DEME

Dredging, Environmental & Marine Engineering

Soil Investigation for the construction of an Offshore Wind Farm at the Thorntonbank - Belgium

Dr. Ir Patrick Mengé

DEME – Dredging International N.V.

Verkenningsboringen

Namen, 10 februari 2009

Les forages de reconnaissance

Namur, le 10 février 2009

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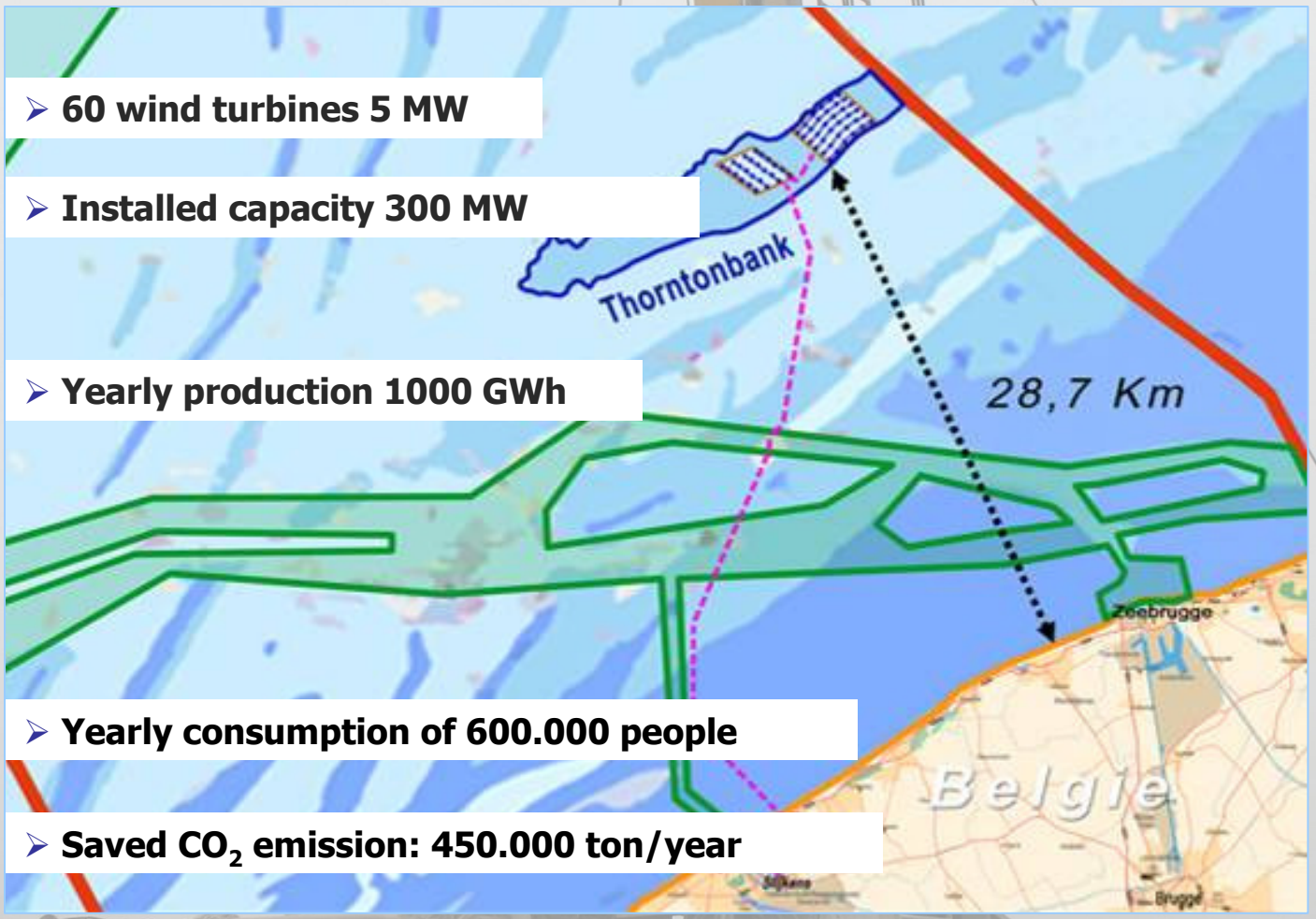
CONTENTS

DESCRIPTION OF THE PROJECT



- 60 wind turbines 5 MW
- Installed capacity 300 MW
- Yearly production 1000 GWh
- Yearly consumption of 600.000 people
- Saved CO_2 emission: 450.000 ton/year

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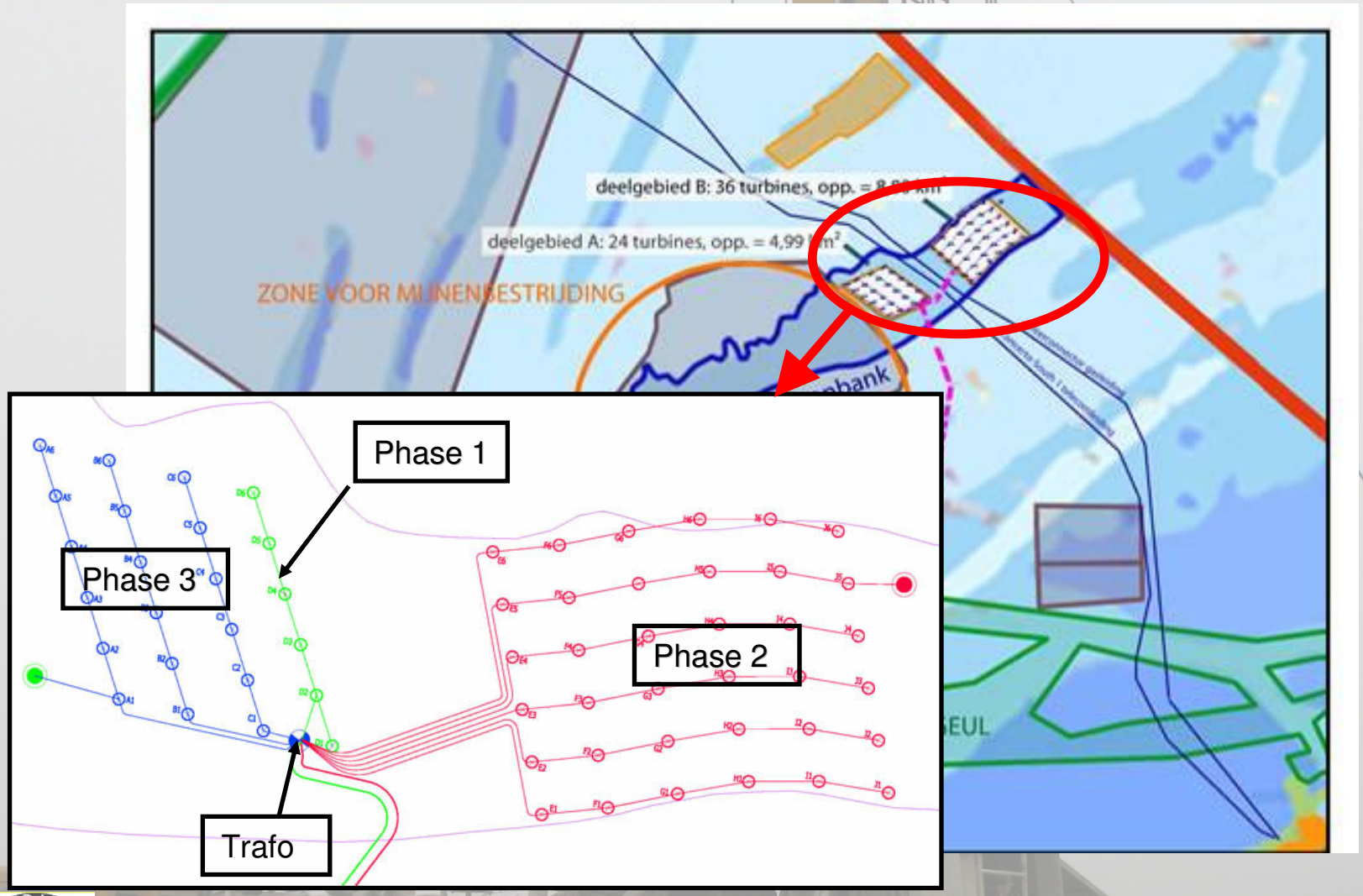
DESCRIPTION OF THE PROJECT



