The Ormen Lange Gas Field, Norway
Field Development, From Exploration to Production

Per A. Kjaernes
Vice president  StatoilHydro Russia
SPE , Moscow  March11th,2008
Ormen Lange, Gas from deepwater Mid-Norway to UK market
Mega project on time and cost
Production Profile

Ormen Lange Recoverable Reserves

<table>
<thead>
<tr>
<th>Expected</th>
<th>P90</th>
<th>P50</th>
<th>P10</th>
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<tbody>
<tr>
<td>RF / Total (%)</td>
<td>75</td>
<td>68</td>
<td>75</td>
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<tr>
<td>Recoverable Gas (GSm3)</td>
<td>399</td>
<td>310</td>
<td>397</td>
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<td>Recoverable Cond. (MSm3)</td>
<td>29</td>
<td>19.5</td>
<td>28.5</td>
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Production Profile P50/70M/85%

Future Compression

Year

GSm3

StatoilHydro
Ormen Lange
- consists of

✓ Field developments offshore

✓ Pipelines to shore

✓ Gas plant on land for processing and export compression

✓ Pipeline to UK

✓ Gas to UK markets
The Storegga Slide:
- One big slide approximately 8200 year ago
- Back wall: 300 km
- Run out: ~800 km
- Slide area: 90,000 km²
- Volume: 3500 km³
- 10 - 15 meter high flood waves along the coast
Ormen Lange Field Location

- The ultimate challenge for pipelaying and marine operations
- Pipelines and installations in slide area
- 850 – 1100 metres water depth
- Sub zero temperatures at sea bottom
Key Information - Ormen Lange Field

- Water depth of 850 - 1100 meter
- 500 GSm³ (18 TCF) GIIP
- Retrograde Condensate GCR $\approx 10,000$ Sm³/Sm³
- 120 km off the coast of Norway
- App. 350 km² areal extent
- Harsh weather /sea conditions
- Sand rich turbidite
- App. : 50 m , 90% ntg and 500 md permeability
- 24 Producers (3 Predrilled)
- Subsea development
- Compression as required
- Gas production 12-22 billion Sm³ / year
The Top Reservoir Structural Depth Map

6305/1-1

6305/4-1 drilled spring 2002
GIIP prognosis confirmed

6305/5-1

6305/7-1

6305/8-1

Giip prognosis confirmed
### Ormen Lange Exploration, appraisal and development plan

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<td>Well interference test proves communication across faults</td>
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**StatoilHydro**
1989 to 1996 - Increased Certainty of Presence of Gas

1989 2D Seismic

Flat spot?

1996 3D Seismic

DHI - Outline

Top Våle

IntraRed
Prognosis 1989-92 (no wells on Ormen) proven by wells

PROGNOSIS BASED ON ANALOGUES WELLS AND SEISMIC DATA

Only minor changes to the GIIP after 1989 for EGGA (main Reservoir)
Key Project Milestones

- **Concept Screening**: Dec. 2000
- **Submit PDO/PIO**: Dec. 2003
- **Pre-Drilling Start**: 4Q 2005
- **Prod Start**: 4Q 2007

**1997**
- **Appraisal**: 1997-2002
- **Concept Selection**: Dec. 2002

**2007**
- **Contract Award**: Medio 2004
- **Marine Install.**: 2006/7

*StatoilHydro*
Ormen Lange Project Summary Schedule

- Tech/Econ
- DG1
- DG2 Concept Screening
- Feasibility Studies: 9 Months
- Conceptual Studies: 23 Months
- Site Selection: 44 Months
- DG3 Concept Selection
- DG4 PDO
- FEED
- Approval: 12 Months
- Approval: Au
Screening Work

- 4 x 4
- step-functions
- transportation
Ormen Lange flow assurance history

Flow assurance highest project risk prior to concept selection
- Risk of hydrate/ice formation
- Lack of viable hydrate remediation method
- Security of gas supply
Ormen Lange Possible well layouts at Concept Selection (2002)

Distributed subsea well cluster

For:
Mitigate against possible segmentation due to Faults

Against
Challenging Flow Assurance Strategy

One main well cluster
One tieback cluster

For:
Easiest Flow Assurance Strategy

Against
Risk of low reserves due to (fault) segmentation

End 2002 (Subsea vs Dry wells) was a significant point in partner discussions
Flow Assurance Definition

“The ability to produce and transport multiphase fluids from the reservoir(s) to the processing plant”

Key issues:
- Thermohydraulic analysis
- Multiphase flow
- Hydrate management
- Operability
- Design premises
- System integrity
Ormen Lange unique environmental conditions challenging flow assurance

- Production area located in slide area - Rough seabed
- Sub-zero temperatures (-1 °C)
- 120 km full wellstream transfer to the onshore processing facilities – Long offset distance

Together, this makes Ormen Lange one of the most challenging field developments worldwide with respect to flow assurance.
Ormen Lange flow assurance technology
Multiphase flow risk mitigation

Flexible system design!

Onshore facilities
- Slugcatchers (2x1500 m³)
- Gas backflow and circulation
- Pipeline monitoring and liquid holdup management system
- MEG injection control and monitoring system

2x6” MEG injection lines
- Redundancy
- Remote control

2x30” multiphase production pipelines
- Improved turndown and swing flexibility
  - Enable production through only one line at low turndowns
  - Enable “dynamic pigging” for liquid holdup management
  - Enable gas circulation to improve liquid holdup management
- Reduced slug volumes during transient operations, i.e. reduced slugcatcher size
- Increased production availability in case hydrates blockage or failure in one line.

