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

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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 ocurred gas leak case and a theoretical oil leak case)

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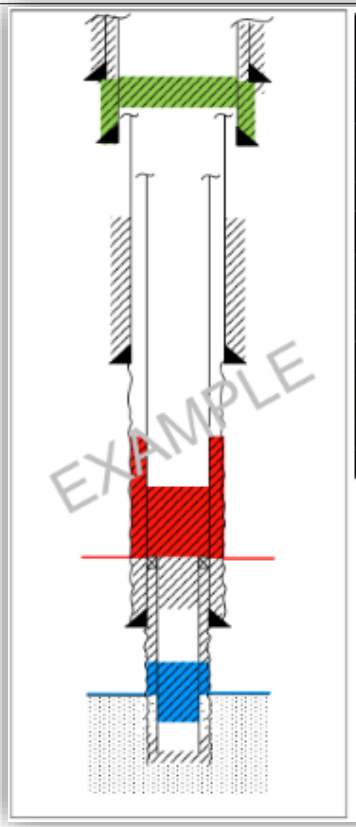
Plug & Abandonment

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



Well barrier elements	EAC table	Verification/monitoring
Primary well barrier		
In-situ formation	51	
Casing	2	
Cement plug	24	
Secondary well barrier		
Formation in-situ	51	
Casing cement	22	
Casing	2	
Cement plug	24	
Open hole to surface well barrier		
Cement plug	24	
Casing cement	22	

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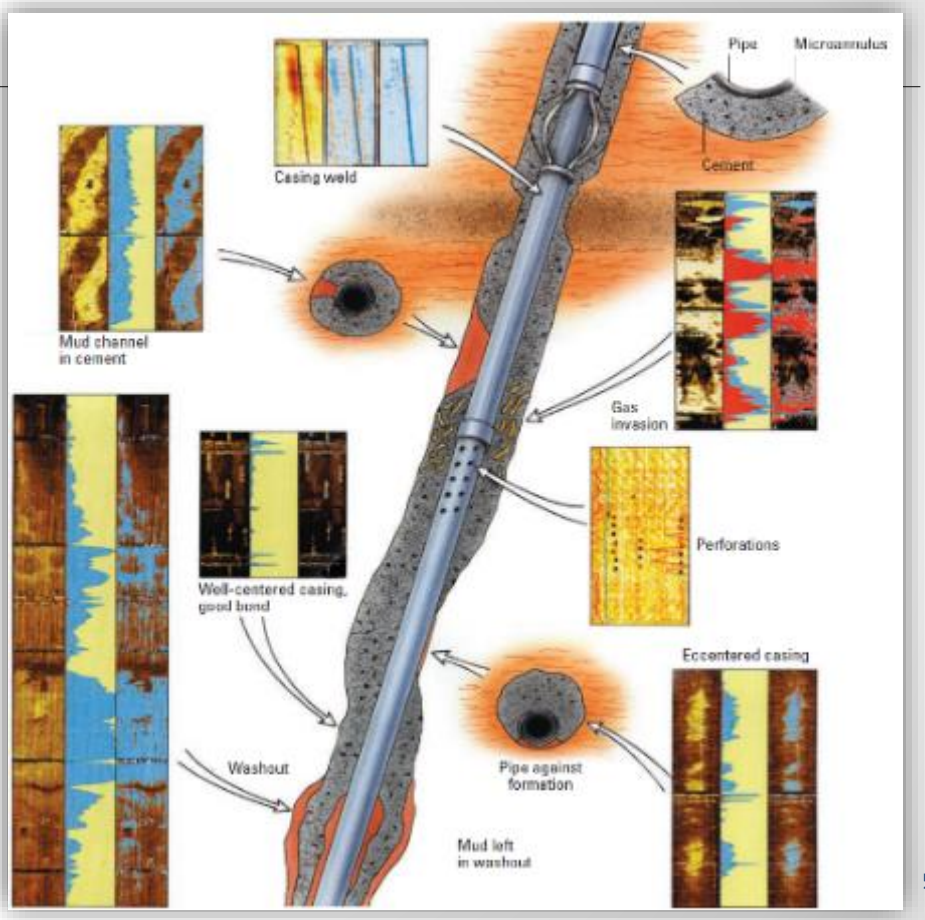
P&A challenges

