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Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz
NLWKN Forschungsstelle Küste

Comparison of different sub-bottom profiling systems to be used in very shallow and tide-influenced areas

A case study in the backbarrier tidal flat of Norderney, Germany

Çiğdem Aşkar

Presentation Outline

1. Motivation
2. Study Area
3. Theoretical background
4. Systems in use
5. Results
6. Discussion
7. Conclusion

Motivation

- Shallow waters have a great importance due to the dominant human activities; thus, it is important to investigate the sub-bottom of these zones. Working in shallow waters is more complex than deep waters.
- Compared to towed seismic methods sub-bottom profiling is a more suitable acoustic method to investigate the sub-seabed in shallow waters.
- Therefore, this thesis aimed to compare different sub-bottom profiling systems available in the market, in a very shallow and tide-influenced area.

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Study Area

The Wadden Sea
https://www.waddensea-worldheritage.org/taking-shape

- The Wadden Sea is an example of the dynamic shallow water environments, which is an intertidal zone that extends between the south-eastern part of the North Sea and the coast of Netherlands, the German Bight, and the Danish coast. It consist of large tidal flats, tidal gullies, inlets and sandy barriers.
- The study area is the Norderney tidal inlet, which is located between the island Norderney and the mainland in the German Wadden Sea.
- It is connected to the North Sea via the channel Norderneyer Seegat.
- Busetief and Riffgat are the main tidal channels in Norderney tidal inlet. Hohes Riff, Itzendorplate and Norderneyer Inselwatt are the most important tidal flats.
- Tidal range is around 2.5 m and increases up to 3.2 m in the spring tides. The tidal inlet is ebb-dominant.

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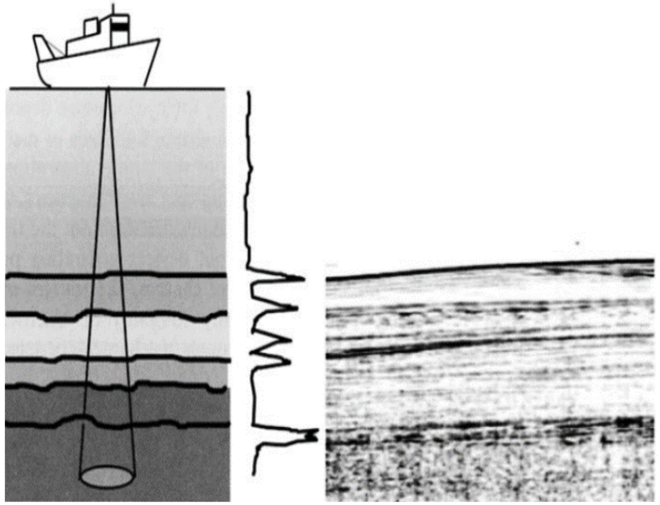
Sub-bottom Profiling (SBP)

- Sub-bottom profiling is used to investigate the characteristics of the seabed and sub-seabed layers as well as detecting buried objects, e.g., pipes or archaeological remains.
- The working principle is similar SBES, but SBP operates at lower frequencies, up to 10-12 kHz, and records the reflected echo not the backscattered.
- Sub-bottom layers are detected according to the difference in acoustic impedance ($Z = \rho c$).
- SBPs are suitable for near-surface investigations due to the used frequency range.
- Common SBP techniques: chirp and parametric systems



(Lurton, 2002)

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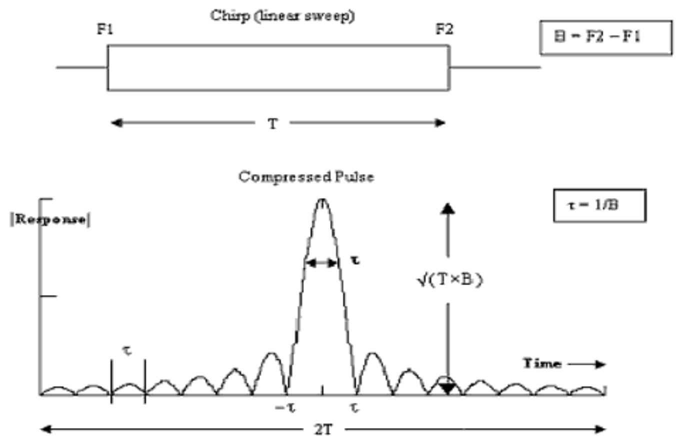
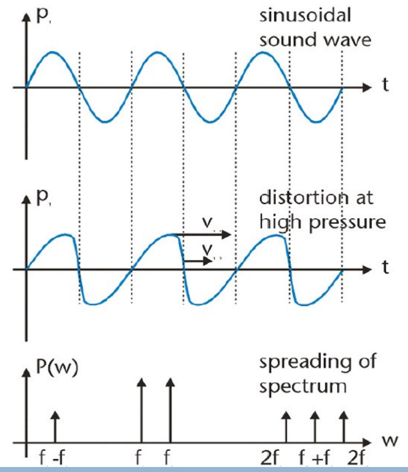
Chirp vs Parametric SBP Systems

- Chirp is a wide-band, frequency-modulated signal that sweeps a wide range of frequencies.
- Chirp SBPs increase the penetration depth with the use of a wide range of low frequencies. Also, a special technique, pulse compression, is applied on the received echo to maintain a good vertical resolution.
- The output signal, after applying the pulse compression, is compressed in time and increased in power.



https://en.wikipedia.org/wiki/Chirp_compression

- Parametric systems work with the nonlinear concept.
- Two high (primary) frequencies are sent into the water, which are superposed due to the medium's nonlinearity and produce new (secondary) frequencies, such as difference (low) frequency.
- The secondary low frequency has the narrow beam width of the primary high frequencies. Therefore, a greater penetration is possible while keeping the good resolution.



(Wunderlich & Müller, 2003)

