



Weatherford[®]



Field Development Planning of Subsea Tie-Backs

Petronas-CCOP-PETRAD-INTSOK

Workshop on Deepwater Subsea Tieback

January 25-26, 2007. Kuching, Malaysia

Johan Tronvoll

Weatherford Petroleum Consultants



Weatherford International

- Head office in Geneva, Switzerland
- USD 10 bn revenue
- 10 Product/business lines
- 57 000 employees
- 809 locations in 108 countries
- 128 Manufacturing facilities
- 16 R&D & training centres



Weatherford Business Segments



Drilling

Weatherford has created a portfolio of drilling services and products that make well construction safer, reduce nonproductive time and enhance reservoir deliverability. Includes Drilling Rigs.



Evaluation

Our extensive portfolio of conveyance systems, coupled with industry qualified measurements, are being applied to open-hole and cased-hole wireline, slickline, LWD, well testing and geoscience services.



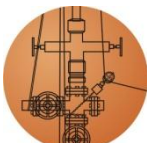
Completion

Weatherford provides everything from a comprehensive line of products for conventional completion in benign reservoir applications to engineered and integrated completion systems for complex and challenging environments.



Production

Weatherford helps maximize reservoir recovery and optimize field production through artificial lift, well optimization services and products, and intelligent completion systems that remotely monitor and control well, facility or field production.



Intervention

Our intervention services help remediate wells that have mechanical or formation problems. We help prolong the life of the well by providing systems to extend production or access and to retrieve remaining or “stranded” oil and natural gas reserves.



Weatherford Norway

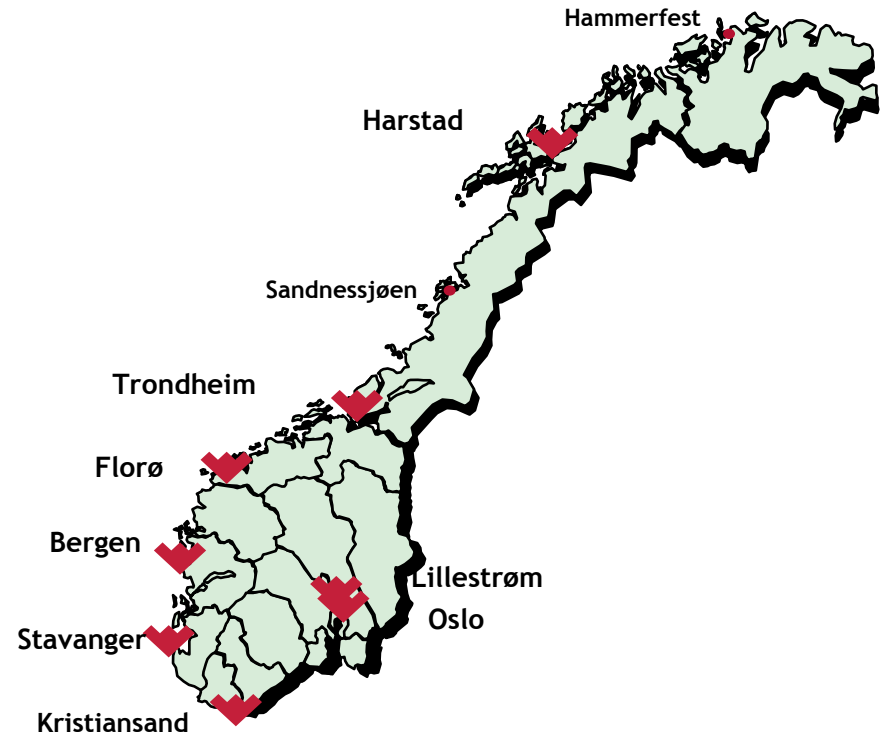
Weatherford Petroleum Consultants

- Established in 2005 (ResLab Integration)
- 100 people, 400 by 2013.
- Trondheim, Bergen, Stavanger, Oslo, Harstad, Mumbai, Mexico, Oman
- More than 60 contracts for Statoil in 2006-10