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



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P&A challenges

Operational challenges

+

Material challenges

+

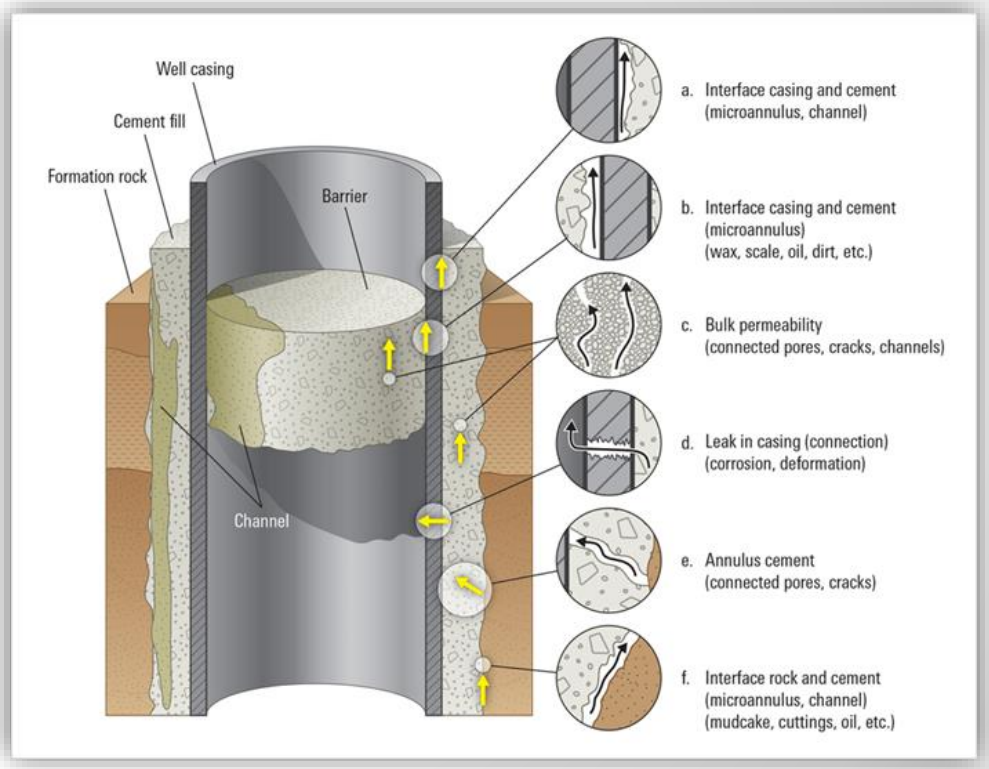
Human factor

+

Qualification challenges

=

Risk of leaks?



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Zero harm = Zero leak?

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Natural hydrocarbon seepages

CGG Geoconsulting, reported seeps across the world

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Natural hydrocarbon seepages

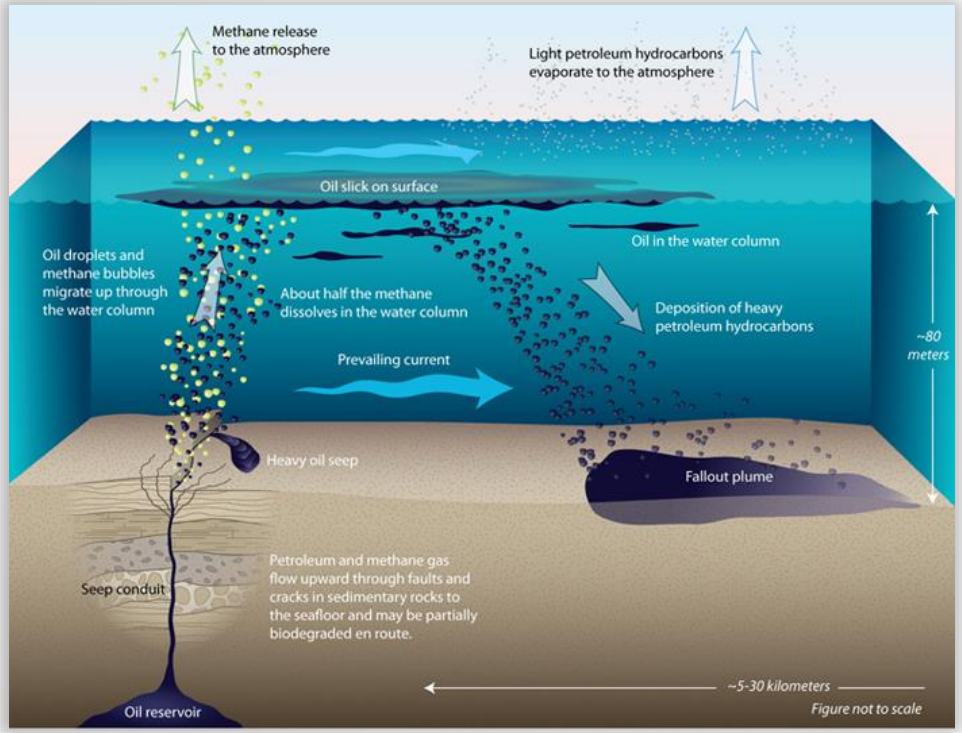

Image from SOS California

- 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

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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

