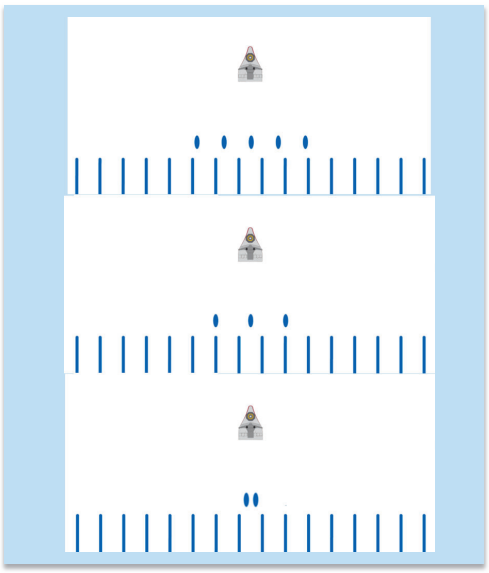
Erfaringer med ulike taue konfigurasjoner av lyttekablene som inkluderer flere små seismiske kilder

Martin Widmaier, Chief Geophysicist PGS Sales & Services

"Fisk og seismikk 2022", Lindesnes, 19.-20. April 2022

Outline

- Fisk & Seismikk, Ålesund, April 2016 - *revisited*
  - *"Marine Seismic Technology" by M. Widmaier*
- Evolution in Marine Seismic Source Configurations (2016 – 2022)
  - Marine seismic sources
  - Multi-source configurations
  - Wide-tow multi-source configurations
- Summary

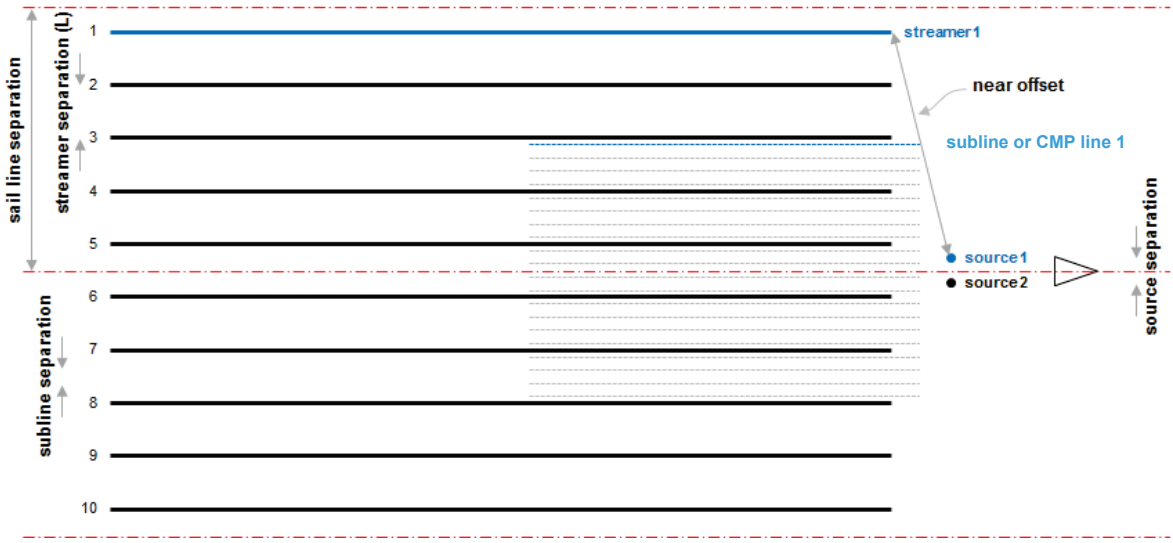


Main Elements of a Marine Seismic Acquisition System

- Marine Seismic Sources:
  - generate sound waves
- Receivers:
  - listening devices (sensors)
- Recording System:
  - store the recorded data

Reference: Widmaier, Fisk og Seismikk 2016, 6.-7. April, Ålesund

Schematic Example for Dual Source Acquisition (nomenclature)



