How deep does an anchor penetrate the seafloor?

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"How deep does an anchor penetrate the seafloor?". This question has been explored by a team of scientists and technicians as well as the crews of three involved ships in the German Bight. One HHP AC 14 and one Hall type anchor have been dropped and dragged in a series of 18 trials following an exact specified procedure. The behaviour of the anchor, especially the impact on the seafloor and the maxiumum penetration depth have been documented and surveyed before, during and after the anchor trials. For this different hydroacoustic methods like Sediment Echosounder (SES) and Sonarsystems (MBES, SSS), videodocumentation and the measurement of pressure and pulling forces have been implemented.

Motivation for this large scale fieldwork is the shore connection of wind-energy parks by sea cables in the German Bight. The actual regulations prescribe a burial depth of 3m for sea cables in shipping channels. The reason for these increased requirements is the risk potential which is seen by anchor manouvres in emergency cases and disasters. On the other hand the realization of a burial depth of 3m is very ambitous from a technical point of view as well as very cost intensive.

Therfore the approving authority (Generaldirektion Wasserstraßen und Schifffahrt, GDWS) and the transmission system operator Tennet Offshore GmbH agreed upon this investigations to determine the real penetration depths of anchors into the seafloor. The results of the tests potentially shall support the improvement of the regulations for the burial depth of sea cables in shipping channels.

Next to Tennet the Federal Maritime Hydrographic Agency (BSH) the dutch research institute Deltares and the Federal Waterways Engineering and Research Institute (BAW) have been involved in the field work, the documentation and the scientific evaluation of the results.

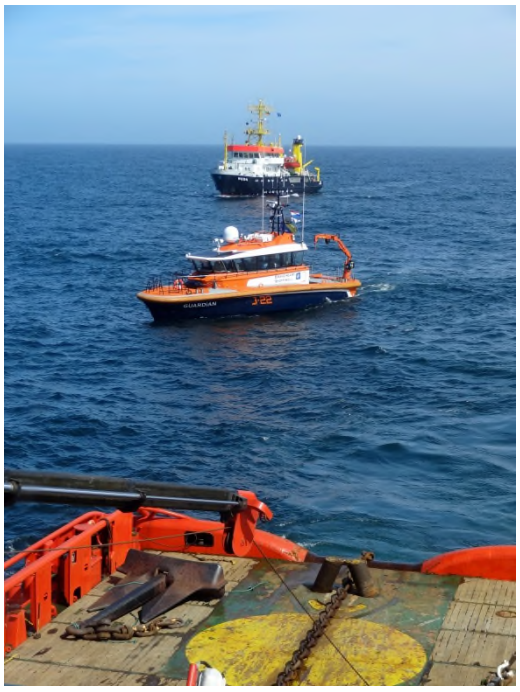

Figure above:
Offshore support vessel „ESVAGT CONNECTOR" during anchor drag

Figure left:
Background: survey vessels "WEGA" (BSH) and "GUARDIAN"
Foreground: HHP AC14 anchor on deck "ESVAGT CONNECTOR"

Bundesanstalt für Wasserbau
Federal Waterways Engineering and Research Institute

How deep does an anchor penetrate the seafloor ?

Anchor tests in the German Bight

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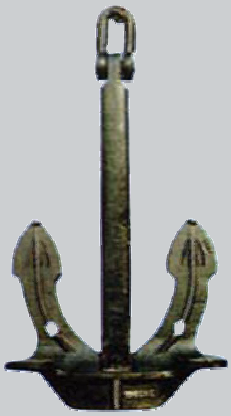
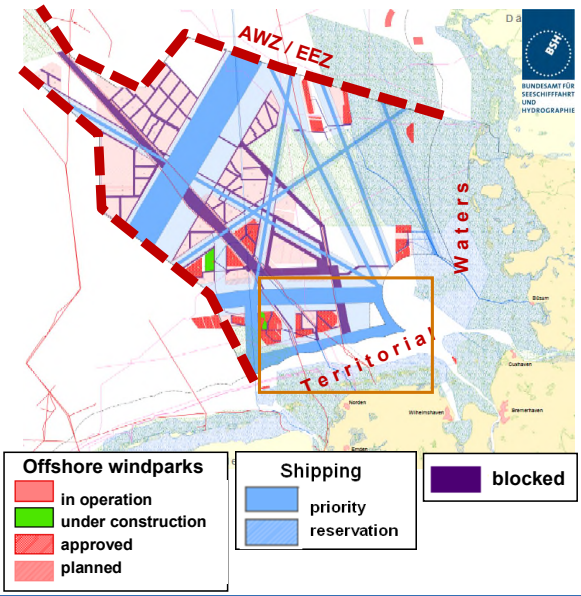
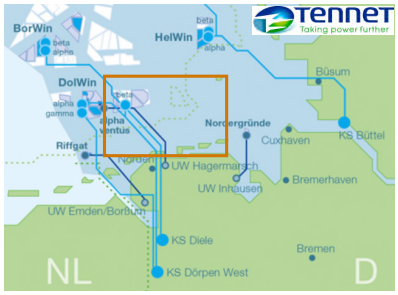
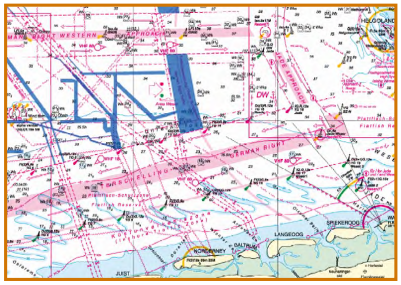


The Northsea
… an undisturbed wideness ?