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Systems in use

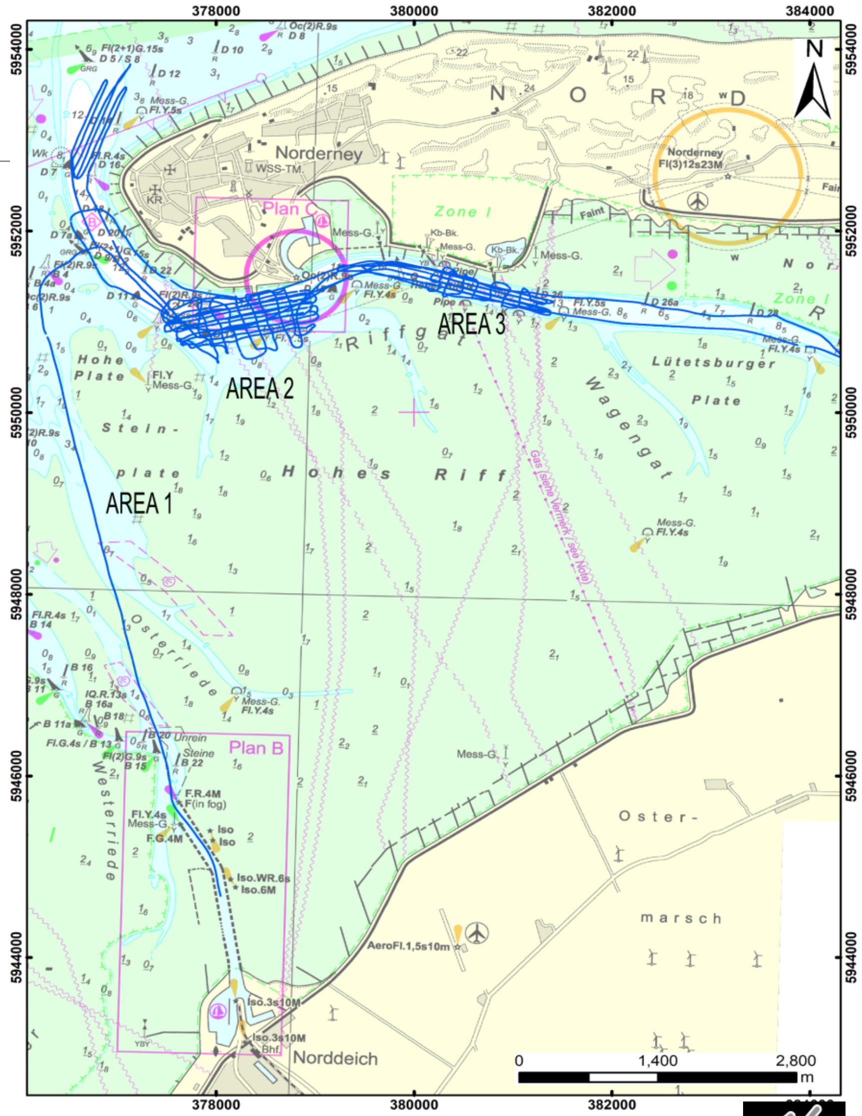
	Echoes 10000	SES-2000 Quattro	Topas PS 120
Company	iXblue	Innomar	Kongsberg
Technique	Chirp	Parametric	Parametric
Sediment Penetration	up to 20 m	up to 50 m	up to 50 m
Frequency	5 - 15 kHz	85 - 115 kHz (P*); 2 - 22 kHz (S**)	70 - 100 kHz (P);2 - 30 kHz (S)
Resolution	< 10 cm	up to 5 cm	up to 5 cm
Directivity	30° @ 10 kHz	±1.5° @ SBM***	4°- 6° (S)
Array Configuration	7 transducers	4 transducers	24 channels in 4 x 6 array

* P = Primary; ** S = Secondary; *** SBM = Single-beam Mode

Data Acquisition

- Vessel = MS Burchana (NLWKN)
- Auxiliary equipment = Motion sensor and GNSS antenna
- Vessel speed = ~ 5-7 knots
- Operating frequency = 8 kHz (parametric); 5-15 kHz (chirp)
- Pulse form = Ricker and chirp
- Pulse length = 1-3 ms
- Time = from March 2019 to May 2019


(Becker P., 2018)



Data Processing and Evaluation

Post-processing Steps:

Software: *Delph Seismic Interpretation by iXblue*

- Tide and sound velocity corrections
- Matched filter for the chirp data
- Bandpass filter for the ricker data
- Automatic Gain Control (AGC)
- Removal of the water column

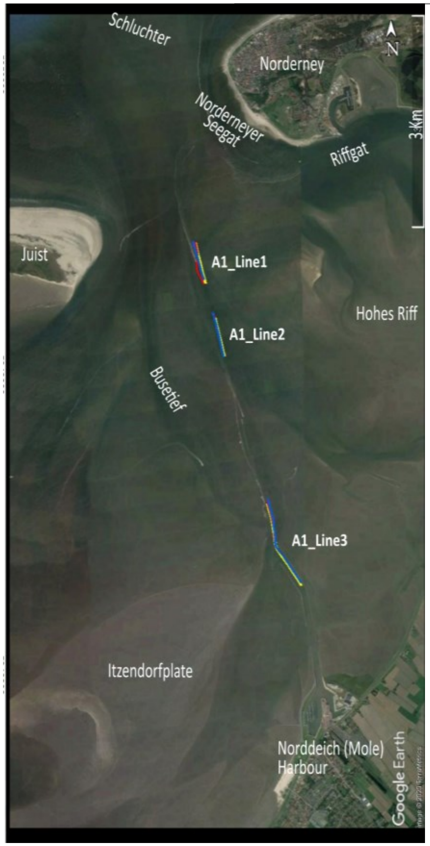
Evaluation Criteria:

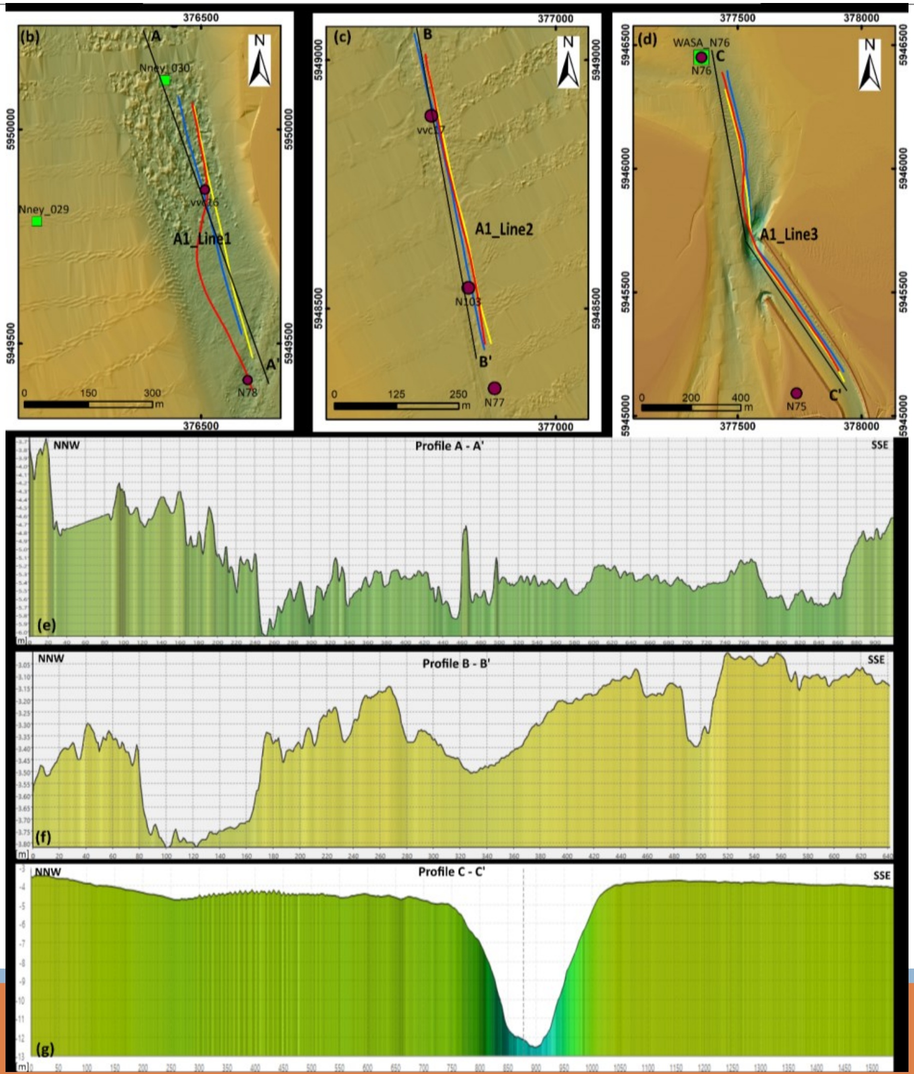
- Penetration depth
- Resolution
- Visualisation of the data

