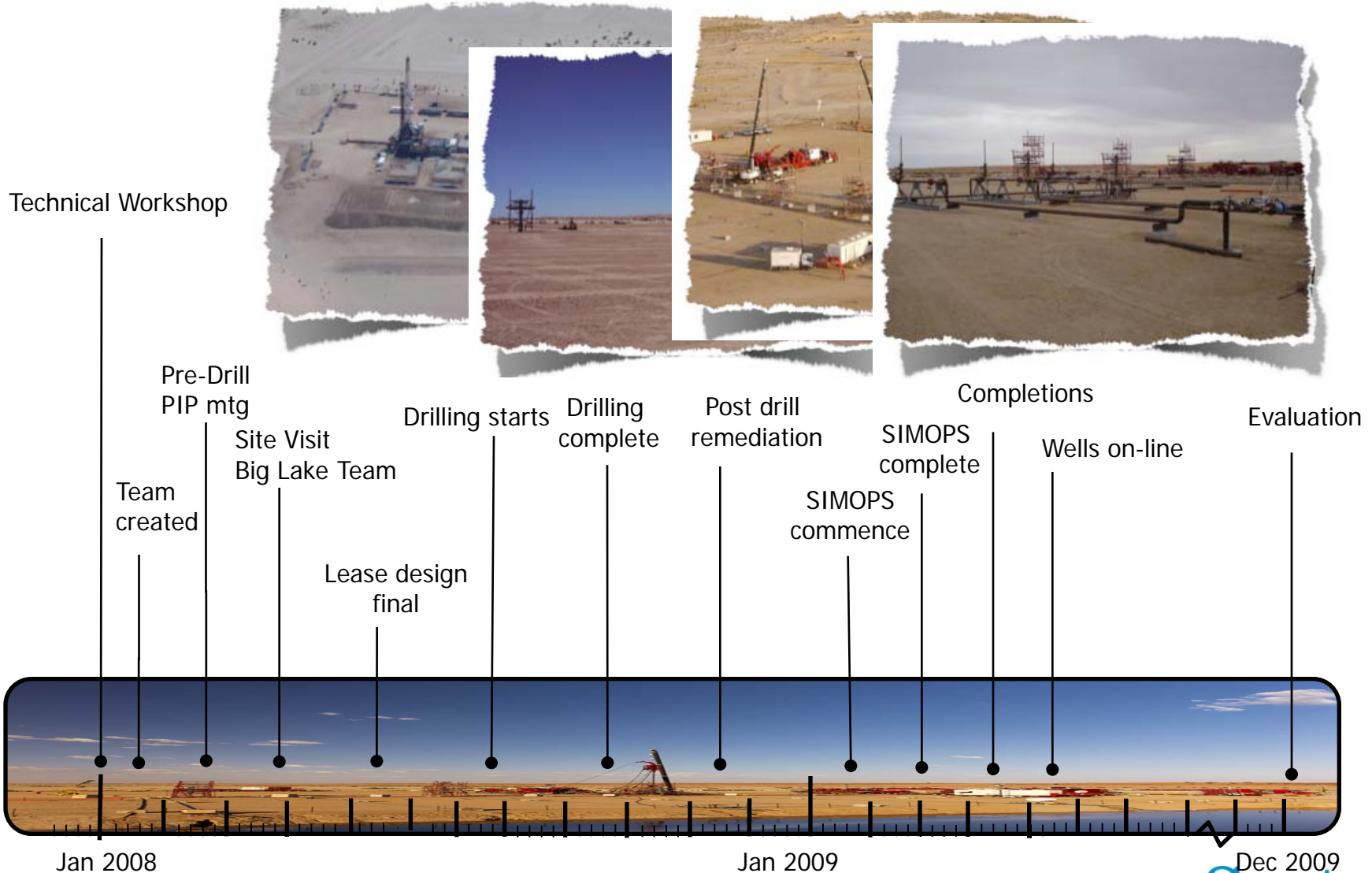
BIG Lake Patchawarra X Section

Big Lake Patchawarra Fluvial Depositional Model



Patchawarra core (showing internal baffling)

# Planning<sup>2</sup>

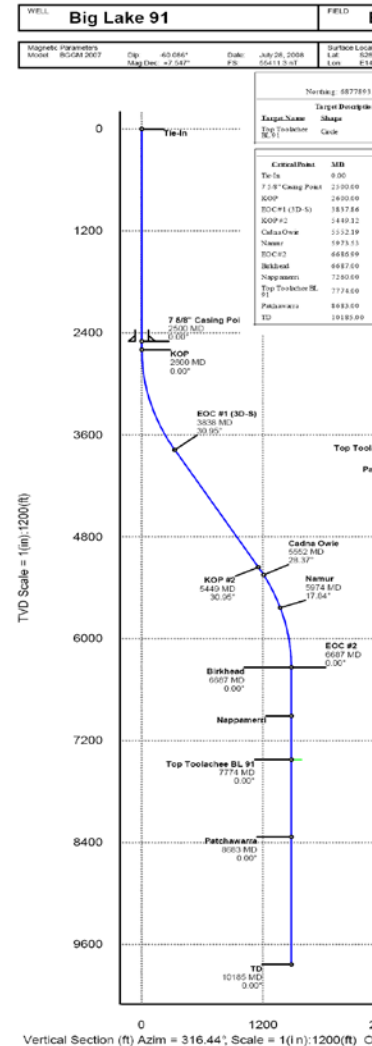


# Drilling Programme

- Drill 3 Gas wells from a single lease, 2 directional, 1 vertical
  - Well targets: Patchawarra, Tirrawarra Gas
- Directional wells
  - 450m horizontal departure
  - Directional drilling in production hole
  - Vertical across well targets
  - Big Lake 89 – Directional – S shape
    - Plan TD: 10344ft MDRT
  - Big Lake 90 – Vertical
    - Plan TD: 9987ft TVDRT
  - Big Lake 91 – Directional – S shape
    - Plan TD: 10215ft MDRT

