DNV·GL

HOLLANDSE KUST (WEST) WIND FARM ZONE

Certification Report
Site Conditions Assessment

Netherlands Enterprise Agency

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Date: 2021-04-16

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Customer:	Netherlands Enterprise Agency Croeselaan 15, 3521 BJ Utrecht, The Netherlands	Services GmbH Brooktorkai 18 20457 Hamburg Germany
Contact person:	Huygen van Steen (RVO)	
Date of issue:	2021-04-16	Tel: +49 40 36149-0
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Objective:

The objective of this report is to confirm that DNV GL as an independent third party has verified the Site Conditions Assessment for the Hollandse Kust (west) Wind Farm Zone according to DNVGL-SE-0190:2020.

Prepared by:	Verified by:	Approved by:
Hunt, Helena Jane 2021.04.14 13:56:40 +02'00'	Digitally signed by Simón-Donaire, José Date: 2021.04.14 14:09:19 +02'00'	Redanz, Pia Digitally signed by Redanz, Pia Date: 2021.04.14 14:32:20 +02'00'
Helena Hunt Project Manager	José Simon-Donaire Senior Engineer	Pia Redanz Project Sponsor

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1 EXECUTIVE SUMMARY

The Hollandse Kust (west) Wind Farm Zone (HKWWFZ) is located in the Dutch Sector of the North Sea, approximately 51 km from the coastline. As part of the tender preparations, the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland, RVO) has requested a site conditions assessment of the Hollandse Kust (west) Wind Farm Zone.

The geotechnical testing program (incl. the ground model program) can be considered as the 'cutting edge' with respect to the amount of detailed factual data that is available by the time of the initiation of the tender phase for an offshore wind farm.

2 CERTIFICATION SCHEME

Document No.	Title
DNVGL-SE-0190:2020-09	Project certification of wind power plants

3 LIST OF REPORTS

The appendices to this report comprise the detailed DNV GL certification reports which normally include reference standards/documents, list of design documentation as well as summary and conclusion of the DNV GL evaluation.

APPENDIX	Revision	Subject
A	0	Wind Investigations
B	1	MetOcean Investigations
C	0	Geophysical Investigations
D	0	Geological Ground Model
E	0	Geotechnical Borehole Locations
F	0	Geotechnical Laboratory Testing
G	0	Geotechnical Parameters
H	0	Morphological and Scour Investigations
I	0	List of Documentation/References

Appendix I contains a list of the documents/references submitted by RVO for this project, including reports and database for review and sources of additional information. RVO has also initiated and received an Archaeological assessment and an UXO Desk study. Those two studies have not been verified by DNV GL:

(1) Regarding the Archaeological assessment reference is made to,
- the archaeological assessment (https://offshorewind.rvo.nl/obstructionsw)
- the methodology used (Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0)
- the approval of the Rijksdienst voor Cultureel Erfgord (RCE) (PDF p3)

(2) UXO Desk Study does not provide any specific limitations yet, it is worth mentioning in the whole set, but it is not verified against standards

MetOcean Measuring campaign

RVO has also initiated a MetOcean Measuring Campaign. A Project Quality Plan (PQP) was issued by Fugro for the supply of metocean data at Hollandse Kust (west). This quality management system consists of a quality assurance of the A) MetOcean systems deployed and B) a monthly validation.

A) Quality Assurance MetOcean systems deployed (pre-campaign validations)

The quality of the Fugro MetOcean measuring systems, the Seawatch wind LiDAR buoys WS 170, WS187 and WS188, is assessed by DNV GL Advisory. Each deployed individual system used is assessed by DNV GL Advisory by means of an offshore in situ verification. DNV GL Advisory conclude that each of the MetOcean measuring systems have demonstrated its capability to produce accurate wind speed and direction data across the range of sea states and meteorological conditions experienced.

B) Monthly validation

A quality management system applies on the monthly results of the MetOcean Campaign. Each monthly data report of Fugro is accompanied by a monthly report from Deltares assuring the quality:

- Deltares performs a monthly validation of the results of the campaign. The validation includes wind, waves, air and water temperature, air pressure, water levels and currents from a variety of reliable sources (anemometer, LiDAR, hydrodynamic model, etc.) in the North Sea; namely LEG, IJmuiden, EPL, P11-B, K13 and Q1. Furthermore, for some variables its general characteristics are qualitatively assessed, such as the respective vertical profiles for current and wind measurements. Deltares has a certified Quality Management System ISO 9001:2008.

4 CONDITIONS

The conditions identified during the technical evaluation are listed in the appendices. The conditions are assigned to the certification phases in which they need to be considered and evaluated.

The conditions listed in the following shall be addressed as part of the certification process.

For the design basis phase the following conditions shall be addressed:

- The Geotechnical Report Investigation Data Seafloor In Situ Test Locations shows an investigation area deviating from the geophysical investigation area. In further, more detailed design steps, it shall be ensured that all turbine locations are sufficiently investigated.
- DNV GL concur with the findings of the DHI report regarding the uncertainties in the SWDWF2020 wave model for predicting the wave roses on top of the two sand banks. For future development on top of the two banks the local effects of the sand banks with regards to the wave directional distribution shall be accounted for.
- The wind turbine configurations incl. cable route have not been determined, it is assumed for the certification that the wind turbines will be placed in the area where borings and/or at least one CPT have been performed within a radius of 30 meters from the centre of the wind turbine foundation. If the wind turbine configurations incl. cable route are placed outside a radius of 30 meters additional assessment shall be performed.
- Power plant configurations with wind turbines more than 30 m from in-situ tests as included in this review require further analysis of geophysical profiles, new in-situ tests and evaluation of existing geotechnical characteristic design profiles. Such modifications are not considered within this statement of compliance for site conditions assessment. If the wind turbine configurations incl. cable route are placed outside a radius of 30 meters additional assessment shall be performed.

For the design phase the following condition shall be addressed:

- If any future boreholes or CPTs performed should deviate significantly from the boreholes at the 46 positions and the soil composed in the 10 batches, then additional dynamic and cyclic tests must be considered.
- Clustering of in-situ tests from various locations can be used as basis for design if both lower and upper fractions of the representative design parameters are included in the design estimates. The variations of the soils in a cluster are higher than the variations of the soils in the surroundings of a selected wind turbine considered. The best estimate at a position is different from the best estimate of the entire cluster.
- Characteristic profiles have been made for selected representative positions only. If foundations shall be optimized for any other wind turbine position within the geotechnical investigation area, site-specific profiles must be carried out on CPTs at the specific position and the methods calibrated as described by Fugro in the geotechnical parameter report.
- The final scour mitigation strategy will have to be defined by the designer, for the actual foundation and cable design to be used.

For the operation and maintenance phases the following condition shall be addressed:

- The seabed levels within the wind farm area shall be monitored and remedial actions taken before the seabed levels are compromised.

5 OUTSTANDING ISSUES

No outstanding issues have been identified.

6 CONCLUSION

6.1 Studies Reviewed by DNV GL

The studies reviewed by DNV GL are further described in the appendices A to H. The reviewed documents are listed in appendix I.

The review conclusions are summarised in the following.

Wind Investigations	DNV GL finds that the wind properties as defined in the documents listed in section A4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 and the basis for the evaluation listed in Section A3 for establishing site assessment.
	
	The properties estimated are:
	• Annual average wind speed (at 100 m MSL): 9.72 m/s
	• Wind roses
	• Wind distributions:
	  ○ Weibull A-parameter (at 100 m MSL): 11.11 m/s
	  ○ Weibull k-parameter (at 100 m MSL): 2.283

MetOcean Investigations	DNV GL has found the presented methods to be in line with industry practice. DNV GL finds that the Metocean study is complete, is plausible and is carried out according to 'state of the art' methods, and that • the Normal Metocean Conditions • the Extreme Metocean Conditions as defined in the documents listed in Section B4 are derived in line with the requirements following Section 2.3.2 of the DNVGL-SE-0190 and the basis for the evaluation listed in Section B3, and are suitable as design input for Hollandse Kust (west) Wind Farm Zone. Furthermore, DNV GL finds that the Metocean database performs well and is suitable for establishing the Metocean design conditions for the Wind Farm Zone Hollandse Kust (west) with due consideration of the condition listed in Section B6.
Geophysical Investigations	The geophysical investigation report may be used to support the Design Basis documentation for the (preliminary) design of future offshore wind farms in the project area. The data in this report is suitable to serve as a geological ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with the basis for the evaluation listed in Section C3.
Geological Ground Model	The geotechnical investigation reports may be used to support the Design Basis documentation for the (preliminary) design of future offshore wind farms in the project area. The data in the reports is suitable to serve as partial input for a geotechnical ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with the basis for the evaluation as listed in Section D3, if the conditions in Section D6 are observed.
Geotechnical Borehole Locations	In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section E4 contributes to fulfil the demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in section E3, if the conditions in Section E6 are observed. The data presented in this report can contribute to the establishment of geotechnical design profiles in accordance with the requirements for design basis for detailed design of foundations, which will be designed after DNVGL-ST-0437 and DNVGL-ST-0126, with due consideration of the conditions listed in Section E3.

