BIS GROUP

GLOBAL CONFERENCES AND EVENTS MANAGEMENT COMPANY

3rd Annual

Advanced Submarine Power Cable and Interconnection Forum

Enhancing Cable Installation, Reducing Repair Cost and Increasing Cable Innovation to Guarantee Maximum Return on Investment

Official Conference Hashtag
#BISsub14

16th - 18th June 2014
Angleterre Hotel, Berlin, Germany

Bundesanstalt für Wasserbau
Federal Waterways Engineering and Research Institute

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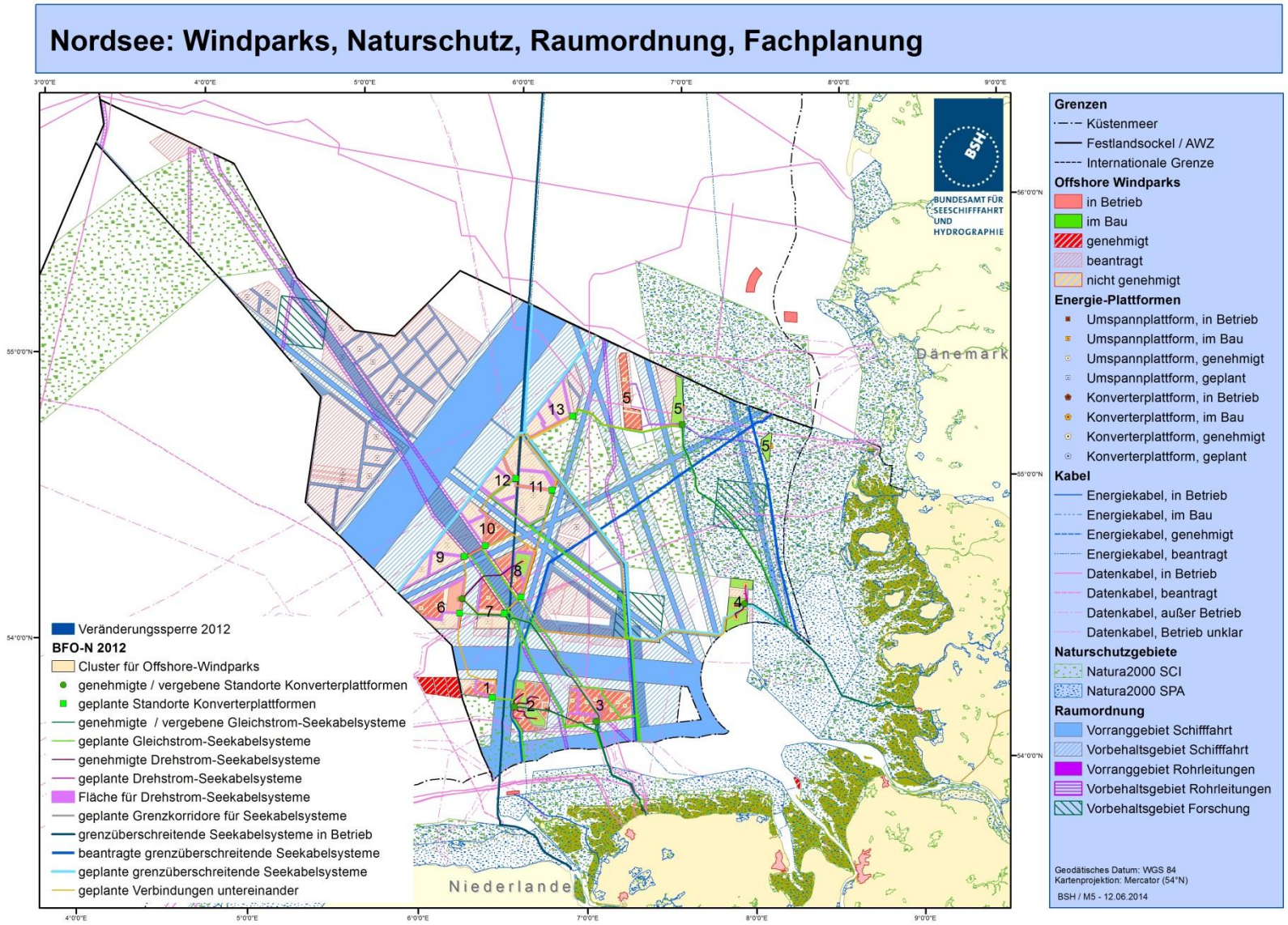
TenneT Offshore GmbH

Anchor Penetration Trials in the North Sea to Optimize Cable Burial Depth

The North Sea
… an undisturbed wideness?



Grid connections for offshore wind farms
… some facts

- → **TenneT is responsible for the grid connection of offshore wind farms in the German sector of North Sea**
- → **HVAC and HVDC grid connection**
- → **~ 1500 km of HVAC or HVDC subsea power cables installed, contracted or tendered (without interconnectors)**
- → **preplanings for another ~1800 km of cables**

Burial depth of seacables
Regulations and risks

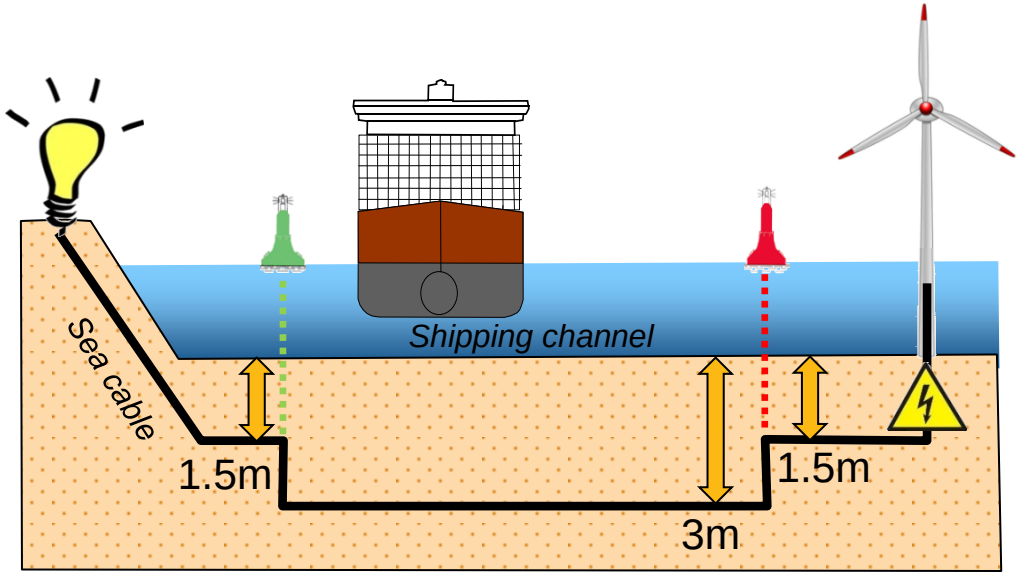
Required burial depth of sea cables

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)



Treatment of cable burial requirements within German consenting processes so far:

- **No individual risk based assessment of burial depth for cables required**
  - *Exception Nearshore Areas: 1,5 – 5 m DoB - in dependence of sediment mobility*
- **Assessment of likelyhood of damage by anchors required**
- **Statistical approach vrs. single case**
  - risk potential is seen by anchor maneuvers in emergency cases and disasters

Challenges of 3 m DoB

- 3 m is no industry standard, no garantee reaching 3 m
- seabed conditions – stiff clays in parts of the routes
- no dredging due to environmental constraints
- remidial trenching exposes cable to a higher risk of damage during installation
- survey – higher measurement uncertainties
- repair – longer times for recover and new reburial challenges

Advantages of a reduced burial depth

- meets industry standards in cable burial
- larger market to deploy burial tools
- time reduction in cable laying operations
- time reduction for cable recover in case of a repair, easier de- and reburial
    - less disturbance for ship traffic

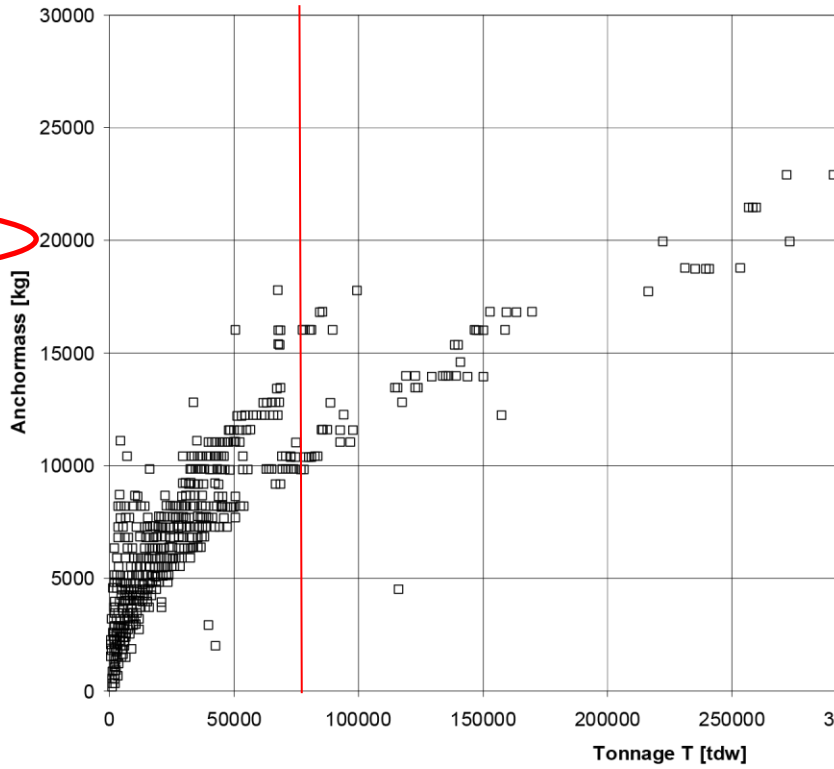
Large Scale Offshore Experiment in the German North Sea

