

# Stepping- and Mile-stones of Monitoring at Tomakomai

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# Monitoring Techniques at Tomakomai

current



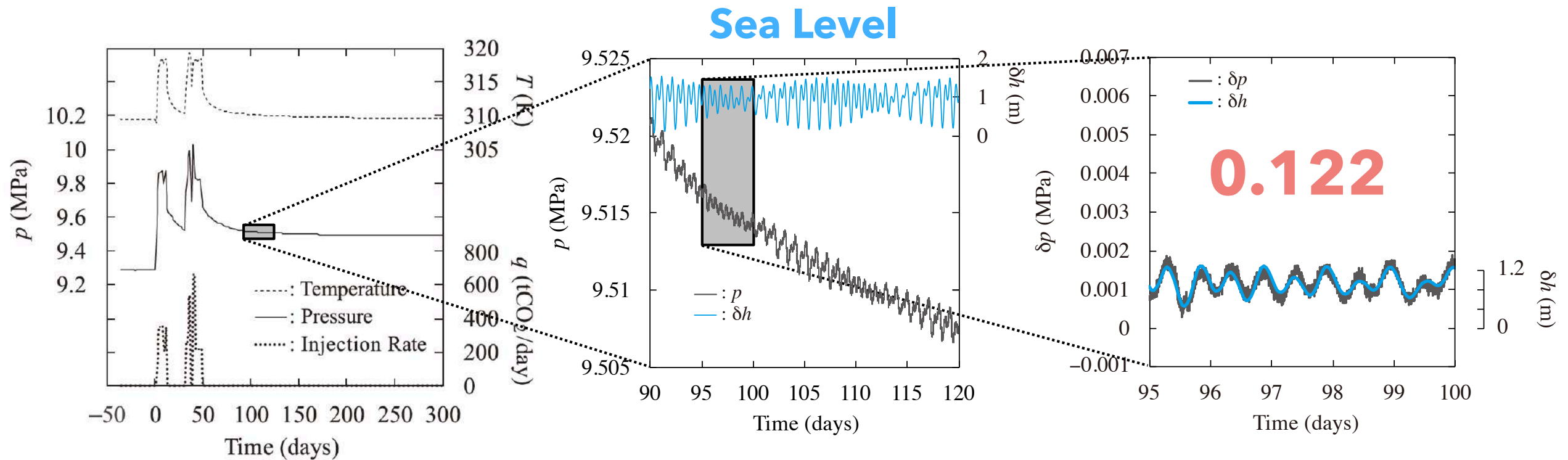
long-term

Monitoring Purpose	Injection Controls	Containment Assurance	Conformance Assurance	Environmental Impacts
Downhole Pres./Temp.	A	O	A	
2D/3D Seismic		A	A	
OBC/OBS	O			A
Surrounding Seismometry	O			A
Water Column Chemistry				A

