Danish Offshore Wind 2030 - North Sea I (A2) - Nymindegab - Endrup Nord

Location 2AA – Landfall, Gammelgab Strand (Natura 2000 and protected area)
Site Investigations for Horizontal Directional Drilling (HDD)

Geo project no. 208116
Report 95, 2024-11-29

Summary

The electrical infrastructure in Denmark is expanding significantly, which includes connecting underground cables from new wind farms in the North Sea and Inner waters in Denmark to the major transformer stations. Due to cables crossing infrastructure, topographic challenges, protected areas, streams etc. the crossings are planned partly as Horizontal Directional Drilling (HDD).

This particular report concerns the landfall 2AA at cable route 2, at Gammelgab Strand (Natura 2000 and protected area). This report must be read in correlation with report no. 16 (location 2A), which contain the general geological description from the boreholes, results of the geophysical survey and laboratory tests from the nearby location 2A carried out onshore.

The field works comprises of two geotechnical boreholes with in situ strength testing, soil sampling and groundwater level monitoring and CPTu onshore.

Energinet has informed Geo, that the landfall HDD will start at the beach in the vicinity of the breaking point from the beach dunes, and will be drilled towards the sea approximately 5-10 m b.g.l. until the end of the off shore part of the cable is reached at sea.

The boreholes carried out onshore for location 2A show deposits of postglacial sand and postglacial gravel. However, in postglacial marine deposits layers of peat and/or gyttja must be expected to be found locally. No Mica is found in the deposits but may be found along the 2 km long stretch.

Geo project no. 208116
Report 95, 2024-11-29
Client ref.: Danish Offshore Wind 2030 - North Sea I (A2) - Nymindegab - Endrup Nord

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Laboratory tests
Reference is made to report no. 16.

95.5: Risk Assessment

1 Project

The electrical infrastructure in Denmark is expanding significantly, which includes connecting underground cables from new wind farms in the North Sea and Inner waters in Denmark to the major transformer stations. Due to cables crossing infrastructure, topographic challenges, protected areas, streams etc. the crossings are planned partly as Horizontal Directional Drilling (HDD).

The project contains geotechnical and geophysical investigations for three cable routes including landfalls from the North Sea (1, 2 and 3), one cable route from Kattegat II (4) and one cable route from Kriegers Flak II (5) as show in Figure 95.1.

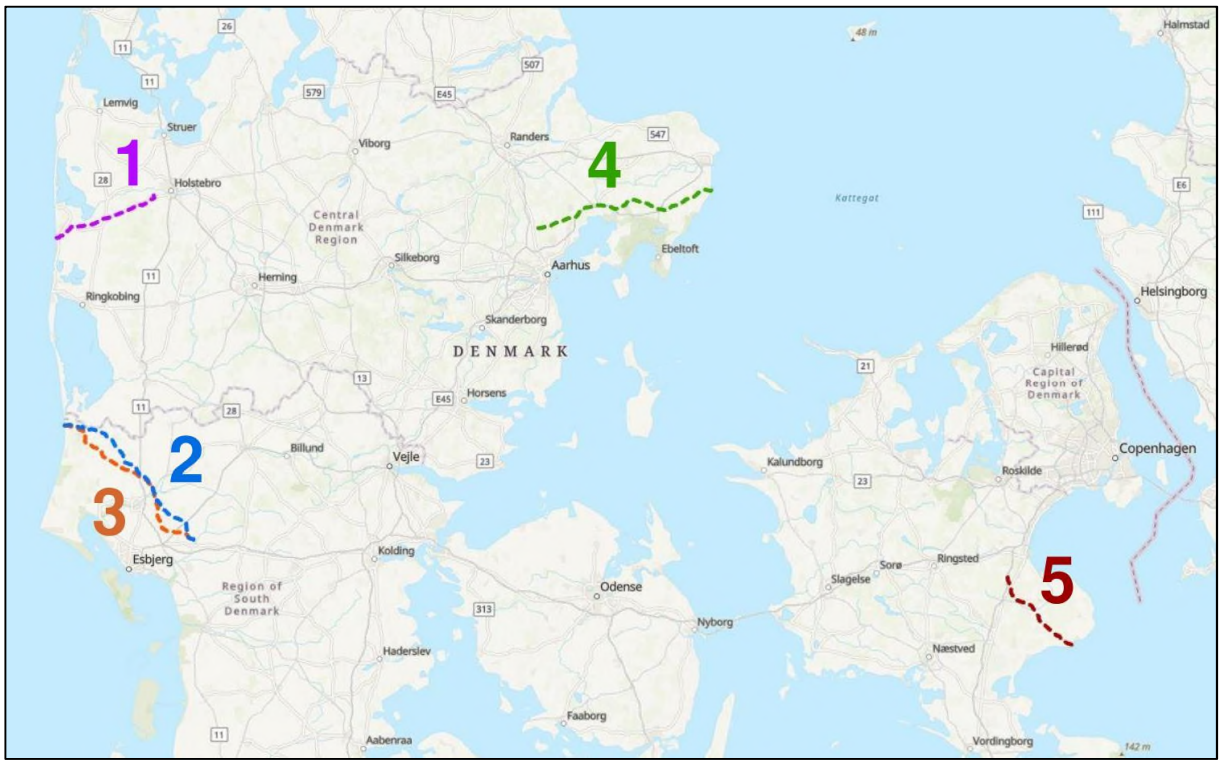


Figure 95.1: Overview map of the five cable routes planned in this project.

This report concerns the landfall part at cable route 2 (Nymindegab to Endrup Nord) at location 2AA as illustrated in Figure 95.2 (and in the overview map cf. enclosure 16.1.1), at Gammelgab strand (Natura 2000[1] and protected area). The landfall part of cable route 2 will be carried out using HDD. Energinet has informed Geo, that the HDD will start at the beach in the vicinity of the breaking point from the beach dunes, and will be drilled towards the sea at 5-10 m b.g.l. until the end of the off shore part of the cable is reached at sea.

[1] Natura 2000 is a term for the EU network for protected areas

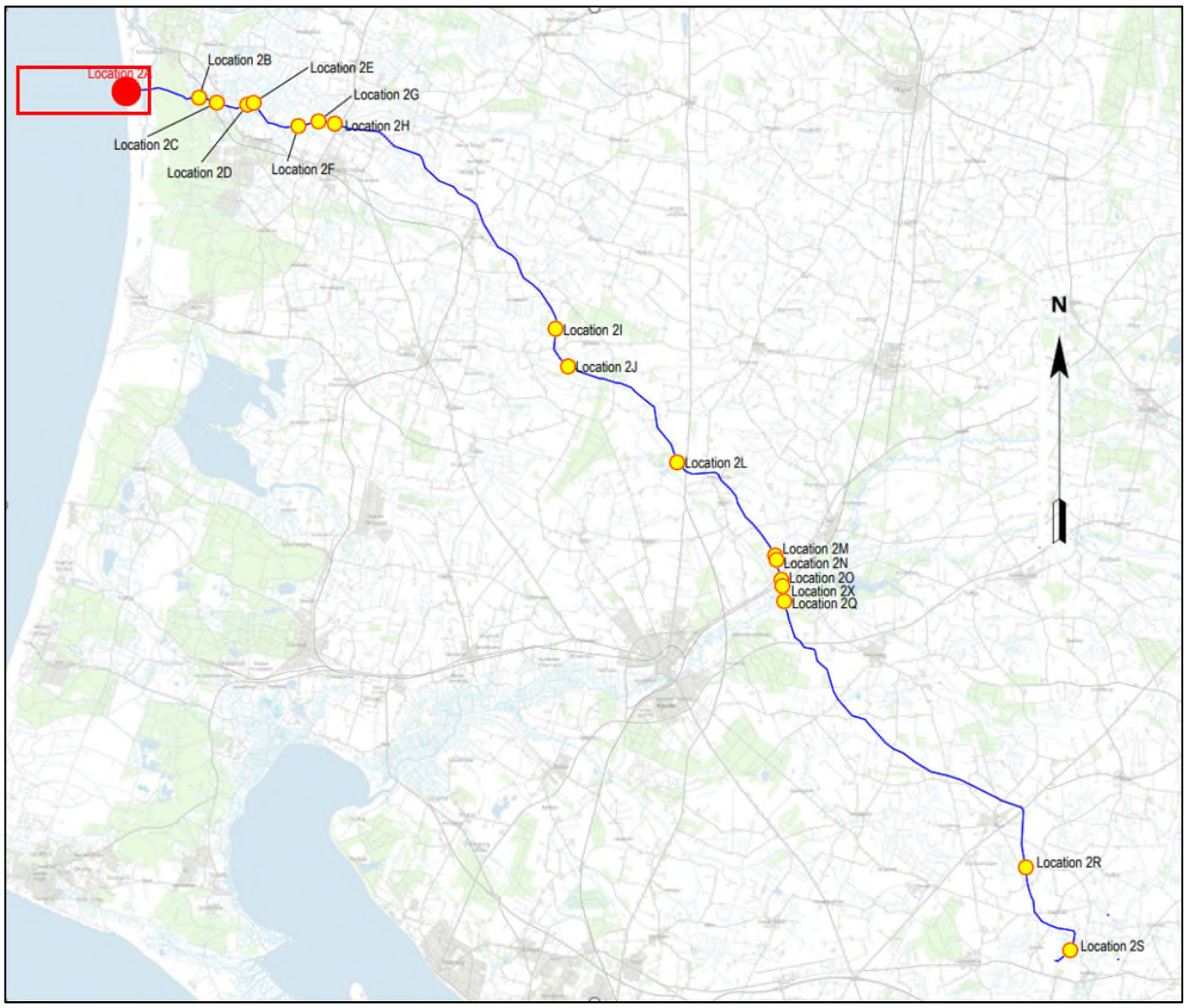


Figure 95.2: Overview map of cable route 2. Location 2A is marked with a red dot. Landfall (2AA) is marked with a red box.

Geo has been requested to investigate the soil and hydrological conditions prior to execution of the HDD at the landfall, which start at the seaside of the dunes, and end at level -10 m approximately 2 km from the coastline.

This report must be read in correlation with report no. 16 (location 2A), which contain the general geological description, results of the geophysical survey and laboratory from the nearby location 2A. As the geology and geotechnical parameters is based on only 2 boreholes and extrapolated 2 km from the boreholes, the likelihood of similar ground conditions is very small. Therefore, the geology and geotechnical parameters has to be used with great precaution.

2 Investigations

The investigation contains geotechnical field and laboratory works (carried out by Geo/Geoboringer) and geophysic works (carried out by WSP).

2.1 Geophysical investigations

For the geophysical survey in the area using ERT (Electrical Resistivity Tomography) method reference is made to report no. 16 (location 2A).

2.2 Geotechnical investigations

Onshore at location 2AA, two CPTu's and two geotechnical boreholes have been executed. The target depths of the boreholes has been reached. Target depth for the CPTu has not been reached due to too high resistance in the soil (gravel). Below the reached depth of the CPTu, standard penetration test has been carried out. The CPTu's have been executed approximately 2 m from the boreholes. The terrain level and coordinates of the investigation points have been measured using GPS in system UTM32N/ETRS89 and with DVR90 as vertical reference. The location of the points are shown on the site plan cf. enclosure 95.1.2.

The CPTu's have been executed by Geoboringer from a CPT-rig with maximum thrust capacity of 10 tons. During testing a 15 cm^2 piezoelectrical cone is pushed into the ground with a constant speed while measuring the tip resistance (q_c), sleeve friction (f_s) and pore pressure just behind the tip of the cone (u_2).

The boreholes have been executed using 6" rotary shell and auger in clay and percussion drilling in sand from a hydraulic drill rig. In the borehole strata are registered, samples taken and in situ tests carried out as required by Energinet.

The sampling at this location consists of:

- Small disturbed samples for geological description and laboratory testing
- Large disturbed samples in frictional soils for further laboratory testing

The in situ tests at this location consists of:

- Standard penetration test (SPT)[2]

The boreholes have been completed with installation of Ø25 (diameter) standpipes made of PVC. The filter screening is carried out during simultaneous withdrawal of the casing. To ensure a tight seal between water aquifers the annulus above/below the screened pipe is sealed with expanding bentonite pellets in cohesive soils. Level of the screened pipe is chosen in accordance with the soil conditions and proposed depth of the planned HDD. The screened pipes is presented on the borehole profiles.

The groundwater levels in borehole 2A.02 has been measured in the standpipe immediately after completing the boreholes and again more than 7 weeks hereafter. The groundwater levels in borehole 2A.01 has been measured in the standpipe more than 7 weeks after completing the boreholes. All results are shown on the borehole profiles cf. enclosure 16.2.1 – 16.2.2.

[2] DS/EN ISO 22476-3 Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test

According to the Danish legislation "Brøndborebekendtgørelse"[3] the boreholes are decommissioned/sealed within a few weeks after the drilling was carried out and the groundwater level is registered. The decommission/sealing is carried out by inserting expanding bentonite bars in the standpipe and thereafter removing the top standpipe approximately 1 m b.g.l.

2.3 Laboratory tests

The geological description of all samples have been carried out in accordance to the Danish dgf-Bulletin 1, 2021 (Danish Geotechnical Society) and standard classification tests required by Energinet have been performed. The standards used for classification tests in Geos laboratory are listed in Table 95.1.

Table 95.1: Standards for classification tests.

Classification test	Standard
Natural water content	DS/EN ISO 17892-1:2014
Grain size distribution	DS/EN ISO 17892-4:2016
Atterberg limits	DS/CEN ISO 17892-12:2018

3 Results

3.1 Geophysical results

For the geophysical results reference is made to report no. 16.

3.2 Geological description of the location

For general geological description of the area reference is made to report no. 16.

3.3 Geotechnical results

The geotechnical investigation carried out for this location is described in section 2.2.

