Netherlands Enterprise Agency

Site Studies Hollandse Kust (zuid) Wind Farm Zone

Geological desk study

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Geological study Hollandse Kust (Zuid) Wind Farm Zone

Deltares

Title
Geological study Hollandse Kust (Zuid) Wind Farm Zone

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Summary
This report presents the publicly available bathymetric, geophysical and geological data of the "Hollandse Kust (Zuid) Wind Farm Zone", as well as the relevant literature. Available seismic data are assessed on their suitability for the construction of a geological model. Based on the currently available data, possible constraints on the construction of a wind farm zone have been addressed.

References
Request for proposal: *RfP WOZ 1500037 Geological Desk Study HKZ Def, dated 16 September 2015*
Deltares' proposal: *1221136-000-BGS-0003-o-Adjusted quotation for Geological study 'Windenergiegebied Hollandse Kust Zuid', dated 1 October 2015*
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Version	Date	Author	Initials	Review	Initials	Approval	Initials
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Managementsamenvatting

De Rijksdienst voor Ondernemend Nederland (RVO) heeft Deltares gevraagd een geologische bureaustudie uitvoeren als voorbereiding op een mogelijk geofysisch veldonderzoek in het " Windgebied Hollandse Kust (Zuid)". Deze studie is een vervolg op een eerdere geologische quickscan van het gebied, die in het rapport 'Quickscan windpark gebied Zuid Hollandse Kust' is beschreven door Vermaas et al. (2014). In deze nieuwe studie wordt een overzicht gepresenteerd van de beschikbare bathymetrische, seismische en geologische gegevens gepresenteerd, en wordt de kwaliteit waar mogelijk van deze gegevens beoordeeld. Daarnaast zijn de mogelijke belemmeringen in relatie tot de ondergrond voor de ontwikkeling van het windpark onderzocht, en worden in het laatste hoofdstuk aanbevelingen voor het ontwerp van een uit te voeren seismisch onderzoek gedaan.

Het Windgebied Hollandse Kust (Zuid) ligt voor de kust van Zuid-Holland, en heeft een oppervlakte van 365 vierkante kilometer. Het is verdeeld in twee zones (oost en west), gescheiden door de 12 nautische mijl lijn. Het onderzoeksgebied voor deze geologische studie beperkt zich tot het gebied tussen 0 en 100 meter onder de zeebodem.

De ondergrond bestaat hoofdzakelijk uit zand voor de eerste 20-25 m, met een aantal lokale dunne kleilagen met variërende dikte (meestal 2-20 cm dik, soms 3 m dik). Heel diep ingesneden geulen ingevuld met zachte sedimenten zijn waarschijnlijk niet in het gebied aanwezig. Het diepere deel (25-100 m diepte) zal naar verwachting bestaan uit fijn zand en klei, maar deze diepte wordt niet door boringen in het studiegebied bereikt.

Een geologisch famework is gebouwd op basis van een selectie van openbaar beschikbare boorgegevens uit DINOLoket, kern beschrijvingen van drie diepe boorgaten even buiten het studiegebied, en literatuur (zie literatuurlijst). De stratigrafische indeling van Rijsdijk et al. (2005) wordt beschouwd als het meest geschikt voor het studiegebied. Als uitzondering hierop wordt voorgesteld om voor de oudere formaties de namen Yarmouth Roads Formatie en Winterton Shoal Formatie te gebruiken.

Een recente bathymetrische kaart is samengesteld op basis van een dataset van 9 bathymetrische metingen die zijn uitgevoerd in het studiegebied. Op basis van de bathymetrische data, is de morfologie beschreven. De morfologie wordt gekenmerkt door zandgolven met een west noordwest - oost zuidoost oriëntatie.

In het gehele studiegebied, zowel landwaarts en zeewaarts van de 12 nautische mijl lijn, zijn geen grote beperkingen om een windpark te ontwikkelingen aangetroffen in deze studie. Kleinere of onbekende mogelijke beperkingen zijn de volgende:

- De aanwezigheid van de stijve lagen, keileem en stenen in het noordelijke deel van het gebied, als gevolg van de vroegere bedekking door landijs, kan een negatieve invloed hebben op de heibaarheid van de palen tot de vereiste funderingsdiepte.
- Ondiep gas is waargenomen ten zuiden van het studiegebied, maar is niet direct waargenomen in het onderzoeksgebied zelf. Aanwezigheid van ondiep gas kan gevolgen hebben voor de installatie van palen maar kan ook het drijfvermogen van schepen negatief beïnvloeden. Dit risico dient zorgvuldig onderzocht te worden. Indien mogelijk moeten gebieden waar ondiep gas voorkomt worden vermeden,.
- Het gebied ligt buiten de bekende aardbevingsgebieden.

Door de beperkte aanwezigheid van diepe boringen in de (omgeving van) het studiegebied, is het inwinnen van seismisch gegevens erg belangrijk om het gebied dieper dan 5 meter onder de zeebodem in kaart te brengen. Hoewel single channel en multi-channel seismische gegevens in het studiegebied beschikbaar zijn, is de kwaliteit van de seismische gegevens relatief laag en daarmee zijn deze data zeer beperkt bruikbaar.

Om de geschiktheid van het studiegebied voor een windmolenpark zone volledig te kunnen beoordelen, adviseren wij om een seismisch onderzoek uit te voeren in het gebied. Het wordt daarnaast geadviseerd om diepe boringen in het studiegebied te verkrijgen, om de seismische gegevens te kunnen interpreteren.

Executive Summary

The Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland, RVO) has requested Deltares to perform a geological desk study as a preparation to a future geophysical field survey in the “Hollandse Kust (Zuid) Wind Farm Zone”. This study is a follow-up to an earlier geological quickscan of the area, which has been described in the report ‘*Quickscan wind farm area Zuid Hollandse Kust’* by Vermaas et al. (2014). In this new study, an overview of available bathymetric, seismic and geological data is presented, and their quality is assessed. Furthermore, possible constraints on the development of the wind farm zone are addressed, and recommendations for a future seismic survey are made in the final chapter.

The “Hollandse Kust (Zuid) Wind Farm Zone is located offshore of Zuid-Holland, covering an area of 365 square kilometres. It is divided into two zones by the 12 nautical mile line (East and West). The zone of interest for this geological study is between 0 and 100 meters below the sea bed.

The subsurface consists mainly of sands for the first 20-25 m, with some local, thin clay layers (normally 2 to 20 cm thick, occasionally reaching 3 m thickness). Very deep incised channels filled with soft sediments are not likely to be present in the area. The deeper part (25-100 m depth) is expected to consist of fine sands and silt-rich clays, do note that no boreholes covered this depth range inside the study area.

A geological framework is constructed based on a selection of publicly available borehole data from DINOloket, core descriptions, from three deep boreholes at some distance from the study area, and literature (see bibliography). The stratigraphic framework of Rijsdijk et al. (2005) is considered to be the most appropriate for the study area. One exception, it is proposed to use the names Yarmouth Roads Formation and Winterton Shoal Formation for the older units.

A recent bathymetric map is constructed based on a dataset of 9 bathymetric surveys that have been performed in and around the study area. Based on the bathymetric data, the morphology has been described. The morphology is characterised by large-scale bed forms (sand waves) with a west-northwest to east-southeast orientation.

In the entire study area, both landward and seaward of the 12 nautical mile line, no major constraints to develop a wind farm have been encountered in the data used for this study. Smaller or unknown possible constraints are the following:

- The presence of consolidated layers, glacial till and stones in the northern part of the area due to the coverage of land ice may adversely affect driveability of the piles.
- Presence of shallow gas has been observed south of the study area, but has not been reported in the study area itself. This hazard, which can also compromise buoyancy of vessels, should be carefully investigated. These areas with shallow gas should be avoided if possible.
- The area is outside of known earthquake hazard zones.

As deep cores are absent in the study area, seismic survey data are very important to evaluate the deposits at 5 meters below the sea bed. Although (limited) data from both single channel and multi-channel seismic surveys are available at the study area, the quality of the seismic sections is relatively low and are not suitable for detailed evaluation.

In order to fully assess the suitability of the study area for a wind farm zone, we would recommend to perform an additional seismic survey in the area. In addition, it is recommended to obtain deeper boreholes in the study area, to be able to make an interpretation of the seismic data.

1 Introduction

1.1 Background

Rijksdienst voor Ondernemend Nederland requested Deltares to provide an overview of the available geological and seismic data at the site of the new Dutch offshore wind zone 'Hollandse Kust (Zuid)'. It is a consecutive study to an earlier geological quickscan of the area, in the report '*Quickscan wind farm area Zuid Hollandse Kust'* by Vermaas et al., 2014. The official request for proposal was received by email dated 16 September 2015 and with reference WOZ 1500037. Deltares submitted a proposal on 1 October 2015 with reference 1221136-000-BGS-0003. The project award was received on 13 October 2015 (reference number: WOZ 1500037).

1.2 Objectives

The objective of this study is to provide a geological framework of the "Hollandse Kust (Zuid) Wind Farm Zone", using publicly available literature, data, information and knowledge of the region. The framework will include an overview of the available bathymetric, morphological and geological information, these data will be used as reference for the development of a geological model at a later stage in the development of the wind farm zone. This study will also provide information on areas within the wind farm zone that might be less suitable for the construction of offshore wind farms. The study area encompasses the wind farm zone including a 1 kilometre buffer. Within the area, a distinction is made between the sections west and east of the 12 nautical mile distance line to Dutch coastline (Figure 1.1).

1.3 Content of the report

In Chapter 2, the available bathymetrical maps, seismic sections are borehole data within the study area will be presented. Subsequently, the geological history based on a literature review is discussed in Chapter 3. In Chapter 4 quality of the available seismic data is assessed. Chapter 5 presents a stratigraphic framework and characteristics of the geology in the study area, including a schematic geological cross-section. In Chapter 6, a set of geological maps of the study area is presented. Chapter 7 elaborates on the possible constraints of the current available data. An overall conclusion is drawn in Chapter 8. More detailed information and examples of the data can be found in the Appendices.

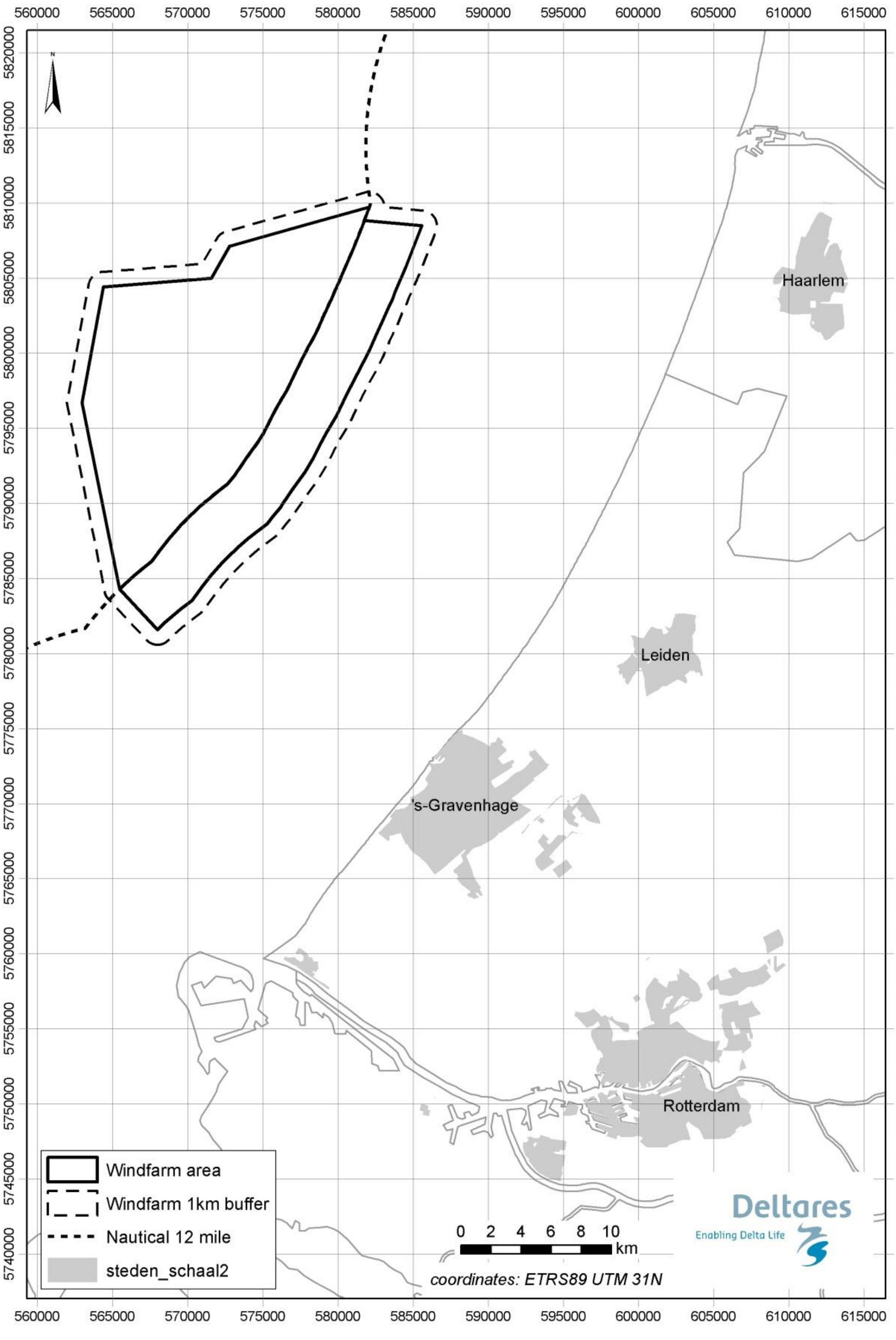

Figure 1.1 Location of the "Hollandse Kust (Zuid) Wind Farm Zone", the 10 to 12 nautical mile zone and area outside 12 nautical miles are indicated as well as a 1 km buffer indicating the total study area.

2 Available data

In this chapter, the available bathymetrical data, borehole data and seismic data are presented. In the study area no cone penetration test (CPT) data are publicly available.

2.1 Bathymetrical surveys

From 1969 to date, a total of 17 bathymetrical surveys were carried out in and around the study area by the Netherlands Hydrographic Office (NLHO, Table 2.1). Locations of these surveys are presented in Appendix A, in which the surveys are shown in three separate figures for the purpose of visual clarity. The bathymetrical data of the individual surveys is available on www.openearth.eu as a grid with 25 x 25 m resolution, with a documentation of the dataset on:
https://publicwiki.deltares.nl/display/OET/Dataset+documentation+bathymetry+NLHO.
Original data can be obtained from NLHO on:
https://www.defensie.nl/onderwerpen/hydrografie/inhoud/verkoop-zeekaarten-en-publicaties/aanvragen-hydrografische-data.

The interpolation to 25 x 25 m grids was done by Deltares in other studies. The data used for the interpolation are on Level of Visualisation 2 (LOV2), meaning that 1 observation per 3 x 5 meter cell was selected and projected to the centre of the cell. For most multibeam surveys the data coverage is high enough to result in one data point every 3 x 5 meter. Singlebeam surveys will have varying density along the track (3 to 5 meter up to 35 meter), the distance between the track lines varies (usually between 50 and 1000 meter).

Side scan sonar surveys are also available from the NLHO. The data is stored on disk but lacks necessary metadata to create a good overview of its availability. The exact coverage is not determined in this study, but it is expected to cover (almost) the entire study area.

For each point in the study area, bathymetry has been determined up to 6 times (Appendix A). A recent bathymetry map of the study area is compiled is based on the most recent bathymetrical survey for each point (Figure 2.1), providing full coverage of the study area (Figure 2.2).

Table 2.1 Bathymetrical surveys carried out in and around the study area. Highlighted lines are the surveys that were used in the recent bathymetry map. Column 'source' indicates the used seafloor mapping system (SBES = single beam echo sounder, MBES = multi beam echo sounder). All datasets are available as 25 x 25 m grids on www.openearth.eu original data is available from the NLHO.

Survey ID	**Start date (day-month-year)**	**End date (day-month-year)**	**Area (km^2)**	**Source**
15542	15-04-69	16-05-69	31	SBES
15541	15-04-69	16-05-69	25	SBES
15534	15-07-84	19-08-84	170	SBES
15514	10-09-84	15-10-84	78	SBES
15535	15-03-85	25-03-85	257	SBES
4823	01-10-99	31-12-99	306	SBES
4709	01-10-99	31-12-99	379	SBES
4819	01-04-00	30-04-00	167	SBES
7087	07-03-01	08-03-01	13	SBES
7305	01-09-01	30-01-02	717	SBES
10149	01-08-02	30-11-02	1077	SBES
13792	20-06-07	11-09-07	182	MBES
13789	26-06-07	06-09-07	187	MBES
14508	17-04-09	20-04-09	23	MBES
15878	20-12-09	10-11-10	128	MBES
16205	23-02-11	16-04-11	54	MBES
16513	29-04-11	14-10-11	779	MBES
16687	24-02-12	21-03-12	140	MBES
16685	24-02-12	11-03-12	137	MBES

While the bathymetrical surveys are now used to construct the most recent bathymetry of the area, they can also be used for morphological description of the area, and in evaluation of local or regional morphodynamics, provided the period and intervals at which bathymetrical measurements were performed is relevant to the time scale at which these dynamics occur.

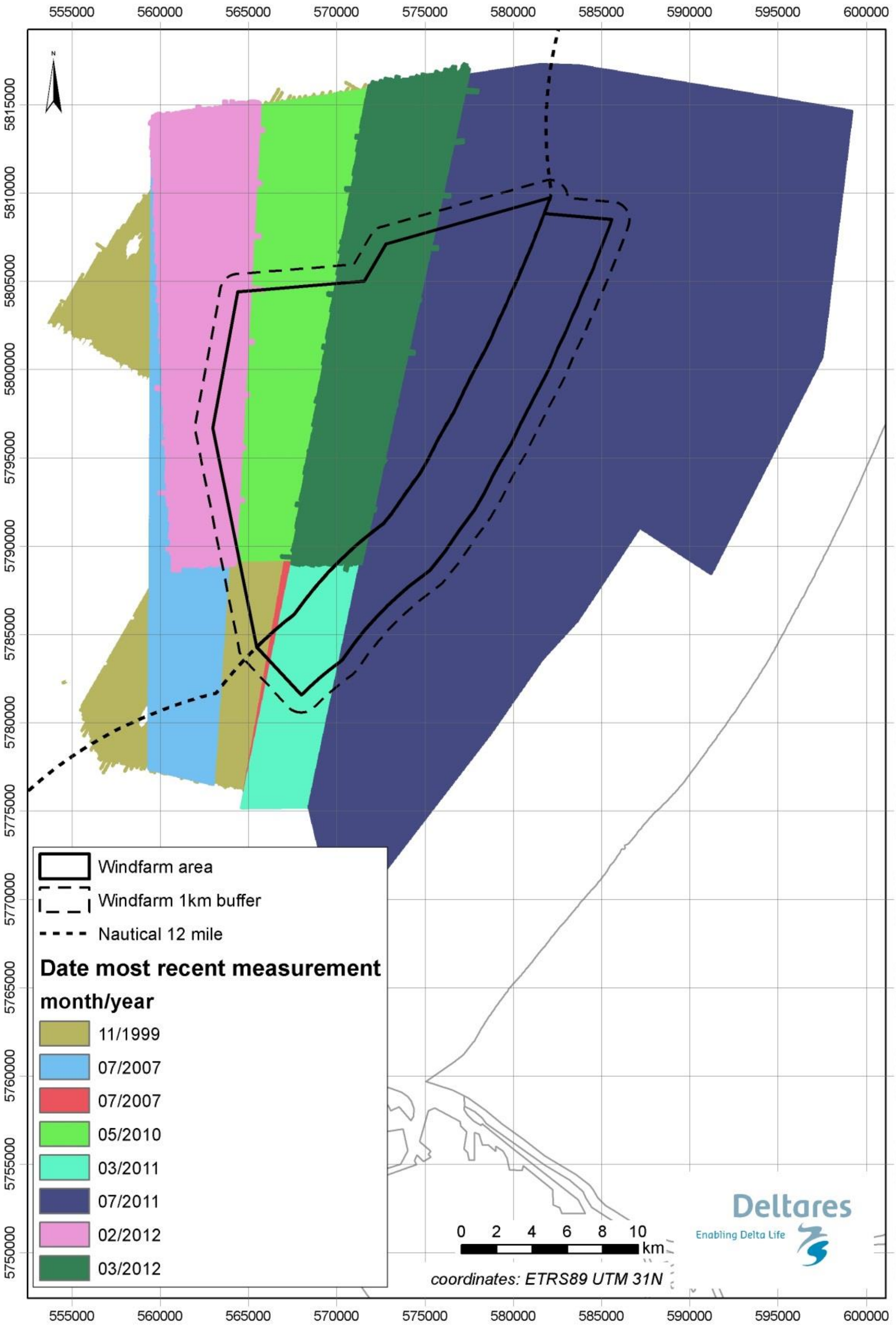

Figure 2.1 Most recent bathymetrical survey for each point on the map (two surveys in 11/1999).

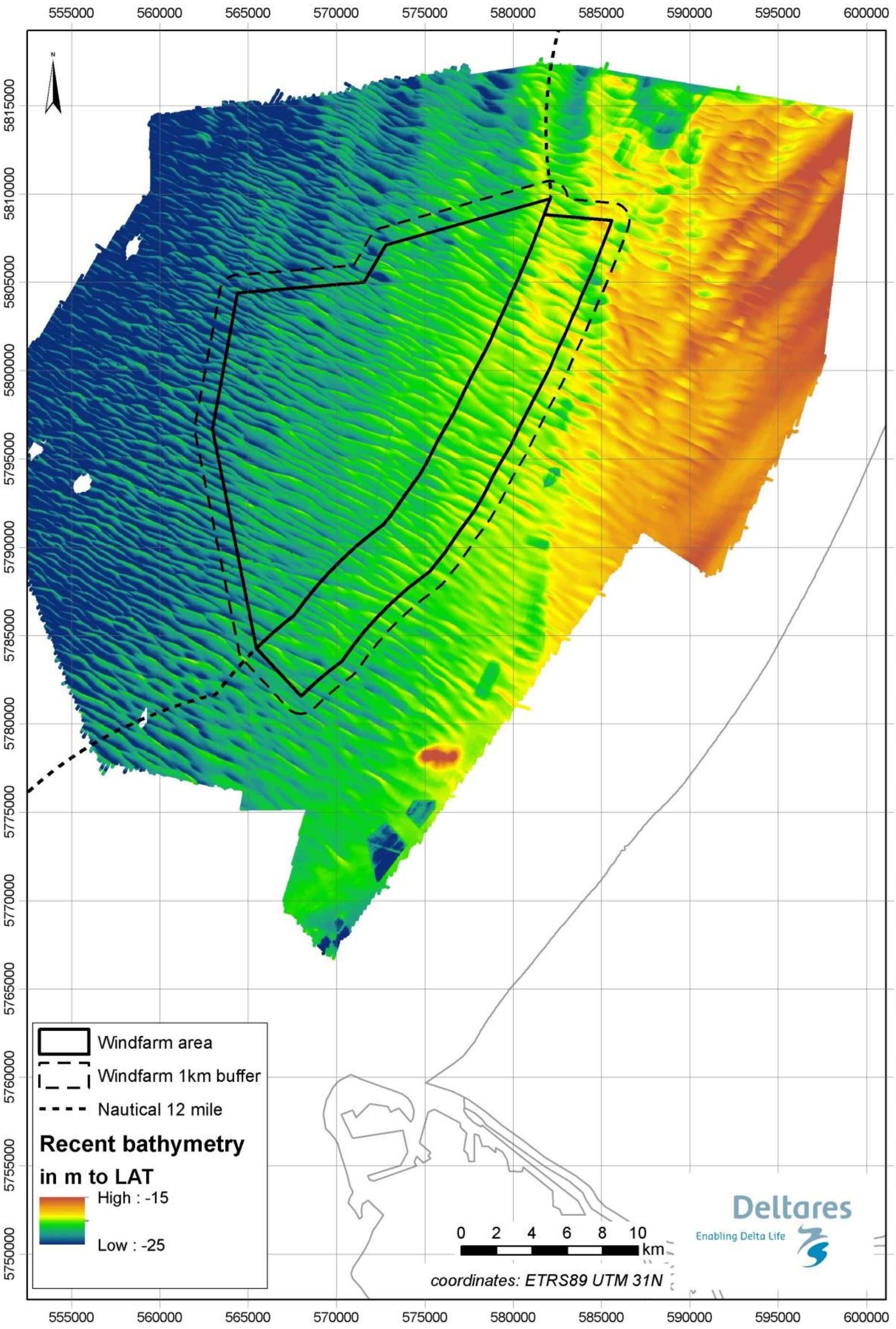

Figure 2.2 Map of recent bathymetry, based on nine bathymetrical surveys carried out between 1999 and 2012.

2.2 Borehole data

2.2.1 Data from DINOloket

A total of 890 cores was extracted from the DINOloket database, 204 of which lie within the study area (Figure 2.3). The remaining boreholes from up to 15 kilometres around the study area are presented to provide further context. In addition to the core descriptions, DINOloket provides grain size analyses results for 527 locations, results of chemical analysis at 83 locations and photos of 50 of the cores. Data were extracted from DINOloket on October 21th, 2015. All data can be obtained from the Netherlands Geological Survey | TNO on www.dinoloket.nl

Data density is the highest coastward of the study area around the 20 meter depth line. The data density gradually decreases with increasing distance from the coast. East of the 12 nautical mile line, a data density of 0.70 boreholes per square kilometre is reached (115 in total), whereas west of this line 0.33 boreholes per square kilometre are available (91 in total).

Part of the borehole data has been visualised in a set of profiles approximately parallel and perpendicular to the coast. Profiles along the areas with the highest density profiles are shown in Figure 2.7, the remaining profiles are provided in Appendix B.

The majority of the boreholes does not exceed a depth of 5 meters below the sea bed. Some of the available core descriptions extend to depth of 12 meters below the sea bed. Resolution of the borehole description varies from 1 meter intervals to cm-scale intervals, depending on the purpose for which the core has been taken (see Appendix B for two examples). There may also be inconsistencies in core descriptions induced by the interpretation of the geologists.

In a small number of cores in the DINOloket dataset, the marine Wormer Member (Naaldwijk Formation) was found to be (locally) present, with cores containing clay layers of centimetres to decimetres thick in the upper 5 meters of the sea bed. Two borehole logs show a clay layer with a thickness of respectively 1.5 meter and 3 meters in the upper 10 meters of the fluviatile Yarmouth Roads Formation is found around 18 to 20 meters below the sea bed. The majority of boreholes, however, consists of medium to very coarse sand, and occasionally thin layers of shells have been described (Vermaas et al., 2014).

The inconsistencies and differences in quality between core descriptions are inevitable, as they are inherent to a database with boreholes from different sources. They should not impose any problems when handling the borehole data with awareness.

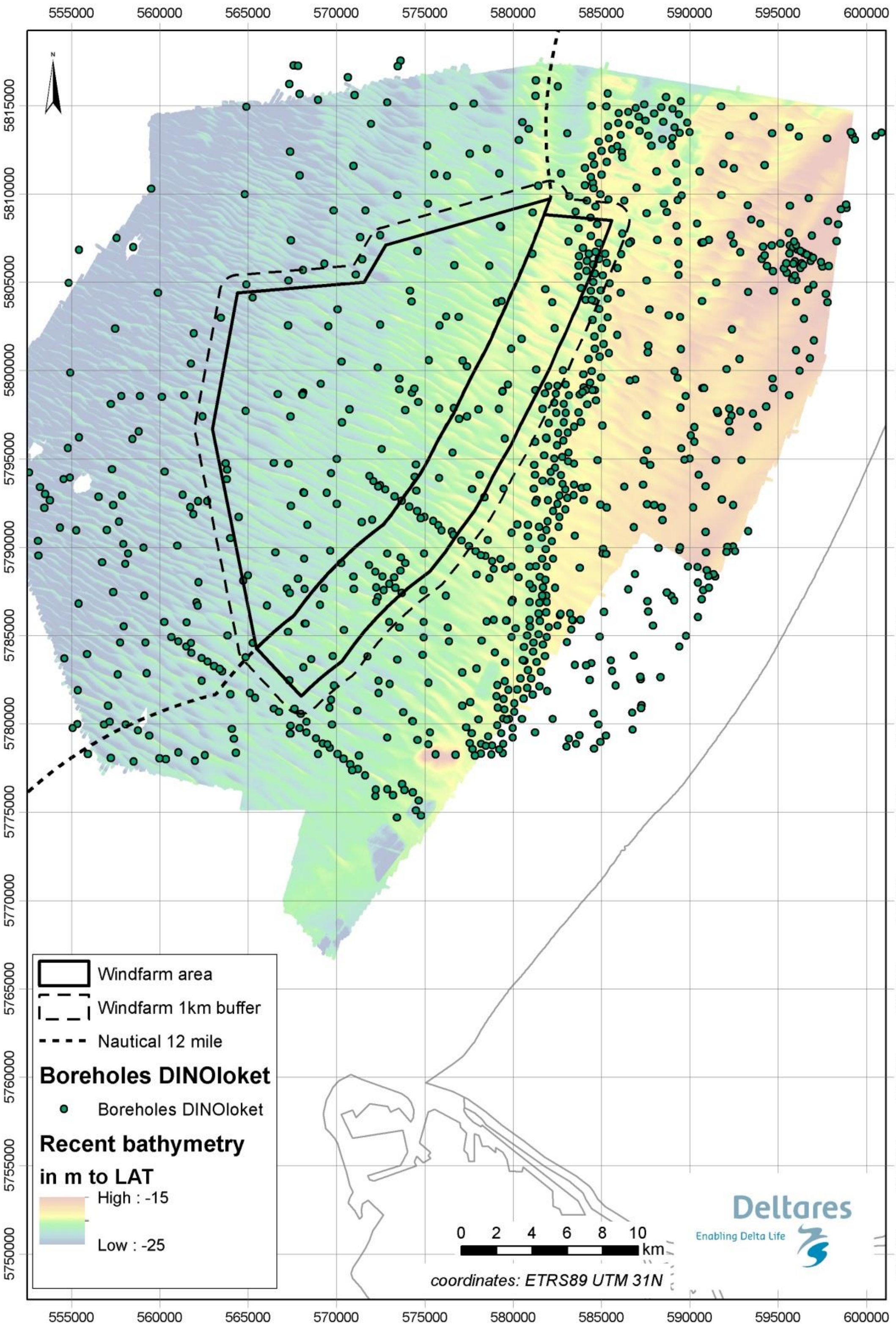

Figure 2.3 Borehole data extracted from DINOloket on October 21st, 2015.

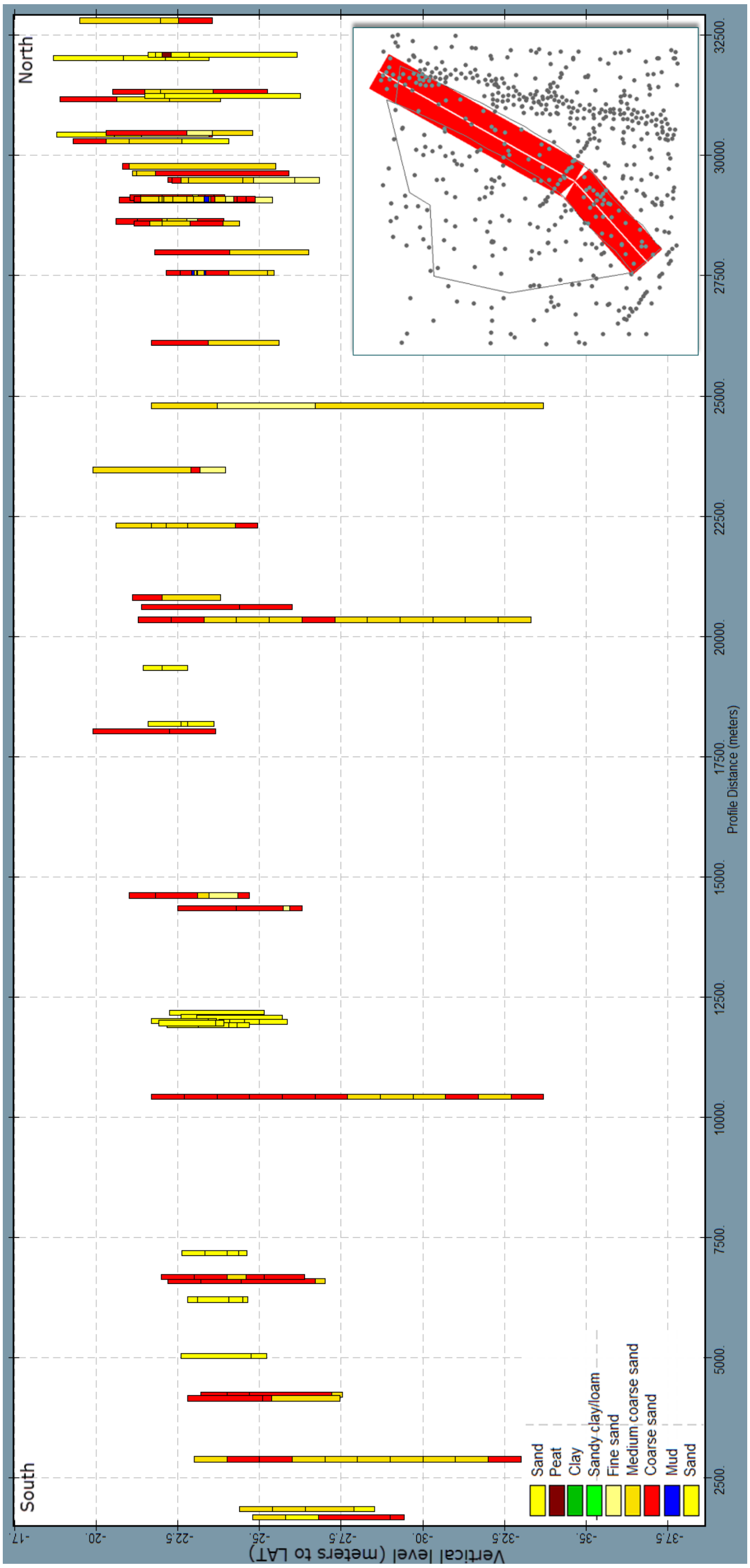

Figure 2.4 North-south profiles through 10-12 nautical mile zone (legend in Figure 2.6). Boreholes visible on map but lacking in the profiles are due to lacking surface level.

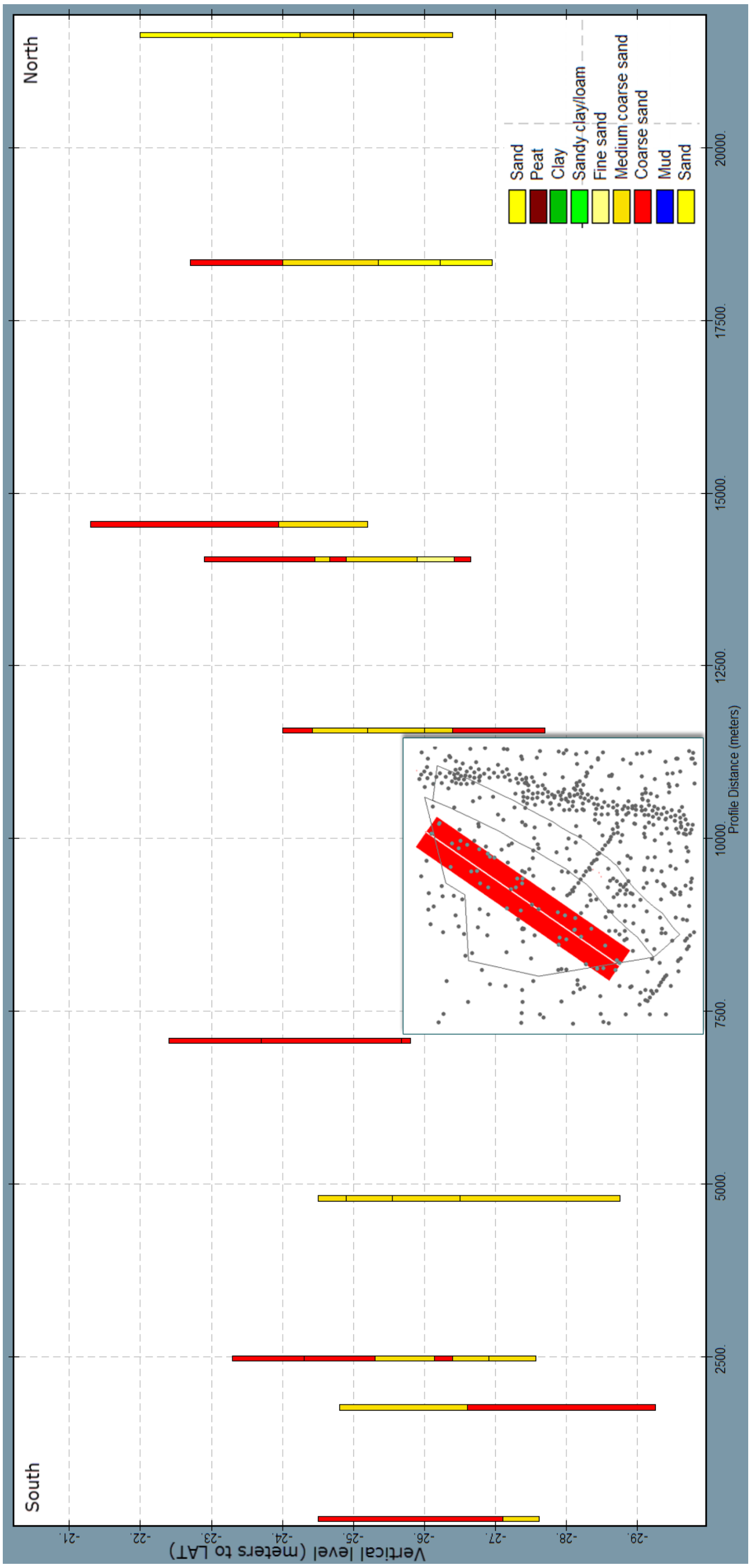

Figure 2.5 North-south profiles through area outside 12 nautical mile line (legend in Figure 2.6). Boreholes visible on map but lacking in the profiles are due to lacking surface level.

