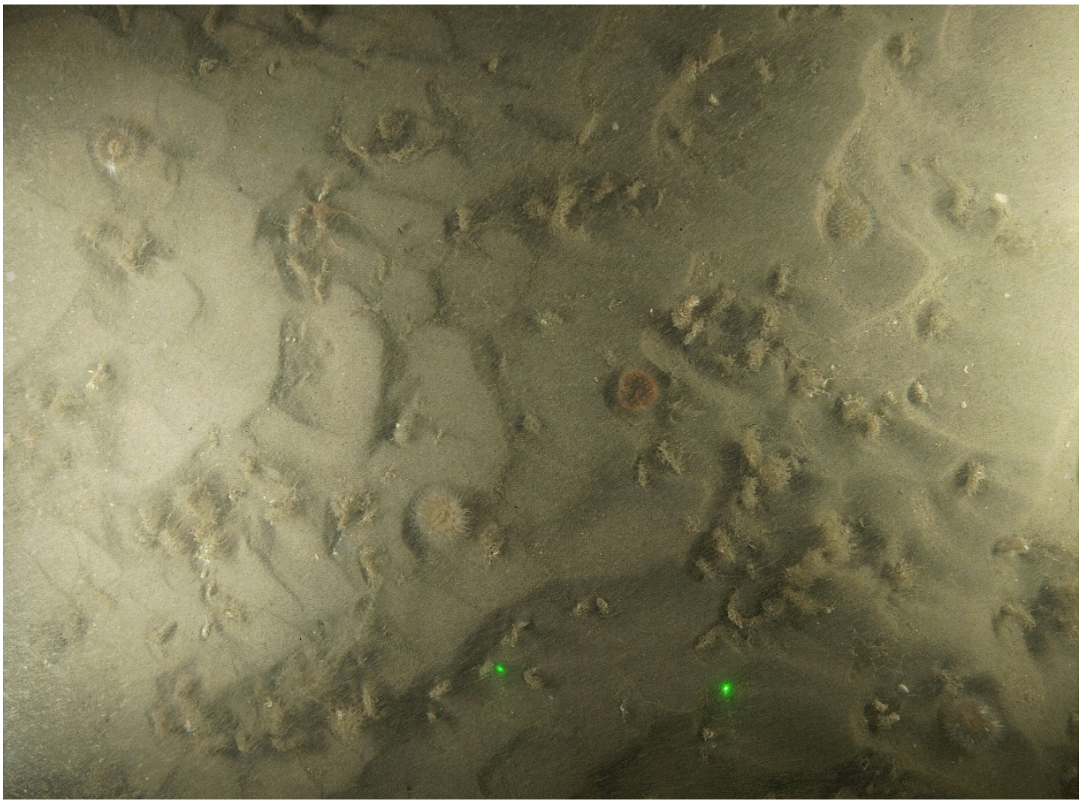
N05A-7-10-0-70044-01-02: Habitat Assessment Report - N05a Platform Area



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Glossary

Abbreviation	Definition
CM	Central Meridian
CLOC	Clear Liquid Optical Chamber
DDV	Drop Down Video
DVV	Dual Van Veen
EBS	Environmental Baseline Survey
EEA	European Environment Agency
EOL	End of Line
EUNIS	European Nature Information System
HAB	Habitat Assessment
HD	High Definition
IUCN	International Union for Conservation of Nature
MBES	Multibeam Echo Sounder
MP	Megapixel
OWF	Offshore Wind Farm
OSPAR	Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)
PC	Physico-chemistry
SBP	Sub-bottom Profiler
SCI	Site of Community Importance
SOL	Start of Line
SOW	Scope of Work
SPA	Special Area of Conservation

SSS	Side Scan Sonar
TOC	Total Organic Carbon
TOM	Total Organic Matter
USBL	Ultra-Short Base Line (positioning beacon)
UTM	Universal Mercator Projection
WWF	World Wildlife Foundation

Executive Summary

MarineSpace Ltd was commissioned by GEOxyz on behalf of ONE-Dyas BV, to produce a Habitat Assessment Report for the N05a platform survey area in Dutch and German waters. The report aimed to identify the occurrence of species or communities of conservation importance listed under Annex I of the EU habitats Directive (1992) as well as any threatened and/or declining species and habitats on the Oslo-Paris (OSPAR) Commission list (OSPAR, 2008).

Geophysical data were collected at the N05a platform survey area using side-scan sonar (SSS) and multi-beam echosounder (MBES). Drop-down video (DDV) was conducted along 2 x 100 m long transects and grab sampling was undertaken at 2 co-located stations. Geophysical data were interpreted during the survey to determine bathymetry and delineated potential features of conservation importance, which were subsequently used to inform the location of the DDV and grab sample locations. Video and stills collected from DDV were reviewed to ascertain presence and absence of species and habitats of conservation importance. Grab samples we also reviewed to identify the occurrence of species of conservation importance.

Within the N05a platform survey area, water depth ranged from 23.7 m lowest astronomical tide (LAT) to 26.2 m LAT. The seabed dipped gently to the north at a negligible gradient of less than 1°. Small areas with relief of up to 0.5 m were observed on the bathymetry data with measured gradients of up to 6° on their flanks. Surface relief within the survey area was interpreted to be largely due to outcropping clay. Seabed sediments were interpreted within the charted area as fine sand with shell fragments and as coarse sand and clay. Numerous SSS contacts were identified within the charted area, with the majority interpreted as boulders.

Habitat within the survey area was found to be homogeneous and predominantly fine sand within areas interpreted as ‘fine sand with shell fragments’ while habitat within the ‘coarse sand and clay’ was predominantly coarse sand and areas of high density *Lanice conchilega*. Correspondingly, 2 x level 3 EUNIS habitats were identified; A5.23 infralittoral fine sand and A5.13 infralittoral coarse sediment as well as 1 x level 4 EUNIS habitat: A5.137 dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand.

As there were no hard substrate areas and associated fauna identified from the 2021 DDV data, the areas observed within the N05a platform area could not be defined as Reefs (H1170) under the Dutch MANFQ guidance (MANFQ, 2014a).

Sediment type, depth and fauna were found to meet the requirement of the EC Habitats Directive Annex I habitat subtype H1110_C (MANFQ, 2014b). However, the geophysical data found no sandbank features within the N05a platform survey area.

Only one individual of Pennatulacea (sea pen) was observed within the N05a platform survey area. Consequently, there is little to no resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat (OSPAR, 2008).

Other than those detailed above there was no further evidence of any Annex I habitats, any species or habitats on the OSPAR (2008) list of threatened and/or declining species or any species on the IUCN Global Red List within the N05a platform survey area.

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1. Project Summary

1.1. Scope of Work

ONE-Dyas BV plans to develop a successfully drilled well in block N04a of the North Sea Dutch Continental Shelf. It is planned to develop the well by installing a minimum facilities platform and gas export pipeline with a connection to the future N05a processing platform (here on in referred to as 'the Project'). The Project runs along the Dutch German border within Dutch blocks N04a and N05a, with a portion crossing over into German waters. A habitat assessment (HAB) in conjunction with an environmental baseline (EBS), geophysical and geotechnical survey, are required prior to well development operations at N04a and export pipeline connection works. The current report details the results of the HAB for the N05a platform area only and includes a summary of relevant results from the geophysical and environmental baseline survey. All other environmental reporting for the Project can be found within the following reporting volumes:

- N05A-7-10-0-70041-01-xx - Habitat Assessment Report - N05a-Riffgat OWF Cable Route Area;
- N04A-7-10-0-70022-01-xx – Habitat Assessment Report – N04a to N05a Pipe Route;
- N04A-7-10-0-70023-01-xx - Habitat Assessment Report - N04a Platform Area;
- N04A-7-10-0-70015-01-xx – Environmental Baseline Survey Report – All Areas.

1.1.1. N05a Platform Area

Environmental and geophysical data were collected around the N05a platform location. The specific aims of the habitats assessment, as defined in the scope of work (SOW; GEOxyz, 2021a), were to assess for the potential presence of important and environmentally sensitive habitats and species, including:

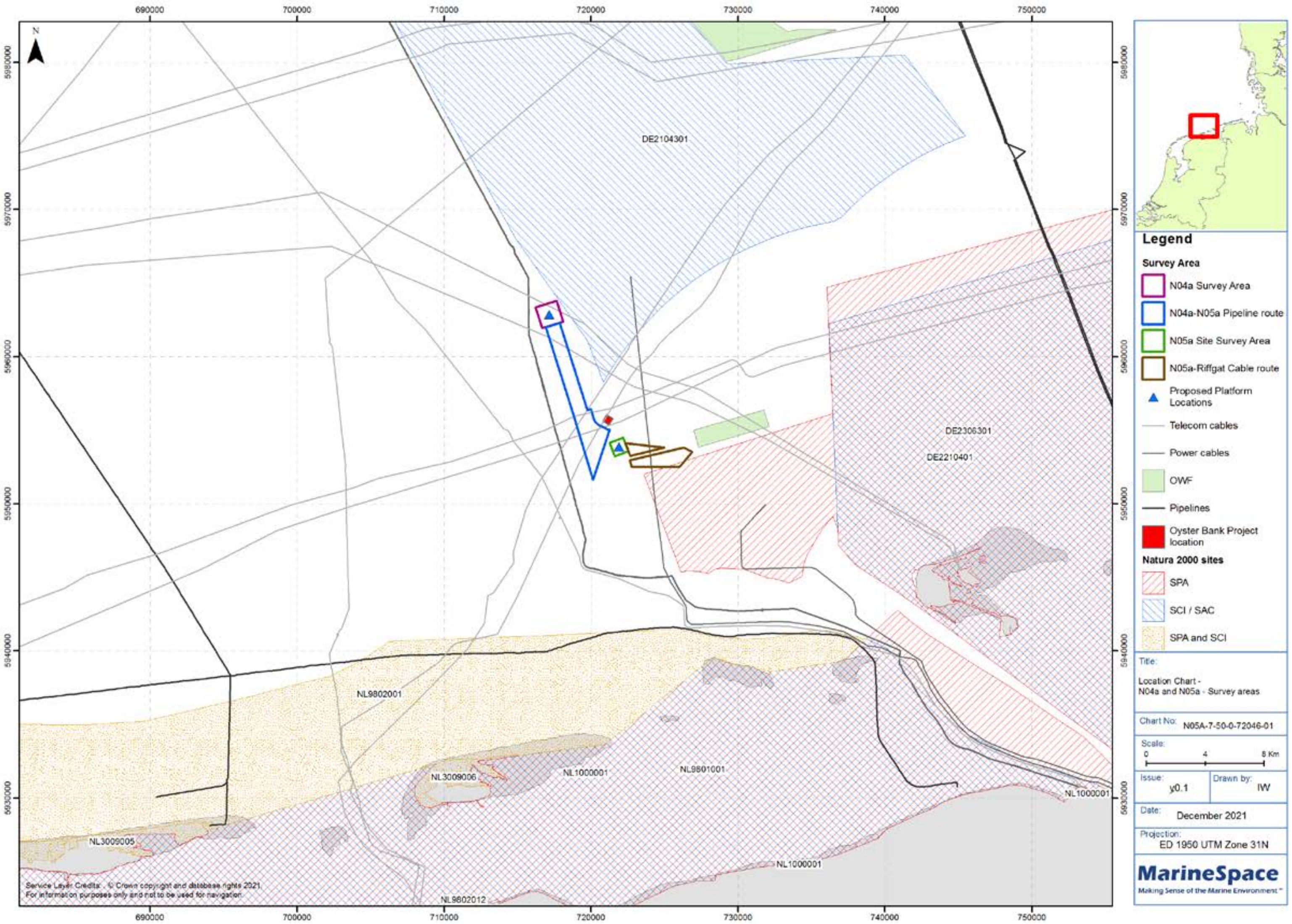
- Annex I habitats of the EU habitats Directive (1992) particularly EU habitat 1170 stony reef and habitat 1110 Sandbanks which are slightly covered by sea water all the time;
- Any evidence of the threatened and/or declining species habitats listed by OSPAR (2008);
- Species on the International Union for Conservation of Nature's (IUCN) Red List of threatened species (IUCN, 2021).

Locations coordinates of the future platforms are presented in Table 1.1. All coordinates within this report are referenced to International 1924 Ellipsoid, European Datum 1950. Grid coordinates are projected using the Universal Mercator Projection (UTM) Zone 31, Central Meridian (CM) 3° E.

Table 1.1: Coordinates of future platform locations

Future Platform Locations	Easting	Northing	Latitude	Longitude
N04a	5962867	717150	53° 46' 04.51" N	006° 17' 41.46" E
N05a	5953858	721896	53° 41' 06.32" N	006° 21' 36.97" E

Figure 1.1: Location of the N05a Site Survey Area



1.2. Environmental Survey Strategy

During October and November 2021, the environmental and geophysical surveys were conducted onboard the GEOxyz survey vessel Geo-Ocean III from 20 October to 16 November. All environmental work was conducted by MarineSpace, supported by Associates from Ocean Ecology Ltd, between 05 - 11 November 2021. The geophysical data acquisition was conducted by GEOxyz between 23 October to 12 November 2021 and has been reported separately by Peak Processing for each survey area (GEOxyz, 2021b; 2021c; 2022a; 2022b).

Geophysical data were collected using a multibeam echo sounder (MBES), side scan sonar (SSS), sub-bottom profiler (SBP) and 2D ultra high resolution (2DUHR) data. Following geophysical data acquisition, SSS and MBES data were reviewed to propose location for benthic grab sampling and camera investigations. Areas of potential conservation value and boundaries between areas of differing reflectivity were factored into sample locations in order to identify potential changes in seabed sediment type and bathymetric highs and lows.

A total of 2 transects and co-located environmental sampling stations were spaced across lower and mixed reflectivity areas within the N05a platform area that were previously not investigated by the 2019 'N5a Development' HAB (GEOxyz, 2019).

Details of the environmental targets and data collected along targeted features of interest observed within the geophysical data, are summarised in Table 1.2 for camera transects and in Table 1.3 for grab targets. Target and actual sampling locations, are presented in the Surveyor's log sheets in Appendix A and in Figure 1.2 along with the surveyed N05a platform area.

Table 1.2: Summary of transect targets and data acquired

Transect	SOL/EOL[1]	Proposed Easting[2]	Proposed Northing[2]	Proposed Length (m)	Rationale	Transect Completed (Y/N)	Length Achieved (m)[3]
ENV26	SOL	721903	5953824	100	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	232
	EOL	721860	5953734				
ENV27	SOL	722143	5953888	100	Along an area of homogenous lower reflectivity.	Y	402
	EOL	722110	5953798				

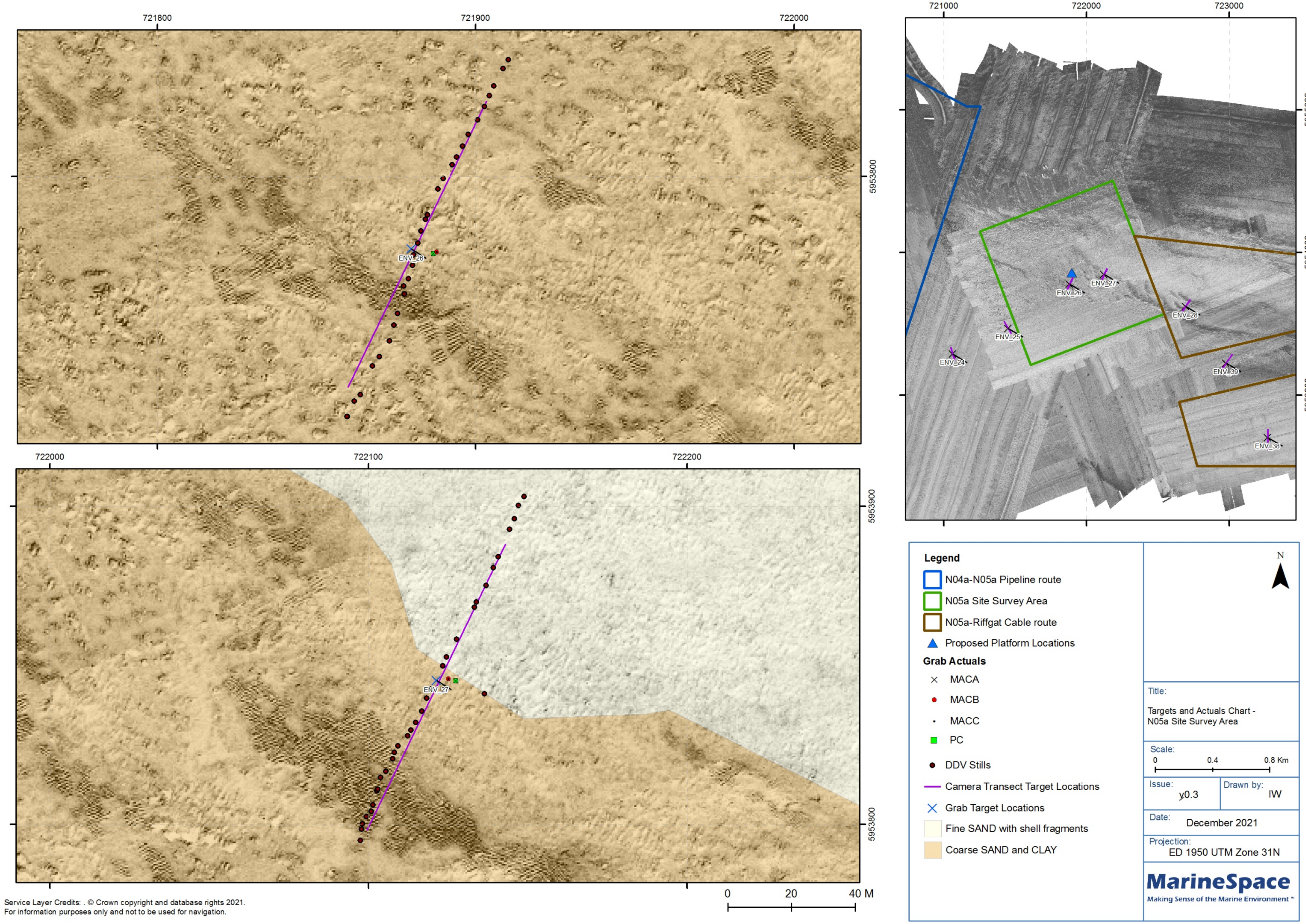
1 Proposed transect locations, actual drop-down video still positions are detailed in Appendix A
2 Start of line (SOL) and end of line (EOL)
3 Length achieved is longer for ENV27 as vessel went off track before getting back on course. Fix 57 was taken during this time and is therefore offset by 15 m from the transect target.

Table 1.3: Summary of grab sample targets and data acquired

Station	Proposed Easting (m)[1]	Proposed Northing (m)[1]	Depth (m LAT)[2]	Rationale	Grab Samples Acquired[3]			
					PC	MACA	MACB	MACC
ENV26	721881	5953778	25.2	Moved 40 m SW of a proposed vibrocore station in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV27	722123	5953846	24.6	Moved 55 m SW of a proposed vibrocore station in an area of homogenous lower reflectivity.	1	1	1	1

1 Grab proposed sample locations, actual sampling positions are detailed in Appendix A
2 Depth at target location recorded from processed MBES data
3 1 physico-chemistry sample (PC) and 3 macrofauna samples (MACA, MACB and MACC)

Figure 1.2: N05a-platform survey area including target and actuals



1.3. Background Habitat Information

1.3.1. Overview

This section presents an overview of sensitive habitats and species that are likely to occur within offshore Dutch and German waters in the vicinity of the Project.

As outlined in Section 1.1, the SOW (GEOxyz, 2021a) called for an assessment for the potential presence of important and environmentally sensitive habitats and species including Annex I habitats (1992), the OSPAR (2008) list of threatened and/or declining species and the IUCN Red List of threatened species (IUCN, 2021).

It is noted that the proposed pipeline route is located adjacent to the Borkum-Rifgrund site of community importance (SCI) and close to the Niedersächsisches Wattenmeer und angrenzendes Küstenmeer special area of conservation (SPA). The Borkum-Riffgrun area was designated as an SCI under the Habitats Directive (1992) based on the presence of protected habitats including sandbanks which are slightly covered by sea water all of the time and reefs as well as the presence of various bird species, shad *Alosa fallax* and grey seals *Halichoerus grypus*. The Niedersächsisches Wattenmeer und angrenzendes Küstenmeer was designated as an SPA in March 2010 due to the presence of numerous protected bird species.

Since 2018, a flat oyster *Ostrea edulis* reef restoration project – World Wildlife Fund (WWF) oyster bank project - has been ongoing in the Borkum Stones area, off the Dutch coast. In September 2019 evidence was obtained that settlement took place in the new established offshore population in 2018. Given its proximity to the project care has been taken to identify and record any oysters collected during the sampling programme for reporting back to the WWF oyster bank project.

The previous survey near the N05a platform (GEOxyz, 2019) identified sediment type and fauna within the survey area associated with the Annex I habitat: sandbanks which are slightly covered by sea water all of the time, which met the requirements outline by Jak *et al*., (2009) based on the Dutch Ministry of Agriculture, Nature and Food Quality (MANFQ, 2008). Additionally, 1 seabed camera transect exhibited potential resemblance to Annex I geogenic reef. However, following an assessment, the area was not considered to be sufficiently noteworthy to be classified as an Annex I stony reef.

The subsections below provides background information of sensitive species and habitats that may occur within the N05a platform area. Figure 1.1 spatially displays Marine Protected Areas (MPAs) in relation to the survey area.

1.3.2. H1170 - Reefs

Reefs (H1170) are one of the habitats listed under Annex I of the EU Habitats Directive (1992) for protection within SPAs. Reefs can be either biogenic concretions or of geogenic origin. Geogenic reefs are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.

Biogenic reefs can be identified as solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms.

Geogenic reefs can be identified where animal and plant communities develop on rock or stable boulders and cobbles. Geogenic reefs are extremely variable, both in structure and in the communities they support. Reefs are characterised by communities of attached algae (where there is sufficient light – on the shore and in the shallow subtidal) and invertebrates, usually associated with a range of mobile animals, including invertebrates and fish. The specific communities that occur vary according to a number of factors. For example, rock type is important, with particularly distinct communities associated with chalk and limestone. There may be further variety associated with topographical features such as vertical rock walls, gully and canyon systems, outcrops from sediment, and rockpools on the shore.

1.3.3. H1110 – Permanently flooded sandbanks

Sandbanks which are slightly covered with seawater all the time (H1110) are listed under Annex I of the EU Habitats Directive (1992). The habitat consists of sublittoral sandbanks that are permanently submerged by shallow sea water, typically at depths less than 20m below chart datum. The habitat comprises distinct banks which may arise from horizontal or sloping plains of sandy sediment.

The diversity and types of community associated with this habitat are determined particularly by sediment type together with a variety of other physical, chemical and hydrographic factors. Shallow sandy sediments are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms. Mobile epifauna at the surface of the sandbank may include shrimps, gastropod molluscs, crabs and fish. Sand-eels *Ammodyte*s spp., an important food for birds, live in sandy sediments. Where coarse stable material, such as shells, stones or maerl is present on the sediment surface, species of foliose seaweeds, hydroids, bryozoans and ascidians may form distinctive communities. Shallow sandy sediments are often important nursery areas for fish, and feeding grounds for seabirds (especially puffins *Fratercula arctica*, guillemots *Uria aalge* and razorbills *Alca torda*) and sea-duck (e.g. common scoter *Melanitta nigra*).

1.3.4. Flat oyster, *Ostrea edulis*

The flat oyster, *Ostrea edulis*, is listed on the OSPAR (2008) list of threatened and/or declining species and habitats. *O. edulis* is a sessile, filter-feeding bivalve, associated with highly productive estuarine and shallow coastal water habitats. *O. edulis* was nominated for inclusion on the OSPAR list with particular reference to global/regional importance, rarity, decline, role as a keystone species, sensitivity and threat, and as a priority for OSPAR Region II and *O. edulis* beds have been nominated as a habitat.

2. Data Acquisition

2.1. Drop-Down Video

DDV was undertaken with a high definition optical camera system. All imagery was collected using Ocean Ecology's SubC PLE subsea camera system providing 1080p High Definition (HD) video and 20 Megapixel (MP) stills imagery. Due to turbidity, the camera was mounted in a Clear Liquid Optical Chamber (CLOC) filled with fresh water to ensure imagery of suitable quality was obtained. Lighting from 2 LED strip lamps and 2 lasers separated by 10 cm were projected into the field of view for illumination and scaling. Positioning was determined by an ultra-short base line (USBL) positioning beacon attached to the camera frame.

Along each camera transect, photographs were taken at least every 10 m and more often when features of interest were encountered. On-board marine ecologists reviewed all video in situ and the DDV was deployed as follows:

- The vessel approached the target location, and the deck personnel were alerted to prepare lifting equipment, camera, and umbilical when on position;
- A test image was taken on the surface prior to deployment at each station to check that the lasers and camera were working correctly;
- The camera was raised using the moon pool A-frame and lowered into the water column to within 2 m of the seabed;
- A shackle system was used to keep the umbilical close to the winch wire. This reduced strain on the umbilical from the tide or vessel movement and prevented excess umbilical being deployed;
- Video recording was then started, and the camera lowered until gently landing on the seabed at which point a positional fix was taken;
- The camera was then kept on the seabed to wait for any suspended sediments in the field of view to disperse before a still image was taken;
- The camera was moved along the transect at a set speed of 0.3-0.5 knots. Where possible the seabed was kept in view throughout;
- Following the capture of the final image, the camera was lifted, video recording was stopped, and the camera was retrieved to the surface;
- The winch operator then took the tension on the wire and the deck crew ensured the camera umbilical was free for recovery;
- The vessel skipper then confirmed sea conditions were suitable for retrieval and the camera system was recovered aboard;
- The camera frame was then lowered onto the deck and the tension released.

2.2. Grab Sampling

A dual (2 x 0.1 m^2) Van Veen (DVV) grab was deployed at each determine stations using the following protocols:

- Vessel approached target location, bridge alerted deck personnel to prepare grab;

- Sea fastening on grab was released to allow deployment from the stern A-frame;
- Winch operator engaged grab system on arrival at target location;
- Vessel skipper confirmed sea conditions were suitable for deployment;
- Grab was deployed safely using the hydraulic winch and stern A-frame;
- When grab landed on bottom, a fix was taken and grab was retrieved to the water surface;
- When the grab reached the surface, the vessel was positioned to reduce pitch and roll;
- The grab was retrieved safely onto the stand and sample was released into a hopper.

Data taken from each station included the position, fix number and water depth.

To ensure consistency in sampling, grab samples were considered unacceptable if:

- Jaws had jammed open due to a large stone or shell allowing sediment washout;
- Small samples were obtained where the grab had not struck a flat area of bottom, or not hit true, causing a side or half bite of sediment;
- The grab was less than 50 % full or contained less than 5 litres;
- The presence of a hag fish (*Myxine glutinosa*) and/or mucous coagulants;
- There was obvious contamination of the sample from equipment, paint chips etc.;
- A sample was collected more than 50 m from the target location;
- Under no circumstances was pooling of samples undertaken.

Samples with a volume less than 5 litres were rejected and sampling at the location was reattempted. If continued attempts also failed to collect a valid sample, then the station was repositioned 50 m away.

A detailed log was compiled for each sample station including:

- Number and type of sample;
- Date and time of sampling;
- Volume of sample achieved;
- Photograph number of sample;
- Water depth (in meters);
- Co-ordinates of samples;
- Sample sediment description.

3. Data Processing and Analysis

3.1. Drop-Down Video

Video footage and stills photographs were successfully acquired along all proposed DDV transects. Stills and video footage were analysed by qualified Marine Ecologists. At each camera station, each photograph was assigned a brief sediment description and analysed for macrofauna, where possible, to species level and recorded for presence/absence. Percentage cover was determined for hydroid/bryozoan turf and Porifera.

A total of 62 DDV stills were captured, a selection of seabed photographs is presented in Appendix B, whilst positional logs for all DDV stills are in Appendix A along with the video logs.

3.2. Grab Sampling

The DVV enabled 2 samples of undisturbed surface sediment to be retrieved simultaneously. 3 replicates (A, B, and C) of hydrocarbons and 2 replicates (A and B) were collected for particle size analysis (PSA) and metals from 1 sample whilst 3 replicates (A, B, and C) of macrofauna were retained from a further 3 samples after being passed through a 0.5 mm sieve.

Detailed descriptions were made of each grab in the field notes and digital photographs were taken of all samples accompanied by a USBL derived fix. Visual descriptions of sediment were made (using the Folk classification categories) at the time of sampling, together with estimates of sample volume (as a measure of sampler efficiency).

Initial processing of sediment samples was undertaken in line with the following methodology:

- Assessment of sample size(s) and acceptability made;
- Photographs of the unreleased samples with station details and scale bar taken;
- 3 replicates (A, B and C) for hydrocarbons and organics (total organic carbon (TOC) and total organic matter (TOM)) analysis were collected using a metal scoop to a nominal depth of 2 cm and placed in a glass sample pot;
- 2 replicates (A and B) for heavy metal analysis were collected using a plastic scoop to a nominal depth of 2 cm and placed in a plastic sample pot;
- 2 replicates (A and B) for PSA were collected;
- Prior to any sub-sampling all sample pots were inspected for contamination and scoops cleaned using acetone.;
- Samples were then frozen and stored at approximately -18°C;
- All physico-chemical samples remained frozen during transport and further storage until analysed;
- Remaining DVV sample (macrofauna A) was then released into a container and photographed;
- Sample emptied onto 0.5 mm sieve net laid over 4mm sieve table and washed through using gentle rinsing with seawater hose;
- Residual sieve contents photographed and described;

- Remaining sample for sorting and identification backwashed into a suitably sized sample container using seawater and diluted 10% formalin solution, and then subsequently diluted with seawater to approximately 4-6%, to fix sample prior to laboratory analysis;
- Sample containers clearly labelled internally and externally with date, sample ID and project name;
- Second deployment conducted to collect a further 2 replicates of macrofauna (B and C)

A full suite of samples were collected from a total of 5 sampling attempts. All sampled stations, were collected within 10 m of the target location.

3.3. Habitat Analysis

3.3.1. Stony Reef Assessment

Characterisation of non-biogenic reefs is the presence of stable hard substrate in the form of large boulders and/or a coarse gravel fraction. There may be a mosaic of a (coarse) sediment types in which different sediment types alternate in appearance: places with gravel boulders alternating with coarse sand.

Under the Dutch MANFQ (2014a) habitat profile, the area of interest must meet the minimum area requirement of 100 m^2. The size may relate to more than one location, provided these locations are functionally related and the mutual distance is no more than 20 m. If an area meets this requirement, the limiting criteria, which partly determines the quality of the habitat type, are the substrate size (>64 mm) and the presence of sessile organisms that dependent on that hard substrate (Table 3.1). Small stones and gravel are only added to the habitat type if sessile organisms live on it. However, it is necessary that these places are part of an area with stones larger than 64 mm.

Table 3.1: Stony reef habitat quality (MANFQ, 2014a)

Good/Mediocre	Restrictive Criteria	Only in mosaic
Good	Area covered with hard compact substrates (whether or not with a thin mobile layer of sediment), where organisms that live on these substrates are dependent.	
Mediocre	Area covered with hard compact substrates at least 64 mm average, without a thin layer of sediment and without organisms depended on hard compact substrates.	
Mediocre	Area covered with hard compact substrates	Only in mosaic with independent qualifying components from H1170.

Other habitat quality characteristics include typical species associated with non-biogenic reefs, see Table 3.2. Other characteristics of good structure and function include low dynamics, good water quality, biotic structuring elements, very high biodiversity and natural build-up community.

Table 3.2: Typical species associated with reef habitat (H1170; MANFQ, 2014a)

Scientific Name	Species Group	Category
Lithothamnion sonderic	Red Algae	K
Alcyonium digitatum	Soft Coral	Cab
Sabellaria spinulosa	Bristle Worm	K + Ca
Chane duneri	Bristle Worm	K
Galathea intermedia	Crustaceans	E
Arcopagia crassa	Mollusc	Cab
Buccinium undate	Mollusc	Cab
Dosinia exoleta	Mollusc	Cab
Pododesmus patelliformis	Mollusc	K + ca
Micrenophrys lilljeborgic	Fish	E
Diplecogaster bimaculata	Fish	E
Haliclona oculata	Sponge	Cab
Aporrhais pespelecani	Mollusc	Cab
Simnia patula	Mollusc	Cab
Lophius piscatorius	Fish	Cab
Aequipecten opercularis	Mollusc	Cab
Urticina sp .	Anemone	Cab

3.3.2. H1110_C - Sandbank Assessment

Habitat type H1110 permanently flooded sandbanks is defined at landscape level based on shapes of the earth's surface and the flow of salt water. It concerns sandbanks in shallow parts of the sea that is constantly under water, with water rarely more than 20 m deep.

The Dutch government has subdivided the H1110 Habitat into three subtypes; H1110_A_Wadden Sea, H1110_B North Sea and H1110_C Offshore (MANFQ, 2014b). Habitat H1110_C has the most relevance to the N05a platform survey area, representing permanently flooded sandbanks in water depths up to 40 m. Subtype C is defined by the change in inclination angle (>0.5°) from the sandbank to the surrounding plain. The limiting criteria, as defined by MANFQ (2014b), which partly determine the quality of the habitat type, are the depth of the water above the sandbar and the substrate size. Characteristics species is another factor which partly determines the quality of the habitat type (Table 3.3).

Table 3.3: Typical species associated with sandbank habitat type H1110_C (MANFQ, 2014b)

Scientific Name	Species Group	Category[1]
Alcyonium digitatum	Soft Coral	K + Ca
Lanice conchilega	Bristle Worm	Cab
Sigalion mathildae	Bristle Worm	Ca
Aphrodita aculeata	Bristle Worm	K + Ca
Goniada maculata	Bristle Worm	Ca
Magelona papillicomis	Bristle Worm	Ca
Nephtys cirrosa	Bristle Worm	Ca
Nephtys hombergii	Bristle Worm	Ca
Spiophanes bombyx	Bristle Worm	Cab
Bathyporeia elegans	Crustacean	Cab
Bathyporeia guilliamsoniana	Crustacean	Ca
Corystes cassivelaunus	Crustacean	Cab
Liocarcinus holsatus	Crustacean	Ca
Urothoe poseidonis	Crustacean	Ca
Pagurus bernhardus	Crustacean	Ca
Acrocnida brachiata	Echinoderm	E
Astropecten irregularis	Echinoderm	Ca
Echinocyamus pusillus	Echinoderm	Ca
Luidia sarsii	Echinoderm	K + Ca

Scientific Name	Species Group	Category[1]
Ophiothrix fragilis	Echinoderm	K + Ca
Ophiura ophiura	Echinoderm	Ca
Amoglossus latema	Fish	Ca
Buglossidium luteum	Fish	Ca
Callionymus lyra	Fish	Ca
Eutrigla gumardus	Fish	Ca
Gadus morhua	Fish	Ca
Limanda limanda	Fish	Ca
Merlangius merlangus	Fish	Ca
Microstomus kitt	Fish	Ca
Pleuronectes platessa	Fish	Ca
Fabulina fabula	Mollusc	Cab
Arctica islandica	Mollusc	Ca
Buccinum undatum	Mollusc	K + Cab
Ensis ensis	Mollusc	Cab
Euspira nitida	Mollusc	Cab
Gari fervensis	Mollusc	Cab
Kurtiella bidentata	Mollusc	Cab
Neptunea antiqua	Mollusc	K + Cab

1 Ca = constant species with indication of good abiotic status, Cb = constant species with indication for food biotic structure, Cab = constant species with indication of good abiotic status and good biotic structure, K = characteristic species, E = exclusive species.

3.4. EUNIS Habitat Classification Assessment

Habitat classification which takes into account both abiotic and biotic features is a relatively new development. The need for a habitat classification system has several driving forces; establishment of habitat protection, inventory of habitats in a biogeographic region country or site; monitoring and reporting description of species' habitat requirements.

To meet the need for a habitat classification, EUNIS was developed between 1996 and 2001 by the European Environment Agency (EEA) in collaboration with European experts. The EUNIS habitat classification is a comprehensive system covering the terrestrial and marine habitat types of the European land mass and its surrounding seas. It is hierarchical in structure and includes a key with criteria for identification of habitats at the first three levels (Table 3.4).

Table 3.4: EUNIS hierarchical structure example

Level	Level Description	Hierarchical Example (EUNIS code)
1	Distinguishes between 'Marine' and terrestrial coastal habitats	Marine (A)
2	Habitats selected based on substrate type and biological zone	Sublittoral sediment (A5)
3	Sediment habitats are subdivided based on broad sediment type.	Sublittoral coarse sediment (A5.1)
4	Sublittoral sediment habitats are subdivided by salinity and more specific biological zone.	Infralittoral coarse sediment (A5.13)
5	At this level biotopes are defined based on their characterising species	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand (A5.137)

EUNIS benthic biotopes can be assigned using analysed faunal and physical data. Within this report, available data for EUNIS assessment includes geophysical data, epifauna and sediment observations from DDV and grab samples.

4. Survey Results

4.1. Geophysical Survey

The following bathymetry and seabed features information is summarised from the N05a platform area geophysical report by GEOxyz (2021b). Data acquired from the current survey has been supplemented by previous survey data acquired in 2019.

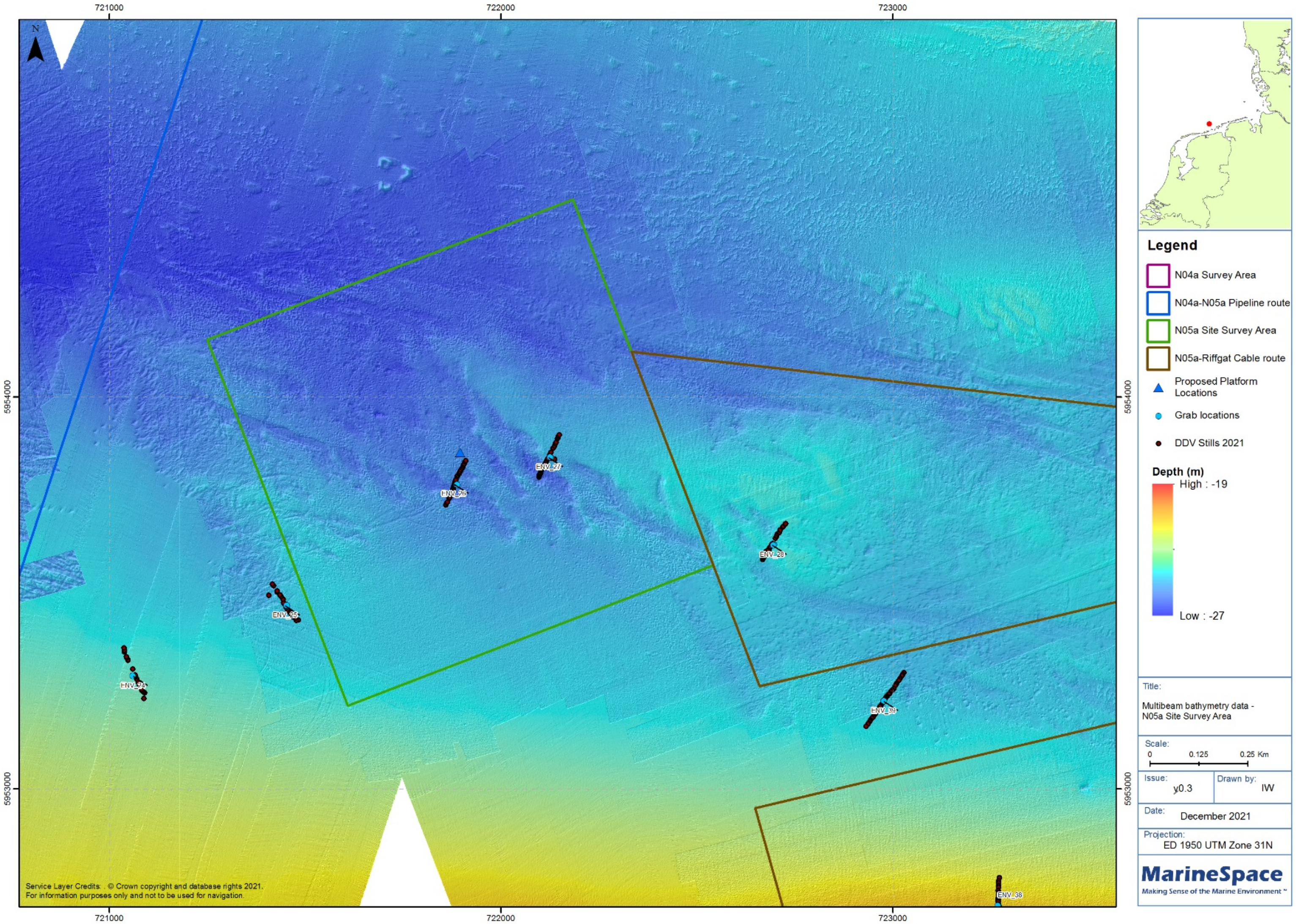
The 2021 geophysical survey comprised multibeam echosounder (MBES), side scan sonar (SSS), magnetometer, sub-bottom profiler (SBP) and 2D ultra high resolution (2DUHR) data over a 1 km x 1 km survey area centred on the proposed N05a Platform Location (see Section 1.1)

4.1.1. Bathymetry

Bathymetry within the N05a platform area is shown in Figure 4.1. Water depths ranged from a minimum of 23.7 LAT in the south to a maximum of 26.2 m LAT in the north.

The seabed dipped gently to the north at a negligible gradient of less than 1°. Small areas with relief of up to 0.5 m were observed on the bathymetry data with measured gradients of up to 6° on their flanks. Surface relief within the survey area was interpreted to be largely due to outcropping clay.

Figure 4.1: Bathymetry across the N05a platform survey area



4.1.2. Seabed Features

Interpretation of seabed features, sediment and seabed contacts from the current and 2019 SSS data is presented in Appendix C.

Seabed sediments were interpreted within the northern half of the 1 km x 1 km survey area as to comprise sand and clay. In the south of the survey area sediments were expected to comprise fine sand with shell fragments.

Outcrops of clay were interpreted within the survey area. These had a positive relief of up to 0.5 m above background seabed levels with measured gradients of up 6° on their flanks.

Numerous SSS contacts were identified within the charted area, with the majority interpreted as boulders within the charted area. Most of these contacts were identified within the areas where seabed sediments were interpreted as coarse sand and clay although occasional contacts were seen outside these areas. The closest contact to N05a platform location occurred 52 m north-north-east and was interpreted as boulder with height of less than 0.5 m.

Several contacts were interpreted as potential debris based on their shape/appearance on SSS records. The closes potential debris to the proposed N05a platform location occurred 191 m south and measured 1.1 m x 0.9 m x 0.1 m. A magnetic anomaly of 35 nT corresponded with the position of this potential item of debris. One item of linear debris was interpreted 217 m north-west and measured 22 m in length and had been interpreted as an abandoned wire/cable.

Several magnetic contacts were detected within the charted area. The closest to the proposed N05a platform location occurred 135 m east-south-east and measured 13 nT.

4.1.3. Shallow Geology

In this report, shallow geology refers to geology that is 0 - 50 m below the seabed.

Interpretation of shallow soils across the survey area was based upon pinger and 2D UHR data. Additional information was gained from vibrocore logs and borehole N5-1. Borehole N5-1 is located 751 m north-north-west of the proposed N05a platform location and was acquired by Fugro in November 2016 (Fugro, 2016). Vibrocores VC_13 and VC_14 were located within the 1 km x 1 km survey area, with the VC_13 sample closest to the proposed N05a platform location, 56 m to the south. Pinger and 2D UHR data examples at the proposed N05a platform location are included as Figure 4.2 and Figure 4.3, respectively.

The uppermost mappable unit was confirmed as fine sand with occasional shell fragments in vibrocore logs. The unit was mapped from pinger data and was only mappable when thicker than 0.5 m: it was likely to be present outside the mapped area (north-east of survey area) but at thicknesses below 0.5 m. The unit was 0.6m thick at the proposed N05a platform location.

The 2D UHR data has been interpreted based on changes in acoustic signature within the survey area. Geophysical contrasts were subtle: a predictable consequence of the similar geological nature of the units sampled within the borehole.

Three sub units within the Quaternary sequence have been interpreted within the area based on the acoustic nature of the sparker data.

The uppermost unit, (besides surficial sand mapped from the Pinger data), present within the survey area was interpreted to infill a south-south-east/north-north-west orientated channel and comprise fine sand based on vibrocore data and seismic characteristics. The unit was absent in the south-west and north-east of the survey area. At the proposed N05a platform location the unit occurred 15.5 m below seabed (BSB).

Below this a chaotic unit, interpreted to represent a succession of interbedded medium to high strength sandy clay and medium dense to dense sand when tied to the N5-1 borehole. At the proposed N05a platform location this unit extended to a depth of 56.5 m BSB. Within the survey area this unit undulated between 4 m and 72 m BSB. This unit is mapped on Chart 5.

Below this, an acoustically higher amplitude unit with intermittent reflectors, interpreted to represent internal layering within the unit was present which also in places had a chaotic, low amplitude response. This unit was expected to comprise dense, poorly sorted gravelly sands and high strength clays with occasional cobbles or boulders. This unit extend to the limit of interpretation of 0.2 seconds (187 m BSB) at the proposed N05a platform location.

This extended to the base of the Quaternary sequence. Caution should be taken when drilling in the Quaternary sequence as boulders and cobbles may be present throughout. There were no diffractions that could be attributed to individual boulders at or close to the proposed N05a platform location. However, due to the presence of boulders on the seabed and the generic possibility of boulders within the Quaternary sediments mean that, despite the lack of direct seismic evidence, the presence of buried boulders at the proposed N05a platform location is possible.

Figure 4.2: Sub-bottom Profiler data example at N05a platform location

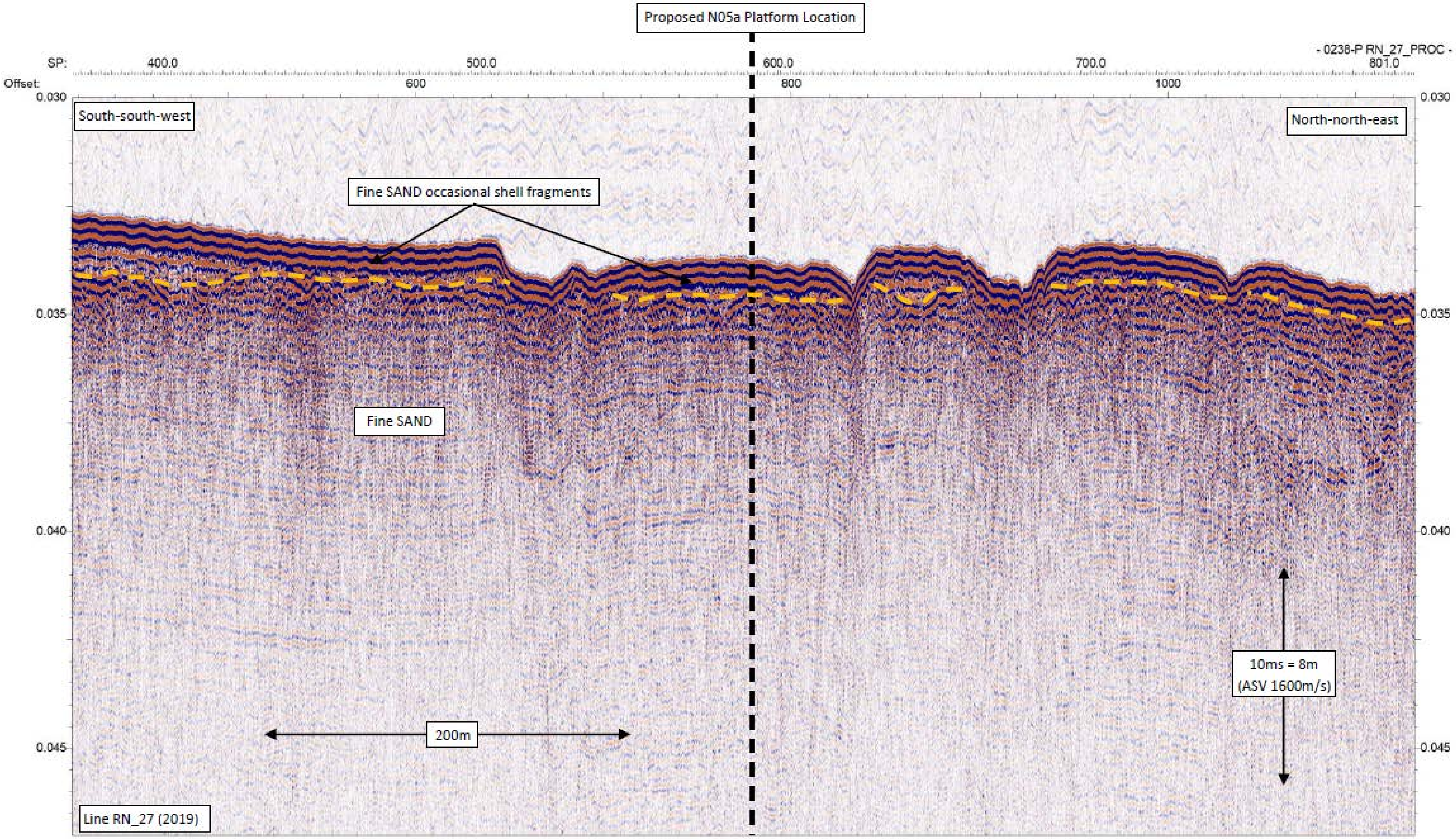
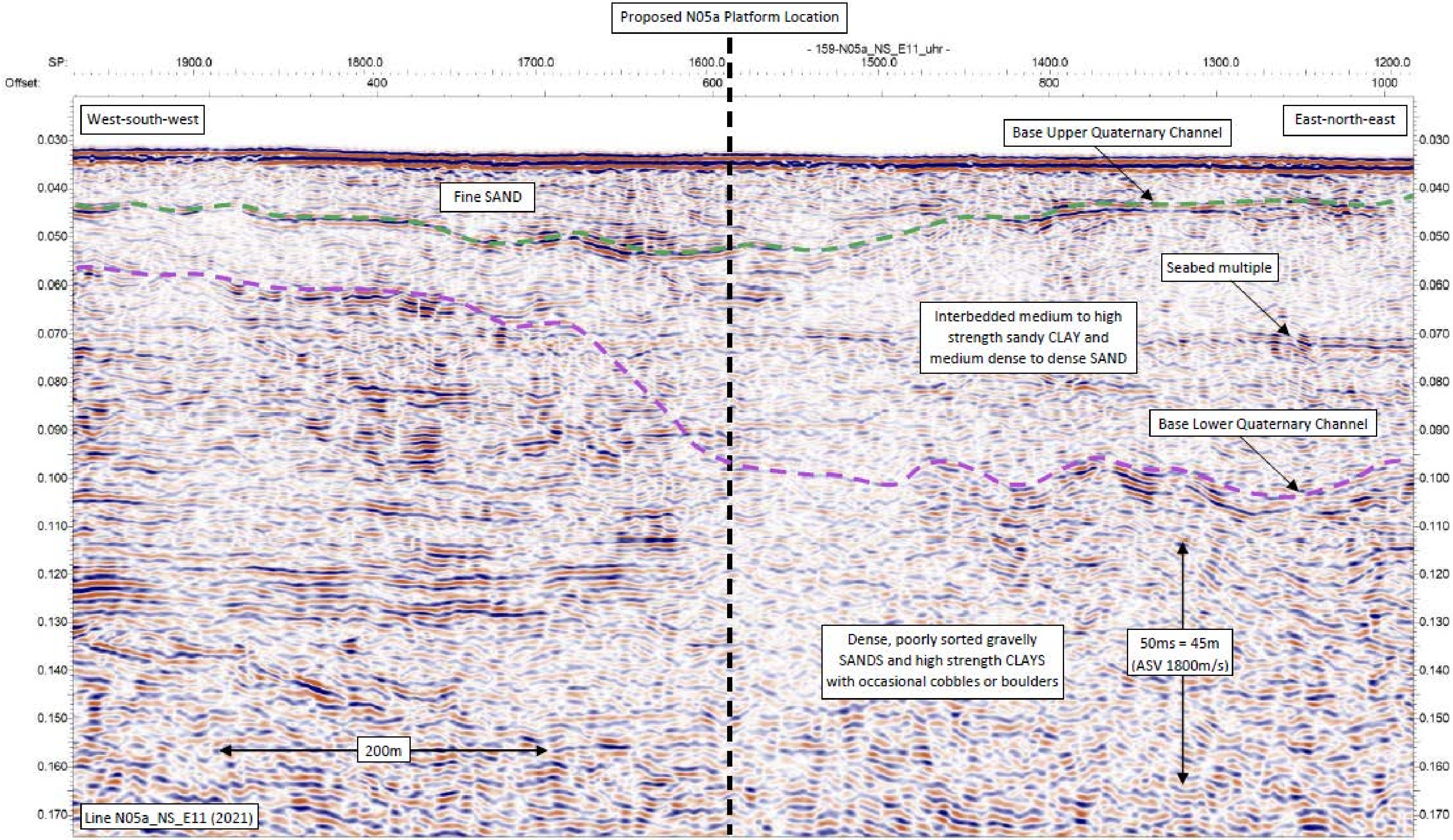


Figure 4.3: UHR data example at N05a platform location



4.2. Habitat Assessment

4.2.1. Seabed Imagery Observations

Seabed imagery ground truthed the areas interpreted by the SSS data as 'fine sand with shell fragments' and 'coarse sand and clay'.

Sediments were confirmed to comprise finer sand within the area described by the SSS data as 'fine sand with shell fragments'. A mixture of coarse sand with shell fragments were observed in the area described as 'coarse sand and clay'.

Visible fauna identified within the N05a platform area, identified to the lowest possible taxon, are listed in Appendix D and included:

- Annelida (*Lanice conchilega*);
- Arthropoda (*Liocarcinus* sp.);
- Chordata (Actinopterygii, Pleuronectiformes) ;
- Cnidaria (*Cylista sp.*, Pennatulacea) ;
- Echinodermata (Asteroidea, *Ophiura albida*, Ophiuroidea);
- Indeterminate turf.

Review of the video footage revealed an additional 3 taxa within the N05a platform area; Caridea, *Limanda limanda* and *Ophiura ophiura*.

The most frequently observed taxa within the DDV stills was the sand mason worm *L. conchilega* (92%) followed by burrowing anemone *Cylista sp.* (45%) and brittle stars Ophiuroidea *(*35%). There were 5 DDV stills which were considered to have high density of *L. conchilega*, all of which occurred along Transect ENV26.

L. conchilega and *O. ophiura* were the only observed species considered typical of H1110_C permanently flooded sandbanks and were observed along both Transects ENV26 and ENV27. Both species are considered constant species with indication of good abiotic status. Also, *L. conchilega* indicates good biotic structure.

Only 1 individual of Pennatulacea was observed within the N05a platform area, at Transect ENV26. Consequently, **there is little resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat** (OSPAR, 2008)**.**

A selection of seabed images, together with descriptions and positions are presented in Appendix B. Also, a summary table of faunal presence and absence is presented in Appendix D and example photographs of the taxa observed is provided in Appendix E.

4.2.2. Seabed Sampling Observations

Grab samples, were all collected from seabed of 'coarse sand and clay' and were described as either sandy gravelly mud or muddy gravelly sand (Folk, 1954).

Typical species observed within the grab samples included but were not limited to Caridea, *Lanice conchilega*, Pectinariidae, Polychaeta, Spatangoida.

4.2.3. Stony Reef Assessment

Substrate larger than 64 mm (cobbles and boulders) was not observed from seabed imagery. Similarly, no typical species associated with Reefs (H1170) were seen within seabed imagery or seabed sampling observations.

As there were no hard substrate areas or typical species identified from the 2021 DDV data, the areas observed within the N05a platform area could not be defined as Reefs (H1170) under the Dutch MANFQ criteria (MANFQ, 2014a)**.**

4.2.4. Sandbank (H1110_C) Assessment

Sediments within the N05a platform location were described as either sandy gravelly mud or muddy gravelly sand, however, only muddy gravelly sand is considered as having sufficient sand content to meet the requirements of the H1110_C habitat subtype. Depths within and around the N05a platform location ranged from 23.7 m LAT to 26.2 m LAT. Review of the macrofauna revealed the presence of 2 species considered typical of the habitat (see Section 4.2.1).

Although, depth, sediment and some typical fauna were characteristic of a sandbank habitat, there were no defined sandbank features identified in this area (see Section 4.1.2). Consequently, this area is unlikely to represent EC Habitats Directive Annex I habitat subtype H1110_C.

4.2.5. EUNIS Habitat Classification

The EUNIS classification hierarchy to biotope level 4 was mainly based on depth and sediment type. Results of the EUNIS habitat classification are based on geophysical data, seabed imagery and grab sediment interpretation and are summarised in Table 4.1. EUNIS level 3 habitat boundaries are presented in Figure 4.4 as well as individual DDV stills EUNIS level assessment.

All habitats observed related to the EUNIS level 1 category marine habitats (EUNIS code A) and level 2 category sublittoral sediment (EUNIS code A5), corresponding to sediment habitats in sublittoral near shore zone extending to 200 m depth.

EUNIS level 3 habitat classification was determined based on geophysical data, seabed imagery and grab interpretation of sediment composition. Sand was the dominant component of the sediment across all targets, therefore all targets were classified either as EUNIS habitat A5.2 sublittoral sand or A5.1 sublittoral coarse sediment. A5.2 sublittoral sand is described by the EEA (2019) as medium to fine sand or non-cohesive slightly muddy sands. A5.1 sublittoral coarse sediment is described by the EEA as coarse sediment including coarse sand, gravel, pebbles, shingles and cobbles, which are often unstable due to tidal currents and/or wave action. Transect ENV27 crossed through more than 1 SSS sediment boundary and so has been assigned more than 1 EUNIS habitat category.

Across the N05a platform location, the corresponding level 4 habitat classifications were identified:

- EUNIS habitat A5.23 infralittoral fine sand is described as clean sand which occur in shallow water, either on open coast or in tide swept channels or marine inlets. The habitat is typically characterised by robust fauna, particularly amphipods (*Bathyporeia*) and robust polychaetes including *Nepthys cirrosa* and *Lanice conchilega*;

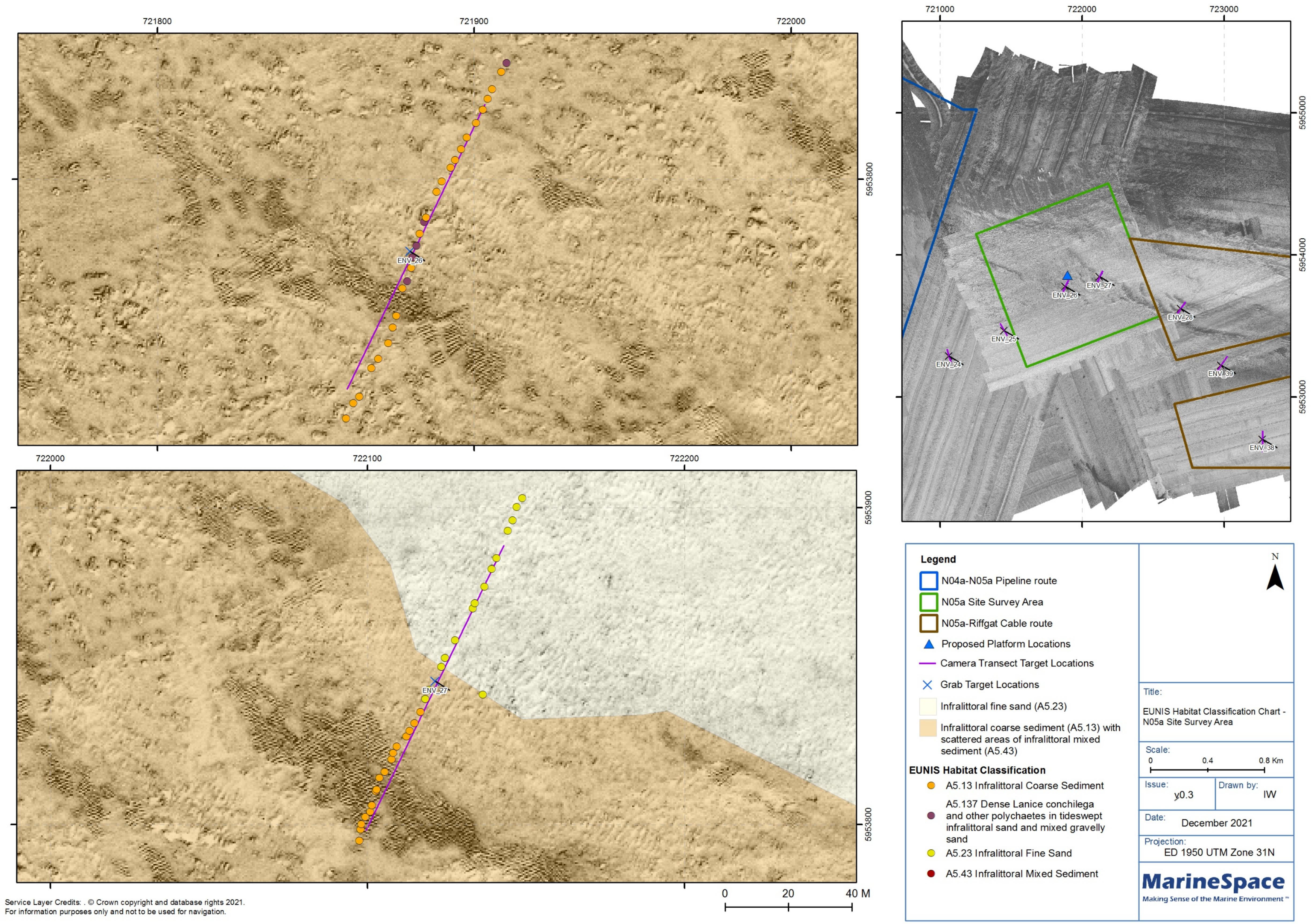
- EUNIS habitat A5.13 infralittoral coarse sediment is described as moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, are subject to disturbance by tidal streams and wave action. This habitat is characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, cumacean crustacea such as *Iphinoe trispinosa* and *Diastylis bradyi*, and venerid bivalves.

In addition, due to the characteristic abundance of *Lanice conchilega*, it was possible to assign the biotope A5.137 dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand to sections of Transects ENV26.

Table 4.1: EUNIS classification with N05a platform survey area

<table>
<tr><th>Station</th><th>Depth (m LAT)</th><th>Sediment description (Folk, 1954) from Grab Observations</th><th>EUNIS Habitat Classification</th></tr>
<tr><td rowspan="2">ENV_26</td><td rowspan="2">24-26</td><td rowspan="2">Sandy Gravelly Mud</td><td>A5.13 Infralittoral Coarse Sediment</td></tr>
<tr><td>A5.137 Dense Lanice conchilega and other polychaetes in tides wept infralittoral sand and mixed gravelly sand</td></tr>
<tr><td rowspan="2">ENV_27</td><td rowspan="2">25 - 26</td><td rowspan="2">Sandy Gravelly Mud to Muddy Gravelly Sand</td><td>A5.13 Infralittoral Coarse Sediment</td></tr>
<tr><td>A5.23 Infralittoral Fine Sand</td></tr>
</table>

Figure 4.4: EUNIS Habitats within N05a platform survey area



5. Conclusion

Seabed imagery supported the geophysical data of ‘fine sand with shell fragments’ and ‘coarse sand with clay’. EUNIS classification identified 2 x 3 level EUNIS habitats A5.13 infralittoral coarse sediment, A5.23 infralittoral fine sand as well as 1 x 4 level EUNIS habitat A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand.

Seabed imagery across the area of ‘coarse sand with clay’ revealed coarser sediment, while revealing fine sand in areas of ‘fine sand with shell fragments’. Fauna was generally scarce except for *L. conchilega*, which was the most frequently observed taxa.

As there were no hard substrate areas or associated species identified from the 2021 DDV data, the areas observed within the N05a platform area could not be defined as Reefs (H1170) under the Dutch guidance (MANFQ, 2014a).

Although, depth, sediment type and some associated fauna were found present, there were no defined sandbank features identified within the N05a platform survey area. Consequently, this area is unlikely to represent EC Habitats Directive Annex I habitat subtype H1110_C.

Only one individual of Pennatulacea was observed within the N05a platform survey area. Consequently, there is little resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat (OSPAR, 2008).

Other than those detailed above there was no further evidence of any Annex I habitats, any species or habitats on the OSPAR (2008) list of threatened and/or declining species or any species on the IUCN Global Red List within the N05a platform survey area.

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Appendix A. Environmental Field Logs

Appendix A1: Stills positional logs

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_26	MARDUT1021_ENV_26_2021_11_05_174342.jpg	70	17:44:23	05/11/2021	53.683908	6.359625	721859.700	5953724.631
ENV_26	MARDUT1021_ENV_26_2021_11_05_174350.jpg	71	17:44:30	05/11/2021	53.683908	6.359624	721859.620	5953724.630
ENV_26	MARDUT1021_ENV_26_2021_11_05_174437.jpg	72	17:45:17	05/11/2021	53.683951	6.359662	721861.900	5953729.460
ENV_26	MARDUT1021_ENV_26_2021_11_05_174500.jpg	73	17:45:41	05/11/2021	53.683968	6.359692	721863.790	5953731.530
ENV_26	MARDUT1021_ENV_26_2021_11_05_174535.jpg	74	17:46:16	05/11/2021	53.684048	6.359757	721867.630	5953740.550
ENV_26	MARDUT1021_ENV_26_2021_11_05_174600.jpg	75	17:46:40	05/11/2021	53.684073	6.359792	721869.810	5953743.470
ENV_26	MARDUT1021_ENV_26_2021_11_05_174634.jpg	76	17:47:14	05/11/2021	53.684115	6.359842	721872.900	5953748.330
ENV_26	MARDUT1021_ENV_26_2021_11_05_174658.jpg	77	17:47:38	05/11/2021	53.684159	6.359868	721874.360	5953753.290
ENV_26	MARDUT1021_ENV_26_2021_11_05_174720.jpg	78	17:48:00	05/11/2021	53.684193	6.359886	721875.430	5953757.050
ENV_26	MARDUT1021_ENV_26_2021_11_05_174742.jpg	79	17:48:22	05/11/2021	53.684246	6.359924	721877.655	5953763.125
ENV_26	MARDUT1021_ENV_26_2021_11_05_174748.jpg	80	17:48:29	05/11/2021	53.684269	6.359922	721877.360	5953765.610
ENV_26	MARDUT1021_ENV_26_2021_11_05_174806.jpg	81	17:48:46	05/11/2021	53.684289	6.359946	721878.890	5953767.930
ENV_26	MARDUT1021_ENV_26_2021_11_05_174818.jpg	82	17:48:58	05/11/2021	53.684326	6.359969	721880.210	5953772.110
ENV_26	MARDUT1021_ENV_26_2021_11_05_174832.jpg	83	17:49:12	05/11/2021	53.684356	6.359977	721880.550	5953775.460
ENV_26	MARDUT1021_ENV_26_2021_11_05_174846.jpg	84	17:49:26	05/11/2021	53.684388	6.359998	721881.760	5953779.110
ENV_26	MARDUT1021_ENV_26_2021_11_05_174901.jpg	85	17:49:42	05/11/2021	53.684422	6.360016	721882.790	5953782.920
ENV_26	MARDUT1021_ENV_26_2021_11_05_174917.jpg	86	17:49:57	05/11/2021	53.684454	6.360040	721884.170	5953786.650
ENV_26	MARDUT1021_ENV_26_2021_11_05_174922.jpg	87	17:50:02	05/11/2021	53.684466	6.360051	721884.840	5953788.030
ENV_26	MARDUT1021_ENV_26_2021_11_05_174945.jpg	88	17:50:25	05/11/2021	53.684538	6.360106	721888.100	5953796.160
ENV_26	MARDUT1021_ENV_26_2021_11_05_174957.jpg	89	17:50:37	05/11/2021	53.684566	6.360133	721889.760	5953799.400
ENV_26	MARDUT1021_ENV_26_2021_11_05_175013.jpg	90	17:50:53	05/11/2021	53.684605	6.360180	721892.620	5953803.780
ENV_26	MARDUT1021_ENV_26_2021_11_05_175022.jpg	91	17:51:02	05/11/2021	53.684625	6.360203	721894.050	5953806.170
ENV_26	MARDUT1021_ENV_26_2021_11_05_175036.jpg	92	17:51:17	05/11/2021	53.684656	6.360233	721895.890	5953809.650

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_26	MARDUT1021_ENV_26_2021_11_05_175054.jpg	93	17:51:34	05/11/2021	53.684688	6.360264	721897.730	5953813.280
ENV_26	MARDUT1021_ENV_26_2021_11_05_175113.jpg	94	17:51:54	05/11/2021	53.684727	6.360310	721900.580	5953817.840
ENV_26	MARDUT1021_ENV_26_2021_11_05_175133.jpg	95	17:52:14	05/11/2021	53.684764	6.360347	721902.800	5953822.080
ENV_26	MARDUT1021_ENV_26_2021_11_05_175147.jpg	96	17:52:27	05/11/2021	53.684794	6.360372	721904.310	5953825.460
ENV_26	MARDUT1021_ENV_26_2021_11_05_175200.jpg	97	17:52:41	05/11/2021	53.684821	6.360395	721905.700	5953828.490
ENV_26	MARDUT1021_ENV_26_2021_11_05_175216.jpg	98	17:52:57	05/11/2021	53.684869	6.360444	721908.660	5953833.999
ENV_26	MARDUT1021_ENV_26_2021_11_05_175229.jpg	99	17:53:09	05/11/2021	53.684893	6.360471	721910.310	5953836.750
ENV_27	MARDUT1021_ENV_27_2021_11_05_165000.jpg	38	16:50:42	05/11/2021	53.684438	6.363270	722097.500	5953794.920
ENV_27	MARDUT1021_ENV_27_2021_11_05_165024.jpg	39	16:51:07	05/11/2021	53.684470	6.363278	722097.880	5953798.500
ENV_27	MARDUT1021_ENV_27_2021_11_05_165035.jpg	40	16:51:18	05/11/2021	53.684484	6.363282	722098.070	5953800.060
ENV_27	MARDUT1021_ENV_27_2021_11_05_165055.jpg	41	16:51:37	05/11/2021	53.684504	6.363304	722099.425	5953802.421
ENV_27	MARDUT1021_ENV_27_2021_11_05_165109.jpg	42	16:51:52	05/11/2021	53.684519	6.363328	722100.910	5953804.079
ENV_27	MARDUT1021_ENV_27_2021_11_05_165117.jpg	43	16:52:00	05/11/2021	53.684537	6.363338	722101.460	5953806.125
ENV_27	MARDUT1021_ENV_27_2021_11_05_165139.jpg	44	16:52:21	05/11/2021	53.684576	6.363359	722102.665	5953810.520
ENV_27	MARDUT1021_ENV_27_2021_11_05_165143.jpg	45	16:52:25	05/11/2021	53.684581	6.363364	722102.985	5953811.075
ENV_27	MARDUT1021_ENV_27_2021_11_05_165200.jpg	46	16:52:42	05/11/2021	53.684613	6.363379	722103.785	5953814.740
ENV_27	MARDUT1021_ENV_27_2021_11_05_165210.jpg	47	16:52:52	05/11/2021	53.684630	6.363406	722105.445	5953816.670
ENV_27	MARDUT1021_ENV_27_2021_11_05_165225.jpg	48	16:53:08	05/11/2021	53.684664	6.363441	722107.605	5953820.545
ENV_27	MARDUT1021_ENV_27_2021_11_05_165232.jpg	49	16:53:14	05/11/2021	53.684681	6.363450	722108.105	5953822.535
ENV_27	MARDUT1021_ENV_27_2021_11_05_165242.jpg	50	16:53:24	05/11/2021	53.684699	6.363469	722109.295	5953824.574
ENV_27	MARDUT1021_ENV_27_2021_11_05_165259.jpg	51	16:53:41	05/11/2021	53.684727	6.363518	722112.320	5953827.841
ENV_27	MARDUT1021_ENV_27_2021_11_05_165311.jpg	52	16:53:54	05/11/2021	53.684742	6.363533	722113.280	5953829.554
ENV_27	MARDUT1021_ENV_27_2021_11_05_165328.jpg	53	16:54:10	05/11/2021	53.684764	6.363559	722114.880	5953832.035
ENV_27	MARDUT1021_ENV_27_2021_11_05_165346.jpg	54	16:54:28	05/11/2021	53.684794	6.363590	722116.760	5953835.540
ENV_27	MARDUT1021_ENV_27_2021_11_05_165407.jpg	55	16:54:49	05/11/2021	53.684830	6.363617	722118.335	5953839.589
ENV_27	MARDUT1021_ENV_27_2021_11_05_165417.jpg	56	16:54:59	05/11/2021	53.684856	6.363635	722119.420	5953842.499
ENV_27	MARDUT1021_ENV_27_2021_11_05_165435.jpg	57	16:55:17	05/11/2021	53.684835	6.363891	722136.390	5953841.000
ENV_27	MARDUT1021_ENV_27_2021_11_05_165452.jpg	58	16:55:34	05/11/2021	53.684919	6.363700	722123.348	5953849.765

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_27	MARDUT1021_ENV_27_2021_11_05_165509.jpg	59	16:55:51	05/11/2021	53.684944	6.363719	722124.453	5953852.572
ENV_27	MARDUT1021_ENV_27_2021_11_05_165533.jpg	60	16:56:15	05/11/2021	53.684993	6.363772	722127.735	5953858.155
ENV_27	MARDUT1021_ENV_27_2021_11_05_165614.jpg	61	16:56:56	05/11/2021	53.685080	6.363863	722133.240	5953868.120
ENV_27	MARDUT1021_ENV_27_2021_11_05_165626.jpg	62	16:57:08	05/11/2021	53.685094	6.363874	722133.940	5953869.805
ENV_27	MARDUT1021_ENV_27_2021_11_05_165643.jpg	63	16:57:26	05/11/2021	53.685140	6.363923	722136.940	5953874.980
ENV_27	MARDUT1021_ENV_27_2021_11_05_165659.jpg	64	16:57:41	05/11/2021	53.685189	6.363962	722139.250	5953880.634
ENV_27	MARDUT1021_ENV_27_2021_11_05_165715.jpg	65	16:57:57	05/11/2021	53.685219	6.363987	722140.715	5953884.045
ENV_27	MARDUT1021_ENV_27_2021_11_05_165746.jpg	66	16:58:28	05/11/2021	53.685295	6.364048	722144.360	5953892.700
ENV_27	MARDUT1021_ENV_27_2021_11_05_165758.jpg	67	16:58:40	05/11/2021	53.685324	6.364072	722145.805	5953895.965
ENV_27	MARDUT1021_ENV_27_2021_11_05_165818.jpg	68	16:59:00	05/11/2021	53.685362	6.364095	722147.110	5953900.205
ENV_27	MARDUT1021_ENV_27_2021_11_05_165838.jpg	69	16:59:20	05/11/2021	53.685385	6.364125	722148.930	5953902.945

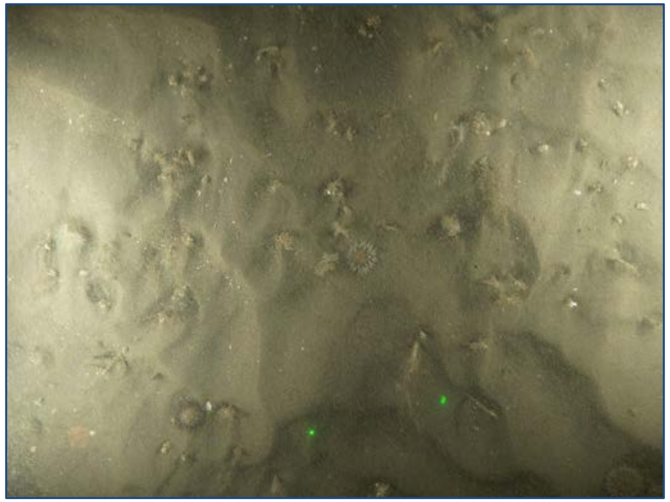
Appendix A2: Drop down video positional logs

Station	Date	Video Start Time (UTC)	Video Length	Video End Time (UTC)	No. of Videos	No. of Images	Video File Name	Depth (m)	Camera System	Freshwater Housing Height Setting	Distance Between Laser Points (cm)	FOCI/OSPAR present (excluding reef)	Potential Annex I reef?	Camera Time Offset	Notes
ENV_26	05/11/2021	17:43:49	00:09:23	17:53:12	1	30	MARDUT1021_ENV_26_2021_11_05_174308	25.0	SubC Imaging PLE System	High	10	N	N	00:00:41	Rippled sand with sand mason worms and burrowing anemones
ENV_27	05/11/2021	16:48:30	00:10:54	16:59:24	2	32	MARDUT1021_ENV_27_2021_11_05_164749, MARDUT1021_ENV_27_2021_11_05_165750	25.0	SubC Imaging PLE System	High	10	N	N	00:00:41	Rippled sand with shells. Sand mason worms and burrowing anemones.

