

NOROG – EMF Seismic

Production Seismic Value Case: Ekofisk LOFS

Production Seismic Challenges

BASIS:

Major investments have been premised on acquisition of repeat seismic over producing and future fields (e.g. Ekofisk, Snorre, Grane etc..)

DRIVER:

Predictable framework conditions, ensuring regular repeat acquisitions, are needed to protect the value of these, and future, investments

RECOMMENDATION:

Introduce a Acknowledgement of Compliance (AoC) type system

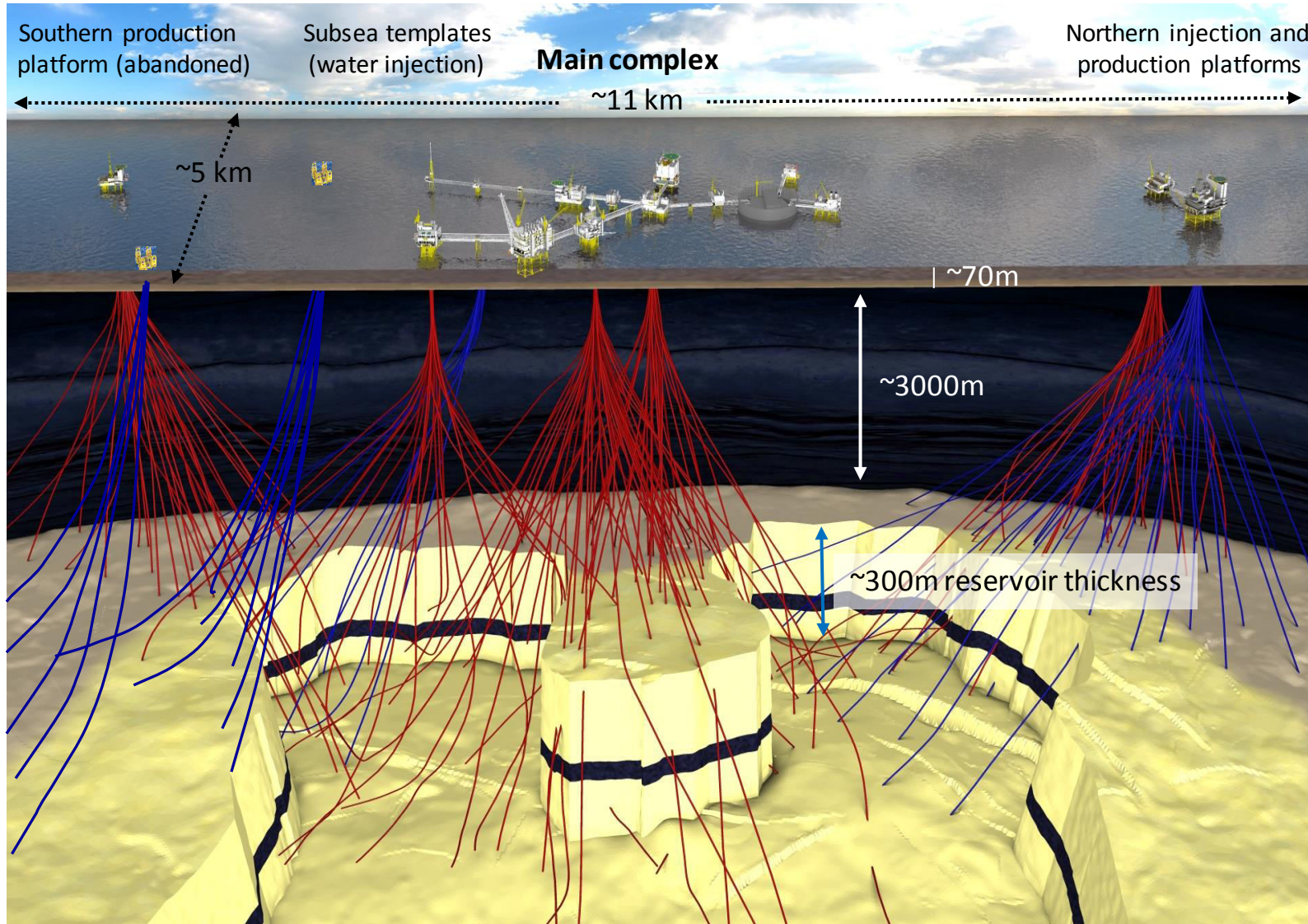
Describes a common understanding of seismic acquisition needs and plans for the lifetime of the field