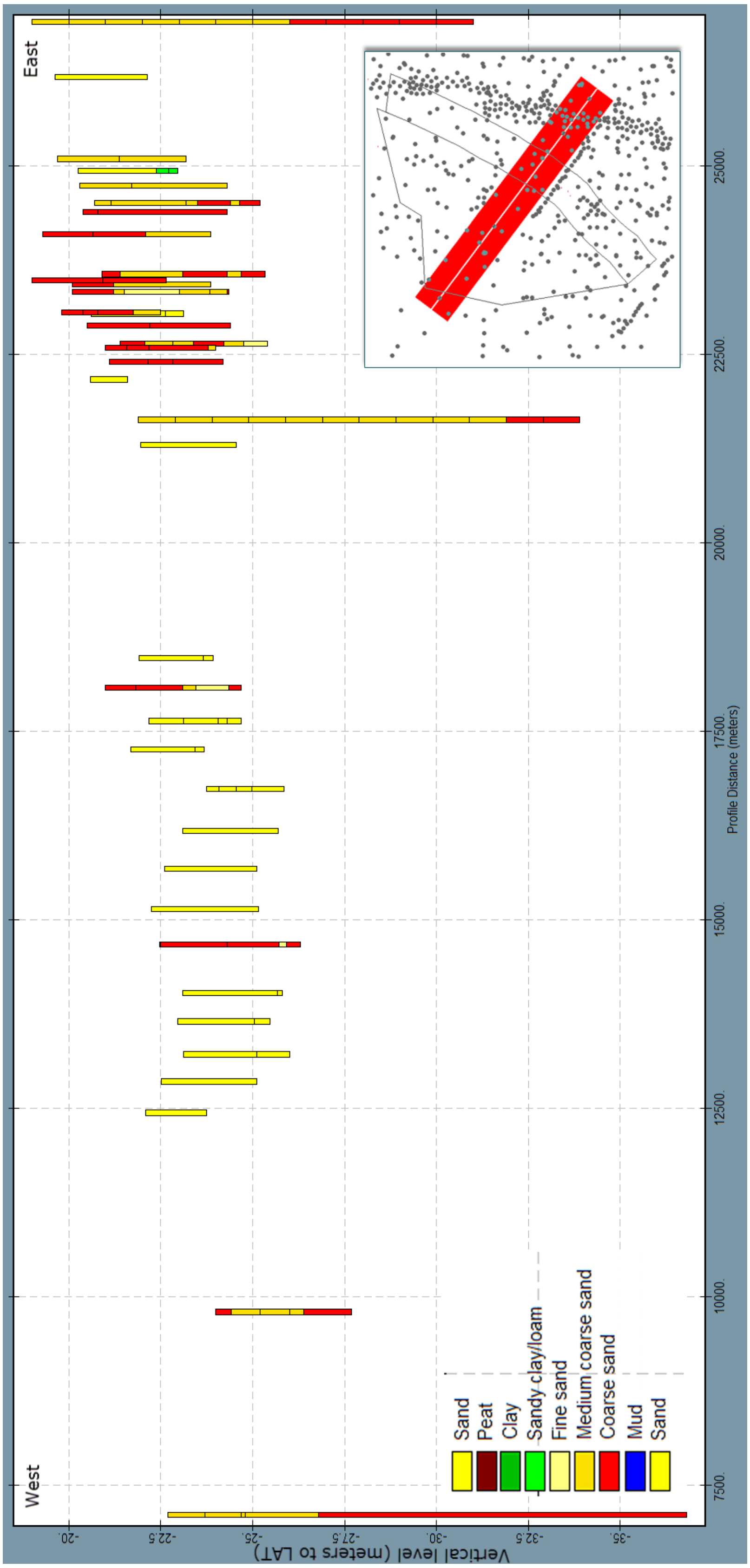

Figure 2.6 West-east profile through both areas. Boreholes visible at the map but are lacking in the profiles due to lacking of the surface levels.

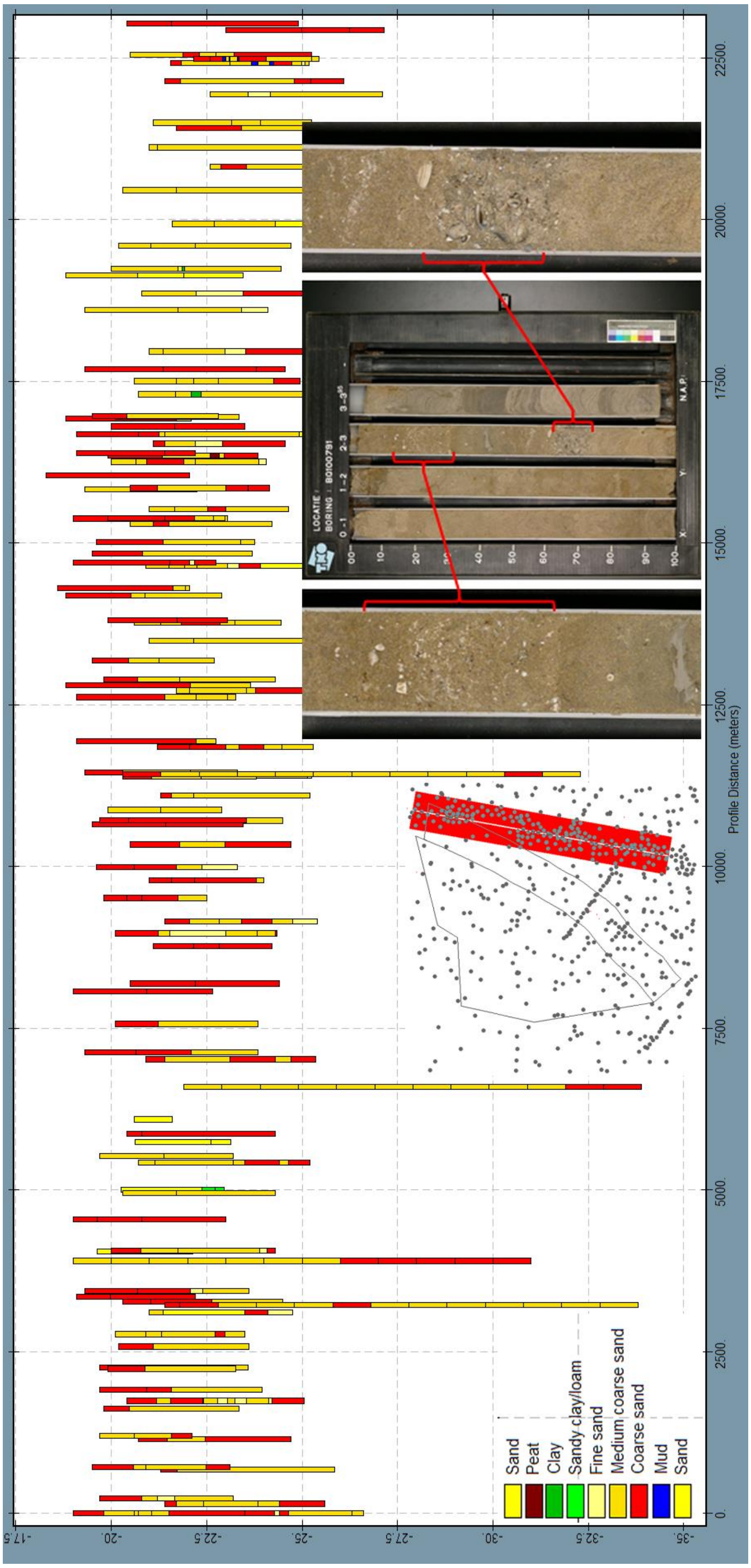

Figure 2.7 North-south profile just east of study area, with indication of small clay layers and example photo of borehole

2.2.2 Deep boreholes

Within the study area of the “Hollandse Kust (Zuid) Wind Farm Zone”, most boreholes do not exceed a depth of 12 meters. However, three boreholes with a penetration of > 75 meters were carried out by Fugro in the vicinity of the area (Figure 2.8). A first order interpretation by TNO of the three deep boreholes is given in Table 2.2. Detailed descriptions and an interpretation of these three boreholes are enclosed as Appendix C. These borehole data can be requested at the Netherlands Geological Survey | TNO.

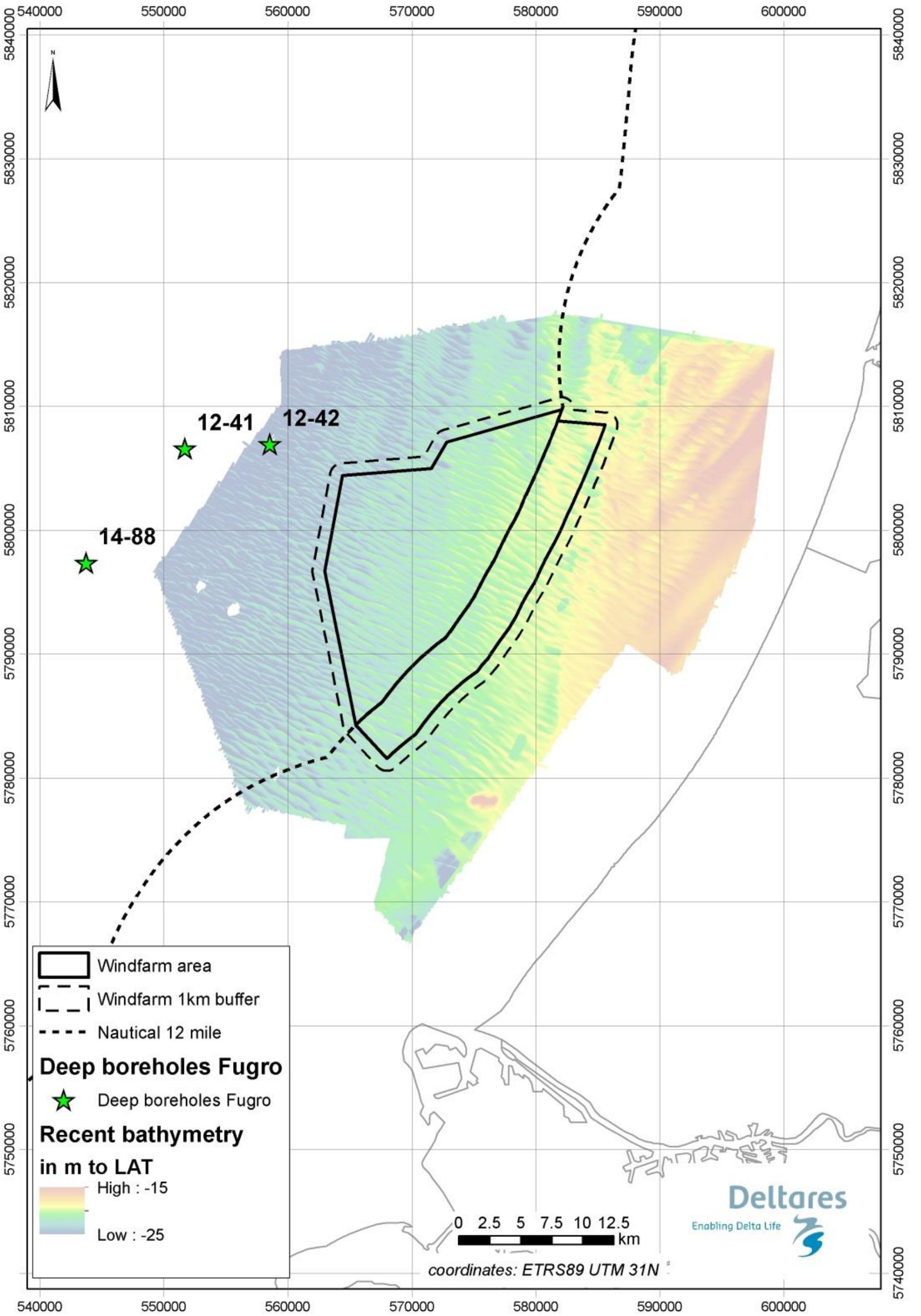

Figure 2.8 Location of three deep boreholes in the vicinity of the study area.

*Table 2.2 Lithostratigraphic interpretation of the deep boreholes. Certainty (C) of the stratigraphy is indicated by * (unknown), ! (certain), or ? (uncertain). Depth is indicated in meters below the sea bed. All information from the Netherlands Geological Survey | TNO*

Core	Depth Top	Depth base	D50 (µm)	C	Lithostratigraphy	Lithology
12-41	0	4.3	210-420	*	Southern Bight Formation, Bligh Bank Member	medium coarse sand
	4.3	9	210-420	*	Kreftenheye Formation	medium coarse sand
	9	12		!	Eem Formation, Brown Bank Member	clay (silty and sandy) with some peat
	12	31.3	150-420	!	Yarmouth Roads Formation	medium coarse sand with clay interbeds
	31.3	42	100-210	?	Yarmouth Roads Formation	fine sand clay and peat interbeds
	42	58	150-420	!	Yarmouth Roads Formation	medium to coarse sand
	58	72	150-300	?	Yarmouth Roads Formation	medium to coarse sand with clay interbeds and organic material
	72	81	150-300	?	Winterton Shoal Formation	medium to coarse sand
12-42	0	3.38	210-420	*	Kreftenheye Formation	medium coarse sand with shell fragments and gravel
	3.38	15.35	150-300	*	Kreftenheye Formation	medium sand , some clay interbeds, gravel
	15.35	32	100-300	!	Yarmouth Roads Formation	medium sand with silt and clay interbeds
	32	44		!	Yarmouth Roads Formation	clay and silt layers 0,5-0,7 m interbedded with sand
	44	78	100-300	!	Yarmouth Roads Formation	medium sand
	78	78.05	150-300	?	Winterton Shoal Formation	medium sand
14-88	0	4	200-600	*		coarse sand, shell fragments, gravel
	4	11.5	200-600	*		coarse sand, clay and silt interbeds
	11.5	14.5		*		silt with sand and clay interbeds
	14.5	21.6	60-600	*		fine to coarse sand with clay and silt interbeds
	21.6	32.7		*		clay with sand and silt interbeds
	32.7	40.6	63-200	*		fine and with silt and clay interbeds
	40.6	53.8		*		clay with some sand
	53.8	81.6	63-200	*		fine sand with clay interbeds and peat
	81.6	84	63-600	*		fine to coarse sand with shell fragments
	84	100	63-200	*		fine sand with silt and peat, shell fragments

2.3 Seismic surveys

Seismic surveys have been carried out in and around the study area for several decades. All data shown is digitally available and can be requested at the Geological Survey of the Netherlands | TNO. This paragraph described the available data, the quality and suitability of these data is assessed in Chapter 4. Large amounts of public seismic data are also available on http://nlog.nl/nl/home/NLOGPortal.html. In the study area mainly analogue seismic data from this source is available. This data was not assessed in this study.

In the study area, both single and multichannel surveys have been performed (Table 2.3 and Figure 2.9). Details on the seismic survey lines are given in Chapter 4 (Table 4.1).

Each dataset has the coordinate reference system European Datum 1950. Spacing in between single channel survey lines in the study area varies between 1.5 and 3.0 kilometres. Most surveys have a west to east orientation, more or less perpendicular to the coast. The fewest survey lines are available in the western and northernmost part of the study area. Multichannel surveys are spaced more irregularly, 2.0 to 5.5 kilometres apart and recordings have been done in all directions. Coverage is good over the entire study area. Some examples of the seismic data are shown in Figure 2.10 to Figure 2.14 and shortly described below. The shown examples are converted from time to depth with a simple formula, no velocity analyses have been done for any line.

Figure 2.10 shows seismic survey *ind95*. A discontinuous strong reflector is present in some sections at a depth of around 30 meters below the sea bed. This reflector may correspond to the top of the clay layer in the Yarmouth Formation. At the same depth, channel-like features can be recognised.

In Figure 2.11 a sample of the seismic survey *ijmgr96* is shown. In general, the analysed multichannel seismic section is characterised by very weak reflectors, indicating rather homogenous sediment in the upper 100 meters.

To demonstrate the possible sedimentary structures that can be recognised and may be expected in the upper tens of meters of the seismic surveys in and around the study area, a section of survey *ijmgr95* located northeast of the study area is presented in Figure 2.12. A deep valley is can be recognised at a depth of 20 to 50 meters below the sediment surface. It is underlain by a strong reflector. This is interpreted as a possible glacial valley with boulder clay or clay at the bottom. This possible glacial valley does not seem to extend towards the study area south of the survey line.

In the single channel sections, a reflector at the base of the sand waves can be observed (Figure 2.13 and Figure 2.14). This may be interpreted as the base of the Blight Bank Member of the Southern Bight Formation. A discontinuous strong reflector is present at around 10 to15 meters depth below the surface. This may correspond to the top of the clay of the Brown Bank Member.

It should be noted that although reflectors in the seismic section may indicate changes in lithology and the presence of certain layers, the thickness of layers cannot (always) be derived. This can be the case when only a reflector is visible for the top of a layer, but not for the bottom. This information should be inferred from core descriptions.

Table 2.3 Total length of seismic survey lines in the study area.

	Total (km)	**Single channel (km)**	**Multi channel (km)**
Wind farm area (356 km^2)	408	225	183
West of 12 nm line (236 km^2)	288	156	132
East of 12 nm line (120 km^2)	120	69	51

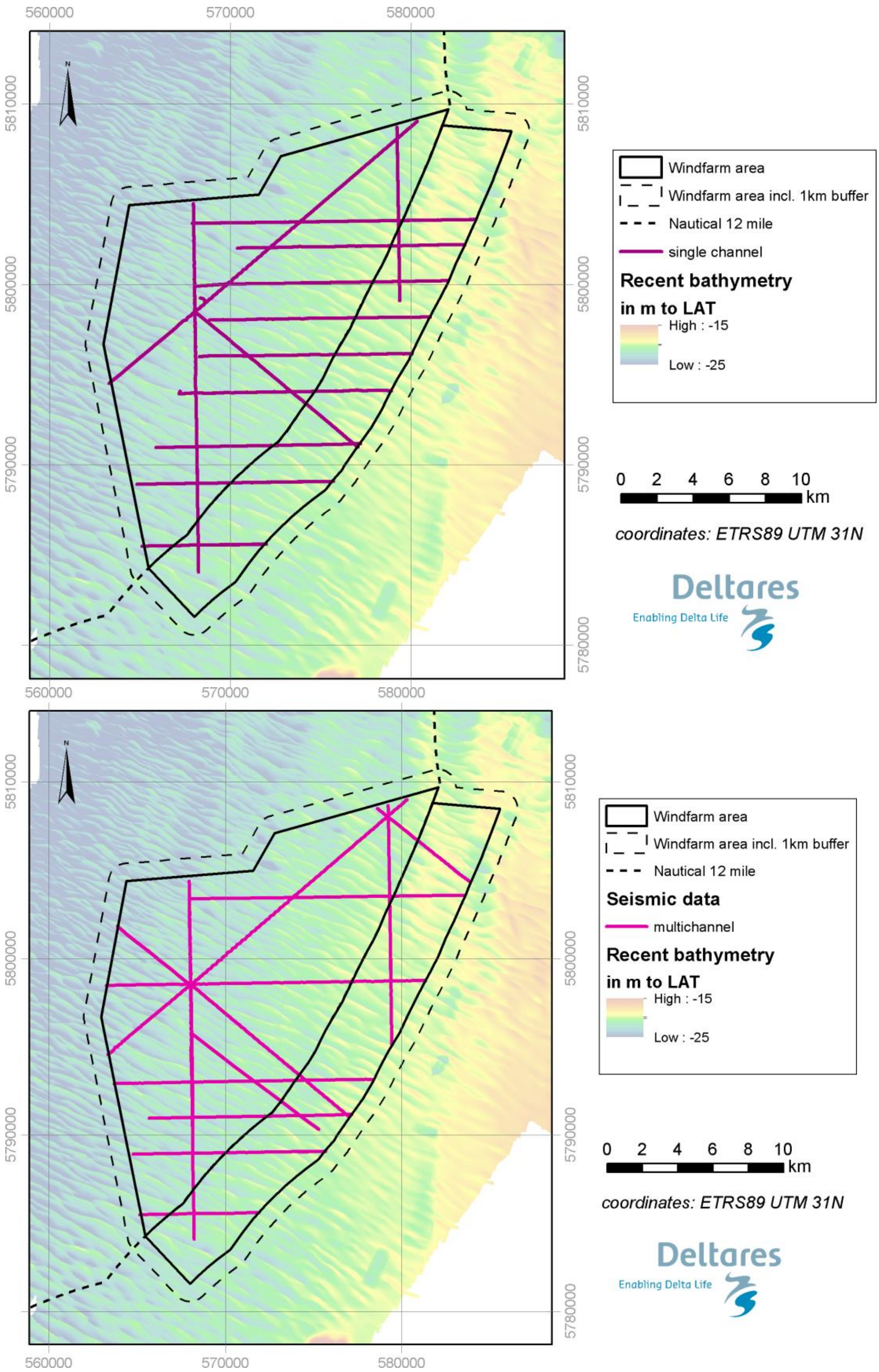

Figure 2.9 Lines of seismic surveys within the study area. While lines are depicted to end at the wind farm zone boundary, most survey lines extend well beyond the 1 kilometre buffer zone around the planned wind farm.

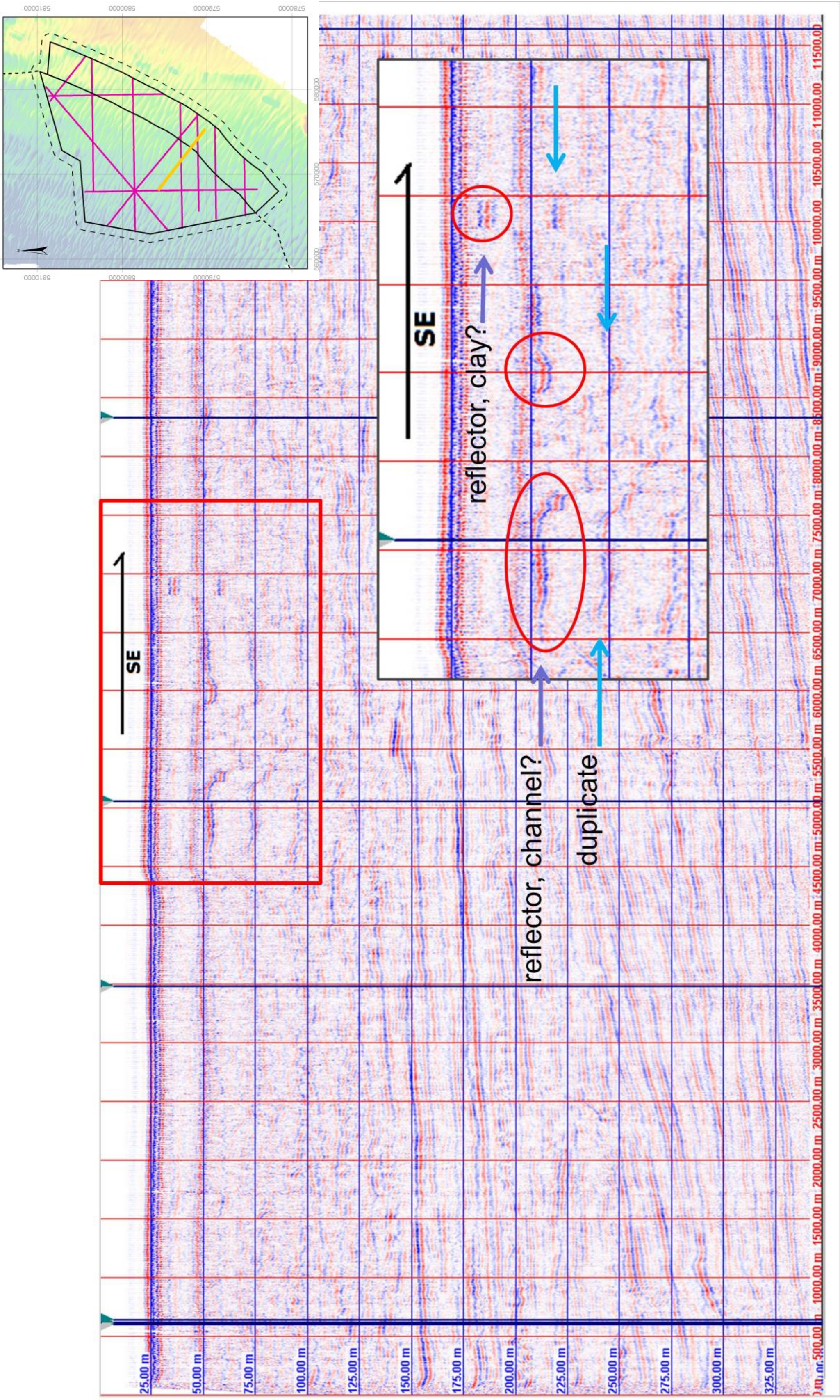

Figure 2.10 Multichannel survey ind95.

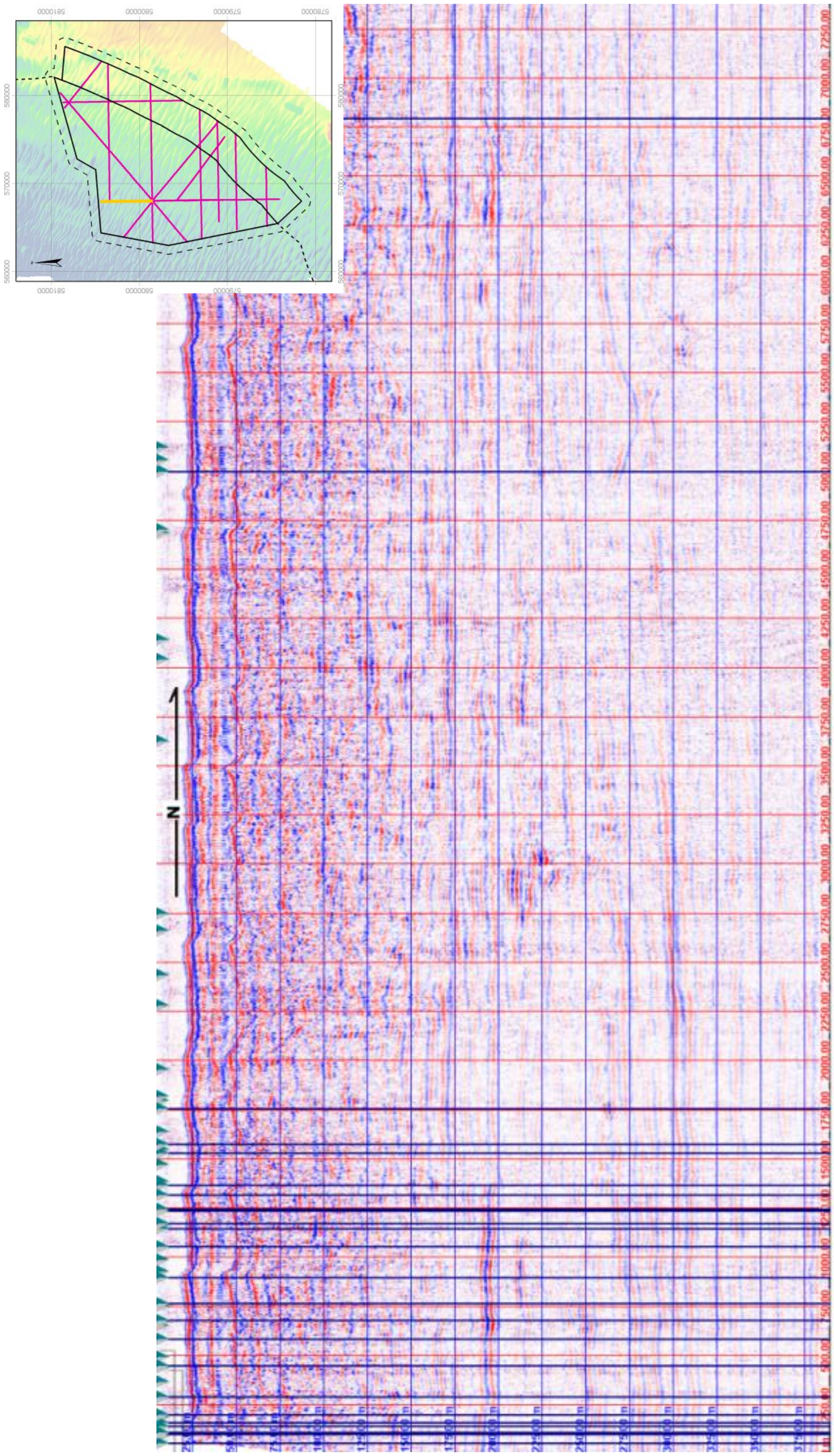

Figure 2.11 Multichannel survey ijmgr96

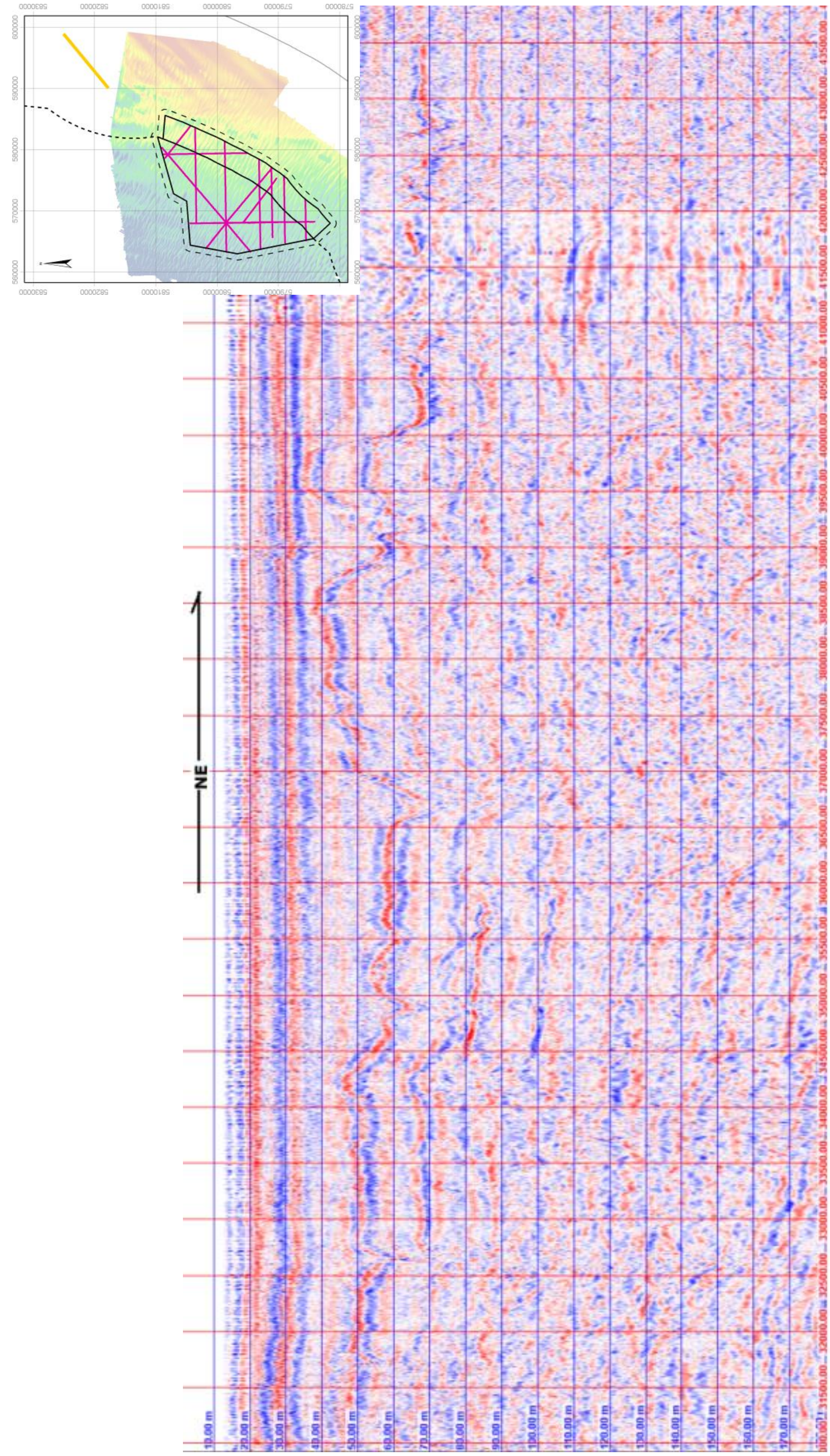

Figure 2.12 Multichannel ijmgr95, northeast of the study area. A deep, possible glacial, valley can be recognised at a depth of 20 to 50 meters below the sediment surface

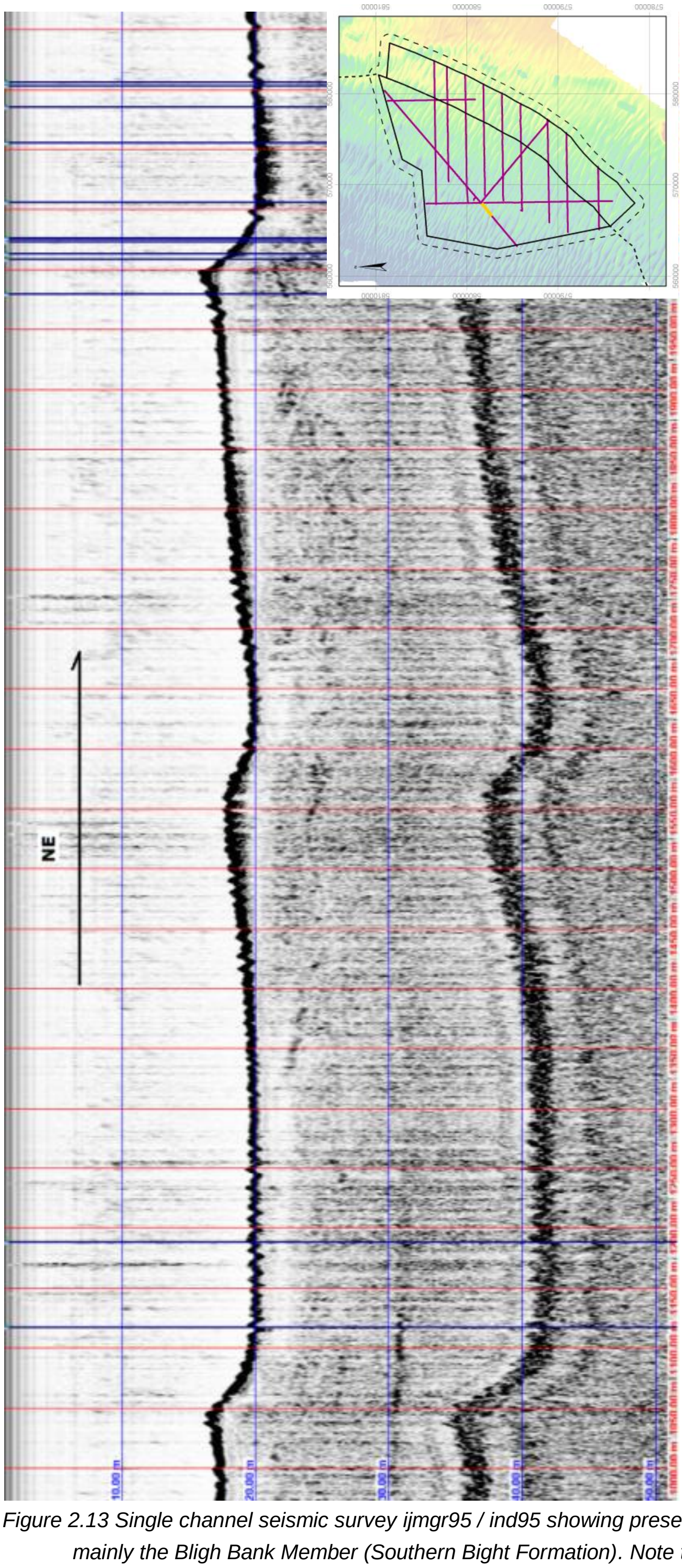

Figure 2.13 Single channel seismic survey ijmgr95 / ind95 showing present seabed morphology and structures of mainly the Bligh Bank Member (Southern Bight Formation). Note that this seismic line is in close vicinity to that in one of the multichannel studies, yet features in the upper 10 meters that were not in the multichannel survey do show up here.