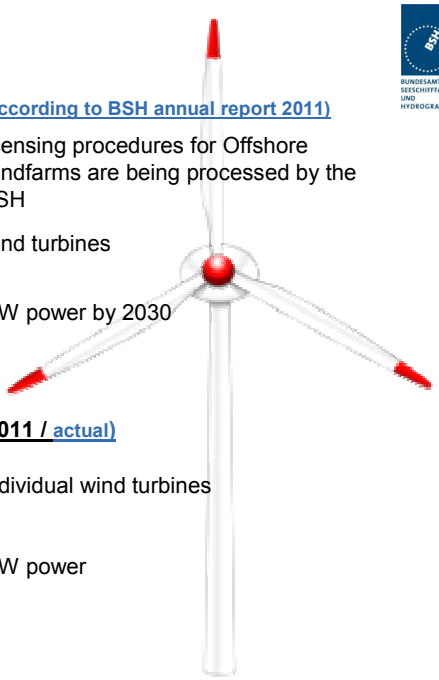
The seas are moving from traffic routes, fishing and recreational areas to an economic ressource as an energy reserve







Offshore wind
… some facts

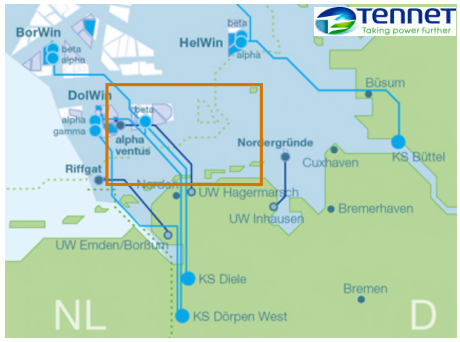


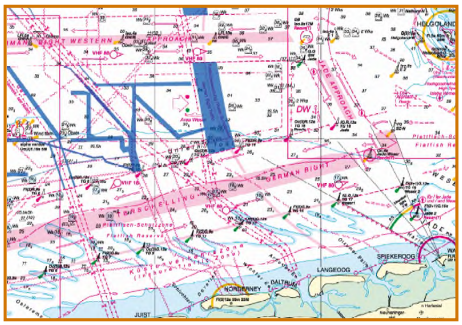
Target figures (according to BSH annual report 2011)

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



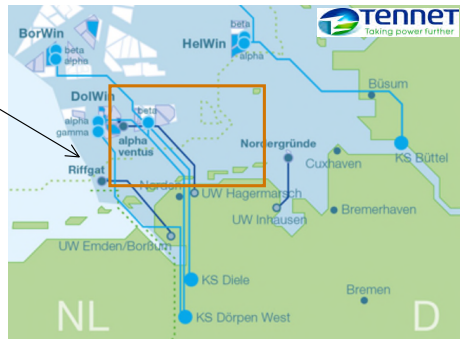


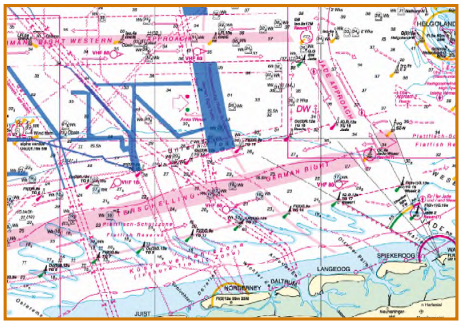
Grid connection
… the challenge

- 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

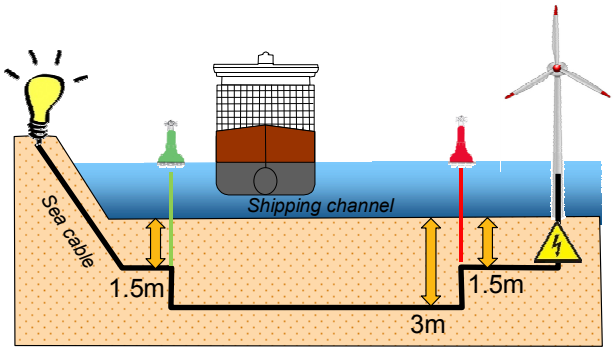
prescribed burial depth of sea cables

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)



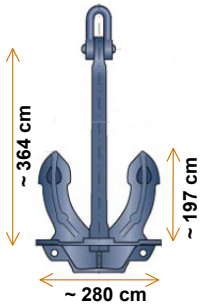
Reason for the increased requirements in shipping channels:

