Wind farm zone Borssele
Geotechnical Investigations WFS I & II
30th March 2015

Rein de Wolff– BLIX Consultancy
Steve Mulley – RPS Energy

Rijksdienst voor Ondernemend Nederland

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Preceding Works

Q3 2014:	Geological + geomorphological desk study
Q3 - Q4 2014:	EU Tender framework contract geophys. & geotechn. survey
Jan - April 2015:	Geophysical investigations WFS I & II
Jan 2015:	Opportunity for participants workshop 15th Dec. 2014 to provide comments Scope of Work
Jan - Febr 2015:	Mini-tender geotechnical survey WFS I &II

On 18th March 2015 contract signed for geotechnical survey WFS I &II with Fugro Engineers

FUGRO

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Objectives

- **Objectives**
  - Determine vertical & lateral variations in seabed conditions
  - Provide relevant data for (conceptual) designs of foundations & cables
  - Create detailed geological model of the site

- **Result is to provide for all relevant soil layers:**
  - Description and index classification
  - Strength parameters
  - Deformation properties
  - Permeability
  - In-situ stress conditions

Scope of Work

- **Generic Scope**
  - Alternating Borehole / PCPT's (target depth 50m - 80m)
  - Seabed PCPT's using bottom mounted PCPT unit with 20t thrust
  - Laboratory testing on relevant parameters

- **Deliverables**
  - Field report including preliminary PCPT results
  - Final report including lab testing results and geological model

Source: Fugro Engineers

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Planning

March/April 2015:	Preparation Project Documentation/ Mobilization
April/May 2015:	Execution Borehole/downhole PCPT campaign
April/May 2015:	Execution Seabed PCPT campaign
May/June 2015:	Completion of Field Report + preliminary PCPT results
May/June 2015:	Lab testing/Reporting
June/July 2015:	Review/Certification of report

All subject to mobilization, weather delay and certification, formal due date still end Q3 2015.

Advanced lab testing results will follow after provision final report

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RVO.nl team

Responsible:

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Project Management:

BLIX hands-on experience in wind energy

Geotechnical advisor

WINDSUPPORT

Offshore reps. / geotech. advisor

RPS Energy

Certification

DNV·GL

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Equipment

It is expected the following vessels will be mobilized by Fugro:

- Bucentaur (Borehole/downhole PCPT)
- Fugro Commandor (Seabed PCPT)

Questions

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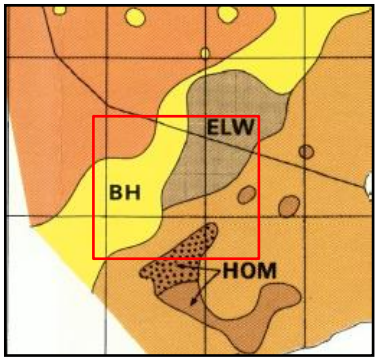
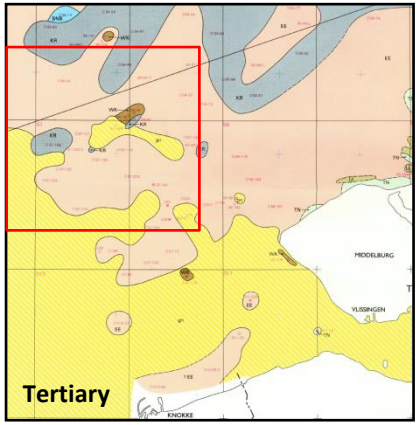
Geotechnical sample locations: formations interpreted

Formations interpreted to be present in general area , but not conclusively proven:



Holocene
Bligh Bank F. – Very Dense sand with clay laminae, (marine)
Banjaard F. - Dense locally clayey sand, (marine tidal deltas), -
HOM = Hompels M.
Buitenbanken F. – Dense to very dense gravelly sand, (marine tidal deltas)
Elbow F. – Low to medium strength clay or sand with clay, (Holocene tidal flats)



Quaternary – (periglacial where terrestrial – marine elsewhere)
Kreftenheye F. - Dense locally gravelly Sand, (Fluvial)
Brown Bank F. – High strength laminated Clay, (Marine regressive)
Eem F. – Dense sand with clay laminae, (Marine)
Westkapelle Ground F. – Dense sand with clay laminae, (Marine)

Tertiary
Rupel F. (Oligocene) – High strength clay with very dense sand layers at top and base and claystone beds and septaria, (shallow marine)
Tongeren F. (Oligocene) – Very dense micaceous sand overlain by high strength clay, (Shallow marine – possibly absent)
Dongen F. (Eocene) – Very high strength calcareous clay with sandstone beds, (Shallow marine)

