



Understanding Leakage Rates in Permanently Abandoned Wells by Studying Natural Hydrocarbon Seepages

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Agenda

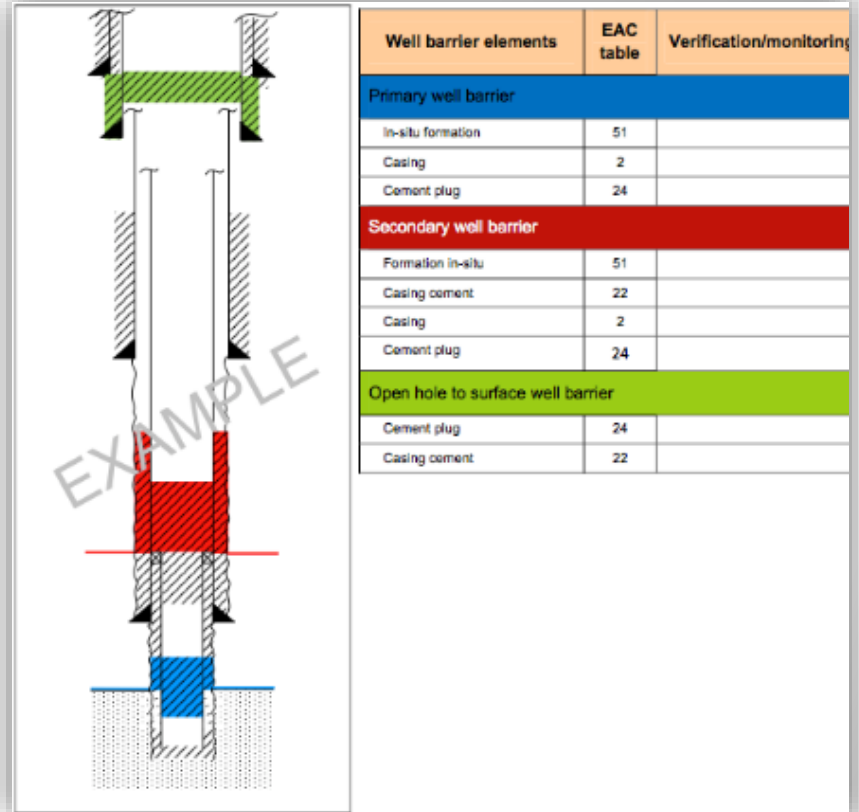
- Objectives
- Why leaks may occur
- Methodology - the OSCAR and Gastrack models
- Results and discussion

Objectives

- Studying natural seepages (with a focus on the NCS)
- Quantitative analysis of oil and gas fate after leaking
- Compare seepages with two real case studies (one occurred gas leak case and a theoretical oil leak case)

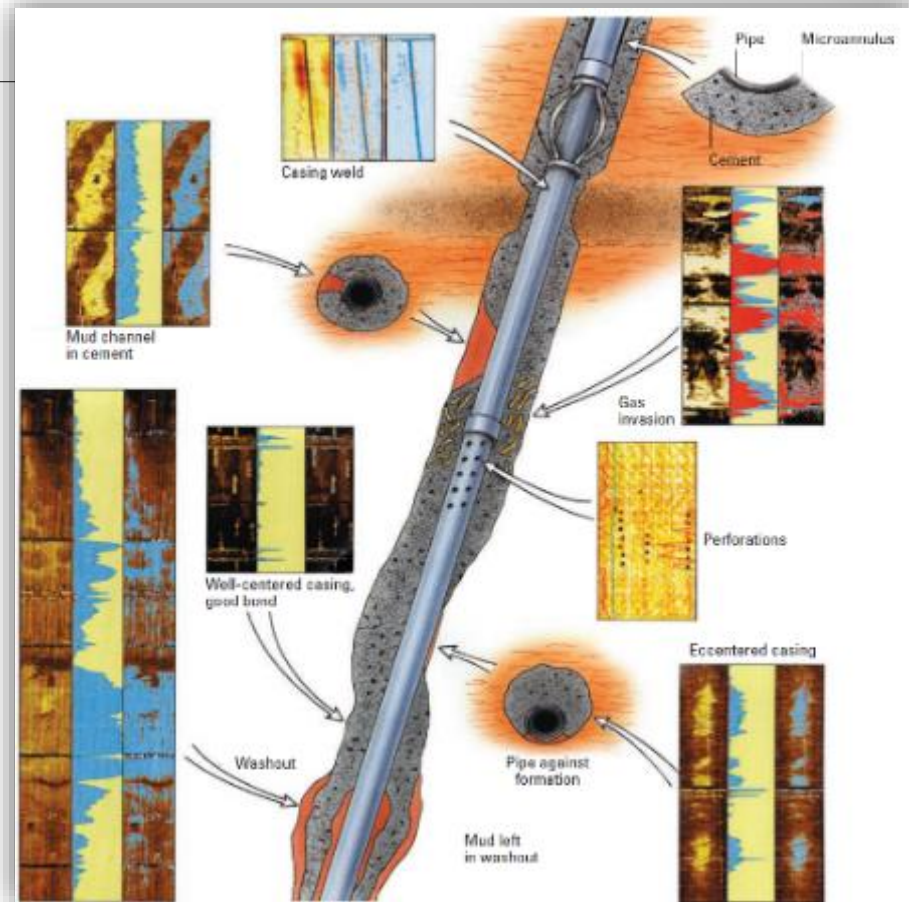
Plug & Abandonment

- Wellhead removed
- Leak is detected
- PSA / NORSOK D-010



P&A challenges

- Deviated wells
- Washout
- Casing collapse
- Formation subsidence
- Cleaning the wellbore



