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Integrated Ground Model Doordewind Investigation Area

Annex 6 - Section V

Scope of Work

Colophon

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REFERENCES

CEN, 2003b. EN 12501-2	Protection of metallic materials against corrosion – corrosion likelihood in soil – Part 2: Low alloyed and non-alloyed ferrous materials, Brussels.
DNV-RP-0416	Recommended Practice Corrosion protection for wind turbines, 2016
DNV-RP-C207	Statistical representation of soil data, DNV, 2019
DNV-RP-C212	Offshore soil mechanics and geotechnical engineering, DNV, 2019
DNV-SE-0190	Project certification of wind power plants, 2023
EN ISO 13823:2008	General principles on the design of structures for durability. Geneva: International Organization for Standardization, 2008.
EN ISO 9001:2015	Quality management systems — Requirements. International Organization for Standardization (ISO), 2015.
EN ISO 19901-2:2022	Petroleum and natural gas industries: specific requirements for offshore structures – Part 2: Seismic design procedures and criteria. International Organization for Standardization (ISO), 2022.
ISO 19901-8:2023	Oil and gas industries including lower carbon energy. Offshore structures Part 8: Marine soil investigations. International Organization for Standardization (ISO), 2014.
EN 1997-1:2004+A1:2013	Eurocode 7 – Geotechnical design – Part 1: General rules. European Committee for Standardisation (CEN), 2004.
EN 1997-2:2007	Eurocode 7 – Geotechnical design – Part 2: Ground investigation and testing. European Committee for Standardisation (CEN), 2007.
EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, Seismic actions, and rules for buildings. European Committee for Standardisation (CEN), 2004.

LIST OF ABBREVIATIONS

BSF	Below seafloor
CMP	Common Mid-Point
CPT	Cone Penetration Test
DRF	Document Response Form
DT	Dissipation Test
GDS	Geological Desktop Study
ETRS	European Terrestrial Reference System
f_s	sleeve friction
G_{max}	small strain shear modulus
GGM	Geological Ground Model
GIR	Geotechnical Interpretative Report
GIS	Geographic Information System
GM	Ground Model Contractor
GP	Geophysical Contractor
GT	Geotechnical Contractor
GW	Giga Watt
HKN	Hollandse Kust Noord
HKW	Hollandse Kust West
DDW	Doordewind
DDWWFS	Doordewind Wind Farm Site
DDWWFZ	Doordewind Wind Farm Zone
DDW IA	Doordewind Investigation Area
IA	Investigation Area
IGM	Integrated Ground Model
IJV	IJmuiden Ver
LDGM	Legacy Data Ground Model
LTAF	Laboratory Test Assignment Form
LTS	Laboratory Testing Strategy
LAT	Lowest Astronomical Tide
MAG	Magnetometer
MBES	Multibeam Echosounder
MW	Mega Watt
MIC	Microbially Induced Corrosion
NW	Nederwiek
PSD	Particle Size Distribution
PCPT	Piezo Cone Penetration Test
PGM	Preliminary Ground Model
P-S Logging	Compressional (P-wave) and Shear (S-wave) acoustic logging
PD	Project Documentation, as an overarching term for documents including for example, but not limited to: project execution

	plan, quality plan, health and safety plan, risk assessments and project schedules.
QA	Quality Assurance
QC	Quality Control
q_t	corrected cone tip resistance
SBP	Sub Bottom Profiler
SCPT	Seismic Cone Penetration Test
SSS	Side Scan Sonar
TCPT	Temperature Cone Penetration Test
TNW	Ten noorden van de Waddeneilanden
UHRS	Ultra-High Resolution Seismic
UTM	Universal Transverse Mercator
u_2	pore pressure
UXO	Unexploded Ordnance
VC	Vibrocore
WFZ	Wind Farm Zone
WPM	Work Progress Meeting

1 Introduction & Background

1.1 Scope of this Document

This document details the scope of the WORK as part of the CONTRACT that CONTRACTING AUTHORITY has awarded to the GEOLOGICAL GROUND MODEL (GGM), INTEGRATED GROUND MODEL (IGM) and GEOTECHNICAL INTERPRETETIVE REPORT (GIR) CONTRACTOR for carrying out the integration of all acquired geophysical and geotechnical data sets across the Doordewind Investigation Area (DDW IA). The DDW IA is located within the Doordewind Wind Farm Zone (DDWWFZ).

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 subsidy for construction and operation of (a) wind farm(s) will be organized under the Offshore Wind Energy Act. 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 soil conditions at the sites will be part of this information package.

Information on the soil conditions at the sites is provided through a sequence of commissions for geological, geophysical, geotechnical and morphodynamical studies. Information will be presented as factual data, integrated, and interpreted data (a Preliminary Ground Model) and will be comprehensively reported. In combination with further site and laboratory data from a geotechnical survey, Integrated Ground Models (IGM) and Geotechnical Interpretative Reports (GIR) will be created. The IGM will be of sufficient precision to allow participants to make initial plans and costings for foundation design and cable installation. Comprehensive reports will be created for the IGMs. In general, the CONTRACTING AUTHORITY is ultimately seeking an Integrated Ground Model that incorporates industry best practice

This assignment is concerned with the Geological Ground Model (GGM), Integrated Ground Model (IGM) and the Geotechnical Interpretative Report (GIR) components, contributing to the information package to be provided to participants in the tender(s).

The locations of the Dutch Offshore Windfarm Zones are summarized in Figure 1. The DDWWFZ is located north of the TNWWFZ (Figure 1). The DDW IA covers approximately 580 km^2. The total capacity of entire DDWWFZ is currently planned to be 4000 MW. After Borssele, Hollandse Kust (zuid, noord and west), Ten Noorden van de Waddeneilanden, IJmuiden Ver, and Nederwiek, the DDWWFZ is the eighth WFZ for which site investigations are executed and ground models are developed within the Netherlands Offshore Wind Energy Roadmap 2030.

This tender comprises the development of an Integrated Ground Model for DDW.

DDW IA

The DDW IA is expected to comprise two development sites, each with an anticipated installed capacity of 2 GW. The total DDWWFZ is expected to hold an installed capacity of 4 GW.

The current schedule indicates that the DDW permits will be tendered in 2027. The site investigation campaigns are scheduled for 2024-2025 (geophysical and geotechnical).

Water depths at DDWWFZ range between 35.4 and 43.6m (LAT). A Geological Desktop Study is available for the DDWWFZ to form the starting point of the Ground Model.

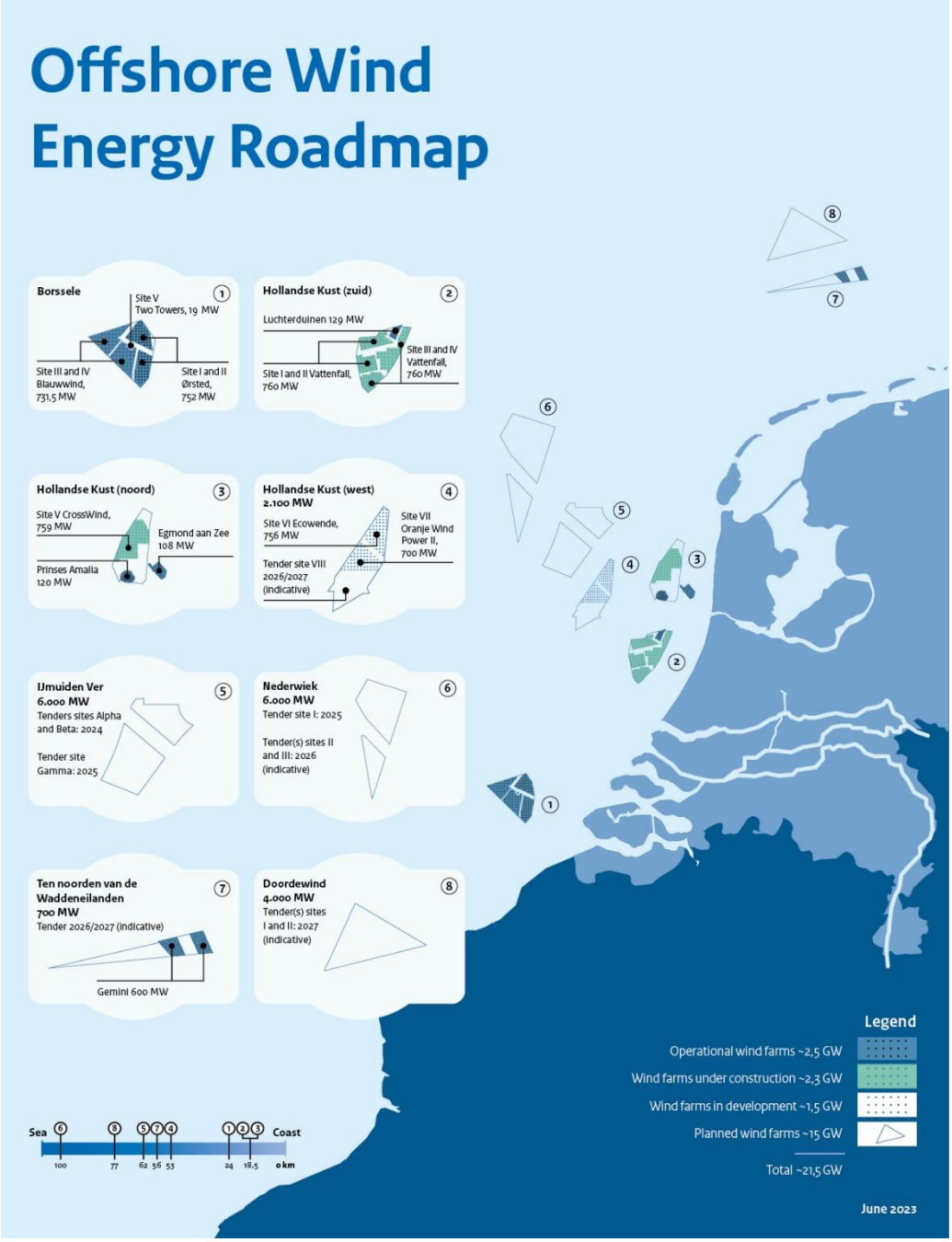

Figure 1: Dutch Offshore Wind Farm Zones overview for road map 2030+. The planned Doordewind WFZ is indicated by #8.

1.3 IGM Investigation Areas

The CONTRACTOR will be working from a set of geotechnical and geophysical data sets acquired for the DDW Investigation Area. Note that the investigation area defined for the Integrated Ground Model may differ from the investigation areas defined in the geophysical and geotechnical contracts. The investigation area referred to in this tender relate to the IGM scope unless explicitly stated otherwise.

Section 1.3.1 describes the DDW IA in more detail.

1.3.1 Doordewind Investigation Area

The Integrated Ground Model (IGM) IA is illustrated in Figure 2.

Geophysical data for the IA will be acquired in three (3) Lots and will be provided by CONTRACTING AUTHORITY. The geophysical data acquired will be seabed (magnetometry, side scan sonar, multibeam echosounder, and grab sampling) and the sub seabed (sub bottom profiler, 2D-UHRS, and 3D-UHRS) data.

The geophysical survey will provide a detailed dataset including bathymetry and backscatter survey (MBES), side-scan sonar (SSS), magnetometry (MAG), sub bottom profiler (SBP), seabed sediment sampling, and 2D-Ultra High Resolution Seismic (2D-UHRS) and/or 3D-Ultra High Resolution Seismic (3D-UHRS) for the entire IA; the southern DDW IA will be covered by 2D-UHRS data and the northern DDW IA will be covered by 3D-UHRS data. The maximum depth of interest for the Integrated Ground Model (IGM) is set to 100 m below seafloor for the Geophysical Survey.

The geophysical survey scope has been divided three (3) Lots over two (2) IAs:

For the southern DDW IA (~268km^2+222km tie-lines to the northern DDW IA and TNWWFZ):

- GP-Lot2:The 2D-UHRS, MBES, SSS, MAG and SBP geophysical survey will consist of 442 survey lines with a total length of approximately 5000 km. Main lines will be spaced at 65 m and east-west and cross lines will be spaced at 420 m and oriented north-south.