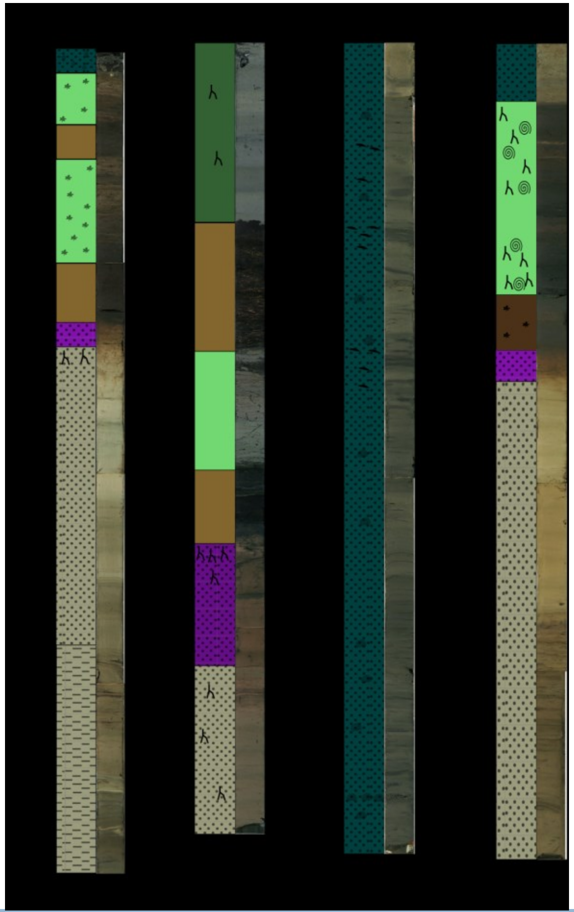
Auxiliary Data (provided by the FSK):

- Bathymetric and backscatter data
- Grab and core sample analyses

Results: Area 1








Source: Wikipedia

Results: Area 1

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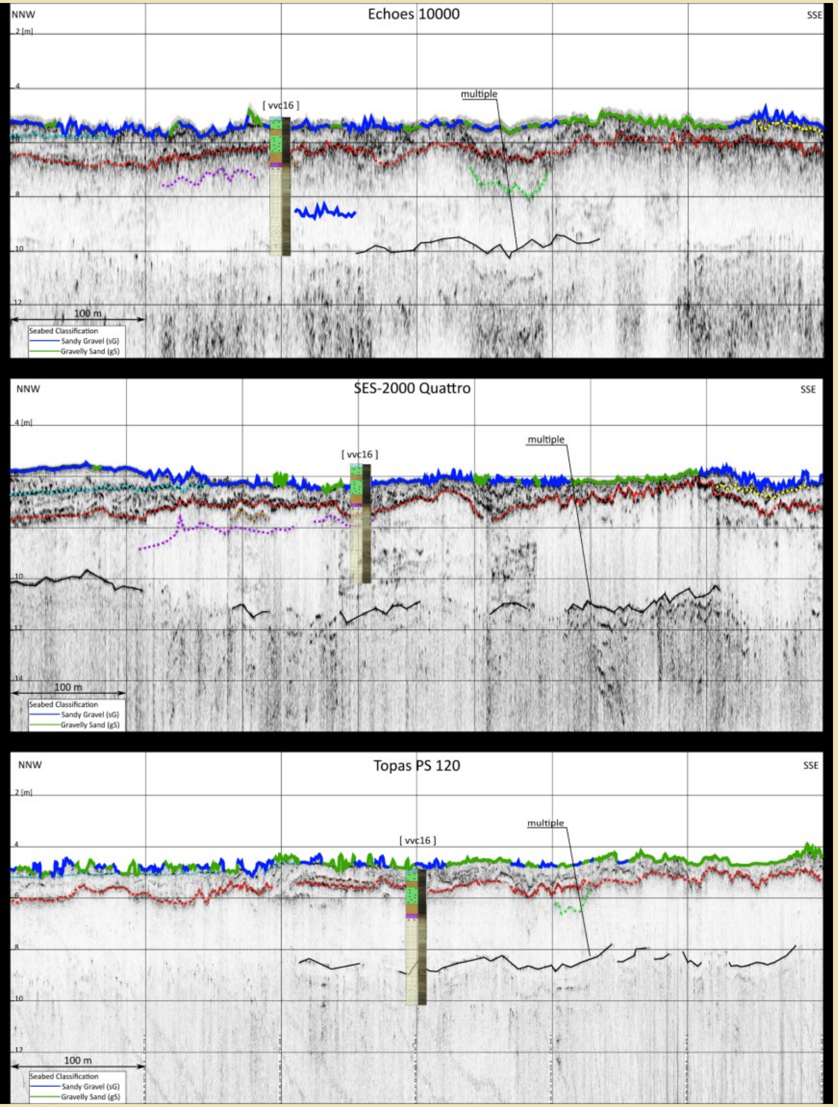