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

- **Anchor penetration trials have been conducted from the 30.04. – 03.05.2013 offshore in the German North Sea**

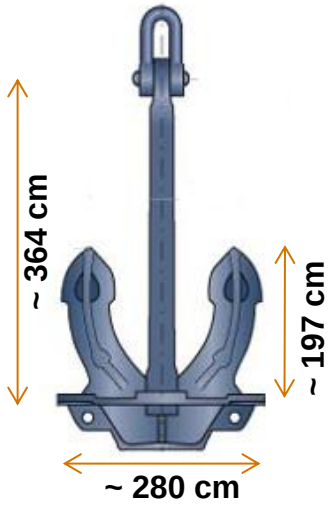
Traffic Analysis to determine a design ship

Fractile	Lenght (m)	dwt (t)	TEU	Tmax (m)
50 %	< 140	13500	800	7,6
75 %	< 212	37000	2600	10,8
80 %	< 231	46000	3300	11,8
90 %	< 294	80000	5700	14,5
95 %	< 333	100000	71000	14,5



Cargo ship with 80.000 dwt
-> Chose of an Hall anchor of 10.5 t
according to GL tables on correlation
on anchor mass and dead-weight of ships

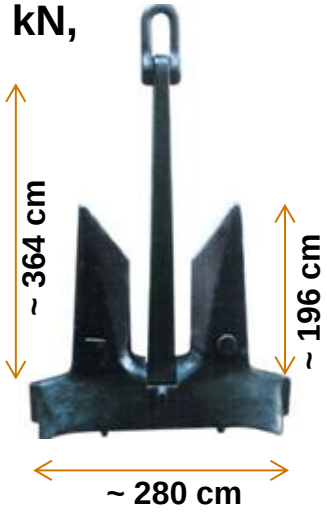
Test anchors



Hall ~11.7 to.

holding capacity –
Hall: 4-6 x its mass-weight – 470 kN to 690 kN,
AC 14: 8-11 x its mass-weight – 620 kN to 950 kN

Up to 294 m length / 80000 DWT



HHP AC14 ~8.3 to.

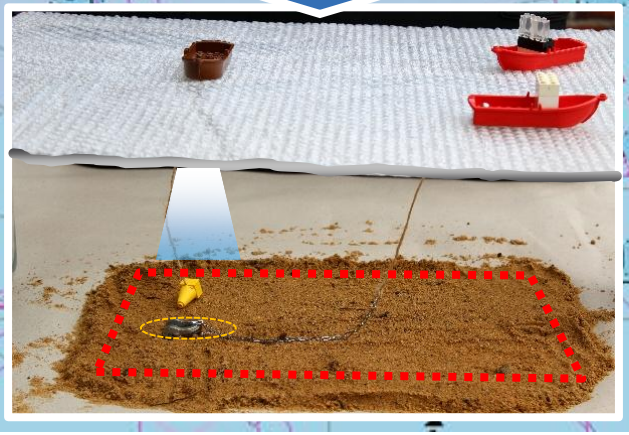
Vessels and tasks

Guardian

Survey vessel: ROV, MBES

ROV inspection during anchor pulls

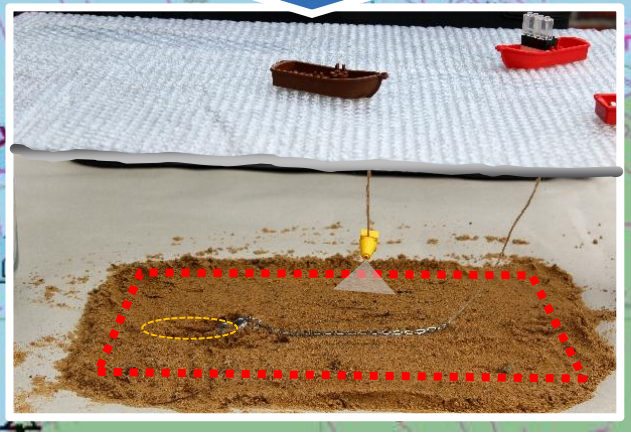
Post-pull MBES surveys



Esvagt Connector

Offshore Tug: Anchorhandling

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

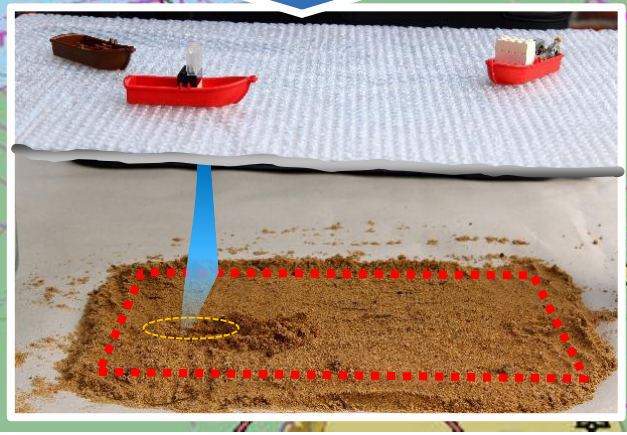


Wega

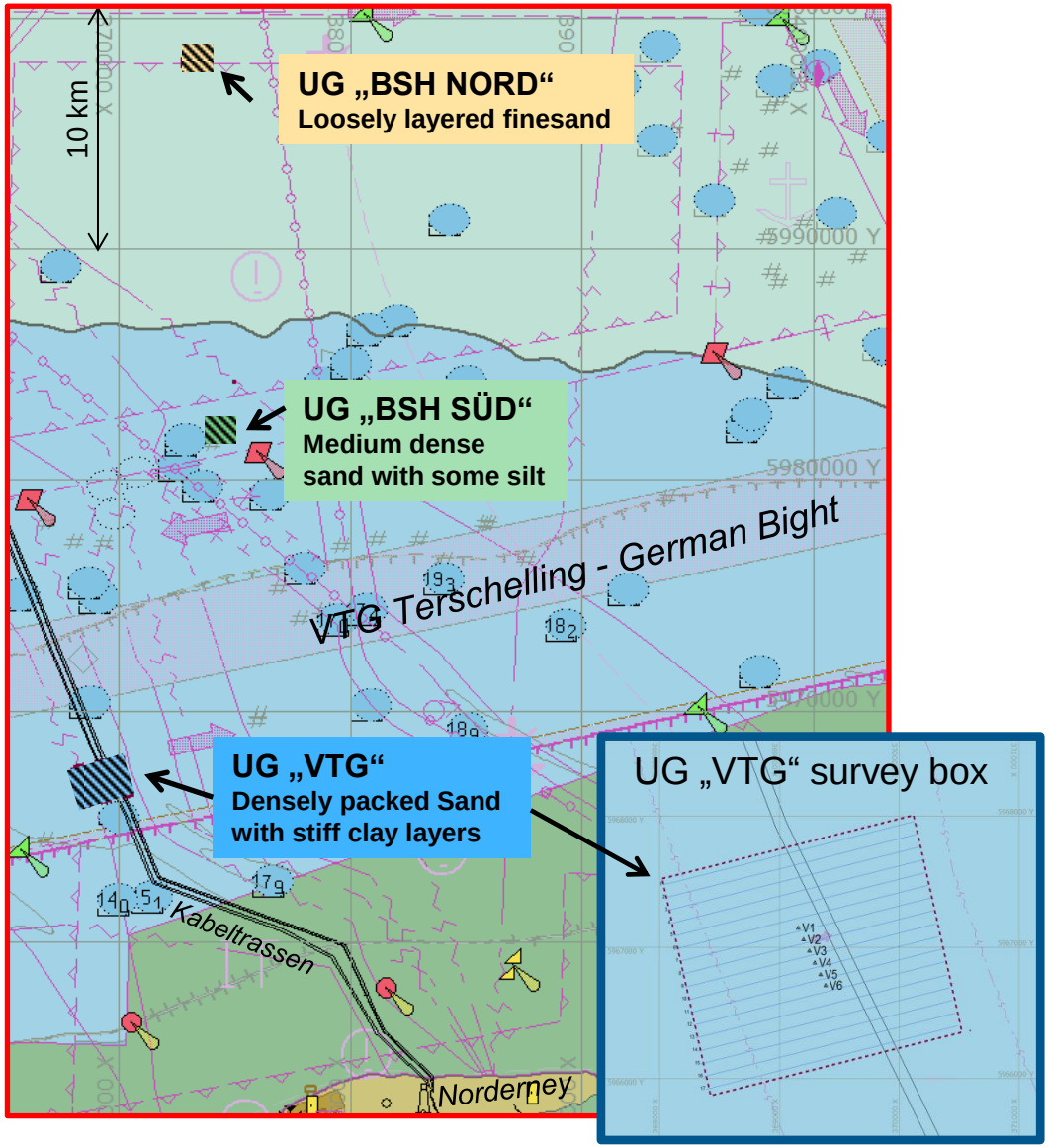
Survey vessel: SSS, SES (MBES)

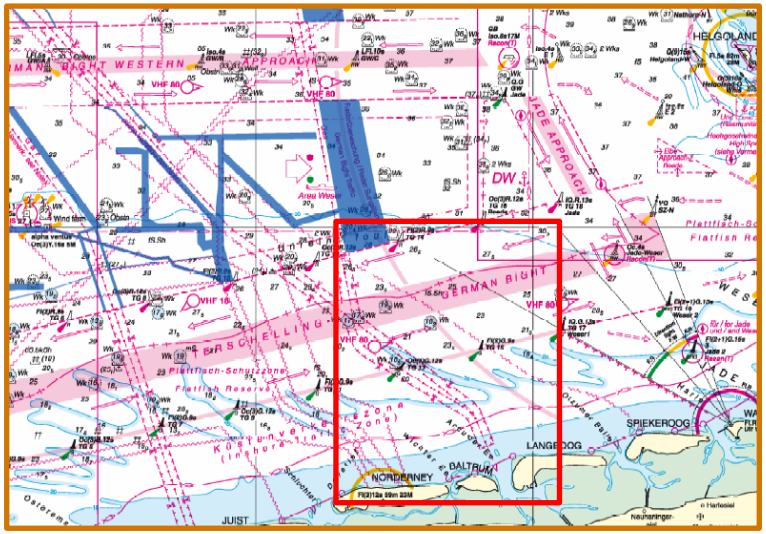
Pre-pull survey (SSS / SES)