# Well Design

- Design Constraints
- Differential sticking across Toolachee/Daralingie/Epsilon
  - Drilled previously as 8-1/2" hole or with bi-centre bits, wellbore required to be vertical
- Hard and abrasive drilling in Birkhead/Hutton
- 450m departure to achieve subsurface spacing requirements
- <10° inclination across targets for stimulation programme
- BHST ≈ 360°F, Motor & MWD limitations
- Design Chosen
- S-shaped well, KOP in production hole (less casing wear)
  - 22.4m wellhead spacing is low risk for surface hole collision, no MWD required
- Vertical by Birkhead fm in case bit trip required – L/D motor & MWD
- Drill TDE with bi-centre bit as per previous 2 Big Lake gas wells
- Maintain vertical to TD with rotary BHA



# Cement Engineering

|             | Surface   | Production   |
|-------------|---|--|
| <b>BL89</b> | <ul style="list-style-type: none"> <li>uneventful, no problems mixing</li> </ul>  | <ul style="list-style-type: none"> <li>Slurry design, 0.3% SA-541, 0.82% HR-12, TT = 1.5hrs (after retesting Big Lake 5)</li> <li>Spacer train = 40bbl SAPP, 10bbl water, 30bbl scavenger, 40bbl tuned E+ spacer</li> <li>51 centralisers run, mixture of bow spring and solid type (across deviated interval)</li> <li>Bumped plug at 5000psi, only P/T lines to 3800psi beforehand</li> </ul>  |
| <b>BL90</b> | <ul style="list-style-type: none"> <li>275bbl lost to formation during cementing</li> <li>Root cause – poor communication, ambiguity of signals</li> <li>CBL conducted – top of cement 400ft</li> </ul> | <ul style="list-style-type: none"> <li>Slurry design, 0.25% SA-541, 0.95% HR-12, TT = 2.0hrs (triple checked, HR-12 problematic)</li> <li>Cement blown 6 times as opposed to 4</li> <li>Spacer train = 60bbl SAPP, 10bbl water, 30bbl scavenger</li> <li>34 centralisers run, all bow spring type</li> <li>Tail pumped at 3.2bbl/min, boost pump losing prime due to thick slurry</li> <li>Bumped plug at 3400psi</li> </ul>   |
| <b>BL91</b> | <ul style="list-style-type: none"> <li>uneventful, no problems mixing</li> </ul>  | <ul style="list-style-type: none"> <li>Slurry design, 0.25% SA-541, 0.9% HR-12, 0.1% CFR-3 (to combat surface gellation), TT = 2.0hrs</li> <li>Spacer train = 40bbl SAPP, 10bbl water, 30bbl scavenger, 40bbl tuned E+ spacer</li> <li>51 centralisers run, mixture of bow spring and solid type (across deviated interval)</li> <li>First 60bbl of tail mixed and pumped well, switch pods and encountered aeration problems (NF-6 unable to overcome)</li> <li>Bumped plug at 2900psi</li> </ul> |

All 3 wells have excellent CBL results  
 – this will be required as each well has > 6 frac targets

# Campaign Highlights/Lowlights

## Highlights

- Successfully drilled and cased 3 wells,
- Wellheads accommodated amongst rig equipment,
- Learnings from BL89 implemented on BL91, significantly faster,
- No recordable HSE incidents.

## Lowlights

- High torque below 'S' shape, limiting ROP (particularly BL89),
- Difficulties logging, high temperature, sticking wireline (BL91),
- Rig NPT

# Campaign Highlights/Lowlights



# Recommendations for Future

## Rig layout / lease design

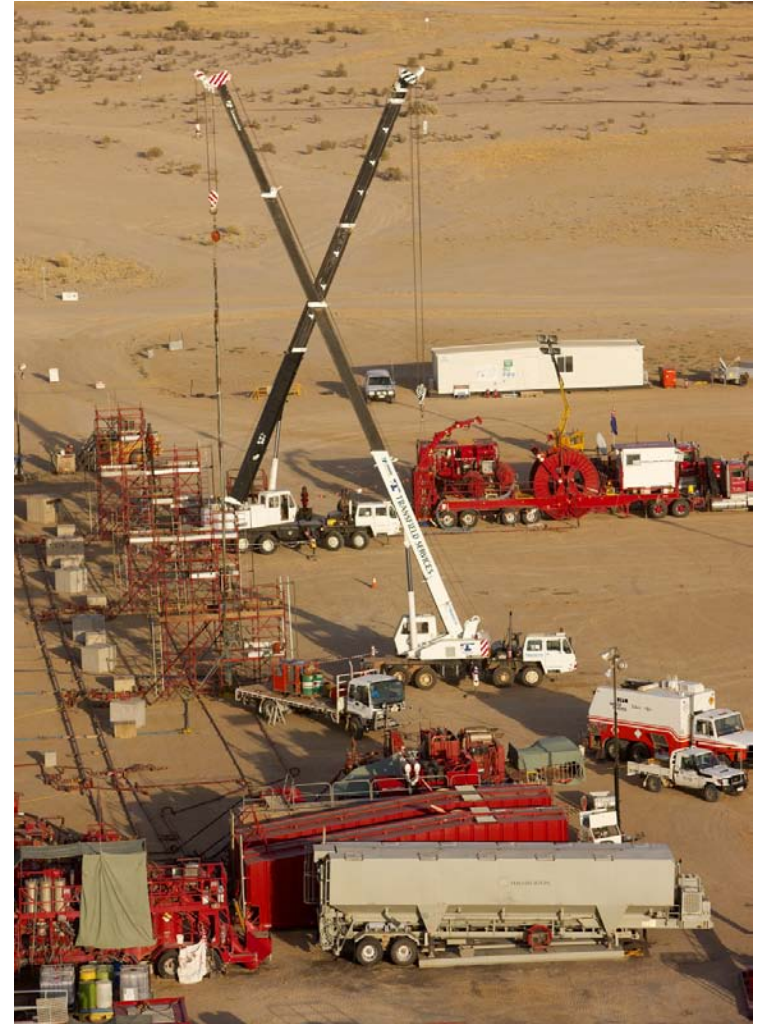
- Reduce wellhead spacing to 10m,
- Move only substructure & shaker tank during interwell rig move,
- Sumpluss drilling to prevent remediation.

