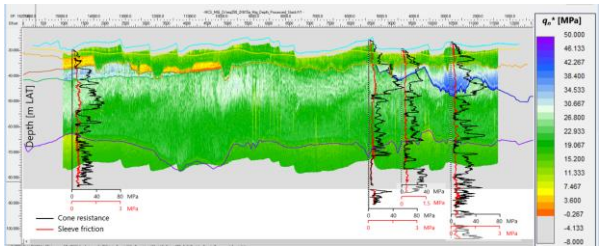
1 500 000

synthetic CPTs for offshore windfarm

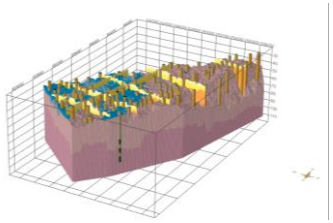


The development of advanced engineering ground models for offshore applications

Joek Peuchen - Fugro

What is a ground model?

Eurocode 7 ground model: site specific outline of the disposition and character of the ground and groundwater based on results from ground investigations and other available data



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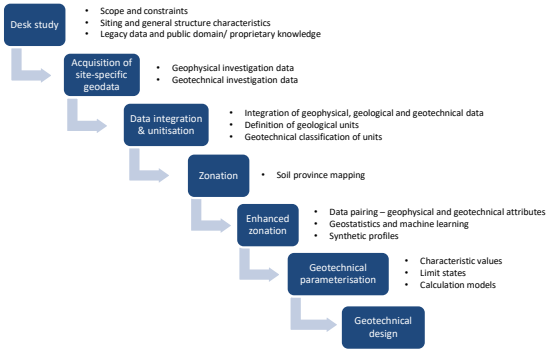
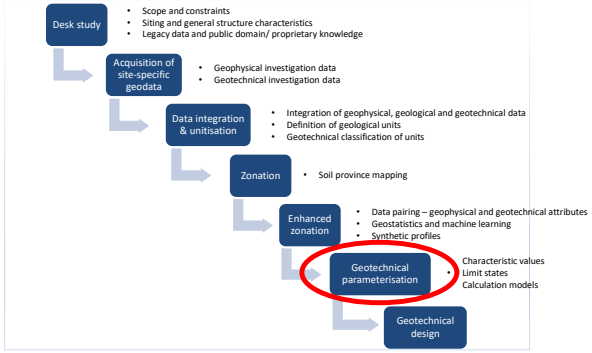
≠ is not equal to ≠

Eurocode 7 geotechnical design model: conceptual representation of the site derived from the ground model for the verification of each appropriate design situation and limit state

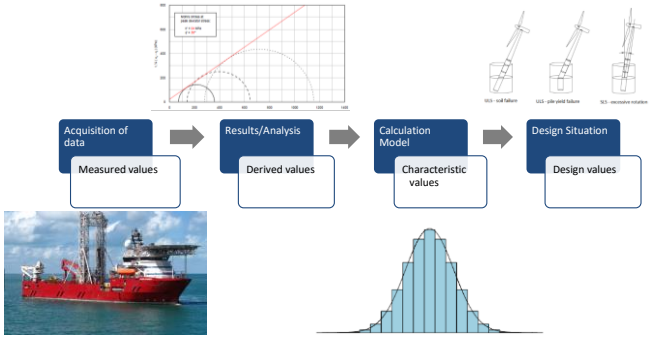
Advanced engineering ground model



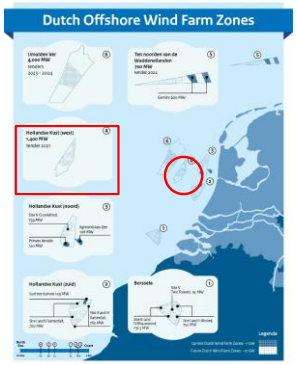
Start with the end in mind …

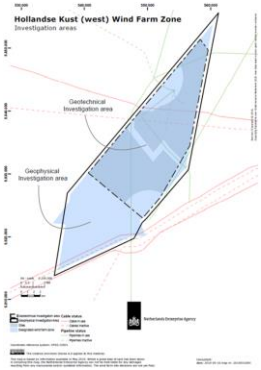


Geotechnical parameters



Ground model for HKW windfarm





Source HKW data:
english.rvo.nl/topics/sustainability/offshore-wind-energy/hollandse-kust-west-wind-farm-zone