Deep  
 Shallow

A Appropriate  
O Occasional

# Tidal Signals in Pressure Transients

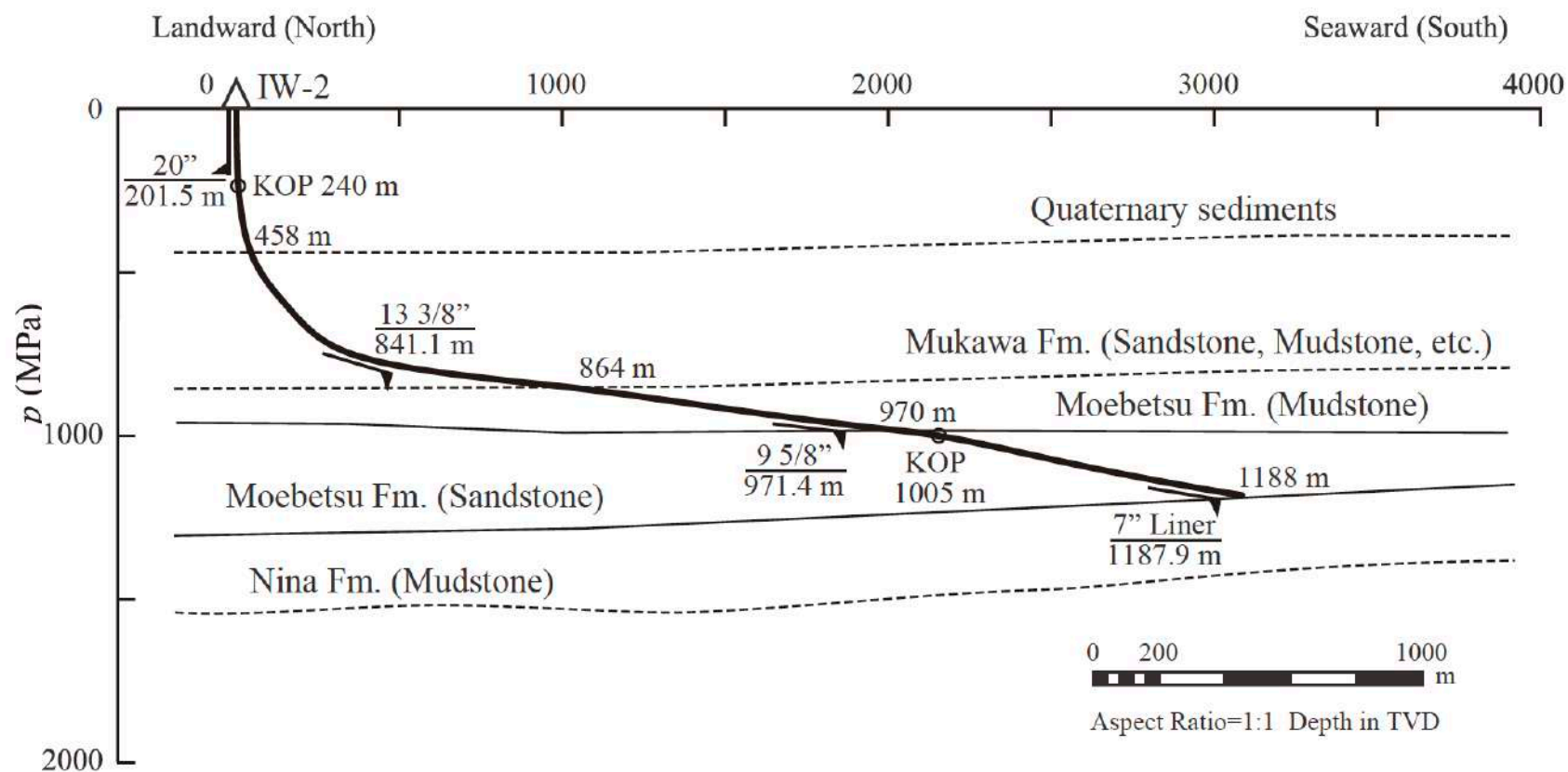


**Resolution: 0.00005% FS**

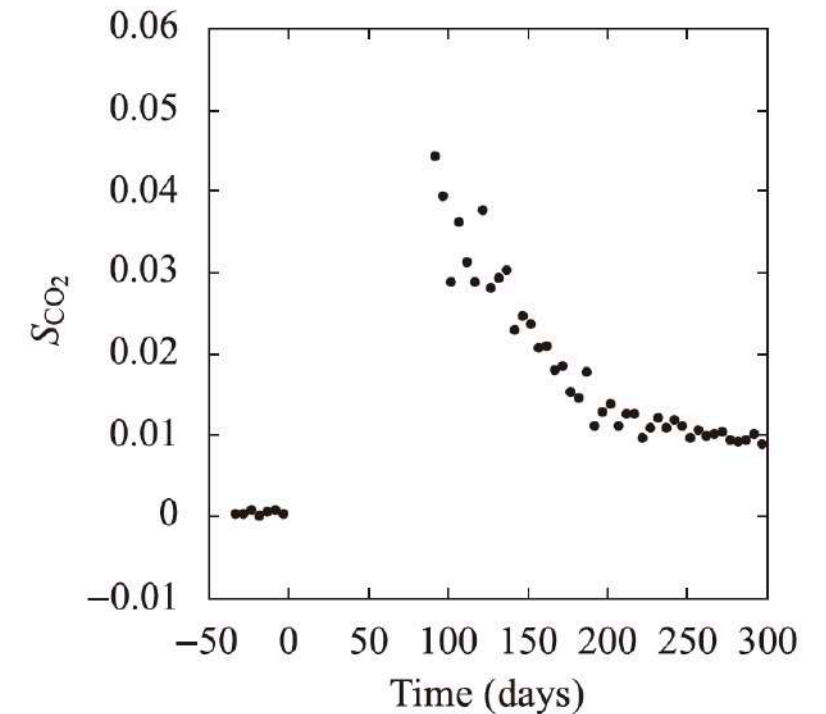
**0.00001 MPa (0.00145 psi)**

$$R = \frac{1}{\rho_w g} \frac{\delta p}{\delta h}$$

# CO<sub>2</sub> Saturation for Conformance Assurance



$$R = f(S_{CO_2}, c_w, c_{CO_2}, c_{pp})$$

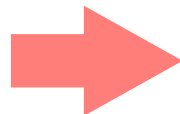


**Saturation Evaluation  
without Well Intervention**

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**current**  **long-term**

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OBC/OBS	O	<b>Baseline Defensive</b>		A
Surrounding Seismometry	O			A
Water Column Chemistry				A