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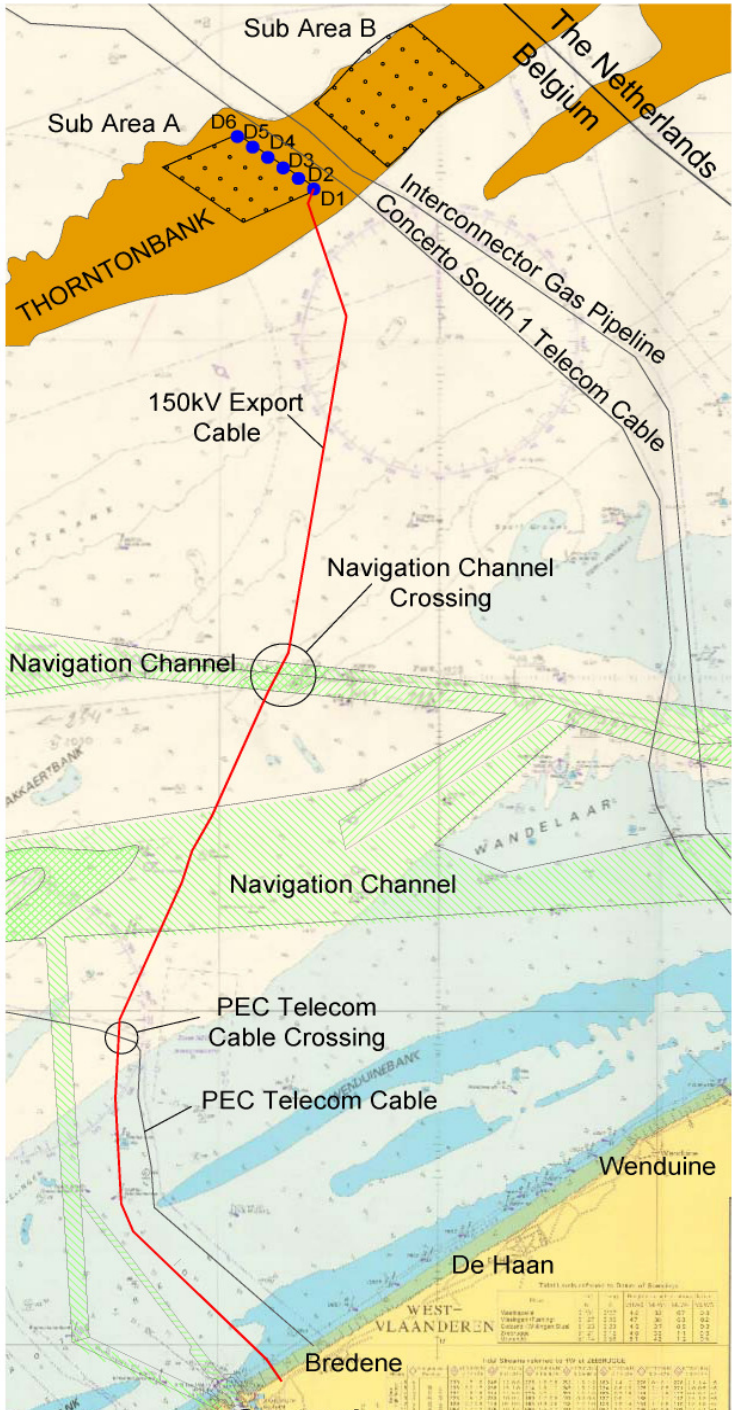
DESCRIPTION OF THE PROJECT

Connection to the land network: 38 km of cable



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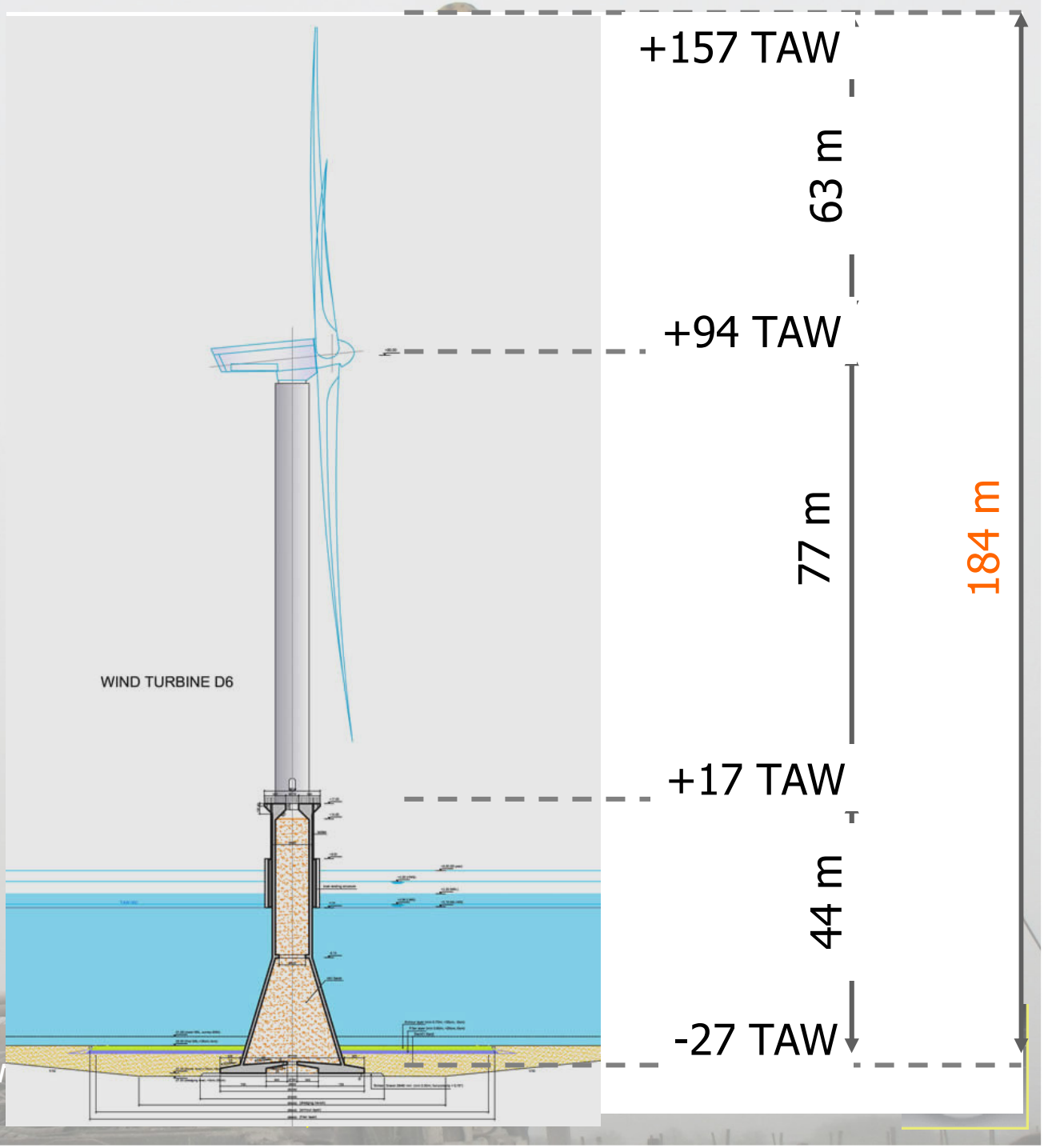