Post-pull survey (SES,SSS)



Test sites



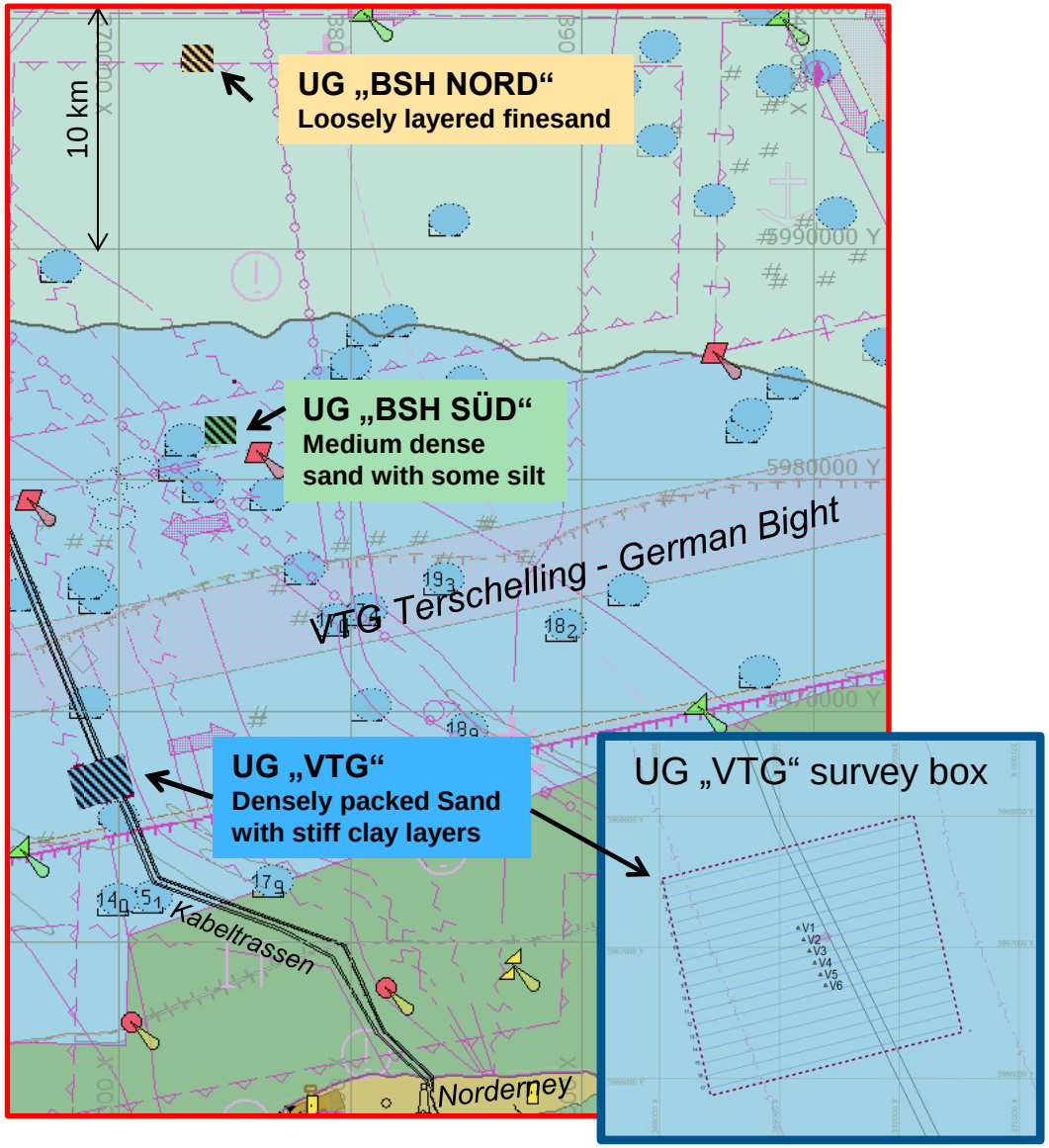


3 test sites with different soil conditions reflecting the interaction between anchor and seabed

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**

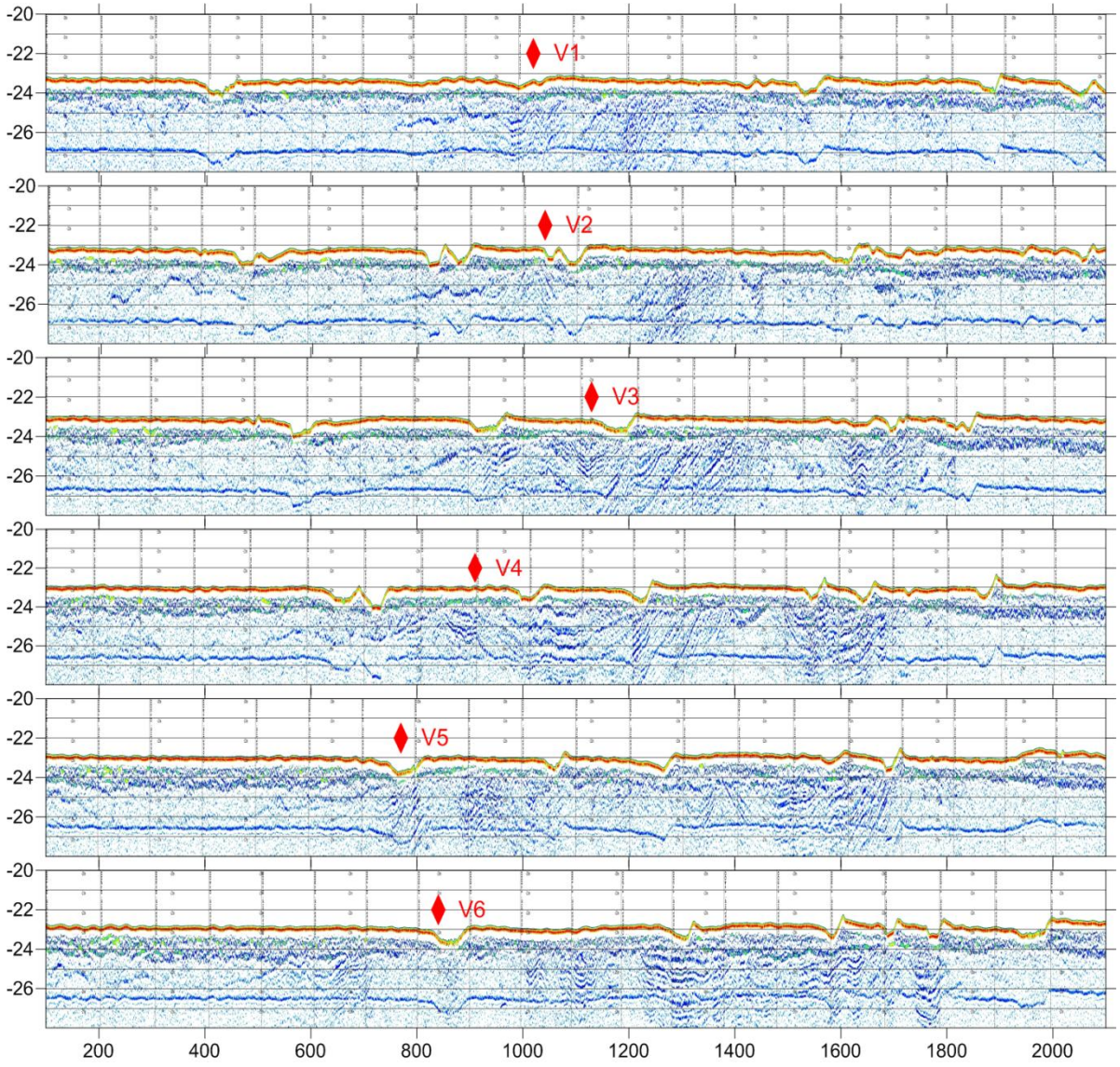
Anchor pulls

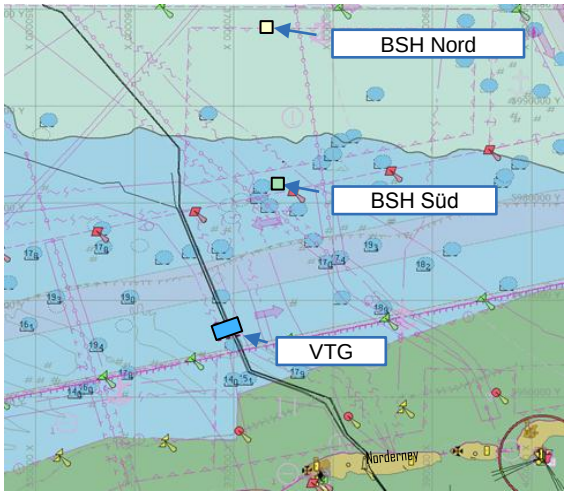
- → **Move offshore tug to drop position**
- → **Dropping anchor**
- → **ROV video check of anchor position and alignment**
- → **Anchor pull up to 80 to. (load cell) or anchor break out**
- → **ROV Video check of final position**
- → **Recover anchor**