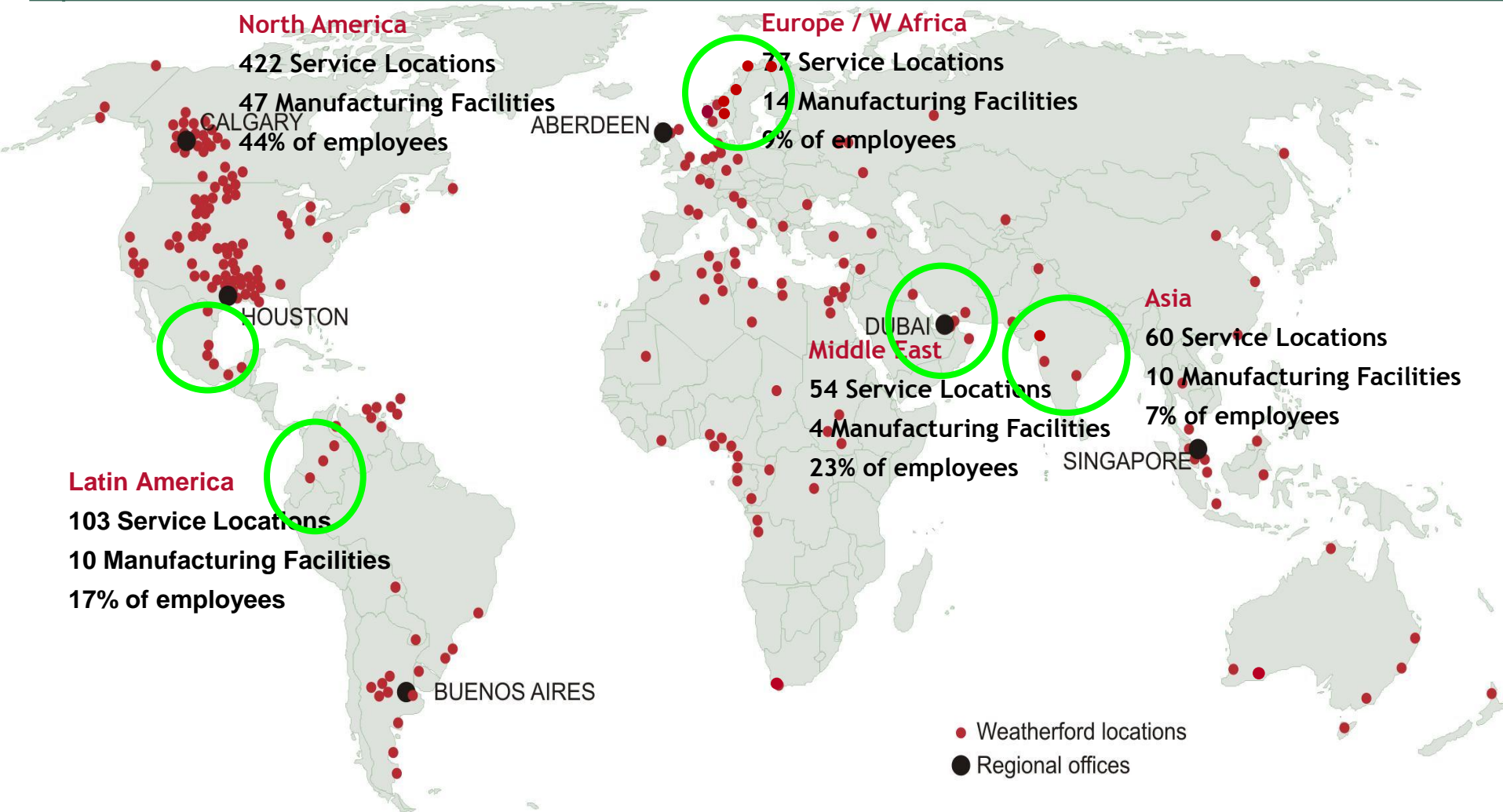
Weatherford Norway

- 200 mill USD revenue
- 620 employees
- 10 locations





Being Part of the Industry's Largest Global Footprint





Structure

- Background
- Exploration
- Field development
- Production optimisation

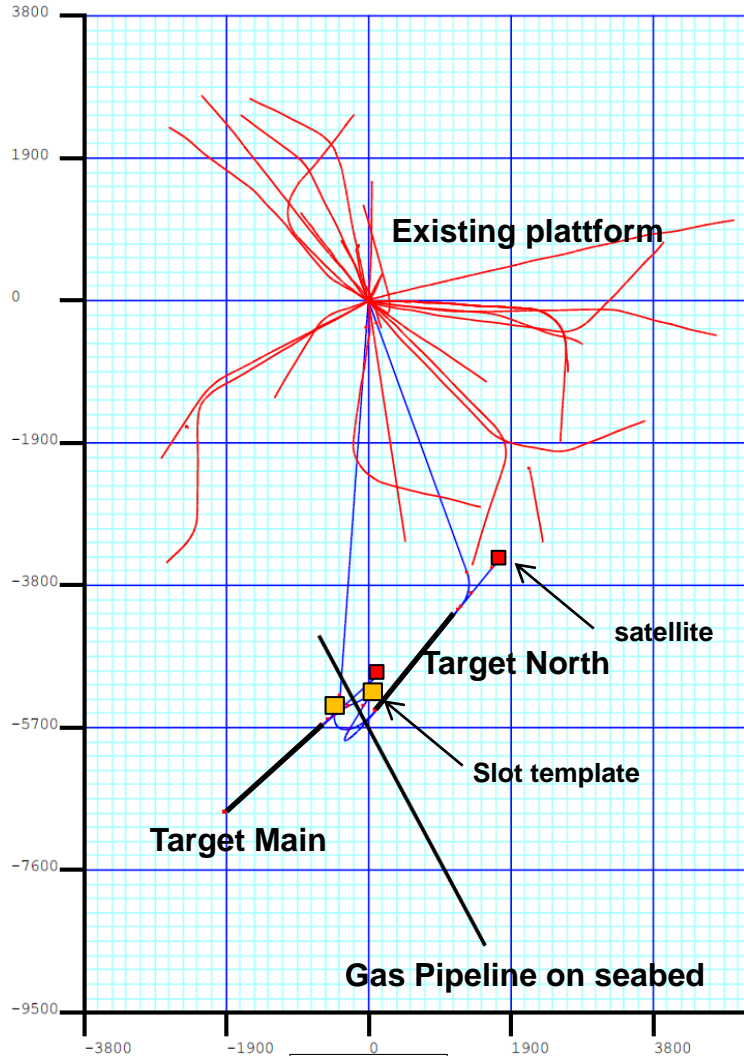


Background

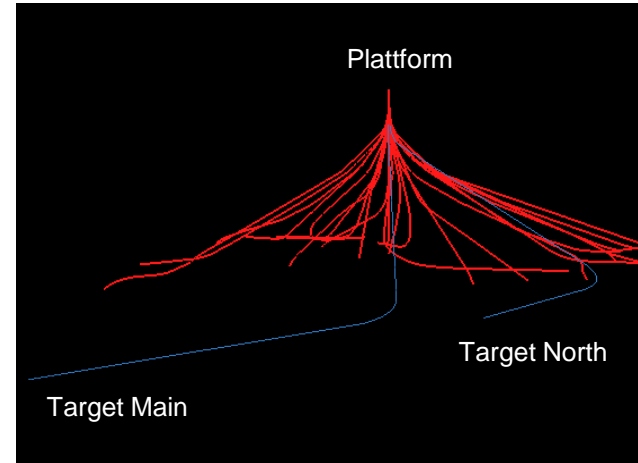
- High demand calls for new developments
- Few major new finds
- Improved exploration & technology has provided additional reserves
- Increasing number of marginal targets
- New enabling technologies makes marginal satellite field developments feasible with tie-back to existing infrastructure



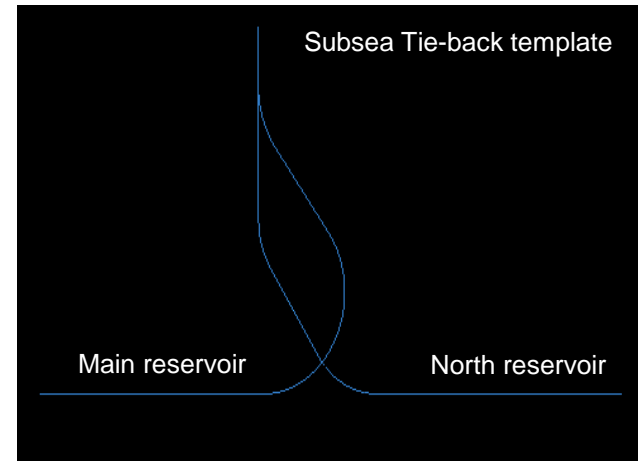
Field Development Options – North Sea case



Platform: 2 ERD wells



Subsea: Slot template or satellite(-s)