Geotechnical Laboratory Testing	In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section F4 contributes to fulfil the relevant demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in section F3, if the condition in chapter F6 is observed. We acknowledge the large number of advanced tests performed and reported. With additional interpretation this can support the design with a high degree of accuracy for cyclic degradation and initial stiffness. The geotechnical testing program can be considered as the 'cutting edge' with respect to the amount of detailed factual data that is available by the time of the initiation of the tender phase for an offshore wind farm. The "geotechnical laboratory test data" report can be used to support the design basis for design of future offshore wind turbines in the project area in accordance with DNVGL-ST-0437 and DNVGL-ST-0126 with due consideration to the condition listed in Section F6.
Geotechnical Parameters	In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section G4 contribute to fulfilling the relevant demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in Section G3, if the conditions in Section G6 are observed. With respect to the location of boreholes, in-situ tests and laboratory tests performed, the evaluations presented in the Geotechnical Parameters report can be used to support the design of future offshore wind farms in the project area. The data presented in this report can be used for establishing a Design Basis in accordance with DNVGL-ST-0437 and DNVGL-ST-0126 with due consideration of the conditions listed in Section G6.

Morphological and Scour Investigations	DNV GL has found that the morphology study is complete, carried out according to industry best practice, is plausible, and that • Best Estimate Bathymetry (BEB) • Lowest Sea Bed Level (LSBL) for the period 2019-2059 • Highest Sea Bed Level (HSBL) for the period 2019-2059 as defined in the documents listed in Section H4 are derived in line with the requirements following Section 2.3.2 of the DNVGL-SE-0190 and the related "Basis for the evaluation" listed in Section H3 can be used as basis for determining design seabed levels for Hollandse Kust (west) Wind Farm Zone. The conditions in Section H6 needs to be observed. Although the actual scour prediction and mitigation strategies must be defined by the designer for the actual foundation and cable concepts, DNV GL has found the presented methods to be in line with industry practice.

As part of the review, the consistency between above studies has been checked:

- The 'wind' in MetOcean Investigation are consistent with the 'wind' found in the Wind Investigation
- The 'seabed levels' in the geophysical surveys are consistent with the 'seabed levels' found in the Morphological and Scour Investigations
- The 'seabed levels' used in the MetOcean investigation are consistent with the data and the 'seabed levels' found in Morphological and Scour Investigations
- The use of buoy data in WRA & MetOcean
- The use of geophysical data to define geotechnical investigation and to update geological ground model with geotechnical data

6.2 Other Site Conditions Studies not Reviewed by DNV GL

- Regarding the data measured in the MetOcean campaign and used in the morphodynamic, MetOcean and wind resource studies: A reference is given to the quality management system of the measuring campaign (the system is validated by DNV GL Advisory , and monthly quality assurance is carried out by Deltares
- Regarding the Archaeological assessment a reference is made to (https://offshorewind.rvo.nl/obstructionsw), to the methodology used (Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0) and to the approval of Rijksdienst voor Cultureel Erfgord (RCE)
- UXO Desk Study is not verified against standards

6.3 Over-All Conclusion

Under consideration of the conditions listed in section 4, DNV GL has found that the site conditions for the Wind Farm Zone Hollandse Kust (west) based on measurements and desk studies,

- have been established correctly
- are complete and fulfil the requirements as given in the certification scheme listed in section 2 of this report
- that the risks and uncertainties have been minimised according to cutting edge methods
- can be used directly as input for design.

APPENDIX A
Wind Investigations

Evaluation of Wind Resource Assessment for Hollandse Kust (west) Wind Farm Zone

A1 Description of verified component, system or item

Within the Wind Farm Zone the wind conditions have been estimated. The resulting site conditions are documented by the customer and build the basis for the verification described in the current report.

A2 Interface to other systems/components:

No interfaces to other systems/components are present.

A3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

A4 Documentation from customer

List of reports:

Document No.	Revision	Title
/1/ HKWWRA/4NT/0704126/000/03	03 2020-10-30	Site Studies Wind Farm Zone Hollandse Kust Wind Resource Assessment (West)
/2/	V03_D	HKW_20200807_Tractebel_DeliverablesAsTables_V03_D.xlsx

List of reports taken for information only:

Document No.	Revision	Title
/A/ Proj. ID: 11822658	Final Draft 0.4 Dated 2020-11-09	MetOcean Study and database for Dutch Wind Farm Zones Hollandse Kust (west)

A5 Evaluation Work

/1/ presents the wind resource assessment for the planned Hollandse Kust (west) Offshore Wind Farm Zone. The assessment has been based on combined use of offshore wind measurements and mesoscale model data. The main outcome of /1/: The long-term mean wind speed at a hub height of 100 m MSL at the center of the zone has been determined to be 9.72 ± 0.31 m/s (± standard deviation) based on one year of buoy measurements. The wind speed variation within the zone is evaluated with the mesoscale model DOWA and found to be about ±0.1 m/s.

A wake analysis has been undertaken which is not part of the certification of this report. However, the report /1/ concludes that the stated losses are uncertain, and that the inclusion of wake loss is left open to the designers. DNV GL agree to this conclusion.

The wind speed was measured in an on-site floating LiDAR campaign at three independent lidars HKW A, HKW B and HKW C at measurement heights of 30, 40, 60, 80, 100, 120, 140, 160, 180, 200 and 250 m MSL. Data from the period 11/02/2019-10/02/2020 was used in the assessment. The on-site measurements are supported by the following other Dutch North Sea offshore wind measurements taken at

- Europlatform met mast and LiDAR
- Lichteiland Goeree (LEG) met mast and LiDAR
- Offshore Wind Farm Egmond aan Zee (OWEZ) met mast
- K13 lidar
- Met mast IJmuiden (MMIJ)
- Floating LiDAR at HKZ Wind Farm Zone
- Floating LiDAR at HKN Wind Farm Zone

In /1/ data from three different reanalysis datasets

- ERA5 reanalysis data
- MERRA2 reanalysis data
- CFSv2 reanalysis data (extended CFSR data)

have been compared with the measurements.

It was found that ERA5 was the best data source and therefore chosen to be used as long-term reference data source for the MCP routine.

For the horizontal extrapolation, data from five different mesoscale models

- KNW mesoscale data
- DOWA mesoscale data
- NEWA mesoscale data
- 3TIER-ERA5
- EMD-WRF-ERA5

have been compared with the measurements.

It was found that DOWA was the best data source and therefore chosen to be used for the horizontal extrapolation at the site.

DNV GL has reviewed

Measurements
Long-term correction
Horizontal extrapolation
The results of the wind climate calculation including

- Air temperature
- Air pressure
- Relative humidity
- Air density Correction
- Time Series presented in /2/

and has found the documentation to be correct.

Furthermore, DNV GL has compared the wind speeds presented in /1/ with in-house knowledge about the 'Design' and 'Measured Wind' on existing Belgian and Dutch offshore wind farms and has found that 9.72 m/s long-term mean wind speed including ± 0.31 m/s (± standard deviation) can be agreed on.

The wind speeds are to be used for design of future the Hollandse Kust (west) offshore wind farm.

It has been checked that the 'wind distribution and wind roses' used in the metocean desk study presented in /A/ are aligned.

A6 Conditions to be considered in other certification phases

No conditions have been identified.

A7 Outstanding issues

There are no outstanding issues.