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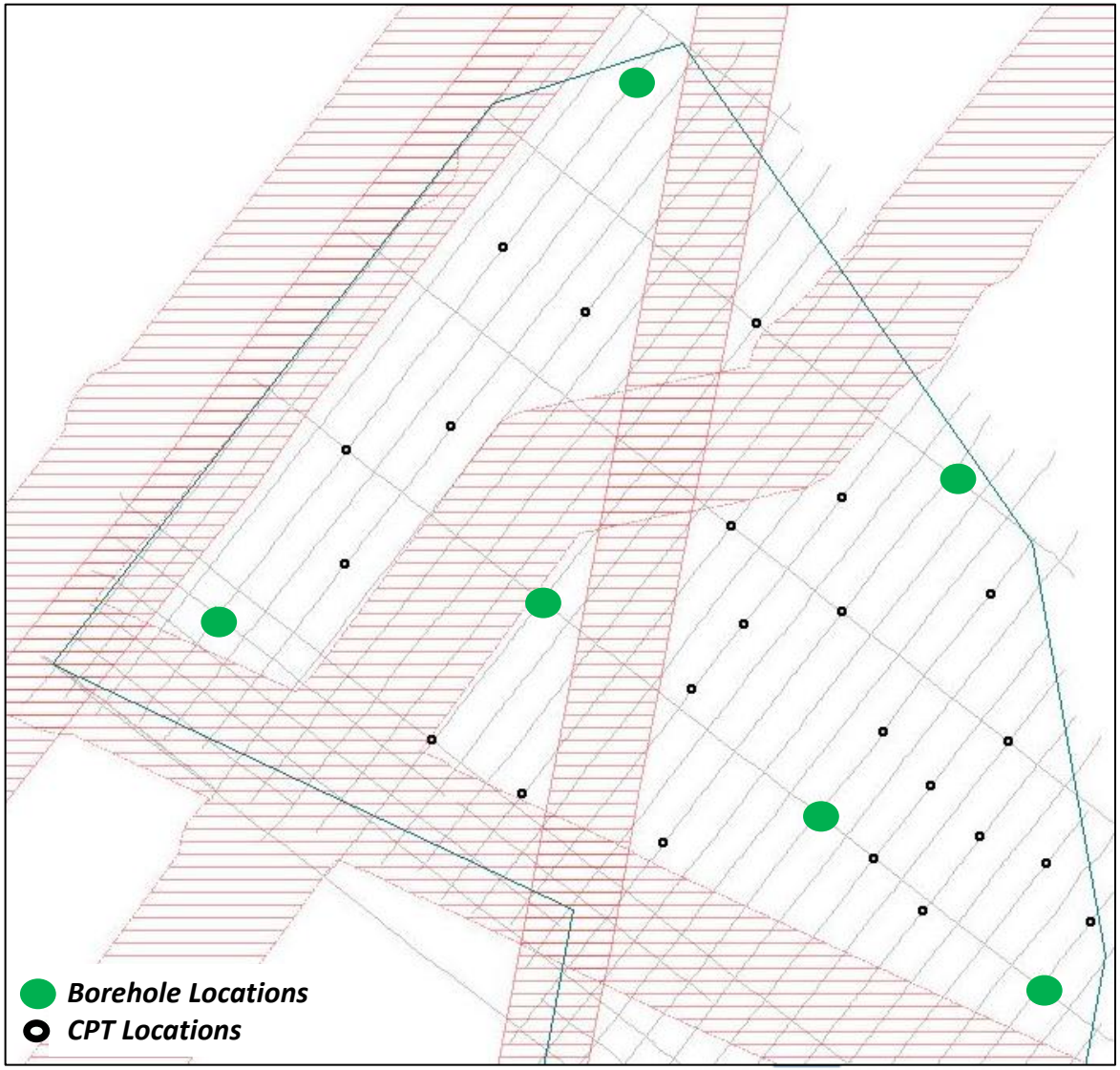
Geotechnical sample locations - considerations

- Determine composition of sea bed sediments and mapped features.
- Determine composition of pre-Holocene (Quaternary soils).
- Provide preliminary soils data for installation vessels, (Jack-up footing behavior).
- Provide preliminary soils data to assist cable installation procedures.
- Verify engineering properties of Quaternary ‘scour feature’ infills.
- Establish presence of ‘coarse lag’ deposits, (gravels).
- Establish soils properties/lateral variation of solid geological formations, (Rupel, Tongeren, Dongen).
- Verify the presence and nature of Geohazard anomalies, (shallow gas, gravel, liquefaction features, channels, mobile sediments).
- Permit integration of geophysical and geotechnical data to develop a reconnaissance engineering geological model for FEED engineering.
- Provide confidence that the area is a viable development prospect.

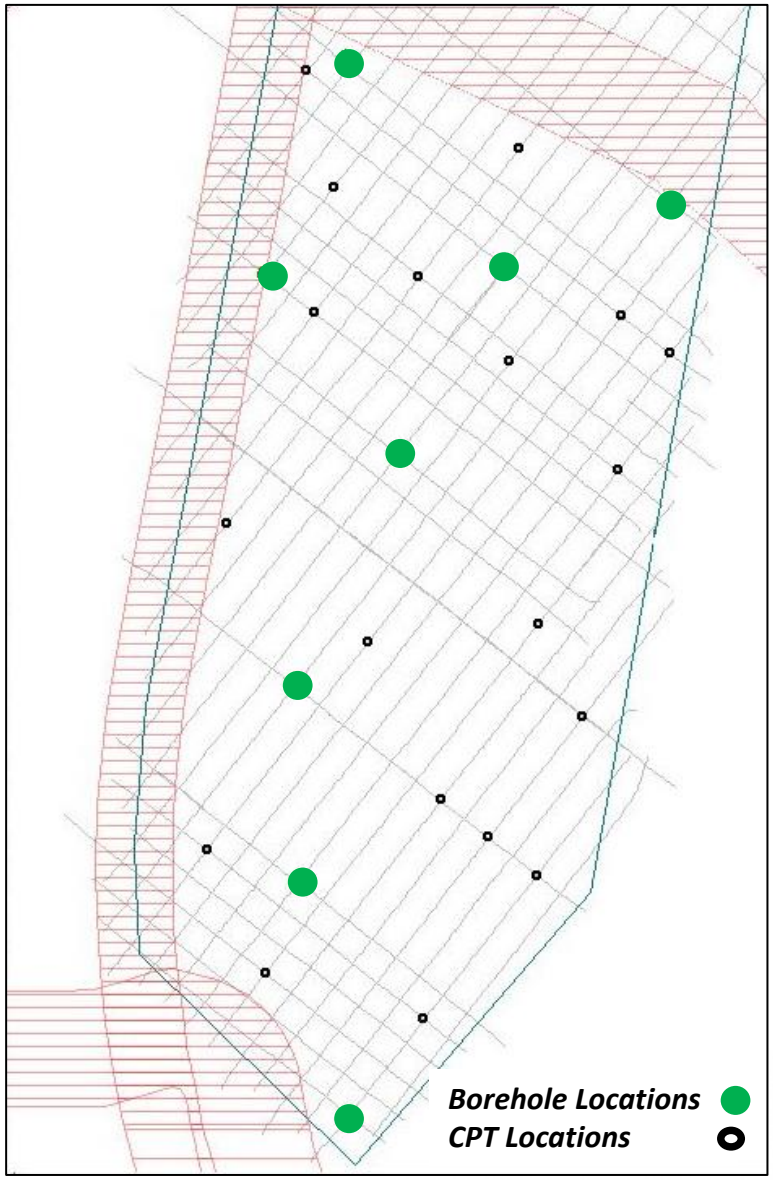
Geotechnical sample locations - WFS I

- 6 Boreholes / PCPT's (target depths 3 x 60m / 3 x 80m)
- 28 PCPT's (target depth up to 50m)