E&P Value Chain

Exploration

**Field
development**

**Production
Optimization**

- Seismic interpretation**

- Regional exploration**

- Additional reserves near existing fields**

- Fast track early phase screening studies**

- Plan for new field Development and Operation**

- Brown-field re-development**

- Production optimization, short and longtime**

- Field tie-in planning**

- Production allocation**

- Flow assurance**



E&P Value Chain

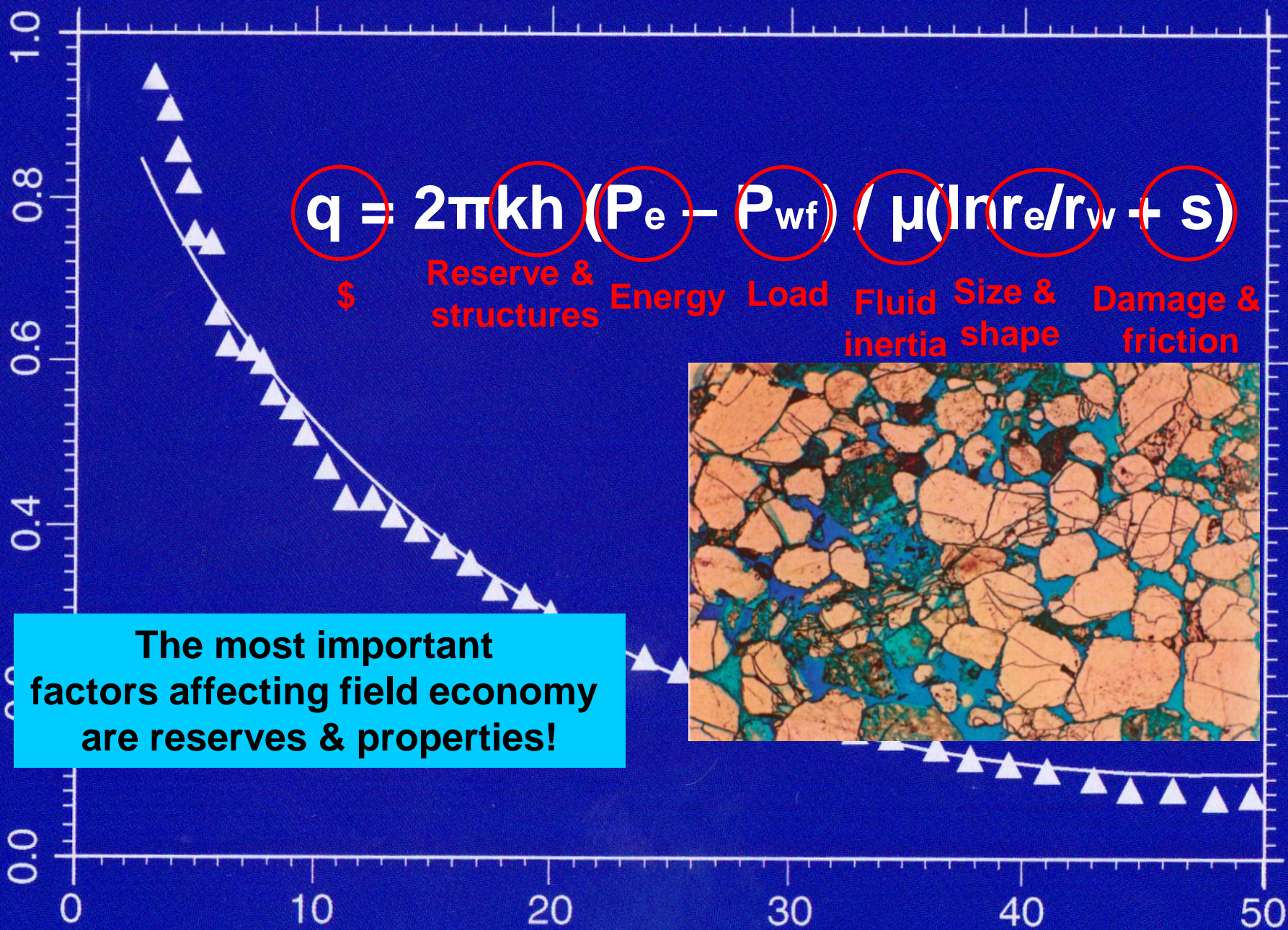


- Seismic interpretation
- Regional exploration
- Additional reserves near existing fields

- Fast track early phase screening studies
- Plan for new field Development and Operation
- Brown-field re-development

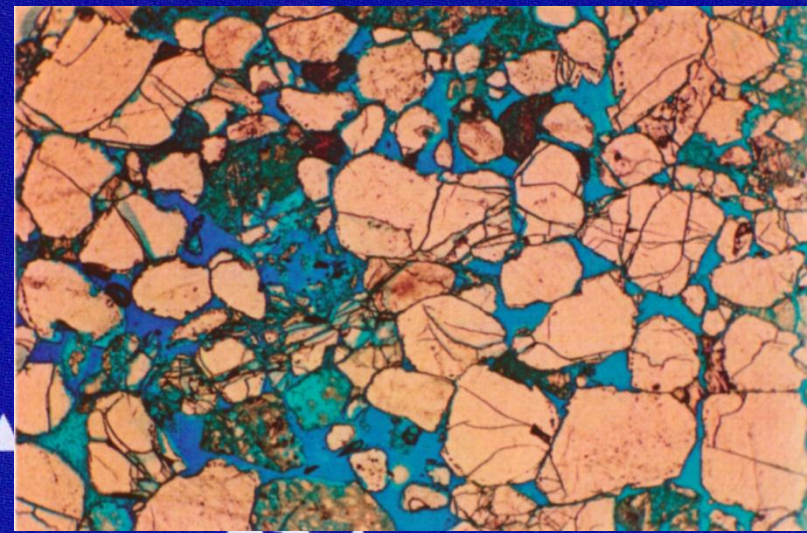
- Production optimization, short and longtime
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- Flow assurance

PRODUCTION



$$q = 2\pi kh (P_e - P_{wf}) / \mu (\ln r_e / r_w + s)$$

\$ Reserve & structures Energy Load Fluid Size & inertia Damage & friction

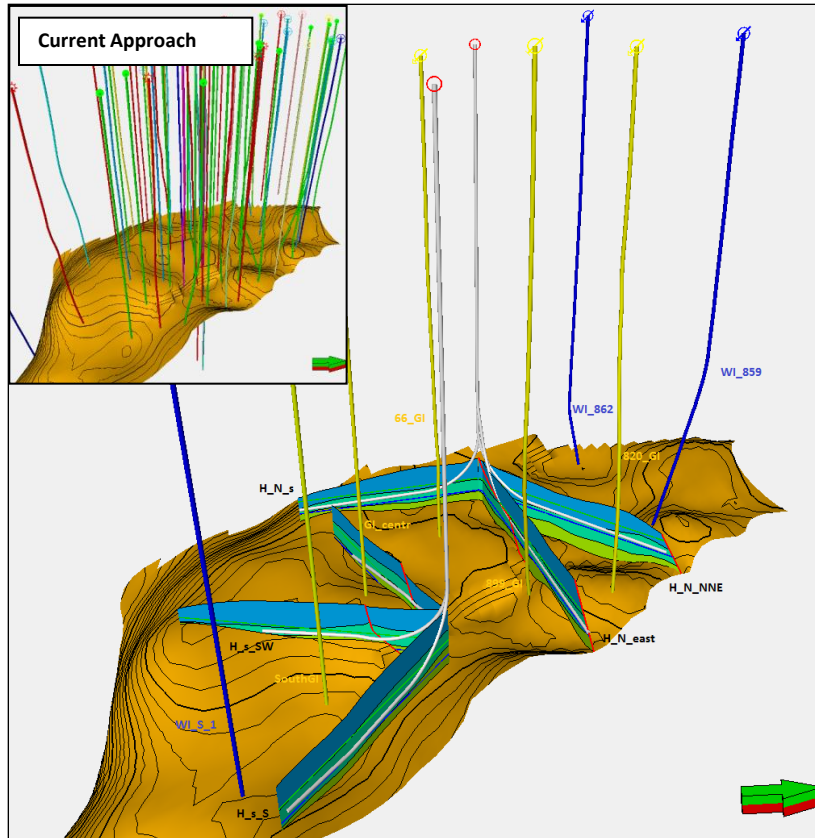


The most important factors affecting field economy are reserves & properties!