A8 Conclusion

DNV GL finds that the wind properties as defined in the documents listed in section A4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 and the basis for the evaluation listed in Section A3 for establishing site assessment.

The properties estimated are:

- Annual average wind speed (at 100 m MSL): 9.72 m/s
- Wind roses
- Wind distributions:
    - Weibull A-parameter (at 100 m MSL): 11.11 m/s
    - Weibull k-parameter (at 100 m MSL): 2.283

APPENDIX B
MetOcean Investigations

Evaluation of metocean investigations for Hollandse Kust (west) Wind Farm Zone

B1 Description of verified component, system or item

Within the wind farm area a metocean study has been performed. The resulting metocean site conditions are documented by the customer and build the basis for the verification described in the current report. The metocean data is made available through a metocean database.

B2 Interface to other systems/components

Currently, no interfaces to other systems/components are present.

B3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

B4 Documentation from customer

List of reviewed reports and database:

Ref.	Document No.	Revision	Title
/1/	Proj. ID: 11822658	Final 0.5 Dated 2020-12-04	DHI report: MetOcean Study and database for Dutch Wind Farm Zones Hollandse Kust (west), incl.
/2/			APPENDIX_F1_NormalConditions_wind_links2STOR2
/3/			APPENDIX_F2_NormalConditions_currents_links2STOR2
/4/			APPENDIX_F3_NormalConditions_waves_links2STOR2
/5/			APPENDIX_G_JointProbabilityParameters_links2STOR2
/6/			MOOD database – https//:www.metocean-on-demand.com datasets for a) Dutch Offshore Wind farms, meteorologicial Parameters (except wind), Harmonie, KNMI/DHI b) Hollandse Kust (west), Water Level and Current (2D), MIKE21 Hydrodynamic Model (HD), DHI c) Hollandse Kust (west), Wave Parameters (integrated), Mike 21 Spectral Wave Model (SW), DHI d) Hollandse Kust (west), Wave Spectra (Directonal-Frequency), MIKE 21 Spectral Wave Model (SW), DHI e) Hollandse Kust (west), Wind Data, CFSR corrected, NOAA/DHI

List of reports taken for information only:

Ref.	Document No.	Revision	Title
/A/	HKWRA/4NT/070 4126/000/03	03 Issued 2020-10-30	Wind Resource Assessment for Hollandse Kust (west) Wind Farm Zone.
/B/			HKW Metocean Campaign 12-Months report – Year 1: February 2019 until February 2020 - Fugro

B5 Evaluation work

/1/ presents the Metocean assessment for the planned Hollandse Kust (west) Wind Farm Zone and contains information for Normal and Extreme Conditions regarding:

- Wind
- Waves
- Current
- Water Levels
- Joint probabilities between the above.
- Other parameters like salt, temperatures, marine growth etc.

The data shall serve as input for the design, installation and maintenance of wind turbines, inter-array cables and substations.

The Metocean conditions are established by hindcast modelling covering the period 1979-2019 (41 years). The hindcast models were forced by wind/pressure field data from the Climate Forecast System Reanalysis (CFSR) dataset established by the National Centers for Environmental Prediction (NCEP). DNV GL considers this wind data set to be state of the art as input for hindcast models and has seen several studies where the wind data set has been successfully applied.

Bathymetry

The bathymetry data for the Hollandse Kust areas used in the hindcast models was based on data collected by Fugro in 2019. For other areas than Hollandse Kust (west), the bathymetric data was obtained from the Digital Terrain Model (DTM) adopted from the EMODnet Bathymetry portal (initiated by the European Commission as part of developing the European Marine Observation and Data Network (EMODnet)). DNV GL considers that both the Fugro data as well as the EMODnet give a correct description of the seabed and can be used as input for hindcast models.

Wind

The CFSR wind used to force the wave model and the HD (water level and current) model has been validated against the following measured data:

Wind measurement location	Measurement period
Europlatform	1996-2020
K14	2006-2020
K13a	1996-2020
LEG	1981-2020
F16	2009-2020
F3	1994-2020
J6	2009-2020
L9	2006-2020
P11	2009-2020
HKNA	April 2017 - April 2019
HKNB	April 2017 - April 2019
HKWA	February 2019 -November 2019

Wind measurement location	Measurement period
HKWB	February 2019 -November 2019
HKWC	August 2019 -November 2019
Hoorn	1994-2020

DNV GL has reviewed the validation of the wind and has found it documented that the CFSR wind model can be used as input for hindcast models.

DHI (/1/) and Tractebel (/A/) have independently of each other calculated the wind speed 100m above the sea-level for the Hollandse Kust (west) and found excellent correlation. DNV GL therefore considers that the wind at around 100m above sea-level can be used to establish the design wind conditions at Hollandse Kust (west) Wind Farm Zone.

Waves Validation/Calibration

The wave hindcast model has been calibrated by varying:

- 'Bottom friction'
- 'The effect of wind-induced currents' and
- 'Cap to the ratio of friction velocity (u*) / wind speed (u10)'

DNV GL has reviewed the calibration and found that the final values used as input for the hindcast models are within the normal applied parameter ranges.

The wave hindcast model has been validated against the following measured data:

Wave measurement location	Measurement period
HKWA	February 2019 -November 2019
HKWB	February 2019 -November 2019
HKWC	August 2019 -November 2019
HKNA	April 2017 - April 2019
HKNB	April 2017 - April 2019
Europlatform	1983-2020
F16	2009-2020
F3	2013-2020
J6	2009 - 2020
K13a	1979 - 2020
K14	2012-2020
L9	2012-2020
LEG	1983-2020
Q1	2007-2020

DNV GL has reviewed the validation of the waves and has found that for the zone not located on the banks, that the hindcast model can be used to establish the design wave conditions at Hollandse Kust (west) Wind Farm Zone. It should be noted that the validation of wave directions (wave roses) on top of one of the banks showed an underprediction of waves from the north. This is considered to be a local effect of the model.

DNV GL concur with the findings of the DHI report regarding the uncertainties in the SWDWF2020 wave model for predicting the wave roses on top of the two sand banks. For future development on top of the two banks the local effects of the sand banks with regards to the wave directional distribution shall be accounted for.

HD (water level and current) Validation/Calibration

The HD hindcast model has been validated/calibrated against the following measured data:

Wave measurement location	Water Level	Current
HKWA	February 2019 -November 2019	February 2019 -November 2019
HKWB	February 2019 -November 2019	February 2019 -November 2019
HKWC	September 2019 -November 2019	September 2019 -November 2019
HKNA	2017-2019	2017-2019
HKNB	2017-2019	2017-2019
Brouwershavensche Gat 2	1979-2020	NA
Europlatform	1983-2020	NA
F16	2009-2020	NA
J6	2009-2020	NA
K13a	1979-2020	NA
K14	2012-2020	NA
L9	2012-2020	NA
LEG	1983-2020	NA
Q1	2007-2020	NA

The hydrodynamic model has been calibrated by varying:

- The Manning number (bottom friction)
- Wind friction

DNV GL has reviewed the validation of the water level and current and has found it documented that the HD (water level and current) hindcast results can be used the establish the design water level and current conditions at Hollandse Kust (west) Wind Farm Zone.

MetOcean Database

The overall goal of the database is to support the establishment of MetOcean conditions for design, installation and maintenance of wind turbines, inter-array cables and substations for the project Wind Farm Zone Hollandse Kust (west). The database is based on the hindcast model results described above and covers meteorology (wind) and hydrodynamics (water levels, currents and waves) for a period of 41 years (1979-2020). The database also includes results from extreme value analysis and correlations (for example correlations between extreme significant wave height and wind-speed, current and water level respectively, and wave periods associated with the extreme individual wave heights).

DNV GL has checked the meteorology (wind) and hydrodynamics (water levels, currents and waves) data available in the database, both for normal conditions (i.e. roses and distributions) and extreme conditions (including associated values), for the positions presented in /1/, and has found that the database is consistent with /1/.

Furthermore, DNV GL has made spot checks of the data output for other positions than presented in /1/ and found that data are plausible and in agreement with the overview maps covering the site (for example highest and lowest astronomical tide, mean significant wave height, extreme wind speed, extreme significant wave height and maximum extreme individual wave height with return period of 100 years), and has confidence that the data included in the database are consistent with the data presented in /1/.