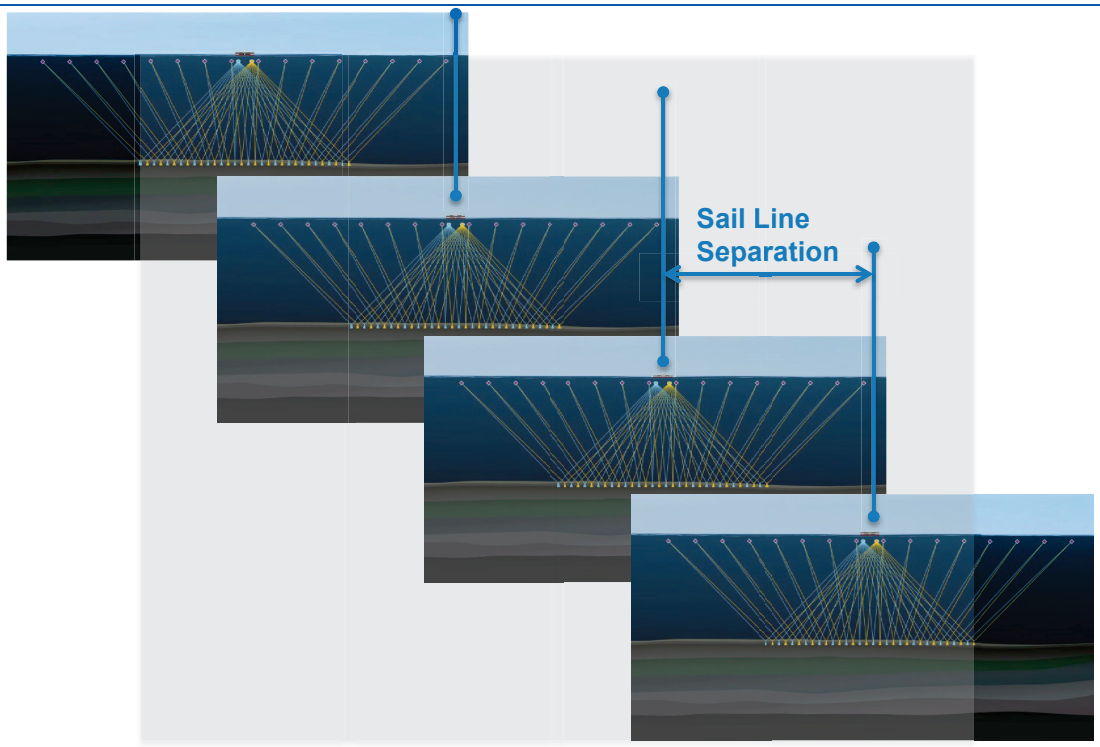
Reference: Long, First Break, November 2017

Increased Efficiency → Reduced Exposure

fewer days on each survey results in a smaller environmental footprint

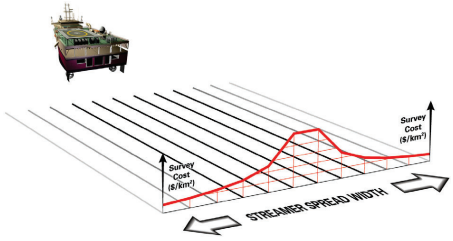
Reference: Widmaier, Fisk og Seismikk 2016, 6.-7. April, Ålesund

Larger Streamer Spreads and Faster Turnaround



Reference: Widmaier, Fisk og Seismikk 2016, 6.-7. April, Ålesund

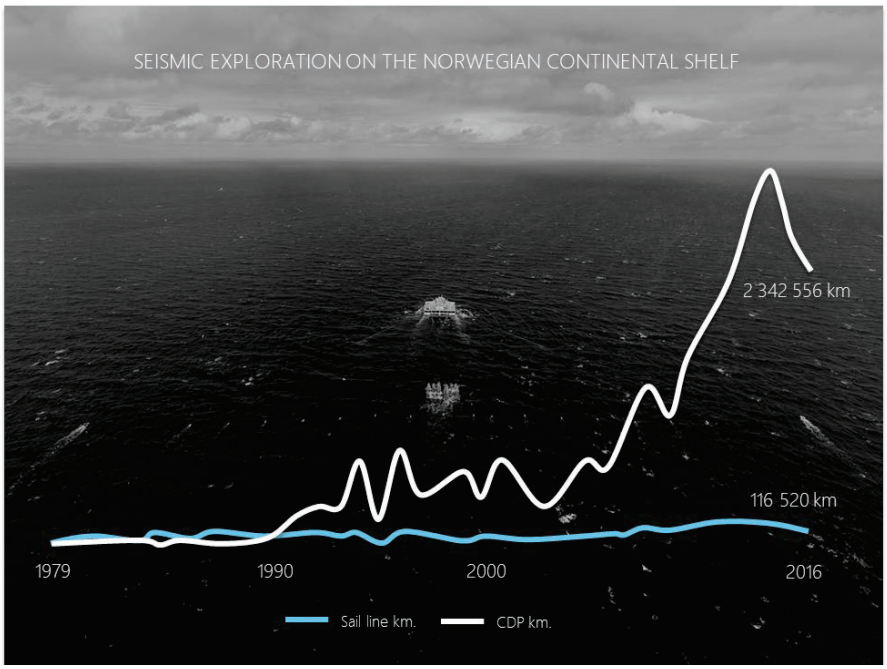
Larger Streamer Spreads and Faster Turnaround



	6 Streamer Vessel (2006)	16 Streamer Vessel (2016)
Configuration	6 streamers with 100m separation	16 streamer with 75m separation
Sail Line Separation	300m	600m
Number of Source Points	N	N/2
Survey Duration	M days	M/2 days

Reference: Widmaier, Fisk og Seismikk 2016, 6.-7. April, Ålesund

Larger Streamer Spreads and Faster Turnaround: Seismic Acquisition on the Norwegian Shelf 1979-2016



CMP line kilometers recorded versus sail line kilometers (boat kilometers).