## Well design / operations

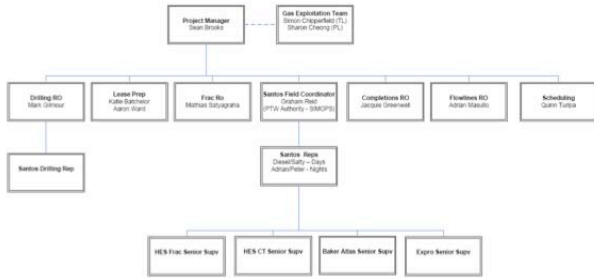
- Design #1 – S shape, KOP in production hole, vertical by top Toolachee fm,
- Design #2 – S shape, KOP in surface hole, set casing at tangent angle, drop angle in production hole, vertical by top Toolachee fm,
- Hydraulically actuated under-reamer as opposed to bi-centre bit – save a bit trip,
- Reduce evaluation phase – no wiper trip between logging runs,
- Incremental learnings (mud, cement, drilling parameters, water haulage etc).

# Innovation – SimOps

- Fracture stimulation spread
- Coiled Tubing Unit
- Electric Line perforating Unit
- Slickline Unit
- 2 X 50 T Cranes
- Trucks
- “Guests”



# Innovation – SimOps



Team Structure



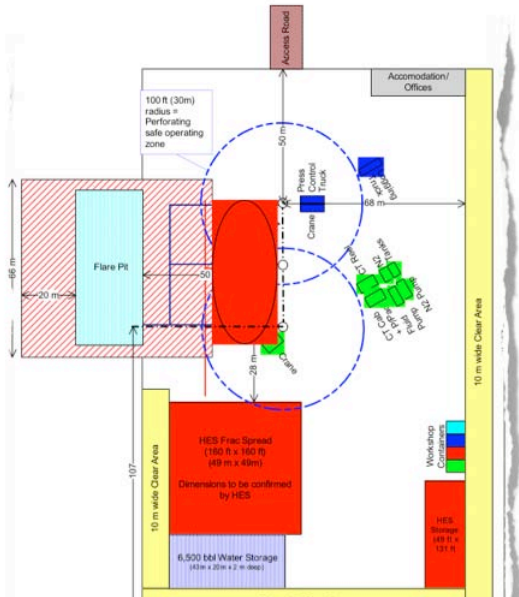
SimOps in Operation

**wellsite**  
*permit to work*  
 system

**RED ALERT DAY**  
 TEMPERATURES MAY  
 EXCEED 40° C

Remember to  
 Accompany  
 the permit to  
 work your well

Wellsite Operations



Lease Layout

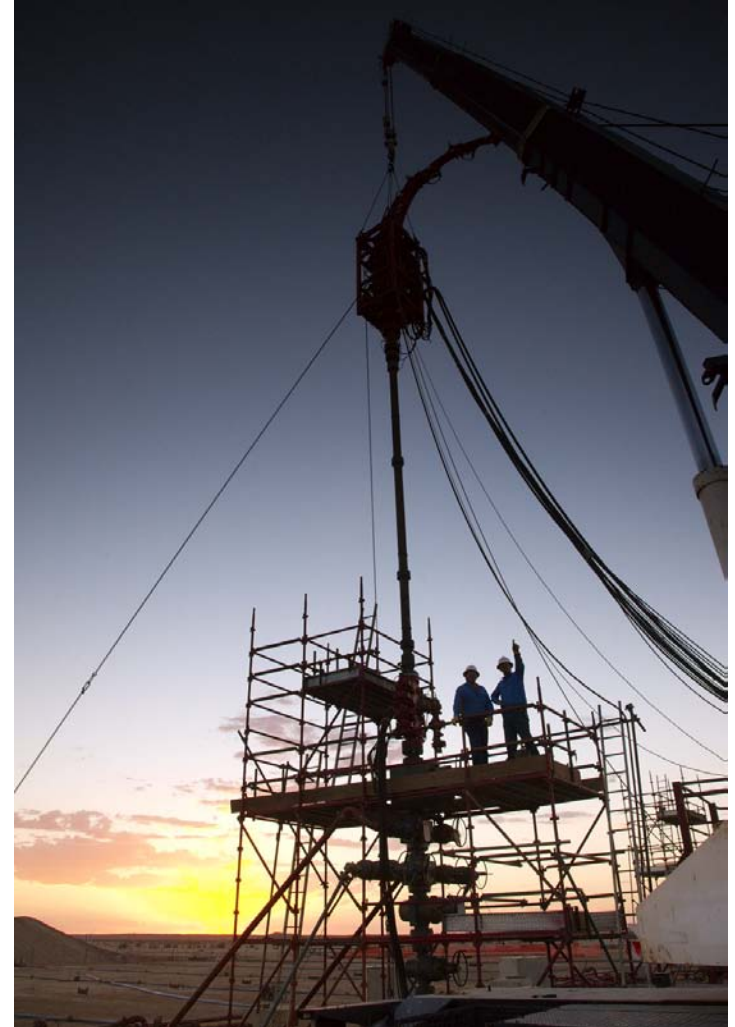
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| Well Name | Well Type  | Well Status | Well Depth | Well Completion | Well Production | Well Injection | Well Monitoring | Well Safety | Well Compliance |
|-----------|------------|-------------|------------|-----------------|-----------------|----------------|-----------------|-------------|-----------------|
| Well 1    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 2    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 3    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 4    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 5    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 6    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 7    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 8    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 9    | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |
| Well 10   | Production | Active      | 10000      | Fractured       | 1000            | 0              | 1000            | 1000        | 1000            |