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

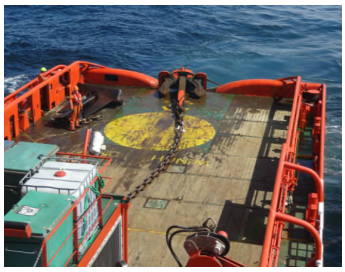
… agreed upon investigations to determine the real penetration depths of anchors into the seafloor

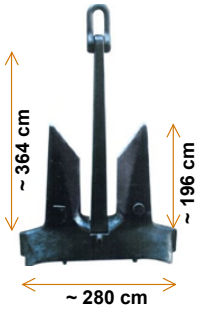
Test anchors

Up to 294 m length / 80000 DWT



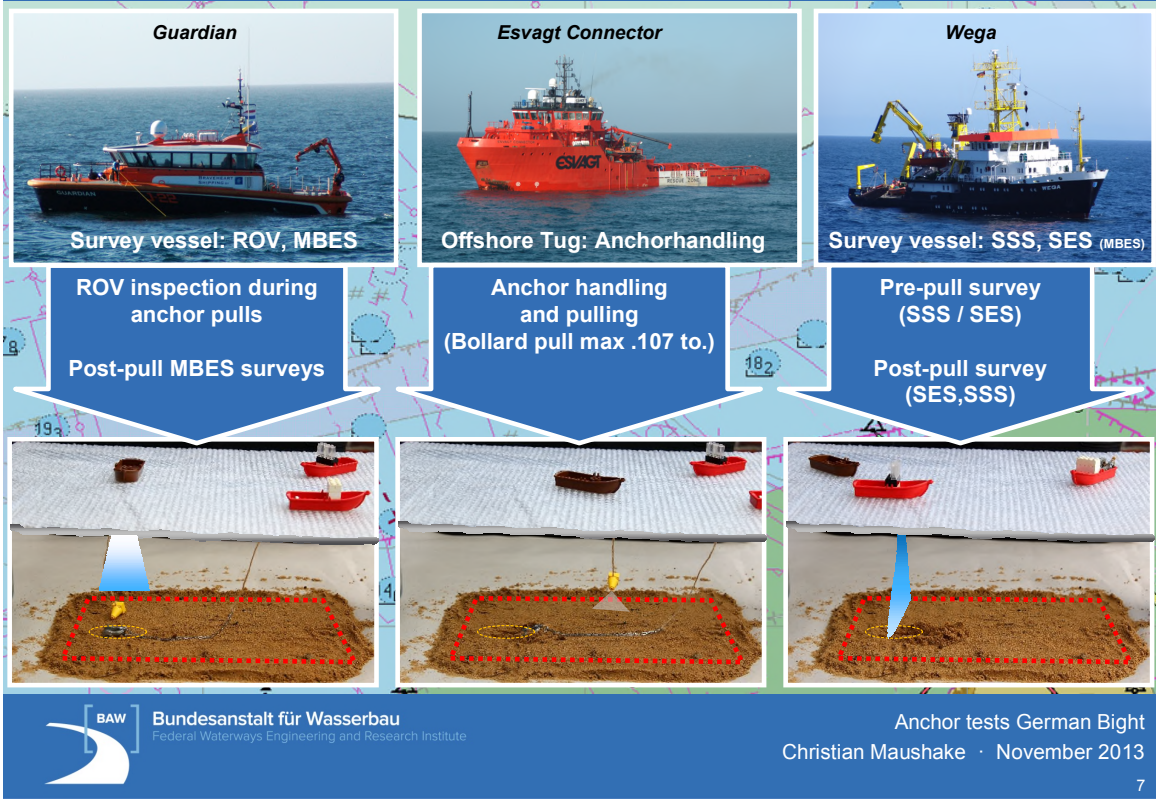
Hall ~11.7 to.



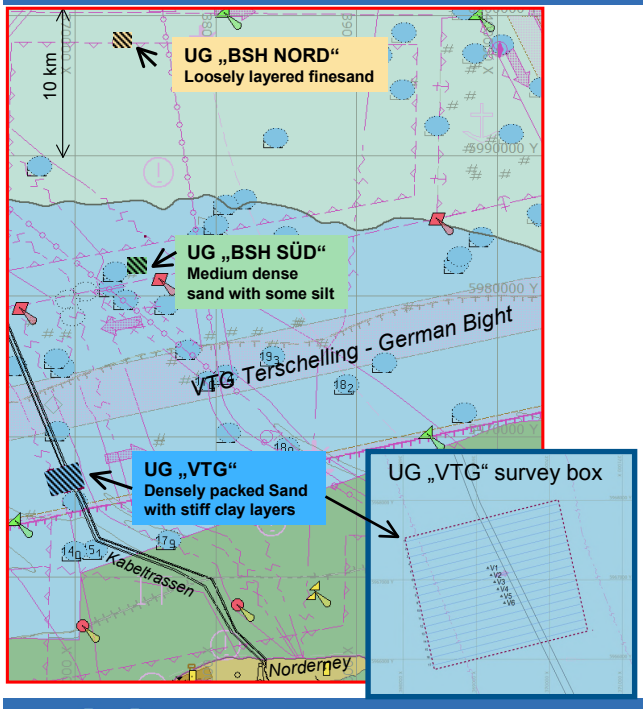


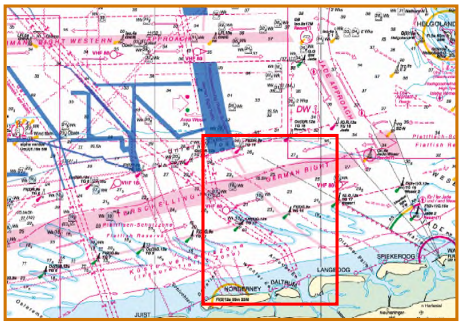
HHP AC14 ~8.3 to.