Quote:

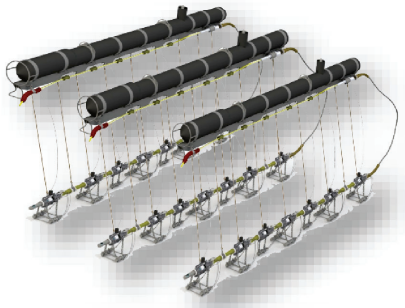
"Data acquisition, especially 3D / 4D data, has become much more efficient, while the use of (…) boat kilometers (blue line) has not changed that much."

Reference:
Facts pages, Norwegian Petroleum Directorate
https://www.npd.no/en/facts/seismic/

Marine Seismic Sources

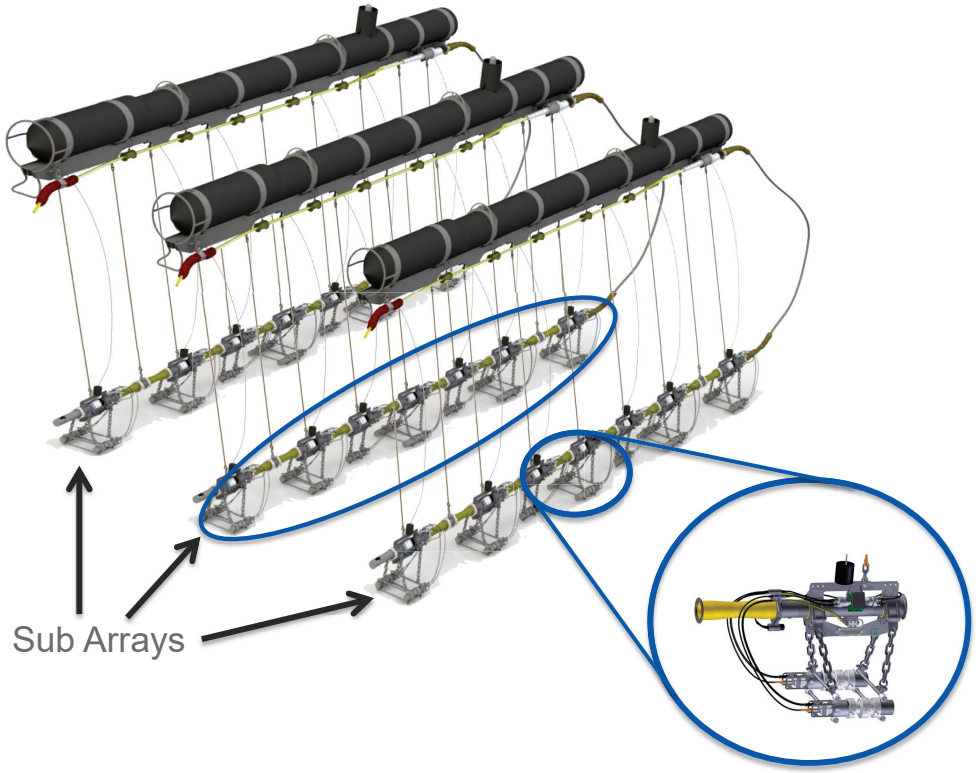
Marine Seismic Sources

- Definition
  - A seismic source releases energy into the earth in the form of seismic waves.
- "Shooting Seismic"
  - The seismic industry switched to non-dynamite marine seismic sources in the late 1960s.
- Seismic Source Arrays
  - Since the 1970's, the main source type in marine seismic is the air gun array.



seismic source array with air guns

Marine Seismic Source Array (Standard Dual Source Acquisition)



standard dual source acquisition

A seismic vessel is typically equipped with 6 sub arrays.

In a standard dual source configuration, each source array comprises 3 sub arrays.

The number of air guns per source array is typically between 30 and 40.

Multi-Source Configurations

From Dual Source to Triple Source (… and even more sources)

Triple-Source Simultaneous Shooting (TS3), A Future for Higher Density Seismic?

J. Langhammer* (TGS) & P. Bennion (TGS)

MADRID 2015
1-4 June 2015 I IFEMA Madrid

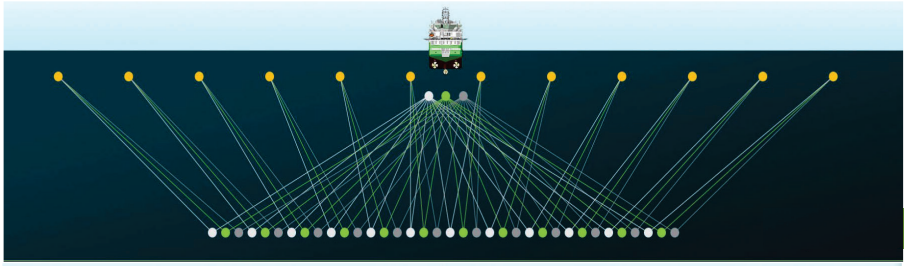
Quote from the publication's summary:

