Bundesanstalt für Wasserbau
Federal Waterways Engineering and Research Institute

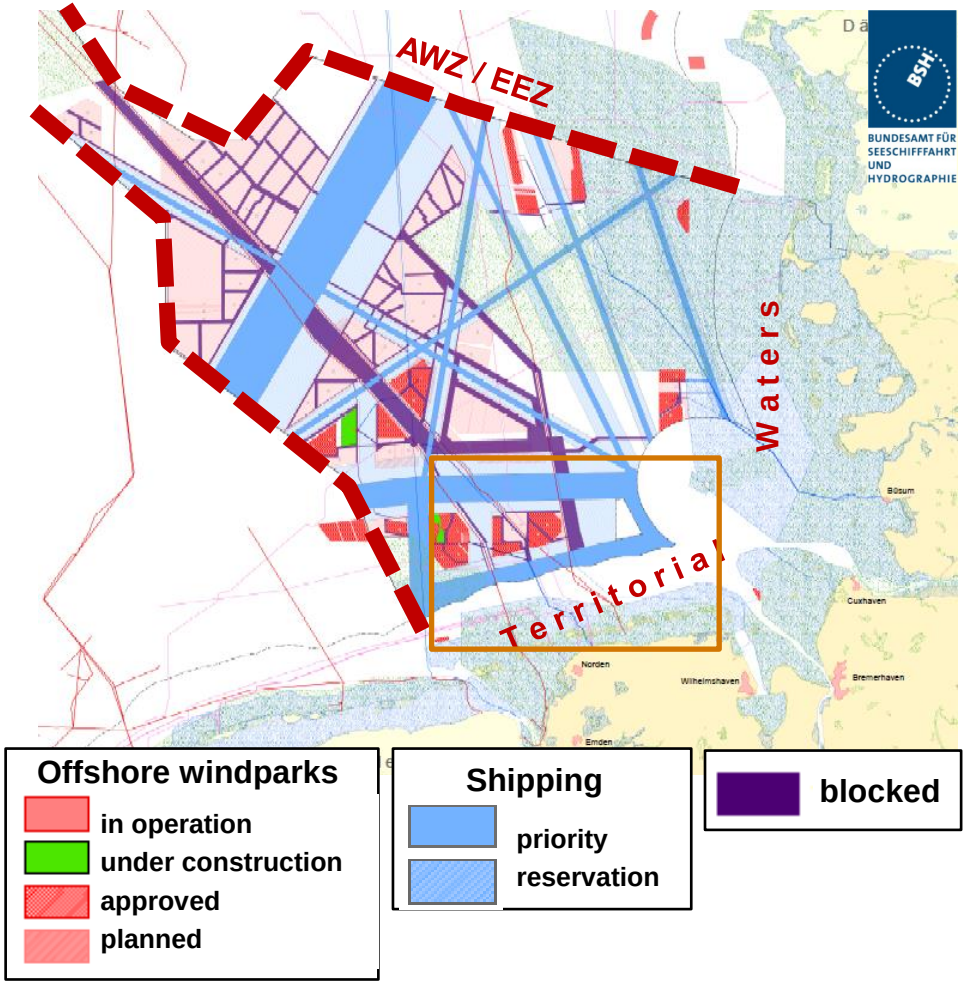
Christian Maushake
Federal Waterways Engineering and Research Institute (BAW)

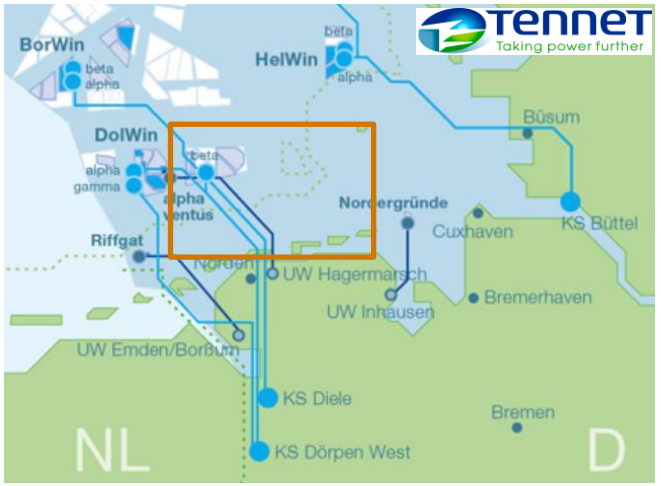
How deep does an anchor penetrate the seafloor?

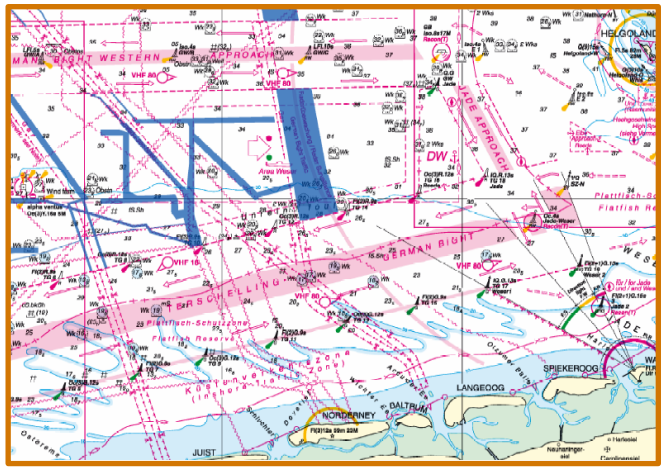
Anchor tests in the German Bight

The Northsea
… an undisturbed wideness ?

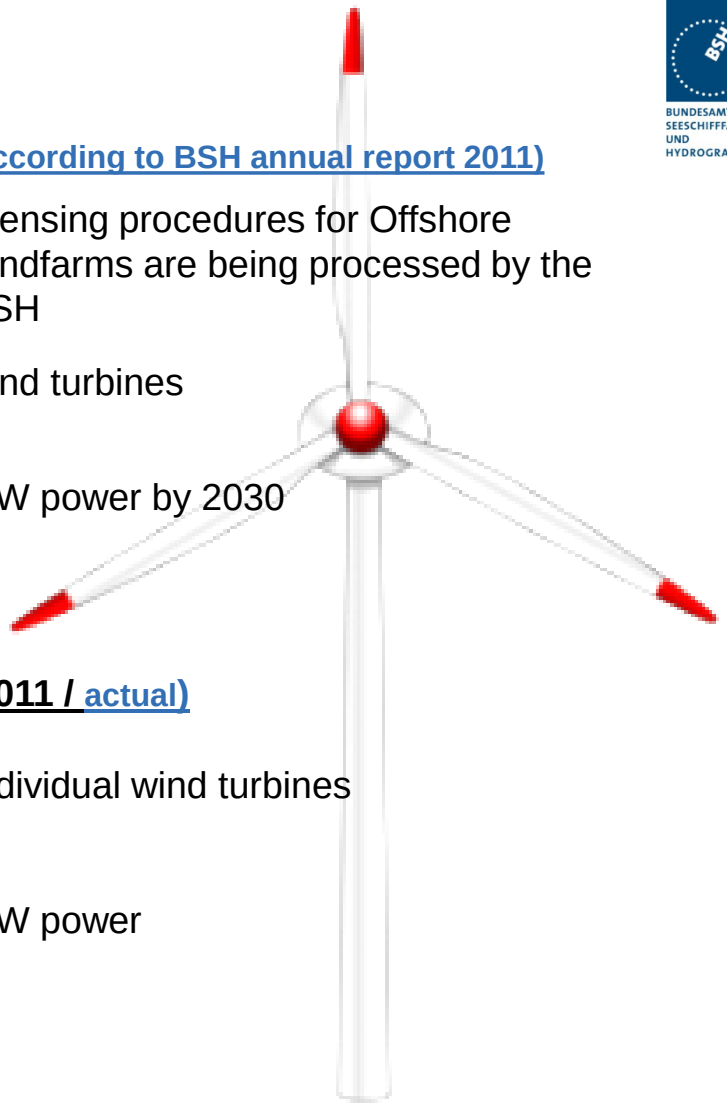
The seas are moving from traffic routes, fishing and recreational areas to an economic ressource as an energy reserve