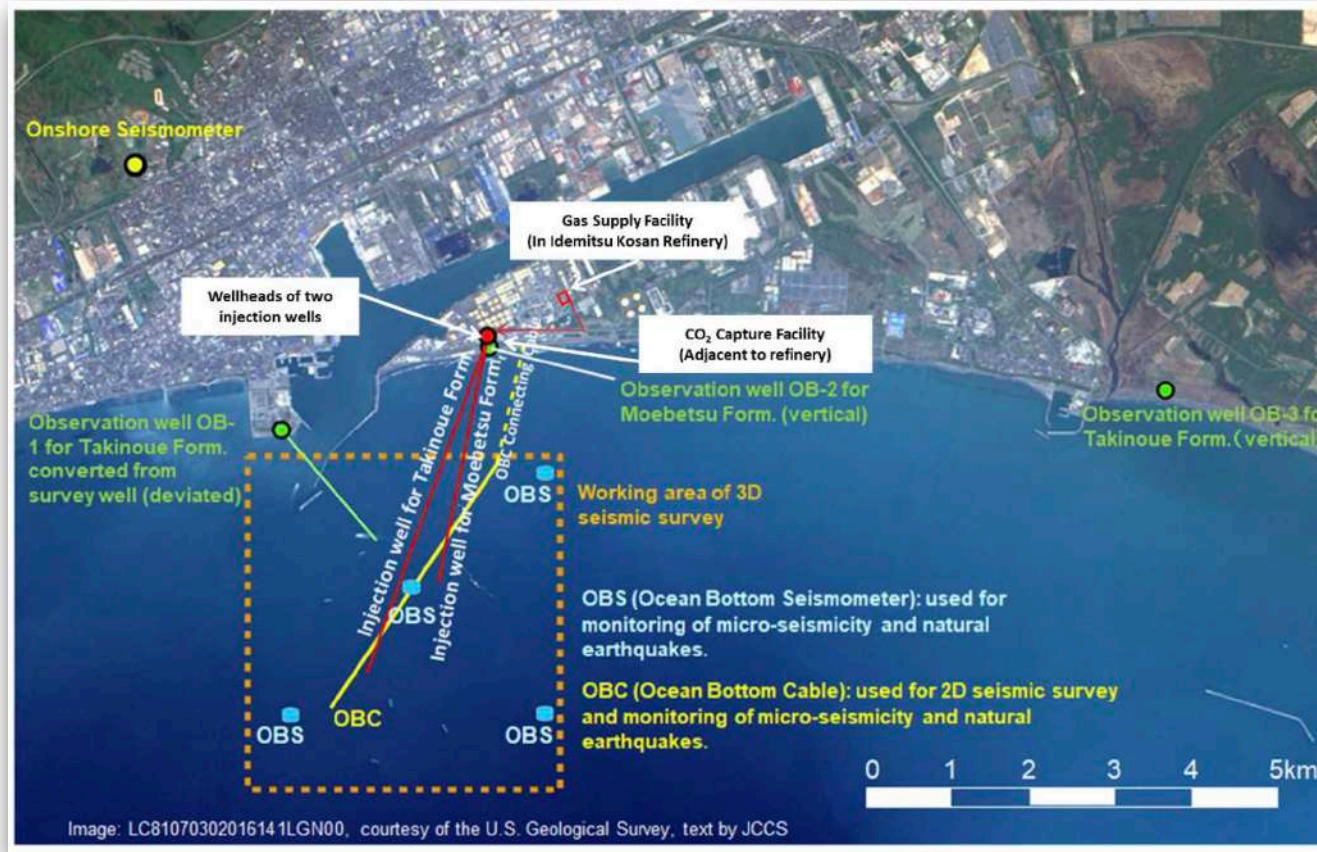
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