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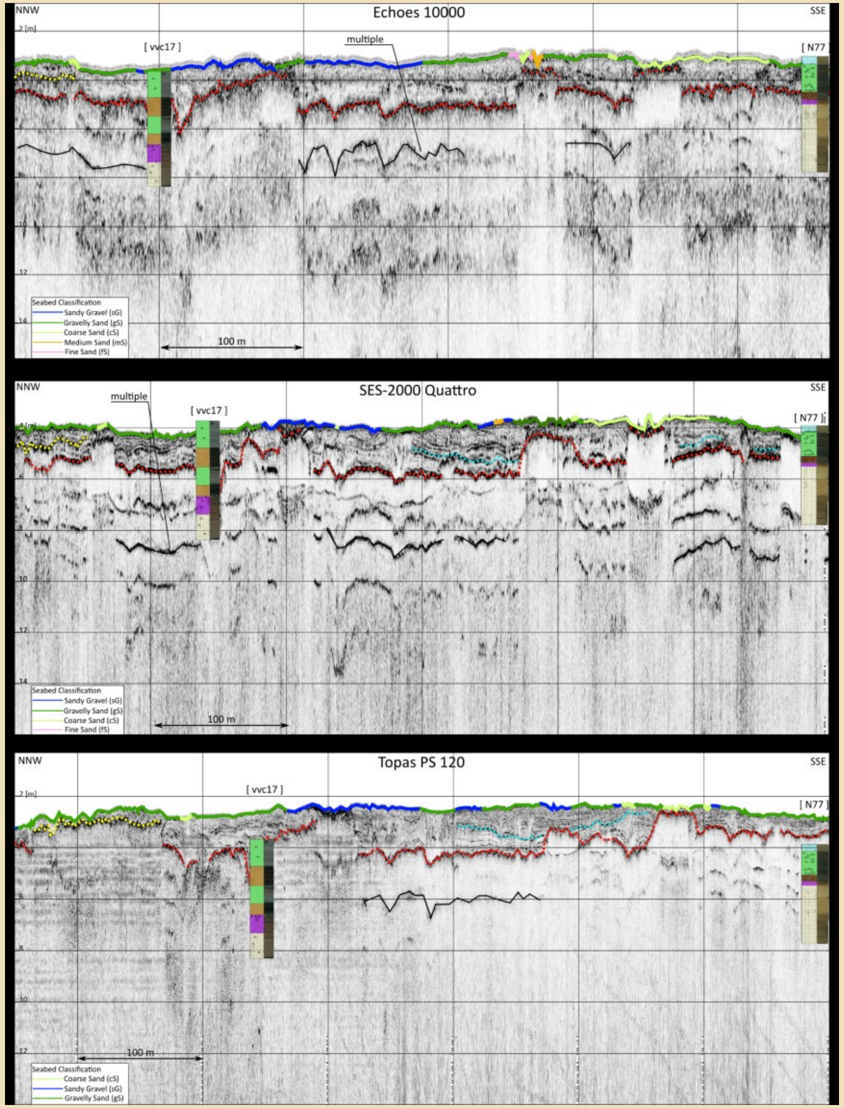

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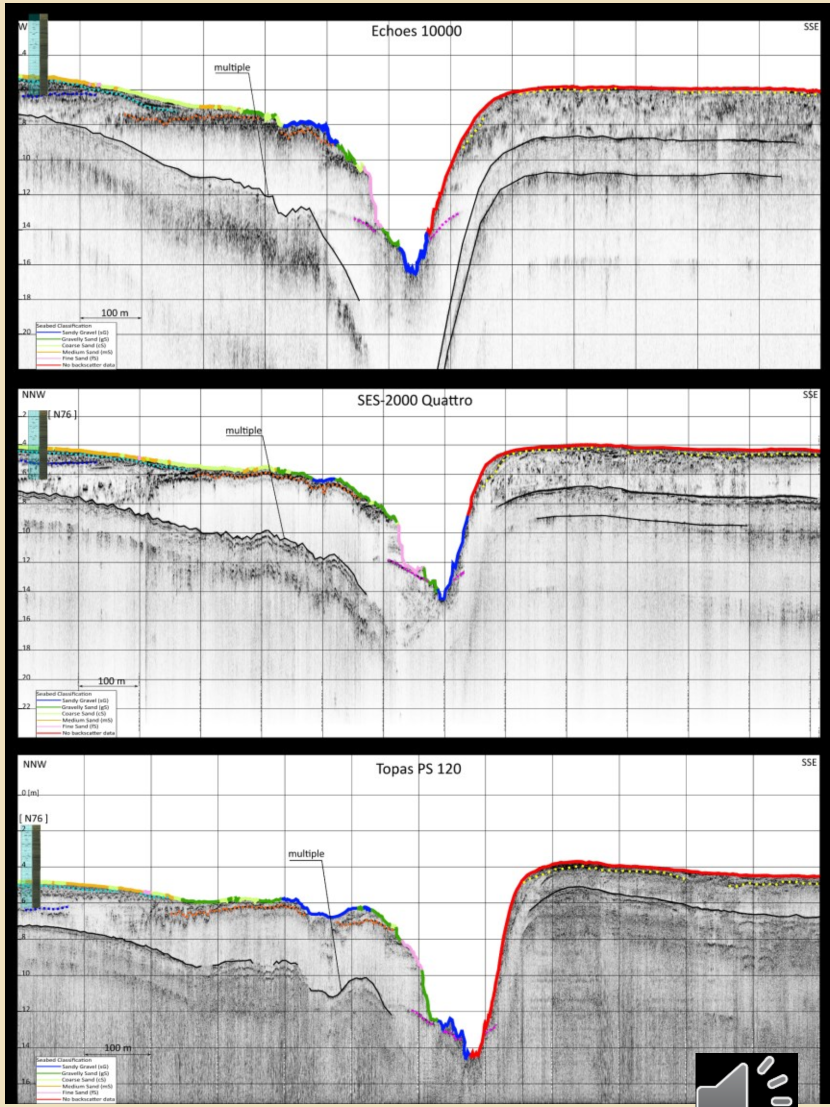