The MetOcean database was validation based on 9 months of data from the MetOcean campaign. On the issuing of the 12-Months report of the MetOcean campaign /B/ an anomaly was detected in the measurements which RVO are investigating further. Regardless of whether the anomaly is a true measurement or not, it is not considered to have an impact on the MetOcean database.

B6 Conditions to be considered in other certification phases

The following condition is to be considered for design basis phase:

DNV GL concur with the findings of the DHI report regarding the uncertainties in the SWDWF2020 wave model for predicting the wave roses on top of the two sand banks. For future development on top of the two banks the local effects of the sand banks with regards to the wave directional distribution shall be accounted for.

B7 Outstanding issues

There are no outstanding issues.

B8 Conclusion

DNV GL has found the presented methods to be in line with industry practice. DNV GL finds that the Metocean study is complete, is plausible and is carried out according to 'state of the art' methods, and that

- the Normal Metocean Conditions
- the Extreme Metocean Conditions

as defined in the documents listed in Section B4 are derived in line with the requirements following Section 2.3.2 of the DNVGL-SE-0190 and the basis for the evaluation listed in Section B3, and are suitable as design input for Hollandse Kust (west) Wind Farm Zone.

Furthermore, DNV GL finds that the Metocean database performs well and is suitable for establishing the Metocean design conditions for the Wind Farm Zone Hollandse Kust (west) with due consideration of the condition listed above in Section B6.

APPENDIX C
Geophysical Investigations

Evaluation of Geophysical Investigations for Hollandse Kust (west) Wind Farm Zone

C1 Description of verified component, system or item

In the Investigation Area of the Hollandse Kust (west) Wind Farm Zone geophysical investigations have been performed. The geophysical investigations were divided into two separate investigations performed from 11th October 2018 to 16th February 2019 and from 22nd October 2018 to 17th February 2019 and consisted of Sidescan Sonar (SSS), Magnetometer (MAG), Multi Beam Echo Sounder (MBES), Single Beam Echo Sounder (SBES), Sub-Bottom Profiler (SBP), ultra-high resolution Single Channel Sparker (SCS-UHR) and ultra-high resolution Multichannel Sparker (MCS-UHR). The results and the found site conditions are documented by the customer and are the basis for the verification of the current report.

C2 Interface to other systems/components

The geophysical investigation reports shall be considered for the Geotechnical Investigations and the Geological Ground Model.

C3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	November 2016	Loads and site conditions for wind turbines
DNVGL-ST-0126	April 2016	Support structures for wind turbines

C4 Documentation from customer

List of reports:

Document No.	Revision	Title
Fugro Document No. P904162	4 19.08.2019	Geophysical Results Report Hollandse Kust (West) Wind Farm Zone Survey 2018

C5 Evaluation work

Based on the regional geology the local geology in the windfarm area has been investigated based on the MCS-UHR, SCS-UHR and SBP results and existing borehole information by Fugro.

This led to an interpretation of mainly seven geological units in the area, namely, A: Holocene – Southern Bight Formation (Bligh Bank), B: Holocene – Naaldwijk Formation, C: Late Pleistocene – Eem Formation (Brown Bank), D: Late Pleistocene – Eem / Egmond Ground Formation, E: Post-Saalian – Valley Infill Formation and F+G: Early to Middle Pleistocene – Yarmouth Roads Formation. The units C, D and E are present only in parts of the investigation area.

An in-depth interpretation is included in the definition of layer boundaries between these geological units. Based on the given information in the report DNV GL assessed the interpretation for plausibility and agrees to the given conclusions presented in the report.

It is further noted that some units are present only in parts of the Wind Farm Zone. Especially for unit D (basin-like depressions) and unit E (glacial channel / valley), due to the deviating infill soil material it is possible that soil parameters may change within short distances.

Additionally, boulders have been detected in the Wind Farm Zone and have been documented in the appendices of the main report, with the note that further boulders may be present.

It shall be noted that due to the distance of track lines during the investigations the level of detail in a 3-dimensional ground model is limited but can be expanded by findings of the geotechnical investigations.

Further limitations and recommendations are mentioned in the corresponding sections of the certification report and shall be considered in the further design process, see section A6.

The quality of the data acquisition has been documented within the report.

DNV GL could not detect any deviations from quality which would have led to a critical error in the performed interpretations.

DNV GL has evaluated that the above referenced document from the customer provides sufficient information to get a good general understanding of the geophysical conditions in the given wind farm area. The above referenced report provides sufficient geophysical details to serve as a geological model for the (preliminary) design of future offshore wind farms. Such a model can be relied upon to establish general geological conditions, support discussions on site variability and establish the scope of a future geotechnical investigation campaign, e.g. with respect to park layout studies.

The given results have been documented in the report and it is evaluated by DNV GL that the conclusions have been determined and presented in detail with good traceability.

The assessed report fulfils the requirements in accordance with the standards specified as the basis for the evaluation.

C6 Conditions to be considered in other certification phases

There are no conditions.

C7 Outstanding issues

No outstanding issues have been identified.

C8 Conclusion

The geophysical investigation report may be used to support the Design Basis documentation for the (preliminary) design of future offshore wind farms in the project area. The data in this report is suitable to serve as a geological ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with the basis for the evaluation listed in Section C3.

APPENDIX D
Geological Ground Model

Evaluation of Geotechnical Investigations for Hollandse Kust (west) Wind Farm Zone

D1 Description of verified component, system or item

In the Investigation Area of the Hollandse Kust (west) Wind Farm Zone geotechnical investigations have been performed. The geotechnical investigations were performed from 15th May to 17th June 2019 and consisted of a large number of cone penetration tests (CPT) including piezocone, seismic cone and temperature cone penetration tests, pressure dissipation tests as well as vibrocore sampling and laboratory tests.

D2 Interface to other systems/components

The geotechnical investigation report shall be considered for further geotechnical investigations and the Geotechnical Ground Model.

D3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	November 2016	Loads and site conditions for wind turbines
DNVGL-ST-0126	April 2016	Support structures for wind turbines

D4 Documentation from customer

Reviewed reports:

Document No.	Revision	Title
Fugro document No. P904711/01	5 10.02.2020	Geotechnical Report Investigation Data Seafloor In Situ Test Locations Hollandse Kust (west) Wind Farm Zone Dutch Sector, North Sea
Fugro document No. P904711/02	5 10.02.2020	Geotechnical Report Investigation Data Seafloor Sample Locations Hollandse Kust (west) Wind Farm Zone Dutch Sector, North Sea

Documents available for information:

Document No.	Revision	Title
P904711/TN11-DIG	1 10.01.2020	Technical Note - Digital Data Seafloor Sample and In Situ Test Locations Hollandse Kust (west) Wind Farm Zone Dutch Sector, North Sea - summarizing report and data files included in: "HKW_Lot 1_digital Data Deliverables.7z"

D5 Evaluation work

DNV GL has evaluated that the above referenced documents from the customer provide sufficient information to get a good general understanding of the geotechnical conditions in the given investigation area. For completeness raw data of the soil investigations has been submitted to DNV GL in case it was needed for further information.

At the wind farm area one hundred and eighteen locations have been investigated by various cone penetration tests with a maximal investigation depth of around 55 m below mudline.

Overall, cone penetration tests at one hundred and eighteen locations, one-hundred and twenty-two piezocone penetration tests at one-hundred and eighteen locations, thirty seismic cone penetration tests at thirty locations, thirty-six temperature cone penetration tests at thirty-five locations and eighty pore pressure dissipation tests at twenty-nine locations have been conducted, distributed across the investigation area. The corresponding information can be found in the Geotechnical report.

Based on the CPT, for each of the one-hundred and eighteen locations two different geotechnical logs have been prepared: One shows a soil classification based on Qtn (normalized cone resistance) and Fr (normalized friction ratio), the other shows a soil classification based on Qtn and Bq (pore pressure ratio). These different soil classification methods are shown in two graphic logs and lead to diverging results regarding cohesive and non-cohesive soils at some test locations. Further interpretations have not yet been executed.