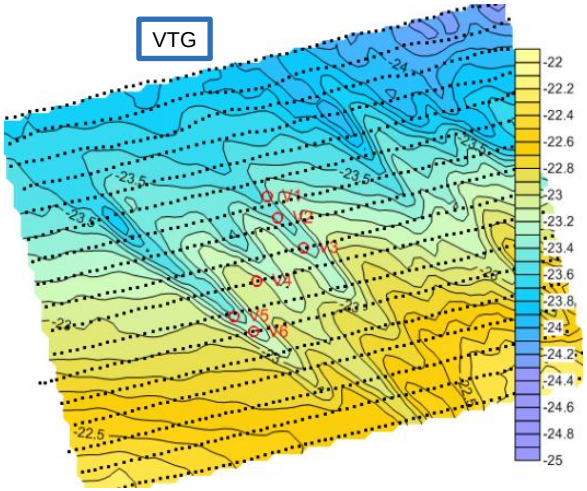
Post - pull - survey

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

SES Pre – pull survey (VTG)



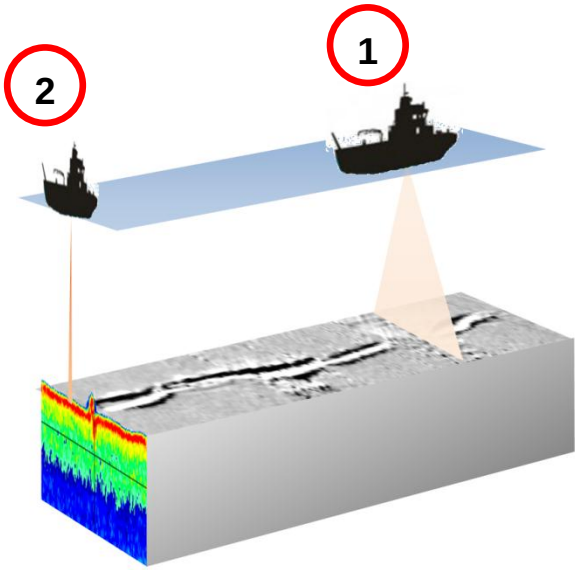


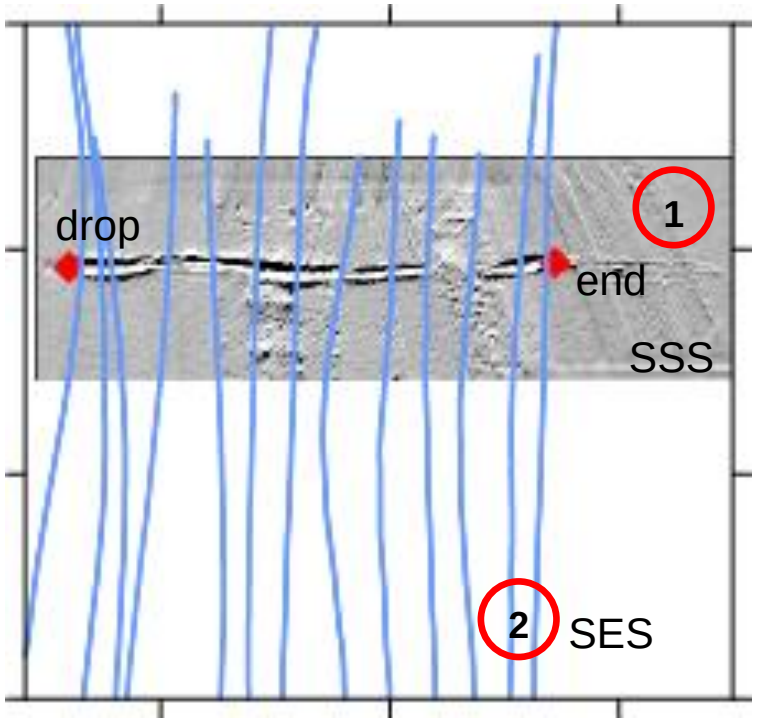


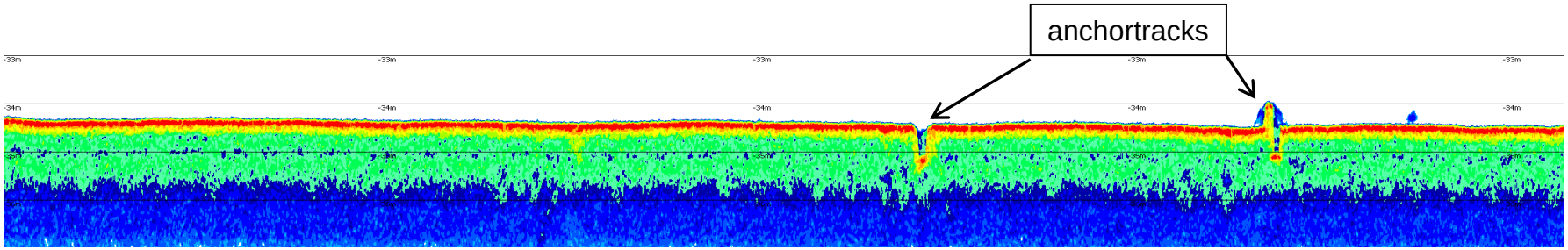
Start of an Anchor pull as recorded by ROV video
Position V2

After Anchor pull – anchor has graded in as recorded by ROV video
Position VTG Position AC14

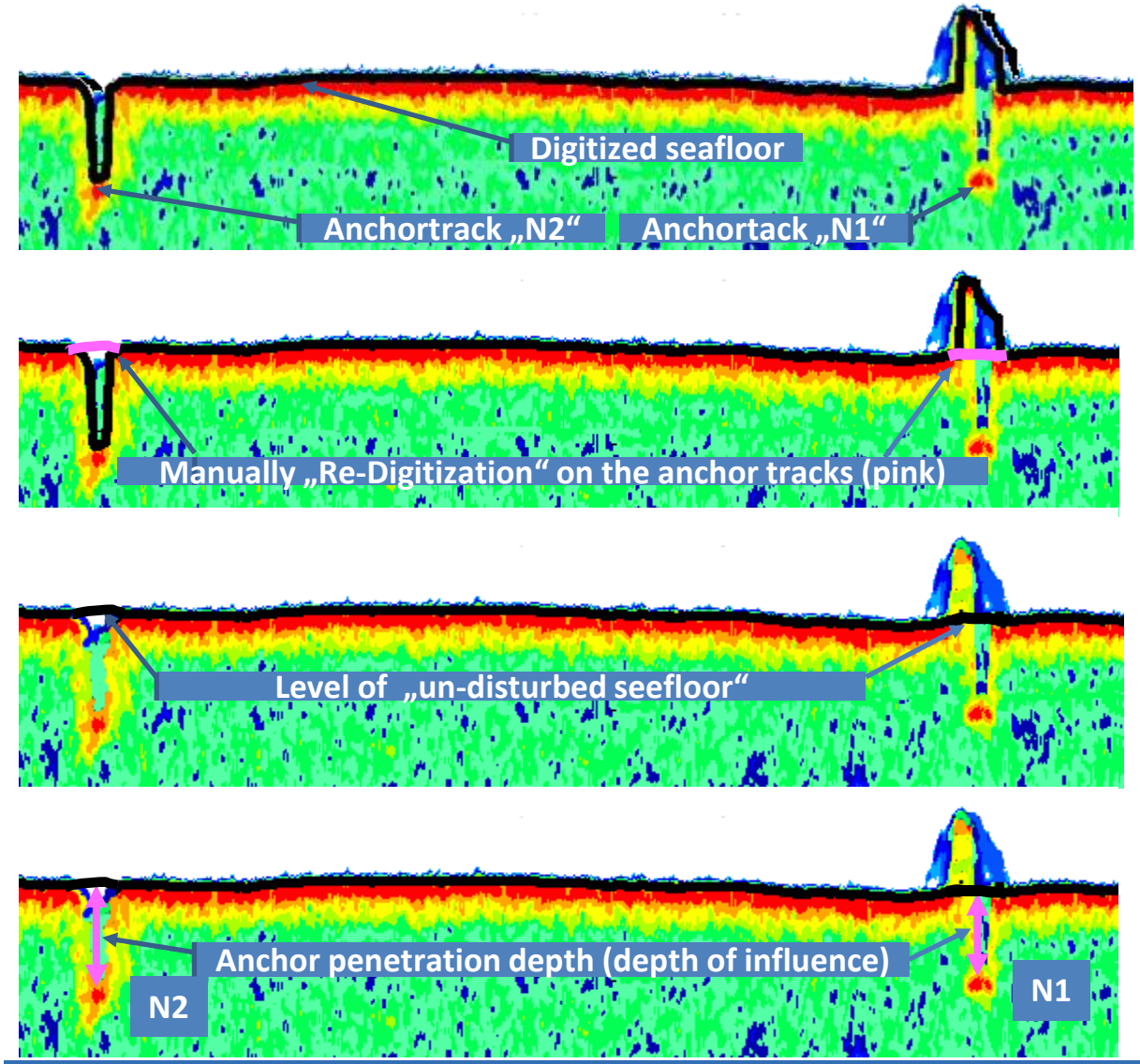
Combined SSS / SES survey of anchor tracks (Post – pull survey)