SITE INVESTIGATION SETUP

- Site investigation Phase I + cable route: 2004; Phase II: 2008
- Focus on Phase I
- Desk Study (Tertiary and Quarternary Geology of the Belgian Shelf)
- Geophysical
  - Multibeam bathymetry
  - Seismic reflection testing
  - Side Scan Sonar
  - Magnetic survey
- Geotechnical
  - CPTU (deep and undeep), where necessary with predrilling
  - Boreholes with disturbed and undisturbed sampling
  - Boreholes with pressiometer testing
  - Laboratory investigation (static and dynamic soil properties)

CPT at each wind turbine locations; no BH at each wind turbine location.
Geophysical testing assists to define optimal locations for BH's

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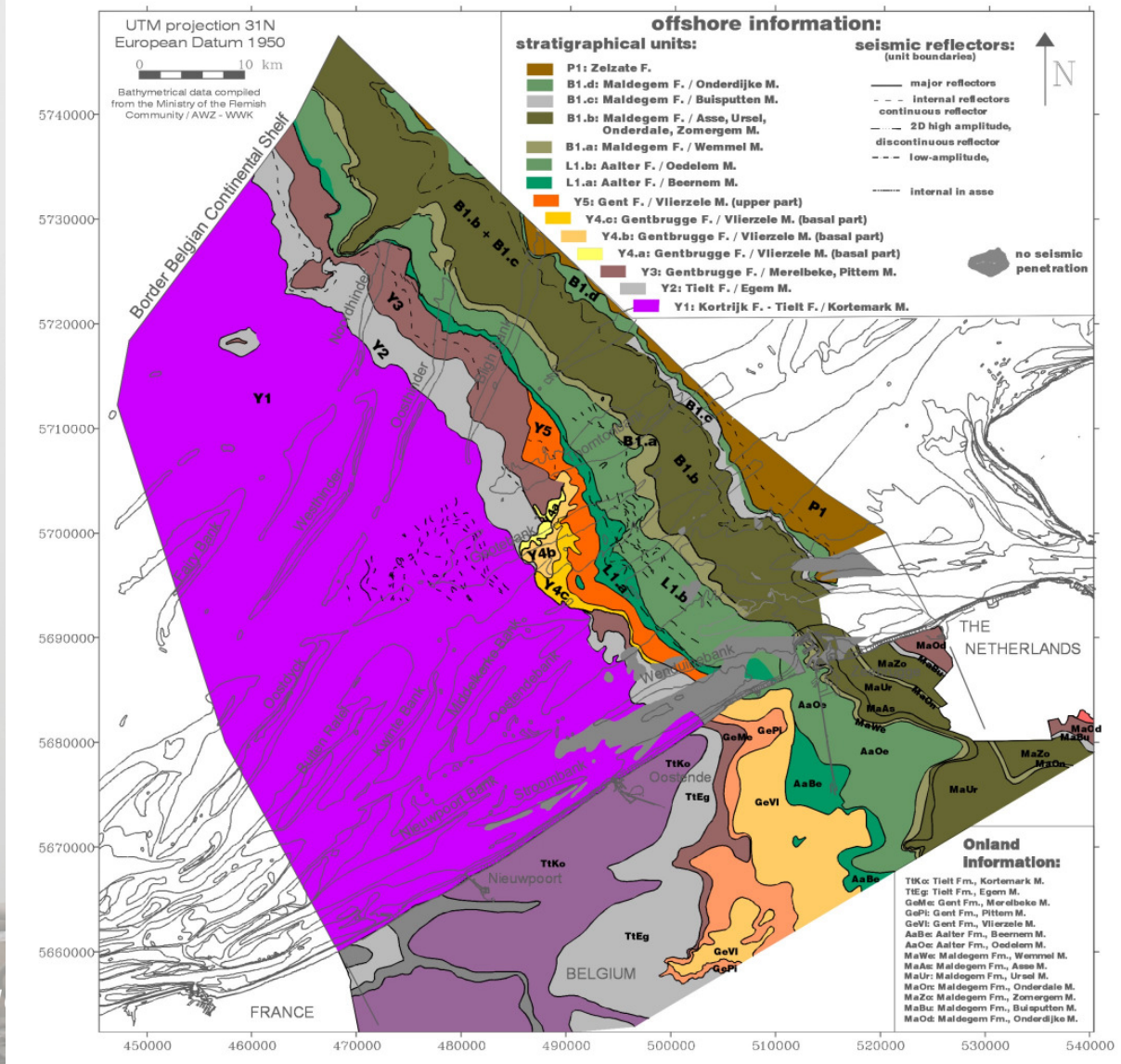
DESK STUDY

- ✓1 BH Belgian Geological Survey on the Thorntonbank
- ✓Document “Teriary and quarternary Geology of the Belgian Continental Shelf”



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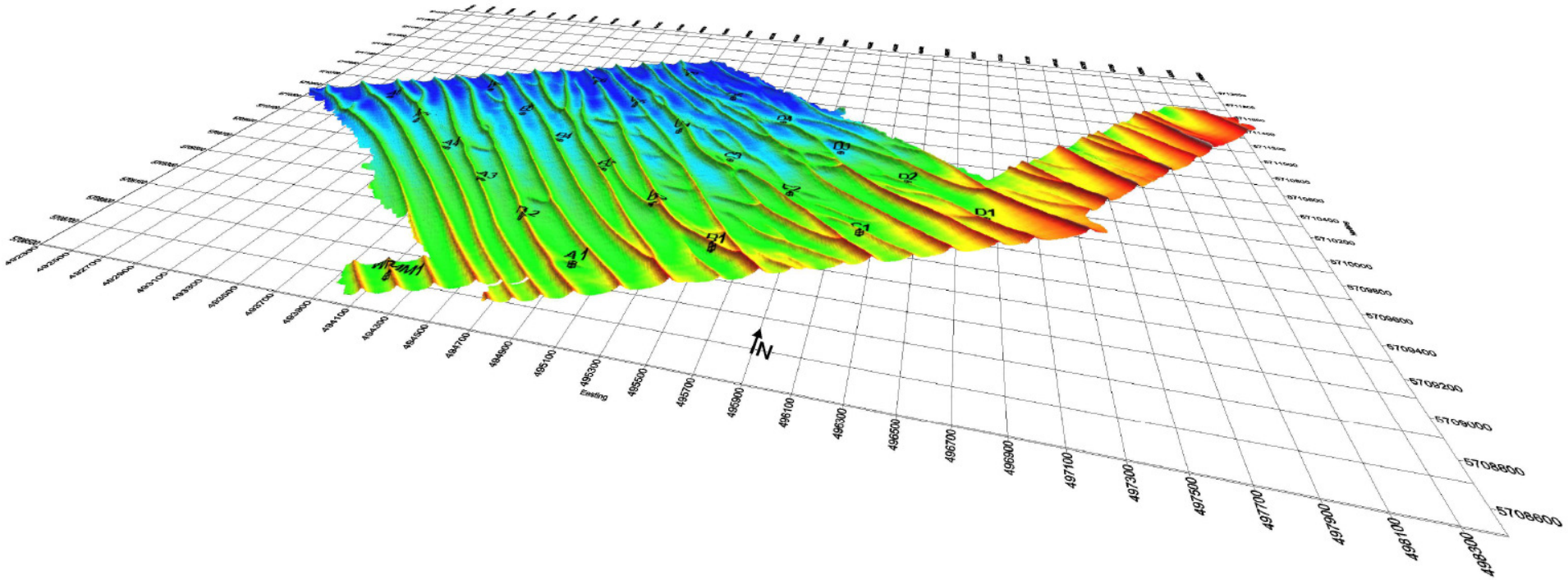
GEOPHYSISCAL TESTING

