DNV·GL

WIND FARM ZONE HOLLANDSE KUST (ZUID)

Certification Report
Site Conditions Assessment

Netherlands Enterprise Agency

Report No.: CR-SC-DNVGL-SE-0190-02664-5
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Objective:

To confirm that the result of A) MetOcean Investigations, B) Geotechnical Investigations and Geological Ground Model, C) Morphological Investigations, D) Wind Investigations and E) Geophysical Investigations, carried out for Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II) can be used for design of future offshore wind farms.

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0	2017-02-24	Draft for RVO.nl comments	Erik Asp	Iris Lohmann	Pia Redanz
1	2017-03-15	RVO.nl comments included	Erik Asp	Iris Lohmann	Pia Redanz
2	2017-03-21	Text regarding buoy measurements Updated	Erik Asp	Iris Lohmann	Pia Redanz
3	2017-04-09	Geophysical appendix added Appendix F revised	Erik Asp	Iris Lohmann	Pia Redanz
4	2017-05-03	RVO.nl comments included	Erik Asp	Iris Lohmann	Pia Redanz
5	2017-11-01	Revised Wind and Metocean Studies	Erik Asp	Iris Lohmann	Pia Redanz

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1 EXECUTIVE SUMMARY

The Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II) is located in the Dutch Sector of the North Sea, approximately 22 km from the coastline. As part of the tender preparations, the Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland, RVO.nl) requested the following investigations of the wind farm site:

- MetOcean- (including a MetOcean database)
- Geotechnical
- Morphological
- Wind
- Geophysical

DNV GL was assigned to validate those studies. DNV GL has further been assigned to:

- verify if the quality management system of the measuring campaign carried out as part of the study is in place
- refer to the Archaeological assessment and to the methodology used (Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0) and to the approval of the RCE
- refer to the UXO Desk Study carried out as part of the site package
- Refer to the validation of the buoys (Trial Campaign validation, followed by a Pre-Deployment validation)

Finally, DNV GL was assigned to ensure the overall quality, completeness and the consistency between parameters found & used in the different studies.

2 CERTIFICATION SCHEME

The following scheme was applied:

Document No.	Title
DNVGL-SE-0190:2015-12	Project certification of wind power plants

The MetOcean Investigations, Geotechnical Investigations and Geological Ground Model, Morphological Investigations and Wind Investigation have been evaluated based on section 2.3.2 Site Assessment of DNVGL-SE-0190.

By fulfilling the requirements in DNVGL-SE-0190, the Site Assessment Requirements listed in

IEC 61400-22:2010-05	Wind turbines – Part 22: Conformity Testing and Certification

are also fulfilled.

3 LIST OF REPORTS

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

APPENDIX	Subject
A	MetOcean Investigations
B	Geotechnical Investigations and Geological Ground Model
C	Morphological Investigations
D	Wind Investigations
E	Geophysical Investigations
F	List of the Documents/References

Appendix F contains a list of the documents/references submitted by RVO.nl for this project, including reports and database for review and sources of additional information. RVO.nl 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 (http://offshorewind.rvo.nl/file/download/45722462)
    - the methodology used (Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0)
    - the approval of the 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.nl has also initiated a MetOcean Measuring Campaign. DNV GL Advisory has verified that a quality management system of the measuring campaign is in place. 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 (trial campaign and pre-deployment validation)

The quality of the Fugro MetOcean measuring systems is assessed by DNV GL Advisory, section Offshore, Germany [1]. The assessment of the Trial campaign validation at IJmuiden concluded that the system has formally qualified for Stage 2 "pre-commercial" in the context of the Floating LiDAR Commercial Roadmap [2].

Each deployed individual system used is assessed by DNV GL Advisory, section Offshore, Germany [1] by means of a pre-deployment validation. DNV GL Advisory concludes that each of the MetOcean measuring systems has demonstrated its capability to produce accurate wind speed and direction data across the range of sea states and meteorological conditions experienced in the trials [3].

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 and a monthly statement from ECN approving 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, K13, P11-b and Q11. 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, applicable to developing and applying expertise in the area of water, subsurface and infrastructure for people, planet and prosperity.
- ECN performs the quality check of the results of each month. After approval an undersigned letter is issued by ECN with a statement about the quality of the results. ECN is ISO/IEC17025 accredited for meteorological measurements.