TIME

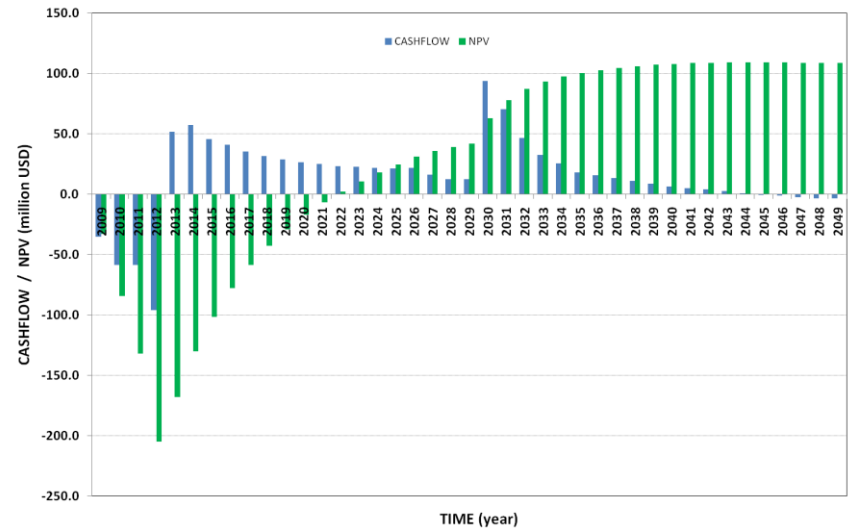
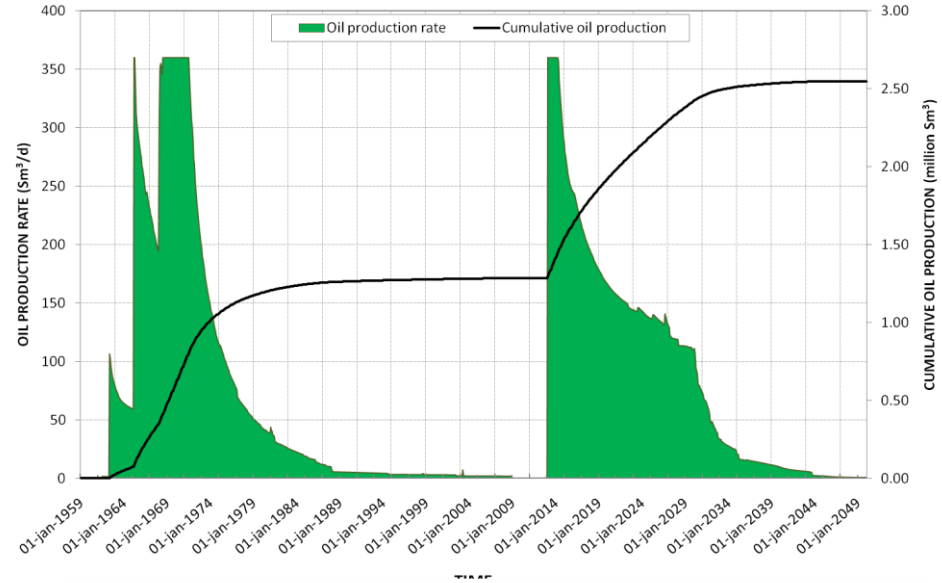


Example field redevelopment prognosis



Proposed Gas Injection Approach

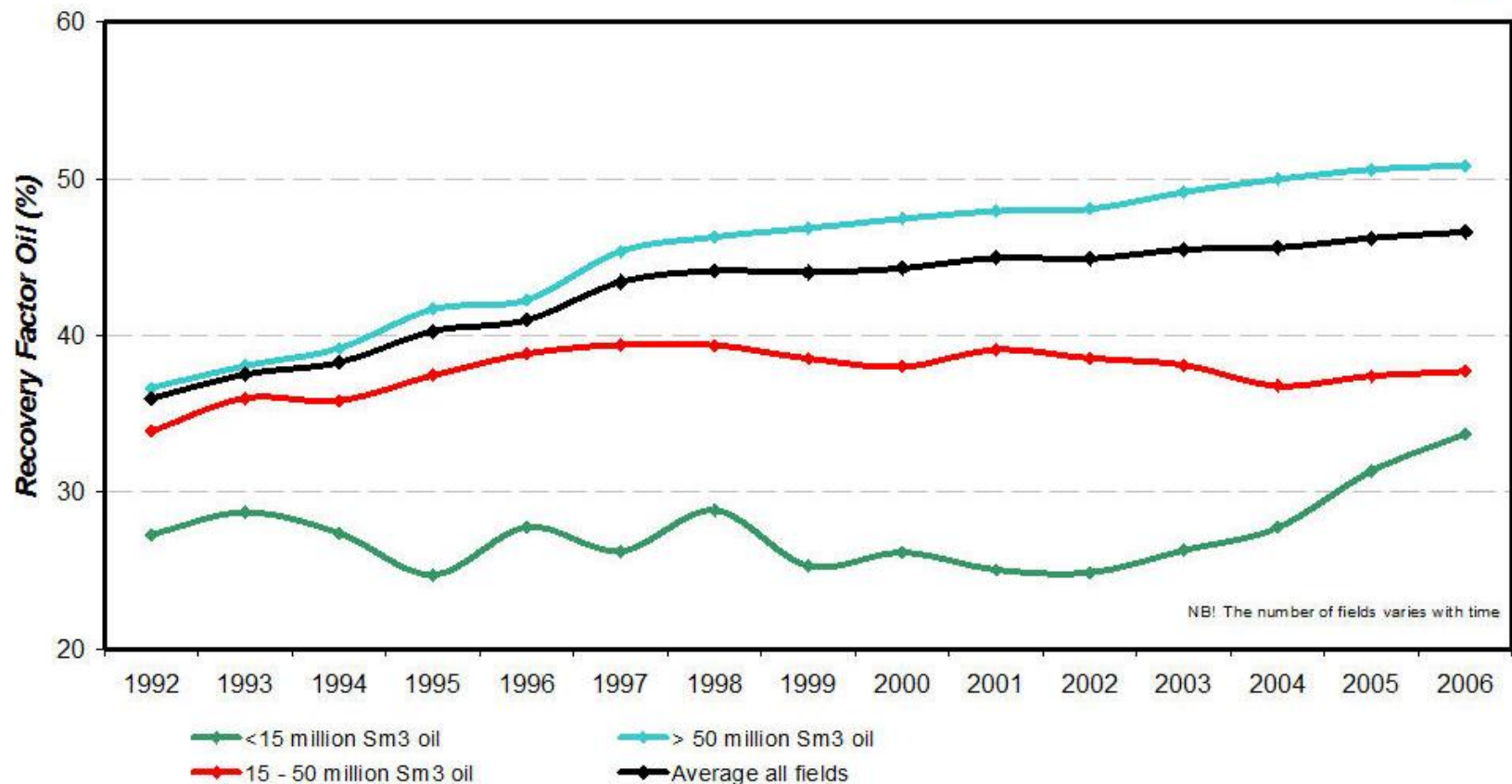
- 6 new horizontal producers (or 2 multilaterals)
- 5 gas injectors (2 new and 3 old wells converted)
- 3 wells for produced water re-injection (optional)