For the northern DDW IA (~310km^2):

- GP-Lot1: The MBES, SSS, MAG and SBP geophysical survey will consist of 151 survey lines with a total length of approximately 5300 km. Main lines will be spaced at 60 m and northwest-southeast and cross lines will be spaced at 420 m and oriented northeast-southwest.
- GP-Lot3: The 3D-UHRS geophysical survey will consist of 293 3D-sail-lines with a total sail-length of approximately 10500 km, which will result in a seismic volume with up to 2.5x2.5bin size with a multiplicity of 48 to 480. MBES will also be acquired on these sail-lines.

Between these three (3) Lots there will be overlapping data. GP-Lot1 and GP-Lot3 include MBES over the same northern DDW IA, GP-Lot2 will have tie-lines running into the northern DDW IA of GP-Lot1/3, and there will be an overlap on the edge between the southern DDW IA of GP-Lot2 and the northern DDW IA of GP-Lot1/3. For further information on the scope of the Geophysical Survey, see section 2.2.1.

The geotechnical investigation that is planned will cover the IGM Investigation Area but is planned to be *exclusive* of an approximately 500 m perimeter buffer zone along the edge of the IA, in which no wind turbines will be installed. For clarity, the geophysical IA and IGM IA include this buffer zone. Target depth of the geotechnical survey will be down to 60 m BSF. The depth of interest for the IGM will cover the seafloor to approximately 100 m depth.

The boundary coordinates of the IA for which the IGM will be developed, are provided in Table 1, section 1.3.1.

Note that a Geological Desktop Study, performed by a separate contractor, is available for the DDWWFZ (covering both the northern and southern DDW IA).

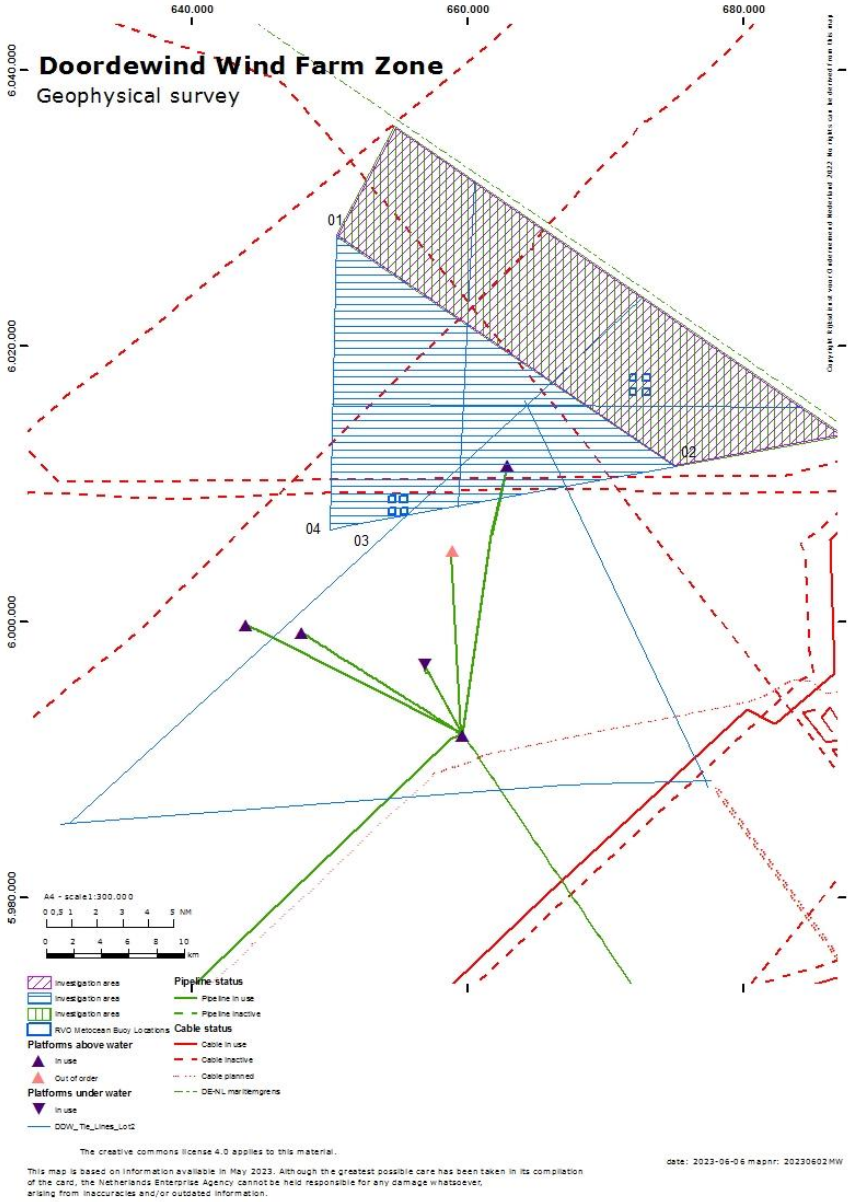

Figure 2: Geophysical Survey Investigation Area and Integrated Ground Model Investigation Area for Doordewind Wind Farm Zone

1.3.2 Coordinate reference system and datum, and project coordinates

The project coordinate reference system, horizontal datum and vertical datum are defined in Annex [5]: Starting Points and Assumptions.

- The vertical datum for this project is Lowest Astronomical Tide (LAT).
- The Integrated Ground Model shall be compiled with the vertical datum LAT.
- Table 1 summarize the boundary coordinates for DDW IA.

Table 1 Coordinates of the Doordewind IGM Investigation Area

Coordinate system : ETRS_1989_UTM_Zone_31N		
EPSG 25831		
IA-DDW-3DUHRS / Northern DDW IA (300 km²)		
Point No.	**Easting**	**Northing**
3D_IA_01	654758.4	6035783.5
3D_IA_02	687040.2	6013535.8
3D_IA_03	674988.3	6011323.1
3D_IA_04	650565.2	6027994.7
Southern DDW IA (268 km²)		
Point No.	**Easting**	**Northing**
2D_IA_01	650459.1	6028068.5
2D_IA_02	675126.0	6011229.1
2D_IA_03	651377.0	6006914.0
2D_IA_04	649971.0	6006646.0

1.4 Additional Information

In addition to the available results from the geophysical survey, the following studies will be provided by CONTRACTING AUTHORITY separately to the CONTRACTOR before start of the works[1]:

- Geological Desktop Study (available at https://offshorewind.rvo.nl/);
- Base map (MPK) containing information on location, attached to Annex [5]: Starting Points and Assumptions;
- Archaeological Desktop Study (available at https://offshorewind.rvo.nl/).

The knowledgebase for the DDWWFZ, as described above, is made available online by the CONTRACTING AUTHORITY and is expected to be considered during the WORK of the CONTRACTOR.

Further results from the DDWWFZ geophysical and geotechnical surveys will be made available by the CONTRACTING AUTHORITY as soon as possible and is expected to be considered during the WORK of the CONTRACTOR.

The results of the soil characterisation investigations carried out for Borssele, HKZ, HKW-I-VIII, HKN, TNW, IJV-Alpha & IJV-Beta, and the NW WFZs are available at http://offshorewind.rvo.nl/. It should be noted that the scope of work for the previous surveys instructed by the CONTRACTING AUTHORITY may deviate from the current scope of work. The results of the TNW soil characterisation investigations are of particular interest, since the TNWWFZ is located directly south of the DDWWFZ.

Further results of the ongoing investigations for the NW, HKW-VIII, IJV-Gamma Wind Farm Sites will be made available by the CONTRACTING AUTHORITY as soon as possible and is expected to be considered during the WORK of the CONTRACTOR.

Directly east of the DDWWFZ, German WFZs and are being (and have been) developed. The results of the soil characterisation investigations carried out for these neighbouring WFZs (e.g. N.7-2, N.6-6, N.6-7, N.6-8, N.9-1, N.9-2, N.9-3) are publicly available at https://pinta.bsh.de/.

2 Scope of Work

2.1 Introduction

The scope of work provides a detailed definition for the project milestones, input parameters, activities, and required deliverables for the CONTRACTOR. The definitions here are binding; further options and flexibilities are explicitly assigned.

Refer to Figure 3 for an overview of the workflow and deliverables as presented in this section.

Refer to Annex [4] for further details on key input and deliverable dates.

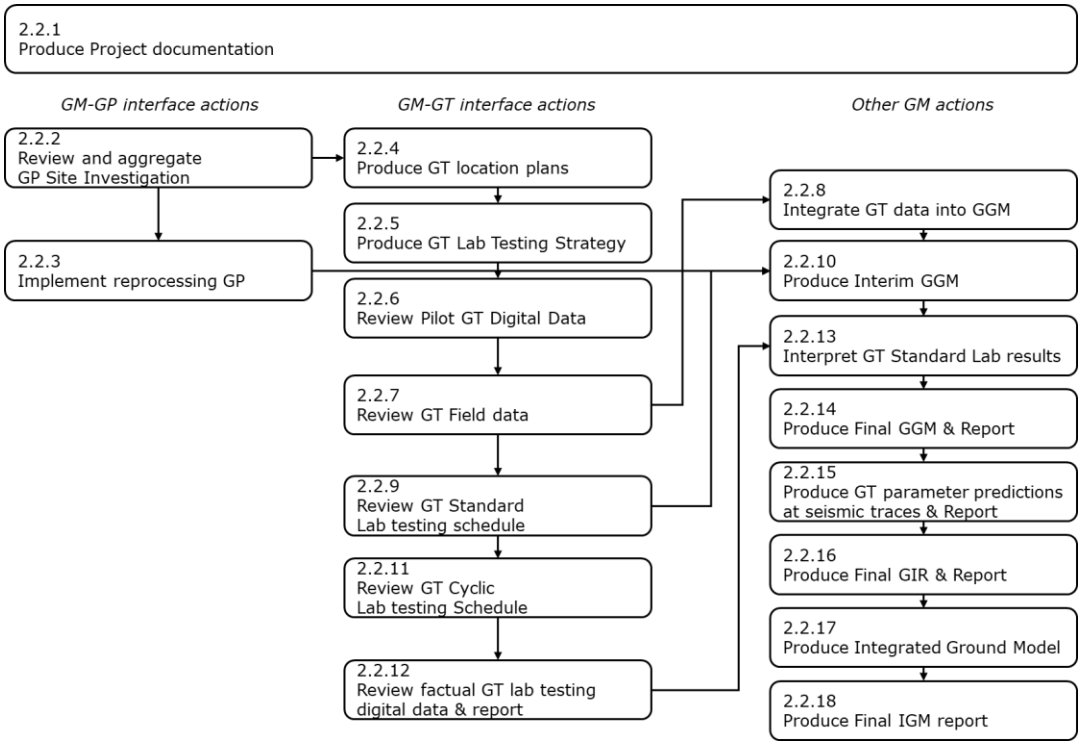

Figure 3: Overview of workflow and deliverables.

In this scope of work, attention should be paid to the following project specific items, which may differ from previous, similar, projects:

1. The DDW Soil Investigation project is a time driven project in which the GM, GT, and GP scopes are interrelated; the scopes depend on, and feed into, each other. To avoid delays and consequential knock-on effects between the scopes, it is crucial that the CONTRACTOR meets the defined timelines and provides constructive input to (e.g.) the GT contractor (see section 3).
2. Preliminary Seabed and Downhole Location Plans and Lab Test Strategies, based on the available Geological Desktop Study, should be submitted as part of the Tender documentation, and will be assessed and scored (see also sections 2.2.4, 2.2.5, and 2.5). After contract award the Location Plans can be updated, if needed, such that these plans can be used by the GT contractor for clearance.
3. The DDW GP scope has been divided in three (3) Lots. The GP data will become available to the CONTRACTOR in phases between September – December 2024. CONTRACTOR shall incorporate this information into the updates of the Seabed and Downhole Location Plans and Lab Test Strategies, which should be available for mid-January-February 2025 (see sections 2.2.2, 2.2.4, 2.2.5)
4. The DDW GT scope has been divided in two (2) Lots; Seabed (GT-Lot1) and Downhole (GT-Lot2):
    - The GT survey will start with the Seabed campaign (mid-January-February 2025) and the Downhole campaign will follow within 2-6

weeks. During this GT campaign period the CONTRACTOR will be responsible for continuous alignment and optimization of the Seabed and Downhole Location Plan. An interfacing & communication plan between the GT-Lot1 and GT-Lot2 contractors and CONTRACTOR should be submitted by CONTRACTOR as part of the Tender documentation and will be assessed and scored (see sections 2.2.4 and 2.5).
    - During the GT laboratory testing period the CONTRACTOR will be responsible for prioritization, efficiency, and flexibility within the laboratory testing strategy (Laboratory Testing Strategy). In the preliminary Laboratory Testing Strategy (to be submitted by CONTRACTOR as part of the Tender documentation) prioritization, efficiency, and flexibility should be described and will be scored (see sections 2.2.5, and 2.5).
5. Innovation in e.g. the fields of processing of seismic data (2.2.3), prediction of GT parameters (2.2.15) from seismic data, and/or other innovations in the GP or GT field. An innovation plan should be submitted as part of the Tender documentation and will be assessed and scored.