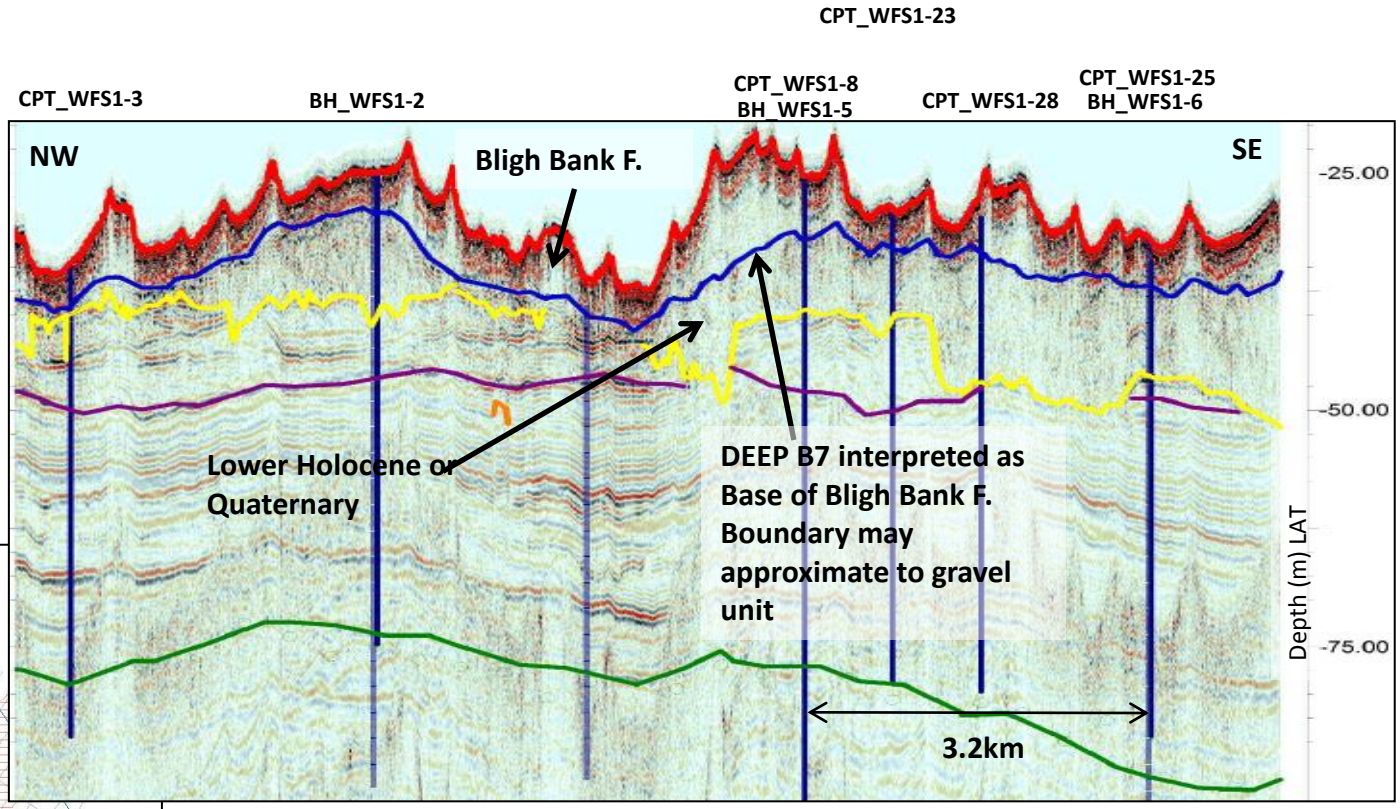


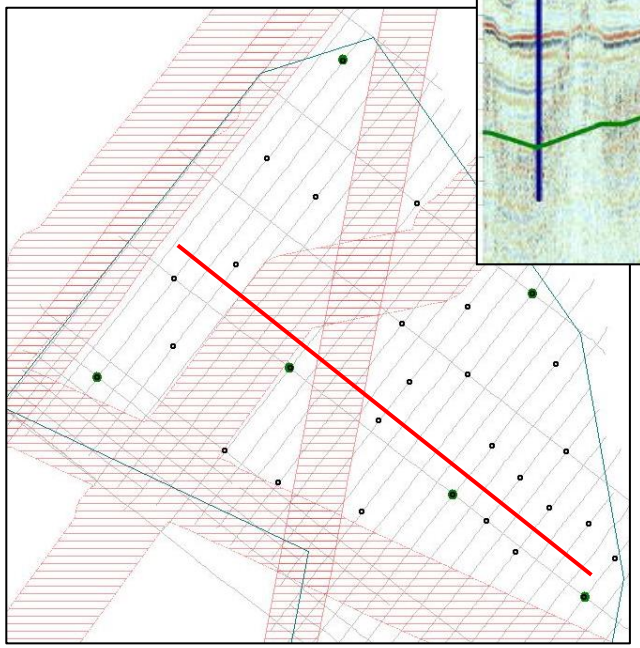
Geotechnical sample locations - WFS 2

- 8 Boreholes / PCPT's (target depths 5 x 50m / 1 x 60m / 1 x 65m / 1 x 80m)
- 27 PCPT's (target depth up to 50m)



Example - Holocene Sediments WFS I





Holocene Stratigraphy:

Bligh Bank F. - comprise Very Dense sand with clay laminae, (marine)

Banjaard F. - Dense locally clayey sand, (marine tidal deltas),

Buitenbanken F. – Dense to very dense gravelly sand, (marine tidal deltas)

Elbow F. – Low to medium strength clay or sand with clay, (marine tidal flats)