Establishing a Production Seismic AoC process

Ensuring long term predictability is a prioritized recommendation from the industry

This would not replace or affect the current notification system, companies will still give notification 3 weeks prior to all survey start-ups

Ekofisk: Field



FACTS

FIELD:

| | |
|-------------------------|-------------|
| Production start | 1971 |
| Produced to date (BBOE) | 4.1 |
| Remaining (MMBOE) | 585* |

WELLS:

| | |
|-----------------|------------|
| Total (No.) | 518 |
| Active (No.) | 186 |
| Abandoned (No.) | 332 |

FACILITIES:

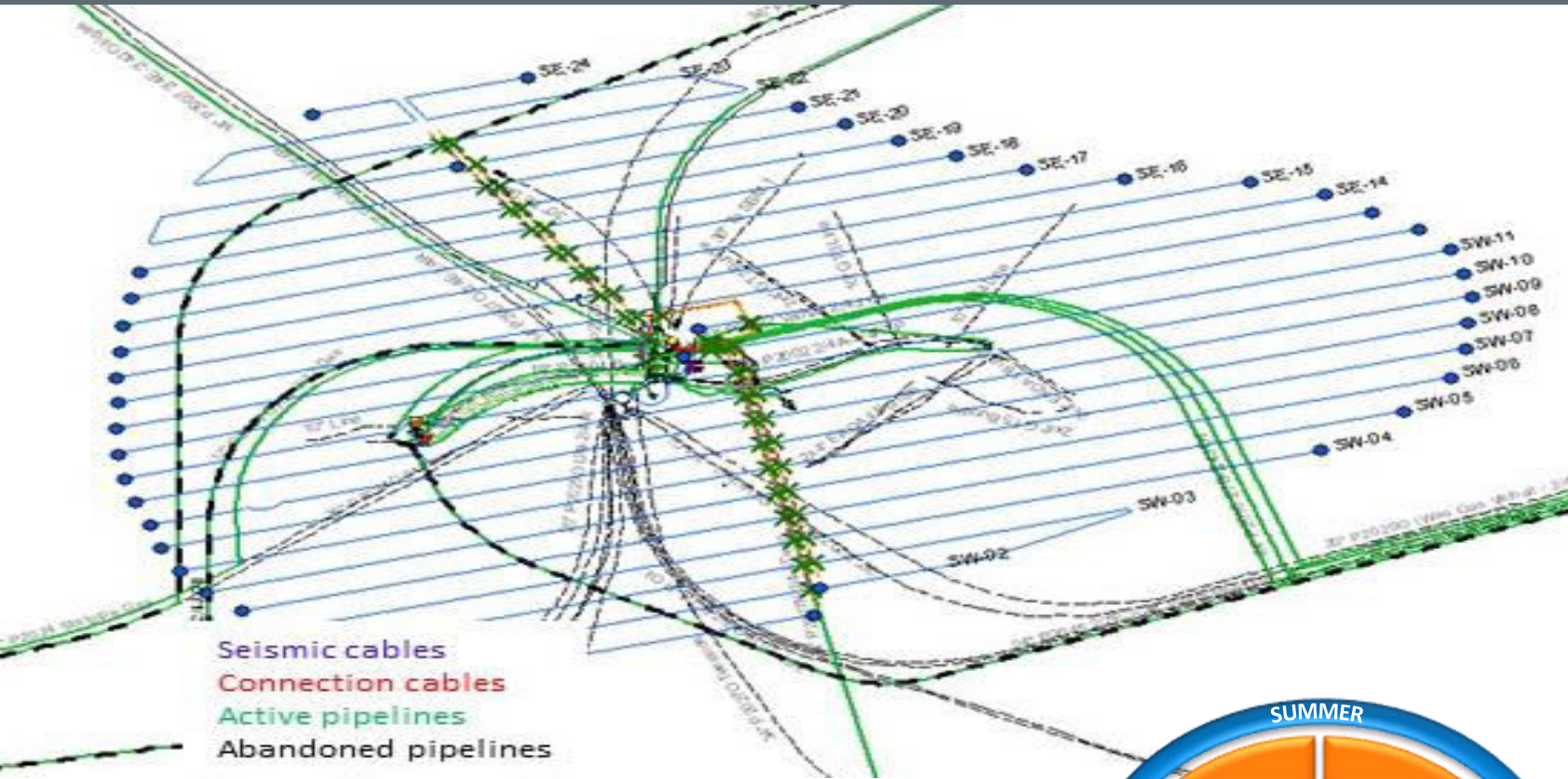
| | |
|--------------------------------------|--------------|
| Active platforms (B, C, K, M, X & Z) | 6 |
| Subsea templates | 2 |
| POB – offshore (Ekofisk-area) | 1000+ |