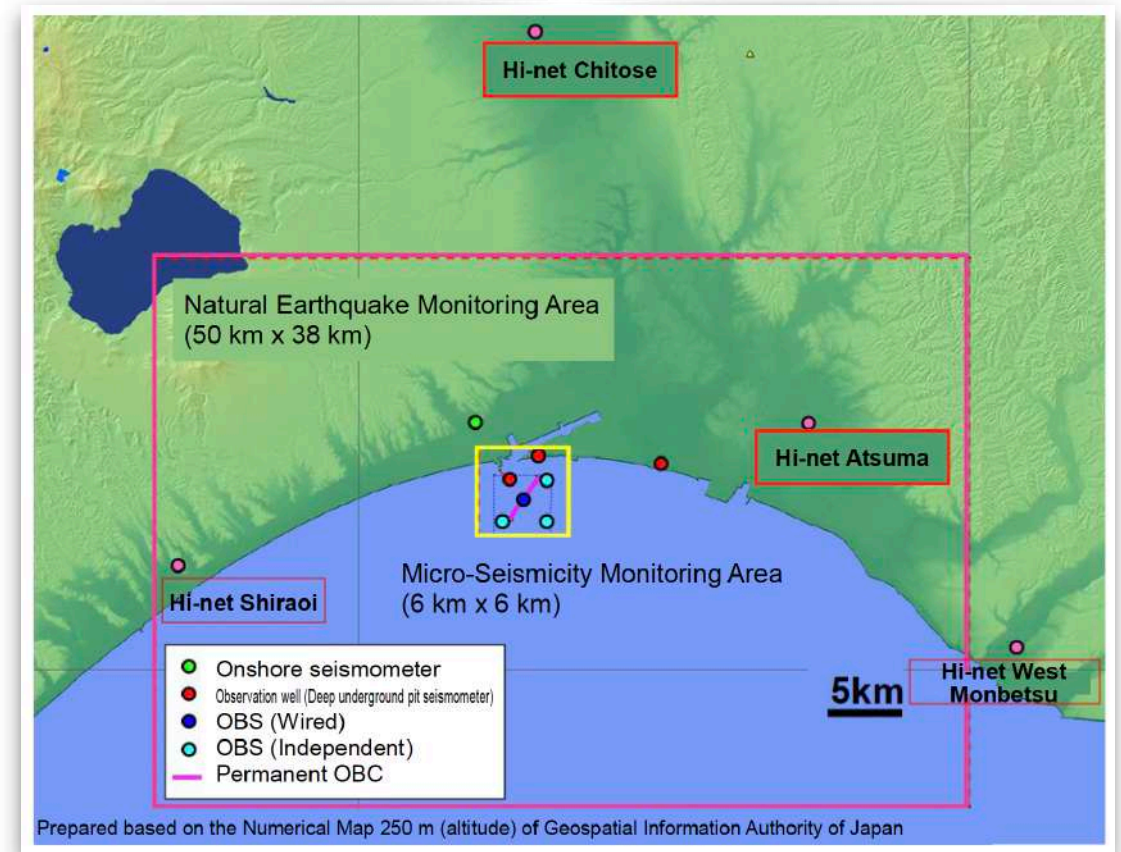
# Comprehensive Monitoring of Seismic Activity