Bathymetry

- Depth: -10m TAW tot -25m TAW
- Sandwaves 5m high, 150m tot 200m long
- Seabottom sinks to the NW
- Orientation of the sandwaves NW-SE



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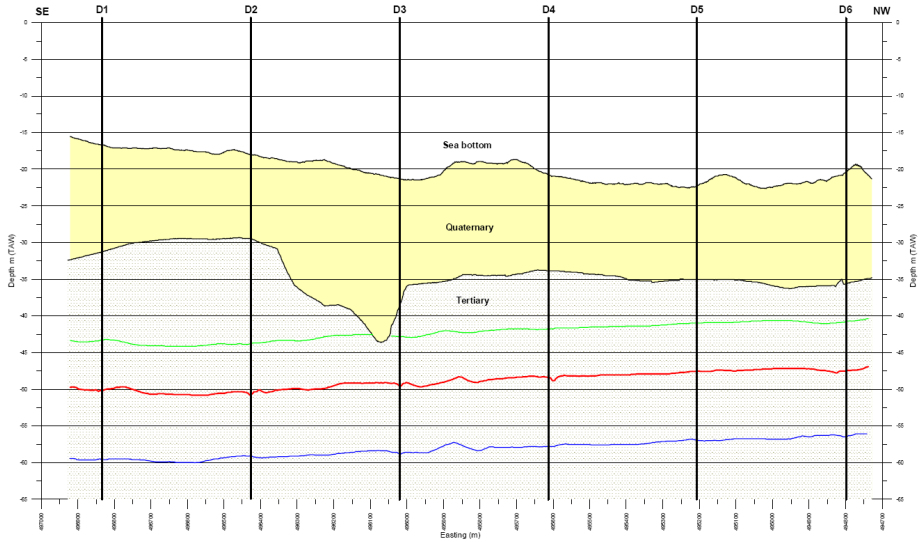
GEOPHYSICAL TESTING

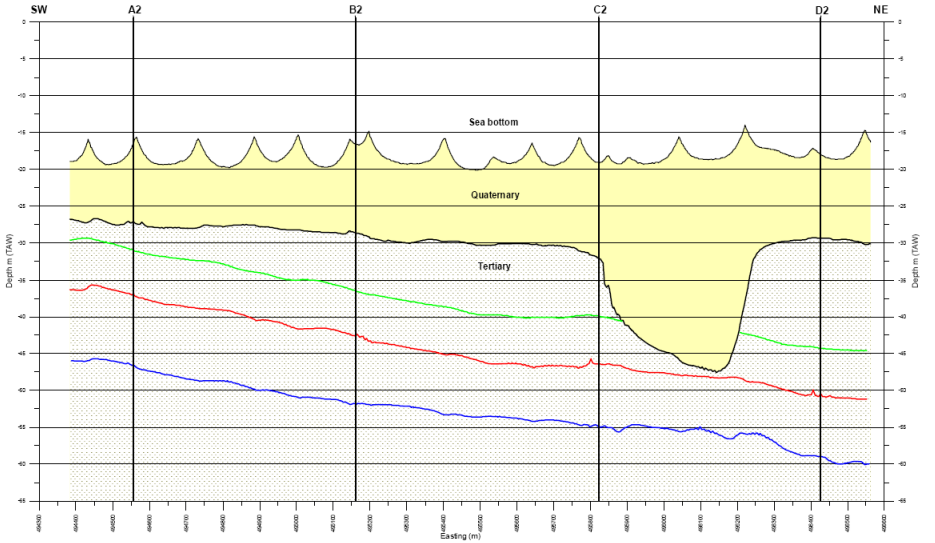
Seismic reflection testing

- First reflector: quartair – tertiair
- Second reflector: clay – sand
- Third reflector: Transition from Maldegem to Aalter formation
- Fourth reflector: not defined; “deepest main reflector”

SE - NW



SW - NE



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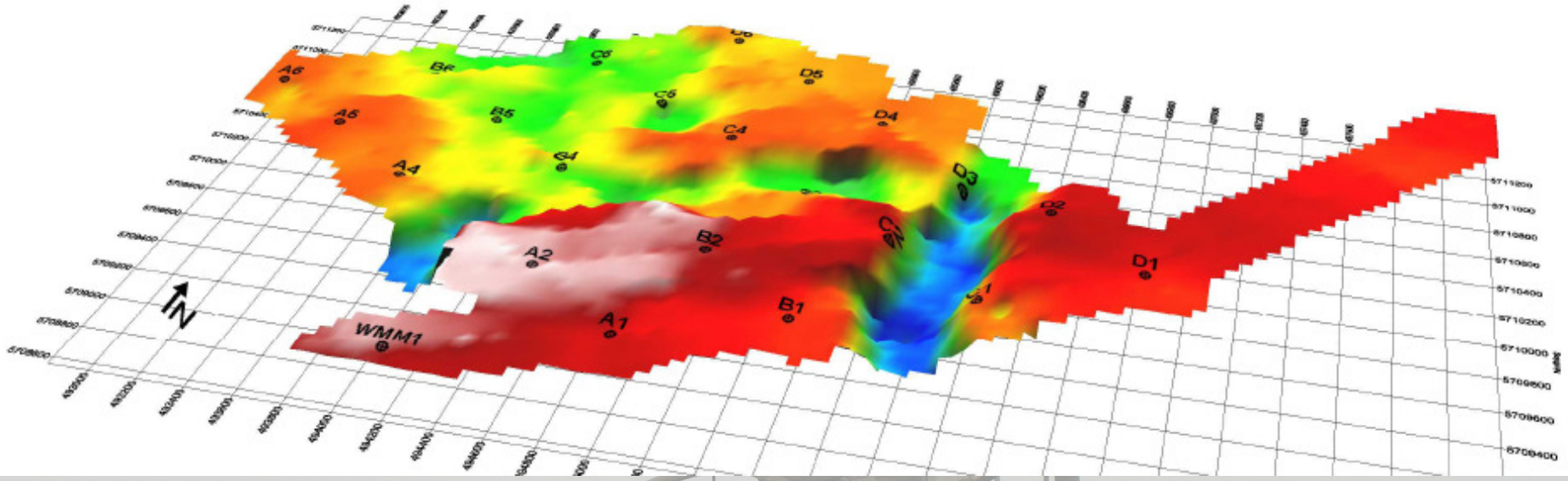
GEOPHYSICAL TESTING