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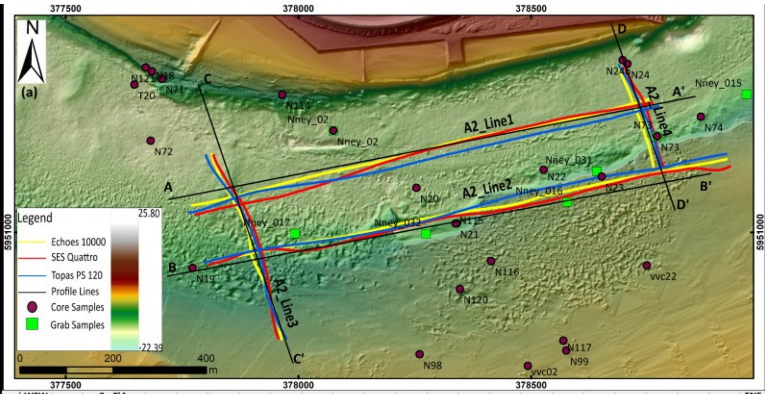
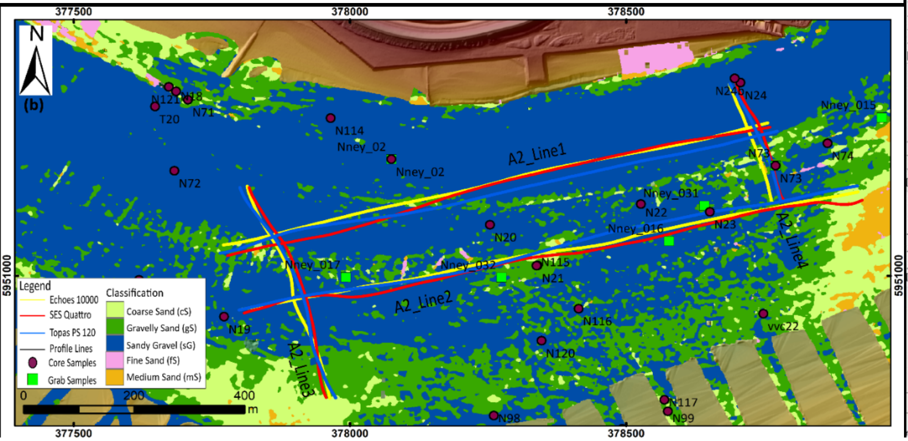
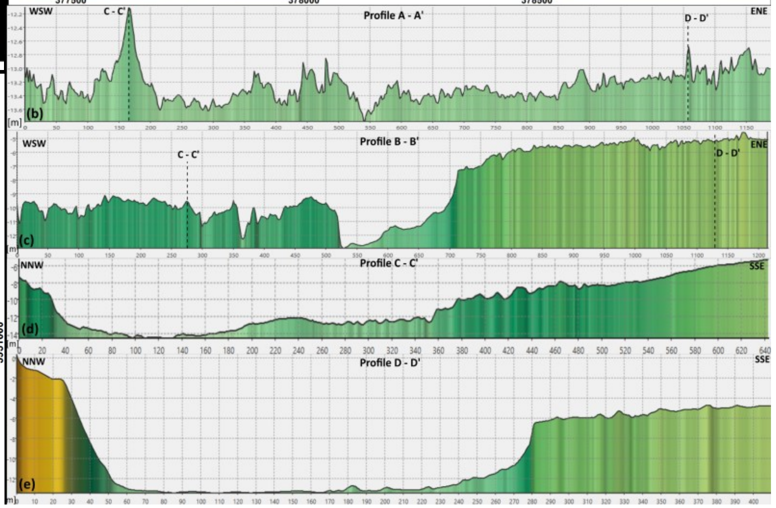
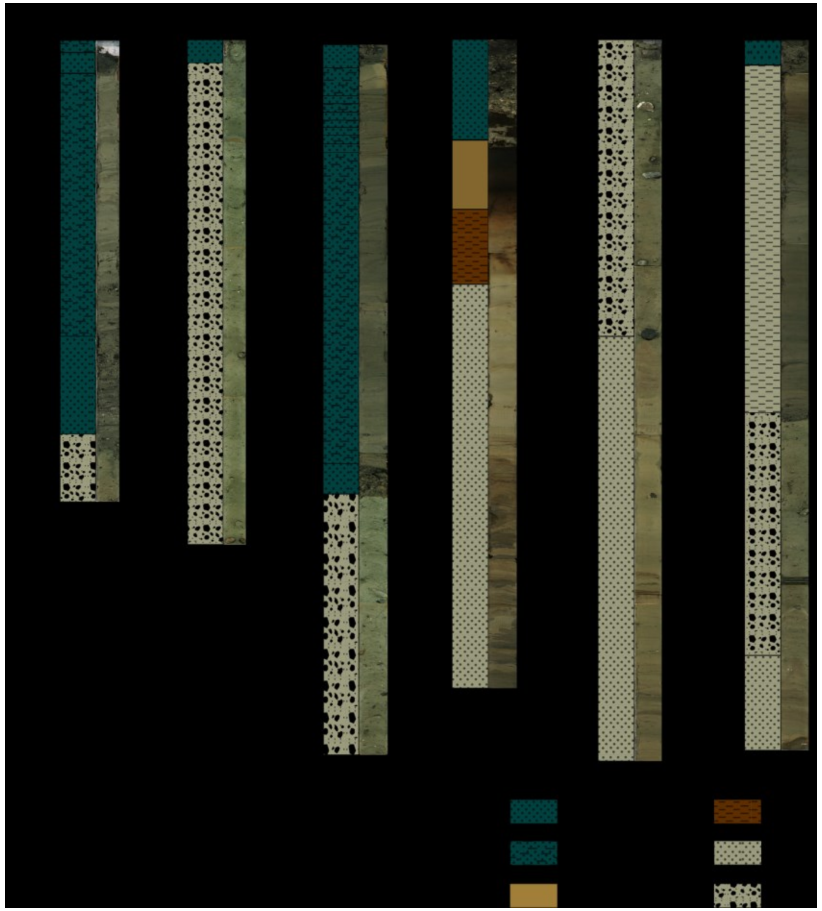
Results: Area 2









Results: Area 2

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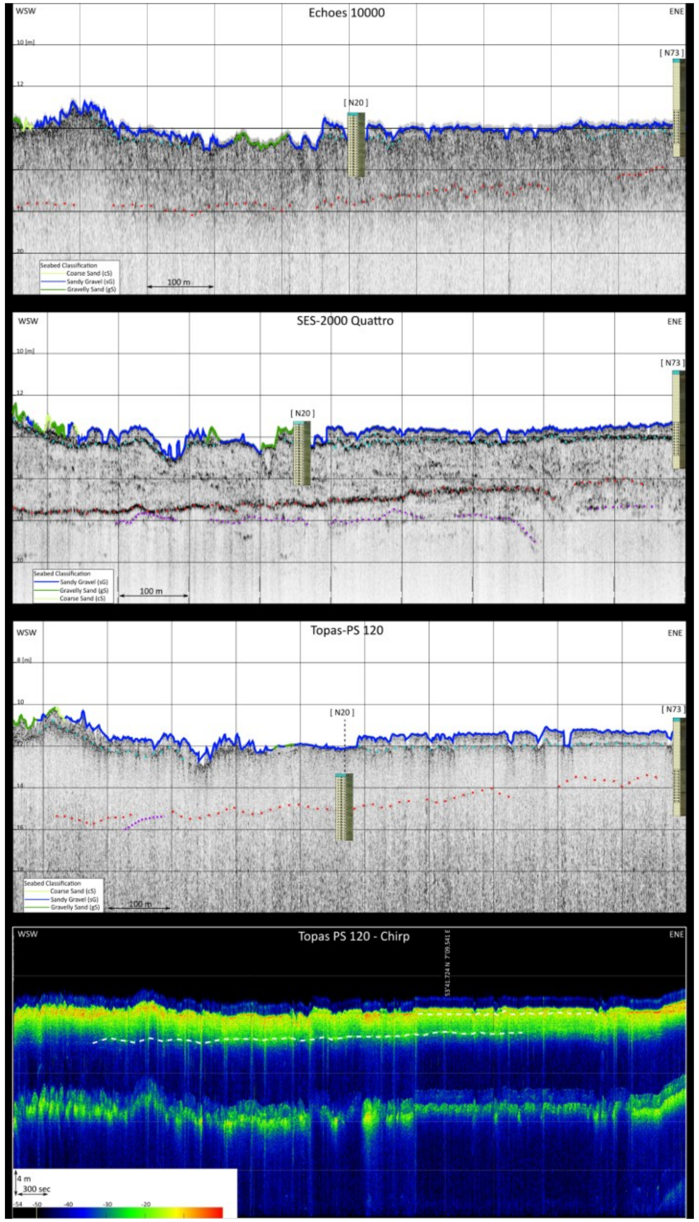