**OBC (3.6 km)**



**4 OBS**

**Surface S. + 4 Hi-net**

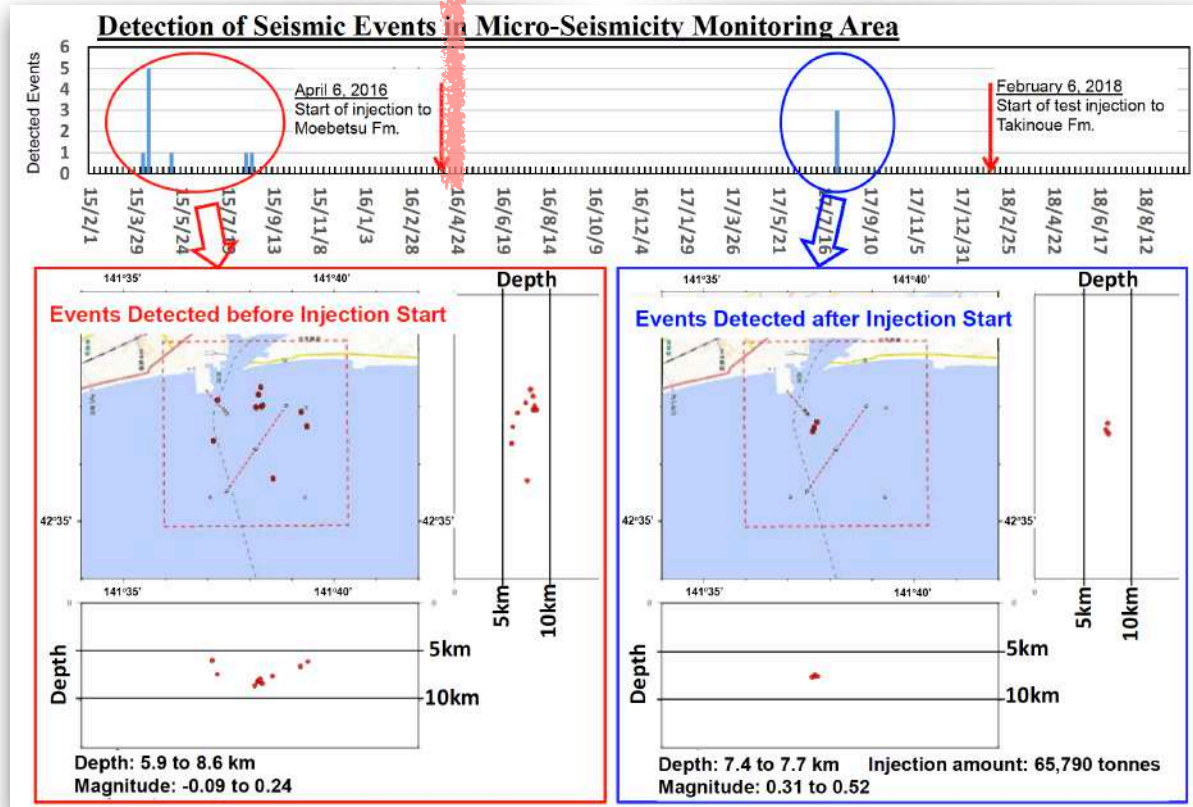


**3 Monitoring Wells**

(JCCS: Summary Report on Tomakomai CCS Demonstration Project, 2020)