[1] FUGRO/OCEANOR SEAWATCH WIND LIDAR BUOY ASSESSMENT OF THE FUGRO/OCEANOR SEAWATCH FLOATING LIDAR VERIFICATION AT RWE IJMUIDEN MET MAST, Technical Note No.: GLGH-4257 13 10378-R-0003, Rev. B Date: 2015-01-30 http://offshorewind.rvo.nl/file/download/43054292
[2] Offshore Wind Accelerator Roadmap for the commercial acceptance of floating lidar technology. The Carbon Trust, 21 November 2013].
[3] Example of WS149: Assessment of the Fugro OCEANOR Seawatch Wind LiDAR Buoy Pre-Deployment Validation on Frøya, Norway, Report No.: GLGH-4257 13 10378-R-0004, Rev. A Date: 2015-03-31, http://offshorewind.rvo.nl/file/download/43054912. All other validation reports to be found at offshorewind.rvo.nl

4 CONDITIONS

The conditions for using the site conditions for design, manufacturing installation, maintenance and decommission of the wind farm, identified during the technical evaluation, are listed in the appendices and summarised in the following. The conditions are assigned to the certification phases in which they need to be considered and evaluated.

MetOcean Investigations	No conditions have been identified.
Geotechnical Investigations and Geological Ground Model	For the Design Basis phase the following conditions shall be addressed: For the final layout of the wind farm zones the detailed geotechnical investigations need to be performed at each specific (e.g. turbine) location.
Morphological Investigations	For the operation and maintenance phases the following conditions shall be addressed: The seabed levels within the wind farm area shall be monitored and remedial actions taken before the seabed levels are outside the design upper and lower ranges.
Wind Investigations	No conditions have been identified.
Geophysical Investigations	No conditions have been identified.

5 OUTSTANDING ISSUES

There are no outstanding issues.

6 CONCLUSION

6.1 Studies Reviewed by DNV GL

The studies reviewed by DNV GL are further described in the appendices A to D. The reviewed documents are listed in appendix F. Although the present report only covers Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II), some of the reviewed reports covers the Wind Farm Zone Hollandse Kust (zuid) (WFS I, WFS II, WFS III, WFS IV).

The review conclusions are summarised in the following.

MetOcean Investigations	DNV GL finds that the MetOcean study is complete, carried out according to industry best practice, is plausible, and that • the Normal MetOcean Conditions • the Extreme MetOcean Conditions 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 are suitable as design input for Wind Farm Zone Hollandse Kust (zuid). 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 (zuid) (WFS I and WFS II).

Geotechnical Investigations and Geological Ground Model	It is evaluated that the used equipment is state-of-the-art in offshore practice and the found results do not deviate from experienced values for parameters of the present soils. The chosen sites of the conducted investigations are sufficient to develop an illustration of lateral and vertical soil and seabed variations. It was evaluated that the geological ground 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.
Morphological Investigations	DNV GL find 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 2016-2056 • Highest Sea Bed Level (HSBL) for the period 2016-2056 as defined in the documents listed in section C4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 and can be used as basis for determining design seabed levels for Hollandse Kust (zuid) (WFS I and WFS II) Wind Farm Zone.
Wind Investigations	DNV GL find that the wind properties, as defined in the documents listed in Section D4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 for establishing site assessment. The properties estimated are: • Wind roses • Wind distributions • Long-term mean wind speed at 100 m above MSL • The long-term mean wind speed is estimated to 9.44 m/s at the center of Wind Farm Zone Hollandse Kust (zuid).
Geophysical Investigations	The geophysical 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 these reports are suitable for the implementation of a geological ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with DNVGL-ST-0437 and DNVGL-ST-0126.

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 Investigations
- The 'seabed levels used in the MetOcean investigation are consistent with the data and the 'seabed levels' found in Morphological 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 and Measnet approved by ECN)
- Regarding the Archaeological assessment a reference is made to (http://offshorewind.rvo.nl/file/download/45722462), to the methodology used (Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0) and to the approval of the 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 (zuid) (WFS I and WFS II) 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 state-of-the-art methods
- can be used directly as input for design

APPENDIX A
MetOcean Investigations

Evaluation of MetOcean Investigations for Hollandse Kust (zuid) (WFS I and WFS II) Wind Farm Zone

A1 Description of verified component, system or item

Within the wind farm areas a MetOcean study has been performed. The results and the found MetOcean site conditions are documented by the customer and build the basis for the verification of the present report. The MetOcean data is made available through a MetOcean database.

A2 Interface to other systems/components

Currently, 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 reviewed reports and database:

Ref.	Document No.	Revision	Title
/1/	Proj. ID: 11820013	Final 2.3 Dated 2017-09-05	DHI report: Wind Farm Zone Hollandse Kust (zuid) & Hollandse Kust (noord) - MetOcean Study
/2/	Proj. ID: 11820013	1.03 Dated 2017-02-17	DHI MetOcean database: Metocean DSS – Mike Workbench by DHI
/3/		V2.3 Dated 2017-09-18	20170918_HKZ_HKN_DHI_Excel_files_Metocean_study_V2.3

List of reports taken for information only:

Ref.	Document No.	Revision	Title
/A/	Proj. ID: 11820013	Final 2.0 Dated 2017-01-31	DHI report: MetOcean Database - Hollandse Kust (zuid) & (noord) – User Guide

A5 Evaluation work

/1/ presents the MetOcean assessment for the planned Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II) and contains information for Normal and Extreme Conditions regarding:

- Wind
- Waves
- Current
- Water Levels

- Joint probabilities between the above.
- Other parameters like salt, temperatures 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 1979-2016 (+37 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 2016. For other areas than Hollandse Kust (zuid) and Hollandse Kust (noord), 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 gives a correct description of the seabed and can be used as input for hindcast models.