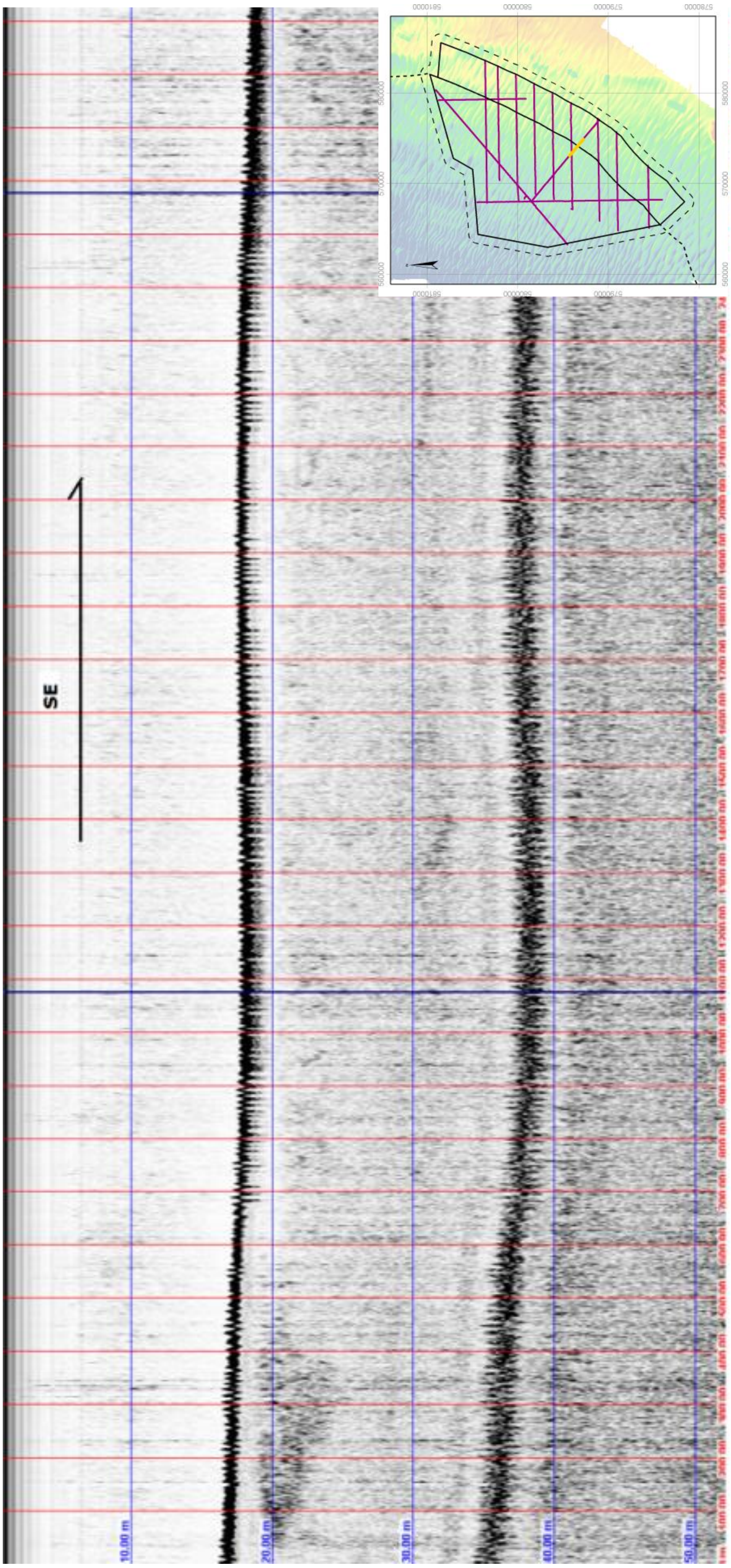

Figure 2.14 Single channel seismic survey ijmgr95 / ind95.

3 Literature review

In this chapter we present an overview of the relevant literature concerning the area of study and the general geological evolution of the offshore and coastal areas of the Netherlands.

The data available in the study area are boreholes (usually not deeper than 12 meter below sea bed) and seismic lines. When this data is correlated with deep boreholes (up to 100 m below sea bed) in the surrounding area and with the large number of boreholes, seismic lines, and studies in the coastal and onshore areas of The Netherlands, it is possible to construct a general picture of the geological evolution of the area and of the composition of the uppermost (<100 m depth) sedimentary units. The level of knowledge and detail progressively diminishes with depth, as less information is available. For this overview we gathered peer reviewed articles, previous reports by Deltares-TNO and the DINO database of TNO (see references).

This overview is structured in four sections:
- Pleistocene geomorphological development
- Glaciations
- Fluvial and landscape evolution in the Late Pleistocene and Holocene
- Geology of nearby wind farm zone Q10

3.1 Pleistocene geomorphological evolution

The geomorphological evolution of The Netherlands and of the North Sea during the last 1 Ma is well described by Cohen et al. (2012) and Cohen et al. (2014). Since 1 million years ago, repeated glaciations have altered the landscape step by step. The shifting of ice masses on land and sea led to river diversion and sediment rerouting. The changes in ice volume during glacial-interglacial phases led to global changes in sea-level, which affected coastline configuration, as well as the location and the type of sediments accumulated. Critical tipping points in the development of the North Sea landscape were exceeded when Elsterian and Saalian ice sheets reached their maximum extents.

Each glaciation since the Middle Pleistocene has induced further drainage diversion and catastrophic erosion-related landscape changes. The most important changes in drainage evolution were the loss of the Eridanos River system, which fed water and sediments from Scandinavia to the North Sea (Pliocene to Early Pleistocene), and the creation of the Dover Strait drainage outlet, which led to the diversion of the Rhine/Meuse and southern Britain rivers towards the English Channel and eventually into the Atlantic Ocean. As for what concerns our study area, deltaic and fluvial deposits were accumulated during the Lower to Middle Pleistocene (Yarmouth Roads Formation and Urk Formation). Phases of deposition alternated with subaerial exposure as a result of sea-level changes and drainage reorganization.

A number of studies focused on the last 150 ka, as most of the sediment analysed was accumulated during this period (Busschers et al., 2007; Busschers et al., 2008, Peeters et al., 2015). These works reconstructed the evolution of the Rhine-Meuse fluvial system based on onshore stratigraphic data. The aggradation and incision dynamics, coastline shift and the position of channels varied as a function of climatic changes, sea-level changes, ice-sheet dynamics, tectonic and isostasy.

3.2 Glaciations

During the Elsterian glaciation the Scandinavian ice sheet reached the northern part of The Netherlands. Glacial deposits, tunnel valleys and ice-pushed ridges are well documented for this region by Beets et al (2002). The extent of ice sheet during the Saalian glaciation, the deposits and the landforms associated with glaciers in the coastal area and in the North Sea were studied by Laban et al. (1984), Joon et al. (1990), Laban (1995), Laban and van der Meer (2011). During the Saalian ice age, the Scandinavian ice sheet progressively extended southwards until the present position of the Rhine river course.

The maximum extend of the ice is marked by a line of ice pushed ridges extending from Germany to offshore Netherlands (Figure 3.1 and Figure 3.2). Offshore of The Netherlands, northeast-southwest oriented glacial valleys filled with Eemian sediments were identified based on boreholes and seismics. Furthermore, tills, granitic boulders and deformation structures were found in boreholes north of the line of maximum ice extent. The morphology of glacial features indicates ice tongues developing in northeast-southwest direction. Based on this reconstruction and on the distribution of glacial features in the North Sea, the northern part of the study area may have been covered by ice and was affected by periglacial processes. Still it is not clear whether this record is preserved, as fluvial incision during the following ice age (Weichselian) removed a large part of it in the North Sea. The smallest glacial valleys can have dimensions around 500 to 1000 m (Joon et al, 1990).

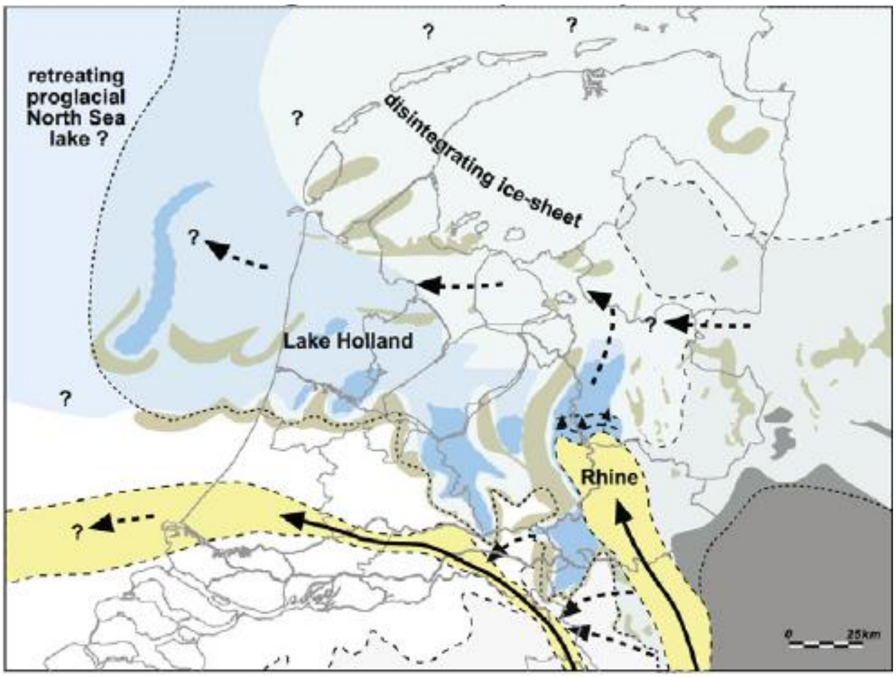

Figure 3.1 Ice sheet cover, glacial landforms and drainage pattern during the Saalian ice age (from Busschers et al., 2007).

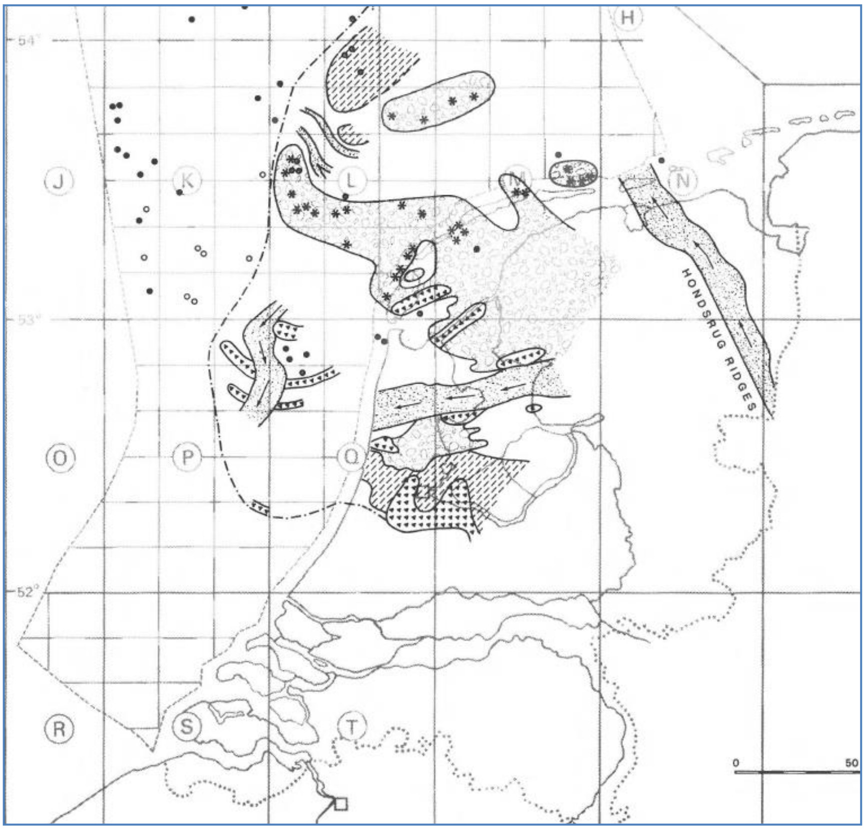

Figure 3.2 Saalian glacial features onshore and offshore the Netherlands (from Joon et al. 1990).

3.3 Fluvial and landscape evolution in the Late Pleistocene and Holocene

The latest stages of fluvial evolution from the last glacial maximum are described by Rijsdijk and Kroon (2013), Rieu et al. (2005), Van Heteren and Van der Spek (2008), Hijma et al. (2009) and Hijma et al. (2010). Since the last glacial maximum, sea-level rise induced transgression and led to flooding of the former fluvial systems in the North Sea and English Channel. The Rhine and Meuse rivers shifted from braiding to meandering systems and their mouth developed to tidal deltas. As the coastline migrated to the present day position, shallow marine deposits accumulated near the migrating coast (tidal delta and barrier islands deposits of the Naaldwijk Formation), whereas fluvial and organic deposits were accumulated in floodplains (the Echteld Formation and Nieuwkoop Formation, respectively).

These deposits are well preserved onshore and offshore near the river mouths, whereas in the marine realm most of them were removed by wave action during transgression. Remnants of the deeper part of old tidal inlets have been mapped offshore the Netherlands (Hijma et al., Rieu et al., 2005). Clay deposits of the Old Rhine Delta do not extent to the study area (Figure 3.3), nor do Holocene tidal channels. On the bottom of the North Sea sand waves have developed as a result of tidal currents (Van Dijk and Kleinhans, 2010). The fluviatile reworked deposits associated with sand waves are ascribed to the Southern Bight Formation.

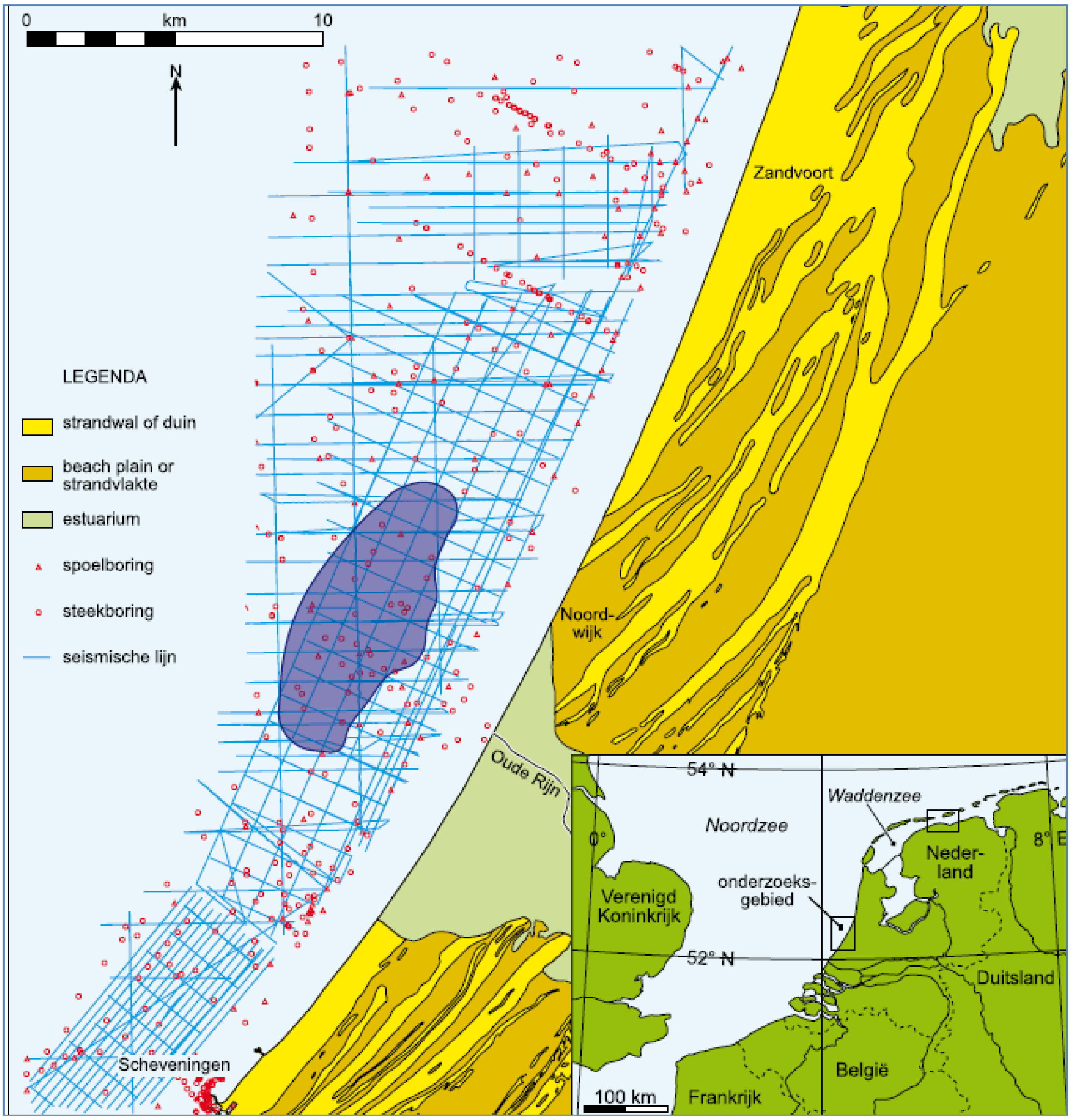

Figure 3.3 Position of the old Rhine Delta offshore Noordwijk, indicated by the purple area (from van Heteren and van der Spek, 2008).

3.4 Geology of nearby wind farm zone Q10

The report Geology and morphodynamics of wind farm location Q1 and Q10 (Van Dijk and Van Heteren, 2009) lists the geological units present in location Q10, partly overlapping the "Hollandse Kust (Zuid) Wind Farm Zone", the northeast of which falls in NCP block Q10.

Seismic lines and borehole data were analysed and correlated (Figure 3.5). In the seismic section the Nieuwkoop Formation and the Buitenbanken Member of the Southern Bight Formation were also encountered.

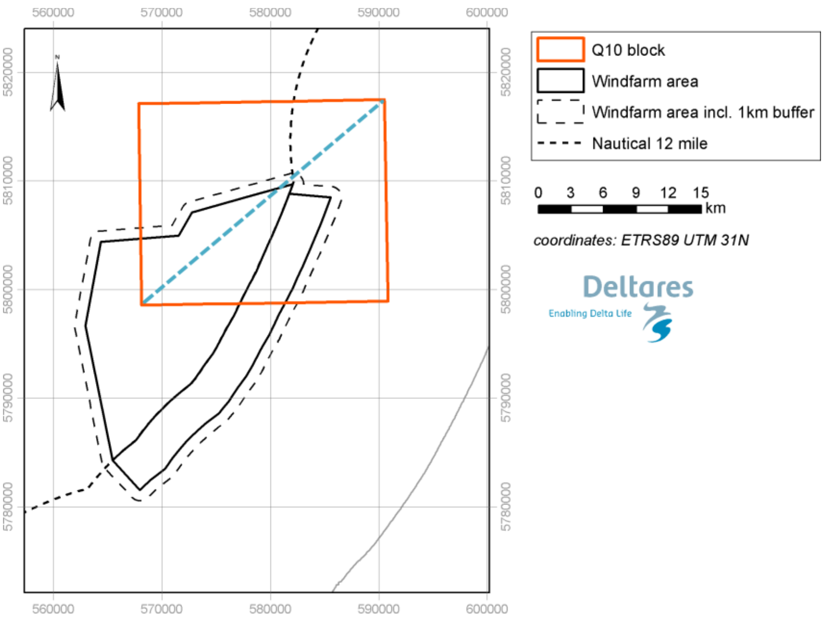

Figure 3.4 Map location of wind Q10 block, blue dashed line is approximately the location of the cross-section in Figure 3.5

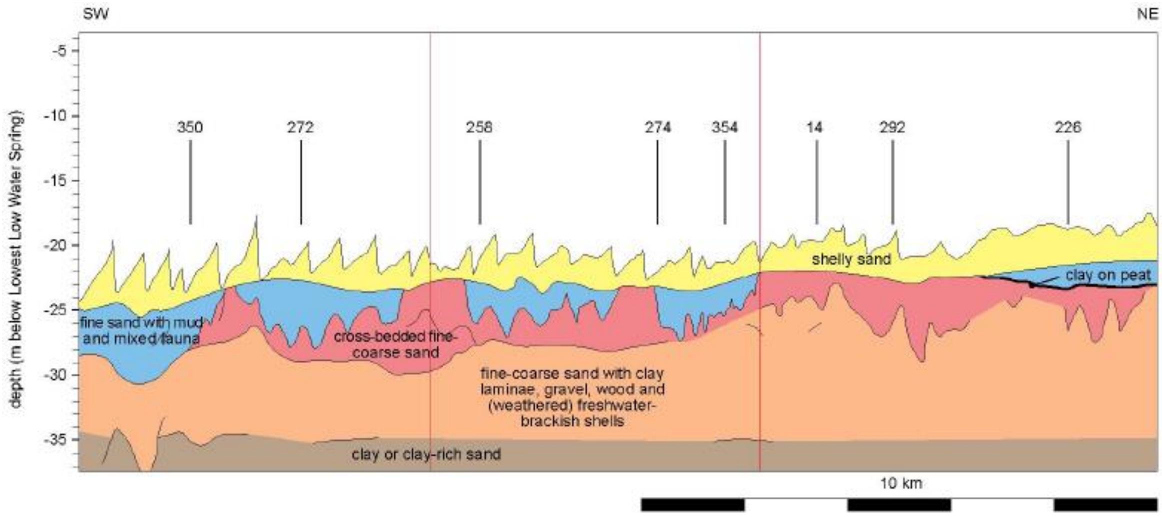

Figure 3.5 Cross-section though wind-farm location Q10. From bottom to top, the sequence includes Eemian marine clay, Eemian marine and estuarine sand with clay laminae, Weichselian fine to coarse fluvial sand, Holocene basal peat, Holocene tidal clay, and modern marine sand. Red lines mark the boundaries of the location. From: Van Dijk en Van Heteren, 2009.

Table 3.1 Geological units in Q10. From: Van Dijk en Van Heteren, 2009.

Unit	Thickness (m)	Depth (m LLWS)	Characteristics
Southern Bight Formation, Bligh Bank Member	0.6-2.5	19.4-24.1	f-m sand, shells and shell fragments
Naaldwijk Formation, Wormer Member	0.2-2.0	20.4-23.6	vf-m sand, clay layers, mixed shell fauna
Nieuwkoop Formation	0.0-0.3	23.0-23.3	peat
Southern Bight Formation, Buitenbanken Member	1.0-1.9	21.5-25.1	f-vc sand, shell and gravel lags
Kreftenheye Formation	1.2-4.2	21.9-28.1	f-c sand, layered, wood
Eem Formation	3.0-12.3	22.9-39.0	f-vc sand, clay layers, gravel, shells, wood
Yarmouth Roads Formation	>11.0	39.0->50.0	f sand

4 Assessment of data

4.1 Seismic data

The available seismic data with high vertical resolution collected with an XSTAR system covers the shallow part of the subsurface, approximately the first 10 to 15 meters (about 5 to 10 meters in sand and to up to 20 meters in unconsolidated clay). The sweeped signal of 500 to 8000 Hz it produces is suitable to map geological units in a shallow depth at high resolution, which is only useful for the more heterogenic units.

The other high frequency source is a 3.5 KHz pinger (3.5 Kc). The penetration depth is similar to that of an XSTAR system: 10 to 15 m. Its vertical resolution is approximately 50 cm.

Water guns and sleeve guns are two types of sources that produce a strong sound wave of 50 to 400 Hz. The water gun and sleeve gun systems used give a lower vertical resolution (resolution of several meters), but penetrate to a depth of several hundreds to 1500 meter. The data is suitable to analyse the larger scale units. The lack of reflectors indicates that there are no thick (1 meter or more) continuous (clay) layers present. Smaller scale geological units and higher resolution heterogeneity of the units will not be visible in these data.

The Sparker source produces a sound wave of 100 to 1500 Hz. Penetration depth is 300 to 500 meters, dependent of the chosen energy level and the geology, and a multi-channel receiver is used. Despite the bad quality of data in the seismic lines in the study area, the Sparker source is well suited for depths below sea bed ranging from 1.5 to 150 meters, especially when combined with a 24-channel streamer with a small group spacing.

If also the prestack data are available, new processing of the data with software can be done to get the best possible seismic profile for the area of interest. All data is available in time, and can be converted to depth with a simple formula, no velocity analyses have been done for any line.

Table 4.1 Available seismic survey data in and around the study area.

Project	Source	First year	Number of channels	Max. depth indication (m)	Prestack available	Suitable for depth 0-100m?	Vertical resolution
eeg87	water gun	1987	12	500?	Yes	barely	5 m
ijmgr95	chirp (XSTAR)	1995	1	15	-	0-10, 15 m	30 cm
ijmgr95	sleeve gun	1995	12	1500	Yes	hardly any reflectors 50 - 100m	4 m
ijmgr96	chirp (XSTAR)	1996	1	15	-	0-10, 15 m	30 cm
ijmgr96	sleeve gun	1996	12	1000?	Yes	hardly any reflectors 50 - 100m	4 m
ind95	chirp (XSTAR)	1995	1	15	-	0-10, 15 m	30 cm
ind95	sleeve gun	1995	12	1500	Yes	hardly any reflectors 50 - 100m	4 m
noordw98	chirp (XSTAR)	1998	1	15	-	0-10, 15 m bad quality	30 cm
noordw98	Sparker	1998	12	500	Yes	bad quality	1 – 2 m
pq91	3.5 Kc	1991	1	15	-	bad quality	50 cm
pvak02	sleeve gun	2002	12	1000?	Yes	moderate quality	4 m

4.2 Discrepancies

Within this study, the deep cores that were drilled by Fugro west of the study area (Table 2.2) have been compared to a study regarding NCP block Q10 by Van Dijk & Van Heteren (2009), which partially overlaps with our study area. There seem to be some mismatches between the description of boreholes by Van Dijk and Van Heteren (2009) and the stratigraphic units assigned to the three deep boreholes. In the latter, the Eem Formation and the Wormer Member of the Naaldwijk Formation are absent. This could be either due to a different stratigraphic interpretation, to the fact that the logs are located west of the pinch out position of Eem Formation and Wormer Member, or that these formations have been eroded.

No major discrepancies have been encountered in this study.

5 Stratigraphic framework

5.1 Stratigraphic classification

In the past two decades, various (national) stratigraphic subdivision schemes for the southern North Sea basin and its surrounding have been proposed. These schemes differ for the following reasons:

- Onshore lithostratigraphic systems (usually based on boreholes) are difficult to correlate with offshore seismostratigraphic units (typically based on seismics).
- Political division of the North Sea among British, Belgian, Dutch, German and Danish areas, with geological surveys mapping with different legends and scales. For example this has led to different names for the same formation or to the attribution of the rank of member, formation, or group to the same geological unit.
- The loss of discriminating lithological detail when units are traced from basin margin to basin centre.

As the study area is close to the offshore British-Dutch border, the stratigraphic classification of sedimentary units is influenced both by the Dutch and the British system. Few works have attempted a correlation/classification scheme between the two schemes. Laban et al. 1994 proposed one based on the geological map Flemish Bight (BGS & RGD, 1984), west of the study area (Figure 5.1). A more comprehensive approach based on regional discontinuities, facies and sedimentary environment correlation and a more precise chronology was proposed by Rijsdijk et al. (2005) (Figure 5.2). The major discontinuities represent regional/global events, such as ice sheet cover and major sea-level fall. Ebbing et al (2003) and Hijma et al. (2008) illustrate the general chronology and stratigraphic classification of geological units in the Late Pleistocene to Holocene in The Netherlands.

A comprehensive chronological classification scheme for the geological units in the Pleistocene and Holocene is presented by Cohen et al. 2014. Seventeen major phases of alternating cold and temperate climate have been recognised in the terrestrial and shallow-marine record of the North Sea basin. The last two glacials are most easily linked to the MIS record and correlated between sub-regions. Isotopic stages are global stages based on isotopic record in ice cores and in foraminifera shell in marine cores and boreholes. For glacials and interglacials before that the linkage is more challenging, because of the diachroneity in ice sheet dynamics, climate change, sea-level change and the impact of these processes on the sedimentary environment and hence on the sedimentary record (Table 5.1).

Currently the most complete and recent framework is that of Rijsdijk et al. (2005), which is considered to be the most appropriate for the study area. However, for the older Pleistocene formations it is proposed to use the older names Yarmouth Roads Formation and Winterton Shoal Formation.

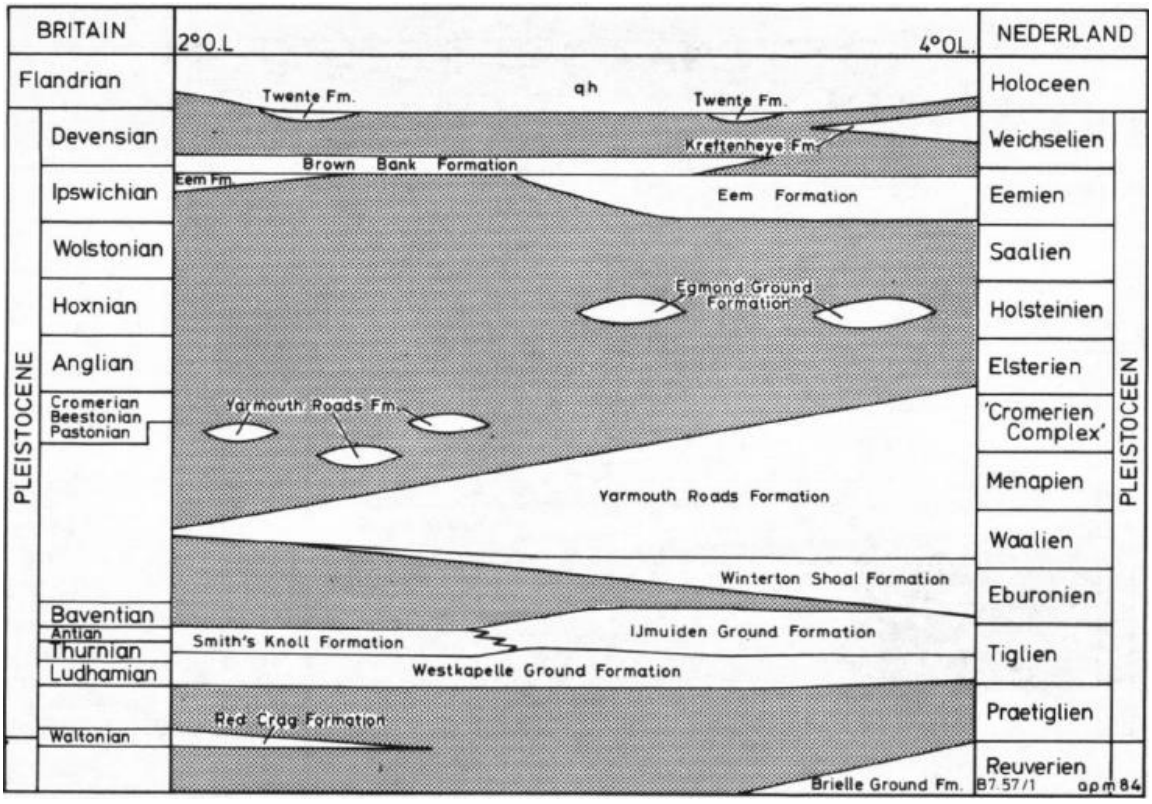

Figure 5.1 Chronostratigraphic correlation of Pleistocene units across the North Sea (from Laban et al., 1994).

Table 5.1 Glacial-interglacial phases nomenclature in the North Sea region.

	Netherlands	**Britain**	**Equivalent to MIS**
Glacial	Weichselian	Devensian	4-2
Interglacial	Eemian	Ipswichian	5
Glacial	Saalian	Wolstonian	6
Interglacial	Holsteinian	Hoxnian	9 or 11
Glacial	Elsterian	Anglian	12

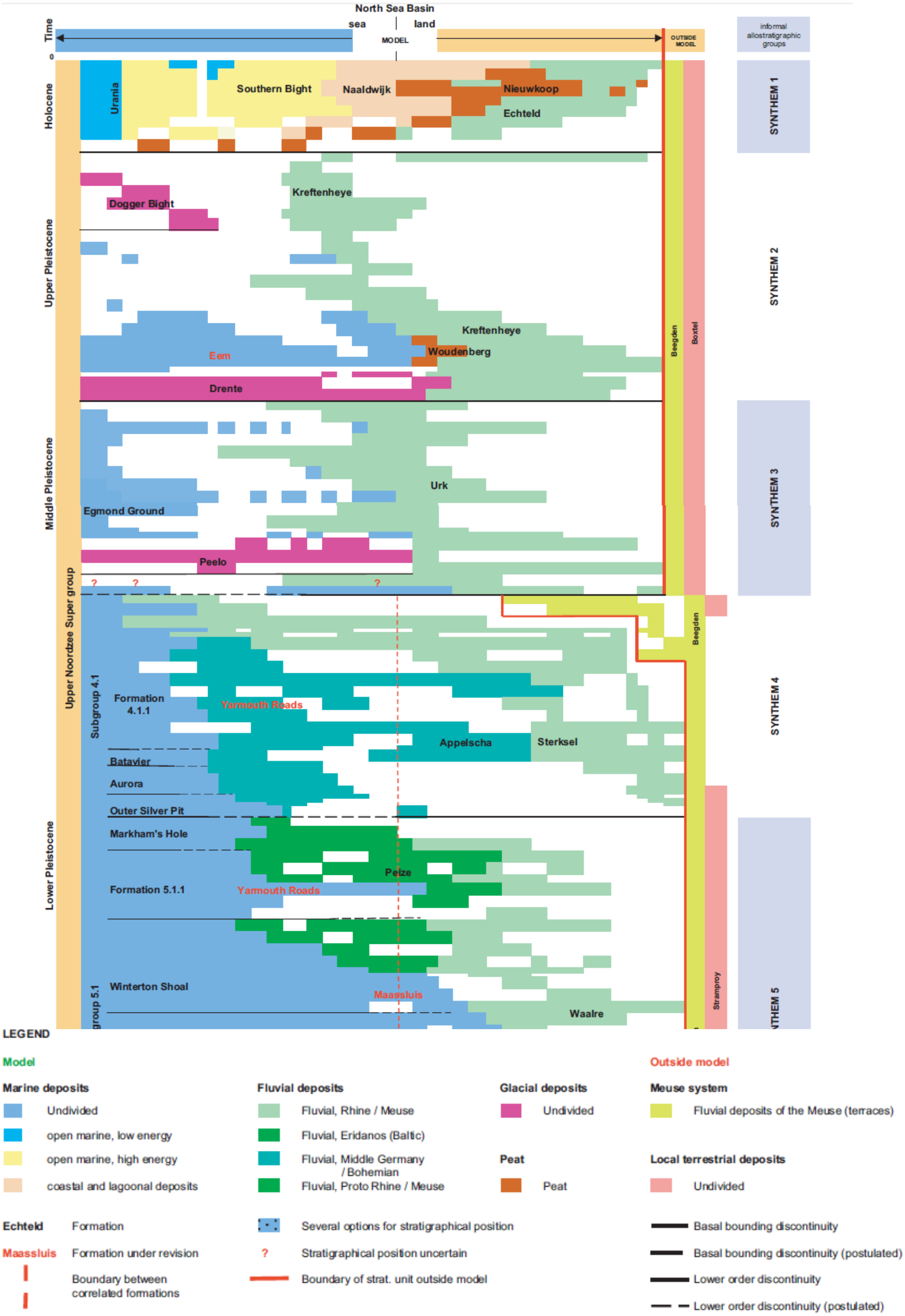

Figure 5.2 Chronostratigraphic/allostratigraphic correlation of Pleistocene units across the North Sea (Rijsdijk et al., 2005).