"The use of triple-sources in marine seismic streamer acquisition has been tested in the past, but with no significant commercial success compared to dual-source acquisition. (…)

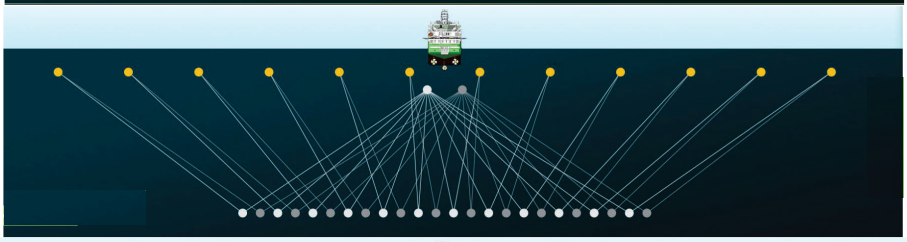
With (…) the ability to record and deblend simultaneous source data, it is time to revisit the use of triple-sources in marine seismic exploration for decreased crossline bin-size leading to better spatial resolution. (…)"

**) Reference: Langhammer and Bennion (2015), EAGE Conference Madrid.*

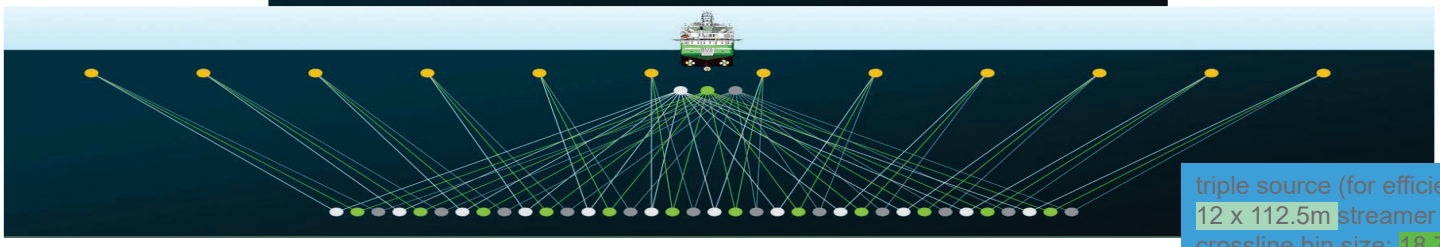
From Dual Source to Triple Source: Quality and/or Efficiency



triple source (for quality)
12 x 75m streamer spread
crossline bin size: 12.5m



dual source
12 x 75m streamer spread
crossline bin size: 18.75m



triple source (for efficiency)
12 x 112.5m streamer spread
crossline bin size: 18.75m

Reference: graphics from www.polarcus.com (ca. 2016; modified for illustration purposes)

From Dual Source to Triple Source (… and even more sources)

Triple-Source Simultaneous Shooting (TS3), A Future for Higher Density Seismic?

J. Langhammer* (TGS) & P. Bennion (TGS)

MADRID 2015
1-4 June 2015 I IFEMA Madrid

Since 2017, nearly all (!) commercial seismic 3D surveys (including ocean bottom surveys) on the Norwegian Continual Shelf (NCS) have been acquired with triple source configurations (or even quad, penta, hexa source).

Only 4D repeat surveys are typically acquired with dual or single source. New 4D baseline surveys tend to use multi-source solutions.

Evolution in Multi-Source Marine Seismic Configurations

Commercial multi-source surveys by seismic industry in Northern Europe (status Q2 2022)

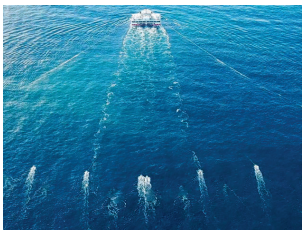
- Dual Source
- Triple Source
- Quad Source
- Penta Source
- Hexa Source

Multi-source solutions are usually based one (up to) 6 sub arrays, i.e., the standard source equipment of a seismic vessel.

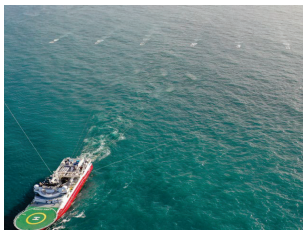
I.e., more source arrays result typically in reduced source volumes.

dual source (PGS)

triple source (CGG, Lundin)



penta source (PGS)



hexa source (PGS, Lundin & partners)

Evolution in Multi-Source Marine Seismic Configurations

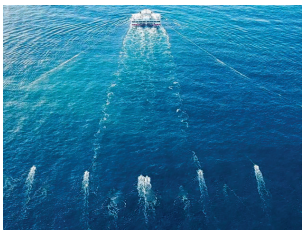
Commercial multi-source surveys by seismic industry in Northern Europe (status Q2 2022)

source	sub arrays per source	number of air guns per source array	source volume [cu. in.]
dual	3	ca 30 - 40	ca. 4000 – 5000
triple	2	ca 20	ca. 3000
quad, penta, hexa	1	ca 5 - 10	ca. 400 – 1500

