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Site Studies Dutch offshore Wind Farm Zones

Metocean Assessment Dutch offshore Wind Farm Zones

Annex 5 - Section III

SCOPE OF WORK

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1 Introduction

1.1 Scope document

This document details the scope of the metocean assessment to be performed for Dutch Offshore Wind Farm Zones (WFZ) IJmuiden Ver and Search Area 1 in detailed design context, and for a broader area in feasibility study context.

1.2 Background

The Ministry of Economic Affairs and Climate Policy is responsible for the legislative framework for the development of offshore wind farms in the Netherlands. Within this framework (a) (concession) tender(s) for construction and operation of (a) wind farm(s) will be organized. As part of the tender documentation, the participants will receive an information package in which detailed information on the offshore site is included. Detailed information on the metocean conditions at the site will be part of this information package.

1.3 Objective metocean study

The purpose of the assignment will be to provide detailed and validated meteorological and oceanographic (metocean) conditions to serve as input for the energy yield estimates, design, installation and maintenance of wind turbines, inter array cables, substations and their support structures at Wind Farm Zone IJmuiden Ver and Search Area 1. The analysis is to be based on the best possible data sources, be carried out with state-of-the-art methods and models and be in accordance with the last revisions Service Specification DNVGL-SE-0190 Edition 2015-12 and Standards DNVGL-ST-0126 Edition 2016-04 and DNVGL-ST-0437 Edition 2016-11 (or equal or better).

In addition, the assignment is to provide meteorological and oceanographic (metocean) conditions for a broader area on a feasibility study level with basic validation.

For areas within the site boundaries of IJmuiden Ver and Search Area 1 the specified metocean conditions shall be made available through reports and a digital metocean database. The reports shall also contain the validation with measurements.

For all other areas within the model domain but outside these areas, the generated metocean data (time series of wind, waves, currents and water levels and statistical derivatives thereof) shall be made available through the metocean database.

There is already an existing study on metocean conditions at IJmuiden Ver (https://offshorewind.rvo.nl/files/view/a352572e-de9f-4cbd-b8a1-24d5394152a8/1554278436hkw-tnw-ijv_20190401_metocean_feasibility_dhi_report-portfolio-f.pdf)

and an accompanying database <https://www.metocean-on-demand.com/>. This package has been disclosed in March 2019. It is anticipated that this study can contribute to a further cost decrease of offshore wind energy.

The focus of this work is on disclosing high quality and validated data for IJmuiden Ver WFZ and Search Area 1 in the framework of the roadmap 2030. In all areas (design level and feasibility level) the metocean data shall be presented through the digital database at the responsibility of the users.

1.4 Planning of the metocean study

The study, i.e. the final and approved report and database, needs to be completed and certified before 2nd of May 2023. Further deliveries are described under 2.2

1.5 Site description

The situation with regard to Dutch Offshore Wind Developments has been described in Annex 7: Starting points & assumptions and in [General Information Hollandse Kust \(west\) · Offshorewind.rvo.nl](https://offshorewind.rvo.nl)

(https://offshorewind.rvo.nl/files/view/3b960c83-6a0c-4d19-9164-f10cdb77873f/1625051036hkw_20210630_project%20and%20site%20description-f.pdf)

Recently, the Government has decided for an addition on this roadmap by 2030. Several search areas have been defined, where wind farms may be developed. To accommodate for this acceleration, some of the most promising areas are to be incorporated in this study as well.

This Metocean Assessment distinguishes two areas with different requirements for the models and database:

1. IJmuiden Ver and Search Area 1 are the areas for which design data is to be provided. The area of IJmuiden Ver and Search Area 1 is presented in Figure 1.
2. The model domain, this is the area which is to be modelled and for which on a coarser grid the data on feasibility level is to be made available. Figure 3 gives the expected area of the model domain, but this needs to be confirmed by the Tenderer. Figure 3 gives an example of expected area of the model domain, with enough offshore boundaries; but this needs to be confirmed by the Tenderer.

Please note that the general requirements (units, quality and communication) of IJmuiden Ver will also apply for the other output areas. The site layout of IJmuiden Ver and the other output areas will be provided separately.