Recent production history offshore Norway

Development in Recovery Factor





E&P Value Chain



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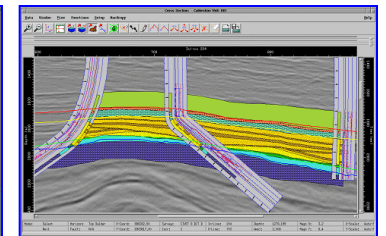
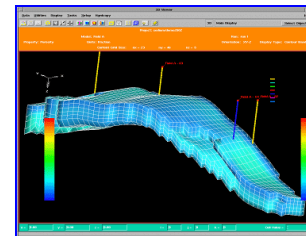
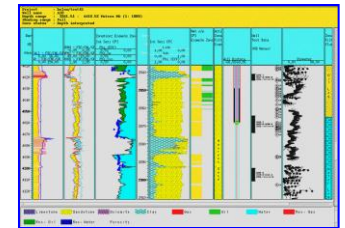
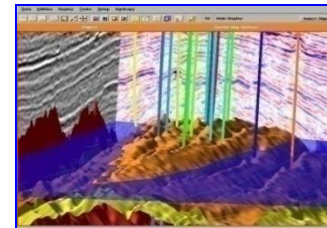


Sub-surface disciplines

PROJECT DEVELOPMENT						
Project planning and definition			Project execution			
Concept development			Engineering		Construction	
Feasibility studies	Screening studies	Concept studies	FEED (pre-engineering)	Detail Engineering	Construction	Completion

Relevant disciplines

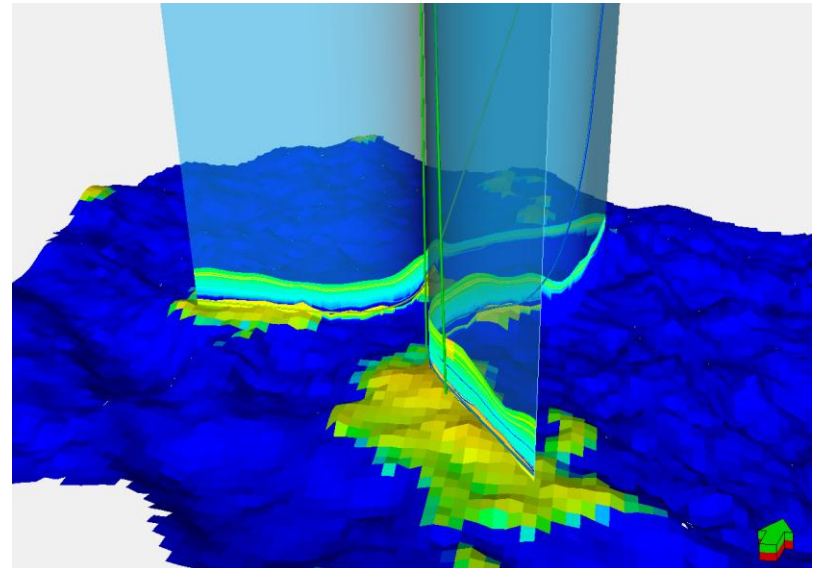
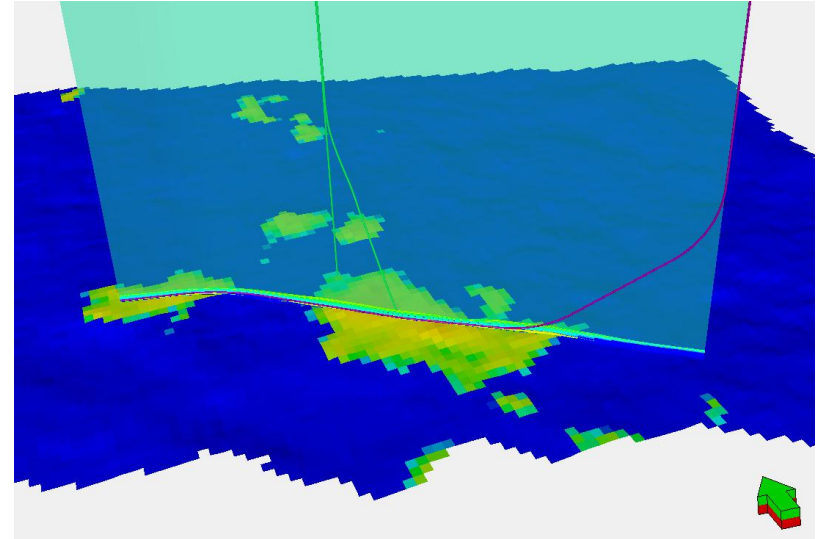
- Seismic interpretation
- Petrophysical modeling
- Geomodeling (static model)
- Geomechanics & rock physics
- Reservoir modeling (dynamic model)
- History matching (Brown Field)
- Reservoir simulation (IOR, production profiles)
- Production engineering (well, template, pipeline)
- Network modeling, including real-time link
- Well planning
- Well completion optimization (ie. ICD modeling)
- Financial and risk analysis
- Field Development Plan





Field Development Feasibility Studies

- Defining potential field development scenarios
- Evaluate economical potential
 - Reserve estimates
 - Production vs time
 - Recovery factor
- Risk analysis of drilling, completing & tie back the proposed reservoir sections from alternative drill centers
 - Probability, budget cost and time estimate
- Evaluate and rank scenarios
 - Economic potential
 - Risk & CAPEX/OPEX



