Turning around the Tern

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DEVEX conference, Aberdeen
10th May 2012

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Outline

• **History and background of Tern area**
  – Example reservoir: Tern Main Brent

• **Phase 1 Re-development ‘staircase’**
  – ‘Make it grow’
  – ‘Make it work’
  – ‘Make it safe’
  – Projects execution
  – Activity planning
  – Re-development scoping
  – Reservoir surveillance
  – Facilities performance

• **Conclusion**
  – Highlights
  – Lessons learned
  – View to the future
Location of Tern Area licences

Shetland Islands

Falcon

Tern

Kestrel
Infrastructure status: December 2008 upon TAQA completion of Asset purchase

Hudson (subsea) Non-operated

Eider platform

Kestrel (subsea)

Tern Brent

- Gas lift
  100 mmscf/d
- Water injection
  277,000 bwpd
- Liquids handling
  246,000 blpd

Liquid production

Water injection

Gas lift
• Tern was discovered in April 1975
• Brent reservoir STOIIP approx. 600 million barrels
• Production and water injection started in 1989
• Typical N Sea down-dip water injection pattern adopted
• Recovery factor to date, approx. 45 %
Tern Brent Reservoir: structural configuration

BMNS Seismic surface
Model: LB_2007 update

Transfer fault zone

BCU
Heather
Brent
BMNS
Rannoch
Dunlin
Cormorant 1
Cormorant 2
Palaeosol
Basement
## Tern Brent Reservoir

### Example log and typical properties

<table>
<thead>
<tr>
<th>Formation</th>
<th>N/G</th>
<th>Av Porosity</th>
<th>Av Perm mD</th>
<th>Av S_{si}</th>
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<tbody>
<tr>
<td>Upper Ness C</td>
<td>0.50</td>
<td>0.20</td>
<td>87</td>
<td>0.75</td>
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<tr>
<td>Lower Ness</td>
<td>0.72</td>
<td>0.26</td>
<td>1504</td>
<td>0.74</td>
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<tr>
<td>Etive</td>
<td>0.84</td>
<td>0.25</td>
<td>1433</td>
<td>0.68</td>
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<td>Rannoch B</td>
<td>0.79</td>
<td>0.23</td>
<td>531</td>
<td>0.75</td>
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<tr>
<td>Broom</td>
<td>0.65</td>
<td>0.18</td>
<td>84</td>
<td>0.46</td>
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</table>
Production evolution: Tern Brent example

Tern Brent
Production 1989 - 2011

Plateau (80,000 bopd in the case of Tern Brent)

Stabilization of water cut with background contribution from Upper Ness, Rannoch, Broom

Strong water breakthrough dominated by Lower Ness – Etive layers
Facilities Performance

- Early focus on understanding facilities capacities, baseline performance and underlying issues
- Recognition of need to improve both production and injection efficiency
- Injection efficiency particularly important, most reservoirs reliant on ‘water-drive’ mechanism
  - Injection the ‘engine’ for sustained production
- Potential was identified for injection facilities capacity increase by dividing 4 HP pump system into 2 * HP pump system and 2 * LP pump system
A programme of surveillance was undertaken to improve understanding of the wells and reservoirs, key elements of which were:

- Improved well test and fluid sampling frequency
- Cased hole production logging
- Cased hole saturation logging
- Flowing gradient surveys: gas lift performance
- Reservoir pressure measurements
- Tracer programme in all Tern Brent water injection wells (tracer example later in the presentation)
- Well mechanical and integrity status review
Redevelopment scoping

- Using historical information and new surveillance data as it became available, the reservoirs were screened for re-development potential and a strategy developed
  - Tern Main Brent: infill production and injection to improve sweep in Upper Ness, Rannoch, Broom
  - Tern Triassic: reduce well spacing, implement water-flood pilot
    - Platform challenge: slot constrained, 25 available slots, most being active...
  - Kestrel: producer well repair
  - Falcon Area: appraisal drilling with view to ‘fast track’ development
Activity Planning