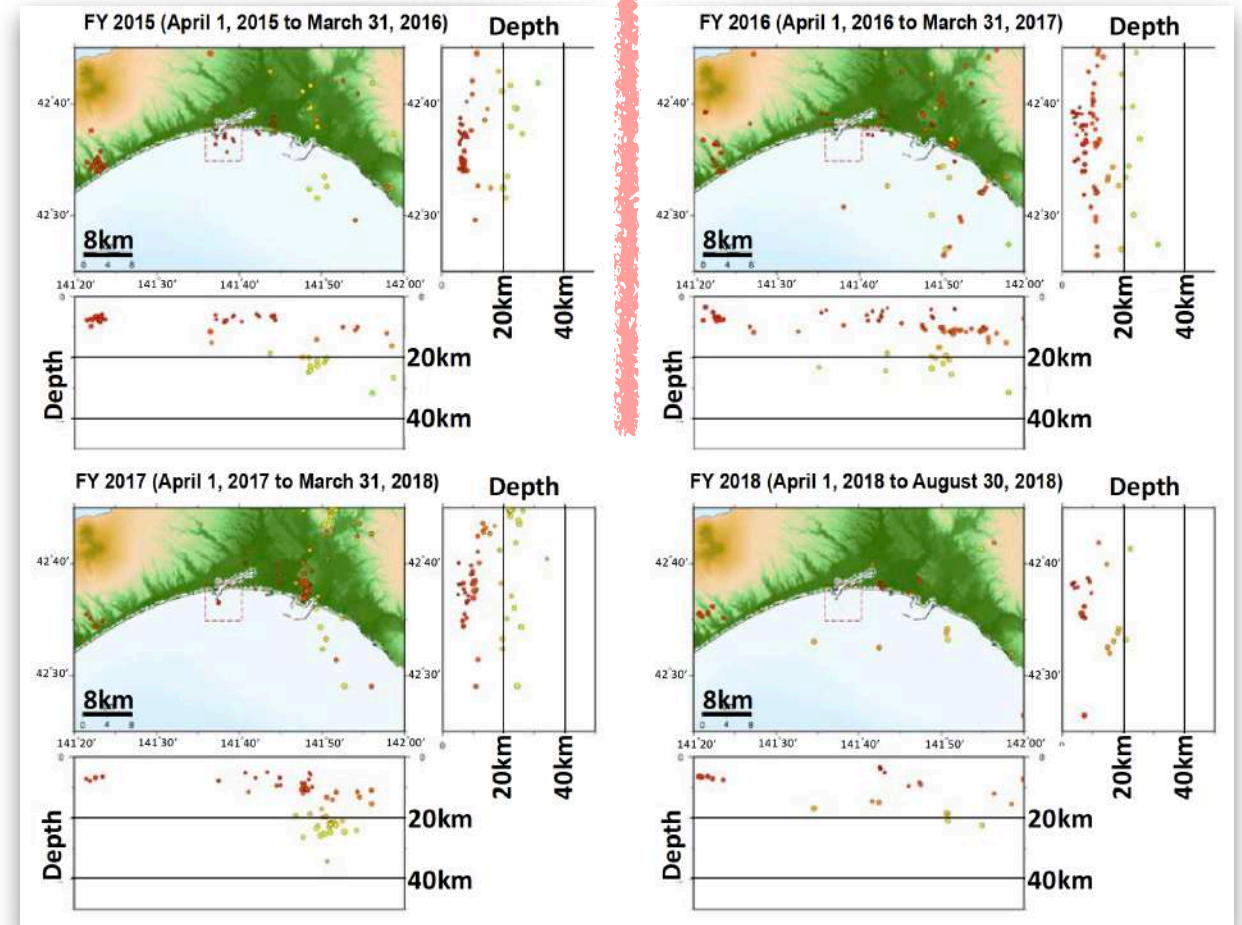
# Accumulation of "Defensive" Baselines

9 vs. 3 events



> 6 km

< M 0.52



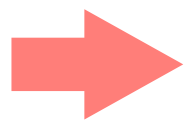