CREATED VALUE (by end of 2016):

2251 BNOK total, of which
1106 BNOK in taxes and fees

* NPD fact pages

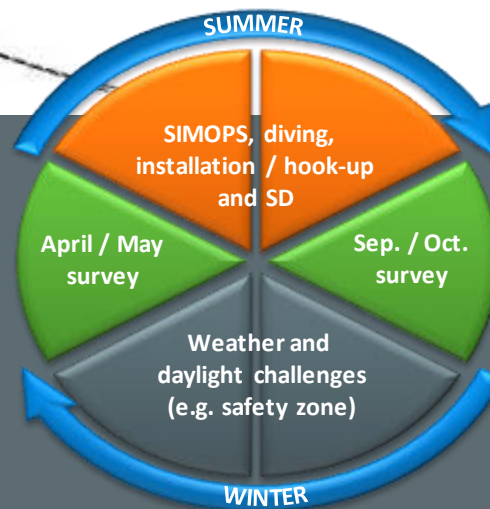
Ekofisk: LoFS



Optimal schedule for field and reservoir management

Acquisition twice a year → spring and fall

- Weather patterns
- Summer field maintenance and project work



FACTS

INVESTMENT:

| | |
|--------------------------|---------------------|
| Installed | Mid 2010 |
| Cost | 932 MMNOK* |
| Acquisition & processing | 419 MMNOK** |
| Future surveys Approx. | 704 MMNOK*** |

FACTS:

- Permanent optical sensor-grid installed on sea bed
- 200 km seismic array cables
- 3966 4C receiver locations
- 300 meter cable separation
- 50 meter sensor interval
- 40 km additional cables
- 98.8 % of sensor stations continue working in 2017
- 13 Ekofisk LoFS surveys acquired