Wind

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

HKZB	Jun 2016 - March 2017
HKZA	Jun 2016 - March 2017
Borssele1	Feb-July 2016
Borssele2	Feb-July 2016
MM Ijmuiden	2011-2015
OWEZ	2005-2010
LEG	2001-2016
K13	2001-2016
K14	2008-2016
Europlatform	2001-2016

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 Ecofys [*Hollandse Kust (zuid) Offshore Wind Farm Zone Combined Wind Resource Assessment*. Doc no. HKZ_20170918_ECOFYS_Combined WRA_v03_F rev 3.0 issued 2017-09-18] have independently of each other calculated the wind speed 100m above the sea-level for the Hollandse Kust (zuid) zone, 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 Wind Farm Zone Hollandse Kust

(zuid) (WFS I and WFS II). It shall be noted that possible small adjustments for the HKN wind climate are possibly depending on results of the Wind Resource Assessment for HKN.

Waves Validation/Calibration

HZKB	Jun 2016 - March 2017
HKZA	Jun 2016 - March 2017
Ijmuiden	1989-2016
Europlatform	1989-2016
LEG	1989-2016
K13a	1989-2016
Borssele1	Feb-July 2016
Borssele2	Feb-July 2016

The a) 'Bottom friction', b) 'The effect of wind-induced currents' and c) 'Cap to the ratio of friction velocity (u*) / wind speed (u10)' have been calibrated. 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.

DNV GL has reviewed the validation of the waves and has found it documented that the hindcast model can be used to establish the design wave conditions at Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II).

HD (water level and current) Validation/Calibration

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

HKZB	Jun 2016- March 2017
MM Ijmuiden	2011-2015
Europlatform	1994-2016
LEG	2012-2016
K13a	1994-2016

The Manning number (bottom friction) and wind friction has been calibrated. DNV GL has reviewed the calibration and found that the final values used as input in the hindcast model are within the normal applied parameter ranges.

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 Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II).

MetOcean Database

The overall goal of the database (/2/) 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 (zuid) (WFS I and WFS II). 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 37 years (1979-2016). 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 two sites (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/.

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 MetOcean study is complete, carried out according to industry best practice, is plausible, and that

- the Normal MetOcean Conditions
- the Extreme MetOcean Conditions

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 are suitable as design input for Wind Farm Zone Hollandse Kust (zuid) (WFS I and WFS II).

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 (zuid) (WFS I and WFS II).

APPENDIX B
Geotechnical Investigations and Geological Ground Model

Evaluation of Geotechnical Investigations and Geological Ground Model for Hollandse Kust (zuid) Wind Farm Zone, Wind Farm Sites I and II

B1 Description of verified component, system or item

Within the wind farm area geotechnical and geological investigations have been performed. The results and the found site conditions are documented by the customer and build the basis for the verification of the current report.

B2 Interface to other systems/components

Knowledge obtained from the Geophysical Site Conditions has been considered during the assessment of the Geotechnical Investigations and the Geological Ground Model.

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
DNVGL-ST-0126	2016-04	Support structures for wind turbines

B4 Documentation from customer

List of reports:

Document No.	Revision	Title
Fugro Report No.: N6196/02	3 14.10.2016	Geotechnical Report - Investigation Data, Seafloor In Situ Test Locations, Wind Farm Site I, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 562 pages
Fugro Report No.: N6196/04	3 14.10.2016	Geotechnical Report - Investigation Data, Seafloor In Situ Test Locations, Wind Farm Site II, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 507 pages
Fugro Report No.: N6196/01	4 14.11.2016	Geotechnical Report - Investigation Data, Geotechnical Borehole Locations, Wind Farm Site I, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 1501 pages
Fugro Report No.: N6196/03	4 14.11.2016	Geotechnical Report - Investigation Data, Geotechnical Borehole Locations, Wind Farm Site II, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 1433 pages
Fugro Report No.: N6196/09	3 14.11.2016	Geological Ground Model, Wind Farm Site I, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 336 pages
Fugro Report No.: N6196/10	3 14.11.2016	Geological Ground Model, Wind Farm Site II, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 319 pages

Document No.	Revision	Title
Fugro Report No.: N6196/13	3 20.01.2017	Geotechnical Report - Laboratory Test Data, Wind Farm Sites I&II, Hollandse Kust (zuid) Wind Farm Zone, Dutch Sector, North Sea, 1396 pages

B5 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 and geological conditions in the given wind farm sites WFS I and WFS II.