Geotechnical parameter G_{max}

i. Calculation model and limit state

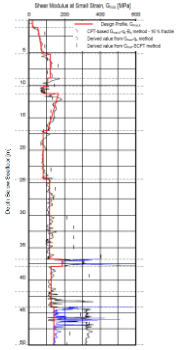
ii. Reference method for calculation model: SCPT

iii. Site-specific CPT-based correlation:
$G_{max} = (1 + 4 \cdot B_q) \cdot YSR^b \cdot 1.634 \cdot (q_c)^{0.25} \cdot (\sigma'_{v0})^{0.375}$

iv. Integration of multiple data sources

v. Soil unit-specific factoring

↳ **Design Profile $G_{max,k}$**



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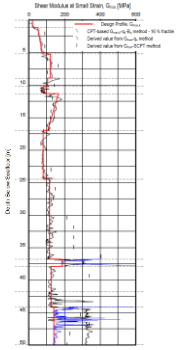

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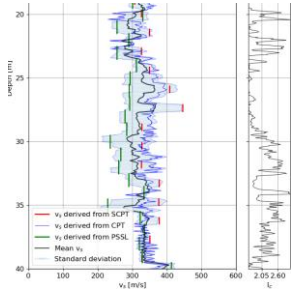
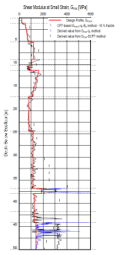
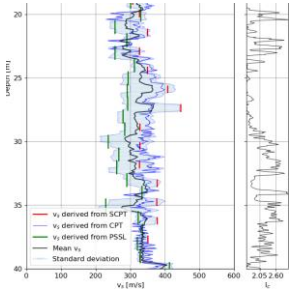
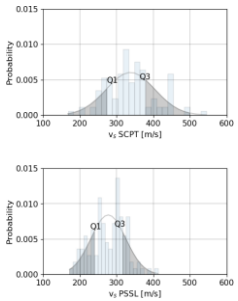




Source:
Peuchen & Gomez Meyer (2021),
http://isc6.org/images/Cikkek/Sessions/ISC2020-521.pdf

Geotechnical parameter G_{max}





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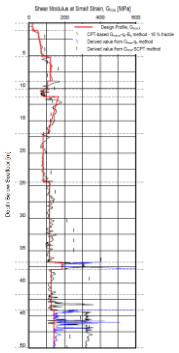
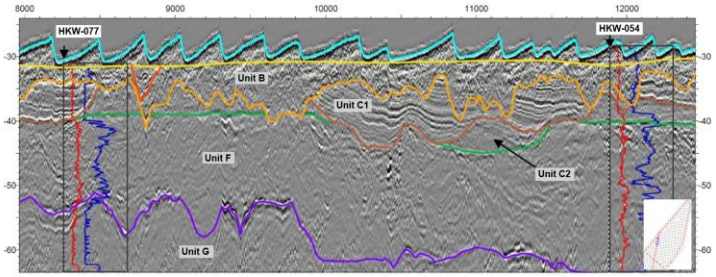
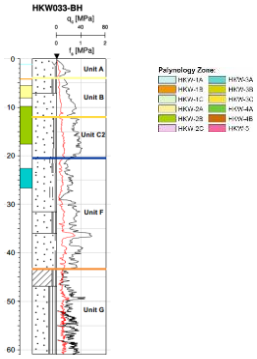