Location 2A is dominated by postglacial marine deposits of sand and gravel to approx. 15 mn b.g.l. In borehole 2A.01, closest to the sea, the deposits consist of postglacial marine sand and gravel from terrain to the bottom of the borehole, 15 m b.g.l. In borehole 2A.02 glacial deposits of mostly sand (with a minor layer of sand till) are encountered from 15.1 m b.g.l. and down to the bottom of the borehole. No Mica is found in the deposits.

3.3.1 Hydrogeology

The groundwater levels in borehole 2A.01 has been measured in the standpipe more than 7 weeks after completing the borehole. he groundwater levels in borehole 2A.02 have been measured in the standpipe immediately after completing the borehole and again more than 7 weeks hereafter. The groundwater level readings are illustrated on the borehole profiles and furthermore listed in Table 95.2.

3 BEK nr. 1260 af 28/10/2013 - Bekendtgørelse om udførelse og sløjfning af boringer og brønde på land.

Table 95.2: Ground water readings/measurements.

Borehole no.	Ground level (m DVR90)	Date	Depth (m b.g.l.)	Level (m DVR90)	Bottom of filter (m b.g.l.)
2A.01	+4.0	2024-07-31	3.0	+1.0	12.0
2A.02	+4.1	2024-07-22 2024-09-17	3.5 3.4	+0.6 +0.7	14.0

3.3.2 Laboratory tests

Results of the laboratory classification tests are presented either on the borehole profile and/or in report no. 16.

4 Derivation of geotechnical parameters

4.1 Strength parameters

4.1.1 Cone penetration test (CPT)

No site specific q_c – φ' correlations are established for derivation of the effective strength parameters for CPTs, which is why international literature and Geos general experience with similar soil has been guiding the recommendations in the following paragraph below.

For sand layers Geo suggest the frictional angle, φ', estimated from the CPT cone resistance, q_c, by the procedure in NGI publication no. 156, cf. ref. /1/.

$$\frac{q_c}{\sigma'_{v0}} = tan^2\left(\frac{\pi}{4}+\frac{\varphi'}{2}\right)exp(\left(\frac{\pi}{3}+4\varphi'\right)tan(\varphi'))$$

where cone resistance q_c is in kPa
σ'_{v0} is effective vertical stress in kPa
frictional angle φ' is in rad (for very silty sand a reduction of 3° should be made)

From the CPT cone resistance, q_c, the undrained shear strength in cohesive soils can be estimated from $c_u = q_c / N_k$, where N_k is a correction factor based on local experience. As default value $N_k = 10$ can be used in many cohesive soils, and $N_k = 10$ is used for late glacial or older clay deposits throughout this project. In postglacial, organic soils (peat, gyttja etc.) $N_k = 15 – 20$ is used throughout this project.

4.1.2 Standard penetration test (SPT)

The frictional angle φ', from SPT are determined by transforming the data obtained to a relative density as described in DS/EN ISO 22476-3, cf. ref. /2/

Derivation of N_{60} values has been carried out using appendix A in DS/EN ISO 22476-3 using an energy ratio, E_r, of 0.6.

$$N_{60} = \frac{E_r}{60}\cdot\lambda\cdot C_N\cdot N$$

The frictional angle φ' has been derived using Teixeira and Hatanaka and Uchida, cf. ref. /3/.

$\varphi'_p = 15° + \sqrt{24 \cdot (N_1)_{60}}$ *(Teixeira, 1996)*

$\varphi'_p = 20° + \sqrt{15.4 \cdot (N_1)_{60}}$ *(Hatanaka and Uchida, 1996)*

4.1.3 Field vane test

No field vane test is carried out at this location.

4.2 Stiffness

4.2.1 Cone penetration test (CPT)

The oedometer stiffness, E_{oed} in sand is stress dependent and can be estimated from q_c using the following algorithm from NGI publication no. 156, cf. ref. /1/.

$$E_{oed} = M_0 \sqrt{\frac{\sigma'_v + \frac{\Delta\sigma'_v}{2}}{\sigma'_v}}$$

where: M_0 = Initial constrained modulus
σ'_v = vertical in situ stress
$\Delta\sigma'_v$ = increase in vertical stress from loading

For normally consolidated sand the initial constrained modulus M_0 is suggested as:

$M_0 = 4 \cdot q_c$ for $q_c < 10$ MN/m^2
$M_0 = 2 \cdot q_c + 20$ for 10 MN/m^2 ≤ q_c ≤ 50 MN/m^2
$M_0 = 120$ for $q_c > 50$ MN/m^2

For over consolidated sand (Over Consolidation Ratio, OCR > 2) the initial constrained modulus M_0 is suggested as:

$M_0 = 5 \cdot q_c$ for $q_c \leq 50$ MN/m^2
$M_0 = 250$ for $q_c > 50$ MN/m^2

As a conservative approach $E_{oed} = M_0$ can be used.

4.2.2 Undrained shear strength

Not relevant at this location.

4.3 Permeability

For uniform graded sand the permeability, k, is suggested estimated by:

$k = 0.01 \cdot d_{10}^2$

where d_{10} is the grain size at 10 % by weight.

5 Evaluation of geotechnical parameters

Recommendations for geotechnical parameters are given in the following paragraphs based on the specific soil type, field tests (CPT, SPT), laboratory tests and Geos general experience with similar soil types.

The values in Table 95.3 are representative values, and both lower and higher values (peak values) must be expected to appear in the actual investigation points as well as in the deposits between the investigation points. Ranges of soil parameters are given and relevant parameters must be selected depending on the situation considered.

The listed geotechnical parameters are:

- q_c Tip resistance (from CPT)
- γ: Weight density above water level
- γ': Effective weight density below water level
- φ': Effective friction angle
- c': Effective cohesion
- c_u: Undrained shear strength
- k: Permeability
- E_{oed}: Oedometer stiffness

Table 95.3: Soil parameters, Borehole 2A.01

Soil description	q_c (MPa)	γ/γ' (kN/m³)	φ' (°)	c' (kPa)	c_u (kPa)	k (m/s)	E_{oed} (MPa)
Sand/gravel, (Pg) Top 1 m	1-5	18/10	32-36	0	N/A	$1{\cdot}10^{-3}$ - $1{\cdot}10^{-4}$	4-20
Sand, (Pg) below 1 m b.g.l.	10-40	18/10	32-38	0	N/A	$1{\cdot}10^{-3}$ - $5{\cdot}10^{-5}$	40-100
Gravel, (Pg) below 1 m b.g.l.	25-50	19/10	38-45	0	N/A	$5{\cdot}10^{-3}$ - $1{\cdot}10^{-4}$	70-120
Sand, (Gc)	-	19/10	38-42	0	N/A	$1{\cdot}10^{-4}$ - $1{\cdot}10^{-5}$	100-150
Sand Till, (Gc)	-	21/11	36-40	0	N/A	$1{\cdot}10^{-6}$ - $1{\cdot}10^{-7}$	50-100

6 Recommendations

At location 2AA, the plan is to carry out HDD at the beach in the vicinity of the breaking point from the beach to the dunes, and will be drilled towards the sea at 5-10 m b.g.l., until the end of the offshore part of the cable is reached at sea.

At the onshore borehole 2A.01 the HDD will mainly penetrate deposits of postglacial sand and postglacial gravel. However, in postglacial marine deposits layers of peat or gyttja must be expected to be found locally. No Mica is found in borehole 2A.01 and 2A.02 but may be found along the 2 km long stretch.

As the location is close to the sea Geo recommend that the risk of high water level is taken into account when establishing drilling pits onshore.

Depending on the drilling method used, minor ground settlements may develop in the vicinity of the HDD centreline as well as close to the drilling pits.

Risks and procedures for execution must be evaluated in detail when a contractor has been assigned and depths, diameter etc. of HDD decided.

Preliminary Risk assessment based on the interpreted geology and the soil conditions met in the boreholes and CPT's, is attached in enclosure 95.5.

7 References

/1/ *NGI Publication #156 - Interpretation of Cone Penetrometer Data for Offshore Sands*, T. Lunne and H. P. Christoffersen , NGI, 1985

/2/ DS/EN ISO 22476-3 Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test.

/3/ *In situ testing in Geomechanics*, Fernando Schnaid, 2009

/4/ *Danmarks digitale jordartskort 1:25.000*, version 7, GEUS, 2024

/5/ *Geomorphological map of Denmark 1:200.000*, version 3, GEUS, 2022

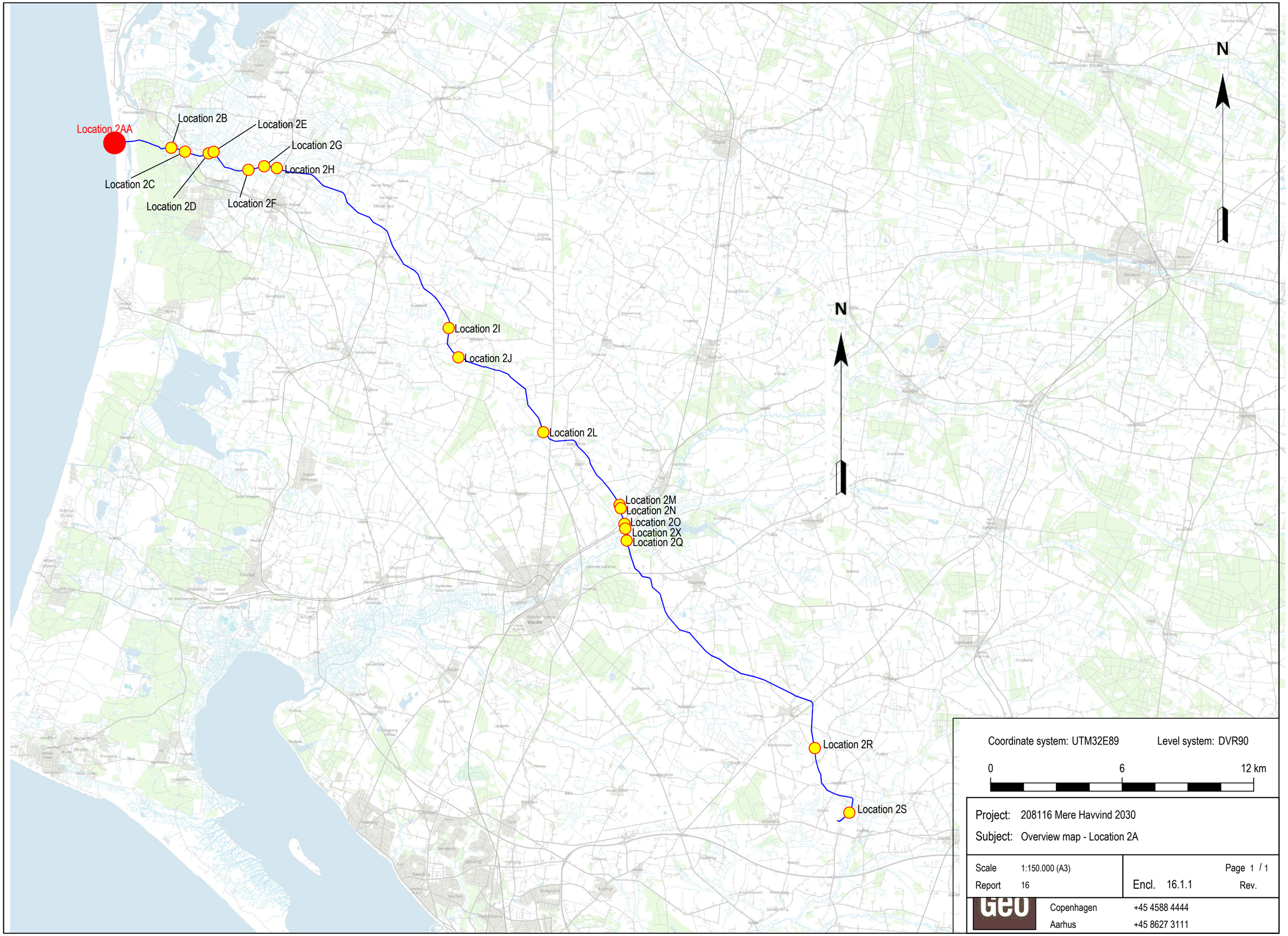
/6/ *Pre-Quaternary surface topography of Denmark 1:250.000*, GEUS, 1994

/7/ *Geologisk Set – det sydlige Jylland,* GEUS, Geografforlaget, 1. udgave, 2004

/8/ *Geologisk Set – det mellemste Jylland,* GEUS, Geografforlaget, 1. udgave, 1994

/9/ *Miocæn 3D, opdateret 2015. Den rumlige geologiske model*, Kristensen, M., Vangkilde-Pedersen, T., Skovbjerg Rasmussen, E., Dybkjær, K., Møller, I., Andersen, L. T, Danmarks og Grønlands Geologiske Undersøgelse, Rapport 2015/90, 2015