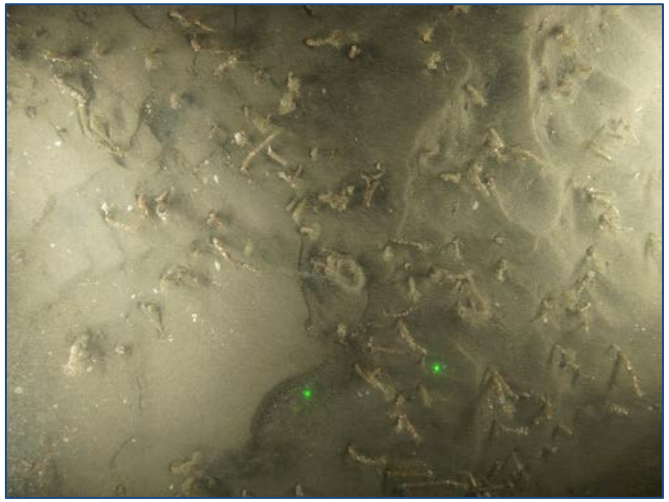
Appendix A3: Grab sampling positional logs

Station Details			Sampling Details								Positional Data							Sample Description	Photos			
Station I.D.	Attempt No.	Sampled Type (Post-Survey)	Method	Vessel	Personnel (Initials)	Water Depth (m)	Fix Number	Date	Time (UTC)	Target Easting	Target Northing	Sampled Easting	Sampled Northing	Coordinate System	Distance from Target (m)	Sample Volume (L)	Sediment Description (Folk)	Unreleased Sample	Released Sample	Sieved Sample	Notes
ENV_26	1	PC/MACA	Dual Van Veen	Geo Ocean III	MM	24.6	9	2021-11-09	09:03:47	721881	5953778	721887	5953776	ED50	6	8	Sandy Gravelly Mud (sgM)	Y	Y	Y	*Lanice conchilega*, Polychaeta
ENV_26	1	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	24.6	10	2021-11-09	09:31:43	721881	5953778	721888	5953776	ED50	7	8	Sandy Gravelly Mud (sgM)	Y	Y	Y	Caridea, *Lanice conchilega*, Pectinariidae, Spatangoida
ENV_27	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	24.9	11	2021-11-09	10:20:29	722123	5953846	722127	5953845	ED50	5	8	Sandy Gravelly Mud (sgM)	Y	Y	Y	Polychaeta, Spatangoida
ENV_27	2	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	24.9	13	2021-11-09	11:07:21	722123	5953846	722125	5953846	ED50	2	8	Muddy Gravelly Sand (mgS)	Y	Y	Y	1st attempt <2 l. Spatangoida.

Appendix B. Selection of Sample and Seabed Photographs



Fix: 71 E: 721859.6 N: 5953724.6 Depth: 25.8 m



Fix: 84 E: 721881.8 N: 5953779.1 Depth: 25.5 m

Station: ENV 26

Image 1: MARDUT1021_ENV_26_2021_11_05_174350

Sediment Description: Rippled sand with few small shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; Ophiuroidea.

Image 2: MARDUT1021_ENV_26_2021_11_05_174846

Sediment Description: Rippled sand with few small shell fragments.

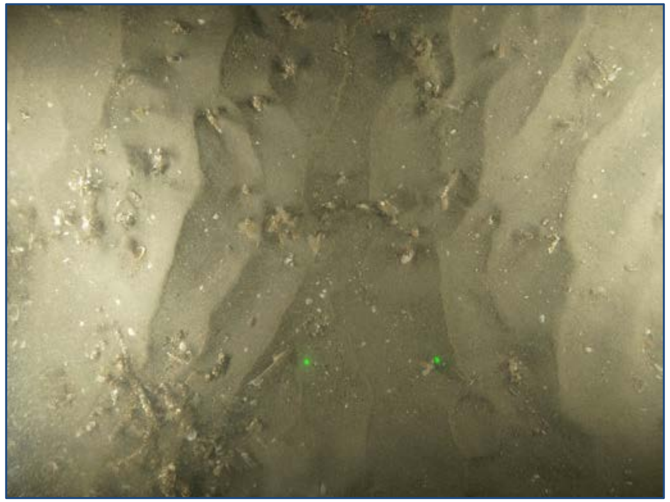
Faunal Description: *Cylista* sp.; *Lanice conchilega.*

Fix: 9 E: 721881.4 N: 5953777.6 Depth: 25 m

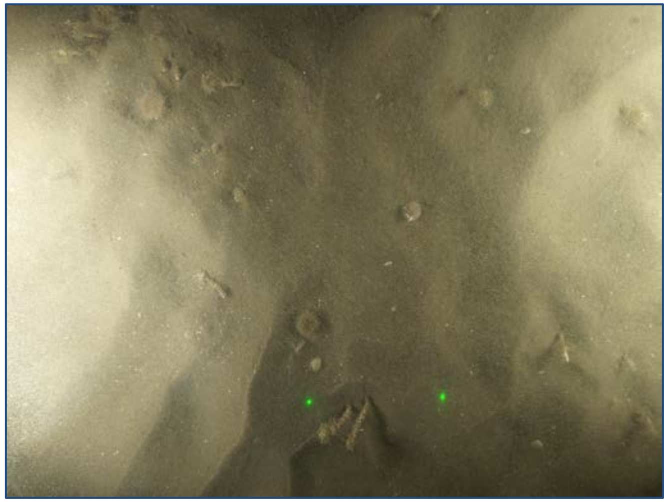
Fix: 9 E: 721881.4 N: 5953777.6 Depth: 25 m

Station: ENV26
Sample: MACA

Sediment Description: Sandy Gravelly Mud (sgM)
Faunal Description: *Lanice conchilega,* Polychaeta



Fix: 51 E: 722112.3 N: 5953827.8 Depth: 24.7 m



Fix: 59 E: 722124.5 N: 5953852.6 Depth: 24.8 m

Station: ENV 27

Image 1: MARDUT1021_ENV_27_2021_11_05_165259

Sediment Description: Rippled sand with scattered shell fragments

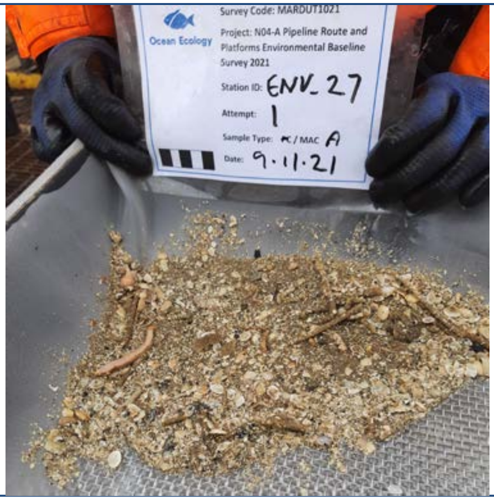
Faunal Description: *Cylista* sp.; *Lanice conchilega*; Ophiuroidea

Image 2: MARDUT1021_ENV_27_2021_11_05_165509

Sediment Description: Rippled sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*.

Fix: 11 E: 722127.5 N: 5953845.1 Depth: 25 m

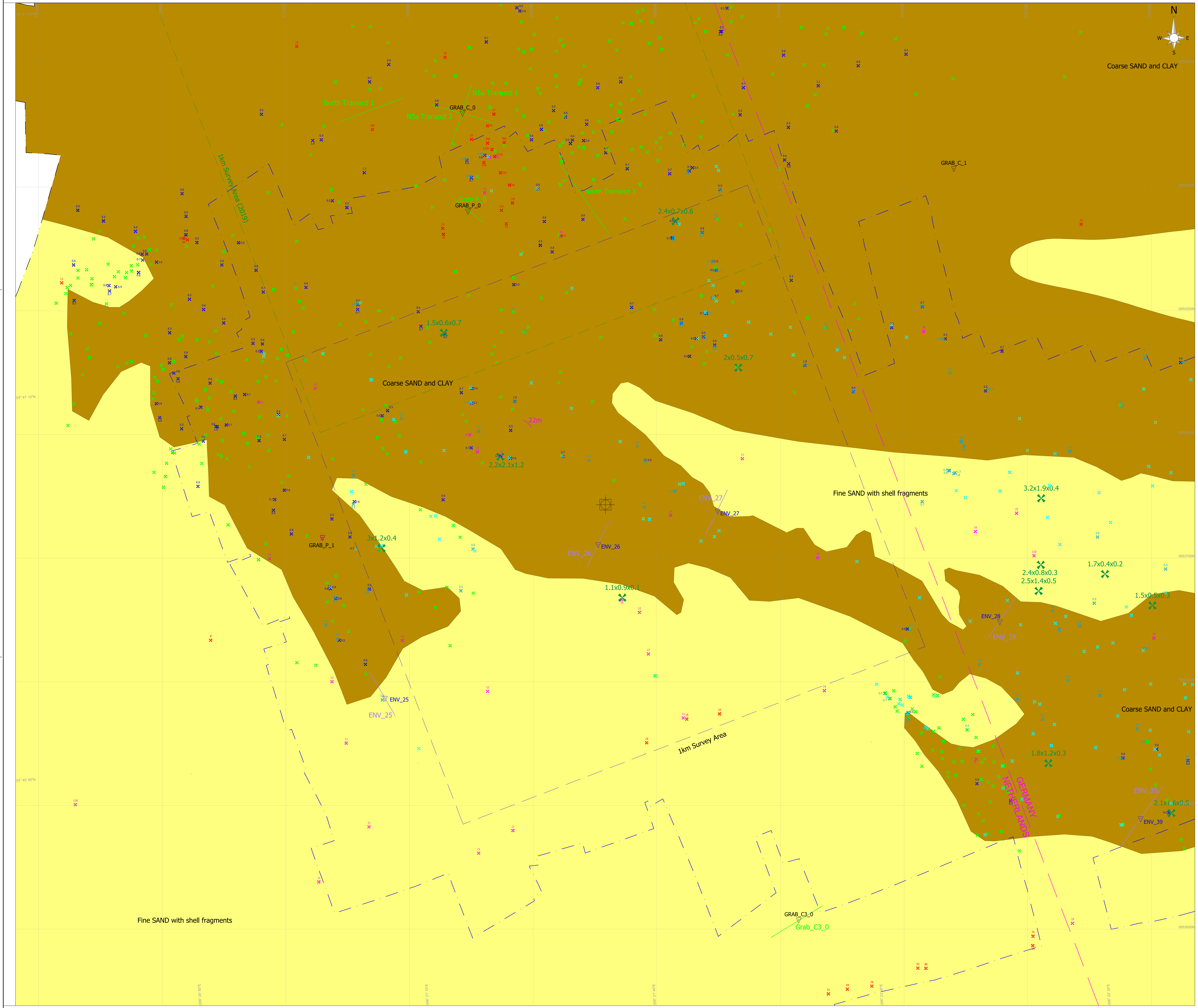


Fix: 11 E: 722127.5 N: 5953845.1 Depth: 25 m

Station: ENV27
Sample: MACA

Sediment Description: Sandy Gravelly Mud (sgM)
Faunal Description: *Lanice conchilega,* Polychaeta, Spatangoida

Appendix C. Seabed Features Chart



LEGEND

Proposed new location for N05-A Platform	
Survey Boundary (2021)	
Survey Boundary (2019)	
Existing Infrastructure	
EEZ Boundary	
U.T.M. grid	Geographical grid

SCALE 1:2500

0 25 50 75 100 125 250 meters
0 160 320 640 1280 feet

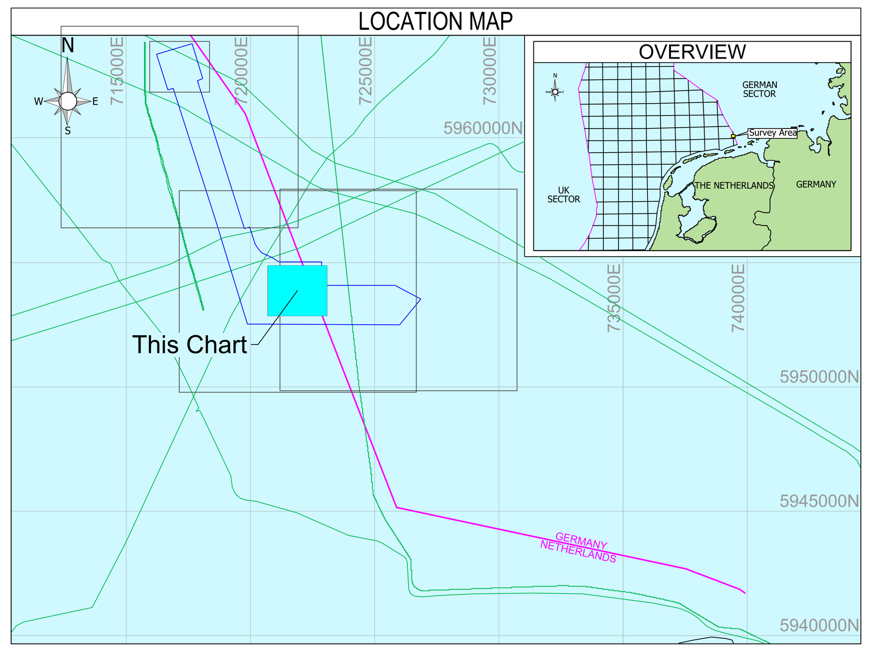
SEABED FEATERS:

- Side scan sonnar contact from 2019 survey. >0.3m (Height removed for clarity)
- 0.3 — Side scan sonnar contact from 2019 survey with height in metres. >0.5m
- Side scan sonnar contact from 2021 survey. >0.3m (Height removed for clarity)
- 0.3 — Side scan sonnar contact from 2021 survey with height in metres. >0.5m
- 16 — Magnetic anomaly from 2019 survey with anomaly size in nanoTeslas
- 16 — Magnetic anomaly from 2021 survey with anomaly size in nanoTeslas
- 1.4 x 0.5 x 0.3 — Debris item from 2019 survey with dimensions (length x width x height) in meters
- 2.4x0.7x0.6 — Debris item from 2021 survey with dimensions (length x width x height) in meters
- Linear debris from 2019 survey with length in metres
- Linear debris from 2021 survey with length in metres
- Camera transects from 2019 survey
- Camera transects from 2021 survey
- GRAB_P_12 — Grab sample from 2019 survey with identification
- ENV_38 — Grab sample from 2021 survey with identification
- Fine SAND with shell fragments
- Coarse SAND with shell fragments
- Coarse SAND and CLAY
- Coarse SAND with high density of sand mason, worms and razor clams

ONE INFORMATION PANEL

1.	N05-A Proposed platform Location	721 896.00 mE 5 953 858.00 mN	53° 41' 06.322" N 06° 21' 36.970" E

LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):

Geo Ocean III: 20/10/2021 untill 16/11/2021

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM
Central meridian:	3° East
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest Astronomical Tide (LAT)

HYDROGRAPHIC SURVEY

N04-A Pipeline Route And Platform Surveys

Platform Area - N05a
Site Survey

ENVIRONMENTAL SEABED FEATURES CHART

Chart: 002/005	Scale: 1/2500	LAT

Drawing made by:

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Issue no:	Datum:	Description:	Drawn:	Checked:
00	15-12-2021	First internal review	KMc	CA
01	20-12-2021	Issued with Report	KMc	CA

ONE Dyas Drawing No.	N05A-7-50-0-72035-01	GEOxyz Drawing No.	NL4658H-553-DR-006

Appendix D. Summary of Faunal Observations

Stations	Annelida - *Lanice conchilega*	Arthropoda - *Liocarcinus* sp.	Chordata - Actinopterygii	Chordata - Pleuronectiformes	Cnidaria – *Cylista* sp.	Cnidaria - Pennatulacea	Echinodermata - Asteroidea	Echinodermata - Ophiuroidea	Echinodermata - *Ophiura albida*	Faunal Turf
ENV_26	27	1			13	1	1	11	6	3
ENV_27	30		1	1	15			11	5	7

Appendix E. Faunal Catalogue

Annelida – *Lanice conchilega*

Polychaete worm which makes a tube out of sand grains and shell fragments, which has a characteristic frayed end that protrudes above the sand.

Arthropoda – *Liocarcinus* sp.

Swimming crab with paddle shaped dactyls on the fifth pereopods. Curved rows of white spots on carapace.

Arthropoda - Caridea

Shrimp

Chordata – Actinopterygii

Indeterminate ray-finned fish.

Chordata – *Limanda limanda*

Both eyes are on the right side of the body. The most characteristic feature is the lateral line, which is strongly arched. The pectoral fin is sometimes orange.

Chordata - Pleuronectiformes

Indeterminate flatfish.

Cnidaria – *Cylista* sp.

Burrowing anemone.

Echinodermata – Asteroidea

Indeterminate starfish

Echinodermata – *Ophiura albida*

A small brittle star with short, tapered, straight arms. The body and arms are red-brown in colour and there are two white marks at the base of each arm.

Echinodermata – c.f. *Ophiura ophiura*

Arms stiff. Dorsally, the base of each arms is bordered by two rows of short spines.

Echinodermata – Ophiuroidea

Indeterminate brittle star

Cnidaria - Pennatulacea

Sea pen

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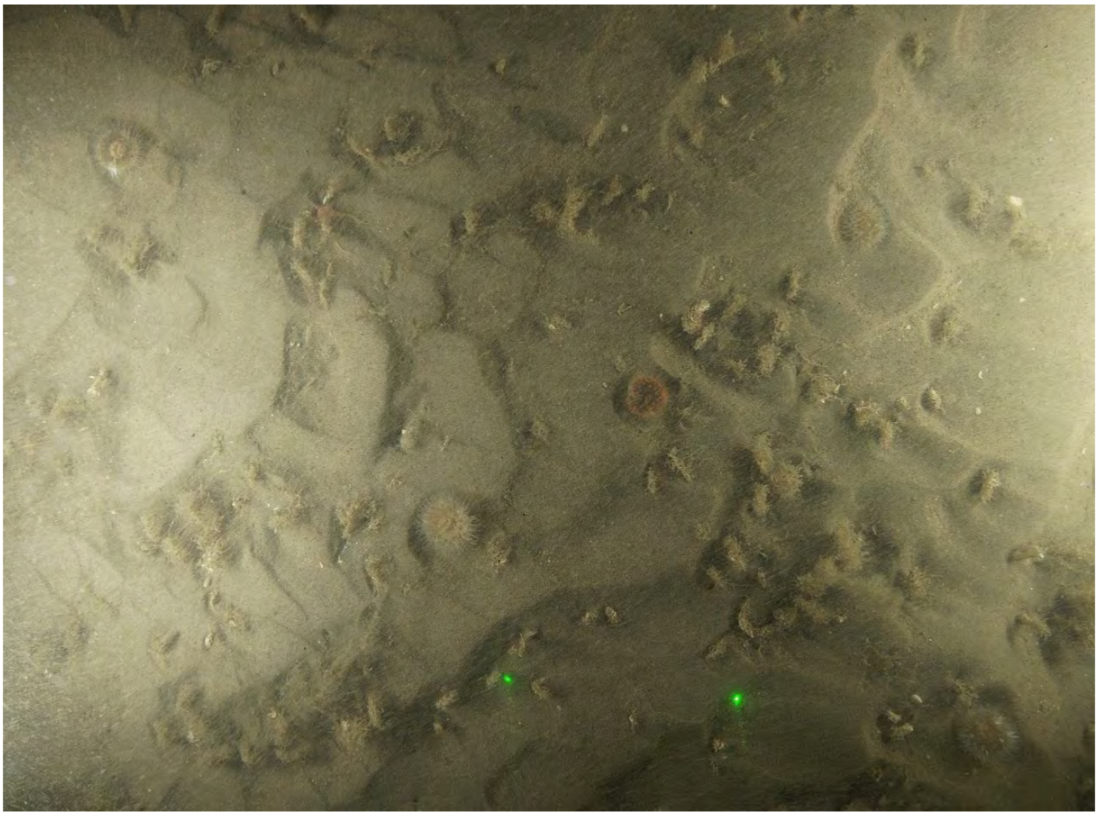
N05A-7-10-0-70041-01-02 - Habitat Assessment Report - N05a-Riffgat OWF Cable Route Area



MarineSpace Document Ref: J/4/94/2 – HAB Report 02 GEOxyz Document No.: NL4658H-553-RR-14	Originator: Ana Chaverra Valencia
Date: 28/01/22	Circulation: Restricted - Commercial-in-confidence

N05A-7-10-0-70041-01-02 - Habitat Assessment Report - N05a-Riffgat OWF Cable Route Area

Prepared by:

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Date	Originator	Version	Action	Signature
22/12/2021	Ana Chaverra	v0.1	Internal Draft	
29/12/2021	Katie Cross	v0.2	Technical Review	
31/12/2021	Ana Chaverra	v0.3	Internal Draft	
31/12/2021	Katie Cross	v0.4	Technical Review / Editorial Review	
31/12/2021	Phil Durrant	v0.5	Editorial Review	
31/12/2021	Phil Durrant	v1.0	Director Sign-off / External Document	
17/01/2022	Ana Chaverra	v1.1	Internal Draft	
28/01/2022	Katie Cross	v1.2	Technical Review / Editorial Review	
28/01/2022	Phil Durrant	v2.0	Director Sign-off / External Document	

Acknowledgements

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Data Licenses

Charts NOT TO BE USED FOR NAVIGATION.

Glossary

Abbreviation	Definition
CM	Central Meridian
CLOC	Clear Liquid Optical Chamber
DDV	Drop Down Video
DVV	Dual Van Veen
EBS	Environmental Baseline Survey
EEA	European Environment Agency
EOL	End of Line
EUNIS	European Nature Information System
HAB	Habitat Assessment
HD	High Definition
IUCN	International Union for Conservation of Nature
MBES	Multibeam Echo Sounder
MP	Megapixel
OWF	Offshore Wind Farm
OSPAR	Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)
PC	Physico-chemistry
SBP	Sub-bottom Profiler
SCI	Site of Community Importance
SOL	Start of Line
SOW	Scope of Work
SPA	Special Area of Conservation

SSS	Side Scan Sonar
TOC	Total Organic Carbon
TOM	Total Organic Matter
USBL	Ultra-Short Base Line (positioning beacon)
UTM	Universal Mercator Projection
WWF	World Wildlife Fund

Executive Summary

MarineSpace Ltd was commissioned by GEOxyz on behalf of ONE-Dyas BV, to produce a Habitat Assessment Report for the N05a-Riffgat OWF Cable route in Dutch and German waters. The report aimed to identify the occurrence of species or communities of conservation importance listed under Annex I of the EU habitats Directive (1992) as well as any threatened and/or declining species and habitats on the Oslo-Paris (OSPAR) Commission list (OSPAR, 2008).

Geophysical data were collected at the N05a-Riffgat OWF cable route using side-scan sonar (SSS) and multi-beam echosounder (MBES). Drop-down video (DDV) was conducted along, 18 x 100 – 200 m long transects and grab sampling was undertaken at 18 co-located stations. Geophysical data were interpreted during the survey to determine bathymetry and delineated potential features of conservation importance, which were subsequently used to inform the location of the DDV and grab sample locations. Video and still collected from DDV were reviewed to ascertain presence and absence of species and habitats of conservation importance. Grab samples we also reviewed to identify the occurrence of species of conservation importance.

Within the N05a-Riffgat OWF cable route, water depth ranged from 18.7 m lowest astronomical tide (LAT) to 26.6 m LAT. A series of natural minor troughs, predominantly trending north-west to south-east, occurred where the acquired data narrows within the Riffgat OWF area. These were interpreted to be related to tidal/current processes. Seabed sediments were interpreted within the charted area as fine sand with shell fragments, coarse sand with shell fragments, coarse sand and clay and coarse sand with a high density of sand mason worms and razor clams. Numerous SSS contacts were identified within the charted area, with the majority interpreted as boulders.

Habitat within the survey area was found to be homogeneous and predominantly fine sand within the area ‘fine sand with shell fragments’ while habitat within the ‘coarse sand and clay’ was predominantly coarse sand with areas of cobbles and boulders and areas of high density *Lanice conchilega*. Correspondingly, 3 x level 3 EUNIS habitats were identified; A5.23 infralittoral fine sand, A5.13 infralittoral coarse sediment, A5.43 infralittoral mixed sediment as well as 1 x level 4 EUNIS habitat: A5.137 dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand.

Substrate larger than 64 mm (cobbles and boulders) were identified from seabed imagery at 12 stations and therefore a stony reef assessment was conducted. Cobbles and boulder observed in the DDV were plotted on geographical information system (GIS) software, this revealed an area less than 100 m^2 for each transect. Furthermore, cobble and boulder areas were separated on average by more than 20 m. From the epifauna observed only a few were associated with Reefs (H1170). Therefore, based on the Dutch Ministry of Agriculture, Nature and Food Quality (MANFQ, 2014a), these areas of cobbles and/or boulders could not be defined as EC Habitats Directive Annex I Reefs (H1170).

Sediment type, depth and fauna were found to meet the requirement of the EC Habitats Directive Annex I habitat subtype H1110_C (MANFQ, 2014b). However, the geophysical data found no sandbank features within the N05a-Riffgat OWF cable route.

The cobbles and boulders presented a hard substrate on which Porifera can grow and potentially form deep-sea sponge aggregation, which are classified as threatened and/or declining habitat (OSPAR, 2008). However, frequency and percentage cover of Porifera was determined as rare across the N05a-Riffgat OWF cable route.

Only one individual of Pennatulacea (sea pen) was observed within the N05a-Riffgat OWF cable route area. Consequently, there is little to no resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat (OSPAR, 2008).

Other than those detailed above there was no further evidence of any Annex I habitats, any species or habitats on the OSPAR (2008) list of threatened and/or declining species or any species on the IUCN Global Red List within the N05a-Riffgat OWF cable route.

Contents

List of Figures

List of Tables

1. Project Summary

1.1. Scope of Work

ONE-Dyas BV plans to develop a successfully drilled well in block N04a of the North Sea Dutch Continental Shelf. It is planned to develop the well by installing a minimum facilities platform and gas export pipeline with a connection to the future N05a processing platform (here on in referred to as 'The Project'). The Project runs along the Dutch German border within Dutch blocks N04a and N05a, with a portion crossing over into German waters. A habitat assessment (HAB) in conjunction with an environmental baseline (EBS), geophysical and geotechnical survey, are required prior to well development operations at N04a and export pipeline connection works. The current report details the results of the HAB for the N05a to Riffgat offshore wind farm (OWF) cable route area only and includes a summary of relevant results from the geophysical and environmental baseline survey. All other environmental reporting for the Project can be found within the following reporting volumes:

- N05A-7-10-0-70044-01-xx - Habitat Assessment Report - N05a Platform Area;
- N04A-7-10-0-70022-01-xx - Habitat Assessment Report - N04a to N05a Pipe Route;
- N04A-7-10-0-70023-01-xx - Habitat Assessment Report - N04a Platform Area;
- N04A-7-10-0-70015-01-xx - Environmental Baseline Survey Report - All Areas.

1.1.1. N05a-Riffgat OWF Cable Route Area

Environmental and geophysical data were collected along the pipeline, platform areas (N04a and N05a) and power cable. The specific aims of the habitats assessment as defined in the scope of work (SOW; GEOxyz, 2021a) were to assess for the potential presence of important and environmentally sensitive habitats and species, including:

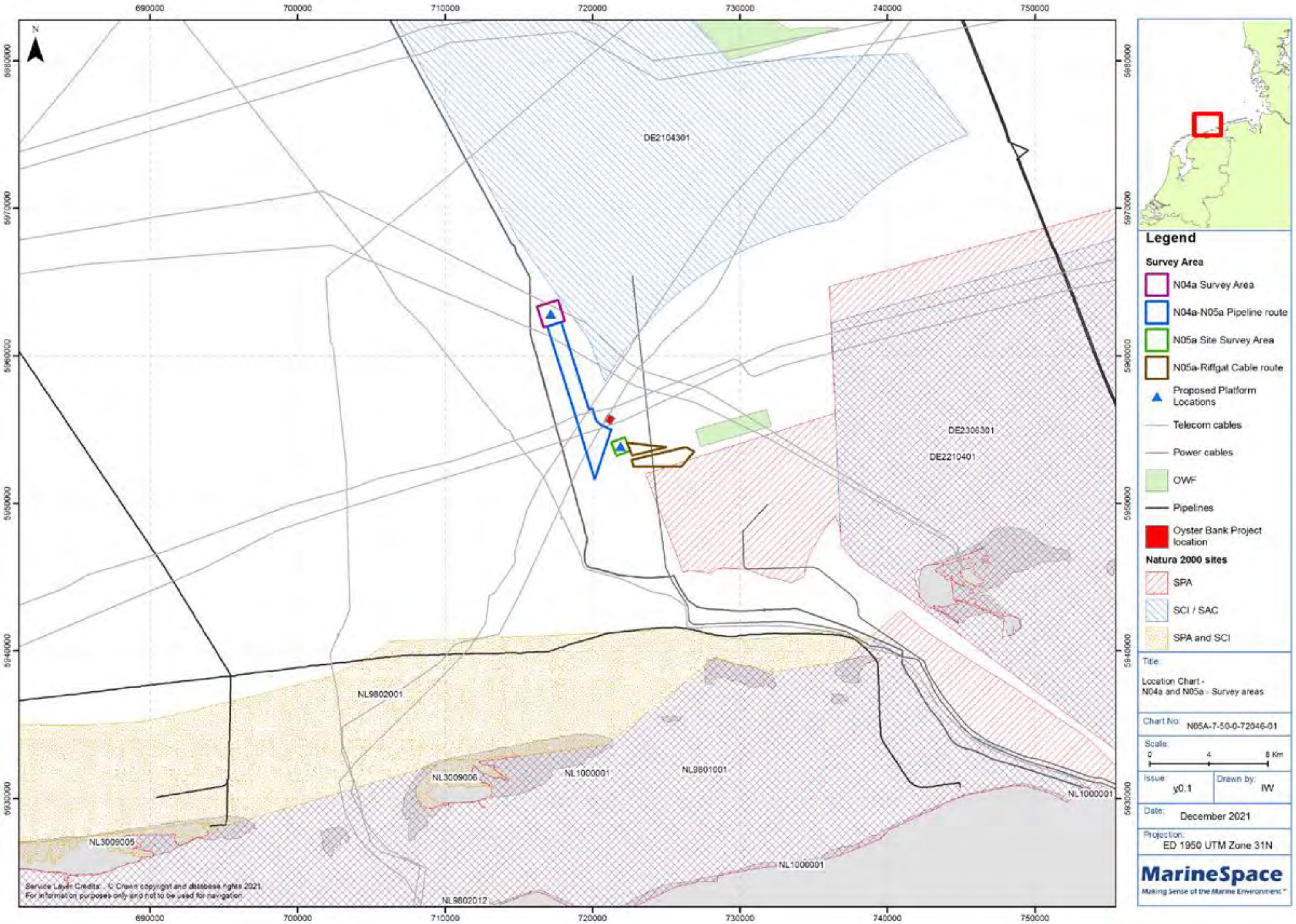
- Annex I habitats of the EU habitats Directive (1992) particularly EU habitat 1170 stony reef and habitat 1110 Sandbanks which are slightly covered by sea water all the time;
- Any evidence of the threatened and/or declining species habitats listed by OSPAR (2008)
- Species on the International Union for Conservation of Nature's (IUCN) Red List of threatened species (IUCN, 2021).

Locations coordinates of the future platforms are presented in Table 1.1. All coordinates within this report are referenced to International 1924 Ellipsoid, European Datum 1950. Grid coordinates are projected using the Universal Mercator Projection (UTM) Zone 31, Central Meridian (CM) 3° E.

Table 1.1: Coordinates of future platform locations

Future Platform Locations	Easting	Northing	Latitude	Longitude
N04A	5962867	717150	53° 46' 04.51" N	006° 17' 41.46" E
N05A	5953858	721896	53° 41' 06.32" N	006° 21' 36.97" E

Figure 1.1: Location of the N05a-Riffgat OWF cable route



1.2. Environmental Survey Strategy

During October and November 2021, the environmental and geophysical surveys were conducted onboard the GEOxyz survey vessel Geo-Ocean III from 20 October to 16 November. All environmental work was conducted by MarineSpace, supported by Associates from Ocean Ecology Ltd, between 05 - 11 November 2021. The geophysical data acquisition was conducted by GEOxyz between 23 October to 12 November 2021 and has been reported separately by Peak Processing for each survey area (GEOxyz, 2021b; 2021c; 2022a; 2022b).

Geophysical data were collected using a multibeam echo sounder (MBES), side scan sonar (SSS), sub-bottom profiler (SBP) and Magnetometer. Following geophysical data acquisition, SSS and MBES data were reviewed to propose location for benthic grab sampling and camera investigations. Areas of potential conservation value and boundaries between areas of differing reflectivity were factored into sample locations in order to identify potential changes in seabed sediment type and bathymetric highs and lows.

A total of 18 transects and co-located environmental sampling stations were spaced across lower, mixed and higher reflectivity areas within the N05a—Riffgat OWF cable route in areas that were previously not investigated by the 2019 N5a Development HAB (GEOxyz, 2019).

Details of the environmental targets and data collected along targeted features of interest observed within the geophysical data, are summarised in Table 1.2 for camera transects and in Table 1.3 for grab targets. Target and actual sampling locations, are presented in the Surveyor’s log sheets in Appendix A and in Figure 1.2 and Figure 1.3 along with the surveyed 2021 N05a-Riffgat OWF cable route area.

Table 1.2: Summary of transect targets and data acquired

Transect	SOL/EOL[1]	Proposed Easting[2]	Proposed Northing[2]	Proposed Length (m)	Rationale	Transect Completed (Y/N)	Length Achieved (m)
ENV20	SOL	725362	5953468	200	Along an area of mixed reflectivity indicative of heterogenous sediments. Following an overall site assessment of high-density boulder/cobble areas, the transect intersects the majority of identified areas.	Y	182
	EOL	725237	5953386				
ENV28	SOL	722143	5953888	100	Along an area of homogenous lower reflectivity.	Y	192
	EOL	722110	5953798				
ENV29	SOL	723781	5953798	200	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	267
	EOL	723706	5953612				
ENV30	SOL	724217	5953761	200	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	275
	EOL	724052	5953647				
ENV31	SOL	723821	5953104	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	218
	EOL	723766	5952964				
ENV32	SOL	724258	5953128	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	206
	EOL	724200	5952988				
ENV33	SOL	724768	5953197	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	219
	EOL	724713	5953057				
ENV34	SOL	725325	5953140	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	219
	EOL	725270	5953280				
ENV35	SOL	725806	5953298	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	205
	EOL	725810	5953148				
ENV36	SOL	726360	5953290	150	Along an area of mixed reflectivity indicative of heterogenous sediments.	Y	186
	EOL	726364	5953140				
ENV37	SOL	726746	5953342	150	Along and area of homogenous sand ripples.	Y	194
	EOL	726688	5953480				
ENV38	SOL	723271	5952761	150	Along an area of homogenous higher reflectivity.	Y	209
	EOL	723270	5952611				
ENV39	SOL	723022	5953288	150	Along an area of heterogenous mixed reflectivity indicative of higher density boulders and cobbles.	Y	228
	EOL	722937	5953164				
ENV40	SOL	724326	5952647	150	Along an area of homogenous higher reflectivity.	Y	236
	EOL	724249	5952776				
ENV41	SOL	724877	5952968	200	Along an area of homogenous higher reflectivity. Intersecting a potential sand bank feature.	Y	245
	EOL	724856	5952769				
ENV42	SOL	725411	5952687	150	Along an area of homogenous higher reflectivity. Intersecting a potential sand bank feature.	Y	235
	EOL	725402	5952837				
ENV43	SOL	725824	5952881	200	Along an area of homogenous higher reflectivity. Intersecting a potential sand bank feature.	Y	264
	EOL	725767	5952689				
ENV44	SOL	726172	5953000	150	Along an area of heterogenous higher reflectivity. Intersecting a potential sand bank feature.	Y	228
	EOL	726124	5952858				

1 Proposed transect locations, actual drop-down video still positions are detailed in Appendix A

2 Start of line (SOL) and end of line (EOL)

Table 1.3: Grab sample targets and data acquired

Station	Proposed Easting (m)[1]	Proposed Northing (m)[1]	Depth (m LAT)[2]	Rationale	Grab Samples Acquired[3]			
					PC	MACA	MACB	MACC
ENV20	725295	5953419	23.7	Area of mixed reflectivity indicative of heterogeneous sediments. Following an overall site assessment of high-density boulder/cobble areas.	1	1	1	1
ENV28	722693.77	5953622	23.9	Moved 133 m SW of a proposed vibrocore station in an area of homogenous lower reflectivity.	1	1	1	1
ENV29	723749	5953719	24.4	Moved 26 m NW of a proposed vibrocore station in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV30	724151	5953716	23.7	Moved 85 m West of a proposed vibrocore station in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV31	723784	5953009	23.8	Area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV32	724234	5953077	24.7	Moved 75 m SW from a proposed vibrocore station and magnetometer anomaly in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV33	724757	5953171	24.3	Moved 50 m SW of a magnetometer anomaly in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV34	725298	5953207	23.7	Area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV35	725808	5953207	23.3	Area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV36	726362	5953211	22.7	Moved 45 m East of a proposed vibrocore station in an area of mixed reflectivity indicative of heterogeneous sediments.	1	1	1	1
ENV37	726717	5953412	22.2	Area of homogenous lower reflectivity sand ripples.	1	1	1	1
ENV38	723270	5952703	20.4	Area of homogenous higher reflectivity.	1	1	1	1
ENV39	722979	5953224	24.3	Station relocated to capture a potential area of mixed reflectivity indicative of heterogenous sediments of higher density boulders/cobbles.	1	1	1	1
ENV40	724291	5952706	21.1	Area of homogenous higher reflectivity.	1	1	1	1
ENV41	724865	5952851	22.6	Moved 80 m north to centralise station over a higher reflectivity potential sandbank feature.	1	1	1	1
ENV42	725410	5952700	21.9	Moved 100 m away from a proposed vibrocore station and magnetometer anomaly. In an area of homogenous higher reflectivity.	1	1	1	1
ENV43	725775	5952715	22	Moved 40 m NW from a proposed vibrocore station. In an area of homogenous higher reflectivity.	1	1	1	1
ENV44	726134	5952885	22.2	Moved 70 m West of a magnetometer anomaly. In an area of potentially heterogenous higher reflectivity.	1	1	1	1

1 Grab proposed sample locations, actual sampling positions are detailed in Appendix A

2 Depth at target location recorded from processed MBES data

3 1 physico-chemistry sample (PC) and 3 macrofauna samples (MACA, MACB and MACC)

Figure 1.2: N05a-Riffgat OWF cable route including target and actuals, Stations ENV20, ENV28-32, ENV38-40

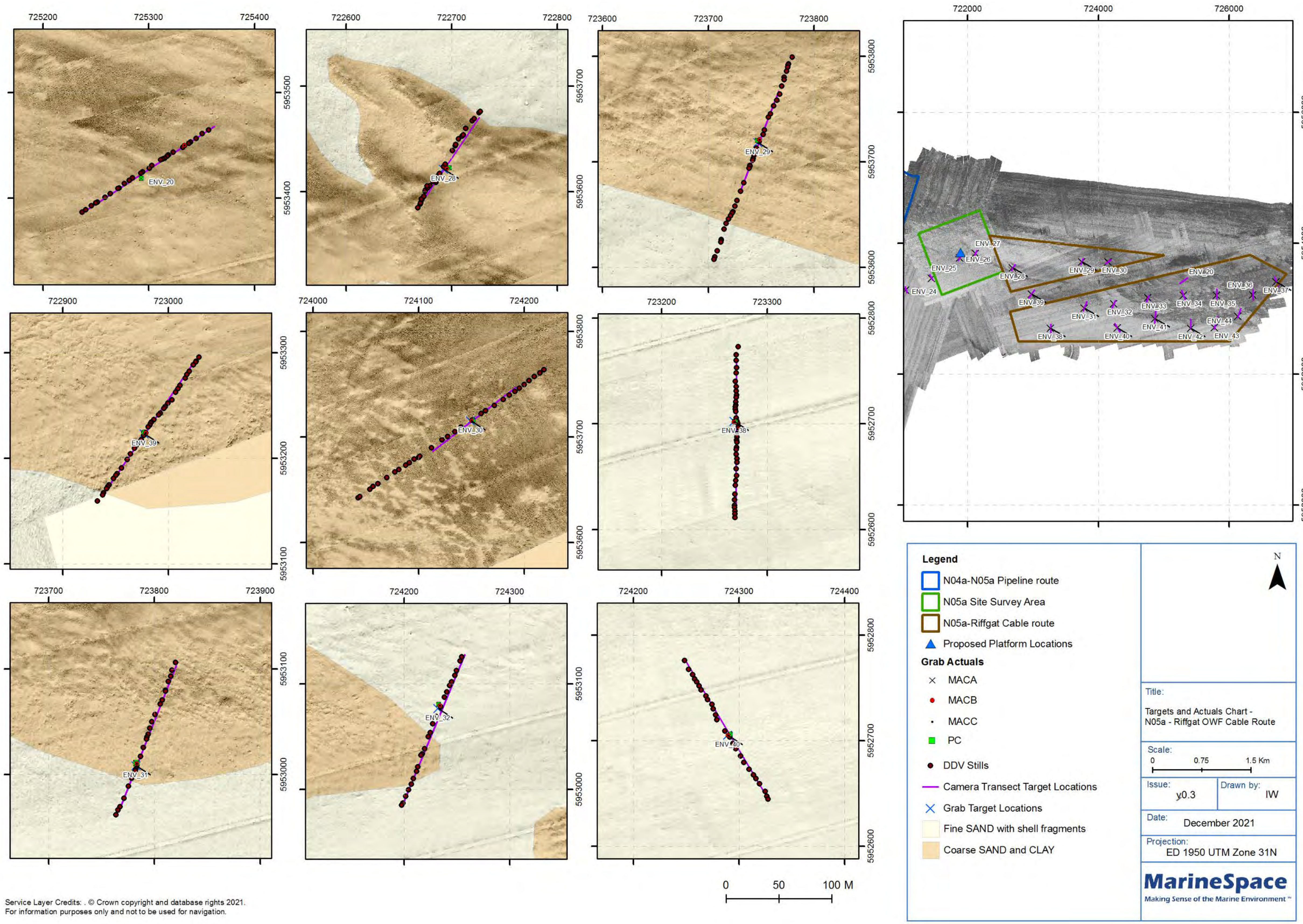
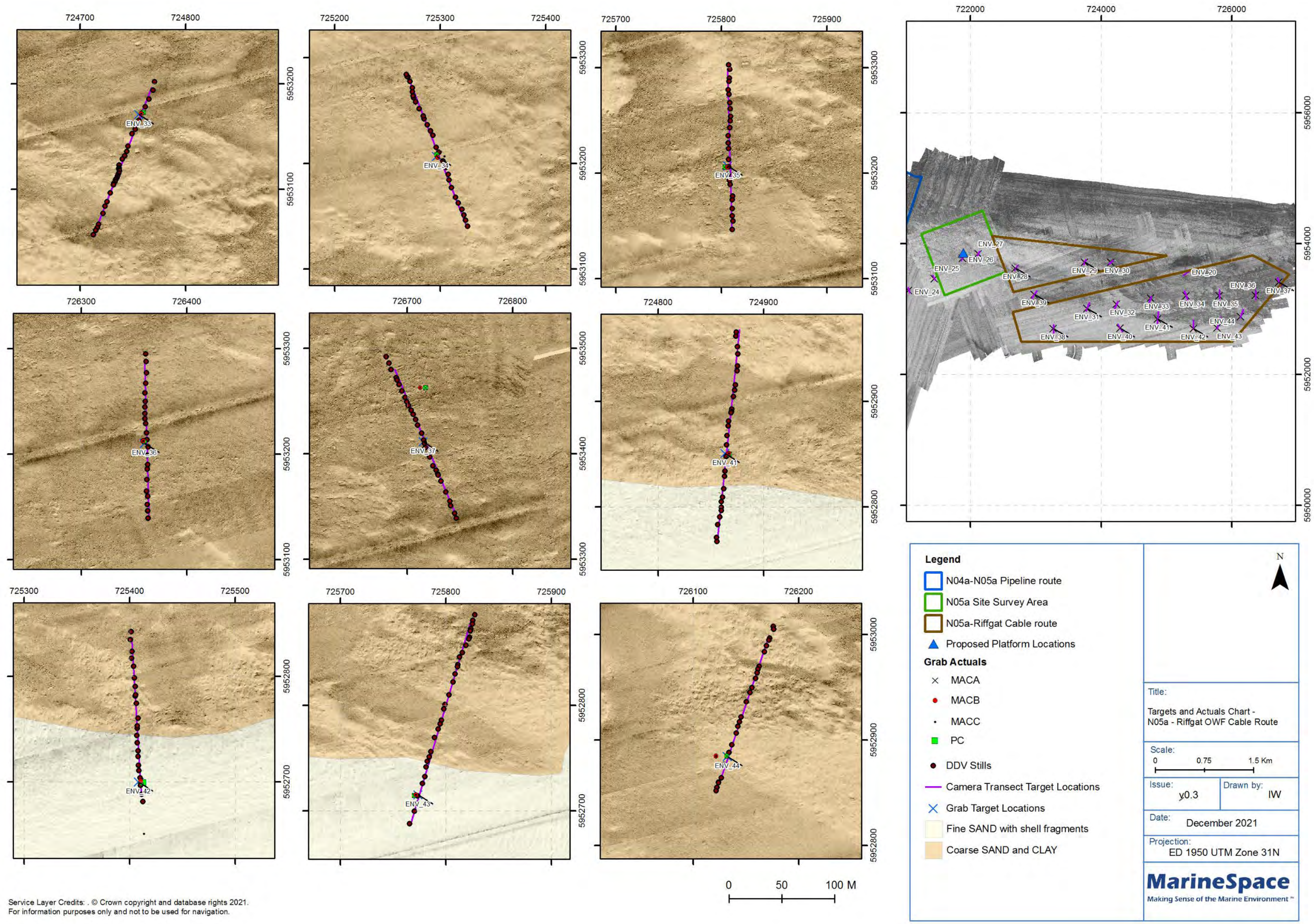


Figure 1.3: N05a-Riffgat OWF cable route including targets and actuals, Stations ENV33-37, ENV41-44



1.3. Background Habitat Information

1.3.1. Overview

This section presents an overview of sensitive habitats and species that are likely to occur within offshore Dutch and German waters in the vicinity of the Project.

As outlined in Section 1.1, the SOW (GEOxyz, 2021a) called for an assessment for the potential presence of important and environmentally sensitive habitats and species including Annex I habitats (1992), the OSPAR (2008) list of threatened and/or declining species and the IUCN Red List of threatened species (IUCN, 2021).

It is noted that the proposed pipeline route is located adjacent to the Borkum-Rifgrund site of community importance (SCI) and close to the Niedersächsisches Wattenmeer und angrenzendes Küstenmeer special area of conservation (SPA). The Borkum-Riffgrun area was designated as an SCI under the Habitats Directive (1992) based on the presence of protected habitats including sandbanks which are slightly covered by sea water all of the time and reefs as well as the presence of various bird species, shad *Alosa fallax* and grey seals *Halichoerus grypus*. The Niedersächsisches Wattenmeer und angrenzendes Küstenmeer was designated as an SPA in March 2010 due to the presence of numerous protected bird species.

Since 2018, a flat oyster *Ostrea edulis* reef restoration project – World Wildlife Fund (WWF) oyster bank project - has been ongoing in the Borkum Stones area, off the Dutch coast. In September 2019 evidence was obtained that settlement took place in the newly established offshore population in 2018. Given its proximity to the project, care has been taken to identify and record any oysters collected during the sampling programme for reporting back to the WWF oyster bank project.

The previous survey near the N05a platform (GEOxyz, 2019) identified sediment type and fauna within the survey area associated with the Annex I habitat: sandbanks which are slightly covered by sea water all of the time, which met the requirements outline by Jak *et al*., (2009) based on the Dutch Ministry of Agriculture, Nature and Food Quality (MANFQ, 2008). Additionally, 1 seabed camera transect exhibited potential resemblance to Annex I geogenic reef. However, following an assessment, the area was not considered to be sufficiently noteworthy to be classified as an Annex I stony reef.

The subsections below provides background information of sensitive species and habitats that may occur within the survey area. Figure 1.1 spatially displays Marine Protected Areas (MPAs) in relation to the survey area.

1.3.2. H1170 - Reefs

Reefs (H1170) are one of the habitats listed under Annex I of the EU Habitats Directive (1992) for protection within SPAs. Reefs can be either biogenic concretions or of geogenic origin. Geogenic reefs are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.

Biogenic reefs can be identified as solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms.

Geogenic reefs can be identified where animal and plant communities develop on rock or stable boulders and cobbles. Geogenic reefs are extremely variable, both in structure and in the communities they support. Reefs are characterised by communities of attached algae (where there is sufficient light – on the shore and in the shallow subtidal) and invertebrates, usually associated with a range of mobile animals, including invertebrates and fish. The specific communities that occur vary according to a number of factors. For example, rock type is important, with particularly distinct communities associated with chalk and limestone. There may be further variety associated with topographical features such as vertical rock walls, gully and canyon systems, outcrops from sediment, and rockpools on the shore.

1.3.3. H1110 – Permanently Flooded Sandbanks

Sandbanks which are slightly covered with seawater all the time (H1110) are listed under Annex I of the EU Habitats Directive (1992). The habitat consists of sublittoral sandbanks that are permanently submerged by shallow sea water, typically at depths less than 20m below chart datum. The habitat comprises distinct banks which may arise from horizontal or sloping plains of sandy sediment.

The diversity and types of community associated with this habitat are determined particularly by sediment type together with a variety of other physical, chemical and hydrographic factors. Shallow sandy sediments are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms. Mobile epifauna at the surface of the sandbank may include shrimps, gastropod molluscs, crabs and fish. Sand-eels *Ammodyte*s spp., an important food for birds, live in sandy sediments. Where coarse stable material, such as shells, stones or maerl is present on the sediment surface, species of foliose seaweeds, hydroids, bryozoans and ascidians may form distinctive communities. Shallow sandy sediments are often important nursery areas for fish, and feeding grounds for seabirds (especially puffins *Fratercula arctica*, guillemots *Uria aalge* and razorbills *Alca torda*) and sea-duck (e.g. common scoter *Melanitta nigra*).

1.3.4. Flat oyster, *Ostrea edulis*

The flat oyster, *Ostrea edulis*, is listed on the OSPAR (2008) list of threatened and/or declining species and habitats. *O. edulis* is a sessile, filter-feeding bivalve, associated with highly productive estuarine and shallow coastal water habitats. *O. edulis* was nominated for inclusion on the OSPAR list with particular reference to global/regional importance, rarity, decline, role as a keystone species, sensitivity and threat, and as a priority for OSPAR Region II and *O. edulis* beds have been nominated as a habitat.

2. Data Acquisition

2.1. Drop-Down Video

DDV was undertaken with a high definition optical camera system. All imagery was collected using Ocean Ecology's SubC PLE subsea camera system providing 1080p High Definition (HD) video and 20 Megapixel (MP) stills imagery. Due to turbidity, the camera was mounted in a Clear Liquid Optical Chamber (CLOC) filled with fresh water to ensure imagery of suitable quality was obtained. Lighting from 2 LED strip lamps and 2 lasers separated by 10 cm were projected into the field of view for illumination and scaling. Positioning was determined by an ultra-short base line (USBL) positioning beacon attached to the camera frame.

Along each camera transect, photographs were taken at least every 10 m and more often when features of interest were encountered. On-board marine ecologists reviewed all video in situ and the DDV was deployed as follows:

- The vessel approached the target location, and the deck personnel were alerted to prepare lifting equipment, camera, and umbilical when on position;
- A test image was taken on the surface prior to deployment at each station to check that the lasers and camera were working correctly;
- The camera was raised using the moon pool A-frame and lowered into the water column to within 2 m of the seabed;
- A shackle system was used to keep the umbilical close to the winch wire. This reduced strain on the umbilical from the tide or vessel movement and prevented excess umbilical being deployed;
- Video recording was then started, and the camera lowered until gently landing on the seabed at which point a positional fix was taken;
- The camera was then kept on the seabed to wait for any suspended sediments in the field of view to disperse before a still image was taken;
- The camera was moved along the transect at a set speed of 0.3-0.5 knots. Where possible the seabed was kept in view throughout;
- Following the capture of the final image, the camera was lifted, video recording was stopped, and the camera was retrieved to the surface;
- The winch operator then took the tension on the wire and the deck crew ensured the camera umbilical was free for recovery;
- The vessel skipper then confirmed sea conditions were suitable for retrieval and the camera system was recovered aboard;
- The camera frame was then lowered onto the deck and the tension released.

2.2. Grab Sampling

A dual (2 x 0.1 m^2) Van Veen (DVV) grab was deployed at each station using the following protocols:

- Vessel approached target location, bridge alerted deck personnel to prepare grab;
- Sea fastening on grab was released to allow deployment from the stern A-frame;

- Winch operator engaged grab system on arrival at target location;
- Vessel skipper confirmed sea conditions were suitable for deployment;
- Grab was deployed safely using the hydraulic winch and stern A-frame;
- When grab landed on bottom, a fix was taken and grab was retrieved to the water surface;
- When the grab reached the surface, the vessel was positioned to reduce pitch and roll;
- The grab was retrieved safely onto the stand and sample was released into a hopper.

Data taken from each station included the position, fix number and water depth.

To ensure consistency in sampling, grab samples were considered unacceptable if:

- Jaws had jammed open due to a large stone or shell allowing sediment washout;
- Small samples were obtained where the grab had not struck a flat area of bottom, or not hit true, causing a side or half bite of sediment;
- The grab was less than 50 % full or contained less than 5 litres;
- The presence of a hag fish (*Myxine glutinosa*) and/or mucous coagulants;
- There was obvious contamination of the sample from equipment, paint chips etc;
- A sample was collected more than 50 m from the target location;
- Under no circumstances was pooling of samples undertaken.

Samples with a volume less than 5 litres were rejected and sampling at the location was reattempted. If continued attempts also failed to collect a valid sample, then the station was repositioned 50 m away.

A detailed log was compiled for each sample station including:

- Number and type of sample;
- Date and time of sampling;
- Volume of sample achieved;
- Photograph number of sample;
- Water depth (in meters);
- Co-ordinates of samples;
- Sample sediment description.

3. Data Processing and Analysis

3.1. Drop-Down Video

Video footage and stills photographs were successfully acquired along all 18 proposed DDV transects. Transect ENV28 was stopped mid transect due to various technical issues and was restarted (referred to in the logs as ENV28 (2)). Stills and video footage were analysed by qualified Marine Ecologists. At each transect, each photograph was assigned a brief sediment description and analysed for macrofauna, where possible, to species level and recorded for presence/absence. Percentage cover was determined for hydroid/bryozoan turf and Porifera.

A total of 540 DDV stills were captured, however positional information was not obtained at 11 images and were therefore omitted from analysis. In addition to the seabed photographs taken across the 18 transects, video footage was reviewed and snapshots were captured whenever features of potential interest occurred. This resulted in 25 video snapshots, which were subsequently analysed.

A selection of seabed photographs is presented in Appendix B, whilst positional logs for all DDV stills are in Appendix A along with the video logs.

3.2. Grab Sampling

The DVV enabled 2 samples of undisturbed surface sediment to be retrieved simultaneously. 3 replicates (A, B, and C) of hydrocarbons and 2 replicates (A and B) were collected for particle size analysis (PSA) and metals from 1 sample whilst 3 replicates (A, B, and C) of macrofauna were retained from a further 3 samples after being passed through a 0.5 mm sieve.

Detailed descriptions were made of each grab in the field notes and digital photographs were taken of all samples accompanied by a USBL derived fix. Visual descriptions of sediment were made (using the Folk classification categories) at the time of sampling, together with estimates of sample volume (as a measure of sampler efficiency).

Initial processing of sediment samples was undertaken in line with the following methodology:

- Assessment of sample size(s) and acceptability made;
- Photographs of the unreleased samples with station details and scale bar taken;
- 3 replicates (A, B and C) for hydrocarbons and organics (total organic carbon (TOC) and total organic matter (TOM)) analysis were collected using a metal scoop to a nominal depth of 2 cm and placed in a glass sample pot;
- 2 replicates (A and B) for heavy metal analysis were collected using a plastic scoop to a nominal depth of 2 cm and placed in a plastic sample pot;
- 2 replicates (A and B) for PSA were collected;
- Prior to any sub-sampling all sample pots were inspected for contamination and scoops cleaned using acetone.;
- Samples were then frozen and stored at approximately -18°C;

- All physico-chemical samples remained frozen during transport and further storage until analysed;
- Remaining DVV sample (macrofauna A) was then released into a container and photographed;
- Sample emptied onto 0.5 mm sieve net laid over 4mm sieve table and washed through using gentle rinsing with seawater hose;
- Residual sieve contents photographed and described;
- Remaining sample for sorting and identification backwashed into a suitably sized sample container using seawater and diluted 10% formalin solution, and then subsequently diluted with seawater to approximately 4-6%, to fix sample prior to laboratory analysis;
- Sample containers clearly labelled internally and externally with date, sample ID and project name;
- Second deployment conducted to collect a further 2 replicates of macrofauna (B and C)

A full suite of samples were collected from a total of 55 sampling attempts, across all stations within the N05a-Riffgat OWF cable route. All sampled stations, except those for ENV44, were collected within 10 m of the target location. Grab Station ENV44 was obtained at 12.3 m from the target location. Following multiple failed attempts grab stations ENV20, ENV37 and ENV42 were moved 50 m from the initial target.

3.3. Habitat Analysis

3.3.1. Stony Reef Assessment

Characterisation of non-biogenic reefs is the presence of stable hard substrate in the form of large boulders and/or a coarse gravel fraction. There may be a mosaic of a (coarse) sediment types in which different sediment types alternate in appearance: places with gravel boulders alternating with coarse sand.

Under the Dutch MANFQ **(2014a)** habitat profile, the area of interest must meet the minimum area requirement of 100 m^2. The size may relate to more than one location, provided these locations are functionally related and the mutual distance is no more than 20 m. If an area meets this requirement, the limiting criteria, which partly determines the quality of the habitat type, are the substrate size (>64 mm) and the presence of sessile organisms that dependent on that hard substrate **(**

Table **3.1**). Small stones and gravel are only added to the habitat type if sessile organisms live on it. However, it is necessary that these places are part of an area with stones larger than 64 mm**.**

Table 3.1: Stony reef habitat quality (MANFQ, 2014a)

Good/Mediocre	Restrictive Criteria	Only in mosaic
Good	Area covered with hard compact substrates (whether or not with a thin mobile layer of sediment), where organisms that live on these substrates are dependent.	
Mediocre	Area covered with hard compact substrates at least 64 mm average, without a thin layer of sediment and without organisms depended on hard compact substrates.	
Mediocre	Area covered with hard compact substrates	Only in mosaic with independent qualifying components from H1170.

Other habitat quality characteristics include typical species associated with non-biogenic reefs, see Table 3.2 . Other characteristics of good structure and function include low dynamics, good water quality, biotic structuring elements, very high biodiversity and natural build-up community.

Table 3.2: Typical species associated with reef habitat type (H1170; MANFQ, 2014a)

Scientific Name	Species Group	Category
Lithothamnion sonderic	Red Algae	K
Alcyonium digitatum	Soft Coral	Cab
Sabellaria spinulosa	Bristle Worm	K + Ca
Chane duneri	Bristle Worm	K
Galathea intermedia	Crustaceans	E
Arcopagia crassa	Mollusc	Cab
Buccinium undate	Mollusc	Cab
Dosinia exoleta	Mollusc	Cab
Pododesmus patelliformis	Mollusc	K + ca

Scientific Name	Species Group	Category
Micrenophrys lilljeborgic	Fish	E
Diplecogaster bimaculata	Fish	E
Haliclona oculata	Sponge	Cab
Aporrhais pespelecani	Mollusc	Cab
Simnia patula	Mollusc	Cab
Lophius piscatorius	Fish	Cab
Aequipecten opercularis	Mollusc	Cab
Urticina sp .	Anemone	Cab

1 Ca = constant species with indication of good abiotic status, Cb = constant species with indication for food biotic structure, Cab = constant species with indication of good abiotic status and good biotic structure, K = characteristic species, E = exclusive species.

3.3.2. H1110_C - Sandbank Assessment

Habitat type H1110 permanently flooded sandbanks is defined at landscape level based on shapes of the earth’s surface and the flow of salt water. It concerns sandbanks in shallow parts of the sea that is constantly under water, with water rarely more than 20 m deep.

The Dutch government has subdivided the H1110 Habitat into three subtypes; H1110_A_Wadden Sea, H1110_B North Sea and H1110_C Offshore (MANFQ, 2014b). Habitat H1110_C has the most relevance to the N05a-Riffgat Cable route, representing permanently flooded sandbanks in water depths up to 40 m. Subtype C is defined by the change in inclination angle (>0.5°) from the sandbank to the surrounding plain. The limiting criteria, as defined by MANFQ (2014b), which partly determine the quality of the habitat type, are the depth of the water above the sandbar and the substrate size. Characteristics species is another factor which partly determines the quality of the habitat type (Table 3.3).

Table 3.3: Typical species associated with sandbank habitat type H1110_C (MANFQ, 2014b)

Scientific Name	Species Group	Category[1]
Alcyonium digitatum	Soft Coral	K + Ca
Lanice conchilega	Bristle Worm	Cab
Sigalion mathildae	Bristle Worm	Ca
Aphrodita aculeata	Bristle Worm	K + Ca

Scientific Name	Species Group	Category[1]
Goniada maculata	Bristle Worm	Ca
Magelona papillicomis	Bristle Worm	Ca
Nephtys cirrosa	Bristle Worm	Ca
Nephtys hombergii	Bristle Worm	Ca
Spiophanes bombyx	Bristle Worm	Cab
Bathyporeia elegans	Crustacean	Cab
Bathyporeia guilliamsoniana	Crustacean	Ca
Corystes cassivelaunus	Crustacean	Cab
Liocarcinus holsatus	Crustacean	Ca
Urothoe poseidonis	Crustacean	Ca
Pagurus bernhardus	Crustacean	Ca
Acrocnida brachiata	Echinoderm	E
Astropecten irregularis	Echinoderm	Ca
Echinocyamus pusillus	Echinoderm	Ca
Luidia sarsii	Echinoderm	K + Ca
Ophiothrix fragilis	Echinoderm	K + Ca
Ophiura ophiura	Echinoderm	Ca
Amoglossus latema	Fish	Ca
Buglossidium luteum	Fish	Ca
Callionymus lyra	Fish	Ca
Eutrigla gumardus	Fish	Ca
Gadus morhua	Fish	Ca
Limanda limanda	Fish	Ca
Merlangius merlangus	Fish	Ca
Microstomus kitt	Fish	Ca
Pleuronectes platessa	Fish	Ca
Fabulina fabula	Mollusc	Cab
Arctica islandica	Mollusc	Ca
Buccinum undatum	Mollusc	K + Cab
Ensis ensis	Mollusc	Cab

Scientific Name	Species Group	Category[1]
Euspira nitida	Mollusc	Cab
Gari fervensis	Mollusc	Cab
Kurtiella bidentata	Mollusc	Cab
Neptunea antiqua	Mollusc	K + Cab

1 Ca = constant species with indication of good abiotic status, Cb = constant species with indication for food biotic structure, Cab = constant species with indication of good abiotic status and good biotic structure, K = characteristic species, E = exclusive species.

3.4. EUNIS Habitat Classification Assessment

Habitat classification which takes into account both abiotic and biotic features is a relatively new development. The need for a habitat classification system has several driving forces; establishment of habitat protection, inventory of habitats in a biogeographic region country or site; monitoring and reporting description of species' habitat requirements.

To meet the need for a habitat classification, EUNIS was developed between 1996 and 2001 by the European Environment Agency (EEA) in collaboration with European experts. The EUNIS habitat classification is a comprehensive system covering the terrestrial and marine habitat types of the European land mass and its surrounding seas. It is hierarchical in structure and includes a key with criteria for identification of habitats at the first three levels (Table 3.4).

Table 3.4: EUNIS hierarchical structure example

Level	Level Description	Hierarchical Example (EUNIS code)
1	Distinguishes between 'Marine' and terrestrial coastal habitats	Marine (A)
2	Habitats selected based on substrate type and biological zone	Sublittoral sediment (A5)
3	Sediment habitats are subdivided based on broad sediment type.	Sublittoral coarse sediment (A5.1)
4	Sublittoral sediment habitats are subdivided by salinity and more specific biological zone.	Infralittoral coarse sediment (A5.13)
5	At this level biotopes are defined based on their characterising species	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand (A5.137)

EUNIS benthic biotopes can be assigned using analysed faunal and physical data. Within this report, available data for EUNIS assessment includes geophysical data, epifauna and sediment observations from DDV and grab samples.

4. Survey Results

4.1. Geophysical Survey

The following bathymetry and seabed features information is summarised from the N05a-Riffgat OWF cable route geophysical report by GEOxyz (2021c). Data acquired from the current survey has been supplemented by previous survey data acquired in 2019.

The 2021 geophysical survey comprised 45 main lines, orientated 76°/ 256° with a 50 m spacing and lengths varying between 69 m and 4.2 km and 4 cross lines, orientated 166°/ 346° with a 1 km spacing and lengths varying between 1.3 km and 2.0 km. These infilled a gap in the 2019 survey area to the east of the N05a platform survey area and also extend the cable route survey area further south.

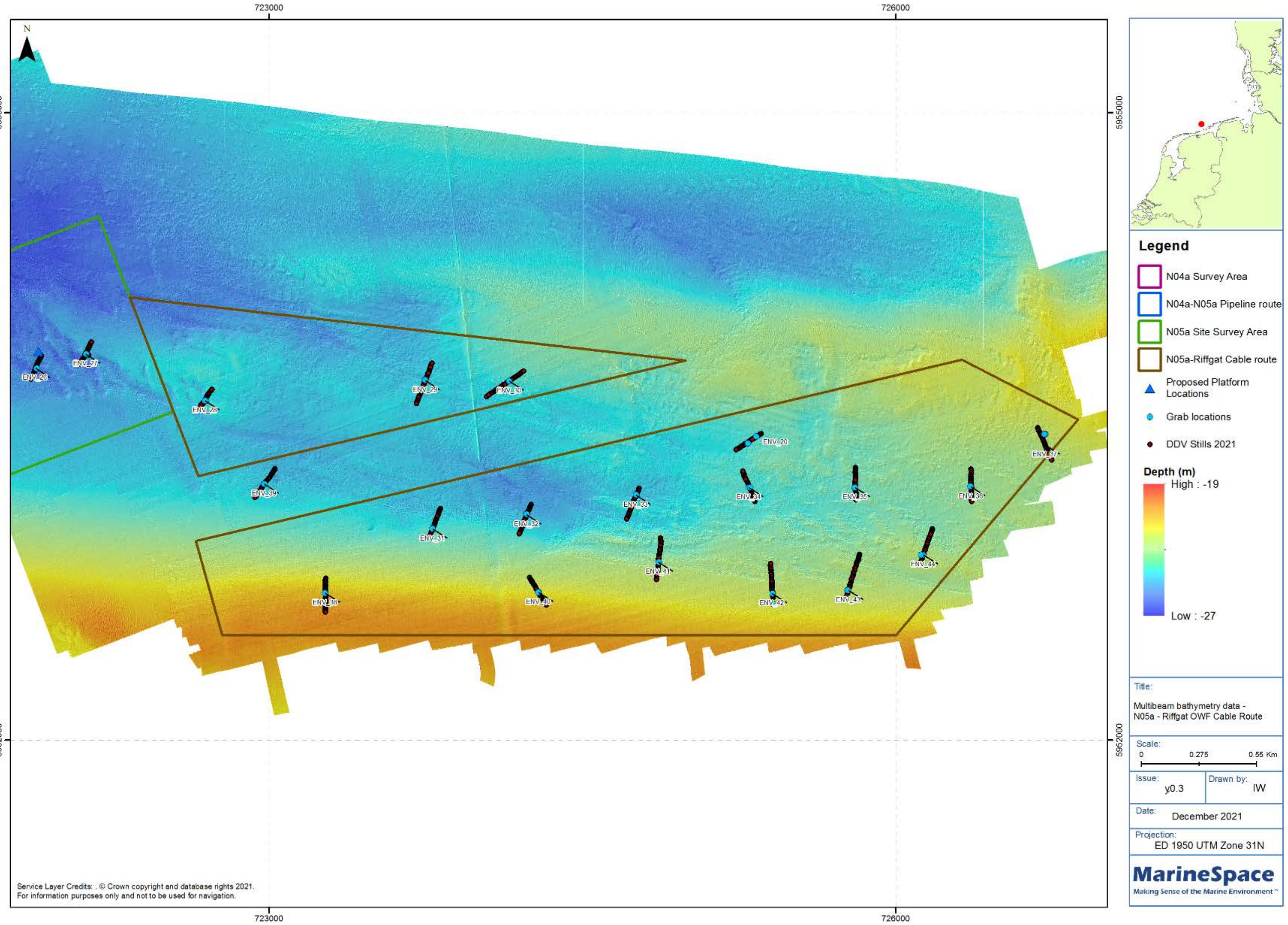
4.1.1. Bathymetry

Bathymetry within the charted N05a-Riffgat OWF cable route is shown in Figure 4.1. Water depths generally shoaled towards the south and east of the charted area, with water depths ranging from 18.7 m LAT towards the eastern end and 26.6 m LAT in the west.

A series of natural minor troughs, predominantly trending north-west to south-east, occurred where the acquired data narrows within the Riffgat OWF area. These were interpreted to be related to tidal/current processes. Natural gradients within the charted area are generally less than 1 . Maximum gradients of up to 7 were confined to the flanks of the more prominent troughs.

Three semi-circular features with 1 m of positive relief, interpreted as being related to previous drilling activity, were imaged in the bathymetry data. They were positioned within a 45 m radius around 721725 m E 5954566 m N and have average dimensions of 30 m x 20 m. The position of the Norned cable was confirmed by MBES data. The cable crosses through the centre of the main body of acquired data in a north/south orientation.

Figure 4.1: Bathymetry across the N05A-Riffgat OWF cable route



4.1.2. Seabed Features

Interpretation of seabed features, sediment and seabed contacts from the current and 2019 SSS data is presented in Appendix C.

Seabed sediments were interpreted within the charted area as fine sand with shell fragments, coarse sand with shell fragments, coarse sand and clay and coarse sand with a high density of sand mason worms and razor clams (*Ensis* sp.). The coarse sand with shell fragments was generally seen in the narrow corridor of data in the east, around the Riffgat OWF, while the main body of the survey area was split between find sand with shell fragments and coarse sand clay with coarse sand and clay generally correlating with the bathymetric highs, with the exception of an area of find sand in the north.

Numerous SSS contacts were identified within the charted area, with the majority interpreted as boulders within the charted area. Most of these contacts were identified within the areas where seabed sediments were interpreted as coarse sand and clay although occasional contacts were seen outside these areas.

Several contacts were interpreted as potential debris based on their shape/appearance on SSS records. The largest of these features is a contact seen in 2019 and 2021 located at 723483.2 m E 5953002.0 m N, measuring 7.9 m x 3.9 m x 0.7 m and interpreted previously as a possible wreck. This feature also has a corresponding magnetic anomaly of 874 nT from the 2021 survey. Two items of linear debris were also interpreted within the chart area. The most significant occurred at 721739.2 m E 5954023.0 m N and measured 22 m in length and was interpreted as an abandoned wire / cable. Three semi-circular features with 1 m of positive relief note in Section 4.1.1, were interpreted as being related to previous drilling activity.