Vessels and tasks



Test sites



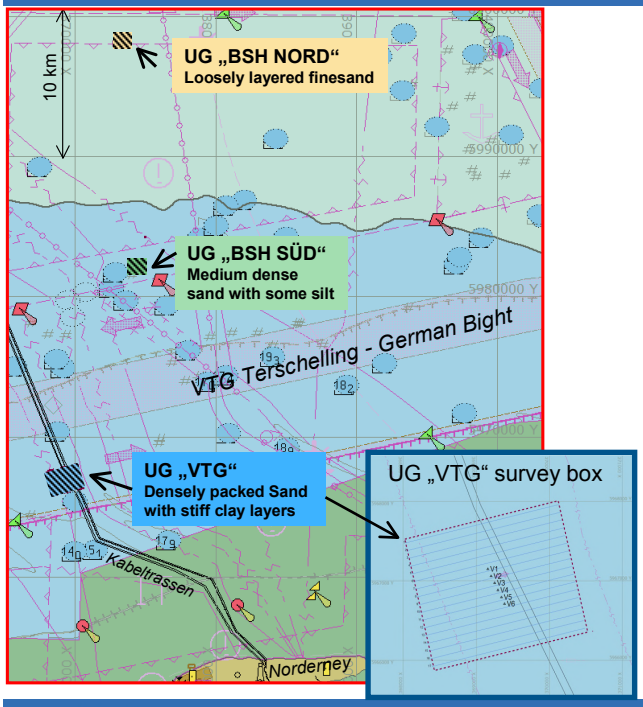


3 test sites with different soil conditions reflecting the interaction between anchor and seabed

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

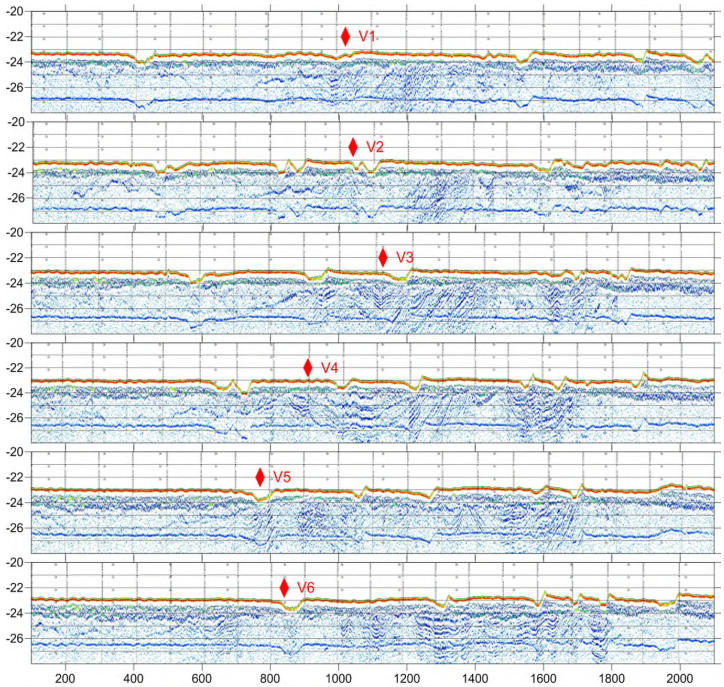
Anchor pulls

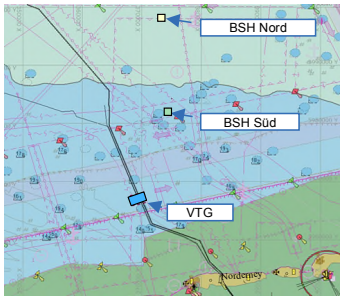
- → **Move offshore tug to drop position**
- → **Dropping anchor**
- → **ROV video check of anchor position and alignment**
- → **Anchor pull up to 80 to. (load cell) or anchor break out**
- → **ROV Video check of final position**
- → **Recover anchor**

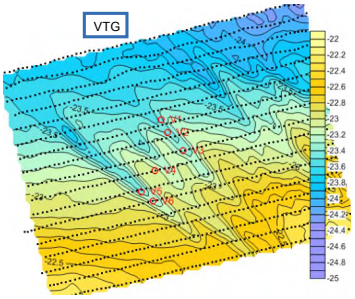
Post - pull - survey

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

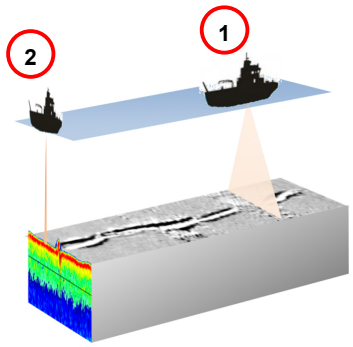
SES Pre – pull survey (VTG)