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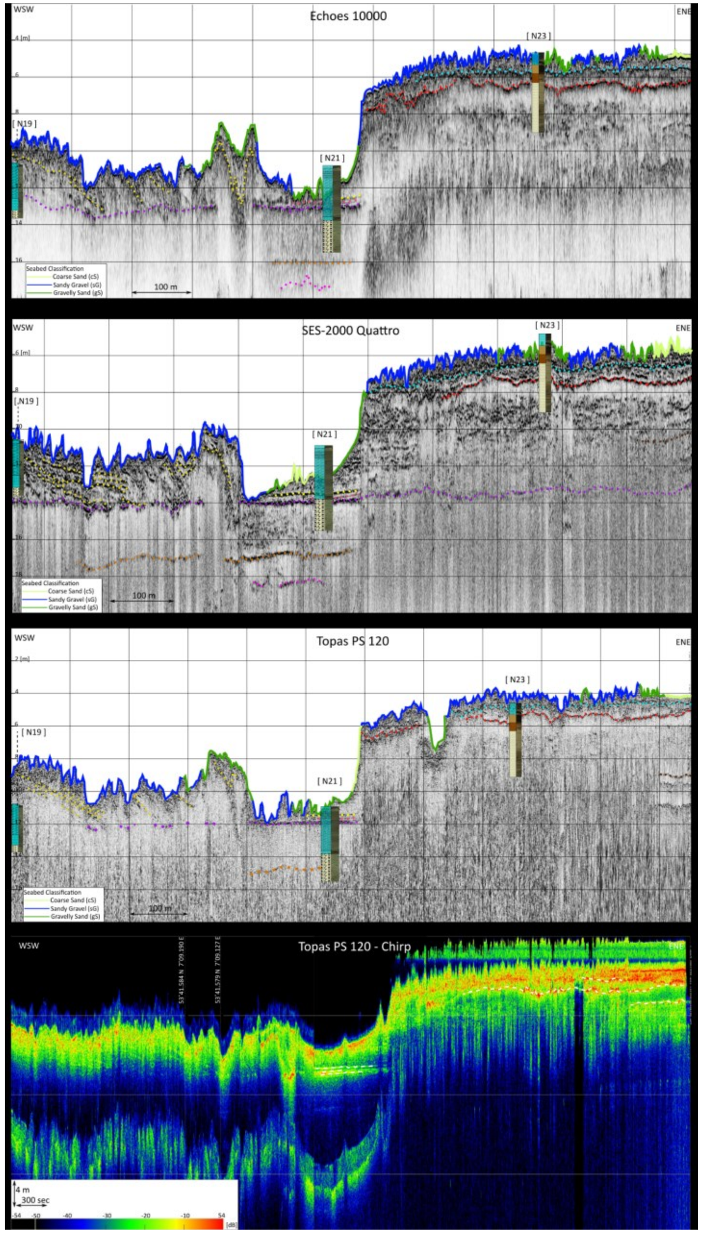

