Managing declining fields with geophysics

Seismic Permanent Reservoir Monitoring

Solutions, Challenges & Opportunities

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Permanent Reservoir Monitoring

- **Permanent Seismic Reservoir Monitoring**
  - Equipment permanently installed
  - Continuous monitoring
  - Highest seismic repeatability – Active & Passive

- **10-25 years of monitoring**
  - Closer long term interaction between contractors & clients
  - Reservoir oriented
Overview

- Challenges of Permanent Reservoir Monitoring
- Existing CGGVeritas PRM solutions – EKOFISK & Schoonebeek
- Conclusion - PRM opportunities
O&G challenge: Optimized hydrocarbons Recovery

- **Worldwide average recovery factor is 32%**
  - Enhanced Oil Recovery (EOR) is key
  - Maximized value of O&G assets

- **4D seismic demonstrated benefits**

- **PRM is designed for managing declining oil fields**
  - Highest seismic repeatability
PRM challenge: Demonstrate value

Are PRM solutions too expensive?

- PRM solutions are more expensive than conventional solution
- PRM costs are loaded upfront

![PRM Return on Investment](chart.png)

Cumulative cost per year

<table>
<thead>
<tr>
<th>Nb of acquisition over the life of field</th>
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<td>1</td>
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<tr>
<td>Permanent Reservoir Monitoring</td>
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<tr>
<td>Conventional solution</td>
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How to make a profitable movie?

- Good scenario
- Initial investment
  - $237,000,000
- Famous actors
- Great film director

⇒ Tell a story

2,782,275,172 $
How to make a profitable seismic movie?

- **Good scenario**
  - finding the optimum repeatability
  - 4D geophysical response & turnaround

- **Initial investment**
  - $100,000,000

- **Knowledgeable actors**

- **Great film director - Integration**

→ **Tell where the oil is going**

Operating cost/Capital cost ~ 6%

PRM Engineering & feasibility study

2,782,000,000$  
~ 27,820Mbbl  
~ 0.8% increase on EKOFISK
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CGGVeritas field of expertise in PRM

CGGVeritas solution

Sercel
Land/SWOBC
Processing & Reservoir

Beyond 4D imaging
Microseismic
Reservoir Studies
Risk surveillance

4D Interpretation & data integration
4D/4C Seismic Processing
4D/Continuous Seismic acquisition
PRM installation
PRM Seismic Equipment
Project Pre-Planning & Management
Survey Design & Engineering
Feasibility Study

PRM project
Offshore example of Ekofisk (CoP/PLO18)

Project location

Key reservoir information:

- Fractured chalk - High porosity (30-50%) but low permeability
- Elliptical anticline at 2900-3250m
- SOA ~ one-third of the field
- Subtle 4D amplitude changes → highly repeatable 4D seismic
Ekofisk: a CGGVeritas integrated solution

- An Optical passive solution: OPTOWAVE
  - First operating full scale fiber optic system

- A dedicated source
  - Flexible containerized source

- Advance 4D Processing:
  - PRM Processing Imaging

- 2,5 years full-field integrated experience on Ekofisk
  - 4th survey acquired June-July 2012
Ekofisk Results *NRMS in 2800ms-3300ms window full stack*
Ekofisk Results *NRMS in 2800ms-3300ms window full stack*

L1/L2: 5.07%  
L1/L3: 5.85%  
L1/L4: 7.46%  
L2/L3: 3.51%  
L2/L4: 4.27%  
L3/L4: 4.06%

(SOA polygon excluded from stats)
Dip filtered stack, 4D difference - Raw

LoFS1

LoFS3

4D diff (scaled up by 2)
Dip filtered stack, 4D difference - after time alignment

LoFS1

LoFS3

4D diff (scaled up by 2)
Capitalization on experience

Operations comparison LoFS01-02-03-04

Turnaround is key

Integrating team with 2.5 year’s intensive experience
Onshore example of Schoonebeek (Shell/NAM)

Project location

- Schoonebeek new field development:
  - 44 productions wells 25 injectors wells
  - Expected recovery 100 to 120 million bbl (out of 300, 40% extra recovery)
A Continuous Land Seismic Monitoring
Seismovie layout

Seismovie on Schoonebeek:
3D Continuous Seismic Monitoring: Movie

Current Day: 07-Apr-2012

Steam injection (t/day)

Amplitude variation (+/- 20%)

Time shift (+/- 0.2ms)
Where is the steam going?
3D View of steam chamber?
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New challenges:
- Carry high sensor resolution benefits to the reservoir & overburden characterization
- Reduce turnaround & price with integration
- Master sensor/source coupling with the underground
- Enhance source repeatability
- 4D Data/knowledge Management

New Opportunities: Extend the usage of PRM
- Go Beyond 4D imaging
- Geomechanical effect on field
- Noise & fracture monitoring
- Seismic While Drilling
- Link with downhole monitoring solutions
Conclusion PRM – a new age for our industry?

- Feasibility & integration are critical to leverage PRM value

- Complete on-off shore offering are helping the industry to enhance PRM solutions – Fields of experiment

- We showed two integrated industrials successful solutions
  - Multi-disciplinary coordination together with client is key
  - Synergies between the two does exist

- New R&D opportunities – PRM isn’t delivering it full potential
Thanks for your attention

Special thanks for their support & for granting us the right to present today to

Shell/NAM &

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