At each wind farm site eight locations have been investigated by boreholes down to a depth of at least 50 m below mudline, supported by standard cone penetration tests (WFS I: at three locations; WFS II: at two locations) and seismic cone penetration tests (WFS I: at three locations; WFS II: at four locations).

Furthermore, cone penetration tests at twenty-six and twenty-three locations, respectively, distributed across WFS I and WFS II have been conducted.

In addition to initial laboratory tests advanced geotechnical laboratory tests have been conducted for the soil units A, B1, B2, C1, C2 and D using samples from boreholes HKZ1-BH01-SA, HKZ1-BH02-SA, HKZ1-BH07-SA, HKZ1-BH08-SA and HKZ2-BH01-SA, HKZ2-BH03-SA, HKZ2-BH04-SA, HKZ2-BH07A-SA, HKZ2-BH08-SA, HKZ2-BH21-SA for WFS I and WFS II, respectively. The tests include geotechnical index tests, static and cyclic strength tests and dynamic tests. The exact numbers and results can be found in the corresponding report. Further, the test procedures are described and failure conditions are specified where necessary.

B6 Conditions to be considered in other certification phases

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

For the Design Basis phase the following conditions shall be addressed:

- For the final layout of the wind farm zones the detailed geotechnical investigations need to be performed at each specific (e.g. turbine) location.

B7 Outstanding issues

There are no outstanding issues.

B8 Conclusion

It is evaluated that the used equipment is state-of-the-art in offshore practice and the found results do not deviate from experienced values for parameters of the present soils.

The chosen sites of the conducted investigations are sufficient to develop an illustration of lateral and vertical soil and seabed variations.

It was evaluated that the geological ground 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.

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 (zuid) Wind Farm Zone as listed under section B4 fulfils the relevant demands set up in the Certification Scheme DNVGL-SE-0190:2015-12, section 2.3.2 and the related "Basis for the evaluation" listed in section B4 if the condition in chapter B6 is observed.

The geotechnical investigation reports and the geological ground model can be used to support the (preliminary) design of future offshore wind farms in the project area. The data presented in those reports can be used for establishing a Design Basis in accordance with DNVGL-ST-0437 and DNVGL-ST-0126.

APPENDIX C
Morphological Investigations

Evaluation of Morphological Investigations for Hollandse Kust (zuid) Wind Farm Zone

C1 Description of verified component, system or item

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

C2 Interface to other systems/components

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

C3 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

C4 Documentation from customer

List of reports:

Ref.	Document No.	Revision	Title
/1/	1230851-000-HY E-0003	Final v2	Morphodynamics of Hollandse Kust (zuid) Wind Farm Zone Prediction of seabed level changes between 2016 and 2051

C5 Evaluation work

/1/ presents the bathymetrical/morphodynamic assessment for the planned Wind Farm Zone Hollandse Kust (zuid). /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 Wind Farm Zone Hollandse Kust (zuid) (HKZ) 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 Turbine 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 3 steps based on the historical and recent seabed bathymetries

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

Future migration

The 2016 HKZ Bathymetry was determined from multibeam survey carried out by Fugro on behalf of RVO.nl: These bathymetrical data together with 2010 survey and other previous surveys were 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 of the mobile seabed components of the most recent 2016 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.

In order to account for a) survey, b) megaripples and c) spatial resolution uncertainty, 0.5 m upward and 0.4 m downward bands 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 reviewed and agreed 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

C6 Conditions to be considered in other certification phases

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

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

- The seabed levels within the wind farm area shall be monitored and remedial actions taken before the seabed levels are outside the design upper and lower ranges.

C7 Outstanding issues

There are no outstanding issues.

C8 Conclusion

DNV GL find 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 2016-2056
- Highest Sea Bed Level (HSBL) for the period 2016-2056

as defined in the documents listed in section C4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 and can be used as basis for determining design seabed levels for Hollandse Kust (zuid) Wind Farm Zone. The condition in Section C6 needs to be observed.

APPENDIX D
Wind Investigations

Evaluation of Wind Speed Investigations for Hollandse Kust (zuid) Wind Farm Zone, Wind Farm Sites I, II, III and IV

D1 Description of verified component, system or item

Within the wind farm area wind speeds have been estimated. The results and the found site conditions are documented by the customer and build the basis for the verification of the current report.

D2 Interface to other systems/components

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

D3 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

D4 Documentation from customer

List of reports:

Document No.	Revision	Title
HKZ_20170918_ECOFYS_Combined WRA_v03_F	3 issued 2017-09-18	Hollandse Kust (zuid) Offshore Wind Farm Zone Combined Wind Resource Assessment
Excel sheets	2017-09-11	20170911_CAL_RVO_Wind Climate_HKZ0_v1.0 20170911_CAL_RVO_Wind Climate_HKZ1_v1.0 20170911_CAL_RVO_Wind Climate_HKZ2_v1.0 20170911_CAL_RVO_Wind Climate_HKZ3_v1.0 20170911_CAL_RVO_Wind Climate_HKZ4_v1.0

D5 Evaluation work

/1/ presents the wind climate assessment for the planned Hollandse Kust (zuid) 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 **9.44 ± 0.37 m/s** (± standard deviation) the variation from the zone center is about ±0.1m/s.