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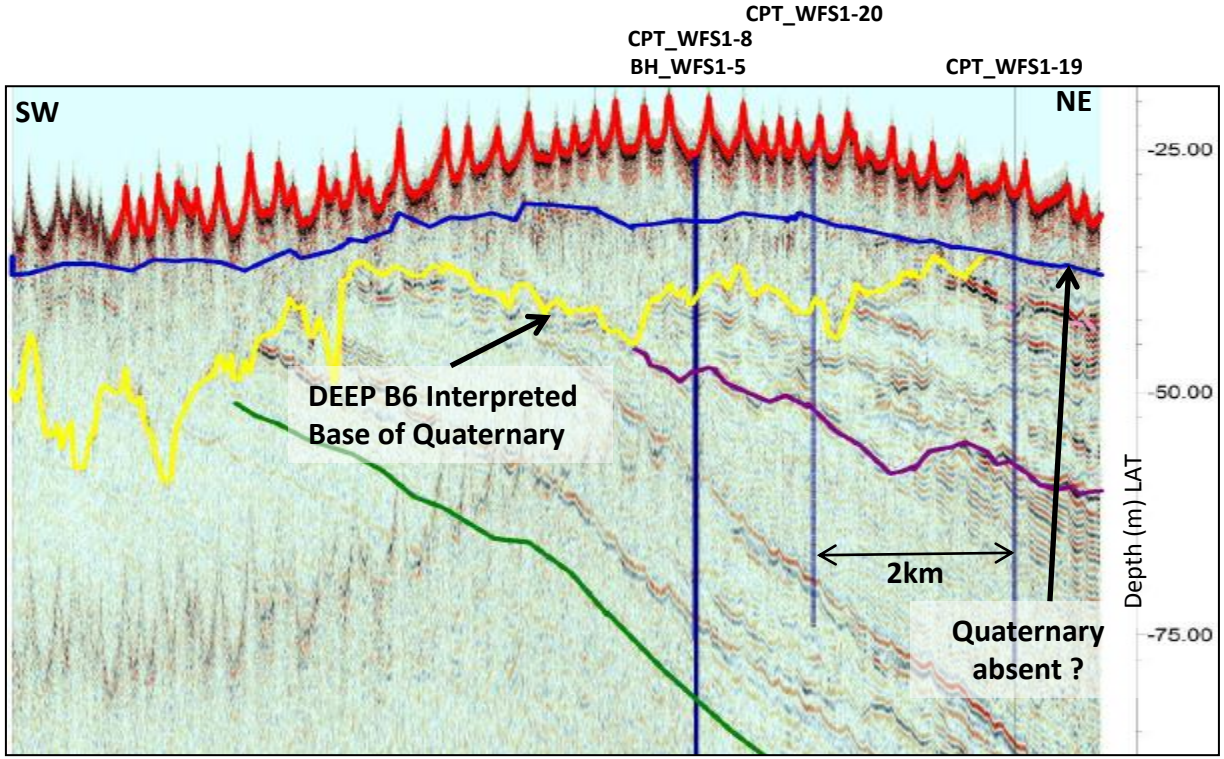
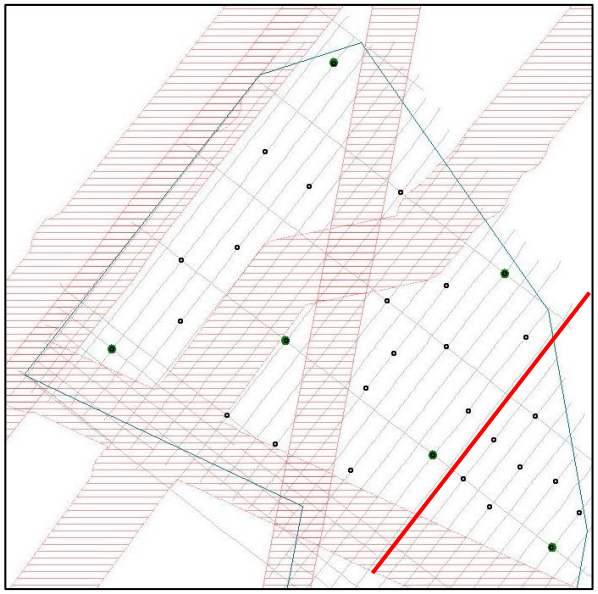
Example - Interpreted base of Quaternary WFS I





Quaternary Stratigraphy:

Kreftenheye F. - Dense locally gravelly Sand, (Fluvial)

Brown Bank F. – High strength laminated Clay, (Marine regressive)

Eem F. – Dense sand with clay laminae, (Marine)

Westkapelle Ground F. – Dense sand with clay laminae, (Marine)

Note: Presence of Quaternary formations to be positively confirmed.

Nature of Quaternary soils to be determined.