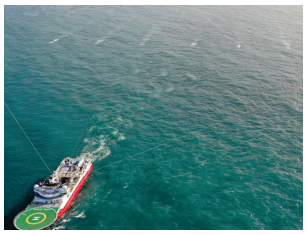
typical multi-source configuration parameters

dual source (PGS)

triple source (CGG, Lundin)



penta source (PGS)

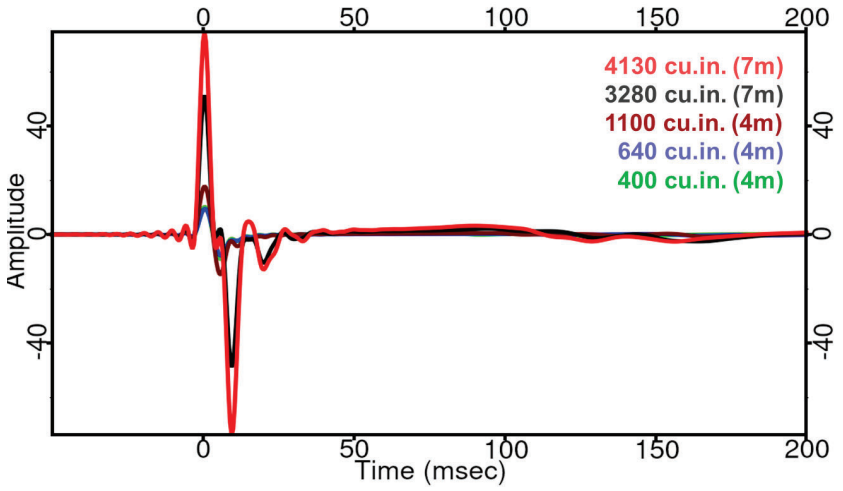


hexa source (PGS, Lundin & partners)

Qualitative Comparison of Output Signals for Multi-Source Solutions

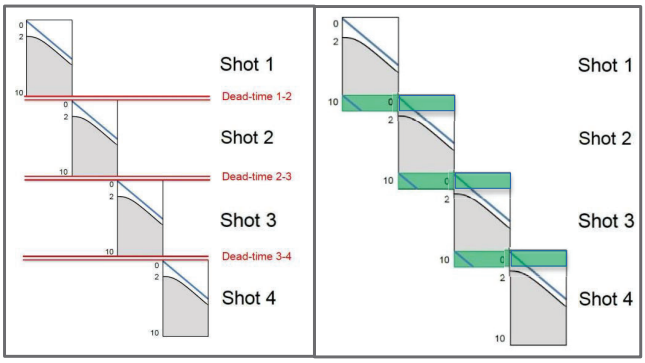
source	sub arrays per source	number of air guns per source array	source volume [cu. in.]
dual	3	ca 30 - 40	ca. 4000 – 5000
triple	2	ca 20	ca. 3000
quad, penta, hexa	1	ca 5 - 10	ca. 400 – 1500

typical multi-source configuration parameters

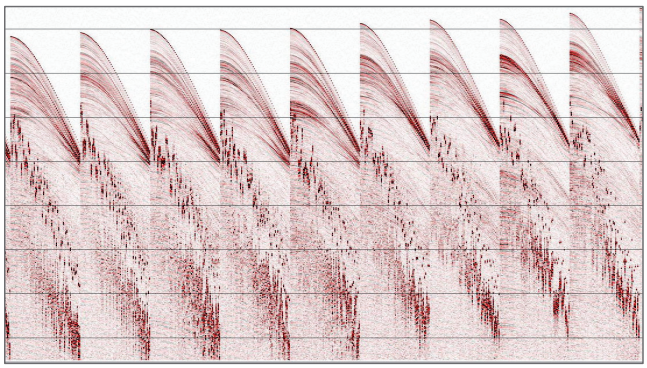


Multi-source arrays are typically designed with lower source volume and reduced peak pressure output compared to standard dual source arrays.