2.2 Workflow and deliverables – DDW IA

2.2.1 Produce Project Documentation

Milestone: Delivery of Project Documentation outlining CONTRACTOR's understanding of the WORK. This documentation will include method statements for quality, safety, health and wellbeing, environmental management, the identification of risks and mitigation measures within the scope of the PROJECT.

Upon award of the WORK, the CONTRACTOR is required to provide the Project Documentation in which the approach, methodologies, and schedule proposed to complete the WORK are set out and explained in sufficient detail. This Project Documentation represents the roadmap for the duration of the CONTRACT. Items listed as milestones in the following sub-sections are expected to be included in the Project Documentation. The Project Documentation is to be delivered as early as possible after project kick off (see Annex [4]).

Periodic updates to the Project Documentation by the CONTRACTOR are expected within the course of the project, reacting to events, changes, data inputs, and evaluations and are dependent upon the achievement of specific milestones. The Project Documentation should be maintained to be as current, accurate, detailed, and specific as is reasonably practicable.

The schedule for the delivery of Project Documentation updates will be determined by the CONTRACTING AUTHORITY during the project phase (exemplary milestones for updates are indicated below, up to two updates additional to the exemplary update points provided may be required at no additional cost).

Input:

- Input available for initial Project Documentation:
    - Relevant geophysical and geotechnical as well as IGM/GIR investigations of other Dutch wind farm zones (available at https://offshorewind.rvo.nl/) and neighbouring German wind farm zones (available at https://pinta.bsh.de/).
    - Geological Desktop Study for DDW including a Legacy Data Ground Model (LDGM) is available at the website https://offshorewind.rvo.nl/.
- Input for update of Project Documentation (expected Q4 2024):
    - Preliminary Ground Model:
        - For the southern DDW IA a complete PGM based on sub-seabed data (GP-Lot2: 2D-UHRS & SBP) and seabed data (GT-Lot2: MBES, SSS, MAG).
        - For the northern DDW IA the PGM is based on sub-seabed data (GP-Lot3: 3D-UHRS). Seabed data (GP-Lot1: MBES,

SSS, MAG, SBP) is available and can be integrated into the PGM by CONTRACTOR, if required.
    - Raw and processed sub-seabed data from geophysical survey (2D-UHRS, 3D-UHRS, SBP) as well as preliminary velocity model and seismic processing methods of the GP contractor.
    - Seabed assessment.
    - Seabed material classification:
        - For southern DDW IA the classification will be based on an integration of MBES, SSS, and seabed samples.
        - For the northern DDW IA the classification will be based on MBES and SSS. Seabed samples will be available and need to be integrated by CONTRACTOR.
- Input for update of Project Documentation along with milestone 2.2.7:
    - Activities of the CONTRACTOR performed up to this project state;
    - Incoming data and information of the geotechnical field campaign.
- Input for update of Project Documentation along with milestone 2.2.13:
    - All activities by the CONTRACTOR up to this stage and explicitly the full reprocessing procedure of the geophysical data to compile a Geological Ground Model (GGM) which meets the requirements for the IGM, as well as the review and (pre-)analysis of the geotechnical field and laboratory data.

Activities:

The CONTRACTOR is required to address the following items in the Project Documentation as well as Project Documentation updates:

- Detailed sections outlining the strategy in which the CONTRACTOR will meet the desired criteria for each project milestone deliverable outlined in the sections 2.2.2 - 2.2.19;
- The preparation of a time schedule of the CONTRACTOR for the execution of all project activities aligned with Annex [4];
- A Quality Plan in accordance with EN ISO 9001:2015, Incorporating elements included below in 'Quality Assurance interface' sections which describe minimum interaction with CONTRACTING AUTHORITY.

Quality Assurance interface:

Project documentation shall be reviewed and approved by the CONTRACTING AUTHORITY using a Document Response Form (DRF), review, and approval process.

Deliverables:

Deliverables are to be provided by the CONTRACTOR as early as possible upon award of the WORK:

- The Project Documentation is to be delivered as text with comprehensive descriptions of the above assigned issues, including:
    - Method statements;
    - Quality Assurance processes, metrics, and deliverables;
    - References for any identified critical methods;
    - Process flow charts;
    - GANTT charts as required;
    - Geological Ground Model Report Template;
    - Integrated Ground Model database format;
    - Geotechnical Interpretative Report Template.
- One meeting to discuss the contents of the Project Documentation with the CONTRACTING AUTHORITY and to initiate further workflow steps.

2.2.2 *Review and aggregation of Geophysical Site Investigation*

Milestone: Preliminary Ground Model (PGM) based on review and aggregation of geophysical site investigation results of the three (3) separate GP Lots and the Legacy Data Ground Model (LDGM).

The CONTRACTING AUTHORITY has appointed a Geological Desktop Study contractor to perform a Geological Desktop Study (GDS) and three (3) geophysical contractors to carry out the geophysical survey scope (GP contractor).

The GDS is available to the CONTRACTOR and includes reprocessing and interpretation of current and legacy seismic data and will include an initial ground model delivered as a report, seismic interpretation products, and a GIS data package.

The execution of the geophysical investigations at DDW is planned for completion in Q4 2024, therefore it is expected to be in progress at the initiation of this IGM scope.

The DDW geophysical survey scope has been divided in three (3) Lots. The GP data will become available in phases between September – early December 2024. The geophysical survey will include a comprehensive geophysical data acquisition campaign with associated seabed sampling at selected locations. The CONTRACTOR shall be invited to participate in workshops to be held with the GP contractor, where feasible. The CONTRACTING AUTHORITY, through its appointment of the GP contractor, will remain responsible for the execution of the geophysical site investigation.

Input:

The results of the geophysical campaign will include the following items on all lines:

- High resolution bathymetric and backscatter survey (MBES);
- Side scan sonar survey (SSS);
- Magnetometer survey (MAG);
- Shallow Penetration Sub-Bottom Profiler (SBP) survey;
- For the southern DDW IA: 2D Ultra High Resolution Seismic (UHRS) data at 65 m x 420m (main line spacing x cross line spacing);
- For the northern DDW IA: 3D Ultra High Resolution Seismic (UHRS) data up to 2.5m x 2.5m (bin size);
- 56 seabed (grab) sampling locations for ground truthing purposes
- A Preliminary Ground Model (PGM) including:
    - estimated base depth of mobile sediments;
    - estimated depth of a set of principal interfaces of geological formations or other horizons of interest;
    - preliminary velocity field from seismic data processing;
    - locations of structural features (faulting, shallow gas, peat, channel infills, sub-glacial and glaciotectonic structures);
    - correlation to the other geophysical and geotechnical interpretations available in this region;
    - a comprehensive report with geohazard risk assessment;
    - For the southern DDW IA a complete PGM based on sub-seabed data (2D-UHRS & SBP) and seabed data and is available.
    - For the northern DDW IA the PGM is based on sub-seabed data (only 3D-UHRS). Seabed data is available and, if required, can be integrated into the PGM by CONTRACTOR.
- Extent of interpreted sub-seabed geological units, geohazards, and seabed classification.
- Seabed material classification:
    - For southern DDW IA the seabed material classification is based on an integration of MBES, SSS, and seabed samples.
    - For the northern DDW IA the classification is based on MBES and SSS. Seabed samples are available and need to be integrated by CONTRACTOR to come to a seabed material classification.

Besides the interpreted data package of the PGM and LDGM, raw datasets and intermediate data will be made available to evaluate, reprocess, reinterpret, and rework.

Activities:

The CONTRACTOR is expected to perform following tasks:

For the purpose of familiarization with, and preparation of, the geophysical data as input for the GT Location Plan, Laboratory Testing Strategy, and IGM:

- Review of all data (raw, intermediate, and interpreted) and statistics from the geophysical site investigation;
- Review of all site investigation documentations and reports;
- Review of the PGM and LDGM project contents and the accompanying report provided by the GP contractor;
- Aggregation of the information from the three (3) GP Lots into one PGM.

For the purpose of preparation for (re)processing (and accompanying update to Project Documentation):

- Definition and presentation of requirements, potential methods, and timings for reprocessing of the 2D-UHRS, 3D-UHRS, and SBP data to support the IGM, and prediction of GT parameters at seismic trace locations(see 2.2.15). It is anticipated that the following aspects of seismic data processing require potential (re)work:
    - General imaging, demultiple and signal quality
        - Improvement in image fidelity
    - Stacking Velocity Analysis
        - Improvement in image fidelity
        - Imaging velocity as a ground model asset
    - Amplitude and spectral consistency
        - Ensure dataset is compatible with anticipated prediction of GT parameters at seismic trace locations (see 2.2.15), adaptation of proposed methods to suit input data.
    - Optional: Innovative reprocessing to improve resolution/geohazard identification (see 2.2.3).

Quality Assurance Interface:

- Interactive dialogue with CONTRACTING AUTHORITY;
- Technical Note review and Document Response Form (DRF). See next item; Deliverables.

Deliverables:

The CONTRACTOR is expected to deliver the following services:

- Technical Note documenting:
    - Evaluation of geophysical and (where available) geotechnical data quality, uncertainty (structural and parametrical), geological complexity, prominent geological features (*e.g.* channel infills, glaciotectonic features, peat horizons) and degree of correlation to nearby wind farm investigations.
    - Evaluation of data suitability for the processes anticipated to be applied in development of the IGM datasets, and updates to method statements for these processes where required.
    - Integrated PGM of three (3) GP Lots.
- Technical Note documenting:
    - Description of geophysical data reprocessing operations to be implemented, including a time schedule.
    - Optional: Description of innovative geophysical data processing to improve resolution/geohazard identification, including a time schedule and cost estimate.
- Beside these Technical Notes, the deliverables will include a GIS project and a single seismic workstation project(Kingdom or equivalent approved by CONTRACTING AUTHORITY) that contains the integrated PGM.
- One meeting with the CONTRACTING AUTHORITY to discuss results, Project Documentation updates and deliverables.

2.2.3 *Implement (Re)processing of Geophysical Sub-Seabed data*

Milestone: Refinement of geophysical datasets to optimise data fidelity in preparation for detailed interpretation and prediction of GT parameters at seismic trace locations. Note that the use of innovative processing methodologies is encouraged and scored in this Tender.

Sub-seabed geophysical data (2D-UHRS, 3D-UHRS) are anticipated to require (re-)processing per the outcome of section 2.2.1 and 2.2.2. Based on the quality of the dataset and the proposed reprocessing methodology and optional innovative processing outlined in the Project Documentation, CONTRACTING AUTHORITY will assess the proposed value and extent of the reprocessing efforts.

Components of this workflow which are independent of the IGM may be initiated as soon as necessary. These may include, but are not limited to, static shifts, denoise, wavelet shaping, demultiple. Interpretative reprocessing, in particular velocity modelling and processes which are dependent on seismic stacking velocity analysis (migration, stack and post-stack processing) are included in section 2.2.10.

Inputs:

- 2D-UHRS, 3D-UHRS, SBP, see 2.2.2;
- PGM and LDGM, see 2.2.2.

Activities:

- Testing and evaluation of (interpretation-independent) processing parameters applied to sub-seabed geophysical data within the DDW IA.
- Velocity analysis (interpretation-dependent) based on the sub-seabed geophysical data within the DDW IA, resulting in a velocity model.
- Optional: Implementation of innovative processing to improve resolution/geohazard identification. E.g. (but not limited to):
    - Resolution improvement (particularly on 3D-UHRS);
    - Diffraction imaging for boulder detection;
    - Other innovative processing that CONTRACTOR would like to implement to e.g. improve resolution / geohazard identification.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY;
- Technical note on:
    - Parameter testing and evaluation notes and displays for all significant (re)processing operations;
    - Velocity analysis QC *e.g.* residual moveout and/or stack power displays;
    - Processing workflow, evaluation, and results.
- Technical note on:
    - Optional: Innovative processing workflow, evaluation, and results.