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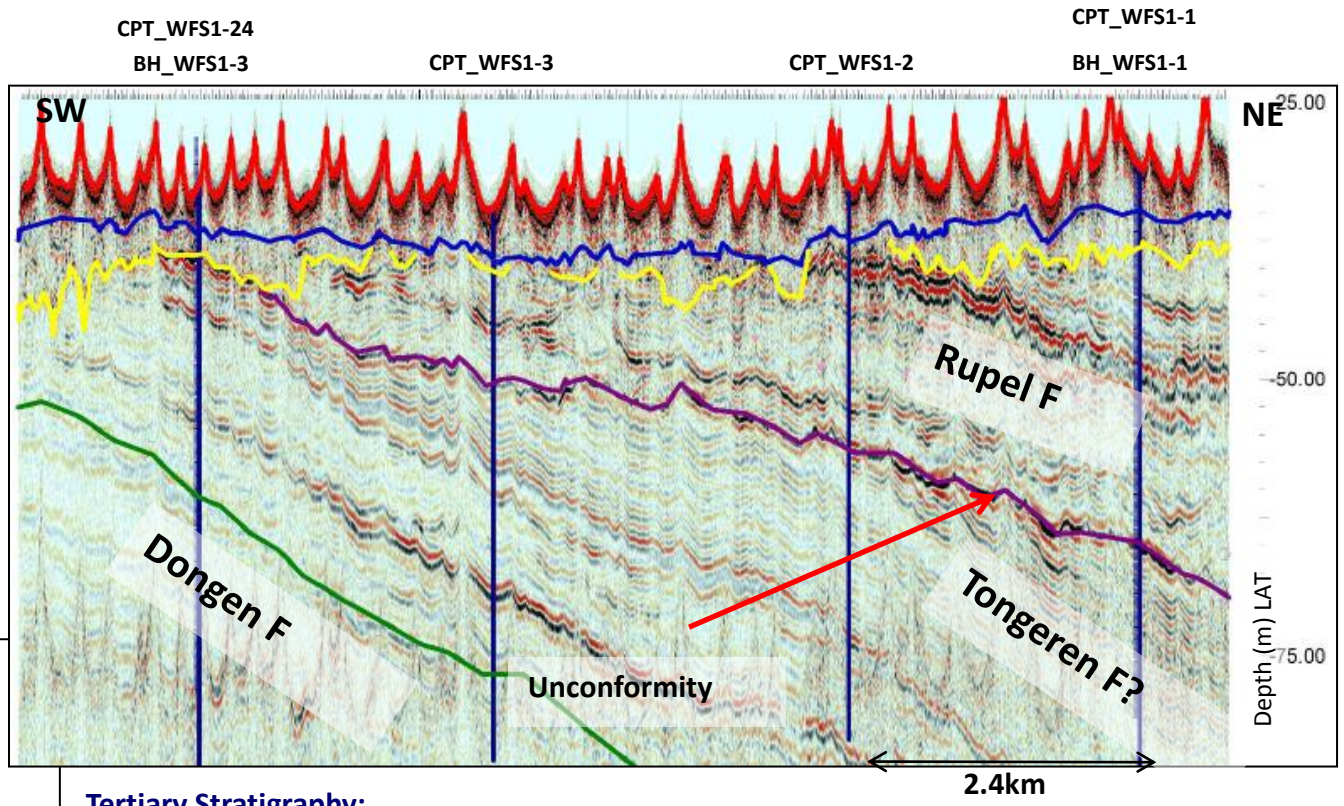
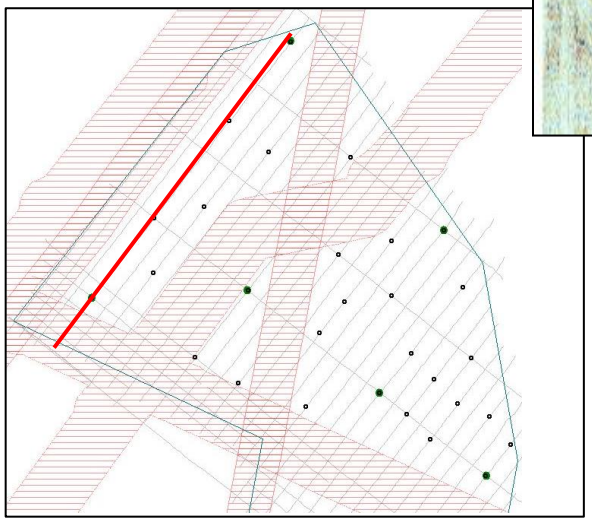
Example – Tertiary Sediments





Tertiary Stratigraphy:

Rupel F. Unit unconformable with underlying formations. Formation dips at @0.5° to NE and interpreted to be present over Borssele I only

Tongeren F. Presence of Tongeren F. not conclusively proven.

Dongen F. Formation may be deeper than target depths except in extreme south west

Note: Presence of beds of sandstone may require rock coring

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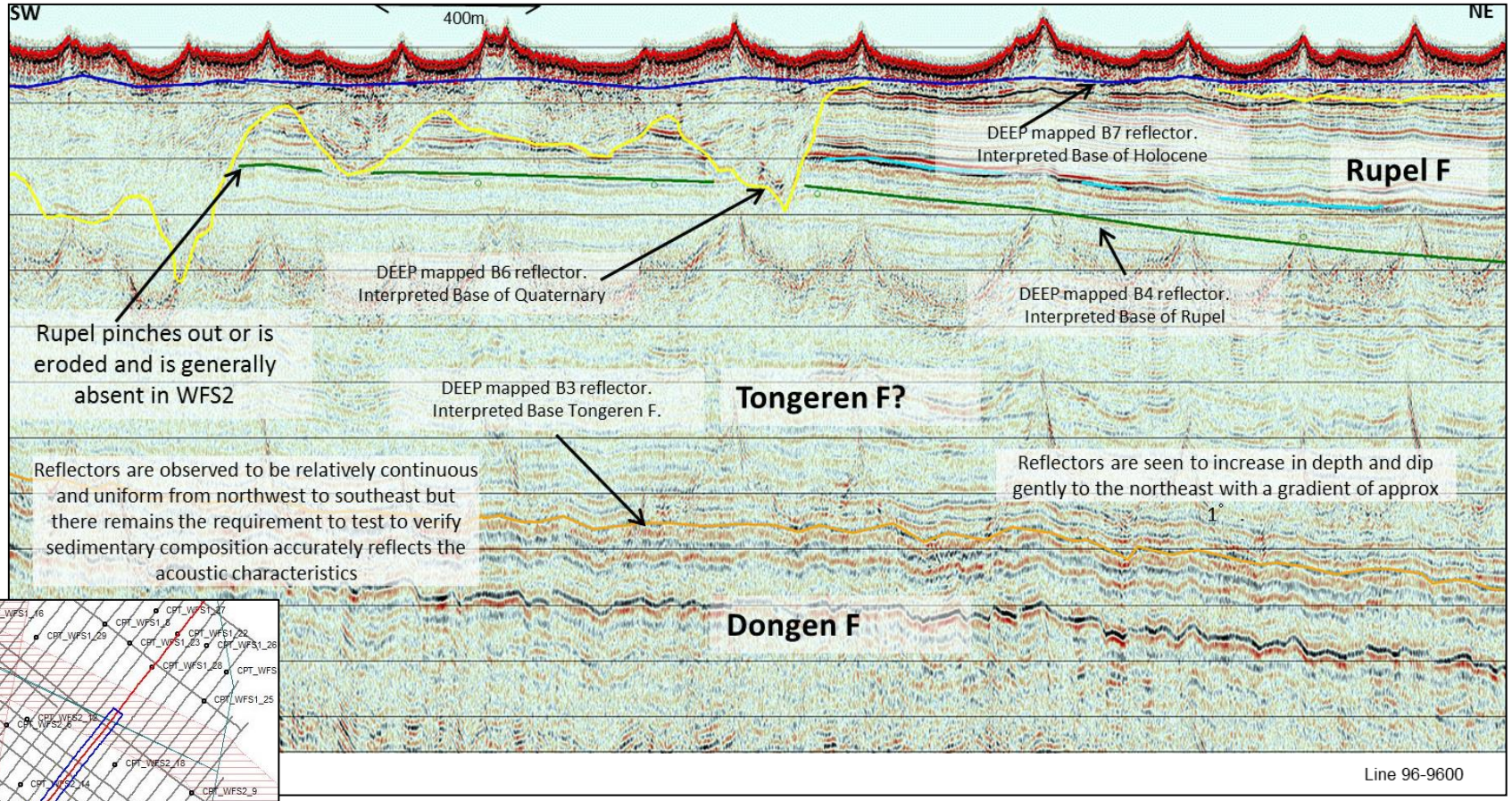
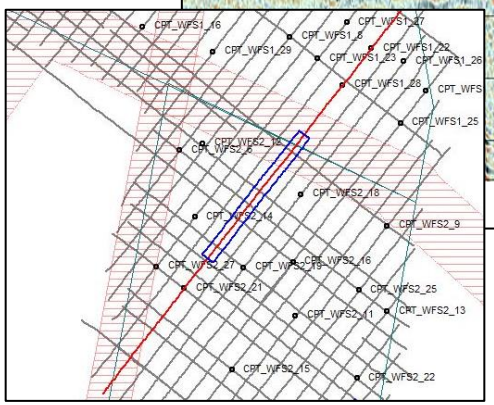
Example - General Relationship of Pre-Quaternary Units