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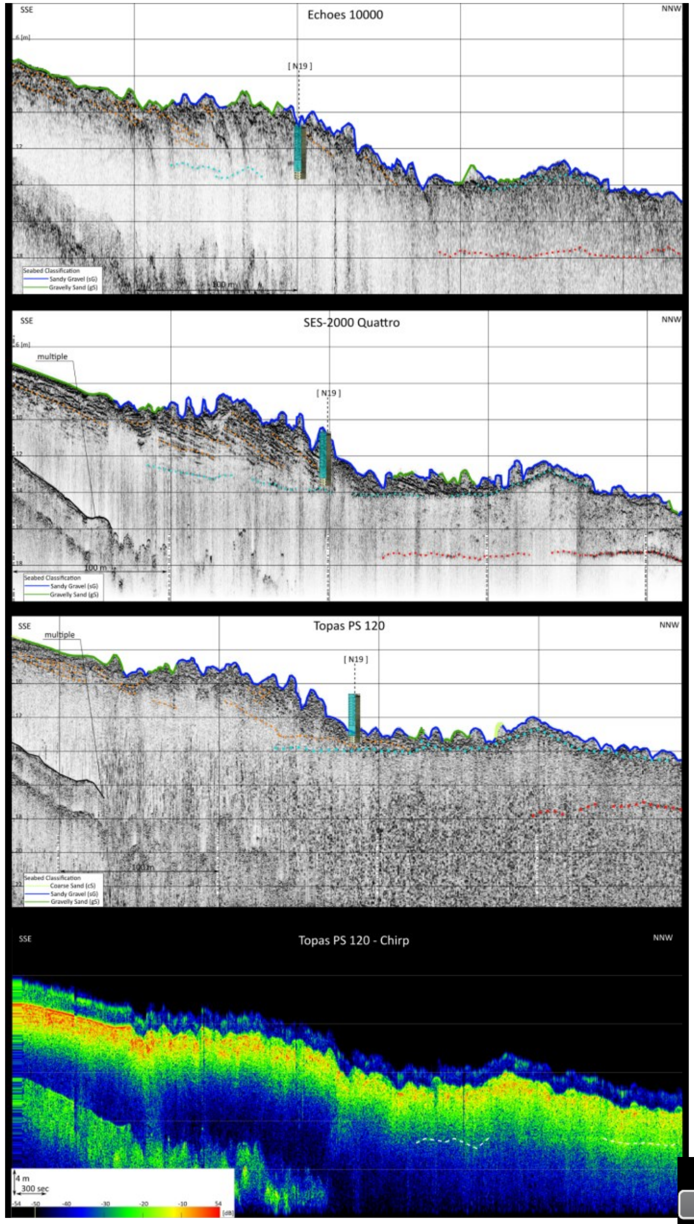
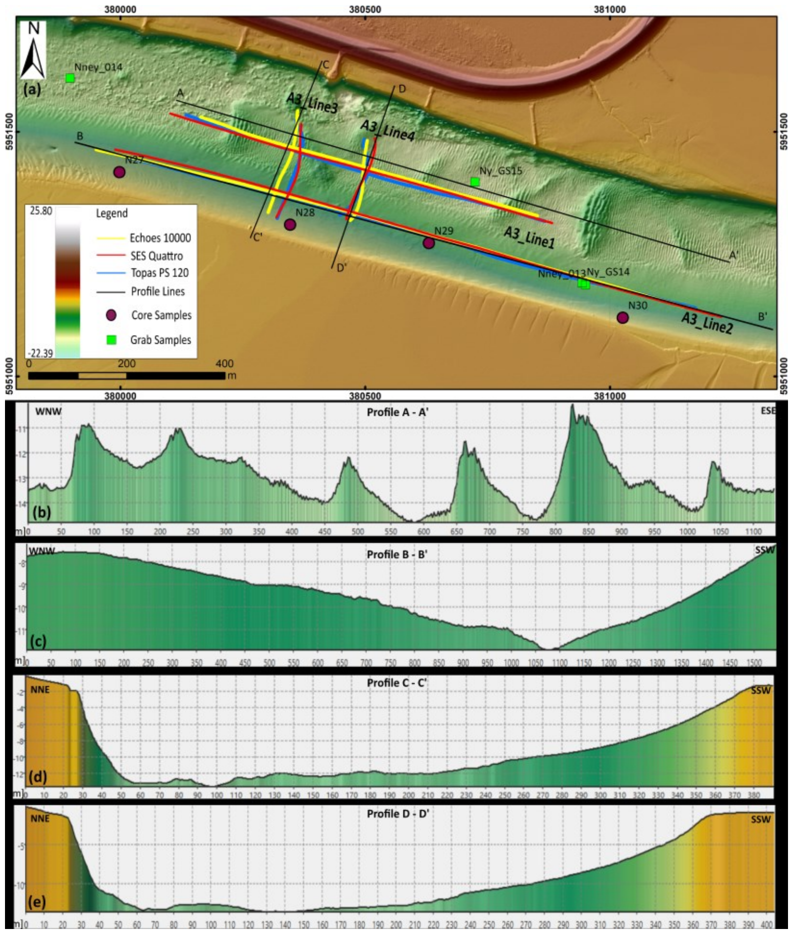
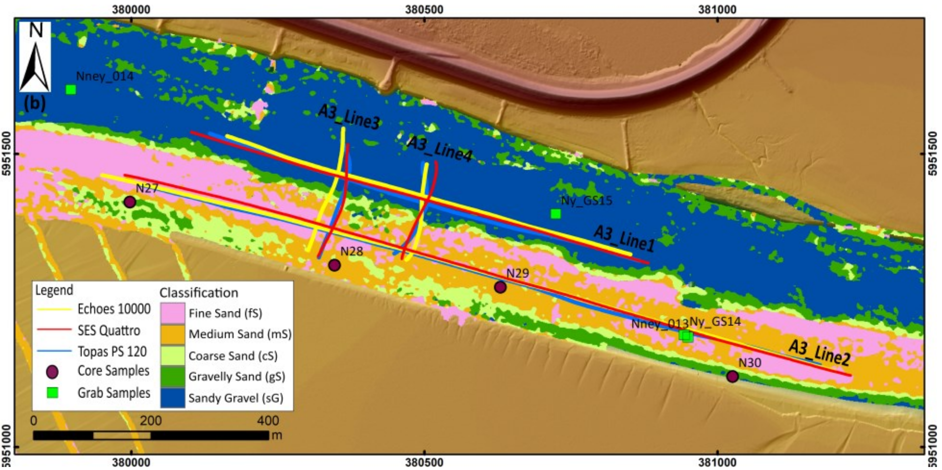
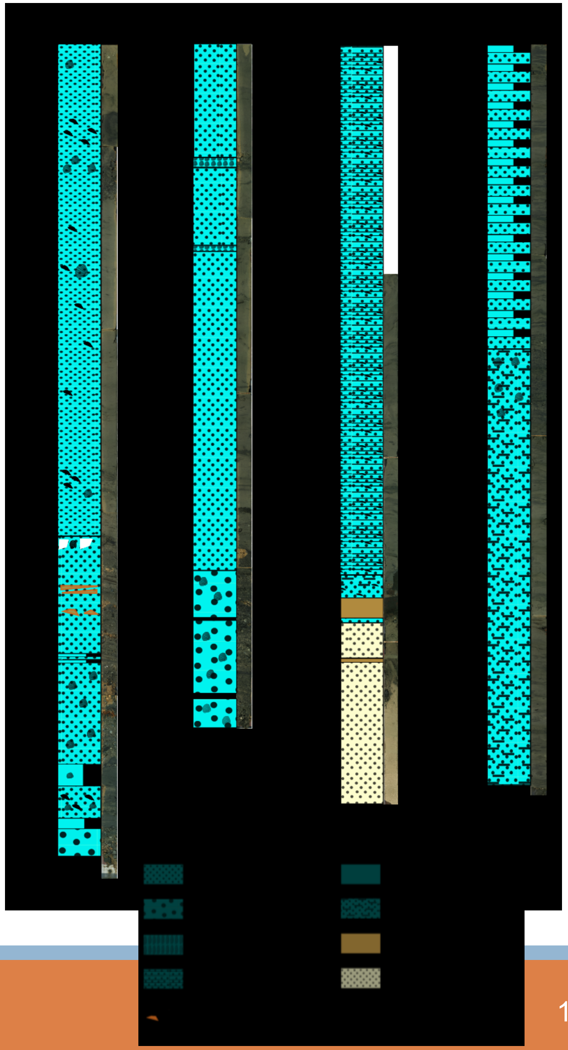


Results: Area 3







Results: Area 3

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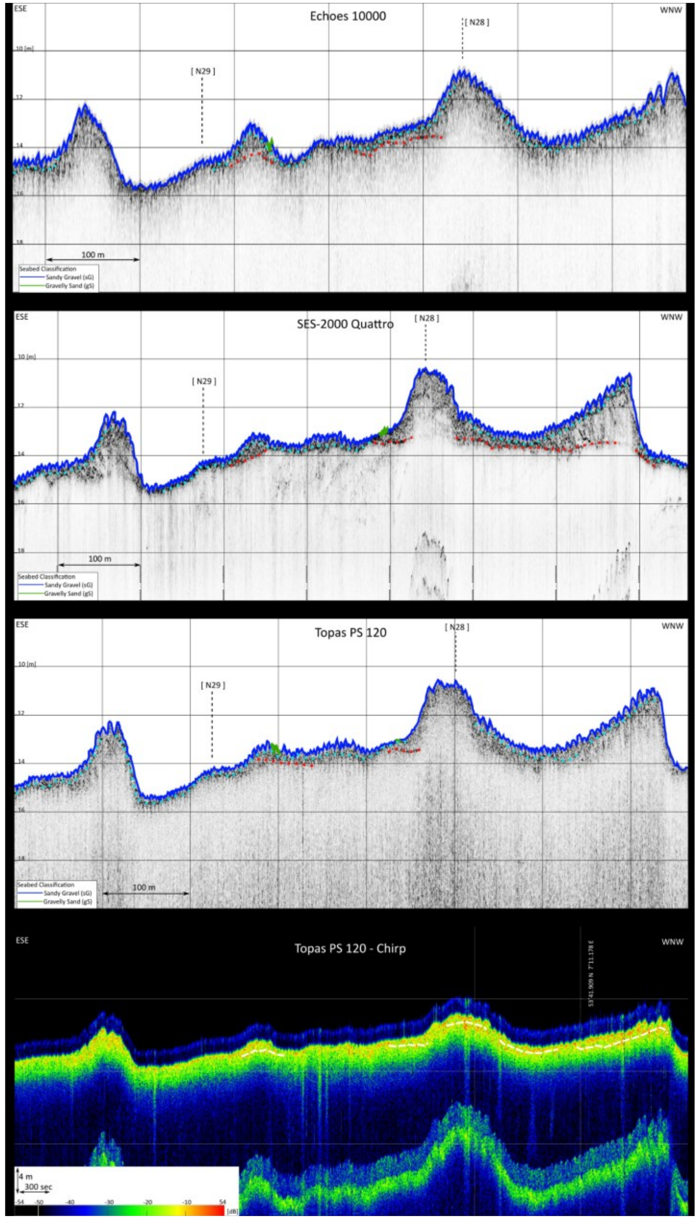