Search areas Offshore wind energy

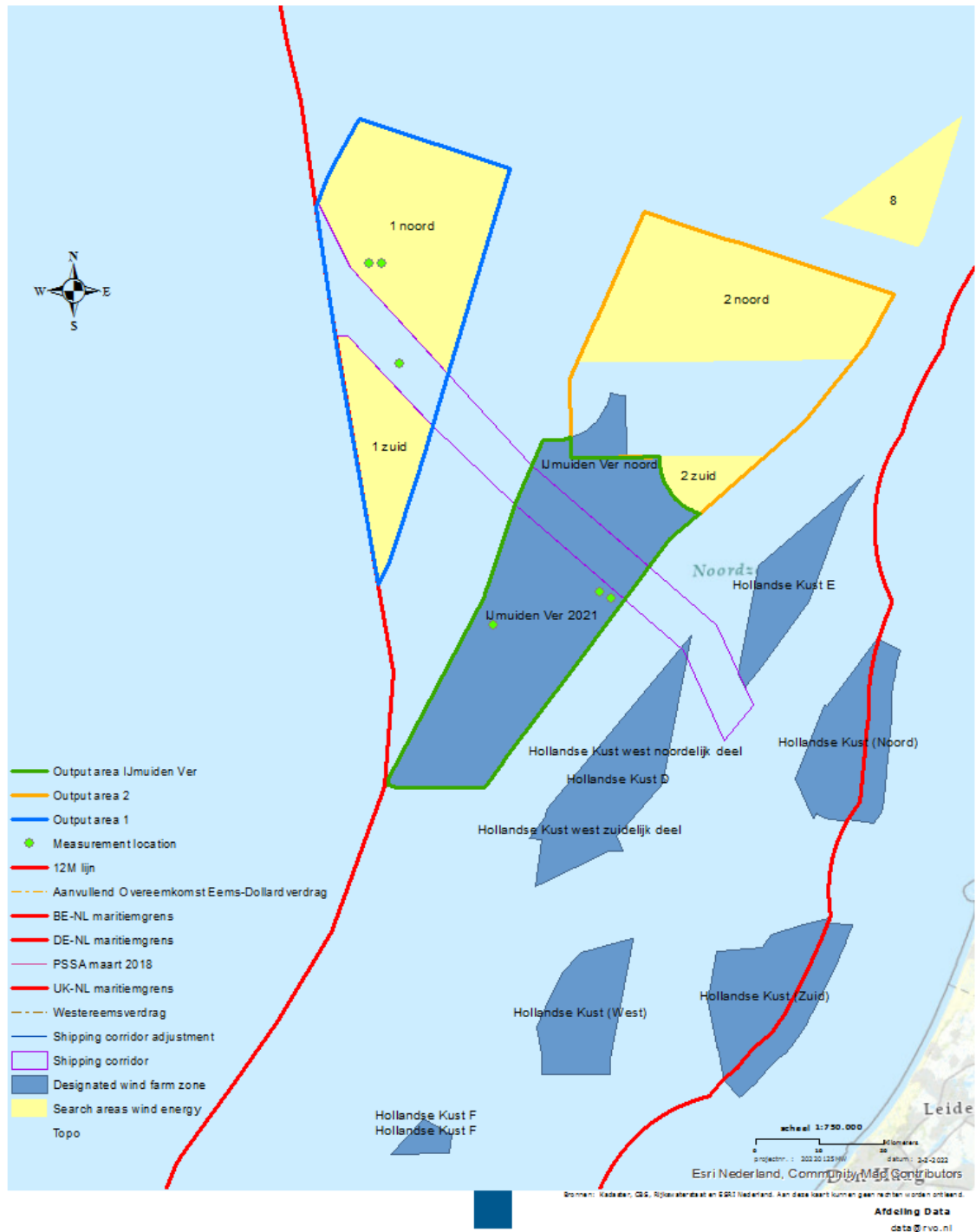


Figure 1: IJmuiden Ver WFZ (green outline), Search Area 1 (blue outline) and Search Area 2 (orange outline) layout. Note 1: measurement locations shown include floating lidar measurements and mast / platform measurements. Note 2: Search Area 1 noord and 1 zuid have been combined into Search/Output area 1, 2 noord and 2 zuid have been combined into Search/Output area 2.



Search areas Offshore wind energy

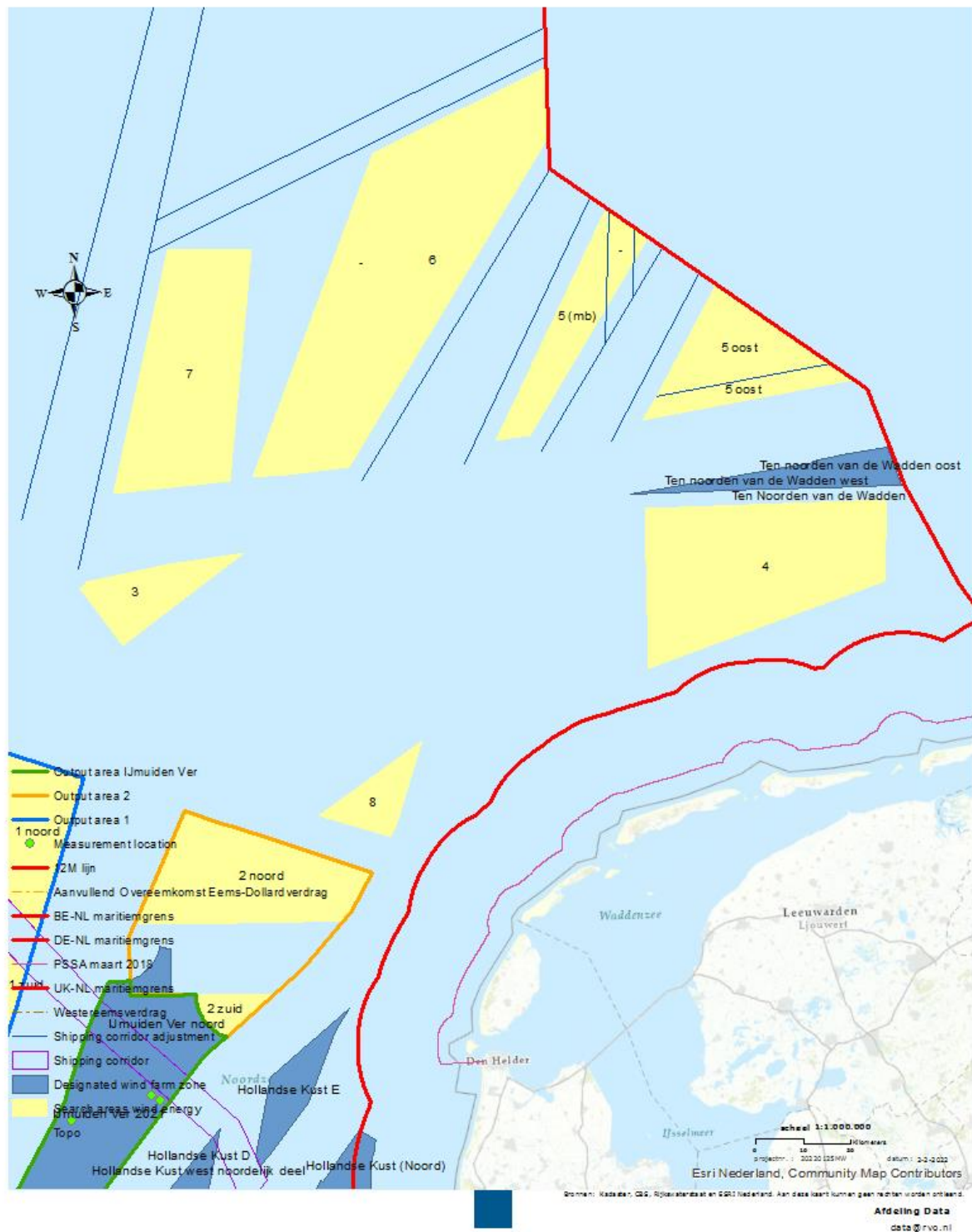


Figure 2: Search Areas in the Northern part of the Dutch North Sea.