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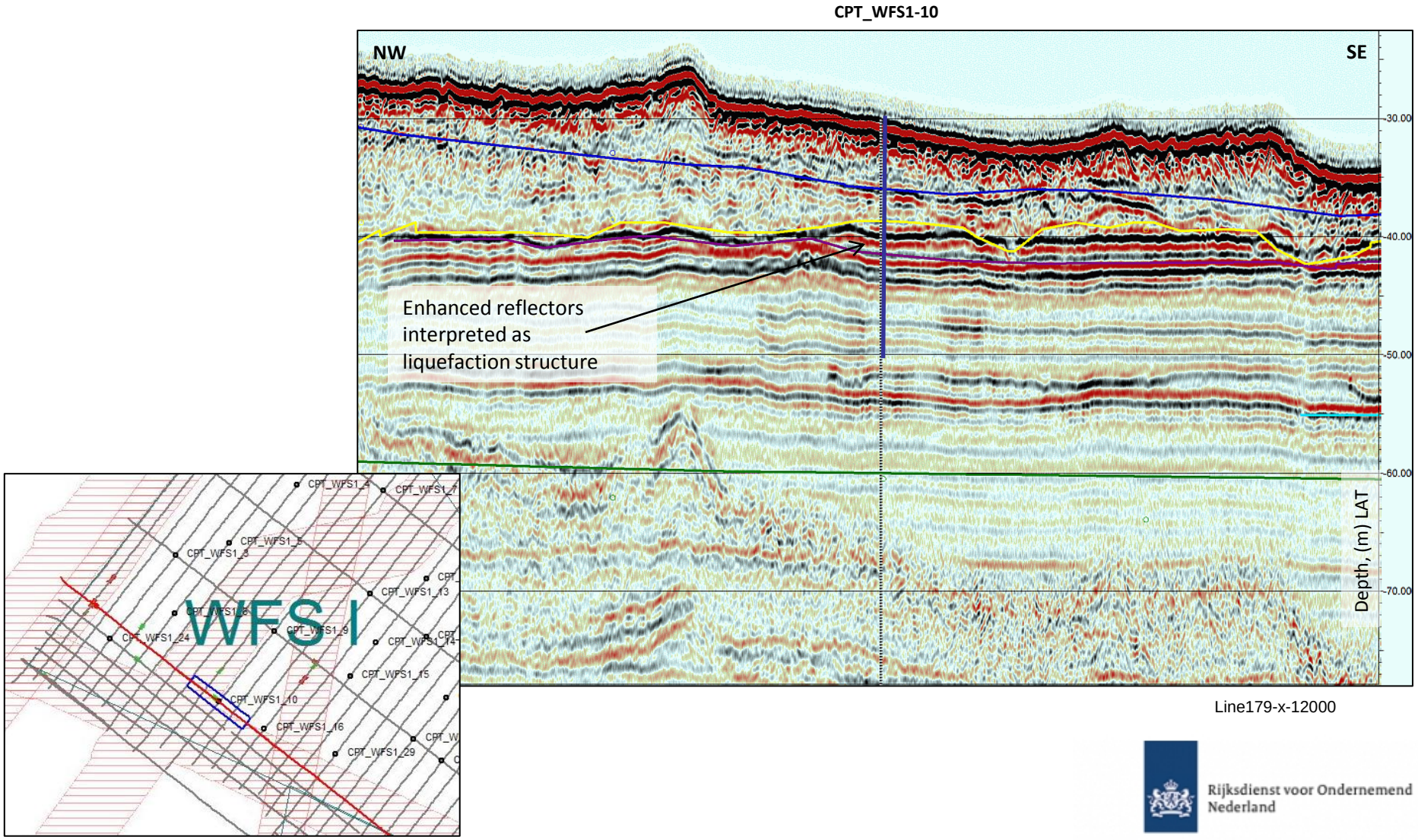
Example – Investigate possible liquefaction structures - WFS I