This assessment is based on two assessments:

The Offshore Windpark Egmond aan Zee (OWEZ) 70 m met mast data have been used as the primary sources for the first wind assessment (WRA1), due to the proximity to the Hollandse Kust (zuid) Zone and low overall uncertainty of the wind measurements. The extrapolation from (OWEZ) to the Hollandse Kust (zuid) Offshore Wind Farm Zone is based on the EMD-ConWx mesoscale model.

A second wind resource assessment (WRA2) was commissioned following a 12-month on-site floating LiDAR campaign. The wind speed measurements of the HKZB buoy are the primary source for this

assessment. Wind measurements from the Lichteiland Goeree platform are selected as the long-term reference.

The results of the two wind resource assessments differ only slightly, with a 0.5% difference in the mean wind speeds at 100 m MSL. Also, the uncertainty of both assessments is comparable. Since the calculations are largely independent, the two results may be combined based on inverse-variance weighting.

The evaluation has been supported by the following other Dutch North Sea offshore wind measurements taken at

- Meteomast IJmuiden.
- Europlatform
- LiDAR (Lot-1) at Borssele offshore windfarm zone.
- Floating LiDAR at HKZA offshore windfarm zones

DNV GL has reviewed

- Measurements
- Mesoscale model
- Long Term Correction

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 9.44 m/s long-term mean wind speed including ± 0.37 m/s (± standard deviation) can be agreed on.

The wind speeds are to be used for design and energy assessment of future offshore wind farms.

It has been checked that the 'wind distribution and wind roses' used in the MetOcean study presented in /1/ are aligned.

D6 Conditions to be considered in other certification phases

No conditions were identified.

D7 Outstanding issues

There are no outstanding issues.

D8 Conclusion

DNV GL find that the wind properties as defined in the documents listed in section D4 are derived in line with the requirements following section 2.3.2 of the DNVGL-SE-0190 for establishing site assessment.

The properties estimated are:

a. Wind roses
b. Wind distributions
c. Long-term mean wind speed at 100 m above MSL

The long-term mean wind speed is estimated to 9.44 m/s at the center of Hollandse Kust (zuid) Wind Farm Zone.

APPENDIX E
Geophysical Investigations

Evaluation of Geophysical Investigations for Hollandse Kust (zuid) Wind Farm Zone, Wind Farm Sites I, II, III and IV

E1 Description of verified component, system or item

Within the wind farm area geophysical investigations have been performed. The results and the found site conditions are documented by the customer and build the basis for the verification of the current report.

E2 Interface to other systems/components

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

E3 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

E4 Documentation from customer

List of reports:

Document No.	Revision	Title
GH176-R1	B 24.08.2016	Geophysical Site Investigation Survey / Hollandse Kust (Zuid) Wind Farm Development Zone / Wind Farm Site I
GH176-R2	B 24.08.2016	Geophysical Site Investigation Survey / Hollandse Kust (Zuid) Wind Farm Development Zone / Wind Farm Site II
GH176-R3	B 24.08.2016	Geophysical Site Investigation Survey / Hollandse Kust (Zuid) Wind Farm Development Zone / Wind Farm Site III
GH176-R4	B 24.08.2016	Geophysical Site Investigation Survey / Hollandse Kust (Zuid) Wind Farm Development Zone / Wind Farm Site IV
GH176-R5	B 24.08.2016	Geophysical Site Investigation Survey / Hollandse Kust (Zuid) Wind Farm Development Zone / Operations & Calibrations

E5 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 geophysical conditions in the given wind farm sites WFS I, II, III, IV. The above referenced reports provide sufficient geophysical detail to establish 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.

E6 Conditions to be considered in other certification phases

No conditions have been identified.

E7 Outstanding issues

There are no outstanding issues.

E8 Conclusion

The geophysical 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 these reports are suitable for the implementation of a geological ground model and can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with DNVGL-ST-0437 and DNVGL-ST-0126.