Deliverables:

- Reprocessed pre-stack seismic data (2D-UHRS, 3D-UHRS) as SEGY with fully populated header for input to velocity analysis and QC as required;
- Reprocessed stacked seismic data (2D-UHRS, 3D-UHRS) as SEGY with fully populated header;
- Reprocessed Interval velocity vs time as SEGY with fully populated header;
- Reprocessed Stacking velocity file (ASCII);
- Optional: Pre-stack results of innovative processing of data (2D-UHRS, 3D-UHRS) as SEGY with fully populated header (if applicable);
- Optional: stacked results of innovative processing of data (2D-UHRS, 3D-UHRS) as SEGY with fully populated header (if applicable));
- A weekly processing status update with respect to the:
    - (Re)processing plan, detailing the testing, evaluation, and processing workflow of the ongoing reprocessing of the 2D-UHRS and 3D-UHRS data, including the QA/QC processes used during the reprocessing.
    - Optional: Innovative processing plan, detailing the testing, evaluation, and processing workflow of the ongoing innovative

processing of the 2D-UHRS and 3D-UHRS data, including the QA/QC processes used during the reprocessing.
- Reprocessing report including a presentation of the workflows, parameter testing, velocity analysis, and results.
- Optional: Innovative processing report including a presentation of the innovative methodology, workflows, parameter testing, and results.

2.2.4 Produce Geotechnical Location Plans

Milestone: Planning of geotechnical site investigation.

The CONTRACTOR is required to prepare a site investigation location plan for the GT contractor(s) for the GT-Lot 1 (seabed) and GT-Lot 2 (downhole) investigations.

The CONTRACTING AUTHORITY may appoint one or two GT contractor(s) for the execution of the site investigations, laboratory testing, and associated factual reporting. The site investigation comprises two Lots:

- GT-Lot 1: seabed scope, comprising seabed *in-situ* PCPTs, SCPTs, vibrocores, thermal testing, dissipation testing, and an initial offshore laboratory testing programme.
- GT-Lot 2: downhole scope, comprising of boreholes with *in-situ* PCPT testing (including SCPT, P-S, and borehole logging), sampling, or a combination of both. Microbially Induced Corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 25 tests) will be also part of the geotechnical survey.

For the seabed investigations (GT-Lot 1), CONTRACTOR is requested to specify the location plan. It is planned that for GT-Lot 1 up to 96 seabed PCPT measurements, 32 seismic CPT measurements, 32 thermal conductivity measurements (TCPT or TVC), and 64 vibrocores (VC) will be carried out. Dissipation tests (DT) will be carried out on selected intervals during the seabed PCPT investigations. The testing intervals and quantity of DT will be decided during field execution (anticipated to be 34 hours).

For the downhole investigations (GT-Lot 2), CONTRACTOR is requested to specify the borehole plan building upon the seabed investigations (GT-Lot1) plan, propose downhole in-situ testing and sampling intervals, specify age dating intervals, and nominate boreholes for geophysical logging. It is planned that up to 96 sampling and testing boreholes will be drilled. The sampling and testing strategy of the boreholes is yet to be defined and may be a combination of *in-situ* PCPTs *in-situ* SCPTs and sampling techniques down to maximum depths of approximately 40-60 m beneath seafloor. It is a requirement that a number of boreholes (~9) will be logged using downhole geophysical logging techniques.

The (maximum) quantities within the GT scope, as indicated above, have been defined by the CONTRACTING AUTHORITY. Nevertheless, the CONTRACTOR is invited to reduce these quantities, for efficiency reasons, if this does not harm the quality of the IGM products.

The CONTRACTING AUTHORITY is responsible for the final geotechnical site investigation plans and communicating these to the GT contractor.

Input:

- Content of activities of 2.2.1: i.e. Project Documentation;
- Content of activities of 2.2.2: e.g. geophysical data and PGM;
- Location information (track plots) for SBP, 2D-UHRS, 3D-UHRS, and MAG, SSS, MBES;
- Information of geotechnical site investigation of nearby WFZ, especially TNWWFZ, see section 1.4;
- Execution guidance as provided by the CONTRACTING AUTHORITIY and broadly outlined above.

For details on GT scope see European Tender Document with reference GT-Lot 1 WOZ2240143 and GT-Lot 2 WOZ2240144.*Activities*:

The CONTRACTOR shall:

- Before the GT-Lot 1 survey: Prepare a location plan for the seabed geotechnical investigation as part of a detailed program for the GT-Lot 1 execution targeting relevant geological layers, seismic facies, and/or important horizons, mapped channels, etc.
- Before the GT-Lot 2 survey: Prepare a proposal location plan for the downhole geotechnical investigation as part of a detailed program for the GT-Lot 2 execution of boreholes (downhole PCPT, SCPT, pore pressure dissipation tests, sampling intervals / sampling and downhole geophysical logging) targeting relevant geological layers, seismic facies and/or important horizons, mapped channels, etc.
- Supply the definition of sampling locations and depths for Geological Age Dating (Geochronological analysis) and Microbially Induced Corrosion (MIC) testing.
- Include consideration for the requirements (if any) for hazard clearance to be provided by the GT contractor via the CONTRACTING AUTHORITY, including but not limited to seabed obstructions, sub seabed obstructions, and UXO.
- Prepare *prognosis sheets* for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below. The prognosis sheets shall contain, but not limited to:
    - A high-resolution plot of the available seismic data and interpretation with annotated soil units and expected conditions at the location with a horizontal distance of 250 m either side of the location, and a depth of 100 m below the seabed.
    - Seabed conditions, obstructions, objects, bathymetry, and slope at a suitable distance.
    - A table of expected geological formations and/or soil types, with expected depths with appropriate uncertainty bounds

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- The CONTRACTING AUTHORITY is responsible for review and approval of the documents forming the Geotechnical Investigation Plan through document review process.

Deliverables:

The CONTRACTOR shall provide the following:

- A Technical Note with recommendations for the seabed and borehole site investigation location plan, including in-situ testing, sampling, and logging.
- Prognosis sheets for each geotechnical investigation location illustrating expected conditions (geological and hazard) at seabed and below.
- Tabular (.csv) and GIS format listing of the proposed locations including comments.
- Workshops and meetings as reasonably required by the CONTRACTING AUTHORITY.

2.2.5 Produce Laboratory Testing Strategy

Milestone: Definition of Laboratory Testing Strategy for GT-Lot-1 and GT-Lot 2.

CONTRACTING AUTHORITY will appoint the execution of the laboratory testing to one or two geotechnical (GT) contractor(s). The laboratory testing will include standard and cyclic soil testing on soils recovered during seabed and downhole investigation campaign (referred to as GT-Lot 1 and GT-Lot 2 in the GT Contract, and hereafter in this document).

An important objective of the GIR and IGM is to provide developers of offshore wind farms with a wide range of geotechnical parameters that enable cost-efficient FEED design without restricting the developers to certain design philosophies. The CONTRACTOR is required to develop a geotechnical Laboratory Testing Strategy for the GT-Lot 1 & 2 to obtain relevant geotechnical, chemical, and thermal parameters

for foundation design. The CONTRACTING AUTHORITY requests from the GT contractor that both undrained and drained cyclic strength testing is carried out.

The CONTRACTOR shall provide a comprehensive Laboratory Testing Strategy that outlines the type of tests and test frequency for various soil types. The Laboratory Testing Strategy should clearly outline the testing requirements such that it can be used by the GT contractor to enable the scheduling of laboratory tests programs during both offshore and onshore phases of work. The CONTRACTOR shall use the laboratory testing quantities from the GT contractor (to be provided upon award) and define a workflow that enables the GT contractor to establish a geographical coverage and depth interval that is in line with the requirements of the CONTRACTOR.

The Laboratory Testing Strategy document should provide clear guidance to the GT contractor when preparing the laboratory test schedule sheets for the standard and cyclic testing (section 2.2.9 and 2.2.11). Test specifications shall be provided by the CONTRACTOR. The CONTRACTOR will clearly state the appropriate standards for all proposed tests and provide a list of minimum deliverables per test in the Laboratory Testing Strategy document. The results of all GT laboratory results are to be interpreted by the CONTRACTOR (sections 2.2.13 and 2.2.16).

As the understanding of the site develops, the requirements of the Laboratory Testing Strategy may change and it is expected that any required changes to the Laboratory Testing Strategy will be updated by the CONTRACTOR.

The Laboratory Testing Strategy shall include a proposal for a practical workflow for interaction between GT contractor, CONTRACTOR, and CONTRACTING AUTHORITY in the development and timely delivery of approved test conditions parameters to the onshore laboratory.

The Laboratory Testing Strategy document should also provide clear guidance on the phasing of the tests. The phasing should allow the project to be executed in a time efficient way. E.g. the classification & age dating tests required for the GGM should be scheduled first, next the Standard tests required for the IGM, and in the end the cyclic laboratory tests should be scheduled.

More details on the geotechnical parameters and the requirements of the requested GIR are given in sections 2.2.11, 2.2.12, 2.2.13 and 2.2.16.

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the Laboratory Testing Strategy.

Input:

- Content of activities of 2.2.1: i.e. Project Documentation;
- Content of activities of 2.2.2: e.g. GP data and PGM;
- Content of activities of 2.2.4: i.e. GT location plan;
- Information of geotechnical site investigation of nearby WFZs, e.g. TNWWFZ, see section 1.4.
- For details on GT scope see European Tender Document with reference GT-Lot 1 WOZ2240143 and GT-Lot 2 WOZ2240144.

Activities:

- Before the GT-Lot 1 & 2 survey: Definition of a geotechnical Laboratory Testing Strategy, clearly outlining the type, reference method, quantity, testing frequency, and intervals of laboratory tests with respect to geological layers, seismic facies, or important horizons, mapped channels, etc. as required by the CONTRACTOR to optimize the IGM and GIR. Offshore and onshore laboratory work is to be included.
- Definition of all required and appropriate test conditions, including, but not limited to, consolidation pressures for estimation of in-situ conditions specific to the site, sample conditioning requirements, shear rates, etc., to CONTRACTING AUTHORITY and the GT contractor within a timescale acceptable to CONTRACTING AUTHORITY.
- Definition of a batching strategy.
- Prioritization of the (classification) testing required for the GGM, IGM, GIR.

- Identification and notification of any need for other priority testing (test dependencies) required for the execution of the laboratory tests in the programme.
- Proposal for appropriate methodology for assessing sample quality for specific undisturbed tests.

Quality Assurance interface:

The CONTRACTING AUTHORITY is responsible for reviewing and approving of the Laboratory Testing Strategy for the GT-Lot 1 & 2 soil investigations through a document review process.

Deliverables:

A Technical Note including, but not limited to:

- The methodology statements, clear tables, workflow, process map, specifying the types of laboratory tests to be undertaken on GT-Lot 1 (seabed) samples, including identification of priority testing.
- The methodology statements, clear tables, workflow, process map, specifying the types of laboratory tests to be undertaken on the GT-Lot 2 (downhole) samples, including identification of priority testing.
- A method statement including forward guidance for selecting samples for samples obtained during the GT-Lot 2 (downhole) investigation for geotechnical purposes, Geological Age Dating testing/analysis, and microbially induced corrosion (MIC) testing/analysis.
- Method statement and description of processes for the cyclic testing program. This may include anticipation of the batching requirements of course grained samples, strength reference testing and cyclic/dynamic strength testing. It must include a clear stipulation of the test conditions regarding the stress state and drainage conditions.
- Method statement to preferred data formats for digital data deliveries of the GT contractor. It is preferable that these formats anticipate and/or align with those proposed in 2.2.6.
- Interaction diagrams that will be produced to present the interpretation of the cyclic/dynamic laboratory test results.

Note that based on the CONTRACTOR's Laboratory Testing Strategy (including a sample batching strategy) the GT contractor will propose laboratory test schedules (including a sample batching schedule), for each geotechnical location. The laboratory test schedule review and subsequent specification of test conditions and specific requirements is the responsibility of the CONTRACTOR and is further specified in sections 2.2.9 and 2.2.11 for the standard downhole testing programme and cyclic testing program respectively.