Vibrocore samples have been taken at 50 locations to investigate the geotechnical characteristics of sand waves across the wind farm area, including laboratory tests at some of the samples. The investigation depths range between 2.4 m to 6.4 m. Laboratory tests mainly consisted of bulk and dry density, particle size analysis as well as organic and carbonate content. Results of the mainly coarse-grained cohesionless material are documented within the corresponding report.

The above referenced reports provide information to create a geotechnical model for the (preliminary) design of future offshore wind farms. Such a model can be relied upon to establish general geotechnical conditions, support discussions on site variability and establish the scope of further future geotechnical investigations like boreholes and laboratory tests.

The given results have been documented in the reports and it is evaluated by DNV GL that the conclusions have been determined and presented in detail with good traceability.

The assessed reports fulfil the requirements in accordance with the standards specified as the basis for the evaluation.

D6 Conditions to be considered in other certification phases

- The Geotechnical Report Investigation Data Seafloor In Situ Test Locations shows an investigation area deviating from the geophysical investigation area. In further, more detailed design steps, it shall be ensured that all turbine locations are sufficiently investigated.
- For the final layout of the wind farm zones geotechnical investigations need to be performed at each specific (e.g. turbine) location.

D7 Outstanding issues

No outstanding issues have been identified.

D8 Conclusion

The geotechnical investigation reports may be used to support the Design Basis documentation for the (preliminary) design of future offshore wind farms in the project area. The data in the reports is suitable to serve as partial input for a geotechnical ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with the basis for the evaluation as listed in Section D3, if the conditions in Section D6 are observed.

APPENDIX E
Geotechnical Borehole Locations

Evaluation of report "Geotechnical Borehole Locations" for Hollandse Kust (west) Wind Farm Zone

E1 Description of verified component, system or item

The following comprises documentation for verification of a geotechnical borehole campaign, which forms a part of the "soil and geotechnical conditions" in accordance with DNVGL-SE-0190 section 2.3 Design basis.

The verified report consists of geotechnical boreholes performed at 46 target locations. The borings consist of

a) geotechnical sampling
b) standard down hole cone penetration testing
c) geophysical logging in selected boreholes
d) geotechnical laboratory tests performed on samples extracted from boreholes

The results from the geotechnical boreholes are documented by the customer and build the basis for the verification described in current verification report.

E2 Interface to other systems/components

Following interfaces must be considered with respect to the geotechnical borehole campaign and the final design basis for soil and geotechnical conditions:

a) Geophysical Site Investigations
b) Bathymetric Surveys
c) Geotechnical Interpretation of factual data
d) Execution of Dynamic/cyclic laboratory tests and interpretation of design graphs
e) Detailed Design of geotechnical structures

The details as referenced in a)-d) have already been performed and included in other reports.

E3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0126	2016-04	Support structures for wind turbines.
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

Standards, which has been used for execution of borings and laboratory tests are detailed in the documentation from costumer.

E4 Documentation from customer

List of reports:

Ref.	Document No.	Revision	Title
/1/	P904711/03	Issue 9, 2020-10-20	Geotechnical Report Investigation Data, Geotechnical Borehole Locations Hollandse Kust (west) Wind Farm Zone, Dutch Sector, North Sea
/2/			Fugro Document, Hollandse Kust (West) WFZ- Dutch Sector, North Sea, (No Title) List of Test Types, Test Facility, Test Method, Accredited to Certificate ID and Certificate Issue Date
/3/	P904711/TN12-DIG (3)		Technical Note, Digital Deliverables, Geotechnical Borehole Locations, Hollandse Kust (west) Wind Farm Zone, Dutch Sector, North Sea

E5 Evaluation work

/1/ presents factual geotechnical data as gathered at 46 locations for the planned Hollandse Kust (west) Wind Farm Zone.

It includes an extensive set of laboratory tests, which have been performed with soils extracted from the boreholes.

DNV GL has evaluated that the information presented in the documents from the customer provides a good basis for establishing site-specific calibrated empirical correlations and design profiles at the 46 locations.

The factual geotechnical data as presented in the borehole report provides a part of the geotechnical design basis. It comprises the following information:

a) Geotechnical soil sampling and logs performed at 46 locations

b) Borehole geophysical logging performed at 5 locations

c) In-situ test results performed at 46 locations (CPT)

d) Geotechnical (Static) Laboratory Test Results including
   - Classification
   - Triaxial (UU, CAU, CIU, CID) with Bender element tests.
   - Direct Shear
   - Ring Shear
   - Compressibility (Oedometer Tests)
   - Permeability
   - Other tests

The standards as presented in the Documentation from Customer are evaluated as representative basis for determination of parameters required for a geotechnical design basis.

Calibrated empirical correlations based on laboratory test results and in-situ test for the 46 locations could be used to develop design profiles at positions, where only CPT's have been performed in the wind farm area.

E6 Conditions to be considered in other certification phases

The conditions identified during the technical evaluation are listed in the following.

For the design basis the following conditions prevails:

- The wind turbine configurations incl. cable route have not been determined, it is assumed for the certification that the wind turbines will be placed in the area where borings and/or at least one CPT have been performed within a radius of 30 meters from the centre of the wind turbine foundation.
- Power plant configurations with wind turbines more than 30 m from in-situ tests as included in this review require further analysis of geophysical profiles, new in-situ tests and evaluation of existing geotechnical characteristic design profiles. Such modifications are not considered within this (partial) statement of compliance for site conditions assessment.

E7 Outstanding issues

There are not outstanding issues.

E8 Conclusion

In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section E4 contributes to fulfil the demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in section E3, if the conditions in Section E6 are observed.

The data presented in this report can contribute to the establishment of geotechnical design profiles in accordance with the requirements for design basis for detailed design of foundations, which will be designed after DNVGL-ST-0437 and DNVGL-ST-0126, with due consideration of the conditions listed above in Section E3.

APPENDIX F
Geotechnical Laboratory Testing

Evaluation of geotechnical laboratory test data for Hollandse Kust (west) Wind Farm Zone

F1 Description of verified component, system or item

The geotechnical laboratory report ref /1/ contains an extensive amount of tests. The soils investigated are composed from soil samples extracted from layers with similar properties from various borings. A total of 10 batches have been created for the investigation.

For identification and normalization, standard classification tests and static strength tests have been performed.

F2 Interface to other systems/components

Currently, following interfaces are identified:

- Geotechnical borehole campaign with respect to type of soil layers
- Static laboratory tests with respect to strength and deformation properties
- Geotechnical Characteristic design properties as established for static loads.
- Design estimates of cyclic degradation of the soils for critical design storm events.

F3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0126	2016-04	Support structures for wind turbines.
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

Standards, which have been used for execution of borings and laboratory tests appear in the Documentation from costumer.

F4 Documentation from customer

List of reports:

Ref.	Document No.	Revision	Title
/1/	P904711/04	Issue 5 2020-10-20	Geotechnical Report, Laboratory Test Data Hollandse Kust (west) Wind Farm Zone, Dutch Sector, North Sea
/2/	-	-	HKW_20201020_FNLM_Technical Note - Digital Deliverables Cyclic and Dynamic_V01_F, zip-file

F5 Evaluation work

/1/ presents the geotechnical laboratory test data for the planned Hollandse Kust (west) Wind Farm Zone. The report contains results from following type of tests:

- Classification
- Triaxial
  - Static load tests, CAUc/CIUc, CAUe, CIDc/CADc
  - Cyclic load tests, CUcyc, CDcyc (CTX)
- Direct Simple Shear
  - Static load tests, DSS drained and undrained soils
  - Cyclic load tests, CSS drained and undrained soils
- Small strain and damping
  - Bender Element Test (BE)
  - Resonant Column Test (RC)

When tests are performed within an accreditation in accordance with ISO/IEC 17025, then no additional verification for certification of the specific tests are required. Performance of the laboratory tests are therefore for information only. The results of the tests as reported are used as background information in the continued verification.

The type of tests made during testing are evaluated to support development of cyclic design graphs as basis for potential reduced strength of soils due to dynamic load scenarios.

The different cyclic tests (Direct Shear Tests, Triaxial Tests) in drained and undrained conditions are documenting how the soils will act within the tested load conditions.

Normalized cyclic shear Stress graphs have been presented showing the various test results for the Batches 1-9 as determined from cyclic DSS tests.