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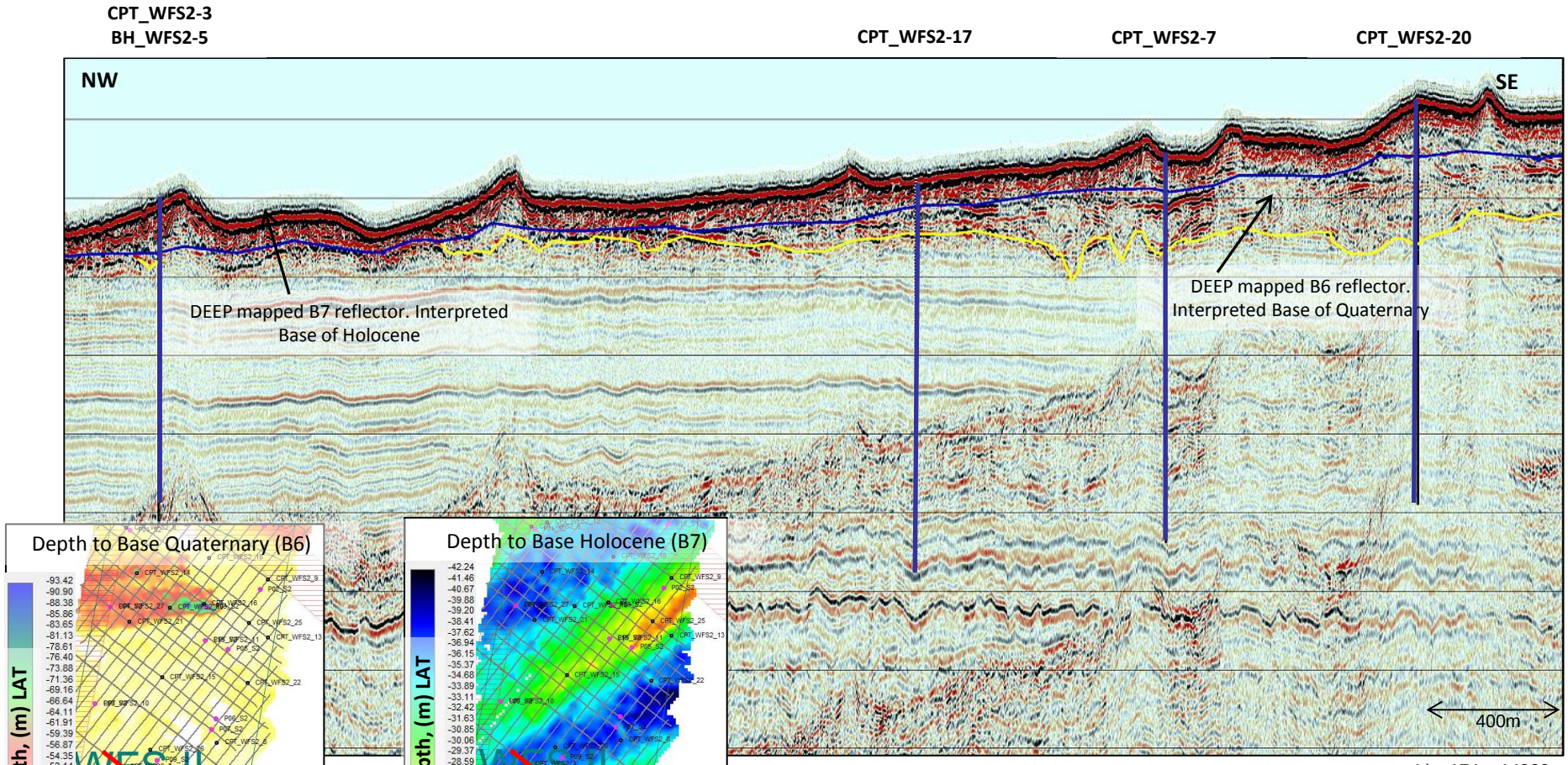
Example - Late Quaternary – Early Holocene thickness comparison



Requirement to better understand the nature, thickness and distribution of Holocene and Quaternary sediments

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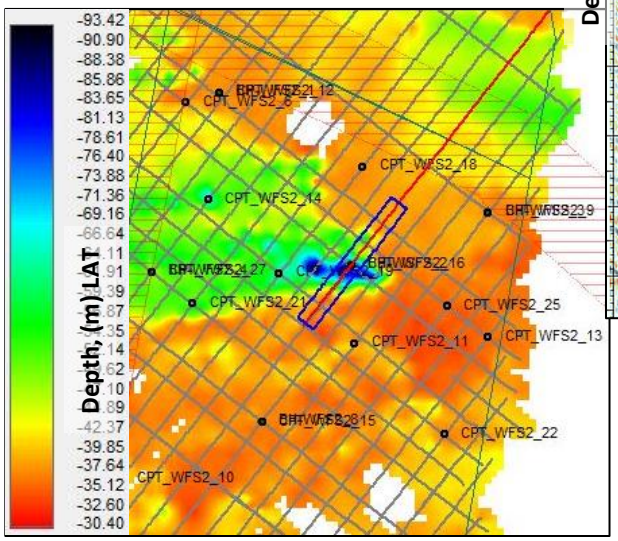
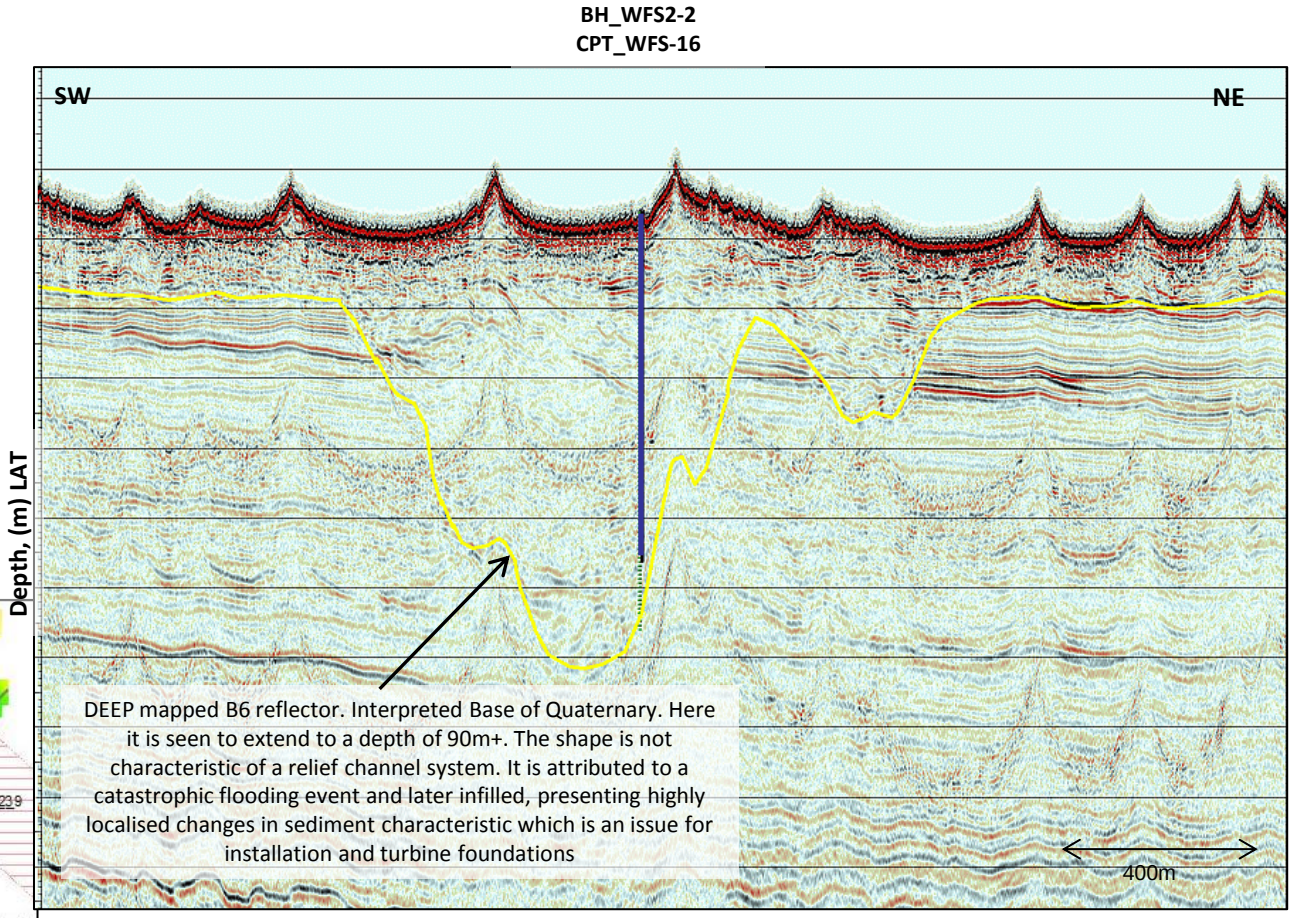
Example - Scour Hollow cut into Dongen F.