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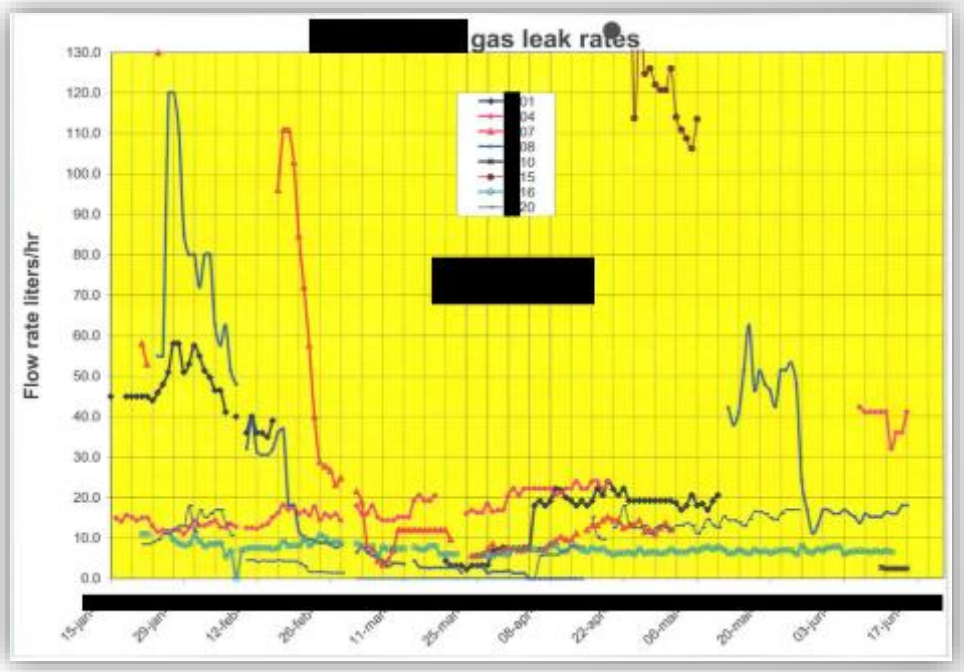
Case #1 - Field A

- 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



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Tommeliten seepage area

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

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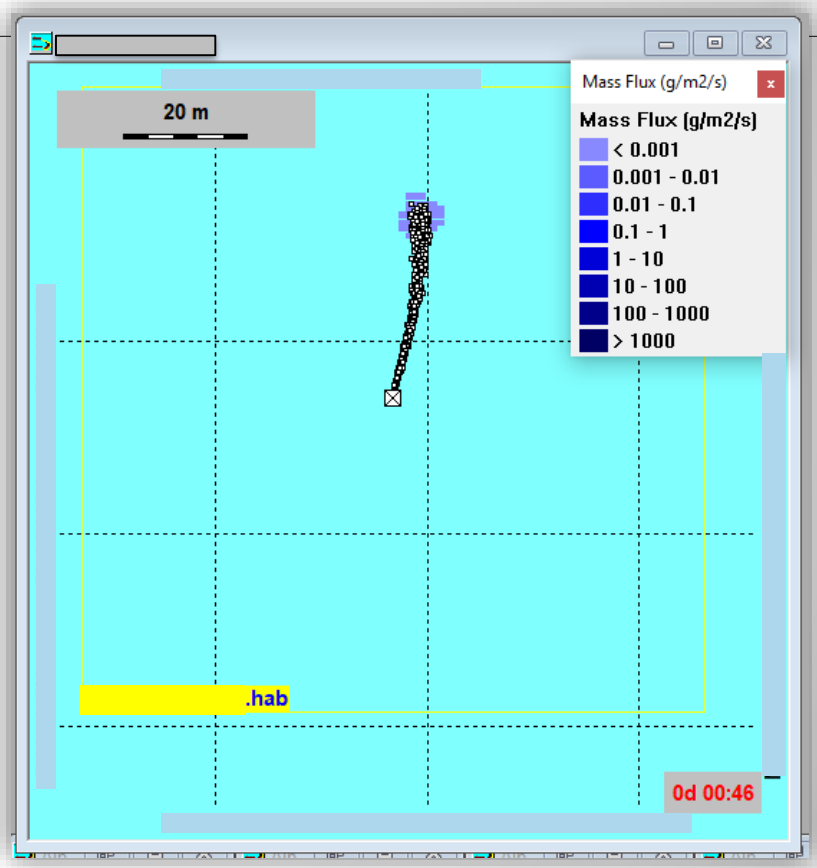
Gastrack