/10/ *Samling af geologiske modeller i Jylland, FOHM – Fælles offentlig hydrologisk model,* Miljøstyrelsen, Modeludtræk fra LARCOS modeldatabase, 2023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Location 2E
Location 2F
Location 2G
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Level system: DVR90
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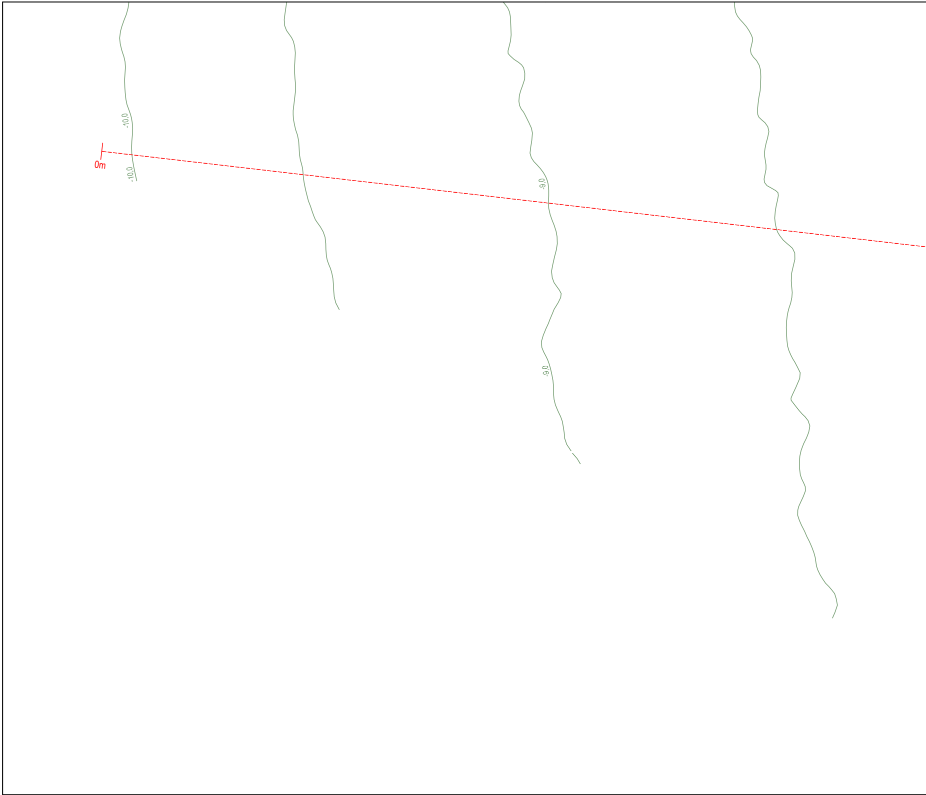
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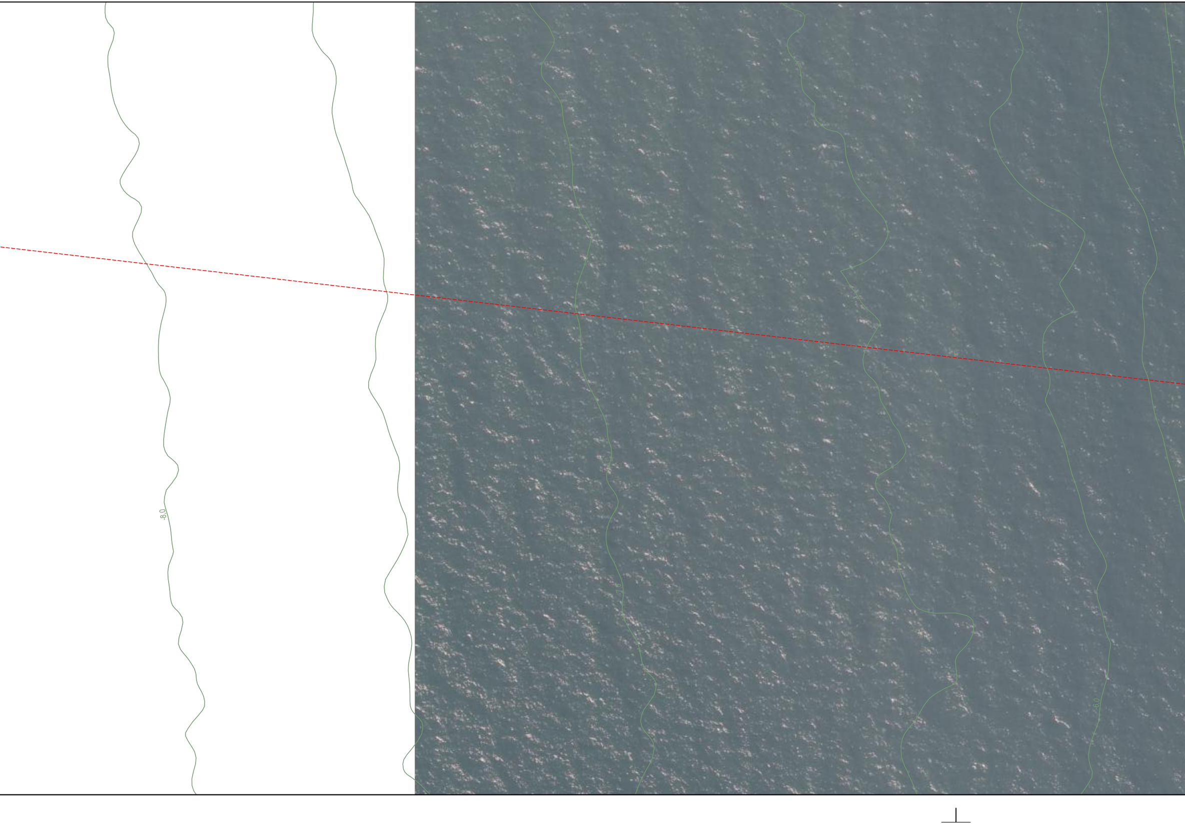

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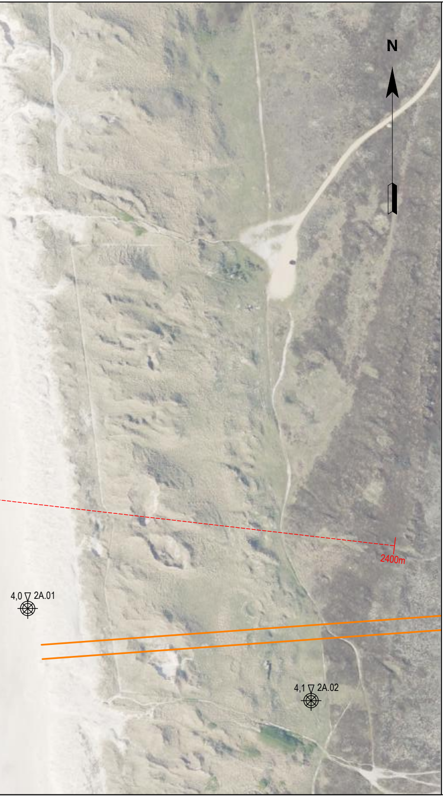
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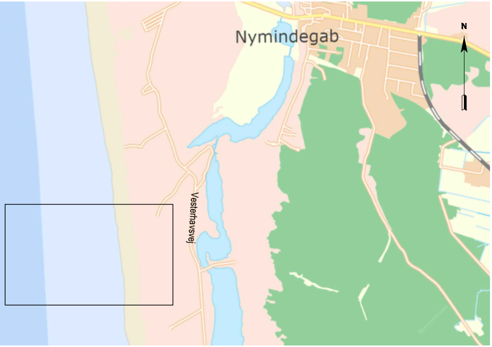
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Legend:

Borehole with CPT

b ▽ a
a: Point no.
b: Terrain level

— Planned cable route

— Planned HDD

⊢ — ⊣ Location of longitudinal profile (Encl. 95.1.3)

— Seabed level 0,5 m

Coordinate system: UTM32E89 Level: DVR90

0 80 160 m

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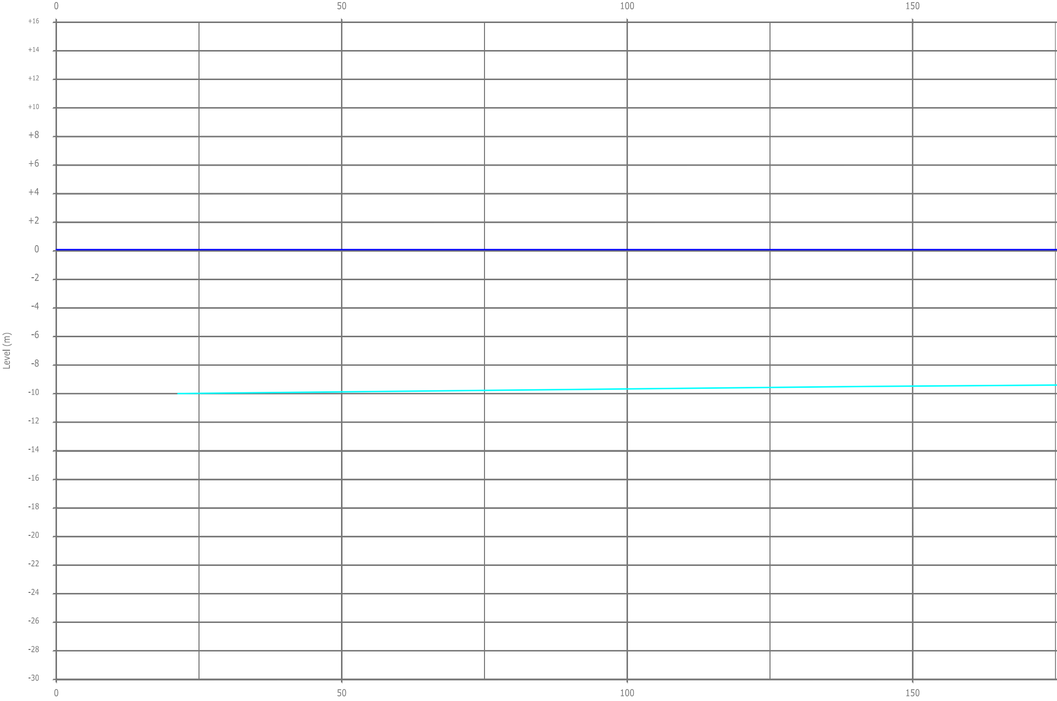