Search areas Offshore wind energy

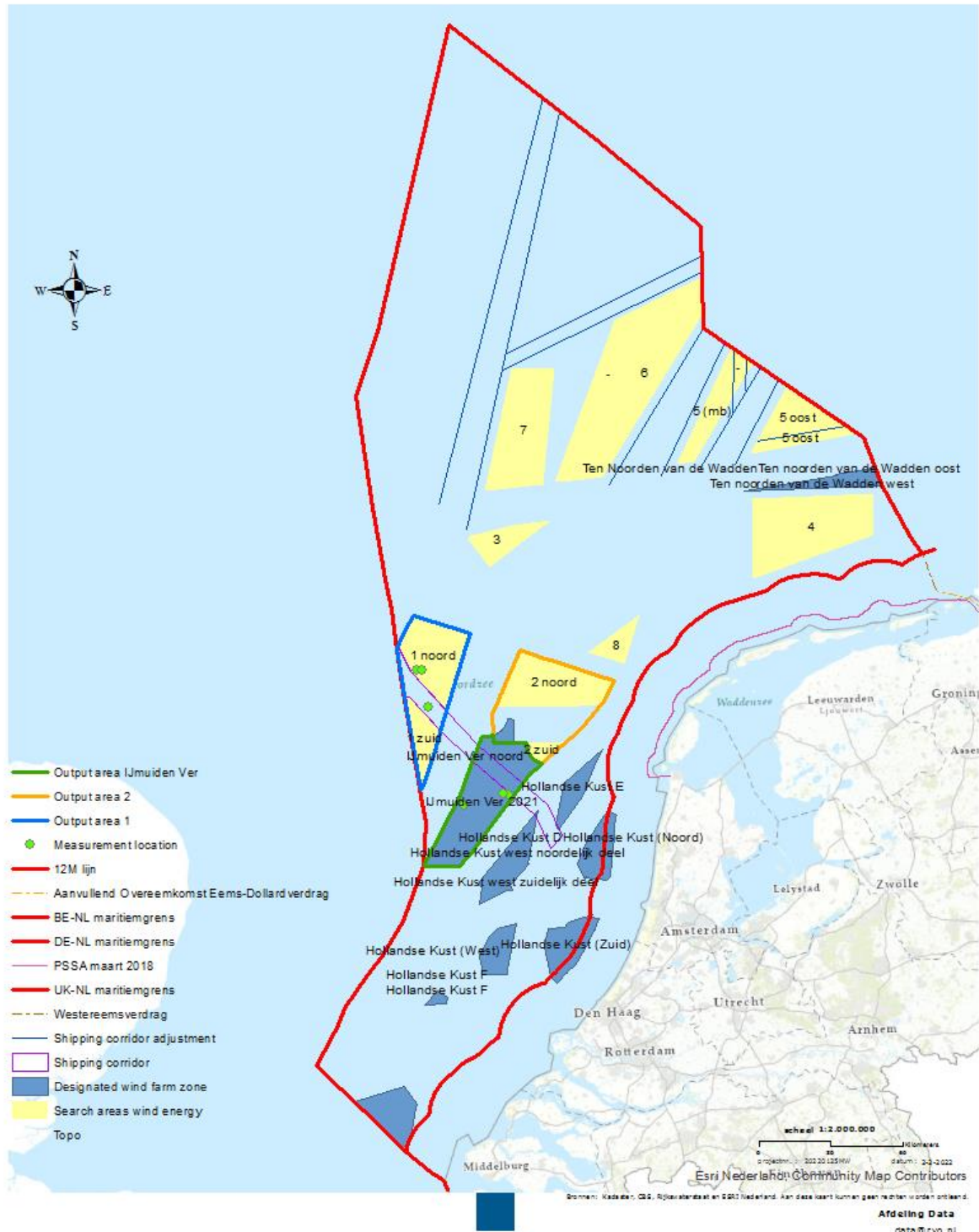


Figure 3: Feasibility level domain (red outline).

1.6 **Interfaces with other studies**

1. The study should utilize the bathymetry data resulting from the geophysical campaign for Ijmuiden Ver (WFS IJV I-IV, conducted in 2021 and WFS V-VI, to be conducted in 2022), and the upcoming metocean campaign for Search Area I (planned for 2023).
2. This study can be considered as an update and an extension of previous metocean studies for the Dutch offshore area. Tenderers are free to make use of the data and information which is already disclosed through <https://offshorewind.rvo.nl/>

2 Scope of work

2.1 Activity A: General scope of metocean study

The scope of work will comprise the following activities:

1. Provide a general characterization of the metocean climate at the sites (e.g. wind conditions, dominant tides, storm severity, spatial uniformity/variability of conditions, description of any meteorological or oceanographic event which is specific to the region of interest) for a continuous long-term period of at least 20 years. Please provide recommendations for the long-term period to be considered for different elements of the analysis.
2. Analyse metocean conditions of
 - Wind
 - Waves
 - Currents
 - Water levels
 - Joint probability distributions
 - Other parameters (see Section 2.3.8)

The analysis shall consist of providing operational, persistence and extreme conditions.

3. Summarize the approach and results (tables, graphs) of one representative output location in IJmuiden Ver and Search Area 1. The choice of the location shall be motivated by Contractor.
4. Provide a digital web-based metocean database that will enable users (e.g. project developers) obtaining output (tables, graphs, times series) at any requested location within the defined model domain (Figure 3) obeying the resolutions as indicated in section 1.5.
5. Validate the normal and extreme metocean conditions in the database with measured metocean data at IJmuiden Ver and Search Area 1 and any other relevant and accurate measurements within the Dutch Exclusive Economic Zone.
6. Perform a validation on feasibility study level of wind, waves, currents and water levels with publicly available data in nearby stations, if applicable.
7. The Wind Resource Assessment component of the study shall provide data that can be used as an input by potential wind farm developers for future wind farm modelling, energy yield assessments and business case calculations for the offshore wind farm to be developed in the IJWVWZ. It is stressed that a full energy yield assessment is not required as part of the scope of work requested here, since Wind Farm Layout is not known.
8. The Wind Resource Assessment (WRA) component shall make use of the on-site metocean measurement data, for the purpose of reducing the uncertainty of the assessment results.
9. The Contractor is invited to consider any other additional offshore wind measurement sources publicly available in the region for the assessment, as the Contractor sees fit, with the purpose of reducing the overall uncertainty in the WRA component. The WRA performed for TNWWFZ (https://offshorewind.rvo.nl/files/view/3e3613fb-3620-4d2f-8740-17766aabb12fb/1628759845tnw_20210812_guidehouse_wra%20report-f.pdf), provides an example of a case where a combination of data sources were made use of, providing the overall lowest uncertainty route. Should the Contractor intend to use additional, off-site measurements to support the WRA component, the Contractor should provide a summary of the measurements under consideration and their proposed approach to incorporating within the WRA. Any approach resulting in an added value for the project and lowering uncertainties for the end users is appreciated by RVO.
10. The WRA shall contain the following steps:
 - Detailed analysis of available wind measurement data;
 - Evaluation and selection of appropriate mesoscale model(s)/measurement stations for extrapolation;
 - Calculation of long-term wind climate across the site;
 - Quantification of uncertainty.
11. The WRA shall make use of a mesoscale model and undertake validation of the model, which shall include:
 - Selection and acquisition of the best available reference wind data at relevant points, to be used for the validation of the mesoscale models;
 - Modelling of the wind climate at each of the reference points for which reliable and relevant measurement data is available;
 - Process each reference measurement time series to produce the highest quality dataset;
 - Filtering of the data for invalid points and carry out a check for inconsistencies;