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



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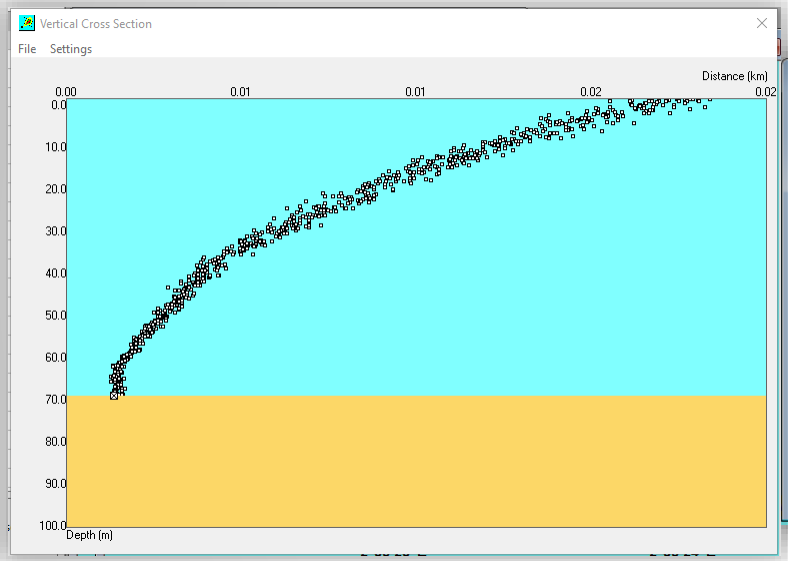
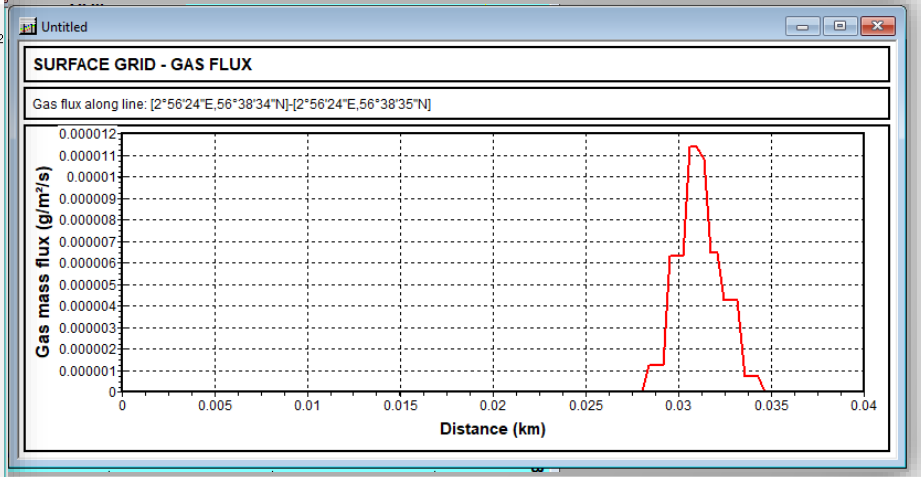
Gastrack - Output examples





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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 %

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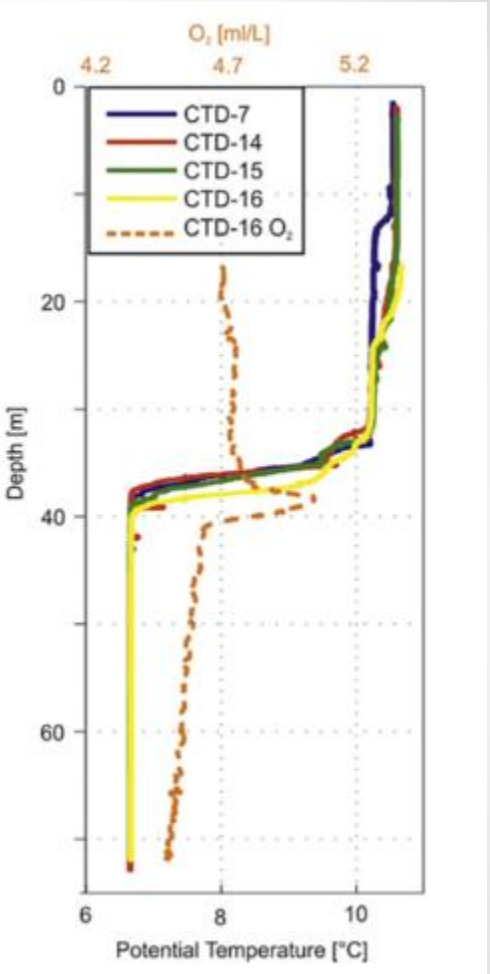
Why winter and summer simulations?

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

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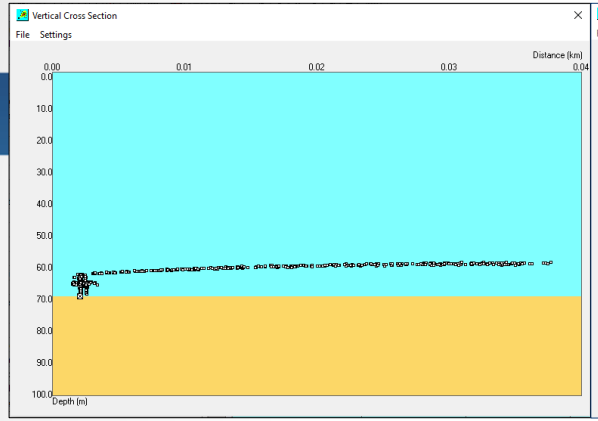
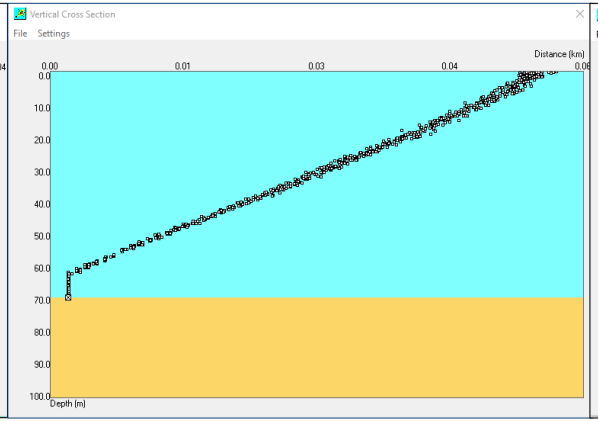
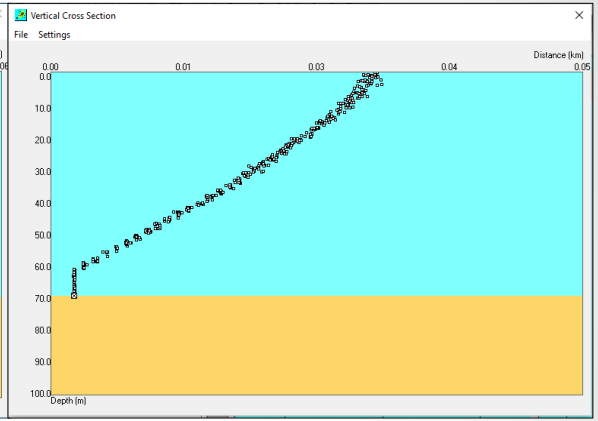
W-16 sensitivity analysis - bubble size