Seismic reflection testing: Top of the Tertiary



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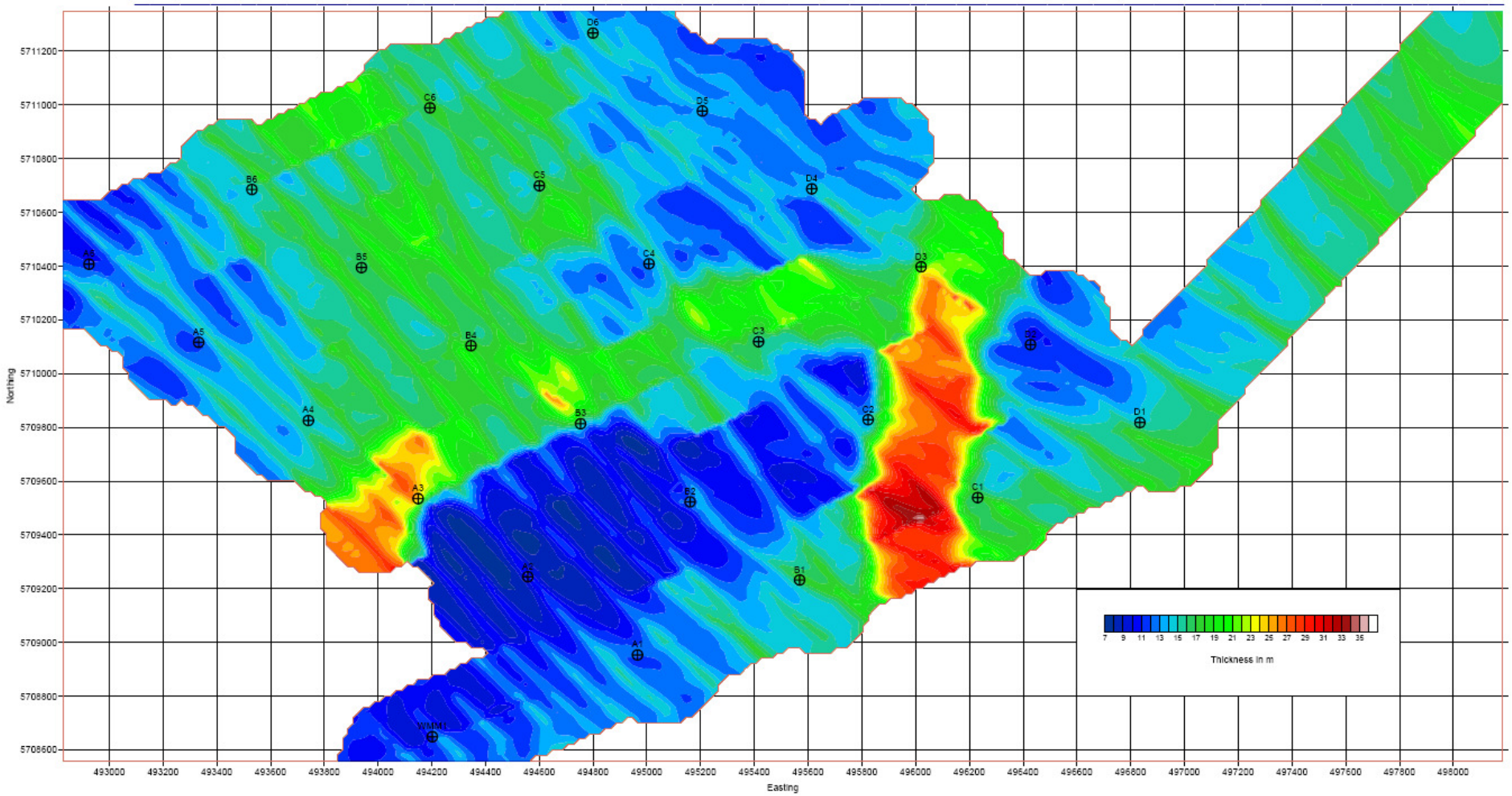
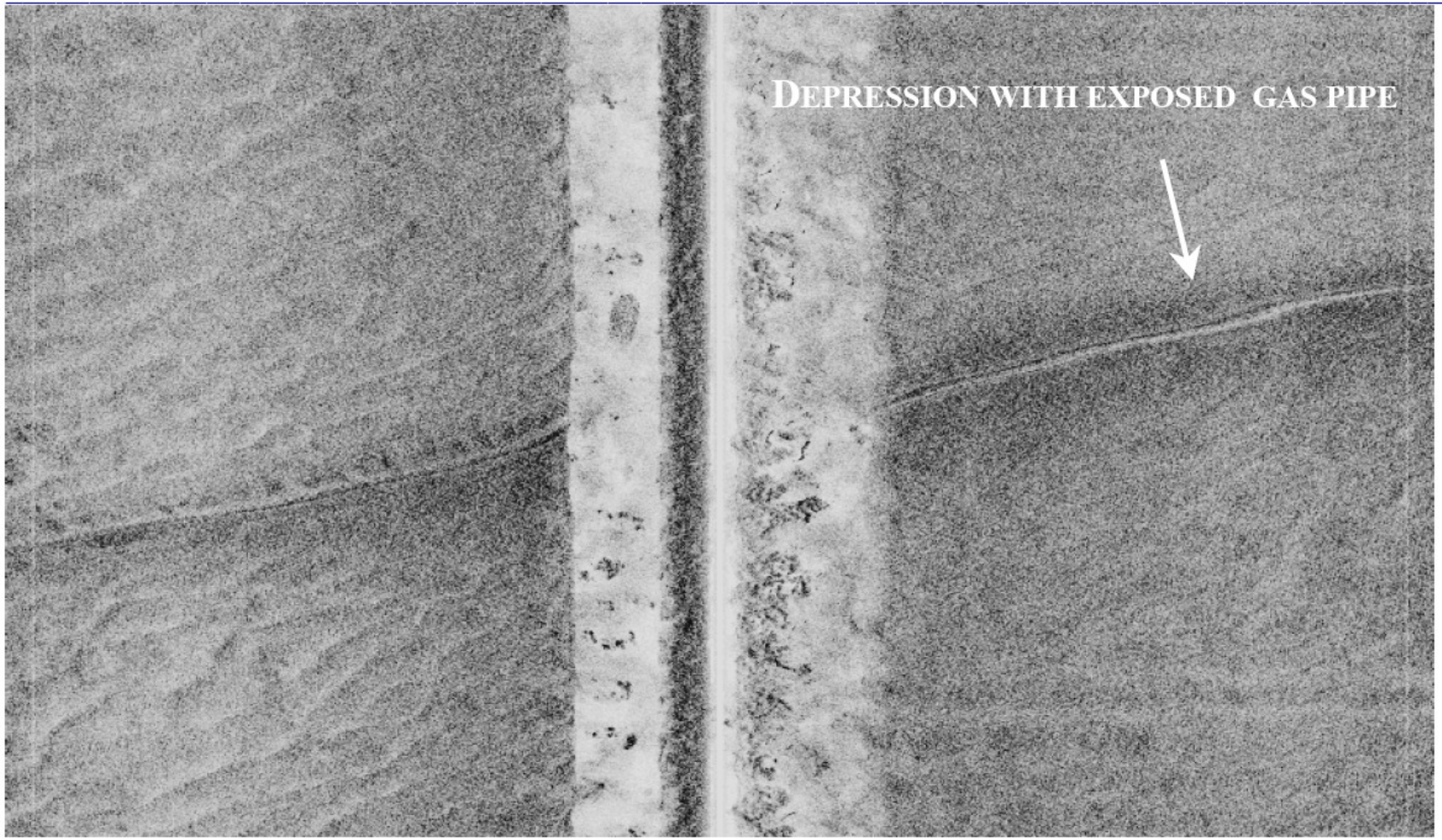
GEOPHYSICAL TESTING

Seismic reflection testing: Thickness of the quarternary



GEOPHYSICAL TESTING

Side Scan Sonar: Visualisation of morfology and obstacles



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BOREHOLES AND CPT'S

- Testing over water: 'Nearshore'; land based techniques from on a jack-up pontoon
- Use of extra protection casings and support casings to bridge the gap between Jack-up and seabottom (20 to 30 m)
- Displacing jackup and installation of casings: working on tide

- CPT at each wind turbine location before BH (define levels of sampling)
- In this case: CPT depth had to be reached; upon refusal destructive predrilling was realised
- Offshore working:
  - Always CPT-U
  - High water pressures, calculation of q_t is necessary, certainly in soft soils
  - Zeroing of the CPT cone: at platform level of at seabottom level?
- CPT Refusal: because of maximum q_c, f_s, u, inclination, total thrust, elastic rebound of the tubes, any other unsafe situation

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BOREHOLES AND CPT'S

- Bottom plate for outer casings
- Alternative for penetration (with the help of a bailor)
- Important when the top soil needs to be tested