Subsea MEG distribution system
- MEG dosage unit
- Wet gas metering
- Formation water detection
- Remote control

Subsea chokes
- Balance/control well production
- Control slugcatcher pressure
- Remote control

Manifolds with dual headers
- Wells may be routed to either of the two manifolds
- Remote control

Pigging loop
Integrated reservoir and pipeline model

• Simulation “from reservoir to processing plant” including
  – Reservoir
  – Coupling to the wellbore
  – Wells and surface pipeline network
  – Processing facilities
  – MEG injection system
in one single simulation model

• Establish and verify production profiles taking into account total production system limitations

• Define operating conditions (Q, P, T, dP) in all parts of the total production system during the entire lifetime of the field

• Define compression requirements
Seismic Interpretation Challenges identified in 2000-2003

- Seismic Interpretation shows more than 1000 faults found as polygonal faults with < 10 m to > 60 m throw
- More faults makes gas move more tortuous;
- Reprocessing (2003)
  - Improved depth data
  - Improved fault imaging main production area for well planning

Faults better defined on reprocessed data but generally small changes
Seismic 1996-2000 (Project Sanction)

- **3D Seismic**
  - Field outline proved
  - Gas Water Contact
    Mappable over extent of field
  - Gas seen on AVO seismic analysis
- **GIIP estimated to 500 GSm3** (still base case)
- **Challenges in Depth conversion (south) -> PSDM reprocessing**
- Faults seen as main issue

Only minor changes to the seismic interpretation since 2001 EGGA
2002: Concept Selection: Water Handling Strategy decided:

- Gas Water Contact on Ormen at 2917 mMSL
- Contact steps more than 100 m northwards due to stratigraphical trapping /Faults
- Perched water (“lakes”)
- Main strategy
  - **Stay away** from main aquifer in the south
  - **Monitor** formation water break trough in producers (multiphase measurements)
  - If considerable formation water breaks trough **reduce well rate** to formation water free production or **shut in** well

Even 2 m oil!!

End 2002: Water was high on risk decision to be closed out
Drainage

Reservoir geometry requires multiple drainage locations, but not necessary multiple platforms.
2003: Project Sanction: Ormen Well and Template Schedule Strategy

"OPEN FAULTS"

"CLOSED FAULTS"

AT PRODUCTION START
2003: Project Sanction:
Ormen Well and Template Schedule
Strategy

HIGH PRESSURE - NO NEED FOR COMPRESSION YET

LOW PRESSURE - NEED FOR COMPRESSION NOW...

"OPEN FAULTS"

"CLOSED FAULTS"

AFTER PRODUCTION START-BEFORE TEMPLATE 3
SOME YEARS AFTER PRODUCTION:
OPTION WITH 3 templates

HIGH PRESSURE - NO NEED FOR COMPRESSION YET

"OPEN FAULTS"

"CLOSED FAULTS"

Put Templates D and C on Production and delay compression

AFTER PRODUCTION START-PLACE TEMPLATE 3 IF AND WHERE REQUIRED
SOME YEARS AFTER PRODUCTION:
OPTION WITH 4 templates

HIGH PRESSURE - NO NEED FOR COMPRESSION YET

"OPEN FAULTS"

"CLOSED FAULTS"

Put Templates D and C on Production and delay compression

AFTER PRODUCTION START-PLACE TEMPLATE 4 IF AND WHERE REQUIRED
Ormen Lange - Main Drilling Program-
Pre-Drilling Strategy

- Spreading of the wells North-South (East-West secondly).
  - Cover large structural segments
  - Wells from template B stretch to the North and wells from template A drill dominantly towards the South and West.
  - Place wells in areas with large segments.
  - Mitigate against the scenario where all faults are sealing.
- Thick Egga Isopach.
  - More Egga reservoir, increased well production potential.
- Proximity to faults.
  - The minimum distance any well should be from a fault is 200 m.

Figure 12: Updated Top Vale map based on the final PSDM velocity model
**Ormen: Status Pre-Drilling Jan 2008**

- Only 3 Wells actually pre-drilled (4-6 planned)
- Remaining wells to be drilled from 2008 and onwards as required
- 3rd template approved by partners in 2006

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<tr>
<th>Target Name</th>
<th>Well Name</th>
<th>Planned Step-out</th>
<th>Original Sequence</th>
<th>Original Step-out</th>
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<td>6305/8-A-7H</td>
<td>350 m</td>
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<td>396 m</td>
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<td>P4-2</td>
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<td>1,075 m</td>
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<td>2,600 m</td>
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<td>2,215 m</td>
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Test Background

During the well tests of A7 and A3 there is an opportunity to investigate potential pressure interference with A2A. The interference test could provide valuable information about the sealing of faults in the Ormen Lange field.

WT and SS control system layout

1. A7 DHGP data available through WOCS system at rig during WT
2. A2 DHGP data available through fiber cable (when commissioned)

Allows for interference testing of A7-A2. Also applicable during A3 WT!
Template A area; reactivated faults

Assumptions for Interference Test

- **Base case parameters (A template area)**
  
  - Pres = 287.59 Bar
  - T = 89.4 deg C
  - k = 523.5 mD
  - phi = 0.283
  - Net Pay = 50m
  - Cg = 2.61e-8 Pa-1
  - Mu = 0.024cp

- **Distance Between wells**
  
  - A7-A2A  2,218m
  - A7-A3  2,435m
  - A2A-A3  1,180m
# Ormen Lange Exploration, appraisal and development plan

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Opening of Ormen Lange Saturday October 6, 2007