Numerous magnetic contacts were detected within the charted area. Several magnetic anomalies were clustered around the position of the three semi-circular features with 1 m of positive relief noted above and interpreted as being related to previous drilling activity. Several magnetic contacts were aligned, trending north/south and were associated with the existing Norned cable. Other examples of magnetic contacts being aligned which did not correspond with the positions of known infrastructure/linear targets were observed on the SSS data and could indicate buried linear debris/unknown cables.

4.1.3. Shallow Geology

In this report, shallow geology refers to geology that is 0 - 50 m below the seabed.

Interpretation of the shallow soils was based upon sub-bottom profiler dataset in conjunction with borehole and vibrocore data. Pinger data examples illustrating shallow soils within the cable route area are presented in Figure 4.2 and Figure 4.3.

Based on vibrocore data the upper unit was expected to comprise fine to medium grained sand. This unit generally thickened to the south and east of the charted area. This correlated with the areas where seabed sediments were interpreted to comprise fine or coarse sand with shell fragments. The unit showed a maximum thickness of 3 m within the charted area.

The upper unit was either absent or so thin it was beyond the resolution of the pinger data set through a large part of the western half of the surveyed area and here clay with layers of sand and silt was expected, interpreted to be the infill of a broad channel (Figure 4.3).

In the east where the upper unit was present based on vibrocore data it was expected to be subcropped by fine sand.

Figure 4.2: Sub-bottom profiler data example for Line CBL_12 (GEOxyz, 2021c)

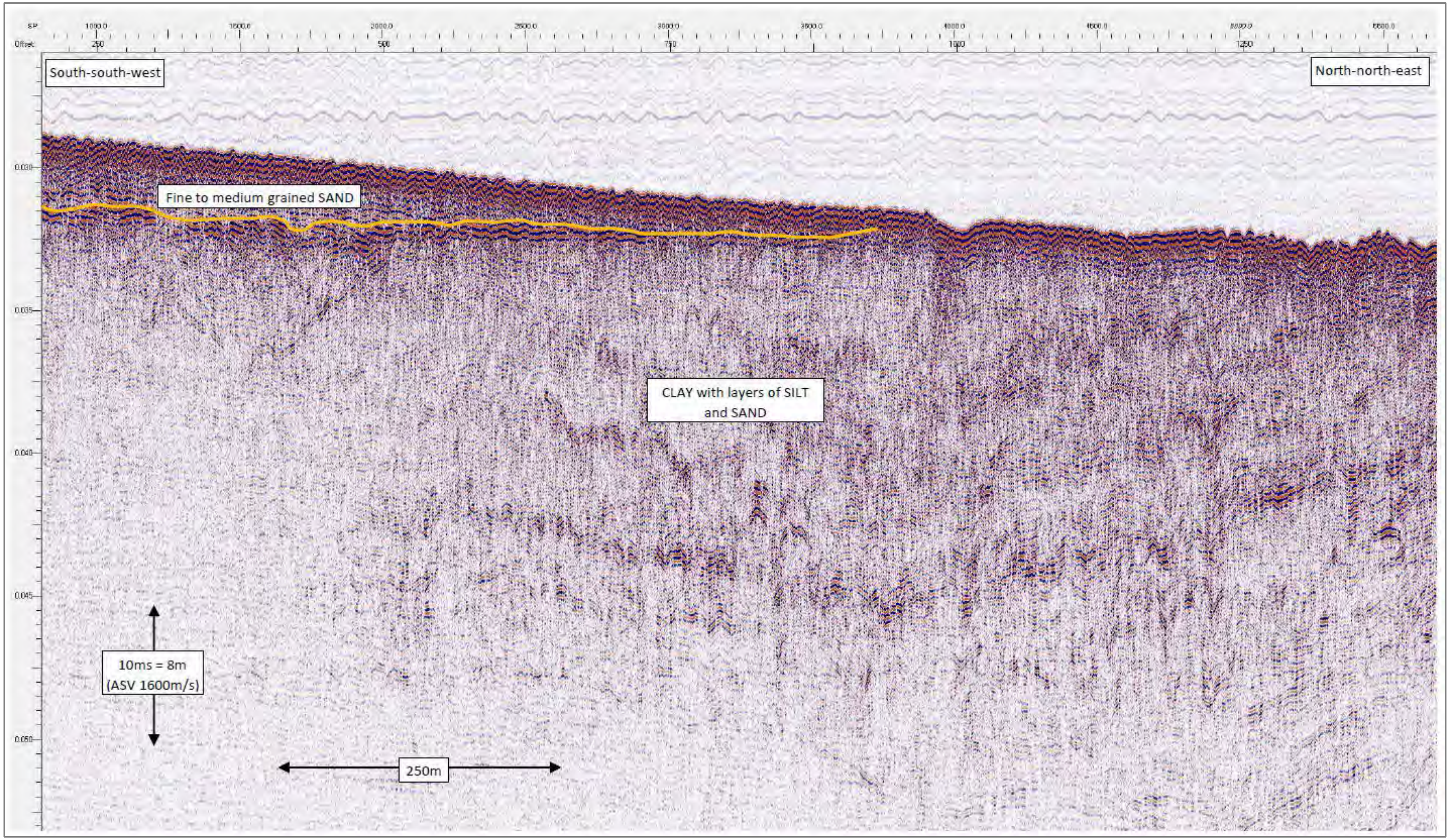
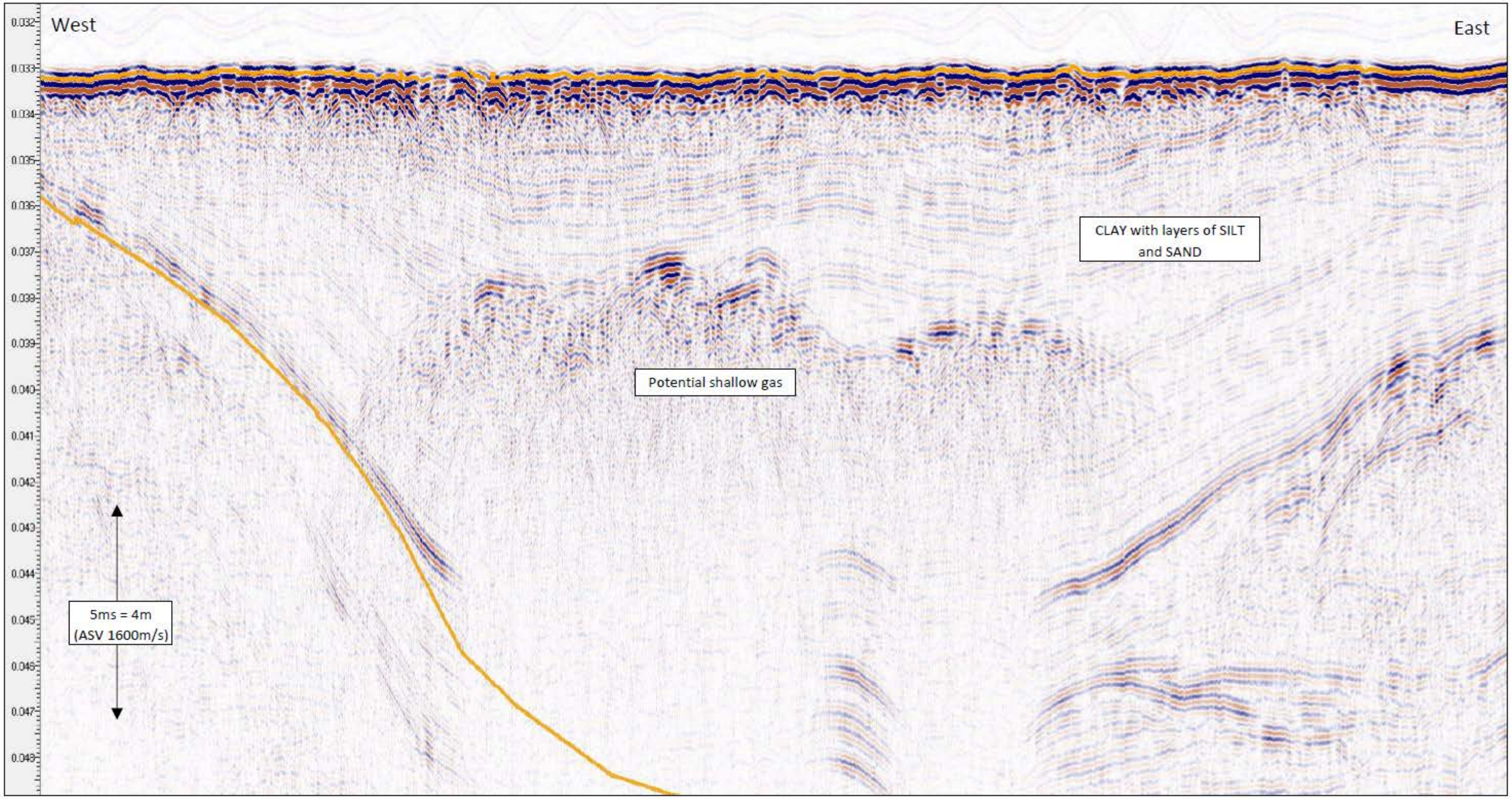


Figure 4.3: Sub-bottom profiler data example for Line CW_6_PROC (Igeotest, 2019)



4.2. Habitat Assessment

4.2.1. Seabed Imagery Observations

Seabed imagery ground truthed the areas interpreted by the SSS data as 'fine sand with shell fragments' and 'coarse sand and clay'. Areas interpreted by the SSS data as 'coarse sand with shell fragments' and 'coarse sand with a high density of sand mason worms and razor clams (Ensis sp.)' were ground truthed in the 2019 HAB (GEOxyz, 2019) and are therefore not discussed below.

Sediments were confirmed to comprise rippled finer sand along the south of the N05a-Riffgat OWF cable route within the area described by the SSS data as 'fine sand with shell fragments'. A mixture of rippled coarse sand with scattered cobbles and boulders were observed in the area described as 'coarse sand and clay'.

Visible fauna identified within the N05a-Riffgat OWF cable route, identified to the lowest possible taxon, are listed in Appendix D and included:

- Annelida (*Lanice conchilega*);
- Arthropoda (Atelecyclidae, *Cancer pagurus*, Caridea, Decapoda, *Homarus gammarus*, *Liocarcinus* sp., Majidae, Paguroidea, Portunidae);
- Chordata (Actinopterygii, *Agonus cataphractus, Limanda limanda*, Lotidae, *Pholis gunnellus*, Pleuronectiformes);
- Cnidaria (Actiniaria, *Alcyonium digitatum*, Anthozoa, Cerianthidae, *Cylista sp.*, Hydrozoa, *Metridium dianthus*, Pennatulacea, Plumulariidae,);
- Echinodermata (*Asterias rubens*, Asteroidea, *Astropecten irregularis*, *Ophiura albida*, *cf. Ophiura ophiura*, Ophiuroidea);
- Mollusca (*Ensis* sp., bivalve siphons);
- Porifera including *cf. Halichondria* (*Halichondria*) *panicea;*
- Indeterminate Animalia, tube and turf.

Review of video footage revealed 1 additional taxa, *Callionymus lyra* , within N05a-Riffgat OWF cable route, which was recorded at Transect ENV41.

The most frequently observed taxa within the images was the sand mason worm *L. conchilega* (65%) followed by burrowing anemone *Cylista sp.* (48%) and brittle star *cf. O. ophiura (*42%).

Fauna observed in the areas identified as 'fine sand with shell fragments' and 'coarse sand and clay' did not differ greatly. Within both sediment types *L. conchilega*, *cf. O. ophiura* and *Cylista sp.* were the most frequently observed taxa. Although, 41% more taxa was recorded within the sediment 'coarse sand and clay' compared to 'fine sand with shell fragments', both recorded 0.1 taxa per image.

In areas were cobbles and/or boulders were present, *Cylista sp.* was the most frequently observed taxa (59%), followed by plumose anemone *M. dianthus* (48%), Porifera (42%) and *L. conchilega* (23%). On average 0.3 taxa were observed per image in areas with cobbles and/or boulders compared to only 0.06 taxa per image in areas were cobbles and boulders were absent.

A. digitatum was observed growing on cobbles along Transect ENV33. *A. digitatum* was the only typical species of Reef (H1170) habitat observed within the seabed imagery and is considered a constant species with indication for good abiotic structure.

The following species were observed from the DDV and are considered typical species of H1110_C permanently flooded sandbanks: *A. digitatum, A. irregularis, C. lyra*, *L. conchilega, L. limanda, O. ophiura*. A minimum of 1 typical species (*L. conchilega*) was observed along every transect and a maximum of 4 was recorded along Transect ENV37. All observed typical species are considered constant species with indication of good abiotic status. In addition, *A. digitatum* is considered a characteristic species and *L. conchilega* a constant species indicating good biotic structure.

The cobbles and boulders presented a hard substrate on which Porifera can grow and potentially form deep-sea sponge aggregation, which are classified as threatened and/or declining habitat (OSPAR, 2008). Only 3 sponge species were identified at Transects ENV20, ENV25, ENV29-30, ENV33-34, ENV39 and ENV43. However, Porifera was only recorded in 20 images with percentage cover limited to below 15%. Porifera is therefore considered rare across the N05a-Riffgat OWF cable route area.

Only 1 individual of Pennatulacea was observed within the N05a-Riffgat OWF cable route area. Consequently, there is little resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat (OSPAR, 2008).

A selection of seabed images, together with descriptions and positions are presented in Appendix B. Also, a summary table of faunal presence and absence is presented in Appendix D and example photographs of the taxa observed is provided in Appendix E.

4.2.2. Seabed Sampling Observations

Grab samples, which were largely collected from seabed of ‘coarse sand and clay’ as interpreted from the SSS, was described as ranging from sandy mud to gravelly muddy sand (Folk, 1954). In contrast, grab samples retrieved from seabed of ‘fine sand with shell fragments’ as interpreted from the SSS, were described as either sandy mud or sand (Folk, 1954).

Typical species found within the grab samples included but were not limited to Bivalvia, Caridea, *Cylista sp.*, Crustacea, *Lanice conchilega* and Ophiouroidea, *Ophiura ophiura*, Pectinariidae, Polychaeta, Spatangoida.

4.2.3. Stony Reef Assessment

Substrate larger than 64 mm (cobbles and boulders) was observed from seabed imagery at 12 stations (ENV20, ENV28-30, ENV33-35, ENV37, ENV39, ENV41, ENV43-44). Cobbles and boulders were generally associated with epifauna, most frequently *Metridium dianthus*. Cobbles and boulders were observed rarely amongst most stations, except for Stations ENV29, ENV33, ENV20 and ENV30 were they were observed in 42%, 37%, 28% and 26% of the DDV imagery, respectively. Although maximum percentage cover of cobbles and/or boulders was 75% at Station ENV29, 70% at ENV33 and 20% at station ENV20 and ENV30, average % cover across all images was lower than 15% (see Figure 4.4).

Cobble and boulder areas were plotted using geographical information system (GIS) software, which revealed that substrates larger than 64 mm did not cover an area of 100 m^2 or more along any transect.

There was no obvious topographic difference in the SSS mosaic in areas where cobbles and boulders were observed. However, observed areas of cobbles and boulders were limited to the 'coarse sand and clay' sediment boundary (Figure 4.4 and Figure 4.5). Therefore, patches of cobbles and boulders are expected to be found across this area. This is consistent with the geophysical data which interpreted boulders to occur across this sediment boundary in high densities (see Section 4-1). Cobble and/or boulder areas observed from all transects were generally spaced at distances greater than 20 m.

Based on Dutch MANFQ habitat profile (MANFQ, 2014a)**, the stony areas observed and identified from the 2021 DDV data were not functionally related and therefore did not form a habitat type greater than 100 m^2. In addition very few typical species were found in association with the observed hard substrate (see Section 4.2.1). These areas, therefore, could not be defined as Reefs (H1170).**

Figure 4.4: Areas of potential stony reef within N05a-Riffgat OWF cable route, Stations ENV20, ENV28-30, ENV33-34

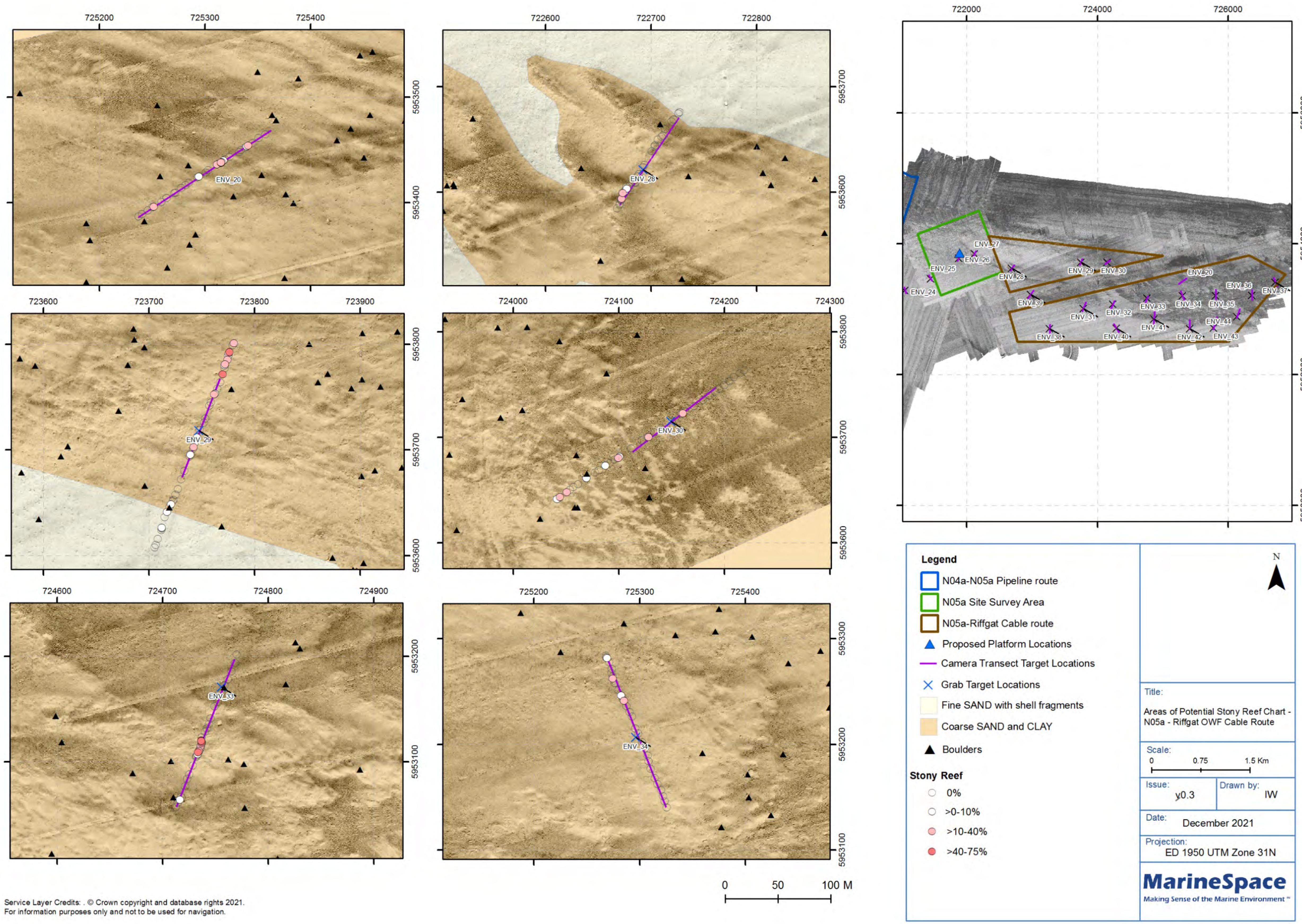
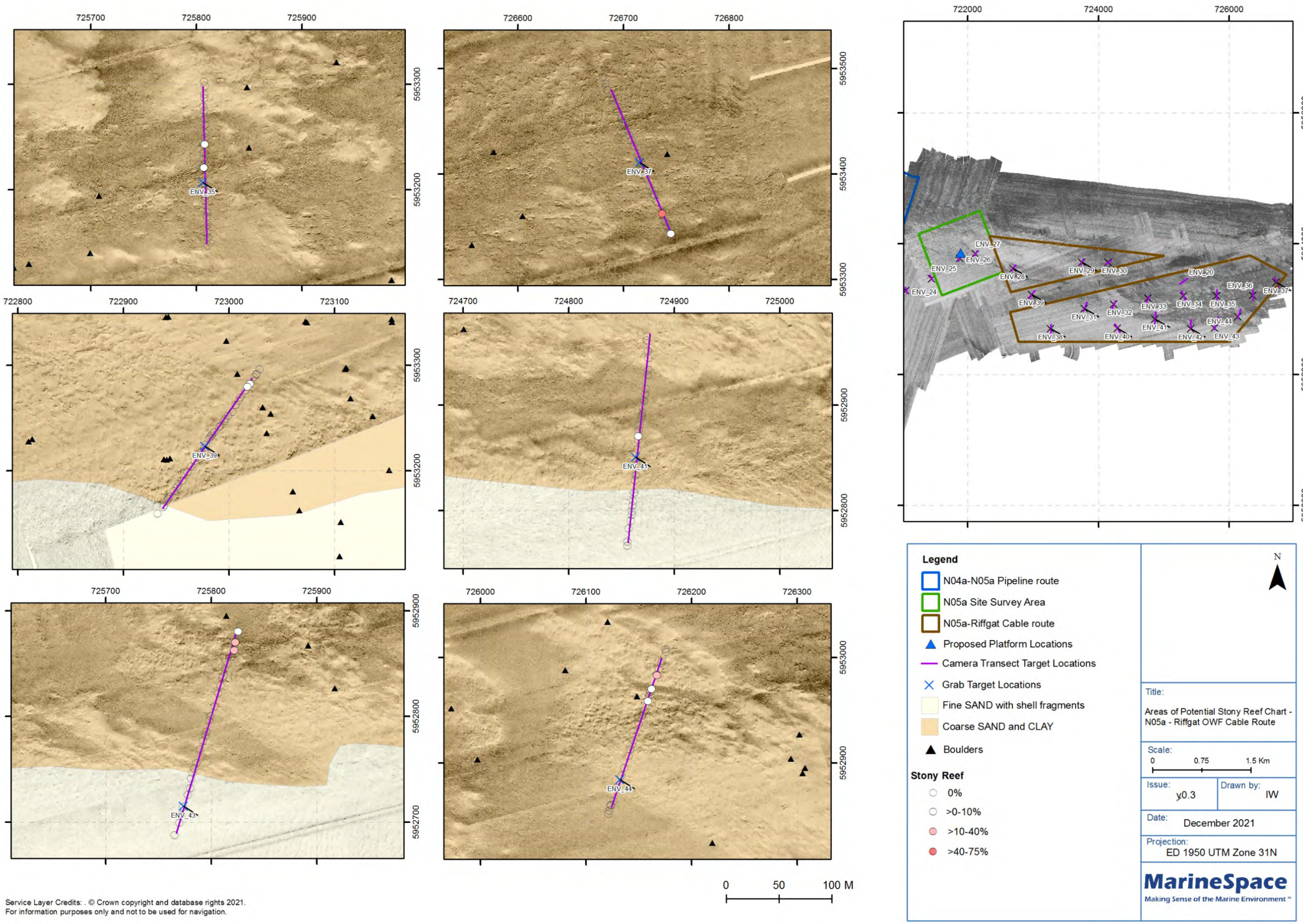


Figure 4.5: Area of potential stony reef within N05a-Riffgat OWF cable route, Stations ENV35, ENV37, ENV39, ENV41, ENV43-44



4.2.4. Sandbank (H1110_C) Assessment

Sediments within the N05a-Riffgat cable route ranged from sandy mud to gravelly muddy sand, however, only 13 stations (ENV20, ENV28-30, ENV33-39, ENV41 and ENV44) were described as containing sufficient sand content to meet the requirements of the H1110_C habitat subtype, which were found across both ‘coarse sand and clay’ and ‘fine sand with shell fragments’ sediment boundaries. Depths within and around the N05a-Riffgat cable route ranged from 18.7 m LAT and 26.6 m LAT. Review of the macrofauna revealed the presence of 6 species considered typical of the habitat (see Section 4.2.1).

Although, depth, sediment type and some typical species were characteristic of a sandbank habitat, there were no defined sandbank features identified in this area (see Section 4.1.2). Consequently, this area is unlikely to represent EC Habitats Directive Annex I habitat subtype H1110_C.

4.2.5. EUNIS Habitat Classification

The EUNIS classification hierarchy to biotope level 4 was mainly based on depth and sediment type. Results of the EUNIS habitat classification are based on geophysical data, seabed imagery and grab sediment interpretation are summarised in Table 4.1. EUNIS level 3 habitat boundaries are presented in Figure 4.6 and Figure 4.7.

All habitats observed related to the EUNIS level 1 category marine habitats (EUNIS code A) and level 2 category sublittoral sediment (EUNIS code A5), corresponding to sediment habitats in sublittoral near shore zone extending to 200 m depth.

EUNIS level 3 habitat classification was determined based on geophysical data, seabed imagery and grab interpretation of sediment composition. Sand was the dominant component of the sediment across all targets, therefore all targets were classified either as EUNIS habitat A5.2 sublittoral sand or A5.1 sublittoral coarse sediment. A5.2 sublittoral sand is described by the EEA (2019) as medium to fine sand or non-cohesive slightly muddy sands. A5.1 sublittoral coarse sediment is described by the EEA as coarse sediment including coarse sand, gravel, pebbles, shingles and cobbles, which are often unstable due to tidal currents and/or wave action. Several targets crossed through more than 1 SSS sediment boundary and so have been assigned more than 1 EUNIS habitat category.

Small areas of increased cobbles and occasionally boulders were seen across a number of stations and so were secondarily classified as EUNIS habitat A5.4 sublittoral mixed sediment. It is described by the EEA as comprising heterogenous muddy gravelly sands and/or also mosaics of cobbles and pebbles embedded in or lying upon sand, gravels or muds. Their fauna community constitutes a rich array or both infauna and epibiota including polychaetes, bivalves, echinoderms, anemones, hydroids and Bryozoa.

Across the N05a-Riffgat cable route, the corresponding level 4 habitat classifications were identified:

- EUNIS habitat A5.23 infralittoral fine sand is described as clean sand which occur in shallow water, either on open coast or in tide swept channels or marine inlets. The habitat is typically characterised by robust fauna, particularly amphipods (*Bathyporeia*) and robust polychaetes including *Nepthys cirrosa* and *Lanice conchilega*;

- EUNIS habitat A5.13 infralittoral coarse sediment is described as moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, are subject to disturbance by tidal streams and wave action. This habitat is characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, cumacean crustacea such as *Iphinoe trispinosa* and *Diastylis bradyi*, and venerid bivalves;
- EUNIS habitat A5.43 infralittoral mixed sediment is described as shallow mixed sediment in fully marine or near fully marine condition. This habitat may include well mixed muddy gravelly sands or very poorly sorted mosaics of shell, cobbles and pebbles embedded in mud, sand or gravel. Due to the quite variable nature of the sediment type, a widely variable array of communities may be found, including those characterised by bivalves, polychaetes and file shells. This has resulted in many species being described as characteristic of this habitat type all contributing only a small percentage to the overall similarity.

In addition due to the characteristic abundance of *Lanice conchilega*, it was possible to assign the biotope A5.137 dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand to sections of Transects ENV33, ENV35-37, ENV39 and ENV41-44.

Table 4.1 : N05a-Riffgat OWF cable route area EUNIS classification

Station	Depth (m LAT)	Folk (1954) from Grab Observation	EUNIS Habitat Classification
ENV20	24	Gravelly Muddy Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
ENV28	24 - 26	Muddy Gravelly Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
ENV29	24	Sandy Gravelly Mud to Muddy Gravelly Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
ENV30	24 - 25	Muddy Gravelly Sand to Muddy Sandy Gravel	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
ENV31	23 - 24	Sandy Mud	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
ENV32	22 - 25	Sandy Mud	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
ENV33	22 - 24	Muddy Sand	A5.13 Infralittoral Coarse Sediment
			A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand
			A5.43 Infralittoral Mixed Sediment
ENV34	23 - 24	Muddy Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
ENV35	23	Sand to Sandy Gravel	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
			A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand
ENV36	23	Sand	A5.13 Infralittoral Coarse Sediment
			A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand
ENV37	22 - 24	Sand to Gravelly Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment

Station	Depth (m LAT)	Folk (1954) from Grab Observation	EUNIS Habitat Classification
			A5.137 Dense *Lanice conchilega* and other polychaetes in tides wept infralittoral sand and mixed gravelly sand
ENV38	20 - 25	Sand	A5.23 Infralittoral Fine Sand
ENV39	24	Muddy Sand	A5.13 Infralittoral Coarse Sediment
			A5.43 Infralittoral Mixed Sediment
			A5.137 Dense *Lanice conchilega* and other polychaetes in tides wept infralittoral sand and mixed gravelly sand
ENV40	20 - 23	Sandy Mud	A5.23 Infralittoral Fine Sand
ENV41	22 - 24	Muddy Sand	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
			A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand
ENV42	22 - 24	Sandy Mud	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
			A5.137 Dense *Lanice conchilega* and other polychaetes in tides wept infralittoral sand and mixed gravelly sand
ENV43	22 - 23	Sandy Mud	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
			A5.43 Infralittoral Mixed Sediment
			A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand
ENV44	22 - 23	Sandy Mud to Sand	A5.13 Infralittoral Coarse Sediment
			A5.23 Infralittoral Fine Sand
			A5.43 Infralittoral Mixed Sediment

Figure 4.6: EUNIS Habitats identified within N05a-Riffgat OWF cable route area, Stations ENV20, ENV28 – ENV32, ENV38, ENV39 and ENV40

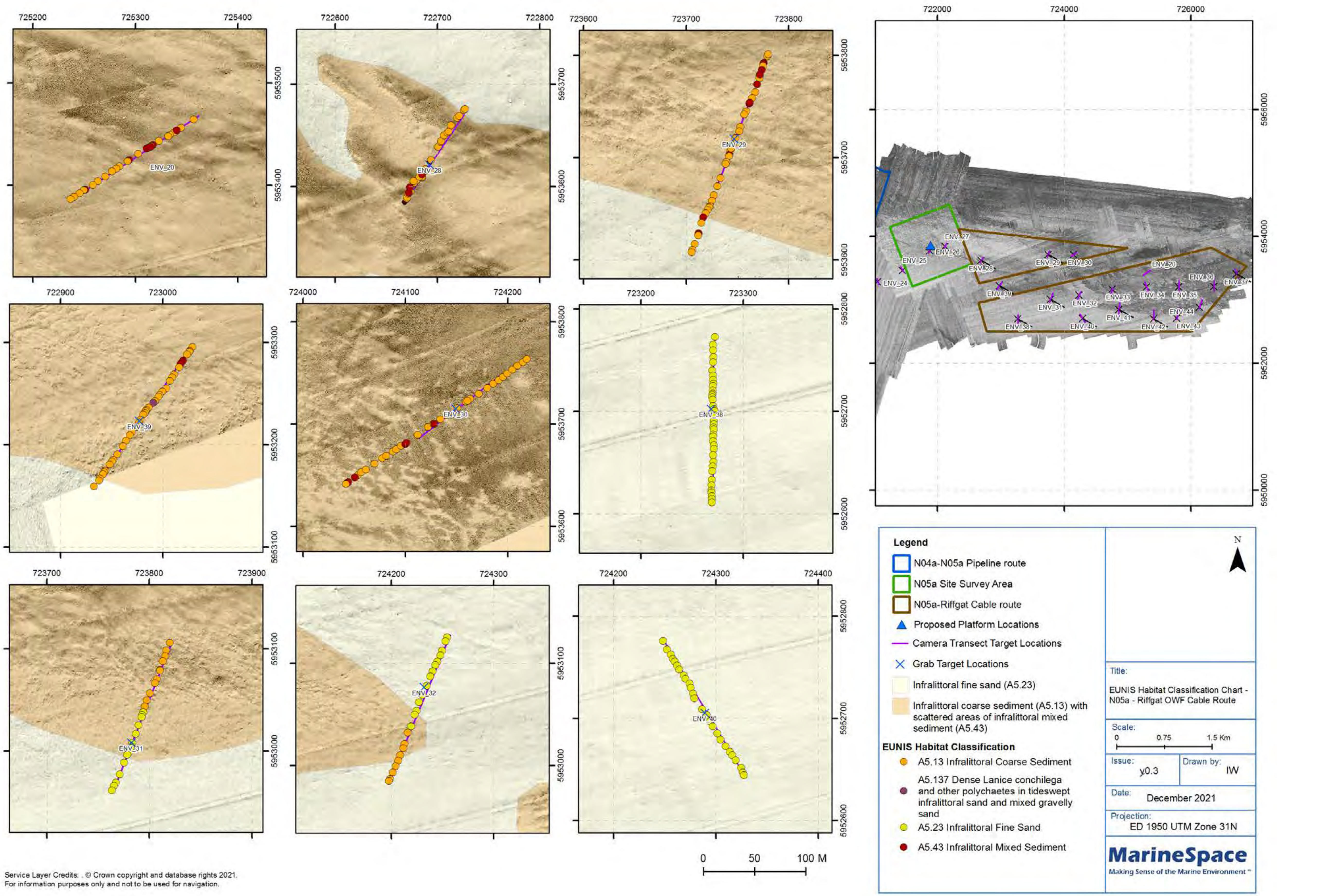
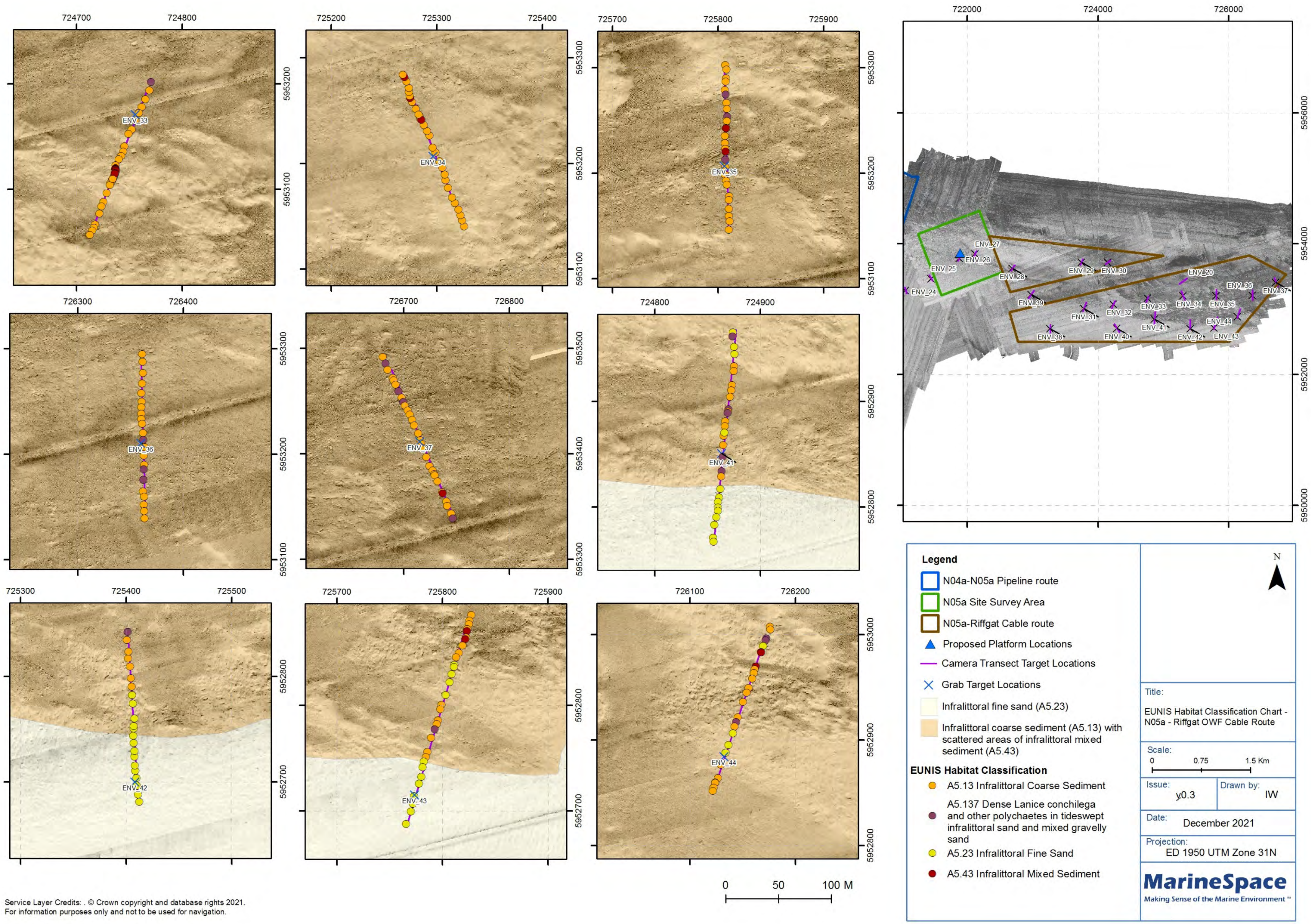


Figure 4.7: EUNIS Habitats identified within N05a-Riffgat OWF cable route area, Stations ENV33 - ENV37 and ENV41 – ENV44



5. Conclusion

Seabed imagery supported the geophysical data of ‘fine sand with shell fragments’ and ‘coarse sand with clay’. EUNIS classification identified 3 x 3 level EUNIS habitats A5.13 infralittoral coarse sediment, A5.23 infralittoral fine sand and A5.43 infralittoral mixed sediment as well as 1 x 4 level EUNIS habitat A5.137 Dense *Lanice conchilega* and other polychaetes in tide swept infralittoral sand and mixed gravelly sand.

Seabed imagery across the area of ‘coarse sand with clay’ revealed coarser sediment with areas of cobbles and boulders, which provided a hard surface for *Metridium dianthus* and Porifera to attached. Seabed imagery across the area of ‘fine sand with shell fragments’ revealed fine sand with sparse fauna.

In accordance with the Dutch guidance the areas of cobbles and boulders identified at stations ENV20, ENV28-30, ENV33-35, ENV37, ENV39, ENV41, ENV43-44 did not constitute a reef habitat (H1170) as the extent of the area was below 100 m^2 and only a few typical species were found.

Although, depth, sediment type and some associated fauna was found present, there were no defined sandbank features identified within the N05a-Riffgat cable route. Consequently, this area is unlikely to represent EC Habitats Directive Annex I habitat subtype H1110_C.

Based on the frequency of Porifera occurrence and percentage cover, they did not represent deep-sea sponge aggregations, classified as a threatened and or declining habitats (OSPAR, 2008).

Only one individual of Pennatulacea was observed within the N05a-Riffgat OWF cable route. Consequently, there is little resemblance to sea pens and burrowing megafauna in circalittoral fine mud, which is listed as a threatened and/or declining habitat (OSPAR, 2008).

Other than those detailed above there was no further evidence of any Annex I habitats, any species or habitats on the OSPAR (2008) list of threatened and/or declining species or any species on the IUCN Global Red List within the N05a-Riffgat OWF cable route.

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Appendix A. Environmental Field Logs

Appendix A1: Stills positional Logs

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_20	MARDUT1021_ENV_20_2021_11_11_160735.jpg	1189	16:07:58	11/11/2021	-	-	-	-
ENV_20	MARDUT1021_ENV_20_2021_11_11_160832.jpg	1190	16:08:55	11/11/2021	-	-	-	-
ENV_20	MARDUT1021_ENV_20_2021_11_11_160845.jpg	1191	16:09:08	11/11/2021	53.681215	6.412562	725356.950	5953464.520
ENV_20	MARDUT1021_ENV_20_2021_11_11_160914.jpg	1192	16:09:36	11/11/2021	53.681187	6.412461	725350.660	5953461.230
ENV_20	MARDUT1021_ENV_20_2021_11_11_160942.jpg	1193	16:10:04	11/11/2021	53.681147	6.412374	725345.060	5953456.410
ENV_20	MARDUT1021_ENV_20_2021_11_11_161006.jpg	1194	16:10:28	11/11/2021	53.681123	6.412292	725339.650	5953453.100
ENV_20	MARDUT1021_ENV_20_2021_11_11_161015.jpg	1195	16:10:37	11/11/2021	53.681111	6.412260	725338.000	5953452.070
ENV_20	MARDUT1021_ENV_20_2021_11_11_161030.jpg	1196	16:10:52	11/11/2021	53.681095	6.412215	725333.980	5953449.720
ENV_20	MARDUT1021_ENV_20_2021_11_11_161042.jpg	1197	16:11:05	11/11/2021	53.681080	6.412157	725332.230	5953448.050
ENV_20	MARDUT1021_ENV_20_2021_11_11_161122.jpg	1198	16:11:44	11/11/2021	53.681040	6.412036	725323.120	5953443.480
ENV_20	MARDUT1021_ENV_20_2021_11_11_161142.jpg	1199	16:12:05	11/11/2021	53.681020	6.411964	725318.750	5953440.850
ENV_20	MARDUT1021_ENV_20_2021_11_11_161151.jpg	1200	16:12:13	11/11/2021	53.681010	6.411940	725317.540	5953439.740
ENV_20	MARDUT1021_ENV_20_2021_11_11_161206.jpg	1201	16:12:28	11/11/2021	53.680996	6.411905	725314.970	5953437.730
ENV_20	MARDUT1021_ENV_20_2021_11_11_161210.jpg	1202	16:12:32	11/11/2021	53.680989	6.411880	725313.270	5953437.070
ENV_20	MARDUT1021_ENV_20_2021_11_11_161217.jpg	1203	16:12:39	11/11/2021	53.680980	6.411850	725311.310	5953436.190
ENV_20	MARDUT1021_ENV_20_2021_11_11_161256.jpg	1204	16:13:18	11/11/2021	53.680937	6.411714	725302.990	5953430.870
ENV_20	MARDUT1021_ENV_20_2021_11_11_161312.jpg	1205	16:13:34	11/11/2021	53.680919	6.411667	725300.690	5953428.340
ENV_20	MARDUT1021_ENV_20_2021_11_11_161341.jpg	1206	16:14:03	11/11/2021	53.680883	6.411583	725294.220	5953424.700
ENV_20	MARDUT1021_ENV_20_2021_11_11_161353.jpg	1207	16:14:15	11/11/2021	53.680874	6.411553	725292.760	5953423.800
ENV_20	MARDUT1021_ENV_20_2021_11_11_161422.jpg	1208	16:14:44	11/11/2021	53.680840	6.411435	725284.660	5953418.910
ENV_20	MARDUT1021_ENV_20_2021_11_11_161437.jpg	1209	16:15:00	11/11/2021	53.680821	6.411380	725281.490	5953416.600
ENV_20	MARDUT1021_ENV_20_2021_11_11_161454.jpg	1210	16:15:17	11/11/2021	53.680799	6.411321	725277.160	5953413.880
ENV_20	MARDUT1021_ENV_20_2021_11_11_161524.jpg	1211	16:15:46	11/11/2021	53.680765	6.411227	725271.930	5953409.480

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_20	MARDUT1021_ENV_20_2021_11_11_161529.jpg	1212	16:15:51	11/11/2021	53.680756	6.411224	725270.980	5953408.940
ENV_20	MARDUT1021_ENV_20_2021_11_11_161600.jpg	1213	16:16:23	11/11/2021	53.680713	6.411106	725263.600	5953404.270
ENV_20	MARDUT1021_ENV_20_2021_11_11_161631.jpg	1214	16:16:53	11/11/2021	53.680687	6.411016	725258.480	5953400.540
ENV_20	MARDUT1021_ENV_20_2021_11_11_161652.jpg	1215	16:17:15	11/11/2021	53.680659	6.410937	725251.530	5953396.020
ENV_20	MARDUT1021_ENV_20_2021_11_11_161708.jpg	1216	16:17:30	11/11/2021	53.680642	6.410884	725249.820	5953395.540
ENV_20	MARDUT1021_ENV_20_2021_11_11_161730.jpg	1217	16:17:52	11/11/2021	53.680618	6.410817	725245.690	5953392.580
ENV_20	MARDUT1021_ENV_20_2021_11_11_161752.jpg	1218	16:18:14	11/11/2021	53.680589	6.410745	725240.300	5953388.940
ENV_20	MARDUT1021_ENV_20_2021_11_11_161810.jpg	1219	16:18:32	11/11/2021	53.680571	6.410683	725236.760	5953386.640
ENV_28	MARDUT1021_ENV_28_2021_11_05_150707.jpg	01	15:07:48	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_150928.jpg	02	15:10:09	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151015.jpg	03	15:10:56	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151018.jpg	04	15:10:59	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151050.jpg	05	15:11:31	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151107.jpg	06	15:11:48	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151116.jpg	07	15:11:57	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151139.jpg	08	15:12:20	05/11/2021	-	-	-	-
ENV_28	MARDUT1021_ENV_28_2021_11_05_151157.jpg	09	15:12:39	05/11/2021	53.682492	6.371928	722679.290	5953605.660
ENV_28	MARDUT1021_ENV_28_2021_11_05_151220.jpg	10	15:13:02	05/11/2021	53.682519	6.372014	722684.880	5953608.930
ENV_28	MARDUT1021_ENV_28_2021_11_05_151231.jpg	11	15:13:12	05/11/2021	53.682524	6.372014	722684.840	5953609.490
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152314.jpg	12	15:23:55	05/11/2021	53.682308	6.371738	722667.770	5953584.550
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152342.jpg	13	15:24:23	05/11/2021	53.682340	6.371777	722670.180	5953588.200
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152354.jpg	14	15:24:35	05/11/2021	53.682350	6.371783	722670.500	5953589.420
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152408.jpg	15	15:24:50	05/11/2021	53.682376	6.371798	722671.350	5953592.290
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152413.jpg	16	15:24:54	05/11/2021	53.682384	6.371797	722671.220	5953593.190
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152427.jpg	17	15:25:09	05/11/2021	53.682401	6.371833	722673.560	5953595.200
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152445.jpg	18	15:25:27	05/11/2021	53.682446	6.371850	722674.440	5953600.250
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152458.jpg	19	15:25:39	05/11/2021	53.682456	6.371861	722675.120	5953601.441
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152513.jpg	20	15:25:55	05/11/2021	53.682475	6.371887	722676.720	5953603.571

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152527.jpg	21	15:26:08	05/11/2021	53.682492	6.371884	722676.450	5953605.460
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152558.jpg	22	15:26:39	05/11/2021	53.682525	6.371976	722682.330	5953609.490
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152620.jpg	23	15:27:02	05/11/2021	53.682573	6.372051	722687.030	5953615.060
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152632.jpg	24	15:27:13	05/11/2021	53.682592	6.372071	722688.230	5953617.240
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152653.jpg	25	15:27:35	05/11/2021	53.682648	6.372132	722691.970	5953623.560
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152706.jpg	26	15:27:47	05/11/2021	53.682669	6.372158	722693.580	5953626.070
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152759.jpg	27	15:28:40	05/11/2021	53.682781	6.372271	722700.430	5953638.780
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152822.jpg	28	15:29:03	05/11/2021	53.682822	6.372319	722703.400	5953643.500
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152831.jpg	29	15:29:12	05/11/2021	53.682833	6.372323	722703.620	5953644.820
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152856.jpg	30	15:29:37	05/11/2021	53.682878	6.372368	722706.330	5953649.910
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152910.jpg	31	15:29:51	05/11/2021	53.682902	6.372421	722709.690	5953652.720
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152920.jpg	32	15:30:01	05/11/2021	53.682911	6.372438	722710.760	5953653.850
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_152944.jpg	33	15:30:26	05/11/2021	53.682966	6.372478	722713.100	5953660.040
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_153012.jpg	34	15:30:53	05/11/2021	53.683028	6.372576	722719.260	5953667.270
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_153022.jpg	35	15:31:03	05/11/2021	53.683044	6.372608	722721.270	5953669.130
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_153047.jpg	36	15:31:28	05/11/2021	53.683094	6.372678	722725.670	5953674.960
ENV_28(2)	MARDUT1021_ENV_28(2)_2021_11_05_153052.jpg	37	15:31:33	05/11/2021	53.683103	6.372696	722726.770	5953675.990
ENV_29	MARDUT1021_ENV_29_2021_11_09_145222.jpg	820	14:52:26	09/11/2021	53.683760	6.388696	723779.540	5953799.300
ENV_29	MARDUT1021_ENV_29_2021_11_09_145252.jpg	821	14:52:56	09/11/2021	53.683702	6.388639	723776.130	5953792.670
ENV_29	MARDUT1021_ENV_29_2021_11_09_145255.jpg	822	14:52:59	09/11/2021	53.683695	6.388632	723775.690	5953791.870
ENV_29	MARDUT1021_ENV_29_2021_11_09_145305.jpg	823	14:53:08	09/11/2021	53.683674	6.388624	723775.260	5953789.520
ENV_29	MARDUT1021_ENV_29_2021_11_09_145321.jpg	824	14:53:25	09/11/2021	53.683640	6.388606	723774.250	5953785.720
ENV_29	MARDUT1021_ENV_29_2021_11_09_145339.jpg	825	14:53:43	09/11/2021	53.683591	6.388565	723771.770	5953780.100
ENV_29	MARDUT1021_ENV_29_2021_11_09_145348.jpg	826	14:53:51	09/11/2021	53.683570	6.388564	723771.850	5953777.751
ENV_29	MARDUT1021_ENV_29_2021_11_09_145418.jpg	827	14:54:21	09/11/2021	53.683519	6.388526	723769.640	5953771.920
ENV_29	MARDUT1021_ENV_29_2021_11_09_145451.jpg	828	14:54:55	09/11/2021	53.683450	6.388492	723767.720	5953764.220
ENV_29	MARDUT1021_ENV_29_2021_11_09_145521.jpg	829	14:55:24	09/11/2021	53.683398	6.388444	723764.850	5953758.290
ENV_29	MARDUT1021_ENV_29_2021_11_09_145545.jpg	830	14:55:48	09/11/2021	53.683351	6.388396	723761.910	5953752.890

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_29	MARDUT1021_ENV_29_2021_11_09_145616.jpg	831	14:56:20	09/11/2021	53.683284	6.388343	723758.760	5953745.240
ENV_29	MARDUT1021_ENV_29_2021_11_09_145632.jpg	832	14:56:35	09/11/2021	53.683258	6.388315	723757.100	5953742.260
ENV_29	MARDUT1021_ENV_29_2021_11_09_145723.jpg	833	14:57:26	09/11/2021	53.683149	6.388250	723753.340	5953729.990
ENV_29	MARDUT1021_ENV_29_2021_11_09_145743.jpg	834	14:57:47	09/11/2021	53.683114	6.388230	723752.240	5953725.990
ENV_29	MARDUT1021_ENV_29_2021_11_09_145816.jpg	835	14:58:20	09/11/2021	53.683055	6.388164	723748.190	5953719.230
ENV_29	MARDUT1021_ENV_29_2021_11_09_145837.jpg	836	14:58:40	09/11/2021	53.682999	6.388122	723745.710	5953712.890
ENV_29	MARDUT1021_ENV_29_2021_11_09_145855.jpg	837	14:58:59	09/11/2021	53.682965	6.388092	723743.910	5953708.980
ENV_29	MARDUT1021_ENV_29_2021_11_09_145905.jpg	838	14:59:08	09/11/2021	53.682940	6.388081	723743.300	5953706.140
ENV_29	MARDUT1021_ENV_29_2021_11_09_145921.jpg	839	14:59:24	09/11/2021	53.682912	6.388066	723742.480	5953702.991
ENV_29	MARDUT1021_ENV_29_2021_11_09_145928.jpg	840	14:59:31	09/11/2021	53.682898	6.388058	723742.040	5953701.410
ENV_29	MARDUT1021_ENV_29_2021_11_09_145949.jpg	841	14:59:53	09/11/2021	53.682856	6.388016	723739.490	5953696.600
ENV_29	MARDUT1021_ENV_29_2021_11_09_145954.jpg	842	14:59:57	09/11/2021	53.682847	6.388013	723739.330	5953695.670
ENV_29	MARDUT1021_ENV_29_2021_11_09_150001.jpg	843	15:00:04	09/11/2021	53.682831	6.388000	723738.530	5953693.860
ENV_29	MARDUT1021_ENV_29_2021_11_09_150048.jpg	844	15:00:52	09/11/2021	53.682711	6.387917	723733.700	5953680.260
ENV_29	MARDUT1021_ENV_29_2021_11_09_150123.jpg	845	15:01:27	09/11/2021	53.682641	6.387865	723730.630	5953672.210
ENV_29	MARDUT1021_ENV_29_2021_11_09_150159.jpg	846	15:02:02	09/11/2021	53.682562	6.387809	723727.370	5953663.330
ENV_29	MARDUT1021_ENV_29_2021_11_09_150222.jpg	847	15:02:26	09/11/2021	53.682515	6.387773	723725.230	5953657.970
ENV_29	MARDUT1021_ENV_29_2021_11_09_150242.jpg	848	15:02:45	09/11/2021	53.682470	6.387743	723723.470	5953652.850
ENV_29	MARDUT1021_ENV_29_2021_11_09_150248.jpg	849	15:02:52	09/11/2021	53.682459	6.387731	723722.720	5953651.600
ENV_29	MARDUT1021_ENV_29_2021_11_09_150302.jpg	850	15:03:06	09/11/2021	53.682434	6.387705	723721.160	5953648.720
ENV_29	MARDUT1021_ENV_29_2021_11_09_150315.jpg	851	15:03:19	09/11/2021	53.682409	6.387677	723719.430	5953645.820
ENV_29	MARDUT1021_ENV_29_2021_11_09_150334.jpg	852	15:03:37	09/11/2021	53.682371	6.387638	723717.080	5953641.490
ENV_29	MARDUT1021_ENV_29_2021_11_09_150352.jpg	853	15:03:55	09/11/2021	53.682326	6.387604	723715.050	5953636.450
ENV_29	MARDUT1021_ENV_29_2021_11_09_150430.jpg	854	15:04:34	09/11/2021	53.682239	6.387556	723712.360	5953626.530
ENV_29	MARDUT1021_ENV_29_2021_11_09_150436.jpg	855	15:04:39	09/11/2021	53.682231	6.387555	723712.320	5953625.740
ENV_29	MARDUT1021_ENV_29_2021_11_09_150443.jpg	856	15:04:46	09/11/2021	53.682218	6.387548	723711.940	5953624.170
ENV_29	MARDUT1021_ENV_29_2021_11_09_150514.jpg	857	15:05:17	09/11/2021	53.682145	6.387488	723708.390	5953615.871
ENV_29	MARDUT1021_ENV_29_2021_11_09_150538.jpg	858	15:05:41	09/11/2021	53.682094	6.387454	723706.380	5953610.101

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_29	MARDUT1021_ENV_29_2021_11_09_150552.jpg	859	15:05:55	09/11/2021	53.682073	6.387437	723705.390	5953607.701
ENV_30	MARDUT1021_ENV_30_2021_11_09_154314.jpg	860	15:43:17	09/11/2021	53.682238	6.392561	724042.760	5953642.230
ENV_30	MARDUT1021_ENV_30_2021_11_09_154321.jpg	861	15:43:25	09/11/2021	53.682247	6.392585	724044.320	5953643.300
ENV_30	MARDUT1021_ENV_30_2021_11_09_154410.jpg	862	15:44:14	09/11/2021	53.682305	6.392732	724053.740	5953650.225
ENV_30	MARDUT1021_ENV_30_2021_11_09_154428.jpg	863	15:44:32	09/11/2021	53.682329	6.392782	724056.870	5953653.060
ENV_30	MARDUT1021_ENV_30_2021_11_09_154455.jpg	864	15:44:58	09/11/2021	53.682349	6.392852	724061.430	5953655.550
ENV_30	MARDUT1021_ENV_30_2021_11_09_154531.jpg	865	15:45:34	09/11/2021	53.682396	6.392982	724069.730	5953661.180
ENV_30	MARDUT1021_ENV_30_2021_11_09_154608.jpg	866	15:46:11	09/11/2021	53.682442	6.393105	724077.590	5953666.610
ENV_30	MARDUT1021_ENV_30_2021_11_09_154627.jpg	867	15:46:30	09/11/2021	53.682460	6.393162	724081.250	5953668.800
ENV_30	MARDUT1021_ENV_30_2021_11_09_154700.jpg	868	15:47:03	09/11/2021	53.682497	6.393262	724087.700	5953673.280
ENV_30	MARDUT1021_ENV_30_2021_11_09_154720.jpg	869	15:47:22	09/11/2021	53.682515	6.393318	724091.300	5953675.410
ENV_30	MARDUT1021_ENV_30_2021_11_09_154749.jpg	870	15:47:52	09/11/2021	53.682543	6.393389	724095.800	5953678.780
ENV_30	MARDUT1021_ENV_30_2021_11_09_154804.jpg	871	15:48:07	09/11/2021	53.682556	6.393449	724099.740	5953680.430
ENV_30	MARDUT1021_ENV_30_2021_11_09_154817.jpg	872	15:48:20	09/11/2021	53.682567	6.393468	724100.930	5953681.690
ENV_30	MARDUT1021_ENV_30_2021_11_09_154900.jpg	873	15:49:03	09/11/2021	53.682634	6.393642	724112.050	5953689.640
ENV_30	MARDUT1021_ENV_30_2021_11_09_154947.jpg	874	15:49:50	09/11/2021	53.682698	6.393798	724121.980	5953697.260
ENV_30	MARDUT1021_ENV_30_2021_11_09_155013.jpg	875	15:50:16	09/11/2021	53.682722	6.393881	724127.330	5953700.190
ENV_30	MARDUT1021_ENV_30_2021_11_09_155044.jpg	876	15:50:48	09/11/2021	53.682762	6.393987	724134.150	5953705.030
ENV_30	MARDUT1021_ENV_30_2021_11_09_155120.jpg	877	15:51:24	09/11/2021	53.682795	6.394081	724140.190	5953708.990
ENV_30	MARDUT1021_ENV_30_2021_11_09_155204.jpg	878	15:52:07	09/11/2021	53.682853	6.394245	724150.680	5953715.980
ENV_30	MARDUT1021_ENV_30_2021_11_09_155244.jpg	879	15:52:47	09/11/2021	53.682904	6.394379	724159.250	5953722.019
ENV_30	MARDUT1021_ENV_30_2021_11_09_155302.jpg	880	15:53:06	09/11/2021	53.682925	6.394442	724163.280	5953724.550
ENV_30	MARDUT1021_ENV_30_2021_11_09_155344.jpg	881	15:53:47	09/11/2021	53.682969	6.394570	724171.520	5953729.870
ENV_30	MARDUT1021_ENV_30_2021_11_09_155418.jpg	882	15:54:21	09/11/2021	53.683016	6.394702	724180.000	5953735.470
ENV_30	MARDUT1021_ENV_30_2021_11_09_155446.jpg	883	15:54:49	09/11/2021	53.683051	6.394794	724185.890	5953739.690
ENV_30	MARDUT1021_ENV_30_2021_11_09_155516.jpg	884	15:55:19	09/11/2021	53.683079	6.394878	724191.250	5953743.050
ENV_30	MARDUT1021_ENV_30_2021_11_09_155536.jpg	885	15:55:40	09/11/2021	53.683106	6.394942	724195.330	5953746.270
ENV_30	MARDUT1021_ENV_30_2021_11_09_155558.jpg	886	15:56:01	09/11/2021	53.683132	6.395011	724199.770	5953749.410

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_30	MARDUT1021_ENV_30_2021_11_09_155622.jpg	887	15:56:25	09/11/2021	53.683165	6.395088	724204.710	5953753.270
ENV_30	MARDUT1021_ENV_30_2021_11_09_155644.jpg	888	15:56:47	09/11/2021	53.683197	6.395163	724209.490	5953757.070
ENV_30	MARDUT1021_ENV_30_2021_11_09_155711.jpg	889	15:57:15	09/11/2021	53.683226	6.395245	724214.700	5953760.560
ENV_30	MARDUT1021_ENV_30_2021_11_09_155732.jpg	890	15:57:35	09/11/2021	53.683251	6.395309	724218.820	5953763.589
ENV_31	MARDUT1021_ENV_31_2021_11_09_141734.jpg	794	14:17:37	09/11/2021	53.677524	6.388812	723820.290	5953106.270
ENV_31	MARDUT1021_ENV_31_2021_11_09_141810.jpg	795	14:18:14	09/11/2021	53.677461	6.388753	723816.720	5953099.000
ENV_31	MARDUT1021_ENV_31_2021_11_09_141833.jpg	796	14:18:36	09/11/2021	53.677411	6.388734	723815.730	5953093.390
ENV_31	MARDUT1021_ENV_31_2021_11_09_141858.jpg	797	14:19:01	09/11/2021	53.677364	6.388695	723813.430	5953088.090
ENV_31	MARDUT1021_ENV_31_2021_11_09_141926.jpg	798	14:19:29	09/11/2021	53.677293	6.388649	723810.785	5953079.970
ENV_31	MARDUT1021_ENV_31_2021_11_09_141935.jpg	799	14:19:39	09/11/2021	53.677286	6.388645	723810.535	5953079.220
ENV_31	MARDUT1021_ENV_31_2021_11_09_142006.jpg	800	14:20:09	09/11/2021	53.677211	6.388596	723807.680	5953070.755
ENV_31	MARDUT1021_ENV_31_2021_11_09_142032.jpg	801	14:20:35	09/11/2021	53.677178	6.388562	723805.625	5953067.009
ENV_31	MARDUT1021_ENV_31_2021_11_09_142120.jpg	802	14:21:24	09/11/2021	53.677089	6.388483	723800.875	5953056.840
ENV_31	MARDUT1021_ENV_31_2021_11_09_142144.jpg	803	14:21:47	09/11/2021	53.677029	6.388432	723797.815	5953050.020
ENV_31	MARDUT1021_ENV_31_2021_11_09_142206.jpg	804	14:22:09	09/11/2021	53.676977	6.388398	723795.885	5953044.064
ENV_31	MARDUT1021_ENV_31_2021_11_09_142230.jpg	805	14:22:33	09/11/2021	53.676924	6.388367	723794.090	5953038.135
ENV_31	MARDUT1021_ENV_31_2021_11_09_142245.jpg	806	14:22:48	09/11/2021	53.676902	6.388348	723792.990	5953035.595
ENV_31	MARDUT1021_ENV_31_2021_11_09_142252.jpg	807	14:22:55	09/11/2021	53.676885	6.388341	723792.570	5953033.710
ENV_31	MARDUT1021_ENV_31_2021_11_09_142319.jpg	808	14:23:22	09/11/2021	53.676815	6.388290	723789.610	5953025.765
ENV_31	MARDUT1021_ENV_31_2021_11_09_142353.jpg	809	14:23:57	09/11/2021	53.676739	6.388243	723786.925	5953017.170
ENV_31	MARDUT1021_ENV_31_2021_11_09_142429.jpg	810	14:24:32	09/11/2021	53.676661	6.388184	723783.435	5953008.326
ENV_31	MARDUT1021_ENV_31_2021_11_09_142444.jpg	811	14:24:47	09/11/2021	53.676632	6.388168	723782.477	5953005.012
ENV_31	MARDUT1021_ENV_31_2021_11_09_142451.jpg	812	14:24:54	09/11/2021	53.676617	6.388158	723781.895	5953003.343
ENV_31	MARDUT1021_ENV_31_2021_11_09_142513.jpg	813	14:25:17	09/11/2021	53.676576	6.388119	723779.590	5952998.600
ENV_31	MARDUT1021_ENV_31_2021_11_09_142525.jpg	814	14:25:28	09/11/2021	53.676560	6.388105	723778.730	5952996.750
ENV_31	MARDUT1021_ENV_31_2021_11_09_142555.jpg	815	14:25:58	09/11/2021	53.676490	6.388053	723775.665	5952988.891
ENV_31	MARDUT1021_ENV_31_2021_11_09_142639.jpg	816	14:26:43	09/11/2021	53.676392	6.387979	723771.320	5952977.680
ENV_31	MARDUT1021_ENV_31_2021_11_09_142714.jpg	817	14:27:18	09/11/2021	53.676320	6.387915	723767.470	5952969.520

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_31	MARDUT1021_ENV_31_2021_11_09_142733.jpg	818	14:27:37	09/11/2021	53.676292	6.387885	723765.645	5952966.285
ENV_31	MARDUT1021_ENV_31_2021_11_09_142752.jpg	819	14:27:55	09/11/2021	53.676254	6.387855	723763.825	5952961.950
ENV_32	MARDUT1021_ENV_32_2021_11_09_165127.jpg	891	16:51:30	09/11/2021	53.677512	6.395395	724254.990	5953125.600
ENV_32	MARDUT1021_ENV_32_2021_11_09_165144.jpg	892	16:51:47	09/11/2021	53.677478	6.395365	724253.210	5953121.740
ENV_32	MARDUT1021_ENV_32_2021_11_09_165223.jpg	893	16:52:26	09/11/2021	53.677395	6.395310	724250.000	5953112.420
ENV_32	MARDUT1021_ENV_32_2021_11_09_165244.jpg	894	16:52:47	09/11/2021	53.677357	6.395281	724248.270	5953108.020
ENV_32	MARDUT1021_ENV_32_2021_11_09_165311.jpg	895	16:53:15	09/11/2021	53.677301	6.395233	724245.410	5953101.640
ENV_32	MARDUT1021_ENV_32_2021_11_09_165329.jpg	896	16:53:32	09/11/2021	53.677272	6.395200	724243.380	5953098.360
ENV_32	MARDUT1021_ENV_32_2021_11_09_165354.jpg	897	16:53:57	09/11/2021	53.677218	6.395154	724240.670	5953092.221
ENV_32	MARDUT1021_ENV_32_2021_11_09_165417.jpg	898	16:54:20	09/11/2021	53.677174	6.395115	724238.290	5953087.199
ENV_32	MARDUT1021_ENV_32_2021_11_09_165455.jpg	899	16:54:58	09/11/2021	53.677095	6.395060	724235.090	5953078.210
ENV_32	MARDUT1021_ENV_32_2021_11_09_165533.jpg	900	16:55:36	09/11/2021	53.677014	6.394987	724230.690	5953068.980
ENV_32	MARDUT1021_ENV_32_2021_11_09_165609.jpg	901	16:56:12	09/11/2021	53.676952	6.394933	724227.460	5953061.950
ENV_32	MARDUT1021_ENV_32_2021_11_09_165634.jpg	902	16:56:38	09/11/2021	53.676880	6.394888	724224.900	5953053.810
ENV_32	MARDUT1021_ENV_32_2021_11_09_165656.jpg	903	16:56:59	09/11/2021	53.676846	6.394858	724223.070	5953049.850
ENV_32	MARDUT1021_ENV_32_2021_11_09_165738.jpg	904	16:57:41	09/11/2021	53.676743	6.394796	724219.510	5953038.271
ENV_32	MARDUT1021_ENV_32_2021_11_09_165759.jpg	905	16:58:02	09/11/2021	53.676702	6.394761	724217.430	5953033.570
ENV_32	MARDUT1021_ENV_32_2021_11_09_165810.jpg	906	16:58:14	09/11/2021	53.676690	6.394743	724216.300	5953032.150
ENV_32	MARDUT1021_ENV_32_2021_11_09_165850.jpg	907	16:58:53	09/11/2021	53.676593	6.394689	724213.290	5953021.200
ENV_32	MARDUT1021_ENV_32_2021_11_09_165913.jpg	908	16:59:16	09/11/2021	53.676554	6.394667	724212.050	5953016.870
ENV_32	MARDUT1021_ENV_32_2021_11_09_165939.jpg	909	16:59:42	09/11/2021	53.676494	6.394617	724209.060	5953009.980
ENV_32	MARDUT1021_ENV_32_2021_11_09_170002.jpg	910	17:00:05	09/11/2021	53.676450	6.394586	724207.210	5953004.980
ENV_32	MARDUT1021_ENV_32_2021_11_09_170025.jpg	911	17:00:29	09/11/2021	53.676402	6.394539	724204.410	5952999.480
ENV_32	MARDUT1021_ENV_32_2021_11_09_170051.jpg	912	17:00:54	09/11/2021	53.676347	6.394492	724201.590	5952993.210
ENV_32	MARDUT1021_ENV_32_2021_11_09_170115.jpg	913	17:01:19	09/11/2021	53.676292	6.394450	724199.070	5952987.030
ENV_32	MARDUT1021_ENV_32_2021_11_09_170128.jpg	914	17:01:31	09/11/2021	53.676275	6.394433	724198.060	5952985.010
ENV_33	MARDUT1021_ENV_33_2021_11_09_190001.jpg	969	19:00:04	09/11/2021	53.677975	6.403241	724770.520	5953201.899
ENV_33	MARDUT1021_ENV_33_2021_11_09_190031.jpg	970	19:00:34	09/11/2021	53.677904	6.403212	724768.990	5953193.930

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_33	MARDUT1021_ENV_33_2021_11_09_190110.jpg	971	19:01:13	09/11/2021	53.677831	6.403153	724765.490	5953185.580
ENV_33	MARDUT1021_ENV_33_2021_11_09_190143.jpg	972	19:01:47	09/11/2021	53.677766	6.403094	724761.970	5953178.240
ENV_33	MARDUT1021_ENV_33_2021_11_09_190209.jpg	973	19:02:12	09/11/2021	53.677714	6.403047	724759.110	5953172.290
ENV_33	MARDUT1021_ENV_33_2021_11_09_190243.jpg	974	19:02:46	09/11/2021	53.677650	6.402992	724755.840	5953165.010
ENV_33	MARDUT1021_ENV_33_2021_11_09_190318.jpg	975	19:03:21	09/11/2021	53.677578	6.402931	724752.170	5953156.750
ENV_33	MARDUT1021_ENV_33_2021_11_09_190337.jpg	976	19:03:40	09/11/2021	53.677540	6.402886	724749.450	5953152.420
ENV_33	MARDUT1021_ENV_33_2021_11_09_190422.jpg	977	19:04:26	09/11/2021	53.677438	6.402817	724745.420	5953140.910
ENV_33	MARDUT1021_ENV_33_2021_11_09_190447.jpg	978	19:04:50	09/11/2021	53.677392	6.402795	724744.220	5953135.680
ENV_33	MARDUT1021_ENV_33_2021_11_09_190500.jpg	979	19:05:04	09/11/2021	53.677357	6.402763	724742.300	5953131.660
ENV_33	MARDUT1021_ENV_33_2021_11_09_190516.jpg	980	19:05:20	09/11/2021	53.677330	6.402728	724740.110	5953128.560
ENV_33	MARDUT1021_ENV_33_2021_11_09_190539.jpg	981	19:05:42	09/11/2021	53.677281	6.402680	724737.220	5953123.000
ENV_33	MARDUT1021_ENV_33_2021_11_09_190549.jpg	982	19:05:52	09/11/2021	53.677255	6.402673	724736.900	5953120.050
ENV_33	MARDUT1021_ENV_33_2021_11_09_190552.jpg	983	19:05:55	09/11/2021	53.677250	6.402672	724736.830	5953119.500
ENV_33	MARDUT1021_ENV_33_2021_11_09_190554.jpg	984	19:05:57	09/11/2021	53.677244	6.402675	724737.080	5953118.860
ENV_33	MARDUT1021_ENV_33_2021_11_09_190557.jpg	985	19:06:00	09/11/2021	53.677243	6.402678	724737.250	5953118.710
ENV_33	MARDUT1021_ENV_33_2021_11_09_190601.jpg	986	19:06:05	09/11/2021	53.677232	6.402678	724737.350	5953117.560
ENV_33	MARDUT1021_ENV_33_2021_11_09_190612.jpg	987	19:06:16	09/11/2021	53.677212	6.402665	724736.580	5953115.210
ENV_33	MARDUT1021_ENV_33_2021_11_09_190621.jpg	988	19:06:25	09/11/2021	53.677193	6.402654	724735.970	5953113.130
ENV_33	MARDUT1021_ENV_33_2021_11_09_190622.jpg	989	19:06:26	09/11/2021	53.677187	6.402649	724735.670	5953112.480
ENV_33	MARDUT1021_ENV_33_2021_11_09_190628.jpg	990	19:06:31	09/11/2021	53.677175	6.402639	724735.060	5953111.030
ENV_33	MARDUT1021_ENV_33_2021_11_09_190637.jpg	991	19:06:40	09/11/2021	53.677166	6.402627	724734.330	5953110.020
ENV_33	MARDUT1021_ENV_33_2021_11_09_190643.jpg	992	19:06:46	09/11/2021	53.677155	6.402617	724733.700	5953108.800
ENV_33	MARDUT1021_ENV_33_2021_11_09_190650.jpg	993	19:06:53	09/11/2021	53.677141	6.402609	724733.290	5953107.150
ENV_33	MARDUT1021_ENV_33_2021_11_09_190656.jpg	994	19:06:59	09/11/2021	53.677126	6.402591	724732.170	5953105.480
ENV_33	MARDUT1021_ENV_33_2021_11_09_190701.jpg	995	19:07:04	09/11/2021	53.677116	6.402582	724731.650	5953104.280
ENV_33	MARDUT1021_ENV_33_2021_11_09_190733.jpg	996	19:07:36	09/11/2021	53.677046	6.402532	724728.660	5953096.380
ENV_33	MARDUT1021_ENV_33_2021_11_09_190805.jpg	997	19:08:08	09/11/2021	53.676974	6.402477	724725.440	5953088.170
ENV_33	MARDUT1021_ENV_33_2021_11_09_190826.jpg	998	19:08:30	09/11/2021	53.676934	6.402445	724723.570	5953083.680