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BOREHOLES AND

CPT-U jacking system

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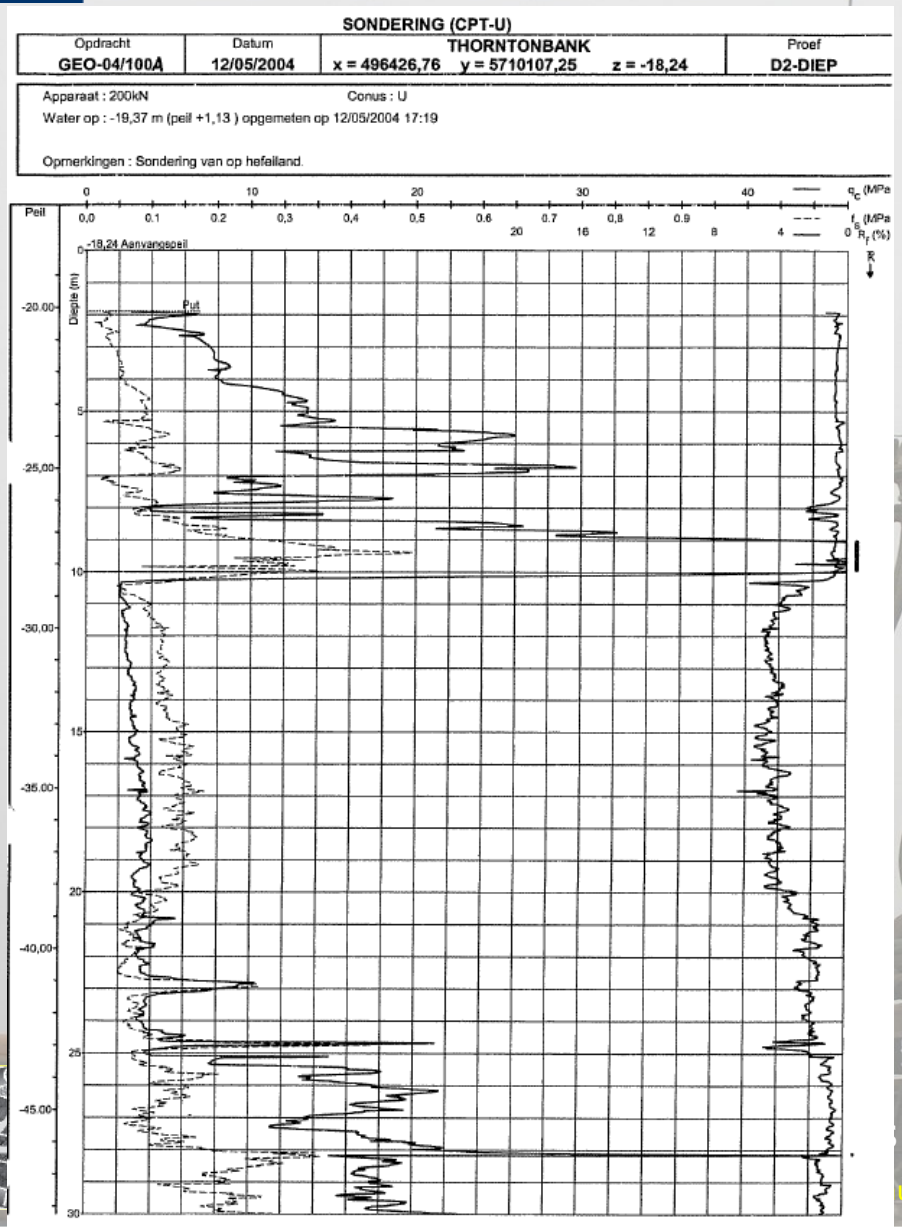
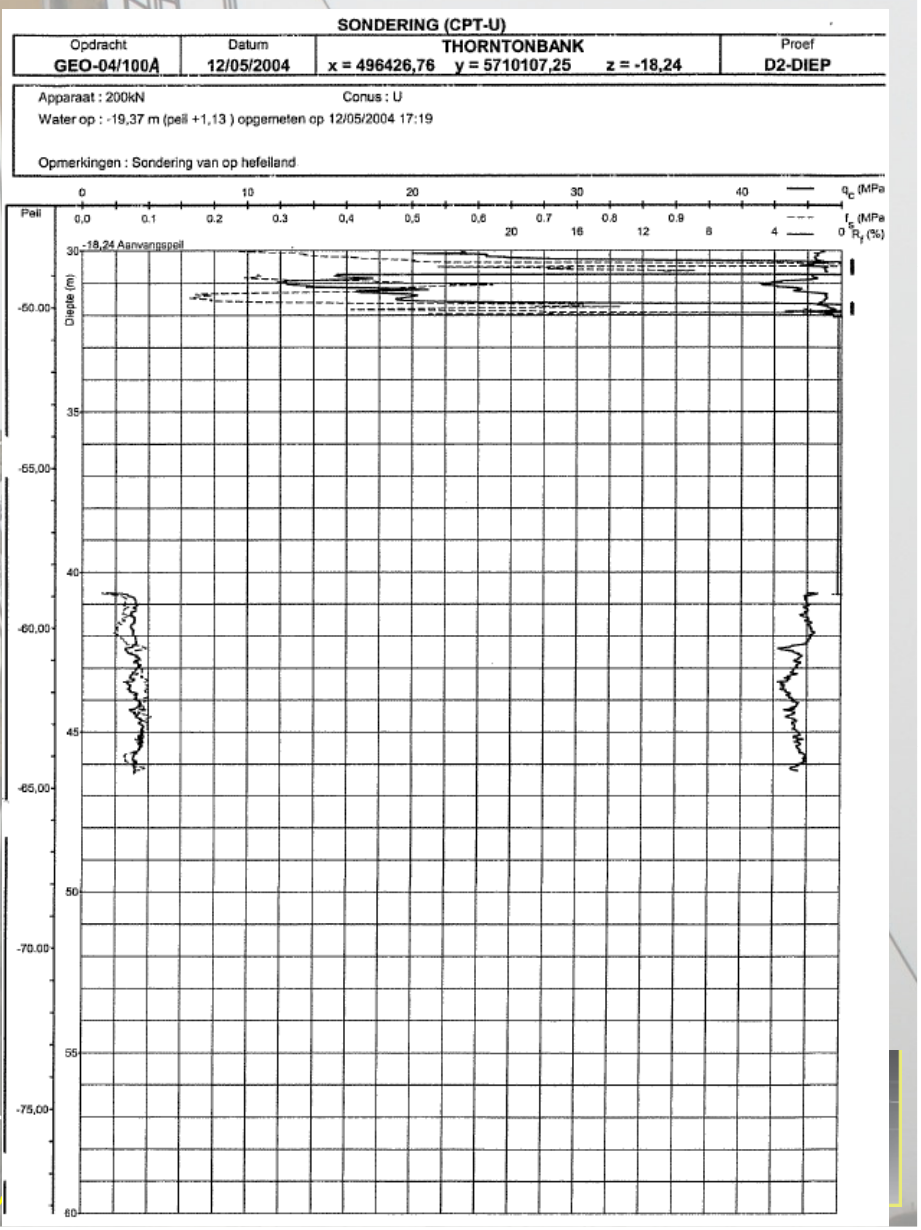
BOREHOLES AND CPT'S





BOREHOLES AND CPT'S

- BH's over water mainly using wire line techniques:
  - Bailor in sand
  - Hammering sampling techniques in cohesive materials
  - Core Drilling techniques in cohesive materials
  - Use of drilling fluids! Accepted for high quality sampling? Attention to system and pressures, maintain difference in levels between drilling with flushing and sampling)
- Sampling
  - Bailor: fully representative PSD?
  - Hammering techniques (e.g. Nordmeyer)
    - Thick walled tubes with casing: class of sample??
    - Thin walled tubes: effect of hammering?
  - Core drilling techniques (e.g. GeoBor)
    - In which soil types succesfull operation?
    - Quality of samples depending on soil type.
  - Push-in techniques with flushing fluid pressure
    - Thin walled tubes
    - Piston samplers