P&A challenges

Operational challenges

+

Material challenges

+

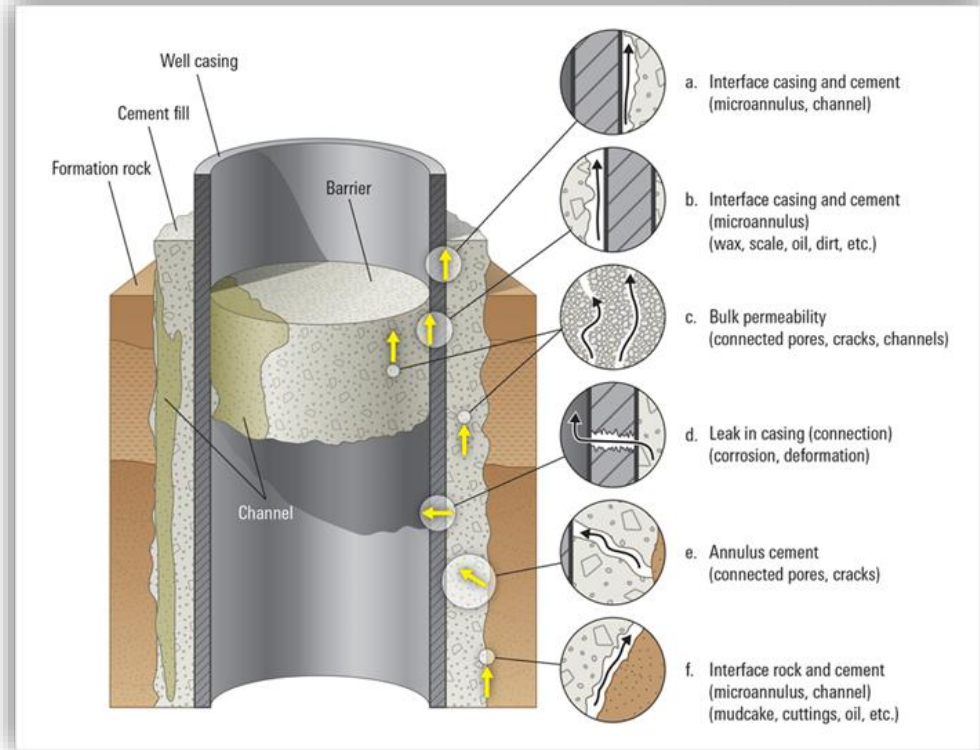
Human factor


+

Qualification challenges

=

Risk of leaks?





Zero harm = Zero leak?

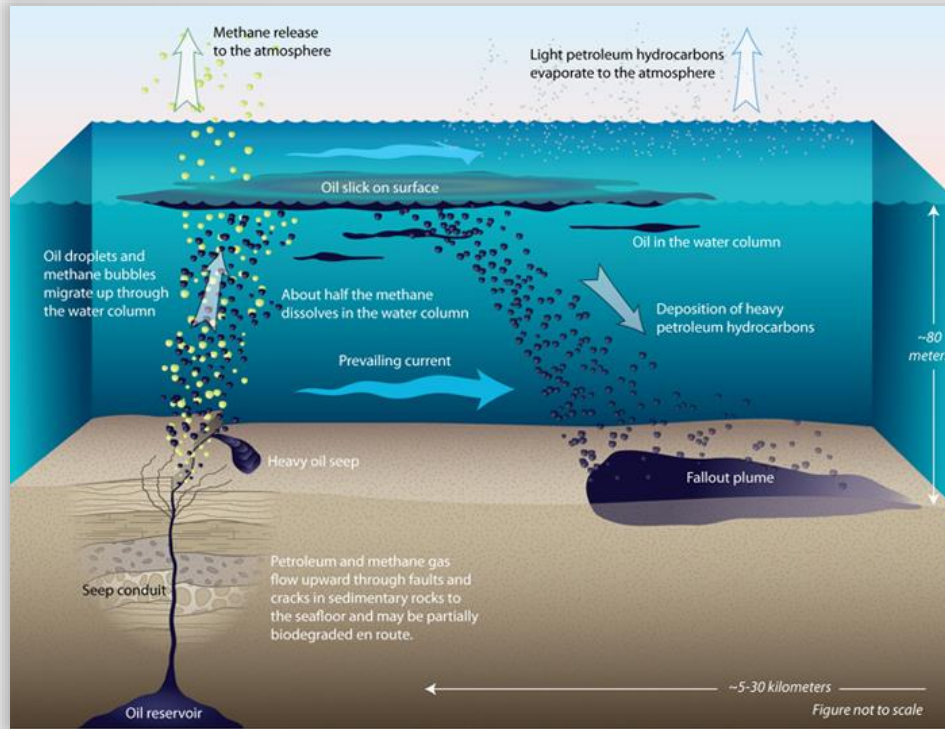


Natural hydrocarbon seepages



[CGG Geoconsulting, reported seeps across the world](#)

Natural hydrocarbon seepages



[Image from SOS California](#)