APPENDIX F
List of Documents/References

The following documents/references were issued by RVO.nl for this project, and include reports and database for DNV GL review and sources of additional information (taken from HKZ_20171024_RVO_Deliverables site studies-1.xlsx, April 7st, 2017):

File type	ID	Description of deliverable	Filename	Date of issue	Publish	Quality approval
Report	A.1	Archaeological desk study report WFS I-IV	HKZ_20160129_Periplus_Archaeological Desk Study_F.pdf	2016-01-29	yes	RCE
GIS	A.2	Archaeological maps with known wrecks WFS I-IV	HKZ_20160304_Periplus_Archaeological Desk Study_Zip files_incl Metadata_ERTS89_F.zip	2016-03-04	yes	RCE
Report	A.3	Archaeological assessment of geophysical data WFS I-IV	HKZ_20161013_Periplus_Archaeological Assessment based on geophysical survey_Phase II_incl appendices_F.pdf	2016-10-13	yes	RCE
GIS	A.4	Archaeological GIS files corresponding with A.3 WFS I-IV	HKZ_20161104_Periplus_Archaeological Assessment based on geophysical survey_Phase II_GIS_F.zip	2016-11-04	yes	RCE
Memo	A.5	Archaeological Programme of Requirements WFS I-IV (phase	HKZ_20161006_Periplus_Programme of Requirements_Archaeological Assessment_Phase II-F.pdf	2016-10-06	yes	RCE
Memo	A.6	Archaeological Programme of Requirements HKZ IV (phase II	HKZ_20170228_Periplus_Programme of Requirements_Archaeological Assessment Phase III_F.pdf	2017-02-28	yes	RCE
Video	A.7	Webinar Archaeological Assessment	Link to webinar	2016-12-13	yes	N/A
Report	B.1	UXO risk assessment report WFS I-IV	HKZ_20160212_REASeuro_UXO Desk Study-F.pdf	2016-02-12	yes	N/A
GIS	B.2	UXO maps corresponding with B.1 WFS I-IV	HKZ_20160215_REASeuro_UXO Desk Study_GIS Data-F.gdb.zip	2016-02-15	yes	N/A
Report	B.3	Revised Naval Mine Field Information and UXO Survey Propert	HKZ_20170329_REASeuro_Revised Naval Mine Field Information and UXO Survey Properties-F.pdf	2017-03-29	yes	N/A
GIS	B.4	Revised Naval Mine Field Information	HKZ_20170612_REASeuro_GIS_Revised Naval Mine Field Information-F.rar	2017-06-12	yes	N/A
Video	B.5	Webinar UXO Risk Assessment	Link to webinar	2016-12-13	yes	N/A
Report	C.1	Geological desk study WFS I-IV	HKZ_20151222_Deltares_Geological Desk Study-F.pdf	2015-12-22	yes	N/A
GIS	C.2	Geological desk study GIS files WFS I-IV	HKZ_20151222_Deltares_Geological Desk Study_GIS Data-F.zip	2015-12-22	yes	N/A
Report	D.1	Geophysical operations report WFS I-IV	HKZ_20160824_Fugro_Operations & Calibrations Report-F.pdf	2016-08-24	yes	DNV GL
Report	D.2	Geophysical site investigation report WFS I	HKZ_20160824_Fugro_Geophysical Report WFS I-F.pdf	2016-08-24	yes	DNV GL
Report	D.3	Geophysical site investigation report WFS II	HKZ_20160824_Fugro_Geophysical Report WFS II-F.pdf	2016-08-24	yes	DNV GL
Report	D.4	Geophysical site investigation report WFS III	HKZ_20160824_Fugro_Geophysical Report_WFS III_F.pdf	2016-08-24	yes	DNV GL
Report	D.5	Geophysical site investigation report WFS IV	HKZ_20160824_Fugro_Geophysical Report_WFS IV_F.pdf	2016-08-24	yes	DNV GL
Data	D.6	Geophysical GIS charts and other raw data WFSI-IV	On request via data order form	2016-12-20	yes	DNV GL
Video	D.7	Webinar Geophysical site investigation	Link to webinar	2016-12-13	yes	N/A
Report	E.1	Geotechnical CPT report WFS I	HKZ_20161014_Fugro_Seafloor In Situ Test Locations_WFS I-F.pdf	2016-10-14	yes	DNV GL
Report	E.2	Geotechnical CPT report WFS II	HKZ_20161014_Fugro_Seafloor In Situ Test Locations_WFS II-F.pdf	2016-10-14	yes	DNV GL
Report	E.3	Geotechnical borehole report WFS I	HKZ_20161114_Fugro_Geotechnical Borehole Locations_WFS I-F.pdf	2016-11-14	yes	DNV GL
Report	E.4	Geotechnical borehole report WFS II	HKZ_20161114_Fugro_Geotechnical Borehole Locations_WFS II-F.pdf	2016-11-14	yes	DNV GL