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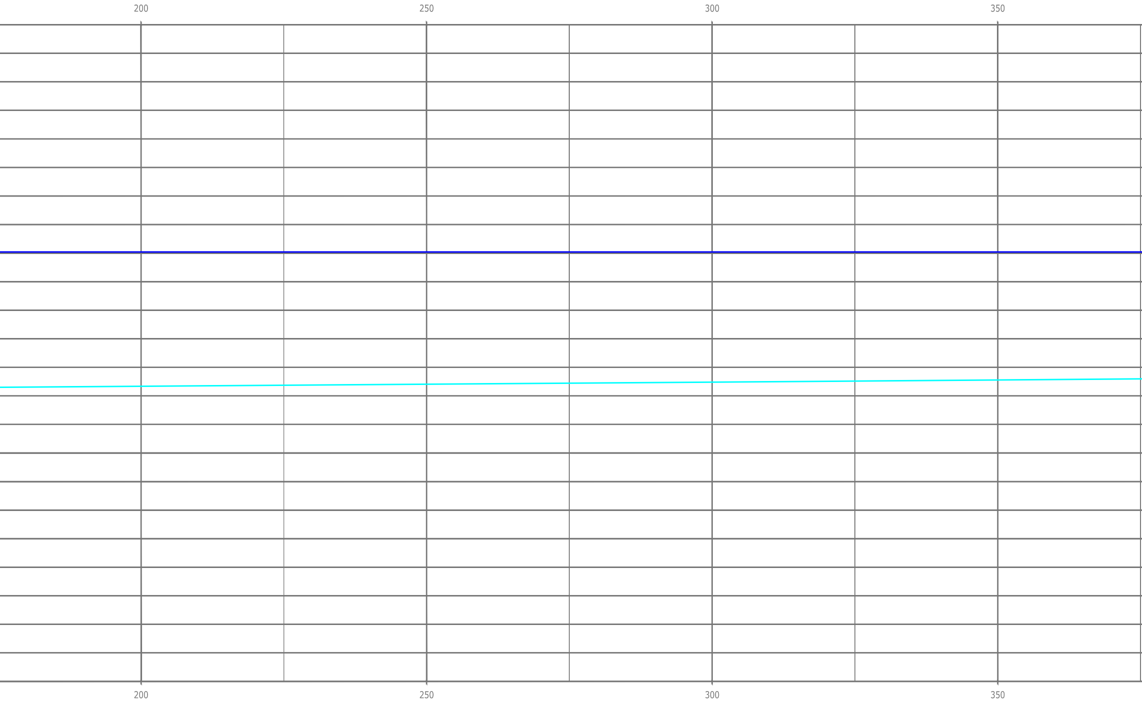
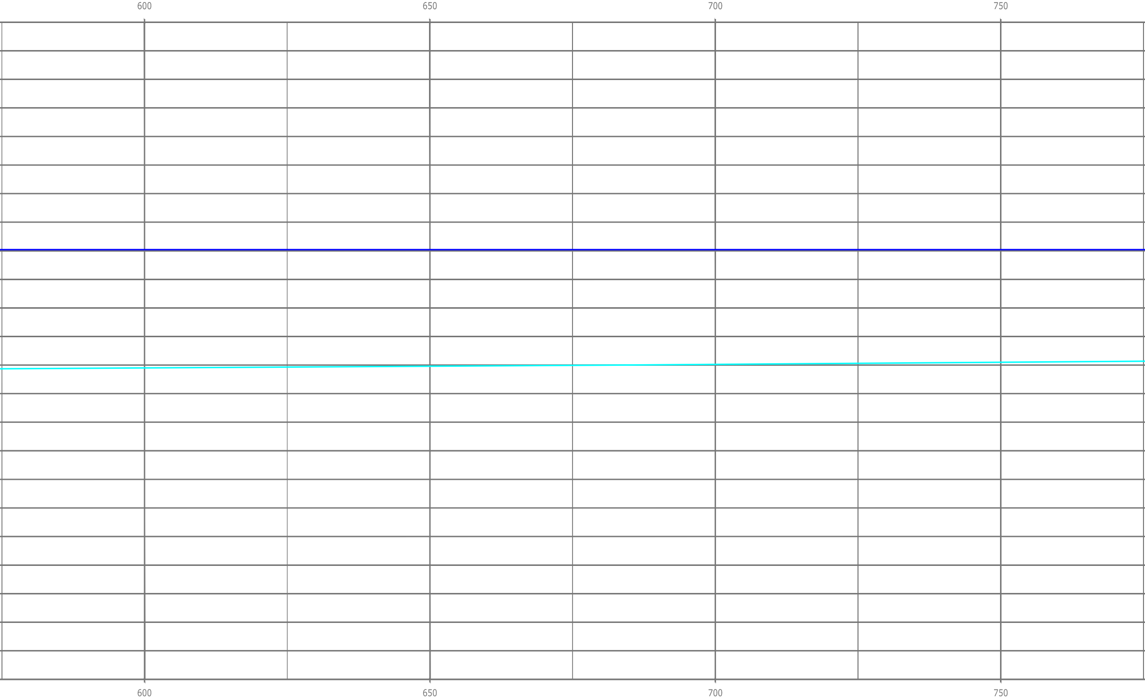
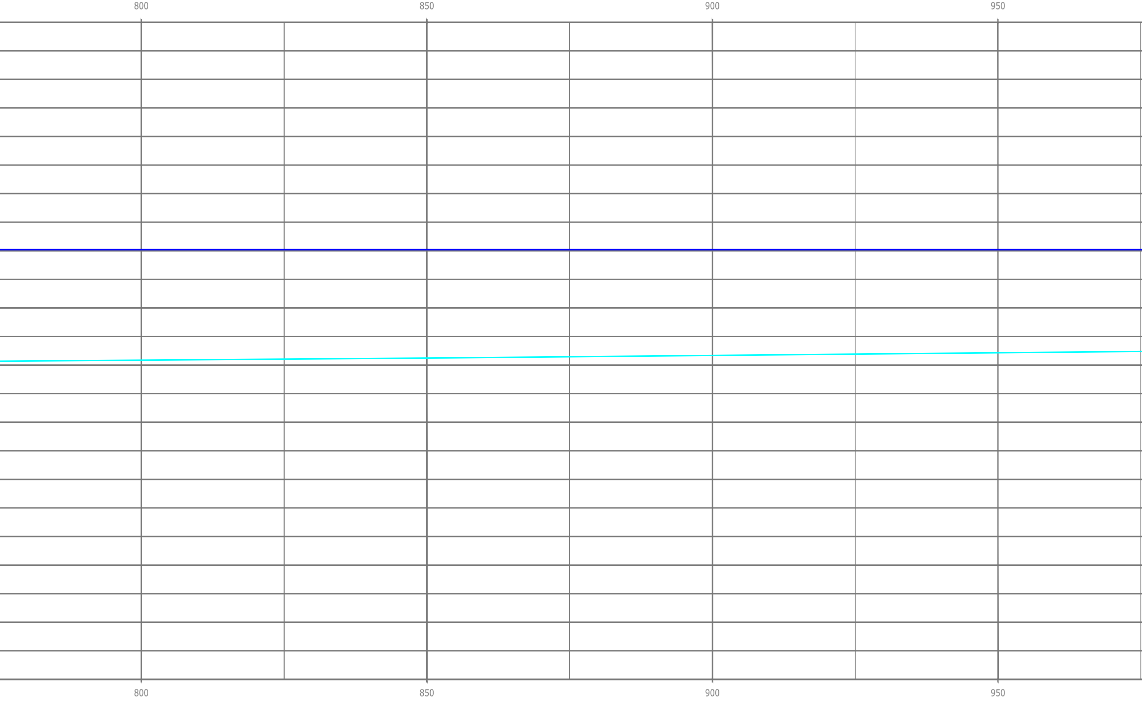
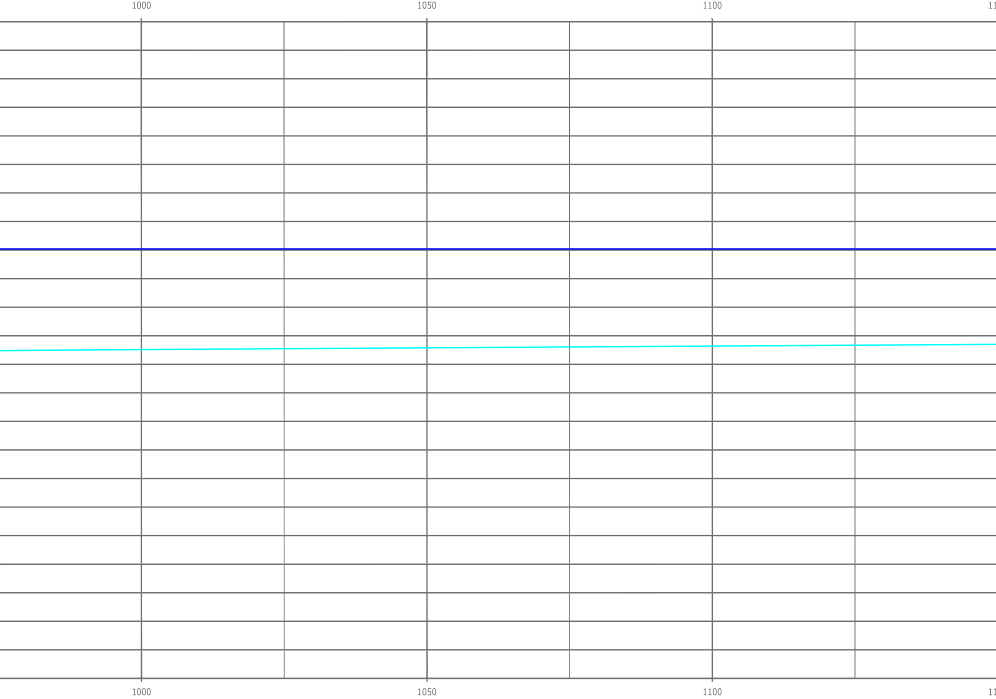
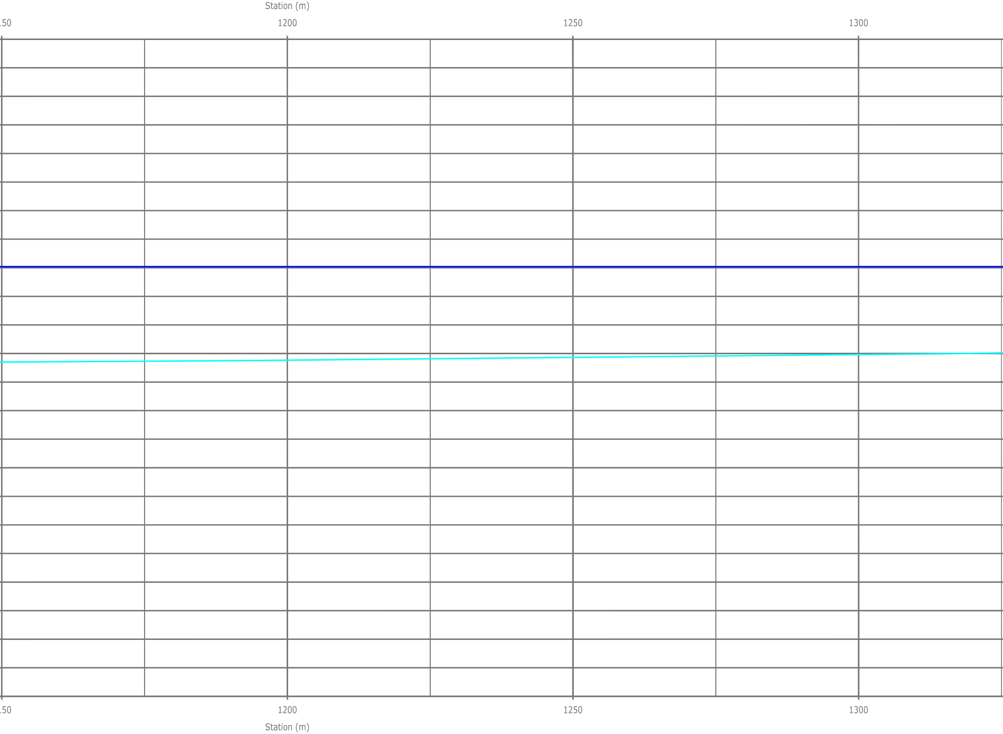
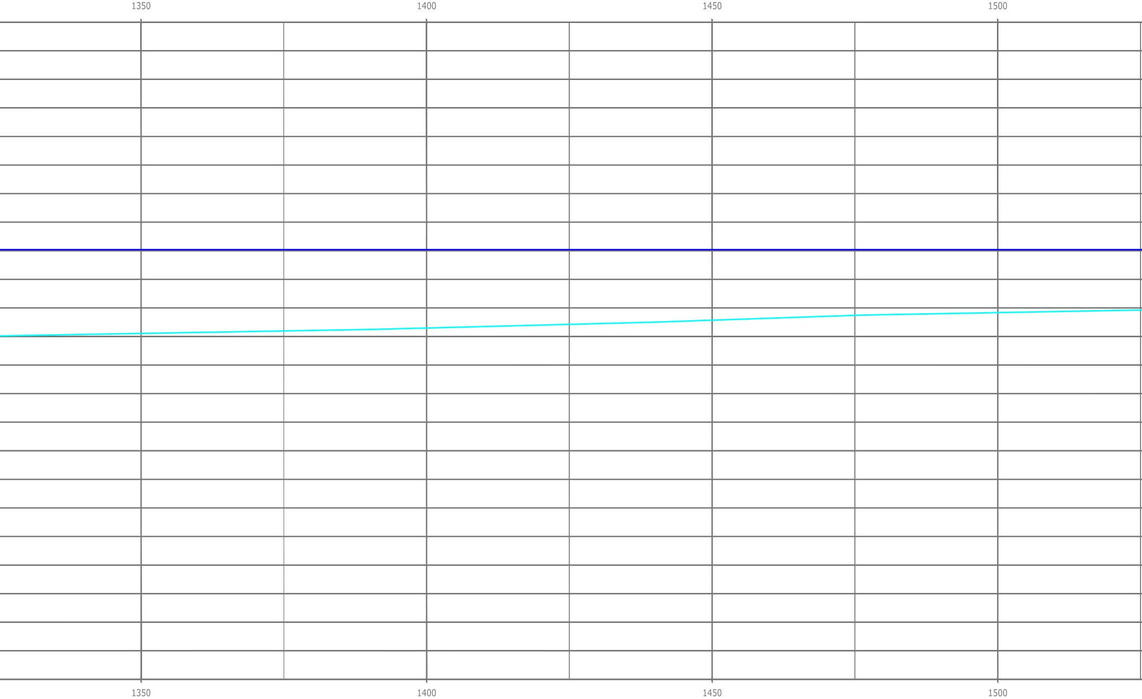