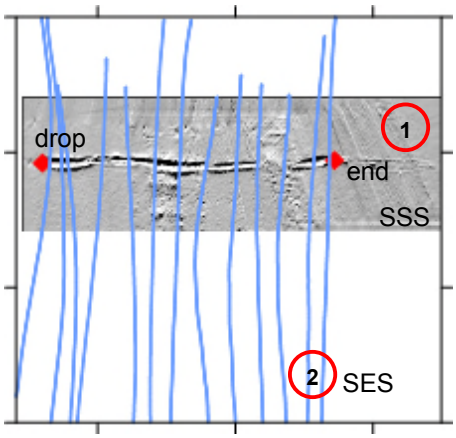


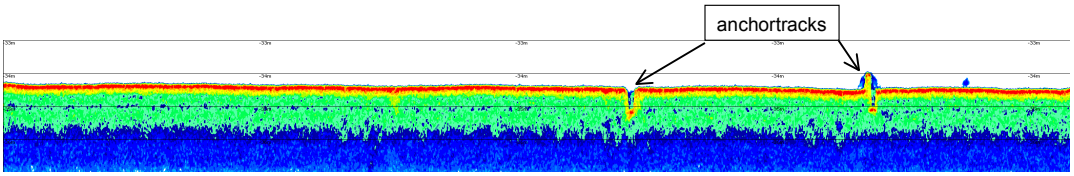




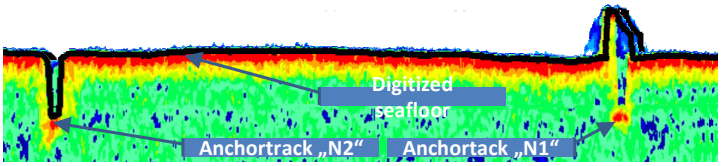
Combined SSS / SES survey of anchor tracks (Post – pull survey)

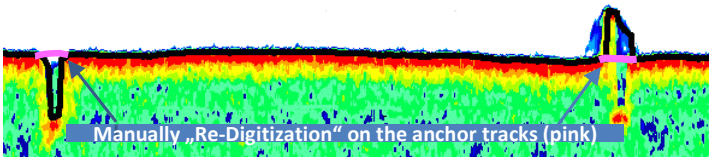


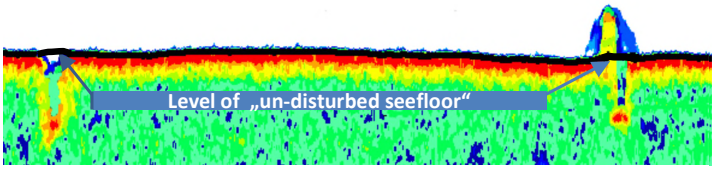


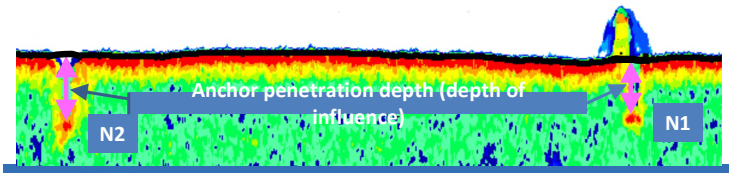


Detection of anchor penetration depth
… as performed with SES processing software ISE