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

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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 %

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Consequences - dissolved gas

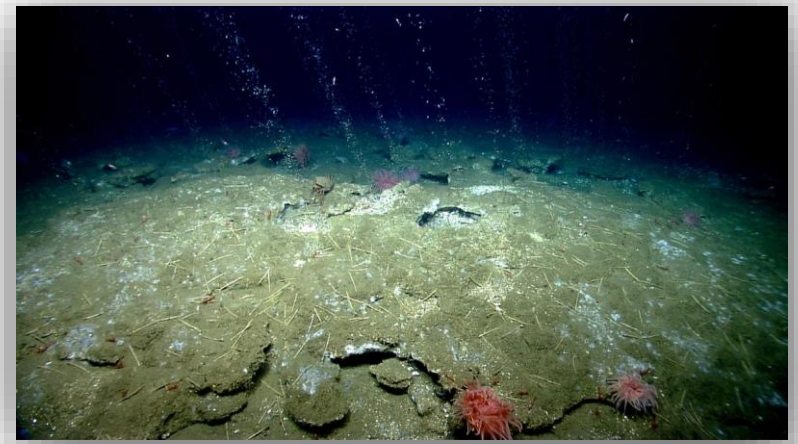
- Microbial degradation in water column:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- 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

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Contribution compared with natural seepage

Field A

- Worst-case scenario: 120 l/h
- Area: 31,700,000 m^2

Tommeliten seep area

- Seepage rate: 4475 l/h
- Area: 139,900 m^2

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

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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

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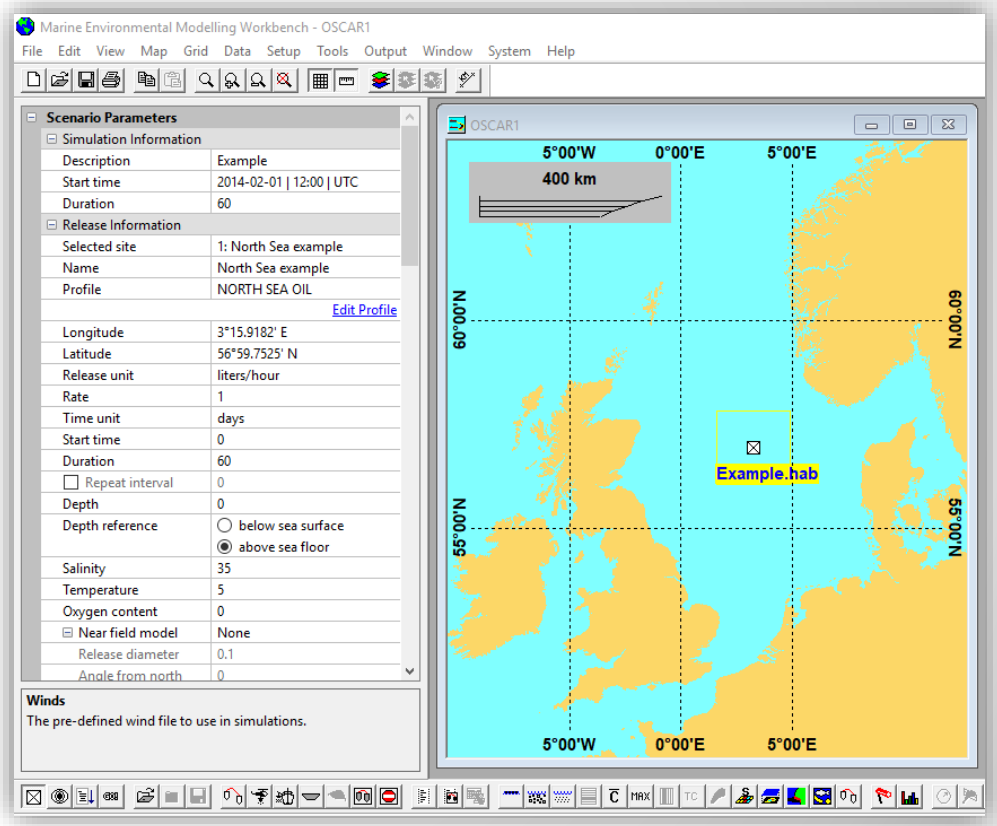
OSCAR