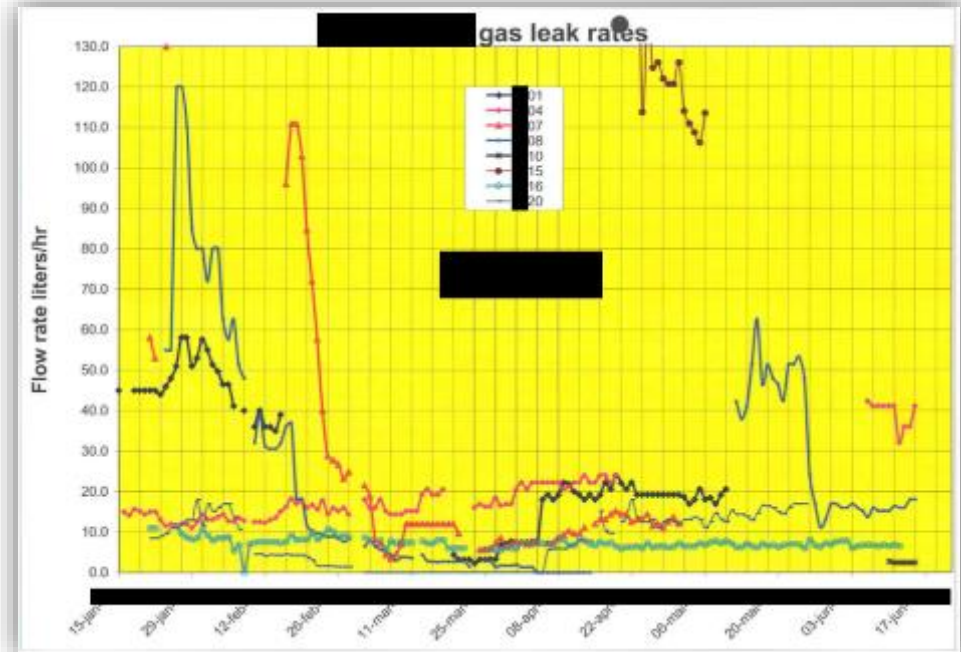
- Release of gas to atmosphere
- Evaporation of light oil components
- Dissolution of gas and oil components in water
- Dispersion / emulsification of oil droplets in water
- Biodegradation
- Sedimentation

MEMW - Marine Environmental Modeling Workbench

- MEMW - Framework
 - OSCAR & Gastrack
- Ekofisk blowout 1977
- Oil spill R&D
- Appx. 40 experimental oil spills have been conducted since 1978

Case #1 - Field A

- Platform wells, 70 m
- Was subject to PP&A some years ago
- All wells experienced leaks through annulus
- Gas cut cement during primary cementing
- Reabandonment → doubled costs of campaign



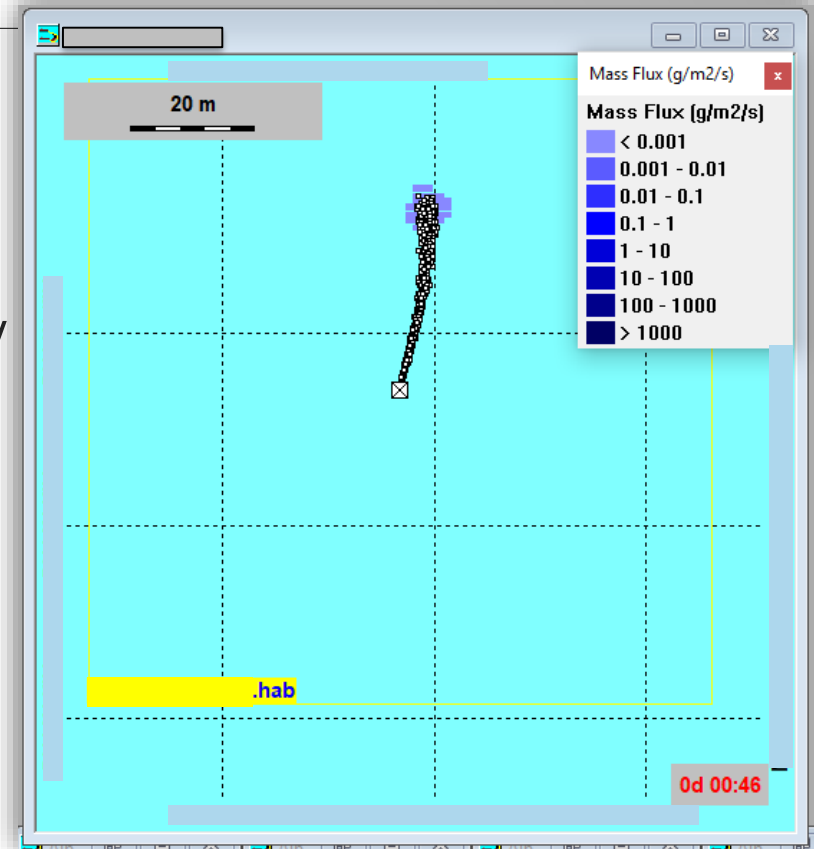
Tommeliten seepage area

- Largest seepage area on the NCS
- Analogue to Field A
- Thermogenic gas
- 4475 l/h
- Atmospheric fraction: 4.5 %