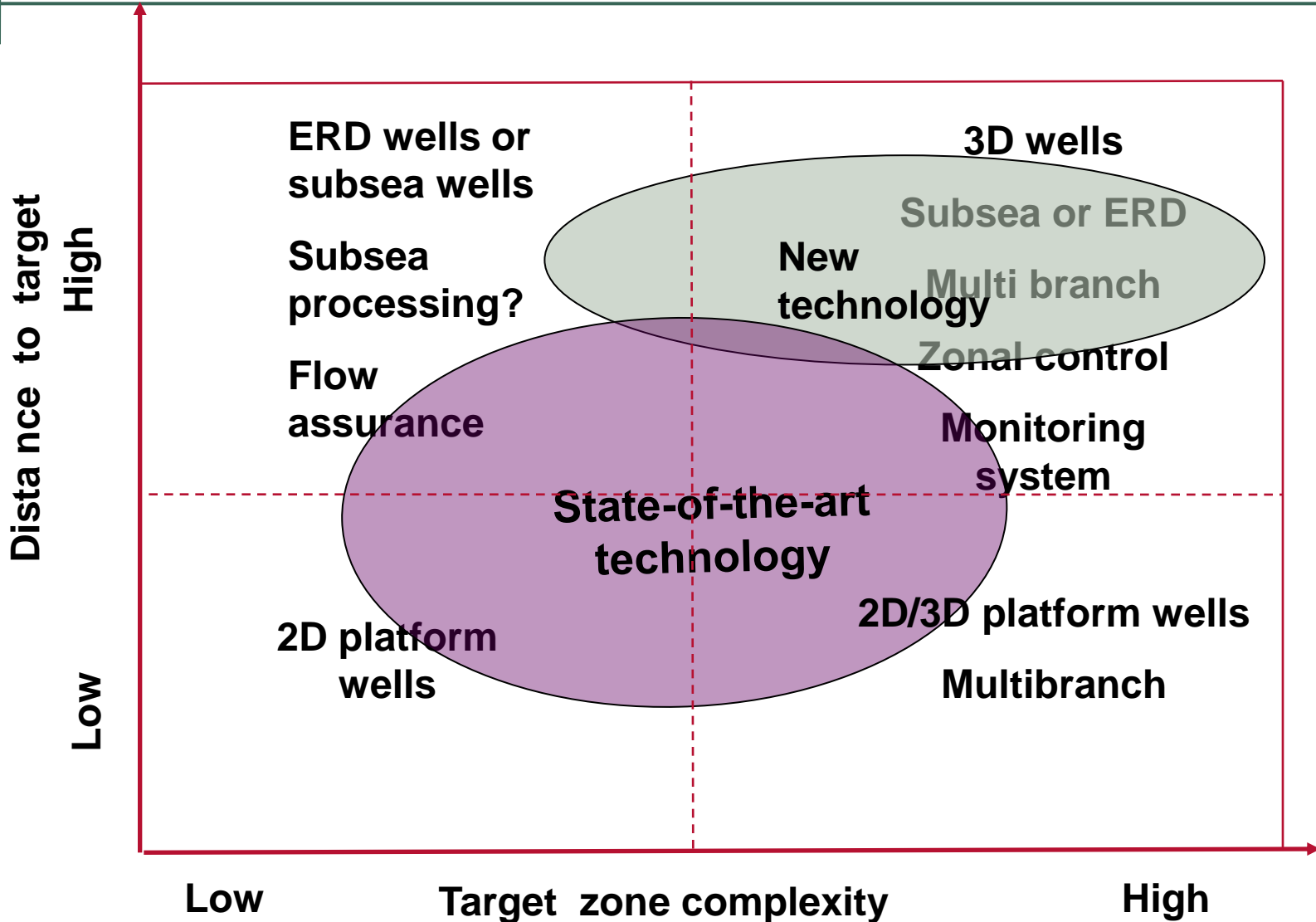


Example Tie-Back Field Development Study Objectives

- Update of regional and local geomodels
 - Re-interpret data: Seismic, offset well data
 - Apply state-of-the-art software
 - Identify possible additional reserves
- Update reservoir dynamic models
- Re-consider local infrastructure & tie back options
- Risk, budget cost and time estimate of drilling and completing production /injection wells in proposed reservoir sections
 - From a remote platform or drill center (xx km ERD wells)
 - As a subsea development from specific locations
- Production profile and recovery for different development scenarios
- Optimize injector/producer geometry & placement
- Evaluate and rank scenarios with respect to
 - CAPEX/OPEX & risk
 - Technical complexity & risk



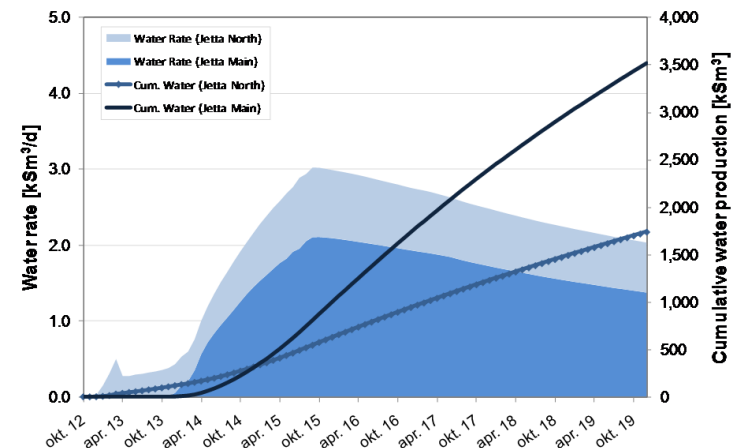
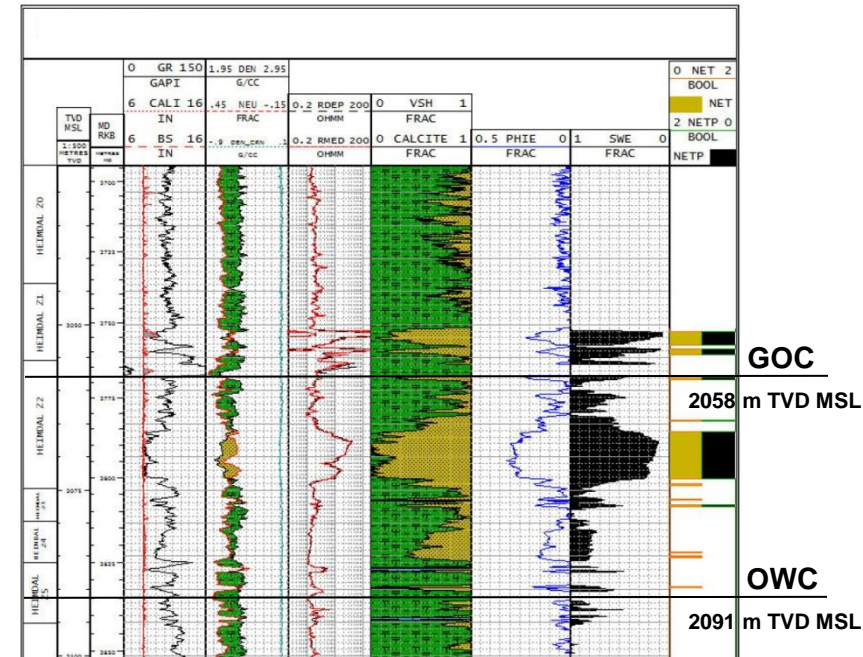
Scenario identification