- Comparison of reference mesoscale time series to the corresponding reference (measurement) time series to evaluate correlation and consistency.
12. Please note the following points of attention:
- Latest mesoscale models and most recent re-analysis datasets as input model source shall be considered.
 - Each modelled reference mesoscale dataset shall be validated separately.
 - The most accurate mesoscale model and input model source shall be selected based on this validation. An ensemble approach could also be considered if this will result in a reduction of uncertainties.
 - Trends observed in the mesoscale model shall be noted and accounted for in the final analysis.
 - Provide an estimation of uncertainty in all relevant components to substantiate the method of deriving the wind climate.
13. Provide advice on future metocean measurement campaigns, including advice on where measurements should be undertaken and parameters to be measured to minimise uncertainty in WRA and MDS assessments.

2.2 Deliverables

1. A comprehensive report for Wind Farm Zone IJmuiden Ver containing at least:
 - A management summary (UK and NL);
 - The applied approach, detailing methodology and description of tools;
 - Data sources that were applied, including detailed validation of the applied sources;
 - General characterization of the metocean climate at IJmuiden Ver;
 - Results of the performed analyses for one output location in IJmuiden Ver Wind Farm Zone, see detailed output parameters in section 2.3;
 - Validation of the metocean database in IJmuiden Ver;
 - Description of spatial variation and general uncertainties with the followed approach;
 - Conclusions and recommendations;
 - Appendices.
2. A comprehensive report for Search Area 1 containing at least:
 - A management summary (UK and NL);
 - The applied approach, detailing methodology and description of tools;
 - Data sources that were applied, including validation of the applied sources;
 - General characterization of the metocean climate at Search Area 1;
 - Results of the performed analyses for one output location in Search Area 1, see detailed output parameters in section 2.3;
 - Validation of the metocean database in Search Area 1;
 - Description of spatial variation and general uncertainties with the followed approach;
 - Conclusions and recommendations;
 - Appendices.
3. Excel tables for IJmuiden Ver wind farm site with
 - All tables of the report;
 - Persistency tables of wind, waves and combined wind-waves.
4. Excel tables for Search Area 1 with
 - All tables of the report;
 - Persistency tables of wind, waves and combined wind-waves.
5. Digital web-based metocean database enabling the provision of output of all spatially varying parameters at any location within the Feasibility level domain (Figure 3). It should allow exporting time series, tables, wave spectra and graphs for any given (x,y) coordinate.
6. Maintenance of the database (e.g. bug fixes) following the use of the database by developers. The requirements of the database are described in section 2.7.
7. Scripts and tools to load and plot downloaded data (e.g. Matlab or Python scripts to load and plot wave spectra).

Comparisons shall be illustrated, at least, by scatter plots, QQ-plots and quantified, at least, by correlation coefficient, root mean square error, scatter index, bias, mean absolute error and regression coefficients. Any relevant statistical distances or illustrations will be considered.

The following time schedule for multiple rounds of deliverables is anticipated:

Deliverables for IJmuiden Ver:

1. An initial, non-public delivery, outputs defined above, is expected based upon existing measurement data sources on 15 November 2022
2. A second delivery should take into account around 6 months of measurement data from the planned floating LiDAR campaign in the IJmuiden Ver WFZ (IJV WFZ) on 2 May 2023
3. A third and fourth delivery will take in account 1 year and 2 years of measurement data respectively in the IJV WFZ on 1 November 2023 and 1 May 2024 respectively.

Deliverable for Search Area 1:

4. The fifth and sixth delivery will provide the deliverables as defined above for Search Area 1, following 1 and 2 years of measurement data provided for this area. The fifth delivery is due in Q3 2024 and the sixth delivery is due in Q3 2025, exact dates to be agreed and depending of the progress of the Metocean Measurement Campaign and the tender schedule for the Roadmap towards 2030.

The third and fourth delivery for IJmuiden Ver should be certified by third party as well as the fifth and sixth delivery of Search Area 1.

Contractor shall allow for sufficient time for review and revision taking into account the review periods by Contracting authority within 15 working days for the first revision and 5 working days for each revision thereafter. It is up to Contractor to organize review and submission of deliverables in the most efficient way allowing for mentioned review periods and of period of 20 working days for certification and fulfilling the defined submission dates for first draft and certificate final deliverables.

2.3 Detailed output parameters for IJmuiden Ver and Search Area 1

The output parameters shall be derived from modelling with detailed level of calibration / validation based on any relevant measurements. It is recommended to use data from recent survey campaigns which are provided by RVO.nl and TNO (windopzee.net) and any other relevant measurement datasets.

The spatial resolution of modelling shall be sufficient to accurately describe the normal and extreme meteorological conditions (deep low pressure system), and the normal and extreme oceanographic conditions, mainly influence by bathymetry and its spatial variability (due to e.g. sand waves).

Contractor is to make clear in their proposal how is dealt with climate change in the numerical modelling and/or derivation and presentation of requested output parameters.