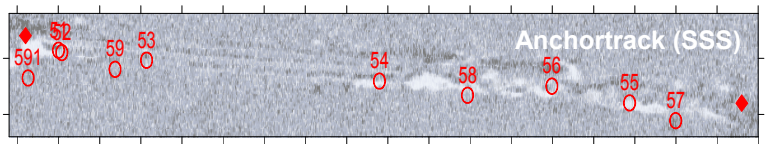


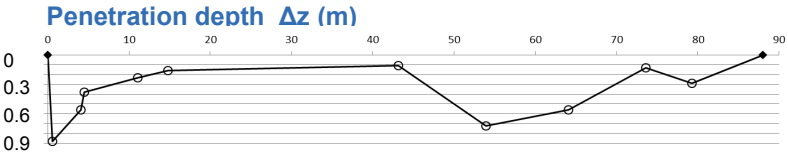


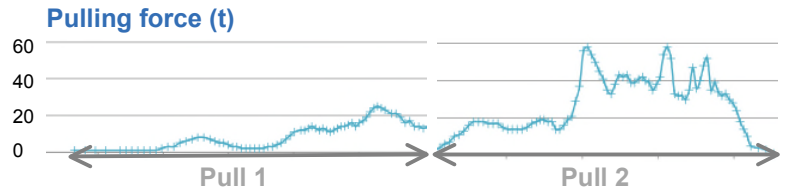


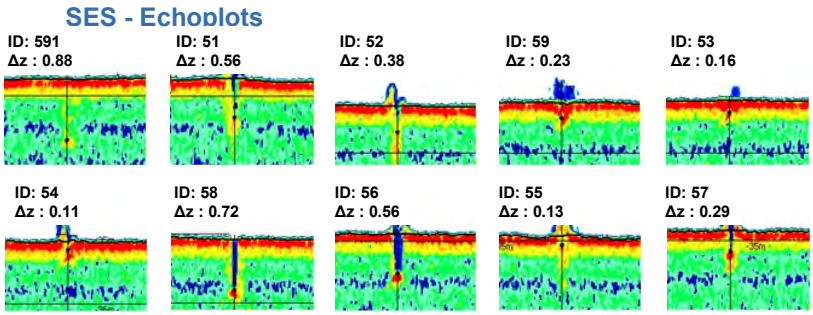


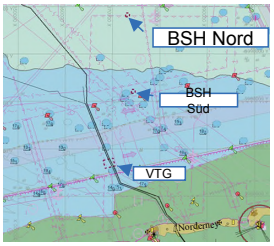
- Digitize seafloor
  → ISE automatically
- Identify anchor track(s)
- Re-Digitize the level of „un-disturbed seafloor" in the zone influenced by the anchor
  → ISE manually
- Overwrite seafloor level
  → ISE automatically
- Detect depth of influence (anchor penetration depth)
  → ISE target picker

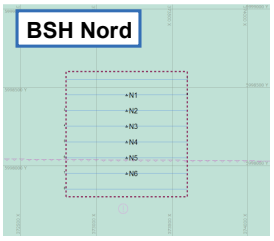




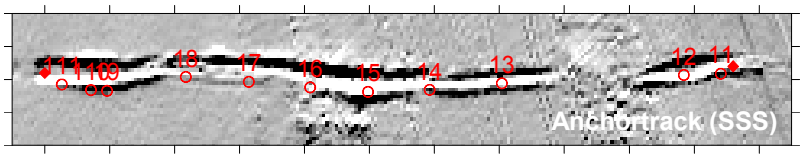


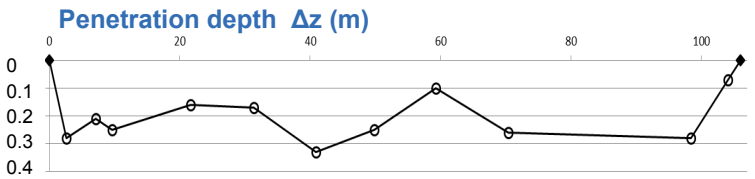


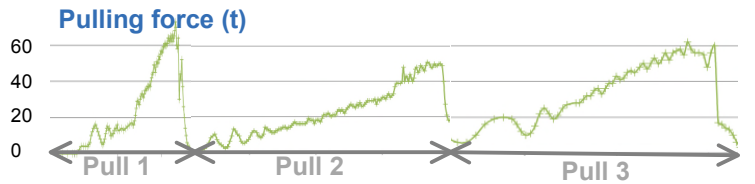


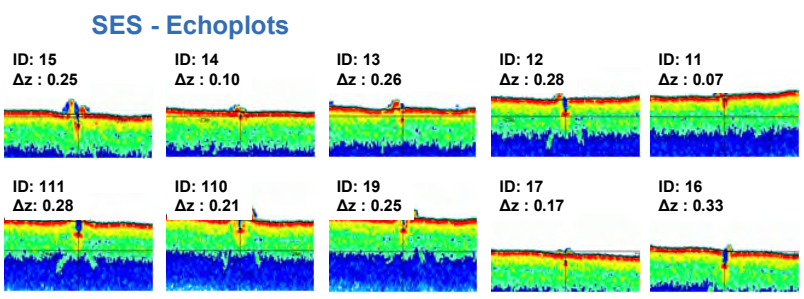


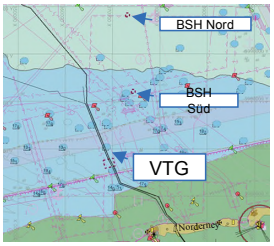
area	Nord
Pos	N5
Typ	Hall
Length	87 m
Max. pull	58 t
Max. Δz	0.88 m