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Possible Quaternary soils infilling scour hollow, requirement to understand nature and variability of infilling material

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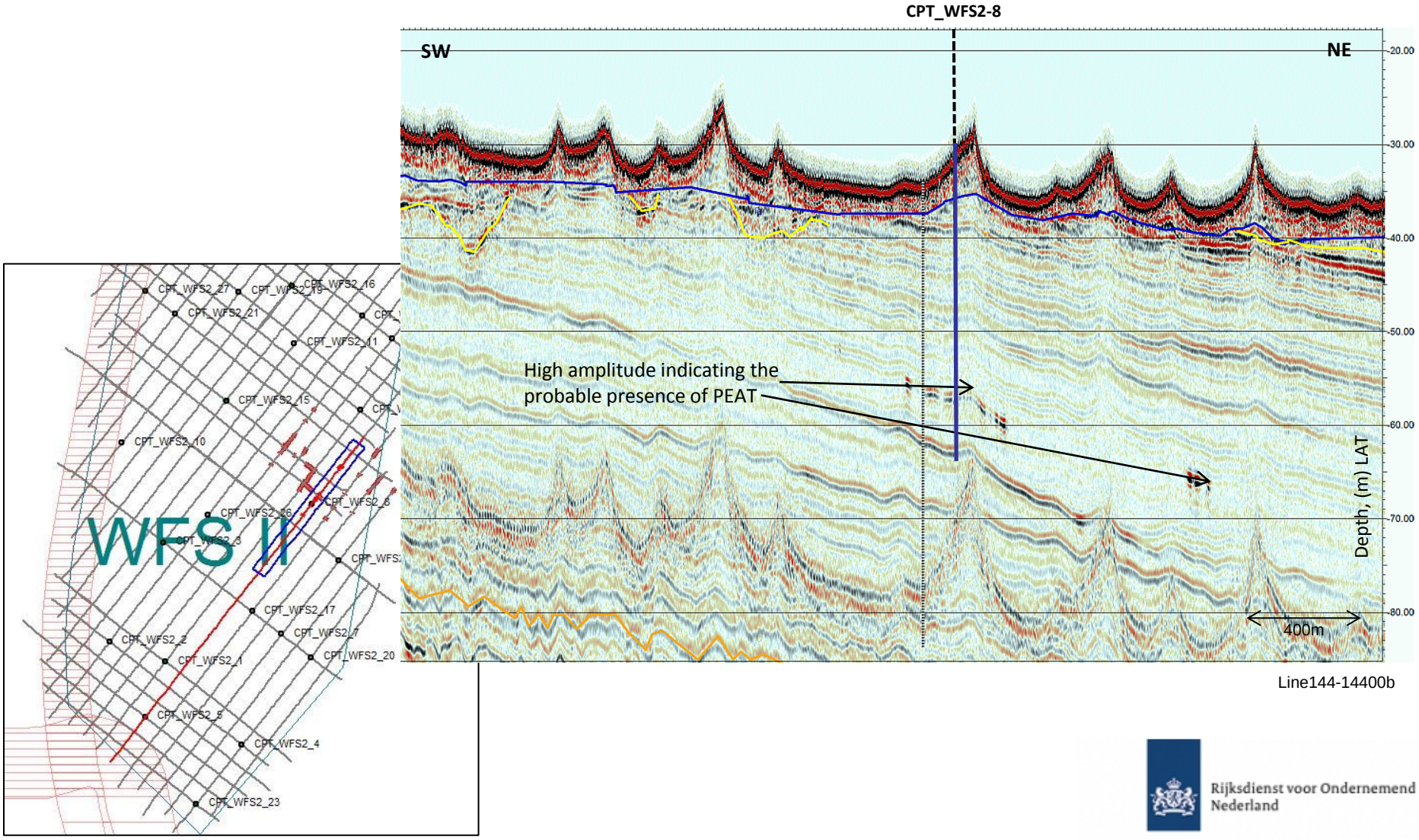
Example - High Amplitudes indicating probable peat



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Questions for the audience

- Need to make borehole samples available to winner SDE tender?
- Any specific requirements for samples to be stored?

Thank you for your attention

- More information: English.rvo.nl/offshore-wind-energy

- Questions:
  - woz@rvo.nl
  - Ruud de Bruijne, RVO.nl
  - Rein de Wolff, BLIX Consultancy

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