Offshore wind
… some facts

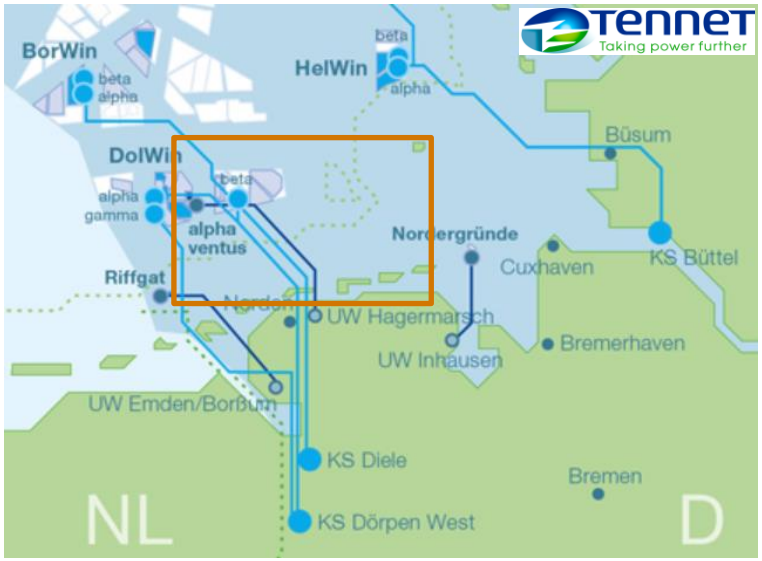


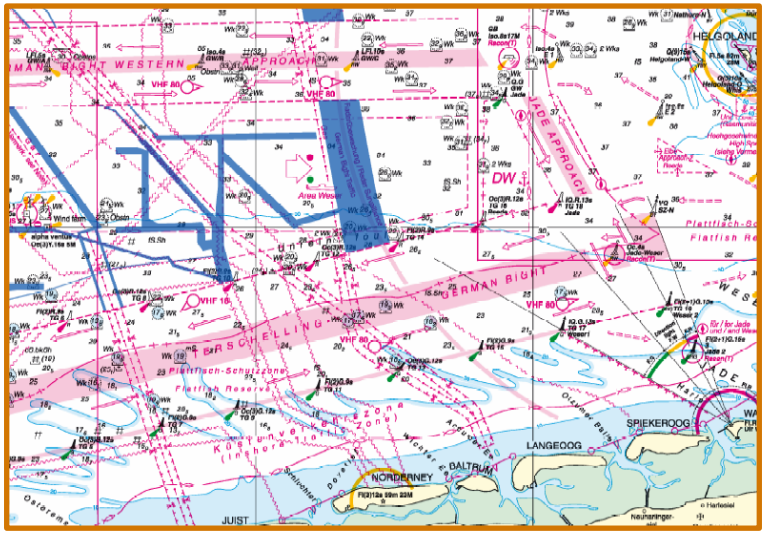
Target figures (according to BSH annual report 2011)

126	licensing procedures for Offshore windfarms are being processed by the BSH
8705	wind turbines
25000 -30000	MW power by 2030

Reality (end of 2011 / actual)

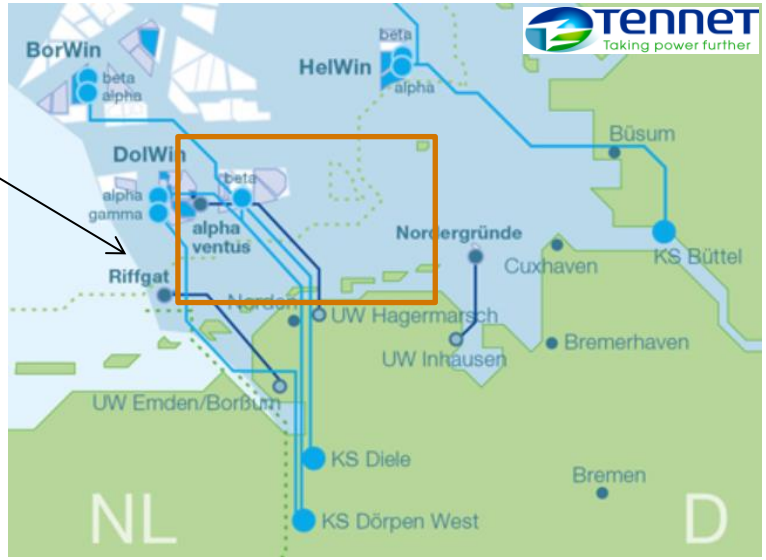
47 (~95)	Individual wind turbines
~175 (~470)	MW power

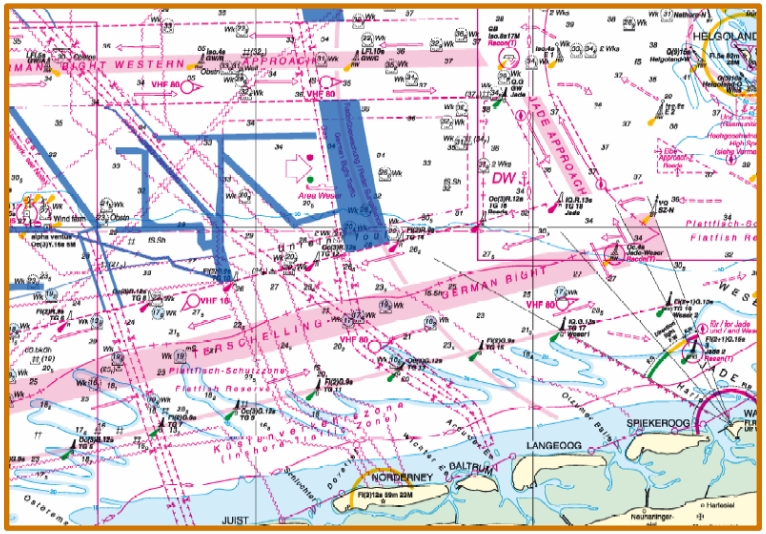




Grid connection
… the challenge

- Far behind the targets
  example: Riffgat starting without grid connection
- Lacking of a systematic regulatory model
  → Offshore network plan by BSH (introduced 2012)
- Offshore network plan
  → jointly developed with other authorities (e.g. GDWS) and the transmission system operator (TenneT)





some issues

- Environmental
- Legal
- Technical
  - Liabillities (e.g. ammunition)
  - **Burial depth of seacables**

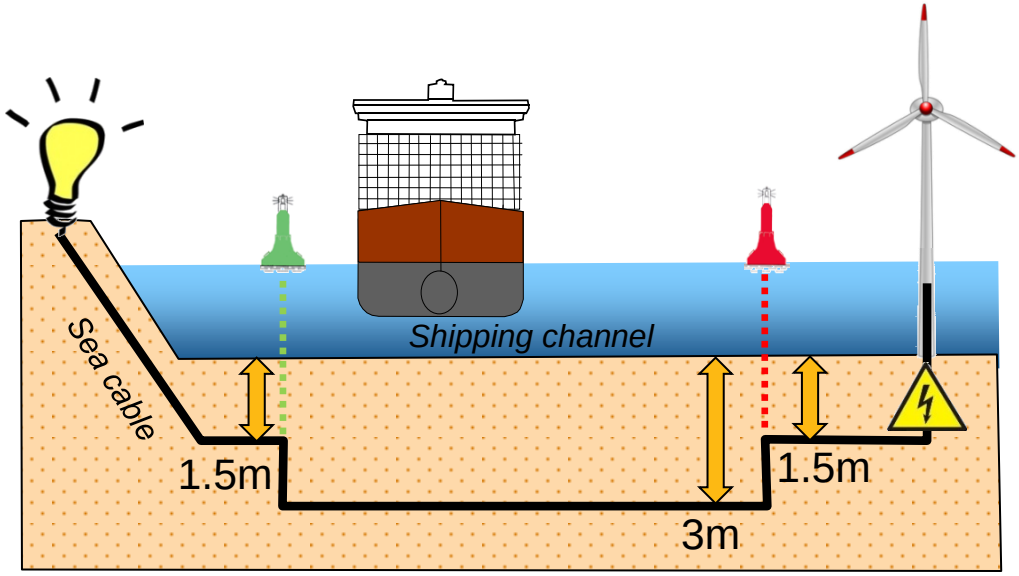
Burial depth of seacables
Regulations and risks

prescribed burial depth of sea cables

1.5 m	**outside**	shipping channels
3.0 m	**inside**	

Complex in terms of

- **Costs** (increasing dramatically with every dm)
- **Technology** (in areas with difficult soil conditions)



Reason for the increased requirements in shipping channels:

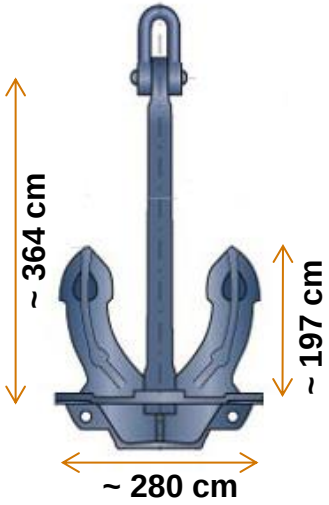
risk potential which is seen by anchor maneuvers in emergency cases and disasters

… agreed upon investigations to determine the real penetration depths of anchors into the seafloor

Anchoring
… and what NOT should happen

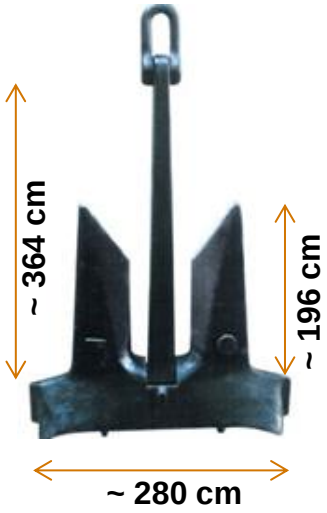
How deep does an anchor penetrate the seafloor ?

Test anchors



Hall ~11.7 to.

Up to 294 m length / 80000 DWT



HHP AC14 ~8.3 to.