SimOps Matrix

# Innovation – SimOps

- 24 hr continuous operations
- 22 separate, consecutive HP fracs
- 22 perforation runs (incl night ops)
- 19 CBP run and milled
- > 30 CT runs
- Flowback, cranes
- Heat stress management during day operations
  - 19 Red Alert days
  - In excess of 16,000 Hours for SIMOPS phase



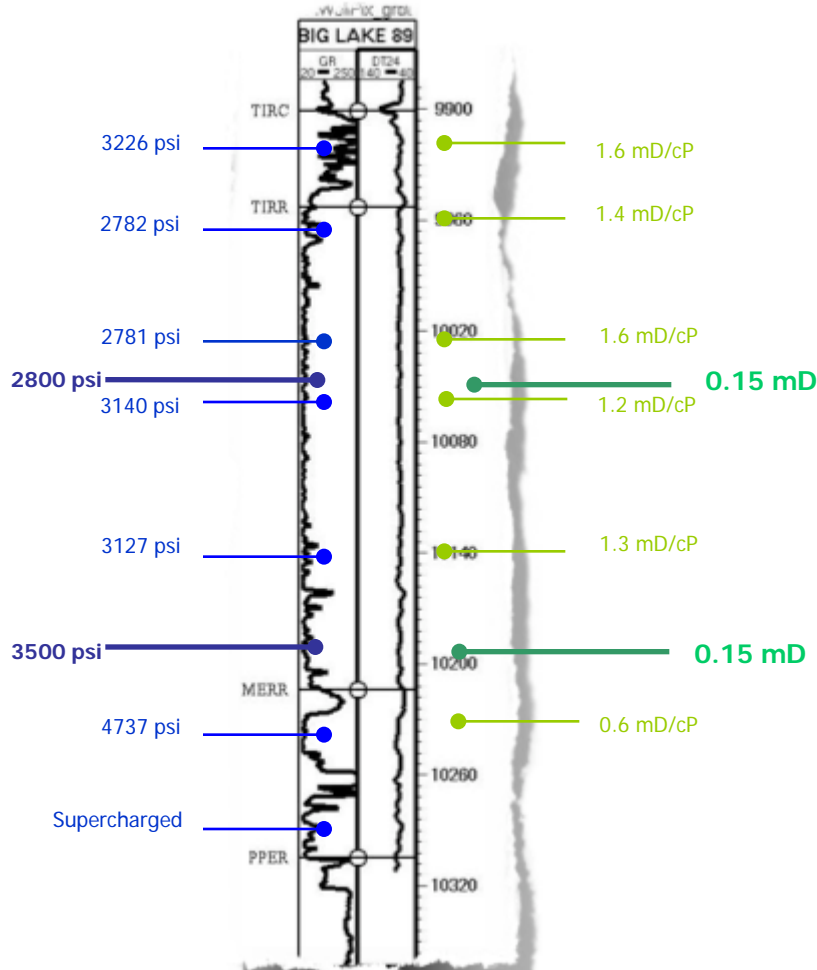
# Learning from the SimOps Experience



- ✓ Direction drilling & severe depletion
- ✓ Improved spacing
- ✓ Operational Efficiency demonstrated
  - 24 hour ops (Perforating at night)
  - 1 frac/day achieved on first attempt
  - Frac innovation (over-displacement)
  - Further improvement areas identified
- ✓ Operational downtime minimised
- ✓ Safe Operation