With respect to specific design requirements, further analysis of the factual laboratory data can be performed from the executed tests.

The digital deliverables /2/ contain test results in .xls-format that have been spot-checked by comparison with the data given in document /1/.

F6 Conditions to be considered in other certification phases

The conditions identified during the technical evaluation are listed in the following.

Soils, which have been tested from the 10 batches, are evaluated as representative for the 46 boreholes.

For the design phase the following condition shall be addressed:

- If any future boreholes or CPTs performed should deviate significantly from the boreholes at the 46 positions and the soil composed in the 10 batches, then additional dynamic and cyclic tests must be considered.

F7 Outstanding issues

There are no outstanding issues.

F8 Conclusion

In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section F4 contributes to fulfil the relevant demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in section F3, if the condition in chapter F6 is observed.

We acknowledge the large number of advanced tests performed and reported. With additional interpretation this can support the design with a high degree of accuracy for cyclic degradation and initial stiffness. The geotechnical testing program can be considered as the 'cutting edge' with respect to the amount of detailed factual data that is available by the time of the initiation of the tender phase for an offshore wind farm.

The "geotechnical laboratory test data" report can be used to support the design basis for design of future offshore wind turbines in the project area in accordance with DNVGL-ST-0437 and DNVGL-ST-0126 with due consideration to the condition listed in Section F6 above.

APPENDIX G
Geotechnical Parameters

Evaluation of geotechnical parameters for Hollandse Kust (west) Wind Farm Zone

G1 Description of verified component, system or item

The following comprises documentation for verification of the Geotechnical Parameters report, which forms a part of the "soil and geotechnical conditions" in accordance with DNVGL-SE-0190 section 2.3 Design basis.

A "Geotechnical Parameters" report has been generated for the soils as encountered in the wind farm area. The properties of the soils have been determined from 46 borehole locations and CPT's performed at 118 locations.

The factual data from geotechnical boreholes, in-situ CPT's, classification tests, static, cyclic and dynamic laboratory tests are presented in other verified reports. Those data provides the basis for geotechnical interpretation and appropriate geotechnical design parameters as presented in the Geotechnical Parameters report which has been evaluated within this review.

G2 Interface to other systems/components

Following interfaces are identified for the review of the "Geotechnical Parameters" Report:

- Geological Ground Model.
- Geotechnical Borehole campaign with respect to type of soil layers.
- Static laboratory tests with respect to strength and deformation properties.
- Geotechnical Laboratory Testing
- Site specific Characteristic Parameters for detailed Design.

G3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

G4 Documentation from customer

List of reports:

Ref.	Document No.	Revision	Title
/1/	P904711/07	Issue 6 2020-10-07	Geotechnical Parameters, Hollandse Kust (west) Wind Farm Zone, Dutch Sector, North Sea

G5 Evaluation work

It appears from the report /1/ section 1.6 that the report must be read in its entirety.

Parameters in the report originate from indirect and direct measurement. The results are compared to both non-calibrated and calibrated methods with respect to statistically defined upper bound, lower bound and best estimates. Utilization of characteristic parameters for design requires therefore continued geotechnical expertise and engineering judgement.

Characteristic parameters for a specific design must be selected and evaluated with respect to available data, accuracy of predicted parameter and risk associated to variation of the specific parameter for the particular element of the structure.

From the borings performed in the wind farm area, 9 soil units have been defined: Soil Unit A, B1, B2, C1, C2, D, E, F and G (Ref /1/, Sec 3. Geotechnical Ground Model table 3.2).

At each location HKW001-HKW118 at least one CPT has been performed. The soil units as defined in the boreholes are identified in the CPT for each location Plate C1-6 to C1-17.

Soil Provinces, as described in /1/ section 3.2 are evaluated as clustering of soil profiles with comparable soil units. Such profiles are therefore valuable for conceptual and preliminary detailed designs. Appendix C of /1/ plate C1-3 shows the design profiles for "Soil Province 1 to 8".

The report contains guidance text and formulas to determine characteristic parameters from various methods related to upper bound estimates, best estimates and lower bound estimates. Following parameters and subjects are evaluated within this review:

- Net Cone Resistance
- Soil Unit Weight
- Relative Density
- Undrained Shear Strength
- External Axial Strain at half the maximum deviator stress
- Peak Effective Angle of internal Friction
- Angle of Interface Friction, Steel/soil
- Coefficient of permeability
- Shear Modulus at small strain
- Damping
- Effect of dynamic actions, strength and deformation properties after cyclic loadings.
- Seismic Hazard Assessment

A design basis for each of the wind turbine positions can be established from the given guidance text, presented formulas, laboratory tests and CPTs as performed at each location.

G6 Conditions to be considered in other certification phases

The conditions identified during the technical evaluation are listed in the following.

For the design phase the following conditions shall be considered:

- Clustering of in-situ tests from various locations can be used as basis for design if both lower and upper fractions of the representative design parameters are included in the design estimates. The variations of the soils in a cluster are higher than the variations of the soils in the surroundings of a selected wind turbine considered. The best estimate at a position is different from the best estimate of the entire cluster.

- Characteristic profiles have been made for selected representative positions only. If foundations shall be optimized for any other wind turbine position within the geotechnical investigation area,

site-specific profiles must be carried out on CPTs at the specific position and the methods calibrated as described by Fugro in the parameter report ref. /1/.

G7 Outstanding issues

There are no outstanding issues.

G8 Conclusion

In summary, the verification work performed by DNV GL confirms that the "Site assessment" as seen by the documentation from customer related to the Hollandse Kust (west) Wind Farm Zone as listed under section G4 contribute to fulfilling the relevant demands set up in the Certification Scheme DNVGL-SE-0190:2020-09, section 2.3.2 and the related "Basis for the evaluation" listed in Section G3, if the conditions in Section G6 are observed.

With respect to the location of boreholes, in-situ tests and laboratory tests performed, the evaluations presented in the Geotechnical Parameters report can be used to support the design of future offshore wind farms in the project area. The data presented in this report can be used for establishing a Design Basis in accordance with DNVGL-ST-0437 and DNVGL-ST-0126 with due consideration of the conditions listed in Section G6 above.

APPENDIX H
Morphological and Scour Investigations

Evaluation of morphological and scour mitigation investigations for Hollandse Kust (west) Wind Farm Zone

H1 Description of verified component, system or item

Within the wind farm area a morphology and scour mitigation study has been performed. The results and the found morphodynamic site conditions are documented by the customer and build the basis for the verification described in the current report.

H2 Interface to other systems/components

Currently, no interfaces to other systems/components are present.

H3 Basis for the evaluation

Applied codes and standards:

Document No.	Revision	Title
DNVGL-ST-0437	2016-11	Loads and site conditions for wind turbines
IEC 61400-3	2009-02	Wind Turbines – Part 3: Design requirements for offshore wind turbines

H4 Documentation from customer

List of reports:

Ref.	Document No.	Revision	Title
/1/	1204811-002-HYE-0001	01 2020-07-06	Morphodynamics for Hollandse Kust (west) Wind Farm Zone
/2/	1204811-002-HYE-0002	01 2020-07-06	Scour and scour mitigation for Hollandse Kust (west) Wind Farm Zone

H5 Evaluation work

/1/ presents the bathymetrical/morphodynamic assessment for the planned Hollandse Kust (west) Wind Farm Zone. /1/ contains information regarding:

- Description of morphodynamic features in the wind farm zone
- An analysis of the morphodynamics
- Extrapolation of historical morphodynamic activities for the estimation of future seabed levels

The seabed bedforms at Hollandse Kust (west) Wind Farm Zone consist of a combination of megaripples and sand waves.

/1/ concludes that from the geological and geophysical data available non-erodible layers exist, but that they are located too deep to influence migration of the sand waves and the megaripples.

The megaripples have migration speeds that are so large that many megaripples will pass each foundation during the lifetime of the wind farms. Therefore, only their dimensions were determined, and their representative statistical values were included as an uncertainty band for predicted bed levels.