Additional notes on batching of samples for coarse-grained material

The laboratory scope for laboratory testing Lot 2 on sand has been optimized with the aim to obtain a more efficient and less time-consuming scope in view of a fit-for-project and time-driven campaign. With this optimization, the need for combining reconstituted sand samples 'batching' is expected to be reduced.

Key assumption for batching is that the sand batches are representative for the in-situ site conditions in a specific layer. Although this assumption can be relatively crude, e.g. due to loss of the in-situ structure of the sand matrix, the batching strategy outlined here is aimed to maximize representativity for each tested sample

Batching between multiple sampler tubes is only allowed in cases where insufficient sample material from one sampler tube is recovered. In any case it is advised to keep samples from one sampler tube together, in either a single disturbed bag sample or together in a single sample transport box.

The GT contractor shall provide required amounts of material for all tests (as included in GT-Annex 4(b)). To assist with the batching of samples the following information shall be recorded in addition to standard sample descriptions:

- For cohesive retained samples (both full retained in shelby and shorter waxed samples) the lengths and diameter shall be recorded;
- For non-cohesive material that is placed in bags the mass per bag shall be recorded

A maximum of six batches for cyclic testing is considered.

For the purpose of the tender/ budget allocation it is assumed that the GT contractor will carry out the batching, either offshore or in the laboratory onshore. With the batching operation included within the indicated price.

When samples are combined, the following conditions apply:

- Only samples with similar grain size distribution curves are allowed to be combined, by evidence of PSD curves for each sample (either performed on the vessel or in onshore lab) and from observations by the OCR or qualified engineering geologist.
- The preliminary assigning of samples to batches shall be carried out offshore by the GT contractor, samples should be retained in separate bags/tubes until below bullet point has been completed.
- Final batching shall be carried out onshore in the laboratory after approval by GM contractor on the basis of received PSDs for each sample, borehole log with description of samples by engineering geologist or qualified laboratory technician, LTAF and CPTU data in same or adjacent borehole.
- Only samples from the same geological (sub)unit are allowed to be combined;

Batching samples from multiple borehole's may be required, in specific cases of highly varying soil conditions. This is only allowed after CONTRACTING AUTHORITY's approval.

When during the laboratory testing program, re-batching appears to be necessary, this will be in the scope of the Contractor to propose the way forward for re-batching, discuss and agree with the CONTRACTING AUTHORITY and/or GM contractor on the re-batching and execute the re-batching.

2.2.6 *Review of Pilot Digital Data Deliverables*

Milestone: Pilot Digital Data Deliverables as provided by GT contractor.

The GT contractor will be requested to provide a pilot data base which will include an example output file of each of the digital deliverables. This dataset may include, but is not limited to:

- AGS 4.0 (or higher) format
- ASCII
- Excel or csv
- Log ASCII Standard (LAS) files

The objective of this deliverable prior to delivery of the factual test results is to agree on the format of the data output as to be applied in a consistent manner throughout the project. This also applies to any interim deliveries of laboratory data prior to provision of the final report.

Input:

- Laboratory test output files, data base files and output data from *in-situ* test results.

Activities:

- Review and agree on digital delivery formats.
- Review and agree on digital platform.

Quality Assurance interface:

- CONTRACTOR and CONTRACTING AUTHORITY shall use the pilot database to set up their workflows, to confirm compatibility.
- CONTRACTING AUTHORITY shall review and respond to pilot data delivery using a DRF approach.

Deliverables:

- Example data files of every data format to be used in final deliverables.
- Written confirmation of acceptance of format.

2.2.7 Review of seabed and downhole geotechnical data (ongoing throughout GT field campaigns)

Milestone: Immediate and continuous review of Geotechnical field work results from field investigation, provide feedback and modifications if required (ongoing).

The review of the ongoing field data acquisition by the GT contractor and documentation shall start immediately after commencement of field work. The contents of each Lot are:

- GT-Lot 1: seabed scope, comprising seabed *in-situ* PCPTs, shallow sampling techniques, thermal testing, dissipation testing and an initial offshore laboratory testing programme.
- GT-Lot 2: downhole scope, comprising of boreholes with *in-situ* PCPT testing (including SCPT, P-S, and borehole logging), sampling, or a combination of both and an initial offshore laboratory testing programme. Microbially Induced Corrosion (MIC) and Geological Age Dating tests (anticipated in the order of 25 samples) will be also part of the geotechnical survey.

The CONTRACTOR is expected to be available to provide input to potential modifications to the prognosis sheets (during/after GT-Lot-1 investigations) within the context of providing support to the ongoing site investigation in dialogue with CONTRACTING AUTHORITY.

Input:

- Deliverables as assigned in 2.2.4 and 2.2.6 approved execution plan of the geotechnical site investigation as decided by the CONTRACTING AUTHORITY.
- All immediate deliverable digital data from the ongoing geotechnical site investigation.
- Vessel and equipment information, offshore progress information.

Activities:

The review shall include following aspects explicitly:

- Review and familiarisation of the Scope of Work for the GT investigations.
- Confirmation that the requirements for the proposed methods for IGM and GIR creation can be fulfilled.
- Proposal for any actions or modifications to be made if any concerns exist.
- Accompanying assessment of incoming field data in combination with the PGM and LDGM (see section 2.2.2).

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities.
- Interactive dialogue with the GT contractor during activities.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Documentation of the seabed and borehole data review process.
- Weekly online meeting or call with CONTRACTING AUTHORITY and GT contractor to clarify progress and identify needed actions with senior personnel.

2.2.8 Integrate seabed and downhole geotechnical data into the Geological Ground Model

Milestone: Geological Ground Model resulting from integration of the geotechnical data and the sub-seabed geophysical data.

Note that a revision of the GGM may be required after the interpretation of the GT Laboratory Testing results (2.2.9). The integration of the geotechnical data and the geophysical data shall be used as a key step to define the Geological Ground Model for which requirements are outlined in section 2.2.10 and 2.2.14.

It is expected that of the order of eighteen (18) geotechnical/geological units may be required to characterise the DDW IA (indicative of the number of units in use at the adjacent wind farm sites), though this is not to be considered a fixed number. Not all units are expected to be present site-wide.

Input:

All results, plans and information from sections 2.2.1 through to 2.2.7.

Activities:

The CONTRACTOR is expected to perform following work:

- Preparation of geotechnical field data and integration into a single seismic workstation project (Kingdom or equivalent approved by CONTRACTING AUTHORITY).
- Initial correlation of geotechnical and geophysical data to deliver time-depth pairs representing each geotechnically relevant layer interface.
- Structural interpretation of all relevant additional geological units and refinement of the interpretation in the PGM.
- Detect and interpret (proximal to the location) as appropriate: sub-layers, and design-sensitive horizons (peat, channel infills, glaciotectonic features) as well as any potential geohazards.
- Assessment of the potential benefit and methods of further reprocessing of the sub-seabed geophysical data.

Quality Assurance interface:

- Prepare cross-sections and other drawings showing the integration of geophysical reflectors and geotechnical stratification as ongoing deliveries following delivery of geotechnical results.
- Bi-weekly update with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Conditioned geotechnical data as LAS files or similar for input to Seismic workstation project (Kingdom or equivalent approved by CONTRACTING AUTHORITY).
- Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to initial unitisation of the soil/rock columns.
- Update of the unitisation with any relevant findings of the ongoing laboratory testing.
- Time-depth pairs, inferred interval velocity and seismic imaging velocity profile at each geotechnical investigation location.
- Technical note to accompany the correlation drawings and velocity data describing the unitisation and observations therein.

2.2.9 Review laboratory test schedules and specification of test parameters

Milestone: Review of Standard laboratory test schedules after fieldwork completion of each geotechnical test location and specification of the test parameters/ conditions.

Upon completion of a geotechnical sampling location the laboratory test schedule will be prepared by the GT contractor based on CONTRACTOR's Laboratory Testing Strategy and location prognosis sheets. This laboratory test schedule will be reviewed by the CONTRACTOR on a timescale that does not cause delay to the laboratory work. Once the laboratory test schedule is reviewed and approved by the CONTRACTING AUTHORITY, the GT contractor can commence testing activities. For some tests, additional information (test conditions) for each sample interval will be required. This information (*e.g.* consolidation pressures, rates of shearing, density) will be requested from the CONTRACTOR ensuring that the appropriate test conditions will be specified in the context of the GIR and IGM.

Input:

- All results, plans and information from sections 2.2.4 through to 2.2.7.
- Provisional priority laboratory test schedules from the GT contractor.
- Provisional standard laboratory test schedules from the GT contractor.
- Test conditions sheet template.

Activities:

Accompanying to the ongoing review activities as described in section 2.2.7, the standard laboratory test progress shall be accompanied and reviewed by the CONTRACTOR, and advised, if needed. The activities of the CONTRACTOR shall include following aspects explicitly:

- Reviewing the provisional laboratory test schedule prepared by the GT contractor for priority standard testing which could serve as input for the specification of *e.g.* sample densities for reconstructed samples or the building of sample batches (*e.g.* minimum / maximum density, and particle size analysis).
- Reviewing the provisional laboratory test schedule prepared by the GT contractor for the standard testing (*e.g.* classification, strength, consolidation, thermal conductivity, and chemical tests).
- Assigning test specifications; after definition and approval of the laboratory test schedule the GT contractor will provide for each test an overview of required test details. Such details may include, but not limited to, test consolidation pressures, shear rates and definition of failure criteria. These test conditions shall be provided by the CONTRACTOR.
- Given the time constraint on this project, a constructive and pragmatic approach is expected of the CONTRACTOR when reviewing and discussing schedules, results, and other input.

Quality Assurance interface:

- Interactive, constructive, and pragmatic dialogue with CONTRACTING AUTHORITY during activities.
- Provision of justifications and/or data used to define batching, parameters, and specialist testing.
- Approval of output by CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Review / confirmation of the standard Laboratory Test Assignment Form (LTAF) sheets per geotechnical location within 48hrs of receipt (except weekends).
- Completion of specification of test parameters (Word or Excel sheets) within no more than 3 days of request.
- Contact as required (online meeting, email, call), typically weekly, with GT contractor and CONTRACTING AUTHORITY to clarify progress and identify and commit to actions. Can be combined with meetings of 2.2.7, if this is beneficial for all parties (CONTRACTOR, GT contractor, and CONTRACTING AUTHORITY).

2.2.10 Produce Interim Geological Ground Model

Milestone: Interim version of the Geological Ground Model as the structural basis for the IGM.

It is expected that of the order of eighteen (18) geotechnical/geological units may be required to characterise the DDW IA (indicative of the number of units in use at the adjacent wind farm sites), though this is not to be considered a fixed number. Not all units are expected to be present site-wide.

Input:

The work performed in 2.2.8 using 2.2.1 through to 2.2.8.

Activities:

The CONTRACTOR is expected to perform following activities:

- Site-wide propagation of local interpretation updates performed in 2.2.8 to all seismic lines / seismic volume of all types within their depth of applicability.
- Site-wide interpretation on all seismic data types of all identified geohazard and intra-soil unit interfaces.
- Correlation of further (litho-)stratigraphical sequences to other nearby WFZ.
- Correlation (or revision) and integration of Geological Age Dating results to confirm the geochronological order, if already available.
- Completion of site-wide update of stacking and interval velocity analyses incorporating updates indicated by ground investigation and unitisation in section 2.2.8
- Test, parameterise, and apply further pre-stack reprocessing as appropriate.
- Test, parameterise, and apply re-migration / stack and post-stack processing as appropriate.
- Specification, parameterisation, and production of seismic attribute set for input to GT parameter prediction methods.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during activities
- Velocity model QA as *e.g.* semblance, residual moveout, stack power displays to be agreed with CONTRACTING AUTHORITY at no greater than 250 m intervals, at significant soil unit boundaries throughout depth range.
- Structural interpretation QA as *e.g.* selected profiles with geotechnical locations.
- Parameter test panels and notes for all significant data processing operations to be agreed with CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR shall provide the following:

- Horizons and grids representing all interpreted unit boundaries and geohazards.
- Seismic Processing Update Technical Note including description of testing, decisions, parameters, and final processing sequence applied.
- Description of derived Seismic Attributes and the data processing used to create them as a Technical Note;
- Additional Seismic Attribute datasets as SEGY with fully populated header, representing all input datasets used in the prediction of GT parameters (section 2.2.15);
- Interval velocity as SEGY trace data at every seismic trace location and Stacking Velocities as ASCII data in ESSOV2 format at intervals to be defined.
- At least one workshop with the CONTRACTING AUTHORITY presenting the Interim version of the Geological Ground Model.
- Geological description(s) provided as a technical note or short note.