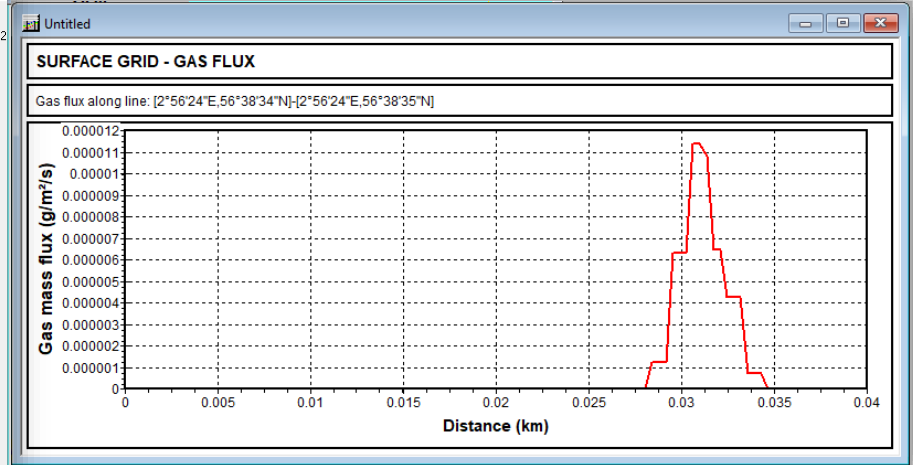
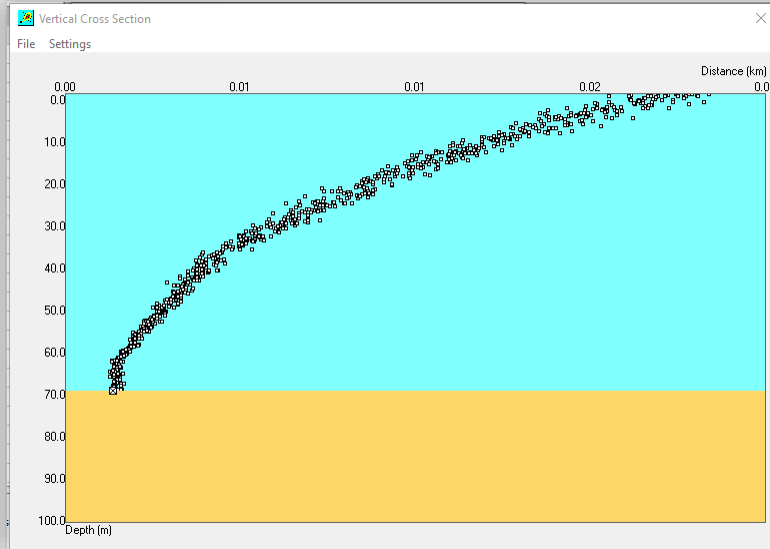


Gastrack

- Simulate pure gas leaks or blowouts
- Track bubbles until surface / they get dissolved
- Surface gas mass flux (mass per time per area)



Gastrack - Output examples



Simulation results by evaluating surface gas mass flux

Well	Leak rate	Bubble size	Winter (01.02.2014)		Summer (01.08.2014)	
			% of gas dissolved	% of gas to atmosphere	% of gas dissolved	% of gas to atmosphere
W-04	45 l/h 1.080 Sm ³ /d	4.5 mm	99.709 %	0.291 %	99.924 %	0.076 %
W-08	120 l/h 2.880 Sm ³ /d	4.5 mm	99.708 %	0.292 %	99.918 %	0.082 %
W-16	7 l/hr 0.168 Sm ³ /d	4.5 mm	99.711 %	0.289 %	99.925 %	0.075 %

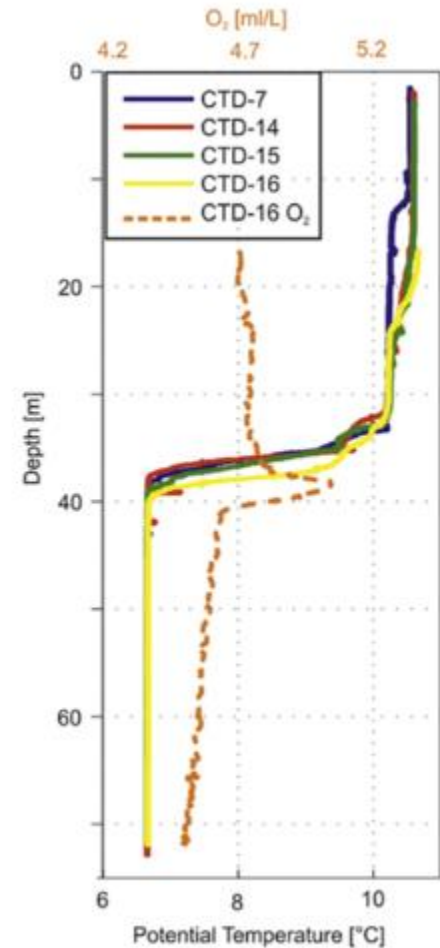
Why winter and summer simulations?