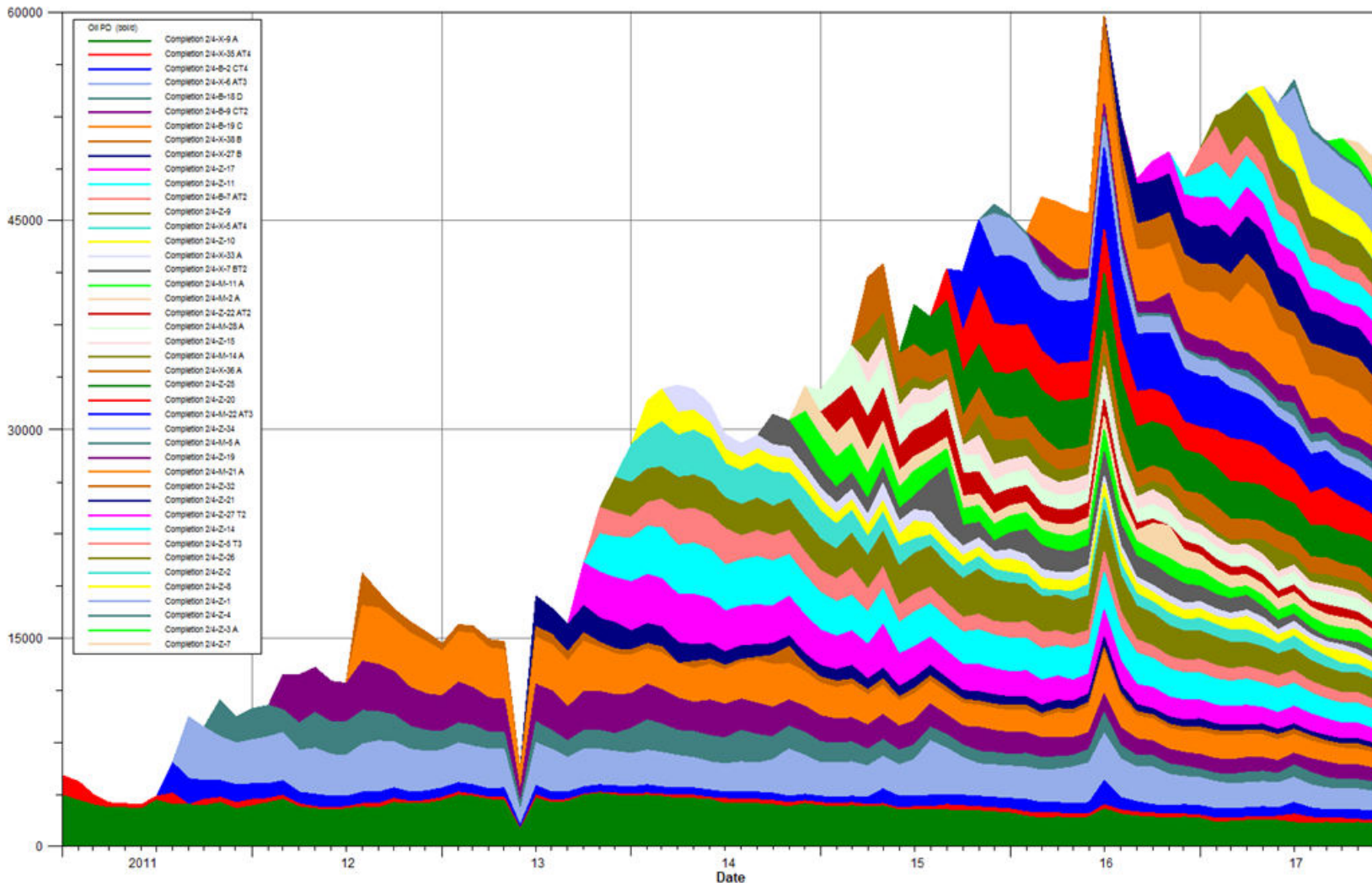
* Includes procurement and installation of the LoFS system, including first (LoFS1) shoot

** LoFS2-LoFS13

*** Based on 15 year lifetime (2 per annum through 2025) of the LoFS system

Ekofisk: Aggregated producers

Producers Drilled Since Jan/2011 - Oil Production



Production maintained at a high level through continuous WI and drilling of new production and injection wells