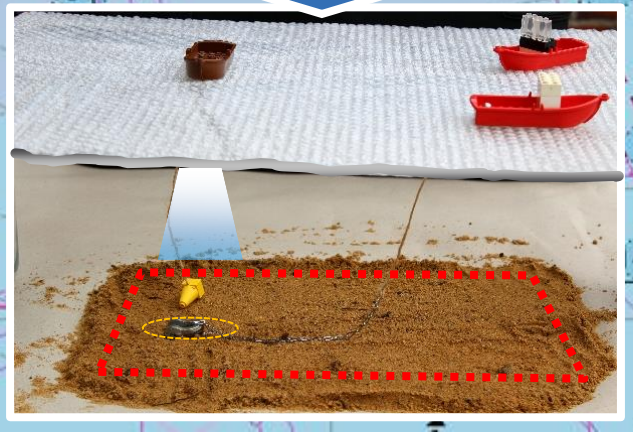
Vessels and tasks

Guardian

Survey vessel: ROV, MBES

ROV inspection during anchor pulls

Post-pull MBES surveys



Esvagt Connector

Offshore Tug: Anchorhandling

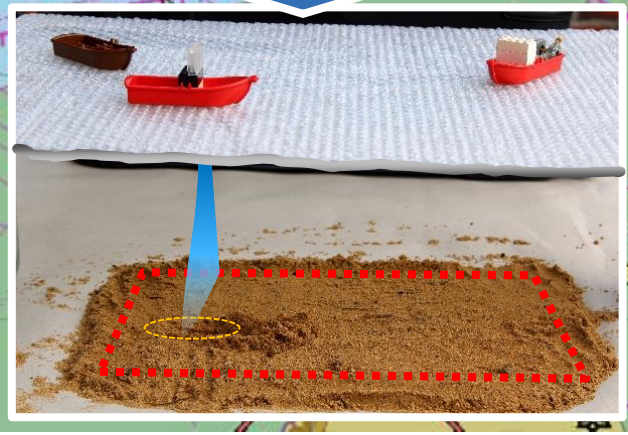
Anchor handling and pulling (Bollard pull max .107 to.)

Wega

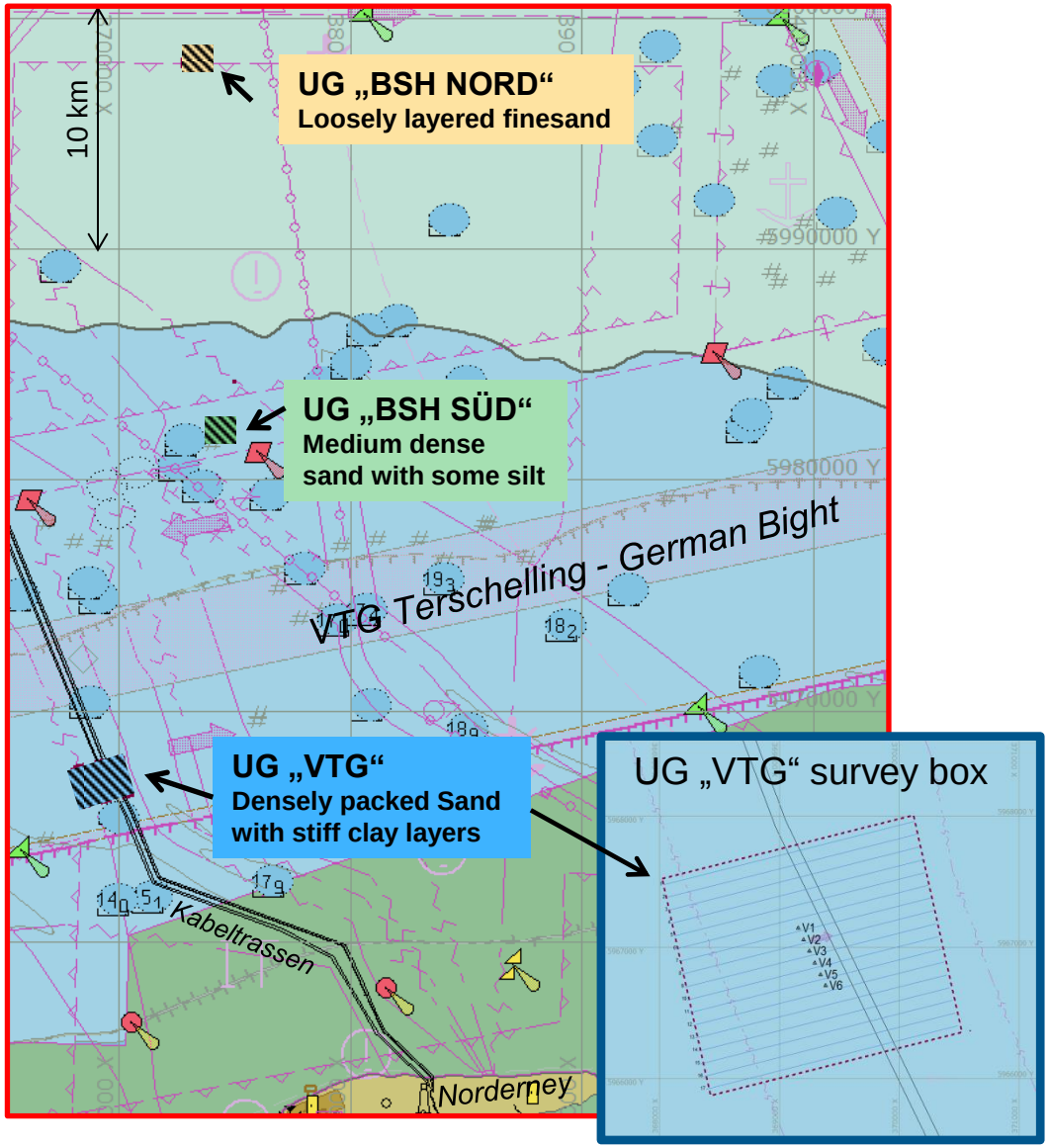
Survey vessel: SSS, SES (MBES)

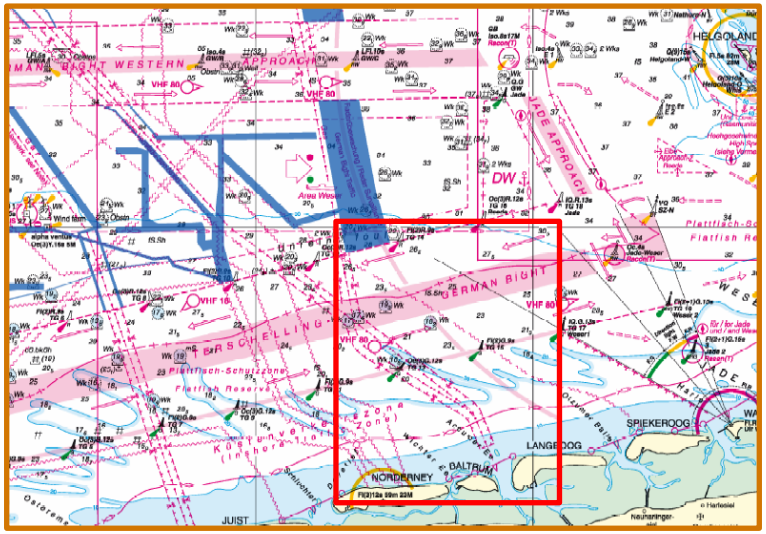
Pre-pull survey (SSS / SES)

Post-pull survey (SES,SSS)