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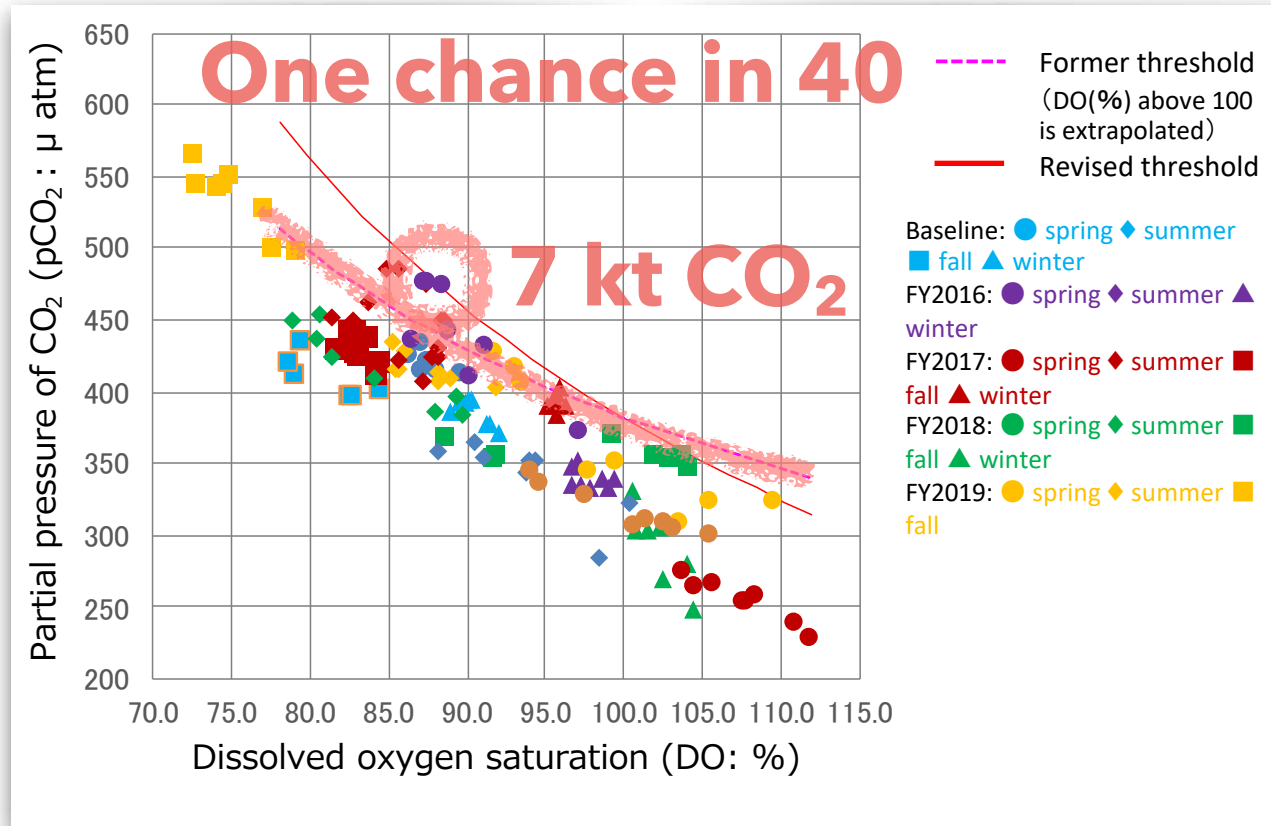
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# Shallow Survey for Containment Assurance?