Seismostratigraphic model



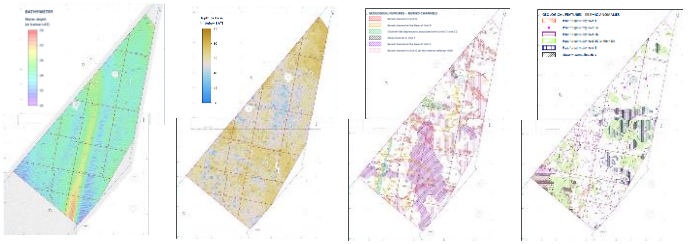
Geological ground model – age dating



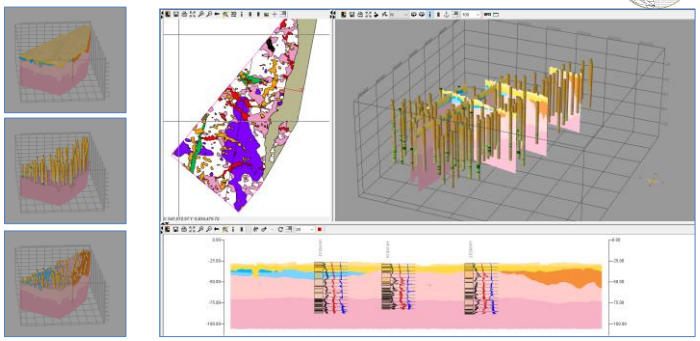
Unit	Rijsdijk et al. 2005		This study		
	Formation [Member]	Age	Seismic Reflector	Depositional Environment	Palynology Zone
A	Southern Bight [Bligh Bank]	Middle to Late Holocene	H02 (base)	marine	HKW-1A
B	Naaldwijk / Kreftenheye / Dogger Bight	Late Pleistocene to Middle Holocene	H05 (base)	coastal to tidal flat and lagoonal glacio-fluvial	HKW-1B HKW-1C HKW-2A
C1	Eem [Brown Bank]	Late Pleistocene	H09 (base)	shallow marine to lagoonal	HKW-2B
C2	Eem	Late Pleistocene	H10 (base)	shallow to open marine	HKW-2B
D	Eem	Late Pleistocene	H15 (base)	shallow to open marine	HKW-2C
E	Eem	Late Pleistocene	H20 (base)	glacio-fluvial to marine	HKW-2B HKW-2C
F	Yarmouth Roads	Early to Middle Pleistocene	H25 (base)	fluvio-deltaic to marine	HKW-3A HKW-3B HKW-3C HKW-4A HKW-4B
G	Yarmouth Roads (possibly partly Winterton Shoal)	Early Pleistocene	H30 (internal)	fluvio-deltaic to marine	HKW-4B HKW-5

Ground model – features

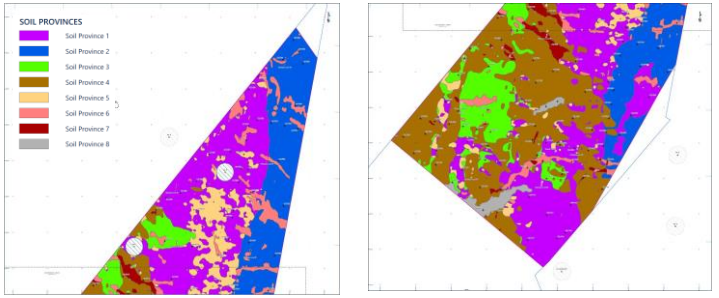
Bathymetry | Depth to Base | Buried Channels | Geophysical Anomalies