Test sites



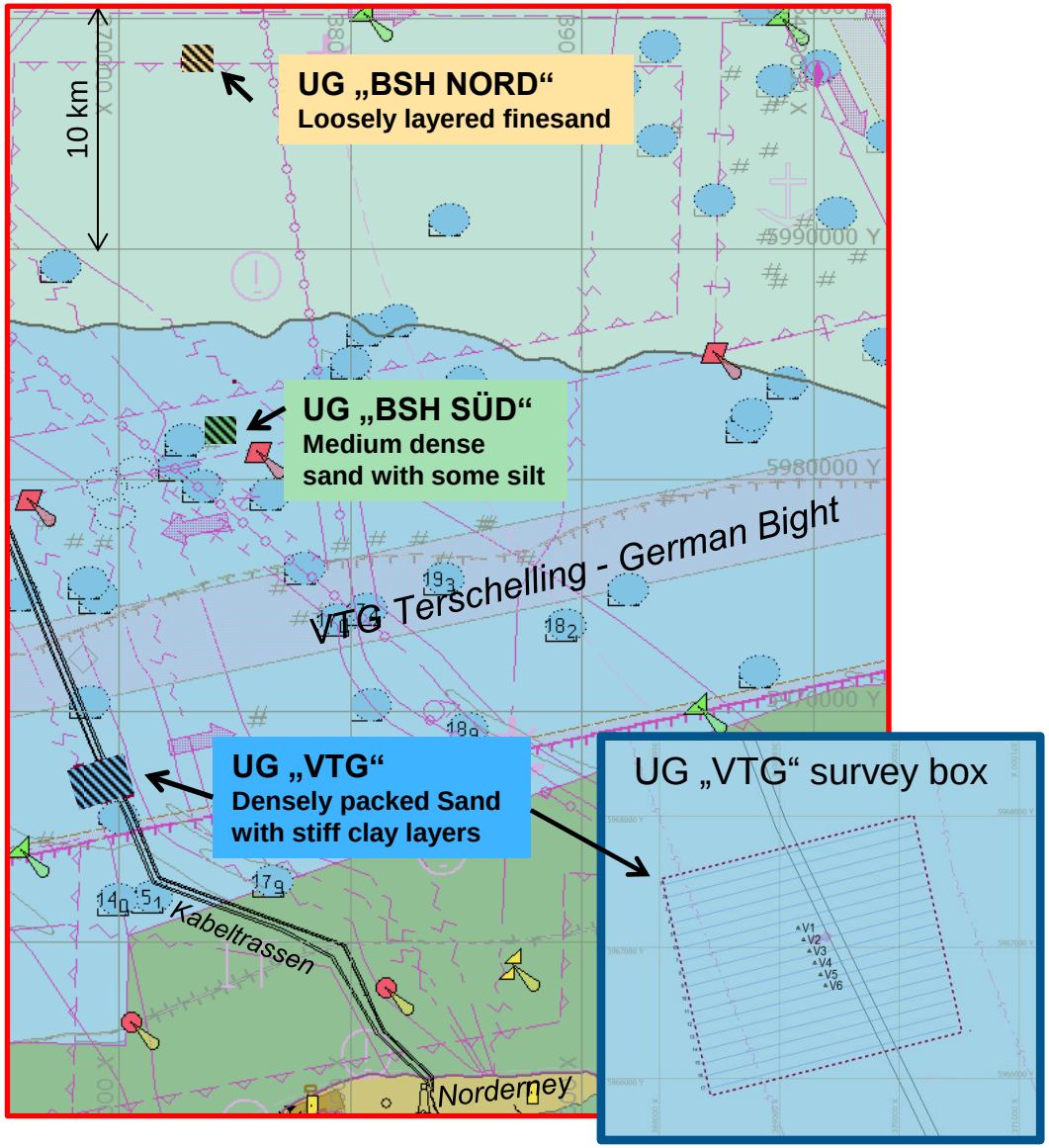


3 test sites with different soil conditions reflecting the interaction between anchor and seabed

3 test sites
2 anchors (Hall, AC14)
3 pulls each anchor

18 pulls

Anchor trial procedure



Pre - pull - survey

Side scan sonar and Sediment Echosounder survey on every test site

- → **Soil conditions,**
- → **detection of obstacles,**
- → **finalization of drop positions**

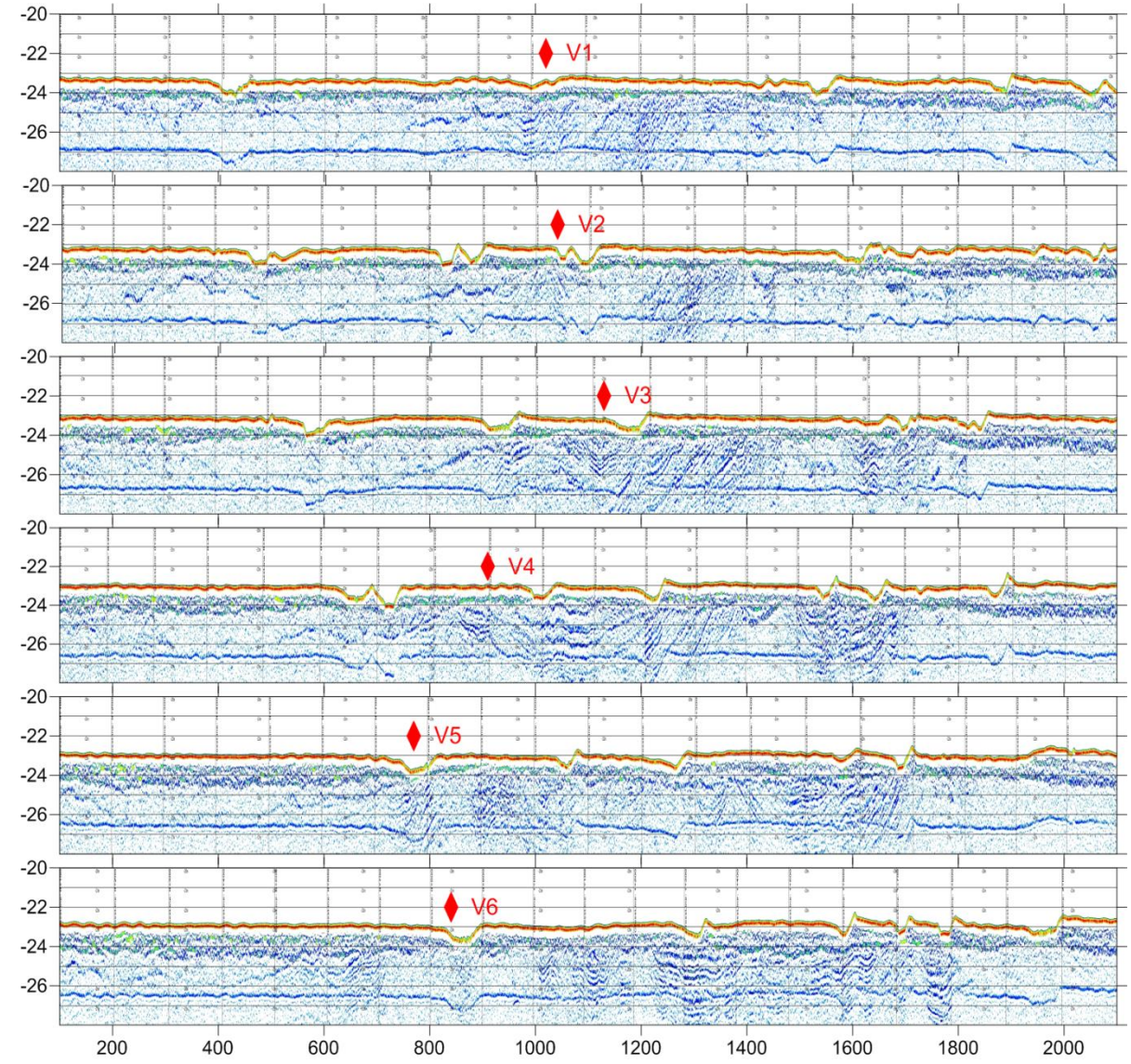
Anchor pulls

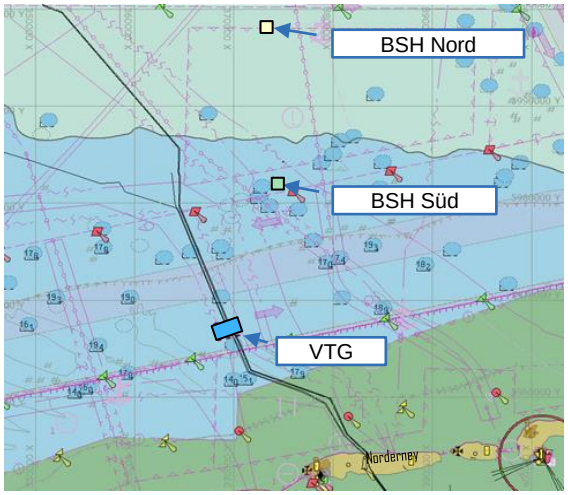
- → **Move offshore tug to drop position**
- → **Dropping anchor**
- → **ROV video check of anchor position and alignment**
- → **Anchor pull up to 80 to. (load cell) or anchor break out**
- → **ROV Video check of final position**
- → **Recover anchor**

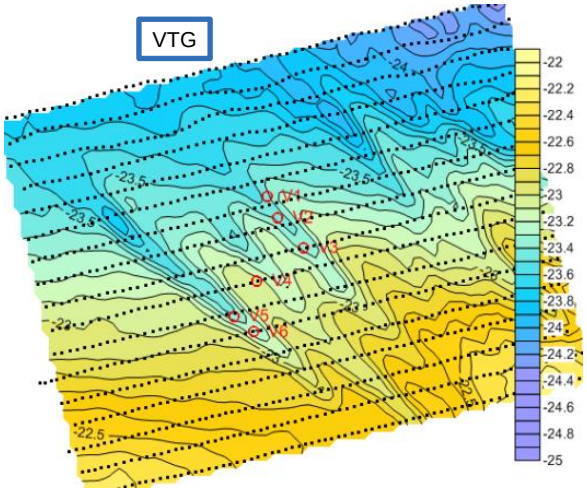
Post - pull - survey

- → **SSS, MBES and SES survey of anchor track**

SES Pre – pull survey (VTG)