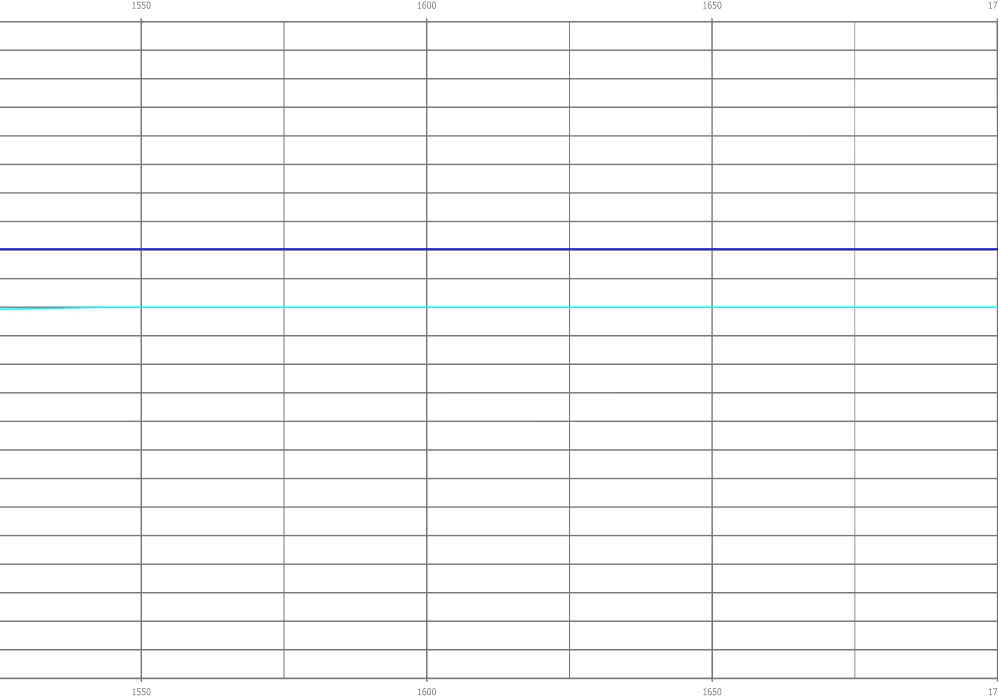


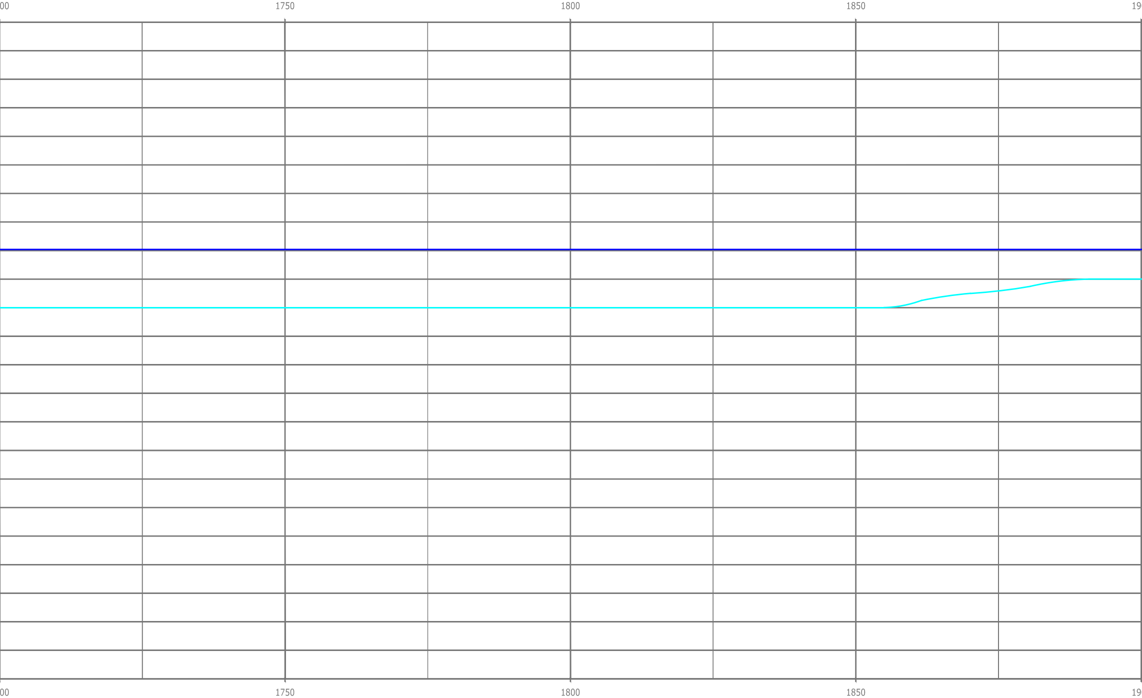


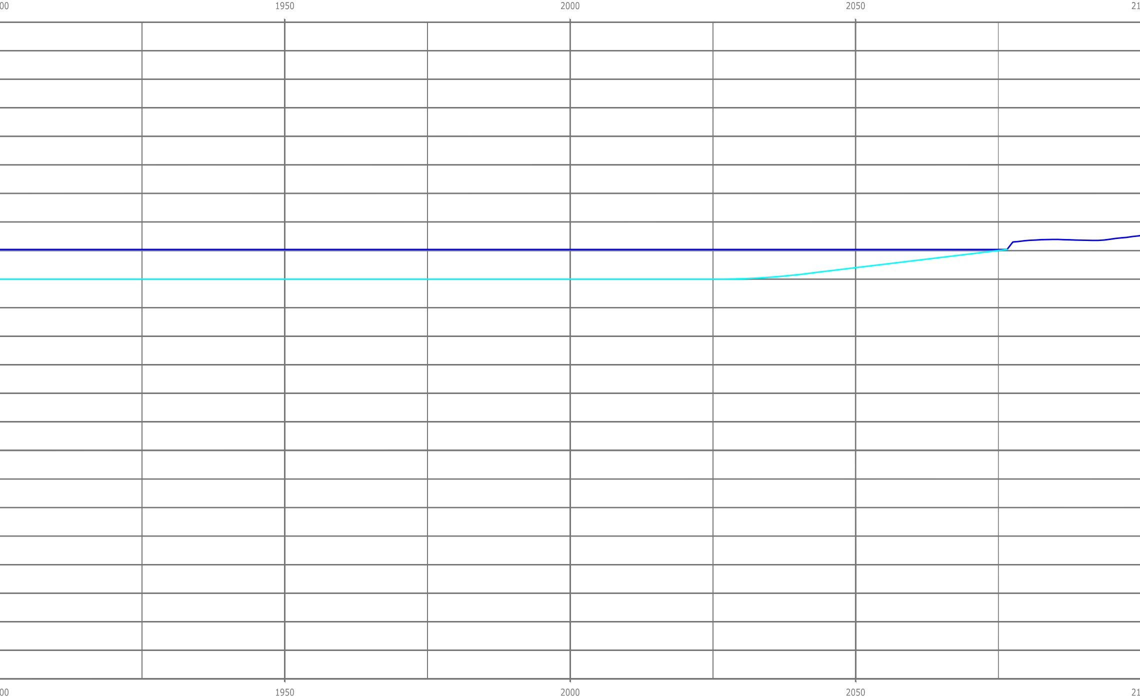


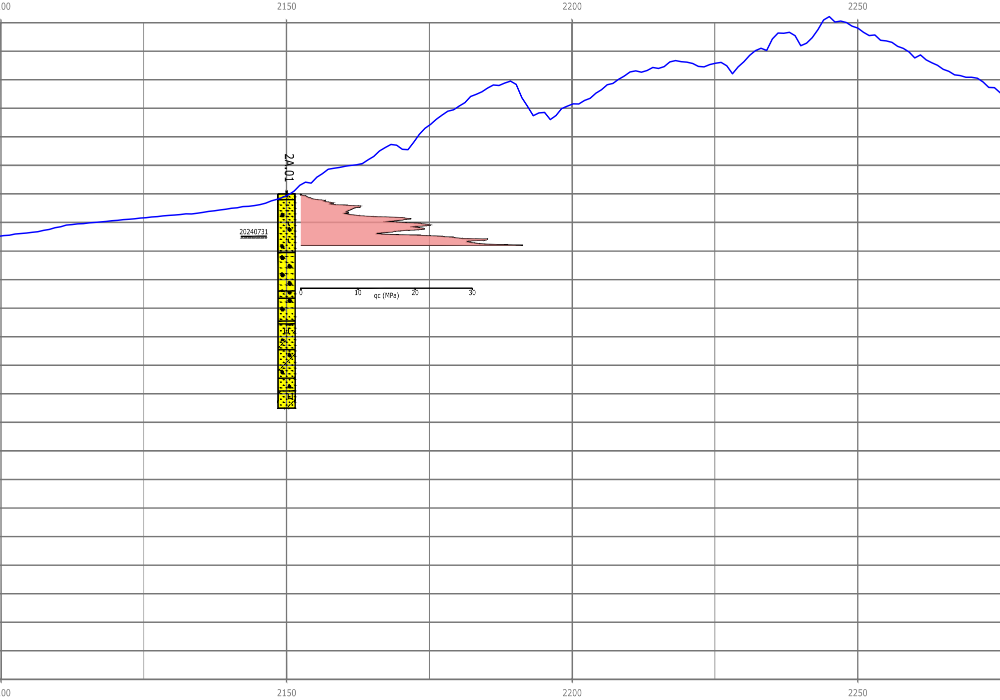


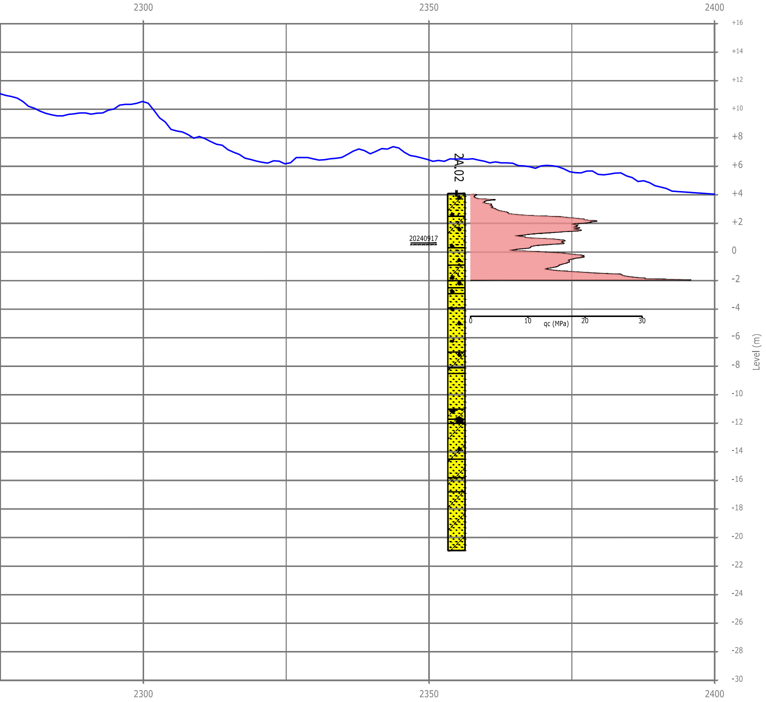


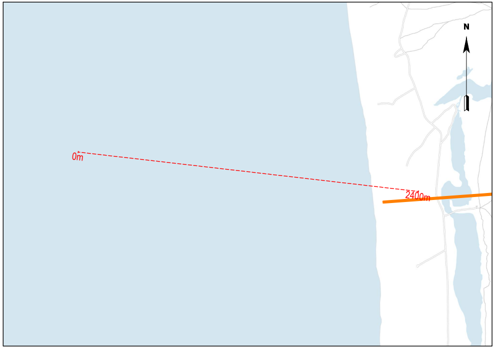












Legend:

🟩 Top soil / Fill
🟨 Sand / Gravel
🟫 Clay till
🟦 Silt
🟦 Clay
🟩 Clay/peat (postglacial)

Terrain (Dansk Højde Model)

Seabed level

Borehole

Cone penetration test, Tip resistance, q_c

d:XXm Distance between ERT-line and borehole

Planned HDD

------ Interpretation of geological boundaries

Highest measured groundwater level

x 1:500 0 20 40 m
y 1:200 0 8 16 m

Project: 208116. Mere Havvind 2030	Scale x 1:500 y 1:200		Page 1 / 1
Subject: Longitudinal profile - Gammelgab Strand 2AA	Report 95	Encl. 95.1.3	Rev.

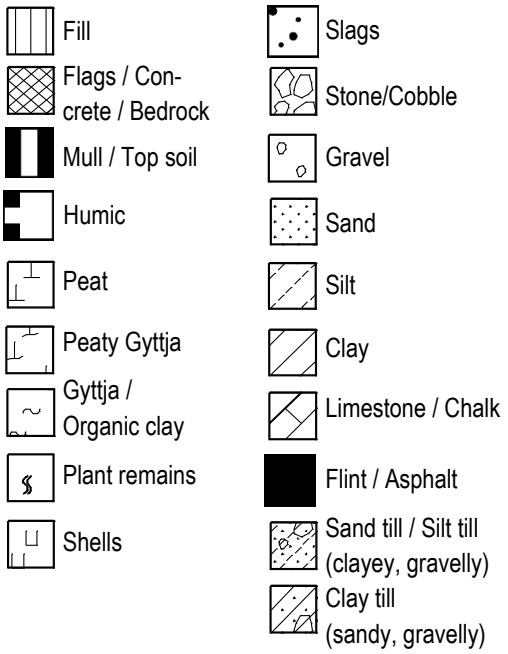
Geo
Copenhagen +45 4588 4444
Aarhus +45 8627 3111

Geo-Standard: Legend and Abbreviations

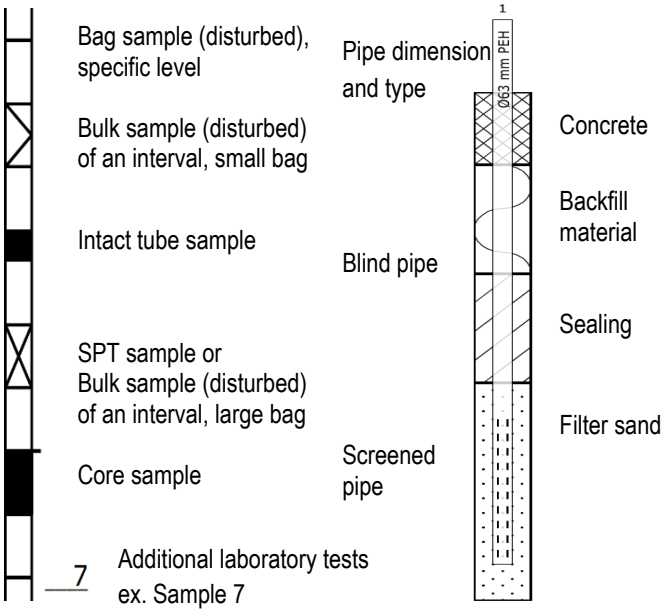
Borehole Profiles. Geotechnical, core and environmental

Description according to dgf-Bulletin 1, rev. 2, December 2021

Soil types



Samples



Pipe dimension and -type

Deposit

Ae	Aeolian (wind)
Br	Brackish
Fi	Fill
Fw	Freshwater
Gl	Glacier
Gr	Igneous/Bedrock
Ls	Landslide
Ma	Marine
Me	Metamorphic
Mw	Meltwater
Ss	Solifluction
Ts	Top soil
Vo	Volcanic
Wd	Wash down

Geological age

Re	Recent
Pg	Postglacial
Lg	Late glacial
Gc	Glacial
Ig	Interglacial
Is	Interstadial
Ng	Neogene
Pn	Paleogene
Mi	Miocene
Ol	Oligocene
Eo	Eocene
Pl	Paleocene
Sl	Selandian
Da	Danian
Ct	Cretaceous
Ju	Jurassic
Tr	Triassic
Si	Silurian
Ca	Cambrian
Pc	Precambrian

General abbreviations

sl.	slightly
v.	very
w.	with
lam.	lamina(e)
fragm.	fragments
biot.	bioturbation
bryo.	bryozoans
calc.	calcareous
noncalc.	non-calcareous
glauc.	glauconite
T	top of sample
B	bottom of sample

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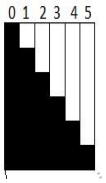
Core samples

Recovery: Ratio in percentage between sample length and length of core run (Total Core Recovery, TCR). Value appears at top of core run.

RQD: Rock Quality Designation. Ratio in percentage between total length of core pieces with length more than 100 mm, and length of core run. Value appears at top of core run.