The detailed output parameters of the analyses which should be reported for IJmuiden Ver and Search Area 1, see Figure 2, and which should be available through the metocean database are specified next:

2.3.1 Wind conditions for input into yield calculation purposes

- The WRA shall present:
 - i. A graphical overview of available wind data (e.g. met masts, buoys);
 - ii. A detailed description of each data source and its characteristics (e.g. type, location, instrumentation, measurement period, data availability percentage, etc.);
 - iii. An assessment of the data quality of each source (e.g. gaps, calibrations, malfunctioning sensors, obstacles) and quantify the uncertainty of each source (e.g. due to instrument accuracy, mounting, data quality and processing);
 - iv. Selection and substantiation of the most appropriate (combination of) data source(s) resulting in the lowest uncertainties;
 - v. A summary of key statistics from the measurements available at each buoy location (for example, monthly mean wind speeds, data coverage, wind rose).
 - vi. representative profile of ambient turbulence intensity at the site (as a function of wind speed) with discussion of how this has been derived from the measurements available.
- The long-term wind climate shall be quantified based on the selected wind data source(s), mesoscale model and possibly a Measure-Correlate-Predict (MCP) procedure to correlate

- short term measurements with a longer-term source. The applied MCP procedure and long-term sources shall be described in detail.
- A long-term wind climate shall be given at site corner nodes and at the site centre (together 'site nodes'). It is suggested to place one node at the location of one of the metocean buoys. Final nodes will be mutually agreed between the Contractor and the Contracting Authority. In addition to selected nodes, the long-term wind climate/gradient is to be horizontally modelled within the WRA Investigation Area
- The results shall cover at the following output parameters per site node:
 - Tabulated annual mean wind speeds for heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Annual mean wind speed profiles (in vertical direction);
 - Annual mean wind speed as a top view plot showing the spatial variation over the investigation area at height(s) relevant to future turbine hub heights on a grid of 100m x 100m resolution;
 - Diurnal, monthly, seasonal and year to year variations of mean wind speed;
 - Tabulated omni and directional mean wind speed distributions including Weibull parameters for heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Mean wind speed for different probability levels (P10, P25, P50, P75, P90);
 - Wind roses (mean wind speed vs direction) per site node at height(s) relevant to future turbine hub heights;
 - Air density, temperature, pressure, humidity;
 - Any other data that could be of relevance for yield calculations

2.3.2 Wind conditions for design purposes

- Wind conditions are to be based on the most accurate hindcast database or generated by using state-of-the-art atmospheric mesoscale model. Contractor shall at least make a comparison of the CSFR, Harmonie and EMD-ConWx databases, and any other Contractor finds suitable, and compare those with measurements in the region of interest to motivate his choice.
- Normal wind conditions
 - Monthly and annual wind roses (10-min mean wind speed and 12 directional bins) at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Monthly and annual joint occurrence tables of 10-min mean wind speed and wind direction at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Weibull parameters (scale and shape parameters) for normal 10-min mean wind speed distribution at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m for 12 directional bins and omnidirectional;
 - Occurrence (persistence) of wind speed with the following parameters:
 - 10-min mean wind speed thresholds of 2m/s, 4m/s, 6m/s, 8m/s, 9m/s, 10m/s, 11m/s, 12m/s, 15m/s, 20m/s and 25m/s;
 - Time windows of 1h, 2h, 4h, 6h, 12h, 24h, 48h and 72h;
 - Probabilities of exceedance of 20%, 50% and 80%;
 - At heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Extreme wind conditions
 - Extreme wind speed for 12 directional bins and omnidirectional;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1000 years;
 - Averaged over periods of 1h, 10min, 1min and 3sec;
 - At heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Extreme omni-directional wind speed per month;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1000 years;
 - Averaged over periods of 1h, 10min, 1min and 3sec;
 - At heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Characteristic wind profiles
 - Vertically extending from 10m to 300m above sea level;
 - For wind speed thresholds of 5m/s, 10m/s, 15m/s, 20m/s and 25m/s;
- Wind energy spectra
 - Based on measurements, when possible;
 - Wind spectra type and characteristics
 - At heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Wind turbulence intensity

- Based on available turbulence data (preferred) or expert judgement, at a height of 100m and 120m;
- Quantify the spatial variations of wind speed and direction across the site under normal and extreme conditions;
- Assess the impact, if any of the presence of all already fully developed wind farms on the wind at IJmuiden Ver and Search Area 1, based on expert judgement.

2.3.3 Wave conditions

- Wave conditions are to be based on a state-of-the-art spectral wave model with, as minimum, 2D spectral boundary conditions and forced by relevant atmospheric and bathymetric fields. Current and water level fields varying in time and space are also recommended input of the wave model;
- The analyses below are to be performed on the total sea state as well as on the wind sea and swell components separately. Contractor has to demonstrate the suitability of the sea-swell partitioning method and has to perform sanity checks on the obtained wave time series (e.g. no negative wave heights or periods, swell wave periods longer than sea wave periods).
- Normal wave conditions – total, wind sea and swell:
 - Monthly and annual roses (12 directional bins; peak wave direction, PWD) of significant wave height (H_s) and peak wave period (T_p);
 - Omnidirectional monthly and annual joint occurrence tables of H_s & T_p , H_s & T_z (mean zero up-crossing period), H_s & MWD (mean wave direction), H_s & PWD, T_p & MWD, and T_p & PWD.
 - Annual joint occurrence tables of H_s and T_p and of H_s and T_z for 12 directional bins (PWD);
 - Directional normal sea state tables for 12 directional bins (PWD);
 - Annual joint occurrence tables of individual wave height and wave period;
 - Occurrence (persistence) of wave height with the following parameters:
 - Wave height thresholds of 0.25m, 0.50m, 0.75m, 1.00m, 1.25m, 1.50m, 1.75m, 2.00m, 2.25m, 2.75m, 3.00m, 3.50m, 4.00m, 4.50m, 5.00m;
 - Time windows of 1h, 2h, 4h, 6h, 12h, 24h, 48h and 72h;
 - Probabilities of exceedance of 20%, 50% and 80%;
- Extreme wave conditions – total, wind sea and swell:
 - Extreme 3hr sea states for return periods of 1, 2, 5, 10, 50, 100, 1,000 and 10,000 years (12 directional PWD bins & omnidirectional)
 - Including H_s , T_z , T_p , H_{max} ($H_{0.1\%}$), Crest height $\eta_{0.1\%}$, $T_{max;lower}$, $T_{max;upper}$;
 - All combined with maximum still water levels and minimum still water level associated with the extreme sea state;
 - Extreme omni-directional 3hr sea states for return periods of 1, 2, 5, 10, 50, 100, 1,000 and 10,000 years per month
 - Including H_s , T_z , T_p , H_{max} ($H_{0.1\%}$), Crest height $\eta_{0.1\%}$, $T_{max;lower}$, $T_{max;upper}$;
 - All combined with maximum still water levels and minimum still water level associated with the extreme sea state.
 - Assess the mean storm duration;
 - Assess the likelihood of shoaling and breaking waves. Provide quantitative recommendations about how to account for shoaling and breaking waves in the design.
- Wave spectrum characteristics:
 - Spectral analysis of nearby measurements buoy and derive a custom spectrum with a peak enhancement factor and directional spreading parameter;
 - if spectral analysis highlights wave climate is characterised by 2 components or more, make a partition between swell and wind sea:
 - peak enhancement and directional spreading parameters shall be given for swell and wind sea for normal and extreme conditions;
 - Monthly percentage of time that wave climate can be characterized as swell or wind sea or as a bi-modal climate.
- Quantify the spatial variations of wave height, period and wave breaking across the site under normal and extreme conditions, including the possible effects of bathymetry, currents and water levels. Breaking wave type shall also be assessed.