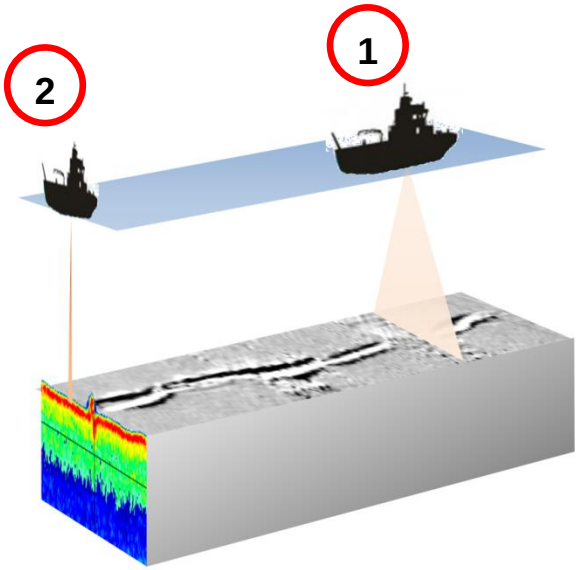


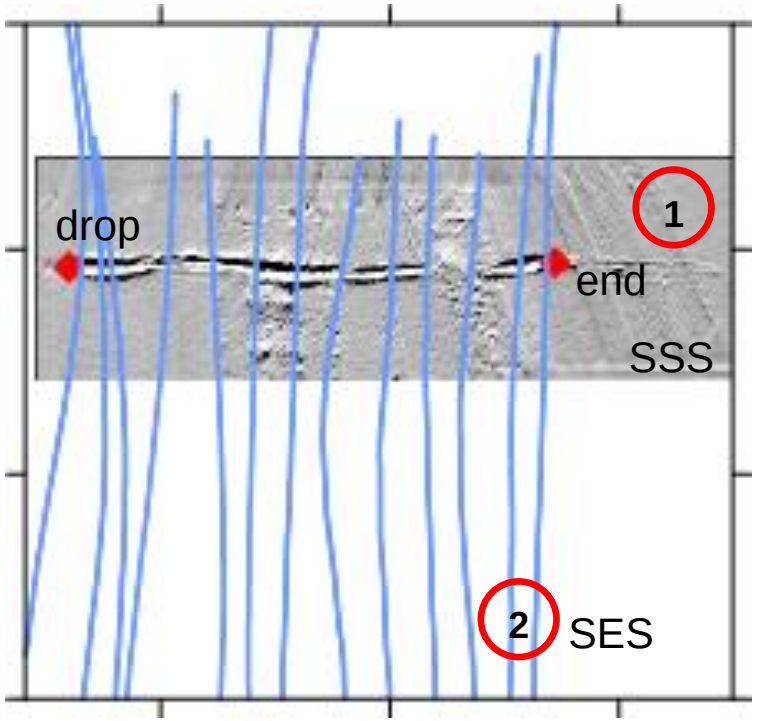


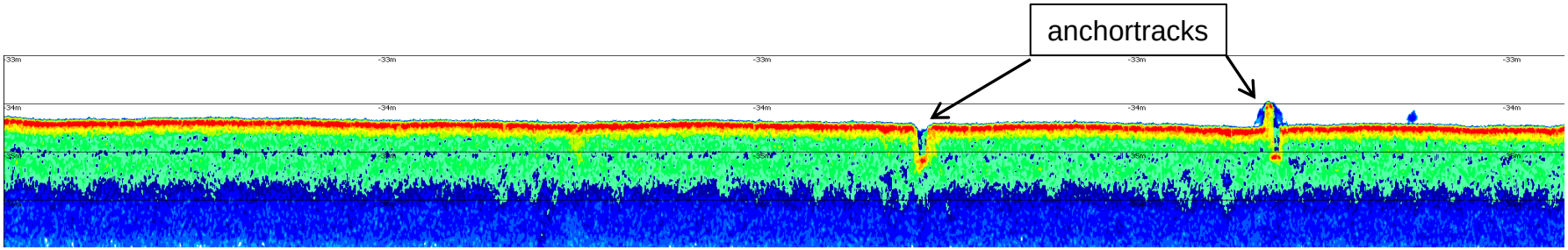


Start of an Anchor pull as recorded by ROV video
Position V2

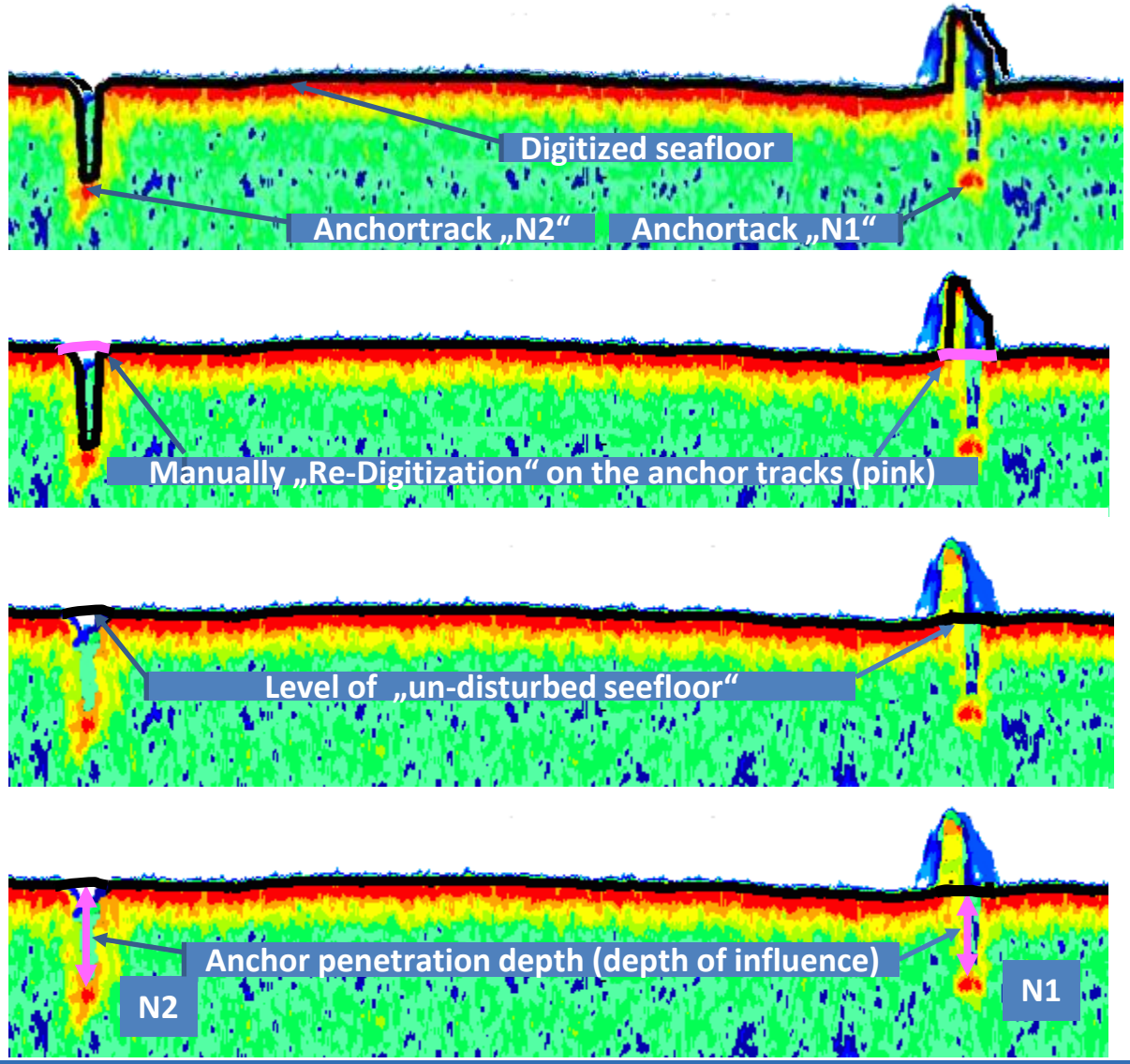
Combined SSS / SES survey of anchor tracks (Post – pull survey)



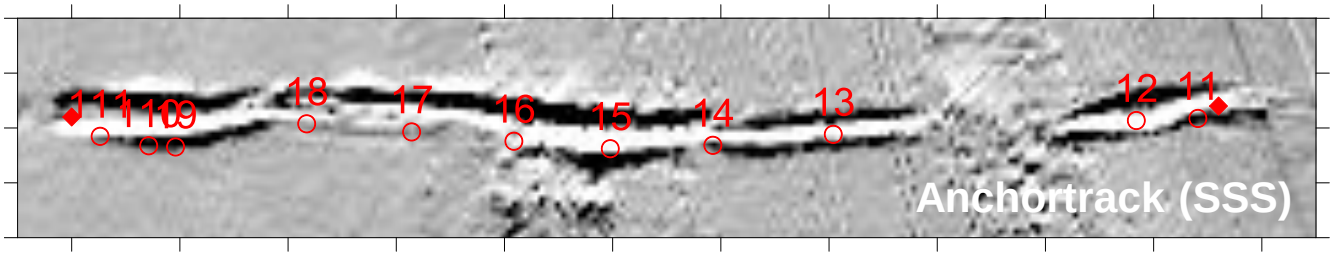




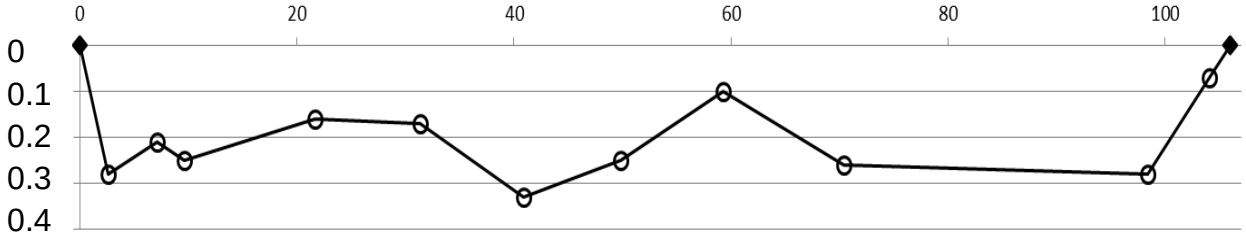
Detection of anchor penetration depth
… as performed with SES processing software ISE