2.2.11 Review Cyclic laboratory test schedule and specification of test parameters

Milestone: Review of Cyclic Laboratory test schedules and specification of test parameters/conditions.

Following the standard laboratory phase, relevant geotechnical data is available to specify cyclic tests. The CONTRACTOR may choose to establish large batches from samples that display similar characteristics and geological context. The CONTRACTOR is to outline this in the Laboratory Test Strategy document discussed in section 2.2.5. After establishing the batches, a second phase of laboratory testing will commence with tests as defined in the Laboratory Test Strategy.

The GT contractor shall provide the cyclic laboratory test schedule based on CONTRACTOR's Laboratory Testing Strategy. This laboratory test schedule will be reviewed by the CONTRACTOR and will be reviewed and approved by the CONTRACTING AUTHORITY. Following the approval, the CONTRACTOR is required to

fill out the test conditions sheets provided by the GT contractor ensuring that the appropriate test conditions will be specified by the CONTRACTOR in the context of the GIR and IGM. Following this, the GT contractor can commence testing activities. The cyclic laboratory test programme shall include cyclic/dynamic tests accompanied by associated static and classification tests and may also include dynamic testing.

Input:

- All results, plans and information from sections 2.2.4 through to 2.2.7 and 2.2.9.
- Provisional cyclic laboratory test schedules from the GT contractor.
- Test conditions sheet template.

Activities:

- Identification of suitable samples for batching (based on available classification test results), as has been required for the cyclic laboratory testing programme on previous CONTRACTING AUTHORITY projects, including the likely need for batching of cohesionless samples from the same soil unit. The data required to select the individual cohesionless samples for batching should be clearly stated. For more information see note on batching in section 2.2.5.
- Review of the cyclic laboratory test schedules for the cyclic testing (i.e., cyclic/dynamic tests including any associated static and classification tests)
- Definition of test parameters associated with the cyclic laboratory testing. During the test execution, several updates of the test conditions sheets will be required due to the interdependency of subsequent cyclic/dynamic tests
- Specifying any specialist testing required to further refine the Integrated Ground Model and Geotechnical Interpretative Report
- The CONTRACTOR should consider that a workshop / kick off meeting will be organised prior to the cyclic laboratory testing.
- Given the time constraint on this project, a constructive and pragmatic approach is expected of the CONTRACTOR when reviewing and discussing schedules, documents, results, and other input.

Quality Assurance interface:

- Interactive, constructive, and pragmatic dialogue with CONTRACTING AUTHORITY during activities.
- Provision of justifications and/or data used to define batching, parameters, and specialist testing.
- Approval of output by CONTRACTING AUTHORITY.

Deliverables:

The CONTRACTOR is expected to provide following services:

- Review / confirmation of the cyclic Laboratory Test Assignment Form (LTAF) sheets per geotechnical location within 48hrs of receipt (except weekend)
- Completion of specification of test parameters (Word or Excel sheets) within no more than 3 days of request.
- Contact as required (online meeting, email, call), typically weekly, with GT contractor and CONTRACTING AUTHORITY to clarify progress and identify and commit to actions. Can be combined with meetings of 2.2.7, if this is beneficial for all parties (CONTRACTOR, GT contractor, and CONTRACTING AUTHORITY)

2.2.12 Review of Factual GT Digital Data and Reports

Milestone: Delivery of Factual digital data and reports by the GT contractor.

The delivery of the GT reports will comprise of (refer to Annex [4]):

- GT-Lot 1 Seabed *in-situ* testing report.
- GT-Lot 1 Seabed sampling report.
- GT-Lot 2 Downhole testing and sampling report: priority for GGM and test dependencies.
- GT-Lot 2 Downhole testing and sampling report: standard.

- GT-Lot 2 Geological Age Dating report: priority for GGM.
- GT-Lot 2 Cyclic testing report: advanced.

Note that GT contractor may be requested to provide interim deliveries of digital laboratory data (for example monthly deliveries) in the agreed data format, enabling the CONTRACTOR to commence interpretations of the data.

Input:

- Factual digital laboratory data and reports associated with the GT-Lot 1 (seabed) investigations.
- Factual priority digital laboratory data and reports associated with the GT-Lot 2 (downhole) investigations.
- Factual standard digital laboratory data and reports associated with the GT-Lot 2 (downhole) investigations.
- Factual digital laboratory data and reports associated with the cyclic testing.
- Additional seabed and downhole data expected to be received from TenneT; anticipated 2x (2 boreholes + 8 CPTs).
- Final MIC and Geological Age Dating factual reports provided by the GT contractor.
- Contents and plan as provided in 2.2.1 (Project Documentation).

Activities:

The CONTRACTING AUTHORITY provides the CONTRACTOR an opportunity to inspect the factual data reports, digital data, and data format and confirm initial acceptability of the data set. The CONTRACTING AUTHORITY will collate any review comments and communicate these to the GT contractor. The CONTRACTING AUTHORITY reserves the right to approve or reject the reports.

After the evaluation of the priority digital laboratory data the lab testing strategy/schedule/parameters can be reconfirmed or fine-tuned for the remaining standard lab testing program (if required).

Given the time constraint on this project, a constructive and pragmatic approach is expected of the CONTRACTOR when reviewing and discussing schedules, results, and other input.

Quality Assurance interface:

The CONTRACTING AUTHORITY shall review and moderate output.

Deliverables:

- Provide review comments (captured in DRF).

2.2.13 *Interpret Geotechnical Standard Laboratory Test Results*

Milestone: Geotechnical Interpretation of standard laboratory test results as provided by the GT contractor.

The interpretation of the standard laboratory test results must be performed before or at least in early stages of the cyclic laboratory test programme as assigned in section 2.2.9 and is already planned in section 2.2.5.

Input: Sections 2.2.4, 2.2.7 and 2.2.8.

Activities:

The CONTRACTOR is expected to develop following items:

- Review and interpretation of relevant test types in support of the execution of the cyclic laboratory testing.
- As part of the GIR, establish a geotechnical Soil Type (Soil Unit) classification for representing similar geotechnical behaviour optimized to parameters important for wind farm and cable installation/foundation services and in a meaningful context to the Geological Ground Model with its contents such as geological layer properties, grading sequences, litho-genetic conceptual design.

- Overview tables showing the results of the laboratory tests undertaken during the geotechnical site investigations, with the following summarised for each Soil Type:
    - total quantity of sample material recovered;
    - total quantity of test results undertaken per test type;
    - minimum, maximum, mean, and median values of selected laboratory tests results.
- Statistical description of the geotechnical parameters for each engineering Soil Type, as derived from laboratory and *in-situ* tests. The statistical analysis must include the assessment and quantification of the associated uncertainties (*e.g.* testing biases, transformation models, spatial variability within the unit) for each parameter and covariance in-between individual parameters. The derived values of the geotechnical parameters shall include the parameters as proposed and approved with the Project Documentation document and updates for, but not limited to, the basic soil types (i.e. cohesive, non-cohesive, transitional soils).

Deliverables:

The CONTRACTOR is expected to deliver following:

- Overview with short descriptions of performed work.

2.2.14 Produce Final Geological Ground Model and Report

Milestone: Final version of the Geological Ground Model and Final Geological Ground Model Report.

The final Geological Ground Model shall be explicitly correlated with the Geotechnical Interpretative Report (2.2.16) such that all geotechnical Soil Unit boundaries are represented within the structural model defined by the geophysical data. The Soil Units shall represent bodies of common geotechnical behaviour and/or properties in the context of wind farm and cable foundation/installation design. Time-depth pairs are to be updated as required, and nomenclature is to be common between the geological and geotechnical unitisation.

Input:

- Section 2.2.10 and 2.2.13 using information from sections 2.2.1 through to 2.2.9.
- Factual GT-Lot1 and GT-Lot2 reports.
- Final MIC and Geological Age Dating results.

Activities:

The CONTRACTOR is expected to finalize the Geological Ground Model and updating the structural model with the geophysical-geotechnical correlation implemented in the GIR. The structural model must include all Soil units included in the GIR. The CONTRACTOR is expected to cooperate with the GT contractor who is responsible for the Geological Age Dating procedure, to build a coherent chronostratigraphic and seismostratigraphic model.

A time-to-depth conversion strategy is required, with the velocity model developed (or inferred) for this process included as a deliverable.

Addition or modification of Soil unit interfaces following Geotechnical Interpretative Reporting.

Quality Assurance interface:

Bi-weekly update meetings, working data deliveries, summary documents and up to two workshops with CONTRACTING AUTHORITY.

CONTRACTING AUTHORITY shall review geophysical horizon picking, time-to-depth conversion, structural model integrity, and geotechnical unitisation and correlation with geophysical data (in an update loop with section 2.2.8, 2.2.10, and 2.2.13).

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- ASCII pick files for each interpreted horizon (including seabed and interfaces/features that were of too small extent or too sparse to be gridded within the resolution specified below) in an exchangeable format with at minimum columns for XY coordinates, survey line name, shot point/trace number, time, and elevation;
- Elevation surfaces as regular grid (raster) files for all interpreted horizons at an appropriate resolution (~0.25-1 x line spacing, to be agreed with CONTRACTING AUTHORITY) reduced to datum, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Vertical thickness as regular grid (raster) files for all interpreted units at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Depth below seabed information for all interpreted unit boundaries at the same resolution as the elevation grids, as an xyz text file (*.xyz/*.pts) and a raster/grid;
- Updated velocity sections (as SEGY with populated headers) and updated time domain and depth converted seismic and/or surfaces, as may be required, in the same format as GP deliverables including:
    - Survey information with acquisition set-up, trace sampling and relevant navigational information (projection information *etc.*)
    - Processing workflow
    - Byte locations of CMP, SP, X Y data and any additional relevant workstation loading parameters;
- Horizon depth uncertainty information, spatially variable or constant per interface as appropriate (to be agreed with CONTRACTING AUTHORTY)
- A single seismic workstation project (Kingdom or equivalent approved by CONTRACTING AUTHORITY) including:
    - Soil profiles for every CPT and borehole location;
    - All CPT traces with each measured parameter loaded with T-D conversion included;
    - Interpretation of seismic data (2D-UHRS, 3D-UHRS, and SBP) supplied as picks on seismic sections or as spatial point/line components (format to be agreed with CONTRACTING AUTHORITY) and as gridded surfaces, for each soil unit boundary in the GIR;
    - All geohazards and intra-formational interfaces as gridded interfaces or pick files (format to be agreed with CONTRACTING AUTHORITY) depending on their extent and continuity;
    - Clear metadata information for all included workstation items.
- A GIS project, including:
    - Location of all seabed samples (geophysical campaign and geotechnical campaign), boreholes, seabed CPTs and vibrocores (geophysical and geotechnical campaigns) as point shape files;
    - Contour maps at an appropriate interval, elevation rasters and extent polygons for all soil unit boundaries;
    - Extent polygons, elevation rasters and contour maps at an appropriate interval showing spatial (lateral and vertical) presence of extended geohazard features dependent on their spatial continuity;
    - Sub-surface point geohazard (such as diffraction apices that may indicate the presence of boulders) table(s) and associated point shapes with columns for X and Y co-ordinates at minimum and depth where appropriate;
    - Extent polygons of pertinent geological features including but not limited to channels, escarpments and potential glaciotectonic features;
    - Faulting as linear features (individual faults mapped at their most shallow extent) and/or polygons (areas of faulting);
    - Metadata for all GIS project deliverables compliant with Annex [5] 'Starting Points and Assumptions'.