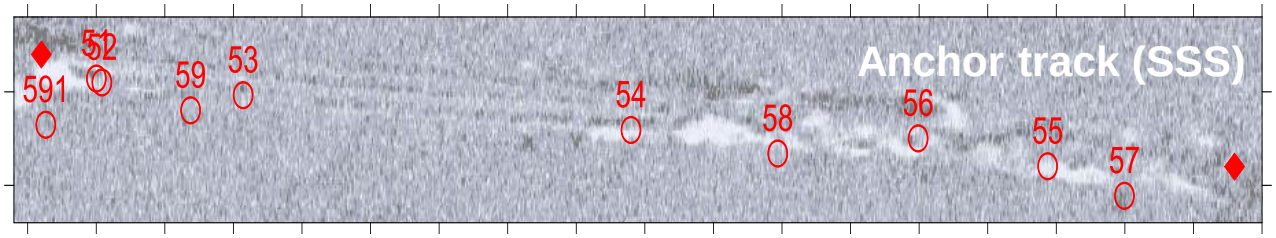




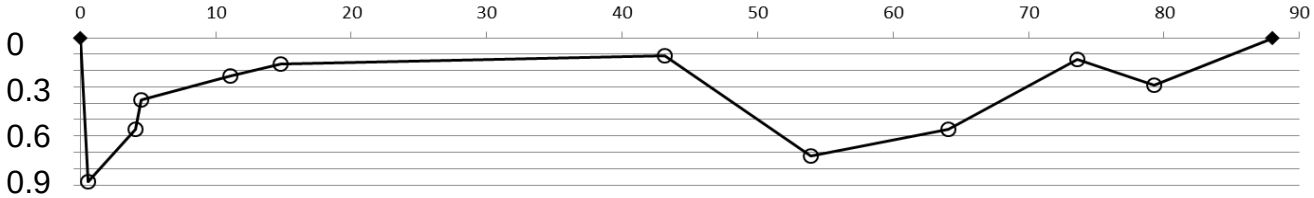
Detection of anchor penetration depth
… as performed with SES processing software ISE



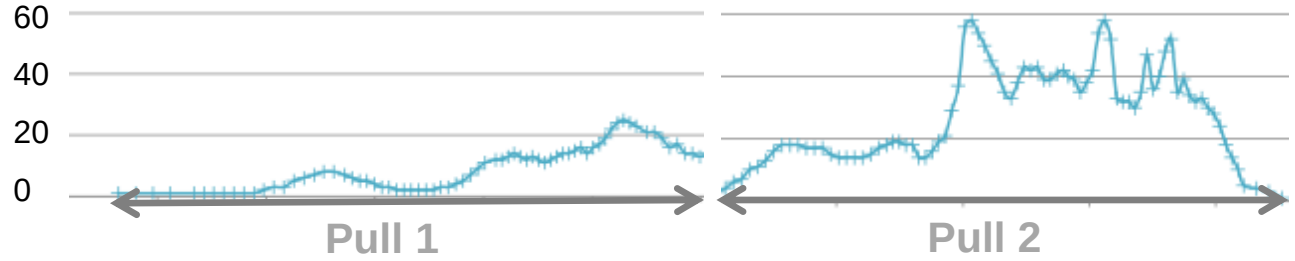
- Digitize seafloor
  → ISE (semi-)automatically
- Identify anchor track(s)
- Re-Digitize the level of „un-disturbed seafloor“ in the zone influenced by the anchor
  → ISE manually
- Overwrite seafloor level
  → ISE automatically
- Detect depth of influence (anchor penetration depth)
  → ISE target picker



Penetration depth Δz (m)

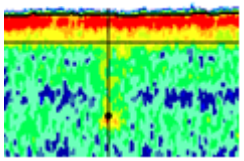


Pulling force (t)

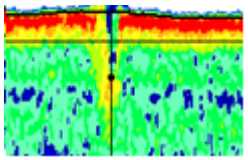


SES - Echoplots

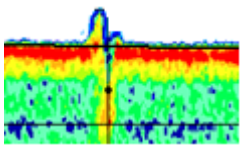
ID: 591
Δz : 0.88



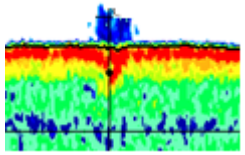
ID: 51
Δz : 0.56



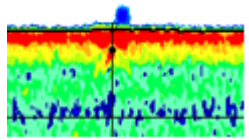
ID: 52
Δz : 0.38



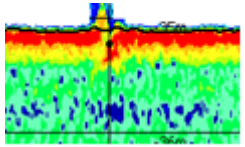
ID: 59
Δz : 0.23



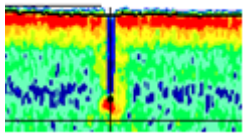
ID: 53
Δz : 0.16



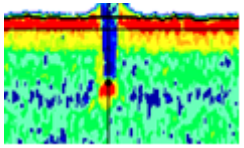
ID: 54
Δz : 0.11



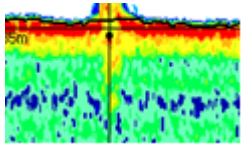
ID: 58
Δz : 0.72



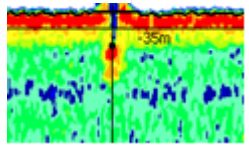
ID: 56
Δz : 0.56

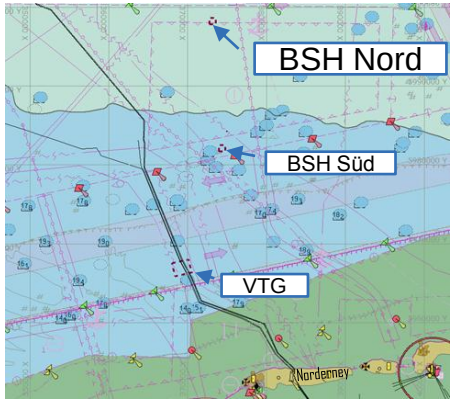


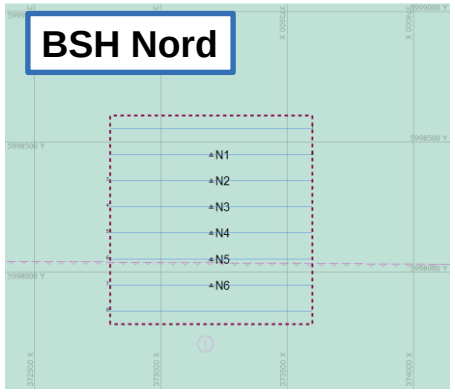
ID: 55
Δz : 0.13



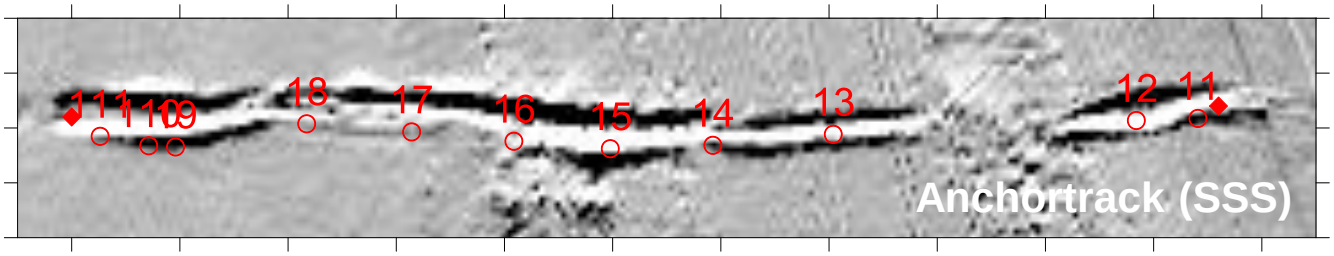
ID: 57
Δz : 0.29



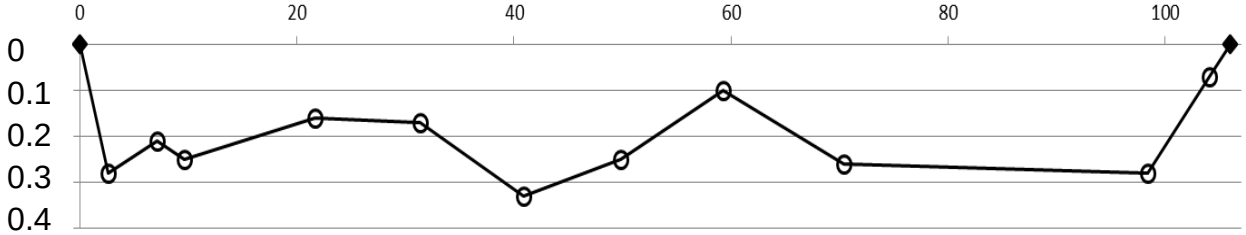




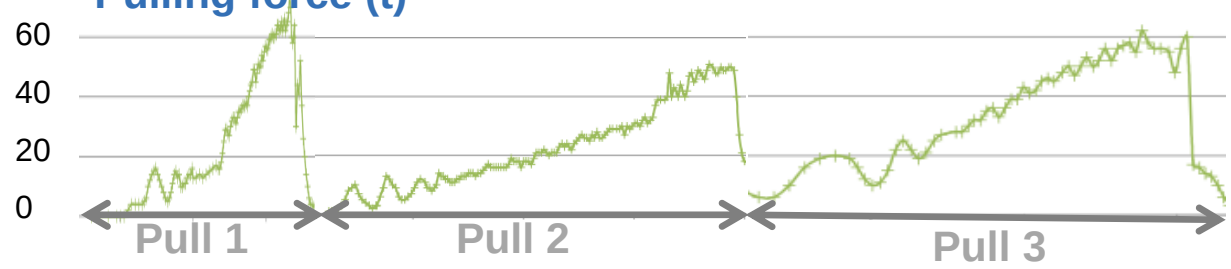
area	**Nord**
Pos	**N5**
Typ	**Hall**
Length	**87 m**
Max. pull	**58 t**
Max. Δz	**0.88 m**