Fractures



0 = S0	Unfractured	No fractures
1 = S1	Very slightly fractured	20 - 60
2 = S2	Slightly fractured	10 - 20
3 = S3	Fractured	6 - 10
4 = S4	Very fractured	2 - 6
5 = S5	Crushed, blocky	< 2 cm

Induration

1 = H1	Unlithified	Can easily be shaped with fingers
2 = H2	Slightly indurated	Can easily be worked with knife
3 = H3	Indurated	Can be worked with knife
4 = H4	Strongly indurated	Can be scratched with knife
5 = H5	Very strongly indurated	Cannot be scratched with knife

Tests

c_{fv}	Field vane shear strength	(kN/m²)	Measured by vane test in undisturbed soil
c_{rv}	Field vane shear strength	(kN/m²)	Measured by vane test in remoulded soil
N	Standard penetrations test (SPT)		Number of blows per 0.3 m penetration of Ø51 mm SPT probe by use of the energy h · G = 0,76 m · 0,635 kN
w	Water content	(%)	Ratio between weight of water and weight of grains
w_p	Plastic limit	(%)	Water content at the boundary between semisolid and plastic state (NP: Non plastic)
w_L	Liquid limit	(%)	Water content at the boundary between plastic and liquid state
I_P	Plasticity index	(%)	$w_L - w_P$
γ	Unit weight	(kN/m³)	Ratio between total weight and total volume
e	Void ratio		Ratio between pore volume and grain volume
e_{max}	Void ratio, loosest state		Void ratio of very loose standard state
e_{min}	Void ratio, densest state		Void ratio of very dense standard state
I_D	Relative density		$(e_{max} - e)/ (e_{max} - e_{min})$
ka	Carbonate content	(%)	Ratio between weight of carbonate and total grain weight
gl	Loss on ignition	(%)	Weight loss by prolonged and high heating, % of total grain weight

Additional tests

In situ tests:

PR	Pressuremeter
FH	Falling Head
PP	Pumping
EL	Elastometer
GA	Gammalog

Laboratory tests:

B	Brazil	S	Simple shear
C	Consolidation	T	Triaxial
D	Specific gravity	U	Unconfined compression
E	e_{max} and e_{min}	V	Shear box
F	Photo	W	Vibration compaction
G	Grain size analysis	SP	Standard proctor test
P	Point load	MP	Modified proctor test

References

Danish Standard:

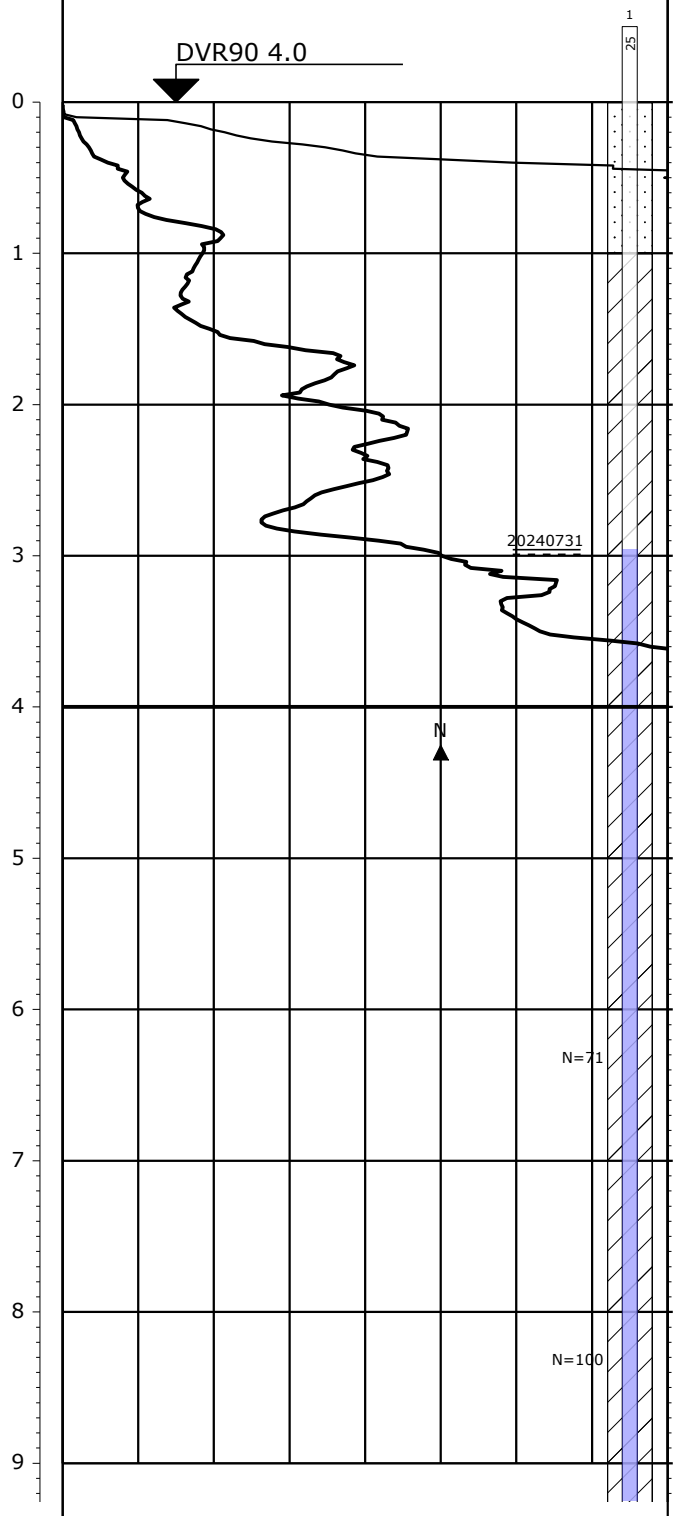
DS/EN 1997-1:2007 – Geoteknik-Del 1

Danish Geotechnical Society:

- ”A guide to engineering geological soil description” (dgf-Bulletin 1, rev. 2, December 2021)
- ”Felthåndbogen” (dgf-Bulletin 14)

Danish Geotechnical Society:

- ”Laboratoriehåndbogen” (dgf-Bulletin 15)
- ”Referenceblad for vingeforsøg”
- ”Referenceblad for SPT-forsøg”



Depth (m)	Level (m)	Geology	Sample	No.	Geological Description	Env.	Age
				1	SAND, medium, uniformly graded, noncalcareous, light grey	Ae	Pg
				2	SAND, medium, uniformly graded, sl. gravelly, noncalcareous, light grey	Ma	Pg
0	+4			3	SAND - -	Ma	Pg
				4	SAND - -	Ma	Pg
1	+3			5	SAND, coarse, uniformly graded, gravelly, noncalcareous, grey	Ma	Pg
				6	SAND, medium - coarse, uniformly graded, sl. gravelly, noncalcareous, grey	Ma	Pg
2	+2			7	SAND, medium - coarse, uniformly graded, sl. gravelly, noncalcareous, light grey	Ma	Pg
				8	SAND, medium, uniformly graded, gravelly, noncalcareous, light grey	Ma	Pg
3	+1			9	SAND, medium - coarse, uniformly graded, very gravelly, noncalcareous, grey	Ma	Pg
				P1	GRAVEL, sandy, noncalcareous, grey	Ma	Pg
4	0			10	GRAVEL - -	Ma	Pg
				11	GRAVEL - -	Ma	Pg
5	-1			12	GRAVEL - -	Ma	Pg
				13	GRAVEL - -	Ma	Pg
6	-2			14	GRAVEL, very sandy, noncalcareous, grey	Ma	Pg
				15	SAND, medium - coarse, graded, very gravelly, noncalcareous, grey	Ma	Pg
7	-3			16	GRAVEL, sandy, noncalcareous, grey	Ma	Pg
				17	GRAVEL, very sandy, noncalcareous, grey	Ma	Pg
8	-4			18	SAND, medium, uniformly graded, gravelly, noncalcareous, yellowish grey	Ma	Pg
9	-5			19	GRAVEL, sandy, noncalcareous, grey	Ma	Pg

Continues

Test results

□	10	20	30
→	1	2	3
▲	10	20	30
→	10	20	30

W (%)
qc (MPa)
N (Blow/30 cm)
qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 448258 (m) Y : 6184570 (m)

Job: 208116 Mere Havvind 2030

Drilled by: Geo LVO/JEP Date: 2024-07-01 Geology by: NIO Borehole: 2A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 16.2.1 Rev.: 0 P. 1/2

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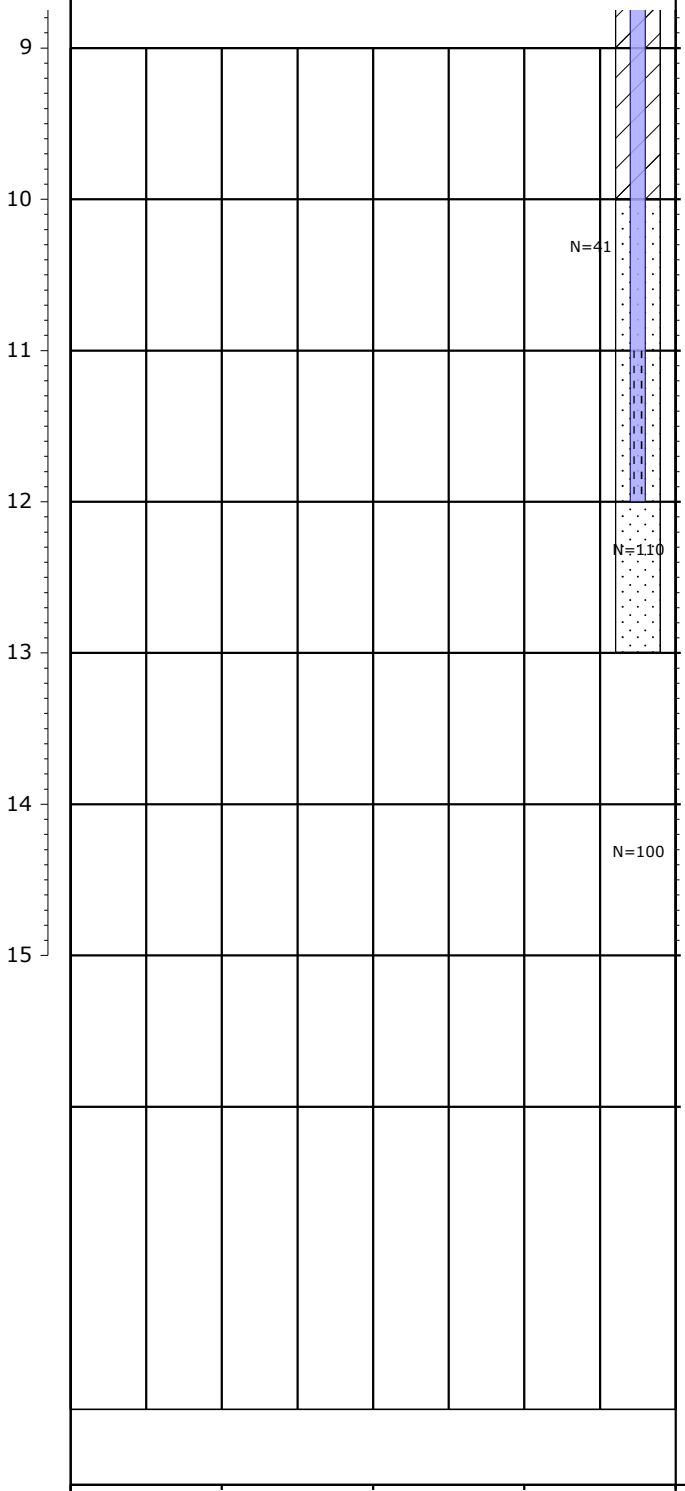
Profile



Depth (m)	Level (m)	No.	Geological Description	Env.	Age
			Continued		
9	-5	19	GRAVEL, sandy, noncalcareous, grey	Ma	Pg
		20	SAND, fine - medium, poorly graded, sl. silty, gravelly, noncalcareous, w. few shells, grey	Ma	Pg
		P2			
			SAND, fine - medium, uniformly graded, gravelly, noncalcareous, w. few shell fragments, grey	Ma	Pg
10	-6	21	SAND - -	Ma	Pg
		22	SAND, medium, uniformly graded, sl. silty, noncalcareous, grey	Ma	Pg
11	-7	23	SAND, medium, uniformly graded, sl. silty, sl. gravelly, noncalcareous, w. few shell fragments, grey	Ma	Pg
		24	SAND, medium, uniformly graded, sl. silty, sl. gravelly, noncalcareous, grey	Ma	Pg
12	-8	25	SAND - -	Ma	Pg
		26	SAND - -	Ma	Pg
13	-9	27	SAND, medium, uniformly graded, noncalcareous, w. few shell fragments, grey	Ma	Pg
		28	SAND, medium, uniformly graded, gravelly, noncalcareous, w. few shell fragments, grey	Ma	Pg
14	-10	29	SAND, fine - medium, uniformly graded, sl. silty, w. shells, grey	Ma	Pg
		30	SAND, fine - medium, uniformly graded, sl. silty, w. shell fragments, grey	Ma	Pg
15	-11	31	SAND - -	Ma	Pg
	-12				

Test results

□	10	20	30	W (%)
→	1	2	3	qc (MPa)
▲	10	20	30	N (Blow/30 cm)
→	10	20	30	qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 448258 (m) Y : 6184570 (m)