5.2 Geological units and expected sequence

A general description of the geological units and an overview of the typical geological sequence are given in Table 5.2. Based on the depth, the heterogeneity and lithology, the relevance of each unit for the proposed geophysical survey and a geological model is indicated. Uniform units with sandy lithology are considered less relevant, soft sediments with a discontinuous occurrence of higher relevance. This description is based on the quick scan report and on the TNO DINO description.

These geological units and there sequence is also indicated in a schematic geological cross-section (Figure 5.3, location of section in Figure 5.4). This cross-section is based on the data of the geological units (presented in next chapter), the boreholes from dinoloket, the deep borehole 12-42 and the recent bathymetry (Chapter 2).

Table 5.2 Characteristics of most important geological units

Stratigraphic Unit	Thickness	Age	Relevance	Lithology
Southern Bight Formation, Bligh Bank Member	0-6 m, typically 5-6 m	Holocene	Low	Brown-yellow, medium to little sorted, medium to coarse sand (D50 = 210 to 350 µm). Contains $CaCO_3$, shells and shells fragments (0 – 20%), sparse clay and silt laminae, locally with gravel up to 1 – 2% fine gravel (2 – 4 mm).
Kreftenheye Formation	0-15 m, typically 5-10 m top becomes deeper in the west	Upper Pleistocene	Medium	Grey medium to very coarse, poorly sorted sands (D50 = 180 - 800 µm), with fine to medium coarse, well rounded, quartz and quarzite gravel (1-10%), shells, wood fragments, and hard clay pebbles. In the North Sea, sediments at the upper boundary are more fine grained and calcareous.
Eem Formation, Brown Bank Member	0-5 m	Upper Pleistocene	High	Clay, peat, silt and sand
Eem Formation	3-15 m	Upper Pleistocene	Medium	Fine to medium coarse sand (D50 = 250 µm), with shells (5 %) and locally, gravel and mud (5 %).
Yarmouth Roads Formation	50-60 m	Lower to Middle Pleistocene	Medium	Fine or medium-grained grey-green sands, typically non-calcareous, with variable clay lamination and local intercalations of reworked peat
Winterton Shoal Formation	30-130 m	Lower to Middle Pleistocene	Low	Fine- or medium grained sands with locally clay laminations

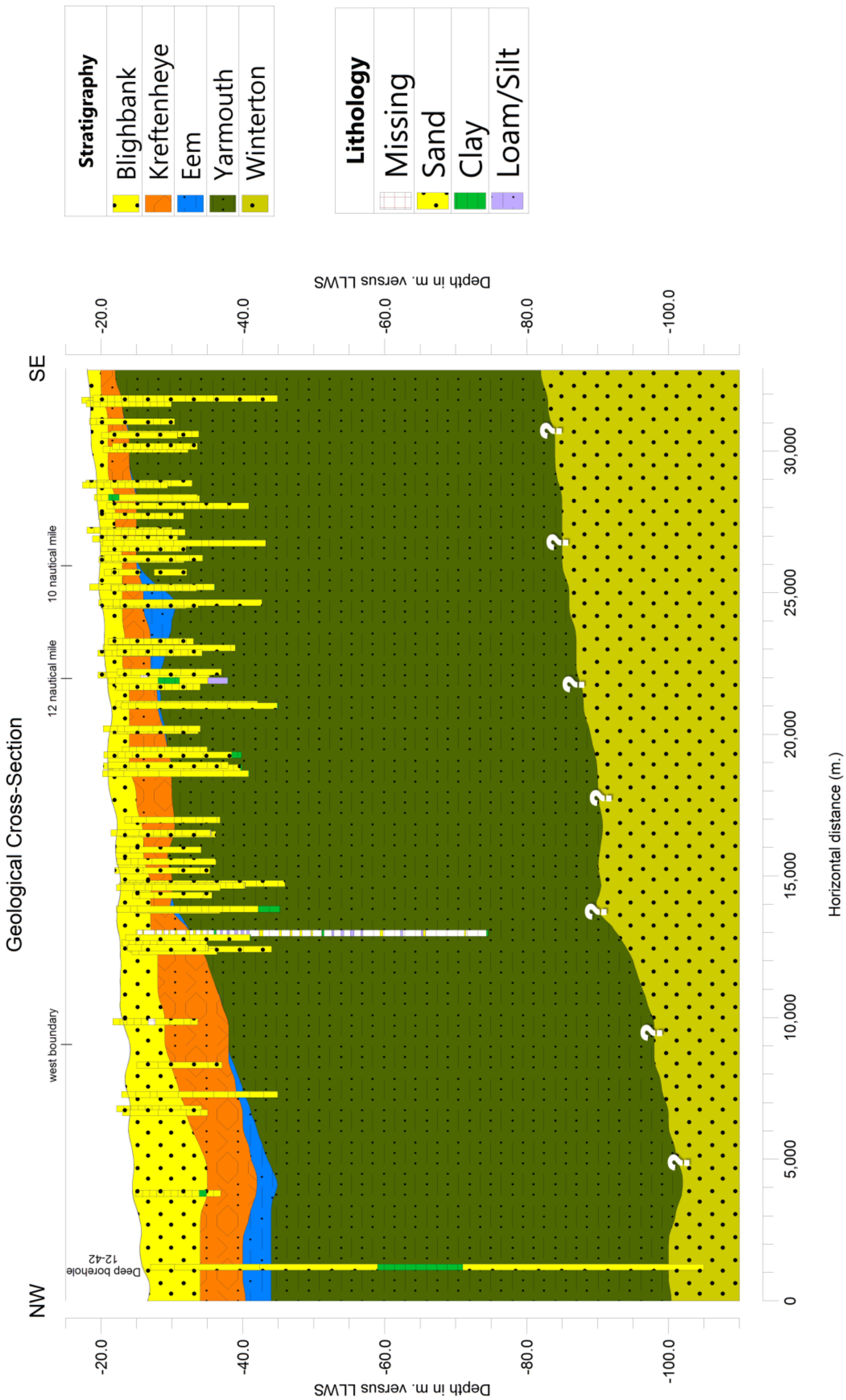

Figure 5.3 Schematic geological cross-section from northwest to southeast (location in Figure 5.4)

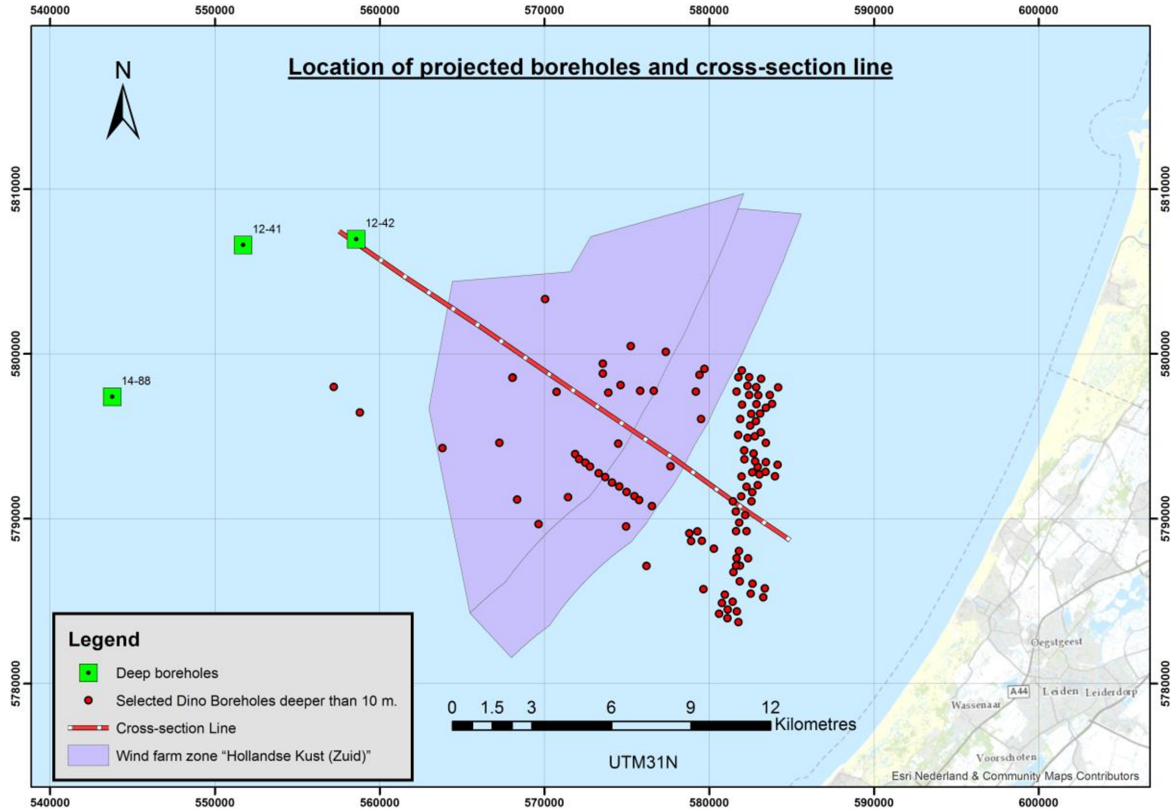

Figure 5.4 Location of cross-section shown in Figure 5.3

6 Geological maps

Part of the North Sea has been mapped at a scale of 1:250.0000 in a map series by the British, Belgian and Dutch geological survey (Figure 5.1). Our study area is located on the edge between the Flemish Bight quadrant and the Broad Fourteen quadrant, although a map of the latter has never been published. Nevertheless, the maps that are available provide some insight in the formations that can be expected in our study area.

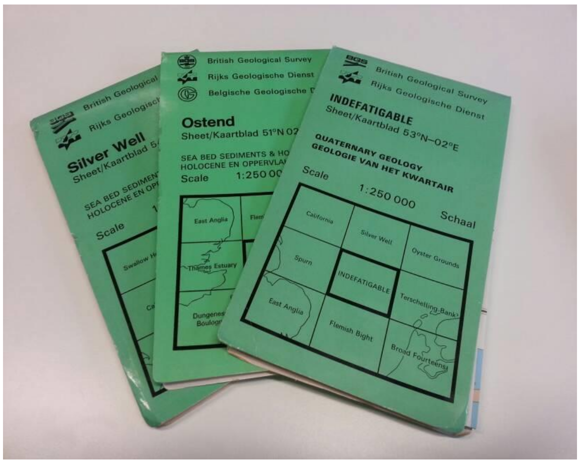

Figure 6.1 Three maps of the 1:250.000 map series by several national geological surveys.

Maps at a scale of 1:250.000 produced by TNO are currently only available in a .pdf-format, hence, the study area is not indicated on the map. It may be possible to retrieve the maps from the original source (TNO) as a shapefile. The 1:250.000 map series includes maps of several formations and also provides information on formations that can be found at the sea bed and at the top of the Pleistocene deposits. Additional maps in this series include grain size information, among which a map of mud and silt content of the sediment at a depth of 1 and 2 meters beneath the sediment surface and the depth of the Pleistocene sands. Maps within this series are presented in Appendix D.

A more detailed map by TNO with a scale of 1:100.000 is available for at least some of the formations that may be expected in our study area (Figure 6.3 to Figure 6.6 show the thickness of the Formations and Members). Using these data, a map showing the first Pleistocene Formations below the Holocene deposits was created (Figure 6.7). Based on this 1:100.000 map, we can state that:

- The Bligh Bank Member of the Southern Bight Formation the is present in the entire study area and lies at the sediment surface in most of the middle and east part of the study area, and at a depth close to 10 meters in the western part of the study area.
- The Buitenbanken Member of the Southern Bight Formation has a very patchy occurrence at is present in two small patches within the zone west of the 12 nautical mile line.
- Although the Naaldwijk Formation occurs in patches in the surroundings of the study area, it does not occur within the planned wind farm zone.
- The Kreftenheye Formation is a continuous layer in our study area, the top of which falls within the depth range 0 to 15 meters below the sediment surface.

- The Twente Formation is mapped as a discontinuous layer. It should be noted that currently, the term Twente Formation is no longer used, as it is currently regarded as a part of the Boxtel Formation.
- The Eem Formation covers large parts of the study area, although this Formation is absent in a zone in the middle of the study area, in areas both west and east of the 12 nautical mile line. This formation includes the Brown Bank Member, which is a discontinuous layer occurring exactly in the zone where the Eem Formation is absent.

To indicate the depth of the base of the Yarmouth Roads Formation, depths from available deep boreholes are shown on a map (
Figure 6.8 and Figure 6.9). The offshore boreholes are presented in paragraph 2.2.2, the onshore boreholes are from www.dinoloket.nl and are included in Appendix E. In the onshore boreholes, the base of the Yarmouth Roads Formation is determined as the top of the Waalre Formation.

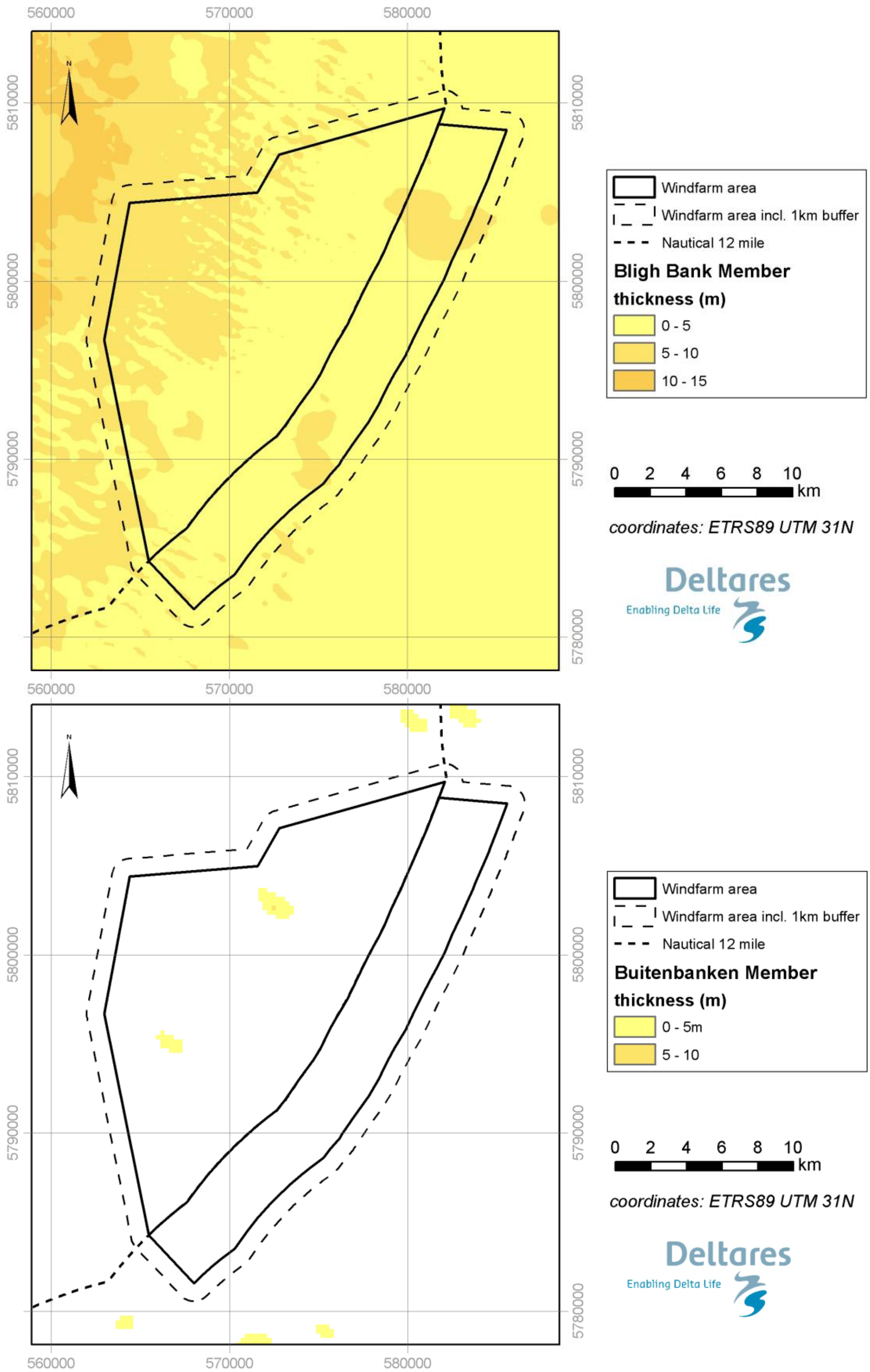

Figure 6.3 Extent of the Bligh Bank Member (upper panel) and Buitenbanken Member (lower panel) of the Southern Bight Formation.

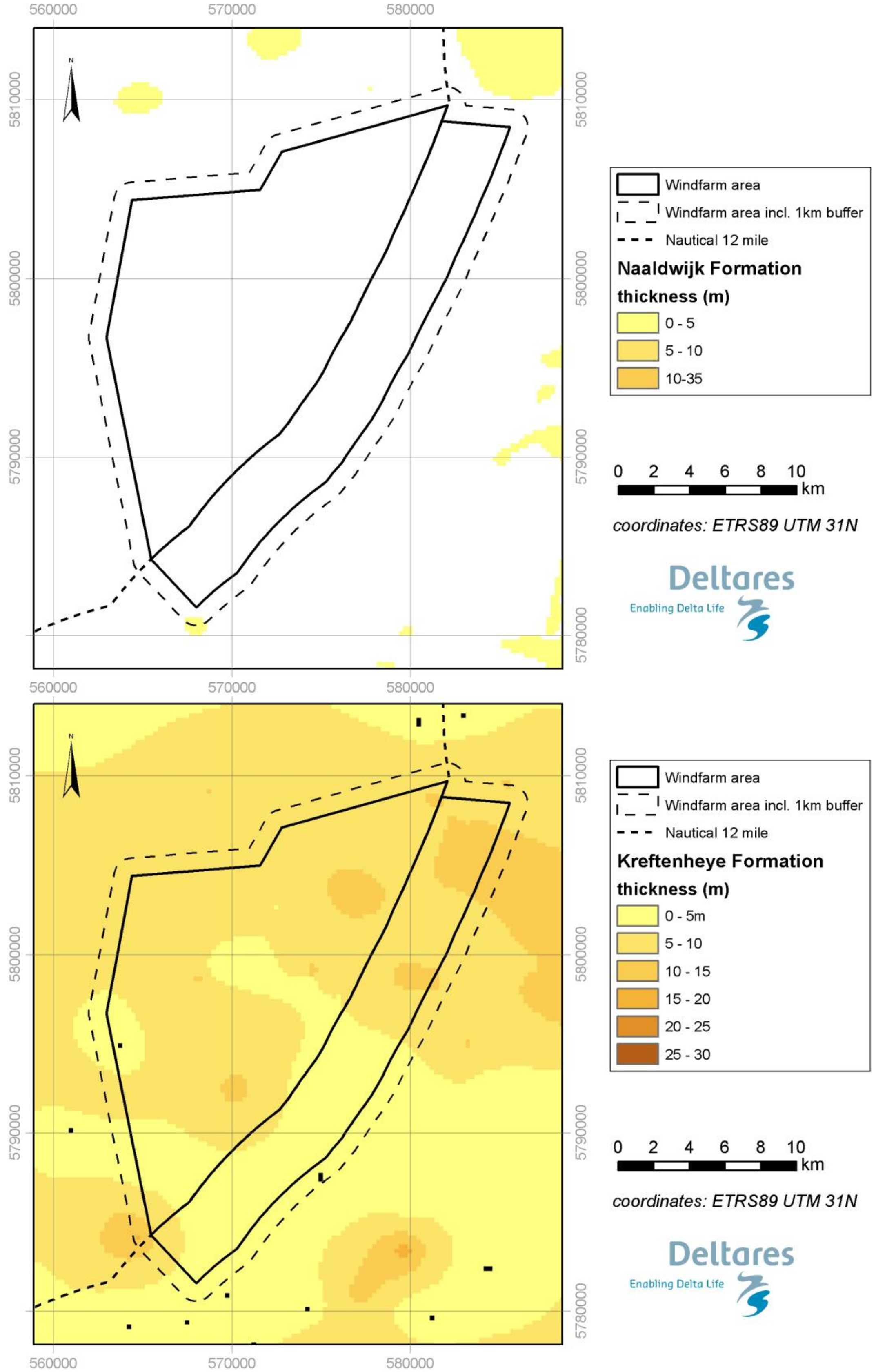

Figure 6.4 Extent of the Wormer Member of the Naaldwijk Formation (upper panel) and Kreftenheye Formation (lower panel).

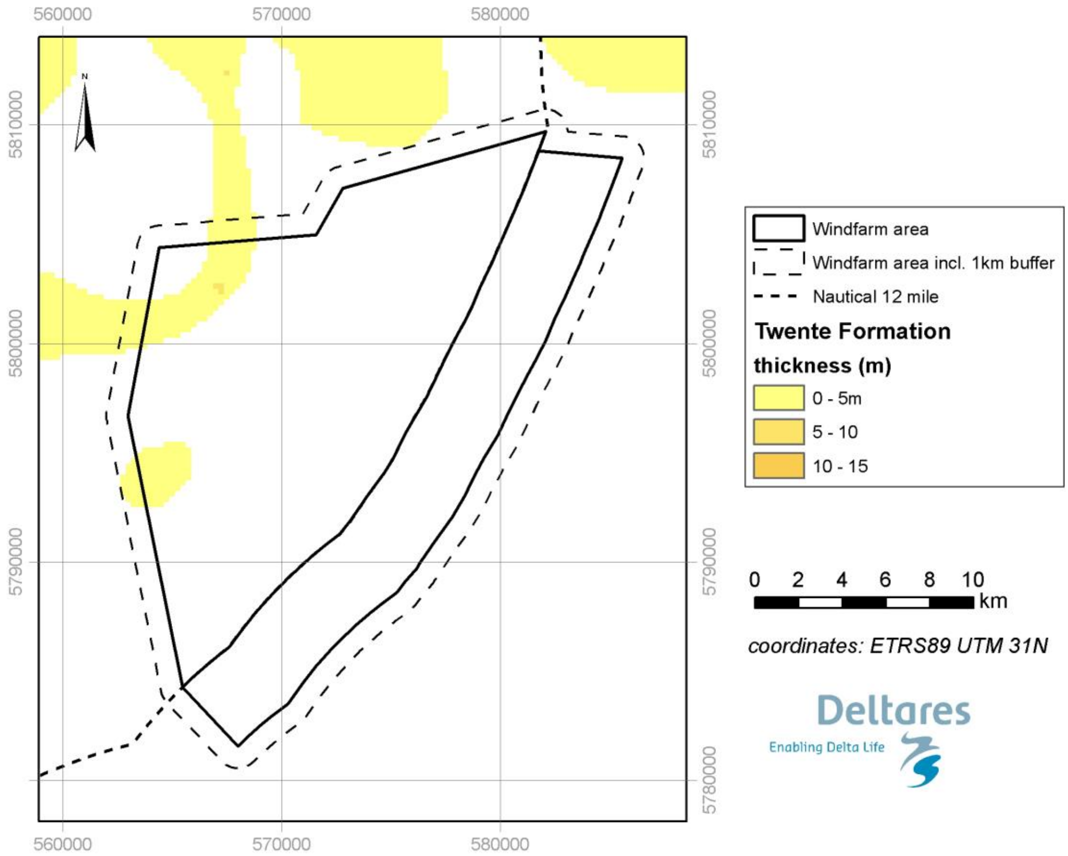

Figure 6.5 Extent of the Twente Formation (now considered to be part of the Boxtel Formation).

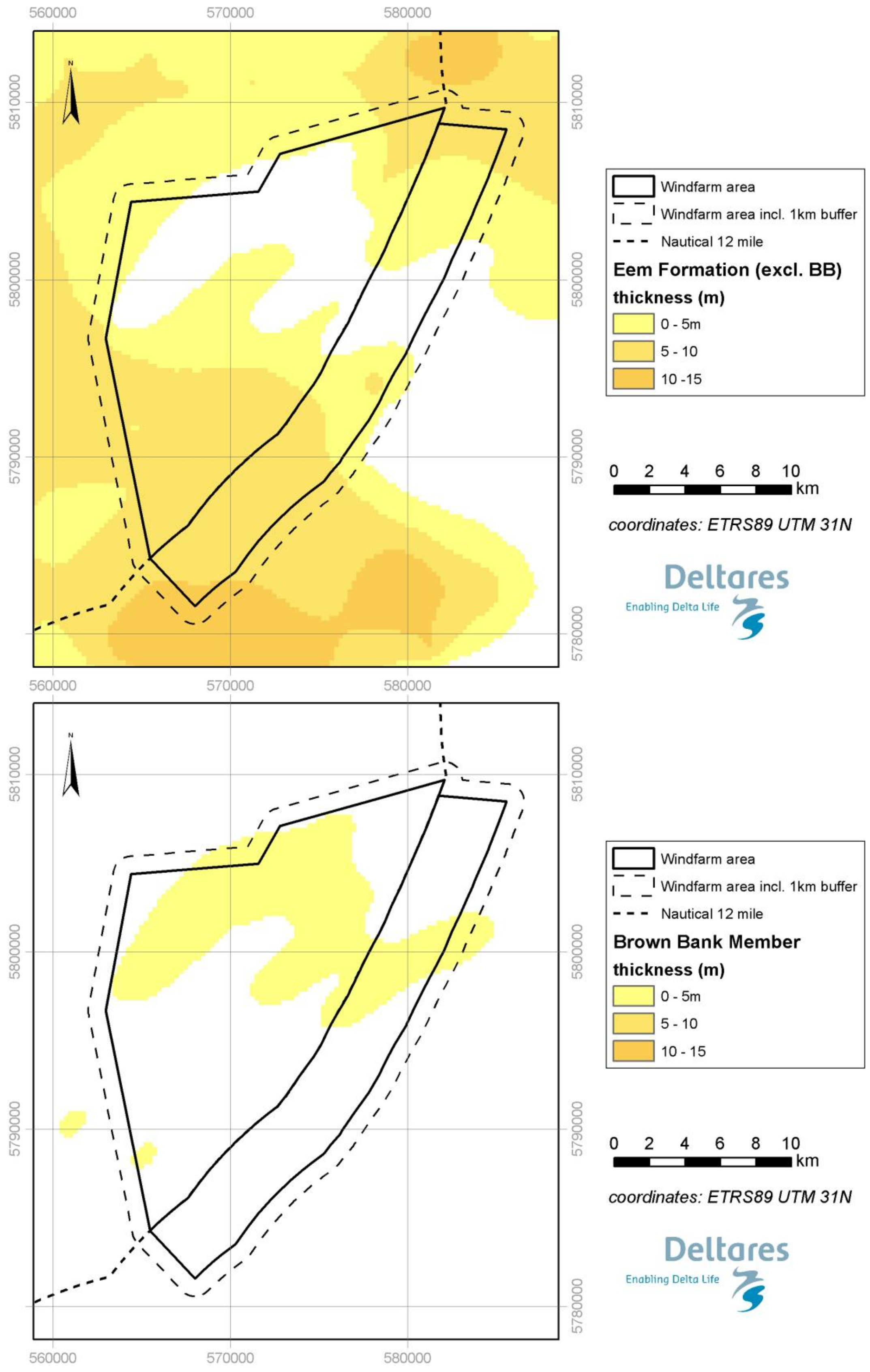

Figure 6.6 Extent of the Eem Formation excluding the Brown Bank Member (upper panel) and the Brown Bank Member of the Eem Formation (lower panel).

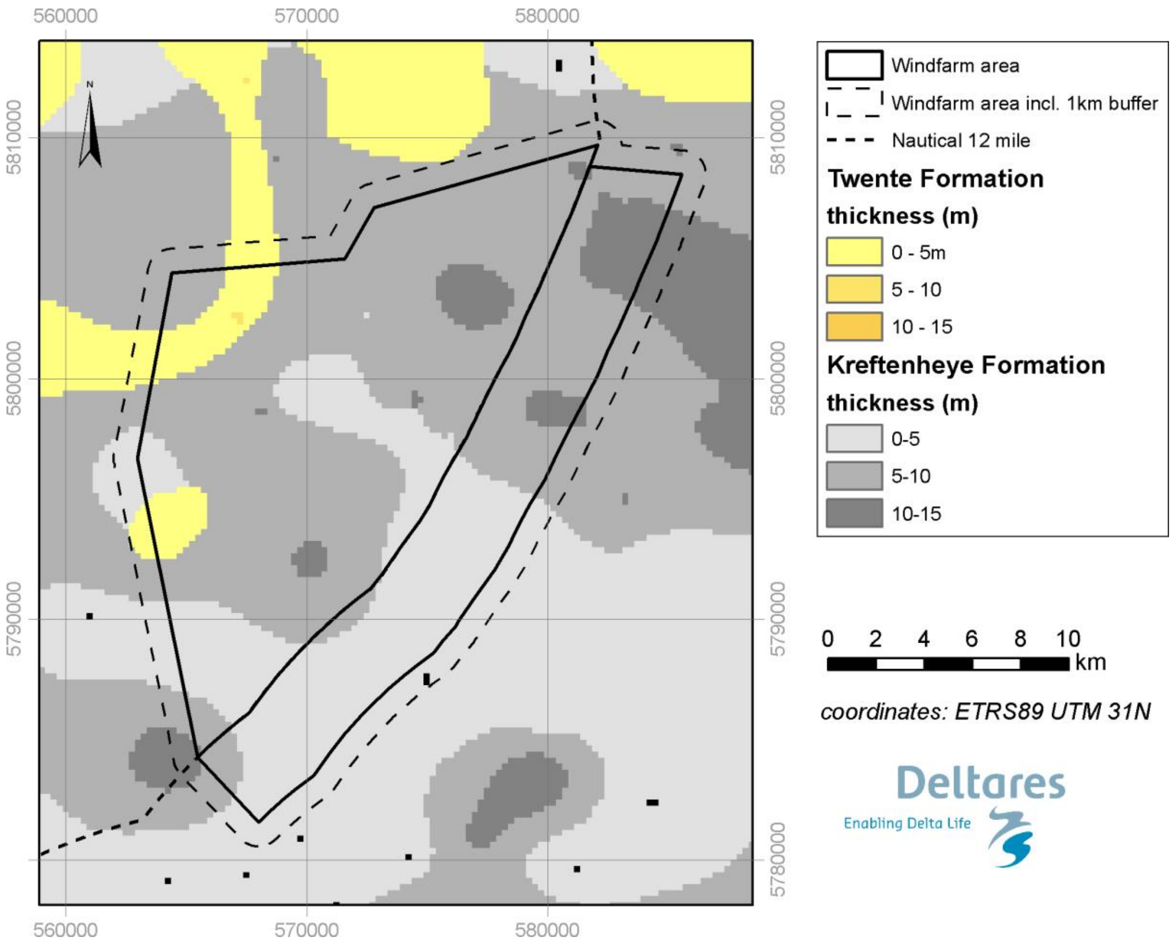

Figure 6.7 Map showing first Pleistocene Formations below the Holocene deposits (subcropmap)

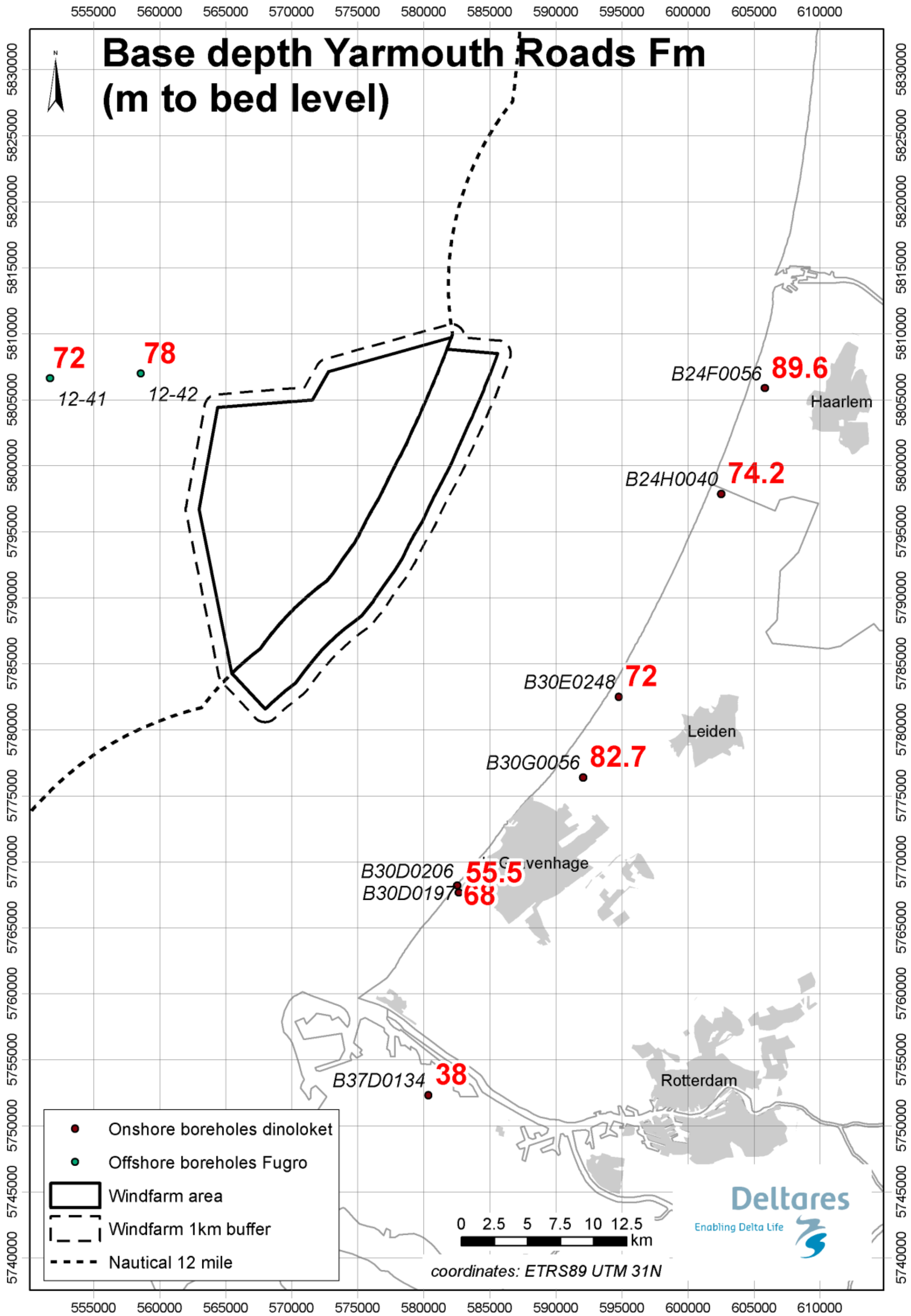

Figure 6.8 Depth of the base of the Yarmouth Roads Formation, relative to the bed level

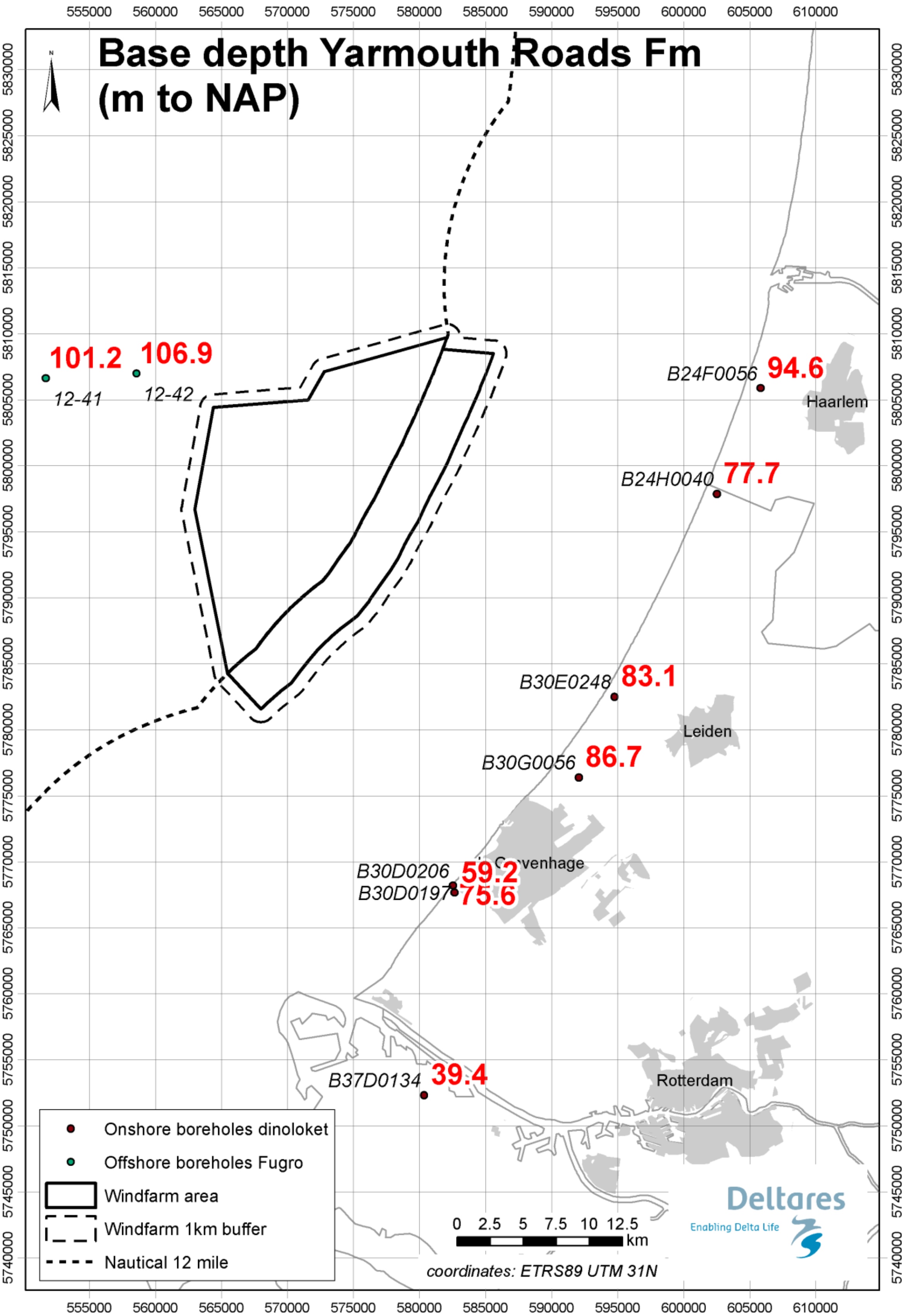

Figure 6.9 Depth of the base of the Yarmouth Roads Formation, relative to the Dutch Ordnance level (NAP)

7 Possible constraints

7.1 Introduction

In this chapter, considerations are given concerning aspects for the design of foundations and structures at or near the seafloor in the study area. The following text is largely taken from Vermaas et al. (2014).