3D visualisation



Engineering ground model – soil provinces

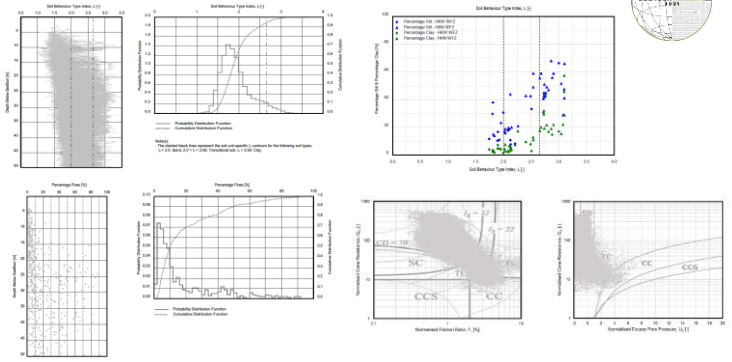


Potential geohazards

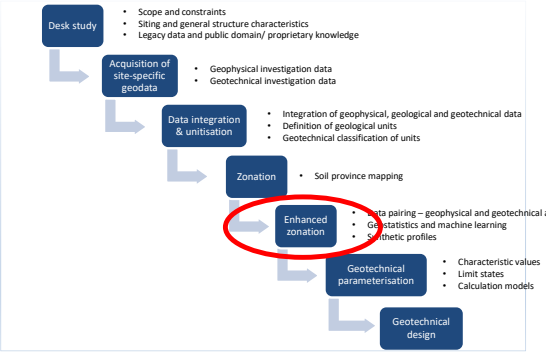
Geological Feature/ Hazard	Occurrence Area	Hazard Probability				
		Pile Foundations	Jack-up Platforms	Gravity Base Foundations	Suction Caisson Foundations	Cables
Bedforms	Entire HKW WFZ	N [N]	L [N]	H [N]	L [N]	L [N]
Mobile seabed sediments	Entire HKW WFZ	H [L]	L [N]	H [N]	H [L]	H [N]
Loose to medium dense sand or silt	Locally Unit A & B	H [N]	L [N]	H [N]	L [N]	L [N]
Alternation of sand and clay/ silt	Infill of (paleo)channels	N [N]	L [N]	N [N]	L [N]	N [N]
Very dense sand	Entire HKW WFZ	L [N]	N [N]	N [N]	L [L]	L [N]
Peat, organic clay/ shallow gas	Locally in Units A, B, C1, D, F & G	N [N]	N [N]	L [N]	L [N]	N [N]
Gravel, cobbles and/or boulders	Locally all units except Unit A	L [N]	N [N]	N [N]	L [L]	L [N]
Glaciotectonic deformation feature	Locally in Units F & G	L [N]	N [N]	N [N]	N [N]	N [N]
Regional subsidence	Entire HKW WFZ	L [N]	N [N]	L [N]	L [N]	N [N]
Existing structures (e.g. cables)	Refer reports	H [N]	H [N]	H [N]	H [N]	H [L]
UXO	Entire HKW WFZ	L [N]	N [N]	L [N]	L [N]	N [N]
Future structures (e.g. wind farm)	Entire HKW WFZ	L [N]	N [N]	L [N]	L [N]	L [N]

- Negligible (N) ; Low (L) ; High (H)
- Descriptor between brackets refers to hazard probability after consideration of mitigation measures

Soil units – geostatistics

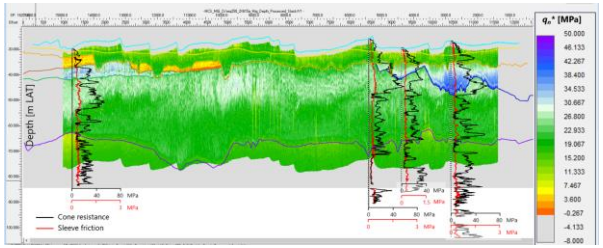


Ground model enhancement

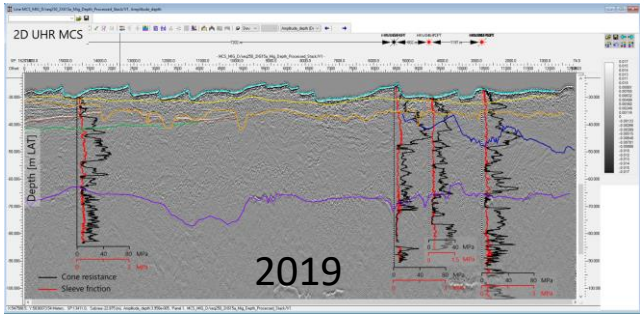


1 500 000

synthetic CPTs for offshore windfarm



Ground model enhancement



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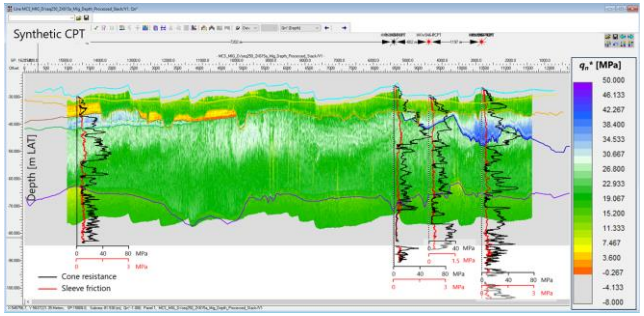
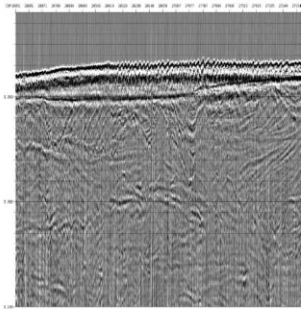
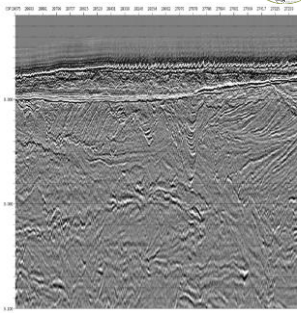