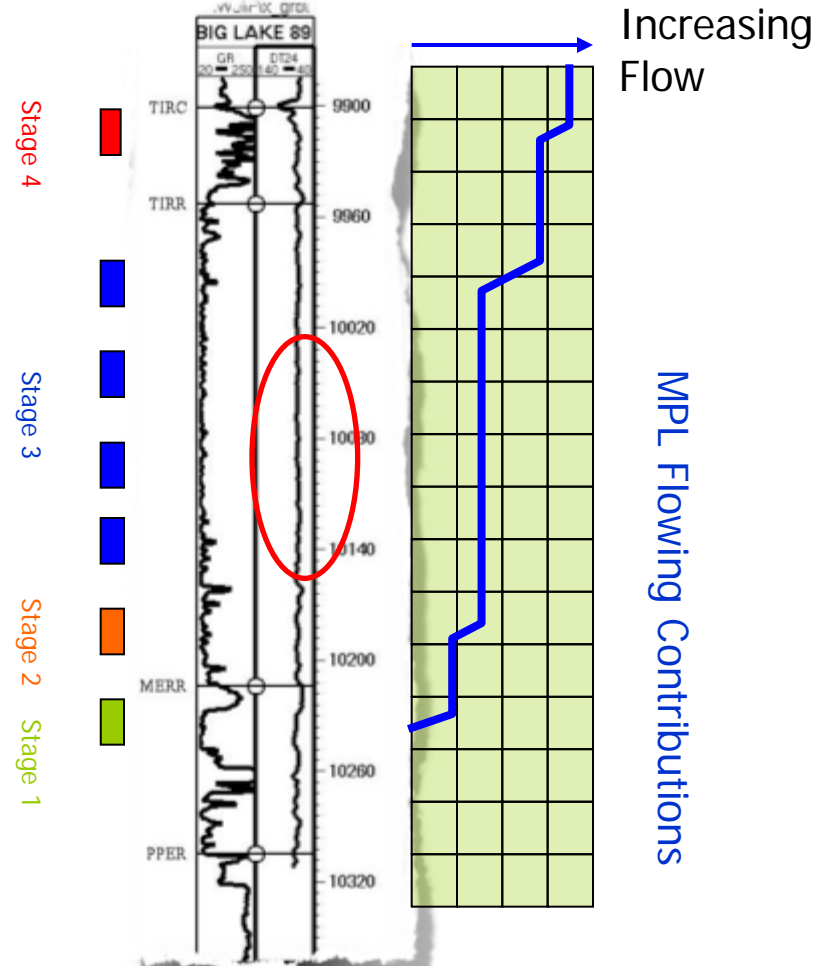
# Innovation – Surveillance

Surveillance quantifies potential & highlights area of future improvements...



Differential Depletion  
(FMT & DFIT)

Similar permeabilities  
(FMT & DFIT)

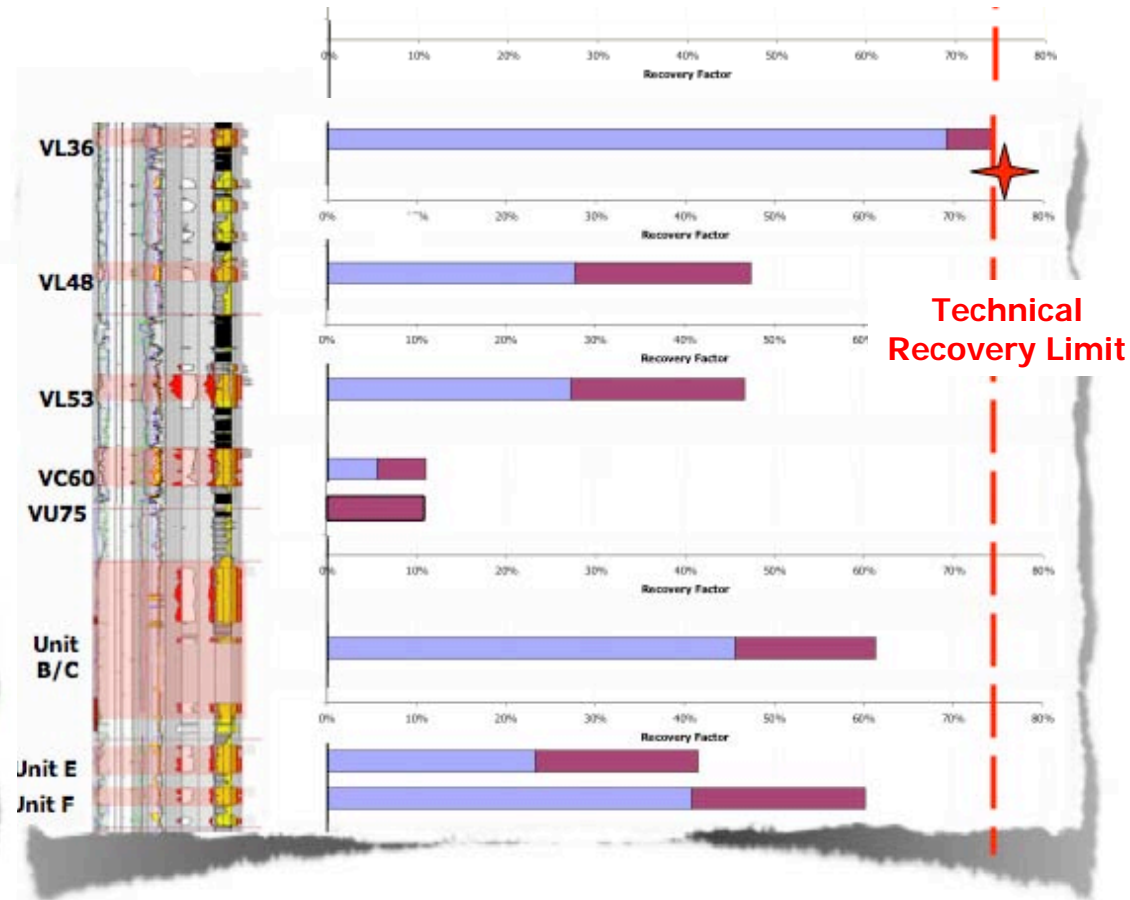
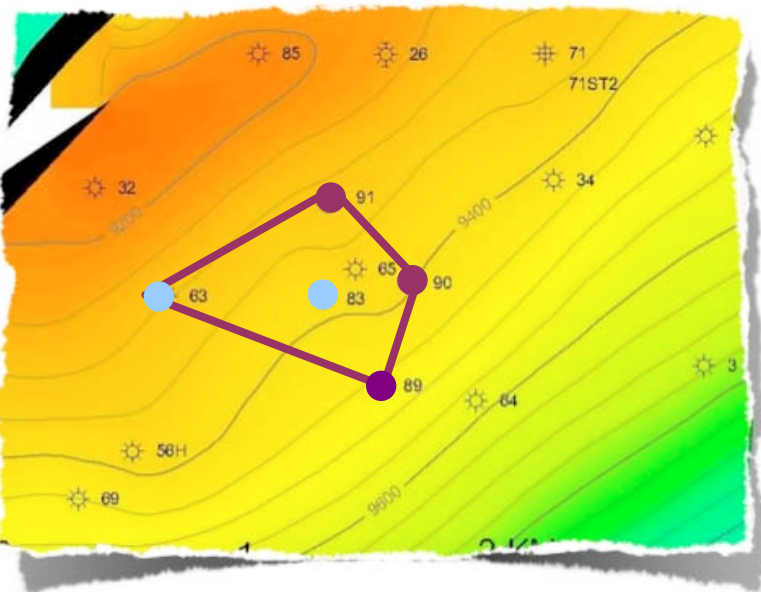