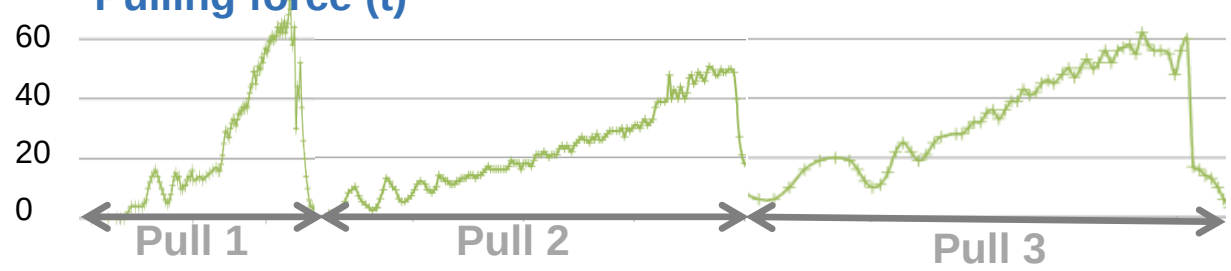
- Digitize seafloor
  → ISE (semi-)automatically
- Identify anchor track(s)
- Re-Digitize the level of „un-disturbed seafloor“ in the zone influenced by the anchor
  → ISE manually
- Overwrite seafloor level
  → ISE automatically
- Detect depth of influence (anchor penetration depth)
  → ISE target picker



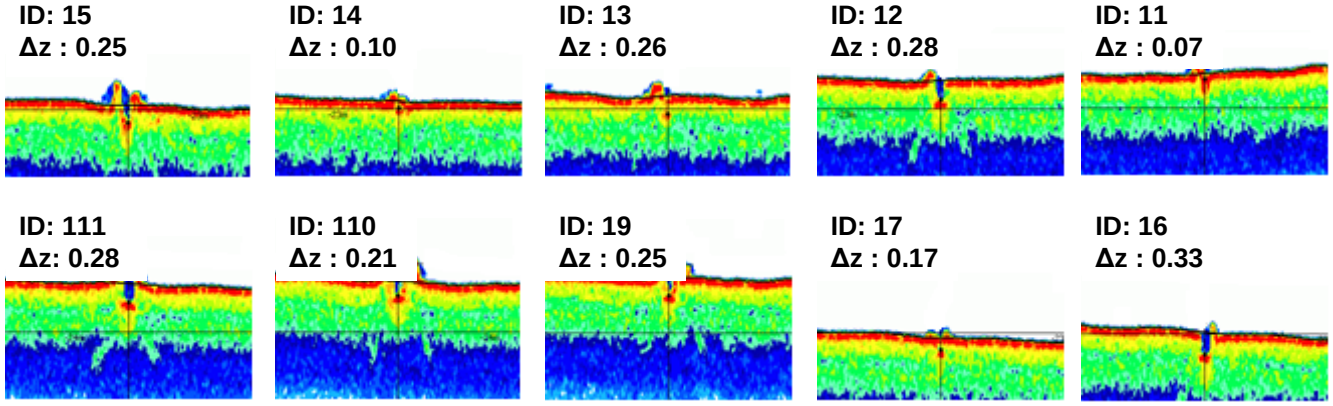
Penetration depth Δz (m)

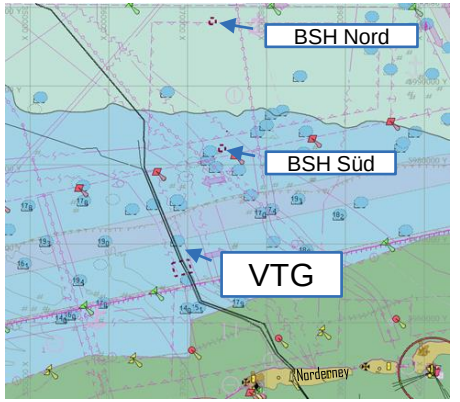


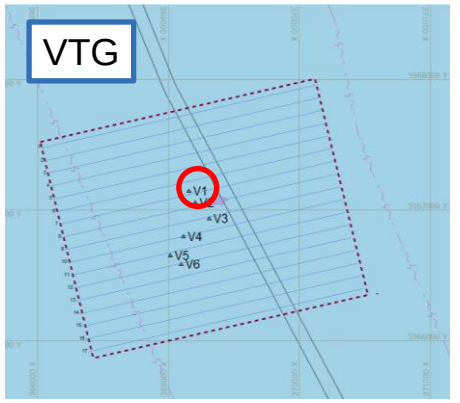
Pulling force (t)



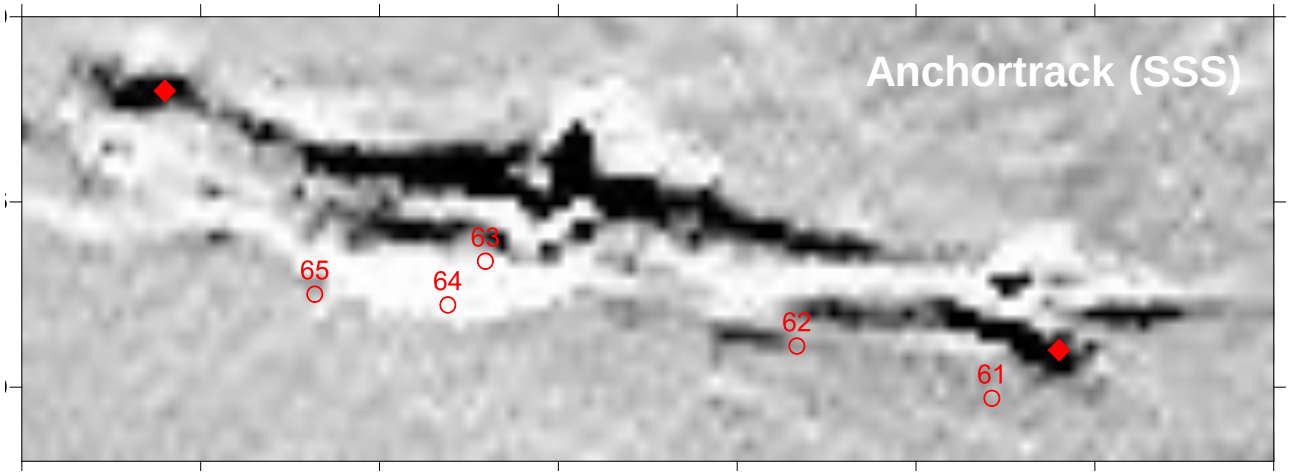
SES - Echoplots

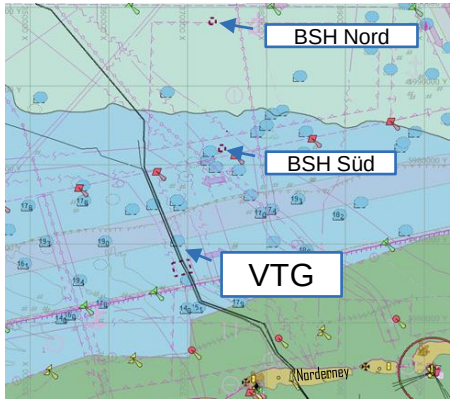


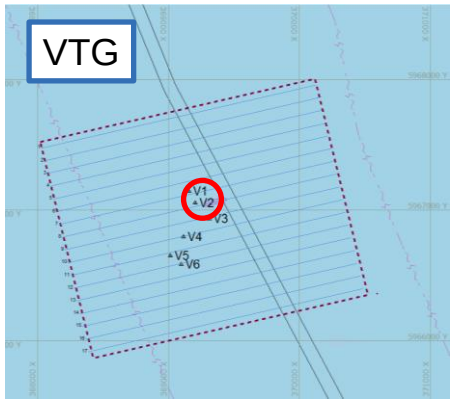




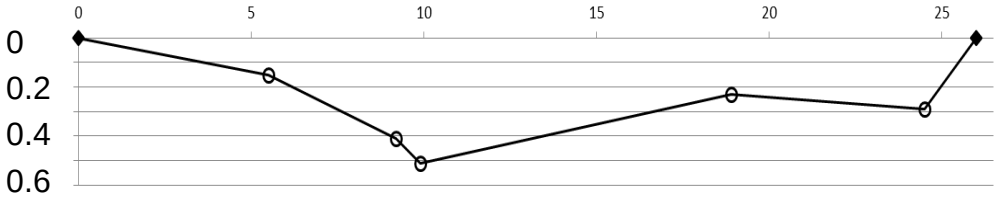
area	**VTG**
Pos	**V1**
Typ	**AC14**
Length	**107 m**
Max. pull	**73 t**
Max. Δz	**0.33 m**



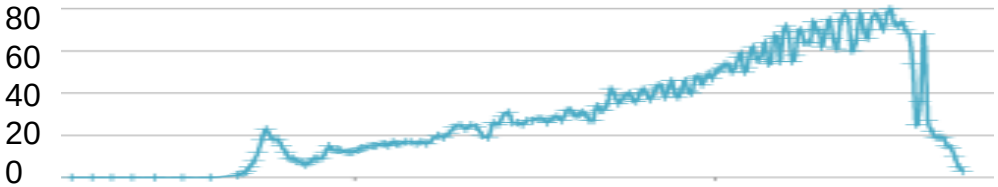




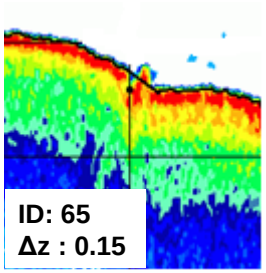
Penetration depth Δz (m)