Winter

- Strong wind
- Cold weather
- Vertical mixing
- Increased transport

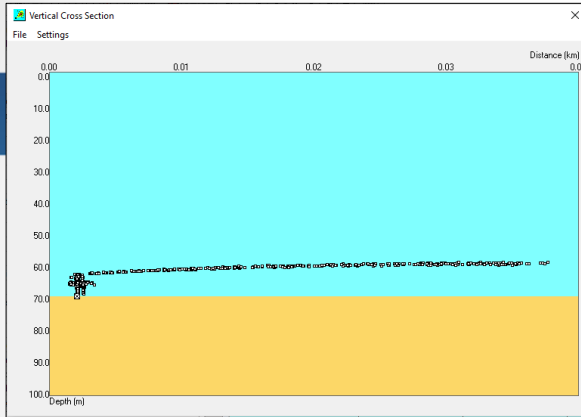
Summer

- Calm weather
- Warm weather
- Thermocline →
- Stratification
- Reduced transport



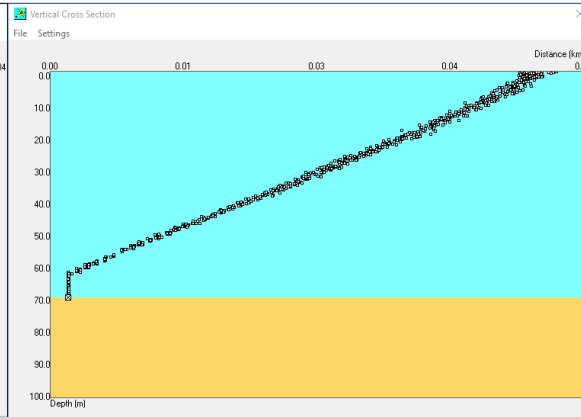
Ocean temperature gradient at Tommeliten seep area, summer 16

W-16 sensitivity analysis - bubble size



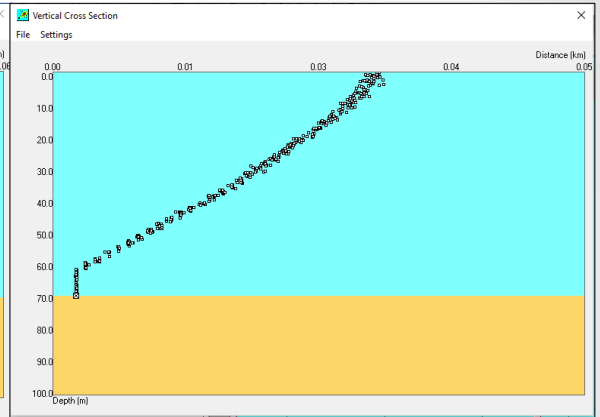
Bubble size = 1 mm

Dissolves completely



Bubble size = 4.5 mm

Reaches atmosphere at
appx 53 m



Bubble size = 10 mm

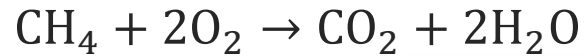
Reaches atmosphere at
appx 34 m

W-16 sensitivity analysis - bubble size

Well W-16	Leak rate	Winter (01.02.2014)		Summer (01.08.2014)	
Initial bubble size		% of gas dissolved	% of gas to atmosphere	% of gas dissolved	% of gas to atmosphere
1 mm	7 l/hr 0.168 Sm ³ /d	100 %	0.000 %	100 %	0.000 %
4.5 mm	7 l/hr 0.168 Sm ³ /d	97.108 %	0.289 %	99.925 %	0.075 %
10 mm	7 l/hr 0.168 Sm ³ /d	95.510 %	4.490 %	96.029 %	3.971 %

Consequences - dissolved gas

- Microbial degradation in water column:



- Nutrient - link in the food chain
- Ocean acidification
- Oxygen depletion
- Diffusion to atmosphere



Offshore gas seep off the coast of Virginia, USA

Credit: [NOAA Okeanos Explorer program 2012 / 2013](#)

Contribution compared with natural seepage

Field A

- Worst-case scenario: 120 l/h
- Area: 31,700,000 m²

Tommeliten seep area

- Seepage rate: 4475 l/h
- Area: 139,900 m²

If the leak from wells in Field A were as intense as natural seepage, what would the leakage rate be?

Answer: **1,013,992 l/h**

One well leaking 120 l/h = **2.7 %** of Tommeliten seeps

Case #2 - Field B

Field B - Norwegian oil field

- Theoretical leak
- Real data on
 - Fluid composition
 - Current / wind data
 - Temperature data
- Leak rates:
 - 0.01, 0.1 and 1.0 l/h
- Droplet sizes:
 - 1, 3, 5 and 10 mm

Natural seepage

- No oil seep reports on the NCS
- Data from the GoM / Offshore California



[Stalagmites of oil / tar seeping through white, bacterial mats](#)
Credit: NOAA Okeanos Explorer Program, Gulf of Mexico 2012

OSCAR

- Oil Spill Contingency And Response
- Create a release scenario
- Release profile (pollutant)

Marine Environmental Modelling Workbench - OSCAR1

File Edit View Map Grid Data Setup Tools Output Window System Help

Scenario Parameters

- Simulation Information
 - Description: Example
 - Start time: 2014-02-01 | 12:00 | UTC
 - Duration: 60
- Release Information
 - Selected site: 1: North Sea example
 - Name: North Sea example
 - Profile: NORTH SEA OIL [Edit Profile](#)
 - Longitude: 3°15.9182' E
 - Latitude: 56°59.7525' N
 - Release unit: liters/hour
 - Rate: 1
 - Time unit: days
 - Start time: 0
 - Duration: 60
 - Repeat interval: 0
 - Depth: 0
 - Depth reference: below sea surface above sea floor
 - Salinity: 35
 - Temperature: 5
 - Oxygen content: 0
 - Near field model: None
 - Release diameter: 0.1
 - Anale from north: 0
- Winds
 - The pre-defined wind file to use in simulations.