Sub-optimal stimulation?

# Innovation - Reservoir Engineering

## The Problem

Infill requires understanding pressure & permeability (insitu & induced) by layer..

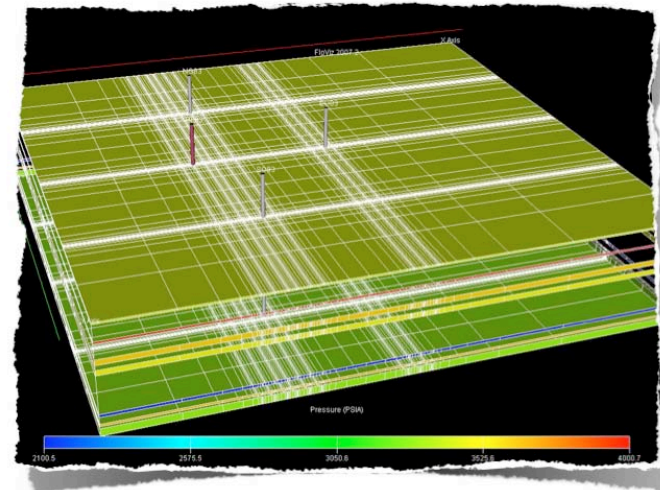
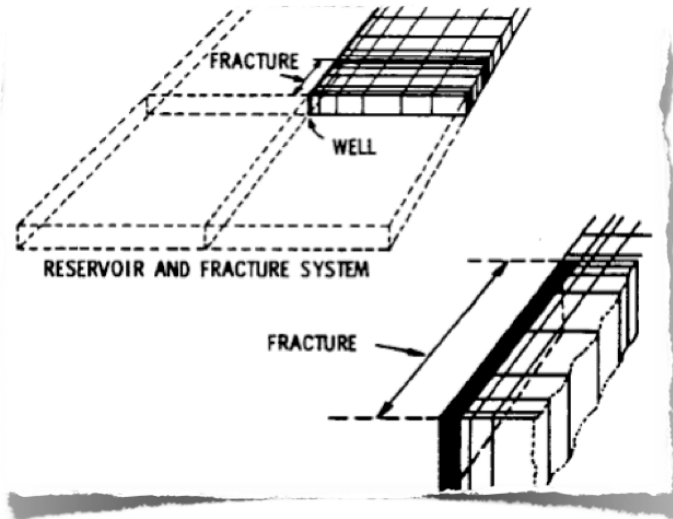


50 acre sector (Initial and New Wells)

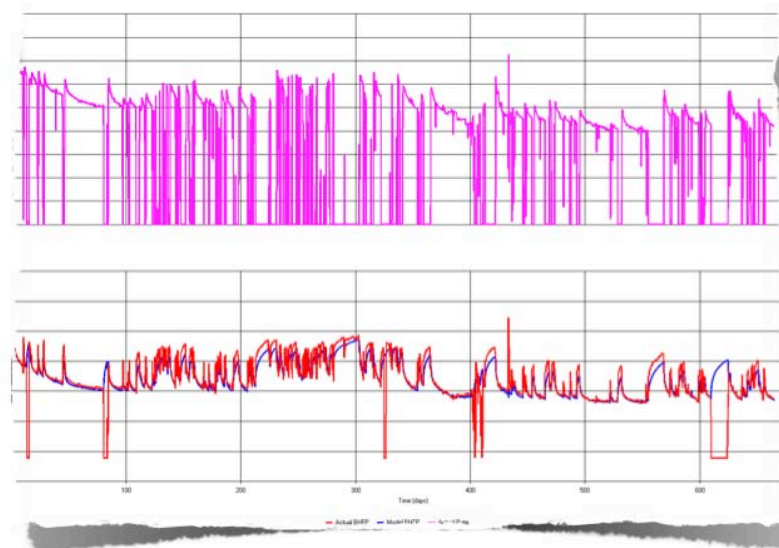
Recovery by sand (Initial and New Wells)