Reservoir Properties & Target Concerns

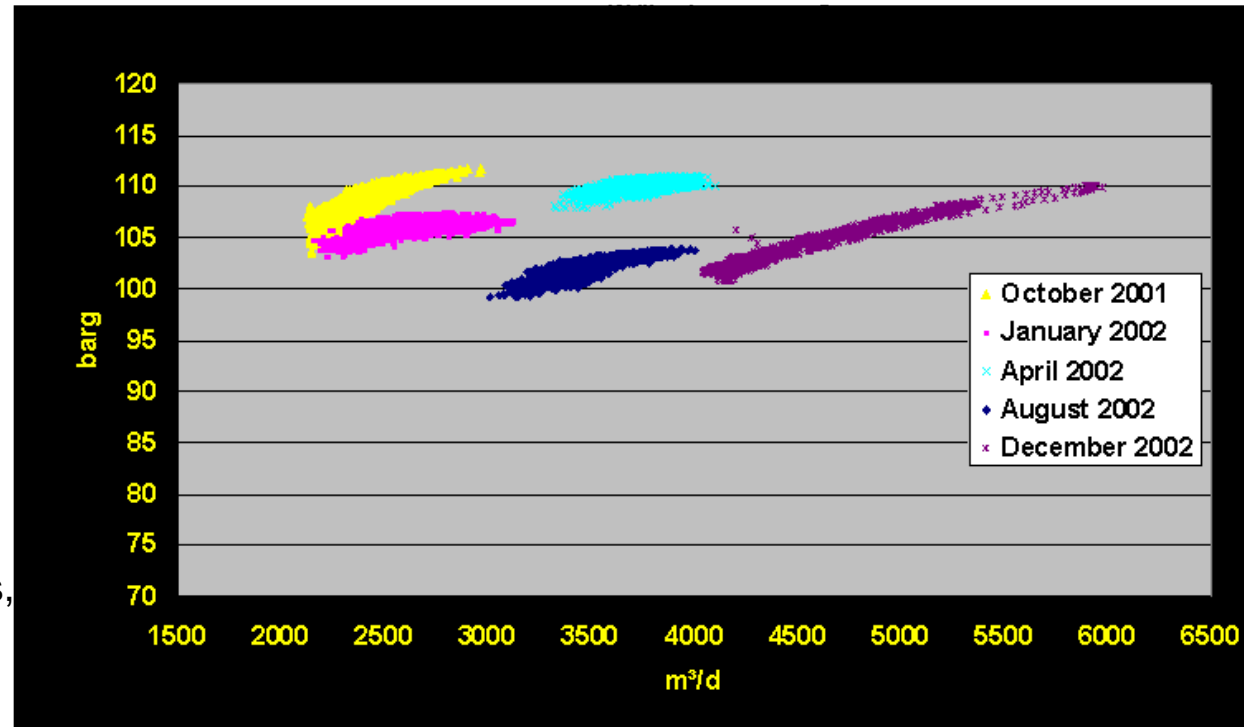
- Challenging to land ERD sub-horizontal well (high position uncertainty) and geosteering well within best pay intervals throughout whole length of reservoir section
 - Relatively thin reservoir intervals (often <30 meters) and main oil bearing sands often 5-10 meter thickness or less
 - Well position uncertainty affect reserve risk evaluation
- Need to maintain distance to OWC due to massive water bearing sands in lower units of the reservoir –often with excellent properties / strong aquifer
- Possible depleted reservoir zone in vicinity of well heel section
- Losses, formation damage and well clean-up
- Sand control & sand management issues





Reservoir & production management issues

- Drainage heterogeneity due to limited no. of wells
- Depletion rate
- Productivity decline
- Injectivity decline
- Fluid fronts
- Zonal control
- Downhole & subsea monitoring
- Stimulation & flow assurance: Scale, wax, asphaltenes, fines, sand, hydrates
- EOR
- Management of water, sand, CO₂





Well & Completion

- Technical feasibility of different drilling & well concepts (i.e. drill center location(s), well types)
 - Tentative csg. programs
 - Friction analysis
 - Hydraulics & hole cleaning
 - Wellbore stability & pore pressure
 - Directional survey uncertainty
 - Time & cost estimates including risk assessment
- Evaluation of completion solutions
 - Zonal coverage & control
 - Sand control/sand management including sand production risk & assessment of specific problems experienced related to well stability/sanding during production (e.g. screen collapse or other malfunction)
 - Economic risk-based evaluation including CAPEX/OPEX as well as economic potential for different scenarios



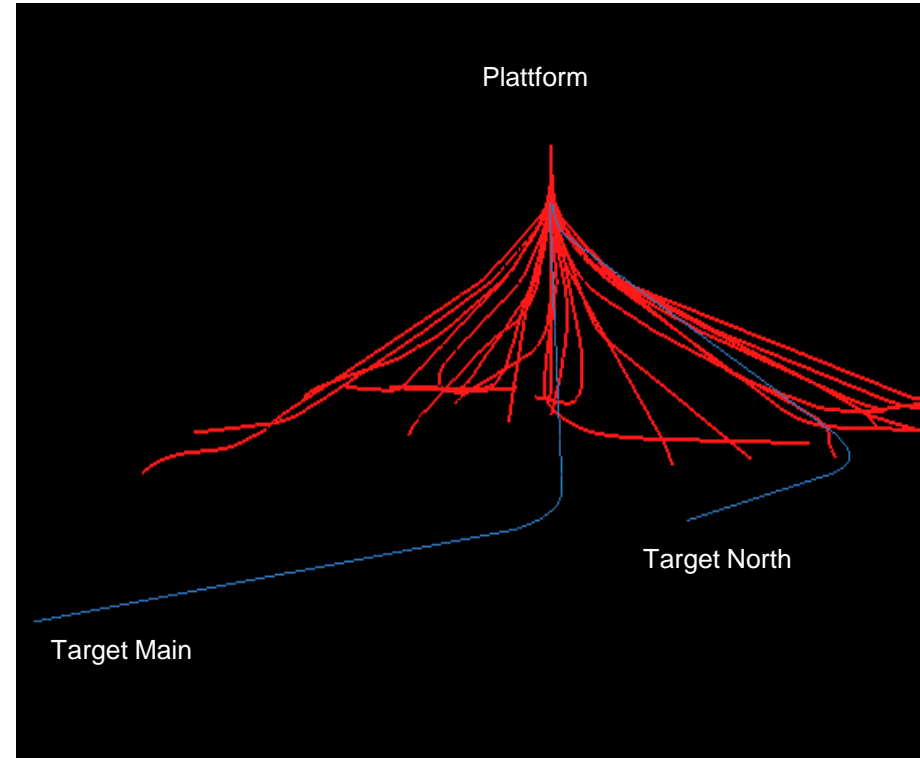
Pros & Cons ERD Wells from existing platform