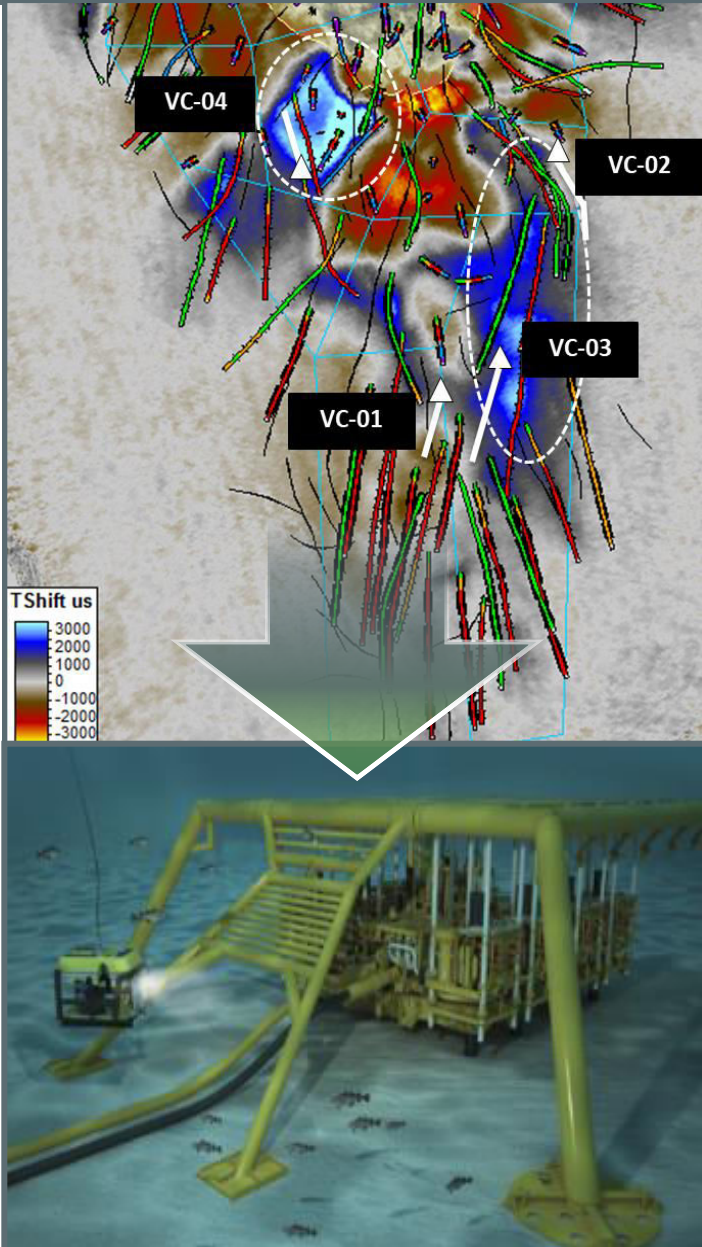
- *Currently producing 120.000BOED*
- *Currently injecting 390.000BWPD*

LOFS provides the cornerstone reference data set that enables this active reservoir and field management

Currently producing 50.000BOED from wells drilled since LOFS installation

43 producers, 18 water injectors and 2 slurry injectors drilled since LOFS installation