- 7 well platform infill campaign scoped and approved, start of ops. planned for August 2010
  - Rig re-activation
  - 5 Brent activities
    - 1 work-over to water injection (dedicated Upper Ness)
    - 1 work-over to reinstate full gas lift (Upper Ness horizontal prod)
    - 1 infill producer (UN, Ra, Br)
    - 1 water injector sidetrack
    - 1 water injector integrity workover
  - 2 Triassic activities
    - 1 infill producer
    - 1 work-over to water inj.

- Mobile drilling 2010
  - Falcon twin branch appraisal well planned for Spring 2010
## Projects execution: achieved timeline

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<td>Tern Platform Rig Reactivation</td>
<td>SCOPING</td>
<td>PLANNING</td>
<td>EXECUTION</td>
<td>LOOK BACK</td>
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<tr>
<td>Water Injection Capacity Increase</td>
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<td>EXECUTION</td>
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### Notes

1. Platform campaign extended from 7 to 8 wells, together with some modification / optimisation of later activities in the campaign vs original plan

2. Falcon appraisal: 1st branch water, 2nd branch oil, selected development subsea via Kestrel
## Evolution of campaign

<table>
<thead>
<tr>
<th>Activity Sequence Number</th>
<th>Original Plan – Slot Number</th>
<th>Original Plan - Description</th>
<th>Actual realised – Slot Number</th>
<th>Actual realised - Description</th>
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<tr>
<td>1</td>
<td>23</td>
<td>Work-over to Water Injection : Triassic</td>
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<td>As per original plan</td>
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<td>Infill producer : Brent</td>
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<td>As per original plan</td>
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<td>Injection Work-over : Brent</td>
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<td>05</td>
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<td>Infill Injector : Brent</td>
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<td>7</td>
<td>28</td>
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<td>8</td>
<td>n/a</td>
<td>n/a</td>
<td>28</td>
<td>Infill producer : Brent</td>
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</table>

**OPTIMIZATION OPPORTUNITIES**

- Tracers unlocked opportunity

**SEQUENCING CHANGES**

- OPTIMIZATION OPPORTUNITIES
Campaign optimization, activities 6 & 8

- Original development: downdip injectors and updip producers
- In 2010, tracers injected in all Brent water injectors
- 2009 seismic identified new fault and refined the fault pattern
- Southern injectors breakthrough in the Northern producers
- Mid-flank producers less well supported
- Southern injector duplication

**Identified**
- New injection point for Mid Flank producers (TA26)
- Bypassed oil target (TA28)
  - Integrity injection work-over became oil producer activity, dry oil production >4500 b/d at start
Production results

Tern Platform Oil Production (excluding Hudson)
Note: Plot does not include Last two Tern producers, on-stream recently

Activity 7 TA30 = 1,800 bopd initial
Activity 8 TA28 = 4,600 bopd initial
Conclusions: highlights & lessons learned

• **Highlights**
  • Commercially successful drilling campaign in highly mature field
    • No subsurface ‘failures’ in the development drilling
    • Significant production growth
    • Costs out-turn generally as per pre-project expectation (one significant exception mentioned in lessons learned below)
  • **Tern platform has strong base performance**
    • Attractive host for subsea and 3rd party tiebacks

• **Main Lessons learned**
  • Infill drilling campaign: challenging slot recoveries on many activities
  • Infill drilling campaign: keep it simple
    • Last well difficult and cost overrun
  • Maintaining improvement in water injection uptime has proved challenging due to significant maintenance backlog.
Conclusions : View to the future

• Build on the information from the first platform campaign with a view to unlock a second campaign in the 2014 timeframe

• Continue to build and drill the near field exploration portfolio with a view to further ‘Falcon-like’ tie back opportunities

• Attract and secure 3rd party business which is value adding and compliant with TAQA core business