Shot Blending for Multi-Source Configurations



*A shorter pop interval leads to **overlapping** seismic records.*

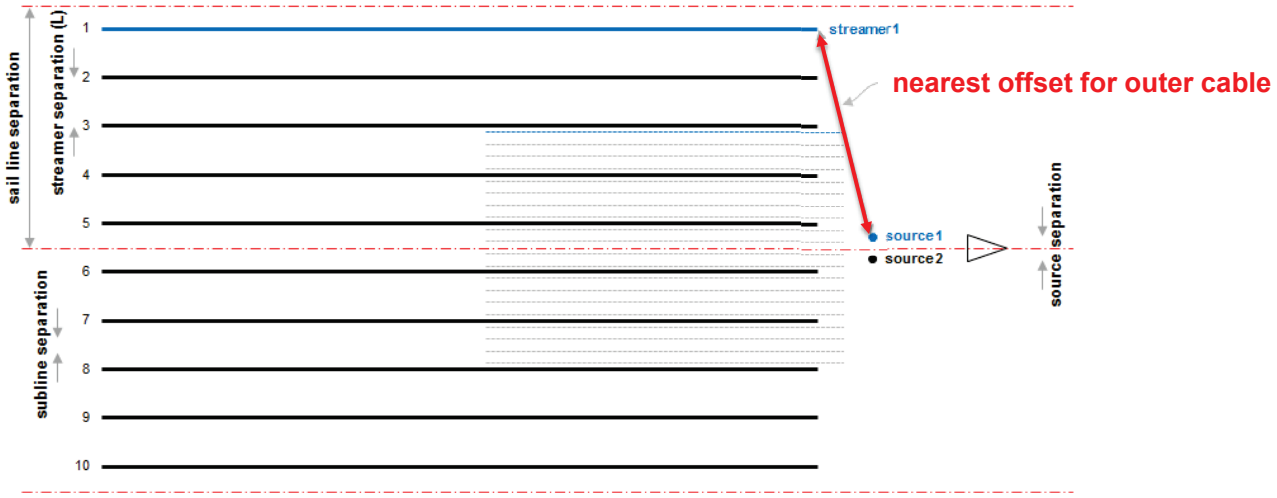


***Dithering/randomization** of source firing times to enable deblending.*

While multi-source geometries improve efficiency and/or spatial sampling in crossline direction, the implications for shot point sampling in inline direction and trace fold need to be addressed. Consequently, it is common practice to reduce the pop interval for multi-source operations compared to standard dual source surveys. Data acquired with a blending technique must be deblended in processing.

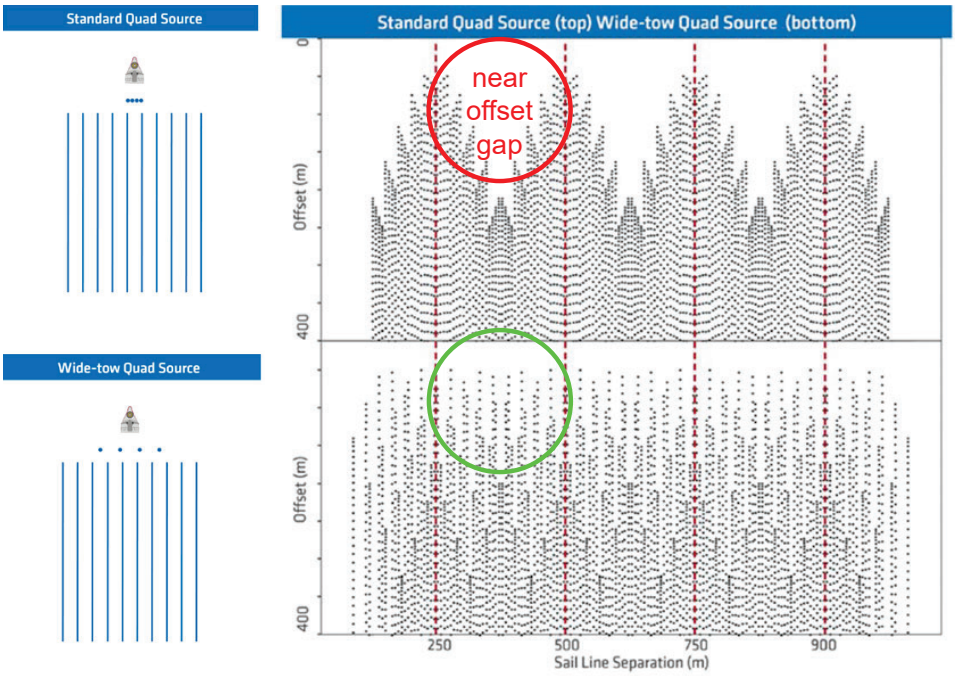
Wide-tow Multi-source Configurations

The Near Offsets Challenge (Standard Dual Source Configuration)



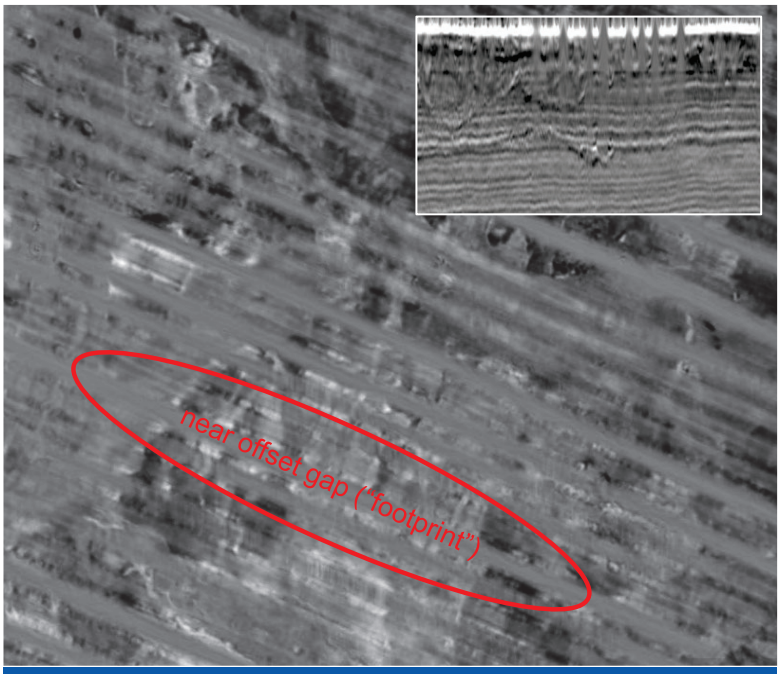
Wide-tow Multi-sources: Mitigating the Near Offset Challenge