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BOREHOLES AND CPT'S

- BH advancement with bailor in sand
- Sampling: mixing over 1 m

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BOREHOLES AN

- Samples in containers (small/large)

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BOREHOLES AND CPT

- Down the hole sampler BPE
- Thick walled samples in PVC liner
- With core catcher

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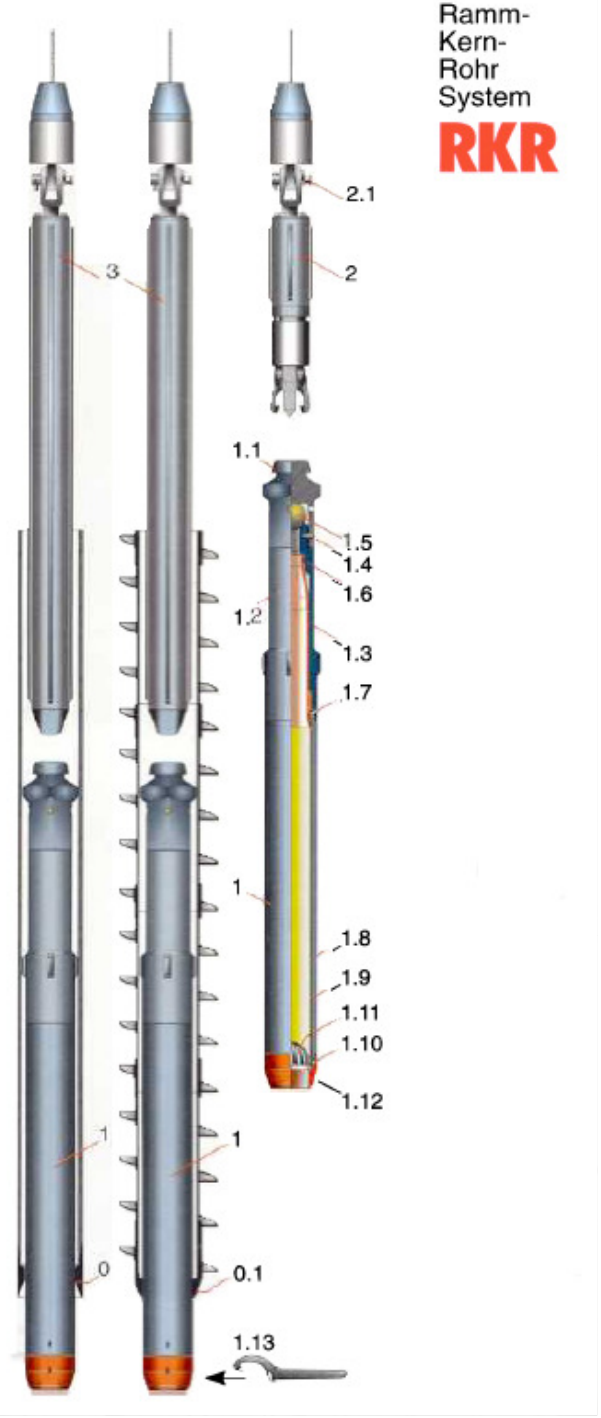
BOREHOLES AND CPT'S

- Down the hole sampler with heavier hammer (RKR system)
- Retrieval system
- Thick walled sample in PVC liner



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BOREHOLES AND CPT'S

- PVC samples

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BOREHOLES AND CP

- Undisturbed thin walled samples

BOREHOLES AND CPT'S

- Undisturbed samples: testing in the field

BOREHOLES AND CPT'S

- Undisturbed thin walled samples

BOREHOLES AND CPT'S

- If possible samples are withdrawn without drilling
- Very often drilling with flushing is necessary
- Other possibility: hollow stem auger is not (often) used over water

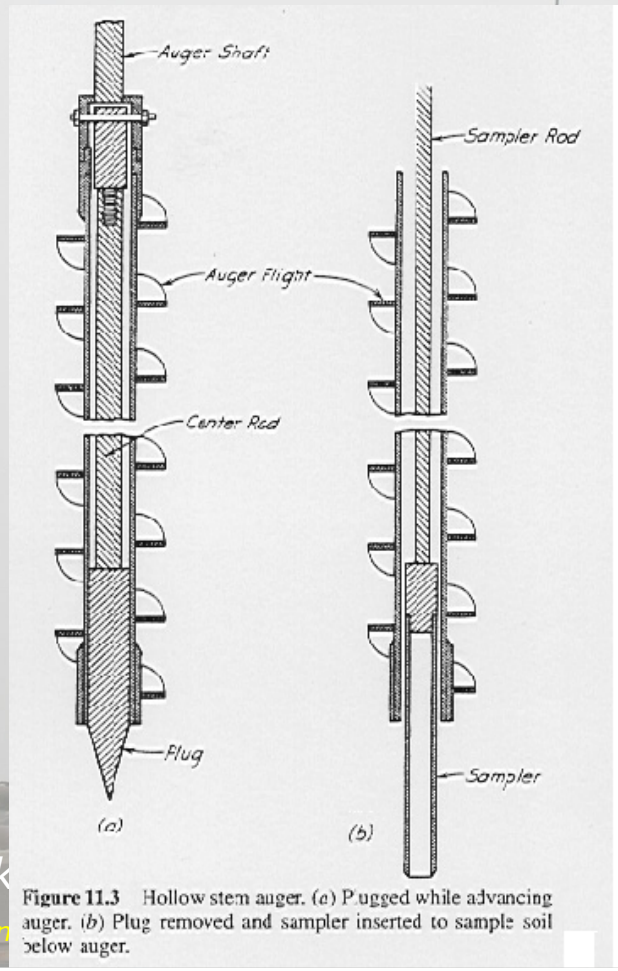

Figure 11.3 Hollow stem auger. (*a*) Plugged while advancing auger. (*b*) Plug removed and sampler inserted to sample soil below auger.

BOREHOLES AND CPT'S

BH log: according to BS 5930

Marine Sampling Holland

Client: GeoSea N.V.
Haven 1025 - Scheldedijk 30
B2070 Zwijndrecht, Belgium

Project name: Wind Farm Thornton Bank Phase 2
Contract name: Site Investigation 2008

easting (X)	: 499415
northing (Y)	: 5714365
deck level (GPS, TAW)	: 14.4 m.
sea bottom (TAW)	: -21.0 m.
Date Started	: 21-02-2008
Date Completed	: 24-02-2008
Drilling Method	: cable percussion
	: / rotary flush
Casing diameter 1	: 324 mm. till 15.6 m. depth
Casing diameter 2	: 219 mm. till 29.5 m. depth

Borehole Number I5 (Page 1 of 3)

Project number	: 4142 GR
Drilled by	: Harms Brunnenbau
Logged by	: G.T. de Vries
Drawn by	: G.T. de Vries

Sampler Type:
(K) Core sample in liner, BPE 150 - centered free fall tool
(B) Disturbed sample from bailer or from cutting shoe / core catcher after K sample
(UP) Thin-walled tube sample / BPE 150 - centered free fall tool