Report	E.5	Geotechnical ground model report WFS I	HKZ_20161114_Fugro_Geological Ground Model_WFS I-F.pdf	2016-11-14	yes	DNV GL
Report	E.6	Geotechnical ground model report WFS II	HKZ_20161114_Fugro_Geological Ground Model_WFS II-F.pdf	2016-11-14	yes	DNV GL
Data	E.7	Geotechnical GIS and Kingdom data WFS I-II	On request via data order form	2017-02-20	yes	DNV GL
Report	E.8	Geotechnical advanced test report WFS I-II	HKZ_20170213_Fugro_Laboratory Test Data_WFS I&II-F.pdf	2017-02-13	yes	DNV GL
Data	E.9	Geotechnical Note - SCPT Digital Deliverables WFS I-II	HKZ_20170519_Fugro_SCPT Digital Deliverables_WFS I&II-F.pdf	2017-05-19	yes	N/A
Report	E.10	Geotechnical Note - Microbial Influenced Corrosion	HKZ_20170711_Fugro_Geotechnical Note_Microbial Influenced Corrosion_F.pdf	2017-07-11	yes	N/A
Video	E.11	Webinar Geotechnical Survey	Link to webinar	2017-01-24	yes	N/A
Report	F.1	Morphology study report WFS I-IV	HKZ_20161222_Deltares_MorphologyStudy_Report-F.pdf	2016-12-22	yes	DNV GL
GIS	F.2	Morphology maps with reference levels WFS I-IV	HKZ_20161222_Deltares_MorphologyStudy_GIS Data-F.zip	2016-12-22	yes	DNV GL
GIS	F.3	Morphology maps with reference levels WFS I-IV ASCII Data	HKZ_20170321_Deltares_MorphologyStudy_ASCII Files-F.zip	2017-03-21	yes	DNV GL
Video	F.4	Morphology webinar WFS I-IV	Link to webinar	2017-01-24	yes	N/A
Report	F.5	Scour study WFS I-IV	HKZ_20170929_Deltares_Scour and scour mitigation for Hollandse Kust (zuid)_FINAL&Signed.pdf	2017-09-29	yes	N/A
Report	G.1	Wind resource assessment WFS I-IV	HKZ_20171010_Combined WRA_F_undersigned.pdf	2017-10-10	yes	DNV GL
XLS	G.2	Wind resource assessment time series WFS I-IV WRA1	HKZ_20170406_Ecofys_Wind Climate WRA_F.zip	2017-04-06	yes	DNV GL
GIS	G.3	Wind resource assessment maps WFS I-IV WRA 1	HKZ_20161214_Ecofys_Calculated Mean Wind Speed-F.zip	2016-12-14	yes	N/A
XLS	G.4	Wind resource assessment time series WFS I-IV WRA 2	20170911_HKZ_Ecofys_Excel_files WRA2 Wind Climate-F	2017-10-10	yes	DNV GL
GIS	G.5	Wind resource assessment maps WFS I-IV WRA 2	HKZ_20170918_ECOFYS_WRA2_100m_wind_speed_map-F	2017-10-10	yes	N/A
Video	G.6	Webinar Wind Resource Assessment	Link to webinar	2017-01-17	yes	N/A
Report	H.1	Metocean study report WFS I-IV	HKZ_20171006_DHI_MetoceanDeskStudy_2.3_signed_F	2017-10-06	yes	DNV GL
Appendix	H.2	Metocean study - Appendix E - Normal Conditions HKZ	HKZ_20170214_DHI_Metocean Study_AppE-F.pdf	2017-02-14	yes	N/A
XLS	H.3	Metocean study report tables WFS I-IV	20170918_HKZ_HKN_DHI_Excel_files_Metocean_study_V2.3.zip	2017-09-18	yes	DNV GL
Data	H.4	Metocean study database WFS I-IV	HKZ_20170216_DHI_Metocean Database-F.zip	2017-02-17	yes	DNV GL
MATLAB	H.5	Metocean study Bin wise U (hub) MATLAB file	20170929_HKZ_HKN_DHI_Metocean desk study bin wise U(hub) with the joint Hs, Tp and gamma_matlab files-F.zip	2017-09-29	yes	N/A
Video	H.6	Webinar Metocean Study	Link to webinar	2017-01-17	yes	N/A
Report	I.1	Metocean campaign system trial validation	20150130_DNVGL_IJmuiden Trial Campaign Validation WS140.pdf	2015-01-30	yes	ECN
Report	I.2	Metocean campaign uncertainty assessment	HKZ_20160902_Ecofys_Floating LiDAR Uncertainty Assessment-F.pdf	2016-09-02	yes	ECN
Report	I.3	Metocean campaign validation buoy WS140	HKZ_20160922_DNVGL_Predeployment Validation Report_WS140-F.pdf	2016-10-19	yes	DNV GL
Report	I.4	Metocean campaign validation buoy WS149	HKZ_20150331_DNVGL_Predeployment Validation Report_WS149-F.pdf	2015-03-31	yes	DNV GL
Report	I.5	Metocean campaign validation buoy WS156	HKZ_20160412_DNVGL_Predeployment Validation Report_WS156-F.pdf	2016-04-12	yes	DNV GL
Report	I.6	Metocean campaign validation buoy WS157	HKZ_20160412_DNVGL_Predeployment Validation Report_WS157-F.pdf	2016-04-12	yes	DNV GL