2.3.4 Current conditions

- Current conditions are preferably to be based on a state-of-the-art hydrodynamic model forced by relevant atmospheric, bathymetry and bottom characteristics fields, and local tidal constituents;
- Normal current conditions:
 - Joint occurrence of current velocity and direction at 5%, 25%, 50%, 75% and 100% of the water depth and for depth-averaged current;
 - Monthly and annual current roses of depth-averaged total currents, tidal currents and residual currents;
 - Monthly and annual current roses at 5%, 25%, 50%, 75% and 100% of the water depth and depth-averaged of the total, tidal and residual currents;
 - Characteristic current velocity profiles (from mean water level (MWL) to seabed);
- Extreme current conditions:
 - Extreme current velocities for 12 directional bins and omnidirectional;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1,000 years;
 - At 5%, 25%, 50%, 75% and 100% of the water depth and depth-averaged;
 - Make a distinction between tidal and residual currents;
 - Extreme omni-directional current velocities per month;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1,000 years;
 - At 5%, 25%, 50%, 75% and 100% of the water depth and depth-averaged;
 - Make a distinction between tidal and residual currents.
- Quantify the spatial variations of the current velocity and direction across the site under normal and extreme conditions and the impact of winds on tidal currents;

2.3.5 Water levels

- Astronomical tidal levels
 - LAT, MLWS, MLWN, MSL, MHWN, MHWS, HAT;
- Extreme water levels for all-year and per month
 - 1, 2, 5, 10, 50, 100 and 1,000 years return period
 - High water level and low water level;
- Assessment of long term sea level rise;
- Quantify the spatial variations of water levels across the site.

2.3.6 Joint probability of various metocean parameters

- Wind & waves
 - Monthly and annual joint occurrence tables of wave direction and wind direction (misalignment) at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Monthly and annual joint occurrence tables of wave height and wind direction at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Directional wind speed versus wave height (for 12 directional bins) at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
 - Occurrence (persistence) of combined wind and waves with the following parameters:
 - Wind speed thresholds of 2m/s, 4m/s, 6m/s, 8m/s, 9m/s, 10m/s, 11m/s, 12m/s, 15m/s, 20m/s and 25m/s;
 - Wave height thresholds of 0.25m, 0.50m, 0.75m, 1.00m, 1.25m, 1.50m, 1.75m, 2.00m, 2.25m, 2.75m, 3.00m, 3.50m, 4.00m, 4.50m, 5.00m;
 - Time windows of 1h, 2h, 4h, 6h, 12h, 24h, 48h and 72h;
 - Probabilities of exceedance of 20%, 50% and 80%;
 - Characterization of the normal sea state per bin (1m/s) of 10-min mean wind speed at 100m and 120m by providing H_s , T_p (5%, 50% and 95%), peak enhancement factor (5%, 50% and 95%) and directional spreading factor (5%, 50% and 95%).
- Current & waves
 - Annual joint occurrence tables of H_s and depth-averaged total current velocity;
 - Annual joint occurrence tables of H_s and depth-averaged residual current velocity;
- Current, waves and wind

- Annual H_s and wind speed associated to extreme depth-averaged total current velocity for 1, 2, 5, 10, 50, 100 and 1000 years return periods;
- Annual H_s and extreme depth-averaged total current velocity associated to extreme wind speeds for 1, 2, 5, 10, 50, 100 and 1,000 years return periods;
- Annual wind speed and depth-averaged total current velocity associated to extreme H_s for 1, 2, 5, 10, 50, 100 and 1,000 years return periods;
- Water levels & waves
 - Annual joint occurrence tables of water level and significant wave height;
 - Annual joint occurrence tables of residual water level (surge height) and significant wave height;
 - Annual joint occurrence of extreme water levels and extreme significant wave height and associated wave period;
- Water levels & current directions
 - Annual joint occurrence tables of water level and residual current direction;
 - Annual joint occurrence tables of water level and total current direction;
- Temperature and wind
 - Monthly and annual joint occurrence tables of air temperature and wind speed at 100m, 120m, 160m, 200m, 250m and 300m;

2.3.7 Time series

As a minimum, the following time series shall be made through the database available on an hourly basis (1-hour time step) on every output grid point of the IJmuiden Ver Wind Farm Site in ASCII, Matlab and NetCDF-format:

- Time series of 10-min wind speed and direction at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Time series of H_s , T_p , T_z (mean zero up-crossing period), MWD (mean wave direction), PWD (peak wave direction) and directional spreading for total sea, swell and wind sea;
- Time series of wave spectra (variance density as function of time and frequency and as function of time and direction);
- Time series of total, tidal and residual current speeds and directions at 5%, 25%, 50%, 75% and 100% of the water depth and depth-averaged;
- Time series of total, tide and residual water level;
- Time series of air temperature at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Humidity at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Air pressure at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;