The sand waves have been analysed in 4 steps based on the historical and recent seabed bathymetries

a. Determination of transect locations
b. Determination of the sand wave migration direction
c. Determination of the sand wave migration speed
d. Characterization of the sand wave shape

Future migration

In /1/ future predictions are made over the period 2019 until 2059. The 2019 Hollandse Kust (west) Wind Farm Zone bathymetry was determined from multibeam survey carried out by Fugro on behalf of RVO. These bathymetrical data together with existing 'historical' bathymetric data for the project site available from the Netherlands Hydrographic Office (NLHO), Royal Netherlands Navy., with three bathymetries covering the period 1996-2002, 2006-2009 and 2014-2015 were obtained and used to determine the seabed dynamics: a) sand wave migration directions, b) sand wave speeds and c) the sand wave characteristics such as wavelength and wave height.

The future bathymetries and corresponding bed level changes have been estimated by artificial shifting the mobile seabed components of the most recent 2019 bathymetry. In order to account for the variability of the migration speed and migration direction, 9 different combinations of 3 migration directions and 3 migration speeds have been considered. Hereby upper and lower bound future seabed level estimates have been obtained. DNV GL has reviewed this method and has found that the method can be used to determine the long-term bathymetrical changes, when contingency accounting for the uncertainties are applied.

In order to account for a) survey, b) megaripples and c) spatial resolution uncertainty, 0.35 m upward and -0.25 m downward bands + spatial varying sand shape uncertainty have been added to the uncertainty. DNV GL has reviewed these uncertainty bands and found them to be on the safe side.

DNV GL has a) reviewed the study, b) has found that the study is carried out according to industry best practice and c) agrees on the following main data provided along with /1/:

- Lowest Seabed Level (LSBL) for time spans of 5 year
- Highest Seabed Level (HSBL) for time spans of 5 year
- Best Estimate Bathymetry (BEB) for time spans of 5 year

Unexploded Ordnances (UXO's)

In addition to the future predictions /1/ also present a hindcast of the seabed levels for the period 2019 to 1945 to detect bandwidths as a vertical demarcation for the location of Unexploded Ordnances (UXO's). DNV GL has reviewed and found the Best (BEOL), Lowest (LOL) and Highest (HOL) object levels are correctly modelled.

Scour Mitigation Strategies

In /2/ different scour mitigation strategies are presented. DNV GL has found that the methods are in line with industry practice.

H6 Conditions to be considered in other certification phases

The conditions identified during the technical evaluation are listed in the following.

For the design phase the following condition shall be addressed:

- The final scour mitigation strategy will have to be defined by the designer, for the actual foundation and cable design to be used.

For the operation and maintenance phases the following condition shall be addressed:

- The seabed levels within the wind farm area shall be monitored and remedial actions taken before the seabed levels are compromised.

H7 Outstanding issues

There are no outstanding issues.

H8 Conclusion

DNV GL has found that the morphology study is complete, carried out according to industry best practice, is plausible, and that

- Best Estimate Bathymetry (BEB)
- Lowest Sea Bed Level (LSBL) for the period 2019-2059
- Highest Sea Bed Level (HSBL) for the period 2019-2059

as defined in the documents listed in Section H4 are derived in line with the requirements following Section 2.3.2 of the DNVGL-SE-0190 and the related "Basis for the evaluation" listed in Section H3 can be used as basis for determining design seabed levels for Hollandse Kust (west) Wind Farm Zone. The conditions in Section H6 needs to be observed.

Although the actual scour prediction and mitigation strategies must be defined by the designer for the actual foundation and cable concepts, DNV GL has found the presented methods to be in line with industry practice.