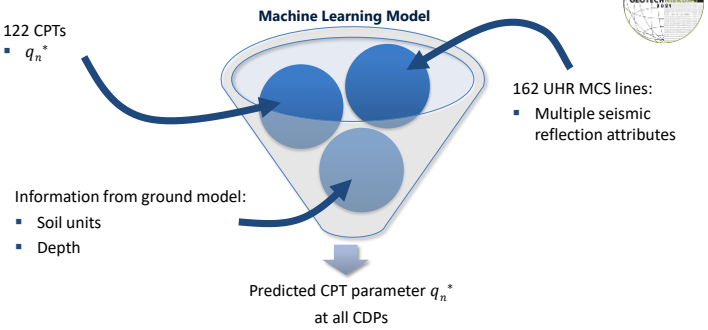
2020



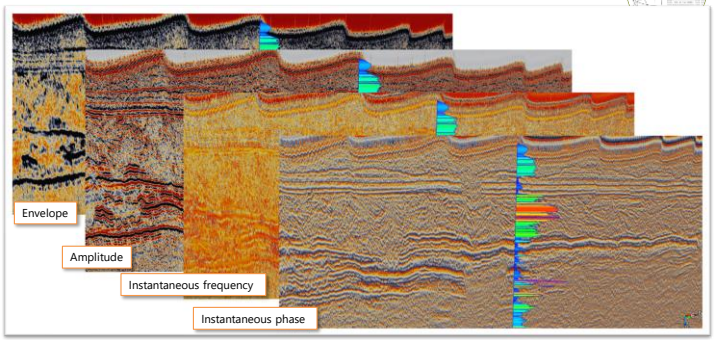
2021



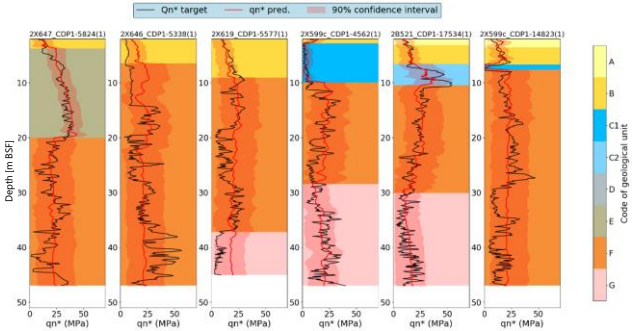
Synthetic CPT prediction



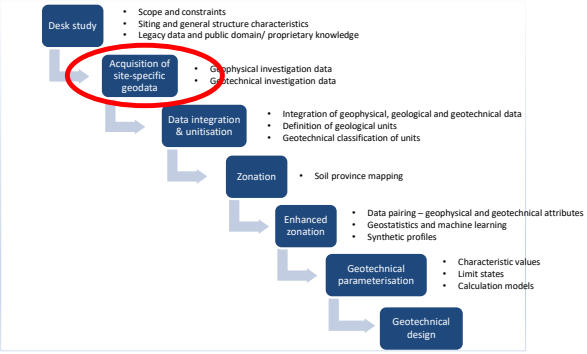
Seismic reflection attributes



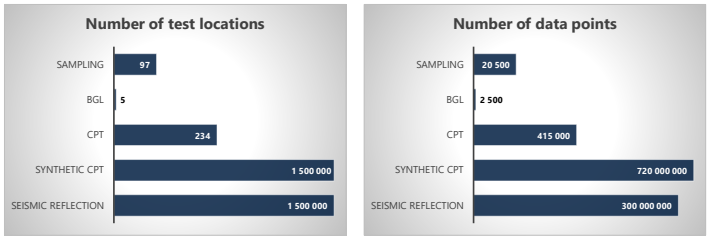
Prediction results



Concluding on geodata acquisition



Acquisition of HKW data points



Not to scale

Acquisition of geodata

- Fugro Deep Drive CPT
- Coiler for push rod
- Reduction of rod friction by mud injection
- > 50 m penetration

Spin-off: robotic system for onshore