Pos.: I5

Depth in Metres	elev. rel. to TAW -15.6	GRAPHIC	DESCRIPTION	Depth (Thick)	Samples	Depth from (m)	Depth to (m)	Blow Count	Lab test program
0	-15.6			0					
1	-16		slightly silty SAND, well sorted, yellowish brown, fine to medium grained with some shell fragments (< 5 mm).	(2)	B1	0	1		1, 4
2	-17			2	B2	1	2		
3	-18		SAND, brownish grey, fine to medium grained with shell fragmetns (< 5 mm.)	(2)	B3	2	3		
4	-19			4	B4	3	4		1, 2, 4, 14, 15
5	-20		slightly gravelly SAND, brownish grey, fine to medium grained with shell fragments < 5 mm.	(0.7)	K1	4	5	58	
6	-21		very sandy GRAVEL to very gravelly SAND with some cobbles, brownish grey, sandfraction medium grained, gravel coarse, rounded (some angular to sub-angular), flint, slate and quartz, cobbles mainly flint, with many shells and shell fragments	4.7 (0.8)	B6	5	5.5		1, 4
7	-22		slightly silty SAND, grey, medium grained, with shell fragments up to 5 mm.	5.5 (0.5)	B7	5.5	6		
8	-23			6	B8	6	7		1, 4, 10, 14
9	-24			(3)	B9	7	8		
10	-25				K2	8	9	104	
			slightly gravelly SAND, grey, medium grained, with many shell fragments up to 1 cm.	9 (0.65)	K3	9	9.9	70	1, 4, 5, 6, 7
			CLAY, light grey - brown, soft to firm	9.65 (0.35)	B10	9.9	10		

NOTE: No description of material in liners or thin walled tubes available. waiting for lab results

Laboratory tests:
(1) PSD, (2) rho s, (3) org. content, (4) calc. content, (5) plast. limits, (6) nat. water content, (7) volume mass, (8) oedometer, (9) CRS, (10) TX CD, (11) TX CU, (12) TX UU, (13) bender, (14) minimax density, (15) permeability

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(B) Disturbed sample from bailer or from cutting shoe / core catcher after K sample
(UP) Thin-walled tube sample / BPE 150 - centered free fall tool

Pos.: I5

Depth in Metres	elev. rel. to TAW -15.6	GRAPHIC	DESCRIPTION	Depth (Thick)	Samples	Depth from (m)	Depth to (m)	Blow Count	Lab test program
10	-25.6			10		10	10.6		Sampler empty
11	-26		slightly gravelly SAND, grey, fine to medium grained, with shells (<2 cm) and shell fragments. gravel coarse to pebble size	(2)	B11	10.6	11		
12	-27			12	K4	11	12	105	
13	-28		slightly gravelly SAND, grey, fine to medium grained, with weathered shell fragments and shells < 2 cm., few larger shells < 6 cm, gravel medium size. some clay- and organic clay pellets.	(1)	B12	12	13		
14	-29		slightly gravelly SAND, moderately sorted, grey, medium grained with many shell fragments and shells < 2 cm, few shells < 7 cm. gravel fine to medium. some wood, some clay pellets, one cobble-sized iron cemented sand pellet.	13 (1.8)	K5	13	13.8	160	
15	-30				B13	13.8	14		1, 4
					B14	14	15		
			shells and shell fragments	14.8 (0.55)					
			slightly gravelly SAND, moderately sorted, with many shells and shell fragments < 2 cm. gravel: rounded, fine to medium size	15.55	K6	15	16	60	1, 5, 6
16	-31		sandy CLAY, stiff to very stiff	(1.15)					
17	-32			16.7	UP1	16.1	16.7	70	
18	-33		CLAY, greenish grey, stiff to very stiff		K7	16.7	17.4	75	
19	-34				B15	17.4	17.5		
20	-35				UP2	17.5	18	38	1, 4, 5, 6, 7, 9, 11
					UP3	18	18.5	38	1, 4, 5, 6, 7, 11
					K8	18.5	18.9	55	
					B16	18.9	19		
					UP4	19	19.5	49	1, 4, 5, 6, 7, 12
					UP5	19.5	20	40	12

NOTE: No description of material in liners or thin walled tubes available. waiting for lab results

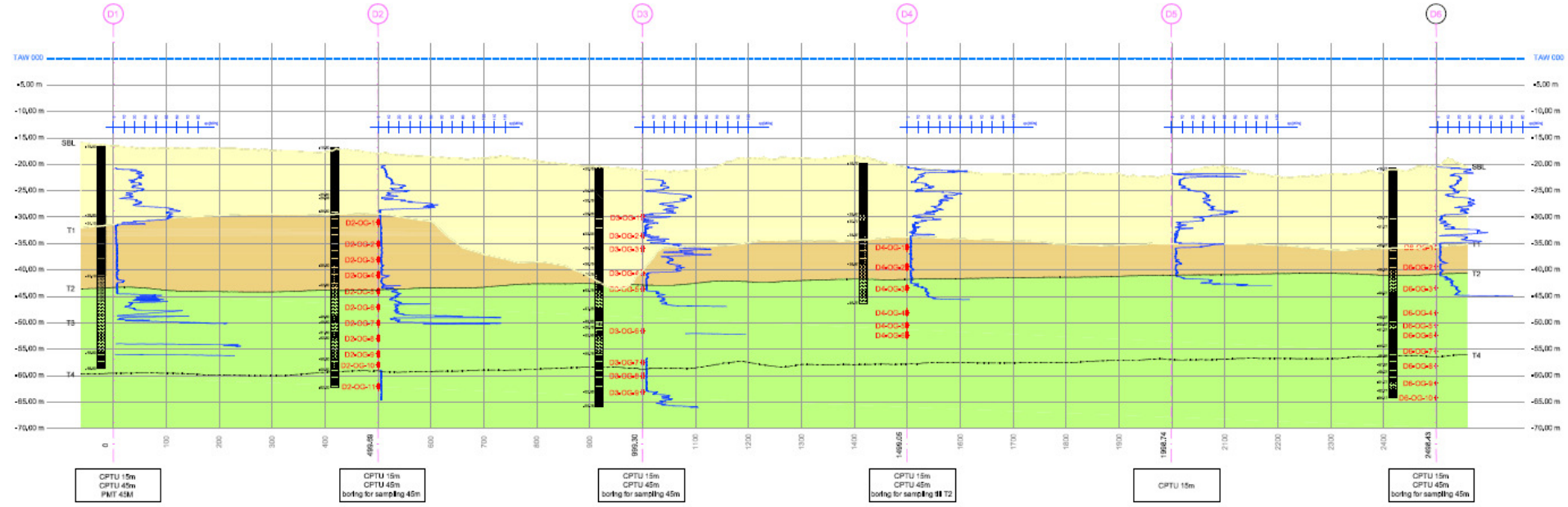
Laboratory tests:
(1) PSD, (2) rho s, (3) org. content, (4) calc. content, (5) plast. limits, (6) nat. water content, (7) volume mass, (8) oedometer, (9) CRS, (10) TX CD, (11) TX CU, (12) TX UU, (13) bender, (14) minimax density, (15) permeability

Borehole Number I5 (Page 2 of 3)

BOREHOLES AND CPT'S

Geotechnical profile with BH's and CPT's – General Layering (Phase I)

- Loose sand
- Dense sand
- Gravel (transitionlayer)
- Stiff clay
- Dense sand (silty/clayey)
- Very dense silty/clayey sand with clay insertions
- Stiff clay



PROFILE D1-D6

OTHER TECHNIQUES: PRESSUREMETER

- Performed lointly by 2 companies: drilling company and other specialised company for PMT testing
- Conclusion: Results very poor

LABORATORY TESTING

- Classification testing (PSD, Plastic Limits, natural water content, carbonates content, organic content, bulk density)
- Compression testing
- Shear strength testing (vane, TX-UU, TX-CU, Simple Shear)
- Dynamic properties: Bender element testing combined with the above, cyclic TX and Simple Shear
- Analysis to material degradation under continuous cyclic loading

- Highest quality of samples needed!

CONCLUSIONS

- Succesful Offshore soil investigation needs good preparation (gathering of available info)
- Offshore Soil Investigation is combination of several techniques: geophysical, in situ testing and laboratory
- Offshore (nearshore) testing: use of land based techniques with special measures to bridge the gap between platform and seabottom
- Use of wire line techniques to speed up the drilling process
- Effect on disturbed and undisturbed sampling: do thick walled samples have to be rejected as high quality undisturbed samples?
- In the soil types encountered here good results with hammering techniques
- Quality of high level laboratory tests?

Thank you for your attention

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