2.3.8 Other metocean parameters

Provide the monthly statistics and distributions (when relevant), preferably from measurements, if available:

- Snow and ice accretion criteria;
- Sea ice conditions;
- Air temperature at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Hourly minimum and maximum temperatures at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Humidity at 2m and heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Air pressure mean sea level and at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Air density at heights of 10m, 60m, 100m, 120m, 160m, 200m, 250m and 300m;
- Seawater temperature at 5%, 25%, 50%, 75% and 100% of the water depth;
- Seawater salinity at 5%, 25%, 50%, 75% and 100% of the water depth;
- Sea water density at 5%, 25%, 50%, 75% and 100% of the water depth;
- Visibility;
- Lightning;
- Marine growth.
- Rainfall

For visibility data, we propose the following approach:

- Acquiring hourly time series of visibility observations from KNMI at Europlatform (EPL), Lichteiland Goeree (LEG) and K14 for the period 2001-present (~20 years).
- Provision of normal conditions (annual and monthly statistics) at the three sites to show the variability.

Lightning data may be taken from NASA's Global Hydrology Resource Center (GHRC) namely the LIS/OTD Gridded Climatology data set. Based on the data, the averaged flash rate at IJmuiden Ver will be provided. Yearly and monthly variations will be provided as well based on the data.

2.3.9 Additional parameters

The proposal may include suggestions for additional parameters than the ones mentioned in Sections 2.3.1 through 2.3.8 to analyse in order to provide an optimal basis for the design, installation and maintenance of wind turbines, inter array cables, substations and their support structures.

2.3.10 Other requirements

The report shall for at least 5 locations spread across IJmuiden Ver and Search Area 1 show details of the extreme value analysis of wind, waves and currents.

2.4 Alignment of results from WRA and MDS

Given the different end purposes of the WRA and MDS it is expected that different models / input sources may be used for each analysis. As such the normal wind conditions derived from the WRA and the MDS may differ.

It is requested by the Contracting Authority to undertake an alignment or calibration of the different models including review the basic boundary conditions (e.g. mesoscale models, vertical/horizontal resolution, wind roses and assumed vertical wind profiles) and to compare the long-term annual mean wind speed derived at the site nodes. Please provide detailed proposal for how this alignment will be undertaken while still ensuring that the best possible input sources / models are used for each part of the study to minimise uncertainty.

The aim of the alignment will be to either eliminate any deviation or to identify any deviation between common site wind characteristics derived in both the MDS and WRA and document the magnitude of this deviation, along with commentary on the potential source of the deviation and significance for the WRA. It is further requested that the final WRA report includes some guidance to the market about which sources of data (between the MDS and WRA) are considered appropriate for the purpose of future wind farm modelling as part of the future wind farm tender.

The length of the data series for normal conditions (WRA) and extreme conditions may well differ. In the alignment of the WRA and MDS it is requested to give clear guidance on how the difference in time scale is taken into account and what is recommended as length of data series to derive averaged conditions and length of data series to derive extreme conditions.

2.5 Comparison against other sources (ie current database)

High level comparison against existing metocean database ([MOODv2 Web App \(metocean-on-demand.com\)](#)) is required.

2.6 Feasibility level output parameters for feasibility level domain (Figure 4)

The feasibility level output parameters of the analyses which should be available through the metocean database on a computational/output grid with a resolution of 5,000 m are specified next:

2.6.1 Wind conditions

- Normal wind conditions
 - Monthly and annual 10-min mean wind velocity roses (12 directional bins) at heights of 10m, 60m, 100m, 120m, 160m and 200m;
 - Monthly and annual joint occurrence tables of 10-min mean wind speed and wind direction at heights of 10m, 60m, 100m, 120m, 160m and 200m;
- Extreme wind conditions
 - Extreme wind speed for 12 directional bins and omnidirectional;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1000 years;
 - Averaged over periods of 1h, 10min, 1min and 3sec;
 - At heights of 10m, 60m, 100m, 120m, 160m and 200m;

2.6.2 Wave conditions

- Normal wave conditions for total sea state and wind sea and swell separately
 - Monthly and annual roses (12 directional bins, peak wave direction PWD) of significant wave height (H_s) and peak wave period (T_p);
 - Omnidirectional monthly and annual joint occurrence tables of H_s & T_p , H_s & T_z (mean zero up-crossing period), H_s & MWD (mean wave direction), H_s & PWD (peak wave direction), T_p & MWD, and T_p & PWD.
 - Annual joint occurrence tables of H_s and T_z for 12 directional bins;
 - Directional Normal Sea State tables for 12 directional bins (PWD);
- Extreme wave conditions for total sea state and wind sea and swell separately
 - Extreme 3hr sea states for return periods 1, 2, 5, 10, 50, 100, 1,000 and 10,000 years (12 directional bins & omnidirectional)
 - Including H_s , T_z , T_p , H_{max} ($H_{0.1\%}$), Crest height $\eta_{0.1\%}$, $T_{max;lower}$, $T_{max;upper}$;
 - All combined with maximum still water levels and minimum still water level associated with the extreme sea state;

2.6.3 Current conditions

- Normal current conditions
 - Joint occurrence of total current velocity and direction at 5%, 25%, 50%, 75% and 100% of the water depth and for depth-averaged;
 - Monthly and annual current roses;
- Extreme current conditions
 - Extreme total current velocities for 12 directional bins and omnidirectional;
 - For return periods of 1, 2, 5, 10, 50, 100 and 1,000 years;
 - at 5%, 25%, 50%, 75% and 100% of the water depth;

2.6.4 Water levels

- Astronomical tidal levels
 - LAT, MLLWS, MLWS, MLWN, MSL, MHWN, MHWS, HAT;
- Extreme water levels
 - 1, 2, 5, 10, 50, 100 and 1000 years return period
 - High water level and low water level;
- Assessment of long term sea level rise;

2.6.5 Time series

As a minimum, the following time series shall be made available on an hourly basis (1-hour time step) for all output grid points of the rest of the model domain (5000 m resolution):

- Time series of 10-min wind speed and direction at heights of 10m, 60m, 100m, 120m, 160m and 200m;
- Time series of H_s , T_p , T_z (mean zero up-crossing period), MWD (mean wave direction) and PWD (peak wave direction) and directional spreading for total sea, swell and wind sea;

- Time series of wave spectra (variance density as function of time and frequency and as function of time and direction);
- Time series of total, tidal and residual current speeds and directions at 5%, 25%, 50%, 75% and 100% of the water depth and depth-averaged;
- Time series of total, tide and residual water level;

2.7 Database requirements

The metocean conditions are expected to vary across the sites. The purpose of the digital database will be to allow users to export metocean conditions at any requested location inside WFZ IJmuiden Ver and in the indicated export cable corridors, allowing designers to make optimized designs for wind turbines, inter array cables, substations and their support structures based on the conditions at their actual locations, instead of using a single conservatively chosen reference point for each zone.