Report	I.7	Metocean campaign validation buoy WS158	HKZ_20160704_DNVGL_Predeployment Validation Report_WS158-F.pdf	2016-07-04	yes	DNV GL
Report	I.8	Trial Campaign Validation Report buoy WS155	20161207_Natural Power_Trial Campaign Validation Report WS155.pdf	2016-12-07	yes	Natural Power
Report	I.9	Post-Incident Data Quality Assessment WS140	HKZ_20170620_DNVGL_Post-Incident Data Quality Assessment WS140.pdf	2017-06-20	yes	DNV GL
Report	I.10	Post-Deployment Validation Report WS149	HKZ_20170707_DNVGL_Post-Deployment Validation Report_WS149-F.pdf	2017-07-07	yes	DNV GL
Data	I.11	Metocean campaign data and reports - 1 - June 2016	HKZ_20170224_Fugro_MetOcean Data&Reports_June 2016_Revised-F.zip	2017-02-24	yes	ECN
Data	I.12	Metocean campaign data and reports - 2 - July 2016	HKZ_20170224_Fugro_MetOcean_Data&Reports_July 2016_Revised-F.zip	2017-02-24	yes	ECN
Data	I.13	Metocean campaign data and reports - 3 - August 2016	HKZ_20170224_Fugro_MetOcean_Data&Reports_August 2016_Revised-F.zip	2017-02-24	yes	ECN
Data	I.14	Metocean campaign data and reports - 4 - September 2016	HKZ_20170120_Fugro_MetOcean_Data&Reports_September 2016-F.zip	2017-01-20	yes	ECN
Data	I.15	Metocean campaign data and reports - 5 - October 2016	HKZ_20170120_Fugro_MetOcean_Data&Reports_October 2016-F.zip	2017-01-20	yes	ECN
Data	I.16	Metocean campaign data and reports - 6 - November 2016	HKZ_20170322_Fugro_MetOcean Data&Reports November 2016-F.zip	2017-03-22	yes	ECN
Data	I.17	Metocean campaign data and reports - 7 - December 2016	HKZ_20170320_Fugro_MetOcean Data&Reports December 2016-F.zip	2017-03-20	yes	ECN
Data	I.18	Metocean campaign data and reports - 8 - January 2017	HKZ_20170406_Fugro_MetOcean Data&Reports January 2017-F.zip	2017-04-06	yes	ECN
Data	I.19	Metocean campaign data and reports - 9 - February 2017	HKZ_20170421_Fugro_MetOcean Data&Reports February 2017-F.zip	2017-04-21	yes	ECN
Data	I.20	Metocean campaign data and reports - 10 - March 2017	HKZ_20170508_Fugro_MetOcean Data&Reports March 2017-F.zip	2017-05-08	yes	ECN
Data	I.21	Metocean campaign data and reports - 11 - April 2017	HKZ_20170612_Fugro_MetOcean Data&Reports April 2017-F.zip	2017-06-12	yes	ECN
Data	I.22	Metocean campaign data and reports - 12 - May 2017	HKZ_20170707_Fugro_MetOcean Data&Reports May 2017-F.zip	2017-07-07	yes	ECN
Data	I.23	Metocean campaign data and reports - 13 - June 2017	HKZ_20171006_Fugro_MetOcean Data&Reports June 2017_F.zip	2017-10-06	yes	ECN
Data	I.24	Metocean campaign data and reports - 14 - July 2017		Q3 2017	no	
Data	I.25	Metocean campaign data and reports - 15 - August 2017		Q3 2017	no	
Data	I.26	Metocean campaign data and reports - 16 - September 2017		Q4 2017	no	
Data	I.27	Metocean campaign data and reports - 17 - October 2017		Q4 2017	no	
Data	I.28	Metocean campaign data and reports - 18 - November 2017		Q4 2017	no	
Data	I.29	Metocean campaign data and reports - 19 - December 2017		Q1 2018	no	
Data	I.30	Metocean campaign data and reports - 20 - January 2018		Q1 2018	no	
Video	I.31	Metocean campaign webinar	Link to webinar	2017-01-17	yes	N/A
Report	J.1	Project & Site Description HKZ I & II	Project & Site Description HKZ I & II, version April 2017	2017-04-14	yes	N/A
Report	J.2	Project & Site Description HKZ I & II, Appendix A	Project & Site Description HKZ I & II; Appendix A, Applicable Law	2016-11-24	yes	N/A
Report	J.3	Project & Site Description HKZ I & II, Appendix B	Project & Site Description HKZ I & II; Appendix B, Environmental Impact Assessment	2017-04-14	yes	N/A
Report	J.4	Project & Site Description HKZ I & II, Appendix C	Project & Site Description HKZ I & II; Appendix C, Boundaries & Coordinates	2017-04-14	yes	N/A

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