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



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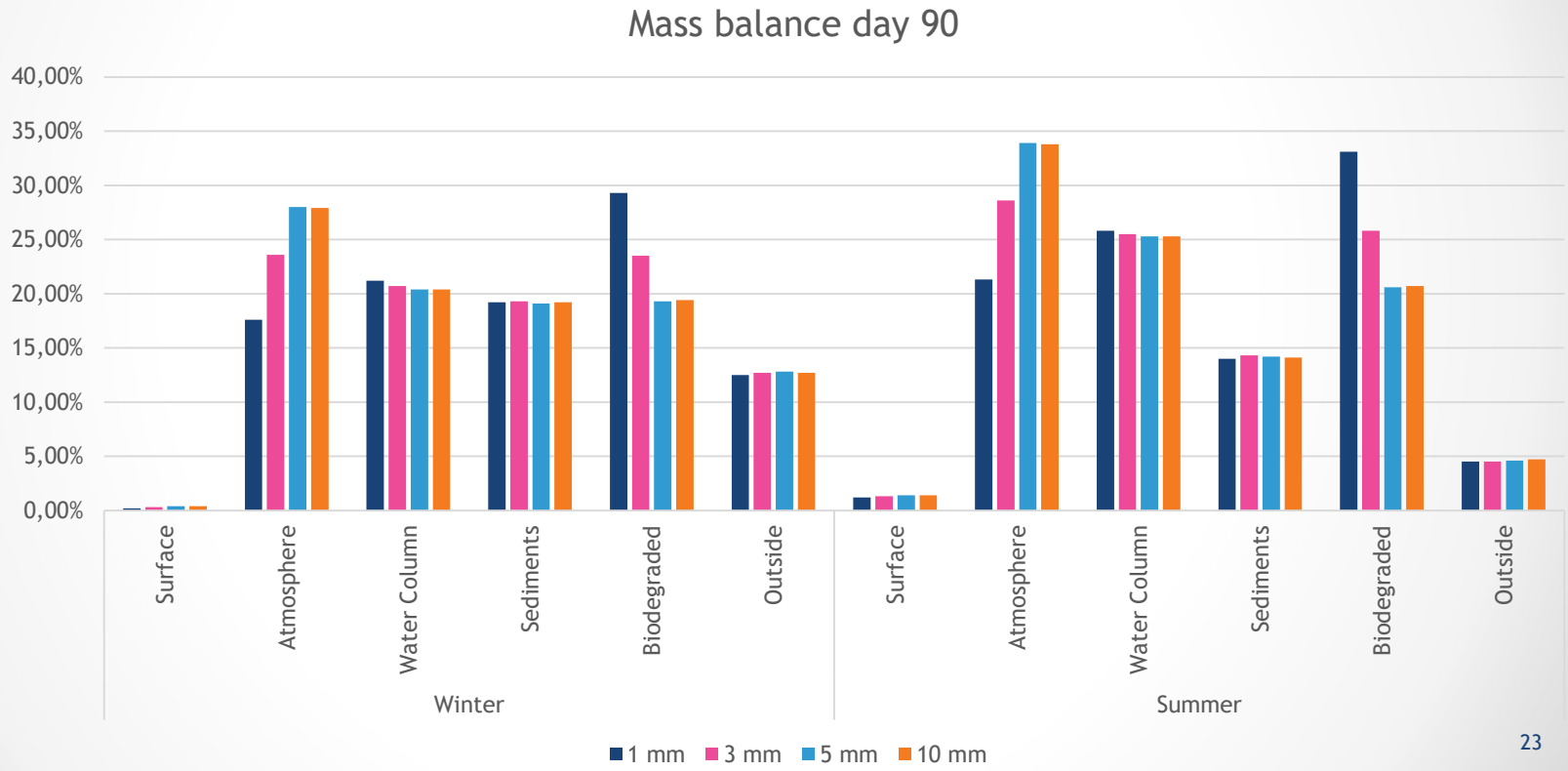
Mass balance results during release