- ✓ The near offset coverage can be improved by spreading out multiple sources without sacrificing efficiency (and without increasing survey cost).
- ✓ Wide-tow sources enable higher streamer counts, and thus higher survey efficiency without comprising the near offset coverage.
- ✓ Imaging workflows and seismic products benefit from modern data with rich near offset coverage.

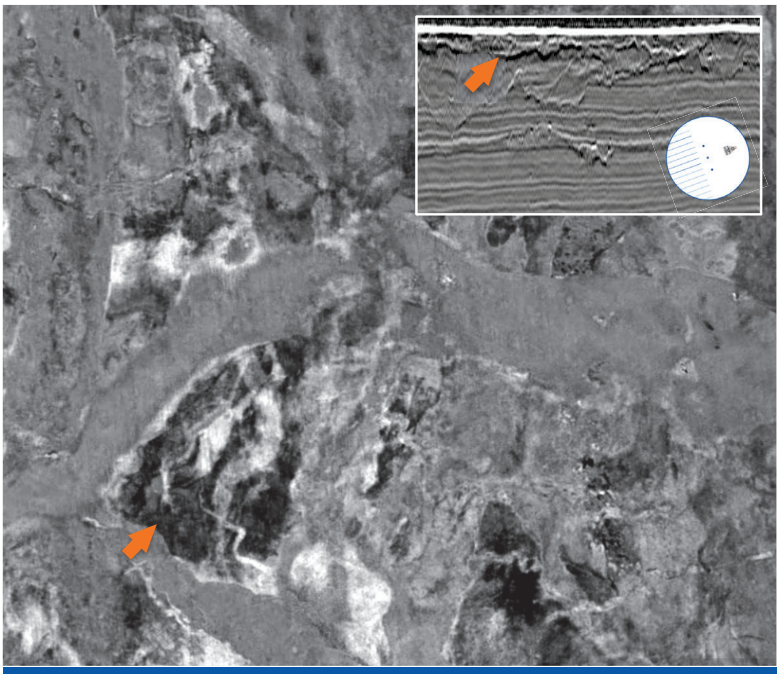


Widmaier, M., O'Dowd, D. and Roalkvam, C. [2019] Redefining marine towed-streamer acquisition. First Break, 37, No. 11

Maximizing Quality and Efficiency with Wide-tow Multi-source Configurations
Wide-tow Triple-source Viking Graben / North Sea 2019