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_33	MARDUT1021_ENV_33_2021_11_09_190857.jpg	999	19:09:00	09/11/2021	53.676874	6.402411	724721.620	5953076.860
ENV_33	MARDUT1021_ENV_33_2021_11_09_190936.jpg	1000	19:09:40	09/11/2021	53.676784	6.402343	724717.600	5953066.640
ENV_33	MARDUT1021_ENV_33_2021_11_09_190951.jpg	1001	19:09:54	09/11/2021	53.676759	6.402324	724716.490	5953063.780
ENV_33	MARDUT1021_ENV_33_2021_11_09_191003.jpg	1002	19:10:06	09/11/2021	53.676735	6.402296	724714.740	5953061.101
ENV_33	MARDUT1021_ENV_33_2021_11_09_191024.jpg	1003	19:10:27	09/11/2021	53.676699	6.402260	724712.590	5953056.921
ENV_34	MARDUT1021_ENV_34_2021_11_09_203152.jpg	1027	20:31:56	09/11/2021	53.677182	6.411589	725325.960	5953140.140
ENV_34	MARDUT1021_ENV_34_2021_11_09_203226.jpg	1028	20:32:30	09/11/2021	53.677235	6.411560	725323.770	5953145.980
ENV_34	MARDUT1021_ENV_34_2021_11_09_203249.jpg	1029	20:32:53	09/11/2021	53.677279	6.411542	725322.300	5953150.859
ENV_34	MARDUT1021_ENV_34_2021_11_09_203316.jpg	1030	20:33:20	09/11/2021	53.677330	6.411520	725320.620	5953156.460
ENV_34	MARDUT1021_ENV_34_2021_11_09_203342.jpg	1031	20:33:46	09/11/2021	53.677385	6.411469	725316.940	5953162.400
ENV_34	MARDUT1021_ENV_34_2021_11_09_203414.jpg	1032	20:34:18	09/11/2021	53.677436	6.411435	725314.430	5953167.930
ENV_34	MARDUT1021_ENV_34_2021_11_09_203442.jpg	1033	20:34:46	09/11/2021	53.677517	6.411384	725310.630	5953176.800
ENV_34	MARDUT1021_ENV_34_2021_11_09_203514.jpg	1034	20:35:18	09/11/2021	53.677584	6.411357	725308.480	5953184.190
ENV_34	MARDUT1021_ENV_34_2021_11_09_203535.jpg	1035	20:35:39	09/11/2021	53.677632	6.411349	725307.680	5953189.420
ENV_34	MARDUT1021_ENV_34_2021_11_09_203614.jpg	1036	20:36:18	09/11/2021	53.677693	6.411318	725305.320	5953196.120
ENV_34	MARDUT1021_ENV_34_2021_11_09_203646.jpg	1037	20:36:50	09/11/2021	53.677748	6.411282	725302.670	5953202.120
ENV_34	MARDUT1021_ENV_34_2021_11_09_203734.jpg	1038	20:37:38	09/11/2021	53.677825	6.411230	725298.800	5953210.570
ENV_34	MARDUT1021_ENV_34_2021_11_09_203756.jpg	1039	20:37:58	09/11/2021	53.677867	6.411191	725296.040	5953215.060
ENV_34	MARDUT1021_ENV_34_2021_11_09_203845.jpg	1040	20:38:49	09/11/2021	53.677970	6.411152	725292.890	5953226.470
ENV_34	MARDUT1021_ENV_34_2021_11_09_203907.jpg	1041	20:39:11	09/11/2021	53.678010	6.411123	725290.730	5953230.800
ENV_34	MARDUT1021_ENV_34_2021_11_09_203937.jpg	1042	20:39:41	09/11/2021	53.678062	6.411079	725287.600	5953236.400
ENV_34	MARDUT1021_ENV_34_2021_11_09_203958.jpg	1043	20:40:01	09/11/2021	53.678115	6.411039	725284.620	5953242.230
ENV_34	MARDUT1021_ENV_34_2021_11_09_204015.jpg	1044	20:40:19	09/11/2021	53.678140	6.411026	725283.680	5953244.920
ENV_34	MARDUT1021_ENV_34_2021_11_09_204046.jpg	1045	20:40:50	09/11/2021	53.678201	6.410974	725279.870	5953251.590
ENV_34	MARDUT1021_ENV_34_2021_11_09_204109.jpg	1046	20:41:13	09/11/2021	53.678262	6.410930	725276.690	5953258.240
ENV_34	MARDUT1021_ENV_34_2021_11_09_204124.jpg	1047	20:41:29	09/11/2021	53.678299	6.410901	725274.580	5953262.210
ENV_34	MARDUT1021_ENV_34_2021_11_09_204134.jpg	1048	20:41:38	09/11/2021	53.678316	6.410902	725274.500	5953264.120
ENV_34	MARDUT1021_ENV_34_2021_11_09_204155.jpg	1049	20:41:59	09/11/2021	53.678350	6.410891	725273.640	5953267.840

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_34	MARDUT1021_ENV_34_2021_11_09_204213.jpg	1050	20:42:17	09/11/2021	53.678384	6.410895	725273.710	5953271.600
ENV_34	MARDUT1021_ENV_34_2021_11_09_204240.jpg	1051	20:42:44	09/11/2021	53.678441	6.410863	725271.270	5953277.870
ENV_34	MARDUT1021_ENV_34_2021_11_09_204254.jpg	1052	20:42:58	09/11/2021	53.678477	6.410838	725269.470	5953281.800
ENV_34	MARDUT1021_ENV_34_2021_11_09_204259.jpg	1053	20:43:03	09/11/2021	53.678483	6.410826	725268.610	5953282.460
ENV_34	MARDUT1021_ENV_34_2021_11_09_204314.jpg	1054	20:43:18	09/11/2021	53.678498	6.410818	725268.000	5953284.130
ENV_35	MARDUT1021_ENV_35_2021_11_09_213351.jpg	1055	21:33:54	09/11/2021	53.678431	6.418978	725807.100	5953302.520
ENV_35	MARDUT1021_ENV_35_2021_11_09_213411.jpg	1056	21:34:13	09/11/2021	53.678393	6.418987	725807.920	5953298.330
ENV_35	MARDUT1021_ENV_35_2021_11_09_213452.jpg	1057	21:34:54	09/11/2021	53.678320	6.418976	725807.550	5953290.140
ENV_35	MARDUT1021_ENV_35_2021_11_09_213505.jpg	1058	21:35:07	09/11/2021	53.678291	6.418973	725807.510	5953286.939
ENV_35	MARDUT1021_ENV_35_2021_11_09_213540.jpg	1059	21:35:42	09/11/2021	53.678219	6.418953	725806.590	5953278.840
ENV_35	MARDUT1021_ENV_35_2021_11_09_213555.jpg	1060	21:35:57	09/11/2021	53.678183	6.418963	725807.440	5953274.870
ENV_35	MARDUT1021_ENV_35_2021_11_09_213626.jpg	1061	21:36:28	09/11/2021	53.678111	6.418966	725808.040	5953266.910
ENV_35	MARDUT1021_ENV_35_2021_11_09_213646.jpg	1062	21:36:49	09/11/2021	53.678060	6.418969	725808.520	5953261.260
ENV_35	MARDUT1021_ENV_35_2021_11_09_213714.jpg	1063	21:37:16	09/11/2021	53.677993	6.418966	725808.680	5953253.839
ENV_35	MARDUT1021_ENV_35_2021_11_09_213732.jpg	1064	21:37:34	09/11/2021	53.677956	6.418958	725808.340	5953249.600
ENV_35	MARDUT1021_ENV_35_2021_11_09_213800.jpg	1065	21:38:03	09/11/2021	53.677898	6.418947	725807.930	5953243.160
ENV_35	MARDUT1021_ENV_35_2021_11_09_213830.jpg	1066	21:38:33	09/11/2021	53.677830	6.418922	725806.650	5953235.489
ENV_35	MARDUT1021_ENV_35_2021_11_09_213853.jpg	1067	21:38:55	09/11/2021	53.677769	6.418918	725806.700	5953228.750
ENV_35	MARDUT1021_ENV_35_2021_11_09_213914.jpg	1068	21:39:16	09/11/2021	53.677719	6.418915	725806.780	5953223.160
ENV_35	MARDUT1021_ENV_35_2021_11_09_213953.jpg	1069	21:39:55	09/11/2021	53.677629	6.418911	725806.990	5953213.080
ENV_35	MARDUT1021_ENV_35_2021_11_09_214021.jpg	1070	21:40:23	09/11/2021	53.677565	6.418908	725807.090	5953206.020
ENV_35	MARDUT1021_ENV_35_2021_11_09_214049.jpg	1071	21:40:52	09/11/2021	53.677500	6.418894	725806.550	5953198.721
ENV_35	MARDUT1021_ENV_35_2021_11_09_214118.jpg	1072	21:41:20	09/11/2021	53.677451	6.418910	725807.850	5953193.350
ENV_35	MARDUT1021_ENV_35_2021_11_09_214133.jpg	1073	21:41:36	09/11/2021	53.677416	6.418914	725808.340	5953189.450
ENV_35	MARDUT1021_ENV_35_2021_11_09_214211.jpg	1074	21:42:13	09/11/2021	53.677315	6.418942	725810.710	5953178.350
ENV_35	MARDUT1021_ENV_35_2021_11_09_214225.jpg	1075	21:42:27	09/11/2021	53.677283	6.418932	725810.240	5953174.740
ENV_35	MARDUT1021_ENV_35_2021_11_09_214253.jpg	1076	21:42:55	09/11/2021	53.677209	6.418931	725810.555	5953166.545
ENV_35	MARDUT1021_ENV_35_2021_11_09_214318.jpg	1077	21:43:20	09/11/2021	53.677146	6.418925	725810.460	5953159.439

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_35	MARDUT1021_ENV_35_2021_11_09_214335.jpg	1078	21:43:38	09/11/2021	53.677102	6.418929	725811.000	5953154.620
ENV_35	MARDUT1021_ENV_35_2021_11_09_214404.jpg	1079	21:44:06	09/11/2021	53.677031	6.418915	725810.470	5953146.680
ENV_36	MARDUT1021_ENV_36_2021_11_09_224635.jpg	1111	22:46:38	09/11/2021	53.678123	6.427343	726361.030	5953294.880
ENV_36	MARDUT1021_ENV_36_2021_11_09_224704.jpg	1112	22:47:06	09/11/2021	53.678059	6.427343	726361.380	5953287.750
ENV_36	MARDUT1021_ENV_36_2021_11_09_224745.jpg	1113	22:47:47	09/11/2021	53.677964	6.427343	726361.900	5953277.230
ENV_36	MARDUT1021_ENV_36_2021_11_09_224823.jpg	1114	22:48:25	09/11/2021	53.677873	6.427321	726360.950	5953266.980
ENV_36	MARDUT1021_ENV_36_2021_11_09_224858.jpg	1115	22:49:01	09/11/2021	53.677791	6.427306	726360.380	5953257.890
ENV_36	MARDUT1021_ENV_36_2021_11_09_224927.jpg	1116	22:49:29	09/11/2021	53.677719	6.427304	726360.610	5953249.850
ENV_36	MARDUT1021_ENV_36_2021_11_09_224948.jpg	1117	22:49:50	09/11/2021	53.677674	6.427296	726360.360	5953244.800
ENV_36	MARDUT1021_ENV_36_2021_11_09_225012.jpg	1118	22:50:14	09/11/2021	53.677619	6.427291	726360.290	5953238.709
ENV_36	MARDUT1021_ENV_36_2021_11_09_225033.jpg	1119	22:50:35	09/11/2021	53.677573	6.427287	726360.260	5953233.540
ENV_36	MARDUT1021_ENV_36_2021_11_09_225051.jpg	1120	22:50:53	09/11/2021	53.677532	6.427296	726361.090	5953229.060
ENV_36	MARDUT1021_ENV_36_2021_11_09_225124.jpg	1121	22:51:28	09/11/2021	53.677454	6.427302	726361.910	5953220.360
ENV_36	MARDUT1021_ENV_36_2021_11_09_225150.jpg	1122	22:51:52	09/11/2021	53.677396	6.427305	726362.410	5953213.880
ENV_36	MARDUT1021_ENV_36_2021_11_09_225217.jpg	1123	22:52:19	09/11/2021	53.677333	6.427313	726363.260	5953206.930
ENV_36	MARDUT1021_ENV_36_2021_11_09_225247.jpg	1124	22:52:50	09/11/2021	53.677261	6.427299	726362.770	5953198.900
ENV_36	MARDUT1021_ENV_36_2021_11_09_225321.jpg	1125	22:53:23	09/11/2021	53.677181	6.427297	726363.040	5953190.040
ENV_36	MARDUT1021_ENV_36_2021_11_09_225343.jpg	1126	22:53:45	09/11/2021	53.677143	6.427291	726362.850	5953185.740
ENV_36	MARDUT1021_ENV_36_2021_11_09_225416.jpg	1127	22:54:18	09/11/2021	53.677055	6.427275	726362.290	5953175.900
ENV_36	MARDUT1021_ENV_36_2021_11_09_225457.jpg	1128	22:54:59	09/11/2021	53.676957	6.427264	726362.060	5953164.981
ENV_36	MARDUT1021_ENV_36_2021_11_09_225518.jpg	1129	22:55:20	09/11/2021	53.676911	6.427274	726363.010	5953159.890
ENV_36	MARDUT1021_ENV_36_2021_11_09_225545.jpg	1130	22:55:47	09/11/2021	53.676844	6.427266	726362.820	5953152.410
ENV_36	MARDUT1021_ENV_36_2021_11_09_225612.jpg	1131	22:56:14	09/11/2021	53.676789	6.427264	726362.990	5953146.300
ENV_36	MARDUT1021_ENV_36_2021_11_09_225636.jpg	1132	22:56:39	09/11/2021	53.676727	6.427265	726363.380	5953139.430
ENV_37	MARDUT1021_ENV_37_2021_11_10_001824.jpg	1159	00:18:27	10/11/2021	-	-	-	-
ENV_37	MARDUT1021_ENV_37_2021_11_10_001955.jpg	1160	00:19:58	10/11/2021	53.679753	6.432308	726680.100	5953492.000
ENV_37	MARDUT1021_ENV_37_2021_11_10_002026.jpg	1161	00:20:29	10/11/2021	53.679697	6.432344	726682.740	5953485.920
ENV_37	MARDUT1021_ENV_37_2021_11_10_002051.jpg	1162	00:20:54	10/11/2021	53.679640	6.432369	726684.700	5953479.630

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_37	MARDUT1021_ENV_37_2021_11_10_002125.jpg	1163	00:21:28	10/11/2021	53.679570	6.432437	726689.580	5953471.990
ENV_37	MARDUT1021_ENV_37_2021_11_10_002137.jpg	1164	00:21:40	10/11/2021	53.679550	6.432445	726690.240	5953469.820
ENV_37	MARDUT1021_ENV_37_2021_11_10_002152.jpg	1165	00:21:55	10/11/2021	53.679511	6.432471	726692.130	5953465.540
ENV_37	MARDUT1021_ENV_37_2021_11_10_002216.jpg	1166	00:22:19	10/11/2021	53.679453	6.432506	726694.730	5953459.270
ENV_37	MARDUT1021_ENV_37_2021_11_10_002241.jpg	1167	00:22:44	10/11/2021	53.679397	6.432550	726697.950	5953453.200
ENV_37	MARDUT1021_ENV_37_2021_11_10_002258.jpg	1168	00:23:02	10/11/2021	53.679360	6.432570	726699.490	5953449.140
ENV_37	MARDUT1021_ENV_37_2021_11_10_002317.jpg	1169	00:23:20	10/11/2021	53.679328	6.432591	726701.020	5953445.591
ENV_37	MARDUT1021_ENV_37_2021_11_10_002335.jpg	1170	00:23:39	10/11/2021	53.679287	6.432627	726703.620	5953441.230
ENV_37	MARDUT1021_ENV_37_2021_11_10_002354.jpg	1171	00:23:57	10/11/2021	53.679250	6.432651	726705.440	5953437.191
ENV_37	MARDUT1021_ENV_37_2021_11_10_002414.jpg	1172	00:24:17	10/11/2021	53.679204	6.432682	726707.740	5953432.180
ENV_37	MARDUT1021_ENV_37_2021_11_10_002433.jpg	1173	00:24:37	10/11/2021	53.679159	6.432711	726709.900	5953427.170
ENV_37	MARDUT1021_ENV_37_2021_11_10_002504.jpg	1174	00:25:07	10/11/2021	53.679087	6.432761	726713.570	5953419.370
ENV_37	MARDUT1021_ENV_37_2021_11_10_002531.jpg	1175	00:25:34	10/11/2021	53.679027	6.432785	726715.470	5953412.770
ENV_37	MARDUT1021_ENV_37_2021_11_10_002544.jpg	1176	00:25:47	10/11/2021	53.679001	6.432794	726716.230	5953409.900
ENV_37	MARDUT1021_ENV_37_2021_11_10_002601.jpg	1177	00:26:04	10/11/2021	53.678961	6.432806	726717.185	5953405.510
ENV_37	MARDUT1021_ENV_37_2021_11_10_002634.jpg	1178	00:26:38	10/11/2021	53.678880	6.432860	726721.240	5953396.650
ENV_37	MARDUT1021_ENV_37_2021_11_10_002709.jpg	1179	00:27:12	10/11/2021	53.678806	6.432902	726724.400	5953388.530
ENV_37	MARDUT1021_ENV_37_2021_11_10_002726.jpg	1180	00:27:29	10/11/2021	53.678766	6.432942	726727.205	5953384.221
ENV_37	MARDUT1021_ENV_37_2021_11_10_002738.jpg	1181	00:27:42	10/11/2021	53.678735	6.432961	726728.670	5953380.819
ENV_37	MARDUT1021_ENV_37_2021_11_10_002744.jpg	1182	00:27:48	10/11/2021	53.678723	6.432968	726729.160	5953379.550
ENV_37	MARDUT1021_ENV_37_2021_11_10_002809.jpg	1183	00:28:12	10/11/2021	53.678672	6.433003	726731.780	5953374.000
ENV_37	MARDUT1021_ENV_37_2021_11_10_002851.jpg	1184	00:28:54	10/11/2021	53.678577	6.433066	726736.460	5953363.610
ENV_37	MARDUT1021_ENV_37_2021_11_10_002926.jpg	1185	00:29:29	10/11/2021	53.678495	6.433116	726740.170	5953354.690
ENV_37	MARDUT1021_ENV_37_2021_11_10_002940.jpg	1186	00:29:44	10/11/2021	53.678459	6.433128	726741.190	5953350.760
ENV_37	MARDUT1021_ENV_37_2021_11_10_003017.jpg	1187	00:30:20	10/11/2021	53.678390	6.433180	726744.950	5953343.240
ENV_37	MARDUT1021_ENV_37_2021_11_10_003035.jpg	1188	00:30:38	10/11/2021	53.678349	6.433196	726746.240	5953338.740
ENV_38	MARDUT1021_ENV_38_2021_11_09_133745.jpg	755	13:37:48	09/11/2021	53.674769	6.380295	723272.570	5952773.070
ENV_38	MARDUT1021_ENV_38_2021_11_09_133818.jpg	756	13:38:22	09/11/2021	53.674701	6.380258	723270.490	5952765.420

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_38	MARDUT1021_ENV_38_2021_11_09_133841.jpg	757	13:38:44	09/11/2021	53.674653	6.380254	723270.430	5952760.060
ENV_38	MARDUT1021_ENV_38_2021_11_09_133911.jpg	758	13:39:14	09/11/2021	53.674592	6.380254	723270.760	5952753.210
ENV_38	MARDUT1021_ENV_38_2021_11_09_133934.jpg	759	13:39:37	09/11/2021	53.674548	6.380244	723270.350	5952748.360
ENV_38	MARDUT1021_ENV_38_2021_11_09_134008.jpg	760	13:40:12	09/11/2021	53.674475	6.380228	723269.710	5952740.200
ENV_38	MARDUT1021_ENV_38_2021_11_09_134026.jpg	761	13:40:29	09/11/2021	53.674431	6.380239	723270.610	5952735.310
ENV_38	MARDUT1021_ENV_38_2021_11_09_134038.jpg	762	13:40:41	09/11/2021	53.674392	6.380236	723270.630	5952730.930
ENV_38	MARDUT1021_ENV_38_2021_11_09_134051.jpg	763	13:40:55	09/11/2021	53.674357	6.380234	723270.700	5952727.050
ENV_38	MARDUT1021_ENV_38_2021_11_09_134058.jpg	764	13:41:01	09/11/2021	53.674337	6.380228	723270.410	5952724.770
ENV_38	MARDUT1021_ENV_38_2021_11_09_134114.jpg	765	13:41:17	09/11/2021	53.674301	6.380221	723270.160	5952720.780
ENV_38	MARDUT1021_ENV_38_2021_11_09_134127.jpg	766	13:41:30	09/11/2021	53.674273	6.380215	723269.920	5952717.640
ENV_38	MARDUT1021_ENV_38_2021_11_09_134132.jpg	767	13:41:35	09/11/2021	53.674259	6.380213	723269.830	5952716.130
ENV_38	MARDUT1021_ENV_38_2021_11_09_134139.jpg	768	13:41:43	09/11/2021	53.674239	6.380211	723269.790	5952713.890
ENV_38	MARDUT1021_ENV_38_2021_11_09_134150.jpg	769	13:41:53	09/11/2021	53.674218	6.380214	723270.140	5952711.581
ENV_38	MARDUT1021_ENV_38_2021_11_09_134209.jpg	770	13:42:12	09/11/2021	53.674163	6.380213	723270.320	5952705.470
ENV_38	MARDUT1021_ENV_38_2021_11_09_134222.jpg	771	13:42:25	09/11/2021	53.674136	6.380223	723271.170	5952702.460
ENV_38	MARDUT1021_ENV_38_2021_11_09_134234.jpg	772	13:42:37	09/11/2021	53.674117	6.380232	723271.840	5952700.410
ENV_38	MARDUT1021_ENV_38_2021_11_09_134246.jpg	773	13:42:50	09/11/2021	53.674081	6.380237	723272.370	5952696.390
ENV_38	MARDUT1021_ENV_38_2021_11_09_134309.jpg	774	13:43:13	09/11/2021	53.674031	6.380217	723271.290	5952690.750
ENV_38	MARDUT1021_ENV_38_2021_11_09_134322.jpg	775	13:43:25	09/11/2021	53.674003	6.380212	723271.100	5952687.630
ENV_38	MARDUT1021_ENV_38_2021_11_09_134333.jpg	776	13:43:37	09/11/2021	53.673975	6.380207	723270.960	5952684.510
ENV_38	MARDUT1021_ENV_38_2021_11_09_134342.jpg	777	13:43:45	09/11/2021	53.673959	6.380208	723271.090	5952682.710
ENV_38	MARDUT1021_ENV_38_2021_11_09_134403.jpg	778	13:44:06	09/11/2021	53.673913	6.380198	723270.710	5952677.530
ENV_38	MARDUT1021_ENV_38_2021_11_09_134412.jpg	779	13:44:15	09/11/2021	53.673896	6.380192	723270.400	5952675.669
ENV_38	MARDUT1021_ENV_38_2021_11_09_134430.jpg	780	13:44:33	09/11/2021	53.673856	6.380191	723270.540	5952671.270
ENV_38	MARDUT1021_ENV_38_2021_11_09_134447.jpg	781	13:44:50	09/11/2021	53.673817	6.380199	723271.280	5952666.880
ENV_38	MARDUT1021_ENV_38_2021_11_09_134500.jpg	782	13:45:04	09/11/2021	53.673785	6.380196	723271.210	5952663.360
ENV_38	MARDUT1021_ENV_38_2021_11_09_134524.jpg	783	13:45:27	09/11/2021	53.673732	6.380183	723270.640	5952657.420
ENV_38	MARDUT1021_ENV_38_2021_11_09_134549.jpg	784	13:45:52	09/11/2021	53.673673	6.380181	723270.800	5952650.840

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_38	MARDUT1021_ENV_38_2021_11_09_134605.jpg	785	13:46:08	09/11/2021	53.673632	6.380165	723269.980	5952646.190
ENV_38	MARDUT1021_ENV_38_2021_11_09_134628.jpg	786	13:46:31	09/11/2021	53.673591	6.380155	723269.540	5952641.610
ENV_38	MARDUT1021_ENV_38_2021_11_09_134655.jpg	787	13:46:58	09/11/2021	53.673515	6.380145	723269.280	5952633.160
ENV_38	MARDUT1021_ENV_38_2021_11_09_134713.jpg	788	13:47:16	09/11/2021	53.673468	6.380139	723269.130	5952627.901
ENV_38	MARDUT1021_ENV_38_2021_11_09_134729.jpg	789	13:47:32	09/11/2021	53.673422	6.380131	723268.850	5952622.780
ENV_38	MARDUT1021_ENV_38_2021_11_09_134737.jpg	790	13:47:40	09/11/2021	53.673405	6.380132	723269.000	5952620.900
ENV_38	MARDUT1021_ENV_38_2021_11_09_134755.jpg	791	13:47:58	09/11/2021	53.673374	6.380134	723269.330	5952617.390
ENV_38	MARDUT1021_ENV_38_2021_11_09_134805.jpg	792	13:48:09	09/11/2021	53.673349	6.380130	723269.200	5952614.640
ENV_38	MARDUT1021_ENV_38_2021_11_09_134819.jpg	793	13:48:23	09/11/2021	53.673316	6.380130	723269.350	5952611.020
ENV_39	MARDUT1021_ENV_39_2021_11_09_131110.jpg	717	13:11:13	09/11/2021	53.679564	6.376988	723028.870	5953295.940
ENV_39	MARDUT1021_ENV_39_2021_11_09_131148.jpg	718	13:11:51	09/11/2021	53.679529	6.376947	723026.305	5953291.864
ENV_39	MARDUT1021_ENV_39_2021_11_09_131154.jpg	719	13:11:57	09/11/2021	53.679522	6.376939	723025.840	5953291.100
ENV_39	MARDUT1021_ENV_39_2021_11_09_131210.jpg	720	13:12:13	09/11/2021	53.679500	6.376904	723023.610	5953288.565
ENV_39	MARDUT1021_ENV_39_2021_11_09_131237.jpg	721	13:12:40	09/11/2021	53.679446	6.376841	723019.765	5953282.270
ENV_39	MARDUT1021_ENV_39_2021_11_09_131259.jpg	722	13:13:02	09/11/2021	53.679422	6.376807	723017.620	5953279.514
ENV_39	MARDUT1021_ENV_39_2021_11_09_131318.jpg	723	13:13:21	09/11/2021	53.679392	6.376776	723015.750	5953276.100
ENV_39	MARDUT1021_ENV_39_2021_11_09_131357.jpg	724	13:14:00	09/11/2021	53.679333	6.376695	723010.755	5953269.244
ENV_39	MARDUT1021_ENV_39_2021_11_09_131411.jpg	725	13:14:14	09/11/2021	53.679305	6.376669	723009.135	5953266.086
ENV_39	MARDUT1021_ENV_39_2021_11_09_131435.jpg	726	13:14:38	09/11/2021	53.679273	6.376629	723006.660	5953262.380
ENV_39	MARDUT1021_ENV_39_2021_11_09_131456.jpg	727	13:14:59	09/11/2021	53.679213	6.376572	723003.240	5953255.509
ENV_39	MARDUT1021_ENV_39_2021_11_09_131511.jpg	728	13:15:14	09/11/2021	53.679184	6.376512	722999.408	5953252.120
ENV_39	MARDUT1021_ENV_39_2021_11_09_131529.jpg	729	13:15:32	09/11/2021	53.679157	6.376469	722996.700	5953249.010
ENV_39	MARDUT1021_ENV_39_2021_11_09_131536.jpg	730	13:15:39	09/11/2021	53.679142	6.376451	722995.613	5953247.321
ENV_39	MARDUT1021_ENV_39_2021_11_09_131557.jpg	731	13:16:00	09/11/2021	53.679103	6.376394	722992.058	5953242.748
ENV_39	MARDUT1021_ENV_39_2021_11_09_131605.jpg	732	13:16:08	09/11/2021	53.679090	6.376372	722990.690	5953241.258
ENV_39	MARDUT1021_ENV_39_2021_11_09_131630.jpg	733	13:16:33	09/11/2021	53.679050	6.376298	722985.990	5953236.590
ENV_39	MARDUT1021_ENV_39_2021_11_09_131638.jpg	734	13:16:42	09/11/2021	53.679031	6.376267	722984.040	5953234.405
ENV_39	MARDUT1021_ENV_39_2021_11_09_131646.jpg	735	13:16:49	09/11/2021	53.679020	6.376252	722983.130	5953233.040

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_39	MARDUT1021_ENV_39_2021_11_09_131652.jpg	736	13:16:55	09/11/2021	53.679006	6.376236	722982.150	5953231.431
ENV_39	MARDUT1021_ENV_39_2021_11_09_131704.jpg	737	13:17:07	09/11/2021	53.678991	6.376215	722980.810	5953229.695
ENV_39	MARDUT1021_ENV_39_2021_11_09_131723.jpg	738	13:17:27	09/11/2021	53.678946	6.376169	722978.070	5953224.585
ENV_39	MARDUT1021_ENV_39_2021_11_09_131739.jpg	739	13:17:42	09/11/2021	53.678921	6.376145	722976.575	5953221.775
ENV_39	MARDUT1021_ENV_39_2021_11_09_131753.jpg	740	13:17:56	09/11/2021	53.678886	6.376106	722974.170	5953217.725
ENV_39	MARDUT1021_ENV_39_2021_11_09_131821.jpg	741	13:18:24	09/11/2021	53.678840	6.376036	722969.795	5953212.405
ENV_39	MARDUT1021_ENV_39_2021_11_09_131838.jpg	742	13:18:42	09/11/2021	53.678815	6.376001	722967.645	5953209.555
ENV_39	MARDUT1021_ENV_39_2021_11_09_131906.jpg	743	13:19:09	09/11/2021	53.678767	6.375944	722964.160	5953204.024
ENV_39	MARDUT1021_ENV_39_2021_11_09_131926.jpg	744	13:19:29	09/11/2021	53.678721	6.375890	722960.785	5953198.700
ENV_39	MARDUT1021_ENV_39_2021_11_09_131959.jpg	745	13:20:03	09/11/2021	53.678651	6.375803	722955.425	5953190.675
ENV_39	MARDUT1021_ENV_39_2021_11_09_132025.jpg	746	13:20:28	09/11/2021	53.678606	6.375738	722951.385	5953185.456
ENV_39	MARDUT1021_ENV_39_2021_11_09_132035.jpg	747	13:20:38	09/11/2021	53.678592	6.375722	722950.405	5953183.885
ENV_39	MARDUT1021_ENV_39_2021_11_09_132055.jpg	748	13:20:58	09/11/2021	53.678567	6.375686	722948.145	5953180.945
ENV_39	MARDUT1021_ENV_39_2021_11_09_132135.jpg	749	13:21:38	09/11/2021	53.678515	6.375616	722943.810	5953174.954
ENV_39	MARDUT1021_ENV_39_2021_11_09_132142.jpg	750	13:21:46	09/11/2021	53.678501	6.375595	722942.500	5953173.301
ENV_39	MARDUT1021_ENV_39_2021_11_09_132149.jpg	751	13:21:52	09/11/2021	53.678485	6.375576	722941.360	5953171.450
ENV_39	MARDUT1021_ENV_39_2021_11_09_132211.jpg	752	13:22:14	09/11/2021	53.678448	6.375529	722938.405	5953167.229
ENV_39	MARDUT1021_ENV_39_2021_11_09_132222.jpg	753	13:22:25	09/11/2021	53.678432	6.375517	722937.680	5953165.410
ENV_39	MARDUT1021_ENV_39_2021_11_09_132241.jpg	754	13:22:44	09/11/2021	53.678381	6.375435	722932.582	5953159.445
ENV_40	MARDUT1021_ENV_40_2021_11_09_173017.jpg	915	17:30:20	09/11/2021	53.674377	6.395041	724248.270	5952775.870
ENV_40	MARDUT1021_ENV_40_2021_11_09_173100.jpg	916	17:31:04	09/11/2021	53.674303	6.395091	724251.960	5952767.790
ENV_40	MARDUT1021_ENV_40_2021_11_09_173122.jpg	917	17:31:25	09/11/2021	53.674256	6.395144	724255.750	5952762.750
ENV_40	MARDUT1021_ENV_40_2021_11_09_173145.jpg	918	17:31:48	09/11/2021	53.674217	6.395174	724257.950	5952758.530
ENV_40	MARDUT1021_ENV_40_2021_11_09_173203.jpg	919	17:32:07	09/11/2021	53.674193	6.395196	724259.530	5952755.920
ENV_40	MARDUT1021_ENV_40_2021_11_09_173220.jpg	920	17:32:23	09/11/2021	53.674156	6.395231	724262.030	5952751.970
ENV_40	MARDUT1021_ENV_40_2021_11_09_173239.jpg	921	17:32:43	09/11/2021	53.674121	6.395259	724264.020	5952748.090
ENV_40	MARDUT1021_ENV_40_2021_11_09_173305.jpg	922	17:33:08	09/11/2021	53.674068	6.395322	724268.500	5952742.480
ENV_40	MARDUT1021_ENV_40_2021_11_09_173325.jpg	923	17:33:28	09/11/2021	53.674038	6.395343	724270.000	5952739.140

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_40	MARDUT1021_ENV_40_2021_11_09_173349.jpg	924	17:33:52	09/11/2021	53.673995	6.395401	724274.090	5952734.610
ENV_40	MARDUT1021_ENV_40_2021_11_09_173419.jpg	925	17:34:22	09/11/2021	53.673957	6.395416	724275.280	5952730.401
ENV_40	MARDUT1021_ENV_40_2021_11_09_173444.jpg	926	17:34:48	09/11/2021	53.673903	6.395446	724277.520	5952724.460
ENV_40	MARDUT1021_ENV_40_2021_11_09_173514.jpg	927	17:35:17	09/11/2021	53.673860	6.395464	724278.970	5952719.800
ENV_40	MARDUT1021_ENV_40_2021_11_09_173603.jpg	928	17:36:06	09/11/2021	53.673761	6.395568	724286.360	5952709.080
ENV_40	MARDUT1021_ENV_40_2021_11_09_173633.jpg	929	17:36:36	09/11/2021	53.673708	6.395633	724290.900	5952703.389
ENV_40	MARDUT1021_ENV_40_2021_11_09_173655.jpg	930	17:36:59	09/11/2021	53.673653	6.395674	724293.950	5952697.360
ENV_40	MARDUT1021_ENV_40_2021_11_09_173717.jpg	931	17:37:20	09/11/2021	53.673609	6.395715	724296.850	5952692.620
ENV_40	MARDUT1021_ENV_40_2021_11_09_173744.jpg	932	17:37:47	09/11/2021	53.673543	6.395776	724301.280	5952685.460
ENV_40	MARDUT1021_ENV_40_2021_11_09_173815.jpg	933	17:38:18	09/11/2021	53.673488	6.395821	724304.530	5952679.470
ENV_40	MARDUT1021_ENV_40_2021_11_09_173839.jpg	934	17:38:43	09/11/2021	53.673426	6.395890	724309.410	5952672.860
ENV_40	MARDUT1021_ENV_40_2021_11_09_173902.jpg	935	17:39:05	09/11/2021	53.673376	6.395948	724313.500	5952667.510
ENV_40	MARDUT1021_ENV_40_2021_11_09_173919.jpg	936	17:39:22	09/11/2021	53.673347	6.395979	724315.710	5952664.350
ENV_40	MARDUT1021_ENV_40_2021_11_09_173942.jpg	937	17:39:45	09/11/2021	53.673299	6.396030	724319.340	5952659.190
ENV_40	MARDUT1021_ENV_40_2021_11_09_174007.jpg	938	17:40:10	09/11/2021	53.673232	6.396102	724324.440	5952651.910
ENV_40	MARDUT1021_ENV_40_2021_11_09_174027.jpg	939	17:40:31	09/11/2021	53.673191	6.396126	724326.210	5952647.460
ENV_40	MARDUT1021_ENV_40_2021_11_09_174039.jpg	940	17:40:43	09/11/2021	53.673167	6.396142	724327.440	5952644.810
ENV_41	MARDUT1021_ENV_41_2021_11_09_182003.jpg	941	18:20:06	09/11/2021	53.675809	6.404634	724874.070	5952965.480
ENV_41	MARDUT1021_ENV_41_2021_11_09_182016.jpg	942	18:20:19	09/11/2021	53.675774	6.404628	724873.840	5952961.541
ENV_41	MARDUT1021_ENV_41_2021_11_09_182053.jpg	943	18:20:56	09/11/2021	53.675683	6.404641	724875.220	5952951.460
ENV_41	MARDUT1021_ENV_41_2021_11_09_182121.jpg	944	18:21:23	09/11/2021	53.675621	6.404642	724875.620	5952944.600
ENV_41	MARDUT1021_ENV_41_2021_11_09_182202.jpg	945	18:22:04	09/11/2021	53.675521	6.404631	724875.410	5952933.440
ENV_41	MARDUT1021_ENV_41_2021_11_09_182221.jpg	946	18:22:23	09/11/2021	53.675479	6.404620	724874.920	5952928.710
ENV_41	MARDUT1021_ENV_41_2021_11_09_182308.jpg	947	18:23:11	09/11/2021	53.675362	6.404586	724873.250	5952915.570
ENV_41	MARDUT1021_ENV_41_2021_11_09_182330.jpg	948	18:23:32	09/11/2021	53.675315	6.404571	724872.560	5952910.330
ENV_41	MARDUT1021_ENV_41_2021_11_09_182358.jpg	949	18:24:00	09/11/2021	53.675260	6.404549	724871.400	5952904.190
ENV_41	MARDUT1021_ENV_41_2021_11_09_182445.jpg	950	18:24:47	09/11/2021	53.675157	6.404519	724869.920	5952892.590
ENV_41	MARDUT1021_ENV_41_2021_11_09_182454.jpg	951	18:24:57	09/11/2021	53.675136	6.404510	724869.480	5952890.270

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_41	MARDUT1021_ENV_41_2021_11_09_182502.jpg	952	18:25:04	09/11/2021	53.675125	6.404504	724869.130	5952888.980
ENV_41	MARDUT1021_ENV_41_2021_11_09_182535.jpg	953	18:25:37	09/11/2021	53.675056	6.404465	724866.890	5952881.230
ENV_41	MARDUT1021_ENV_41_2021_11_09_182557.jpg	954	18:25:59	09/11/2021	53.675014	6.404453	724866.360	5952876.460
ENV_41	MARDUT1021_ENV_41_2021_11_09_182635.jpg	955	18:26:37	09/11/2021	53.674932	6.404433	724865.470	5952867.320
ENV_41	MARDUT1021_ENV_41_2021_11_09_182707.jpg	956	18:27:10	09/11/2021	53.674852	6.404419	724864.960	5952858.349
ENV_41	MARDUT1021_ENV_41_2021_11_09_182746.jpg	957	18:27:49	09/11/2021	53.674755	6.404404	724864.510	5952847.490
ENV_41	MARDUT1021_ENV_41_2021_11_09_182836.jpg	958	18:28:38	09/11/2021	53.674630	6.404378	724863.460	5952833.560
ENV_41	MARDUT1021_ENV_41_2021_11_09_182858.jpg	959	18:29:00	09/11/2021	53.674587	6.404367	724862.960	5952828.720
ENV_41	MARDUT1021_ENV_41_2021_11_09_182937.jpg	960	18:29:39	09/11/2021	53.674482	6.404348	724862.240	5952817.010
ENV_41	MARDUT1021_ENV_41_2021_11_09_183010.jpg	961	18:30:12	09/11/2021	53.674412	6.404323	724860.980	5952809.100
ENV_41	MARDUT1021_ENV_41_2021_11_09_183027.jpg	962	18:30:29	09/11/2021	53.674371	6.404307	724860.150	5952804.560
ENV_41	MARDUT1021_ENV_41_2021_11_09_183047.jpg	963	18:30:50	09/11/2021	53.674324	6.404299	724859.850	5952799.310
ENV_41	MARDUT1021_ENV_41_2021_11_09_183101.jpg	964	18:31:03	09/11/2021	53.674296	6.404297	724859.870	5952796.180
ENV_41	MARDUT1021_ENV_41_2021_11_09_183121.jpg	965	18:31:23	09/11/2021	53.674245	6.404274	724858.610	5952790.381
ENV_41	MARDUT1021_ENV_41_2021_11_09_183200.jpg	966	18:32:02	09/11/2021	53.674180	6.404238	724856.630	5952783.090
ENV_41	MARDUT1021_ENV_41_2021_11_09_183247.jpg	967	18:32:49	09/11/2021	53.674070	6.404212	724855.440	5952770.739
ENV_41	MARDUT1021_ENV_41_2021_11_09_183304.jpg	968	18:33:06	09/11/2021	53.674036	6.404213	724855.750	5952766.940
ENV_42	MARDUT1021_ENV_42_2021_11_09_195133.jpg	1004	19:51:36	09/11/2021	53.673025	6.412566	725412.660	5952681.050
ENV_42	MARDUT1021_ENV_42_2021_11_09_195209.jpg	1005	19:52:11	09/11/2021	53.673089	6.412551	725411.330	5952688.040
ENV_42	MARDUT1021_ENV_42_2021_11_09_195240.jpg	1006	19:52:43	09/11/2021	53.673162	6.412540	725410.200	5952696.170
ENV_42	MARDUT1021_ENV_42_2021_11_09_195317.jpg	1007	19:53:19	09/11/2021	53.673227	6.412542	725410.020	5952703.410
ENV_42	MARDUT1021_ENV_42_2021_11_09_195343.jpg	1008	19:53:46	09/11/2021	53.673290	6.412530	725408.840	5952710.390
ENV_42	MARDUT1021_ENV_42_2021_11_09_195405.jpg	1009	19:54:08	09/11/2021	53.673335	6.412525	725408.310	5952715.390
ENV_42	MARDUT1021_ENV_42_2021_11_09_195437.jpg	1010	19:54:41	09/11/2021	53.673411	6.412526	725407.950	5952723.790
ENV_42	MARDUT1021_ENV_42_2021_11_09_195458.jpg	1011	19:55:01	09/11/2021	53.673458	6.412527	725407.790	5952729.070
ENV_42	MARDUT1021_ENV_42_2021_11_09_195525.jpg	1012	19:55:27	09/11/2021	53.673527	6.412526	725407.360	5952736.710
ENV_42	MARDUT1021_ENV_42_2021_11_09_195552.jpg	1013	19:55:55	09/11/2021	53.673590	6.412522	725406.750	5952743.760
ENV_42	MARDUT1021_ENV_42_2021_11_09_195621.jpg	1014	19:56:23	09/11/2021	53.673652	6.412531	725407.010	5952750.680

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_42	MARDUT1021_ENV_42_2021_11_09_195633.jpg	1015	19:56:35	09/11/2021	53.673671	6.412536	725407.200	5952752.730
ENV_42	MARDUT1021_ENV_42_2021_11_09_195659.jpg	1016	19:57:01	09/11/2021	53.673736	6.412553	725407.970	5952760.080
ENV_42	MARDUT1021_ENV_42_2021_11_09_195802.jpg	1017	19:58:04	09/11/2021	53.673863	6.412541	725406.520	5952774.080
ENV_42	MARDUT1021_ENV_42_2021_11_09_195827.jpg	1018	19:58:29	09/11/2021	53.673926	6.412526	725405.170	5952781.080
ENV_42	MARDUT1021_ENV_42_2021_11_09_195833.jpg	1019	19:58:36	09/11/2021	53.673936	6.412532	725405.520	5952782.180
ENV_42	MARDUT1021_ENV_42_2021_11_09_195901.jpg	1020	19:59:03	09/11/2021	53.674008	6.412533	725405.260	5952790.200
ENV_42	MARDUT1021_ENV_42_2021_11_09_195935.jpg	1021	19:59:38	09/11/2021	53.674079	6.412530	725404.680	5952798.120
ENV_42	MARDUT1021_ENV_42_2021_11_09_200017.jpg	1022	20:00:19	09/11/2021	53.674182	6.412525	725403.790	5952809.510
ENV_42	MARDUT1021_ENV_42_2021_11_09_200055.jpg	1023	20:00:57	09/11/2021	53.674249	6.412499	725401.670	5952816.930
ENV_42	MARDUT1021_ENV_42_2021_11_09_200119.jpg	1024	20:01:22	09/11/2021	53.674307	6.412513	725402.330	5952823.360
ENV_42	MARDUT1021_ENV_42_2021_11_09_200214.jpg	1025	20:02:16	09/11/2021	53.674406	6.412494	725400.550	5952834.360
ENV_42	MARDUT1021_ENV_42_2021_11_09_200234.jpg	1026	20:02:36	09/11/2021	53.674476	6.412513	725401.390	5952842.180
ENV_43	MARDUT1021_ENV_43_2021_11_09_220130.jpg	1080	22:01:33	09/11/2021	53.674682	6.418982	725827.460	5952885.640
ENV_43	MARDUT1021_ENV_43_2021_11_09_220156.jpg	1081	22:01:59	09/11/2021	53.674637	6.418949	725825.520	5952880.490
ENV_43	MARDUT1021_ENV_43_2021_11_09_220209.jpg	1082	22:02:13	09/11/2021	53.674605	6.418941	725825.170	5952876.940
ENV_43	MARDUT1021_ENV_43_2021_11_09_220232.jpg	1083	22:02:35	09/11/2021	53.674565	6.418915	725823.630	5952872.390
ENV_43	MARDUT1021_ENV_43_2021_11_09_220240.jpg	1084	22:02:43	09/11/2021	53.674548	6.418906	725823.120	5952870.470
ENV_43	MARDUT1021_ENV_43_2021_11_09_220308.jpg	1085	22:03:11	09/11/2021	53.674493	6.418891	725822.450	5952864.341
ENV_43	MARDUT1021_ENV_43_2021_11_09_220317.jpg	1086	22:03:20	09/11/2021	53.674478	6.418879	725821.710	5952862.670
ENV_43	MARDUT1021_ENV_43_2021_11_09_220343.jpg	1087	22:03:46	09/11/2021	53.674427	6.418834	725819.050	5952856.779
ENV_43	MARDUT1021_ENV_43_2021_11_09_220414.jpg	1088	22:04:17	09/11/2021	53.674364	6.418778	725815.690	5952849.630
ENV_43	MARDUT1021_ENV_43_2021_11_09_220437.jpg	1089	22:04:40	09/11/2021	53.674329	6.418737	725813.130	5952845.660
ENV_43	MARDUT1021_ENV_43_2021_11_09_220504.jpg	1090	22:05:07	09/11/2021	53.674265	6.418708	725811.570	5952838.420
ENV_43	MARDUT1021_ENV_43_2021_11_09_220515.jpg	1091	22:05:18	09/11/2021	53.674247	6.418696	725810.910	5952836.320
ENV_43	MARDUT1021_ENV_43_2021_11_09_220544.jpg	1092	22:05:48	09/11/2021	53.674185	6.418660	725808.810	5952829.410
ENV_43	MARDUT1021_ENV_43_2021_11_09_220618.jpg	1093	22:06:21	09/11/2021	53.674119	6.418622	725806.690	5952821.870
ENV_43	MARDUT1021_ENV_43_2021_11_09_220704.jpg	1094	22:07:07	09/11/2021	53.674011	6.418560	725803.135	5952809.675
ENV_43	MARDUT1021_ENV_43_2021_11_09_220740.jpg	1095	22:07:43	09/11/2021	53.673931	6.418494	725799.210	5952800.570

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_43	MARDUT1021_ENV_43_2021_11_09_220757.jpg	1096	22:08:01	09/11/2021	53.673893	6.418474	725798.130	5952796.290
ENV_43	MARDUT1021_ENV_43_2021_11_09_220839.jpg	1097	22:08:43	09/11/2021	53.673799	6.418429	725795.650	5952785.750
ENV_43	MARDUT1021_ENV_43_2021_11_09_220856.jpg	1098	22:08:58	09/11/2021	53.673768	6.418411	725794.620	5952782.160
ENV_43	MARDUT1021_ENV_43_2021_11_09_220916.jpg	1099	22:09:19	09/11/2021	53.673725	6.418377	725792.590	5952777.270
ENV_43	MARDUT1021_ENV_43_2021_11_09_220949.jpg	1100	22:09:53	09/11/2021	53.673652	6.418322	725789.390	5952769.070
ENV_43	MARDUT1021_ENV_43_2021_11_09_221048.jpg	1101	22:10:51	09/11/2021	53.673534	6.418261	725785.950	5952755.740
ENV_43	MARDUT1021_ENV_43_2021_11_09_221107.jpg	1102	22:11:11	09/11/2021	53.673491	6.418230	725784.190	5952750.830
ENV_43	MARDUT1021_ENV_43_2021_11_09_221128.jpg	1103	22:11:31	09/11/2021	53.673455	6.418204	725782.620	5952746.720
ENV_43	MARDUT1021_ENV_43_2021_11_09_221145.jpg	1104	22:11:48	09/11/2021	53.673408	6.418178	725781.140	5952741.470
ENV_43	MARDUT1021_ENV_43_2021_11_09_221225.jpg	1105	22:12:29	09/11/2021	53.673326	6.418157	725780.240	5952732.230
ENV_43	MARDUT1021_ENV_43_2021_11_09_221250.jpg	1106	22:12:54	09/11/2021	53.673267	6.418116	725777.830	5952725.560
ENV_43	MARDUT1021_ENV_43_2021_11_09_221338.jpg	1107	22:13:42	09/11/2021	53.673166	6.418040	725773.360	5952714.040
ENV_43	MARDUT1021_ENV_43_2021_11_09_221410.jpg	1108	22:14:14	09/11/2021	53.673099	6.418014	725772.000	5952706.550
ENV_43	MARDUT1021_ENV_43_2021_11_09_221441.jpg	1109	22:14:44	09/11/2021	53.673034	6.417980	725770.100	5952699.260
ENV_43	MARDUT1021_ENV_43_2021_11_09_221530.jpg	1110	22:15:33	09/11/2021	53.672931	6.417902	725765.490	5952687.490
ENV_44	MARDUT1021_ENV_44_2021_11_09_233438.jpg	1133	23:34:40	09/11/2021	53.675629	6.424334	726175.740	5953007.970
ENV_44	MARDUT1021_ENV_44_2021_11_09_233451.jpg	1134	23:34:52	09/11/2021	53.675604	6.424334	726175.900	5953005.200
ENV_44	MARDUT1021_ENV_44_2021_11_09_233531.jpg	1135	23:35:32	09/11/2021	53.675529	6.424270	726172.050	5952996.680
ENV_44	MARDUT1021_ENV_44_2021_11_09_233544.jpg	1136	23:35:45	09/11/2021	53.675513	6.424260	726171.510	5952994.850
ENV_44	MARDUT1021_ENV_44_2021_11_09_233606.jpg	1137	23:36:07	09/11/2021	53.675465	6.424223	726169.280	5952989.400
ENV_44	MARDUT1021_ENV_44_2021_11_09_233630.jpg	1138	23:36:31	09/11/2021	53.675417	6.424187	726167.185	5952983.955
ENV_44	MARDUT1021_ENV_44_2021_11_09_233723.jpg	1139	23:37:25	09/11/2021	53.675295	6.424104	726162.320	5952970.130
ENV_44	MARDUT1021_ENV_44_2021_11_09_233740.jpg	1140	23:37:41	09/11/2021	53.675272	6.424084	726161.130	5952967.510
ENV_44	MARDUT1021_ENV_44_2021_11_09_233742.jpg	1141	23:37:43	09/11/2021	53.675272	6.424082	726161.050	5952967.430
ENV_44	MARDUT1021_ENV_44_2021_11_09_233759.jpg	1142	23:38:01	09/11/2021	53.675240	6.424071	726160.490	5952963.900
ENV_44	MARDUT1021_ENV_44_2021_11_09_233816.jpg	1143	23:38:17	09/11/2021	53.675194	6.424043	726158.850	5952958.680
ENV_44	MARDUT1021_ENV_44_2021_11_09_233853.jpg	1144	23:38:54	09/11/2021	53.675117	6.423984	726155.370	5952949.901
ENV_44	MARDUT1021_ENV_44_2021_11_09_233912.jpg	1145	23:39:13	09/11/2021	53.675075	6.423951	726153.440	5952945.140

Station	Image File Name	Fix	Fix Time (UTC)	Date	Sampled Latitude	Sampled Longitude	Sampled Easting	Sampled Northing
ENV_44	MARDUT1021_ENV_44_2021_11_09_233952.jpg	1146	23:39:53	09/11/2021	53.675000	6.423893	726150.010	5952936.600
ENV_44	MARDUT1021_ENV_44_2021_11_09_234047.jpg	1147	23:40:48	09/11/2021	53.674870	6.423808	726145.050	5952921.920
ENV_44	MARDUT1021_ENV_44_2021_11_09_234105.jpg	1148	23:41:06	09/11/2021	53.674830	6.423785	726143.760	5952917.390
ENV_44	MARDUT1021_ENV_44_2021_11_09_234127.jpg	1149	23:41:29	09/11/2021	53.674793	6.423756	726142.090	5952913.160
ENV_44	MARDUT1021_ENV_44_2021_11_09_234156.jpg	1150	23:41:57	09/11/2021	53.674736	6.423727	726140.420	5952906.730
ENV_44	MARDUT1021_ENV_44_2021_11_09_234238.jpg	1151	23:42:40	09/11/2021	53.674637	6.423655	726136.250	5952895.530
ENV_44	MARDUT1021_ENV_44_2021_11_09_234306.jpg	1152	23:43:07	09/11/2021	53.674573	6.423610	726133.600	5952888.240
ENV_44	MARDUT1021_ENV_44_2021_11_09_234355.jpg	1153	23:43:56	09/11/2021	53.674473	6.423533	726129.050	5952876.880
ENV_44	MARDUT1021_ENV_44_2021_11_09_234441.jpg	1154	23:44:42	09/11/2021	53.674360	6.423484	726126.400	5952864.210
ENV_44	MARDUT1021_ENV_44_2021_11_09_234501.jpg	1155	23:45:02	09/11/2021	53.674325	6.423442	726123.850	5952860.190
ENV_44	MARDUT1021_ENV_44_2021_11_09_234504.jpg	1156	23:45:05	09/11/2021	53.674323	6.423438	726123.590	5952859.850
ENV_44	MARDUT1021_ENV_44_2021_11_09_234527.jpg	1157	23:45:28	09/11/2021	53.674279	6.423416	726122.340	5952854.950
ENV_44	MARDUT1021_ENV_44_2021_11_09_234541.jpg	1158	23:45:42	09/11/2021	53.674253	6.423402	726121.610	5952851.980

Appendix A2: Drop-down video positional Logs

Station	Date	Video Start Time (UTC)	Video Length	Video End Time (UTC)	No. of Videos	No. of Images	Video File Name	Depth (m)	Camera System	Freshwater Housing Height Setting	Distance Between Laser Points (cm)	FOCI/OSPAR present (excluding reef)	Potential Annex I reef?	Camera Time Offset	Notes
ENV_20	11/11/2021	16:07:50	00:10:37	16:18:27	2	31	MARDUT1021_ENV_20_2021_11_11_160727, MARDUT1021_ENV_20_2021_11_11_161729	23.4	SubC Imaging PLE System	High	10	N	N	00:00:23	Rippled sand with shells. Occasional boulders with plumose anemones. Occasional gravel. Poor visibility.
ENV_28	05/11/2021	15:07:40	00:06:28	15:14:08	1	11	MARDUT1021_ENV_28_2021_11_05_150659	24.0	SubC Imaging PLE System	High	10	N	N	00:00:41	Technical issue with USBL. Aborted transect and restarted. Rippled Sand with shells occasional cobbles and pebbles, sand mason worms, burrowing anemones.
ENV_28(2)	05/11/2021	15:22:50	00:08:47	15:31:37	1	26	MARDUT1021_ENV_28(2)_2021_11_05_152209	24.0	SubC Imaging PLE System	High	10	N	N	00:00:41	Rippled Sand with shells occasional cobbles and pebbles, sand mason worms, burrowing anemones.
ENV_29	09/11/2021	14:51:31	00:14:20	15:05:51	2	40	MARDUT1021_ENV_29_2021_11_09_145128, MARDUT1021_ENV_29_2021_11_09_150129	24.3	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled sand with gravel and shells. Occasional boulders and cobbles with plumose anemones.
ENV_30	09/11/2021	15:42:30	00:15:04	15:57:34	2	31	MARDUT1021_ENV_30_2021_11_09_154227, MARDUT1021_ENV_30_2021_11_09_155229	23.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Muddy gravelly sand with ripples. Occasional boulders and cobbles with plumose anemones.
ENV_31	09/11/2021	14:17:05	00:10:48	14:27:53	2	26	MARDUT1021_ENV_31_2021_11_09_141702, MARDUT1021_ENV_31_2021_11_09_142704	23.4	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy shelly sand with burrowing anemones and sand mason worms.
ENV_32	09/11/2021	16:51:16	00:10:13	17:01:29	2	24	MARDUT1021_ENV_32_2021_11_09_165113, MARDUT1021_ENV_32_2021_11_09_170114	23.7	SubC Imaging PLE System	High	10	N		00:00:03	Rippled muddy sand. Burrowing anemones.
ENV_33	09/11/2021	18:58:51	00:11:34	19:10:25	2	35	MARDUT1021_ENV_33_2021_11_09_185848, MARDUT1021_ENV_33_2021_11_09_190850	25.0	SubC Imaging PLE System	High	10	N	Y	00:00:03	Rippled sand with shells. Burrowing anemones and sand mason worms. Occasional cobbles and boulders plus an area of higher density cobbles with plumose and sponges.

Station	Date	Video Start Time (UTC)	Video Length	Video End Time (UTC)	No. of Videos	No. of Images	Video File Name	Depth (m)	Camera System	Freshwater Housing Height Setting	Distance Between Laser Points (cm)	FOCI/OSPAR present (excluding reef)	Potential Annex I reef?	Camera Time Offset	Notes
ENV_34	09/11/2021	20:31:41	00:11:34	20:43:15	2	28	MARDUT1021_ENV_34_2021_11_09_203138, MARDUT1021_ENV_34_2021_11_09_204139	23.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand with shells. Occasional boulder. Sand mason worms and brittlestars.
ENV_35	09/11/2021	21:33:46	00:10:18	21:44:04	2	25	MARDUT1021_ENV_35_2021_11_09_213343, MARDUT1021_ENV_35_2021_11_09_214345	23.5	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand with shells. Sand mason worms, burrowing anemones and brittlestars
ENV_36	09/11/2021	22:46:21	00:10:16	22:56:37	2	22	MARDUT1021_ENV_36_2021_11_09_224618, MARDUT1021_ENV_36_2021_11_09_225620	21.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Ripply muddy sand with shells. Sand mason worms.
ENV_37	10/11/2021	00:18:16	00:12:25	00:30:41	2	30	MARDUT1021_ENV_37_2021_11_10_001813, MARDUT1021_ENV_37_2021_11_10_002815	21.9	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand. Burrowing anemones.
ENV_38	09/11/2021	13:37:25	00:10:55	13:48:20	2	39	MARDUT1021_ENV_38_2021_11_09_133722, MARDUT1021_ENV_38_2021_11_09_134723	23.5	SubC Imaging PLE System	High	10	N	N	00:00:03	Muddy sand with ripples.
ENV_39	09/11/2021	13:10:36	00:12:06	13:22:42	2	38	MARDUT1021_ENV_39_2021_11_09_131033, MARDUT1021_ENV_39_2021_11_09_132034	24.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled silty sand with shells, occasional cobble and gravel. Sand mason worms.
ENV_40	09/11/2021	17:29:31	00:11:09	17:40:40	2	26	MARDUT1021_ENV_40_2021_11_09_172928, MARDUT1021_ENV_40_2021_11_09_173930	22.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand. Burrowing anemones.
ENV_41	09/11/2021	18:20:01	00:13:03	18:33:04	2	28	MARDUT1021_ENV_41_2021_11_09_181958, MARDUT1021_ENV_41_2021_11_09_183000	22.1	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled sand with burrowing anemones and sand mason worms.
ENV_42	09/11/2021	19:50:37	00:11:58	20:02:35	2	24	MARDUT1021_ENV_42_2021_11_09_195034, MARDUT1021_ENV_42_2021_11_09_200035	22.0	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand with shells. Burrowing anemones and sand mason worms.
ENV_43	09/11/2021	22:01:26	00:14:04	22:15:30	2	31	MARDUT1021_ENV_43_2021_11_09_220123, MARDUT1021_ENV_43_2021_11_09_221125	21.5	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand with shells. Occasional cobbles and gravel at the start. Sand mason worms and burrowing anemones.
ENV_44	09/11/2021	23:33:16	00:11:29	23:44:45	2	26	MARDUT1021_ENV_44_2021_11_09_233413, MARDUT1021_ENV_44_2021_11_09_234415	22.4	SubC Imaging PLE System	High	10	N	N	00:00:03	Rippled muddy sand. Burrowing anemones.

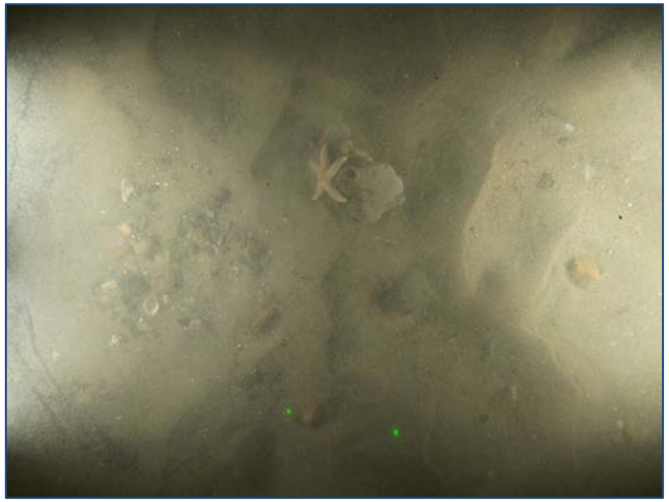
Appendix A3: Grab sampling positional logs

Station Details			Sampling Details							Positional Data					Sample Description			Photos			
Station I.D.	Attempt No.	Sampled Type (Post-Survey)	Method	Vessel	Personnel (Initials)	Water Depth (m)	Fix Number	Date	Time (UTC)	Target Easting	Target Northing	Sampled Easting	Sampled Northing	Coordinate System	Distance from Target (m)	Sample Volume (L)	Sediment Description (Folk)	Unreleased Sample	Released Sample	Sieved Sample	Notes
ENV_28	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	23.9	14	2021-11-09	11:45:35	722694	5953622	722698	5953623	ED50	4	8	Muddy Gravelly Sand (mgS)	Y	Y	N	-
ENV_28	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	23.9	15	2021-11-09	12:01:57	722694	5953622	722695	5953622	ED50	2	8	Muddy Gravelly Sand (mgS)	Y	Y	Y	Polychaeta
ENV_37	4	PC/MACA	Dual Van Veen	Geo Ocean III	MM	21.9	19	2021-11-10	01:31:35	726717	5953412	726718	5953463	ED50	51	10	Sand (S)	Y	Y	Y	1st attempt failed due to mason worms in jaws, 2nd attempt failed due to shells in jaws, 3rd attempt failed due to shells in jaws ...move station 50m north- good sample. *Lanice conchilega*.
ENV_37	3	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	21.9	23	2021-11-10	02:12:31	726717	5953412	726712	5953463	ED50	51	5	Gravelly Sand (gS)	Y	Y	Y	1st attempt failed due to stone in jaws, 2nd attempt failed due to mason worms in jaws. *Lanice conchilega*, Polychaeta.
ENV_36	1	PC/MACA	Dual Van Veen	Geo Ocean III	MM	22.9	24	2021-11-10	02:45:43	726362	5953211	726360	5953212	ED50	2	7	Sand (S)	Y	Y	Y	sand fine sediment, *Lanice conchilega*
ENV_36	1	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	22.9	25	2021-11-10	03:12:07	726362	5953211	726359	5953213	ED50	3	7	Sand (S)	Y	Y	Y	fine sand sediment shells, *Lanice conchilega*, Crustacea
ENV_44	3	PC/MACA	Dual Van Veen	Geo Ocean III	MM	22.2	28	2021-11-10	03:54:17	726134	5952885	726132	5952885	ED50	2	5	Sand (S)	Y	Y	Y	1st attempt <2 l. *Lanice conchilega*, Spatangoida
ENV_44	1	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	22.2	29	2021-11-10	05:02:19	726134	5952885	726122	5952885	ED50	12	5	Sandy Mud (sM)	Y	Y	Y	fine sand, muddy. *Ophiura ophiura*, Polychaeta
ENV_43	2	PC/MACA	Dual Van Veen	Geo Ocean III	MM	22.0	31	2021-11-10	05:48:59	725775	5952715	725770	5952714	ED50	5	5	Sandy Mud (sM)	Y	Y	Y	1st attempt <2l, 2nd attempt good, fine sand & mud, *Lanice conchilega*, Spatangoida
ENV_43	1	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	22.1	32	2021-11-10	06:15:17	725775	5952715	725772	5952715	ED50	4	5	Sandy Mud (sM)	Y	Y	Y	fine sand, mud, *Lanice conchilega*, *Ophiura ophiura*, Pectinariidae
ENV_35	1	PC/MACA	Dual Van Veen	Geo Ocean III	MM	23.4	33	2021-11-10	06:55:39	725808	5953207	725803	5953206	ED50	4	7	Sand (S)	Y	Y	Y	fine sediment fragment shell, *Lanice conchilega*
ENV_35	1	MACB/MACC	Dual Van Veen	Geo Ocean III	MM	23.4	34	2021-11-10	07:19:25	725808	5953207	725806	5953206	ED50	2	6	Sandy Gravel (sG)	Y	Y	Y	gravelly sand with sand mason worms, *Lanice conchilega*, Ophiuroidea
ENV_34	1	PC/MACA	Dual Van Veen	Geo Ocean III	MM	23.7	36	2021-11-10	07:58:27	725298	5953207	725297	5953208	ED50	1	5	Muddy Sand (mS)	Y	Y	Y	fine muddy sand
ENV_34	1	MACB	Dual Van Veen	Geo Ocean III	MM	23.7	35	2021-11-10	07:51:49	725298	5953207	725298	5953206	ED50	2	5	Muddy Sand (mS)	N	Y	Y	fine muddy sand
ENV_34	1	MACC	Dual Van Veen	Geo Ocean III	MM	23.7	37	2021-11-10	08:24:02	725298	5953207	725304	5953207	ED50	6	7	Muddy Sand (mS)	N	Y	Y	fine muddy sand, *Lanice conchilega*, Polychaeta
ENV_42	2	PC	Dual Van Veen	Geo Ocean III	MM	21.8	39	2021-11-10	09:07:36	725410	5952700	725413	5952699	ED50	3	5	Sandy Mud (sM)	Y	Y	Y	1st attempt <5l, muddy sand, dark sediment, smelly
ENV_42	3	MACA	Dual Van Veen	Geo Ocean III	MM	21.9	40	2021-11-10	09:22:00	725410	5952700	725411	5952701	ED50	1	6	Sandy Mud (sM)	N	Y	Y	1st and 2nd attempt < 5l, muddy sand, dark sediment, smelly. *Cylista sp.*, *Lanice conchilega*.
ENV_42	1	MACB	Dual Van Veen	Geo Ocean III	MM	21.9	41	2021-11-10	09:26:40	725410	5952700	725411	5952701	ED50	1	6	Sandy Mud (sM)	Y	Y	Y	Muddy sand, dark sediment, smelly. Bivalvia, *Lanice conchilega*, *Ophiura ophiura*, Polychaeta
ENV_42	1	MACC	Dual Van Veen	Geo Ocean III	MM	21.9	42	2021-11-10	09:39:28	725410	5952700	725414	5952650	ED50	50	8	Sandy Mud (sM)	Y	Y	Y	Station moved 50 m to the south. *Lanice conchilega*, Polychaeta
ENV_41	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	24.0	43	2021-11-10	11:24:04	724865	5952851	724867	5952850	ED50	3	8	Muddy Sand (mS)	Y	Y	Y	*Lanice conchilega*
ENV_41	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	24.0	44	2021-11-10	11:32:02	724865	5952851	724867	5952850	ED50	3	8	Muddy Sand (mS)	Y	Y	Y	Black layering in sediment.
ENV_33	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	21.0	45	2021-11-10	12:02:36	724757	5953171	724760	5953173	ED50	3	8	Muddy Sand (mS)	Y	Y	Y	Shelly. *Lanice conchilega*, Ophiuroidea
ENV_33	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	21.0	46	2021-11-10	12:13:38	724757	5953171	724758	5953172	ED50	1	8	Muddy Sand (mS)	Y	Y	Y	High density sand mason worms. Shelly. *Lanice conchilega*, Ophiuroidea, Polychaeta.
ENV_32	3	PC/MACA	Dual Van Veen	Geo Ocean III	KB	22.4	49	2021-11-10	12:47:54	724234	5953077	724233	5953080	ED50	4	8	Sandy Mud (sM)	Y	Y	Y	Black colour to sediment and annoxic smell. *Lanice conchilega*.
ENV_32	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	22.4	50	2021-11-10	13:06:54	724234	5953077	724234	5953079	ED50	2	8	Sandy Mud (sM)	Y	Y	Y	Black colour to sediment and annoxic smell. *Cylista sp.*, Polychaeta.
ENV_40	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	23.2	51	2021-11-10	13:35:08	724291	5952706	724292	5952706	ED50	1	8	Sandy Mud (sM)	Y	Y	Y	*Lanice conchilega*, Polychaeta
ENV_40	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	23.2	52	2021-11-10	13:48:48	724291	5952706	724289	5952705	ED50	1	8	Sandy Mud (sM)	Y	Y	Y	Clumps of clay/mud, *Lanice conchilega*, Polychaeta
ENV_30	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	24.0	53	2021-11-10	14:22:11	724151	5953716	724151	5953716	ED50	0	8	Muddy Sandy Gravel (msG)	Y	Y	Y	Shelly
ENV_30	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	24.0	54	2021-11-10	14:34:41	724151	5953716	724150	5953716	ED50	1	8	Muddy Gravelly Sand (mgS)	Y	Y	Y	Shelly
ENV_29	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	21.5	55	2021-11-10	15:10:39	723749	5953719	723747	5953720	ED50	3	8	Muddy Gravelly Sand (mgS)	Y	Y	Y	*Lanice conchilega*, Polychaeta
ENV_29	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	21.5	56	2021-11-10	15:21:11	723749	5953719	723749	5953721	ED50	2	8	Sandy Gravelly Mud (sgM)	Y	N	Y	-
ENV_31	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	22.6	57	2021-11-10	16:05:49	723784	5953009	723783	5953011	ED50	2	6	Sandy Mud (sM)	Y	Y	Y	Polychaeta
ENV_31	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	22.6	58	2021-11-10	17:03:31	723784	5953009	723783	5953010	ED50	2	7	Sandy Mud (sM)	Y	Y	Y	Polychaeta

Station Details			Sampling Details							Positional Data					Sample Description			Photos			
Station I.D.	Attempt No.	Sampled Type (Post-Survey)	Method	Vessel	Personnel (Initials)	Water Depth (m)	Fix Number	Date	Time (UTC)	Target Easting	Target Northing	Sampled Easting	Sampled Northing	Coordinate System	Distance from Target (m)	Sample Volume (L)	Sediment Description (Folk)	Unreleased Sample	Released Sample	Sieved Sample	Notes
ENV_38	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	23.4	59	2021-11-10	17:23:47	723270	5952703	723270	5952702	ED50	1	7	Sand (S)	Y	Y	Y	-
ENV_38	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	23.4	60	2021-11-10	17:40:01	723270	5952703	723269	5952702	ED50	2	7	Sand (S)	Y	Y	Y	-
ENV_39	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	24.0	61	2021-11-10	18:09:59	722979	5953224	722977	5953224	ED50	2	8	Muddy Sand (mS)	Y	Y	Y	*Lanice conchilega*
ENV_39	1	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	24.0	62	2021-11-10	18:21:55	722979	5953224	722978	5953224	ED50	0	5	Muddy Sand (mS)	Y	Y	Y	*Cylista sp.*, *Lanice conchilega*, Spatangoida
ENV_20	1	PC/MACA	Dual Van Veen	Geo Ocean III	KB	23.6	96	2021-11-11	17:08:55	725295	5953419	725293	5953419	ED50	2	8	Gravelly Muddy Sand (gmS)	Y	Y	Y	-
ENV_20	4	MACB/MACC	Dual Van Veen	Geo Ocean III	KB	23.8	100	2021-11-11	17:41:23	725295	5953419	725334	5953450	ED50	50	8	Gravelly Muddy Sand (gmS)	Y	Y	Y	All 3 attempts gravel caught in jaws. Moved station 50 m.

Appendix B. Selection of Sample and Seabed Photographs

Fix: 1191 E: 725357.0 N: 5953464.5 Depth: 23.7 m



Fix: 1200 E: 725317.5 N: 5953439.7 Depth: 23.8 m

Station: ENV 20

Image 1: MARDUT1021_ENV_20_2021_11_11_160845

Sediment Description: Rippled coarse sand with shell fragments and pebbles

Faunal Description: *Asterias rubens*; *Cylista* sp.; *Ophiura ophiura*; Ophiuroidea.