The requirements for the database are described below:

- The database shall enable visualization of all metocean conditions specified in Sections 2.3 at any specified location within the IJmuiden Ver Wind Farm site, including, roses, times series, scatter plots, polar plot and wave spectrum, fields of extreme values of wind speed, wave height (total sea, swell and wind sea components) and current, field of tidal levels.
- The database shall enable visualization of all metocean conditions specified in Section 2.6 for any given location in the model domain.
- The database shall enable export of all metocean conditions at any specified location within the indicated Wind Farm Zones, and the model domain. The export should include, when available, raw data (time series in ASCII, NetCDF and Matlab files), tables (Excel) and graphs; the spatial resolution associated with the extracted grid point location shall be given in the export file. The location will be specified by providing xy coordinates (single or multiple points). The database should be setup in a way that it will allow extension for more sites in the future.
- The domain covered by the database shall cover the feasibility study area.
- The output spatial resolutions shall be at least 100m in IJmuiden Ver Wind Farm Site, 500m in other Wind Farm Zones and export cable corridors and 5km outside the Wind Farm Zones but in the domain of interest, as defined above.
- The database shall be web-based and as such shall not require installation of software other than an internet browser. The database will be made available through <http://offshorewind.rvo.nl/>, either by a download link or a direct link to the database website (to be hosted by the contractor).
- The data needs to be freely available and be maintained (i.e. correct bug fixes) by the supplier for a period of five years. Updates (new versions) are only foreseen in case the site boundaries change, new sites are added or when other bathymetrical and/or metocean measurement data becomes available.
- The data should be stored with state-of-the-art methods (e.g. using appropriate metadata) in an efficient way.
- All values derived from the database should be suitable to use for the purpose of (preliminary) design and to assess weather windows for installation and maintenance.
- The database should include a manual and/or instruction video.
- A one day of training course shall be given in the RVO.nl office in Utrecht.

2.8 Certification

On behalf of Contracting Authority DNV GL is contracted with the aim to issue a Statement of Compliance that the metocean assessment has been derived by best practice, according to applicable norms and industry standards (e.g. DNV GL-SE-0190:2015-12 or equal or better).

Contractor is requested to cooperate in the process towards this Statement of Compliance. The scope should include time to adjust the results based on review rounds of Contracting Authority and the certifying body. The work can and will only be accepted once the Statement of Compliance is received.

2.9 **Webinar**

It is anticipated that the end results will be disclosed through a webinar. See examples at <https://offshorewind.rvo.nl/cms/view/8c258104-fbaf-4934-a6f0-1c2797d5187b/wind-en-water-hollandse-kust-west>

Contractor is requested to include in their offer (Activity A in Annex 4 – Prices) following activities;

- Prepare for a presentation, including illustrations
- Present the presentation at a location in Amsterdam with one expert.
- Participate with one expert in the panel at location in Amsterdam to support in the answering of questions
- Support in the answering of questions after the webinar.

Facility of webinar will be at cost of Contracting Authority.

2.10 **Activity B: Answering additional questions regarding the Metocean Assessment at the IJmuiden Ver Wind Farm Zone and Search Area 1.**

It is anticipated that additional market questions regarding this Metocean Assessment will be made after delivery of the study results. Contractor is requested to support Contracting Authority in answering these questions for a period of 5 years.

Contractor is requested to offer a tariff for a Senior Expert. It is requested to budget **700 hours** of a Senior Expert for these tasks.

The requested budget for answering questions is included in Annex 4 Prices as Activity B. Please note that it is to be expected that the questions will be raised by third parties after publication of the database and reports by the Contracting Authority.

2.11 **Optional scope item: Activity C – update of database and delivery of detailed output parameters for an additional Search Area(s)**

Contractor is requested to include an optional scope item in their proposal regarding to update the feasibility level metocean database of for an additional Search Area as presented on Figure 1 or Figure 2 to a validated metocean database and to deliver a detailed output parameter report. This work is to be conducted once bathymetrical data of the additional search area have become available from the geophysical campaign and once a number of months of metocean data has been measured at this site. The requirements as per sections 2.3 and 2.7 are also applicable to this requested update of the metocean data base. Potential additional Search Areas are those shown in Figure 4, which are with the requested domain of the Feasibility area.

For the update a separate report is to be provided according to the requirements as per section 2.2 point 1 and a presentation is to be given in a webinar for which Contractor has to provide the services as specified in section 2.7.

The budget for this optional scope item is to be included in Annex 4 Prices as Activity C. This option may be included in the contract scope between 2023 and 2025, depending on availability of additional metocean data measurements, developments on future wind farm sites and received feedback of developers on the use of the metocean database.

2.12 **Optional scope item: Activity D – additional support from project team**

Contracting Authority may ask additional support from the project team for analysis, answering questions or support in coordination with other studies.

The budget for this optional scope item is to be included in Annex 4 Price as Activity D. This option may be included in the contract scope throughout the duration of the Agreement.

2.13 Required grid resolutions

In Table 1 the required grid resolutions for the various study areas and scope options are summarized.

Table 1: Summary of maximum required grid resolutions in meters

	IJmuiden Ver	Search Area 1	Other Search Areas	Feasibility level domain
Deliverables 1-4 (for IJV)	400	1,000	1,000	5,000
Deliverables 5-6 (for Search Area 1)	400	400	1,000	5,000
Optional scope item, activity C (for an additional Search Area)	400	400	400 ¹	5,000

1 – maximum required grid resolution for the specific Search Area requested in the update