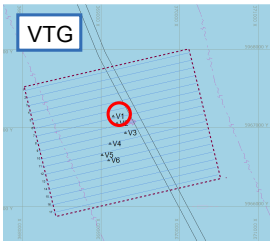




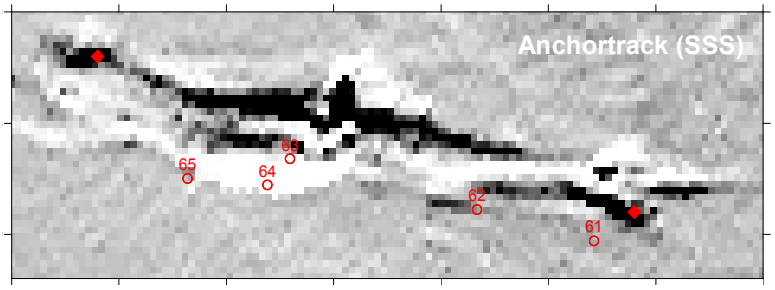


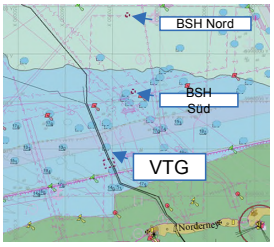


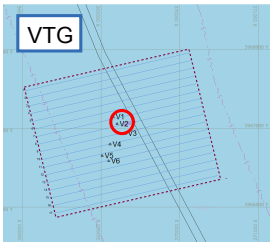




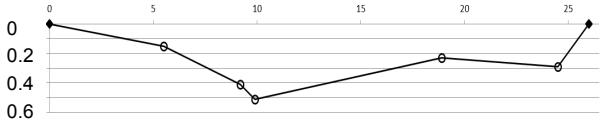
area	VTG
Pos	V1
Typ	AC14
Length	107 m
Max. pull	73 t
Max. Δz	0.33 m





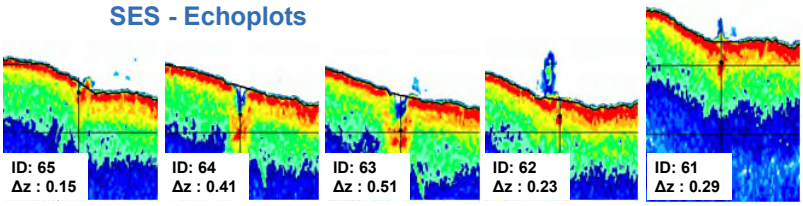


Penetration depth Δz (m)



Pulling force (t)

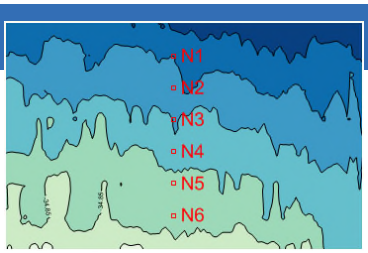
SES - Echoplots



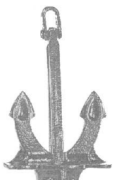
area	VTG
Pos	V6
Typ	Hall
Length	26 m
Max. pull	80 t
Max. Δz	0.51 m

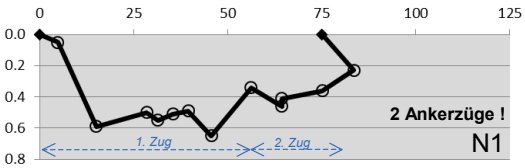
Ankerzugversuche
BSH - Nord – Ankerspuren

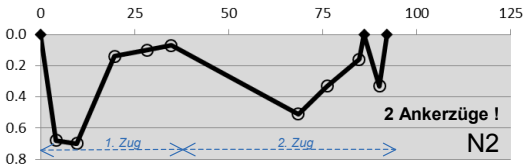
AC14

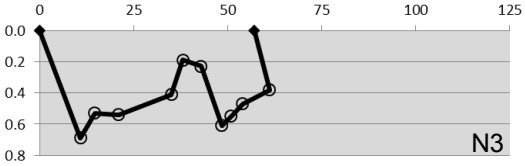


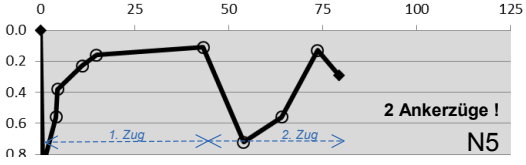
Hall

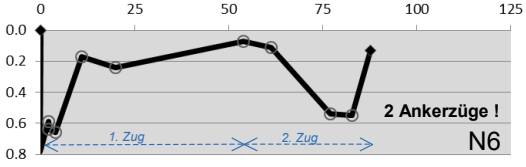








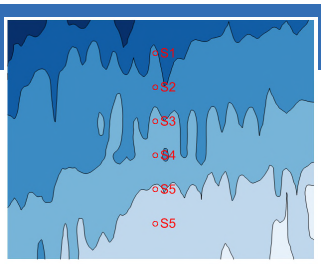




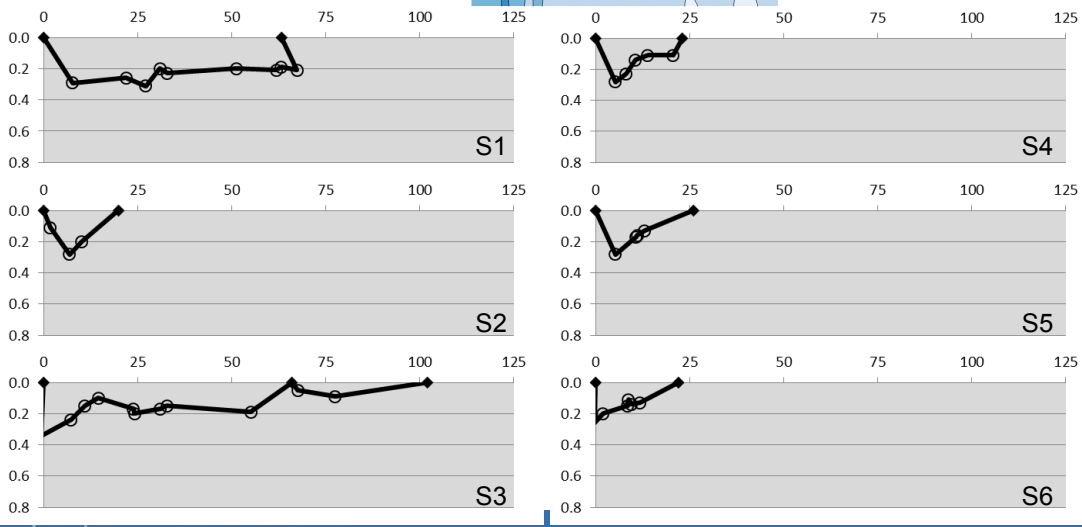
Anmerkung: Länge des 1. und des 2. Zuges aus Ankerspur abgeschätzt