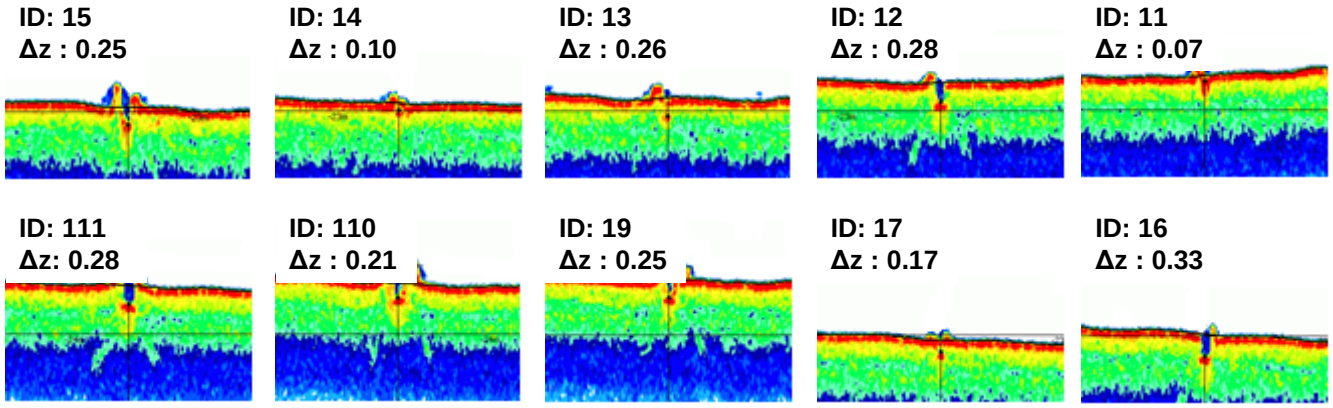
Penetration depth Δz (m)

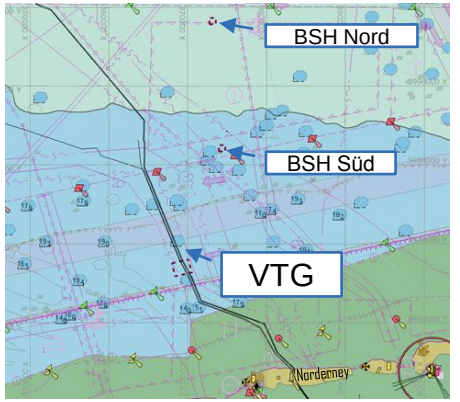


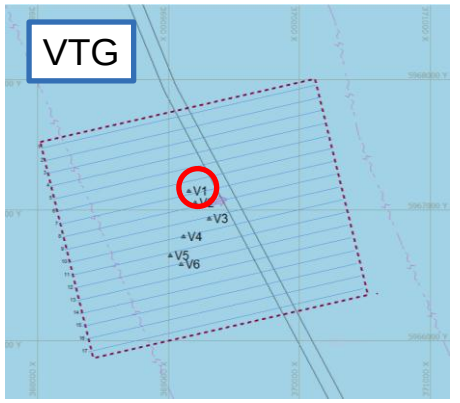
Pulling force (t)



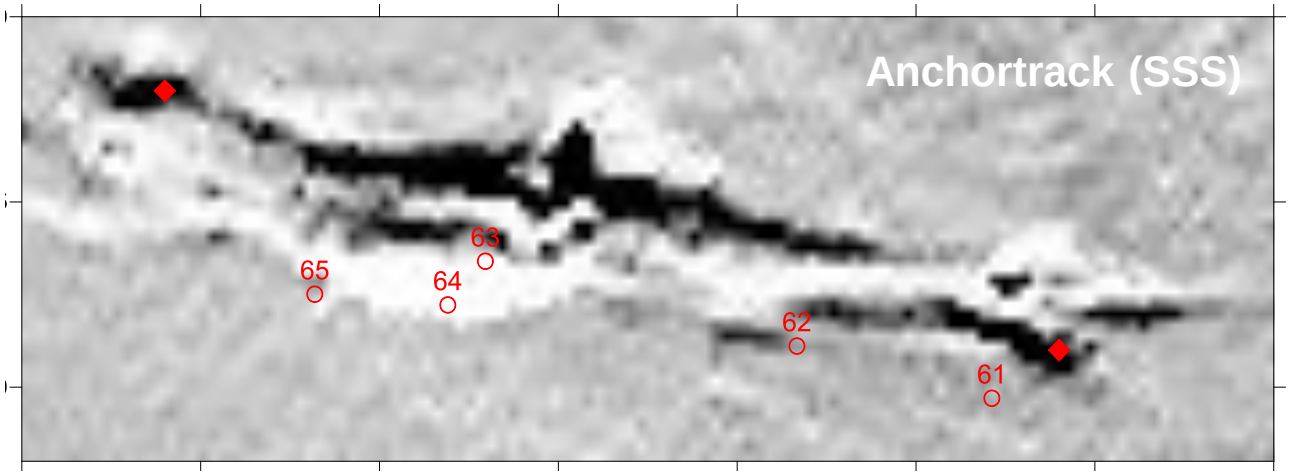
SES - Echoplots

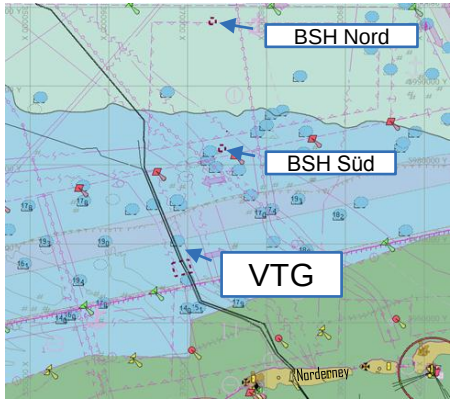


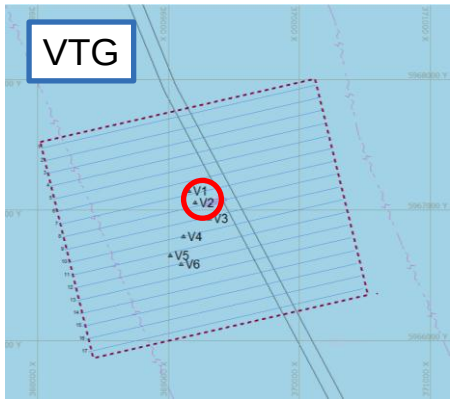




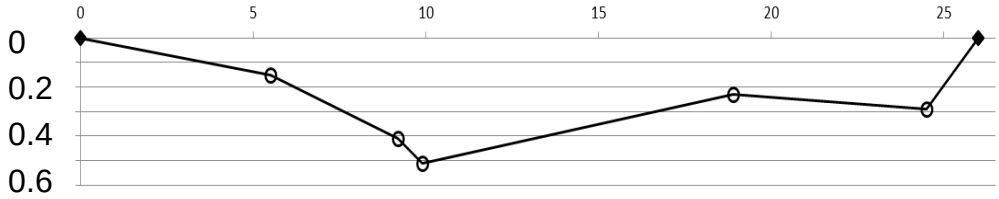
area	**VTG**
Pos	**V1**
Typ	**AC14**
Length	**107 m**
Max. pull	**73 t**
Max. Δz	**0.33 m**



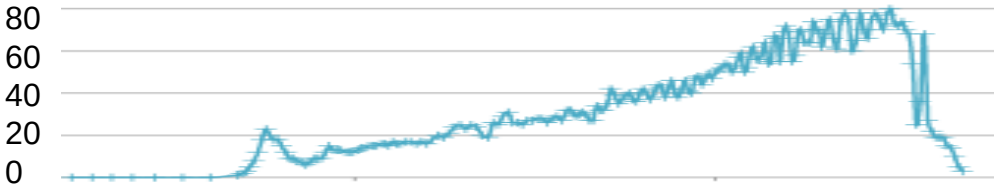




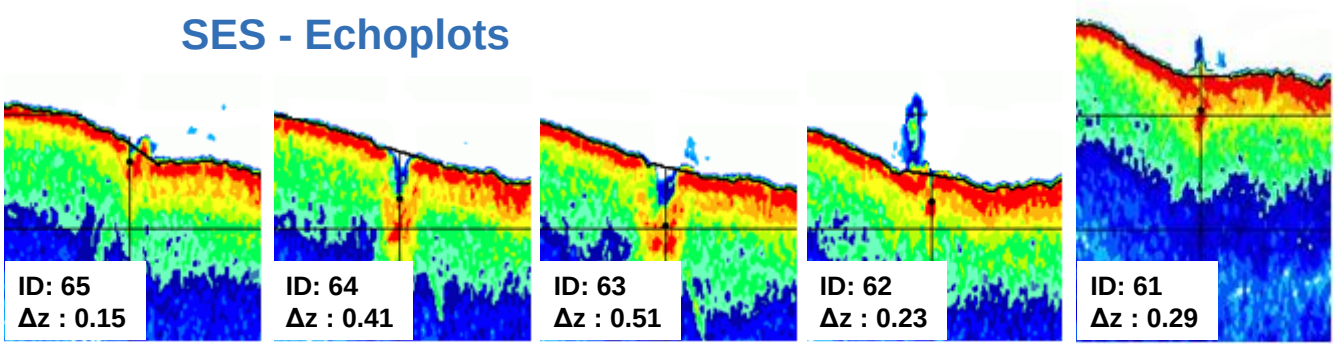
Penetration depth Δz (m)



Pulling force (t)



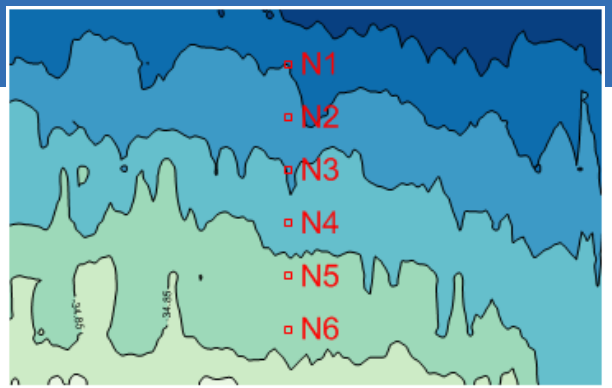
SES - Echoplots



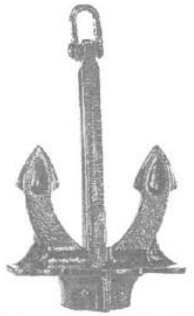
area	**VTG**
Pos	**V6**
Typ	**Hall**
Length	**26 m**
Max. pull	**80 t**
Max. Δz	**0.51 m**