- Pros:

- Lower rig rate
- Operations less weather sensitive
- Dry tree, topside tie-in & gas lift
- Favorable wrt flow assurance (scale, wax & hydrate mitigation)
- Production allocation / well testing
- Availability for well intervention

- Cons:

- "Cold" demobilized drilling rig
- Major rig mobilization/demob efforts & costs
- ERD wells often required
- Challenging drilling & completion operations
- Wellbore stability, losses in sands & hole cleaning issues
- Tight torque, drag & ECD margins
- High risk of technical & geological sidetracks
- Shut-in of existing producers / deferred production due to anti-collision measures
- Single well case less feasible & limited no. of wells due to limited available slots.





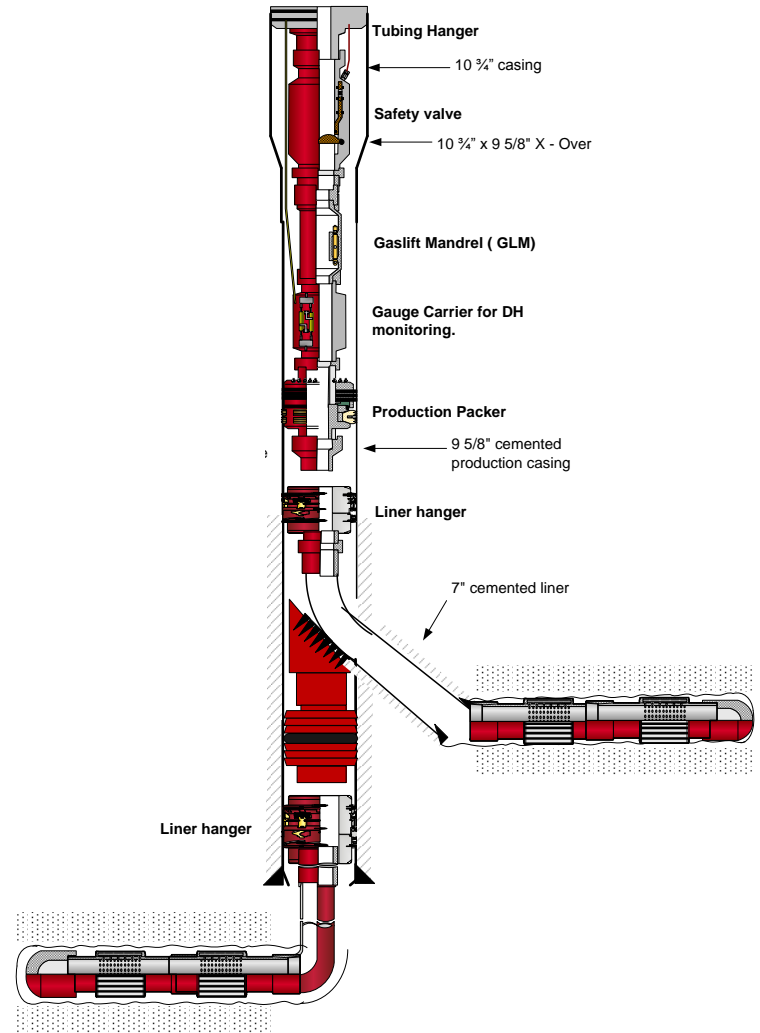
Pros & Cons Subsea Wells

- Pros:

- "Hot" semi-submersible rig
- Low rig mobilization cost
- Shorter & less complex well paths
- Improved stratigraphic control w/close proximity to exploration wells
- Less risk of technical & geological sidetrack
- Drilling close to target reservoir reducing the risk of drilling depleted reservoir zones
- Flexibility regarding number of wells

- Cons:

- Higher rig rate than platform drilling
- Weather sensitive drilling & subsea operations
- Subsea facilities cost & lead time
- Complex tie-in (umbilical, control system, lift gas, chemicals etc.)
- Access to installation & intervention tool pool
- Flow assurance (scale, wax and hydrate mitigation)
- Production allocation / well testing
- Costly well intervention
- Clean-up to semi-submersible rig





E&P Value Chain



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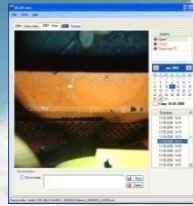
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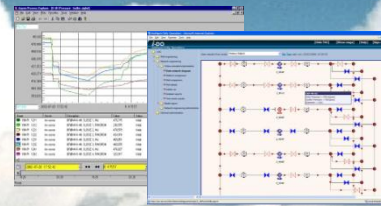
Production Optimization

Integrated Operation

- Data handoff
- Remote assistance
- Reporting
- System monitoring



iScan video /
Leakage detection SW



Trend

i-Do

Optimization

- Field Office
- iDo (Daily Operation)
 - Reo
 - WellFlo

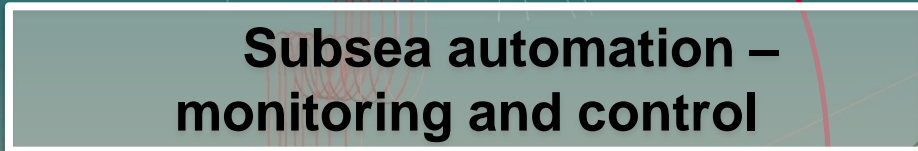
Decision tools

Other Production Optimization sensors:

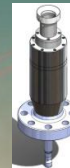
- Flow assurance
- Sand detection
- MPFM
- Downhole vendors interfaces



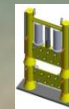
- Copper
- Fiber



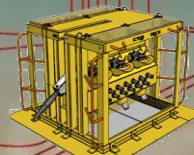
SCM



Subsea Redeye
Water cut meter



OC
H



OCH



iScan leakage
detection
– video surveillance



Key enabling technologies

- Horizontal & multilateral drilling
- Robust & customised completion
- Zonal control for optimum drainage
- Artificial lift solutions
- Pressure management & flooding
- Stimulation technologies
- Subsea processing
- Subsea & downhole monitoring & communication
- Flow assurance technologies
- Subsea well intervention possibilities



Summary

- Technical-economical feasibility studies consider different scenarios for developing tie-back candidates
- Technical issues related to geology, drilling, completion, production, reservoir management, downhole/subsea monitoring & communication as well as subsea processing & flow assurance are key elements to identify optimum solution
- New enabling technologies push the limits for feasible developments
- Marginal fields contribute increasingly to overall area output