LoFS value case example: VC Water Injection Project



LOFS indicating lower pressure blocks

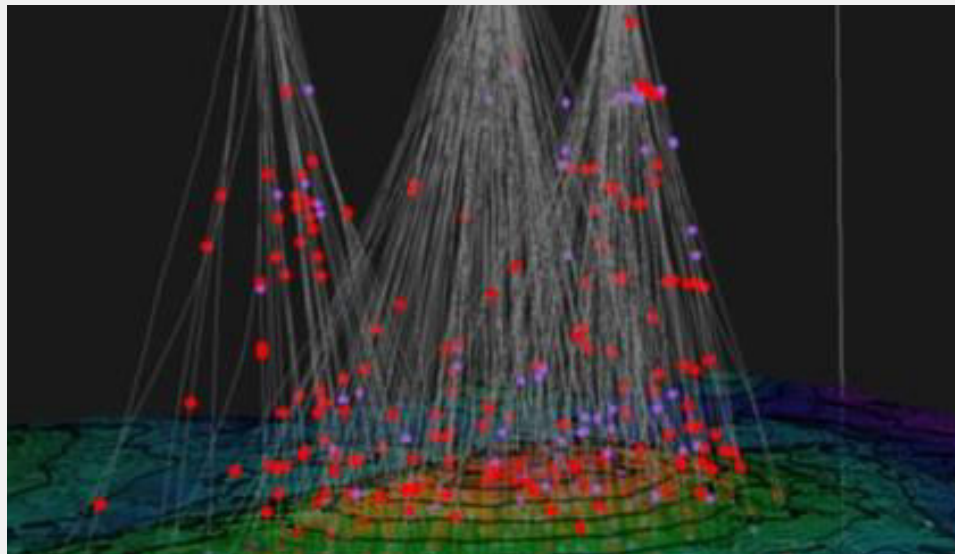
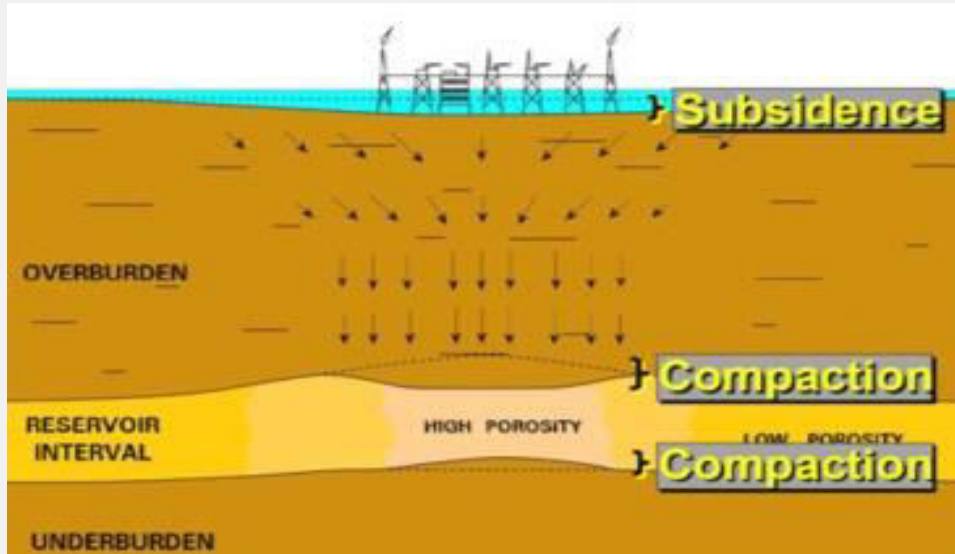
- Used to indicate where water injection is needed
- Also used to optimize water injection in blocks that are higher pressure

VC water injection project

SAFEGUARD current producers, **INCREASING** pressure and **ADD** resources

- VC 4 slot template - Ekofisk south focused water injection project
- Template on the sea floor
- Drilling rig arrival Spring 2018 to drill 4 water injectors

LoFS Containment Assurance: Reservoir & overburden monitoring



40 years of production has led to reservoir compaction and subsequent overburden subsidence

LOFS utilized for proactive subsurface containment assurance monitoring

- Water injection
- Controlled slurrification re-injection
- Permanently plugged and abandoned wellbores

LOFS utilization manage and minimize risk

associated with the field operation activities by early detection of any abnormal behavior

LoFS: Disruption exposure scenarios

LONG TERM PREDICTABILITY ON ACQUISITION WINDOWS IS STRONGLY RECOMMENDED

Disruptions erode value and challenge integrity monitoring

One missed shoot (i.e. 12 months between surveys)

- **Loss of detailed reservoir management information for simulation model calibration/history match assistance**
- **Loss of valuable information leading to suboptimal well trajectories and well placements:**
 - Monitoring overburden geomechanical stress changes
→ trajectories and prediction of wells at risk for mechanical failure
 - Lack information for improved new well placement
→ less production and increased costs
- **Reservoir pressure changes both in water and oil filled zones**
- **Gas in/out of solution due to pressure changes which indicate remaining oil pockets**
- **Base line survey for new wells as continuous activity across the field**
- **Early observations of well changes in reservoir (Injectors & producers)**
→ missed opportunity to mitigate (e.g. well intervention)
- **Would limit the regular monitoring of CSRI***
→ changes to injection patterns and / or potential out of zone injection
- **Limit early warning of stress changes in the overburden**
→ Can result in early shut-in of wells

* Controlled slurrification re-injection

Halt of LOFS activities

- **Loss of seismic PLTs**
→ Unable to track/ predict water movements
- **Less successful wells**
→ May need to drill significantly more wells to get same production
Delayed production, lost opportunities & potentially reduced ultimate recovery
- **Unable to monitor the overburden for containment events, including the CSRI wells**
- **Unable to monitor subsurface geomechanical changes due to reservoir subsidence**

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