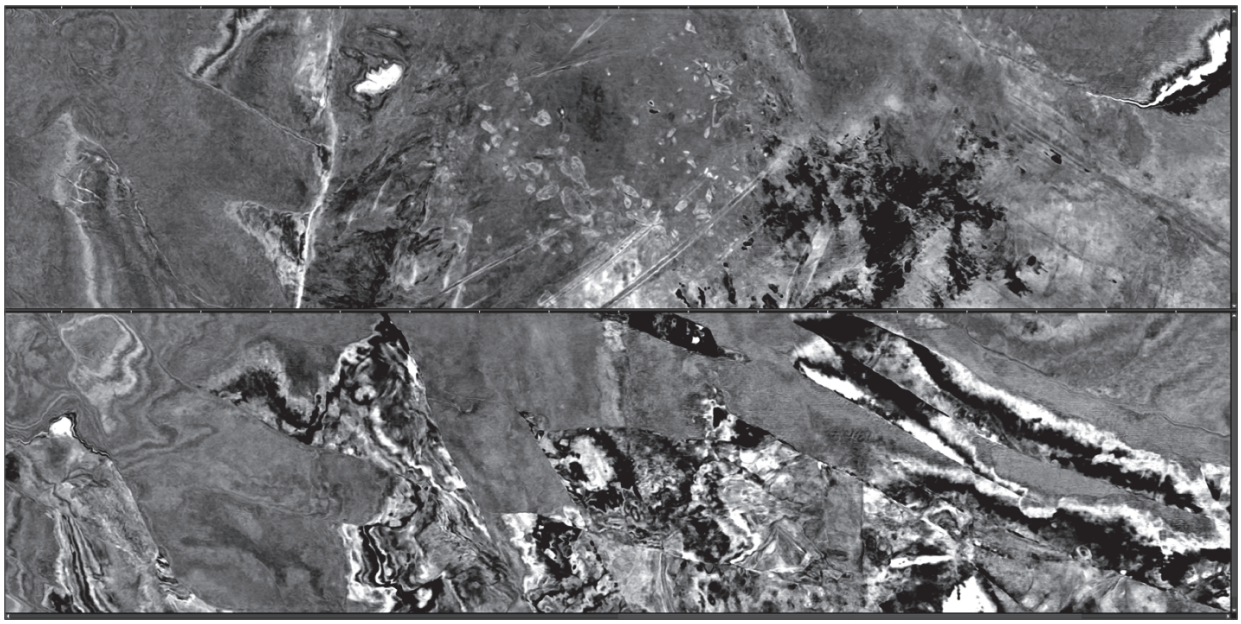


Legacy seismic data acquired with standard dual source



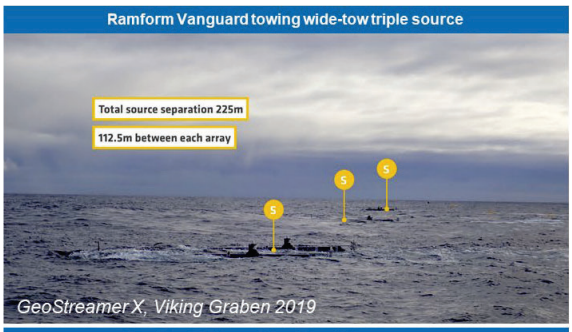
New wide-tow triple-source survey (2019)

Maximizing Quality and Efficiency with Wide-tow Multi-source Configurations
Wide-tow Penta-source Hammerfest Basin / Barents Sea 2020



- Depth slices at 410m and 468m below main sea level
- Water depth:
  - ca. 300m - 400m
- Processing bin size:
  - 6.25m x 6.25m
- Surface dimensions:
  - 21.9km x 5.3km
- High resolution near surface images *without* the typical near offset gaps at the sail line boundaries.

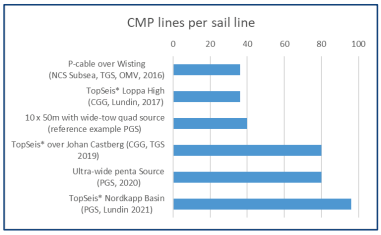
Wide-tow Multi-sources: PGS Examples & Experience 2019 - 2022



10 wide-tow multi-source surveys acquired since 2019. Survey number 11 has just started recently.

Maximizing Quality and Efficiency with Wide-tow Multi-source Configurations
Barents Sea 2016 – 2021: Acquisition Review

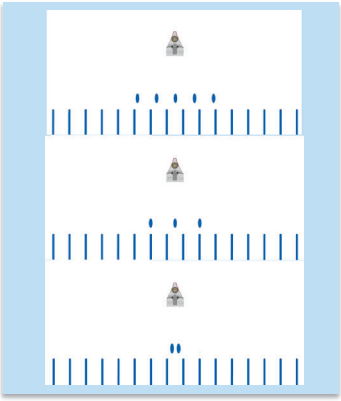
	number of streamers (pre-plot)	streamer separation [m]	number of sources N	sail line separation (based on streamer coverage) [m]	source separation	total source spread width [m]	XL bin size [m]	Normalized efficiency (sailline separation)	CMP lines acquired per sail line
P-cable over Wisting (NCS Subsea, TGS, OMV, 2016)	18	12.5	2	112.5	6.25	6.25	3.13	100%	36
TopSeis* Loppa High (CGG, Lundin, 2017)	12	50	3	300	66.67	133.33	8.33	267%	36
10 x 50m with wide-tow quad source (reference example PGS)	10	50	4	250	62.50	187.50	6.25	222%	40
TopSeis* over Johan Castberg (CGG, TGS 2019)	16	62.5	5	500	75.00	300.00	6.25	444%	80
Ultra-wide** penta source (PGS, 2020)	16	62.5	5	500	87.50	350.00	6.25	444%	80
TopSeis* Nordkapp Basin (PGS, Lundin 2021)	16	75	6	600	87.50	437.50	6.25	533%	96



The table summarizes advanced seismic survey configurations applied in the Barents Sea.
**) Two vessel operation*
***) Source separation slightly modified/optimized for comparison/illustration purposes.*

Summary

- Prior to ~2015/2016 efficiency and quality gains in marine seismic streamer acquisition were mainly driven by streamer technology and particularly by larger number of streamers and wider streamer spreads.
- Commercial multi-source operations, e.g., triple source acquisition, were (re-)introduced around 2016.
- Since 2016, the combination of multi-sources with large streamer counts have been instrumental to further optimize efficiency and data quality.
- Wide-tow multi-sources are the most recently commercialized technology advance and are effective in areas with shallow geological targets.
- Multi-source arrays are typically designed with lower source volume and reduced peak pressure output compared to standard dual source arrays.



Thank You!