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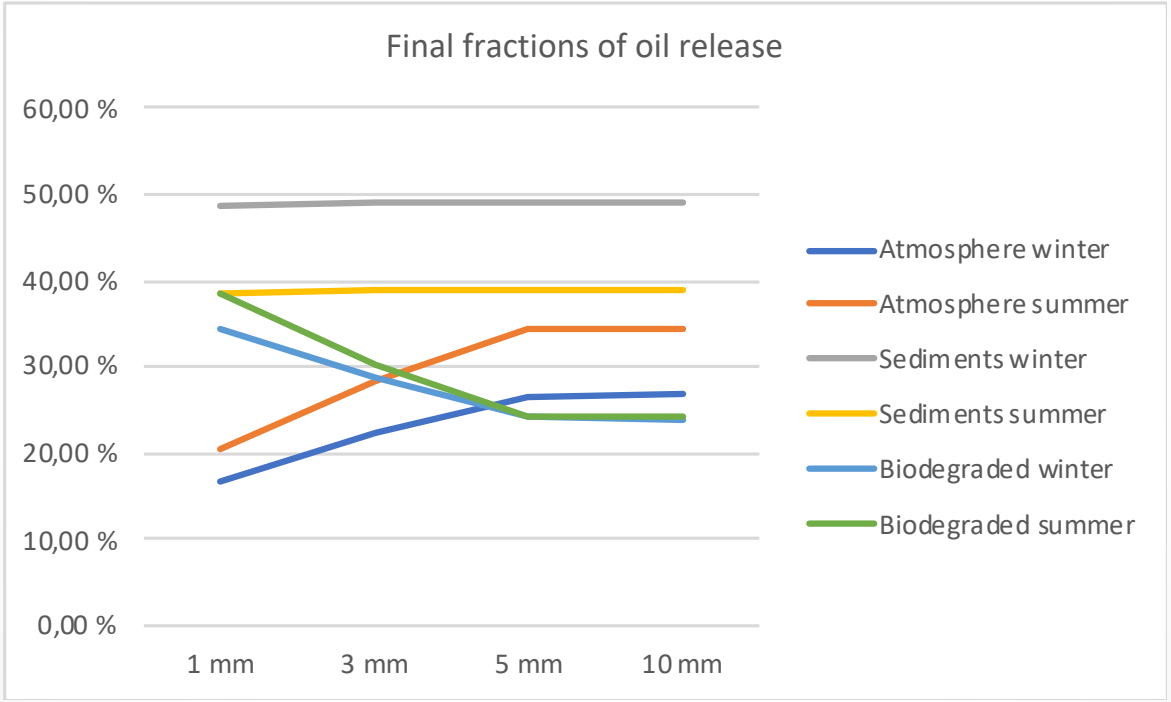
Mass balance results after release



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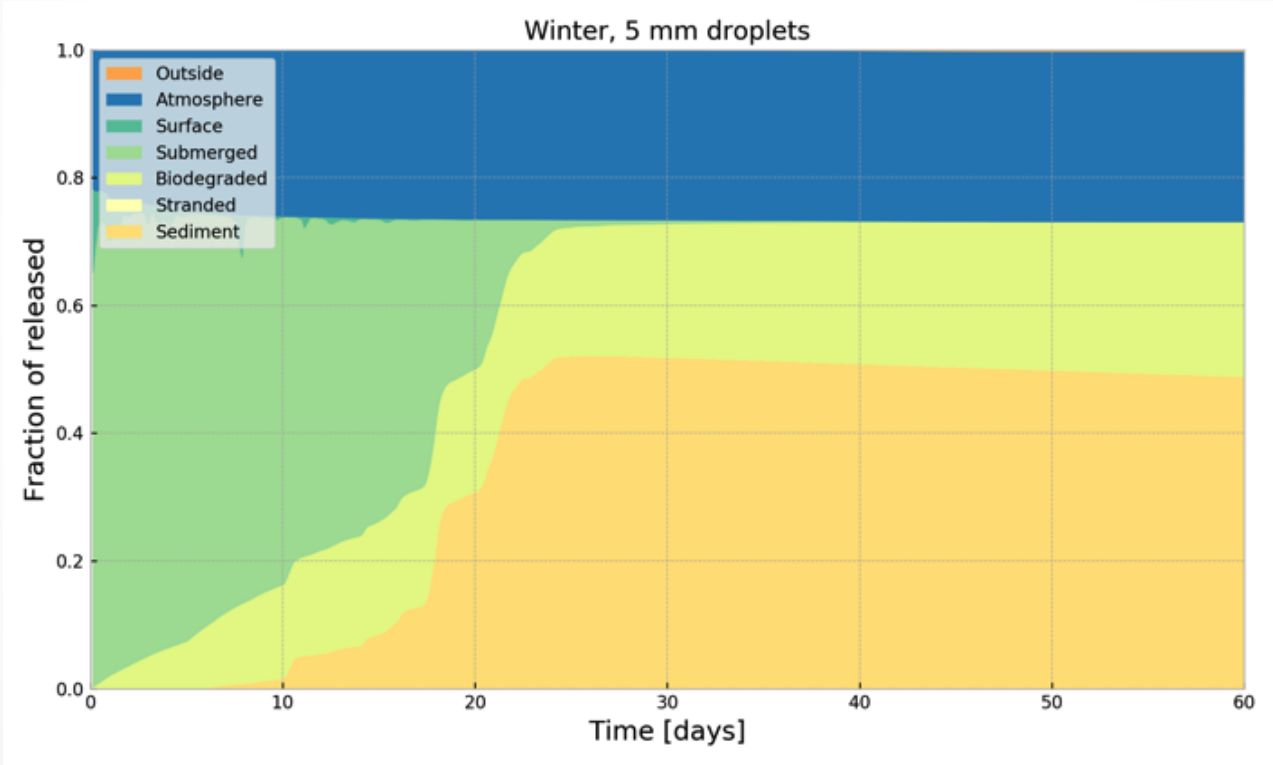
After 5 day release of 1.0 l/h