- A comprehensive Final Geological Ground Model Report in digital format (*e.g.* .pdf), five (5) copies on physical media (*e.g.* flash drive, HDD drive) or on a CONTRACTING AUTHORITY approved equivalent, documenting and describing all aspects of the Geological Ground Model including:
    - Summary of the data processing for the integration of the geotechnical and geophysical field data into the model;
    - Summary of reprocessing methods used;
    - Complete description of the geological layers and sub-layers in their stratigraphical context and their seismic facies properties as defined in the final Geological Ground Model;
    - Correlation drawings illustrating the geophysical and geotechnical data correlation corresponding to final unitisation of the soil/rock columns;
    - P- and/or S-wave velocity (or velocity field if data support variability) for each soil unit from time-depth pairs, stacking velocity analysis and geophysical borehole logging results;
    - Quantification and description of the global spatial lithological variability of the subsurface within the entire IA and additionally for each individual defined geological unit, *e.g.* as variography over particle sizes, as well as description of striking grading sequences (fining up, coarsening up) observed and identified in geotechnical investigations;
    - (Appendix) At least 6 representative primary-line sections through geotechnical location (superimposed), time/depth corrected, and additionally in time-space, with picked horizons and fully annotated;
    - (Appendix) At least 3 representative cross-line sections through geotechnical location (superimposed), time/depth corrected and additionally in time-space, and fully annotated;
    - (Appendix) Charts illustrating the base surface of each soil unit identified and as assigned above. Scale to be approved by CONTRACTING AUTHORITY;
    - (Appendix) Charts illustrating the vertical thickness of each of the Soil Unit. Scale to be approved by CONTRACTING AUTHORITY;
    - (Appendix) Charts illustrating the geohazards as assigned above. Scale to be approved by CONTRACTING AUTHORITY;
    - (Appendix) Charts illustrating the extent of geotechnically important geological features including but not limited to channels, escarpments and potential glaciotectonics or other geobodies. Scale to be approved by CONTRACTING AUTHORITY;
    - (Appendix) Charts illustrating the subcrop geology below mobile seabed sediment, with mobile sediment thickness as contours superposed. Scale to be approved by CONTRACTING AUTHORITY.

2.2.15 Produce GT parameter predictions at seismic trace locations and Report

<u>*Milestone*</u>: GT parameter predictions at seismic trace locations for 2D-UHRS and 3D-UHRS datasets, including a Report. The use of innovative prediction methodologies is encouraged.

<u>*Inputs*</u>:

- Measured geotechnical data;
- Derived, calculated, or correlated geotechnical data;
- Seismic amplitude, seismically derived velocity, and other attribute data;
- Seismic interpretation data.

<u>*Activity*</u>:

At least two sets of predictions shall be generated:

- One set of linear parameter profiles representing best fit linear approximations within each soil unit, to be vertically and laterally variable or constant as appropriate;

- One set of continuously variable (vertically and laterally) geotechnical parameter profiles derived as a function of one or more input datasets derived from the seismic datasets. These may be produced by correlation with seismic and attribute traces by using machine learning or advanced (geo)statistical simulations or algorithms designated for this purpose.

It is encouraged to implement innovative methodologies/ inversion/ conditioning to improve predictions/decrease uncertainty/predict additional GT parameters.

Multiple prediction methods are to be evaluated and predictions optimised for each of the above two datasets.

The CONTRACTOR shall provide a set of appropriate quality metrics indicative of the relative confidence in predicted GT parameter values at appropriate spatial and depth intervals.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during course of activity;
- Leave-one-out comparisons of predicted vs measured parameters at each GT investigation location;
- Geostatistical comparison of variability of predicted vs measured results;
- Confidence and/or quality metrics to be defined by the CONTRACTOR with approval of the CONTRACTING AUTHORITY and with the input of the CERTIFIER;
- Documentation to be reviewed using DRF process.

Deliverables:

- All input parameters including attributes calculated from seismic traces if not specified in other work packages;
- Output predicted GT parameters for each prediction set as SEGY at all input seismic trace locations including:
  - q_t, corrected cone resistance,
  - f_s, sleeve friction;
- Optional output predicted GT parameters as SEGY at all input seismic trace locations including, but not limited to:
  - G_{max}, small strain shear modulus,
  - u_2, pore pressure or equivalent derived pore-pressure property (B_q etc.);
- Output all predicted GT parameters at GT locations as AGS 4.0 or later, including but not limited to:
  - q_t, corrected cone resistance,
  - f_s, sleeve friction;
- A comprehensive Report on the Prediction of GT parameters based on seismic data in digital format (*e.g.* .pdf), five (5) copies on physical media (*e.g.* flash drive, HDD drive) or on a CONTRACTING AUTHORITY approved equivalent, documenting and describing all aspects of the GT parameter prediction work, including:
  - data preparation including full description of the development of each and all seismic attributes used as contributors to the predicted GT parameter calculations;
  - method selection, evaluation and optimisation including documentation of all tested prediction methods and optimisation criteria;
  - structural and parametric uncertainty in predicted GT parameters;
- Workshops required to discuss progress and preliminary findings.

2.2.16 *Produce Geotechnical Interpretative Report (GIR)*

Milestone: Final Geotechnical Interpretative Report (GIR), including Final Cyclic Test Report

Input: Contents and deliverables of prior sections.

The CONTRACTOR shall develop the contents of the GIR concurrently, precisely in an iterative supporting way, to the GGM and IGM compilation, so that the contents and the results of the GIR, GGM and the IGM are fully coherent and complementary. The GIR is expected to provide geotechnical characterisation of all identified GGM units, whereas the IGM is expected to provide the spatial distribution of those units within the windfarm zones.

Activities:

The CONTRACTOR is expected to perform the following tasks in accordance to the delivered and approved Project Documentation by the CONTRACTING AUTHORITY:

- Derivation of the design relevant parameters for the identified geological units for the purpose of providing ranges to allow the preliminary design and installation assessment of monopiles, jacket piles, and alternative foundations (*e.g.* suction caissons) under static and cyclic/dynamic loading conditions.
- Present clear methodology for selecting characteristic values of geotechnical parameters. The characteristic values of geotechnical parameters shall be selected in the sense required by EN 1997-1:2004 or assessed according to the approach outlined in DNV-RP-C207 (2021) and DNV-RP-C212 (2021).
- The characteristic values and profiles of geotechnical parameters should be derived for, or be appropriate for use in, a range of state-of-the-art calculation models used for the design the foundation, including installation analyses.
- A seismic (earthquake) hazard assessment:
    - Probabilistic and deterministic assessment of the seismic hazard;
    - Assessment of soil liquefaction potential;
    - Assessment of induced seismicity;
    - Assessment of the design parameters as per ISO 19901-2:2022 and EN 1998-1:2004 Eurocode 8;
    - Seismic zone classification according to ISO 19901-2:2022.
- Recommendations for microbially influenced corrosion (MIC) of steel piles that can be used as input into durability limit states for pile design (EN ISO 13823:2008; EN ISO 9001:2015; CEN, 2003b; DNV GL:2016), based on a review of applicable codes of practice, information available in the public domain, an assessment of the general site setting, and the site-specific MIC test results / analysis carried out as part of the Geotechnical Site Investigation.

A statistical evaluation of the Derived Values of the geotechnical parameters shall be undertaken (accounting for and quantifying of all uncertainties, *e.g.*, testing biases, transformation models, sampling locations, etc.) and engineering judgement shall be applied and documented. Any inconsistencies in the Derived Values, particularly between different test types should be highlighted and discussed.

The ranges in characteristic values of geotechnical parameters shall consider the spatial soil variability and the general requirements of the various design approaches and methods currently being used in the offshore wind energy industry for piled foundations.

Quality Assurance interface:

- Interactive dialogue with CONTRACTING AUTHORITY during course of activity.
- Review and approval cycle by CONTRACTING AUTHORITY through DRF process.
- Review and approval cycle by independent verification body through DRF process.

Deliverables:

The Final Geotechnical Interpretative Report shall include in accordance with ISO 19901-8:2023, EN 1997-2:2007 or similar:

- A full description and interpretation of relevant geotechnical parameters suitable for the design and installation of WTG foundations and cable design and installation as outlined in detail above.

- Any structural and parametric uncertainty evaluations for the interpreted and concluded contents of the GIR.
- Informative and easily-readable figures to present the recommended parameter ranges together with the relevant laboratory data.
- Informative summary tables for a quick review, work with contents and extraction of parameters.
- Including a Final Cyclic Test Report

2.2.17 Produce Integrated Ground Model (IGM)

Milestone: Integrated Ground Model (IGM).

Input: All contents and deliverables of sections 2.2.1 through to 2.2.16.

The CONTRACTOR shall develop the contents of the IGM. The IGM is expected to provide the spatial distribution of the units identified in the GGM and geotechnically characterised in the GIR.

Activities:

The CONTRACTOR is expected to perform following work:

- The zonation of the entire DDW IA into Geotechnical Provinces for depth intervals as proposed and approved with the Project Documentation. The Geotechnical Provinces must align with contents of the GIR and show a similarity of entire downhole geotechnical behaviour within each Province optimized to wind farm and cable foundation/installation purposes.
- Based on the work above, spatial value allocation of all geotechnical parameters and characteristic values corresponding to the presence and lateral/vertical extent of each Soil Units and in coherence to the litho-genetic design established with the Geological Ground Model.
- Based on the work above, the inclusion of interpolated, predicted GT parameter data at an appropriate resolution dependent on the appointed IGM level-of-detail (*e.g.* 20m x 20m x 10cm voxel size) or (in approval with the CONTRACTING AUTHORITY) technical innovations for dynamic 3D multi-attribute model deliveries. One set of linear approximations of predicted GT parameter and any geotechnical parameter measurements is to be produced, using the linear predictions developed in 2.2.15. One additional set of predicted GT parameters is to be produced derived from the continuously variable (vertically and laterally) parameter profiles developed in 2.2.15. Description and quantification of all structural and parametric uncertainties of the transformed geotechnical property distribution for each set of predictions accounting as well for the results of the laboratory tests.

Deliverables:

The CONTRACTOR is expected to deliver following items and services:

- A single seismic workstation project, using Kingdom (or equivalent approved by CONTRACTING AUTHORITY).
- A Geological Ground Model including at a minimum but not limited to:
    - Interpolated soil profiles / cross-sections showing Soil Type (Soil Unit) with at least primary fraction, density, consistency tracing every CPT and borehole location and, if possible, cross sections for arbitrary coordinates within the wind farm zone;
    - Cross-sections with CPTs (seabed and downhole) showing at least cone resistance, pore pressure ratio and friction ratio versus depth profiles including their statistical description;
    - Profiles in cross-section showing downhole particle size analysis in context to Soil Unit definition, CPTs and seismic signals;
    - A 3D volume as a grid (voxel) or SEGY containing predicted GT parameters including at least the above assigned parameters (see *Activities*) in the appointed resolution with confidence intervals and feature importance values (if available) as approved with the Project Documentation;

    - Implementation of additional parameters or correlated geotechnical parameter(s) in the 3D volume / format described above;
    - Structural and/or parametric uncertainty data, including characteristic values per agreed geotechnical / design standard as appropriate;
    - The spatial extent as polygons of assigned Geotechnical Provinces as established in above-described activities;
    - Clear metadata and version information for all included workstation items.
- GGM GIS project including at minimum but not limited to:
    - All Geological Ground Model GIS content;
    - All raster deliverables;
    - All vector deliverables;
    - Content of the Geophysical and Geotechnical survey deliverables unchanged in the IGM activity;
    - Elevation (top/base) contour maps at an appropriate interval and extent polygons for all Soil Unit bodies with the IA;
    - Thickness (vertical) contour maps at an appropriate interval and extent polygons for all Soil Unit bodies with the IA;
    - All measured and calculated geotechnical parameters that can be represented as spatial data per soil unit;
    - 3D GIS representation of the 3D volume described above;
    - Metadata for all GIS project deliverables compliant with Annex [5] 'Starting Points and Assumptions'.
- Provision of all essential and design relevant contents of the IGM in at least one non-proprietary file format using binary or ASCII open-source file formats, such as ASCII 2D/3D grids, ASCII tables, Simple File Format, SEGY or file formats usable in open-source software packages (*e.g.* ESRI shapefile);
- Provision of the 3D IGM Voxel model (open software) as a structured multi-dimensional data volume containing all essential and design relevant contents that can be represented spatially. This should be a fully documented and readily readable non-proprietary file format and preference is given towards the use of Network Common Data Form (NetCDF). This can be a single file containing all design properties, or multiple files provided that they share common data structure and dimensionality and are readily accessible for the extraction and comparison of data. Other non-proprietary formats will be considered provided that they are machine and software independent open file formats, and documentation and read/write instructions are provided. This can exclude non-voxel data (vector data, profiles, sections etc.), provided they are provided in another suitable non-proprietary format.