Image 2: MARDUT1021_ENV_20_2021_11_11_161151

Sediment Description: Rippled coarse sand with shell fragments, few pebbles and cobbles

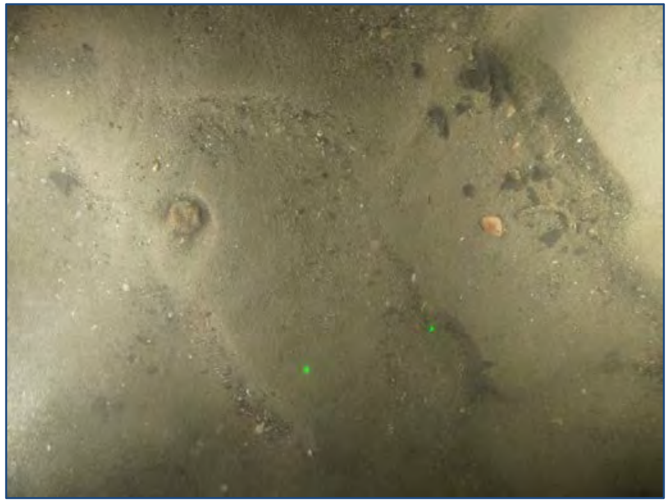
Faunal Description: *Asterias rubens*; *Lanice conchilega*; Ophiuroidea

Fix: 96 E: 725293.1 N: 5953418.8 Depth: 23.6 m

Fix: 96 E: 725293.1 N: 5953418.8 Depth: 23.6 m

Station: ENV 20
Sample: MACA

Sediment Description: Gravelly Muddy Sand (gmS)
Faunal Description: No visible fauna



Fix: 17 E: 722673.6 N: 5953595.2 Depth: 24.0 m

Fix: 11 E: 722684.8 N: 5953609.5 Depth: 24.1 m

Station: ENV 28

Image 1: MARDUT1021_ENV_28(2)_2021_11_05_152427

Sediment Description: Rippled coarse sand with shell fragments and few pebbles

Faunal Description: *Cylista* sp.; *Lanice conchilega*

Image 2: MARDUT1021_ENV_28_2021_11_05_151231

Sediment Description: Rippled coarse sand with shell fragments and few pebbles

Faunal Description: Actinopterygii; *Lanice conchilega*

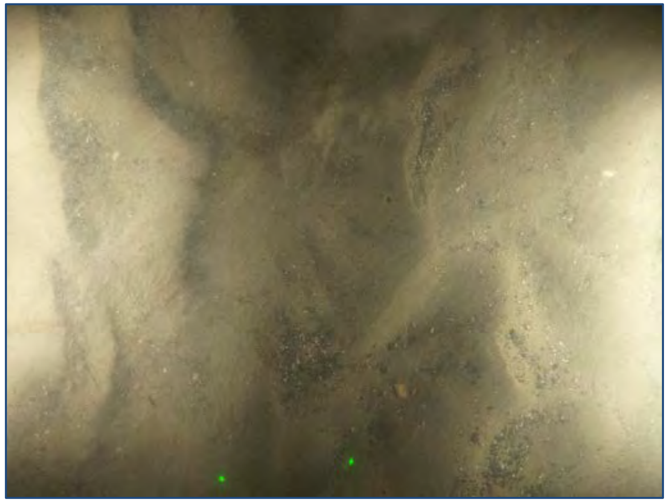
Fix: 14 E: 722697.9 N: 5953622.6 Depth: 23.9 m

Fix: 14 E: 722697.9 N: 5953622.6 Depth: 23.9 m

Station: ENV 28
Sample: MACB

Sediment Description: Muddy Gravelly Sand (mgS)
Faunal Description: No visible fauna

Fix: 281 E: 723776.1 N: 5953792.7 Depth: 24.3 m



Fix: 835 E: 723748.2 N: 5953719.2 Depth: 24.2 m

Station: ENV 29

Image 1: MARDUT1021_ENV_29_2021_11_09_145252

Sediment Description: Coarse sand with boulder

Faunal Description: *Cancer pagurus*; *Metridium dianthus*

Image 2: MARDUT1021_ENV_29_2021_11_09_145816

Sediment Description: Rippled coarse sand with shell fragments and pebbles

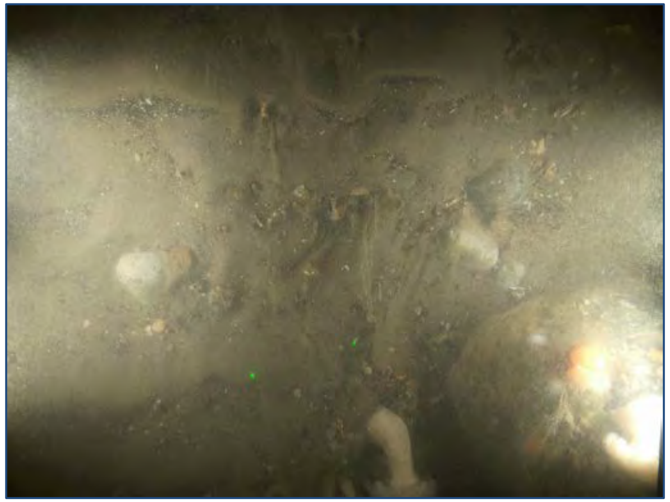
Faunal Description: Hydrozoa

Fix: 55 E: 723746.6 N: 5953720.2 Depth: 21.5 m

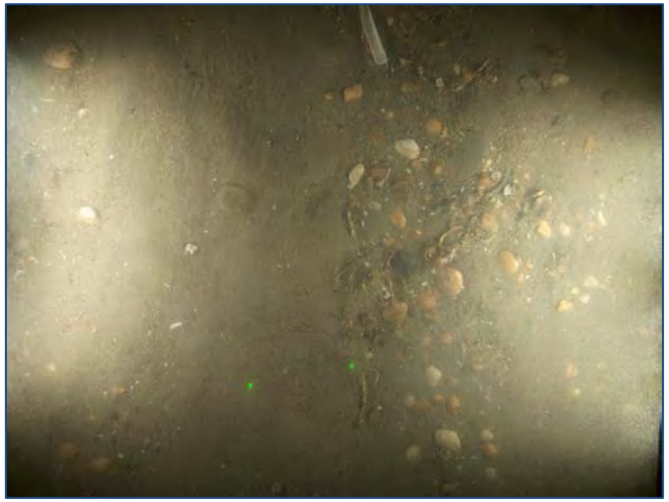
Fix: 55 E: 723746.6 N: 5953720.2 Depth: 21.5 m

Station: ENV 29
Sample: MACA

Sediment Description: Muddy Gravelly Sand (mgS)
Faunal Description: *Lanice conchilega*, Polychaeta



Fix: 861 E: 724044.3 N: 5953643.3 Depth: 24.1 m



Fix: 885 E: 724195.3 N: 5953746.3 Depth: 24.9 m

Station: ENV 30

Image 1: MARDUT1021_ENV_30_2021_11_09_154321

Sediment Description: Rippled coarse sand with shell fragments, few pebbles and scattered cobbles

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Metridium dianthus*; Plumulariidae

Image 2: MARDUT1021_ENV_30_2021_11_09_155536

Sediment Description: Rippled coarse sand with scattered shell fragments and few pebbles

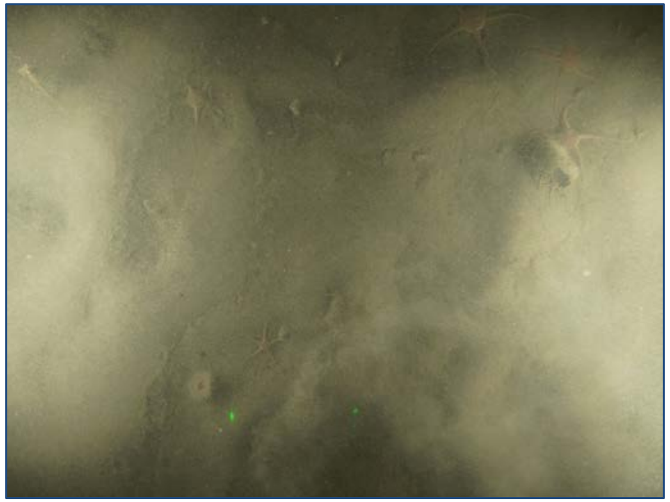
Faunal Description: *Cylista* sp.; Hydrozoa; *Lanice conchilega*

Fix: 53 E: 724151.3 N: 5953715.5 Depth: 26.2 m

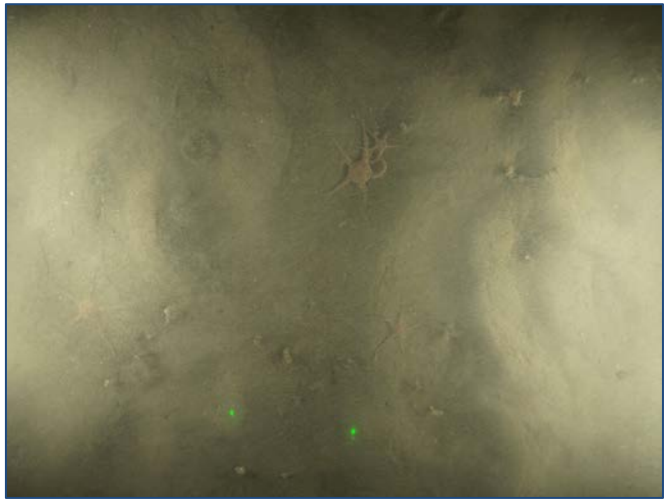
Fix: 53 E: 724151.3 N: 5953715.5 Depth: 26.2 m

Station: ENV 30
Sample: MACA

Sediment Description: Muddy Sandy Gravel (msG)
Faunal Description: No visible fauna



Fix: 809 E: 723786.9 N: 5953017.2 Depth: 23.4 m



Fix: 812 E: 723781.9 N: 5953003.3 Depth: 24.3 m

Station: ENV 31

Image 1: MARDUT1021_ENV_31_2021_11_09_142353

Sediment Description: Rippled sand with few shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*

Image 2: MARDUT1021_ENV_31_2021_11_09_142451

Sediment Description: Rippled sand with few shell fragments

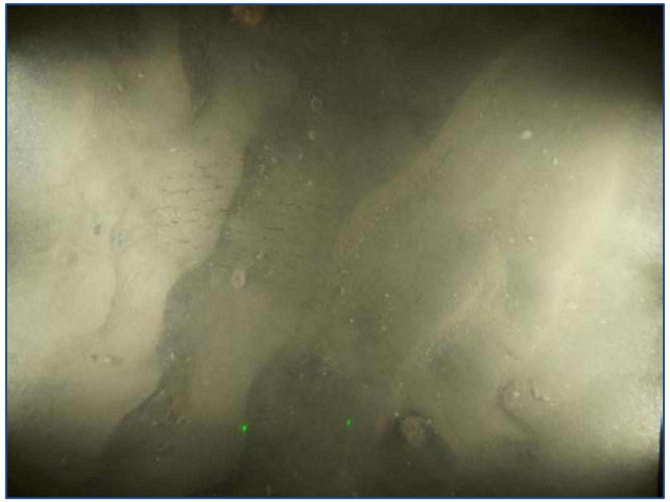
Faunal Description: Cylista sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*

Fix: 57 E: 723783.0 N: 5953010.6 Depth: 26.0 m

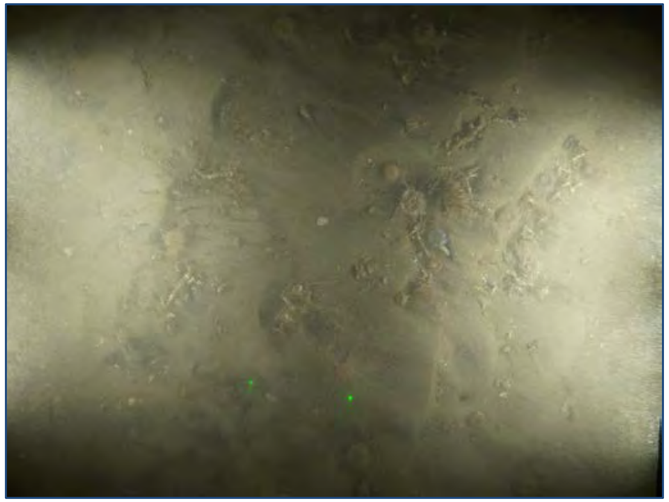
Fix: 57 E: 723783 N: 5953010.6 Depth: 26.0 m

Station: ENV 31
Sample: MACA

Sediment Description: Sandy Mud (sM)
Faunal Description: Polychaeta



Fix: 901 E: 724227.5 N: 5953062 Depth: 24.1 m



Fix: 907 E: 724213.3 N: 5953021.2 Depth: 22 m

Station: ENV 32

Image 1: MARDUT1021_ENV_32_2021_11_09_165609

Sediment Description: Rippled sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; Ophiuroidea

Image 2: MARDUT1021_ENV_32_2021_11_09_165850

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*

Fix: 49 E: 724232.9 N: 5953080.4 Depth: 24.0 m

Fix: 49 E: 724232.9 N: 5953080.4 Depth: 24.0 m

Station: ENV 32
Sample: MACA

Sediment Description: Sandy Mud (sM)
Faunal Description: *Lanice conchilega*

Fix: 971 E: 724765.5 N: 5953185.6 Depth: 24.2 m

Fix: 984 E: 724737.1 N: 5953118.9 Depth: 23.9 m

Station: **ENV 33**

Image 1: MARDUT1021_ENV_33_2021_11_09_190110

Sediment Description: Rippled coarse sand with scattered shell fragments

Faunal Description: *Lanice conchilega*; *Liocarcinus* sp.; *Ophiura ophiura*; Ophiuroidea

Image 2: MARDUT1021_ENV_33_2021_11_09_190554

Sediment Description: Coarse sand with scattered shell fragments and cobbles

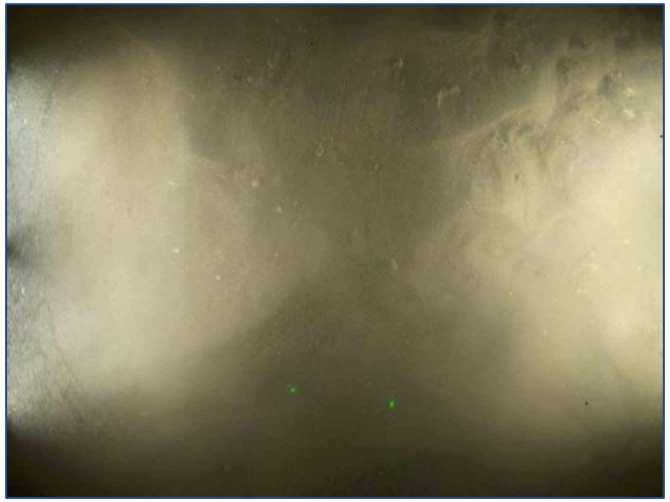
Faunal Description: Asteroidea; Caridea; *Cylista* sp.; Hydrozoa; *Lanice conchilega*; *Metridium dianthus*; Paguroidea; Plumulariidae

Fix: 45 E: 724760.2 N: 5953172.7 Depth: 23.6 m

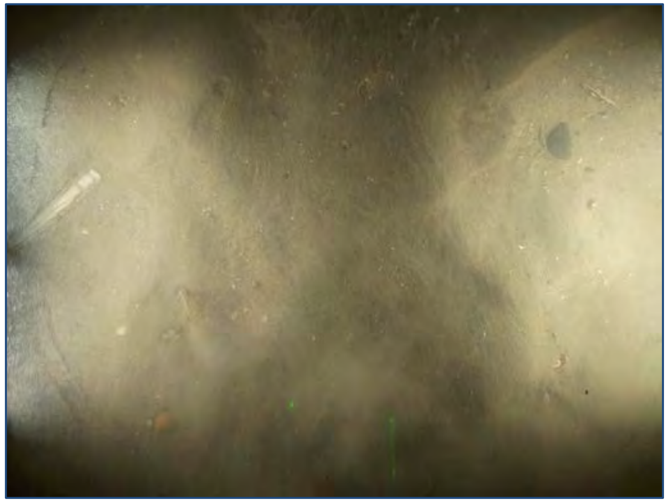
Fix: 45 E: 724760.2 N: 5953172.7 Depth: 23.6 m

Station: ENV 33
Sample: MACA

Sediment Description: Muddy Sand (mS)
Faunal Description: *Lanice conchilega*, Ophiuroidea



Fix: 1036 E: 725305.3 N: 5953196.1 Depth: 23.9 m



Fix: 1046 E: 725276.7 N: 5953258.2 Depth: 23.6 m

Station: ENV 34

Image 1: MARDUT1021_ENV_34_2021_11_09_203614

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Lanice conchilega*

Image 2: MARDUT1021_ENV_34_2021_11_09_204109

Sediment Description: Rippled coarse sand with shell fragments and few pebbles

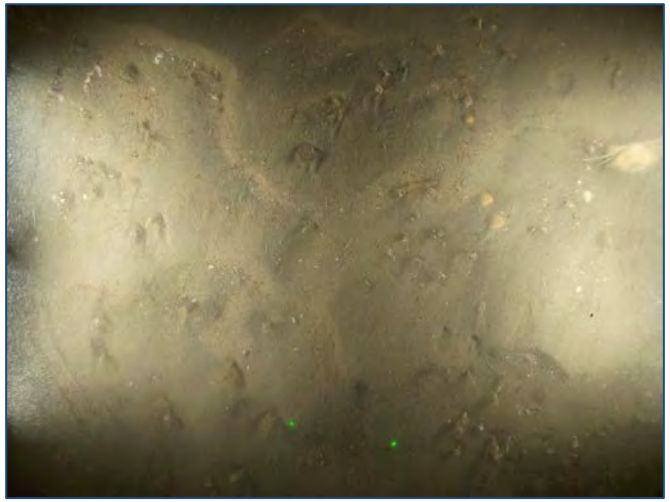
Faunal Description: *Lanice conchilega*

Fix: 36 E: 725296.8 N: 5953208.2 Depth: 24.2 m

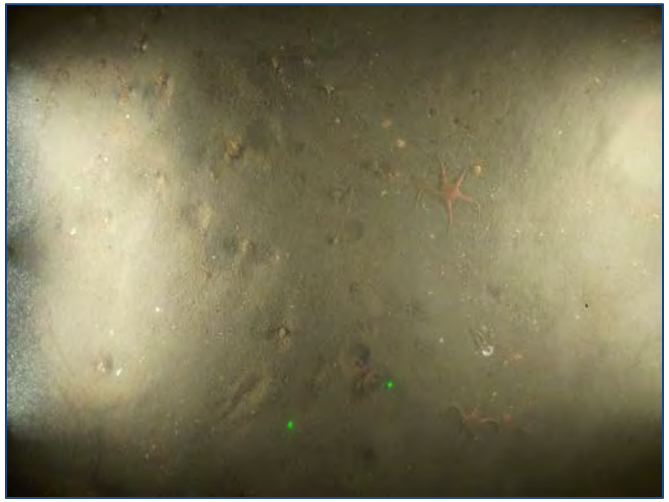
Fix: 36 E: 725296.8 N: 5953208.2 Depth: 24.2 m

Station: ENV 34
Sample: MACA

Sediment Description: Muddy Sand (mS)
Faunal Description: No visible fauna



Fix: 1064 E: 725808.3 N: 5953249.6 Depth: 23.3 m



Fix: 1075 E: 725810.2 N: 5953174.7 Depth: 22.7 m

Station: ENV 35

Image 1: MARDUT1021_ENV_35_2021_11_09_213732

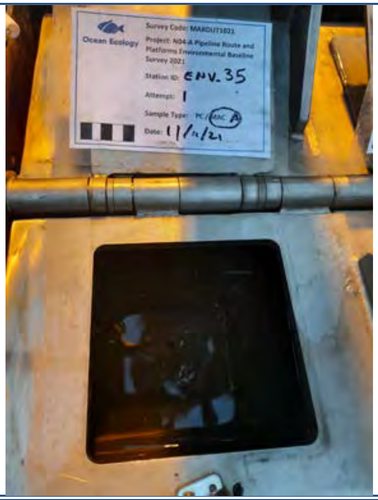
Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; Ophiuroidea; Portunidae

Image 2: MARDUT1021_ENV_35_2021_11_09_214225

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Ophiura ophiura*; Ophiuroidea; Portunidae

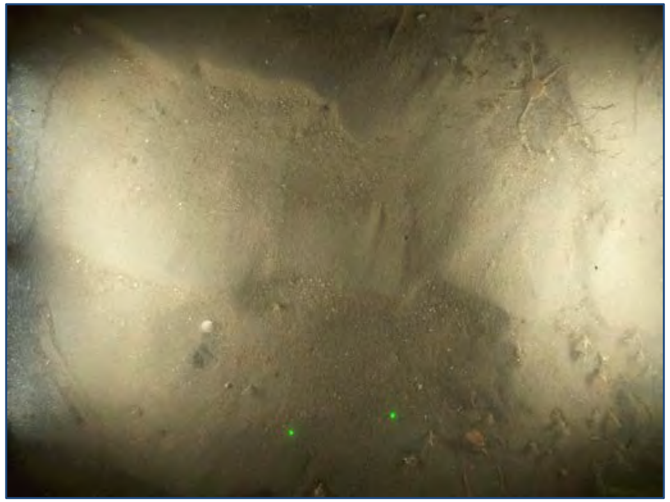


Fix: 33 E: 725803.4 N: 5953205.6 Depth: 23.9 m

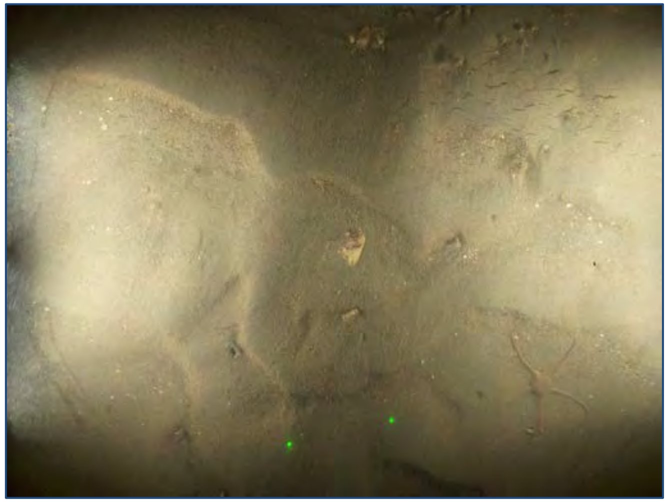
Fix: 33 E: 725803.4 N: 5953205.6 Depth: 23.9 m

Station: ENV 35
Sample: MACA

Sediment Description: Sand (S)
Faunal Description: *Lanice conchilega*



Fix: 1121 E: 726361.9 N: 5953220.4 Depth: 22.6 m



Fix: 1130 E: 726362.8 N: 5953152.4 Depth: 23 m

Station: ENV 36

Image 1: MARDUT1021_ENV_36_2021_11_09_225124

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*; Ophiuroidea

Image 2: MARDUT1021_ENV_36_2021_11_09_225545

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: Actinopterygii; *Lanice conchilega*; *Ophiura ophiura*; Portunidae

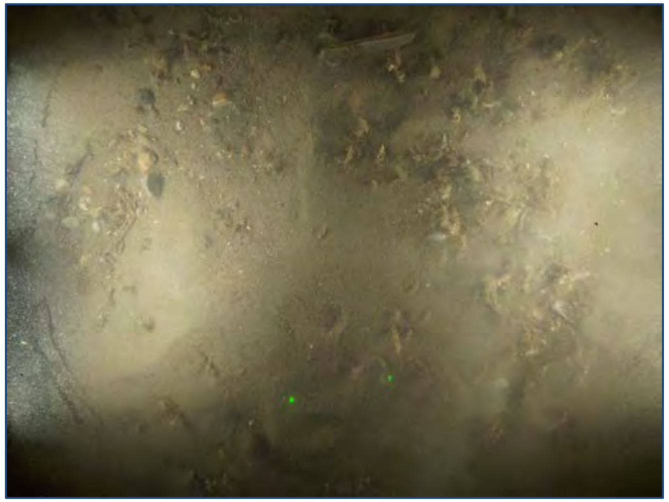
Fix: 24 E: 726360.2 N: 5953211.9 Depth: 22.8 m

Fix: 24 E: 726360.2 N: 5953211.9 Depth: 22.8 m

Station: ENV 36
Sample: MACA

Sediment Description: Sand (S)
Faunal Description: *Lanice conchilega*

Fix: 1168 E: 726699.5 N: 5953449.1 Depth: 22.2 m



Fix: 1178 E: 726721.2 N: 5953396.6 Depth: 22.2 m

Station: **ENV 37**

Image 1: MARDUT1021_ENV_37_2021_11_10_002258

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*; Ophiuroidea

Image 2: MARDUT1021_ENV_37_2021_11_10_002634

Sediment Description: Rippled coarse sand with shell fragments and few pebbles

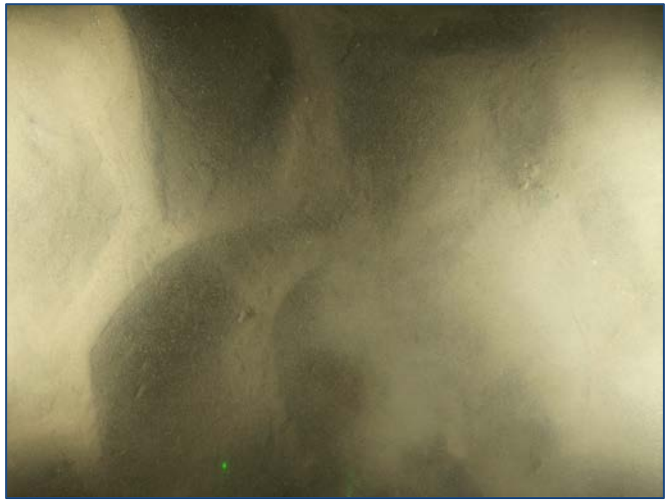
Faunal Description: *Cylista* sp.; *Lanice conchilega*

Fix: 19 E: 726717.6 N: 5953462.7 Depth: 24.9 m

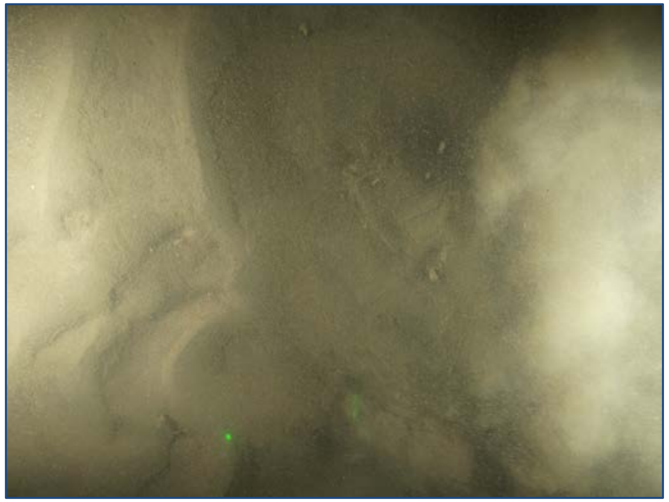
Fix: 19 E: 726717.6 N: 5953462.7 Depth: 24.9 m

Station: ENV 37
Sample: MACA

Sediment Description: Sand (S)
Faunal Description: *Lanice conchilega*



Fix: 765 E: 723270.2 N: 5952720.8 Depth: 20.3 m



Fix: 774 E: 723271.3 N: 5952690.8 Depth: 20 m

Station: ENV 38

Image 1: MARDUT1021_ENV_38_2021_11_09_134114

Sediment Description: Rippled sand with rare shell fragments

Faunal Description: *Lanice conchilega*; *Ophiura ophiura*

Image 2: MARDUT1021_ENV_38_2021_11_09_134309

Sediment Description: Rippled sand with rare shell fragments

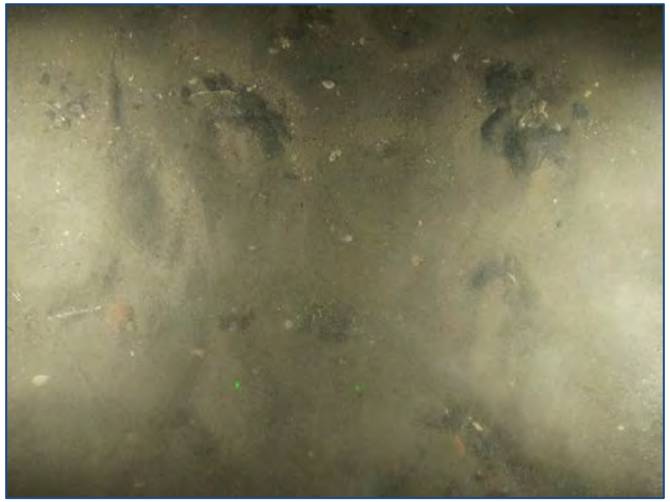
Faunal Description: *Lanice conchilega*

Fix: 59 E: 723269.5 N: 5952702.0 Depth: 23.9 m

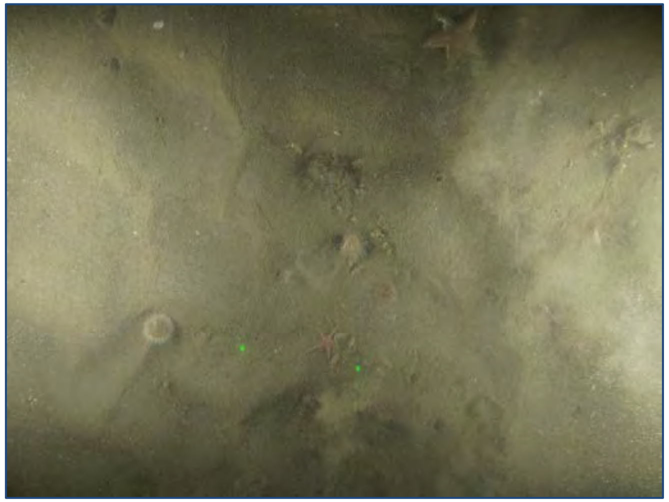
Fix: 59 E: 723269.5 N: 5952702.0 Depth: 23.9 m

Station: ENV 38
Sample: MACA

Sediment Description: Sand (S)
Faunal Description: No visible fauna



Fix: 717 E: 723028.9 N: 5953295.9 Depth: 24.4 m



Fix: 736 E: 722982.1 N: 5953231.4 Depth: 24.4 m

Station: ENV 39

Image 1: MARDUT1021_ENV_39_2021_11_09_131110

Sediment Description: Rippled coarse sand with shell fragments and few pebbles

Faunal Description: *Lanice conchilega*

Image 2: MARDUT1021_ENV_39_2021_11_09_131652

Sediment Description: Rippled coarse sand with shell fragments

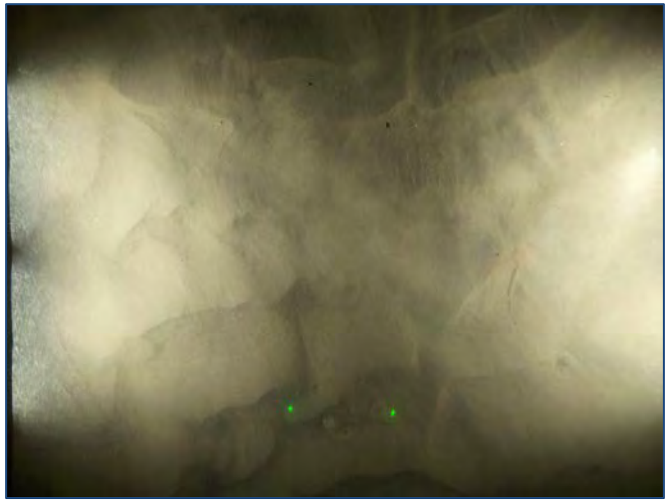
Faunal Description: *Astropecten irregularis*; *Cylista* sp.; *Lanice conchilega*; *Ophiura albida*

Fix: 61 E: 722977.2 N: 5953224.4 Depth: 23.6 m

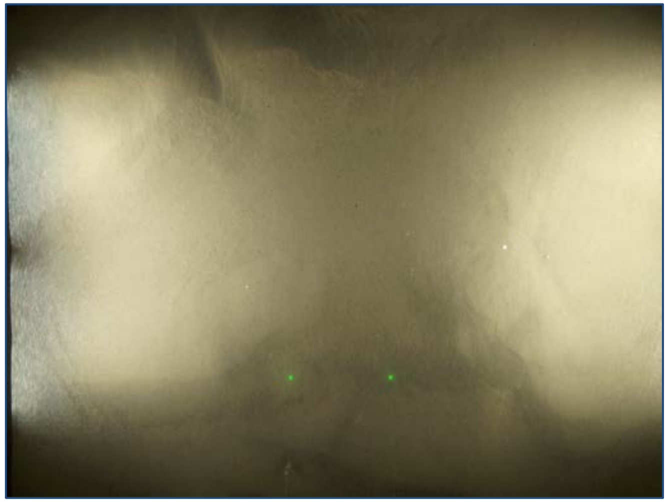
Fix: 61 E: 722977.2 N: 5953224.4 Depth: 23.6 m

Station: ENV 39
Sample: MACA

Sediment Description: Muddy Sand (mS)
Faunal Description: *Lanice conchilega*



Fix: 924 E: 724274.1 N: 5952734.6 Depth: 20.8 m



Fix: 934 E: 724309.4 N: 5952672.9 Depth: 23.3 m

Station: **ENV 40**

Image 1: MARDUT1021_ENV_40_2021_11_09_173349

Sediment Description: Rippled sand with rare shell fragments

Faunal Description: *Cylista* sp.; *Ophiura ophiura*

Image 2: MARDUT1021_ENV_40_2021_11_09_173839

Sediment Description: Rippled sand with rare shell fragments

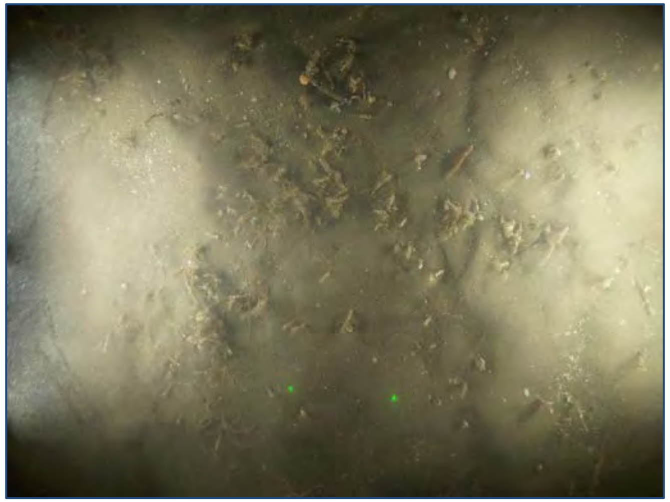
Faunal Description: *Lanice conchilega*

Fix: 51 E: 724292.0 N: 5952706.2 Depth: 21.0 m

Fix: 51 E: 724292.0 N: 5952706.2 Depth: 21.0 m

Station: ENV 40
Sample: MACA

Sediment Description: Sandy Mud (sM)
Faunal Description: *Lanice conchilega*, Polychaeta



Fix: 942 E: 724873.8 N: 5952961.5 Depth: 23.2 m

Fix: 950 E: 724869.9 N: 5952892.6 Depth: 22.5 m

Station: ENV 41

Image 1: MARDUT1021_ENV_41_2021_11_09_182016

Sediment Description: Rippled sand with shell fragments

Faunal Description: *Asterias rubens*; *Cylista* sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*; Ophiuroidea

Image 2: MARDUT1021_ENV_41_2021_11_09_182445

Sediment Description: Rippled sand with shell fragments

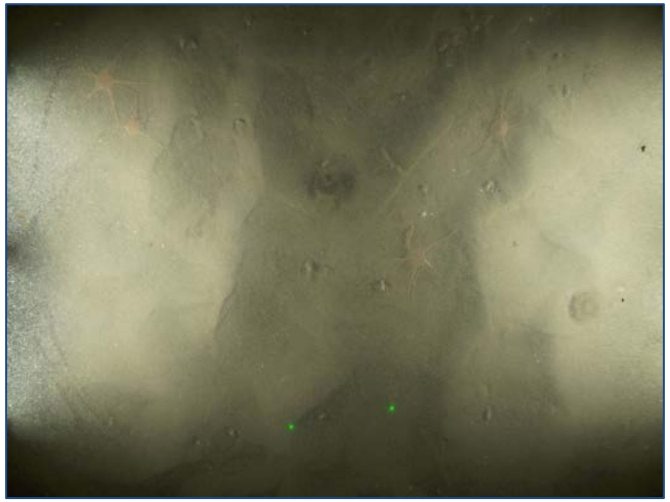
Faunal Description: *Lanice conchilega*; Ophiuroidea; Paguroidea

Fix: 43 E: 724867.4 N: 5952849.9 Depth: 21.5 m

Fix: 43 E: 724867.4 N: 5952849.9 Depth: 21.5 m

Station: ENV 41
Sample: MACA

Sediment Description: Muddy Sand (mS)
Faunal Description: *Lanice conchilega*



Fix: 1013 E: 725406.7 N: 5952743.8 Depth: 22.7 m

Fix: 1023 E: 725401.7 N: 5952816.9 Depth: 23.8 m

Station: **ENV 42**

Image 1: MARDUT1021_ENV_42_2021_11_09_195552

Sediment Description: Rippled sand with rare shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Ophiura ophiura*

Image 2: MARDUT1021_ENV_42_2021_11_09_200055

Sediment Description: Rippled sand with shell fragments

Faunal Description: *Lanice conchilega*

Fix: 39 E: 725412.7 N: 5952699.1 Depth: 23.5 m

Fix: 39 E: 725412.7 N: 5952699.1 Depth: 23.5 m

Station: ENV 42
Sample: MACA

Sediment description: Sandy Mud (sM)
Faunal Description: *Cylista* sp., *Lanice conchilega*

Fix: 1090 E: 725811.6 N: 5952838.4 Depth: 22.6 m

Fix: 1099 E: 725792.6 N: 5952777.3 Depth: 22.0 m

Station: ENV 43

Image 1: MARDUT1021_ENV_43_2021_11_09_220504

Sediment Description: Rippled sand and clay with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*; Paguroidea

Image 2: MARDUT1021_ENV_43_2021_11_09_220916

Sediment Description: Rippled coarse sand with shell fragments

Faunal Description: *Cylista* sp.; *Lanice conchilega*; Lotidae; *Ophiura albida*; *Ophiura ophiura*

Fix: 31 E: 725770.1 N: 5952714.4 Depth: 21.9 m

Fix: 31 E: 725770.1 N: 5952714.4 Depth: 21.9 m

Station: ENV 43
Sample: MACA

Sediment Description: Sandy Mud (sM)
Faunal Description: *Lanice conchilega*, Spatangoida

Fix: 1142 E: 726160.5 N: 5952963.9 Depth: 22.4 m

Fix: 1152 E: 726133.6 N: 5952888.2 Depth: 21.9 m

Station: ENV 44

Image 1: MARDUT1021_ENV_44_2021_11_09_233759

Sediment Description: Rippled sand with shell fragments and few pebbles

Faunal Description: *Astropecten irregularis*; Caridea; *Cylista* sp.; *Lanice conchilega*; *Liocarcinus* sp.

Image 2: MARDUT1021_ENV_44_2021_11_09_234306

Sediment Description: Rippled sand with shell fragments

Faunal Description: Actinopterygii; Cylista sp.; *Lanice conchilega*; *Ophiura albida*; *Ophiura ophiura*; Ophiuroidea

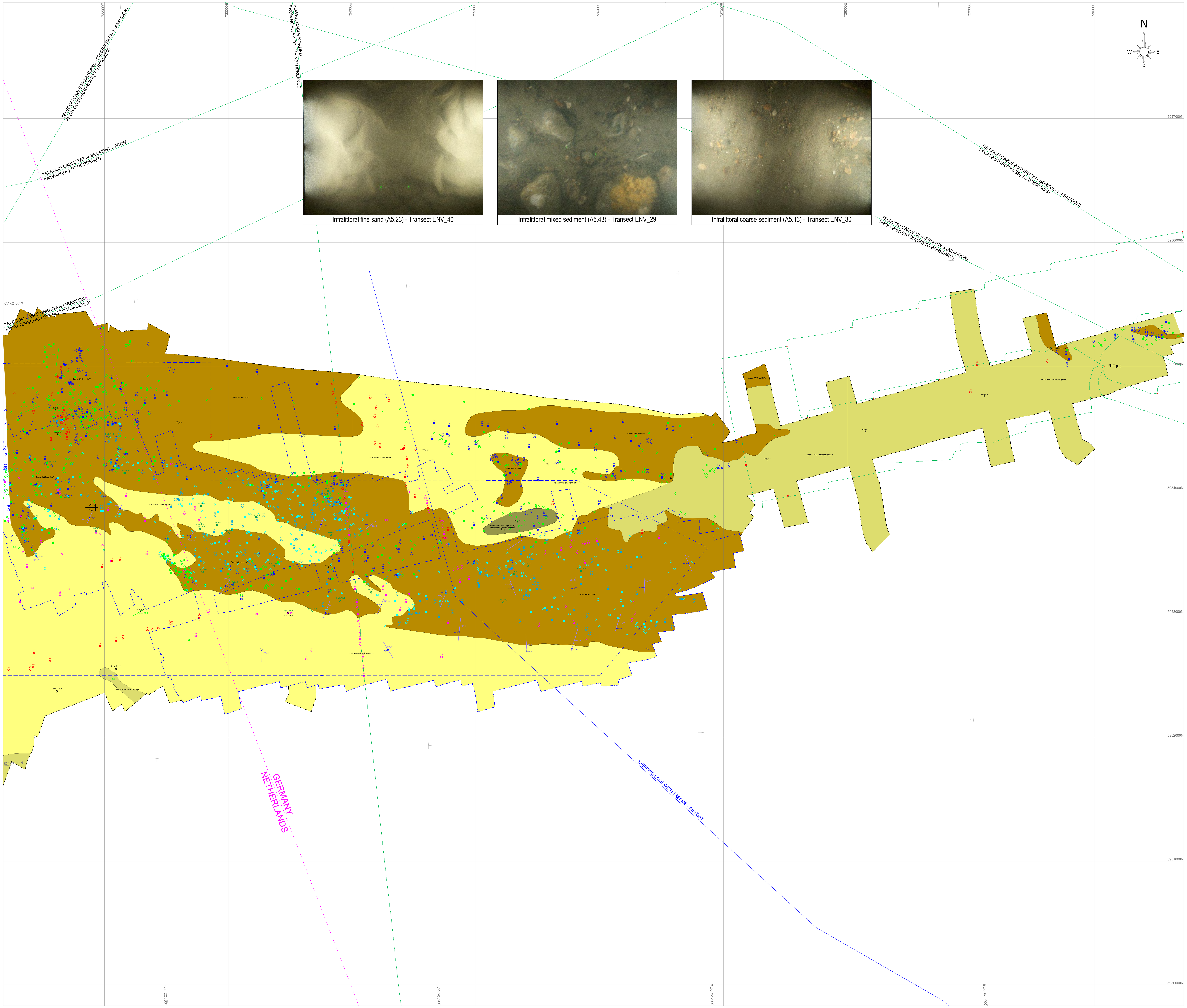
Fix: 28 E: 726131.8 N: 5952885.0 Depth: 22.6 m

Fix: 28 E: 726131.8 N: 5952885.0 Depth: 22.6 m

Station: ENV 44
Sample: MACA

Sediment Description: Sand (S)
Faunal Description: No visible fauna

Appendix C. Seabed Features Chart



LEGEND

- Proposed new location for N05-A Platform
- U.T.M. grid
- Geographical grid
- Survey Boundary
- Existing Infrastructure
- EEZ Boundary
- Shipping Lane
- Monopile location Riffgat

SCALE 1:10000

0 100 200 300 400 500 1000 meters
0 400 800 1600 3200 feet

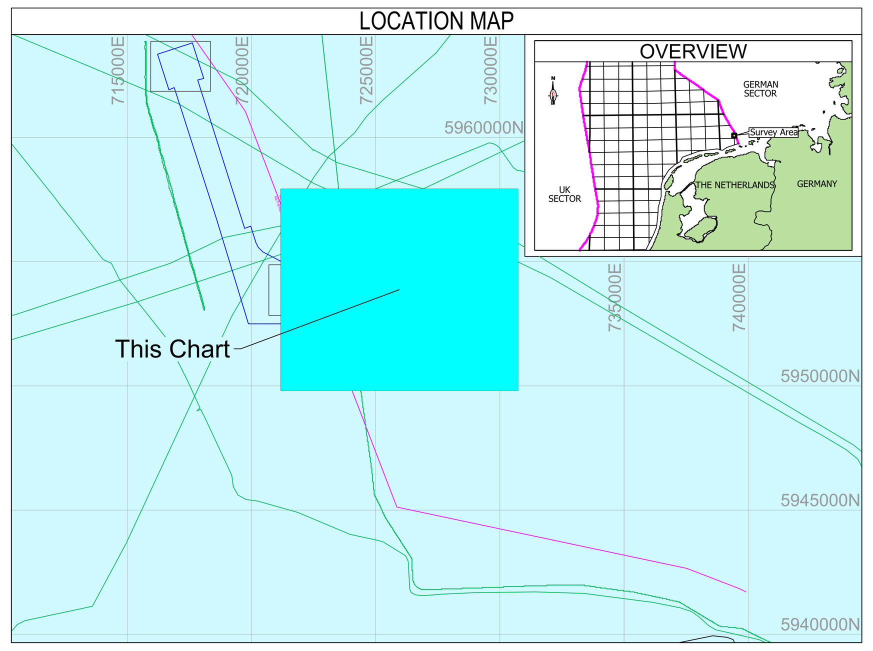
SEABED FEATERS:

- Side scan sonnar contact from 2019 survey. >0.3m (Height removed for clarity)
- 0.3 — Side scan sonnar contact from 2019 survey with height in metres. >0.5m
- Side scan sonnar contact from 2021 survey. >0.3m (Height removed for clarity)
- 0.3 — Side scan sonnar contact from 2021 survey with height in metres. >0.5m
- 16 — Magnetic anomaly from 2019 survey with anomaly size in nanoTeslas
- 16 — Magnetic anomaly from 2021 survey with anomaly size in nanoTeslas
- 1.4 x 0.5 x 0.3 — Debris item from 2019 survey with dimensions (length x width x height) in meters
- 2.4x0.7x0.6 — Debris item from 2021 survey with dimensions (length x width x height) in meters
- Linear debris from 2019 survey with length in metres
- Linear debris from 2021 survey with length in metres
- Camera transects from 2019 survey
- Camera transects from 2021 survey
- GRAB_P_12 — Grab sample from 2019 survey with identification
- ENV_38 — Grab sample from 2021 survey with identification
- Infralittoral fine sand (A5.23)
- Infralittoral coarse sediment (A5.13)
- Infralittoral coarse sediment (A5.13) with scattered areas of Infralittoral mixed sediment (A5.43)
- Infralittoral mixed sediment (A5.43)

ONE INFORMATION PANEL

1.	N05-A Proposed platform Location	721 896.00 mE 5 953 858.00 mN	53° 41' 06.322" N 06° 21' 36.970" E

LOCATION MAP



SURVEY EQUIPMENT

Positioning:	Fugro seastar 9205
Multibeam:	R2Sonic 2024
Motion sensor:	POS-MV OceanMaster
Sound velocity probe:	Valeport - Swift
Side scan sonar:	Edgetech - 4200
USBL:	Sonardyne Ranger 2
Magnetometer:	Geometrics - G882
Sub Bottom Profiler	Massa TR1075D
Seismic source:	GSO 180 Sparker

SURVEY DATES

Geophysical acquisition (MBES, MAG, SSS, SBP):

Geo Ocean III: 20/10/2021 untill 16/11/2021

GEODETIC INFORMATION

Horizontal datum:	European datum 1950 (ED 50)
Spheroid:	International 1924
Semi-major axis:	a = 6378388.00m
Semi-minor axis:	b = 6356911.95m
First eccentricity squared:	e2 = 0.006723
Inverse flattening:	1/f = 297.000
EPSG code:	23031
Projection:	UTM
Central meridian:	3° East
Latitude of origin:	0°
False easting:	500000.00m
False northing:	0.00m
Scale factor at central meridian:	0.9996
Units:	Metres
Vertical datum:	Lowest Astronomical Tide (LAT)

HYDROGRAPHIC SURVEY

N04-A Pipeline Route And Platform Surveys

N05a to Riffgat OWF

Cable Route Survey

ENVIRONMENTAL SEABED FEATURES CHART

Chart: 002/004 | Scale: 1/10000 | LAT

Drawing made by:

GEOXYZ
2 Route D'Arlon
Windhof Business center block A
L-8388 WINDHOF
Luxembourg

Client:

Oranje-Nassau Energie B.V.
UNStudio, 7th floor
Parnassusweg 815
1082 LZ Amsterdam (The Netherlands)

Tel: +31 20 535 41 00
Fax: +31 20 535 41 22

Issue no:	Date:	Description:	Drawn:	Checked:
00	16-11-2021	Preliminary Chart	CA	SC
01	30-11-2021	Draft Issue	CA	SC
02	08-12-2021	SSS contact interpretation updated / environmental sediment desrcriptions added	CA	SC
03	16-12-2021	Issued with Report	KMc	CA

ONE Dyas Drawing No.	N05A-7-50-0-72039-01	GEOxyz Drawing No.	NL4658H-553-DR-014

Appendix D. Summary of Faunal Observations

Stations	Animalia indeterminate 01	Animalia tube	Annelida - *Lanice conchilega*	Arthropoda – Atelecyclidae	Arthropoda - *Cancer pagurus*	Arthropoda - Caridea	Arthropoda - Decapoda	Arthropoda - *Homarus gammarus*	Arthropoda - *Liocarcinus* sp.	Arthropoda - Majidae	Arthropoda - Portunidae	Arthropoda - Paguroidea	Chordata - Actinopterygii	Chordata - *Agonus cataphractus*	Chordata - *Limanda limanda*	Chordata – Lotidae	Chordata - *Pholis gunnellus*	Chordata - Pleuronectiformes	Cnidaria - Anthozoa	Cnidaria - Actiniaria	Cnidaria - *Alcyonium digitatum*	Cnidaria - Certianthidae	Cnidaria – *Cylista* sp.	Cnidaria - Hydrozoa	Cnidaria - Plumulariidae	Cnidaria - *Metridium dianthus*	Cnidaria - Pennatulacea	Echinodermata - Asteroidea	Echinodermata - *Asterias rubens*	Echinodermata - *Astropecten irregularis*	Echinodermata - Ophiuroidea	Echinodermata - *Ophiura albida*	Echinodermata – *cf. Ophiura ophiura*	Faunal Turf	Mollusca - *Ensis* sp.	Mollusca - bivalve siphon	Porifera - *cf. Halichondria (Halichondria) panicea*	Porifera 01	Porifera 02
ENV_20			2					1											1				17		1	7		5	4		5	2	8	3			1	3	
ENV_28			2										1										1																
ENV_28(2)		5	13								1												11						1		1			4		1			
ENV_29			7		2															1			10	2		10		3	1	1	1			2			1		1
ENV_30			21				1				1		1										16	1	2	3			6		8	4		3			1	2	1
ENV_31			19						1	1	1							1					10						1		7	3	13	1					
ENV_32		2	16																				17							1	13	4	8	10					
ENV_33			25			2	1		2		2	4	1								2		27	5	4	11		8	7		17	3	14	5	1		3	6	3
ENV_34		1	25				1						1	1									9		1	2			1	1	11	7	20	7	1	1	1	1	1
ENV_35		3	24			1			2		2	1	4					1				1	12					1	1		19	14	20	4		1	1		2
ENV_36		2	22								1	1	4					2					13						3		17	12	18	4	1				
ENV_37	1	1	26			2					1	1	4		1							1	15						2	1	16	11	18	2					1
ENV_38			8																				2								4		11	1					
ENV_39			32							2	1		1	1				1	1				24						1	2	13	8	10	6	1			1	
ENV_40	1	1	17										1										5								4		12	1					
ENV_41		1	27								1	4	3				1						16						2		8	3	24	7		1			
ENV_42			19										2										11						1		6	2	16						
ENV_43		5	27								2	2	5			1							24						4		15	12	24	7				3	
ENV_44		1	26	2		5			1			1	5									1	22			2			4	1	14	7	18	2					1

Appendix E. Faunal Catalogue

Animalia indeterminate 01

Worm like

Animalia tube

Annelida – *Lanice conchilega*

Polychaete worm which makes a tube out of sand grains and shell fragments, which has a characteristic frayed end that protrudes above the sand.

Arthropoda – Atelecyclidae

These crabs have smooth, rounded carapaces, typically with numerous sharp teeth around its edges. The chelipeds are rather short and robust.

Arthropoda – *Cancer pagurus*

Heavy, oval carapace, with piecrust edge. Massive black-tipped chelae.

Arthropoda - Caridea

Shrimp

Arthropoda – Decapoda

Small and crab like.

Arthropoda – *Homarus gammarus*

Large distinctive chelae of a common lobster.

Arthropoda – *Liocarcinus* sp.

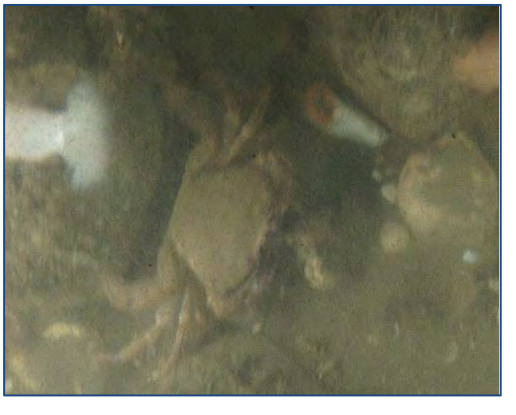
Swimming crab with paddle shaped dactyls on the fifth pereopods. Curved rows of white spots on carapace.

Arthropoda – Majidae

Characterized by slender log pereopods. Carapace oval or pear shaped.

Arthropoda - Paguroidea

Hermit crab.



Arthropoda - Portunidae

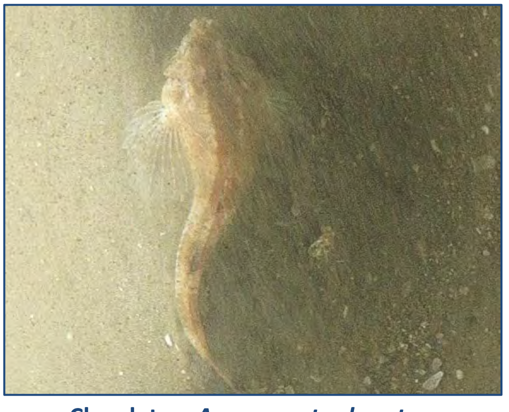
Swimming crab with paddle shaped dactyls on the fifth pereopods

Chordata - Lotidae

Elongated fish with barbels.

Chordata – Actinopterygii

Indeterminate ray-finned fish.



Chordata – *Agonus cataphractus*

Wide, flattened, triangular head with an elongated, tapering body. This fish is completely covered in hard bony plates, that form lateral rows of sharp spines.

Chordata – *Limanda limanda*

Both eyes are on the right side of the body. The most characteristic feature is the lateral line, which is strongly arched. The pectoral fin is sometimes orange.

Chordata – cf. *Pholis gunnellus*

Elongate, laterally compressed body. A series of black spots, outlines in white are present along the base of the long dorsal fin.

Chordata - Pleuronectiformes

Indeterminate flatfish.

Chordata – cf. *Callionymus lyra*

Broad and triangular head, with a longer snout and jutting lower jaw. Females and immature males are brown and lighter ventrally with a series of 6 brown blotches along the sides.

Cnidaria – Actiniaria

Indeterminate anemone

Cnidaria – *Alcyonium digitatum*

Mature colonies form thick, fleshy masses of irregular shape, typically of stout, finger-like lobe.

Cnidaria – Anthozoa

Indeterminate Anthozoa.

Cnidaria – Cerianthidae

Tube-dwelling anemone with two rings of tentacles.

Cnidaria – *Cylista* sp**.**

Burrowing anemone.

Cnidaria – Hydrozoa

Erect hydrozoa.

Cnidaria – *Metridium dianthus*

The base is wider than the column and often irregular. When expanded, the numerous tentacles form a 'plume' above a conspicuous parapet at the top of the smooth column.

Cnidaria - Pennatulacea

Sea pen

Cnidaria – Plumulariidae

Erect colonies, usually pinnate (feather shaped).

Echinodermata – *Asterias rubens*

Variable in colour, though usually orange, pale brown or violet. Deep-water specimens are pale. It has five tapering arms, broad at the base that are often slightly turned up at the tip when active.

Echinodermata – Asteroidea

Indeterminate starfish

Echinodermata – *Astropecten irregularis*

Stiff flattened body. At the edge of each arm there is a double series of large marginal plates. It often has purple spots at the end of each arm.

Echinodermata – *Ophiura albida*

A small brittle star with short, tapered, straight arms. The body and arms are red-brown in colour and there are two white marks at the base of each arm.

Echinodermata – *cf. Ophiura ophiura*

Arms stiff. Dorsally, the base of each arms is bordered by two rows of short spines.

Echinodermata – Ophiuroidea

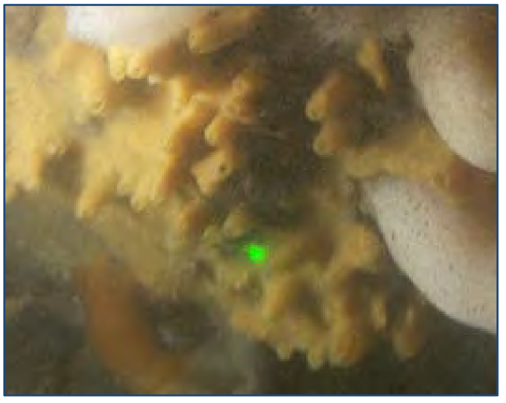
Fauna description

Mollusca – Bivalvia siphon

Bivalve siphons

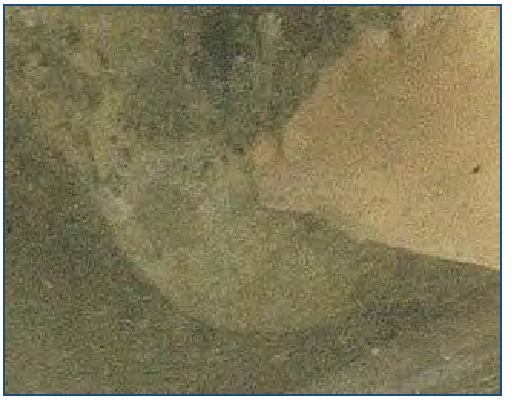
Mollusca – *Ensis* sp.

Razor shells have an elongate and fragile shell with valves gaping at both ends



Porifera - *cf. Halichondria (Halichondria) panicea*

Very polymorphic, varying from thin sheets, massive forms and cushions to branching-repent forms. Prone to giving off stout branching processes which develop into oscular chimneys.



Porifera 01

White/cream encrusting sponge.

Porifera 02

Orange encrusting sponge.

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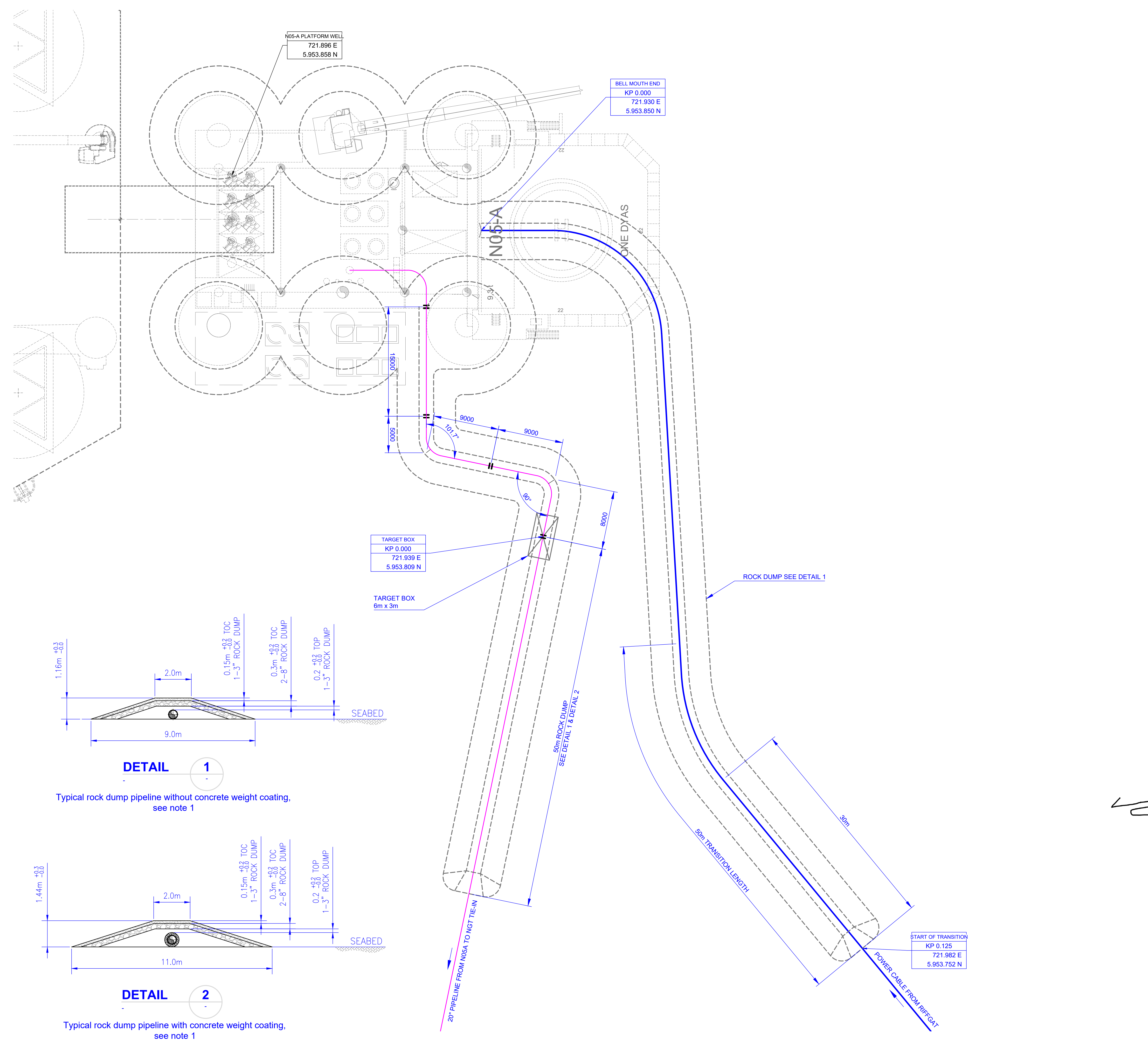


GENERAL NOTES

1 COMPOSITION AND STABILITY TO BE DETERMINED BY CONTRACTOR. MINIMUM REQUIRED DOWNWARD FORCE BASED ON ROCK BERM HEIGHT 0,8 m T.O.P. AND 3300 kg/m³ ROCK DENSITY.

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06

LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

ROCKDUMP VOLUME			
	LAYER 1 (1"-3")	LAYER 2 (2"-8")	LAYER 3 (1"-3")
BURIED	250 m3	200 m3	125 m3
UNBURIED	425 m3	275 m3	150 m3
LEGS	650 m3	425 m3	250 m3
CABLE	325 m3	275 m3	175 m3

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

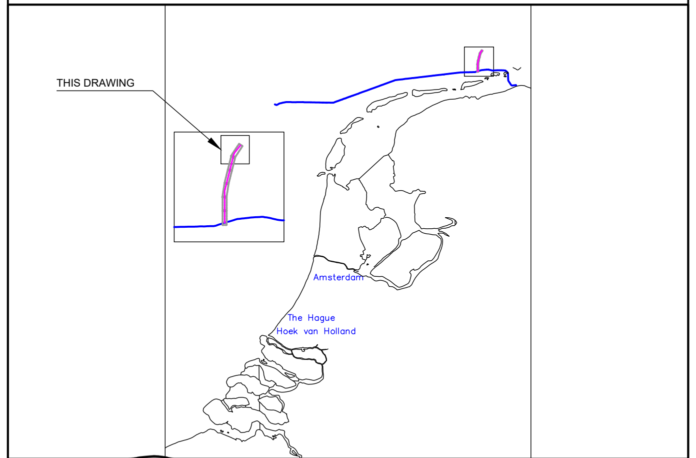
Horizontal Datum Name: European Datum 1950 North Sea -UKCS

Projection Name: Universal Transverse Mercator

Ellipsoid: International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000	Zone	:	=	North 31
Semi minor axis	b	=	6 356 911.946	Central meridian	:	=	3° East
Inverse ELattening	1/f	=	297.000	Latitude of origin	:	=	Equator
Excentricity squared	e	=	0.006 722 670	False Easting	:	=	500 000.00 m
				False Northing	:	=	0.00 m
				Scale factor on C.M.	:	=	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV	-	PF	PF	

enersea
Jan Evertsenweg 12
3115 JA Schiedam
The Netherlands
+31(0) 103132100
info@enersea.nl

Client: ONEDyas B.V.

Project: N05-A TO NGT PIPELINE

Document: Alternative platform location Approach drawing - @ N05A

Scale: 1:250
Size: A1

Project number: 19018

Document Number: N05A-7-50-0-72051-01

N05-A Pipeline design

Basic Design Report

DOCUMENT NUMBER:

N05A-7-10-0-70029-01

22-12-2021

Rev.	Date	Description	Originator	Checker	Approver
01	31-01-2020	For Comments	EvW	VH/PF	PF
02	13-03-2020	Client Comments Incorporated	EvW	PF	PF
03	20-12-2021	Updated	DK	PF	PF

Client

ONE-Dyas B.V.

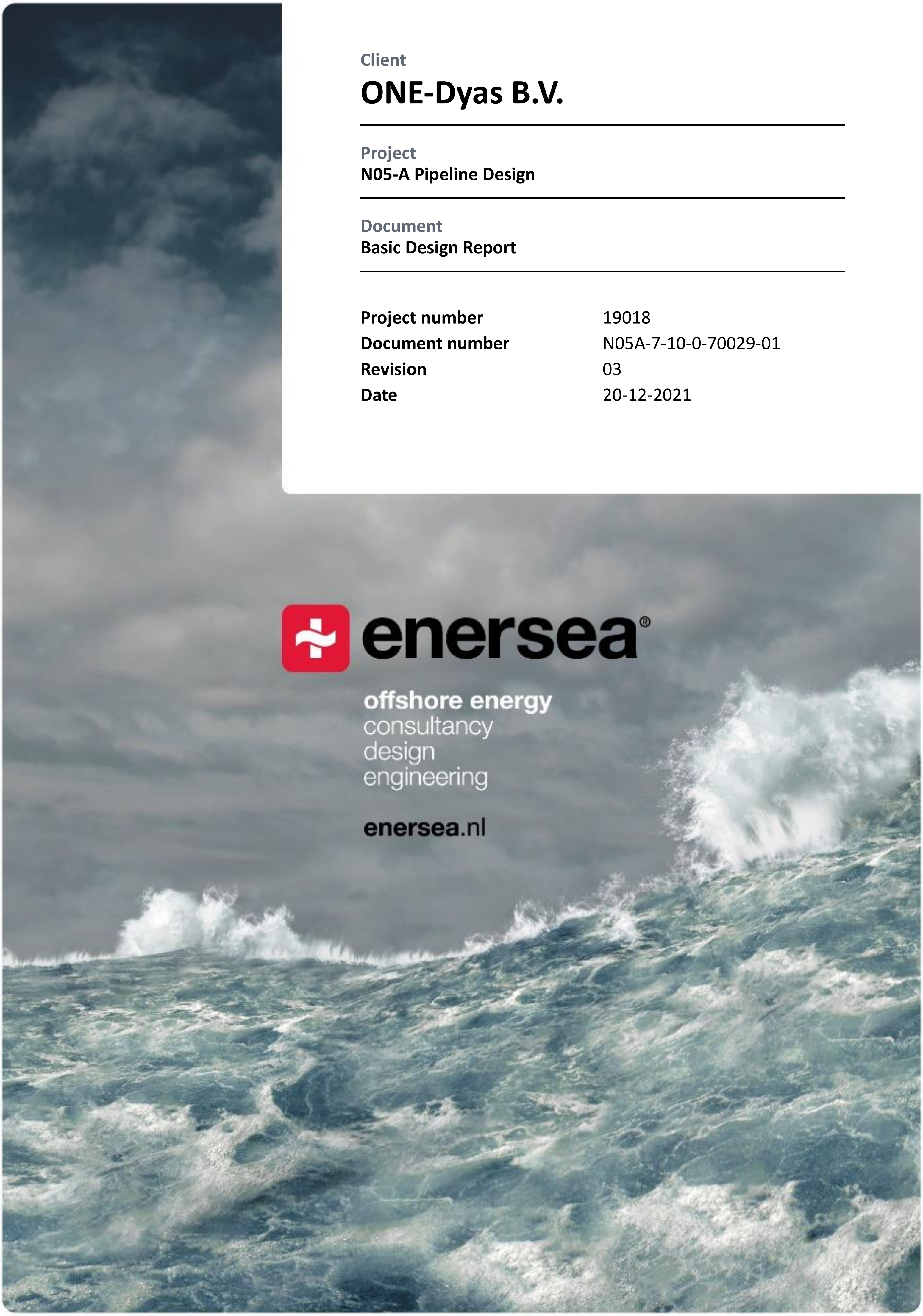
Project

N05-A Pipeline Design

Document

Basic Design Report

Project number	19018
Document number	N05A-7-10-0-70029-01
Revision	03
Date	20-12-2021



enersea®

offshore energy
consultancy
design
engineering

enersea.nl

Revision History

Revision	Description
01	For client comments
02	Client comments incorporated
03	Platform and routing update

Revision Status

Revision	Description	Issue date	Prepared	Checked	Enersea approval	Client approval
01	For client comments	31-01-2020	EvW	VH/PF	PF	
02	Client comments incorporated	13-03-2020	EvW	PF	PF	
03	Updated	20-12-2021	DK	PF	DK	

Table of content

1. Introduction

1.1. Project Introduction

ONEDyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a subsea connection to the NGT pipeline's existing side tap connection @KP141.4. The approximate length of the pipeline is 14.6 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

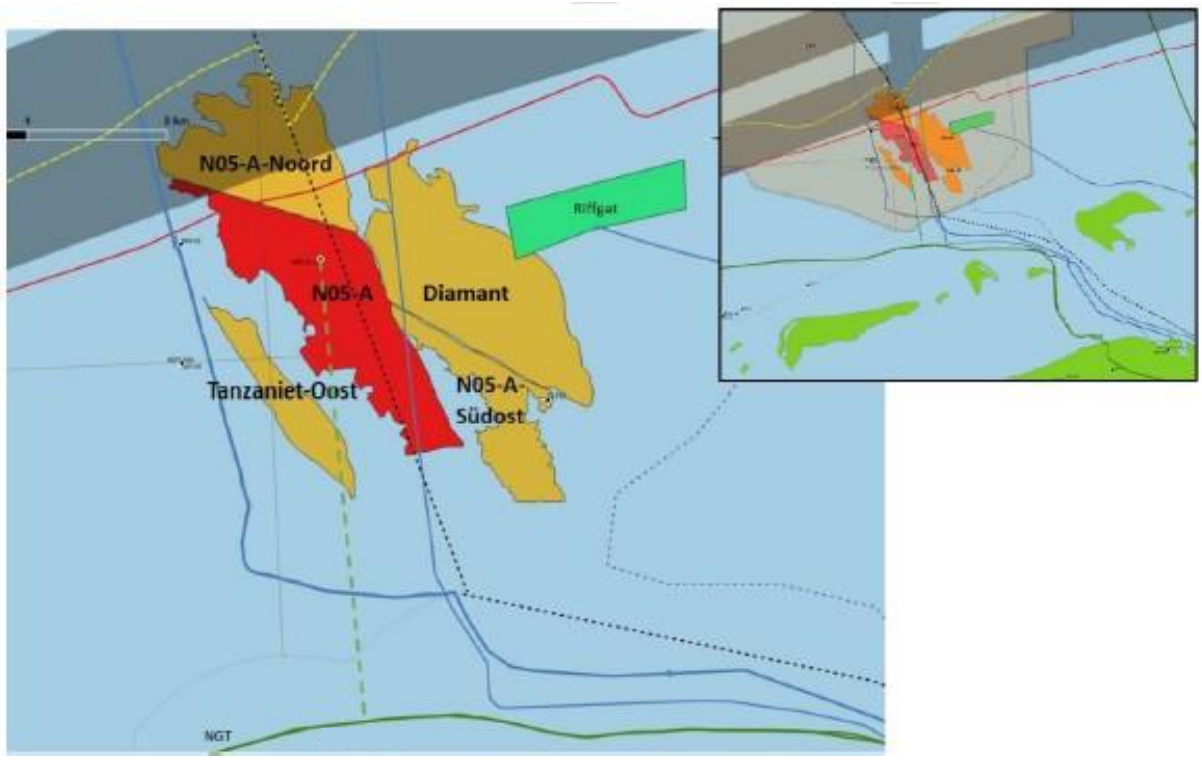


Figure 1, N05A Field layout

1.2. Purpose and Scope Document

The Basic Design Report documents the results of the calculations for the flowline, including:

- Wall Thickness analysis
- On-Bottom Stability analysis
- Buckling & Collapse analysis
- Static & Dynamic Free Span analysis
- Bottom roughness analysis
- Upheaval buckling analysis

1.3. System of Units

All dimensions and calculations shall be documented using the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

BoD = Basis of Design

FEA = Finite Element Analysis

LAT = Lowest Astronomical Tide

MTO = Material Take Off

TB = Target Box

TOP = Top of Pipe

VIV = Vortex Induced Vibrations

WD = Water Depth

1.5. References

1.5.1. Regulations, Codes, Standards and Guidelines

[1] NEN3656:2015 “Eisen voor stalen buisleidingsystemen op zee” December 2015

[2] DNV-OS-F101. “Submarine Pipeline Systems.” October 2010.

[3] DNV-RP-F105. “Free Spanning Pipelines.” June 2017.

[4] DNV RP-F107. “Risk Assessment of Pipeline Protection.” May 2017.

[5] DNV-RP-F109. “On-Bottom Stability Design of Submarine Pipelines.” May 2017

[6] DNV-RP-F110. “Global Buckling of Submarine Pipelines” April 2018.

[7] DNV-RP-C203. “Fatigue Design of Offshore Steel Structures.” April 2016.

[8] DNV-RP-C204. “Design against accidental loads.” November 2014.

[9] 21. American Lifelines Alliance. “Guidelines for the Design of Buried Steel Pipe.
ASCE July 2001.

[10] ASME Boiler and Pressure Vessel Code. Section VIII Rules for Construction of Pressure vessels. Division 1. July 2013.

[11] Design of Submarine Pipelines Against Upheaval Buckling OTC 6335 by A.C. Palmer e.a. May 1990

[12] DNVGL-RP-F114 – “Pipe-soil interaction for submarine pipelines”, May 2017

1.5.2. Company Engineering Standards and Specifications

1.5.3. Project Reference Documents

[i] N05A-7-10-0-70028-01-02 – “Basis of Design Flowline”

[ii] N05A-7-10-0-70031-01-01 – “Route Selection Report”

[iii] N05A-7-51-0-72510-01-04 – “Overall field layout drawing”

[iv] N05A-7-50-0-72019-01-02 – Approach drawing @N05A

[v] N05A-7-10-0-70032-01-02 – “Approach drawing @NGT

[vi] N05A-7-10-0-70027-01-03 – “Flow Assurance Design Report”

[vii] N05A-7-10-0-70036-01-01 – “Flow Assurance Design report - Transient Analysis”

[viii] N05A-7-10-0-70035-01-01 – “On Bottom Stability Analysis Design Report”

[ix] Metocean Criteria for the N05A Platform – 181892_1_R2

[x] Metocean criteria for the N05A Platform Side Tap – 191146_1_R2

[xi] N5A VC-C-7 S-3 0300m CID

[xii] N5A VC-P-3 S-2 0405m CID

[xiii] N5A VC-P-8 S-4 0240m CID

[xiv] No5A-7-10-0-70030-01-02 Risk assessment dropped object analysis

[xv] 19018-10-PRE-01001-02-02 N05-A Progress meeting + Minutes of meeting, 2019-11-07

1.6. Holds

2. Summary

This document reports on the basic design stage of the flowline from the N05-A platform to the tie-in with the NGT pipeline. This includes:

- Wall Thickness analysis
- On-Bottom Stability analysis
- Buckling & Collapse analysis
- Static & Dynamic Free Span analysis
- Bottom roughness analysis
- Upheaval buckling analysis

The wall thickness analysis showed that a wall thickness of approximately 15mm would be required. It was chosen to select a wall thickness of 20.62 mm. The extra steel weight will assist the stability of the pipeline, which is further documented in a separate report (ref. [viii]).