APPENDIX I
List of Documents/References

List of Deliverables Site Studies on offshorewind.rvo.nl

Netherlands Enterprise Agency

Tender Hollandse Kust (west) Wind Farm Zone

January 11, 2021

File type	ID	Description of deliverable	Filename	Date of publication	Published	Quality approval
Report	A.1	Archaeological desk study - report	HKW_20190111_Periplus_Archaeological Desk Study_F.pdf	2019-01-11	yes	RVO
GIS	A.2	Archaeological maps with known wrecks	HKW_20190111_GIS Archaeological Assessment.zip	2019-01-11	yes	RVO
Report	A.3	Archaeological Assessment (Phase II) - Report	HKW_20191219_Periplus_Archaeo Phase II_Report-F.zip	2019-12-20	yes	RVO
GIS	A.4	Archaeological Assessment (Phase II)- GIS	HKW_20200207_Archaeo Phase II_GIS-F.zip	2020-02-07	yes	RVO
Memo	A.5	Archaeological Programme of Requirements (phase II)	HKW_20181019_PoR archaeological assessment phase II.pdf	2018-10-19	yes	RVO
Memo	A.6	Archaeological Programme of Requirements (phase III)			no	
Report	A.7	Archaeological Assessment of Borehole data HKW (phase III)			no	
Video	A.8	Link to Webinar Archaeological Assessment held on October 15th, 2020	HKW_20201015_Archaeo_Link to Webinar_Periplus.MP4	2020-10-21	yes	N/A
Presentation	A.9	Presentation held during Webinar Archaeological Assessment Oct. 15th 2020	HKW_20201015_Periplus_Presentation Webinar.pdf	2020-10-21	yes	N/A
Report	B.1	UXO risk assessment report	HKW_20180813_REASeuro_UXO Desk Study-F.pdf	2018-08-13	yes	RVO
GIS	B.2	UXO maps corresponding with B.1	HKW_20180910_REASeuro_UXO_GIS Data HKWWFZ_F.zip	2018-09-10	yes	RVO
Video	B.3	Webinar UXO Risk Assessment, October 8th 2020	HKW_20201008_REASeuro_Webinar UXO Risk Assesment.MP4	2020-10-21	yes	N/A
Presentation	B.4	Presentation held during Webinar UXO Risk Assessment October 8th 2020	HKW_20201008_REASeuro_Presentation Webinar.pdf	2020-10-21	yes	N/A
Report	C.1	Geological desk study	HKW_20180626_Arcadis_Geological desk study-F.pdf	2018-11-02	yes	RVO
GIS	C.2	Geological desk study GIS files	HKW_20180702_Arcadis_Geological Desk Study_GIS.7z	2018-07-02	yes	RVO
HDD	D.1	Complete set of all geophysical deliverables	Data Order Form - Geophysical Results HKW	2019-11-21	yes	DNV GL
Report	D.2	Geophysical site investigation report	HKW_20191121_Fugro_Report Geophysical Results-F.pdf	2019-11-21	yes	DNV GL
Data	D.3	Geophysical GIS charts and other raw data	HKW_20191121_Fugro_Geophysical Results_Appendix B-L_Final.7z	2019-11-21	yes	DNV GL
Video	D.4	Webinar Geophysical site investigation	HKW_20201105_FNLM_Link to webinar GP and GT Assessments.MP4	2020-11-19	yes	N/A
Report	E.1	Seafloor Sample Locations	HKW_20200213_FNLM_Geotechnical Survey_Seafloor Sample Locations-F.zip	2020-02-14	yes	DNV GL
Report	E.2	Seafloor in Situ Test Locations	HKW_20200213_FNLM_Geotechnical Survey_Seafloor in Situ Test Locations-F.zip	2020-02-14	yes	DNV GL
Report	E.3	Geological Ground Model report	HKW_20200828_FNLM_Geological Ground Model-V03-F.zip	2020-08-28	yes	DNV GL
GIS	E.4	Geological ground model GIS files	RVO_HKW_20200819_FNLM_Geological Ground Model_GIS_V05-F.zip	2020-08-21	yes	DNV GL
Data	E.5	Geological ground model digital deliverables: Kingdom files, horizons and Synthetic CPT Profiles	Available on a flashdrive upon request	2020-08-21	yes	DNV GL
Desktop exe	E.6	Subsurface Viewer	HKN_20191028_Geotech_SubsurfaceViewer_7_6_Reader_Setup_en_64	2020-08-21	yes	RVO
Model	E.7	Combined (Subsurface Viewer) Model	HKW_20200731_FNLM_Subsurface Viewer 3D model_V02-F.SVP	2020-08-21	yes	DNV GL
Report	E.8	Geotechnical Borehole Locations	HKW_20201021_FNLM_Report_Geotechnical Borehole Locations-zi;	2020-10-22	yes	DNV GL
Data	E.9	Geotechnical Borehole Locations	HKW_20201016_FNLM Data_Geotechnical Borehole locations	2020-10-21	yes	DNV GL
Report	E.10	Sample Photographs Volume 1	HKW_20200920_FNLM_Sample Photographs Volume 1_V02-F.pdf	2020-09-29	yes	DNV GL
Report	E.11	Sample Photographs Volume 2	HKW_20200920_FNLM_Sample Photographs Volume 2_V02-F.pdf	2020-09-29	yes	DNV GL
Data	E.12	Digital deliverables Seafloor Sample Locations and In Situ Test Locations	HKW_20200221_FNLM_Geotechnical Survey_Digital Deliverables_Seafloor Sample Locations and In Situ Test Locations-F.zip	2020-02-21	yes	DNV GL
Report	E.13	Laboratory Test Data	HKW_20201028_FNLM_Report_Laboratory Test Data.zip	2020-10-28	yes	DNV GL
Report	E.14	Geotechnical Parameters	HKW_20201016_FNLM_Geotechnical Parameters.zip	2020-10-21	yes	DNV GL
Report	E.15	Synthetic CPT Profiles	HKW_20201109_FNLM_Synthetic CPT Profiles.zip	2020-11-09	yes	DNV GL
Data	E.16	Digital deliverables Laboratory Test Data	HKW_20201021_Fugro_Digital Deliverables Laboratory Test Data.zip	2020-10-22	yes	DNV GL
Report	E.17	Technical Note Digital Deliverables (geological ground model report)	HKW_20200825_FNLM_GT Technical Note_Digital Deliverables_V02-F.pdf	2020-08-25	yes	RVO
Video	E.18	Webinar Geotechnical and Geophysical Assessment	HKW_20201105_FNLM_Link to webinar GP and GT Assessments.MP4	2020-11-19	yes	N/A
Presentation	E.19	Presentation from webinar Geotechnical and Geophysical Assessment	HKW_20201119_FNLM_Presentation from webinar Geotechnical and Geophysical Assessments.pdf	2020-11-20	yes	N/A
Video	E.20	Webinar Ground Model and Synthetic CPT's	HKW+20201119_FNLM_Link to webinar Ground Model and Synthetic CPT's.MP4	2020-11-26	yes	N/A
Presentation	E.21	Presentation from Webinar Ground Model and Synthetic CPT's	HKW_20201119_FNLM_Presentation from webinar Ground Model and Synthetic CPT's.pdf	2020-11-20	yes	N/A
Report	F.1	Morphodynamical Investigation	HKW_20200903_Deltares_Morphodynamics Report-F.zip	2020-09-03	yes	DNV GL
Data	F.2	Morphodynamics: xyz-data	HKW_20200707_Deltares_Morphodynamics_xyz_Data-F.zip	2020-09-07	yes	DNV GL
GIS	F.3	Morphodynamics: MPK-file	HKW_20200722_Deltares_Morphodynamics_Data.mpk	2020-09-07	yes	DNV GL
GIS	F.4	Morphodynamics: Metadata	HKW_20200707_Deltares_Morphodynamics_Metadata-F.zip	2020-09-03	yes	DNV GL
Report	F.5	Scour and Scour Mitigation	HKW_20200903_Deltares_Scour and scour mitigation Report-F.zip	2020-09-03	yes	DNV GL
Data	F.6	Scour and Scour Mitigation: xyz-data	HKW_20200707_Deltares_Scour and scour mitigation_xyz_Data-F.zip	2020-09-03	yes	DNV GL
GIS	F.7	Scour and Scour Mitigation: MPK-file	HKW_20200707_Deltares_Scour and scour mitigation_Data.mpk	2020-09-03	yes	DNV GL
GIS	F.8	Scour and Scour Mitigation: Metadata	HKW_20200707_Deltares_Scour and scour mitigation_Metadata-F.zip	2020-09-03	yes	DNV GL
Video	F.9	Webinar Morphodynamics and Scour Mitigation	HKW_20201106_Deltares_Link to webinar Morpho and Scour.MP4	2020-11-12	yes	N/A
Presentation	F.10	Presentation held during Webinar Morphodynamics and Scour Mitigation	HKW_20201106 Deltares_Presentation Webinar.pdf	2020-11-25	yes	N/A
Report	G.1	Wind Resource Assessment	HKW_20201201_Tractebel_Wind Resource Assessment-Report.pdf	2020-12-01	yes	DNV GL
XLS	G.2	Wind Resource Assessment Time Series	HKW_20201201_Tractebel_Wind Resource Assessment-Time Series.xlsx	2020-12-01	yes	DNV GL
GIS	G.3	Wind Resource Assessment GIS Files	HKW_20201201_Tractebel_Wind Resource Assessment-GIS.mpk	2020-12-01	yes	DNV GL
Video	G.4	Webinar Wind Resource Assessment, October 8th, 2020	HKW_20201008_Link to Webinar WRA- Tractebel.MP4	2020-11-19	yes	N/A
Presentation	G.5	Presentation held during Webinar Wind Resource Assessment, Oct. 8th, 2020	HKW_20201008_Tractebel_Presentation held during Webinar WRA.pdf	2020-10-21	yes	N/A
Report	H.1	Metocean study report	HKW_20201221_DHI_Metocean Desk Study-F	2020-12-21	yes	DNV GL
XLS	H.2	Metocean study report tables	HKW_20201204_DHI_Metocean Study_Appendices F,G and J-EVA-F	2020-12-21	yes	DNV GL
Link	H.3	Metocean study database	https://www.metocean-on-demand.com/	2020-12-21	yes	RVO
Video	H.4	Webinar Metocean Study, October 15th, 2020	HKW_20201015_Link to Webinar Metocaen Desk Study, October 15th, 2020.MP4	2020-10-21	yes	N/A
Presentation	H.5	Presentation held during Webinar Metocean Desk Study, October 15th, 2020	HKW_20201015_DHI_Presentation Webinar Metocean Desk Study.pdf	2020-10-21	yes	N/A
Report	H.6	Metocean Study (Feasibility Report)	HKW-TNW-IJV_20190401_Metocean_Feasibility_DHI_Report-Portfolio-F.pdf	2019-04-03	yes	RVO
Report	H.7	Metocean Study (Appendices D, E, F and EVA of the Feasibility report)	HKW-TNW-IJV_20191213_Metocean Feasibility_DHI_Appendices D,E,F and EVA-F	2019-12-13	yes	RVO
Memo	I.1	Explanatory memo Pre-deployment Validation WS187 and WS188	HKW_20200107_DNV GL_MC Validation memo Fugro WS187&WS188-F	2020-01-10	yes	DNV GL
Report	I.2	Metocean campaign Validation Report WS187	HKW_20191128_DNV GL_MC_Pre-deployment validation WS187 Fugro-F	2019-12-30	yes	DNV GL
Report	I.3	Metocean campaign Validation Report WS188	HKW_20191128_DNV GL_MC_Pre-deployment validation WS188 Fugro-F	2019-12-30	yes	DNV GL
Report	I.4	Metocean campaign Verification Reports ZX Lidars	HKW_20201028_DNV GL_MC_Performance verification reports ZX Lidars.zip	2020-10-28	yes	DNV GL
Data	I.5	Metocean campaign data and reports - 1 -	HKW_20201021_Fugro_Data and Reports February March 2020	2020-10-28	yes	RVO
Data	I.6	Metocean campaign data and reports - 2 -	HKW_20201222_Fugro_Data and Reports_April 2020	2020-12-22	yes	RVO
Data	I.7	Metocean campaign data and reports - 3 -			no	
Data	I.8	Metocean campaign data and reports - 4 -			no	
Data	I.9	Metocean campaign data and reports - 5 -			no	
Data	I.10	Metocean campaign data and reports - 6 -			no	
Data	I.11	Metocean campaign data and reports - 7 -			no	
Data	I.12	Metocean campaign data and reports - 8 -			no	
Data	I.13	Metocean campaign data and reports - 9 -			no	
Data	I.14	Metocean campaign data and reports - 10 -			no	
Data	I.15	Metocean campaign data and reports - 11 -			no	
Data	I.16	Metocean campaign data and reports - 12 -			no	
Data	I.17	Metocean campaign data and reports 12 months			no	

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Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our professionals are dedicated to helping our customers make the world safer, smarter and greener.