Ankerzugversuche
BSH - Süd – Ankerspuren

AC14

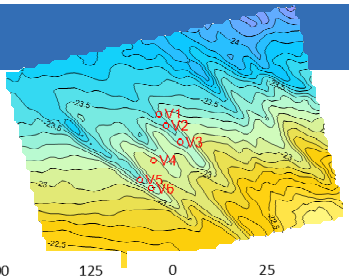


Hall

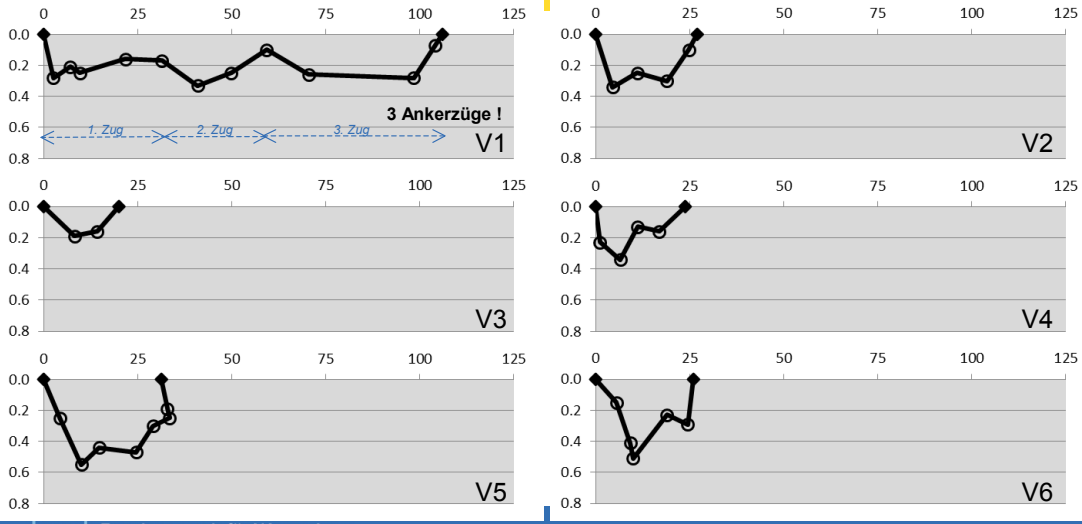


Ankerzugversuche
VTG – Ankerspuren

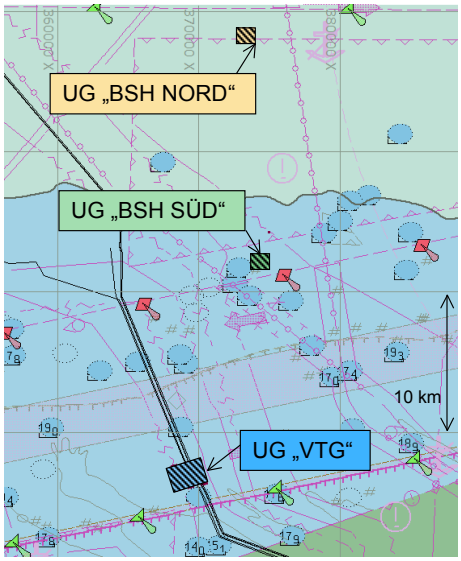
AC14



Hall



Anchor test
Summary of all anchor pulls



Position	Ankertyp	tracklength	Max. pull	Max. Δ z
		[m]	[t]	[m]
N1	AC14	67	62	0.65
N2	Hall	**92**	64	0.70
N3	AC14	57	**82**	0.69
N5	Hall	87	58	**0.88**
N6	Hall	92	65	0.78
S1	AC14	63	86	0.33
S2	AC14	20	**95**	0.28
S3	AC14	**102**	64	**0.34**
S4	Hall	23	76	0.28
S5	Hall	27	72	0.28
S6	Hall	22	80	0.26
V1	AC14	**107**	73	0.33
V2	Hall	27	75	0.34
V3	AC14	20	78	0.19
V4	Hall	24	79	0.26
V5	AC14	31	**80**	**0.67**
V6	Hall	26	**80**	**0.67**

For all anchor tests a maximum depth of influence of not more then 1.0 m could be reported, accounting for all potential errors . In the (critical) traffic seperation zone (VTG) this value this value does not exeed **0.8 m**.

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