# Reservoir Engineering

## The Solution



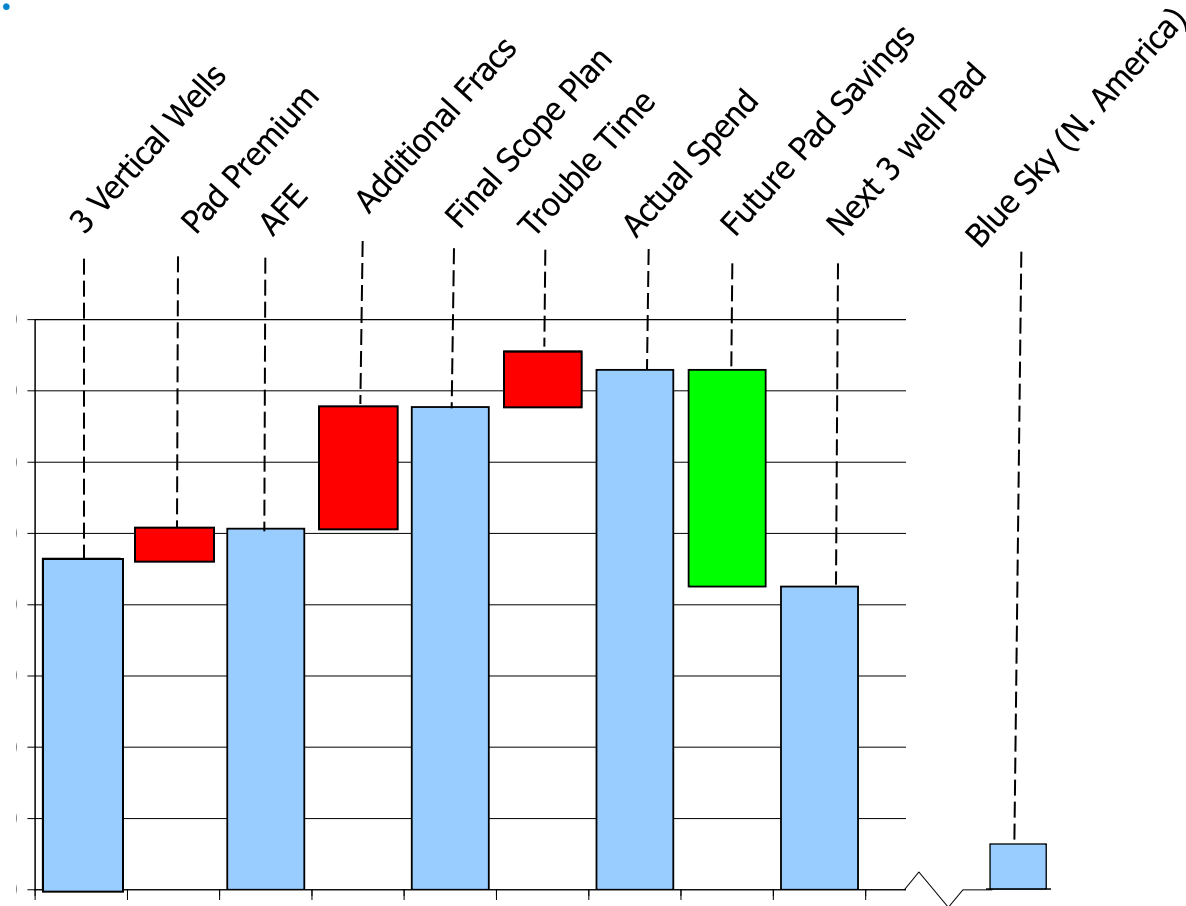
Gas 3D – Numerical simulator (Automated multi-layer variable gridding)



Production History Match

# Big Lake Infill - Cost Waterfall

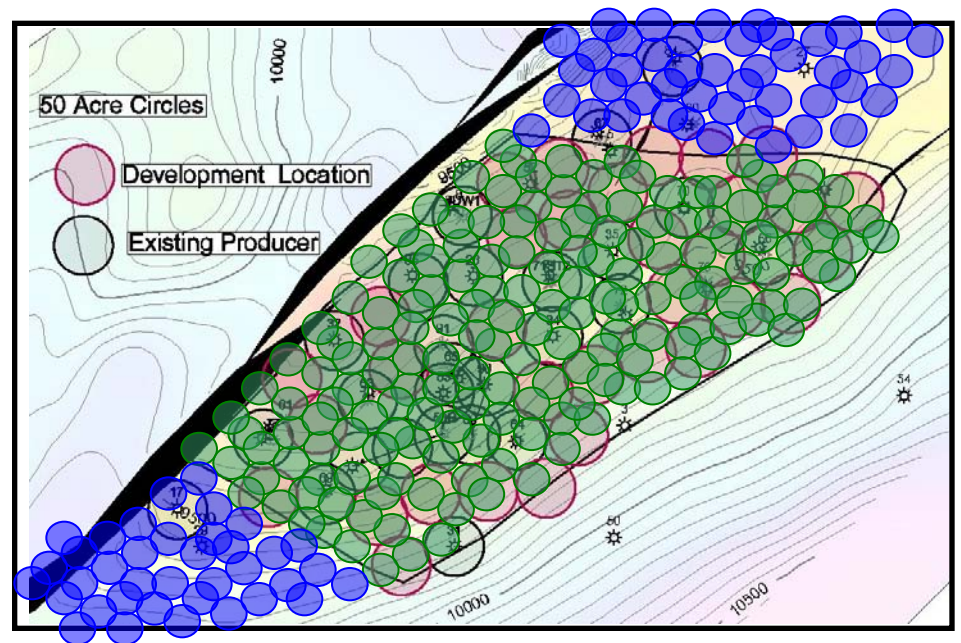
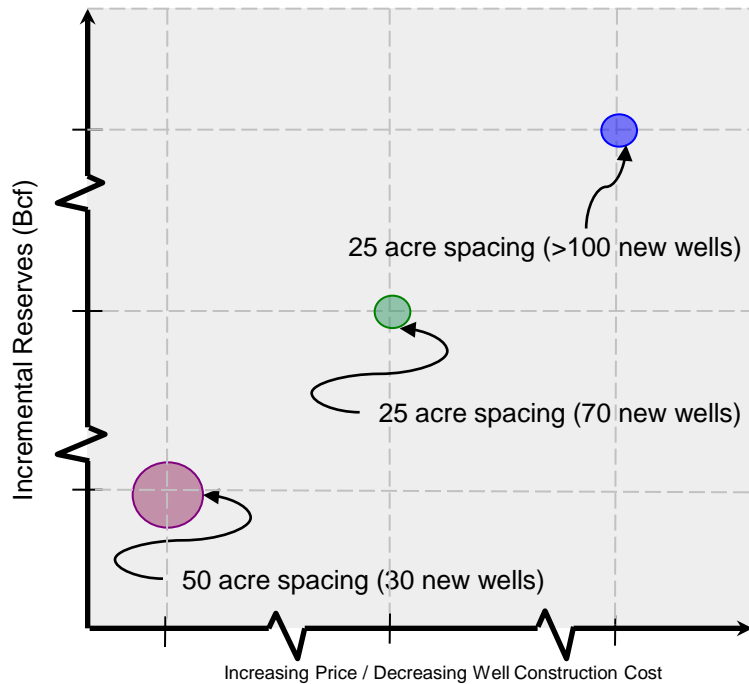
Pad costs can be significantly reduced on next project with current practices...