7.2 Morphological characteristics

The morphology of the study area is visible in the recent bathymetry (Figure 2.2). Most of the area was surveyed between 2010 and 2012. The depth varies between -17.1 m and -24.5 m in the 10-12 nautical mile zone and -18.3 m and -26.6 m in the area outside 12 nautical miles, both relative to the Lowest Astronomical Tide (LAT). The average depth is -20.6 m LAT in the 10-12 nautical mile zone and -22.1 m LAT outside the 12 nautical mile. In the study area the LAT level lies between 0.75 and 0.95 m below mean sea level (MSL) due to tidal differences in the North Sea. The northeast side of the study area, close to the 10 nautical miles line, is the shallowest area. The seafloor gradually deepens in offshore direction.

The most important morphological features in the area are sand waves and are present in the entire area. Sand waves are dynamic bed forms with wavelengths in the order of 100-1000 m and heights between trough and crest in the order of several meters (Van Dijk and Kleinhans, 2005). The sand waves present in this area are visible in cross-sections A-B and C-D (Figure 7.1 and Figure 7.2, location indicated in Figure 7.3). Based on these cross-sections an approximate estimate of the dimensions is made. In profile A-B the sand waves have a length of ~700 m (horizontally measured from trough to trough) and are ~2.5 m high (vertically measured from trough to crest). In profile C-D the sand waves have a length of ~500 m (trough to trough) and are ~4 m high (trough-crest). The sand waves seem to become shorter in length and larger in height in offshore direction. The dimensions are similar to the ones reported by Van Santen et al. (2011), who report nearby sand wave fields, with average wavelengths of between 480 m and 720 m.

Smaller bed forms, megaripples, are expected to be present in the area as well but are not visible on the 25 x 25 m resolution rasters. Their migration rates are much higher than those of sand waves, but their small dimension makes them of lower relevance for wind farm development.

Sand waves have a typical migration rate in the order of 1-10 m per year. Van der Meulen et al. (2004) report a migration rate of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 m/year) field near Rotterdam Harbour. Observed migration rates in the Prinses Amalia Wind Park (further north) were recently assessed to be in the order of 4 m/year. In Luchterduinen, which is located in the north of the study area, the sand waves migration rates have been estimated at 2-3 m/year.

A good quantification of the migration rates of sand waves in the area will require more than one high resolution bathymetric measurement in time. Availability of the bathymetric measurements (paragraph 2.1 and Appendix A) shows that there are multiple measurements in this area, however only one with a high resolution.

Sand waves can have a significant influence on the future cable burial depth and need to be taken into account when defining the locations of the cables. Also the pile fixation levels are dependent on the sand wave dynamics. For any foundation design, the bearing capacity may be reduced by the removal of surface load due to the mobility of the surface sediments.

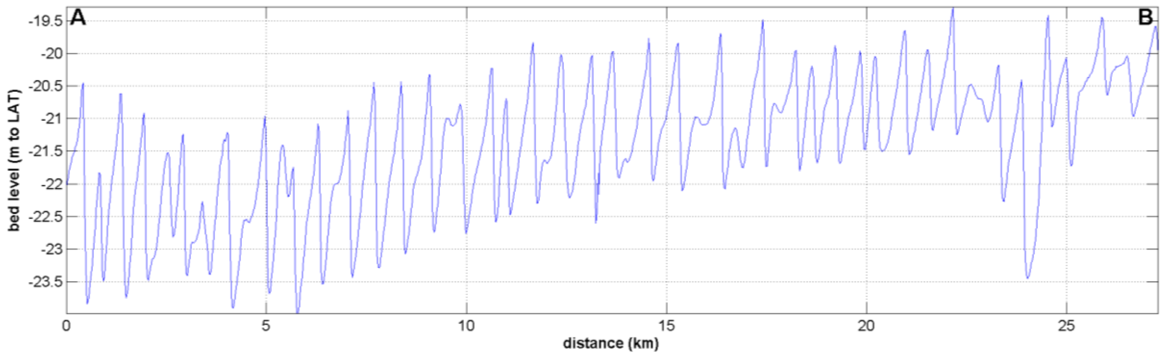

Figure 7.1 Cross-section A-B of the recent bathymetry, showing present sand waves in the western part of the study area

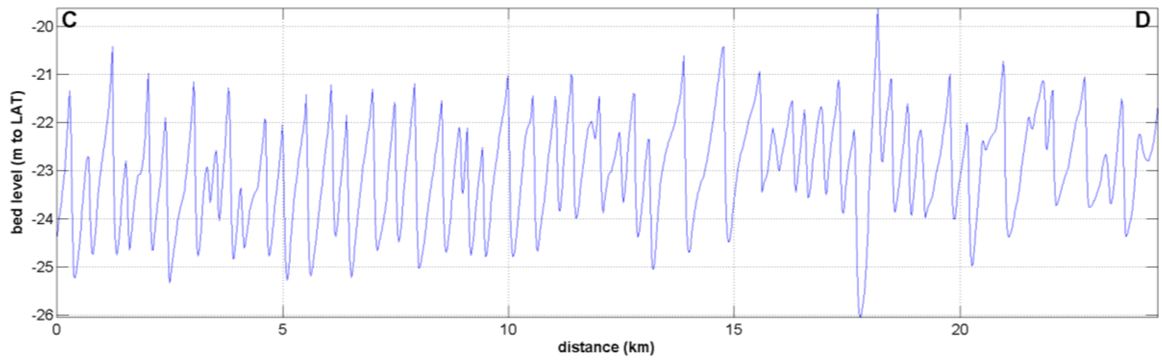

Figure 7.2 Cross-section C-D of the recent bathymetry, showing present sand waves around the 12 nautical mile line

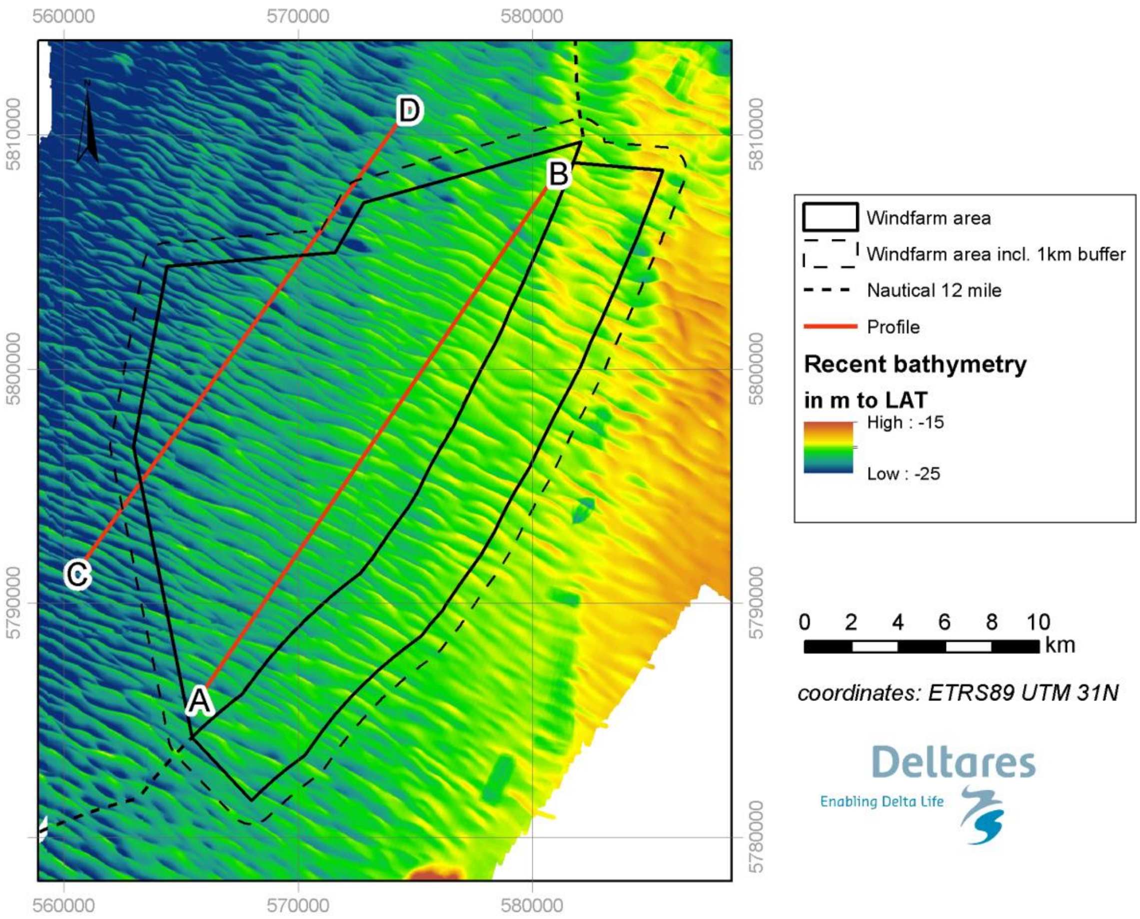

Figure 7.3 Locations of cross-sections A-B and C-D

7.3 Geotechnical characteristics and design recommendations

Given the relatively small water depths, the geology of the area, and experience with neighbouring windfarms, piled foundations can be considered suitable. For the purpose of geotechnical considerations it is assumed here that monopiles will be used, but the remarks and conclusions are valid for any piled foundation type and also penetration depths of skirts. Considering a minimum turbine size of 4 MW, which is the industry standard at the time of this study, and the empirical findings in the region, it is assessed that monopile diameters will typically be in the order of 5 to 7 meters, possibly increasing to 8 to 9 meters for future larger turbine sizes, that might be deployed in the latest developed wind parks in the study area.

For the geotechnical assessment it is assumed that the wind turbines will have a foundation of monopiles, consisting of driven open ended pipe piles with a diameter of about 5 – 7 m diameter extending 30 meters or more below seabed. The actual foundation requirements will determine the dimensioning of the piles.

Cone penetration tests, except for some shallow surveys, are not available in the database of DINO. A summary of geotechnical information as gathered during the mapping of the North Sea is quoted in
Table *7.1*, adopted from the Quaternary Geology Map of the neighbouring Flemish Bight area (BGS and RGD, 1984). Note that the values are not from the study area and may well differ from the actual values.

Table 7.1 Summary of geotechnical parameters of formations encountered in the ZHK- area, based on Quaternary Geology map Flemish Bight (BGS and RGD, 1984), Quaternary Geology map Ostend (BGS,RGD and BGD, 1984) and expert knowledge (for Wormer Member).

Litho and seismo-stratigraphic units	**Lithology**	**Bulk density**	**Cone resistance MN/m^2**
Bligh Bank Member	Fine to medium grained sand	Loose to medium dense	
Wormer Member	Fine sand	Medium dense	
Kreftenheye Formation	Medium to coarse grained sand		32-41 (Flemish Bight) 20-68 (Ostend)
Eem Formation	Fine to coarse grained sand	1900 kg/m^3	31-61 (Ostend)
Yarmouth Roads Formation	Fine to medium · grained sand, with locally clay lamination	1900 kg/m^3	variable
Winterton Shoal Formation	Fine to medium grained sand, with locally clay intercalations	1900 kg/m^3	

Vertical bearing capacity

Whether the effect of the Bligh Bank Member on vertical bearing capacity can (completely or partly) be taken into account depends on the seabed mobility in the design period (large-scale and small-scale morphological processes, such as sand wave migration and scour development. Mobile sands are known to be present in the entire area. Note that the estimated thickness of the Bligh Bank Member (about 5 meter) is only slightly larger than the height of the sand waves, being 2.5 to 4 meters implying that the sand of the member may be completely removed or may accumulate to a meters thick layer in a period of several decades. This removal and deposition of sediment load should be taken into account in the determination of the geostatic load in bearing capacity calculations. A varying bed load should be taken into account in strength requirements of structures on or buried in the sea bed.

Below the Bligh Bank Member the upper ca. 20 meters of the soil profile consists of sands of the Kreftenheye Formation. These Pleistocene sands generally have moderate to high cone resistances (see

Table 7.1).

The Eemian deposits underlying the sand of the Kreftenheye Formation are generally sandy and expected to exhibit a lower cone resistance, than the Kreftenheye sands due to the possible admixture of fines.

Below 20 to 25 meters below the seabed the Yarmouth Roads Formation continues to a depth of approximately 80 meters below seabed. It consists of intermittent layers of fine sand, and silt-rich clay. Below this Formation the Winterton Shoal Formation is present, to well beneath 100 meters below seabed. A high density and higher stiffness of the layers in these formations is expected, attributed to the considerable age of the deposits, which varies from Early to Middle Pleistocene, and due to ice sheet loading. The deposits are expected to show over-consolidation behaviour. Due to the lithology the cone resistances will vary.

A considerable part of the northern study area is expected to have been glacially loaded. The upper layers of the Yarmouth Roads Formation may therefore express very high cone resistances resulting in very dense sand and silt layers. Ice pushed ridges have not been identified on seismic records in the area under consideration. Some deformation of the original layered structure may be expected, but will not have led to a reduction of the strength in comparison to the surrounding area.

The respective sand silt and clay layers have variable thickness. Based on empirical evidence in the area, it is expected that sufficient vertical bearing capacity can be achieved in the Yarmouth Roads Formation.

Lateral bearing capacity
The lateral bearing capacity of the compact sediments of the Yarmouth Roads Formation is expected to be high based on the findings described above. Major variations in lateral bearing capacity are expected to be caused by the presence or absence of the Bligh Bank Member deposits and by the possible presence of soft clay layers in the upper layers of the profile, possibly up to 6 meters below the seabed. The surficial sediments can have a loose consistency and generate a low lateral bearing capacity.

Pile driveability
In the borehole information of the area no indications of very coarse gravel cobbles and boulders associated with boulder clay were encountered. Nevertheless, occurrence of cobbles and boulders cannot be excluded.

Very dense silt and sand layers in the top ca. 10 meter of the Yarmouth Roads Formation may be present, which may adversely affect driveability to the required foundation depth of the piles.

More extensive site investigation (geophysics) to a sufficient depth is required to determine the possible occurrence of boulders.

Earthquake hazard
The last hazard analysis for the southern part of the Netherlands was carried out in 1996. Currently KNMI is performing an update of that hazard analysis, where 260 Events in the Netherlands, Belgium and Germany from 1750 - 2007 are used. The magnitude of the events ranges from 2.5 to 6.0, the depth from 5 - 20 kilometres.

Natural, tectonic seismicity
Following the analyses carried out in 1996, the seismicity in the Netherlands and Belgium and Germany is presented in the figure below.

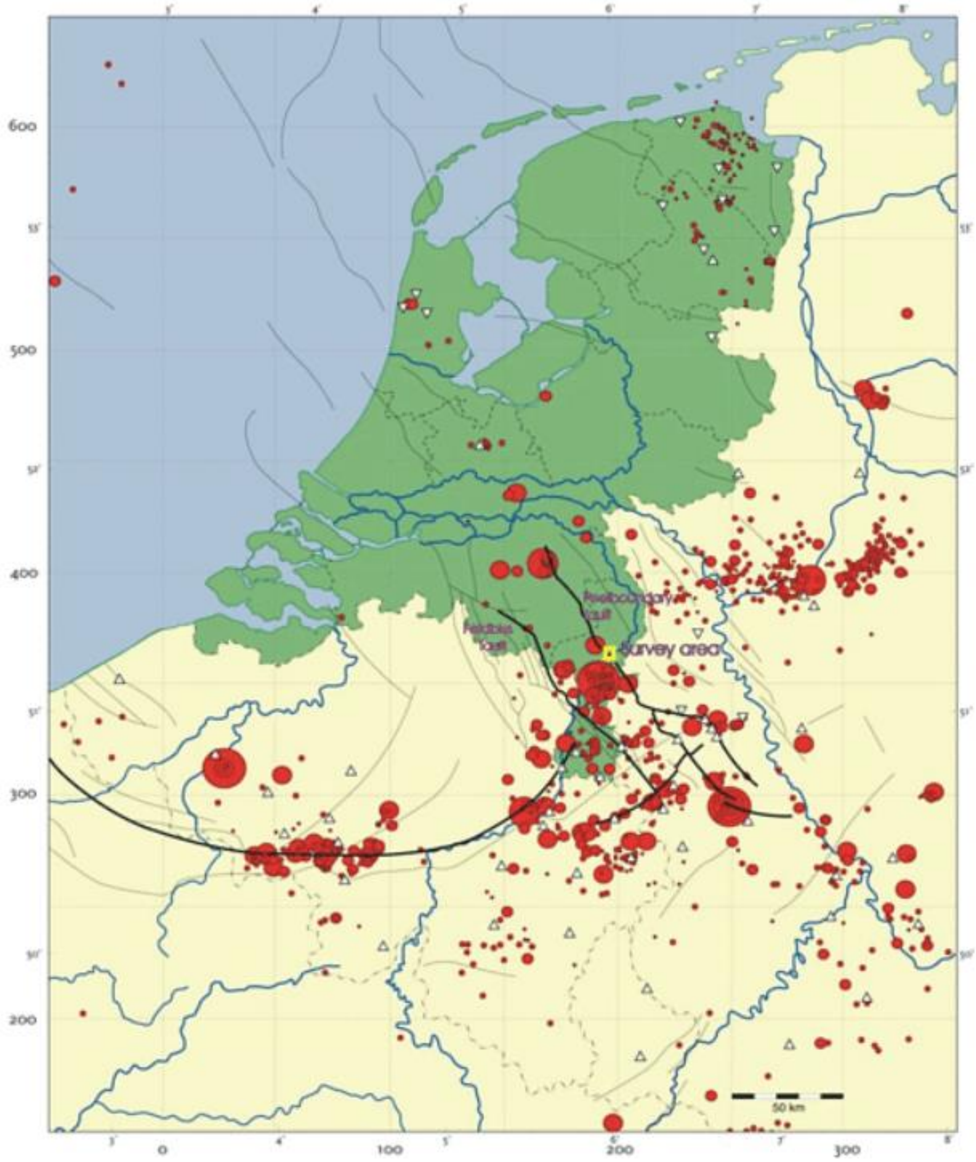

Figure 7.4 Seismicity in The Netherlands between 1900 and 1996 (red circles). (source: www.KNMI.nl)

This figure indicates that natural seismicity is mainly restricted to the Southern part of the Netherlands. The project area lies within the tectonic region known as the West Netherlands Basin. This area is considered seismically quiet and no active faults have been recognised in the Neogene and Quaternary sediment column (Worum, 2005).

The earthquake hazard was calculated from this historical earthquake catalogue. Figure 7.5 shows the seismic hazard in the Netherlands by tectonic earthquakes with a return period of 475 years. This implies that in the red areas intensity VII can be reached ones every 475 years, or with a probability of 10% in 50 years. For the areas with intensity lower than V, there are not enough data to specify in more detail. The hazard due to induced earthquakes by gas extraction is not included in this map. The intensities are according to the European Macroseismic Scale (EMS). Figure 7.6 presents the same data as Peak Ground Acceleration (PGA).

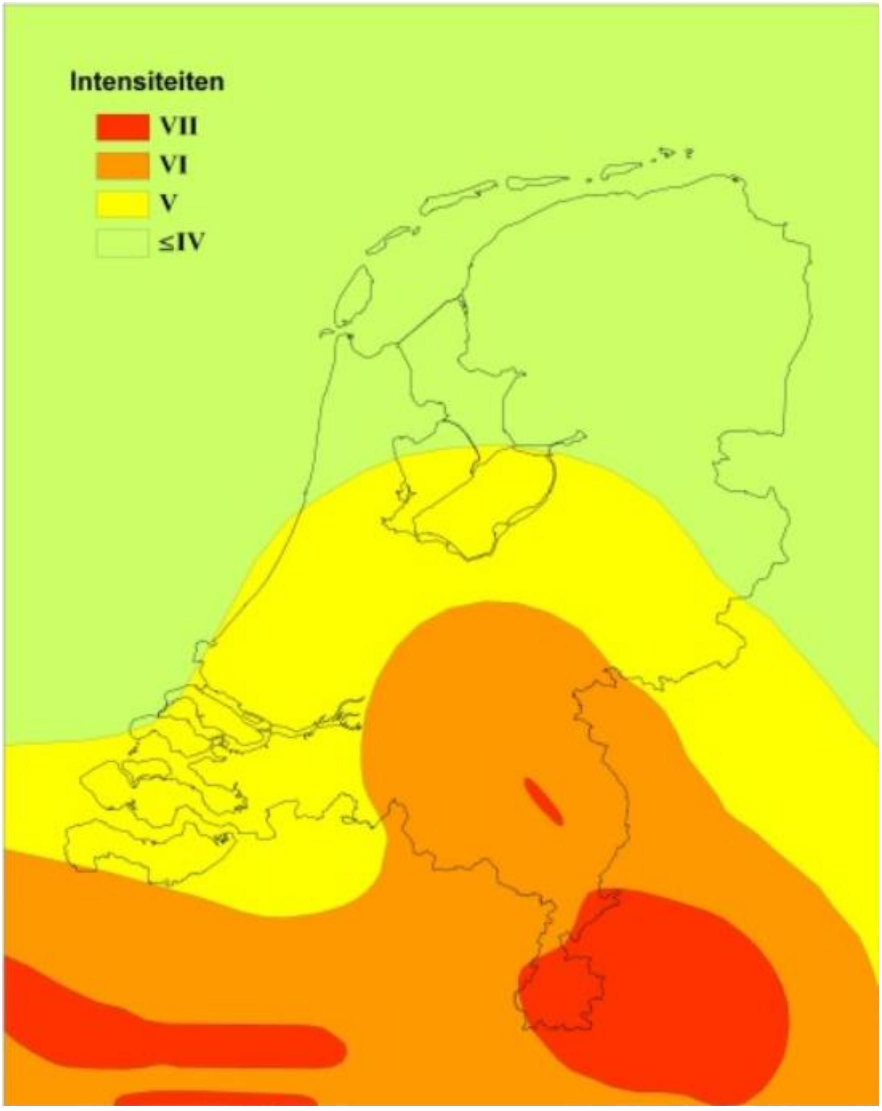

Figure 7.5 Results from Crook, 1996. The study is performed using intensities to determine the seismic hazard, and afterwards the intensities are translated to peak ground accelerations.

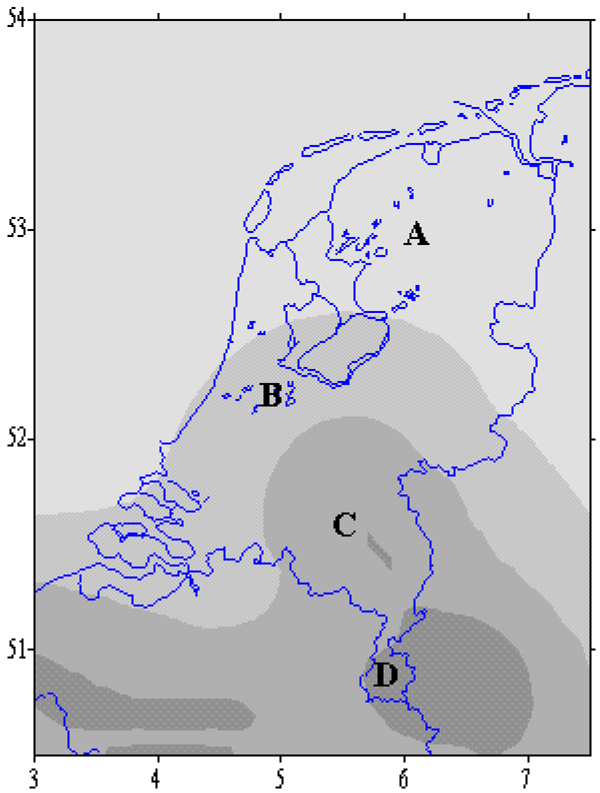

Figure 7.6 Seismic zones in the Netherlands and adjacent North Sea. In this map a zonation is applied based on the expected horizontal Peak Ground Acceleration (PGA). PGA for zones A, B, C and D are 0.1, 0.22, 0.5 and 1 m/s^2 respectively. It is assumed that at the ground surface/sea bottom the horizontal component of the movement is the greatest. Source: de Crook, 1996.

In recent years similar maps have been made for the British and Belgian sectors of the North Sea (Figure 7.7). Based on archive research it was concluded that historical earthquakes of magnitudes up to M=6 in the adjacent area of the English Channel could be deduced from the historical documents. Incorporation of these earthquakes in the calculation of the seismic hazard map contours of North Western Europe has produced a higher value of PGA, when extrapolated onto the offshore area (Grünthal et al. 1999, Figure 7.8). The map shows that in the area offshore Hoek van Holland a PGA with a probability of 10% in 50 years may be expected in the order of 0.2-0.3 m/s2. The PGA contours were adjusted in 2003 (Jiménez et al, 2003) using up-to-date ground motion prediction equations. This resulted in generally lower PGA values. The given values may therefore be considered as conservative estimates.
It should be noted that these values apply to stiff upper ground conditions. When soft layers, like Holocene clays or peats are encountered at foundation locations the amplitudes may be amplified. In that case adjusted PGA values should be derived using procedures described in Eurocode 8 (CEN, 2004-2006).

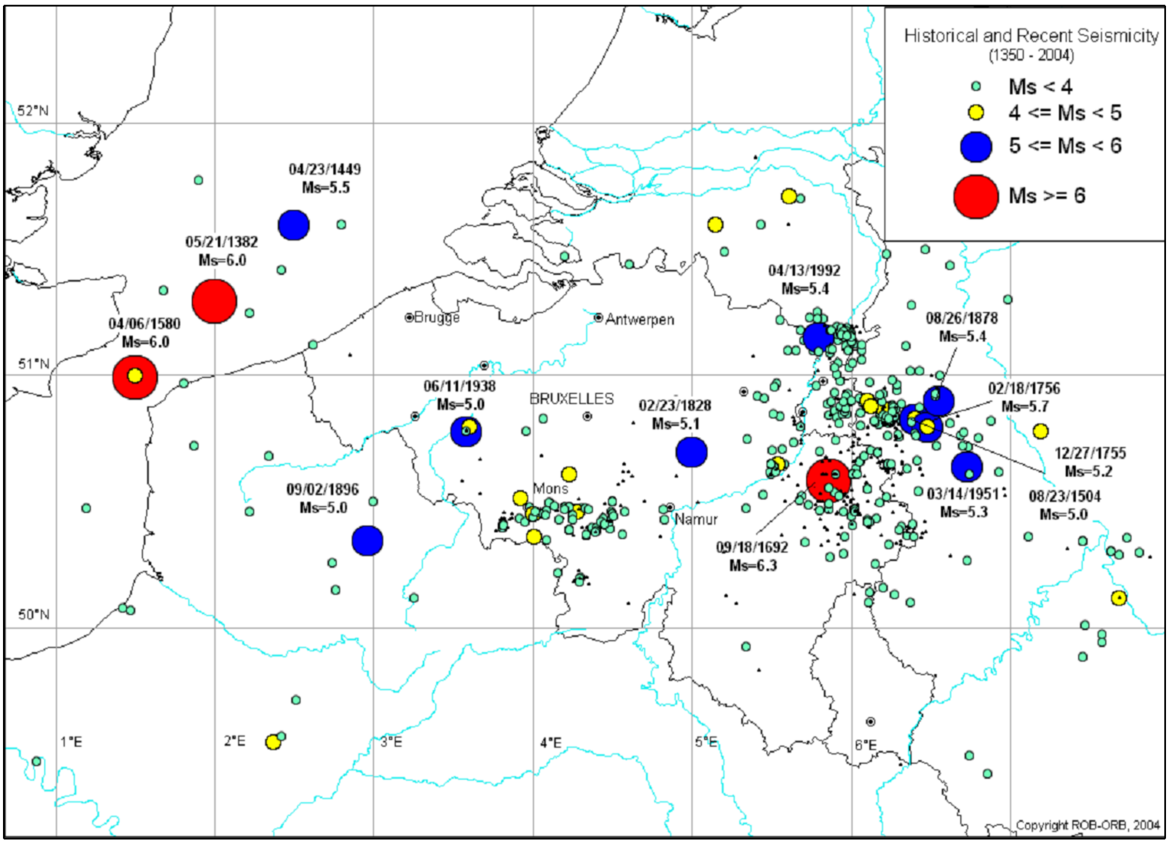

Figure 7.7 Catalog of historical and recent earthquake. Epicenter and Magnitude of the earthquakes are indicated [Rosset, 2005].

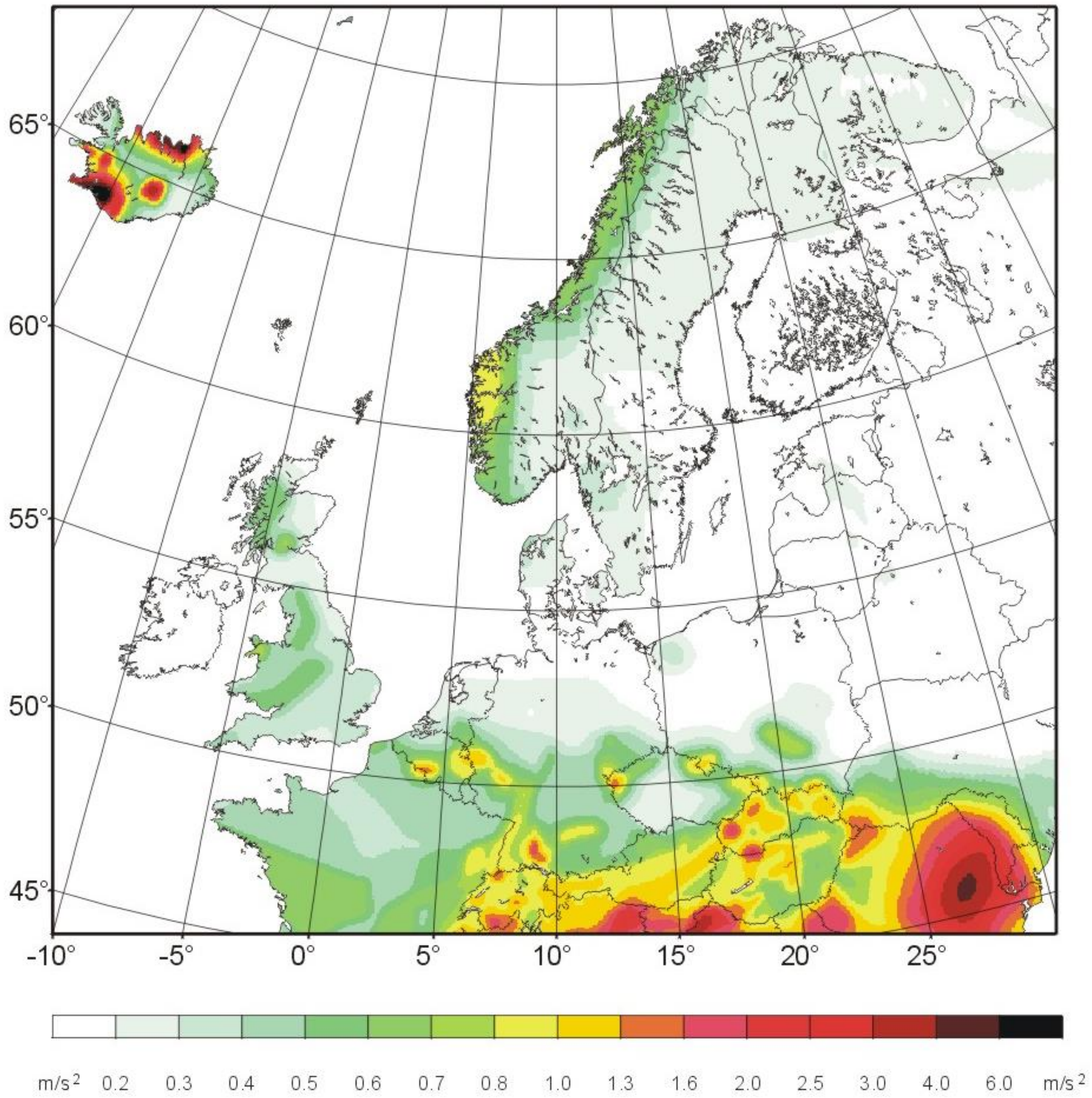

Figure 7.8 Horizontal peak ground acceleration seismic hazard map representing stiff site conditions for an exceedance or occurrence rate of 10% within 50 years for the GSHAP Region 3 (Grünthal et al, 1999)

Induced seismicity

The extraction of natural gas is known to produce induced earthquakes. The area lies in an area of existing oil and gas exploration (Figure 7.9). There are no known records of induced seismicity for these fields above the detection threshold of magnitude 1.5 to 2 (Dost et al., 2012). For neighbouring on- and nearshore fields, which also have not shown induced seismicity this hazard is considered to be very low to negligible (TNO report 2012 R10198), However, a seismic hazard study comparable to studies required for on- and nearshore fields has not been performed. It is recommended that a deterministic seismic hazard analysis is performed for the gas fields that are within a 5 km radius of the project area according to the TNO report (Deterministische hazard analyse voor geinduceerde seismiciteit in Nederland (TNO-rapport 2012 R10198, 25 juni 2012) to confirm the actual seismic hazard.