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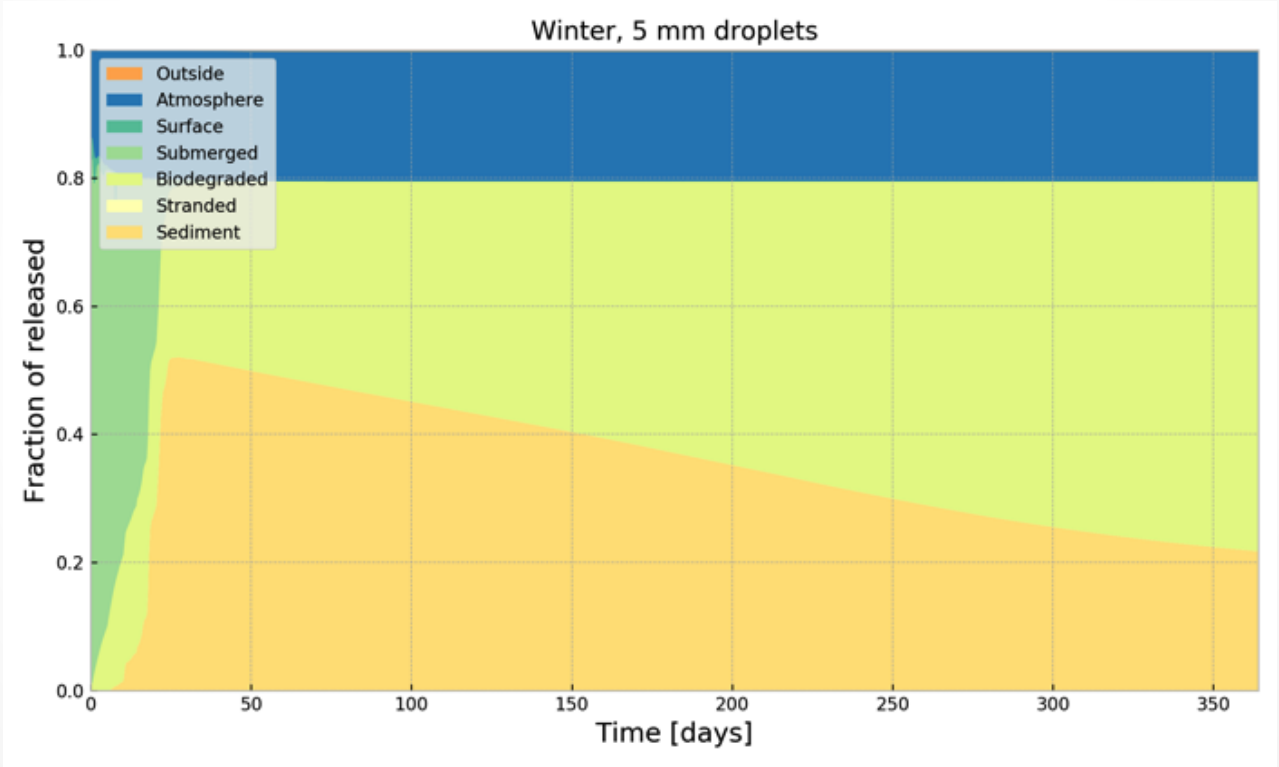
After 5 day release of 1.0 l/h



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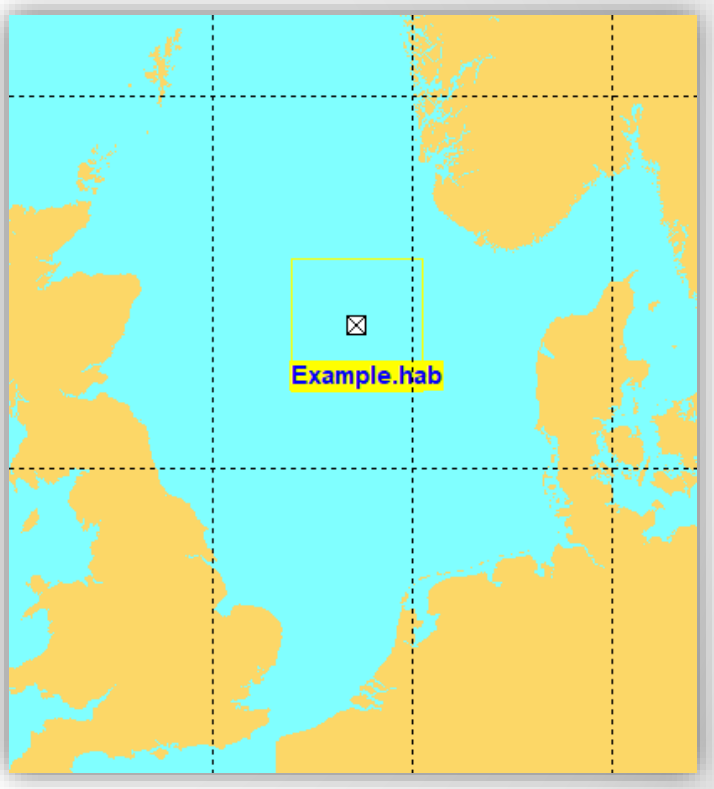
Concentration data

- Oil is persistant 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



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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

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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!

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Zero harm = Zero leak?

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Thank you!

Questions?

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