The maximum allowable spans following from buckling & collapse and static and dynamic span analyses are determined for three depths: 8, 17, and 26 m (LAT), which corresponds to the water depths at the end, approximate middle, and start of the pipeline, respectively.

Criterion	8 m	17 m	26 m
B&C – bending and external pressure – Maximum span	62.6m (install/hydrotest) 76.7m (operation)	59.2m (install/hydrotest) 53.3m (operation)	56.0m (install/hydrotest) 43.8m (operation)
Static free span	66.3m (install/hydrotest) 91.3m (operation)	63.1m (install/hydrotest) 61.4m (operation)	60.1m (install/hydrotest) 52.1m (operation)
Dynamic free span: in-line VIV	21.9m (install/hydrotest) 20.9m (operation)	22.9m (install/hydrotest) 21.6m (operation)	25.2m (install/hydrotest) 23.7m (operation)
Dynamic free span: cross-flow VIV	36.0m (install/hydrotest) 35.3m (operation)	33..0m (install/hydrotest) 30.8m (operation)	37.2m (install/hydrotest) 30.7m (operation)

The bottom roughness analysis showed that the as-surveyed seabed will result in 1 span that is of unacceptable length during the installation phase. This span (27m) is present at KP0.4 at 26 m of water depth (section 9.3). The span criterion is based on in-line VIV, which could be mitigated if the pipeline dynamic response is investigated in the detail design phase.

Finally, an analytical upheaval buckling analysis was performed to determine a relation between the sand cover, imperfection heights and vulnerability to buckling under operational conditions (section 8.1).

3. Design Parameters

This chapter describes the design data to be considered for the pipeline (incl. spool pieces near the riser and the hot tap) from the new N05A-Platform to the NGT pipeline.

3.1. Pipe Data

The basic line pipe design and spool piece data to be considered in the analysis for the export gas line are presented in Table 3-1. Steel material properties considered in the design are presented in Table 3-2.

Property	
Product transported	Natural gas (dry)
Design life (years)	25
Approx. length (km)	14.6
Material grade	L360 NB
Manufacturing process	HFIW
Pipe outside diameter (“)	20”
Pipe outside diameter (mm)	508
Pipe internal diameter	466.76
Wall thickness (mm)	20.62 (Sch60)
Wall thickness tolerance (%)	7.3
Wall thickness tolerance (mm)	+/- 1.5mm
Internal corrosion allowance (mm)	3
Anti-corrosion coating	3LPP
Anti-corrosion coating thickness (mm)	3
Anti-corrosion coating density (kg/m^3)	930
(Concrete) weight coating thickness (mm)	N.A
concrete weight coating density (kg/m^3)	3300
Minimum hot bend radius (mm)	2540 (5D)

Table 3-1 Pipeline data

Property	
Material	L360NB
Density (kg/m3)	7850 kg/m^3
Specified Minimum Yield Strength at 20°C (MPa)	360
Specified Minimum Yield Strength at 50°C (MPa)	360
Specified Minimum Tensile Strength (MPa)	460
Young’s modulus (Pa)	2.07 x 10^{11}
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m·ºC)	1.17 x 10^{-5}

Table 3-2 Material properties

3.2. Process Conditions

Table 3-3 presents the pipeline and spool design process parameters considered in the analysis.

Property	Export gas line
Design pressure	111.1 bar(g)
Operating pressures	95 bar(g)
Design temperature (min / max)	-20 °C / 50 °C
Operating temperature (min / max)	1 / 43 °C
Ambient (air / surface) temperature	-6.8°C / +24.2 °C
Content density (arrival, nominal operation)	88.7 / 96.1 kg/m^3
Design flowrate (min/max)	0.14 / 6.0 MMNm3/d

Table 3-3 Process design parameters

Figure 3-1 shows the operational thermal profile along the pipeline, ref. [vii] .

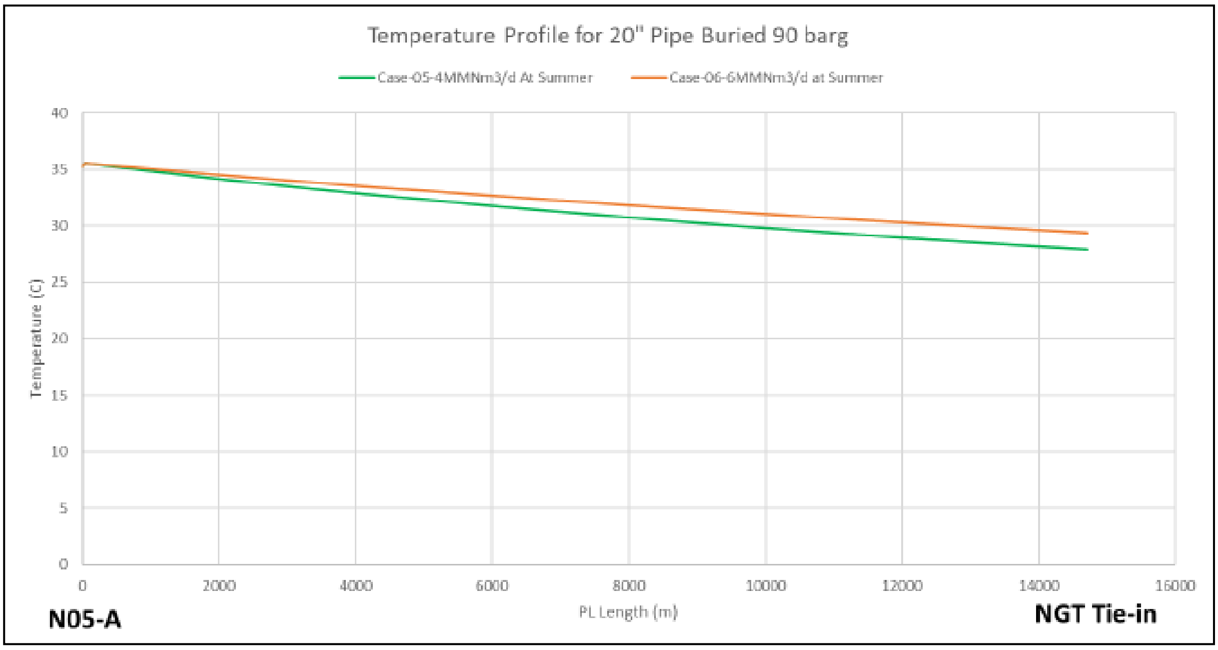


Figure 3-1 Operational thermal profile, nominal operation in summer

3.3. Coating Material Properties

Typical material properties of the coating are given in Table 3-4.

Property	Value
Anti-corrosion material type	3LPP
Anti-corrosion coating density	930 kg/m^3
Anti-corrosion coating thermal conductivity	0.22 W/m°C
Anti-corrosion coating specific heat capacity	2000 J/kg°C

Table 3-4 Steel pipe coating material properties

3.4. Flange Properties

Table 3-5 presents the flange classes and main characteristics. The flange loads will be checked by using the ASME BPVC [10] flange integrity check. Note that table 3-5 is applicable to all flanges on the flowline and spool pieces.

Property	Export gas line
Flange rating	ANSI/ASME Class 1500
Flange type	RTJ Swivel / Weld Neck
Weld end thickness	20.62mm

Table 3-5 Flange properties

3.5. Environmental Data

For the design of the pipeline, environmental data has been taken from Ref. [ix] and [x]. Where Ref [ix] contains the metocean data for the platform (water depth 26 m); Ref [x] contains the Metocean data for the NGT tie-in (water depth 8 m) target box. Tables 3-6 to 3-11 present the relevant metocean data for the 1 and 100 year design conditions for the applicable locations.

The shallow water depths encountered along the pipeline route pose problems in determining the hydrodynamics loads encountered by the pipeline. Enersea has developed a calculation method based on Stokes 5th order wave theory, however in shallow waters this method is not applicable. The metocean reports [ix, x] provide a wave orbital velocity at 1 m above the sea bed, denoted as U_{1m}. For the water depth of 26 m, the Stokes theorem is at the limit of applicability and produces wave velocity approximately 10% higher than provided in the metocean report for this depth. To remain conservative, the higher velocity has been used for the location of 26 m water depth.

In order to establish environmental conditions at an intermediate pipeline location with a water depth of 17m, current and wave particle velocities have been averaged. This approach has been agreed with One-Dyas [xv].

Property	1-year return period	100-year return period
Positive surge (m) @26m	1.58	3.04
Negative surge (m)	-1.02	-1.79
LAT with respect to MSL (m)	-1.41	
HAT with respect to MSL (m)	1.31	

Table 3-6 Near platform extreme water level data [ref. II]

Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								OMNI
	N	NE	E	SE	S	SW	W	NW	
1-year									
Near-surface	0.36	0.94	0.98	0.70	0.42	0.77	0.98	0.59	0.98
Mid-Depth	0.40	0.89	0.90	0.53	0.27	0.62	0.90	0.51	0.90
Near-bed	0.38	0.74	0.74	0.42	0.25	0.56	0.74	0.43	0.74
100-years									
Near-surface	0.46	1.21	1.27	0.91	0.55	1.00	1.27	0.76	1.27
Mid-Depth	0.51	1.15	1.16	0.68	0.35	0.79	1.16	0.66	1.16
Near-bed	0.49	0.95	0.96	0.55	0.32	0.72	0.96	0.55	0.96

Table 3-7- Near platform design current data [ref. II]

Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	5.3	9.2	11.7	5.9	9.3	9.5	1.67
North-east	3.8	6.8	8.3	4.3	6.7	8.5	1.04
East	2.6	5.2	6.6	3.0	4.7	7.5	0.55
South-east	2.1	4.6	5.2	2.3	3.6	6.9	0.34
South	2.4	4.7	5.2	2.8	4.3	7.3	0.48
South-west	3.2	5.6	6.2	3.6	5.6	8.0	0.78
West	4.7	8.0	10.5	5.3	8.3	9.1	1.43
North-west	6.5	9.9	12.4	7.3	11.4	10.1	2.19
100-years							
North	8.1	11.5	14.3	9.1	13.8	10.8	2.73
North-east	5.9	8.1	10.4	6.6	10.0	9.7	1.84
East	4.0	5.9	8.2	4.5	6.9	8.6	1.07
South-east	3.1	4.9	6.0	3.5	5.4	7.9	0.71
South	3.7	5.0	6.0	4.2	6.4	8.4	0.95
South-west	4.9	6.4	7.3	5.5	8.3	9.1	1.43
West	7.2	9.8	12.9	8.1	12.3	10.4	2.40
North-west	9.9	12.3	14.9	11.1	16.9	11.5	3.20

Table 3-8 Near platform design wave data [ref. II]

Property	1-year return period	100-year return period
Positive surge (m) @8m	1.48	2.72
Negative surge (m)	-0.90	-1.26
LAT with respect to MSL (m)	-1.89	
HAT with respect to MSL (m)	1.61	

Table 3-9 Near tie-in extreme water level data [ref. III]

Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								Omni
	N	NE	E	SE	S	SW	W	NW	
1-year									
Surface	0.31	0.52	1.04	0.51	0.27	0.50	1.04	0.59	1.04
Mid-depth	0.30	0.50	1.01	0.44	0.25	0.43	1.00	0.55	1.01
Near-bed	0.26	0.45	0.89	0.23	0.10	0.19	0.61	0.39	0.89
100-years									
Surface	0.37	0.63	1.25	0.62	0.32	0.60	1.25	0.71	1.25
Mid-depth	0.36	0.60	1.21	0.53	0.31	0.52	1.20	0.66	1.21
Near-bed	0.33	0.57	1.12	0.29	0.13	0.23	0.77	0.49	1.12

Table 3-10 Near side tao tie-in design current data [ref. III]

Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	3.6	6.2	10.3	3.3	4.8	7.5	1.2
North-east	2.2	4.9	7.7	2.0	2.9	6.5	0.6
East	1.6	3.9	5.0	1.5	2.2	5.9	0.4
South-east	1.5	3.6	3.7	1.4	2.0	5.8	0.3
South	1.4	3.5	3.9	1.3	1.9	5.7	0.3
South-west	2.0	4.1	4.5	1.9	2.7	6.3	0.5
West	3.0	5.7	10.2	2.8	4.1	7.2	0.9
North-west	3.9	6.4	12.1	3.6	5.2	7.7	1.3
100-years							
North	3.9	6.4	10.6	4.2	5.7	7.9	1.5
North-east	2.4	5.1	7.9	2.6	3.5	6.8	0.8
East	1.7	4.1	5.2	1.9	2.6	6.2	0.5
South-east	1.6	3.7	3.8	1.8	2.4	6.1	0.4
South	1.6	3.7	4.1	1.7	2.3	6.0	0.4
South-west	2.2	4.3	4.6	2.4	3.2	6.7	0.7
West	3.3	6.0	10.7	3.6	4.9	7.5	1.2
North-west	4.2	6.6	12.6	4.5	6.2	8.1	1.6

Table 3-11 Near tie-in design wave data [ref. III]

3.6. Marine Growth

The following marine growth has been assumed, in accordance with NEN 3656 [1]

From	To	Thickness	Density
+2m LAT	Seabed	50mm	1300 kg/m3

Table 3-12 Assumed marine growth properties

3.7. Geotechnical Data

Three lab result reports , Refs [xi] through [xiii], present properties of soil samples taken. These classify the soil as fine to medium sand. The soil properties are listed in Table 3-13, data has been taken from the lab reports and recommended values as per NEN3656 table H.1 ref[1] based on the soil description as presented in. A SBP data example of the north end of the proposed route is presented in figure 3-14.

Soil type	Applicable area	Submerged Unit Weight (kN/m³)	Angle of internal friction (°)
Medium sand (measured)		10.2-10.5	32.5-34.9
Medium sand	Pipe on surface	10	32.5
	Trench backfill	8.5	28
Rock dump	Crossing / Tie-in	10	40

Table 3-13 Assumed soil geotechnical properties

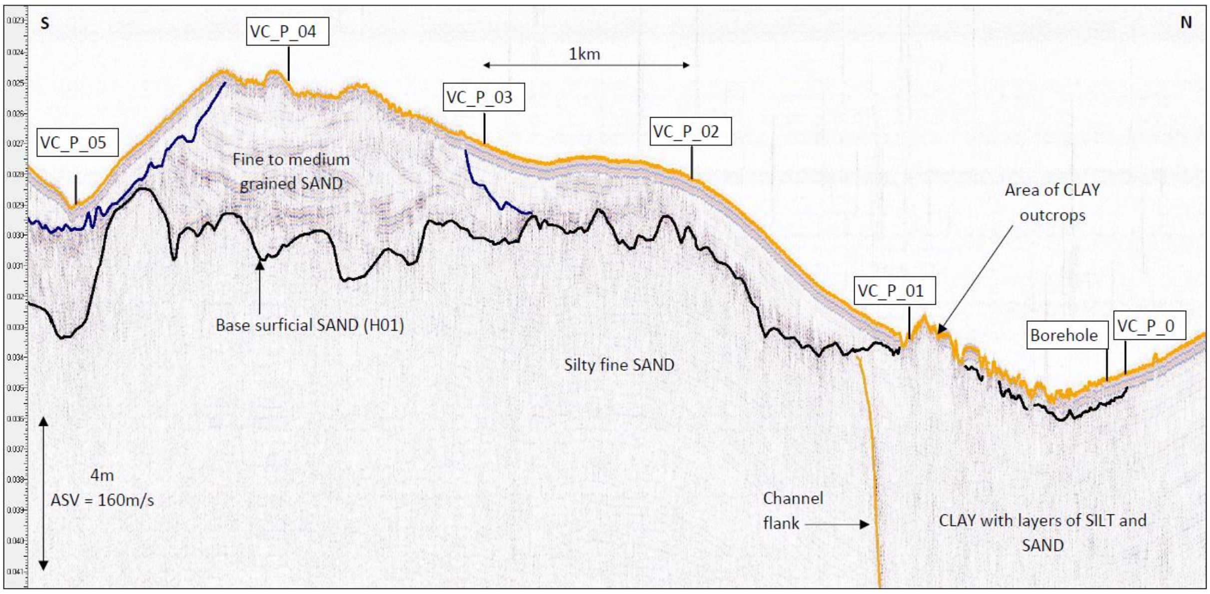


Figure 3-2 Soil profile from KP 0.0 to KP 6.0

4. Pipeline Route Data

This chapter deals with the pipeline route data describing the starting and end point of the pipeline, the used coordinate system, pipeline route coordinates and key facilities as well as the route bathymetry and contacts detected along the pipeline route. Based on this info the most optimal pipeline routing has been selected (ref. [ii].

4.1. General

The new pipeline to be installed originates at the new N05-A Platform and terminates at the NGT platform via a dedicated tie-in connection. The pipeline length is approx. 14.6 km.

An installation of the pipeline on top of the seabed has been indicated as an opportunity. The final cover height, or required concrete coating thickness will be determined based on the results of a risk assessment study [xiv], the on-bottom stability analysis [viii] and the upheaval buckling analysis.

Two pipeline/cable crossings are foreseen along the route. An overview of the field lay out is given in Figure 4-1.

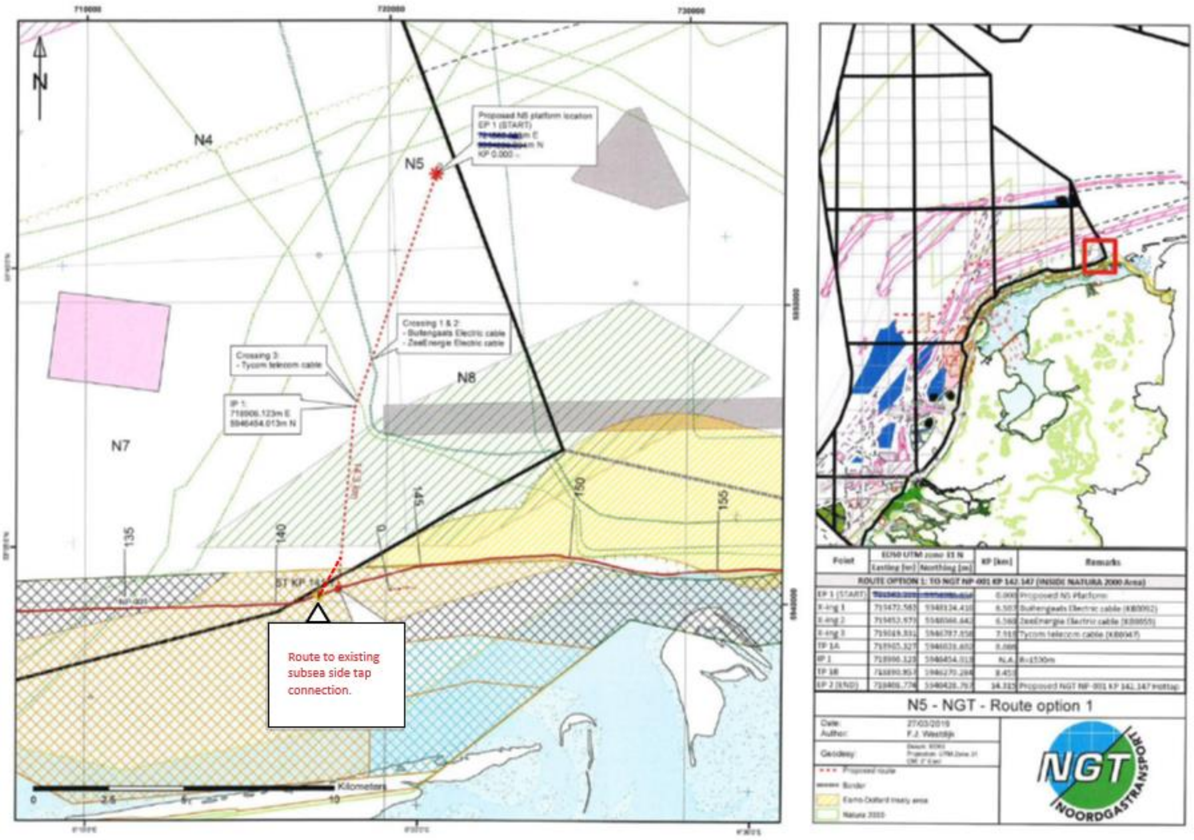


Figure 4-1 Overview N05A platform to the existing side tap tie-in location (left)

4.2. Coordinate System

The parameters of the geodetic system to be used for horizontal positions are listed in Table 4-1.

Item	Value
Datum	European Datum 1950 (ED50)
Projection	ED50 / UTM zone 31 N
Ellipsoid name	International 1924
Semi major axis	6 378 388 m
Inverse flattening	297.000
Central Meridian	03º00"00' E
Latitude of Origin	00º00"00' N
False Northing	0 mN
False Easting	500 000 mE
Scale Factor	0.9996

Table 4-1: Geodetic parameters

The vertical position is given relative to the Lowest Astronomical Tide (LAT).

4.3. Key Facility Coordinates

The following platform and tie in locations have been derived from Ref. [ii] and are presented in Table 4-2.

Item	Northing (m)	Easting (m)
N05A Platform target box	5 953 858	721 896
NGT target box	5 940 213	718 687
NGT hot tap location KP142.1	5 940 197	718 698
Water depth at N05A Platform	25.3m LAT	
Water depth at NGT hot tap	9.8 m LAT	

Table 4-2 Key Facility coordinates

4.4. Bathymetry

Figure 4-3 shows the bathymetry along the surveyed flowline route. The water depths recorded during survey along the proposed N05-A platform and the NGT pipeline side tap location ranges between 9.8 m LAT and 25.3m LAT.

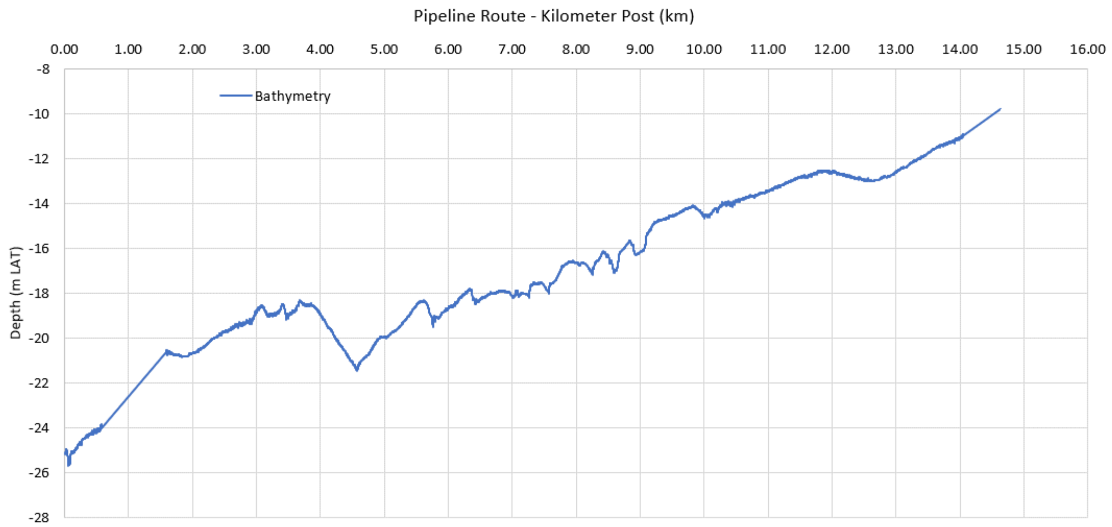


Figure 4-3 Seabed profile along pipeline route from N05-A Platform to NGT side tap connection

4.5. Side Scan Sonar Contacts & Magnetometer Anomalies

Ref. [5] describes the seafloor sediments across the N05-A to the proposed NGT hottap location survey area to consist of a top layer of fine to coarse sand, with occasional areas of coarse sand and clay with gravel and shell fragments. Photographs taken along the proposed route show the presence of small ripples covering the majority of the seabed within the survey corridor area.

Numerous boulders and items of debris are observed in the survey area. Most of the boulders occur in the north of the survey area and coincide with areas of clay exposure.

4.5.1. Magnetometer Anomalies

A total of 241 magnetic anomalies (appendix A) were picked within the surveyed N05-A platform to the 36" NGT Tie-in and N05-A platform to Riffgat Tie-in route corridor. Most of these anomalies can be attributed to unknown identified seabed features the following seabed infrastructures are known, one (1) pipeline and four (4) cables. However, one (1) unknown linear feature.

The following existing pipelines and cable are detected:

- 36" Pipeline from L10-AR to Uithuizen
- Tycom Telecom cable
- Buitengaats Power cable
- Zeeenergie Power cable
- Norned Power cable

4.5.2. Side Scan Sonar Contacts

Eight-Hundred-Thirty (830) side scan sonar contacts were observed within the route survey. Most of the contacts are boulders located around the N05-A platform and stretching to the east side to Riffgat, besides the bolders the following contacts are found, twenty-six (26) debris items, two (2) wrecks.

4.6. Pipeline and Cable Crossings

The following crossings along the pipeline route are envisaged:

Infrastructure Name	KP	Northing (m)	Easting (m)
Buitengaats Electric cable	5.956	5.948.587	719.395
ZeeEnergie Electric cable	6.036	5.948.510	719.373
Tycom Telecom Cable Hunmanby GAP - Eemshaven	7.629	5.946.979	718.931

*) The N05A Pipeline will be connected to the NGT Pipeline with a side tap. This side tap is not part of the scope of this design report.

4.7. Approach

Near the platform a T-piece will be installed including 2 ball valves for the purpose of a future pipeline connection. At the NGT tie-in location 2 ball valves and a check valve will be placed for tie-in purposes. Figures 4-4 and 4-5 present an overview of respectively the platform and the tie-in location.

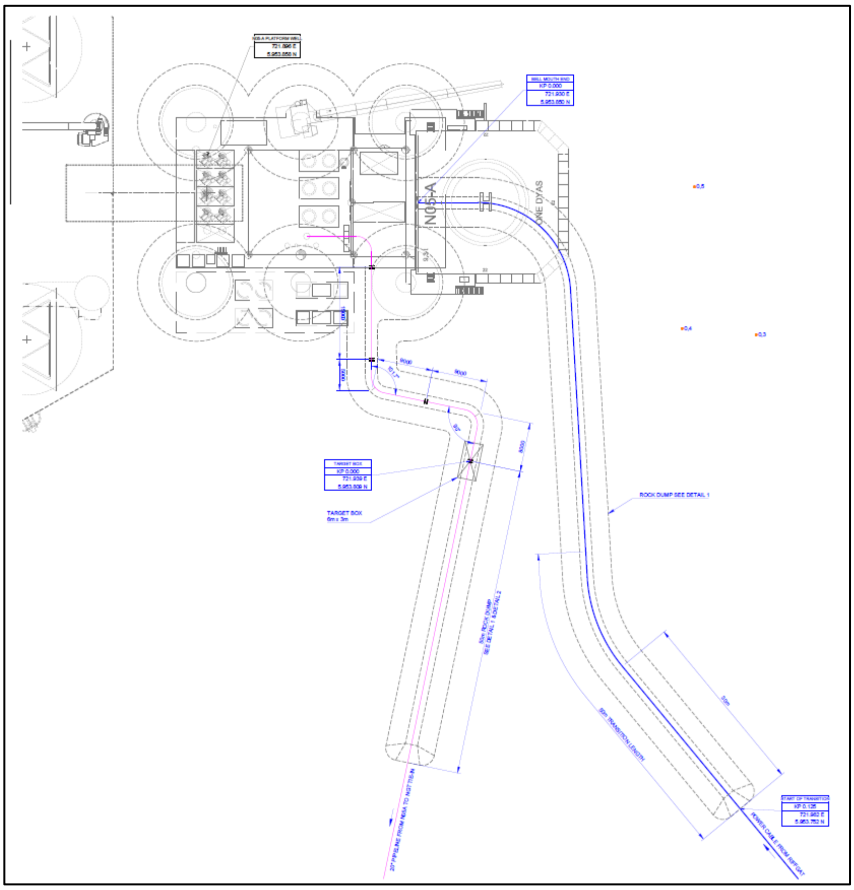


Figure 4-4 approach layout near the platform

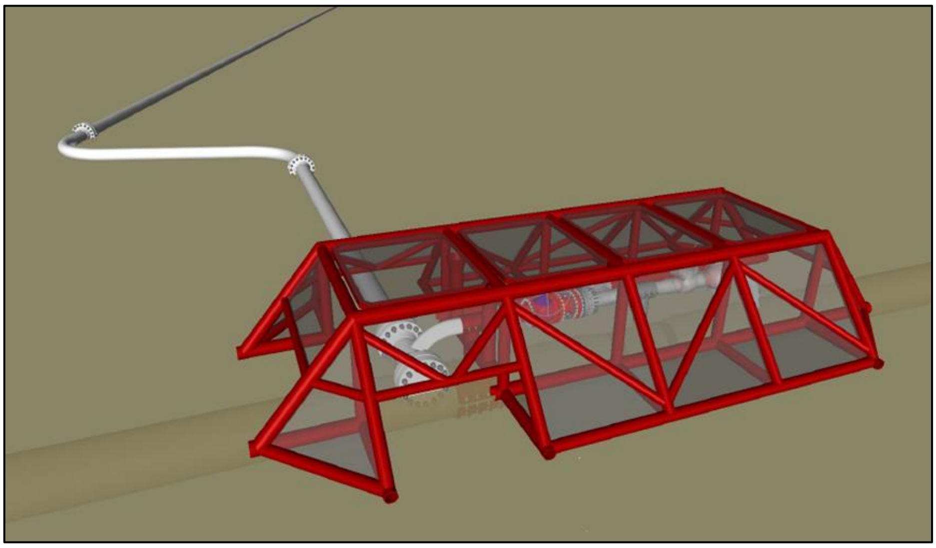


Figure 4-5 approach layout near the NGT side tap tie-in

5. Stress Criteria & Load Factors

5.1. Stress Criteria

Stresses in the flowline will be assessed according NEN 3656 (Ref. [1])
The analysis will account for the load history of the pipe over the design life by considering the following three load cases:

- Installation
- Hydrotest
- Operational

Considering the design cases listed above the following design loads will be considered when performing the stress analysis, see Table 5-1. The hydrodynamic loads for pipeline stability and maximum span are included via analytical calculations, see chapters 6 and 7.

Load	Installation	Hydrotest	Operation
Pressure	N/A	Hydrotest Pressure	Operational Pressure
Temperature	Seawater Temperature	Seawater Temperature	Operational Temperature
Internal Fluid	Seawater	Seawater	Product Filled
Wall Thickness	Nominal	Nominal	Nominal / Fully corroded
Hydrodynamic Loads	1-year wave + 1-year current	1-year wave + 1-year current	100/10-year wave + 10/100-year current

Table 5-1 Design loads

Calculated equivalent stresses for the various design conditions will be checked against the allowable stress values, as per NEN3656 (Ref. [1]), see Table 5-2.

Case	Load Combination As Per NEN3656 Table 3.	Limit Stress	Allowable Equivalent Stress (L360NB)
Installation	LC1	$R_{e(\theta)} / \gamma_m$	327 MPa
Hydrotest	LC4	$0.85\ (R_e + R_{e(\theta)})/ \gamma_m$	556 MPa
Operation (Nominal / Corroded)	LC4	$0.85\ (R_e + R_{e(\theta)})/ \gamma_m$	556 MPa

Table 5-2 Applied stress limits

Where:

Re = specified minimum yield strength at 20ºC (N/mm^2).

$R_{e(\theta)}$ = the yield strength of the material at design temperature.

γ_m = material factor (for steel 1.1).

5.2. Load Factors

All design loads applied will be factored as per the requirements of NEN 3656 (Ref. [1]), see Table 5-3.

Loads	**Load factors for load combinations (a)**								
Load combinations	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6	LC 7a	LC 7b	LC 8
Internal pressure (design pressure)	-	1.25	-	-	-	-	1.0		1.0
Internal pressure (In combination)	-	-	-	1.15	1.15	-	-	1.0	1.15
Internal pressure (max. Incidental pressure)	-	1.10	-	-	-	-	-		1.1
Temperature differences (c g)	1.0	-	-	1.10	1.10	-	1.0	1.0	-
Soil parameters (d)	-	-	(d)	(d)	(d)	-	-	Low	-
Forced deformation (e)	-	-	1.1	1.1	1.1	1.1	-		-
Own weight	1.1	-	1.1	1.1	1.1	1.1	1.0		1.0
(Possible) coating (h)	1.2	-	1.2	1.2	1.2	1.2	1.0	1.2	1.0
Pipe contents (h)	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	1.0
Installation loads (f)	1.1	-	1.10	-	-	1.1	-		-
Hydrostatic pressure	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	
Marine growth (h)	-	-	1.2	1.2	1.1	-	1.0	1.0	1.0
Hydrodynamic forces	1.1	-	1.2	1.2	1.1	1.1	1.0	1.2	1.0
(a)	If a load has a favorable influence on the considered case this will not be considered if the load is variable and for a permanent load a multiplication factor of 0.9 is applied.								
(b)	The maximum incidental pressure does not need to be checked separately however must be ascertained by the pressure control system.								
(c)	During calculations of stress variations caused by temperature differences the highest and lowest occurring operation temperature should be considered. The displacements loads and moments exerting on connected equipment and/or structures are to be considered based on the design temperatures i.e. the temperature difference between the installation temperature and the maximum operational temperature.								
(d)	Reference is made to ref. [1] – K.4 to determine load spreading factors								
(e)	Forced deformations can be caused by: settling differences trench roughness execution sacking differences deformations due to prevented thermal expansion distortions in horizontal drilling and bottom-tow installation.								
(f)	Examples of installation loads are those applied during pipelay tie-ins trenching landfalls and HDD etc.								
(g)	Combined with measurements.								
(h)	In the stability check (BC 7b) the most unfavorable combination must be chosen. If necessary divide by the relevant factor.								

Table 5-3 Load factors

A description of the load combinations is shown below;

LC 1: Installation

LC 2: Only internal pressure, operating pressure, incidental pressure

LC 3: External load with zero internal pressure

LC 4: External load with internal pressure and temperature difference

LC 5: Variable load (primarily static load, e.g., temperature changes and pressure)

LC 6: External pressure, external load and internal pressure zero

LC 7a: Incidental load (other than internal pressure)

LC 7b: Incidental load (meteorological)

LC 8: Dynamic loading

5.3. Hydrodynamic Loads

Hydrodynamic loads arise from the relative motions between pipe and seawater. They consist of drag, lift and inertia forces.

The drag force F_D is given by:

$$F_D = C_D \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V \cdot |V|$$

Where:

C_D	=	drag force coefficient (-)
OD_{tot}	=	total diameter of coated pipe (m)
ρ	=	mass density of surrounding fluid (kg/m^3)
V	=	velocity of the fluid normal to the pipe axis (m/s)

The lift force F_L is calculated by the following equation:

$$F_L = C_L \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V^2$$

Where:

C_L	=	lift force coefficient (-)

The inertia force F_I is determined by the following equation:

$$F_I = \rho \cdot C_I \cdot \frac{\pi}{4} \cdot OD_{tot}{}^2 \cdot a$$

Where:

C_I	=	inertia force coefficient (-)
a	=	Fluid particle acceleration (m/s^2)

The recommended values of hydrodynamic coefficients for the on-bottom stability design as a function of the embedment of the pipeline are listed in Table 5-4.

Coefficient	Pipe embedment		
	0%	**10%**	**20%**
Drag	0.70	0.63	0.53
Lift	0.90	0.90	0.81
Inertia	3.29	2.80	2.30

Table 5-4 Overview hydrodynamic coefficients

Typically, the peak hydrodynamic load is experienced just after the peak wave particle velocity, due to the additional inertia contribution. As stated in Section 3.5, wave models are not used in the shallow water depths, but only the peak velocity from the metocean report. No information on the particle acceleration is provided, however. The contribution of the inertia term is typically <10% of the drag term at peak velocity. To be conservative, a 20% margin is added to the drag term.

6. Wall Thickness Analysis

Several phenomena are to be investigated prior to finalising the selected wall thickness. Elements to be taken into account:

- pressure containment;
- on-bottom stability;
- implosion;
- progressive plastic collapse;
- local buckling;
- bar buckling;

6.1. Pressure Containment

6.1.1. Design Condition

NEN 3656, states that for every load combination the design resistance (R_d) must be greater than or equal to the loading effect (S_d) or:

$$R_d \geq S_d$$

R_d is defined as:

$$R_d = R_{e(\Theta)} / \gamma_m$$

Where:

$R_{e(\Theta)}$	=	yield strength of the material at design temperature (N/mm^2)
γ_m	=	material factor (1.1 for steel)

For load combination LC2 (internal pressure only), the equation for hoop stress can be expressed as:

$$\sigma_h = \frac{\gamma_p \cdot P_d \cdot (OD - t_{\min})}{2 \cdot t_{\min}}$$

Where:

S_h	=	hoop stress (N/mm^2)
γ_p	=	load factor as per Table 5-3 (-) => 1.25
Pd	=	design pressure (N/mm^2)
OD	=	outside diameter of steel pipe (mm)
t_{min}	=	minimum wall thickness (mm)

The selected wall thickness (t_{nom}) is then determined by:

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

CA	=	applicable corrosion Allowance (mm)
f_{tol}	=	fabrication tolerance (%)

Further to this, NEN 3656 specifies additional requirements for bends with a bending radius R_b < 10 OD, to adjust the hoop stress of straight pipe (torus effect).

$$S_h(bi) = \frac{2R_b - \frac{1}{2}OD}{2R_b - OD} \cdot S_h \quad \text{(for inside bend)}$$

$$S_h(bo) = \frac{2R_b + \frac{1}{2}OD}{2R_b + OD} \cdot S_h \quad \text{(for outside bend)}$$

6.1.2. Hydrostatic Testing

The hydrostatic testing of pipeline / riser systems has two objectives:

- verify the strength of the system
- verify that there are no leaks from the system

The test pressure, P_t, will be determined as per as per Section 10.18.3 of NEN 3656 (Ref. [1]).

$$P_{t.\min} = C_p \cdot P_d \cdot \frac{R_e}{R_{ev}}$$

Where:

C_p	=	pressure test coefficient (-) => 1.30 for gas lines; 1.25 for others
P_d	=	design operating pressure (N/mm^2)
R_e	=	minimum yield stress at 20 °C (N/mm^2)
R_{ev}	=	minimum yield stress at design temperature (N/mm^2)

The maximum hydrostatic test pressure is based on the weakest part of the pipeline/riser system to be tested. The pressure shall not exceed either $P_{t,max}$ or $P_{T,mill}$, the mill test pressure. Respectively, these are defined as:

$$P_{t.\max} = \frac{2.R_e \cdot t_{\min}}{(OD - t_{\min})}$$

$$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot t_{nom}}{OD}$$

Where:

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

t_{nom}	=	nominal wall thickness (mm)
t_{min}	=	minimum wall thickness (mm)
CA	=	applicable corrosion Allowance (mm)
f_{tol}	=	fabrication tolerance (%)

6.1.3. Results

An overview of the results of the wall thickness calculations is given in Table 6-1.

Property	Inside 500 m	Outside 500 m
Minimum WT (mm)	11.50	10.55
Minimum WT inside bend (mm)	12.13	11.14
Minimum WT outside bend (mm)	10.97	10.07
Nominal (with corrosion allowance) minimum WT (mm)	14.50	13.55
Nominal WT inside bend (mm)	15.13	14.14
Nominal WT outside bend (mm)	13.97	13.07
Selected minimum WT	20.62	20.62
Hoop stress (MPa)	232	212
Hoop stress inside bend (MPa)	244	224
Hoop stress outside bend (MPa)	221	203
Allowable stress at design temperature (MPa)	327	327
Minimum hydrotest pressure (barg)	144	144
Maximum hydrotest pressure (barg)	281	281
Mill test pressure (barg)	263	263

Table 6-1 Overview wall thickness analysis results

Reference is made to Appendix A for the detailed calculations.

6.2. On-Bottom Stability

The aim of the stability analysis is to verify that the submerged weight of the pipeline ensures lateral stability against environmental loading.

Reference is made to report “N05A-7-10-0-70035-01 N05A On Bottom Stability Analysis Design Report” (ref. [viii]) for detailed OBS analyses.

From this report it can be seen that in order to provide absolute stability during the pipeline lifetime, in which the 100-year storm conditions are applied (non-buried pipeline), an excessively thick concrete weight coating would be required (>> 500 mm). Relaxation of the displacement criterium to allow up to 10D displacement would require a minimal concrete weight coating of over 130 mm. As the determined pipeline displacements are for a single storm only, it cannot be guaranteed that the pipeline will settle in a final position. Hence the pipeline can displace even further during a next storm, potentially causing (too) high stresses/strain.

This, in combination with shallow water depths and installation limitations, results in the recommendation to bury the pipeline.

A buried pipeline is exposed to 1-year return period conditions, but still absolute stability cannot be guaranteed. However viable designs are possible when 0.5D - 10D displacements are allowed. As the timespan between the flooded lay of the pipe and trenching thereof will be minimum, it is deemed acceptable that for a buried pipeline, no additional weight coating is applied.

6.3. Implosion

6.3.1. External Overpressure

The collapse pressure p_c causing implosion (radial instability) can be determined using:

$$(P_c - P_e)\cdot(P_c^2 - P_p^2) = P_c \cdot P_e \cdot P_p \cdot 2 \cdot \delta_0 \cdot \frac{D_g}{t}$$

Where:

D_g	=	nominal diameter of pipe (mm)
P_c	=	critical external pressure for collapse (N/mm2)
P_e	=	critical external pressure for elastic deformation (N/mm^2)
P_p	=	critical external pressure for plastic deformation (N/mm^2)
P_L	=	actual external pressure (N/mm^2)
δ_0	=	initial deformation (mm)
t	=	nominal wall thickness (mm)

$$D_g = \frac{1}{2}\cdot\{OD_{nom} - (OD_{nom} - 2\cdot t_{min})\}$$

The critical external pressure for plastic deformation is calculated from:

$$P_p = \frac{2\cdot R_e \cdot t}{D_{nom}}$$

The critical external pressure for elastic deformation is calculated from:

$$P_e = \frac{2 \cdot E}{1-\nu^2} \cdot (\frac{t}{D_{nom}})^3$$

Where:

ν	=	Poisson's ratio for elastic deformation (-) => 0.3

As a part of this the initial deformation is derived from:

$$\delta_0 = \frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}}$$

Where:

D_{max}	=	largest diameter of the ovalized pipe cross section
D_{min}	=	smallest diameter of the ovalized pipe cross section

The maximum allowable external pressure is defined as:

$$\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$$

Where:

$\gamma_{g,p}$	=	load factor (-) => 1.05
γ_M	=	model factor (-) => 0.93
$\gamma_{m,p}$	=	material factor (-) => 1.45

6.3.2. Bending Moment

In case of a bending moment on the pipe, the moment which will cause buckling is calculated from the plastic moment of the pipe section.

$$M_c = D_{nom}{}^2 \cdot t \cdot R_e$$

The maximum allowable bending moment is defined as:

$$\gamma_{g,M} \cdot M_L \leq \frac{\gamma_M \cdot M_c}{\gamma_{m,M}}$$

Where:

$\gamma_{g,M}$	=	load factor (-) => 1.1
γ_M	=	model factor (-) => 1.0
$\gamma_{m,M}$	=	material factor (-) => 1.3
M_L	=	allowable bending moment for buckling (Nm)
M_c	=	critical bending moment for buckling (Nm)

6.3.3. Combined External Pressure and Bending Moment

When external pressure exists in combination with a bending moment besides the checks above the condition for combined stresses as shown below shall be fulfilled.

$$\frac{\gamma_{g,p} \cdot P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,m} \cdot M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$$

Where:

$$n = 1 + 300 \cdot \frac{t}{D_{nom}}$$

Where:

$\gamma_{g,p}$	=	load factor for pressure (-) => 1.05
$\gamma_{g,m}$	=	load factor for bending (-) => 1.55
γ_M	=	model factor (-) => 0.93
$\gamma_{m,p}$	=	material factor for pressure (-) => 1.25
$\gamma_{m,M}$	=	material factor for bending (-) =>1.15
M_L	=	allowable bending moment for buckling (Nm)
M_c	=	critical bending moment for buckling (Nm)

6.4. Progressive Plastic Collapse

Progressive plastic deformation load cycle will lead to extreme deformation, collapse and cracks initiation through the wall.

The condition for avoiding buckle propagation is:

$$\varepsilon_{\max} = \alpha \cdot \Delta T \leq \left[\frac{R_{ev}}{E} \cdot \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_h}{R_{ev}}\right)^2} + \frac{R_e}{E}\sqrt{0.9 - \frac{3}{4}\left(\frac{\sigma_h}{R_e}\right)^2} \right]$$

Where:

α	=	coefficient of linear thermal expansion (m/ m/ ° C)
ΔT	=	temperature differential [° C] (design – installation)

Parameters have to be factored as defined in section 5.

6.5. Local Buckling

In accordance with NEN 3656, if OD / t < 55, an assessment on local buckling can generally be omitted.

For this project it would mean that a local buckling check is required for a wall thickness of minimal 9.2 mm, which will be much smaller than the anticipated wall thickness. This will be checked during detailed design.

6.6. Bar Buckling

In a free span the pipeline will be susceptible to bar buckling. Bar buckling may occur due to an effective axial compressive force (N) in the pipeline. The compressive force in an axially restrained pipeline is based on the longitudinal stress:

$$N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$$

Where:

A	=	cross sectional area of steel (mm^2)
ν	=	Poisson's ratio for elastic deformation (-) => 0.3
S_h	=	factored hoop stress (N/mm^2)
γ_t	=	load factor as given in Table 5-3 (-)
α	=	coefficient of thermal expansion (m/m/°C)
ΔT	=	pipeline temperature differential (° C) (design – installation)

The factored hoop stress (S_h) is calculated from:

$$S_h = \gamma_P \cdot \sigma_h$$

and

$$\sigma_h = \frac{P_d \cdot (OD - t_{min})}{2 \cdot t_{min}}$$

Where:

P_d	=	design pressure (N/mm^2)
t_{min}	=	minimum pipe wall thickness (mm)
OD	=	outside diameter of steel pipe (mm)
γ_P	=	load factor as given in Table 5-3 (-)

The buckling length is based on the Euler buckling load definition, defined in Ref. [3]. Bar buckling is avoided if the span length fulfils:

$$L \leq \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Where:

L	=	allowable span length (mm)
I	=	moment of inertia (mm^4)

6.7. Results Buckling & Collapse

Appendix B contains the calculation sheet for the buckling and collapse calculations discussed in the previous sub-sections. The results are also summarized in Table 6-3 (8m WD), Table 6-4 (17m WD) and Table 6-5 (26m WD).

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-0.14		-0.78
Hmax (m)	5.2		6.2
Tass (s)	7.7		8.1
Current velocity @ 1m ASB (m/s)	0.89		1.12
Collapse – external pressure only			
Actual external pressure (MPa)	0.19		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	1001		1001
Maximum span length collapse (m)	62.6	62.6	76.7
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compressive force)	61.7

Table 6-3 Buckling & Collapse analysis - result summary – 8 m water depth

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-0.58		-1.29
Hmax (m)	8.3		11.55
Tass (s)	8.9		9.8
Current velocity @ 1m ASB (m/s)	0.82		1.04
Collapse – external pressure only			
Actual external pressure (MPa)	0.30		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	1000		1000
Maximum span length collapse (m)	59.2	59.2	53.3
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compres- sive force)	61.7

Table 6-4 Buckling & Collapse analysis - result summary – 17 m water depth

Property	Install (flooded	Hydrotest	Operation
Material	L360		
Temperature (deg. C)	15	15	65
Yield at temperature (N/mm2)	360	360	360
Pressure (barg)	2	144	111
Content density (kg/m3)	1025	1025	96
Storm surge (m)	-1.02		-1.79
Hmax (m)	11.4		16.9
Tass (s)	10.1		11.5
Current velocity @ 2m ASB (m/s)	0.74		0.96
Collapse – external pressure only			
Actual external pressure (MPa)	0.42		
Allowable external pressure (MPa)	16.0		
Check	OK		
Collapse – bending moment only			
Maximum allowable bending moment (kNm)	1256		
Collapse – external pressure & bending moment			
Maximum allowable bending moment (kNm)	999.4		999.4
Maximum span length collapse (m)	56.0	56.0	43.8
Progressive plastic collapse			
Actual strain (-)	0.0001	0.0001	0.0005
Allowable strain (-)	0.0033	0.0028	0.0030
Check	OK	OK	OK
Local buckling			
OD/t ratio	23.9		
Allowable ratio	55		
Check	OK		
Bar buckling			
Maximum span length (m)	93.1	- (No compres-sive force)	61.7

Table 6-5 Buckling & Collapse analysis - result summary – 26 m water depth

7. Free Span Analysis

Spanning of a pipeline on the seabed causes forces and stresses in the pipe. The criterion for accepting a pipeline configuration is that the pipe should not be subjected to over-stressing, nor to excessive dynamic loading because of resonant oscillations of the pipe caused by the vortex shedding phenomenon during installation, testing and throughout its operating life.

The pipeline span assessment includes the following items:

- Static span analysis
- Dynamic span analysis.

The static analysis concerns the determination of the pipe stresses under functional- and static environmental loads for a given span length.

The dynamic span analysis is based on criteria for prevention of vortex induced vibrations (VIV) as outlined in NEN 3656 considering both current- and wave induced velocities.

In addition, operational limits of the trenching equipment, limits the span gap (distance between the pipe and the seabed).

Although the pipeline will be buried below the seabed prior to its operation, the pipeline must be checked for spanning for the period between installation and burial.

In the analysis, along with the seabed topography, both functional and environmental loads are taken into consideration to check pipeline structural integrity under the considered load cases.

7.1. Static Span

Combining hoop, longitudinal and bending stresses in the pipeline, which shall satisfy criteria for equivalent stresses, gives the maximum allowable static span lengths. Checks are to be made for the installation, hydro test and operational load case.

The maximum bending moment is calculated from the (vector) combination of the pipelines' own weight and hydrodynamic forces for the maximum wave condition:

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Where:

γ_W	=	load factor as per Table 5-3 (-)
γ_H	=	load factor as per Table 5-3 (-)

End fixity of an actual span is commonly assumed between fixed - fixed and fixed – pinned and the bending moment (M) calculated from:

$$M = \frac{q \cdot L^2}{10}$$

Where:

L	=	Maximum allowable span length [m]

The maximum allowable bending moment (M_{all}) is given by:

$$M_{all} = \frac{2 \cdot I \cdot \sigma_b}{OD}$$

Where:

I	=	moment of inertia (m^4)
OD	=	pipeline outside diameter (m)
s_b	=	maximum allowable bending stress

The maximum allowable static span can then be determined by:

$$L\max = \sqrt{\frac{20 \cdot \sigma_b \cdot I}{OD \cdot q}}$$

The maximum allowable span length follows from the condition that the equivalent stress (S_e) from the load combination satisfies the following conditions:

For the operational and hydrotest cases:

$$S_e \leq 0.85 \times (R_e + R_{ev}) / \gamma_m$$

For the installation case:

$$S_e \leq R_e / \gamma_m$$

Where:

R_e	=	minimum yield stress at 20 °C (N/mm^2)
R_{ev}	=	minimum yield stress at design temperature (N/mm^2)
γ_m	=	material factor (-) => 1.1

7.1.1. Load Cases

The maximum static span will be determined for the load cases, and considering the environmental load return periods, as detailed in Table 7-1:

Condition	Wave Height Return Period	Current velocity Return Period
Installation	$H_{max,1yr}$	1 yr
Hydrotest	$H_{max,1yr}$	1 yr
Operational,1	$H_{max,100yr}$	10 yr
Operational,2	$H_{max,10yr}$	100 yr

Table 7-1 Load Cases for Span Assessment

7.1.2. Results

Tables 7-2 thru 7-5 show the results for the maximum allowable static span lengths during installation, hydro-test and operational phase. The calculation can be found in Appendix C.

7.1.2.1. Flooded installation

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	2.9	2.9	2.9	2.9
Max. longitudinal stress (MPa)	328.7	-325.8	328.7	-325.8
Longitudinal hoop stress (MPa)	1.2	1.2	0.9	0.9
Thermal expansion stress (MPa)	N/A	N/A	-26.8	-26.8
Max. allowable bending stress (MPa)	327.3	-327.1	327.3	-299.9
Max. allowable span (m) – 8 m WD	69.3	69.3	69.3	66.3
Max. allowable span (m) – 17 m WD	65.9	65.9	65.9	63.1
Max. allowable span (m) – 26 m WD	62.8	62.7	62.8	60.1

Table 7-2 Maximum span for flooded pipe

7.1.2.2. Hydrotest

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	249.7	249.7	249.7	249.7
Max. longitudinal stress (MPa)	637.5	-387.8	637.5	-387.8
Longitudinal hoop stress (MPa)	85.8	85.8	74.9	74.9
Thermal expansion stress (MPa)	N/A	N/A	-29.5	-29.5
Max. allowable bending stress (MPa)	551.6	-473.6	556.4	-433.2
Max. allowable span (m) – 8 m WD	89.3	82.6	89.7	79.0
Max. allowable span (m) – 17 m WD	84.4	78.2	84.8	74.8
Max. allowable span (m) – 26 m WD	79.9	74.2	80.3	70.9

Table 7-3 Maximum span during hydrotest

7.1.2.3. Operation LC1

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	191.8	191.8	191.8	191.8
Max. longitudinal stress (MPa)	626.9	-435.1	626.9	-435.1
Longitudinal hoop stress (MPa)	66.2	66.2	57.6	57.6
Thermal expansion stress (MPa)	N/A	N/A	-123.3	123.3
Max. allowable bending stress (MPa)	556.4	-501.2	556.4	-369.4
Max. allowable span (m) – 8 m WD	112.2	106.4	112.2	91.3
Max. allowable span (m) – 17 m WD	75.4	71.5	75.4	61.4
Max. allowable span (m) – 26 m WD	63.9	60.7	63.9	52.1

Table 7-4 Maximum span for Load Case 1

7.1.2.4. Operation LC2

Property	Unrestrained pipe		Restrained pipe	
	Tension	Compression	Tension	Compression
Hoop stress (MPa)	191.8	191.8	191.8	191.8
Max. longitudinal stress (MPa)	626.9	-435.1	626.9	-435.1
Longitudinal hoop stress (MPa)	66.2	66.2	57.6	57.6
Thermal expansion stress (MPa)	N/A	N/A	-123.3	123.3
Max. allowable bending stress (MPa)	556.4	-501.2	556.4	-369.4
Max. allowable span (m) – 8 m WD	112.4	106.5	112.4	91.5
Max. allowable span (m) – 17 m WD	84.3	80.0	84.3	68.7
Max. allowable span (m) – 26 m WD	73.6	70.0	73.6	60.0

Table 7-5 Maximum span for Load Case 2

7.2. Dynamic Span

Flow of water particles induced by currents and waves perpendicular to a spanning pipeline or riser span can lead to vortices being shed. This will disrupt the flow around the pipe and thereby potentially cause periodic loads on the pipeline or riser, also known as Vortex Induced Vibration (VIV).

The natural frequency of a span being close to the vortex shedding frequency can result in a resonant oscillation, possibly resulting in fatigue failure of the pipeline or riser.

The oscillations of the span may occur in two directions:

- in line with the flow (parallel to the flow direction of the water particles)
- in cross flow direction (perpendicular to the flow direction of the water particles)

When assessing VIV, the span should be confirmed to be within acceptable limits set by either avoidance of VIV or an acceptable fatigue life for both the installation and operational condition.

Relevant dimensionless parameters governing the VIV phenomenon are the reduced velocity (V_r) and stability parameter (K_s).

The reduced velocity (V_r) parameter is defined by:

$$V_r = \frac{V_s}{f_{n \cdot OD_{tot}}}$$

Where,

V_s	=	water particle velocity due to current and significant wave (m/s)
f_n	=	1st natural frequency of the pipe span (1/s)
OD_{tot}		total outside diameter of the pipe (m)

The 1st natural frequency can be calculated from:

$$f_n = \frac{a}{2\pi} \cdot \sqrt{\frac{E \cdot I}{m_e \cdot L^4}}$$

Where,

a	=	frequency factor (-) => 15.4 for a fixed-pinned beam, which is used for the pipe
E	=	Young's modulus (N/m^2)
I	=	moment of inertia (m^4)
L	=	length of span in pipeline / riser (m)

The stability parameter (K_s) is defined by:

$$K_s = \frac{2 \cdot m_e \cdot \delta}{\rho_{sw} \cdot OD_{tot}^2}$$

Where,

m_e	=	effective mass of pipe (kg/m)
ρ_{sw}	=	density seawater (kg/m^3)
δ	=	logarithmic decrement of damping (-) => δ = 0.126 for steel

The effective mass of the pipe can be calculated as:

$$m_e = m + \pi/4 \cdot C_M \cdot \rho_{sw} \cdot OD_{tot}{}^2$$

Where,

m	=	Pipeline / riser mass (kg/m)
Cm	=	added mass coefficient (-)

NEN 3656 states that In-line oscillations will occur if $K_s \leq 1.8$ and cross flow oscillations will occur if $K_s \leq 16$.

7.2.1. In-line VIV

NEN 3656 furthermore states that in-line oscillations of the span occur if the reduced velocity is within the range of: $1.0 \leq Vr \leq 3.5$

Vortices around a spanning pipe occur in a relatively steady state environment. The wave induced velocity varies from a maximum at t=0, to zero at t=1/4*Twave. Furthermore, the system does not respond instantaneously to the applied forcing. To ignore the wave induced velocity in assessing the allowable dynamic span length would be too optimistic, to account for the maximum induced value would be too conservative, therefore reference is made to DNV-RP-F105. "Free Spanning Pipelines." (ref. [3]).

According to Ref. [3], fatigue damage due to in-line VIV can be neglected if the current flow velocity ratio α, as defined by the equation below is smaller than 0.5. In the domain 0.5< α<0.8, in-line VIV is described as 'reduced' and requires additional work in determining the response amplitude. This additional work is left for the detail design phase.

$$\alpha = \frac{v_{cur}}{v_{cur} + v_{wave}}$$

Where,

v_{cur}	=	Particle velocity due to current [m/s]
v_{wave}	=	Particle velocity due to waves [m/s]

7.2.2. Cross-flow VIV

The occurrence of cross flow oscillations depends on the magnitude of the Reynolds number, Re, and the reduced velocity as given in Figure 7-1.

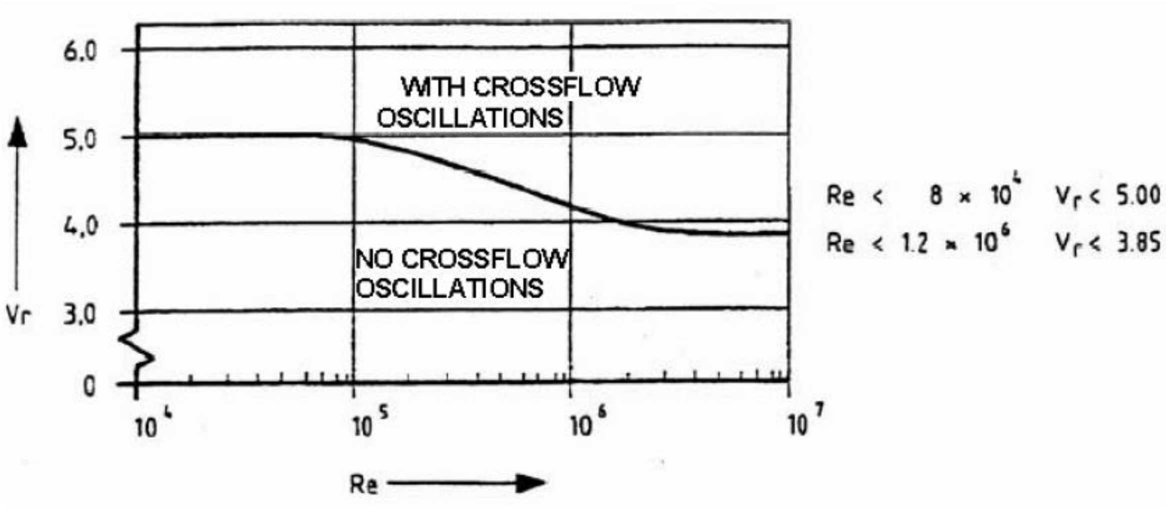


Figure 7-1 Reduced velocity for cross flow oscillations

$$Re = \frac{v \cdot OD_{tot}}{\nu}$$

Where,

v	=	particle velocity (m/s)
OD_{tot}	=	pipeline outside diameter (m)
n	=	Kinematic viscosity water (m^2/s) => 1,307 x 10^{-6} (at 10 °C)

7.2.3. Results

The results for the VIV analyses are presented in Tables 7-6 through 7-8. Reference is made to appendix C for more detailed calculations.

In-line VIV:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
8m WD - Wave hor. particle velocity (m/s)	1.3	1.3	1.6	1.5
8m WD - Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
8m WD - Current velocity ratio (-)	0.35	0.35	0.35	0.37
17m WD - Wave hor. particle velocity (m/s)	1.33	1.33	2.08	1.76
17m WD - Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
17m WD - Current velocity ratio (-)	0.33	0.33	0.26	0.32
26m WD - Wave hor. particle velocity (m/s)	1.35	1.35	2.56	2.01
26m WD - Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
26m WD - Current velocity ratio (-)	0.28	0.28	0.19	0.26

Table 7-6 Current velocity ratio per load case

The current flow velocity ratio (α) is <0.5 for all load cases. Below this ratio, in-line VIV due to vortex shedding becomes negligible (DNV-RP-F105, Ref [3]). In the limit of $\alpha = 0.5$, the acceptable span is determined below:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
Effective mass (kg/m)	682.9	682.9	522.7	522.7
Stability parameter (-)	0.63	0.63	0.49	0.49
Reduced velocity limit (-)	1	1	1	1
Outer P/L diameter (mm)	514	514	514	514
8m WD				
Wave hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.75	2.75	3.09	3.46
Allowable span length (m)	21.9	21.9	22.1	20.9
17m WD				
Wave hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.52	2.52	2.84	3.21
Allowable span length (m)	22.9	22.9	23.0	21.6
26m WD				
Wave hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Current velocity ratio (-)	0.5	0.5	0.5	0.5
Span frequency (1/s)	2.07	2.07	2.35	2.69
Allowable span length (m)	25.2	25.2	25.3	23.7

Table 7-7 Allowable span due to in-line VIV

There is relatively little difference between the allowable span in the various conditions. This is because the VIV phenomenon is governed by the steady current, which is of similar magnitude at all locations. The selected limit of current flow velocity ratio, α=0.5, is also a significant factor. If this is increased to α=0.6, the allowable span (in-line VIV) for installation condition at 26m water depth is increased from 25.2m to 27.6m. Selecting a higher current flow velocity ratio requires that the pipeline amplitude response is further investigated, this is left to the detail design phase.

Cross flow VIV:

Property	Installation (flooded)	Hydrotest	Operation LC1	Operation LC2
8m WD				
Wave hor. particle velocity (m/s)	1.3	1.3	1.6	1.5
Current hor. particle velocity (m/s)	0.71	0.71	0.79	0.81
Reynolds nr. (-)	$2.07 * 10^6$	$2.07 * 10^6$	$2.47 * 10^6$	$2.46 * 10^6$
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	1.01	1.01	1.21	1.21
Allowable span length (m)	36.0	36.0	35.3	35.3
17m WD				
Wave hor. particle velocity (m/s)	1.33	1.33	2.08	1.76
Current hor. particle velocity (m/s)	0.65	0.65	0.73	0.83
Reynolds nr. (-)	$2.03 * 10^6$	$2.03 * 10^6$	$2.90 * 10^6$	$2.66 * 10^6$
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	1.00	1.00	1.42	1.30
Allowable span length (m)	36.4	36.4	32.6	34.0
26mWD				
Wave hor. particle velocity (m/s)	1.35	1.35	2.56	2.01
Current hor. particle velocity (m/s)	0.53	0.53	0.60	0.69
Reynolds nr. (-)	$1.94 * 10^6$	$1.94 * 10^6$	$3.26 * 10^6$	$2.78 * 10^6$
Reduced velocity limit (-)	3.85	3.85	3.85	3.85
Span frequency (1/s)	0.95	0.95	1.60	1.36
Allowable span length (m)	37.2	37.2	30.7	33.2

Table 7-7 Allowable span due to cross-flow VIV

8. Upheaval Buckling – Analytical

Buried pipelines exposed to compressive effective axial forces may get unstable beyond its anchor point and move vertically out of the seabed if the cover has insufficient resistance. An out-of-straightness configuration will result in forces acting on the cover, perpendicular to the pipeline. In case these vertical forces exceed the cover resistance the pipeline will buckle upwards.

The relation between minimum required cover height and the imperfection height (out-of-straightness) will be established in accordance with ref. [11].

Parameters used in the assessment of upheaval buckling are the dimensionless imperfection length parameter (Φ_L):

$$\Phi_L = L \cdot \sqrt{\frac{N_e}{EI}}$$

Where:

L	=	exposure length (m)
N_e	=	effective axial compressive force (N)
EI	=	bending stiffness (N m^2)

And the dimensionless maximum download parameter (Φ_w):

$$\Phi_w = \frac{w \cdot E \cdot I}{\Delta_{calc} \cdot N_e^2}$$

Where:

w	=	required download [N/m]
Δ_{calc}	=	imperfection height [m]

Depending on the Φ_L value the required download is derived from Φ_w in accordance with:

$$\Phi_w = 0.0646 \text{ for } \Phi_L < 4.49$$

$$\Phi_w = \frac{5.68}{\phi_L^2} - \frac{88.35}{\phi_L^4} \text{ for } 4.49 < \Phi_L < 8.06$$

$$\Phi_w = \frac{9.6}{\phi_L^2} - \frac{343}{\phi_L^4} \text{ for } \Phi_L > 8.06$$

In cohesionless soils the uplift resistance (q) due to the cover of the pipe can be calculated from:

$$q = \gamma \cdot H \cdot OD \cdot \left(1 + f \cdot \frac{H}{OD}\right)$$

Where:

γ	=	effective under water weight of soil (N/m^3)
H	=	depth of cover (m)
OD	=	outside diameter of pipe (m)
f	=	uplift coefficient 0.5 for dense material 0.1 for loose material

The calculated required download (w) shall be smaller than the actual combination of the submerged weight and uplift resistance of the pipeline.

The simplified method from Reference [11] is conservative, in that it does not model a number of mitigating factors such as:

- The finite axial stiffness of the pipeline, which determines how rapidly the axial force diminishes as the pipeline moves upwards
- The pipeline resistance to axial movement through the soil determines how far the pipeline can slide towards a developing buckle.

Both the above factors may cause progressive upheaval buckling, as predicted by the analysis method in Reference [11], not to occur.

Further, the sinusoidal imperfection profile assumed in the model is envisaged to yield conservative download requirements.

8.1. Results

The results are presented as the minimum safe length for a given imperfection height and cover height, at the maximum operational temperature of 43°C and operational pressure of 95 barg. An 'x' denotes that there is no risk of upheaval buckling for the given condition. An excerpt of the calculations is presented in Appendix D.

Minimum required Imperfection Length (m)		**Cover Height to TOP [m]**													
		1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Available Download, q [N/m]		9929	9232	8553	7889	7243	6613	6000	5403	4823	4260	3714	3184	2671	2174
Imperfection Height [m]	0.05	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.15	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.25	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.3	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	0.35	x	x	x	x	x	x	x	x	x	x	x	x	x	42.6
	0.4	x	x	x	x	x	x	x	x	x	x	x	x	x	50.9
	0.45	x	x	x	x	x	x	x	x	x	x	x	x	46.3	56.3
	0.5	x	x	x	x	x	x	x	x	x	x	x	x	51.8	70.5
	0.55	x	x	x	x	x	x	x	x	x	x	x	47.7	56.0	78.0
	0.6	x	x	x	x	x	x	x	x	x	x	43.0	52.1	68.2	84.0
	0.65	x	x	x	x	x	x	x	x	x	x	48.4	55.7	75.2	89.2
	0.7	x	x	x	x	x	x	x	x	x	44.5	52.1	65.4	80.5	94.0
	0.75	x	x	x	x	x	x	x	x	x	48.7	55.2	72.6	85.1	98.5
	0.8	x	x	x	x	x	x	x	x	45.2	51.9	58.0	77.6	89.4	>100
	0.85	x	x	x	x	x	x	x	x	48.8	54.6	70.1	81.8	93.3	>100
	0.9	x	x	x	x	x	x	x	45.5	51.6	57.1	74.9	85.6	97.0	>100
	0.95	x	x	x	x	x	x	x	48.7	54.1	67.3	78.8	89.1	>100	>100
	1	x	x	x	x	x	x	45.6	51.2	56.3	72.3	82.4	92.4	>100	>100

Table 8-1 Out of straightness table

9. Bottom Roughness Analysis

9.1. General

The pipeline route experiences significant undulations in the sea bed, which may create free spans of the pipeline. In order to assess if the pipeline spans are greater than allowed in the time between installation and burial, a bottom roughness analysis. A FEA model is created which incorporates the surveyed sea floor profile, the interaction between pipe and sea floor, and the structural behaviour of the pipeline.

The finite element calculation is carried out using industry proven software package ANSYS. The analysis is at this stage of the design is limited to identifying locations with more than critical span length between installation and burial, no modifications to the sea floor are determined.

The pipeline will be modelled by ANSYS' PIPE288 element. This is a 3D pipe element consisting of 3 'layers': an internal layer to account for the weight of the internal fluid, a structural layer used for the structural calculations, and an outer layer to account for the coating. Additionally, the buoyancy of the displaced seawater is accounted for.

The pipeline is modelled with an element length of 1 m and accounts for undulations in the vertical direction. Pipe-soil interaction is simulated using three independent non-linear spring elements attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction.

Seabed roughness will be simulated by displacing the vertical springs representing the soil bearing capacity to the correct depth based on the bathymetric data and allowing the pipe to move and rest on the vertical springs.

When the support force of a vertical spring is 0, a free span is identified. Similar succeeding points indicate a larger span. The length of the free span is determined by subtracting the coordinates of the beginning of the span from the coordinates of the span end. Based on the acceptable spans identified in this document, the locations where spans are larger than the critical span are found and reported.

9.2. Definition of Soil Springs

The characteristics of the springs which simulate the pipe-soil interaction are defined through non-linear force-deflection curves. These force-deflection curves describe the frictional restraint provided by the soil to the pipeline in axial, lateral and vertical direction.

Axial and lateral restraint for the unburied pipeline is included as Coulomb friction. The amount of restraint per length of pipeline depends on the friction coefficient and the submerged weight of the pipeline. A friction coefficient of 0.6 was used in both directions, this excludes the effect of soil berms created by lateral movement of the pipeline. In accordance with DNV-RP-F109, the friction coefficient of a pipe on sand is set to 0.6. The maximum friction force is only reached when a nominal displacement has been reached, the mobilization displacement. In the present analysis, mobilization displacement is set to 5 mm. A third point in the spring reaction diagram is set at a displacement of 1m with a reaction force of 1.001 time the maximum friction force, this prevents extrapolation of the first section of the spring slope.

Vertical support follows from the bearing capacity of the idealized 2D strip foundation theory. A touchdown lay factor k_{lay} of 2 has been considered during the installation load case, according to DNV-RP-F114, ref [12]. The 'installation' type supports do not provide resistance against upwards movement of the pipe.

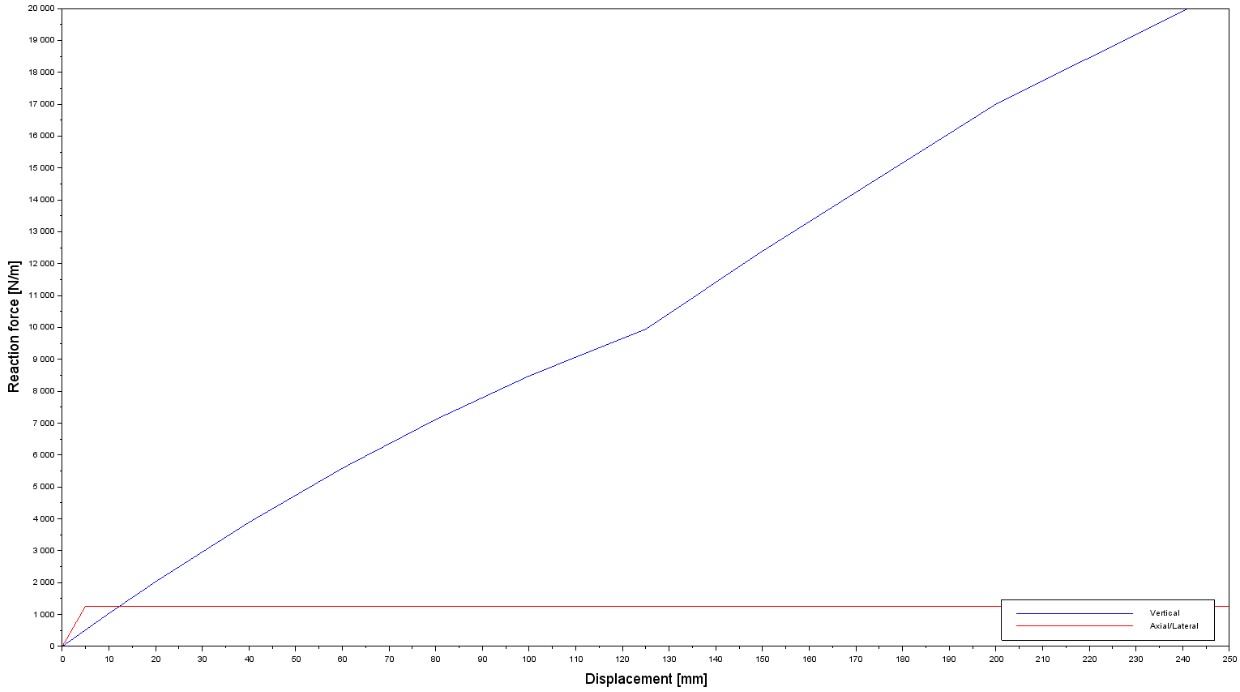


Figure 8-1 Vertical and axial support

9.3. Results

The result of pipeline installation on the as-surveyed sea bed profile is given in Table 8-1, and Figures 8-2 through 8-5. Two (2) spans longer than 20 m were found. If the critical span criterium is set as 25m between KP0 and KP2, 23m between KP2 and KP10, and 22 m from KP10 to the end of the pipeline, only the span of 39m between KP0.048-0.087 violates these criteria. These criteria are based on on the 1-year environmental conditions, for the installation and hydrotest condition.