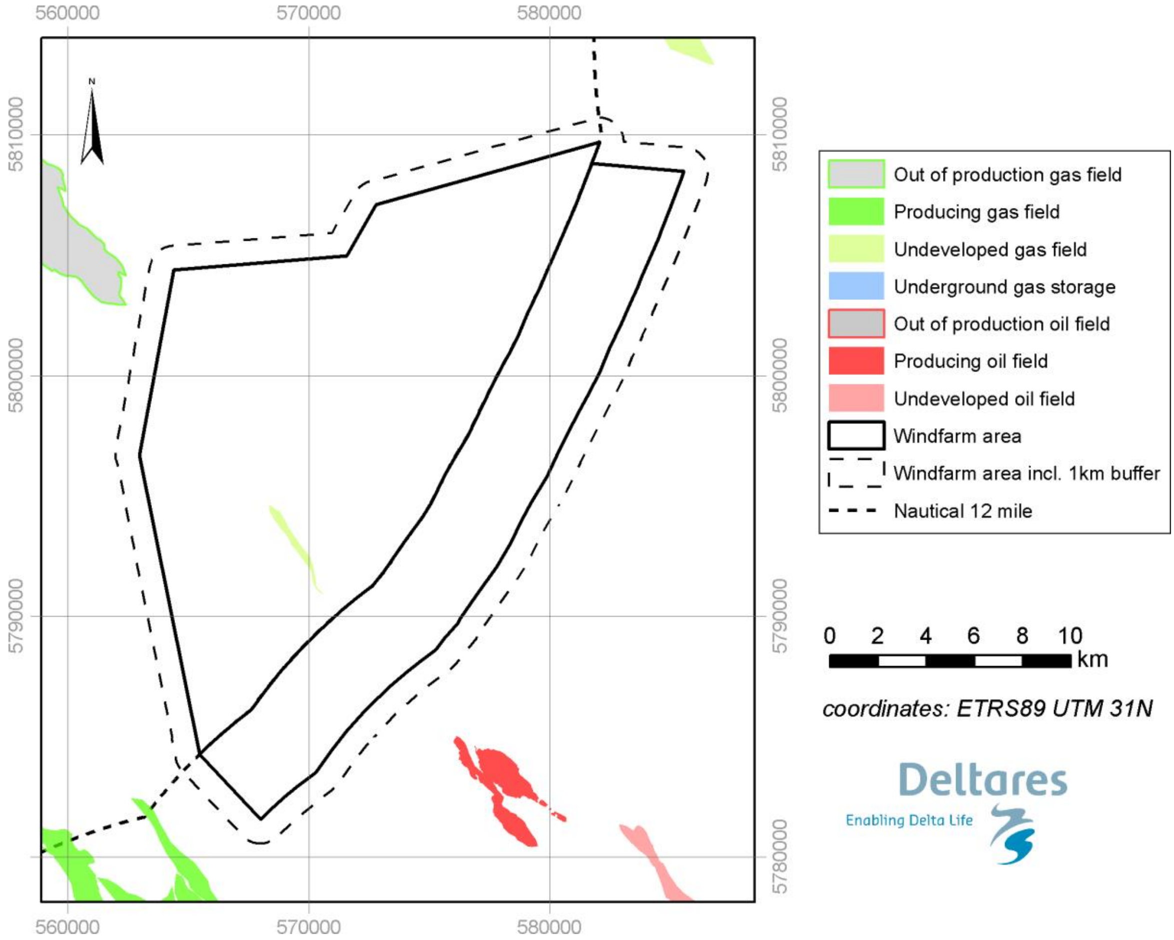

Figure 7.9 Locations of oil and gas fields in the project area (source national oil and gas portal www.nlog.nl)

Shallow gas pockets

In seismic sections, blurred zones are locally encountered at different depths in the present sections. Also a pock mark was discovered in the mouth of the Maas river just offshore Hoek van Holland (Brouwer & Laban, 2005; Figure 7.10 to Figure 7.12). This indicates that sediments with shallow gas are present in the area. The gas is mainly trapped in or under cohesive layers. These are patches and can have dimensions of several tens of metres. The geotechnical effect is a weakening of cohesive layers. Instances have been reported elsewhere and on the adjacent land area that during penetration of clay layers trapped gas escaped to the surface and caught fire. This hazard, which can also compromise buoyancy of vessels, should be carefully investigated on recorded seismic sections. Designated areas should be avoided if possible.

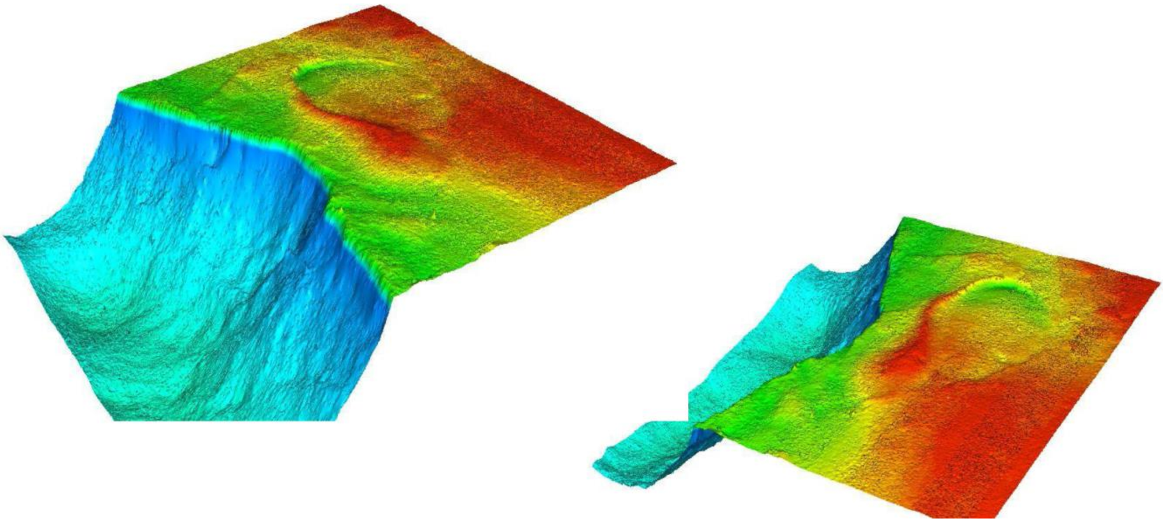

Figure 7.10 Bathymetric (multibeam) survey of pockmark structure next to the 72 feet deep Euro-Maas shipping route, no scale was presented in the source (Brouwer and Laban, 2005)

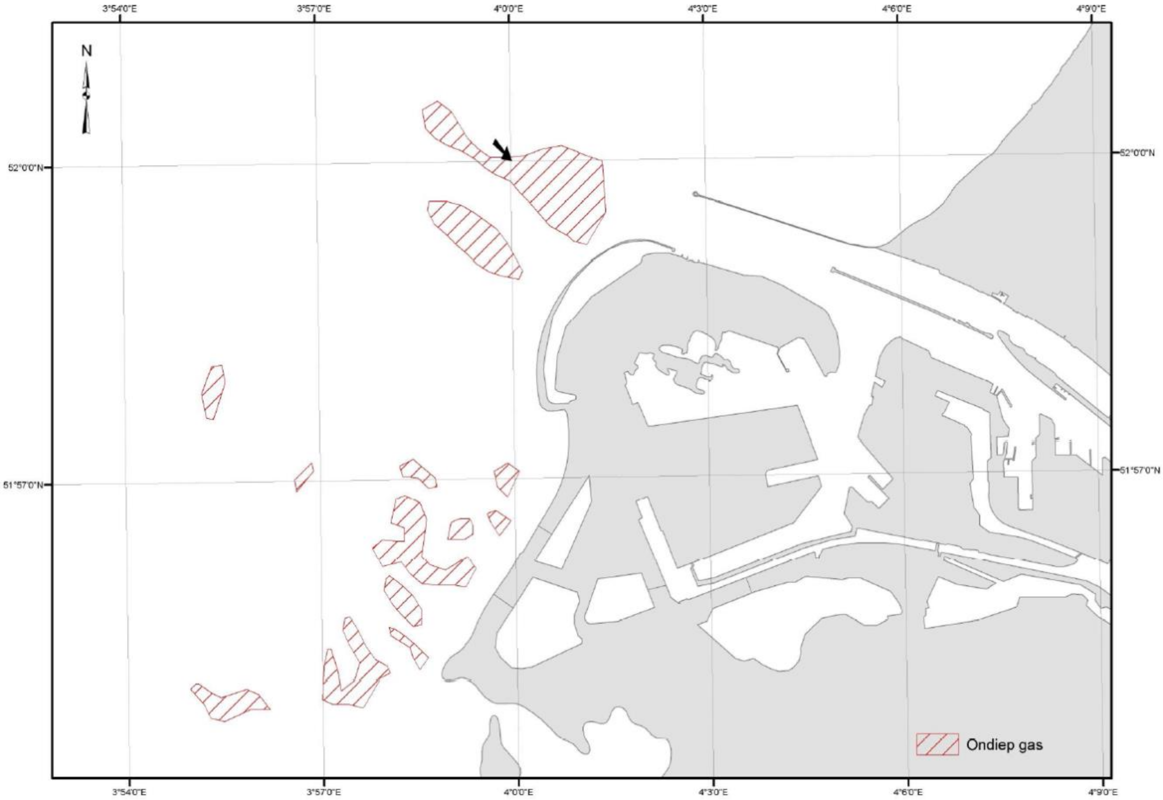

Figure 7.11 Indication of areas where shallow gas is observed in seismic surveys. Arrow indicates location of pockmarks of Figure 7.10. Source: Brouwer and Laban, 2005

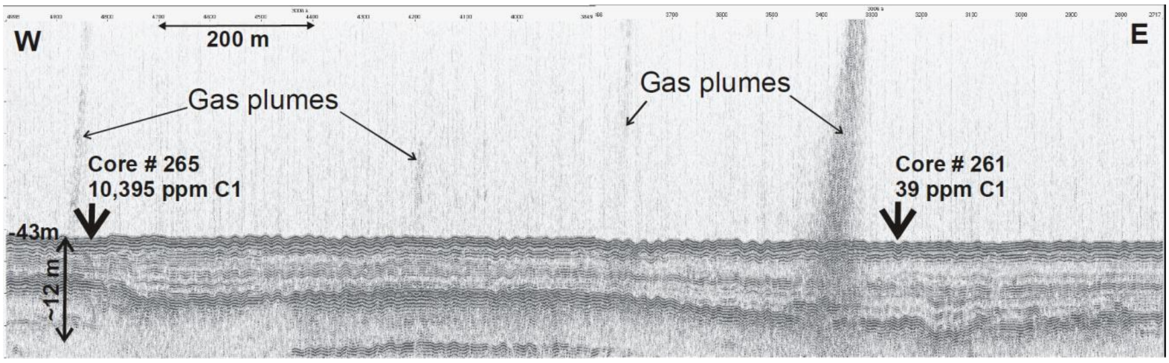

Figure 7.12 Gas plumes visible on seismic survey and two measurements of gas concentration in the subsurface in the Northern part of the Dutch Continental Shelf. Source: Brouwer and Laban, 2005

8 Conclusions

Based on a selection of the most recent data from a set of 17 bathymetrical surveys, a map of recent bathymetry has been created. The subsurface information that is currently available within the study area are single channel and multichannel seismic survey data, and a total of 204 boreholes, of which most have a maximum depth of 5 meters below the sea floor. Several hundreds of core descriptions in the vicinity of the study area are also available. Furthermore, three deep boreholes carried out by Fugro at approximately 6 to 20 km from the study area provide insight in lithology at depths of up to 80 meters below the sea floor. At least 408 km of seismic survey lines are available in the study area, the length of which is equally divided between single channel and multichannel data. No cone penetration tests are publicly available in the study area. Data coverage is similar in the 10 to 12 nautical mile zone (West) as outside the 12 nautical miles (East) of the study area.

The available seismic surveys in and nearby the study area provide good coverage, however the data are not very suitable for the depth range of interest for this study, i.e. 0 to 100 meters below the sea floor. The multi-channel data are suitable to analyse the larger scale geology up to a depth of 500-1000 meter below the sea floor, but have a vertical resolution too low for more detailed analyses for the purpose of this study. Single channel data have higher vertical resolution, but only cover the first 10-15 meter which consists for a large part of uniform geology (sandy deposits of the Southern Bight Formation, Bligh Bank Member).

The subsurface consists mainly of sands for the first 20-25 m, with some local, thin clay layers (normally 2 to 20 cm thick, occasionally reaching 3 m thickness). Based on the characteristics of the geological units, very deep incised channels filled with soft sediments are not likely to be present in the area. The deeper part (25-180 m depth) is expected to consist of fine sands and silt-rich clays, but no boreholes are present in the area that penetrate this depth range. In the northern part of the study area land ice is expected to have been present during the Saalien ice age. Here in the subsurface overconsolidated layers can be present due to preloading and other (peri) glacial processes. Therefore, stiffer layers and possibly glacial till and (large) stones can be present in the northern area. The geology in the 10 to 12 nautical mile zone (West) and outside the 12 nautical miles (East) appears to be similar.

The most complete and recent framework is that of Rijsdijk et al. (2005), which is to be the most appropriate for the study area. However, for the older Pleistocene Formations, it is proposed to use the older names Yarmouth Roads Formation and Winterton Shoal Formation.

In the entire study area, both landward and seaward of the 12 nautical mile line, no major constraints to develop a wind farm have been encountered in this study. Smaller or unknown possible constraints are the following:

- The presence of consolidated layers, glacial till and stones in the northern part of the area a result of coverage of land ice during the past may adversely affect driveability of the piles.
- Presence of shallow gas has been observed south of the study area, but has not been reported in the study area itself. This hazard, which can also compromise buoyancy of vessels, should be carefully investigated. Areas where shallow gas is present should be avoided, if possible.

- The area is in an area of low natural earthquake hazard. The hazard of induced earthquakes of gas field in the area is not known. It is recommended to perform a deterministic seismic hazard analysis according to TNO-report 2012 R10198.

In order to fully assess the geological setting of the study area for the use as a wind farm zone, we would recommend to perform an additional seismic survey in the area.

Removal of the 10-12 nautical mile zone will not result in other conclusions than presented in this report.

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A Bathymetrical surveys

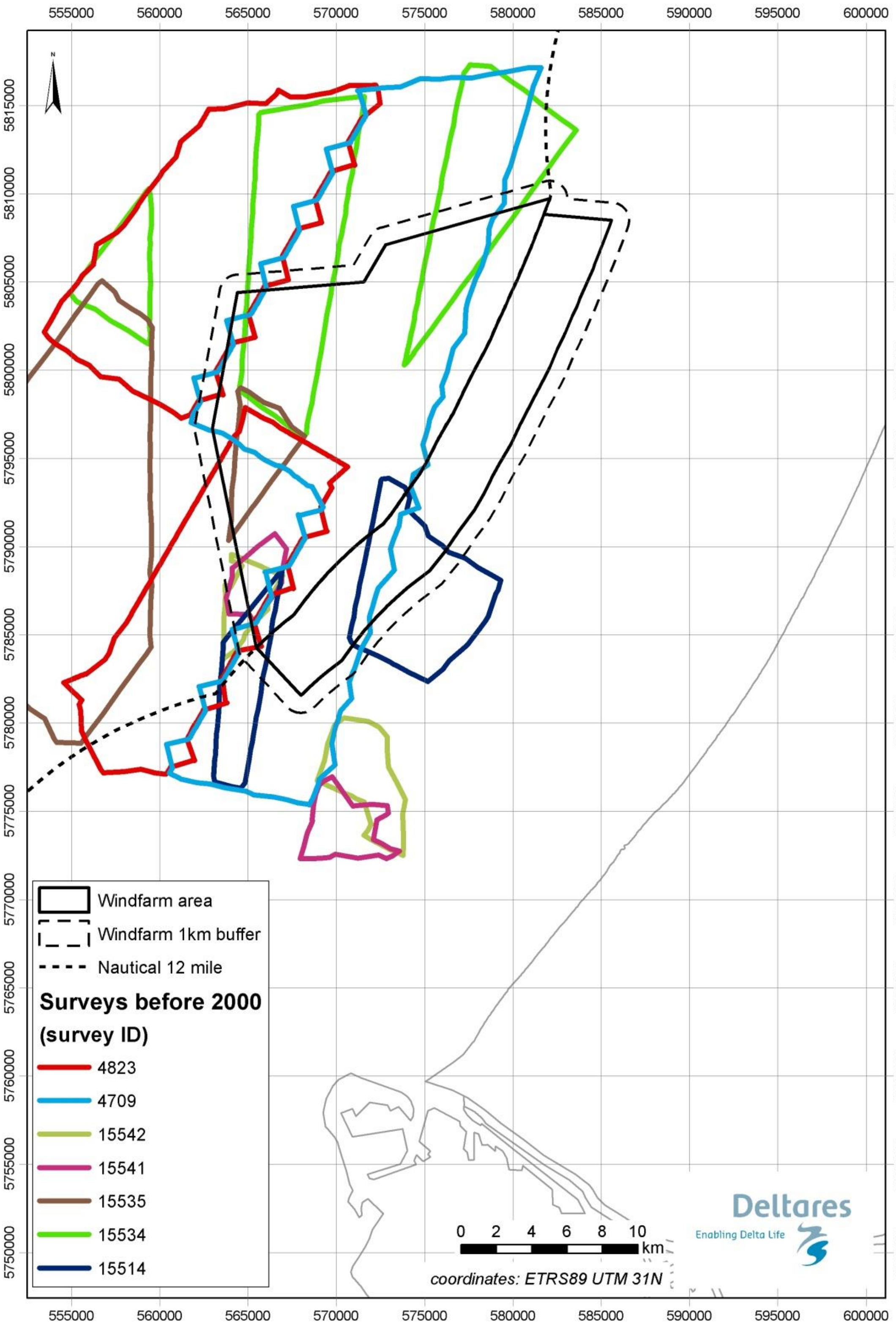


Figure A.A.1 *Bathymetrical surveys carried out before 2000.*

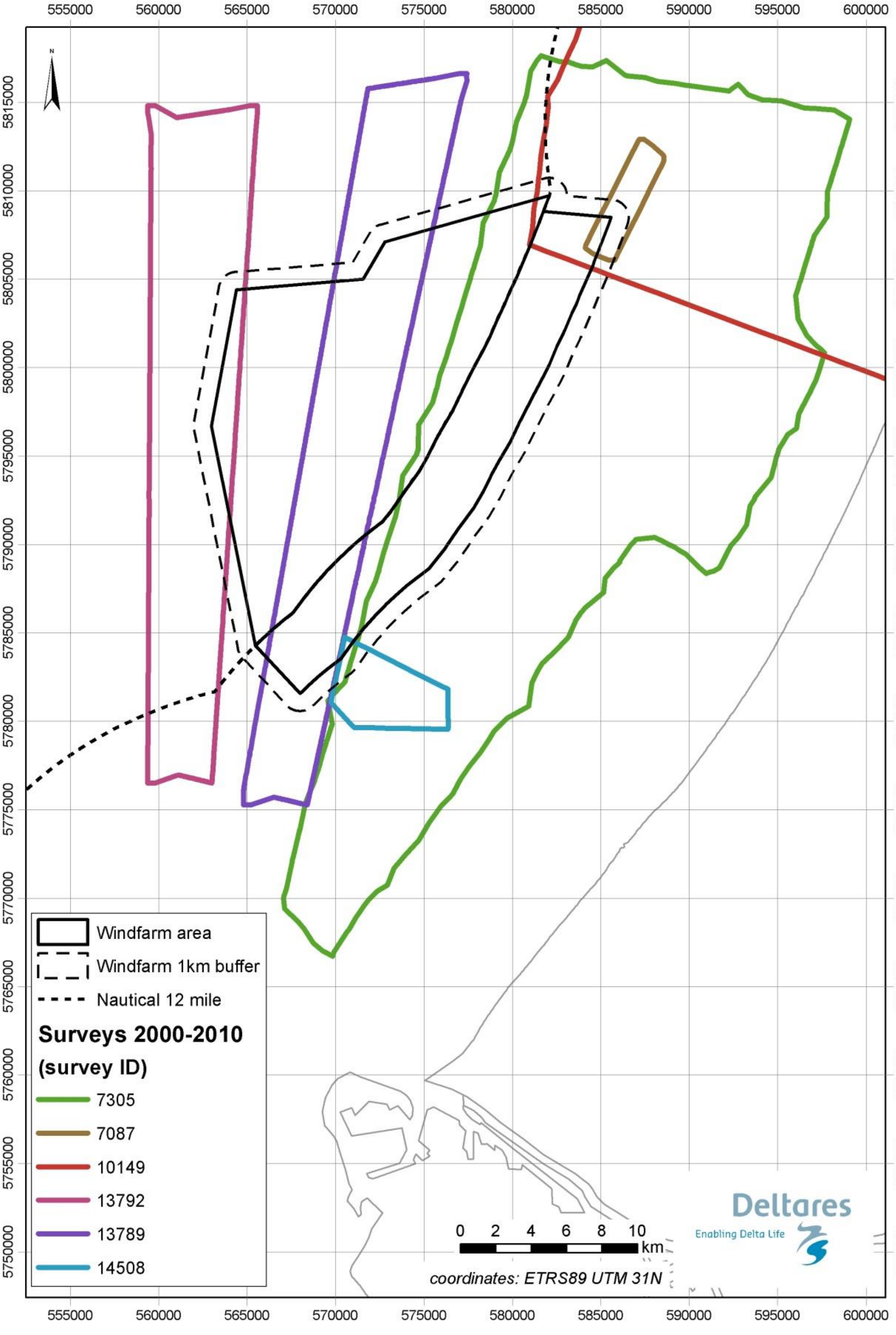


Figure A.A.2 Bathymetrical surveys carried out between 2000 and 2010.

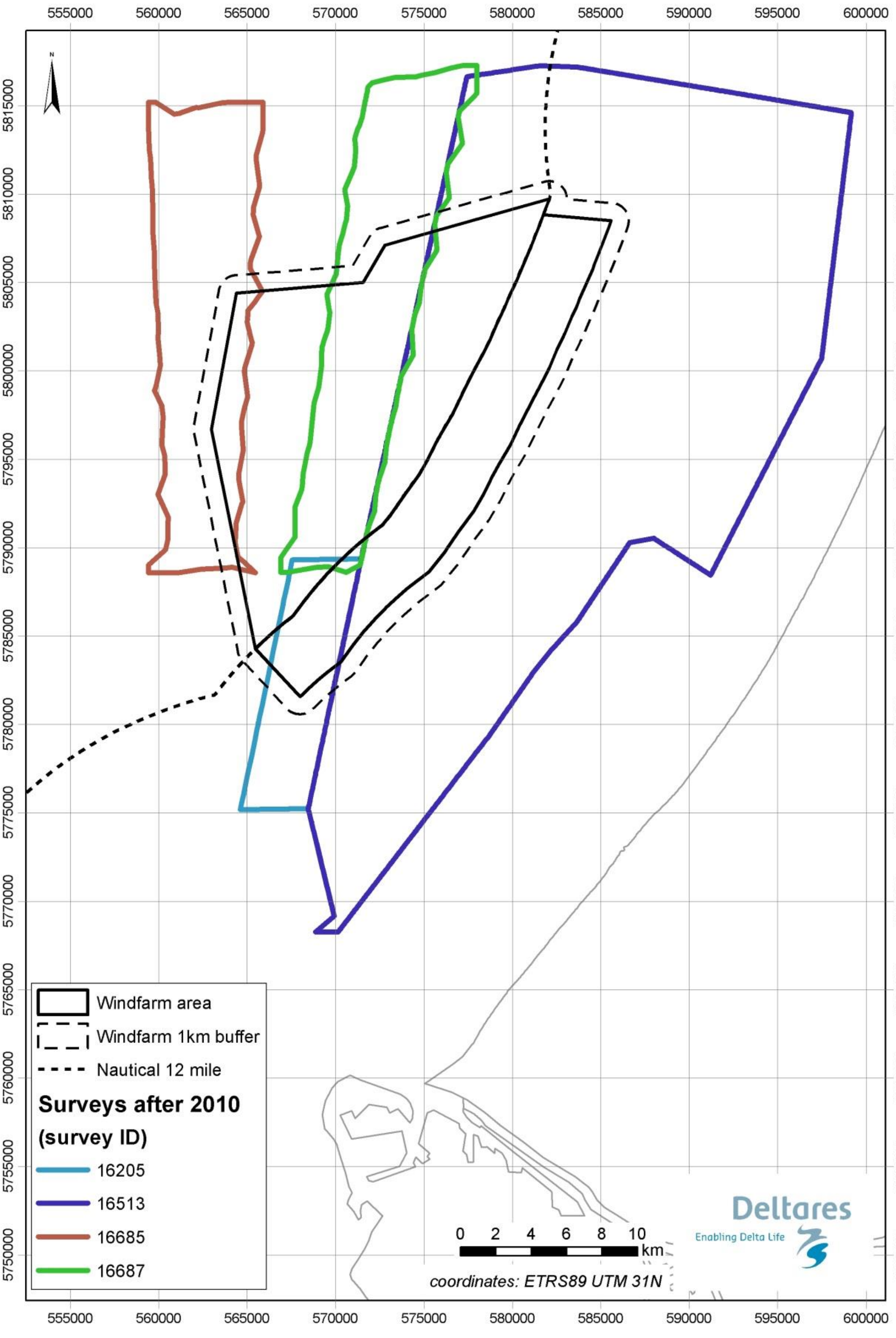


Figure A.A.3 *Bathymetrical surveys carried out after 2010.*

B DINOloket data

Figure 8.1

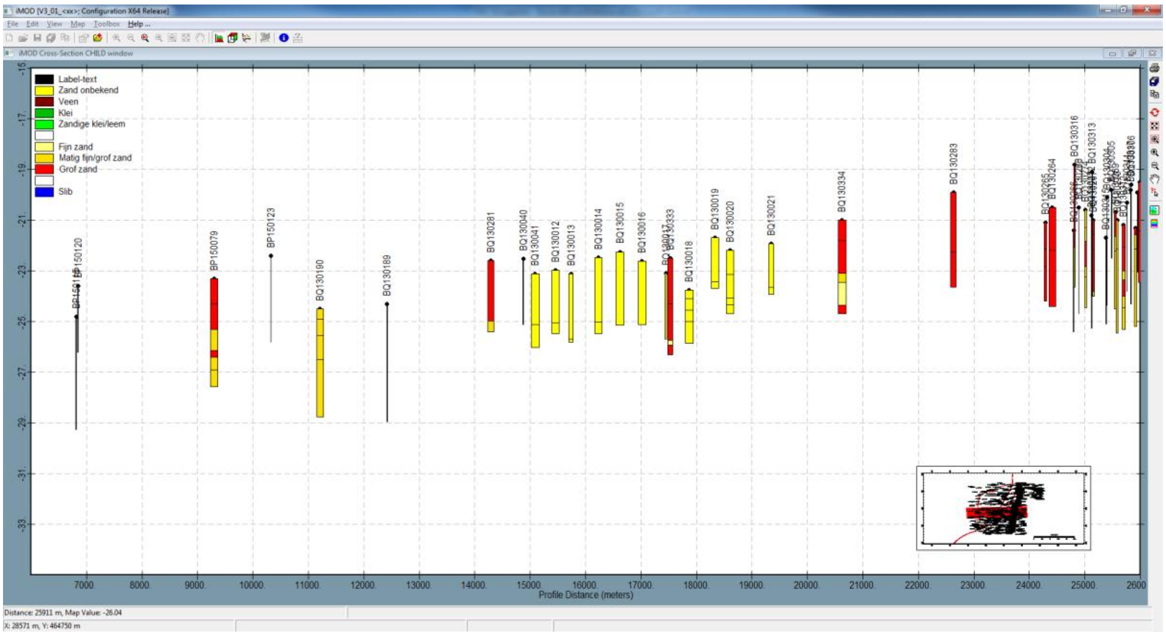


Figure 8.2

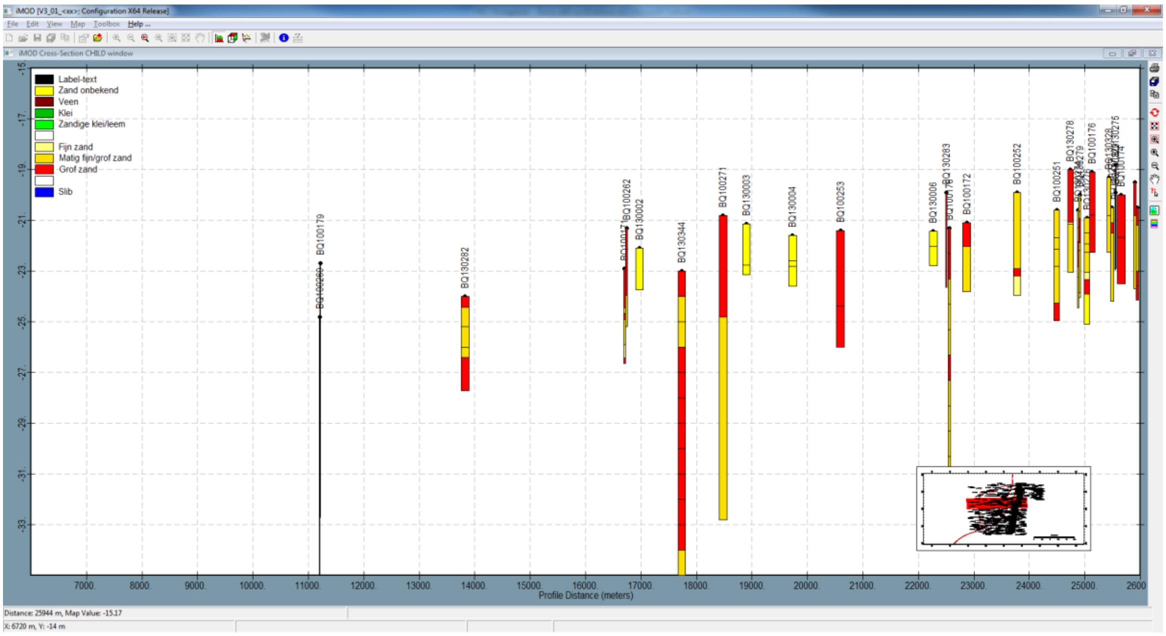


Figure 8.3

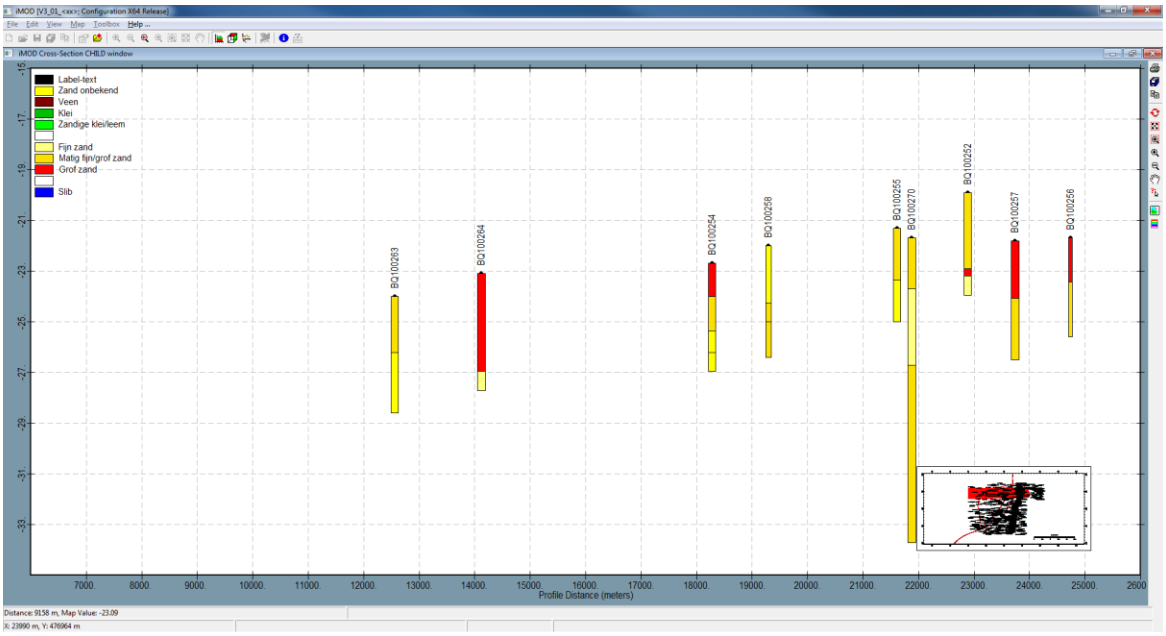


Figure 8.4

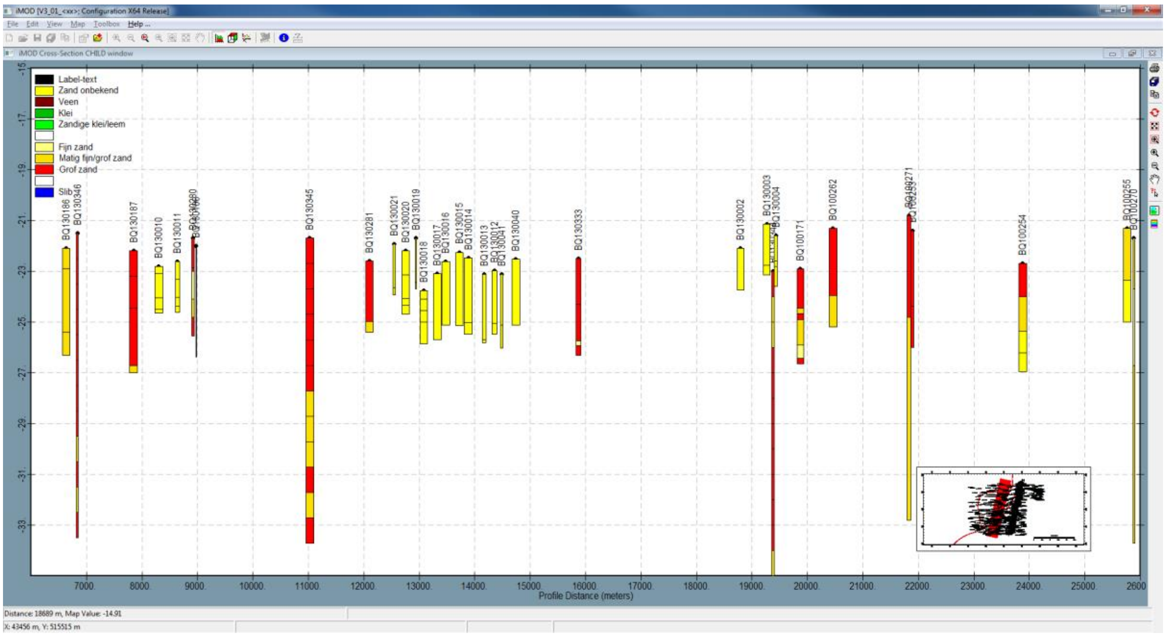


Figure 8.5

Figure 8.6

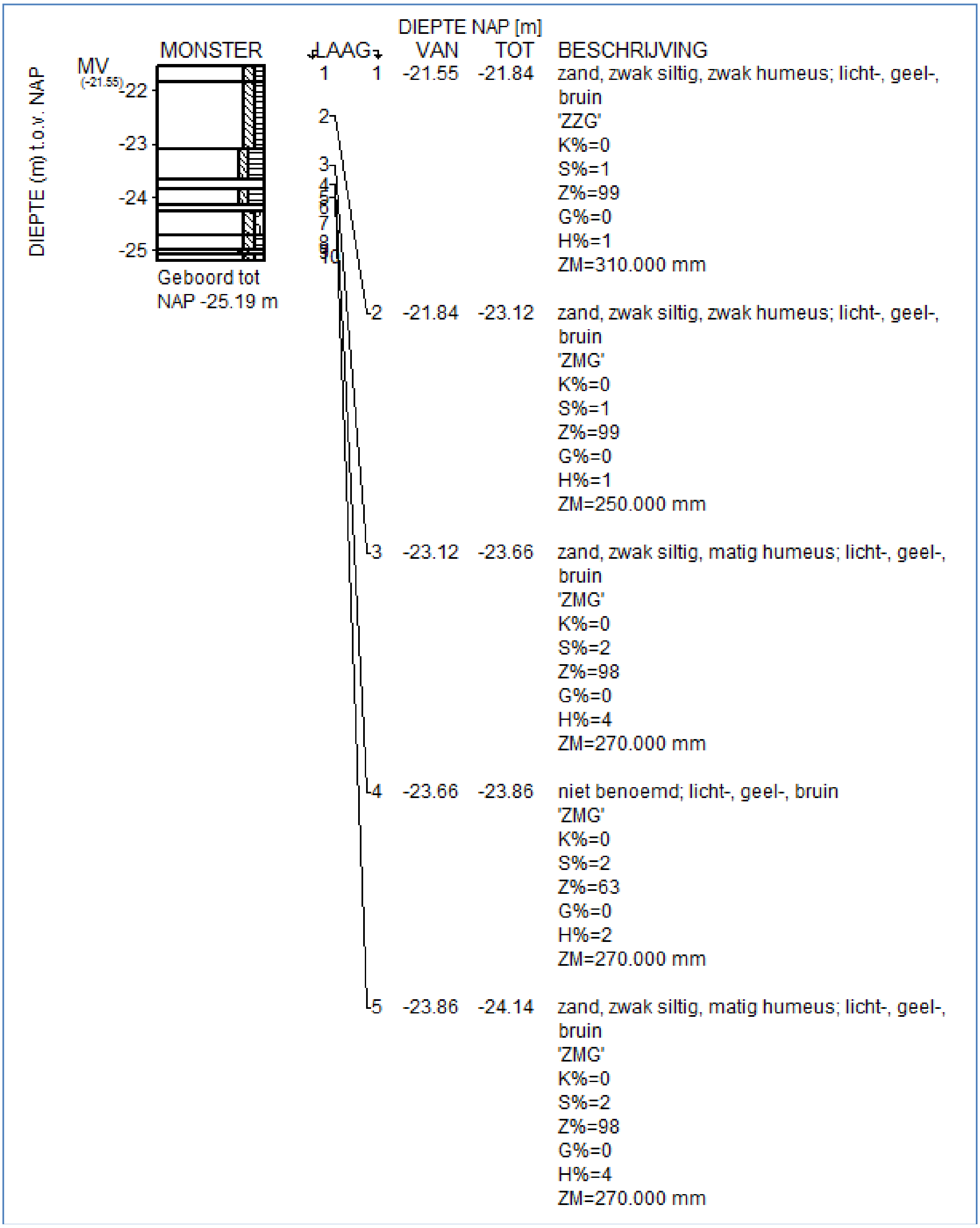


Figure 8.7 Example of a shallow core, described in high detail at cm-resolution (BQ100791).