Job: 208116 Mere Havvind 2030

Drilled by: Geo LVO/JEP Date: 2024-07-01 Geology by: NIO Borehole: 2A.01

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 16.2.1 Rev.: 0 P. 2/2

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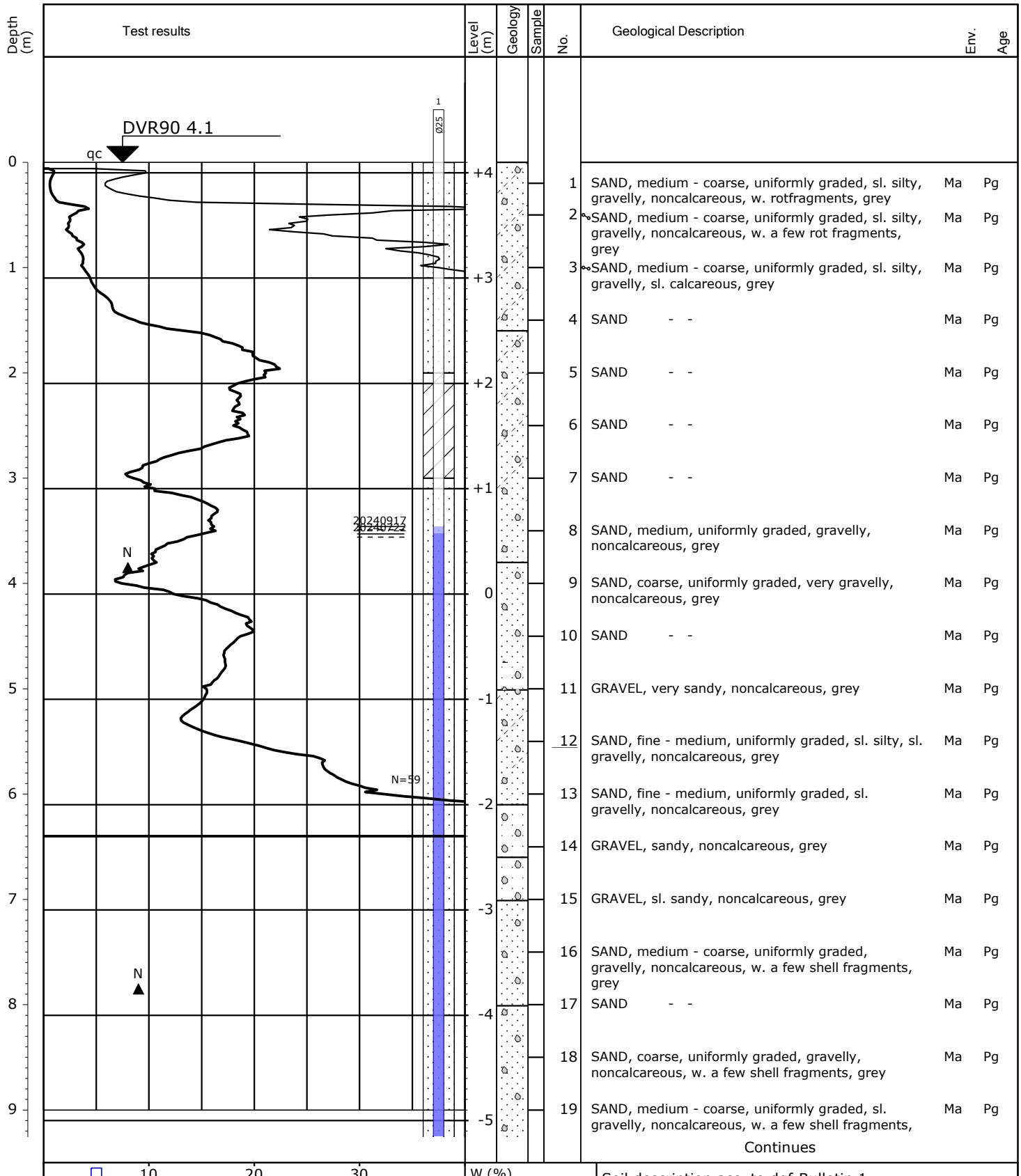
Profile



Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 448457 (m) Y : 6184505 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo Date: 2024-07-22 Geology by: NIO Borehole: 2A.02

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 16.2.2 Rev.: 0 P. 1/3

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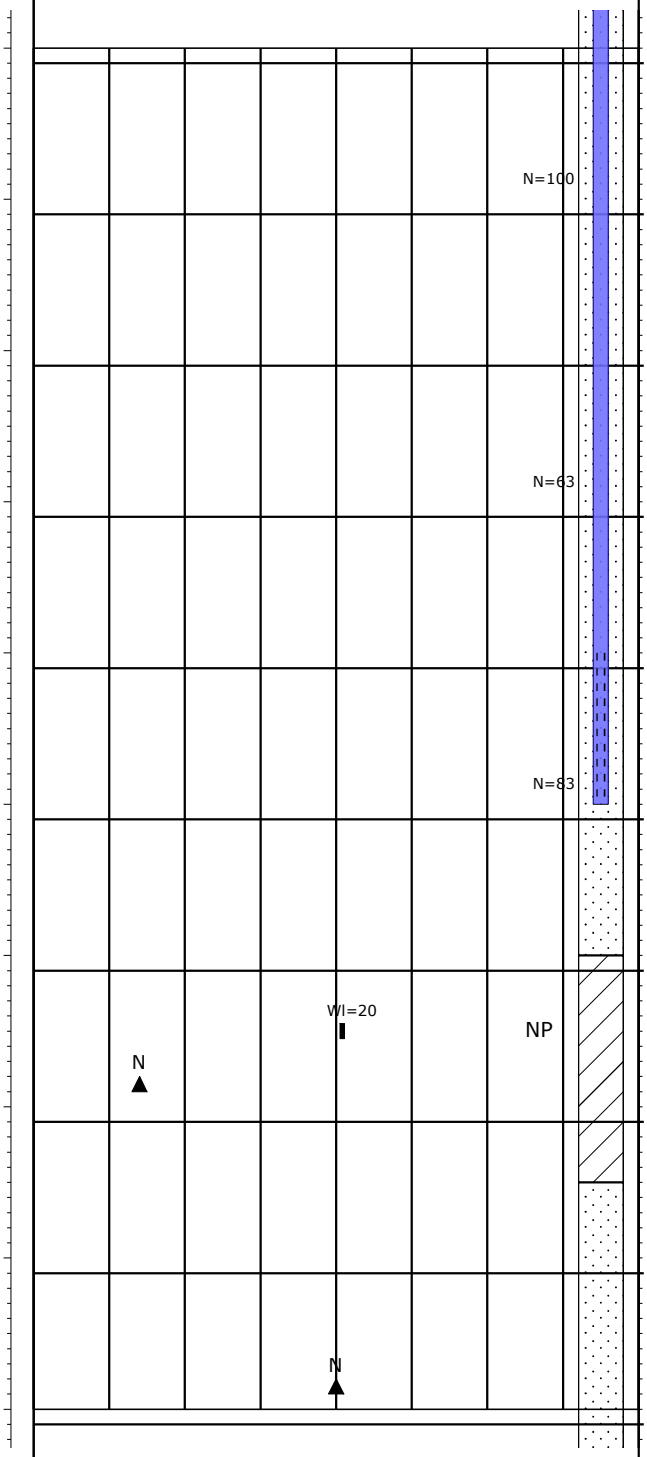
Profile



Depth (m)	Level (m)	Sample	No.	Geological Description	Env.	Age
				Continued		
9	-5		19	SAND, medium - coarse, uniformly graded, sl. gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
			20	SAND, medium, uniformly graded, sl. gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
10	-6		21	SAND, medium, uniformly graded, sl. gravelly noncalcareous, w. a few gyttja parts, w. a few shell fragments, grey	Ma	Pg
			22	SAND, medium, uniformly graded, very gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
11	-7		23	SAND - -	Ma	Pg
			24	SAND, medium, uniformly graded, sl. silty, gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
12	-8		25	SAND, medium, uniformly graded, sl. silty, sl. gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
			26	SAND, fine - medium, uniformly graded, sl. silty, noncalcareous, w. a few shell fragments, grey	Ma	Pg
13	-9		27	SAND, fine, uniformly graded, sl. gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
			28	SAND, fine, uniformly graded, noncalcareous, w. a few shell fragments, grey	Ma	Pg
14	-10		29	SAND, fine, uniformly graded, sl. gravelly, noncalcareous, w. a few shell fragments, grey	Ma	Pg
			30	SAND, fine, uniformly graded, noncalcareous, w. a few shell fragments, grey	Ma	Pg
15	-11		31	SAND - -	Ma	Pg
	-12		32	SAND TILL, clayey, sl. gravelly, noncalcareous, dark grey	Gl	Gc
16			33	SAND TILL - -	Gl	Gc
			34	SAND, medium, poorly graded, silty, noncalcareous, dark grey	Gl	Gc
17	-13		35	SAND, medium, poorly graded, silty, w. a few clay laminae, noncalcareous, dark grey	Gl	Gc
			36	SAND, medium, poorly graded, silty, sl. gravelly, noncalcareous, dark grey	Gl	Gc
18	-14		37	SAND - -	Gl	Gc
				Continues		

Test results

□	10	20	30
→	1	2	3
▲	10	20	30
→	10	20	30

W (%)
qc (MPa)
N (Blow/30 cm)
qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 448457 (m) Y : 6184505 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo Date: 2024-07-22 Geology by: NIO Borehole: 2A.02

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 16.2.2 Rev.: 0 P. 2/3

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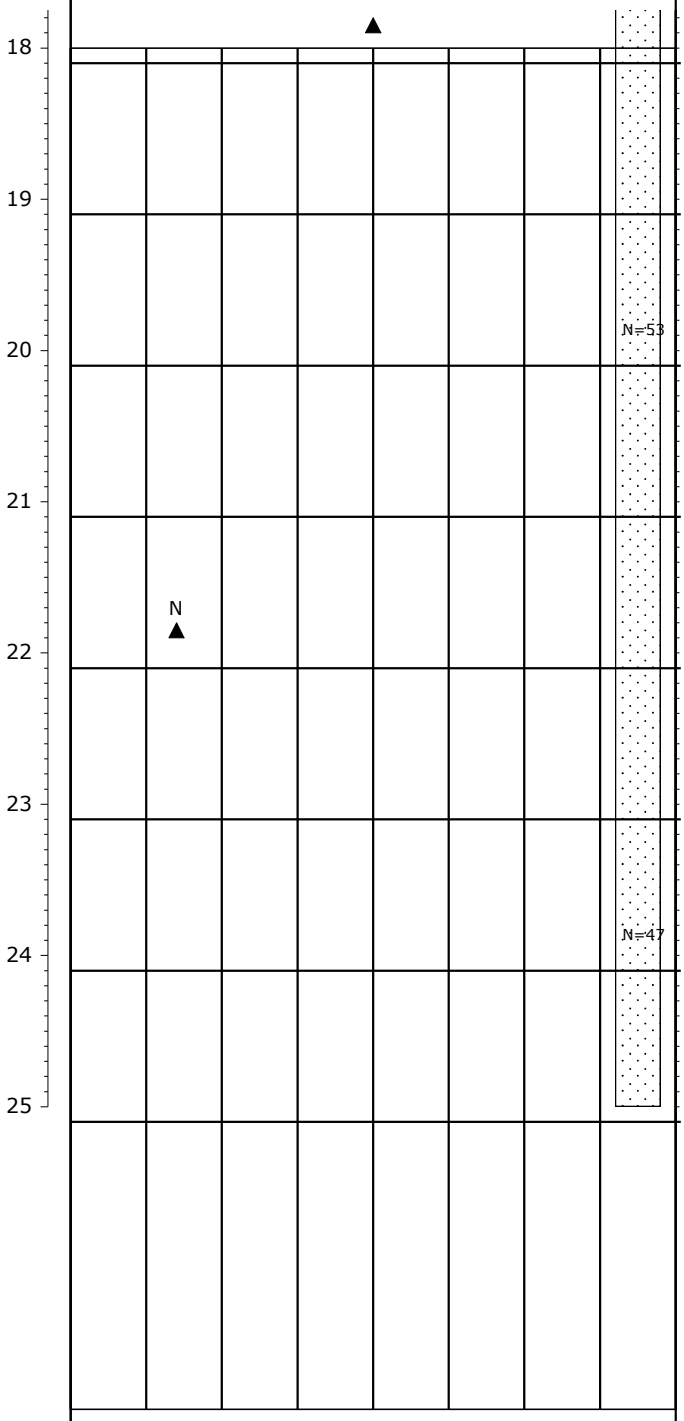
Profile



Level (m)	Geology	Sample	No.	Geological Description	Env.	Age
				Continued		
-14			37	SAND - -	Gl	Gc
			38	SAND - -	Gl	Gc
-15			39	SAND, medium, poorly graded, silty, noncalcareous, dark grey	Gl	Gc
			40	SAND, fine - medium, poorly graded, silty, noncalcareous, dark grey	Gl	Gc
-16			41	SAND, fine, uniformly graded, silty, noncalcareous, dark grey	Gl	Gc
			42	SAND - -	Gl	Gc
-17			43	SAND, fine, graded, very silty, noncalcareous, dark grey	Gl	Gc
			44	SAND - -	Gl	Gc
-18			45	SAND - -	Gl	Gc
			46	SAND, fine, graded, very silty, w. a single piece of brown coal (relocated), noncalcareous, dark grey	Gl	Gc
-19			47	SAND, fine, poorly graded, silty, noncalcareous, dark grey	Gl	Gc
			48	SAND, fine, graded, very silty, noncalcareous, dark grey	Gl	Gc
-20			49	SAND - -	Gl	Gc
			50	SAND - -	Gl	Gc
-21			51	SAND - -	Gl	Gc

□	10	20	30 W (%)
→	1	2	3 qc (MPa)
▲	10	20	30 N (Blow/30 cm)
→	10	20	30 qc (MPa)

Soil description acc. to dgf-Bulletin 1, Revision 2, December 2021.