Table 8-1 Overview largest spans

Span #	Start of span [m]	End of span [m]	Span length [m]	Span criterium [m]
1	48	87	39	<25m NOT OK
2	5.749	5.772	23	<23m OK

The design criterion of span length is exceeded by span 1. Nevertheless it should be noted that the gap at mid span is only 2cm between the pipeline and the seabed. Additional investigations are left for the detail design phase of the pipeline with the aim to remove the need for sea bed modifications.

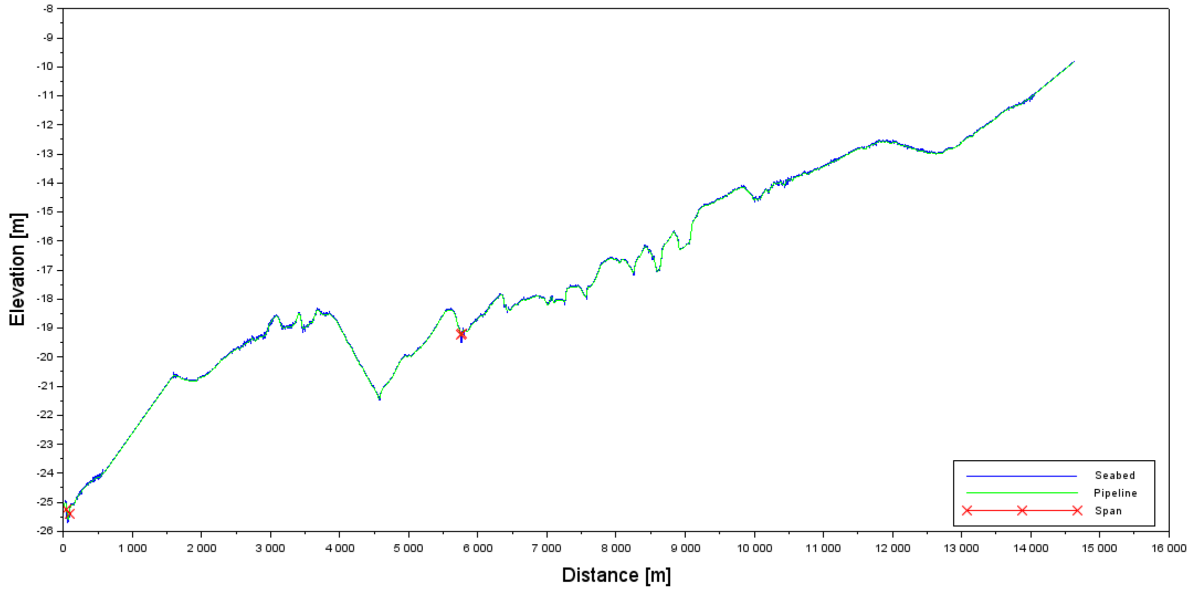


Figure 8-2 Pipeline on sea floor, complete route

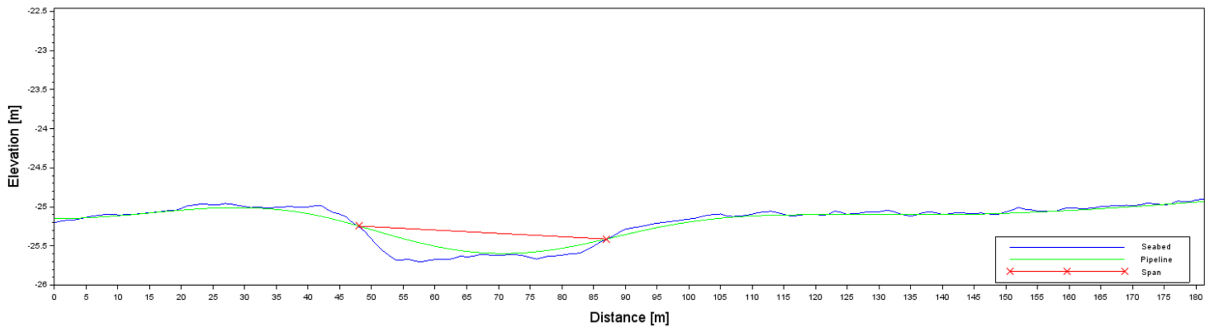


Figure 8-3 Pipeline on sea floor – section at KP 0.048 with spans length =39m (25m allowed)

It should be noted that the gap at mid span is only 2cm between the pipeline and the seabed.

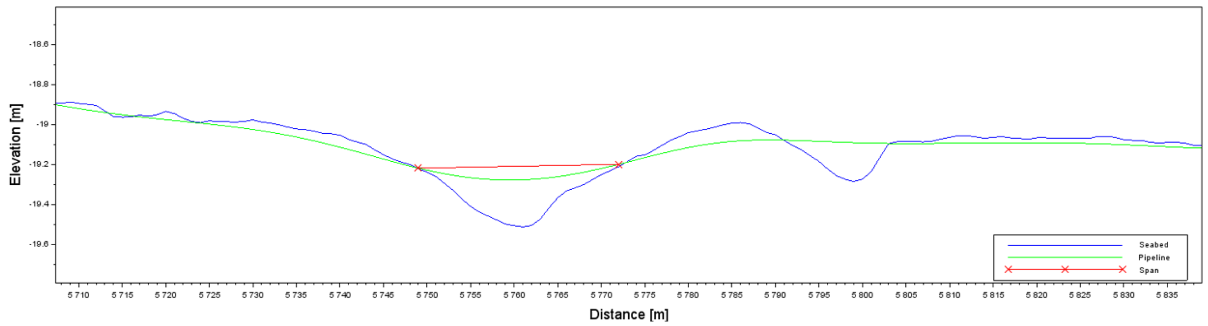


Figure 8-4 Pipeline on sea floor – section at KP 5.749 with spans length =23m (23m allowed)

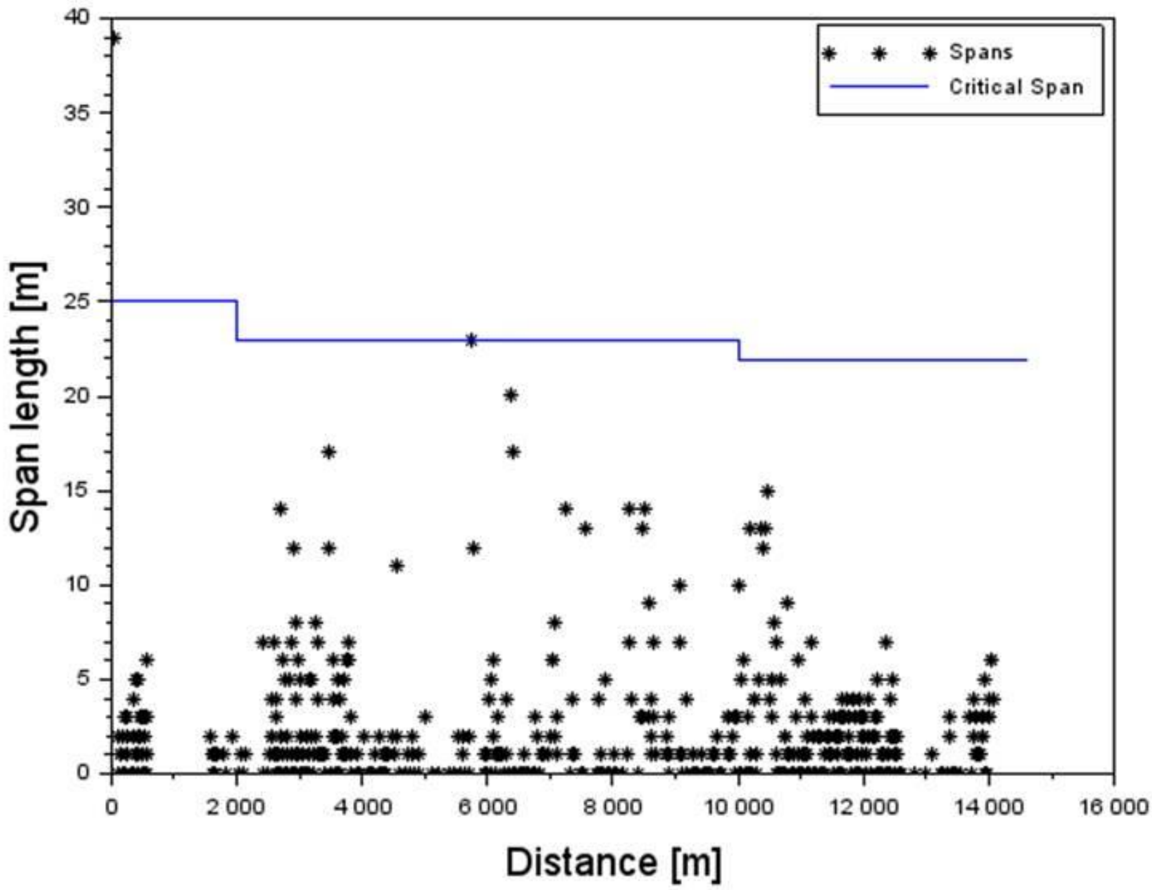


Figure 8-5 Overview of all spans and critical span

A. Wall Thickness Analysis

The following Wall Thickness Analyses were performed:

- 19018-60-CAL-01001-01-01 20” x 20.6 mm – inside 500m zone
- 19018-60-CAL-01001-01-01 20” x 20.6 mm – outside 500m zone

(4 pages)

Project	:	**N05-A Pipeline basic design**
Project #	:	19018
Subject	:	Wall thickness calculation N05-A Pipeline
File #	:	#N/A
Client	:	ONE-Dyas
Client File #	:	

Originator	: HvH	Checked	: PF
Date	: 21.10.2019		
Revision	: 01		

20" Pipeline - Inside 500m zone

Material properties

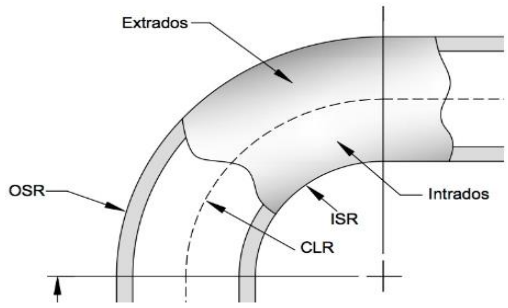
Material			=	L360NB	
Design temperature		T_d	=	50	°C
Yield at ambient temperature		R_e	=	360.00	N/mm²
Yield at design temperature		R_{ed}	=	360.00	N/mm²
Material factor (Table 4 NEN 3656)		γ_m	=	1.10	-
Allowable stress	$\sigma_v = \frac{R_{ed}}{\gamma_m}$	σ_v	=	327.27	N/mm²

Pipeline properties

Outside diameter		OD	=	508	mm
Design pressure		P_d	=	111.1	barg
Minimum outside presssure		P_o	=	0	barg
Fabrication Tolerance		f_{tol}	=	7.3	%
Corrosion allowance		CA	=	3	mm
Pipeline within the 500 meter zone?				y	(Y or N)
Load factor (Table 3 NEN 3656): 1,25 outside 500m zone; 1,364 inside 500m zone		γ_s	=	1.364	-
Bend radius				2540	mm
Fabrication tolerance bends		f_{tolB}	=	7.3	%
Inside bend factor	$\frac{2R-0.5D_e}{2R-D_e}$		=	1.06	
Outside bend factor	$\frac{2R+0.5D_e}{2R+D_e}$		=	0.95	

Minimum wall thickness determination, d_{min}

minimum wall thickness (excl. CA):	$d_{min} = \frac{\gamma_m \cdot \gamma_s \cdot P_d^* \cdot D_e}{2 \cdot R_e(T_d) + \gamma_m \cdot \gamma_s \cdot P_d^*}$	=	11.50	mm
Inside bend		=	12.13	mm
Outside bend		=	10.97	mm



Minimum required wall thickness (incl. CA) after bending, d_{min} [Note 2]

Straight part / along bend radius @ CLR	=	14.50	mm
Inside bend @ ISR	=	15.13	mm
Outside bend @ OSR	=	13.97	mm
Selected nominal wall thickness	=	20.6	mm

Project	**:**	**N05-A Pipeline basic design**
Project #	**:**	19018
Subject	**:**	Wall thickness calculation N05-A Pipeline
File #	**:**	#N/A
Client	**:**	ONE-Dyas
Client File #	**:**	

Originator	: HvH		Checked	: PF
Date	: 21.10.2019			
Revision	: 01			

20" Pipeline - Inside 500m zone

Hoop stress

Hoop stress straight parts	$\sigma_{hoop} = \frac{\gamma_s \cdot P_d^* \cdot (D_e - d_{min})}{2 \cdot d_{min}}$	=	231.56	N/mm^2
Hoop stress inside bend	$\sigma_{hoop}(BI) = \frac{2 \cdot R - \frac{1}{2} \cdot D_e}{2 \cdot R - D_e} \cdot \sigma_{hoop}$	=	244.42	N/mm^2
Hoop stress outside bend	$\sigma_{hoop}(BO) = \frac{2 \cdot R + \frac{1}{2} \cdot D_e}{2 \cdot R + D_e} \cdot \sigma_{hoop}$	=	221.03	N/mm^2

Stress Check

Hoop stress (N/mm2)	Occurring	Allowable
Straight parts	231.56	327.27
Inside bend	244.42	327.27
Outside bend	221.03	327.27

Test pressure

Hydrotest temperature		=	15	°C
Yield at hydrotest temperature		=	360	N/mm^2
Product (gas / others)			gas	
Design factor, CP (1.3 for gas; 1.25 for others)			1.30	
Minimum hydrotest pressure	$P_{T,min} = C_p \cdot P_d \cdot \frac{R_e(20^\circ C)}{R_e(T_d)}$	=	144.43	barg
Maximum allowable hydrotest pressure	$P_{T,max} = \frac{2 \cdot d_{nom} \cdot (1 - f_{tol}) \cdot R_e(20^\circ C)}{(D_e - d_{nom} \cdot (1 - f_{tol}))}$	=	281.23	barg
Mill test pressure	$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot d_{nom}}{D_e}$	=	262.77	barg

Max. allowable hydro test pressure exceeds mill test pressure!!

Note 1:	Outside 500m zone:	Pd***** = (Pd - Pe)
	Within 500m zone:	Pd***** = Pd
Note 2:	The bend manufacturer to ensure that the finished products does meet with these minimum WT. requirements.	

Project	**: N05-A Pipeline basic design**	
Project #	: 19018	
Subject	: Wall thickness calculation N05-A Pipeline	
File #	: 19018-60-CAL-01001-02-01a_Wall thickness_20x20.6_L360_outside 500m.xlsx	
Client	: ONE-Dyas	
Client File #	:	
Originator	: HvH	Checked : PF
Date	: 21.10.2019	
Revision	: 01	

20" Pipeline - Outside 500m zone

Material properties

Material			=	L360NB	
Design temperature		T_d	=	50	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Material factor (Table 4 NEN 3656)		γ_m	=	1.10	-
Allowable stress	$\sigma_v = \frac{R_{ed}}{\gamma_m}$	σ_v	=	327.27	N/mm^2

Pipeline properties

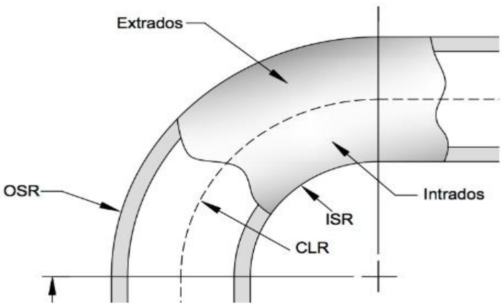
Outside diameter		OD	=	508	mm
Design pressure		P_d	=	111.1	barg
Minimum outside presssure		P_o	=	0	barg
Fabrication Tolerance		f_{tol}	=	7.3	%
Corrosion allowance		CA	=	3	mm
Pipeline within the 500 meter zone?				n	(Y or N)
Load factor (Table 3 NEN 3656): 1,25 outside 500m zone; 1,364 inside 500m zone		γ_s	=	1.250	-
Bend radius				2540	mm
Fabrication tolerance bends		f_{tolB}	=	7.3	%
Inside bend factor	$\frac{2R-0.5D_e}{2R-D_e}$		=	1.06	
Outside bend factor	$\frac{2R+0.5D_e}{2R+D_e}$		=	0.95	

Minimum wall thickness determination, d_{min}

minimum wall thickness (excl. CA): $d_{min} = \frac{\gamma_m \cdot \gamma_s \cdot P_d^* \cdot D_e}{2 \cdot R_e(T_d) + \gamma_m \cdot \gamma_s \cdot P_d^*}$ = 10.55 mm

Inside bend = 11.14 mm

Outside bend = 10.07 mm



Minimum required wall thickness (incl. CA) after bending, d_{min} [Note 2]

Straight part / along bend radius @ CLR	=	13.55	mm
Inside bend @ ISR	=	14.14	mm
Outside bend @ OSR	=	13.07	mm

Selected nominal wall thickness = 20.6 mm

Project	**:**	**N05-A Pipeline basic design**
Project #	**:**	19018
Subject	**:**	Wall thickness calculation N05-A Pipeline
File #	**:**	19018-60-CAL-01001-02-01a_Wall thickness_20x20.6_L360_outside 500m.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	

Originator	: HvH	Checked	: PF
Date	: 21.10.2019		
Revision	: 01		

20" Pipeline - Outside 500m zone

Hoop stress

Hoop stress straight parts $\sigma_{hoop} = \frac{\gamma_s \cdot P_d^* \cdot (D_e - d_{\min})}{2 \cdot d_{\min}}$ = 212.20 N/mm^2

Hoop stress inside bend $\sigma_{hoop}(BI) = \frac{2 \cdot R - \frac{1}{2} \cdot D_e}{2 \cdot R - D_e} \cdot \sigma_{hoop}$ = 223.99 N/mm^2

Hoop stress outside bend $\sigma_{hoop}(BO) = \frac{2 \cdot R + \frac{1}{2} \cdot D_e}{2 \cdot R + D_e} \cdot \sigma_{hoop}$ = 202.56 N/mm^2

Stress Check

Hoop stress (N/mm2)	Occurring	Allowable
Straight parts	212.20	327.27
Inside bend	223.99	327.27
Outside bend	202.56	327.27

Test pressure

Hydrotest temperature = 15 °C

Yield at hydrotest temperature = 360 N/mm^2

Product (gas / others) gas

Design factor, CP (1.3 for gas; 1.25 for others) 1.30

Minimum hydrotest pressure $P_{T,\min} = C_p \cdot P_d \cdot \frac{R_e(20^\circ C)}{R_e(T_d)}$ = 144.43 barg

Maximum allowable hydrotest pressure $P_{T,\max} = \frac{2 \cdot d_{nom} \cdot (1 - f_{tol}) \cdot R_e(20^\circ C)}{(D_e - d_{nom} \cdot (1 - f_{tol}))}$ = 281.23 barg

Mill test pressure $P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot d_{nom}}{D_e}$ = 262.77 barg

Max. allowable hydro test pressure exceeds mill test pressure!!

Note 1: Outside 500m zone: Pd***** = (Pd - Pe)
Within 500m zone: Pd***** = Pd

Note 2: The bend manufacturer to ensure that the finished products does meet with these minimum WT. requirements.

B. Buckling & Collapse Analysis

The following buckling and collapse analyses were performed:

- 19018-60-CAL-01003-01-01 Buckling & Collapse calculation – 26m – operation
- 19018-60-CAL-01003-02-01 Buckling & Collapse calculation – 26m – installation flooded
- 19018-60-CAL-01003-03-01 Buckling & Collapse calculation – 26m - hydrotest
- 19018-60-CAL-01003-04-01 Buckling & Collapse calculation – 8m - operation
- 19018-60-CAL-01003-05-01 Buckling & Collapse calculation – 8m - installation flooded
- 19018-60-CAL-01003-06-01 Buckling & Collapse calculation – 8m - hydrotest
- 19018-60-CAL-01003-07-01 Buckling & Collapse calculation – 17m - operation
- 19018-60-CAL-01003-08-01 Buckling & Collapse calculation – 17m - installation flooded
- 19018-60-CAL-01003-09-01 Buckling & Collapse calculation – 17m - hydrotest

(66 pages) only 26m with Stokes+hydroload pages

Project	:	**N05-A Pipeline design**
Project #	:	19018
Subject	:	Buckling and Collapse
File #	:	19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx
Client	:	ONE-Dyas
Client File #	:	

Originator	: EvW	Checked	:
Date	: 24/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

4 — Operational

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom}	=	20	
Nominal diameter		OD_{nom}	=	508	mm
Nominal wall thickness		d_{nom}	=	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$	=	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$	=	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max}	=	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min}	=	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0	=	0.014	-
Cross sectional area of steel		A	=	31572	mm^2
Moment of Inertia		I	=	939135656	mm^4
Corrosion allowance		CA	=	3	mm
Fabrication Tolerance		f_{tol}	=	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min}	=	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g	=	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$	=	0	mm
Nominal wall thickness	$d_{nom,p}$	=	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material		=	L360NB	
Design temperature		T_d =	50	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	$m/m/^oC$
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Operational		96.1	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	2636.6	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	29.68	m LAT
Minimum water depth		WD_{min} =	26	m LAT
Other water depth (to be used for calculations)		WD =	26	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	24.21	m LAT
Highest Astronomical Tide		HAT =	2.72	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	11.4	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	10.1	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	16.9	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	11.5	s

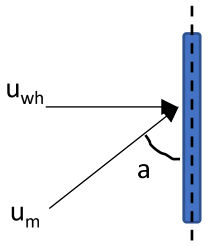
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0130

$\frac{SWL}{g \cdot T_z^2} =$ 0.0187

Wave theory selected: **2** Stokes 5th

1. Airy/linear wave; 2. Stokes 5th



Maximum wave particle velocity	u_{wm} =	4.00	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	4.00	m/s

Current:

Height above seabed at which velocity is known	z* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height	U_{czr} =	0.96	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.69	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 4320 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by: $$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm²

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm²

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm²

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 40.85 m

0.4085 N/mm²

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.42 N/mm²

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-
$n = 1 + 300 \cdot d_{nom} / OD_g$ n =	13.6	-

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	389	N/m
$F_D + F_I$ =	4320	N/m
g_w =	1.1	-
g_h =	1.2	-

Table 3 - NEN3656

q = 5202 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 43.8 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0,9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT =	46	-
R_e =	360.00	N/mm^2
R_{ed} =	360.00	N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 169.3 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0,9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p =	1.15	-
g_t =	1.1	-
N =	-2.05E+06	N
$L_{max,bb}$ =	**61.7**	**m**

Originator	: EvW	Checked	:
Date	: 24/01/2020		
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Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.79	m
Storm surge water level	$SWL = WD + ss$ =	24.21	m
Wave height	H =	16.9	m
Wave period	T =	11.5	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g \cdot T^2}{2 \cdot \pi}$ =	206.5	m

Solving for wave length (L) and λ

$$\frac{\pi \cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3 \cdot B_{33} + \lambda^5 \cdot (B_{35} + B_{55})\right\} = 0 \quad (\text{I})$$

$$\frac{SWL}{L_O} - \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) \cdot \left\{1 + \lambda^2 \cdot C_1 + \lambda^4 \cdot C_2\right\} = 0 \quad (\text{II})$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **184.228 m**

$A = SWL / L_O$ = 0.1172

$B = \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right)$ = 0.0891

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1 \cdot B \ \pm \sqrt{D}}{2 \cdot C_2 \cdot B}$$

$D = (C_1 \cdot B)^2 - 4 \cdot (C_2 \cdot B) \cdot (-(A - B))$ = 0.5724

	-	eq. (I)	eq. (II)
λ1	0.227	-0.0004	0.0000
λ2	Numerator of X < 0		
λ3	-0.227	4.3864	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	0.9228	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3607	-
A11	$A_{11} = \frac{1}{s} =$	1.0837	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-3.5482	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-7.5755	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.5172	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	-1.8403	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.1534	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1815	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0013	-

$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^8 + 324000\cdot c^6 - 432000\cdot c^4 + 163470\cdot c^2 - 16245}{61440\cdot s^{11}\cdot(6\cdot c^2 - 1)\cdot(8\cdot c^4 - 11\cdot c^2 + 3)} =$$ -0.0282 -

B22 $$B_{22} = \frac{(2\cdot c^2 + 1)\cdot c}{4\cdot s^3} =$$ 2.0361 -

B24 $$B_{24} = \frac{c\cdot(272\cdot c^8 - 504\cdot c^6 - 192\cdot c^4 + 322\cdot c^2 + 21)}{384\cdot s^9} =$$ -0.3177 -

B33 $$B_{33} = \frac{3\cdot(8\cdot c^6 + 1)}{64\cdot s^6} =$$ 3.9311 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^8 - 21816\cdot c^6 + 6264\cdot c^4 - 54\cdot c^2 - 81}{12288\cdot s^{12}\cdot(6\cdot c^2 - 1)} =$$
= 5.1509 -

B44 $$B_{44} = c\cdot\frac{768\cdot c^{10} - 488\cdot c^8 - 48\cdot c^6 + 48\cdot c^4 + 106\cdot c^2 - 21}{384\cdot s^9\cdot(6\cdot c^2 - 1)} =$$ 7.9561 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^8 + 7160\cdot c^6 - 1800\cdot c^4 - 1050\cdot c^2 + 225}{12288\cdot s^{10}\cdot(8\cdot c^4 - 11\cdot c^2 + 3)\cdot(6\cdot c^2 - 1)} =$$
= 19.0981 -

C1 $$C_1 = \frac{8\cdot c^4 - 8\cdot c^2 + 9}{8\cdot s^4} =$$ 3.7260 -

$$C_2 = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^8 - 1008\cdot c^6 + 5944\cdot c^4 - 1830\cdot c^2 + 147}{512\cdot s^{10}\cdot(6\cdot c^2 - 1)} =$$ 46.0838 -

C3 $$C_3 = -\frac{1}{4\cdot c\cdot s} =$$ -0.1991 -

C4 $$C_4 = \frac{12\cdot c^8 + 36\cdot c^6 - 162\cdot c^4 + 141\cdot c^2 - 27}{192\cdot c\cdot s^9} =$$ 0.3806 -

K1 $$K_1 = \lambda\cdot A_{11} + \lambda^3\cdot A_{13} + \lambda^5\cdot A_{15} =$$ 0.2001 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0218	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0019	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Project : **N05-A Pipeline design**
Project # : 19018
Subject : Buckling and Collapse
File # : 19018-60-CAL-01003-01-01 - Buckling & Collapse calculations - 26m - operation.xlsx

Client : ONE-Dyas
Client File # :

Originator	: EvW	Checked	:
Date	: 24/01/2020		
Revision	: 01		

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed) 0.5080 m

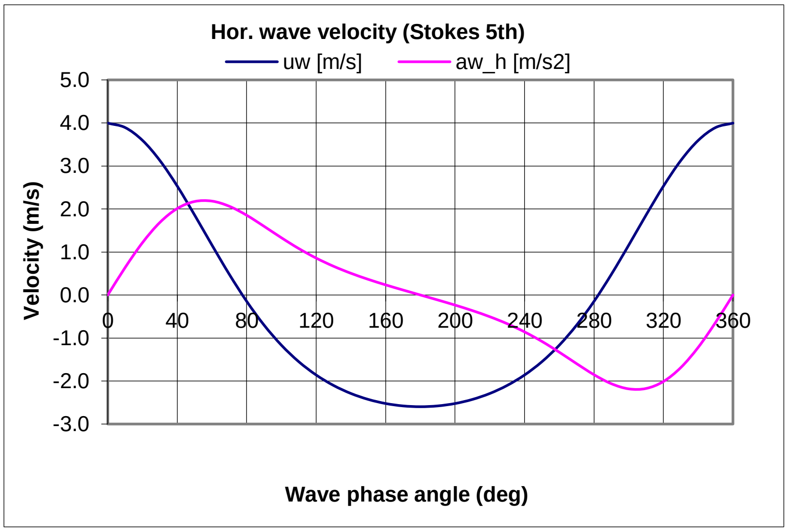
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	3.9954	0.0000
10.00	3.8927	0.6377
20.00	3.5942	1.2167
30.00	3.1271	1.6861
40.00	2.5326	2.0102
50.00	1.8601	2.1734
60.00	1.1605	2.1823
70.00	0.4796	2.0627
80.00	-0.1478	1.8534
90.00	-0.6996	1.5968
100.00	-1.1669	1.3301
110.00	-1.5511	1.0793
120.00	-1.8596	0.8578
130.00	-2.1025	0.6679
140.00	-2.2893	0.5054
150.00	-2.4276	0.3633
160.00	-2.5229	0.2353
170.00	-2.5788	0.1156
180.00	-2.5972	0.0000
190.00	-2.5788	-0.1156
200.00	-2.5229	-0.2353



210.00	-2.4276	-0.3633
220.00	-2.2893	-0.5054
230.00	-2.1025	-0.6679
240.00	-1.8596	-0.8578
250.00	-1.5511	-1.0793
260.00	-1.1669	-1.3301
270.00	-0.6996	-1.5968
280.00	-0.1478	-1.8534
290.00	0.4796	-2.0627
300.00	1.1605	-2.1823
310.00	1.8601	-2.1734
320.00	2.5326	-2.0102
330.00	3.1271	-1.6861
340.00	3.5942	-1.2167
350.00	3.8927	-0.6377
360.00	3.9954	0.0000

U_{wm} = max. wave particle velocity = 4.00 m/s

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	12.1350
10.00	11.3883
20.00	9.3802
30.00	6.6968
40.00	4.0097
50.00	1.7992
60.00	0.2151
70.00	-0.8738
80.00	-1.7036
90.00	-2.4374
100.00	-3.0936
110.00	-3.5987
120.00	-3.8987
130.00	-4.0330
140.00	-4.1177
150.00	-4.2594
160.00	-4.4749
170.00	-4.6819
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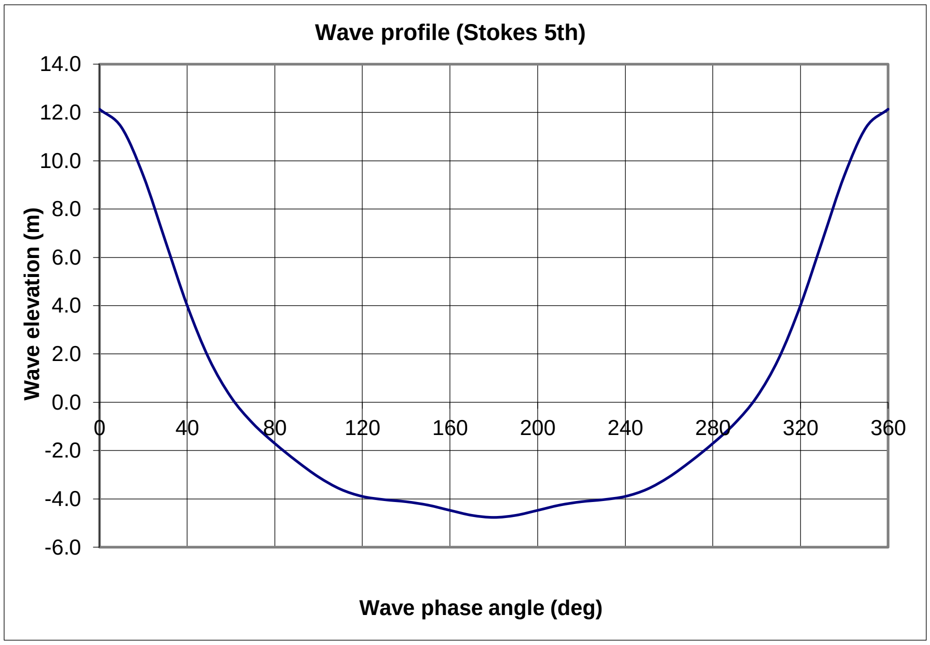


Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-02-01 - Buckling & Collapse calculations - 26m - installation flooded.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-02-01 - Buckling & Collapse calculations - 26m - installation flooded.xlsx

Originator	: EvW	Checked	:
Date	: 24/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

2
Installation: filled

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	15	°C
Yield at ambient temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m^3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled	1025	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air	$W_{pg,a}$ =	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$ =	2109.4	N/m

Soil

Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	29.68	m LAT
Minimum water depth		WD_{min} =	26	m LAT
Other water depth (to be used for calculations)		WD =	26	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	24.98	m LAT
Highest Astronomical Tide		HAT =	2.72	m

Waves (H_{max} & T_{max}):

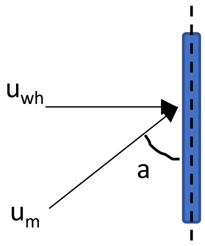
Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$ =	11.4	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	10.1	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	16.9	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	11.5	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0114

$\frac{SWL}{g \cdot T_z^2} =$ 0.0250

Wave theory selected:
1. Airy/linear wave; 2. Stokes 5th — **2** — Stokes 5th



Maximum wave particle velocity	u_{wm} =	2.39	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	2.39	m/s

Current:

Height above seabed at which velocity is known	z^* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height	U_{czr} =	0.74	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L — $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.53	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1822 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 40.85 m
0.4085 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.42 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-
$n = 1 + 300 \cdot d_{nom} / OD_g$ n =	13.6	-

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe; L = span length

$$q = \sqrt{\gamma_W^2 \cdot W_S^2 + \gamma_H^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	2109	N/m
$F_D + F_I$ =	1822	N/m
g_w =	1.1	-
g_h =	1.2	-
Table 3 - NEN3656		
q =	3188	N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 56.0 m

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Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT	=	11	-
R_e	=	360.00	N/mm^2
R_{ed}	=	360.00	N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 3.1 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p	=	1.15	-
g_t	=	1.1	-
N	=	-8.97E+05	N
$L_{max,bb}$	**=**	**93.1**	**m**

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Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL = WD + ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g \cdot T^2}{2 \cdot \pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi \cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3 \cdot B_{33} + \lambda^5 \cdot (B_{35} + B_{55})\right\} = 0 \quad (\text{I})$$

$$\frac{SWL}{L_O} - \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) \cdot \left\{1 + \lambda^2 \cdot C_1 + \lambda^4 \cdot C_2\right\} = 0 \quad (\text{II})$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **143.093 m**

$A = SWL / L_O$ = 0.1568

$B = \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right)$ = 0.1395

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1 \cdot B \pm \sqrt{D}}{2 \cdot C_2 \cdot B}$$

$D = (C_1 \cdot B)^2 - 4 \cdot (C_2 \cdot B) \cdot (-(A - B))$ = 0.1581

	-	eq. (I)	eq. (II)
λ1	0.228	0.0005	0.0000
λ2	Numerator of X < 0		
λ3	-0.228	2.8669	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3304	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.6643	-
A11	$A_{11} = \frac{1}{s} =$	0.7516	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-1.2336	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-2.4101	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.1197	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	0.0907	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.0041	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1402	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0025	-

$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^{8} + 324000\cdot c^{6} - 432000\cdot c^{4} + 163470\cdot c^{2} - 16245}{61440\cdot s^{11}\cdot(6\cdot c^{2}-1)\cdot(8\cdot c^{4}-11\cdot c^{2}+3)} =$$ -0.0003 -

B22 $$B_{22} = \frac{(2\cdot c^{2}+1)\cdot c}{4\cdot s^{3}} =$$ 1.1556 -

B24 $$B_{24} = \frac{c\cdot(272\cdot c^{8} - 504\cdot c^{6} - 192\cdot c^{4} + 322\cdot c^{2} + 21)}{384\cdot s^{9}} =$$ 1.5737 -

B33 $$B_{33} = \frac{3\cdot(8\cdot c^{6}+1)}{64\cdot s^{6}} =$$ 1.4457 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^{8} - 21816\cdot c^{6} + 6264\cdot c^{4} - 54\cdot c^{2} - 81}{12288\cdot s^{12}\cdot(6\cdot c^{2}-1)} =$$
= 5.1727 -

B44 $$B_{44} = c\cdot\frac{768\cdot c^{10} - 488\cdot c^{8} - 48\cdot c^{6} + 48\cdot c^{4} + 106\cdot c^{2} - 21}{384\cdot s^{9}\cdot(6\cdot c^{2}-1)} =$$ 2.0428 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^{8} + 7160\cdot c^{6} - 1800\cdot c^{4} - 1050\cdot c^{2} + 225}{12288\cdot s^{10}\cdot(8\cdot c^{4}-11\cdot c^{2}+3)\cdot(6\cdot c^{2}-1)} =$$
= 3.3386 -

C1 $$C_{1} = \frac{8\cdot c^{4} - 8\cdot c^{2} + 9}{8\cdot s^{4}} =$$ 1.9240 -

$$C_{2} = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^{8} - 1008\cdot c^{6} + 5944\cdot c^{4} - 1830\cdot c^{2} + 147}{512\cdot s^{10}\cdot(6\cdot c^{2}-1)} =$$ 8.9142 -

C3 $$C_{3} = -\frac{1}{4\cdot c\cdot s} =$$ -0.1129 -

C4 $$C_{4} = \frac{12\cdot c^{8} + 36\cdot c^{6} - 162\cdot c^{4} + 141\cdot c^{2} - 27}{192\cdot c\cdot s^{9}} =$$ 0.1419 -

K1 $$K_{1} = \lambda\cdot A_{11} + \lambda^{3}\cdot A_{13} + \lambda^{5}\cdot A_{15} =$$ 0.1552 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

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Horizontal wave particle velocities

Water depth at which data required, z — 0.5080 m
(w.r.t. seabed)

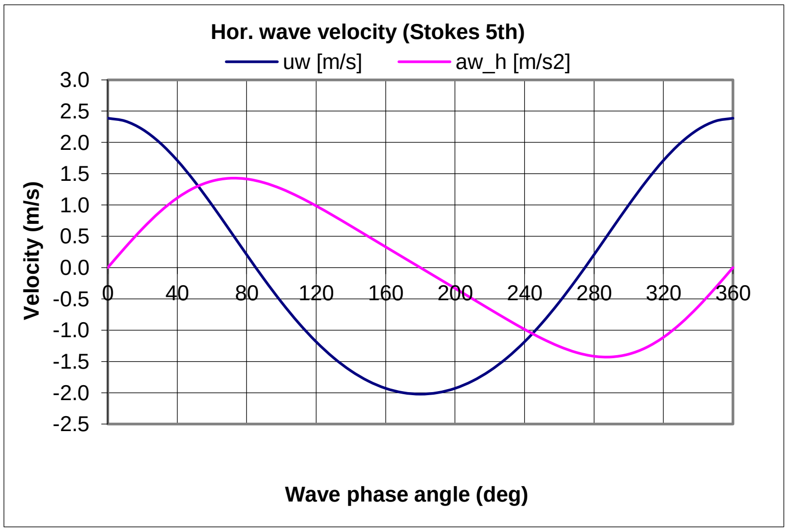
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3878	0.0000
10.00	2.3427	0.3202
20.00	2.2098	0.6227
30.00	1.9965	0.8913
40.00	1.7141	1.1129
50.00	1.3773	1.2783
60.00	1.0025	1.3832
70.00	0.6068	1.4278
80.00	0.2066	1.4167
90.00	-0.1836	1.3575
100.00	-0.5515	1.2596
110.00	-0.8877	1.1329
120.00	-1.1853	0.9867
130.00	-1.4402	0.8286
140.00	-1.6498	0.6646
150.00	-1.8129	0.4982
160.00	-1.9293	0.3316
170.00	-1.9990	0.1655
180.00	-2.0222	0.0000
190.00	-1.9990	-0.1655
200.00	-1.9293	-0.3316



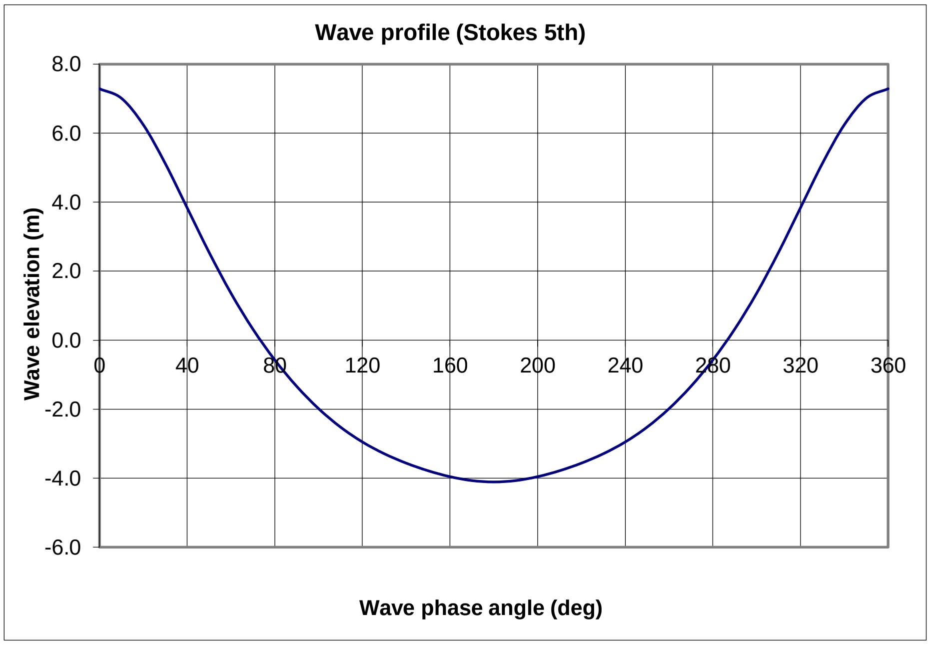
210.00	-1.8129	-0.4982
220.00	-1.6498	-0.6646
230.00	-1.4402	-0.8286
240.00	-1.1853	-0.9867
250.00	-0.8877	-1.1329
260.00	-0.5515	-1.2596
270.00	-0.1836	-1.3575
280.00	0.2066	-1.4167
290.00	0.6068	-1.4278
300.00	1.0025	-1.3832
310.00	1.3773	-1.2783
320.00	1.7141	-1.1129
330.00	1.9965	-0.8913
340.00	2.2098	-0.6227
350.00	2.3427	-0.3202
360.00	2.3878	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	7.2865
10.00	7.0115
20.00	6.2418
30.00	5.1225
40.00	3.8366
50.00	2.5478
60.00	1.3619
70.00	0.3219
80.00	-0.5728
90.00	-1.3376
100.00	-1.9847
110.00	-2.5198
120.00	-2.9504
130.00	-3.2916
140.00	-3.5642
150.00	-3.7849
160.00	-3.9567
170.00	-4.0697
180.00	-4.1095
190.00	-4.0697
200.00	-3.9567
210.00	-3.7849
220.00	-3.5642
230.00	-3.2916
240.00	-2.9504
250.00	-2.5198
260.00	-1.9847
270.00	-1.3376
280.00	-0.5728
290.00	0.3219
300.00	1.3619
310.00	2.5478
320.00	3.8366
330.00	5.1225
340.00	6.2418
350.00	7.0115
360.00	7.2865



Originator	: EvW	Checked	:
Date	: 24/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

3
Hydrotest

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx

Originator	: EvW	Checked :
Date	: 24/01/2020	
Revision	: 01	

Material			=	L360NB	
Design temperature		T_d	=	15	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Density		ρ_{st}	=	7850	kg/m^3
Youngs modulus		E_s	=	210000	N/mm^2
Poisson's ratio		u	=	0.3	-
Linear thermal expansion coefficient		a	=	1.16E-05	$m/m/^oC$
Contents					
Sea water density				1025	kg/m^3
Pipeline product density				96.1	kg/m^3
Pipeline content density used for this case:	Hydrotest			1025	kg/m^3
Pipeline Weights					
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$	=	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$	=	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$	=	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$	=	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$	=	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$	=	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$	=	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$	=	2109.4	N/m
Soil					
Submerged density		ρ_{ss}	=	1000	kg/m^3
Depth of burial		d_b	=	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres}	=	0.008	N/mm^2
Environmental conditions					
Water depths:					
Seawater density		ρ_{sw}	=	1025	kg/m3
Maximum water depth		WD_{max}	=	29.68	m LAT
Minimum water depth		WD_{min}	=	26	m LAT
Other water depth (to be used for calculations)		WD	=	26	m LAT
Storm surge, RP1 yr		ss_{1yr}	=	-1.02	m LAT
Storm surge, RP100 yr		ss_{100yr}	=	-1.79	m LAT
Storm surge water level	SSWL = WD + ss	SSWL	=	24.98	m LAT
Highest Astronomical Tide		HAT	=	2.72	m
Waves (H_{max} & T_{max}):					
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$	=	11.4	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$	=	10.1	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$	=	16.9	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$	=	11.5	s

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx

Originator	: EvW	Checked	:
Date	: 24/01/2020		
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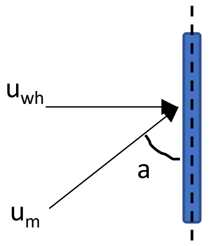
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures") $\frac{H_{max}}{g \cdot T_z^2} =$ 0.0114

$\frac{SWL}{g \cdot T_z^2} =$ 0.0250



Wave theory selected:			
1. Airy/linear wave; 2. Stokes 5th	**2**	Stokes 5th	
Maximum wave particle velocity	u_{wm} =	2.39	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	2.39	m/s

Current:			
Height above seabed at which velocity is known	z^* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s
Current velocity at reference height	U_{czr} =	0.74	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.53	m/s

Hydrodynamic coefficients:			
Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-
Maximum absolute hydrodynamic force		1822	N/m
Temperatures:			
Ambient temperature	T_{amb} =	4	deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by: $$(p_c - p_e)\cdot(p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 40.85 m

0.4085 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.42 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **= OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \leq \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-
$n = 1 + 300 \cdot d_{nom} / OD_g$ n =	13.6	-

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 9.994E+05 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe; L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	2109	N/m
$F_D + F_I$ =	1822	N/m
g_w =	1.1	-
g_h =	1.2	-
Table 3 - NEN3656		
q =	3188	N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 9.99E+05 N·m

Maximum span length, L_{max} = 56.0 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ — Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

Stokes 5th order wave theory

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL = WD + ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g \cdot T^2}{2 \cdot \pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi \cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3 \cdot B_{33} + \lambda^5 \cdot (B_{35} + B_{55})\right\} = 0 \quad \text{(I)}$$

$$\frac{SWL}{L_O} - \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) \cdot \left\{1 + \lambda^2 \cdot C_1 + \lambda^4 \cdot C_2\right\} = 0 \quad \text{(II)}$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L = **143.093 m**

$$A = SWL / L_O = 0.1568$$

$$B = \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) = 0.1395$$

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1 \cdot B \pm \sqrt{D}}{2 \cdot C_2 \cdot B}$$

$$D = (C_1 \cdot B)^2 - 4 \cdot (C_2 \cdot B) \cdot (-(A - B)) = 0.1581$$

	-	eq. (I)	eq. (II)
λ1	0.228	0.0005	0.0000
λ2	Numerator of X < 0		
λ3	-0.228	2.8669	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.3304	-
c	$c = \cosh\left(\frac{2 \cdot \pi \cdot WL}{L}\right) =$	1.6643	-
A11	$A_{11} = \frac{1}{s} =$	0.7516	-
A13	$A_{13} = \frac{-c^2 \cdot (5 \cdot c^2 + 1)}{8 \cdot s^5} =$	-1.2336	-
	$A_{15} = -\frac{1184 \cdot c^{10} - 1440 \cdot c^8 - 1992 \cdot c^6 + 2641 \cdot c^4 - 249 \cdot c^2 + 18}{1536 \cdot s^{11}} =$	-2.4101	-
A22	$A_{22} = \frac{3}{8 \cdot s^4} =$	0.1197	-
A24	$A_{24} = \frac{192 \cdot c^8 - 424 \cdot c^6 - 312 \cdot c^4 + 480 \cdot c^2 - 17}{768 \cdot s^{10}} =$	0.0907	-
A33	$A_{33} = \frac{13 - 4 \cdot c^2}{64 \cdot s^7} =$	0.0041	-
	$A_{35} = \frac{512 \cdot c^{12} + 4224 \cdot c^{10} - 6800 \cdot c^8 - 12808 \cdot c^6 + 16704 \cdot c^4 - 3154 \cdot c^2 - 107}{4096 \cdot s^{13} \cdot (6 \cdot c^2 - 1)} =$	0.1402	-
A44	$A_{44} = \frac{80 \cdot c^6 - 816 \cdot c^4 + 1338 \cdot c^2 - 197}{1536 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$	-0.0025	-

$$A_{55} = -\frac{2880 \cdot c^{10} - 72480 \cdot c^8 + 324000 \cdot c^6 - 432000 \cdot c^4 + 163470 \cdot c^2 - 16245}{61440 \cdot s^{11} \cdot (6 \cdot c^2 - 1) \cdot (8 \cdot c^4 - 11 \cdot c^2 + 3)} =$$ -0.0003 -

B22 $$B_{22} = \frac{(2 \cdot c^2 + 1) \cdot c}{4 \cdot s^3} =$$ 1.1556 -

B24 $$B_{24} = \frac{c \cdot (272 \cdot c^8 - 504 \cdot c^6 - 192 \cdot c^4 + 322 \cdot c^2 + 21)}{384 \cdot s^9} =$$ 1.5737 -

B33 $$B_{33} = \frac{3 \cdot (8 \cdot c^6 + 1)}{64 \cdot s^6} =$$ 1.4457 -

$$B_{35} = \frac{88128 \cdot c^{14} - 208224 \cdot c^{12} + 70848 \cdot c^{10} + 54000 \cdot c^8 - 21816 \cdot c^6 + 6264 \cdot c^4 - 54 \cdot c^2 - 81}{12288 \cdot s^{12} \cdot (6 \cdot c^2 - 1)} =$$
= 5.1727 -

B44 $$B_{44} = c \cdot \frac{768 \cdot c^{10} - 488 \cdot c^8 - 48 \cdot c^6 + 48 \cdot c^4 + 106 \cdot c^2 - 21}{384 \cdot s^9 \cdot (6 \cdot c^2 - 1)} =$$ 2.0428 -

$$B_{55} = \frac{192000 \cdot c^{16} - 26720 \cdot c^{14} + 83680 \cdot c^{12} + 20160 \cdot c^{10} - 7280 \cdot c^8 + 7160 \cdot c^6 - 1800 \cdot c^4 - 1050 \cdot c^2 + 225}{12288 \cdot s^{10} \cdot (8 \cdot c^4 - 11 \cdot c^2 + 3) \cdot (6 \cdot c^2 - 1)} =$$
= 3.3386 -

C1 $$C_1 = \frac{8 \cdot c^4 - 8 \cdot c^2 + 9}{8 \cdot s^4} =$$ 1.9240 -

$$C_2 = \frac{3840 \cdot c^{12} - 4096 \cdot c^{10} + 2592 \cdot c^8 - 1008 \cdot c^6 + 5944 \cdot c^4 - 1830 \cdot c^2 + 147}{512 \cdot s^{10} \cdot (6 \cdot c^2 - 1)} =$$ 8.9142 -

C3 $$C_3 = -\frac{1}{4 \cdot c \cdot s} =$$ -0.1129 -

C4 $$C_4 = \frac{12 \cdot c^8 + 36 \cdot c^6 - 162 \cdot c^4 + 141 \cdot c^2 - 27}{192 \cdot c \cdot s^9} =$$ 0.1419 -

K1 $$K_1 = \lambda \cdot A_{11} + \lambda^3 \cdot A_{13} + \lambda^5 \cdot A_{15} =$$ 0.1552 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-03-01 - Buckling & Collapse calculations - 26m - hydrotest.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	

Originator	: EvW	Checked	:
Date	: 24/01/2020		
Revision	: 01		

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed) 0.5080 m

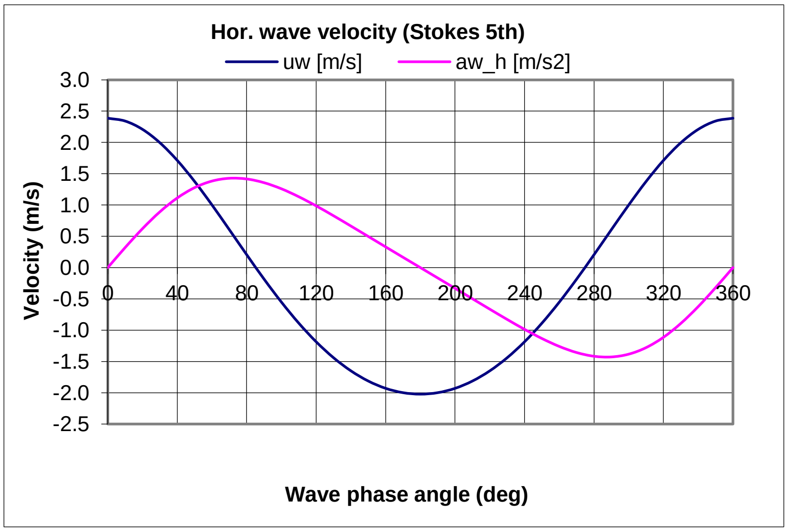
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3878	0.0000
10.00	2.3427	0.3202
20.00	2.2098	0.6227
30.00	1.9965	0.8913
40.00	1.7141	1.1129
50.00	1.3773	1.2783
60.00	1.0025	1.3832
70.00	0.6068	1.4278
80.00	0.2066	1.4167
90.00	-0.1836	1.3575
100.00	-0.5515	1.2596
110.00	-0.8877	1.1329
120.00	-1.1853	0.9867
130.00	-1.4402	0.8286
140.00	-1.6498	0.6646
150.00	-1.8129	0.4982
160.00	-1.9293	0.3316
170.00	-1.9990	0.1655
180.00	-2.0222	0.0000
190.00	-1.9990	-0.1655
200.00	-1.9293	-0.3316



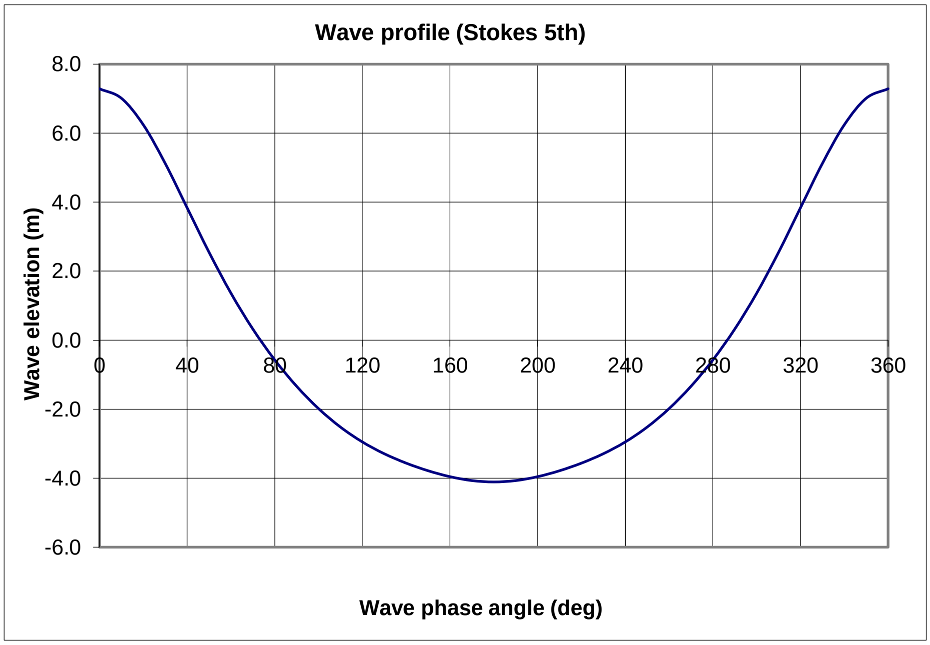
210.00	-1.8129	-0.4982
220.00	-1.6498	-0.6646
230.00	-1.4402	-0.8286
240.00	-1.1853	-0.9867
250.00	-0.8877	-1.1329
260.00	-0.5515	-1.2596
270.00	-0.1836	-1.3575
280.00	0.2066	-1.4167
290.00	0.6068	-1.4278
300.00	1.0025	-1.3832
310.00	1.3773	-1.2783
320.00	1.7141	-1.1129
330.00	1.9965	-0.8913
340.00	2.2098	-0.6227
350.00	2.3427	-0.3202
360.00	2.3878	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	7.2865
10.00	7.0115
20.00	6.2418
30.00	5.1225
40.00	3.8366
50.00	2.5478
60.00	1.3619
70.00	0.3219
80.00	-0.5728
90.00	-1.3376
100.00	-1.9847
110.00	-2.5198
120.00	-2.9504
130.00	-3.2916
140.00	-3.5642
150.00	-3.7849
160.00	-3.9567
170.00	-4.0697
180.00	-4.1095
190.00	-4.0697
200.00	-3.9567
210.00	-3.7849
220.00	-3.5642
230.00	-3.2916
240.00	-2.9504
250.00	-2.5198
260.00	-1.9847
270.00	-1.3376
280.00	-0.5728
290.00	0.3219
300.00	1.3619
310.00	2.5478
320.00	3.8366
330.00	5.1225
340.00	6.2418
350.00	7.0115
360.00	7.2865



Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

4
Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	:	**N05-A Pipeline design**
Project #	:	19018
Subject	:	Buckling and Collapse
File #	:	19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx
Client	:	ONE-Dyas
Client File #	:	19018-60-CAL-01003-04-01 - Buckling & Collapse calculations - 8m - operation.xlsx

Originator	: EvW	Checked :
Date	: 27/01/2020	
Revision	: 01	

Material		=	L360NB	
Design temperature		T_d =	50	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	$m/m/^oC$
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Operational		96.1	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	2636.6	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (to be used for calculations)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	7.22	m LAT
Highest Astronomical Tide		HAT =	3.5	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	7.7	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	8.1	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

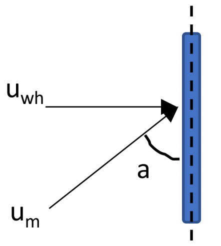
$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0096

$\frac{SWL}{g \cdot T_z^2} =$ 0.0112

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th

Wave particle velocity from metocean data



Maximum wave particle velocity	u_{wm} =	1.60	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.60	m/s

Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.89	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	1	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.12	m/s
Current velocity at reference height	U_{czr} =	1.12	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.89	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1372 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by: $$(p_c - p_e)\cdot(p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m

0.181 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-
$n = 1 + 300 \cdot d_{nom} / OD_g$ n =	13.6	-

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	389	N/m
$F_D + F_I$ =	1372	N/m
g_w =	1.1	-
g_h =	1.2	-
Table 3 - NEN3656		
q =	1700	N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 76.7 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT =	46	-
R_e =	360.00	N/mm^2
R_{ed} =	360.00	N/mm^2
$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$ s_p =	169.3	N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p =	1.15	-
g_t =	1.1	-
N =	-2.05E+06	N
$L_{max,bb}$ =	**61.7**	**m**

Project	**: N05-A Pipeline design**
Project #	: 19018
Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

2
Installation: filled

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-05-01 - Buckling & Collapse calculations - 8m - installation flooded.xlsx

Originator	: EvW	Checked :
Date	: 27/01/2020	
Revision	: 01	

Material			=	L360NB	
Design temperature		T_d	=	15	°C
Yield at ambient temperature		R_e	=	360.00	N/mm^2
Yield at design temperature		R_{ed}	=	360.00	N/mm^2
Density		ρ_{st}	=	7850	kg/m^3
Youngs modulus		E_s	=	210000	N/mm^2
Poisson's ratio		u	=	0.3	-
Linear thermal expansion coefficient		a	=	1.16E-05	m/m/°C
Contents					
Sea water density				1025	kg/m^3
Pipeline product density				96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled			1025	kg/m^3
Pipeline Weights					
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$	=	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$	=	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$	=	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$	=	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$	=	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$	=	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$	=	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$	=	2109.4	N/m
Soil					
Submerged density		ρ_{ss}	=	1000	kg/m^3
Depth of burial		d_b	=	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres}	=	0.008	N/mm^2
Environmental conditions					
Water depths:					
Seawater density		ρ_{sw}	=	1025	kg/m3
Maximum water depth		WD_{max}	=	11.5	m LAT
Minimum water depth		WD_{min}	=	8	m LAT
Other water depth (to be used for calculations)		WD	=	8	m LAT
Storm surge, RP1 yr		ss_{1yr}	=	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr}	=	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL	=	7.86	m LAT
Highest Astronomical Tide		HAT	=	3.5	m
Waves (H_{max} & T_{max}):					
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$	=	5.2	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$	=	7.7	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$	=	6.2	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$	=	8.1	s

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

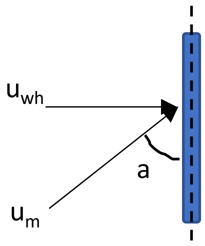
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2}$ = 0.0089

$\frac{SWL}{g \cdot T_z^2}$ = 0.0135

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from metocean data

Maximum wave particle velocity	u_{wm} =	1.30	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.30	m/s

Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.89	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	1	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.12	m/s
Current velocity at reference height	U_{czr} =	0.89	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.71	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 891 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}(\frac{d_{nom}}{OD_{av}})^3$ = 34.0 N/mm²

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm²

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm²

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m
0.181 N/mm²

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm²

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$	=	1.05	-
g_M	=	0.93	-
$g_{m,p}$	=	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **= OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \leq \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$	=	1.1	-
g_M	=	1	-
$g_{m,M}$	=	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$	=	1.05	-
$g_{g,M}$	=	1.55	-
$g_{m,p}$	=	1.25	-
$g_{m,M}$	=	1.15	-
g_M	=	0.93	-

$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe; L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight;	Ws	=	2109	N/m
	$F_D + F_I$	=	891	N/m
	g_w	=	1.1	-
	g_h	=	1.2	-
	Table 3 - NEN3656			
	q	=	2555	N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 62.6 m

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT =	11	-
R_e =	360.00	N/mm²
R_{ed} =	360.00	N/mm²

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 3.1 N/mm²

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p =	1.15	-
g_t =	1.1	-
N =	-8.97E+05	N

$L_{max,bb}$ = 93.1 m

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-06-01 - Buckling & Collapse calculations - 8m - hydrotest.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

3
Hydrotest

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Originator	: EvW	Checked	:
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Material		=	L360NB	
Design temperature		T_d =	15	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	m/m/^{o}C
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Hydrotest		1025	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (to be used for calculations)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	7.86	m LAT
Highest Astronomical Tide		HAT =	3.5	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	7.7	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	8.1	s

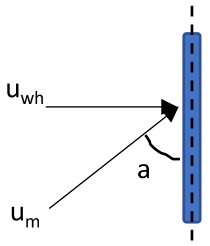
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$$\frac{H_{max}}{g \cdot T_z^2} = 0.0089$$

$$\frac{SWL}{g \cdot T_z^2} = 0.0135$$

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from metocean data

Maximum wave particle velocity	u_{wm} =	1.30	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.30	m/s

Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.89	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	1	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.12	m/s
Current velocity at reference height	U_{czr} =	0.89	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.71	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 891 N/m

Temperatures:

Ambient temperature	T_{amb} =	4	deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p): $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 18.1 m

0.181 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.19 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ = 1.05 -
g_M = 0.93 -
$g_{m,p}$ = 1.45 -

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **= OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \leq \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ = 1.1 -
g_M = 1 -
$g_{m,M}$ = 1.3 -

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ = 1.05 -
$g_{g,M}$ = 1.55 -
$g_{m,p}$ = 1.25 -
$g_{m,M}$ = 1.15 -
g_M = 0.93 -

$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.001E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 891 N/m
g_w = 1.1 -
g_h = 1.2 -
Table 3 - NEN3656
q = 2555 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 62.6 m

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Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

Project	**: N05-A Pipeline design**
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Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Operational

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

4
Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	:	**N05-A Pipeline design**
Project #	:	19018
Subject	:	Buckling and Collapse
File #	:	19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx
Client	:	ONE-Dyas
Client File #	:	19018-60-CAL-01003-07-01 - Buckling & Collapse calculations - 17m - operation.xlsx

Originator	: EvW	Checked	:
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Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m^3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Operational	96.1	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$ =	2636.6	N/m
Piggyback weight in air	$W_{pg,a}$ =	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$ =	2109.4	N/m

Soil

Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	15.72	m LAT
Highest Astronomical Tide		HAT =	3.11	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	9.8	s

Project	: **N05-A Pipeline design**
Project #	: 19018
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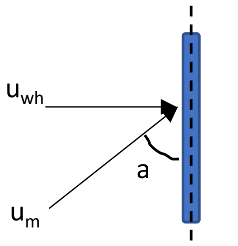
Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$\frac{H_{max}}{g \cdot T_z^2} =$ 0.0123

$\frac{SWL}{g \cdot T_z^2} =$ 0.0167

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from interpolated data

Maximum wave particle velocity	u_{wm} =	2.80	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	2.80	m/s

Current:

Height above seabed at which velocity is known	z^* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s
Current velocity at reference height	U_{czr} =	1.04	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L — $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.83	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 2909 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e)\cdot(p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3 =$ 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}} =$ 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT =$ 29.485 m

0.29485 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres} =$ 0.30 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \le \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \le \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \le \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-

$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	389	N/m
$F_D + F_I$ =	2909	N/m
g_w =	1.1	-
g_h =	1.2	-

Table 3 - NEN3656

q = 3517 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 53.3 m

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Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 46 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$ s_p = 169.3 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0005 < 0.0030 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = -2.05E+06 N

$L_{max,bb}$ = 61.7 m

Project	**: N05-A Pipeline design**
Project #	: 19018
Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Installation: filled

Situation

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

2

Installation: filled

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Originator	: EvW	Checked	:
Date	: 27/01/2020		
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Material

	=	L360NB	
Design temperature	T_d =	15	°C
Yield at ambient temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m^3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	$m/m/^oC$

Contents

Sea water density		1025	kg/m^3
Pipeline product density		96.1	kg/m^3
Pipeline content density used for this case:	Installation: filled	1025	kg/m^3

Pipeline Weights

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

Pipeline weight in air	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air	$W_{pg,a}$ =	0.0	N/m

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Buoyancy force pipeline	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback	$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty	$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight	$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty	$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled	$W_{T,s,f}$ =	2109.4	N/m

Soil

Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2

Environmental conditions

Water depths:

Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	16.42	m LAT
Highest Astronomical Tide		HAT =	3.11	m

Waves (H_{max} & T_{max}):

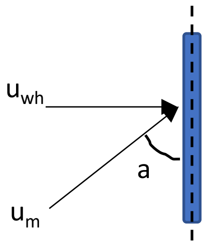
Maximum wave height, RP1 yr - installation/hydrotes	$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	9.8	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

$$\frac{H_{max}}{g \cdot T_z^2} = 0.0107$$

$$\frac{SWL}{g \cdot T_z^2} = 0.0211$$

Wave theory selected:
1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from interpolated data

Maximum wave particle velocity	u_{wm} =	1.85	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.85	m/s

Current:

Height above seabed at which velocity is known	z^* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s
Current velocity at reference height	U_{czr} =	0.82	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.65	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1380 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by:

$$(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}\left(\frac{d_{nom}}{OD_{av}}\right)^3$ = 34.0 N/mm^2

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}}$ = 29.2 N/mm^2

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm^2

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT$ = 29.485 m
0.29485 N/mm^2

Actual external pressure (P_L) $WC_{max} + SC_{pres}$ = 0.30 N/mm^2

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **=** **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \leq \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-

$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,** q = load acting on pipe; L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws =	2109	N/m
$F_D + F_I$ =	1380	N/m
g_w =	1.1	-
g_h =	1.2	-

Table 3 - NEN3656

q = 2851 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.00E+06 N·m

Maximum span length, L_{max} = 59.2 m

Project	**: N05-A Pipeline design**	
Project #	: 19018	
Subject	: Buckling and Collapse	
File #	: 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx	
Client	: ONE-Dyas	
Client File #	: 19018-60-CAL-01003-08-01 - Buckling & Collapse calculations - 17m - installation flooded.xlsx	

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT	=	11	-
R_e	=	360.00	N/mm^2
R_{ed}	=	360.00	N/mm^2
$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$ s_p	=	3.1	N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \leq \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E}\sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0033 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ Table 3 - NEN3656 - BC4

g_p	=	1.15	-
g_t	=	1.1	-
N	=	-8.97E+05	N
$L_{max,bb}$	**=**	**93.1**	**m**

Project	**: N05-A Pipeline design**
Project #	: 19018
Subject	: Buckling and Collapse
File #	: 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx
Client	: ONE-Dyas
Client File #	: 19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Buckling and Collapse - 20in x 20.62mm - Hydrotest

Situation

3
Hydrotest

1. Installation: empty
2. Installation: filled
3. Hydrotest
4. Operational

	Pressure (barg)	Temperature (deg. C)
Installation (P_{in}, T_{in})	2	15
Design (P_d, T_d)	111	50
Hydrotest (P_t, T_t)	144	15

Pipeline properties

Nominal diameter		OD_{nom} =	20	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Max. OD deviation	$OD_{max,dev} = 0.35 \cdot d_{min}$	$OD_{max,dev}$ =	7.22	mm
Min. OD deviation	$OD_{min,dev} = 0.35 \cdot d_{min}$	$OD_{min,dev}$ =	7.22	mm
Max. ovalised diameter	$OD_{max} = OD_{nom} + 0.35 \cdot dmin$	OD_{max} =	515.217	mm
Min. ovalised diameter	$OD_{min} = OD_{nom} - 0.35 \cdot dmin$	OD_{min} =	500.783	mm
Initial ovalisation	$\delta_0 = \frac{OD_{max} - OD_{min}}{OD_{max} + OD_{min}}$	d_0 =	0.014	-
Cross sectional area of steel		A =	31572	mm^2
Moment of Inertia		I =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$ =	0	mm
Nominal wall thickness	$d_{nom,p}$ =	0.0	mm

Coating data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Project	**:**	**N05-A Pipeline design**
Project #	**:**	19018
Subject	**:**	Buckling and Collapse
File #	**:**	19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx
Client	**:**	ONE-Dyas
Client File #	**:**	19018-60-CAL-01003-09-01 - Buckling & Collapse calculations - 17m - hydrotest.xlsx

Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Material		=	L360NB	
Design temperature		T_d =	15	°C
Yield at ambient temperature		R_e =	360.00	N/mm^2
Yield at design temperature		R_{ed} =	360.00	N/mm^2
Density		ρ_{st} =	7850	kg/m^3
Youngs modulus		E_s =	210000	N/mm^2
Poisson's ratio		u =	0.3	-
Linear thermal expansion coefficient		a =	1.16E-05	$m/m/^oC$
Contents				
Sea water density			1025	kg/m^3
Pipeline product density			96.1	kg/m^3
Pipeline content density used for this case:	Hydrotest		1025	kg/m^3
Pipeline Weights				
Pipeline weight in air	$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$	$W_{pl,a}$ =	4195.8	N/m
Piggyback weight in air		$W_{pg,a}$ =	0.0	N/m
Buoyancy force pipeline	$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$	$F_{B,pl}$ =	2086.5	N/m
Buoyancy force piggyback		$F_{B,pb}$ =	0.0	N/m
Submerged pipeline weight,empty		$W_{pl,s,e}$ =	388.8	N/m
Submerged piggyback weight		$W_{pg,s}$ =	0.0	N/m
Total submerged bundle weight,empty		$W_{T,s,e}$ =	388.8	N/m
Total submerged bundle weight,water filled		$W_{T,s,f}$ =	2109.4	N/m
Soil				
Submerged density		ρ_{ss} =	1000	kg/m^3
Depth of burial		d_b =	0.80	m
Soil cover pressure	$SC_{pres} = r_{ss} \times d_b \times g$	SC_{pres} =	0.008	N/mm^2
Environmental conditions				
Water depths:				
Seawater density		ρ_{sw} =	1025	kg/m3
Maximum water depth		WD_{max} =	20.6	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (to be used for calculations)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.29	m LAT
Storm surge water level	SSWL = WD + ss	SSWL =	16.42	m LAT
Highest Astronomical Tide		HAT =	3.11	m
Waves (H_{max} & T_{max}):				
Maximum wave height, RP1 yr - installation/hydrotes		$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr		$T_{ass,1}$ =	8.9	s
Maximum wave height, RP100 yr - operational		$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr		$T_{ass,100}$ =	9.8	s

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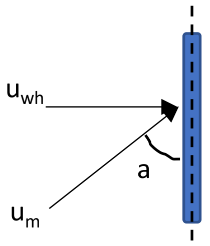
Originator	: EvW	Checked	:
Date	: 27/01/2020		
Revision	: 01		

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures") $\frac{H_{max}}{g \cdot T_z^2} =$ 0.0107

$\frac{SWL}{g \cdot T_z^2} =$ 0.0211

Wave theory selected:

1. Airy/linear wave; 2. Stokes 5th



Wave particle velocity from interpolated data

Maximum wave particle velocity	u_{wm} =	1.85	m/s
Angle of attack relative to pipeline axis	α_{uw} =	90	deg
Horizontal wave velocity ⊥ to P/L	u_{wh} =	1.85	m/s

Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s
Current velocity at reference height	U_{czr} =	0.82	m/s
Angle of attack relative to pipeline axis	α_{uc} =	90	deg
Horizontal current velocity ⊥ to P/L $\frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc}) =$	u_{ch} =	0.65	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Maximum absolute hydrodynamic force 1380 N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Collapse - external pressure only (K.3.3.5.1)

External implosion pipe collapse pressure (P_c) given by: $(p_c - p_e) \cdot (p_c^2 - p_p^2) = p_c \cdot p_e \cdot p_p \cdot 2 \cdot \delta_o \cdot \frac{OD_g}{d_{nom}}$

External elastical pipe collapse pressure (P_e): $P_e = \frac{2E_s}{1-\nu^2}(\frac{d_{nom}}{OD_{av}})^3 =$ 34.0 N/mm²

External plastic pipe collapse pressure (P_p) $P_p = \frac{2 R_e d_{nom}}{OD_{nom}} =$ 29.2 N/mm²

External implosion pipe collapse pressure (P_c): P_c = 16.0 N/mm²

Maximum water column above mudline (WC_{max}) $WC_{max} = WD_{max} + 0.5 \cdot H_{max,100} + HAT =$ 29.485 m
0.29485 N/mm²