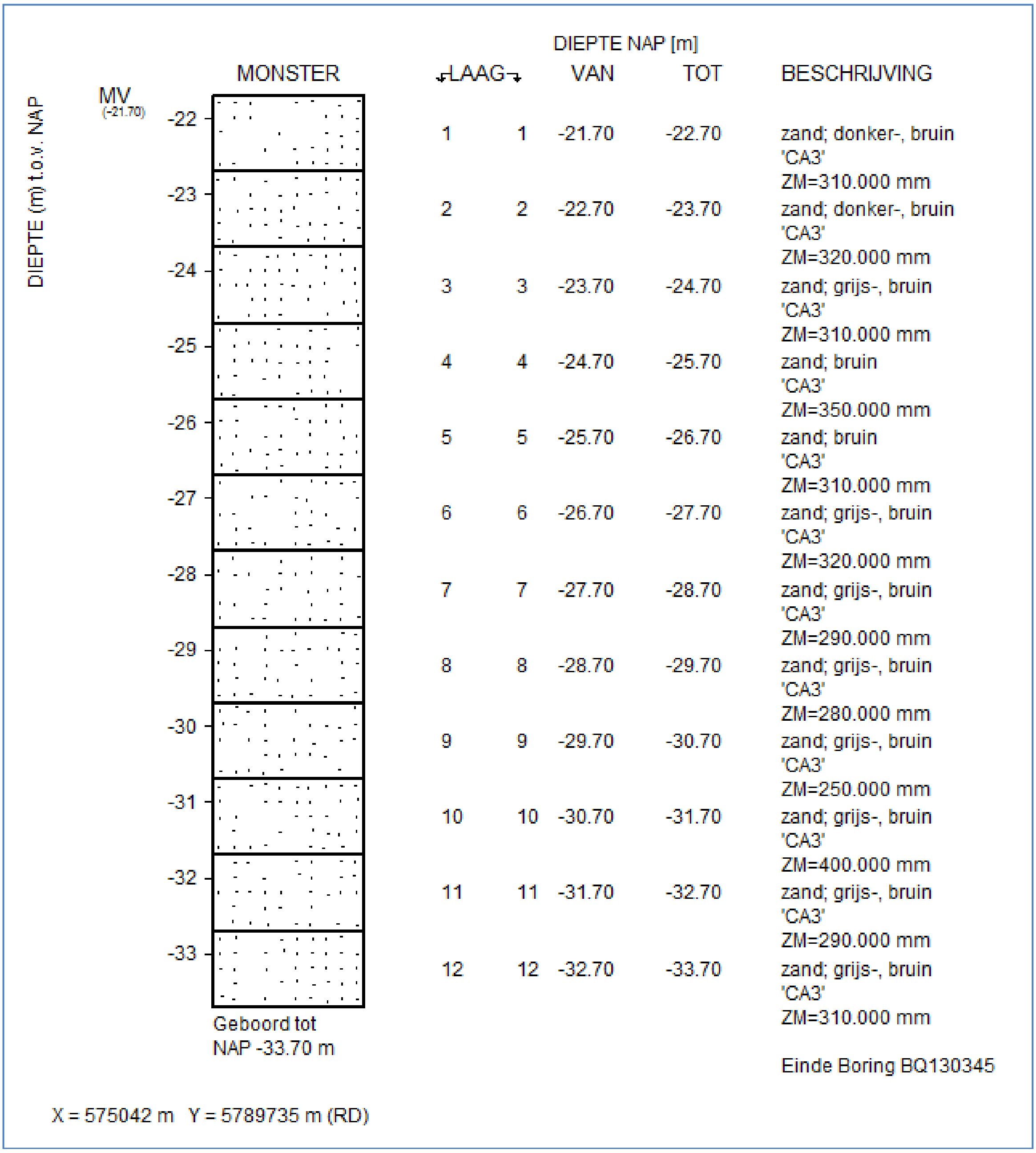


Figure 8.8 Example of a deep core, described in low detail at a resolution of 1 meter (BQ130345).

C Deep cores

Bouw en Ondergrond

KAARTBLAD	P12
BORING	41
COORDINATEN	52 24 26.4
	3 45 36.8

UITVOERING	FUGRO	UTM COORDINATEN	5806.739 N /	551.716 E
WERKNUMMER	N2694/02	ANDERE COORDINATEN		
ONDERZ./PROJECTNR	B2			
DATUM	17- 7- 1989			
WERKWIJZE		EINDDIEPTE	81.00	meter
LOCATIE		GEMETEN WATERDIEPTE	0.00	meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	29.15	m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	G CA
	0.00-4.30	ZAND MATIG GROF T/M ZEER GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2 ENKELE SCHELPFRAGMENTEN ENKELE GRINDJES	210-420							
	4.30-9.00	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS HUE 5Y 5/1 ENKELE SCHELPFRAGMENTEN	210-420							
	9.00-11.10	KLEI , ZEER SILTIG, ENIGZINS ZANDIG, ZEER STUG TOT HARD KLEUR: DONKERGROEN HUE 5GY 4/1 SPOOR ORGANISCH MATERIAAL GELAAGD MET EEN ENKEL BANDJE VEEN A/D TOP								
	11.10-12.00	ZANDIGE KLEI , ZEER STUG KLEUR: DONKERGROEN HUE 5GY 4/1 GELAAGD MET ZAND								
	12.00-24.00	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 PLAATSELIJK ENIGZINS SILTIG/KLEIIG ENKELE KLEI-INSLUITSELS WISSELEND GELAAGD MET SILT	150-300							
	24.00-27.50	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS HUE 5Y 5/1	210-420							
	27.50-31.30	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS HUE 5Y 5/1 EEN ENKELE KLEI-INSLUITING ENKELE GRINDJES	210-420							
	31.30-42.00	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: OLIJF GRIJS TOT DONKERGRIJS HUE 5Y 3/2 KLEI/VEEN INSLUITSELS, SILTIG GELAAGD MET KLEI EN VEEN	105-210							
	42.00-47.50	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS HUE 5Y 5/1	210-420							
	47.50-58.00	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 4/1 SPOOR ORGANISCH MATERIAAL	150-300							
	58.00-61.60	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 KLEI INSLUITSELS SPOOR ORGANISCH MATERIAAL	150-300							

FILE: OP BORING# 385 15-OCT-15 13:53:14

Bouw en Ondergrond

KAARTBLAD	P12
BORING	41
COORDINATEN	52 24 26.4
	3 45 36.8

UITVOERING	FUGRO	UTM COORDINATEN	5806.739 N /	551.716 E
WERKNUMMER	N2694/02	ANDERE COORDINATEN		
ONDERZ./PROJECTNR	B2			
DATUM	17- 7- 1989			
WERKWIJZE		EINDDIEPTE	81.00	meter
LOCATIE		GEMETEN WATERDIEPTE	0.00	meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	29.15	m- NAP
BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00				norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	G CA
	58.00-61.60	ZAND	150-300							
		MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 KLEI INSLUITSELS SPOOR ORGANISCH MATERIAAL GELAMINEERD MET KLEI								
	61.60-72.00	ZAND	150-300							
		MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 SILTIG GELAMINEERD MET ORG.MAT.								
	72.00-81.00	ZAND	150-300							
		MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1								

diepte van 0.00 tot 0.20m 274.00 D50 Malvern meting
diepte van 0.00 tot 0.20m 1.66 spreiding Malvern meting
diepte van 0.00 tot 0.20m 1.41 % < 63 um Malvern meting
diepte van 0.00 tot 0.20m 0.31 % grind Malvern meting
diepte van 1.00 tot 1.20m 267.00 D50 Malvern meting
diepte van 1.00 tot 1.20m 1.56 spreiding Malvern meting
diepte van 1.00 tot 1.20m 0.52 % < 63 um Malvern meting
diepte van 1.00 tot 1.20m 0.37 % grind Malvern meting
diepte van 17.00 tot 17.20m 194.00 D50 Malvern meting
diepte van 17.00 tot 17.20m 1.61 spreiding Malvern meting
diepte van 17.00 tot 17.20m 2.02 % < 63 um Malvern meting
diepte van 17.00 tot 17.20m 0.00 % grind Malvern meting
diepte van 15.00 tot 15.20m 132.00 D50 Malvern meting
diepte van 15.00 tot 15.20m 1.79 spreiding Malvern meting
diepte van 15.00 tot 15.20m 12.63 % < 63 um Malvern meting
diepte van 15.00 tot 15.20m 0.00 % grind Malvern meting
diepte van 18.00 tot 18.20m 163.00 D50 Malvern meting
diepte van 18.00 tot 18.20m 1.73 spreiding Malvern meting
diepte van 18.00 tot 18.20m 5.01 % < 63 um Malvern meting
diepte van 18.00 tot 18.20m 0.00 % grind Malvern meting
diepte van 19.00 tot 19.20m 186.00 D50 Malvern meting
diepte van 19.00 tot 19.20m 1.60 spreiding Malvern meting
diepte van 19.00 tot 19.20m 2.76 % < 63 um Malvern meting
diepte van 19.00 tot 19.20m 0.00 % grind Malvern meting
diepte van 2.00 tot 2.20m 364.00 D50 Malvern meting
diepte van 2.00 tot 2.20m 1.80 spreiding Malvern meting
diepte van 2.00 tot 2.20m 0.40 % < 63 um Malvern meting
diepte van 2.00 tot 2.20m 0.00 % grind Malvern meting
diepte van 31.00 tot 31.20m 393.00 D50 Malvern meting
diepte van 31.00 tot 31.20m 1.98 spreiding Malvern meting
diepte van 31.00 tot 31.20m 3.81 % < 63 um Malvern meting
diepte van 31.00 tot 31.20m 0.00 % grind Malvern meting
diepte van 3.00 tot 3.20m 321.00 D50 Malvern meting
diepte van 3.00 tot 3.20m 1.82 spreiding Malvern meting
diepte van 3.00 tot 3.20m 0.63 % < 63 um Malvern meting
diepte van 3.00 tot 3.20m 0.46 % grind Malvern meting
diepte van 4.00 tot 4.20m 257.00 D50 Malvern meting
diepte van 4.00 tot 4.20m 1.83 spreiding Malvern meting
diepte van 4.00 tot 4.20m 3.03 % < 63 um Malvern meting
diepte van 4.00 tot 4.20m 0.63 % grind Malvern meting
diepte van 51.00 tot 51.20m 194.00 D50 Malvern meting

FILE: OP BORING# 385 15-OCT-15 13:53:14

Bouw en Ondergrond

KAARTBLAD	P12
BORING	41
COORDINATEN	52 24 26.4
	3 45 36.8

UITVOERING	FUGRO	UTM COORDINATEN	5806.739 N /	551.716 E
WERKNUMMER	N2694/02	ANDERE COORDINATEN		
ONDERZ./PROJECTNR	B2			
DATUM	17- 7- 1989			
WERKWIJZE		EINDDIEPTE	81.00	meter
LOCATIE		GEMETEN WATERDIEPTE	0.00	meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	29.15	m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)	KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	G CA

diepte van 0.00 tot 0.20m 274.00 D50 Malvern meting
diepte van 0.00 tot 0.20m 1.66 spreiding Malvern meting
diepte van 0.00 tot 0.20m 1.41 % < 63 um Malvern meting
diepte van 0.00 tot 0.20m 0.31 % grind Malvern meting
diepte van 1.00 tot 1.20m 267.00 D50 Malvern meting
diepte van 1.00 tot 1.20m 1.56 spreiding Malvern meting
diepte van 1.00 tot 1.20m 0.52 % < 63 um Malvern meting
diepte van 1.00 tot 1.20m 0.37 % grind Malvern meting
diepte van 17.00 tot 17.20m 194.00 D50 Malvern meting
diepte van 17.00 tot 17.20m 1.61 spreiding Malvern meting
diepte van 17.00 tot 17.20m 2.02 % < 63 um Malvern meting
diepte van 17.00 tot 17.20m 0.00 % grind Malvern meting
diepte van 15.00 tot 15.20m 132.00 D50 Malvern meting
diepte van 15.00 tot 15.20m 1.79 spreiding Malvern meting
diepte van 15.00 tot 15.20m 12.63 % < 63 um Malvern meting
diepte van 15.00 tot 15.20m 0.00 % grind Malvern meting
diepte van 18.00 tot 18.20m 163.00 D50 Malvern meting
diepte van 18.00 tot 18.20m 1.73 spreiding Malvern meting
diepte van 18.00 tot 18.20m 5.01 % < 63 um Malvern meting
diepte van 18.00 tot 18.20m 0.00 % grind Malvern meting
diepte van 19.00 tot 19.20m 186.00 D50 Malvern meting
diepte van 19.00 tot 19.20m 1.60 spreiding Malvern meting
diepte van 19.00 tot 19.20m 2.76 % < 63 um Malvern meting
diepte van 19.00 tot 19.20m 0.00 % grind Malvern meting
diepte van 2.00 tot 2.20m 364.00 D50 Malvern meting
diepte van 2.00 tot 2.20m 1.80 spreiding Malvern meting
diepte van 2.00 tot 2.20m 0.40 % < 63 um Malvern meting
diepte van 2.00 tot 2.20m 0.00 % grind Malvern meting
diepte van 31.00 tot 31.20m 393.00 D50 Malvern meting
diepte van 31.00 tot 31.20m 1.98 spreiding Malvern meting
diepte van 31.00 tot 31.20m 3.81 % < 63 um Malvern meting
diepte van 31.00 tot 31.20m 0.00 % grind Malvern meting
diepte van 3.00 tot 3.20m 321.00 D50 Malvern meting
diepte van 3.00 tot 3.20m 1.82 spreiding Malvern meting
diepte van 3.00 tot 3.20m 0.63 % < 63 um Malvern meting
diepte van 3.00 tot 3.20m 0.46 % grind Malvern meting
diepte van 4.00 tot 4.20m 257.00 D50 Malvern meting
diepte van 4.00 tot 4.20m 1.83 spreiding Malvern meting
diepte van 4.00 tot 4.20m 3.03 % < 63 um Malvern meting
diepte van 4.00 tot 4.20m 0.63 % grind Malvern meting
diepte van 51.00 tot 51.20m 194.00 D50 Malvern meting
diepte van 51.00 tot 51.20m 1.78 spreiding Malvern meting
diepte van 51.00 tot 51.20m 3.11 % < 63 um Malvern meting
diepte van 51.00 tot 51.20m 0.00 % grind Malvern meting
diepte van 55.00 tot 55.20m 251.00 D50 Malvern meting
diepte van 55.00 tot 55.20m 1.77 spreiding Malvern meting
diepte van 55.00 tot 55.20m 1.24 % < 63 um Malvern meting
diepte van 55.00 tot 55.20m 0.00 % grind Malvern meting

diepte van 59.00 tot 59.20m 240.00 D50 Malvern meting
diepte van 59.00 tot 59.20m 2.10 spreiding Malvern meting
diepte van 59.00 tot 59.20m 1.49 % < 63 um Malvern meting
diepte van 59.00 tot 59.20m 0.44 % grind Malvern meting
diepte van 67.00 tot 67.20m 133.00 D50 Malvern meting
diepte van 67.00 tot 67.20m 1.81 spreiding Malvern meting
diepte van 67.00 tot 67.20m 13.29 % < 63 um Malvern meting
diepte van 67.00 tot 67.20m 0.00 % grind Malvern meting

FILE: OP BORING# 385 15-OCT-15 13:53:14

Bouw en Ondergrond

KAARTBLAD	P12
BORING	41
COORDINATEN	52 24 26.4
	3 45 36.8

UITVOERING	FUGRO	UTM COORDINATEN	5806.739 N /	551.716 E
WERKNUMMER	N2694/02	ANDERE COORDINATEN		
ONDERZ./PROJECTNR	B2			
DATUM	17- 7- 1989			
WERKWIJZE		EINDDIEPTE	81.00	meter
LOCATIE		GEMETEN WATERDIEPTE	0.00	meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	29.15	m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)	KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	G SCHELPEN %	CA

diepte van 59.00 tot 59.20m 240.00 D50 Malvern meting
diepte van 59.00 tot 59.20m 2.10 spreiding Malvern meting
diepte van 59.00 tot 59.20m 1.49 % < 63 um Malvern meting
diepte van 59.00 tot 59.20m 0.44 % grind Malvern meting
diepte van 67.00 tot 67.20m 133.00 D50 Malvern meting
diepte van 67.00 tot 67.20m 1.81 spreiding Malvern meting
diepte van 67.00 tot 67.20m 13.29 % < 63 um Malvern meting
diepte van 67.00 tot 67.20m 0.00 % grind Malvern meting
diepte van 71.00 tot 71.20m 211.00 D50 Malvern meting
diepte van 71.00 tot 71.20m 2.14 spreiding Malvern meting
diepte van 71.00 tot 71.20m 6.13 % < 63 um Malvern meting
diepte van 71.00 tot 71.20m 0.80 % grind Malvern meting
diepte van 77.00 tot 77.20m 197.00 D50 Malvern meting
diepte van 77.00 tot 77.20m 1.64 spreiding Malvern meting
diepte van 77.00 tot 77.20m 1.13 % < 63 um Malvern meting
diepte van 77.00 tot 77.20m 0.00 % grind Malvern meting

STRATIGRAFIE (BETROUWBAARHEID ONBEKEND(*), ONZEKER(?) ,ZEKER(!)) :

0.00 - 4.30 m:* HOLOCEEN BH Bligh Bank formatie
4.30 - 9.00 m:* PLEISTOCEEN KR Kreftenheye formatie
9.00 - 12.00 m:! PLEISTOCEEN WEICHSELIEN BNB Bruine Bank formatie
12.00 - 31.30 m:! PLEISTOCEEN CROMERIEN YM Yarmouth Roads formatie
31.30 - 42.00 m:? PLEISTOCEEN CROMERIEN YM Yarmouth Roads formatie
42.00 - 58.00 m:! PLEISTOCEEN CROMERIEN YM Yarmouth Roads formatie
58.00 - 72.00 m:? PLEISTOCEEN CROMERIEN YM Yarmouth Roads formatie
72.00 - 81.00 m:? PLEISTOCEEN WAALIEN WN Winterton Shoal formatie

EINDE BORING

N.B. DE KORRELGROOTTES ZIJN GESCHAT

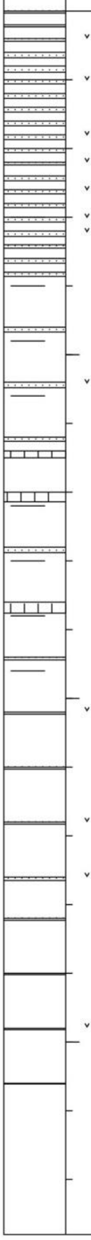
FILE: OP BORING# 385 15-OCT-15 13:53:14

TNO Bouw en Ondergrond

KAARTBLAD	P12
BORING	42
COORDINATEN	52 24 35.5
	3 51 40.1

UITVOERING	FUGRO	UTM COORDINATEN	5807.097 N / 558.578 E
WERKNUMMER	N2694/03	ANDERE COORDINATEN	
ONDERZ./PROJECTNR	B3		
DATUM	18- 7- 1989		
WERKWIJZE		EINDDIEPTE	82.00 meter
LOCATIE		GEMETEN WATERDIEPTE	0.00 meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	28.90 m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	G SCHELPEN CA %
	0.00-0.15	ZAND MATIG GROF T/M ZEER GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 ENKELE SCHELPFRAGMENTEN ENKELE GRINDJES , AFGEROND	210-420						
	1.00-1.15	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS BRUIN HUE 2.5Y 4/2 SCHELPFRAGMENTEN	210-420						
	2.00-2.20	ZAND MATIG GROF T/M ZEER GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 SPOOR ORGANISCH MATERIAAL ENKELE GRINDJES	210-420						
	3.00-3.38	ZAND MATIG GROF T/M ZEER GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 ENKELE SCHELPFRAGMENTEN	210-420						
	4.00-4.45	ZAND MATIG FIJN T/M MATIG GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2	150-300						
	5.00-5.30	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 SPOOR ORGANISCH MATERIAAL	150-300						
	6.00-6.35	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1	150-300						
	7.00-7.35	ZAND MATIG GROF T/M ZEER GROF KLEUR: DONKERGRIJS HUE 5Y 4/1	210-420						
	8.00-8.35	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1	150-300						
	9.00-9.35	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: OLIJF GRIJS HUE 5Y 4/2 SPOOR ORGANISCH MATERIAAL ENKELE GRINDJES	105-210						
	10.00-10.32	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: OLIJF GRIJS HUE 5Y 4/2	105-210						
	11.00-11.20	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 SPOOR ORGANISCH MATERIAAL	150-300						

FILE: OP BORING# 386 15-OCT-15 13:53:20

Bouw en Ondergrond

KAARTBLAD	P12
BORING	42
COORDINATEN	52 24 35.5
	3 51 40.1

UITVOERING	FUGRO	UTM COORDINATEN	5807.097 N / 558.578 E
WERKNUMMER	N2694/03	ANDERE COORDINATEN	
ONDERZ./PROJECTNR	B3		
DATUM	18- 7- 1989		
WERKWIJZE		EINDDIEPTE	82.00 meter
LOCATIE		GEMETEN WATERDIEPTE	0.00 meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	28.90 m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	G SCHELPEN %	CA
	12.00-12.35	ZAND MATIG GROF T/M ZEER GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2 ENKELE KLEI INSLUITSELS ENKELE GRINDJES	210-420							
	13.00-13.30	ZAND MATIG GROF T/M ZEER GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2 ENIGZINS SILTIG, KLEI INSLUITSELS SPOOR ORGANISCH MATERIAAL	210-420							
	14.00-14.30	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 SILTIG, KLEI INSLUITSELS GELAMINEERD MET ORG.MAT.	150-300							
	15.00-15.35	ZAND MATIG GROF T/M ZEER GROF KLEUR: GRIJS HUE 5Y 5/1 SPOOR ORGANISCH MATERIAAL	210-420							
	16.00-16.42	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 ENKELE KLEI INSLUITSELS SPOOR ORGANISCH MATERIAAL	150-300							
	17.00-17.26	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 KLEILENSJES	150-300							
	18.00-18.35	ZAND MATIG FIJN T/M MATIG GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2 ENKELE KLEILENSJES	150-300							
	19.00-19.30	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: OLIJF GRIJS HUE 5Y 3/2 GELAMINEERD MET KLEI	105-210							
	23.00-23.37	ZAND MATIG FIJN T/M MATIG GROF KLEUR: OLIJF GRIJS HUE 5Y 3/2 SILTIG, ENIGZINS KLEIIG, KLEI INSLUITSEL GELAMINEERD MET SILT	150-300							
	27.00-27.38	ZAND MATIG FIJN T/M MATIG GROF KLEUR: DONKERGRIJS HUE 5Y 4/1 SILTIG, KLEIIG DUNNE VEENLAAG A/D TOP SPOOR ORGANISCH MATERIAAL GELAMINEERD MET SILT EN KLEI	150-300							

FILE: OP BORING# 386 15-OCT-15 13:53:20

Bouw en Ondergrond

KAARTBLAD	P12
BORING	42
COORDINATEN	52 24 35.5 3 51 40.1

UITVOERING	FUGRO	UTM COORDINATEN	5807.097 N / 558.578 E
WERKNUMMER	N2694/03	ANDERE COORDINATEN	
ONDERZ./PROJECTNR	B3		
DATUM	18- 7- 1989		
WERKWIJZE		EINDDIEPTE	82.00 meter
LOCATIE		GEMETEN WATERDIEPTE	0.00 meter
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	28.90 m- NAP

BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00 norm: ONB

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	G CA
	31.00-31.31	ZAND MATIG GROF T/M ZEER GROF KLEUR: OLIJF GRIJS HUE 5Y 4/2 ENKELE SILT INSLUITSELS EN KLEILENSJES	210-420							
	32.00-32.50	KLEI ZEER SILTIG KLEUR: DONKERGRIJS HUE 5Y 4/1 ZAND INSLUITSELS								
	35.00-35.70	SILT KLEUR: DONKERGRIJS HUE 5Y 4/1 GELAAGD MET EEN ENKEL BANDJE ZAND								
	39.00-39.40	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1 ZEER SILTIG GELAAGD MET DUNNE LAAGJES KLEI	105-210							
	43.00-43.80	KLEI (SILTIG) EN SILT (ZEER ZANDIG) KLEUR: DONKERGRIJS HUE 5Y 4/1 GELAAGD MET ZAND								
	47.00-47.20	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1 GELAMINEERD MET SILT	105-210							
	51.00-51.14	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1 SILT INSLUITSELS SPOOR ORGANISCH MATERIAAL	105-210							
	55.00-55.16	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1 ENIGZINS SILTIG	105-210							
	59.00-59.16	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 SPOOR ORGANISCH MATERIAAL	150-300							
	63.00-63.23	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 SPOOR ORGANISCH MATERIAAL	150-300							
	66.00-66.16	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1 ENIGZINS SILTIG	105-210							

FILE: OP BORING# 386 15-OCT-15 13:53:21

Bouw en Ondergrond

KAARTBLAD	P12
BORING	42
COORDINATEN	52 24 35.5
	3 51 40.1

UITVOERING	FUGRO	UTM COORDINATEN	5807.097 N /	558.578 E	
WERKNUMMER	N2694/03	ANDERE COORDINATEN			
ONDERZ./PROJECTNR	B3				
DATUM	18- 7- 1989				
WERKWIJZE		EINDDIEPTE	82.00	meter	
LOCATIE		GEMETEN WATERDIEPTE	0.00	meter	
TYPE BORING	STEEKBORING	GECORRIGEERDE WATERDIEPTE	28.90	m- NAP	
BESCHRIJVER LITHOSTRATIGRAFIE:MESDAG & RIJSDIJK 00				norm: ONB	G

LITH. 1:500	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	CA
	70.00-70.10	ZAND ZEER FIJN T/M MATIG FIJN KLEUR: GRIJS HUE 5Y 5/1	105-210							
	74.00-74.10	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1 SPOOR ORGANISCH MATERIAAL	150-300							
	78.00-78.05	ZAND MATIG FIJN T/M MATIG GROF KLEUR: GRIJS HUE 5Y 5/1	150-300							

diepte van 0.00 tot 0.15m 261.00 D50 Malvern meting
diepte van 0.00 tot 0.15m 1.58 spreiding Malvern meting
diepte van 0.00 tot 0.15m 0.74 % < 63 um Malvern meting
diepte van 0.00 tot 0.15m 0.22 % grind Malvern meting
diepte van 1.00 tot 1.15m 258.00 D50 Malvern meting
diepte van 1.00 tot 1.15m 1.58 spreiding Malvern meting
diepte van 1.00 tot 1.15m 0.59 % < 63 um Malvern meting
diepte van 1.00 tot 1.15m 0.37 % grind Malvern meting
diepte van 11.00 tot 11.20m 213.00 D50 Malvern meting
diepte van 11.00 tot 11.20m 1.99 spreiding Malvern meting
diepte van 11.00 tot 11.20m 2.42 % < 63 um Malvern meting
diepte van 11.00 tot 11.20m 0.26 % grind Malvern meting
diepte van 27.00 tot 27.38m 234.00 D50 Malvern meting
diepte van 27.00 tot 27.38m 1.68 spreiding Malvern meting
diepte van 27.00 tot 27.38m 2.81 % < 63 um Malvern meting
diepte van 27.00 tot 27.38m 0.44 % grind Malvern meting
diepte van 55.00 tot 55.16m 152.00 D50 Malvern meting
diepte van 55.00 tot 55.16m 1.77 spreiding Malvern meting
diepte van 55.00 tot 55.16m 7.24 % < 63 um Malvern meting
diepte van 55.00 tot 55.16m 0.00 % grind Malvern meting
diepte van 6.00 tot 6.35m 231.00 D50 Malvern meting
diepte van 6.00 tot 6.35m 1.59 spreiding Malvern meting
diepte van 6.00 tot 6.35m 1.72 % < 63 um Malvern meting
diepte van 6.00 tot 6.35m 0.29 % grind Malvern meting
diepte van 74.00 tot 74.10m 224.00 D50 Malvern meting
diepte van 74.00 tot 74.10m 1.58 spreiding Malvern meting
diepte van 74.00 tot 74.10m 1.08 % < 63 um Malvern meting
diepte van 74.00 tot 74.10m 0.20 % grind Malvern meting

STRATIGRAFIE (BETROUWBAARHEID ONBEKEND(*), ONZEKER(?) ,ZEKER(!)) :

0.00 - 15.35 m:* PLEISTOCEEN KR Kreftenheye formatie
16.00 - 74.10 m:! PLEISTOCEEN CROMERIEN YM Yarmouth Roads formatie
78.00 - 78.05 m:? PLEISTOCEEN WAALIEN WN Winterton Shoal formatie

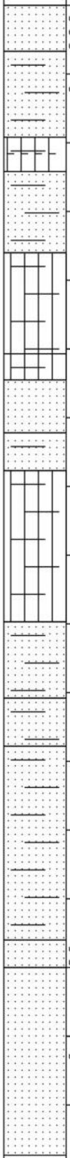
EINDE BORING
N.B. DE KORRELGROOTTES ZIJN GESCHAT

FILE: OP BORING# 386 15-OCT-15 13:53:21

Bouw en Ondergrond

KAARTBLAD	P14
BORING	88
COORDINATEN	52 19 30.9
	3 38 31.8

UITVOERING	FUGRO	UTM COORDINATEN	5797.531 N / 543.767 E
WERKNUMMER	N2899/01	ANDERE COORDINATEN	
ONDERZ./PROJECTNR			
DATUM	0- 12- 1991		
WERKWIJZE		EINDDIEPTE	100.40 meter
LOCATIE		GEMETEN WATERDIEPTE	27.60 meter
TYPE BORING	STRAIGHT-FLUSH	GECORRIGEERDE WATERDIEPTE	0.00 m-norm: ONB

LITH. 1:600	DIEPTE VAN - TOT (m)		KORRELGROOTTE um	<63um %	S	GRIND %	M um	D50 um	SCHELPEN %	G CA
	0.00-4.00	ZAND MATIG GROF T/M UITERST GROF KLEUR: OLIJF GRIJS HUE 5Y-5/2 SCHELPFRAGMENTEN SPOOR ORGANISCH MATERIAAL WEINIG GRIND	200-600							
	4.00-11.50	ZAND MATIG GROF T/M UITERST GROF SILTIG KLEUR: GRIJS HUE 7.5Y-4/1 WEINIG SCHELPFRAGMENTEN STERK GELAAGD MET KLEI EN VEEN EN SILT WEINIG GRIND	200-600							
	11.50-14.50	SILT ZANDIG KLEUR: OLIJF HUE 5Y-3/1 GELAAGD MET KLEI EN ZAND								
	14.50-21.60	ZAND UITERST FIJN T/M UITERST GROF KLEUR: GRIJS HUE 5Y-4/1 GELAAGD MET KLEI EN SILT	63-600							
	21.60-30.40	KLEI KLEUR: GRIJS HUE 5Y-4/1 STERK GELAAGD MET ZAND LOKAAL OOK SILTLAGEN								
	30.40-32.70	KLEI KLEUR: GRIJS HUE 5Y-4/1 STERK GELAAGD MET ZAND								
	32.70-37.30	ZAND UITERST FIJN T/M MATIG FIJN KLEIBROKJES SILTIG KLEUR: GRIJS HUE 5Y-4/1 SILTBROKJES	63-200							
	37.30-40.60	ZAND UITERST FIJN T/M MATIG FIJN SILTIG KLEUR: GRIJS HUE 5Y-4/1 GELAAGD MET KLEI	63-200							
	40.60-53.80	KLEI KLEUR: GRIJS HUE 5Y-4/1 STERK GELAAGD MET SLIB HOUDEND ZAND								
	53.80-60.50	ZAND UITERST FIJN T/M MATIG FIJN SILTIG KLEUR: GRIJS HUE 10Y-4/1 STERK GELAAGD MET KLEI	63-200							

FILE: MAGWEG BORING# 5 14-APR-14 09:31:36

Bouw en Ondergrond

KAARTBLAD	P14
BORING	88
COORDINATEN	52 19 30.9
	3 38 31.8

UITVOERING	FUGRO	UTM COORDINATEN	5797.531 N / 543.767 E
WERKNUMMER	N2899/01	ANDERE COORDINATEN	
ONDERZ./PROJECTNR			
DATUM	0- 12- 1991		
WERKWIJZE		EINDDIEPTE	100.40 meter
LOCATIE		GEMETEN WATERDIEPTE	27.60 meter
TYPE BORING	STRAIGHT-FLUSH	GECORRIGEERDE WATERDIEPTE	0.00 m-norm: ONB

LITH.	DIEPTE	KORRELGROOTTE	<63um	S	GRIND	M	D50	SCHELPEN	G
1:600	VAN - TOT (m)	um	%		%	um	um	%	CA

60.50-64.70 ZAND 63-200
UITERST FIJN T/M MATIG FIJN
STERK SILTIG
KLEUR: GRIJS HUE 10Y-4/1
STERK GELAAGD MET KLEI

64.70-81.60 ZAND 63-200
UITERST FIJN T/M MATIG FIJN
STERK SILTIG
KLEUR: GRIJS HUE 7.5Y-5/1
LOKAAL VEENLAMINATIES
WEINIG BROKJES VEEN
STERK GELAAGD MET KLEI

81.60-84.00 ZAND 63-600
UITERST FIJN T/M UITERST GROF
KLEUR: GRIJS HUE 7.5Y-4/1
VEEL SCHELPFRAGMENTEN

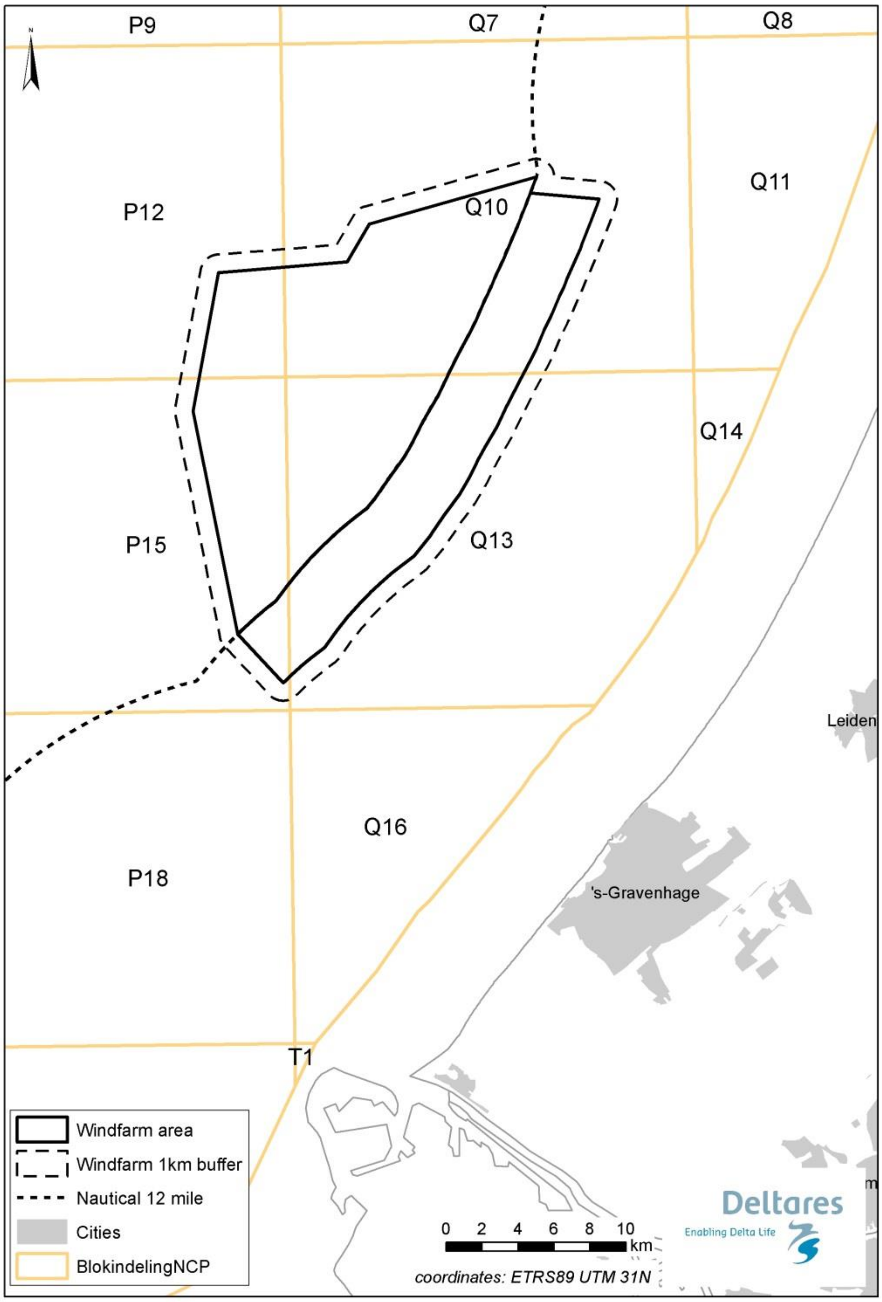
84.00-100.40 ZAND 63-200
UITERST FIJN T/M MATIG FIJN
SILTIG
KLEUR: GRIJS HUE 10Y-4/1
A/D TOP ENIGE VEENLAMINAEA
OP 99.0 M ENIGE KLEI- EN SILTBROKJES
SPOOR SCHELPFRAGMENTEN

diepte van 1.00 tot 1.10m 260.00 D50 geschat
diepte van 1.00 tot 1.10m 1.56 spreiding geschat
diepte van 4.10 tot 4.20m 280.00 D50 geschat
diepte van 4.10 tot 4.20m 5.56 spreiding geschat
diepte van 8.00 tot 8.10m 320.00 D50 geschat
diepte van 8.00 tot 8.10m 2.00 spreiding geschat
diepte van 17.10 tot 17.20m 130.00 D50 geschat
diepte van 17.10 tot 17.20m 66.67 spreiding geschat
diepte van 30.00 tot 30.10m 90.00 D50 geschat
diepte van 30.00 tot 30.10m 25.00 spreiding geschat
diepte van 35.00 tot 35.10m 105.00 D50 geschat
diepte van 35.00 tot 35.10m 8.33 spreiding geschat
diepte van 47.50 tot 47.60m 105.00 D50 geschat
diepte van 47.50 tot 47.60m 4.00 spreiding geschat
diepte van 52.20 tot 52.30m 102.00 D50 geschat
diepte van 52.20 tot 52.30m 1.86 spreiding geschat
diepte van 56.00 tot 56.10m 100.00 D50 geschat
diepte van 56.00 tot 56.10m 7.33 spreiding geschat
diepte van 60.50 tot 60.60m 38.00 D50 geschat
diepte van 60.50 tot 60.60m 7.14 spreiding geschat
diepte van 68.00 tot 68.10m 54.00 D50 geschat
diepte van 68.00 tot 68.10m 10.00 spreiding geschat
diepte van 81.50 tot 81.60m 240.00 D50 geschat
diepte van 81.50 tot 81.60m 2.50 spreiding geschat
diepte van 87.00 tot 87.10m 110.00 D50 geschat
diepte van 87.00 tot 87.10m 1.92 spreiding geschat
diepte van 93.00 tot 93.10m 100.00 D50 geschat
diepte van 93.00 tot 93.10m 8.33 spreiding geschat
diepte van 99.00 tot 99.10m 180.00 D50 geschat
diepte van 99.00 tot 99.10m 4.00 spreiding geschat