## 95% Confidence Interval



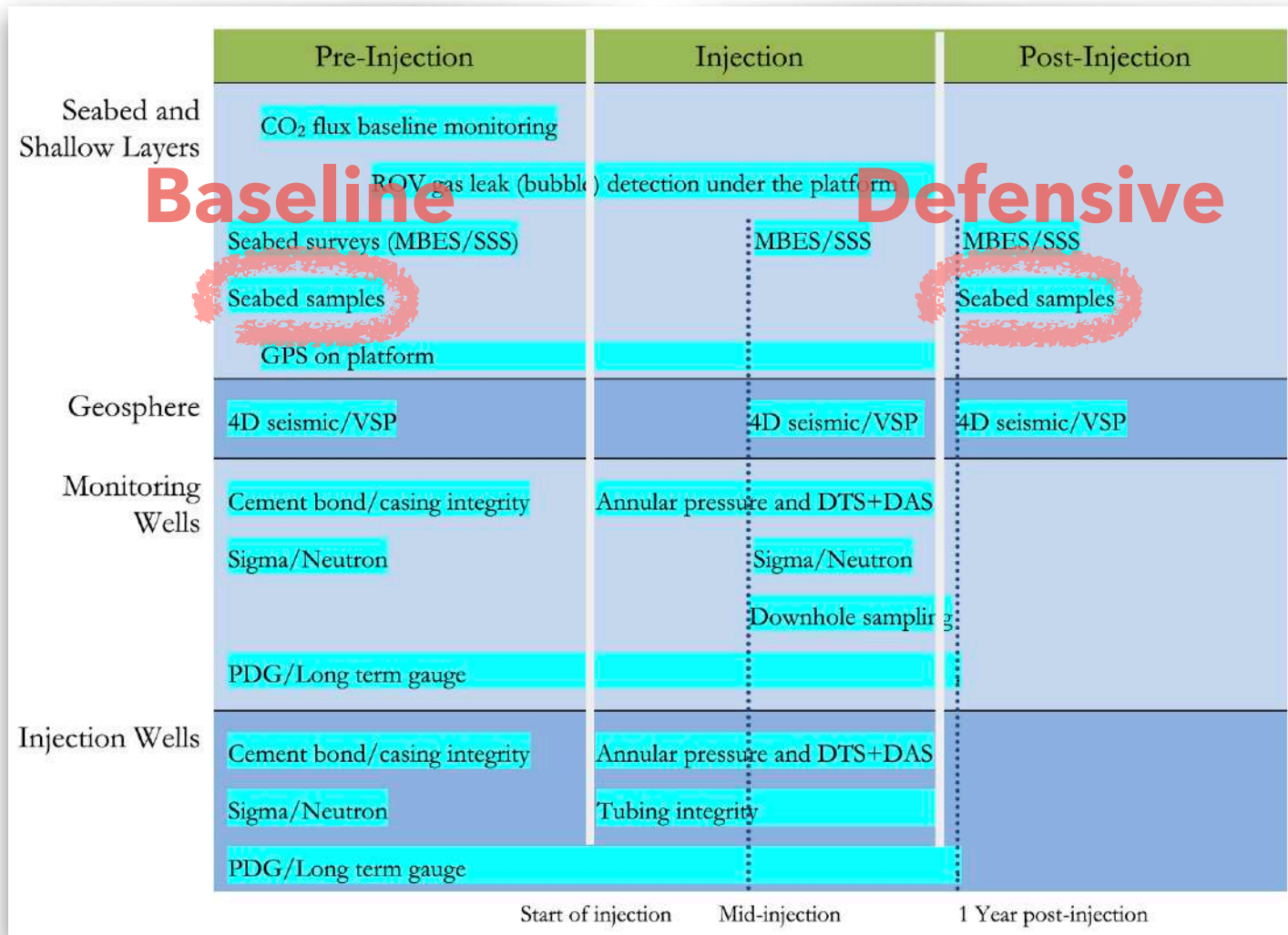
(JCCS: Summary Report on Tomakomai CCS Demonstration Project, 2020)

## Project Suspension (6 months) due to False Positive

Shallow properties "are all part of open systems that are perturbed by many more things than containment failure."

# M&V Reviewed and Revised: Quest to Peterhead

**M&V plan reviewed every 3 years**



(Dean and Tucker: IJGGC 61, 2017)

“Measurements intended to detect unlikely hazards were dropped or relegated to backup status.”

“... shallow monitoring should focus mainly on assuring against environmental impacts.”

(Jenkins et al.: IJGGC 40, 2015)

(Jenkins: IJGGC 100, 2020)

# Concluding Remarks (1)

- Investigative Data Acquisition
  - ▶ Invariably measured pressure (with high resolution) was successfully used for estimating CO<sub>2</sub> saturation changes through tidal-signal analyses.
  - ▶ Comprehensive monitoring of seismicity provides sufficient evidence to dismiss the causal relationship between the Tomakomai CCS and the 2018 Hokkaido Eastern Iburi earthquake.

# Concluding Remarks (2)

- Overuse of Shallow Monitoring
  - ▶ Loose correlation between pCO<sub>2</sub> and DO resulted in false positive and eventually hindered the operation.
  - ▶ A well-defined issue “containment” needs to be distinguished from vague concerns “environmental impact.”

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