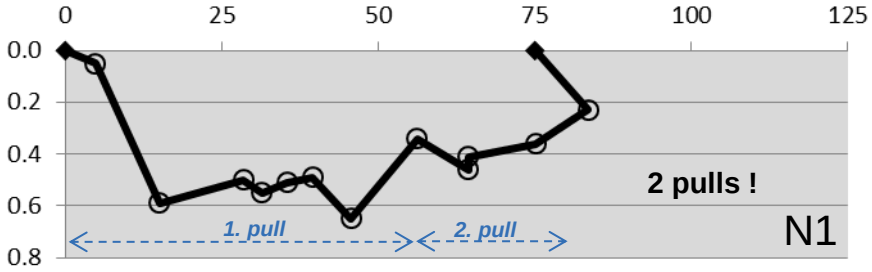
BSH - Nord – Anchortracks

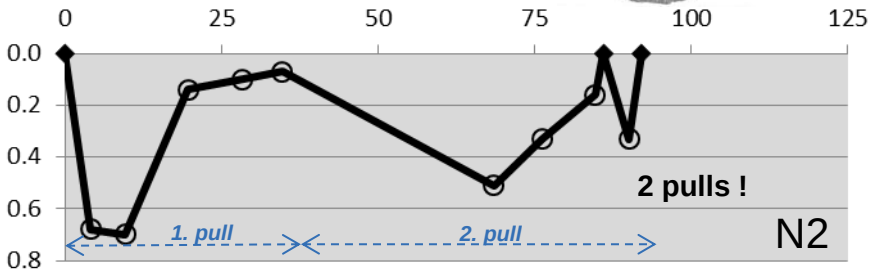
AC14

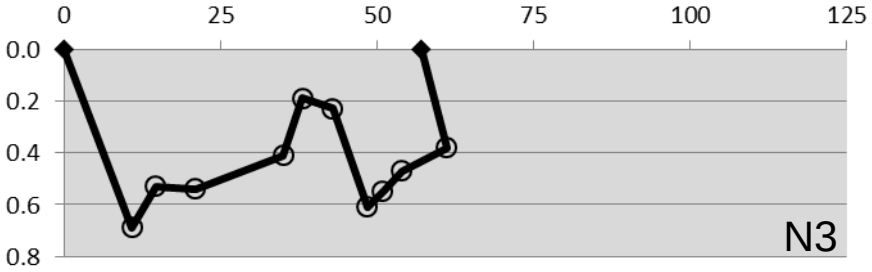


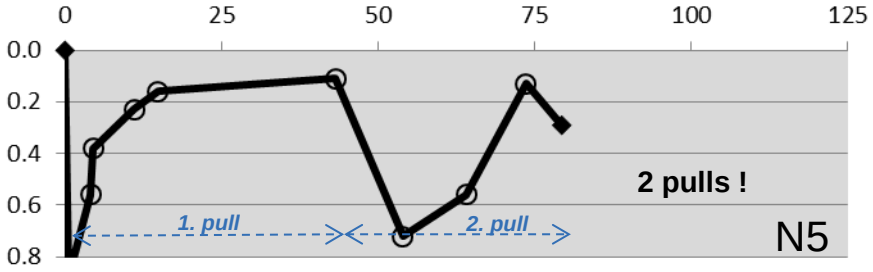
Hall

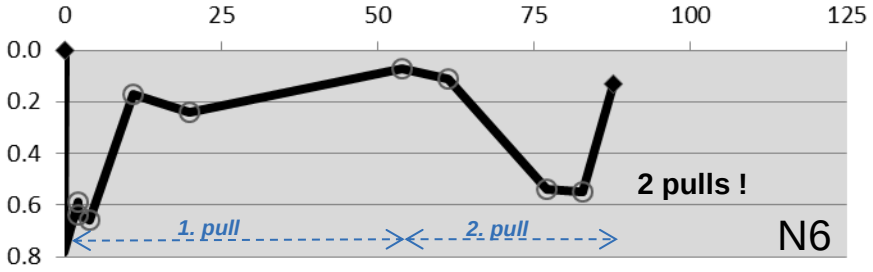






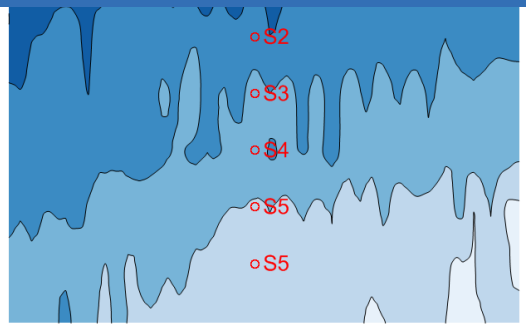




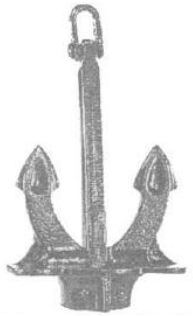


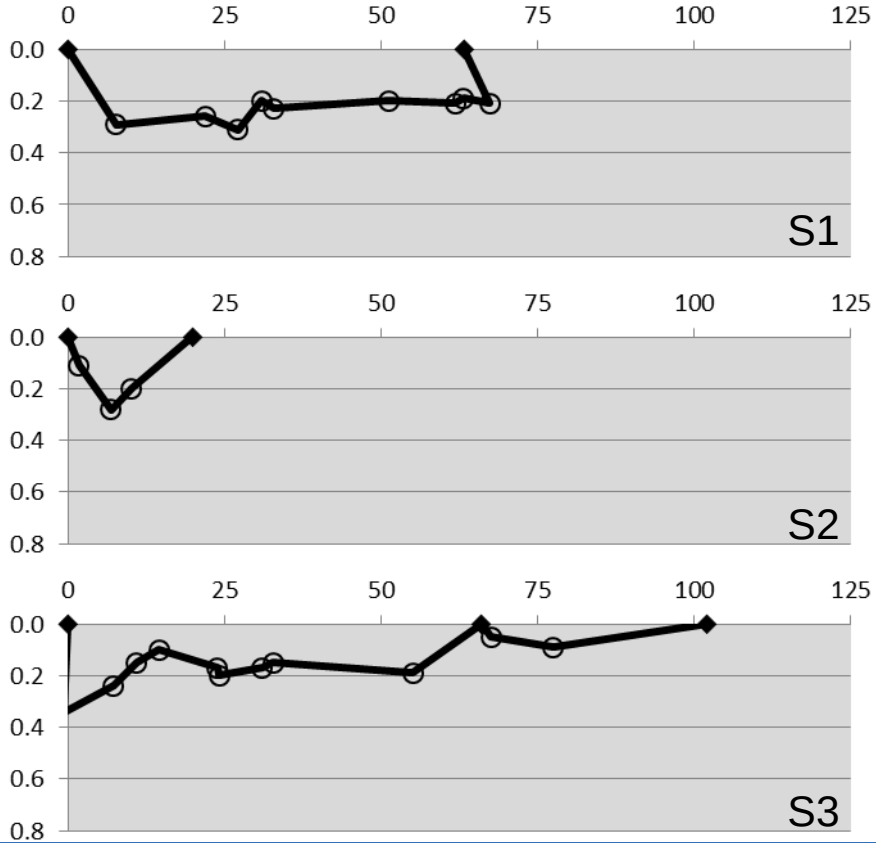
BSH - Süd – Anchortracks

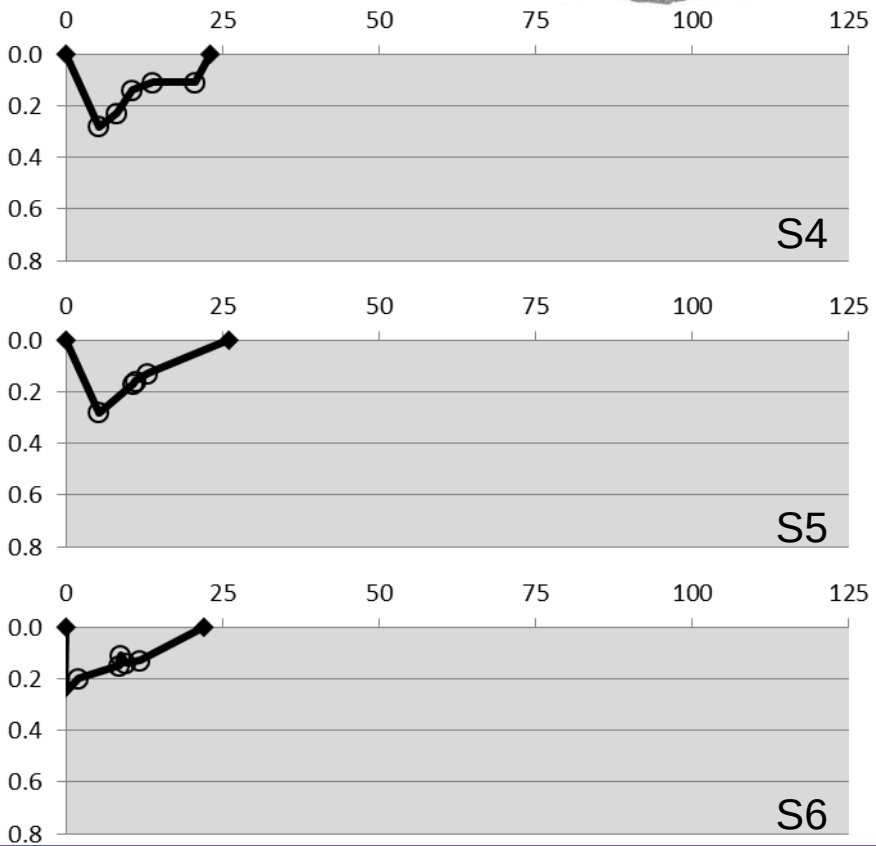
AC14



Hall

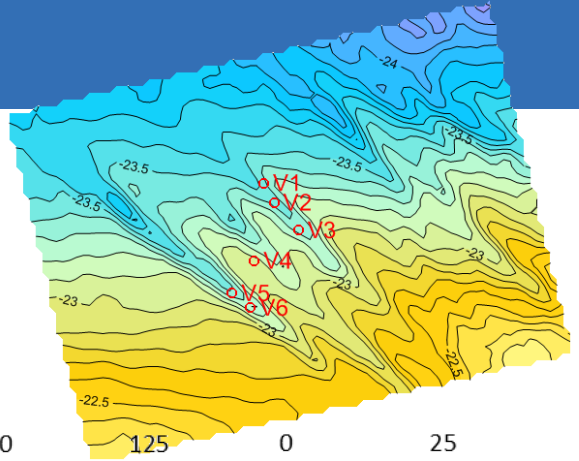


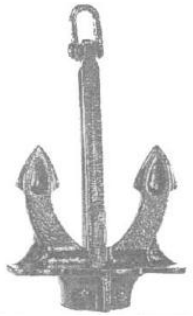




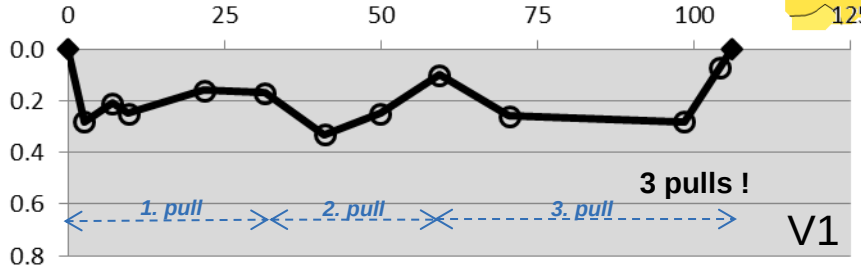
BSH - VTG – Anchortracks

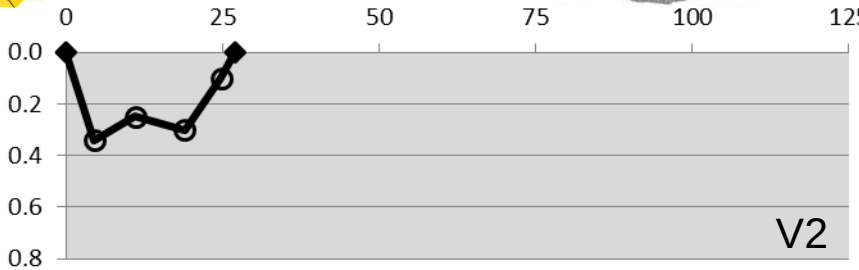
AC14

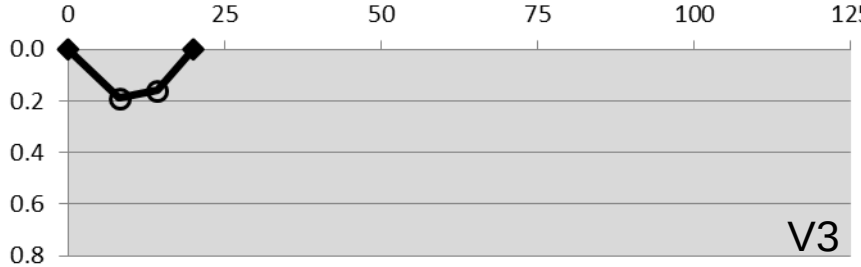


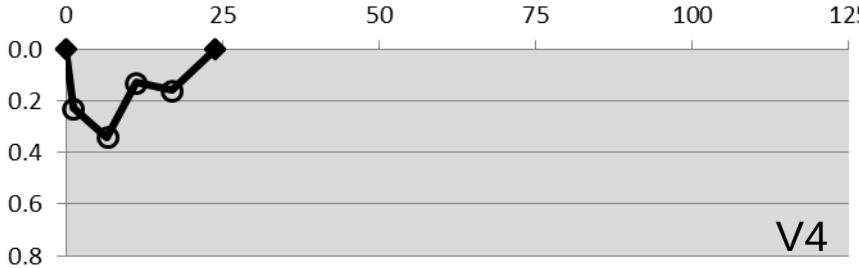


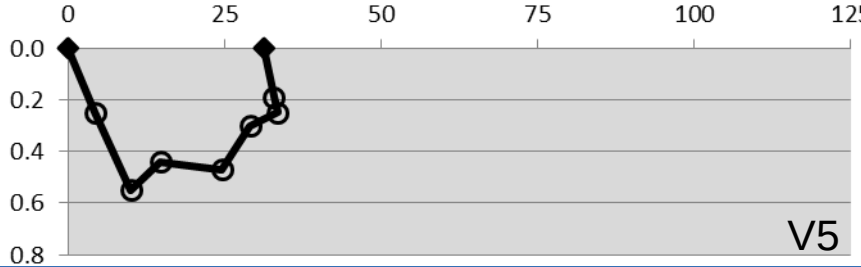
Hall

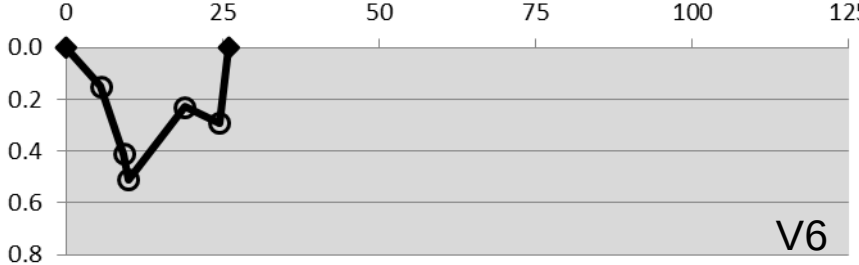




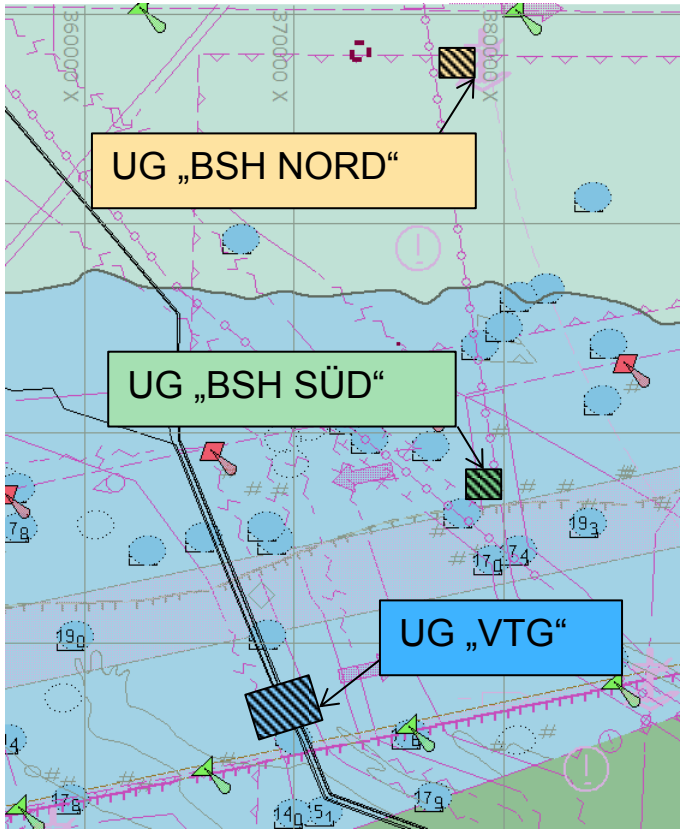








Anchor test
Summary of all anchor pulls



Position	Anchor	tracklength	Max. pull	Max. Δ z
		[m] (#pulls)	[kn]	[m]
N1	AC14	67 (2x)	620	0.65
N2	Hall	**92** (2x)	640	0.70
N3	AC14	57	**820**	0.69
N5	Hall	87 (2x)	580	**0.88**
N6	Hall	92 (2x)	650	0.78
S1	AC14	63	860	0.33
S2	AC14	20	**950**	0.28
S3	AC14	**102**	640	**0.34**
S4	Hall	23	760	0.28
S5	Hall	27	720	0.28
S6	Hall	22	800	0.26
V1	AC14	**107** (3x)	730	0.33
V2	Hall	27	750	0.34
V3	AC14	20	780	0.19
V4	Hall	24	790	0.26
V5	AC14	31	**800**	**0.67**
V6	Hall	26	**800**	**0.67**

- **Max. penetration depth less then 1,0 m***
- **Critical VTG area less than 0,8 m***
- **Pulling forces comply and exceed the holding power of anchors -> results are realistic**

(*including measurement uncertainties)

Measured Results

- No anchor penetration deeper than 1m has be observed (including all measurement errors)
- anchor crown resists on seabed after drop

Additional calculations and interpretations

- the fluke tip to shank distance may be used as an estimate for the penetration depth (1,0 m and 1,2 m for AC14 and Hall respectively)
- addition of geometry error gives a theoretical maximum penetration depth of 1,2 m
- extrapolation to a 29 t anchor gives a theoretical penetration depth of 1,6 m

Changes in the burial requirements in the German North Sea

- Results have been accepted by the consenting authorities
  - Burial depth requirements have been reduced from 3 m to 1,5 m
  - Result will be integrated into the new offshore grid plan 2014

Data Availability and outlook

One of the best documented large scale experiement on anchor penetration

Reports and Videos will be made public available on the SCUK web page

or

send me an email with your request: **anja.drews@tennet.eu**

Future research using the recorded experimental data:

- Numerical Modelling of test results – PhD thesis at the Technical University of Hamburg – Harburg
- JIP Safetrech – development of numerical models on anchor behaviour, Reseach project lead by Deltares