2.2.18 Produce Integrated Ground Model Report

Milestone: Final Integrated Ground Model report as accompanying document to the digital IGM package (section 2.2.17).

Input: sections 2.2.1 through to 2.2.17.

The CONTRACTOR is expected to deliver a report to document all performed work to create the IGM in a comprehensive, informative way. Where components are deliverables of prior work packages, it is anticipated that these will be compiled into the IGM report with minimal additional editorial or review work.

Activities:

The CONTRACTOR is expected to prepare a document with following content:

- Full description of the geophysical integration and (re-)interpretation explicitly mentioning these aspects:
    - Description of the gridding methods and parameters used to generate interface grids from the original pick files. Relevant gridding information included in the label for each chart. Detailed descriptions of the gridding methods should be presented in appendices.

    - Description of how a final cumulative gridded interface of a seismic data interpretation was derived from the picks of each seismic dataset. A quantitative description of the elevation uncertainty of all interfaces must be included.
    - Comprehensive representation of the explicit correlation of geotechnical parameters and seismic intersections to illustrate the unitisation of both.
- Full description of the geotechnical data integration and the interpolation, regionalization, or mapping methodologies for all IGM contents;
- Full description of used algorithms for the attribution of geotechnical target parameters with characteristic values to the geophysical model, if not covered by above mentioned topics;
- Full description of the spatial variability of geotechnical relevant parameters is to be added, *e.g.* per variography, as global assessment (entire area) and for each individual Soil Unit. Full description of compiling methods of GT parameter prediction including but not limited to:
    - Prediction method for each of the predicted GT parameters as provided in 2.2.15 and 2.2.16;
    - Sensitivity analysis for use or choice of different methodologies as well as for parametrical uncertainty assessment;
    - Information about the dependencies of the variability and spatial variability of input parameters, as well as distance of seismic signals to geotechnical measurements, to the confidence values, performance (*e.g.* convergence, cross-validation) and feature importance values of the chosen machine learning method, if used;
    - If geostatistical methods will be used to predict GT parameters, then full (cross-) variography of all input parameters must be added (Soil Unit wise, dependent on methodology) as well as cross-validations for all final prediction runs.
- Documentation and discussion of the derivation and distribution of engineering characteristic values for each unit in relation to aleatoric and epistemic uncertainty of the natural materials and the measurement and prediction systems, in the context of the 3D integrated model. Documentation and discussion of the derivation and distribution of structural uncertainty (elevations, thicknesses, depths) for each unit. Combination of parametric and structural uncertainty to be discussed;
- Statements to the data validity in context to the geological complexity and the investigation resolution;
- Statements to Geological Age Dating Analysis incorporated into the IGM and descriptive comparison to Geological Age Dating results in nearby WFZs;
- Identification of areas within the DDW IA that can be qualified in terms of suitability and quantified in terms of reduced or elevated development and installation costs;
- Identification and definition of the likelihood of the suitability of or possible constraints across the DDW IA regarding:
    - Foundation capacity, stability, and installation consideration;
    - Microbially induced corrosion (MIC);
    - Piling of foundations *e.g.* presence of boulders, rocks, or other hard substrate;
    - The use of jack-ups;
    - The design and installation of intra array cables.

Deliverables:

The CONTRACTOR is expected to deliver a comprehensive Final Integrated Ground Model Report with informative graphs, charts and tables with required content as outlined above. The report shall be provided in digital format (*e.g.* .pdf), five (5) copies on flash drive, HDD drive or on a CONTRACTING AUTHORITY approved equivalent, Moreover, the appendices shall include:

- The mapped top and/or base of each major Soil Unit surface identified;
- The mapped vertical thickness of each of the major Soil Unit;
- User guide for the 3D IGM, delivered as a short note or appendix to the report, and digital documentation provided with the chosen digital deliverable of 2.2.17.

Charts are to be provided in PDF and with the same layout as implemented within the GIS project as assigned in section in 2.2.17.

2.2.19 Final Delivery IGM and GIR

Milestone: Delivery of the reviewed and revised version of the IGM and the GIR, ready for publication.

Input: sections 2.2.14, 2.2.16 and 2.2.17.

Activities:

The CONTRACTOR must ensure there is version control across all presented data. The CONTRACTOR shall provide a method of data validation for electronic and physical deliverables, *i.e. validation of data completeness and integrity.*

Quality Assurance interface:

CONTRACTOR is required to specify a data transfer protocol to enable the safe and secure transfer of digital data.

All data deliveries must pass validation and version checks.

Deliverables:

The deliverables comprise all deliverables requested with sections 2.2.14, 2.2.16 and 2.2.17 in a reviewed, revised and accepted version, which is verified and prepared for publication.

A validation tool (*e.g.* checksum or file hash listing) with instruction guide to qualify successful transfer of digital data, suitable for both CONTRACTING AUTHORITY and third-party use. Open tools are preferable, where proprietary tools are proposed licences and software will be made available by the CONTRACTOR to the CONTRACTING AUTHORITY and any third-party users.

The CONTRACTOR is expected to provide following additional services:

- Project and Site Description.
- Attendance to at least four workshops and/or online meetings with the CONTRACTING AUTHORITY discussing results and reviews for the IGM and GIR. Provisional rates for additional required meetings with the CONTRACTING AUTHORITY should be considered and proposed.

2.2.20 Certification

Milestone: CONTRACTOR shall participate in meetings, workshops and support the certification process for all deliverables as required, also if Certification is expected to take place after the Final Delivery of the IGM and IGM. The CONTRACTOR shall assist the CONTRACTING AUTHORITY during the certification process including final review cycle(s) and the answering of queries from the Certifying Authority.

Certification will follow the process outlined in the appropriate section of the latest version of document DNV-SE-0190 (2023) *Project Certification of wind power plants* and documentation referenced therein.

CONTRACTING AUTHORITY will submit approved deliverables for review by a certification provider which may return requests for clarification and/or amendment. The CONTRACTOR (including potential subcontractors) shall assist to answer these requests. The certification provider may require support to develop sufficient understanding of the methods applied and CONTRACTING AUTHORITY may be proactive in introducing personnel from the certification provider into selected meetings and workshops (by mutual agreement with CONTRACTOR).

Up to five (5) half-day workshops should be included in the workshops allocation to accommodate requirements in support of certification.

2.3 Additional Activities

2.3.1 Progress and Regular Interface Meeting

The CONTRACTOR shall be available to provide regular updates during Work Progress Meetings (WPM) with the CONTRACTING AUTHORITY. It is estimated that meetings will be scheduled at least on a bi-weekly basis for 1.5 hrs. The CONTRACTOR shall attend these meetings with the designated project manager and relevant technical specialists. Occasionally multiple technical specialists may be required to attend to discuss specific topics of the WORK. The CONTRACTING AUTHORITY will prepare a meeting agenda, track actions in an action list and document meeting notes. CONTRACTOR will be required to provide a weekly report at least 24 hrs prior to the WPM. The weekly report shall contain up to date information on the progress of the WORK, risks, and opportunities, forecasted delivery dates and potential changes to scope as required.

During the execution of the WORK multiple interfaces are recognised. The main interfaces are with the GP contractor and the GT contractor. The CONTRACTING AUTHORITY requests the CONTRACTOR to participate in Joint Progress Meetings to discuss relevant interfaces and interdependencies of the WORK and to promote collaboration between parties. The CONTRACTOR shall attend these meetings with the designated project manager and relevant technical specialists. Joint Progress Meetings will be scheduled on 4-weekly basis for the duration of the contract (1.5 hrs per meeting).

2.3.2 Workshops/Meetings to discuss outside of WPM

The CONTRACTOR is required to attend various meetings and workshops. The workshops and meetings will be required at various stage throughout the contract period and will be utilised to, for example, discuss the results and output of various deliverables, alignment with interfaces or to discuss issues that may arise during the execution of the work. In some instances, preparation in the form of a presentation may be requested by the CONTRACTING AUTHORITY. For this Tender, workshops and regular meetings will be required and the CONTRACTOR is expected to cost these appropriately.

2.3.3 Webinars

The CONTRACTOR is requested to present the GIR and IGM results to the market through participation of at least two webinars. For this, the CONTRACTOR shall provide:

- Preparation of presentations including PowerPoint slides and script.
- Attendance and presentation of webinars at RVO (CONTRACTING AUTHORITY) location in the Netherlands or, if it is not possible to travel, by virtual attendance by at least two senior experts.
- Provision of suitable number and qualified personnel to staff back office during and after webinars to respond to questions from the audience.

2.3.4 Project and Site Description

The CONTRACTOR is requested to provide a 2-5-page summary including the aims, objectives and approach and the main results to be published in the Project and Site Description. (Examples available from https://offshorewind.rvo.nl/generalnh). The summary for the Project and Site Description shall be provided in Word format.

2.3.5 Answering Additional Questions

It is anticipated that additional questions (from the market or CONTRACTING AUTHORITY) regarding this Integrated Ground Model and Geotechnical Interpretative Report will be received after delivery of the study results. The CONTRACTOR is requested to support the CONTRACTING AUTHORITY in answering these questions.

2.4 HSE and team redundancy

CONTRACTOR shall provide adequate cover, team, and IT redundancy in order to adequately manage the impact of unforeseen events, *e.g.* restrictions on travel and entry, availability of personnel. Backup team members shall be as, a minimum, equally qualified and experienced as the primary team.

2.5 Roles and Responsibilities

The DDW Soil Investigation project is a project in which the GM, GT, and GP scopes are interrelated; the scopes depend on and feed into each other. Table 2 gives an overview of the responsibilities for the different work items; which party/contractor will supply/execute the work item and which party/contractor will approve the work item.

Table 2: Responsibilities at GT GM interface items.

Responsibility GT-Lot1	**Party/Contractor**			
P=Produce E = Evaluate & Execute A=Approve	**CLIENT**	**GT-Lot1 CONTRACTOR**	**GT-Lot2 CONTRACTOR**	**GM CONTRACTOR**
Preliminary Ground Model	A	-	-	P
GT Location Plan: CPTs GT-Lot 1	A	E	-	P
GT Location Plan: Vibrocores GT-Lot 1	A	E	-	P
Lab Test Strategy GT-Lot 1	A	E	-	P
Sample Batching Strategy	A	E	-	P
Clearance of CPT/VC locations GT-Lot 1	-	PE	-	-
Archaeological Analysis GT-Lot1	AP	E	-	-
Standard lab test schedule GT-Lot 1	A	PE	-	A
Standard lab test conditions GT-Lot 1	A	E	-	P
Sample Batching schedule	A	PE	-	A

Responsibility GT-Lot2	**Party/Contractor**			
P=Produce E = Evaluate & Execute A=Approve	**CLIENT**	**GT-Lot1 CONTRACTOR**	**GT-Lot2 CONTRACTOR**	**GM CONTRACTOR**
Preliminary Ground Model	A	-	-	P
GT Location Plan: BH GT-Lot 2	A	-	E	P
Lab Test Strategy GT-Lot 2	A	-	E	P
Sample Batching Strategy	A	-	E	P
Geological Age Dating Strategy GT-Lot2	A	-	E	P
Clearance of BH locations GT-Lot 2	-	-	PE	-
Standard lab test schedule GT-Lot 2	A	-	PE	A
Sample Batching schedule	A	-	PE	A
Geological Age Dating Analysis GT-Lot2	A	-	PE	A
Standard lab test conditions GT-Lot 2	A	-	E	P
Cyclic lab test conditions GT-Lot2	A	-	E	P

3 SCHEDULE OF KEY DATES

The DDW Soil Investigation project is a time driven project in which the GM, GT, and GP scopes are interrelated; the scopes depend on and feed into each other. To avoid delays and consequential knock-on effects between the scopes, it is crucial that the CONTRACTOR meets the defined timelines. The GM scope has the following interfaces where it is required that the CONTRACTOR provides timely and constructive input to the GT contractor):

- 2.2.4 Produce Geotechnical Location Plans;
- 2.2.5 Produce Laboratory Testing Strategy, as input for the GT laboratory program;
- 2.2.6 Review of Pilot Digital Data Deliverables;
- 2.2.7 Review of seabed and downhole geotechnical data (ongoing throughout GT field campaigns);
- 2.2.9 Review laboratory test schedules and specification of test parameters;
- 2.2.11 Review Cyclic laboratory test schedule and specification of test parameters;
- 2.2.12 Review of Factual GT Digital Data.