...further potential through fit for purpose equipt and practices

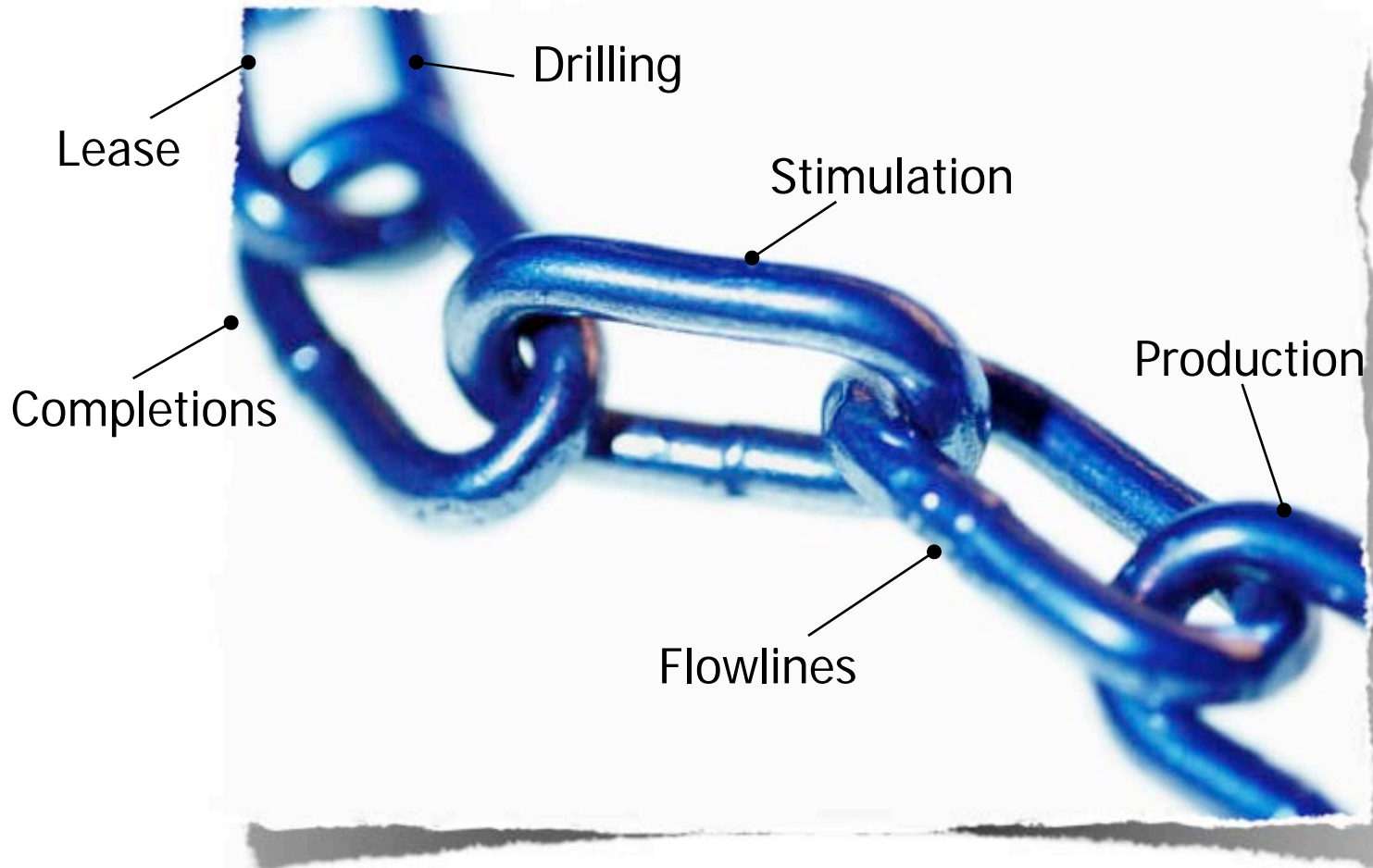
# Implications on Field Development..

Ongoing pilot evaluation will be used to assess incremental reserves vs spacing..



..with final outcome contingent on further production & Santos cost projections

# Multi-disciplinary team work is key



# Taking Teamwork to the next level..

**SimOps  
more phases**  
(Drilling, Completions,  
Flowline)

**Flowing gas in-  
line during  
SimOps**

**More wells  
from one pad  
(6+)**

**Fit For Purpose  
Skid-able Rig**



Ultra Petroleum

**"The whole is greater than the sum of the parts."**

Anonymous

**Santos**  
We have the energy.