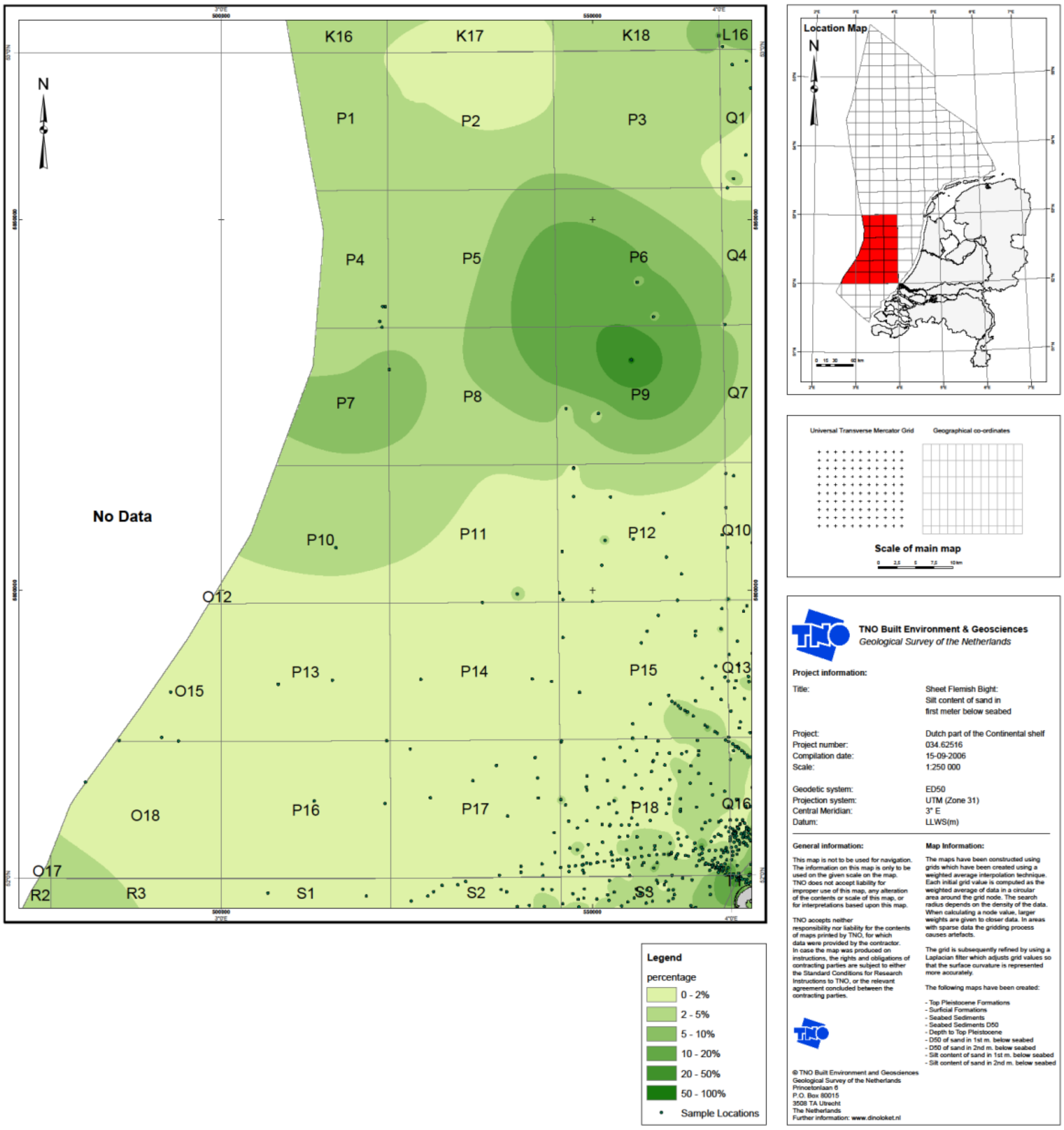
N.B. DE KORRELGROOTTES ZIJN GESCHAT EINDE BORING

FILE: MAGWEG BORING# 5 14-APR-14 09:31:36

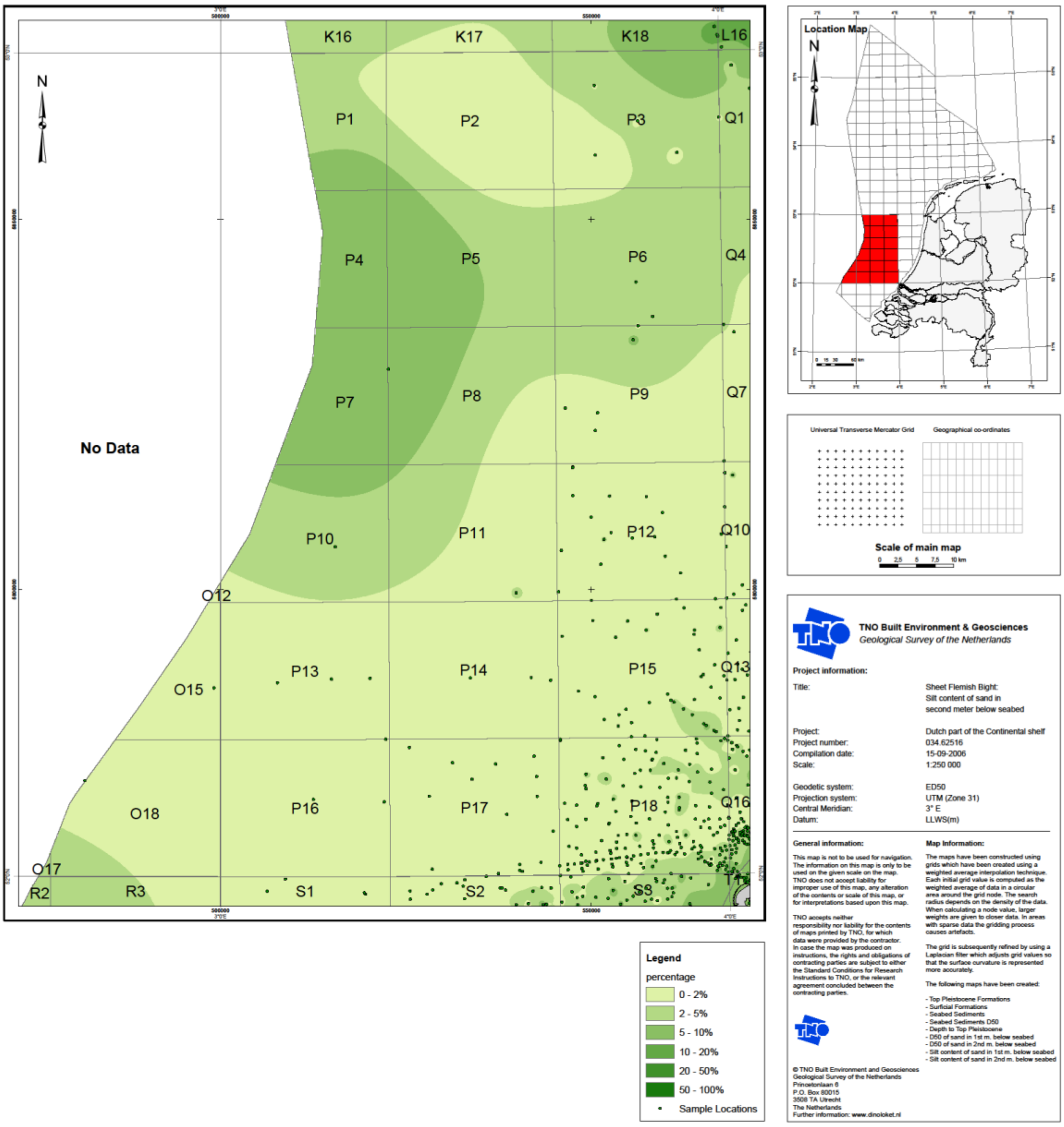
D Seabed sediments maps 1:250.000

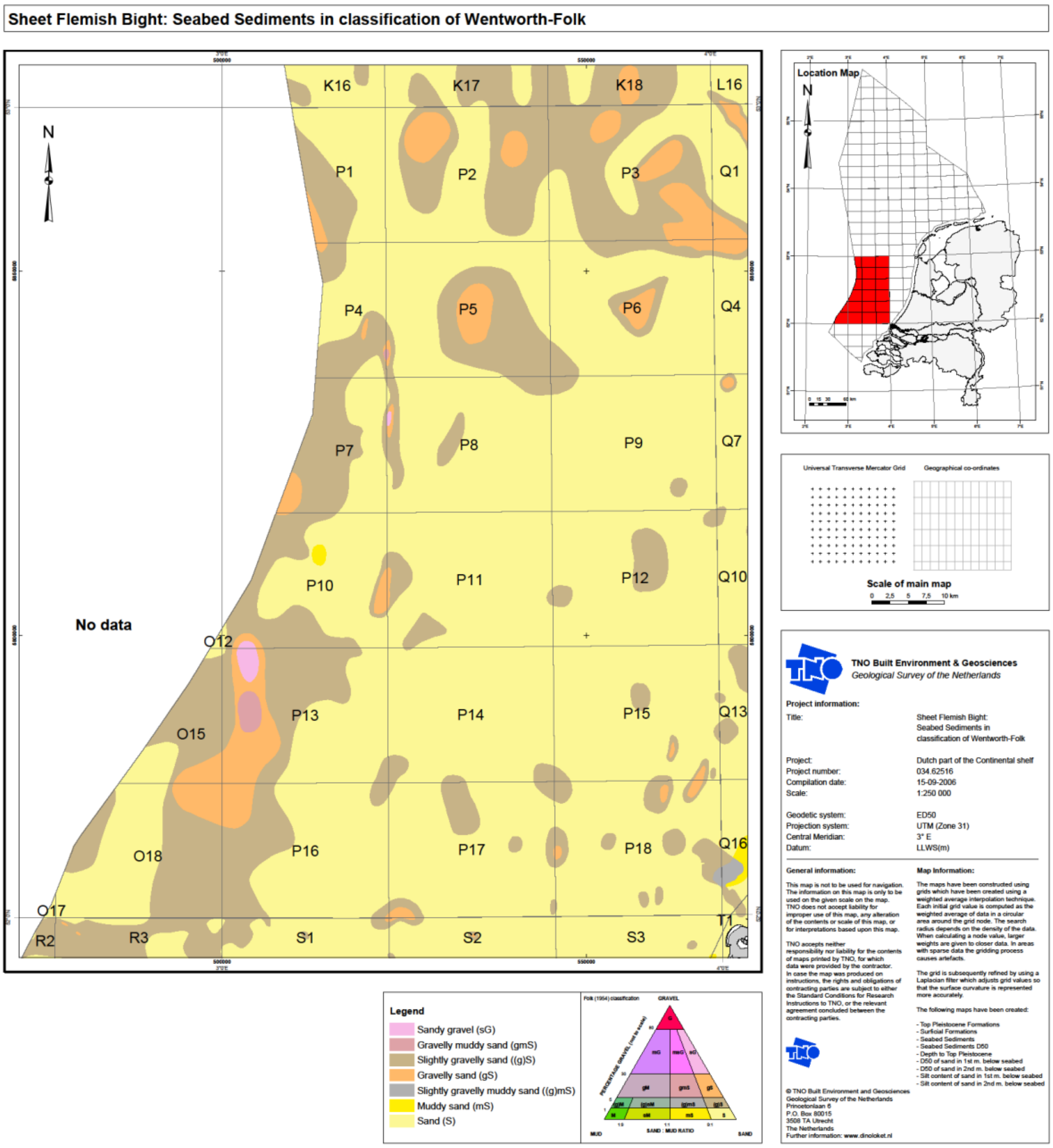


Sheet Flemish Bight: Silt content of sand in first meter below seabed



Sheet Flemish Bight: Silt content of sand in second meter below seabed




Sheet Flemish Bight: Seabed Sediments in classification of Wentworth-Folk
N
No data
K16
K17
K18
L16
P1
P2
P3
Q1
P4
P5
P6
Q4
P7
P8
P9
Q7
P10
P11
P12
Q10
O12
O15
P13
P14
P15
Q13
O18
P16
P17
P18
Q16
O17
R2
R3
S1
S2
S3
T1
500000
550000
Location Map
Universal Transverse Mercator Grid
Geographical co-ordinates
Scale of main map
0 2,5 5 7,5 10 km
TNO Built Environment & Geosciences
Geological Survey of the Netherlands
Project information:
Title: Sheet Flemish Bight: Seabed Sediments in classification of Wentworth-Folk
Project: Dutch part of the Continental shelf
Project number: 034.62516
Compilation date: 15-09-2006
Scale: 1:250 000
Geodetic system: ED50
Projection system: UTM (Zone 31)
Central Meridian: 3° E
Datum: LLWS(m)
General information:
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Map Information:
The maps have been constructed using grids which have been created using a weighted average interpolation technique. Each initial grid value is computed as the weighted average of data in a circular area around the grid node. The search radius depends on the density of the data. When calculating a node value, larger weights are given to closer data. In areas with sparse data the gridding process causes artefacts.
The grid is subsequently refined by using a Laplacian filter which adjusts grid values so that the surface curvature is represented more accurately.
The following maps have been created:
- Top Pleistocene Formations
- Surficial Formations
- Seabed Sediments
- Seabed Sediments D50
- Depth to Top Pleistocene
- D50 of sand in 1st m. below seabed
- D50 of sand in 2nd m. below seabed
- Silt content of sand in 1st m. below seabed
- Silt content of sand in 2nd m. below seabed
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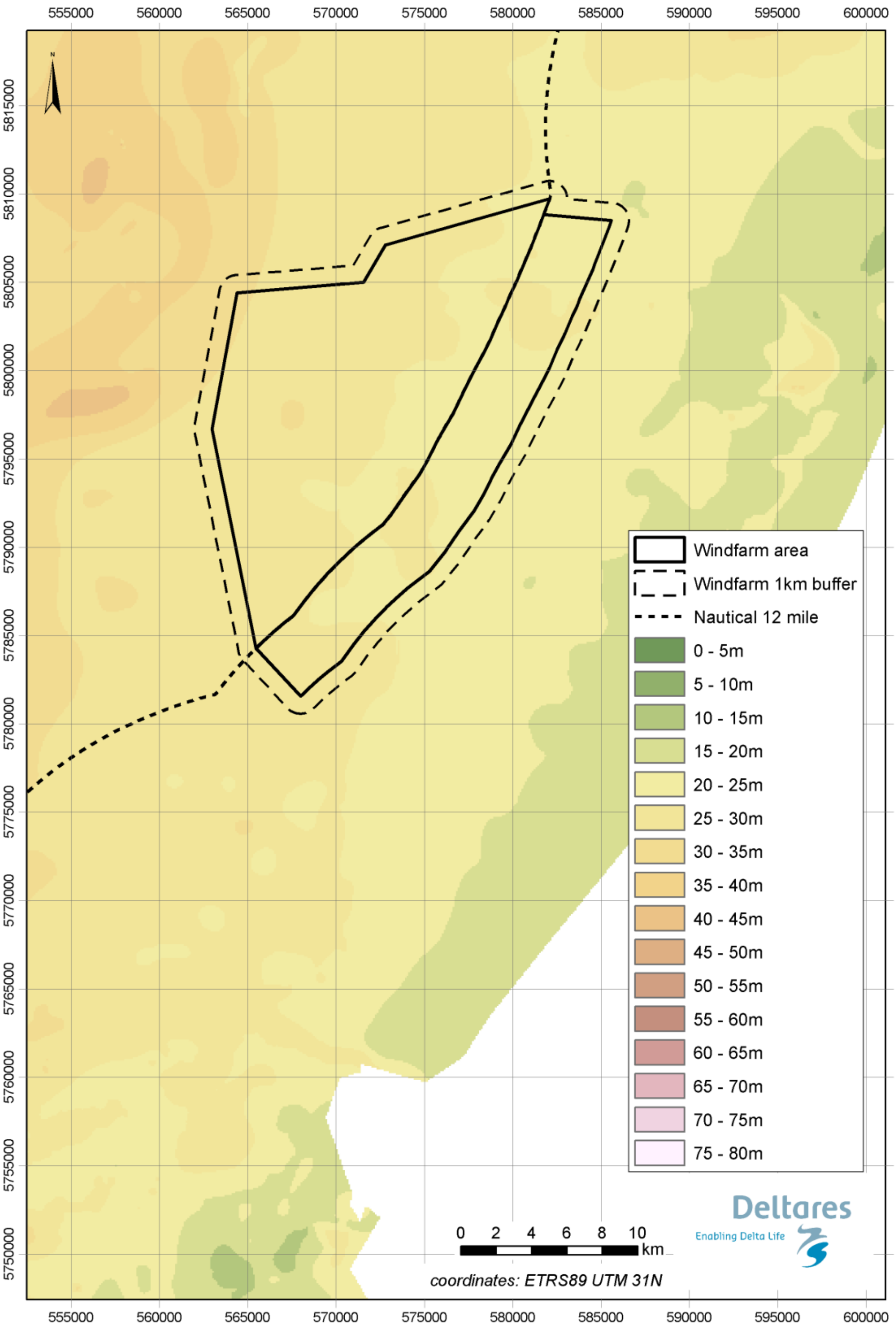
Geological Survey of the Netherlands
Princetonlaan 6
P.O. Box 80015
3508 TA Utrecht
The Netherlands
Further information: www.dinoloket.nl
Legend
Sandy gravel (sG)
Gravelly muddy sand (gmS)
Slightly gravelly sand ((g)S)
Gravelly sand (gS)
Slightly gravelly muddy sand ((g)mS)
Muddy sand (mS)
Sand (S)
Folk (1954) classification
GRAVEL
PERCENTAGE GRAVEL (not to scale)
G
mG
msG
sG
gM
gmS
gS
(g)M
(g)sM
(g)mS
(g)S
M
sM
mS
S
1:9
1:1
9:1
MUD
SAND : MUD RATIO
SAND

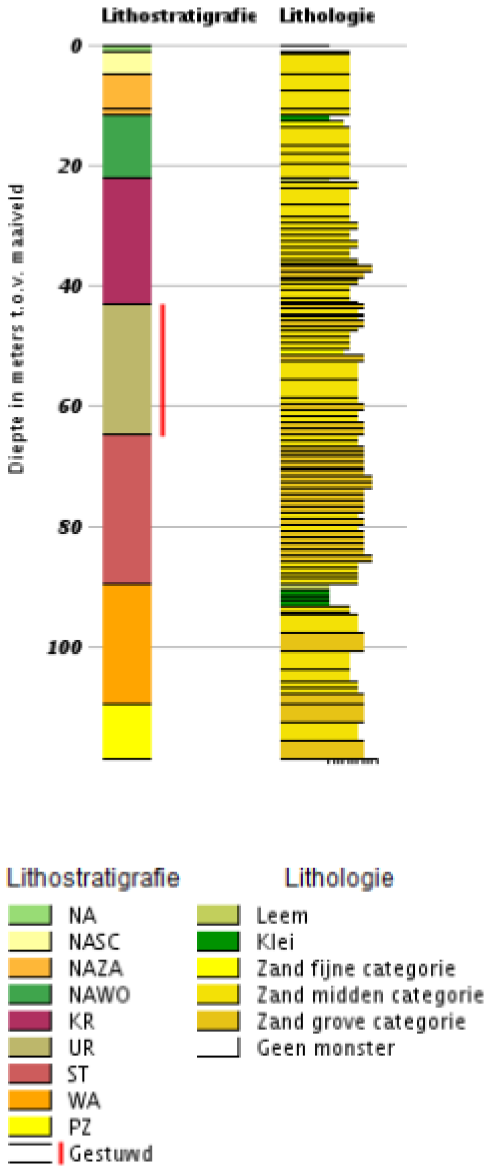

555000
560000
565000
570000
575000
580000
585000
590000
595000
600000
5815000
5810000
5805000
5800000
5795000
5790000
5785000
5780000
5775000
5770000
5765000
5760000
5755000
5750000
Windfarm area
Windfarm 1km buffer
Nautical 12 mile
0 - 5m
5 - 10m
10 - 15m
15 - 20m
20 - 25m
25 - 30m
30 - 35m
35 - 40m
40 - 45m
45 - 50m
50 - 55m
55 - 60m
60 - 65m
65 - 70m
70 - 75m
75 - 80m
0 2 4 6 8 10
km
coordinates: ETRS89 UTM 31N
Deltares
Enabling Delta Life

E Deep boreholes onshore

Following boreholes are used to indicate the base of the Yarmouth Roads Formation. Source is www.dinoloket.nl

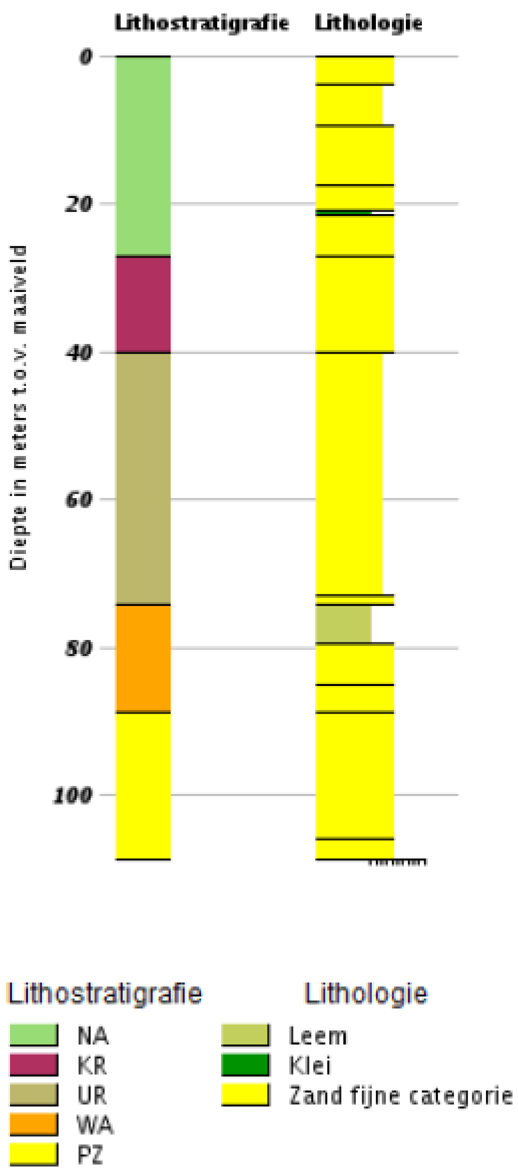
Boormonsterprofiel en interpretatie

Identificatie: B24F0056
Coördinaten: 98350, 489650
Maaiveld: 5,00 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 118,60 m



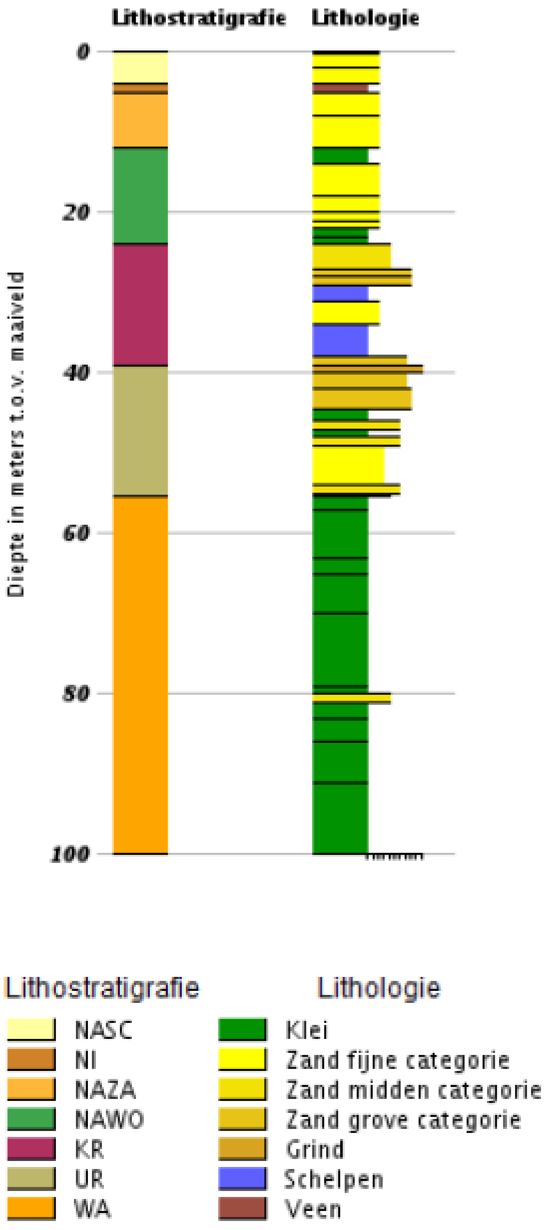
Boormonsterprofiel en interpretatie

Identificatie: B24H0040
Coördinaten: 94776, 481768
Maaiveld: 3,50 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 108,60 m



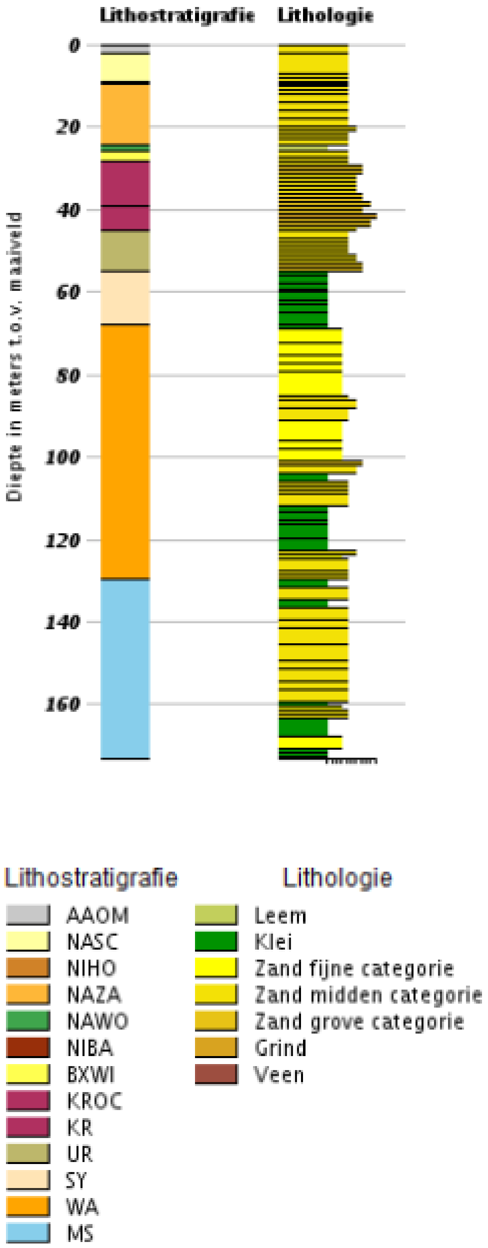
Boormonsterprofiel en interpretatie

Identificatie: B30D0197
Coördinaten: 73921, 452216
Maaiveld: 3,69 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 100,00 m



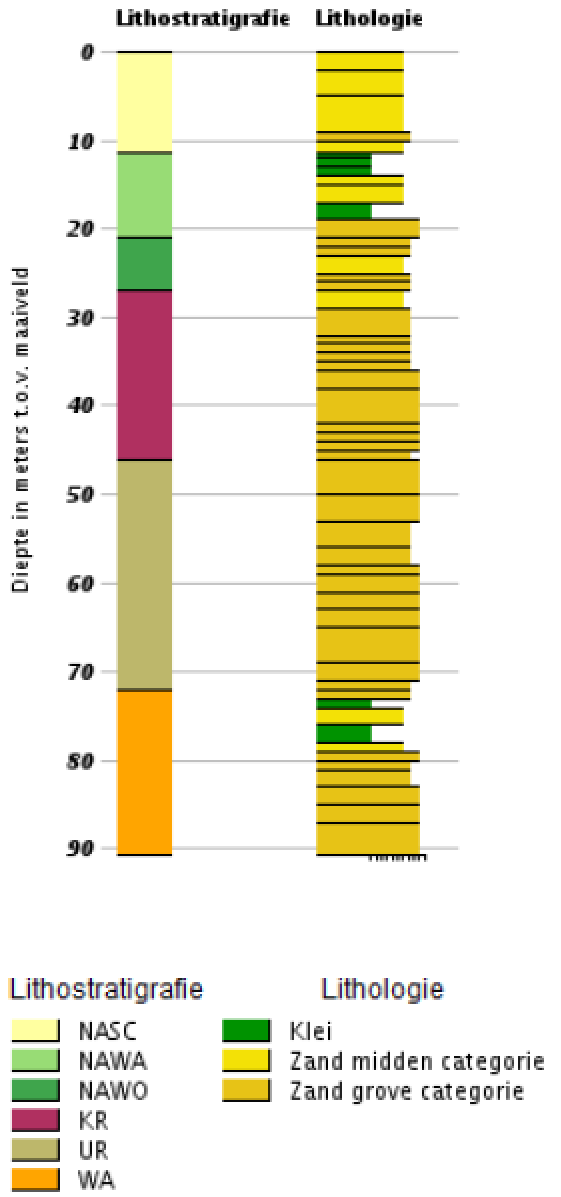
Boormonsterprofiel en interpretatie

Identificatie: B30D0206
Coördinaten: 73815, 452761
Maaiveld: 7,63 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 173,18 m



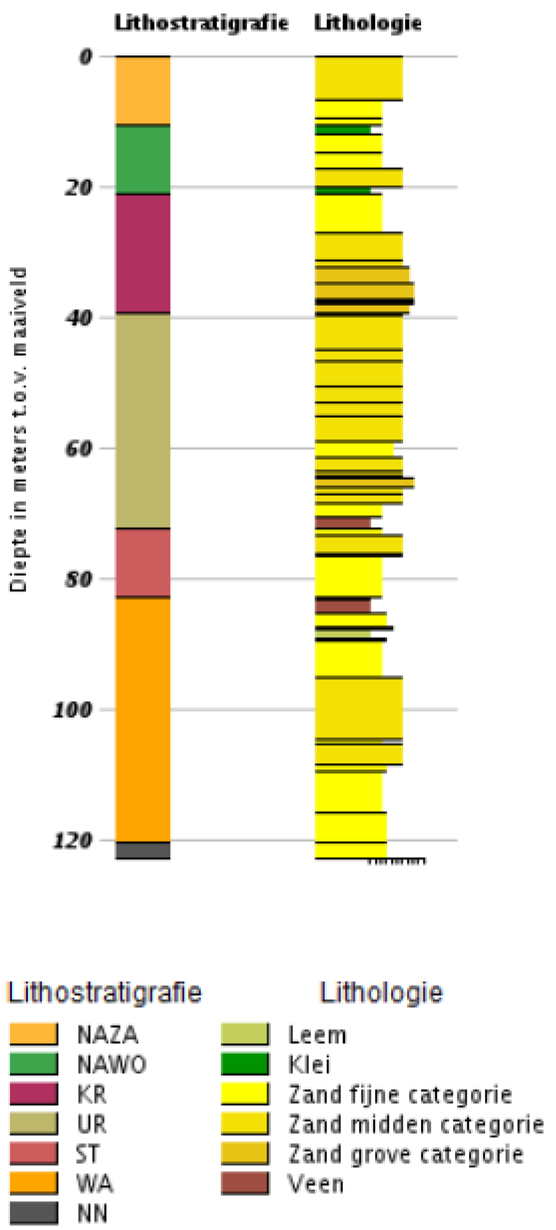
Boormonsterprofiel en interpretatie

Identificatie: B30E0248
Coördinaten: 86525, 466663
Maaiveld: 11,10 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 90,65 m



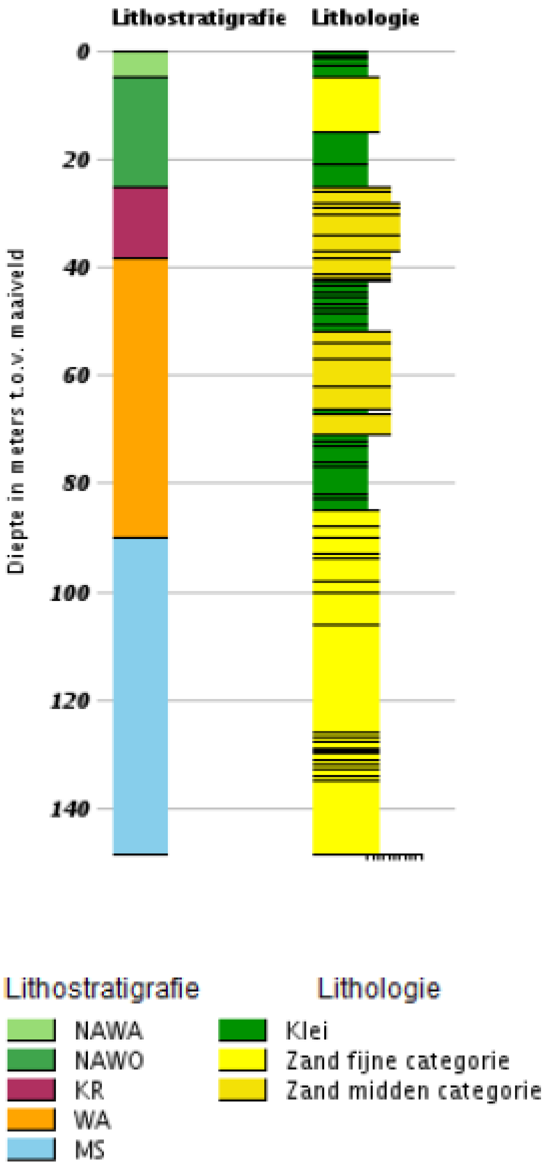
Boormonsterprofiel en interpretatie

Identificatie: B30G0056
Coördinaten: 83630, 460650
Maaiveld: 4,00 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 122,79 m



Boormonsterprofiel en interpretatie

Identificatie: B37D0134
Coördinaten: 71139, 436979
Maaiveld: 1,35 m t.o.v. NAP
Dieptetraject t.o.v. Maaiveld: 0,00 m - 148,60 m



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www.rvo.nl / http://english.rvo.nl

Netherlands Enterprise Agency (RVO.nl) | January 2016