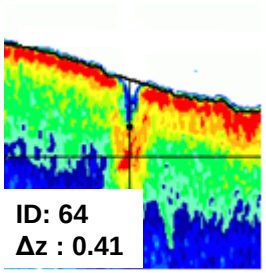


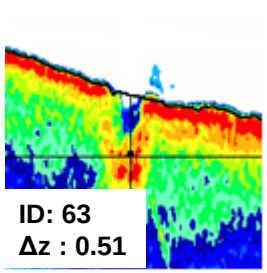
Pulling force (t)

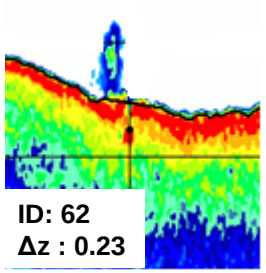


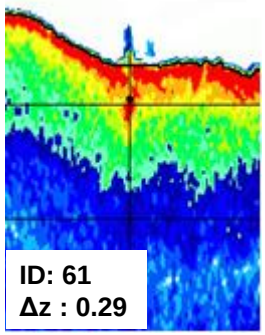
SES - Echoplots







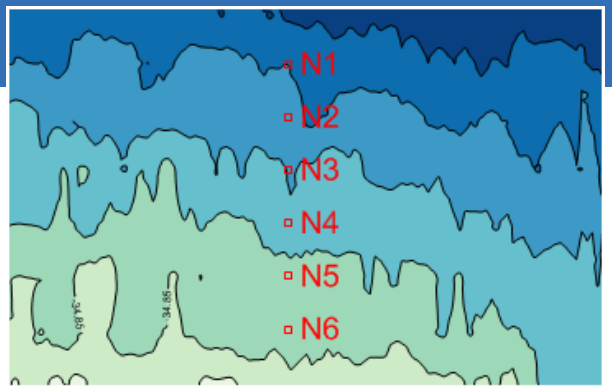




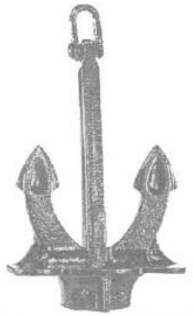
area	**VTG**
Pos	**V6**
Typ	**Hall**
Length	**26 m**
Max. pull	**80 t**
Max. Δz	**0.51 m**