Coordinate system: UTM32E89
X : 448457 (m) Y : 6184505 (m)

Job: 208116 Energinet. Mere Havvind 2030

Drilled by: Geo Date: 2024-07-22 Geology by: NIO Borehole: 2A.02

Method: Cased Shell & Auger 6'' DGU no: Encl. No.: 16.2.2 Rev.: 0 P. 3/3

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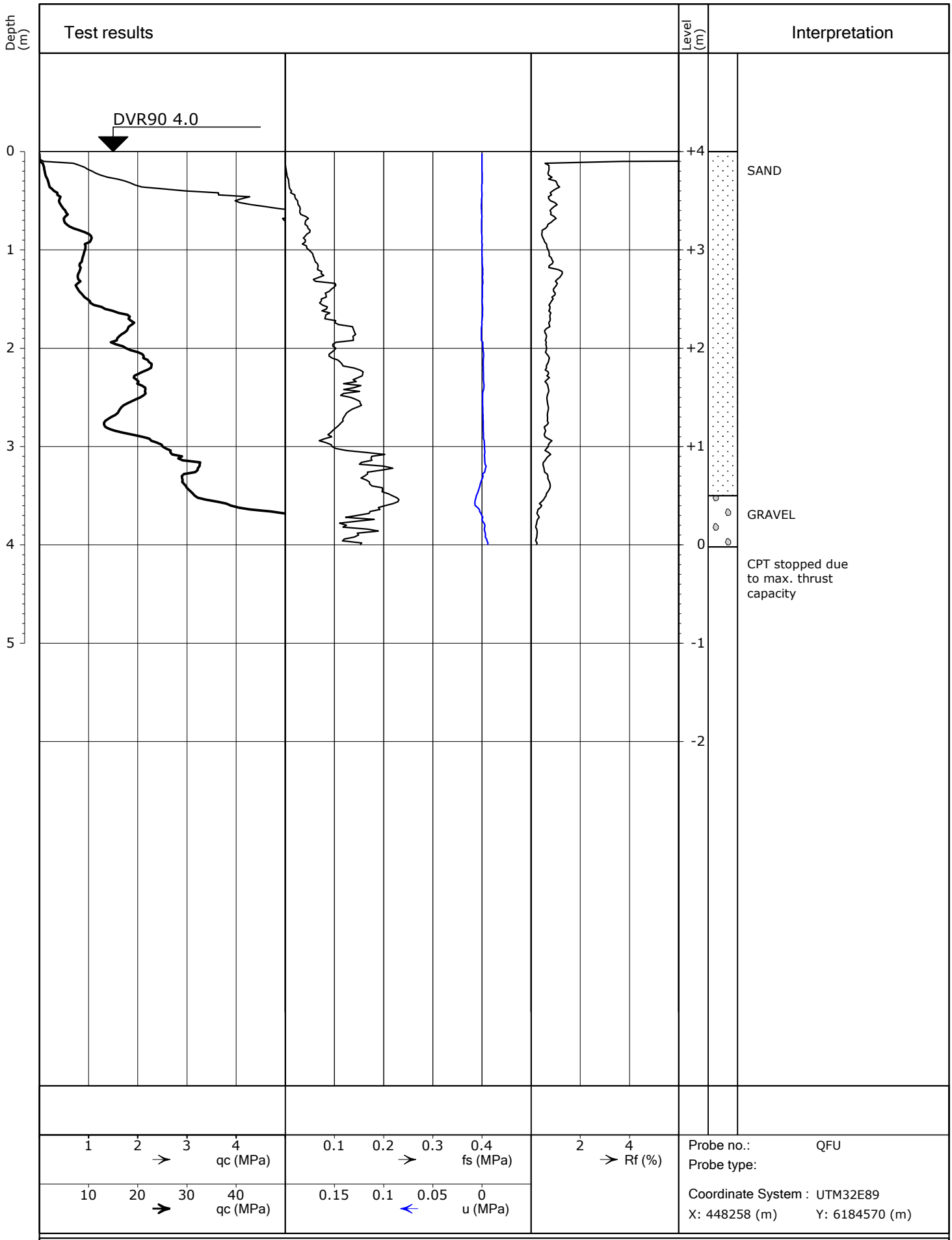
Profile



Project:	208116	Energinet. Mere Havvind 2030							
CPT by:	Geoboringer	Date:	2024-06-11	Interpretation:	JDO			Point no. :	2A.01.CPT
Profile by:	JDO	Control:	NIO	Approved:	LAB	Date:	2024-09-30	Encl.: 16.3.1	Rev.: 0 S. 1/1

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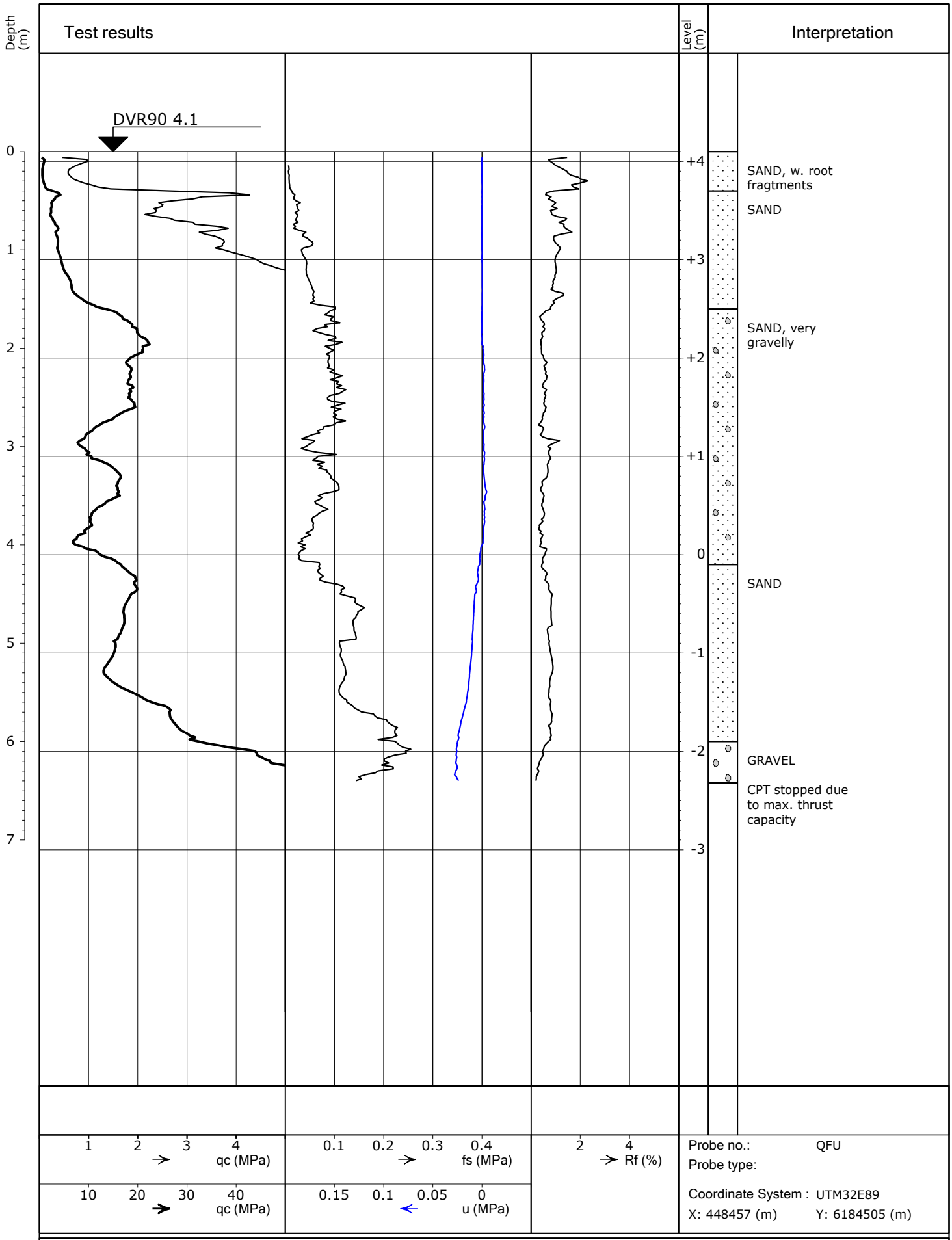
CPT profile



Probe no.: QFU
Probe type:

Coordinate System : UTM32E89
X: 448457 (m) Y: 6184505 (m)

Project: 208116 Energinet. Mere Havvind 2030

CPT by: Geoboringer Date: 2024-06-10 Interpretation: JDO Point no. : 2A.02.CPT

Profile by: JDO Control: NIO Approved: LAB Date: 2024-09-30 Encl.: 16.3.2 Rev.: 0 S. 1/1

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CPT profile

Risk Assessment - Horizontal Directional Drilling

Risk	Consequence (s)	Category	Degree of Risk		Countermeasure (s)	Residual Risk	
			C	L		C	L
Horizontal Directional Drilling							
Difficult/challenging access to the drilling pits due to loose sand, soft terrain / slippery surface at the beach. Especially in depressions combined with high precipitation periods.	Drilling supplier / equipment getting stuck in the field	I/T/F	1	D	Steel plates can be used to secure access.	1	A
Clay causing high friction on drilling rod (may be relevant)	Drilling speed decreases or drillings stops	T/F	3	B	Drilling supplier must use a suitable drilling mud to reduce friction. The drilling mud can have additive suitable to the soil conditions.	3	A
Unstable borehole (especially in frictional soils under the groundwater table)	Drilling borehole collapse and causes minor settlements of surface Drilling speed decreases / stops	F/T	3	D	Drilling supplier must use a suitable drilling mud to prevent collapse of the borehole. The drilling mud can have additive suitable to the soil conditions.	3	A
Very permeable soils (with and without groundwater pressure) causing loss of drill mud / dilution of drilling mud	Reduce lubricating effect (additives) Drilling mud leaks out in the formation and can cause unstable borehole	T/E	2	C	Drilling supplier has to be prepared for an increased consumption of drilling mud and handling of excess mud/water. Use a thick drilling mud if necessary.	2	A
Use of additive in the drilling mud	Additive (chemicals) and can cause pollution of the surrounding soil and water environment.	E	3	B	Drilling supplier must only use additive suitable for the specific soil formation and has to make sure that the additive are approved/documented for the project.	3	A
HDD penetrating soft soil deposits like peat, gyttja, mull, etc.	Difficulty in maintaining the alignment of the HDD. Risk of blowout.	F/T	3	C	Changing the drilling alignment to higher/lower altitude (during the project planning process)	2	B
Blowout	Unintended loss of drilling mud to terrain or water environment.	T/F/E	4	C	Drilling supplier has to monitor/observe/detect if there is a sudden pressure drop during the drilling works and have a procedure of in action if blowout happens (ex. small decompression holes). Reduce the length of the cable route, because long cable routes have higher risk of blowout due to the higher pressure in the drilling mud. Investigation points (boreholes/CPT) are placed in a secure distance from the planned HDD line.	3	B

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					Ensure sufficient depth of HDD.		
Flooding of drilling pit due to heavy precipitation, insufficient lowering/draining of the groundwater table etc.	Drilling stops until pit is drained Loss/damaged of equipment	I/T/F	4	C	Establishing a water lowering/draining system prior to start of drilling. Execution of drilling from terrain if possible.	4	B

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Severity of Consequence (C)					Increasing Likelihood (L)→				
Rating	**Injury /illness** abbreviation (I)	**Property/ Financial** abbreviation (F)	**Time/Quality** abbreviation (T)	**Environment** abbreviation (E)	**Rare** May occur but only in exceptional circumstances (ie. Never heard of in the Industry)	**Unlikely** Could occur in some circumstances (ie. Heard of in the Industry)	**Possible** Might occur in some circumstances (ie. Has happened in the Organisation or more than once per year in the Industry	**Likely** Will probably occur in most circumstances (happened at a Location or more than once per year in the Organisation)	**Almost Certain** Is expected to happen in most circumstances (ie. Has happened more than once per year in the Location)
					A	**B**	**C**	**D**	**E**
5	Multiple fatalities	Extensive damage Incurred significant financial loss	Serious Breach	Massive effect	Medium	**High**	**High**	**High**	**High**
4	Permanent total disability or 1 fatality	Major damage Substantial financial loss incurred	Major Breach	Major effect	Low	Medium	**High**	**High**	**High**
3	Major health effect / injury	Localised damage. Moderate financial loss incurred	Considerable impact	Localised effect	Low	Medium	Medium	Medium	**High**
2	Minor health effect / injury	Minor damage. Minor financial loss incurred	Limited impact	Minor effect	Low	Low	Medium	Medium	**High**
1	Slight health effect / injury	Slight damage Low financial loss incurred	Slight impact	Slight effect	Low	Low	Low	Low	Medium

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Rating	Injury/illness	Property – Premises, and 3rd party	Time/Quality	Environment
5	**Multiple fatalities** - From an accident or occupational illness	**Extensive damage** - Substantial or total loss of operation. Incurred significant financial loss		**Massive effect** - Persistent severe environmental damage or severe nuisance over a large area. Loss of commercial, recreational use or nature conservancy, resulting in major financial consequences for the company. Ongoing breaches well above statutory or prescribed limits.
4	**One to three fatalities or permanent total disability** - From an accident or occupational illness. Irreversible health damage with serious disability or death	**Major damage** - Partial operation loss, 2 weeks shutdown, Substantial financial loss incurred	**Major impact –** Partial operation loss, 2 weeks shutdown, Extensive adverse effect on quality. Potentially restrictive measures and/or impact on grant of licences. Mobilisation of action groups	**Major effect** - Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment. Extended breaches of statutory or prescribed limits, or widespread nuisance.
3	**Major injury or health effects** (including Permanent Partial Disability) - Affecting work performance in the longer term, such as a prolonged absence from work. Irreversible health damage without loss of life, e.g. noise induced hearing loss, chronic back injuries	**Moderate damage** - Partial shutdown Moderate financial loss incurred	**Considerable impact –** Partial shutdown Extensive adverse effect on quality. Mobilisation of action groups	**Localised effect** - Limited discharges affecting the neighbourhood and damaging the environment. Repeated breaches of statutory or prescribed limit, or many complaints.
2	**Minor injury or health effects** - Affecting work performance, such as restriction to activities (Restricted Work Case) or a Lost Time Injury. Limited health effects which are reversible, e.g. skin irritation, food poisoning	**Minor damage** - Brief disruption, Minor financial loss incurred	**Limited impact –** Brief disruption Multiple Stakeholder upset	**Minor effect** - Sufficiently large contamination or discharge to damage the environment, but no lasting effect. Single breach of statutory or prescribed criterion, or single complaint.
1	**Slight injury or health effects** (including first aid case and medical treatment case and occupational illness) - Not affecting work performance or causing disability	**Slight damage** - No disruption to operations, Low financial loss incurred	**Slight impact** – No disruption to operations Individual Stakeholder upset	**Slight effect** – Slight environmental damage, within the fence and within systems. Negligible financial consequences

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