OSCAR1

5°00'W 0°00'E 5°00'E

400 km

60°00'N 55°00'N

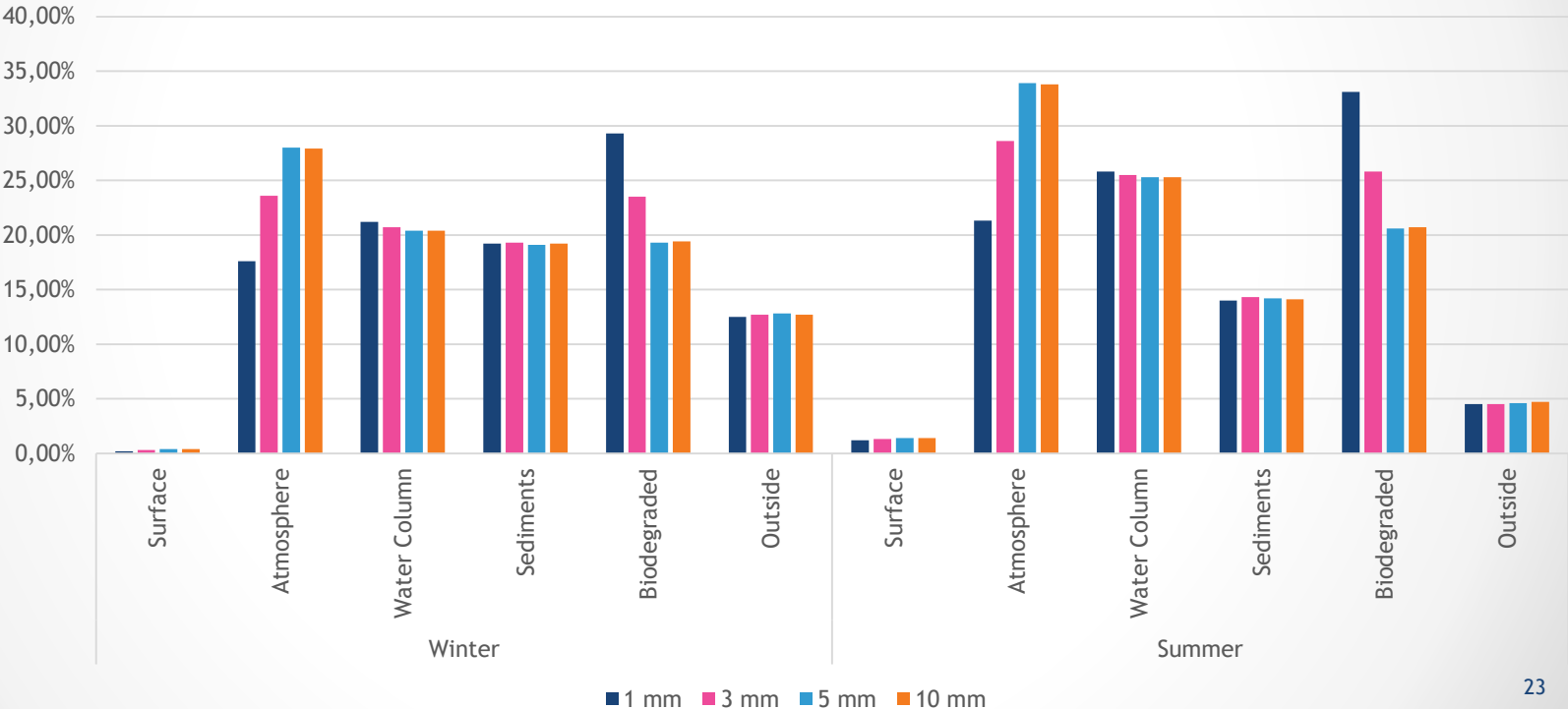
N.00.09 N.00.95

Example.hab

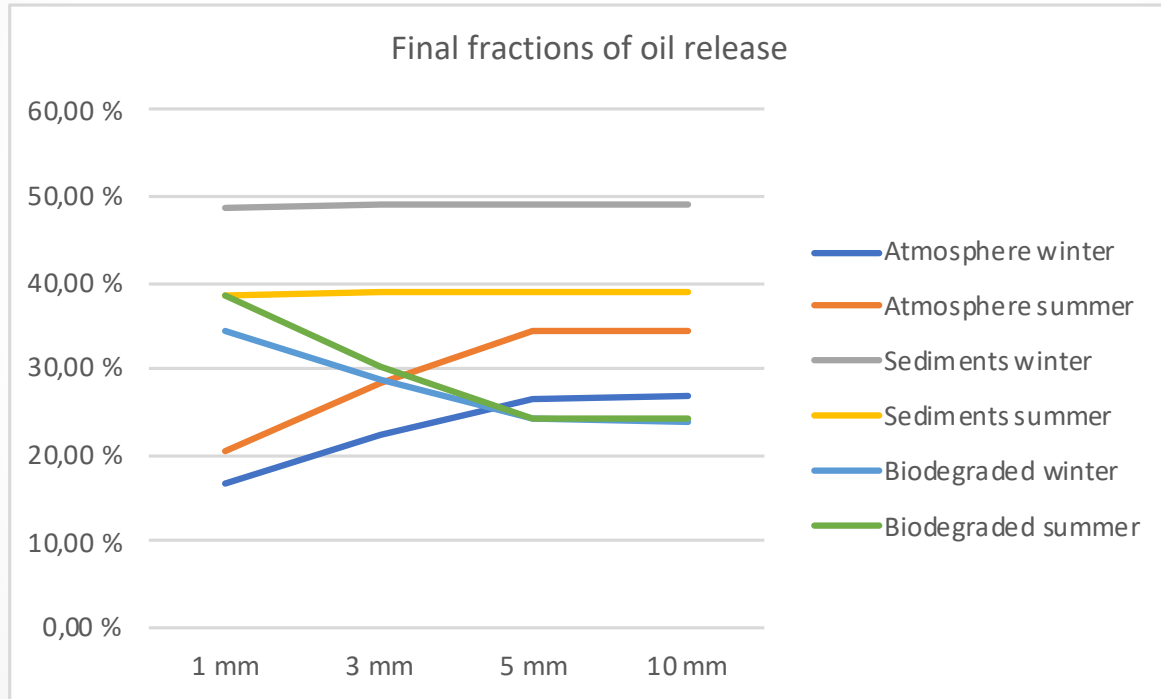
5°00'W 0°00'E 5°00'E

Mass balance results during release

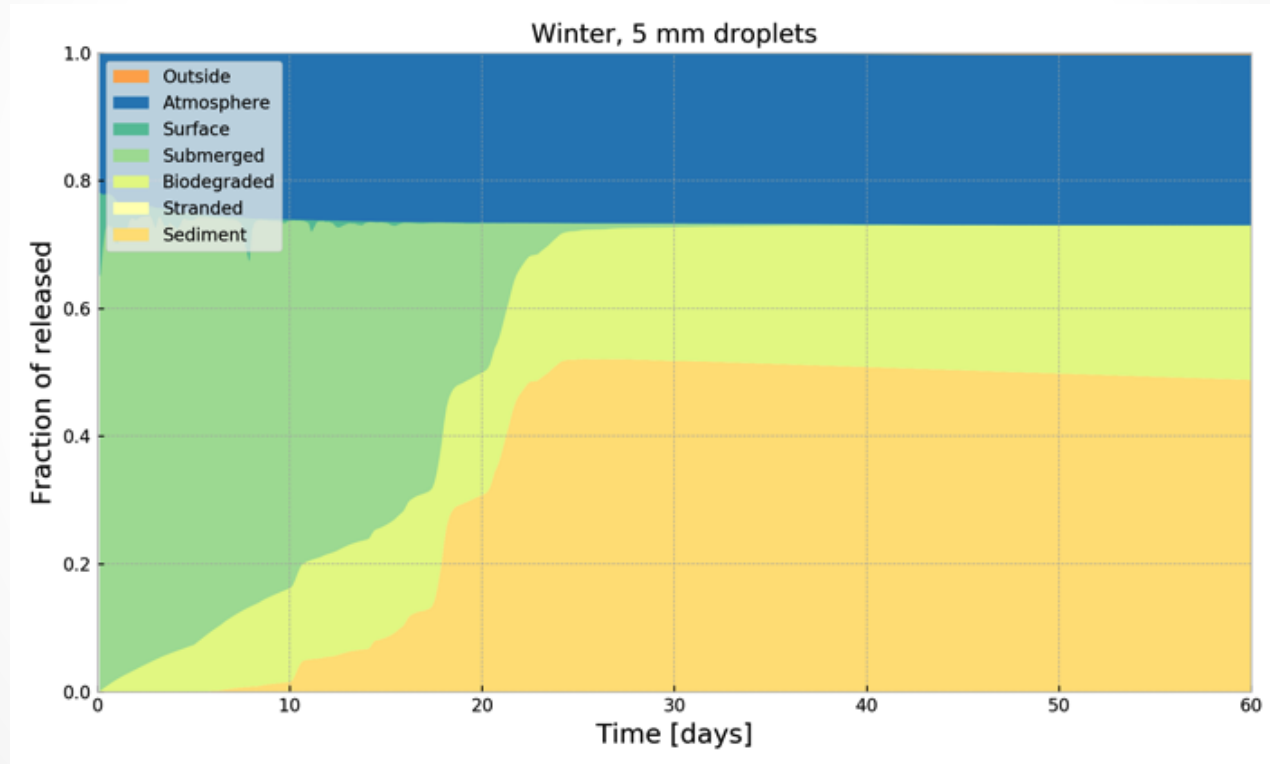
Mass balance day 90



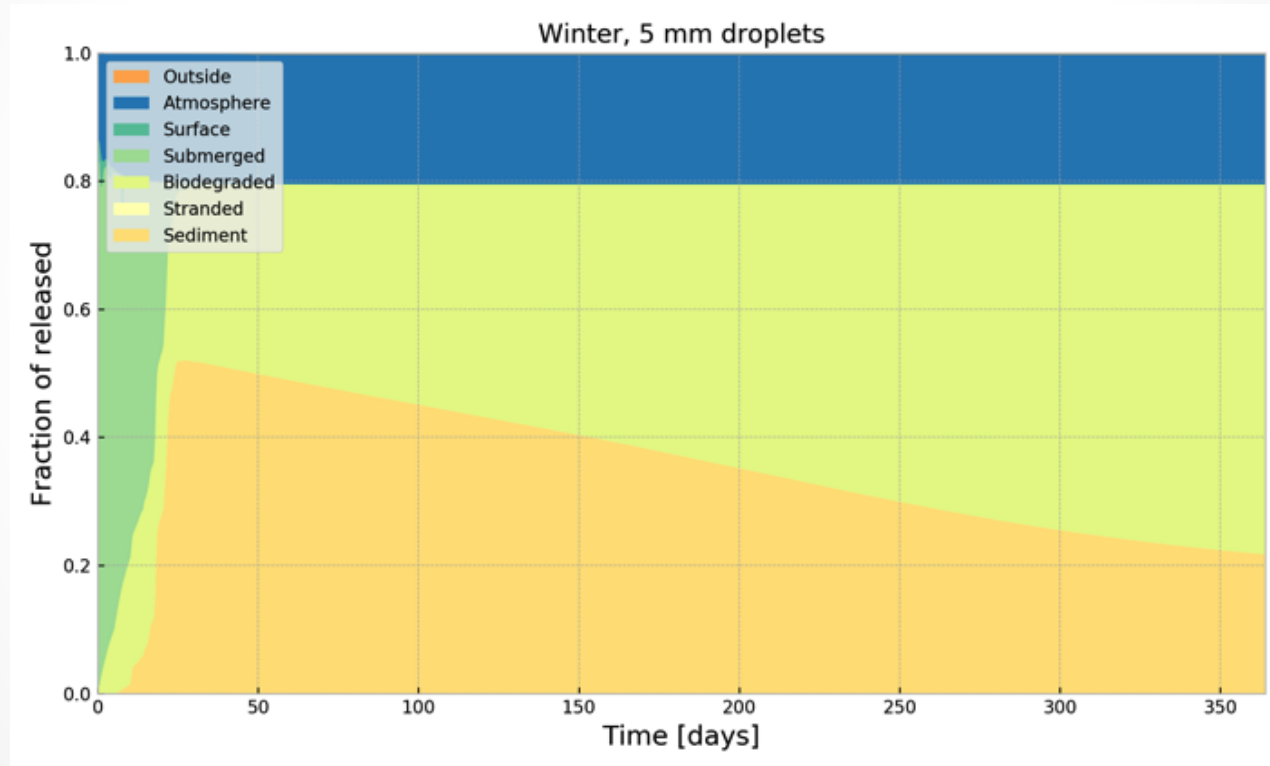
Mass balance results after release



After 5 day release of 1.0 l/h

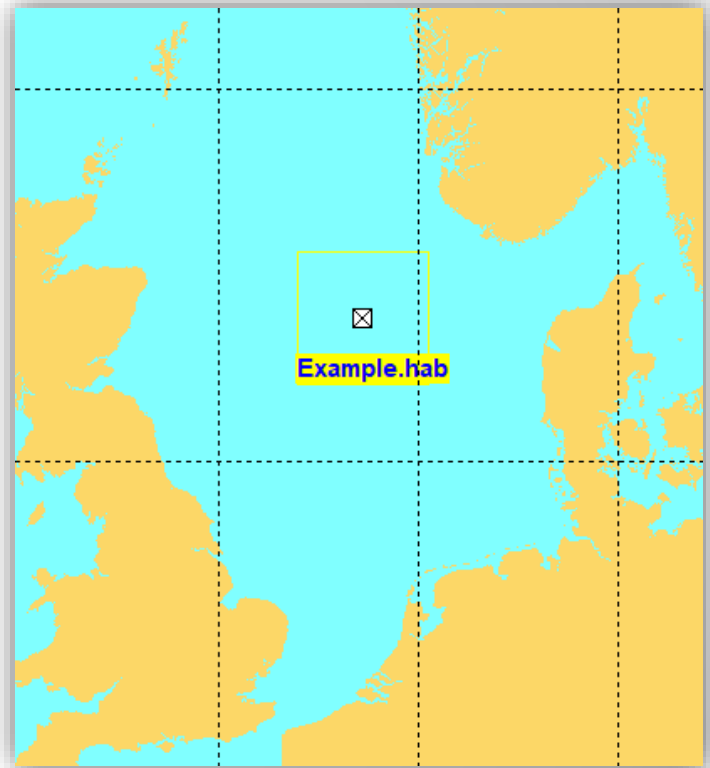


After 5 day release of 1.0 l/h



Concentration data

- Oil is persistent in the environment
 - travels over large distances
 - high level of dilution
 - 4% / 13% outside the grid (grid size 200 km x 200 km)
- Toxicity dependent on concentration, different benchmark values exist



Summary

Gas leaks

- May already be occurring in abandoned wells
- Studied rates are small compared to natural seepage
- 95 - 99 % dissolves in the ocean, may diffuse to atmosphere at later stage
- Dissolved gas = nutrient

Oil leaks

- No oil seepage on the NCS
- Released oil travel over large distances
- Dilutes quickly into small concentrations
- Oil is very persistent in the environment

Both cases: Fate is dependent on initial bubble / droplet size, not leak rate

Summary

- If a leak happens, what is your course of action?
- Is it possible to evaluate the rate and the consequences, before deciding on a reabandonment?
- The information and methodology here should be used by others to evaluate consequences
- I draw no conclusions, but believe actions should be based on knowledge!



Zero harm = Zero leak?



Thank you!

Questions?

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