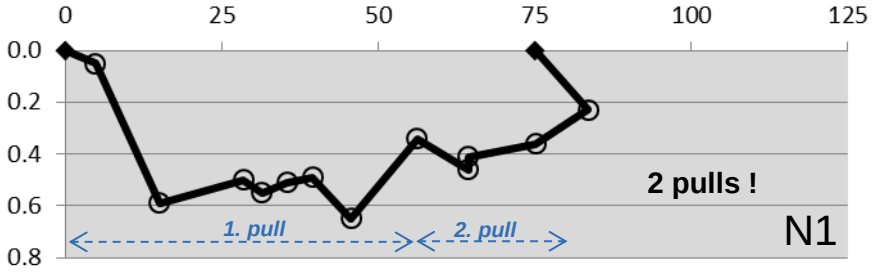
BSH - Nord – Anchortracks

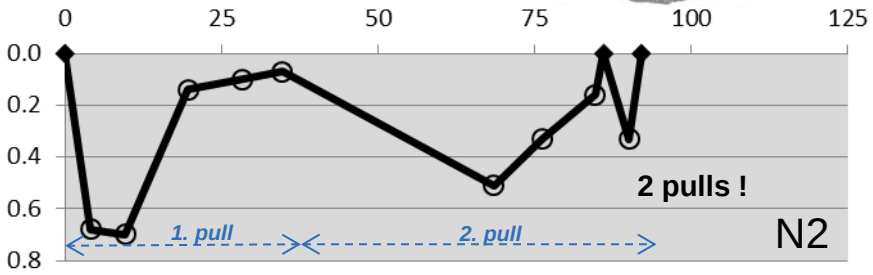
AC14

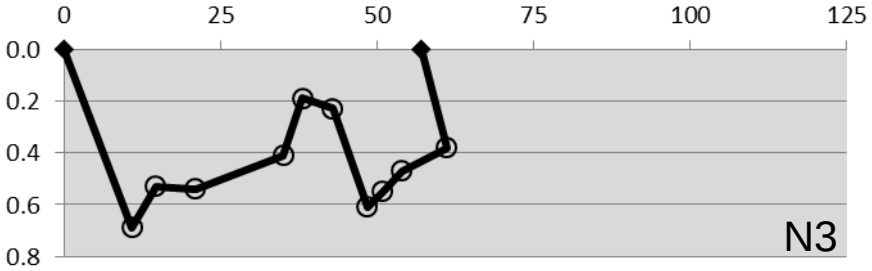


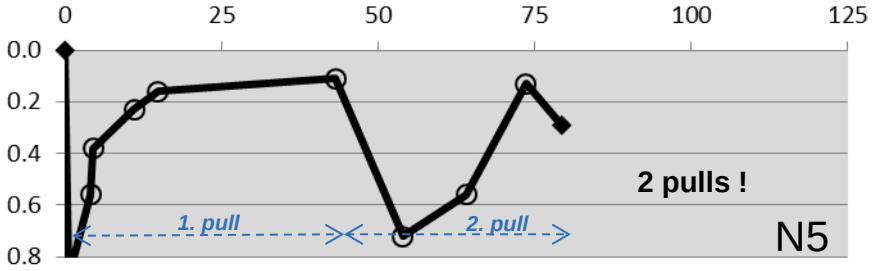
Hall

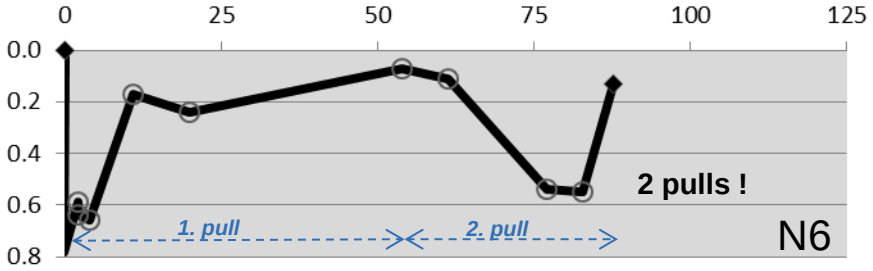






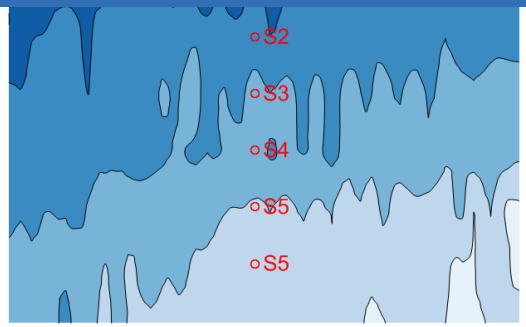




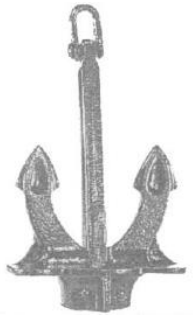


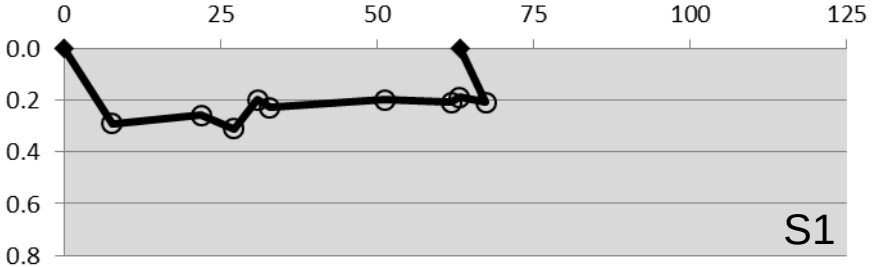
BSH - Süd – Anchortracks

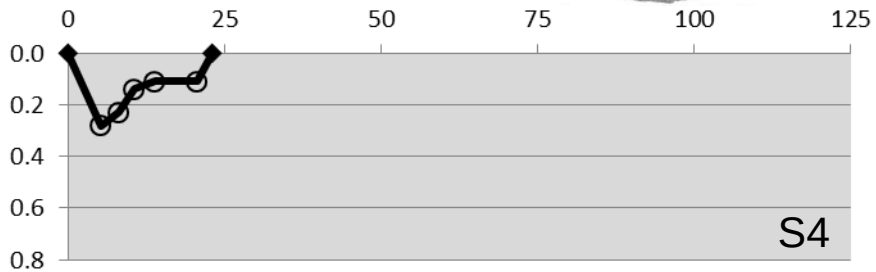
AC14

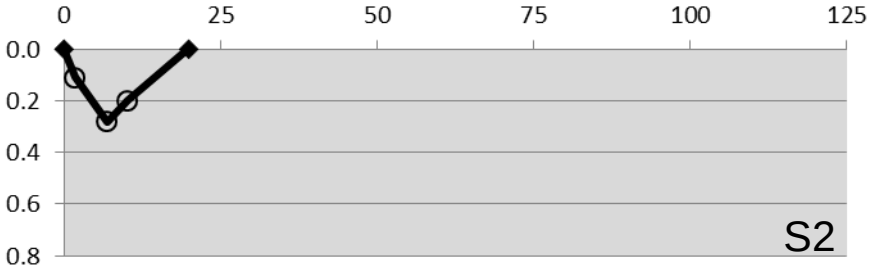


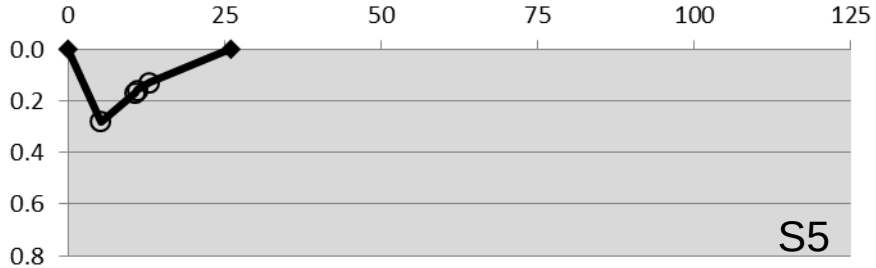
Hall

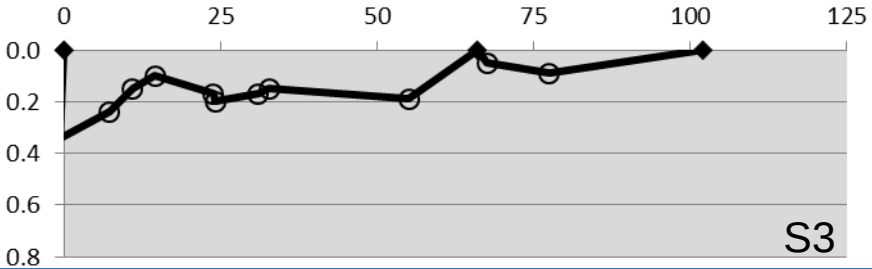


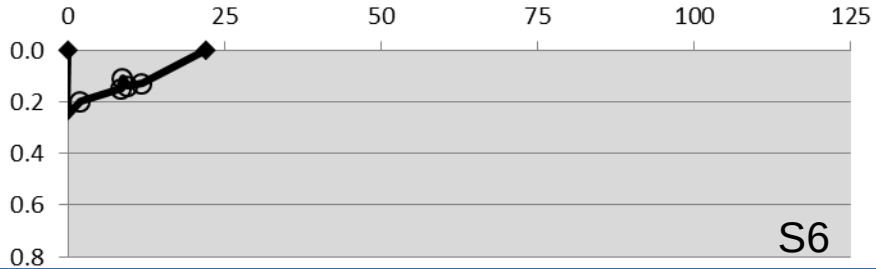




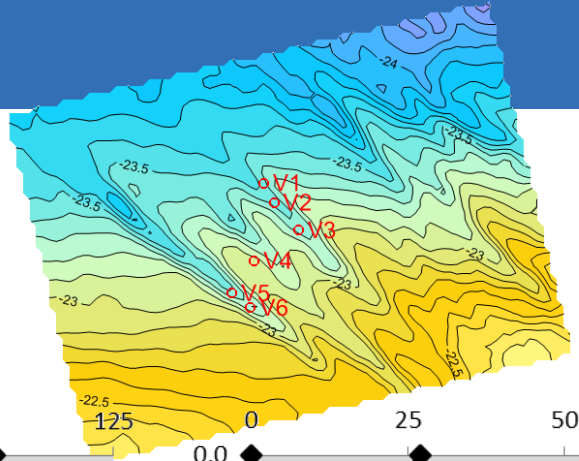


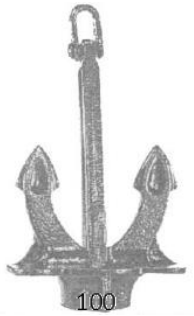




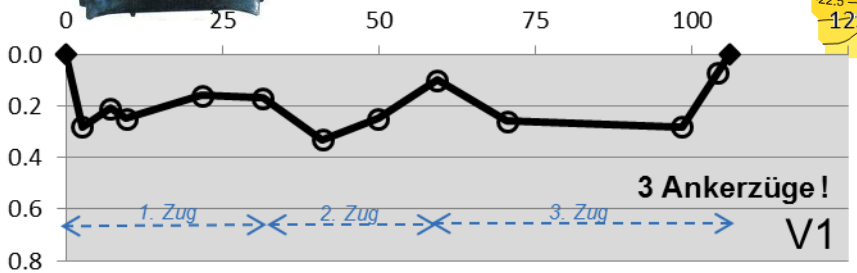


BSH - VTG – Anchortracks

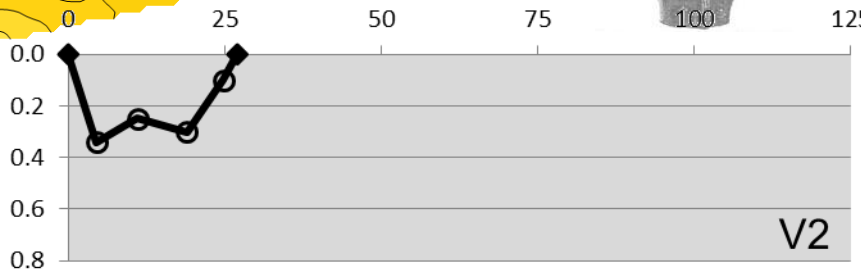


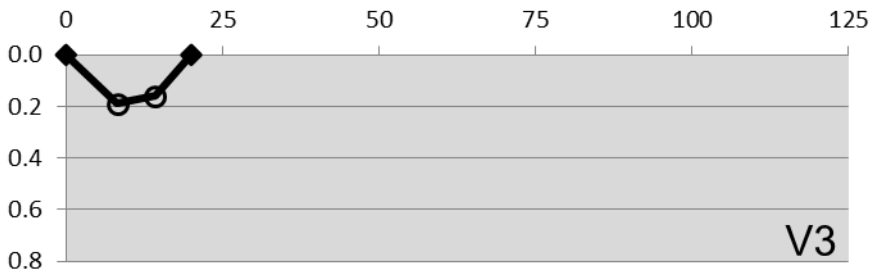


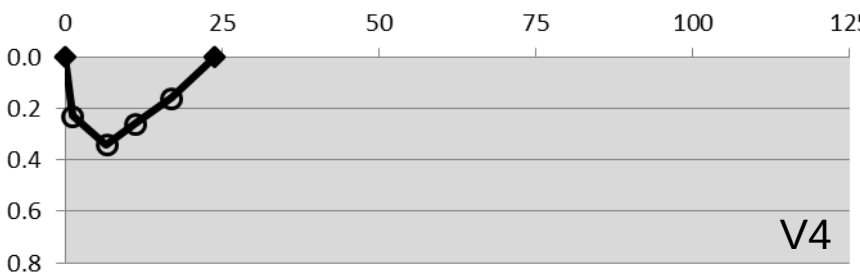
AC14

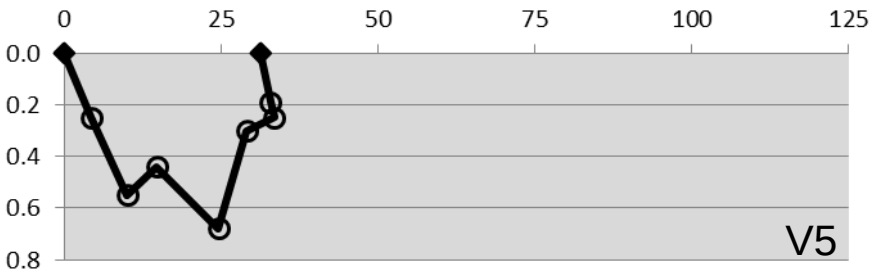


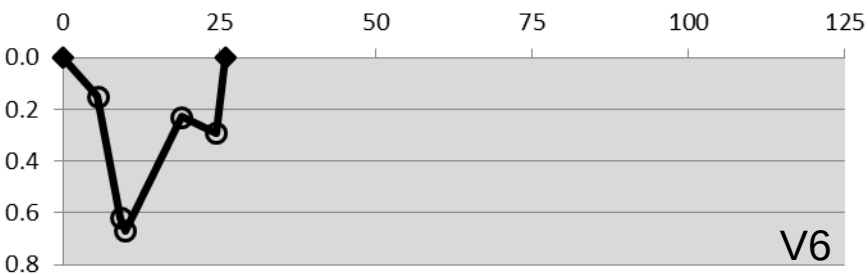
Hall











Conclusion

- SES is a powerfull tool to detect small buried structures like anchor tracks
- No anchor penetration deeper than 1m could be observed (accounting for potential errors)
- One of the best documented large scale anchor trials ever have been reported
- Results have been accepted by the approving authorities
- German offshore network plan will be updated based on the results and the expertise of Deltares and BAW → reduction of burial depth
- saving of Millions for electricity consumers