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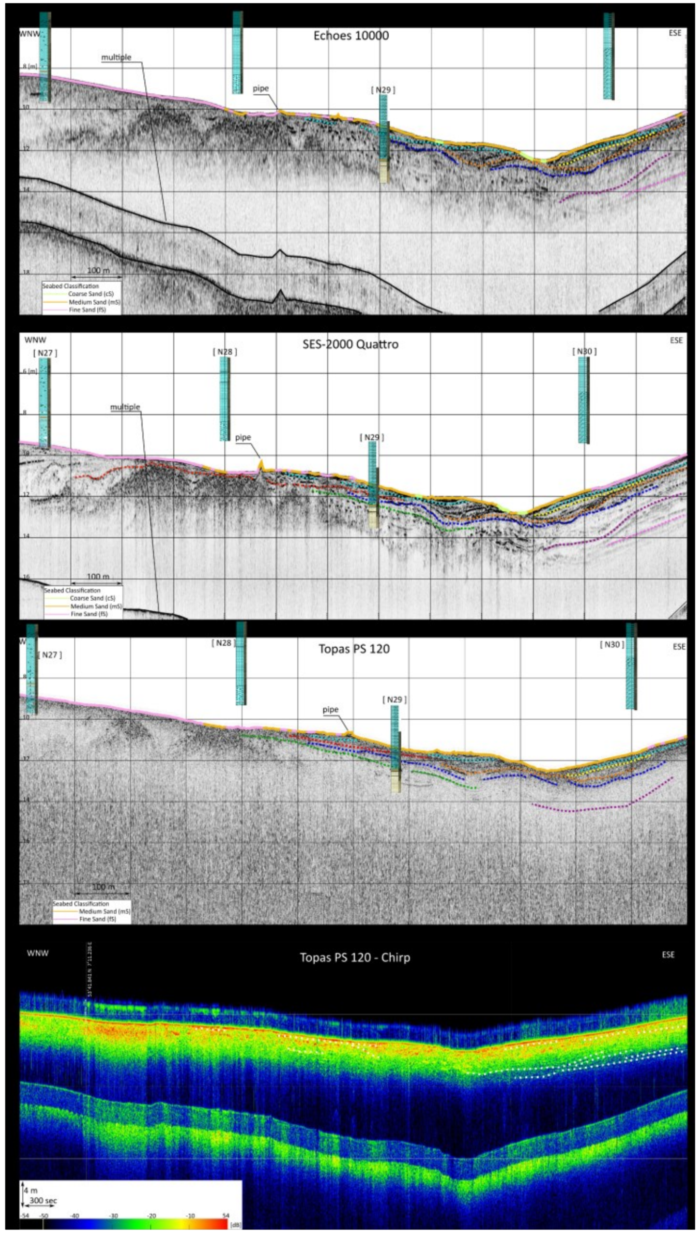

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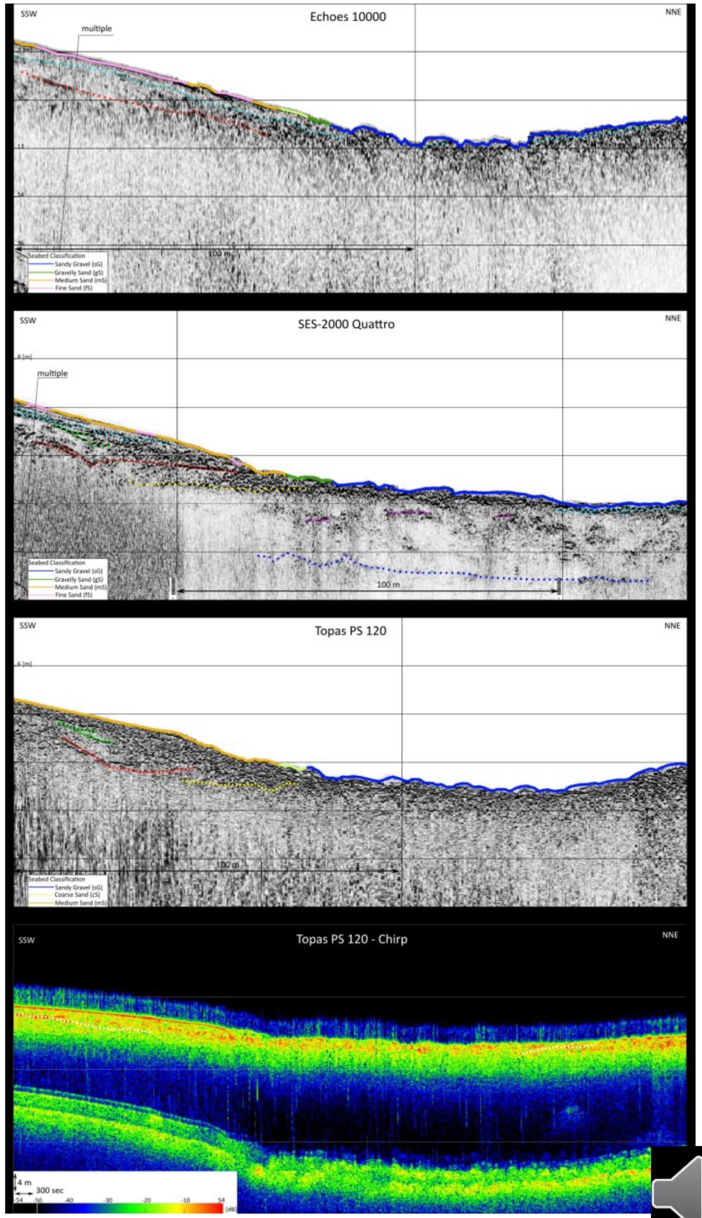

Discussion

- **Penetration** was around 4 - 7 m in the study area.
  - Less than their stated penetration capabilities
  - Limited by the characteristics of the areas, e.g. shallow water, coarse sediments, gaseous sediments, homogenous deposits.
- Each system offered a good **vertical resolution,** the best around 7- 9 cm.
- **Visual presentation of the reflectors** were stronger on SES-2000 Quattro.

Conclusion

- Each system used in the study promised a reliable performance; although, they were affected by the surveyed areas' complex settings.
- The parametric SES-2000 Quattro provided better penetration capability while maintaining a good resolution.
- The parametric Topas PS 120 and chirp system Echoes 10000 performed similarly in the penetration they achieved.
- The visual representation of reflectors on Echoes 10000 was weaker than on the parametric SES-2000 Quattro, whereas the parametric Topas PS 120 also provided a weak visualization.
- All systems performed well regarding the vertical resolution. The thinnest layers displayed by each profiler were as thin as 7-9 cm.
- The setup and the handling of the software during data acquisition/processing were straightforward for all systems.

Thank you for your interest.