Actual external pressure (P_L) $WC_{max} + SC_{pres} =$ 0.30 N/mm²

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
g_M =	0.93	-
$g_{m,p}$ =	1.45	-

Assessment: $\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$ = **OK**

Collapse - bending moment only (K.3.3.5.2)

Buckling bending moment (M_c) $M_c = D_g^2 d_n R_e$ = 1.8E+09 N·mm

Assessment: $\gamma_{g,M} \times M_L \leq \frac{\gamma_M \times M_c}{\gamma_{m,M}}$ **Where,**

Table 4 - NEN3656

$g_{g,M}$ =	1.1	-
g_M =	1	-
$g_{m,M}$ =	1.3	-

Maximum allowable bending moment ($M_{L,b}$) $M_{L,b}$ = 1.3E+09 N·mm
= 1.256E+06 N·m

Collapse - external pressure + bending moment only (K.3.3.5.3)

Assessment: $\frac{\gamma_{g,p} \times P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,M} \times M_L}{M_c / \gamma_{m,M}}\right)^n \leq \gamma_M$ **Where,**

Table 4 - NEN3656

$g_{g,p}$ =	1.05	-
$g_{g,M}$ =	1.55	-
$g_{m,p}$ =	1.25	-
$g_{m,M}$ =	1.15	-
g_M =	0.93	-

$n = 1 + 300 \cdot d_{nom} / OD_g$ n = 13.6 -

Maximum allowable bending moment ($M_{L,pb}$) $M_{L,pb}$ = 1.0E+09 N·mm
= 1.000E+06 N·m

Determination maximum span length due to bending only or bending & external pressure

Assessment: $M_{L,m} = \frac{q \cdot L^2}{10}$ **Where,**

q = load acting on pipe
L = span length

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Ws = submerged pipeline weight; Ws = 2109 N/m
$F_D + F_I$ = 1380 N/m

g_w =	1.1	-
g_h =	1.2	-

Table 3 - NEN3656

q = 2851 N/m

Maximum allowable bending moment ($M_{L,m}$) is smallest of $M_{L,b}$ and $M_{L,pb}$ $M_{L,m}$ = 1.000E+06 N·m

Maximum span length, L_{max} = 59.2 m

Progressive plastic collapse (K.3.3.6)

Assessment: $\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$

Temperature difference with ambient; DT = 11 -

R_e = 360.00 N/mm^2

R_{ed} = 360.00 N/mm^2

$$\sigma_p = \frac{p \cdot (OD_{nom} - d_{min})}{2 \cdot d_{min}}$$

s_p = 219.6 N/mm^2

$$\varepsilon_{max} = \alpha \times \Delta T \le \left[\frac{R_e(\theta)}{E} \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_p}{R_e(\theta)}\right)^2} + \frac{R_e}{E} \sqrt{0{,}9 - \frac{3}{4}\left(\frac{\sigma_p}{R_e}\right)^2} \right]$$

Assessment: 0.0001 < 0.0028 **OK**

Local buckling (K.3.3.3)

Assessment: $\frac{(OD_{nom} - d_{min})}{d_{nom}} < 55$: no check on local buckling required = 23.9 **OK**

Bar buckling:

Assessment: $L_{max,bb} = \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$

Effective axial force $N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$

$S_h = g_p \cdot s_h$ — Table 3 - NEN3656 - BC4

g_p = 1.15 -

g_t = 1.1 -

N = 1.46E+06 N

$L_{max,bb}$ = No compressive force m

C. Static and Dynamic Span Analysis

The following static and dynamic span analyses were performed:

- 19018-60-CAL-01004-01-01 Allowable free span (static & dynamic) calculations -26m
- 19018-60-CAL-01004-02-01 Allowable free span (static & dynamic) calculations -8m
- 19018-60-CAL-01004-03-01 Allowable free span (static & dynamic) calculations -17m

(25pages)

Project	**: N05-A Pipeline Design**	
Project #	: 19018	
Subject	: Static & Dynamic Span Analysis	
File #	: 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm	
Client	: ONE-Dyas	
Client File #	: 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm	

Originator	: EvW	Checked	: PF
Date	: 24/01/2020		
Revision	: 01		

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom} =	20"	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID =	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s =	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s =	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm
Piggyback				
Nominal diameter		$OD_{nom,p}$ =	0	mm
Nominal wall thickness		$d_{nom,p}$ =	0.0	mm

Coating and insulation data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient/hydrotest temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	m/m/°C

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

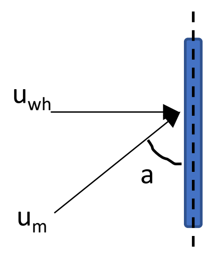
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	29.68	m LAT
Minimum water depth		WD_{min} =	26	m LAT
Other water depth (user input)		WD =	26	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-1.02	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-1.4	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.79	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	24.98	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	24.6	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	24.21	m LAT
Highest Astronomical Tide		HAT =	2.72	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	11.4	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	10.1	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	14.5	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	10.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	16.9	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	11.5	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0114	0.0124	0.0130
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0250	0.0211	0.0187
theory	Stokes	Stokes	Stokes
maximum wave particle velocity (u_{wm})	2.39	3.26	4.00
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	2.39	3.26	4.00



Current:

Height above seabed at which velocity is known	z* =	2	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.74	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.84	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	0.96	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ =	0.74	m/s
$U_{czr,10}$ =	0.84	m/s
$U_{czr,100}$ =	0.96	m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥ to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ =	0.532	m/s
$u_{cm,perp,10}$ =	0.604	m/s
$u_{cm,perp,100}$ =	0.691	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	1824	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	4175	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	3124	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Table 3 - NEN 3656 load factors

Load factor	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	3071	3193	5045	3796	N/m; $q=\sqrt{\gamma_W{}^2\cdot W_S{}^2+\gamma_H{}^2\cdot(F_D+F_I)^2}$
Pressure	2	144	111	111	barg
DT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression		
Hoop stress	4.4	4.4	4.4	4.4	N/mm^2	$\sigma_H=\frac{(\gamma i\cdot Pi-\gamma e\cdot Pe)\cdot(OD-d_{min})}{2\cdot d_{min}}$
Max. long. Stress	329.4	-325.1	329.4	-325.1	N/mm^2	$\sigma_{max.long.stress}=\frac{\sigma_H\pm\sqrt{-3\cdot\sigma_H^2+4\cdot\sigma_{allow}^2}}{2}$
Long. hoop stress	1.8	1.8	1.3	1.3	N/mm^2	$\sigma_{long.hoop.stress}=\nu\cdot\sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{thermal}=-\gamma_t\cdot\alpha\cdot E_s\cdot\Delta T$
Max. allow. bending stress	327.3	-326.8	327.3	-299.6	N/mm^2	$\sigma_{b,max}=\sigma_{max.long.stress}-\sigma_{lonh.hoop.stress}-\sigma_{thermal}$
Maximum span	62.8	62.7	62.8	60.1	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression	
Hoop stress	248.2	248.2	248.2	248.2	N/mm^2
Max. long. Stress	637.3	-389.1	637.3	-389.1	N/mm^2
Long. hoop stress	85.8	85.8	74.5	74.5	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.4	-474.9	556.4	-434.0	N/mm^2
Maximum span	79.9	74.2	80.3	70.9	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression	
Hoop stress	190.3	190.3	190.3	190.3	N/mm^2
Max. long. Stress	626.6	-436.2	626.6	-436.2	N/mm^2
Long. hoop stress	66.2	66.2	57.1	57.1	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-502.4	556.4	-370.1	N/mm^2
Maximum span	63.9	60.7	63.9	52.1	m

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	190.3	190.3	190.3	190.3	N/mm^2
Max. long. Stress	626.6	-436.2	626.6	-436.2	N/mm^2
Long. hoop stress	66.2	66.2	57.1	57.1	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-502.4	556.4	-370.1	N/mm^2
Maximum span	73.6	70.0	73.6	60.0	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \times \delta}{\rho_w \times D_o^2}$$

Where,

d = damping factor water: 0.02 x 2 x π	=	0.126	-
r_w = seawater density	=	1025	kg/m³
D_o = outer diameter (incl. coating)	=	514	mm
m = effective mass			
m = W_{bundle} + M_{added}			
$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$			
C_m = added mass coefficient	=	1.2	-
$D_{o,eq}$ = equivalent diameter (incl. coating)	=	514	mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

$v_{tot} = (v_{wave} + v_{cur}) \times (1 + f_{int})$; $f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:
Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$

if $1{,}0 \le V_r \le 3{,}5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

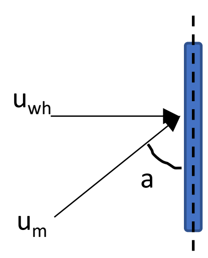
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	6.5	m
Associated wave period, RP1 yr	$T_{z,1}$ =	9.9	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	8.4	m
Associated wave period, RP10 yr	$T_{z,10}$ =	11.3	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	9.9	m
Associated wave period, RP100 yr	$T_{z,100}$ =	12.3	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0068	0.0067	0.0067
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0260	0.0196	0.0163
theory	Stokes	Stokes	Stokes
maximum wave particle velocity (u_{wm})	1.35	2.01	2.56
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	1.35	2.01	2.56



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.53	0.53	0.60	0.69	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.53	0.53	0.60	0.69	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.06	1.06	1.21	1.38	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.07	2.07	2.35	2.69	1/s
$L_{span,in}$	25.2	25.2	25.3	23.7	m

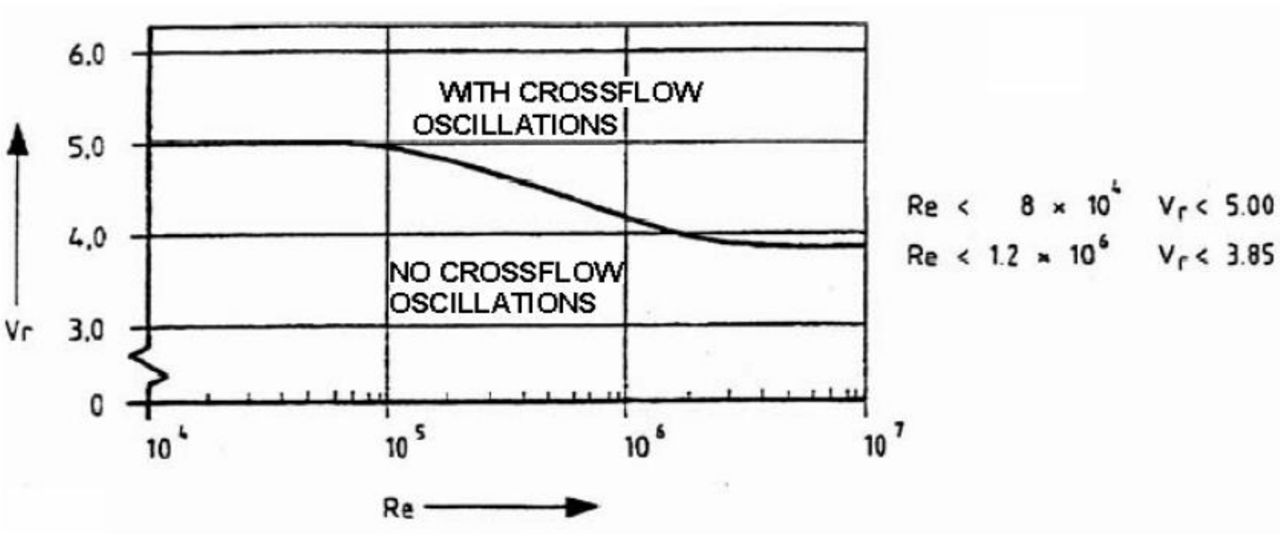
note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:

Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e)

$$R_e = \frac{v \cdot D_o}{\nu_d}$$

v = horizontal particle velocity (v_{tot})			
D_o = outer diameter (incl. coating)	=	514	mm
u_d = dynamic viscosity seawater	u_d =	4.99E-07	m^2/s
Vr is set to 3.85 as conservative value;	Vr =	3.85	-



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
u_{wh}	1.35	1.35	2.56	2.01	m/s
$u_{cm,perp}$	0.53	0.53	0.60	0.69	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.89	1.89	3.17	2.70	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	1.94E+06	1.94E+06	3.26E+06	2.78E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	0.95	0.95	1.60	1.36	1/s
$L_{span,cross}$	37.2	37.2	30.7	33.2	m

SUMMARY - SPAN ANALYSIS

	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
$L_{span,in}$	25.2	25.2	25.3	23.7	m
$L_{span,cross}$	37.2	37.2	30.7	33.2	m

Maximum Span Length = 23.7 m

Static & Dynamic Span - 10" x 12.7mm

Water depth	WD =	26	m (LAT)
Storm surge	ss =	-1.02	m
Storm surge water level	$SWL = WD + ss$ =	24.98	m
Wave height	H =	11.4	m
Wave period	T =	10.1	s
Grav. Acceleration	g =	9.81	m/s^2
Deep water wave length	$L_o = \frac{g \cdot T^2}{2 \cdot \pi}$ =	159.3	m

Solving for wave length (L) and λ

$$\frac{\pi \cdot H}{SWL} - \frac{L}{SWL}\left\{\lambda + \lambda^3 \cdot B_{33} + \lambda^5 \cdot (B_{35} + B_{55})\right\} = 0 \quad (\text{ I })$$

$$\frac{SWL}{L_O} - \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) \cdot \left\{1 + \lambda^2 \cdot C_1 + \lambda^4 \cdot C_2\right\} = 0 \quad (\text{ II })$$

Choosing L and solving for λ in (II) results in 4 roots for λ

Estimate actual wave length, L **143.109** **m**

$$A = SWL / L_O = 0.1568$$

$$B = \frac{SWL}{L} \cdot \tanh\left(\frac{2 \cdot \pi \cdot SWL}{L}\right) = 0.1395$$

$$\lambda = \pm\sqrt{X}$$

$$X = \frac{-C_1 \cdot B \pm \sqrt{D}}{2 \cdot C_2 \cdot B}$$

$$D = (C_1 \cdot B)^2 - 4 \cdot (C_2 \cdot B) \cdot (-(A - B)) = 0.1583$$

	-	eq. (I)	eq. (II)
λ1	0.228	-0.0006	0.0000
λ2	Numerator of X < 0		
λ3	-0.228	2.8680	0.0000
λ4	Numerator of X < 0		

Item	Formula	Value	Unit
s	$s = \sinh\left(\frac{2\cdot\pi\cdot WL}{L}\right) =$	1.3302	-
c	$c = \cosh\left(\frac{2\cdot\pi\cdot WL}{L}\right) =$	1.6642	-
A11	$A_{11} = \frac{1}{s} =$	0.7518	-
A13	$A_{13} = \frac{-c^2\cdot(5\cdot c^2+1)}{8\cdot s^5} =$	-1.2341	-
	$A_{15} = -\frac{1184\cdot c^{10} - 1440\cdot c^8 - 1992\cdot c^6 + 2641\cdot c^4 - 249\cdot c^2 + 18}{1536\cdot s^{11}} =$	-2.4111	-
A22	$A_{22} = \frac{3}{8\cdot s^4} =$	0.1198	-
A24	$A_{24} = \frac{192\cdot c^8 - 424\cdot c^6 - 312\cdot c^4 + 480\cdot c^2 - 17}{768\cdot s^{10}} =$	0.0907	-
A33	$A_{33} = \frac{13 - 4\cdot c^2}{64\cdot s^7} =$	0.0041	-
	$A_{35} = \frac{512\cdot c^{12} + 4224\cdot c^{10} - 6800\cdot c^8 - 12808\cdot c^6 + 16704\cdot c^4 - 3154\cdot c^2 - 107}{4096\cdot s^{13}\cdot(6\cdot c^2 - 1)} =$	0.1403	-
A44	$A_{44} = \frac{80\cdot c^6 - 816\cdot c^4 + 1338\cdot c^2 - 197}{1536\cdot s^{10}\cdot(6\cdot c^2 - 1)} =$	-0.0025	-

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$$A_{55} = -\frac{2880\cdot c^{10} - 72480\cdot c^{8} + 324000\cdot c^{6} - 432000\cdot c^{4} + 163470\cdot c^{2} - 16245}{61440\cdot s^{11}\cdot (6\cdot c^{2} - 1)\cdot (8\cdot c^{4} - 11\cdot c^{2} + 3)} =$$ -0.0003 -

B22 $$B_{22} = \frac{(2\cdot c^{2} + 1)\cdot c}{4\cdot s^{3}} =$$ 1.1558 -

B24 $$B_{24} = \frac{c\cdot (272\cdot c^{8} - 504\cdot c^{6} - 192\cdot c^{4} + 322\cdot c^{2} + 21)}{384\cdot s^{9}} =$$ 1.5738 -

B33 $$B_{33} = \frac{3\cdot (8\cdot c^{6} + 1)}{64\cdot s^{6}} =$$ 1.4462 -

$$B_{35} = \frac{88128\cdot c^{14} - 208224\cdot c^{12} + 70848\cdot c^{10} + 54000\cdot c^{8} - 21816\cdot c^{6} + 6264\cdot c^{4} - 54\cdot c^{2} - 81}{12288\cdot s^{12}\cdot (6\cdot c^{2} - 1)} =$$

= 5.1741 -

B44 $$B_{44} = c\cdot \frac{768\cdot c^{10} - 488\cdot c^{8} - 48\cdot c^{6} + 48\cdot c^{4} + 106\cdot c^{2} - 21}{384\cdot s^{9}\cdot (6\cdot c^{2} - 1)} =$$ 2.0437 -

$$B_{55} = \frac{192000\cdot c^{16} - 26720\cdot c^{14} + 83680\cdot c^{12} + 20160\cdot c^{10} - 7280\cdot c^{8} + 7160\cdot c^{6} - 1800\cdot c^{4} - 1050\cdot c^{2} + 225}{12288\cdot s^{10}\cdot (8\cdot c^{4} - 11\cdot c^{2} + 3)\cdot (6\cdot c^{2} - 1)} =$$

= 3.3404 -

C1 $$C_{1} = \frac{8\cdot c^{4} - 8\cdot c^{2} + 9}{8\cdot s^{4}} =$$ 1.9244 -

$$C_{2} = \frac{3840\cdot c^{12} - 4096\cdot c^{10} + 2592\cdot c^{8} - 1008\cdot c^{6} + 5944\cdot c^{4} - 1830\cdot c^{2} + 147}{512\cdot s^{10}\cdot (6\cdot c^{2} - 1)} =$$ 8.9186 -

C3 $$C_{3} = -\frac{1}{4\cdot c\cdot s} =$$ -0.1129 -

C4 $$C_{4} = \frac{12\cdot c^{8} + 36\cdot c^{6} - 162\cdot c^{4} + 141\cdot c^{2} - 27}{192\cdot c\cdot s^{9}} =$$ 0.1420 -

K1 $$K_{1} = \lambda\cdot A_{11} + \lambda^{3}\cdot A_{13} + \lambda^{5}\cdot A_{15} =$$ 0.1553 -

K2	$K_2 = \lambda^2 \cdot A_{22} + \lambda^4 \cdot A_{24} =$	0.0065	-
K3	$K_3 = \lambda^3 \cdot A_{33} + \lambda^5 \cdot A_{35} =$	0.0001	-
K4	$K_4 = \lambda^4 \cdot A_{44} =$	0.0000	-
K5	$K_5 = \lambda^5 \cdot A_{55} =$	0.0000	-

Horizontal wave particle velocities

Water depth at which data required, z (w.r.t. seabed) 0.5080 m

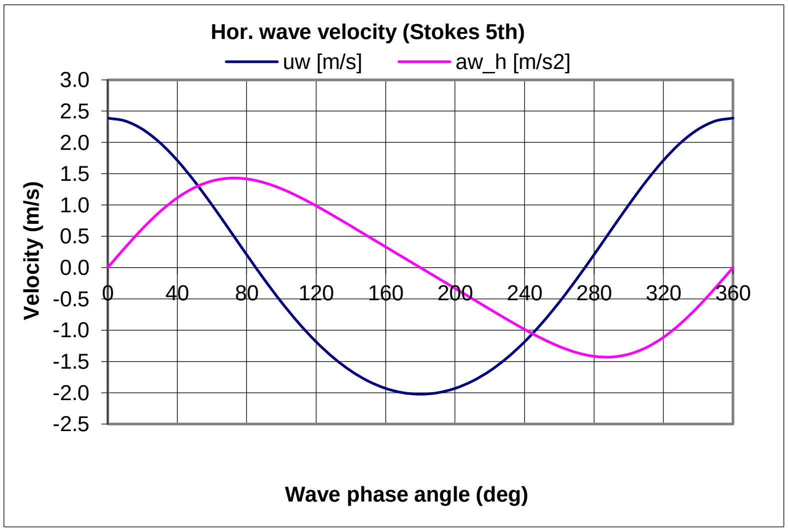
Horizontal velocity, u_w

$$u_w = \frac{L}{T} \cdot \sum_{n=1}^{5} n \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \cos(n \cdot \varphi)$$

Horizontal acceleration, $a_{w,h}$

$$a_{w,h} = \frac{2 \cdot \pi \cdot L}{T^2} \cdot \sum_{n=1}^{5} n^2 \cdot K_n \cdot \cosh\left(n \cdot \frac{2 \cdot \pi}{L} \cdot z\right) \cdot \sin(n \cdot \varphi)$$

ϕ [deg.]	uw [m/s]	aw_h [m/s^2]
0.00	2.3895	0.0000
10.00	2.3444	0.3205
20.00	2.2113	0.6233
30.00	1.9978	0.8921
40.00	1.7152	1.1138
50.00	1.3781	1.2793
60.00	1.0030	1.3842
70.00	0.6070	1.4288
80.00	0.2065	1.4177
90.00	-0.1839	1.3583
100.00	-0.5520	1.2602
110.00	-0.8883	1.1334
120.00	-1.1862	0.9871
130.00	-1.4411	0.8289
140.00	-1.6507	0.6647
150.00	-1.8139	0.4983
160.00	-1.9303	0.3317
170.00	-2.0000	0.1656
180.00	-2.0233	0.0000
190.00	-2.0000	-0.1656
200.00	-1.9303	-0.3317



210.00	-1.8139	-0.4983
220.00	-1.6507	-0.6647
230.00	-1.4411	-0.8289
240.00	-1.1862	-0.9871
250.00	-0.8883	-1.1334
260.00	-0.5520	-1.2602
270.00	-0.1839	-1.3583
280.00	0.2065	-1.4177
290.00	0.6070	-1.4288
300.00	1.0030	-1.3842
310.00	1.3781	-1.2793
320.00	1.7152	-1.1138
330.00	1.9978	-0.8921
340.00	2.2113	-0.6233
350.00	2.3444	-0.3205
360.00	2.3895	0.0000

U_{wm} = max. wave particle velocity = 2.39 m/s

Project : **N05-A Pipeline Design**
Project # : 19018
Subject : Static & Dynamic Span Analysis
File # : 19018-60-CAL-01004-01-01 - Allowable free span (static & dynamic) calculations - 26m.xlsm

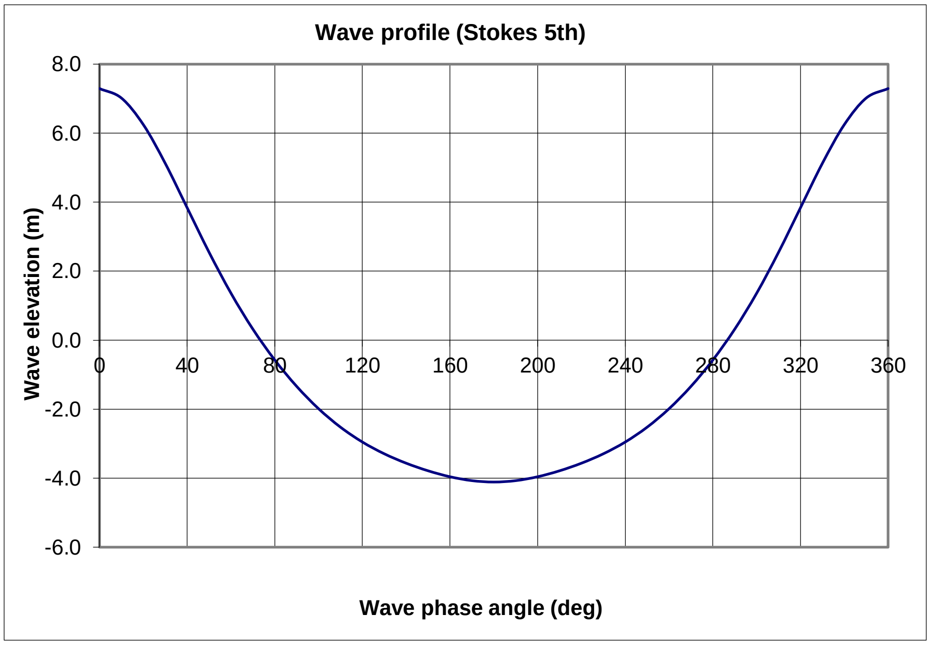
Client : ONE-Dyas
Client File # :

Originator	: EvW	Checked	: PF
Date	: 24/01/2020		
Revision	: 01		

Wave profile h(t)

$$\eta(t)=\frac{L}{2\cdot\pi}\left\{\lambda\cdot\cos(\varphi)+\left(\lambda^2\cdot B_{22}+\lambda^4\cdot B_{24}\right)\cdot\cos(2\varphi)+\left(\lambda^3\cdot B_{33}+\lambda^5\cdot B_{35}\right)\cdot\cos(3\varphi)+\lambda^4\cdot B_{44}\cdot\cos(4\varphi)+\lambda^5\cdot B_{55}\cdot\cos(5\varphi)\right\}$$

ϕ (deg.)	η(t) (m)
0.00	7.2930
10.00	7.0176
20.00	6.2468
30.00	5.1259
40.00	3.8385
50.00	2.5483
60.00	1.3614
70.00	0.3208
80.00	-0.5742
90.00	-1.3393
100.00	-1.9865
110.00	-2.5217
120.00	-2.9522
130.00	-3.2934
140.00	-3.5660
150.00	-3.7866
160.00	-3.9586
170.00	-4.0716
180.00	-4.1115
190.00	-4.0716
200.00	-3.9586
210.00	-3.7866
220.00	-3.5660
230.00	-3.2934
240.00	-2.9522
250.00	-2.5217
260.00	-1.9865
270.00	-1.3393
280.00	-0.5742
290.00	0.3208
300.00	1.3614
310.00	2.5483
320.00	3.8385
330.00	5.1259
340.00	6.2468
350.00	7.0176
360.00	7.2930



Project	: **N05-A Pipeline Design**	
Project #	: 19018	
Subject	: Static & Dynamic Span Analysis	
File #	: 19018-60-CAL-01004-02-01 - Allowable free span (static & dynamic) calculations - 8m.xlsm	
Client	: ONE-Dyas	
Client File #	: 19018-60-CAL-01004-02-01 - Allowable free span (static & dynamic) calculations - 8m.xlsm	

Originator	: EvW	Checked	: PF
Date	: 27/01/2020		
Revision	: 01		

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom} =	20"	
Nominal diameter		OD_{nom} =	508	mm
Nominal wall thickness		d_{nom} =	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID =	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s =	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s =	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s =	939135656	mm^4
Corrosion allowance		CA =	3	mm
Fabrication Tolerance		f_{tol} =	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min} =	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g =	491.9	mm
Piggyback				
Nominal diameter		$OD_{nom,p}$ =	0	mm
Nominal wall thickness		$d_{nom,p}$ =	0.0	mm

Coating and insulation data

Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g =	9.81	m/s^2

Material

	=	L360NB	
Design temperature	T_d =	50	°C
Yield at ambient/hydrotest temperature	R_e =	360.00	N/mm^2
Yield at design temperature	R_{ed} =	360.00	N/mm^2
Density	ρ_{st} =	7850	kg/m3
Youngs modulus	E_s =	210000	N/mm^2
Poisson's ratio	u =	0.3	-
Linear thermal expansion coefficient	a =	1.16E-05	m/m/°C

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

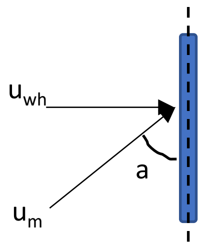
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	11.5	m LAT
Minimum water depth		WD_{min} =	8	m LAT
Other water depth (user input)		WD =	8	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.14	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-0.46	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-0.78	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	7.86	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	7.54	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	7.22	m LAT
Highest Astronomical Tide		HAT =	3.5	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	5.2	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	7.7	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	5.7	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	7.9	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	6.2	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	8.1	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0089	0.0093	0.0096
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0135	0.0123	0.0112
theory	Wave particle velocity directly from metocean data		
maximum wave particle velocity (u_{wm})	1.30	1.50	1.60
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	1.30	1.50	1.60



Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.89	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	1	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.12	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ =	0.89	m/s
$U_{czr,10}$ =	1	m/s
$U_{czr,100}$ =	1.12	m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ =	0.707	m/s
$u_{cm,perp,10}$ =	0.794	m/s
$u_{cm,perp,100}$ =	0.890	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	891	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	1269	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	1264	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Project	**: N05-A Pipeline Design**		
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Originator	: EvW	Checked	: PF
Date	: 27/01/2020		
Revision	: 01		

Table 3 - NEN 3656 load factors

Load factor	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	2523	2559	1635	1629	N/m; $q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$
Pressure	2	144	111	111	barg
DT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe		Restrained pipe			
	tension	compression	tension	compression		
Hoop stress	1.3	1.3	1.3	1.3	N/mm^2	$\sigma_H = \frac{(\gamma i \cdot Pi - \gamma e \cdot Pe) \cdot (OD - d_{min})}{2 \cdot d_{min}}$
Max. long. Stress	327.9	-326.6	327.9	-326.6	N/mm^2	$\sigma_{max.long.stress} = \frac{\sigma_H \pm \sqrt{-3 \cdot \sigma_H^2 + 4 \cdot \sigma_{allow}^2}}{2}$
Long. hoop stress	0.7	0.7	0.4	0.4	N/mm^2	$\sigma_{long.hoop.stress} = \nu \cdot \sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{thermal} = -\gamma_t \cdot \alpha \cdot E_s \cdot \Delta T$
Max. allow. bending stress	327.3	327.3	327.3	-300.2	N/mm^2	$\sigma_{b,max} = \sigma_{max.long.stress} - \sigma_{lonh.hoop.stress} - \sigma_{thermal}$
Maximum span	69.3	69.3	69.3	66.3	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	251.2	251.2	251.2	251.2	N/mm^2
Max. long. Stress	637.7	-386.4	637.7	-386.4	N/mm^2
Long. hoop stress	85.8	85.8	75.4	75.4	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.8	-472.3	556.4	-432.3	N/mm^2
Maximum span	89.3	82.6	89.7	79.0	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	193.3	193.3	193.3	193.3	N/mm^2
Max. long. Stress	627.2	-433.9	627.2	-433.9	N/mm^2
Long. hoop stress	66.2	66.2	58.0	58.0	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-500.1	556.4	-368.6	N/mm^2
Maximum span	112.2	106.4	112.2	91.3	m

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	193.3	193.3	193.3	193.3	N/mm^2
Max. long. Stress	627.2	-433.9	627.2	-433.9	N/mm^2
Long. hoop stress	66.2	66.2	58.0	58.0	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-500.1	556.4	-368.6	N/mm^2
Maximum span	112.4	106.5	112.4	91.5	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \text{ x } \delta}{\rho_w \text{ x } D_o^2}$$

Where,

d = damping factor water: 0.02 x 2 x π	=	0.126	-
r_w = seawater density	=	1025	kg/m³
D_o = outer diameter (incl. coating)	=	514	mm
m = effective mass			
m = W_{bundle} + M_{added}			
$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$			
C_m = added mass coefficient	=	1.2	-
$D_{o,eq}$ = equivalent diameter (incl. coating)	=	514	mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

$v_{tot} = (v_{wave} + v_{cur}) \times (1 + f_{int})$; $f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:

Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$ if $1,0 \le V_r \le 3,5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

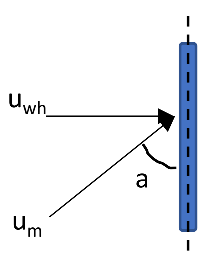
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	3.9	m
Associated wave period, RP1 yr	$T_{z,1}$ =	6.4	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	4.1	m
Associated wave period, RP10 yr	$T_{z,10}$ =	6.5	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	4.2	m
Associated wave period, RP100 yr	$T_{z,100}$ =	6.6	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0097	0.0099	0.0098
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0196	0.0182	0.0169
theory	Wave particle velocity directly from metocean data		
maximum wave particle velocity (u_{wm})	1.30	1.50	1.60
angle of attack relative to P/L axis (a)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.30	1.50	1.60



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.71	0.71	0.79	0.89	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.71	0.71	0.79	0.89	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.41	1.41	1.59	1.78	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.75	2.75	3.09	3.46	1/s
$L_{span,in}$	21.9	21.9	22.1	20.9	m

note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:

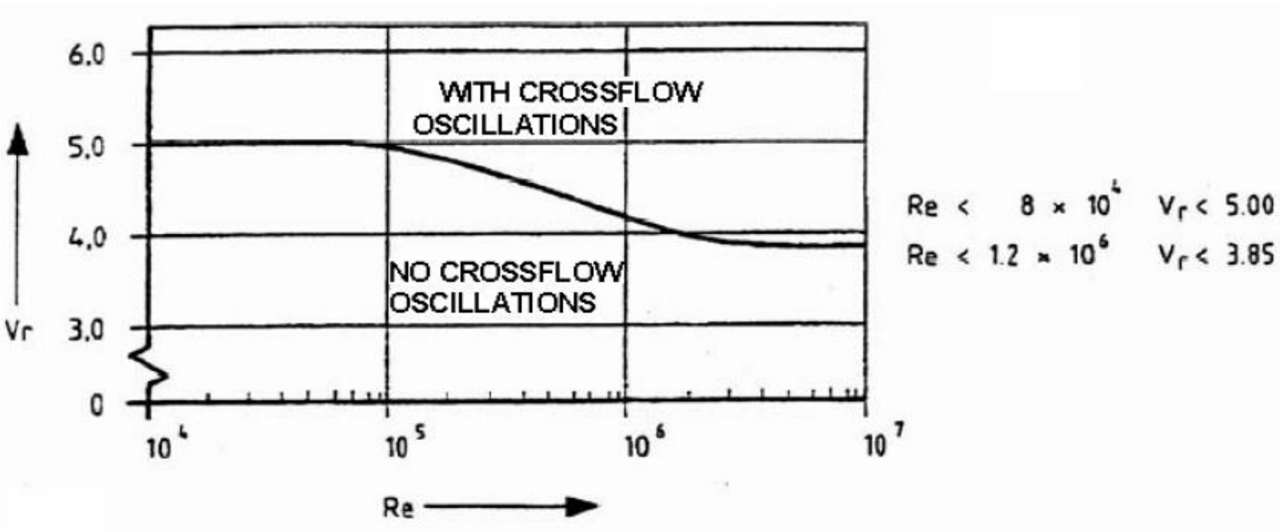
Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e) $R_e = \frac{v \cdot D_o}{v_d}$

v = horizontal particle velocity (v_{tot})

D_o = outer diameter (incl. coating) = 514 mm

u_d = dynamic viscosity seawater u_d = 4.99E-07 m^2/s

Vr is set to 3.85 as conservative value; Vr = 3.85 -



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
u_{wh}	1.30	1.30	1.60	1.50	m/s
$u_{cm,perp}$	0.71	0.71	0.79	0.89	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	2.01	2.01	2.39	2.39	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	2.07E+06	2.07E+06	2.47E+06	2.46E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	1.01	1.01	1.21	1.21	1/s
$L_{span,cross}$	36.0	36.0	35.3	35.3	m

SUMMARY - SPAN ANALYSIS

	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
$L_{span,in}$	21.9	21.9	22.1	20.9	m
$L_{span,cross}$	36.0	36.0	35.3	35.3	m

Maximum Span Length = 20.9 m

Static & Dynamic Span - 20" x 20.62 mm

Condition Overview

	Pressure (barg)	Temp. (deg. C)	Content (kg/m3)
Installation (P_{in}, T_{in})	2	15	1025
Hydrotest (P_t, T_t)	144	15	1025
Design (P_d, T_d)	111	50	88.7

Pipeline properties

Nominal diameter		OD_{nom}	=	20"	
Nominal diameter		OD_{nom}	=	508	mm
Nominal wall thickness		d_{nom}	=	20.62	mm
Internal diameter	$ID = OD_{nom} - 2 \cdot d_{nom}$	ID	=	466.76	mm
Cross sectional area of steel	$A_s = \frac{\pi}{4} \cdot \{OD_{nom}^2 - ID^2\}$	A_s	=	31572	mm^2
Section modulus	$W_s = \frac{\pi}{32} \cdot \frac{\{OD_{nom}^4 - ID^4\}}{OD_{nom}}$	W_s	=	3697384	mm^3
Moment of Inertia	$I_s = \frac{\pi}{64} \cdot \{OD_{nom}^4 - ID^4\}$	I_s	=	939135656	mm^4
Corrosion allowance		CA	=	3	mm
Fabrication Tolerance		f_{tol}	=	7.25	%
Minimum wall thickness	$d_{min} = d_{nom} \cdot \{1 - f_{tol}\} - CA$	d_{min}	=	16.1	mm
Average pipe diameter	$OD_g = 1/2 \cdot \{OD_{nom} + (OD_{nom} - 2 \cdot t_{min})\}$	OD_g	=	491.9	mm

Piggyback

Nominal diameter	$OD_{nom,p}$	=	0	mm
Nominal wall thickness	$d_{nom,p}$	=	0.0	mm

Coating and insulation data

		Value	Unit
Thickness line pipe	=	3	mm
Thickness piggyback	=	0	mm
Density	=	930	kg/m^3

Constants

gravitational acceleration	g	=	9.81	m/s^2

Material

		=	L360NB	
Design temperature	T_d	=	50	°C
Yield at ambient/hydrotest temperature	R_e	=	360.00	N/mm^2
Yield at design temperature	R_{ed}	=	360.00	N/mm^2
Density	ρ_{st}	=	7850	kg/m3
Youngs modulus	E_s	=	210000	N/mm^2
Poisson's ratio	υ	=	0.3	-
Linear thermal expansion coefficient	α	=	1.16E-05	m/m/°C

Weights

		installation (N/m)	hydrotest (N/m)	operation (N/m)
air	line pipe	2431.3	2431.3	2431.3
	content	1720.6	1720.6	148.9
	coating	43.9	43.9	43.9
	piggyback	0.0	0.0	0.0
	coating pb	0.0	0.0	0.0
buoyancy	line pipe	2086.5	2086.5	2086.5
	piggyback	0.0	0.0	0.0

$$W_{pipe} = \{A_s \cdot \rho_s + A_{coat} \cdot \rho_{coat} + A_{inside} \cdot \rho_{content}\} \cdot g$$

$$F_b = \frac{\pi}{4} \cdot OD_{tot}^2 \cdot \rho_{seawater} \cdot g$$

Static & Dynamic span to be checked for the following environmental load combinations

Condition	Wave velocity	Current velocity	Comment
Installation	$H_{max,1yr}$	1 yr	
Hydrotest	$H_{max,1yr}$	1 yr	
Operational	$H_{max,100yr}$	10 yr	LC1
	$H_{max,10yr}$	100 yr	LC2

Environmental conditions

Water depths:

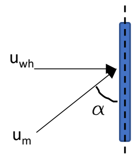
Seawater density		ρ_{sw} =	1025	kg/m³
Maximum water depth		WD_{max} =	20.59	m LAT
Minimum water depth		WD_{min} =	17	m LAT
Other water depth (user input)		WD =	17	m LAT
Storm surge, RP1 yr		ss_{1yr} =	-0.58	m LAT
Storm surge, RP10 yr		ss_{10yr} =	-0.93	m LAT
Storm surge, RP100 yr		ss_{100yr} =	-1.285	m LAT
Storm surge water level, RP1 yr	$SSWL_{1yr} = WD + ss_{1yr}$	$SSWL_{1yr}$ =	16.42	m LAT
Storm surge water level, RP10 yr	$SSWL_{10yr} = WD + ss_{10yr}$	$SSWL_{10yr}$ =	16.07	m LAT
Storm surge water level, RP100 yr	$SSWL_{100yr} = WD + ss_{100yr}$	$SSWL_{100yr}$ =	15.715	m LAT
Highest Astronomical Tide		HAT =	3.11	m

Waves (H_{max} & T_{max}):

Maximum wave height, RP1 yr - installation/hydrotest	$H_{max,1}$ =	8.3	m
Associated maximum wave period, RP1 yr	$T_{ass,1}$ =	8.9	s
Maximum wave height, RP10 yr - operational	$H_{max,10}$ =	10.1	m
Associated maximum wave period, RP10 yr	$T_{ass,10}$ =	9.4	s
Maximum wave height, RP100 yr - operational	$H_{max,100}$ =	11.55	m
Associated maximum wave period, RP100 yr	$T_{ass,100}$ =	9.8	s

Applied wave theory (per fig. 6.36 "Dynamics of Fixed Marine Structures")

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0107	0.0117	0.0123
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0211	0.0185	0.0167
theory	interpolation between data of 8 and 26m water depth		
maximum wave particle velocity (u_{wm})	1.85	2.38	2.80
angle of attack relative to P/L axis (α)	90	90	90
horizontal wave velocity ⊥ to P/L (u_{wh})	1.85	2.38	2.80



Current:

Height above seabed at which velocity is known	z* =	1	m
Spring tide	u_{st} =	0	m/s
Storm surge, RP1 yr	$u_{ss,1}$ =	0.82	m/s
Storm surge, RP10 yr	$u_{ss,10}$ =	0.92	m/s
Storm surge, RP100 yr	$u_{ss,100}$ =	1.04	m/s

Current velocity at reference height: $U_{czr} = u_{st} + u_{ss}$

$U_{czr,1}$ =	0.82	m/s
$U_{czr,10}$ =	0.92	m/s
$U_{czr,100}$ =	1.04	m/s

Angle of attack relative to pipeline axis α_{uc} = 90 deg

Horizontal current velocity ⊥ to P/L:

$$u_{cm,perp} = \frac{7}{8} \cdot U_{czr} \cdot \left(\frac{OD_{nom}}{z_r}\right)^{1/7} \cdot \sin(\alpha_{uc})$$

$u_{cm,perp,1}$ =	0.647	m/s
$u_{cm,perp,10}$ =	0.731	m/s
$u_{cm,perp,100}$ =	0.826	m/s

Hydrodynamic coefficients:

Drag coefficient	C_D =	0.7	-
Lift coefficient	C_L =	0.9	-
Inertia coefficient	C_I =	3.29	-

Hydrodunamic forces:

Maximum absolute hydrodynamic force (F_D+F_I), RP1 yr (installation/hydrotest condition)	1392	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP100/10 yr (LC 1 operational condition)	2976	N/m
Maximum absolute hydrodynamic force (F_D+F_I), RP10/100 yr (LC 2operational condition)	2360	N/m

Temperatures:

Ambient temperature T_{amb} = 4 deg. C

Table 3 - NEN 3656 load factors

Load factor	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
Self weight & content	1.1	1.1	1.1	1.1	
Coating	1.2	1.2	1.2	1.2	
Marine growth	0	0	1.2	1.2	
Internal pressure	0	1.15	1.15	1.15	
external pressure	1.1	1.1	1.1	1.1	
temperature	1	1.1	1.1	1.1	
environmental load	1.1	1.2	1.2	1.2	
Pipe bundle weight in air	4619.8	4619.8	2891.0	2891.0	N/m; incl. load factors
Submerged bundle weight, Ws	2324.7	2324.7	595.9	595.9	N/m; incl. load factors
Factored load acting on pipe, q	2784	2863	3621	2894	N/m; $q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$
Pressure	2	144	111	111	barg
ΔT	11	11	46	46	deg. C
Material factor (table 3; D3.1)	1.1	1.1	1.1	1.1	
Allowable stress (table 3; D3.1)	327.3	556.4	556.4	556.4	N/mm^2

STATIC SPAN LENGTH - INSTALLATION

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression		
Hoop stress	2.9	2.9	2.9	2.9	N/mm^2	$\sigma_H = \frac{(\gamma i \cdot Pi - \gamma e \cdot Pe) \cdot (OD - d_{min})}{2 \cdot d_{min}}$
Max. long. Stress	328.7	-325.8	328.7	-325.8	N/mm^2	$\sigma_{max.long.stress} = \frac{\sigma_H \pm \sqrt{-3 \cdot \sigma_H^2 + 4 \cdot \sigma_{allow}^2}}{2}$
Long. hoop stress	1.2	1.2	0.9	0.9	N/mm^2	$\sigma_{long.hoop.stress} = \nu \cdot \sigma_H$
Thermal exp. stress	n/a	n/a	-26.8	-26.8	N/mm^2	$\sigma_{thermal} = -\gamma_t \cdot \alpha \cdot E_s \cdot \Delta T$
Max. allow. bending stress	327.3	-327.1	327.3	-299.9	N/mm^2	$\sigma_{b,max} = \sigma_{max.long.stress} - \sigma_{lonh.hoop.stress} - \sigma_{thermal}$
Maximum span	65.9	65.9	65.9	63.1	m	

STATIC SPAN LENGTH - HYDROTEST

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression	
Hoop stress	249.7	249.7	249.7	249.7	N/mm^2
Max. long. Stress	637.5	-387.8	637.5	-387.8	N/mm^2
Long. hoop stress	85.8	85.8	74.9	74.9	N/mm^2
Thermal exp. stress	n/a	n/a	-29.5	-29.5	N/mm^2
Max. allow. bending stress	551.6	-473.6	556.4	-433.2	N/mm^2
Maximum span	84.4	78.2	84.8	74.8	m

STATIC SPAN LENGTH - OPERATION LC1

	Unrestrained pipe tension	Unrestrained pipe compression	Restrained pipe tension	Restrained pipe compression	
Hoop stress	191.8	191.8	191.8	191.8	N/mm^2
Max. long. Stress	626.9	-435.1	626.9	-435.1	N/mm^2
Long. hoop stress	66.2	66.2	57.6	57.6	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-501.2	556.4	-369.4	N/mm^2
Maximum span	75.4	71.5	75.4	61.4	m

STATIC SPAN LENGTH - OPERATION LC2

	Unrestrained pipe		Restrained pipe		
	tension	compression	tension	compression	
Hoop stress	191.8	191.8	191.8	191.8	N/mm^2
Max. long. Stress	626.9	-435.1	626.9	-435.1	N/mm^2
Long. hoop stress	66.2	66.2	57.6	57.6	N/mm^2
Thermal exp. stress	n/a	n/a	-123.3	-123.3	N/mm^2
Max. allow. bending stress	556.4	-501.2	556.4	-369.4	N/mm^2
Maximum span	84.3	80.0	84.3	68.7	m

DYNAMIC SPAN ANALYSIS (NEN 3656 - I.5.2.5)

Assessment Stability parameter, Ks < 1.8 => in-line vibration
Stability parameter, Ks < 16 => cross flow vibration

$$K_s = \frac{2m \text{ x } \delta}{\rho_w \text{ x } D_o^2}$$

Where,

δ = damping factor water: 0.02 x 2 x π	=	0.126	-
ρ_w = seawater density	=	1025	kg/m³
D_o = outer diameter (incl. coating)	=	514	mm

m = effective mass

m = W_{bundle} + M_{added}

$$M_{added} = \frac{\pi}{4} \cdot C_m \cdot \rho_w \cdot D_{o,eq}^2$$

C_m = added mass coefficient	=	1.2	-
$D_{o,eq}$ = equivalent diameter (incl. coating)	=	514	mm

Due to the presense of 2 objects attached to eachother, velocity flow intensification occurs:

v_{tot} = (v_{wave} + v_{cur}) x (1 + f_{int}); $f_{int} = \left\{1 + \left(\frac{D_{ob}^2}{4 \cdot CL^2}\right)\right\}$

Where,
D_{ob} = diameter of obstruction
CL = centerline distance P/L - obstruction

IN-LINE VIV:

Given the stability factor (Ks), the horizontal particle velocity (v), possibly including vicinity factor and the reduced velocity (Vr), the first eigen frequency (f1) can be determined prior to vibration occurring.

Reduced velocity, Vr, based on NEN 3656 I.5.2.5.2

$$V_r = \frac{v}{f_1 \times D_o}$$

if $1,0 \leq V_r \leq 3,5$ then oscillation occurs => Vr<1,0 design criterium

Vr is set to 1 as conservative value; Vr = 1.0 -

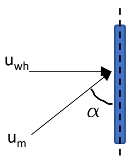
$$f_1 = \frac{a}{2\pi}\sqrt{\frac{E \times I}{m \times L^4}}$$

Where,
a = frequency factor (22 for fixed/fixed; 9.87 for pinned/pinned)
a = 15.4 for fixed/pinned a = 15.4 -

Waves (Hs & Tz):

Significant wave height, RP1 yr - installation/hydrotest	$H_{s,1}$ =	5.2	m
Associated wave period, RP1 yr	$T_{z,1}$ =	8.2	s
Significant wave height, RP10 yr - operational	$H_{s,10}$ =	6.25	m
Associated wave period, RP10 yr	$T_{z,10}$ =	8.9	s
Significant wave height, RP100 yr - operational	$H_{s,100}$ =	7.05	m
Associated wave period, RP100 yr	$T_{z,100}$ =	9.45	s

	1 yr	10 yr	100 yr
$\frac{H}{g \cdot T_{ass}^2}$	0.0080	0.0080	0.0080
$\frac{SWL}{g \cdot T_{ass}^2}$	0.0252	0.0207	0.0179
theory	interpolation between data of 8 and 26m water depth		
maximum wave particle velocity (u_{wm})	1.33	1.76	2.08
angle of attack relative to P/L axis (α)	90	90	90
horizontal wave velocity⊥ to P/L (u_{wh})	1.33	1.76	2.08

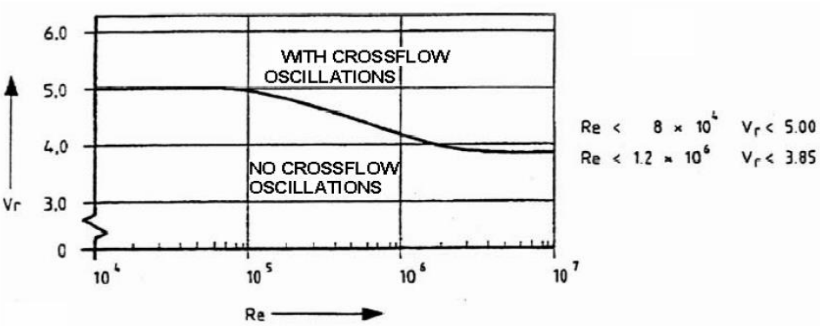


	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
effective mass	682.9	682.9	522.7	522.7	kg/m
K_s	0.63	0.63	0.49	0.49	-
In-line VIV	yes	yes	yes	yes	-
cross flow VIV	yes	yes	yes	yes	-
Vr	1.00	1.00	1.00	1.00	-
u_{wh}	0.65	0.65	0.73	0.83	m/s, set equal to Ucm, for velocity ratio 0.5
$u_{cm,perp}$	0.65	0.65	0.73	0.83	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.29	1.29	1.46	1.65	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
f1	2.52	2.52	2.84	3.21	1/s
$L_{span,in}$	22.9	22.9	23.0	21.6	m

note: f_{int} is taken into account for 50% as system doesn't instantaneously respond and vortices occur in a relatively steady state environment, which this isn't.

CROSS FLOW VIV:
Oscillation area for cross flow is given by the figure below and depends on the Reynolds number (R_e) $R_e = \frac{v \cdot D_o}{\nu_d}$

v = horizontal particle velocity (v_{tot})
D_o = outer diameter (incl. coating) = 514 mm
ν_d = dynamic viscosity seawater ν_d = 4.99E-07 m^2/s
Vr is set to 3.85 as conservative value; Vr = 3.85 -



	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
u_{wh}	1.33	1.33	2.08	1.76	m/s
$u_{cm,perp}$	0.65	0.65	0.73	0.83	m/s
D_{ob}	0.0	0.0	0.0	0.0	mm
CL	294.0	294.0	294.0	294.0	mm
f_{int}	0.000	0.000	0.000	0.000	-
$(u_{wh} + u_{cm,perp}) \times (1+0.5 \cdot f_{int}) = v_{tot}$	1.97	1.97	2.81	2.58	m/s
D_o	0.5140	0.5140	0.5140	0.5140	m
Reynolds nr.	2.03E+06	2.03E+06	2.90E+06	2.66E+06	-
Vr	3.850	3.850	3.850	3.850	-
f1	1.00	1.00	1.42	1.30	1/s
$L_{span,cross}$	36.4	36.4	32.6	34.0	m

SUMMARY - SPAN ANALYSIS

	Installation	Hydrotest	LC 1 Operation	LC 2 Operation	
$L_{span,in}$	22.9	22.9	23.0	21.6	m
$L_{span,cross}$	36.4	36.4	32.6	34.0	m

Maximum Span Length = 21.6 m

D. Analytical Upheaval Buckling Analysis

The following documents are included:

- 19018-60-CAL-01005-01-01 Upheaval Buckling Analysis – 43 deg

(4 pages)

Client	**:**	ONE-Dyas
Project	**:**	N05A Flowline
Project No.	**:**	19018
Subject	**:**	Pipeline Upheaval Buckling - analytical
Doc. No.	**:**	19018-60-CAL-01005-01
Client Doc. No.	**:**	-

enersea®

Calc'd by	**:**	EvW	**Rev.**	**:**	01
Checked	**:**		**Date**	**:**	24-1-2020

Upheaval buckling calculation

Pipe data

Outside pipe diameter		OD_s =	508	mm
Pipe wall thickness		t_s =	20.62	mm
Internal pipe diameter	$= OD\_s - 2 \cdot t\_s$	ID_s =	466.76	mm

Steel data

Material			L360NB	
Density steel		ρ_s =	7850	kg/m^3
Young's modulus		E_s =	206000	N/mm^2
Poisson's ratio		ν =	0.3	-
Thermal expansion coefficient		α =	1.17E-05	m/m/°C
Steel area	$= \frac{1}{4} \cdot \pi \cdot (OD^2\_s - ID^2\_s)$	A_s =	31572.3	mm^2
Internal pipe area	$= \frac{1}{4} \cdot \pi \cdot ID^2\_s$	A_i =	1.71E+05	mm^2
Moment of inertia	$= \frac{\pi}{64} \cdot (OD^4\_s - ID^4\_s)$	I_s =	9.39E+08	mm^4
Pipe weight in air		W_{pe} =	247.8	kg/m
Sea water density		r_{sw} =	1025	kg/m^3
Pipeline contents density		r_{cont} =	88.7	kg/m^3

Internal lining

Thickness		t_l =	0	mm
Density		r_l =	0	kg/m^3
Lining weight		W_l =	0.0	kg/m

Coating data

Outer coating layer 1

Thickness		t_{c1} =	3	mm
Density		ρ_{c1} =	930	kg/m^3
Layer 1 weight	$W_{l1} = \frac{\pi}{4} \cdot \{(OD + 2 \cdot t_{c1})^2 - OD^2\} \cdot \rho_{c1}$	W_{l1} =	4.5	kg/m

Weight piggy back line

Piggy back weight		W_{l2} =	0.0	kg/m

Concrete coating

Thickness		t_{con} =	0	mm
Density		ρ_{con} =	0	kg/m^3
Concrete weight	$W_{con} = \frac{\pi}{4} \cdot \{(OD + 2 \cdot t_{c1} + 2 \cdot t_{c2} + 2 \cdot t_{con})^2 - (OD + 2 \cdot t_{c1} + 2 \cdot t_{c2})^2\} \cdot \rho_{con}$	W_{con} =	0.0	kg/m

Marine growth

Thickness		t_{mg} =	0	mm
Density		ρ_{mg} =	0	kg/m^3
Marine growth weight	$W_{mg} = \pi/4 \cdot \{(OD + 2 \cdot t_{c1} + 2 \cdot t_{c2} + 2 \cdot t_{con} + 2 \cdot t_{mg})^2 - (OD + 2 \cdot t_{c1} + 2 \cdot t_{c2} + 2 \cdot t_{con})^2\} \cdot \rho_{mg}$	W_{mg} =	0.0	kg/m

Weight data

Total outside diameter	$ODtot = OD + 2 \cdot t \cdot + 2 \cdot t_{c2} + 2 \cdot t_{con} + 2 \cdot t_{mg}$	OD_{tot} =	514.0	mm
Contents weight	$W_{cont} = \pi/4 \cdot (ID - 2 \cdot t_l)^2 \cdot \rho_{cont}$	W_{cont} =	15.2	kg/m
Pipeline weight in air	$w_r = w_{pe} + w_l + w_{l1} + w_{l2} + w_{con} + w_{mg} + w_{cont}$	W_r =	267.5	kg/m
Buoyancy force, F_B	$F_B = \pi/4 \cdot OD_{tot}^2 \cdot \rho_w$	F_B =	212.7	kg/m
Submerged pipeline weight, W_{sm}	$W_{sm} = W_r - F_B$	W_{sm} =	54.8	kg/m

Soil data

Submerged soil cover density		γ' =	850	kg/m^3
Angle of internal friction		ϕ_{soil} =	28	deg.
Potyondy coeff. Soil		p_{soil} =	0.6	-
Height soil cover from top of pipe		Htop =	0.8	m
Height soil cover from center of pipe		H	1.06	
Soil uplift coefficient		f_{soil} =	0.1	-

(0.5 for dense materials and 0.1 for loose materials)

Soil weight on top of pipe	$q = \gamma' H \cdot OD_{tot} \cdot (1 + f \cdot H / OD_{tot})$	q =	5461.9	N/m
Imperfection height		δ =	600	mm

Pressure data

Design pressure		P_d =	111	barg
Maximum operating pressure		P_i =	95	barg
Minimum external pressure		P_e =	1.01	barg

Temperature data

Seawater temperature, T_{sea}		T_{sea} =	3	^{o}C
Temperature of gas, T_{gas}		T_{gas} =	43	^{o}C

Pipeline forces

Compressive temperature force, F_T	$F_T = E \cdot A \cdot \alpha \cdot (T_{gas} - T_{sea})$	F_T =	3043822.4	N
Tensile Poisson force, F_P	$F_P = A_i \cdot \nu \cdot \frac{\{P_D - P_e\} \cdot OD_s}{2 \cdot t}$	F_P =	1283345.0	N
Compressive member end force, F_e	$F_e = \{P_D - P_e\} \cdot \pi/4 \cdot ID_s^2$	F_e =	1882123.1	N

Is area under considerations within anchor zone (y/n) ? = n

(y: F_T can be neglected)

Effective compressive axial force, F_{eff}	$F_{eff} = F_T - F_P + F_e$	F_{eff} =	3642600.5	N

Required down load

The required download depends on:

- dimensionless maximum download parameter, F_W
- dimensionless imperfection length parameter, F_L

$$\Phi_w = \frac{w \cdot EI}{\delta \cdot F_{eff}^2} \quad \text{and} \quad \Phi_L = L \cdot \sqrt{\frac{F_{eff}}{EI}}$$

where,

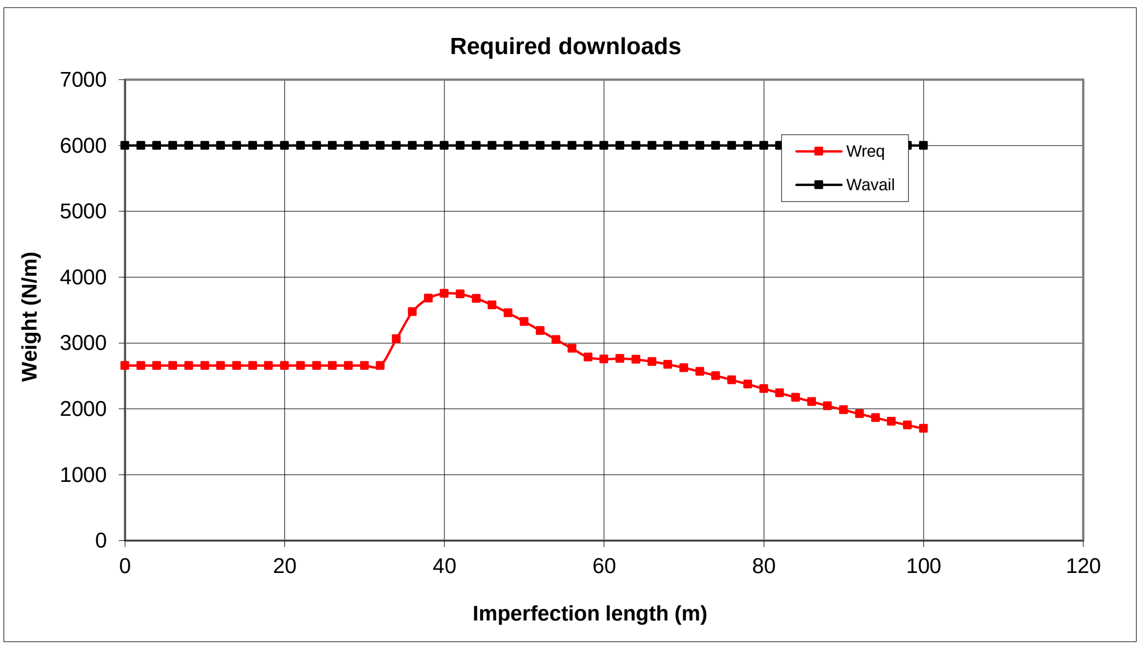
F_W = dimensionless maximum download parameter
w = required download (N/mm)
F_{eff} = effective axial force (N)
EI = bending stiffness pipeline (N/mm^2)
d = imperfection height (mm)
F_L = dimensionless imperferction length parameter
L = imperfection / exposure length (mm)

Requirements:

$$\Phi_L \le 4.49 \qquad \Phi_W = 0.0646$$
$$4.49 < \Phi_L \le 8.06 \qquad \Phi_W = 5.68 / \Phi_L^2 - 88.35 / \Phi_L^4$$
$$\Phi_L > 8.06 \qquad \Phi_W = 9.6 / \Phi_L^2 - 343 / \Phi_L^4$$

L [m]	F_L	F_w	W_{req} [N/m]	W_{avail} [N/m]
0	0.000	0.0646	2658.345	6000
2	0.274	0.0646	2658.345	6000
4	0.549	0.0646	2658.345	6000
6	0.823	0.0646	2658.345	6000
8	1.098	0.0646	2658.345	6000
10	1.372	0.0646	2658.345	6000
12	1.647	0.0646	2658.345	6000
14	1.921	0.0646	2658.345	6000
16	2.195	0.0646	2658.345	6000
18	2.470	0.0646	2658.345	6000
20	2.744	0.0646	2658.345	6000
22	3.019	0.0646	2658.345	6000
24	3.293	0.0646	2658.345	6000
26	3.568	0.0646	2658.345	6000
28	3.842	0.0646	2658.345	6000
30	4.117	0.0646	2658.345	6000
32	4.391	0.0646	2658.345	6000
34	4.665	0.0745	3064.458	6000
36	4.940	0.0844	3472.879	6000
38	5.214	0.0894	3678.596	6000
40	5.489	0.0912	3752.716	6000
42	5.763	0.0909	3741.640	6000
44	6.038	0.0893	3676.014	6000
46	6.312	0.0869	3576.265	6000
48	6.586	0.0840	3456.096	6000
50	6.861	0.0808	3324.726	6000
52	7.135	0.0775	3188.350	6000
54	7.410	0.0741	3051.110	6000

56	7.684	0.0709	2915.740	6000
58	7.959	0.0677	2784.008	6000
60	8.233	0.0670	2756.057	6000
62	8.507	0.0672	2763.740	6000
64	8.782	0.0668	2749.280	6000
66	9.056	0.0661	2718.373	6000
68	9.331	0.0650	2675.386	6000
70	9.605	0.0638	2623.669	6000
72	9.880	0.0624	2565.802	6000
74	10.154	0.0608	2503.772	6000
76	10.428	0.0593	2439.109	6000
78	10.703	0.0577	2372.987	6000
80	10.977	0.0560	2306.308	6000
82	11.252	0.0544	2239.758	6000
84	11.526	0.0528	2173.858	6000
86	11.801	0.0513	2108.996	6000
88	12.075	0.0497	2045.461	6000
90	12.350	0.0482	1983.458	6000
92	12.624	0.0467	1923.133	6000
94	12.898	0.0453	1864.581	6000
96	13.173	0.0439	1807.859	6000
98	13.447	0.0426	1752.995	6000
100	13.722	0.0413	1699.993	6000



N05-A Pipeline & Spoolpiece – Basic Design

Basis of Design Pipeline & Tie-in Spools

DOCUMENT NUMBER:

N05A-7-10-0-70028-01

21-12-2021

Rev.	Date	Description	Originator	Checker	Approver
01	15-01-2020	Issued for Comments	HvH	PF	PF
02	17-03-2020	Issued for Approval	PF	EvW	PF
03	15-12-2021	Updated	DK	PF	DK

Client

ONE-Dyas B.V.

Project

ONE-Dyas N05A Pipeline & Spool piece – Basic Design

Document

Basis of Design Pipeline & Tie-in Spools

Project number	19018
Document number	N05A-7-10-0-70028-01
Revision	03
Date	15.12.2021

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Revision History

Revision	Description
01	Initial Issue – For Client comments
02	Client comments incorporated
03	Platform and routing update

Revision Status

Revision	Description	Issue date	Prepared	Checked	Enersea approval	Client approval
01	For Client Comments	15-01-2020	HvH	PF	PF	
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Table of content

1. Project Introduction

1.1. Project Introduction

ONEDyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a subsea connection to the NGT pipeline existing side tap connection @KP141.4. The approximate length of the pipeline is 14.6 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

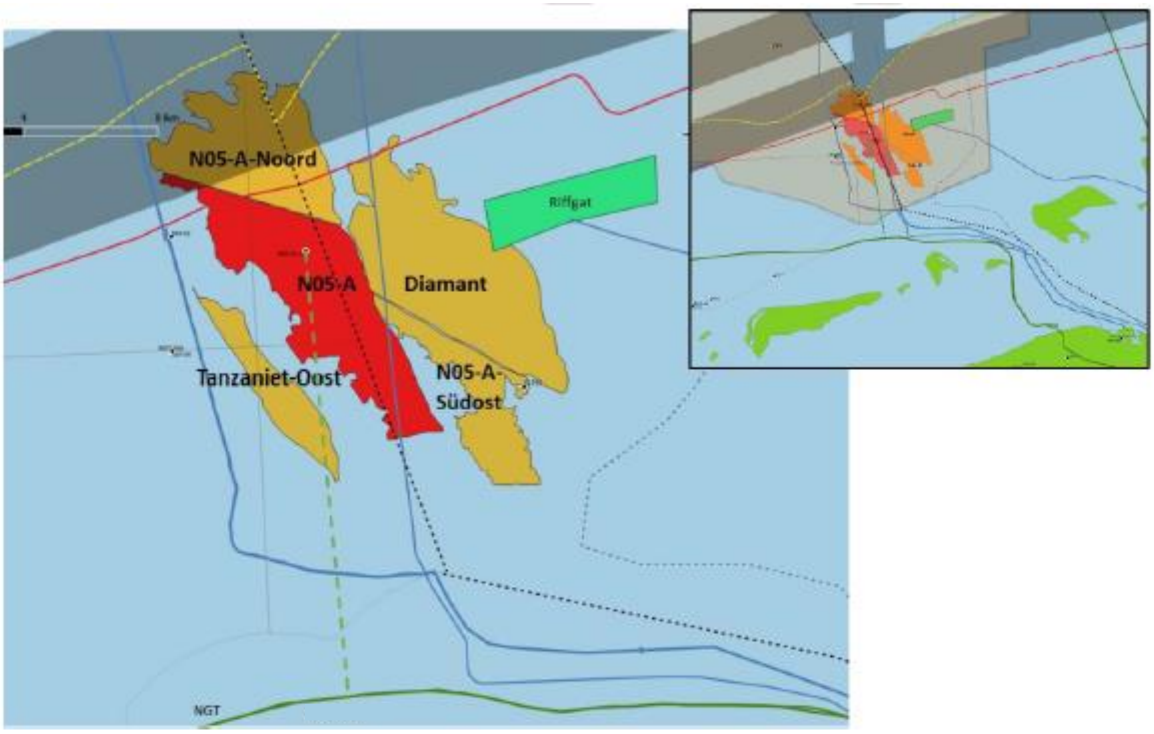


Figure 1: N05-A Field layout

1.2. Purpose Document

The Basis of Design defines the methodology and design data to be used throughout the flowline design from the new N05A platform to the connection to the NGT pipeline existing side tap @KP141.4. This document is to be read in conjunction with documents as listed below in order of precedence.

Number	Title
N05A-7-10-0-70026-01-01	N05-A Pipeline Design – Basis of Design Flow Assurance

The following engineering items are described in subsequent sections of this Basis of Design report:

- Regulations, Guidelines and Specifications
- Pipeline Routing
- Seabed Geology
- Materials and Corrosion Protection
- Operational and Product Data
- Environmental Data
- Design Philosophy & Criteria

1.3. System of Units

All dimensions and calculations shall be documented using the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

BoD	Basis of Design
CWC	Concrete Weight Coating
FEA	Finite Element Analysis
LAT	Lowest Astronomical Tide
MTO	Material Take Off
PUF	Poly Urethane Foam
TB	Target Box
TOP	Top of Pipe
VIV	Vortex Induced Vibrations

2. Regulations, Guidelines and Specifications

The references, codes, regulations, guidelines and specifications used throughout the project are outlined in the following sections.

2.1. Regulations, Codes, Standards and Guidelines

[1] NEN3656:2015 "Eisen voor stalen buisleidingsystemen op zee" December 2015

[2] DNV-OS-F101. "Submarine Pipeline Systems." October 2013.

[3] DNV-RP-F105. "Free Spanning Pipelines." June 2017.

[4] DNV RP-F107. "Risk Assessment of Pipeline Protection." May 2017.

[5] DNV-RP-F109. "On-Bottom Stability Design of Submarine Pipelines." May 2017.

[6] DNV-RP-F110. "Global Buckling of Submarine Pipelines. Structural Design due to High Temperature/High Pressure." April 2018.

[7] DNV-RP-C203. "Fatigue Design of Offshore Steel Structures." April 2016.

[8] -

[9] DNV-RP-F114. "Pipe-soil interaction for submarine pipelines." May 2017.

[10] 21. American Lifelines Alliance. "Guidelines for the Design of Buried Steel Pipe. ASCE July 2001.

[11] ASME Boiler and Pressure Vessel Code. Section VIII Rules for Construction of Pressure vessels. Division 1. July 2013.

[12] Design of Submarine Pipelines Against Upheaval Buckling OTC 6335 by A.C. Palmer e.a. May 1990

[13] ISO 15589-2. "Petroleum petrochemical and natural gas industries — Cathodic protection of pipeline transportation systems - Part 2: Offshore pipelines" 2nd edition - 2012

[14] NEN-EN 1993-1-8 – Design of Steel Structures

[15] NEN-EN-ISO 19902 – Fixed Steel Offshore Structures

[16] ASME N16.9-2001 – Factory made wrought buttwelding fittings

2.2. Project Reference Documents

[I] N5-1-10-0-10000-01, Statement of Requirements for Platform N05-A

[II] Metocean Criteria for the N05A Platform – 181892_1_R2

[III] Metocean Criteria for the N05A Platform Side Tap - 191146_1_R2

[IV] Pipeline Bathymetry: LU0022H-553_DR-007_PR_1-4_v1.0 / 2-4 / 3-4 / 4-4

[V] N05A-7-10-0-70018-01, N5A-Development-Pipeline Route and Platform Area Survey R1

[VI] N05A-7-10-0-70020-01, Environmental Baseline Survey Report 1.0

[VII] N05A-7-10-0-70027-01-03 Flow Assurance Design Report

[VIII] N05A-7-10-0-70036-01-01 Flow Assurance Design Report -transient analysis

[IX] N05A-7-10-0-70031-01-01 Route Selection Report

[X] LU0022H-553-RR-03-2.1 N5a Lab Test Results Report

[XI] N5A VC-C-7 S-3 0300m CID

[XII] N5A VC-P-3 S-2 0405m CID

[XIII] N5A VC-P-8 S-4 0240m CID

3. Design Parameters

This chapter describes the design data to be considered for the pipeline (incl. spool pieces near the riser and the side tap) from the new N05A-Platform to the NGT pipeline.

3.1. Pipe Data

The basic line pipe design and spool piece data to be considered in the analysis for the export gas line are presented in Table 3-1. Steel material properties considered in the design are presented in Table 3-2.

Property	
Product transported	Natural gas (dry)
Design life (years)	25
Approx. length (km)	14.6
Material grade	L360 NB
Manufacturing process	HFIW
Pipe outside diameter (“)	20”
Pipe outside diameter (mm)	508
Pipe internal diameter	466.76
Wall thickness (mm)	20.62 (Sch60) TBC
Wall thickness tolerance (%)	7.3
Wall thickness tolerance (mm)	+/- 1.5mm
Internal corrosion allowance (mm)	3
Anti-corrosion coating	3LPP
Anti-corrosion coating thickness (mm)	3
Anti-corrosion coating density (kg/m^3)	930
(Concrete) weight coating thickness (mm)	t.b.d
concrete weight coating density (kg/m^3)	3300
Minimum hot bend radius (mm)	2540 (5D)

Table 3-1 Pipeline data

Property	
Material	L360NB
Density (kg/m3)	7850 kg/m^3
Specified Minimum Yield Strength at 20°C (MPa)	360
Specified Minimum Yield Strength at 50°C (MPa)	360
Specified Minimum Tensile Strength (MPa)	460
Young’s modulus (Pa)	2.07×10^{11}
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m·°C)	1.17×10^{-5}

Table 3-2 Material properties

3.2. Process conditions

Table 3-3 presents the pipeline and spool design process parameters considered in the analysis.

Property	Export gas line
Design pressure	111.1 bar(g)
Operating pressures	95 bar(g)
Design temperature (min / max)	-20 °C / 50 °C
Operating temperature (min / max)	1 / 43 °C
Ambient (air / surface) temperature	-6.8°C / +24.2 °C
Content density (arrival, nominal operation)	88.7 / 96.1 kg/m³
Design flowrate (min/max)	0.14 / 6.0 MMNm3/d

Table 3-3 Process design parameters

Figure 3-1 shows the operational thermal profile along the pipeline, ref. [vii] .

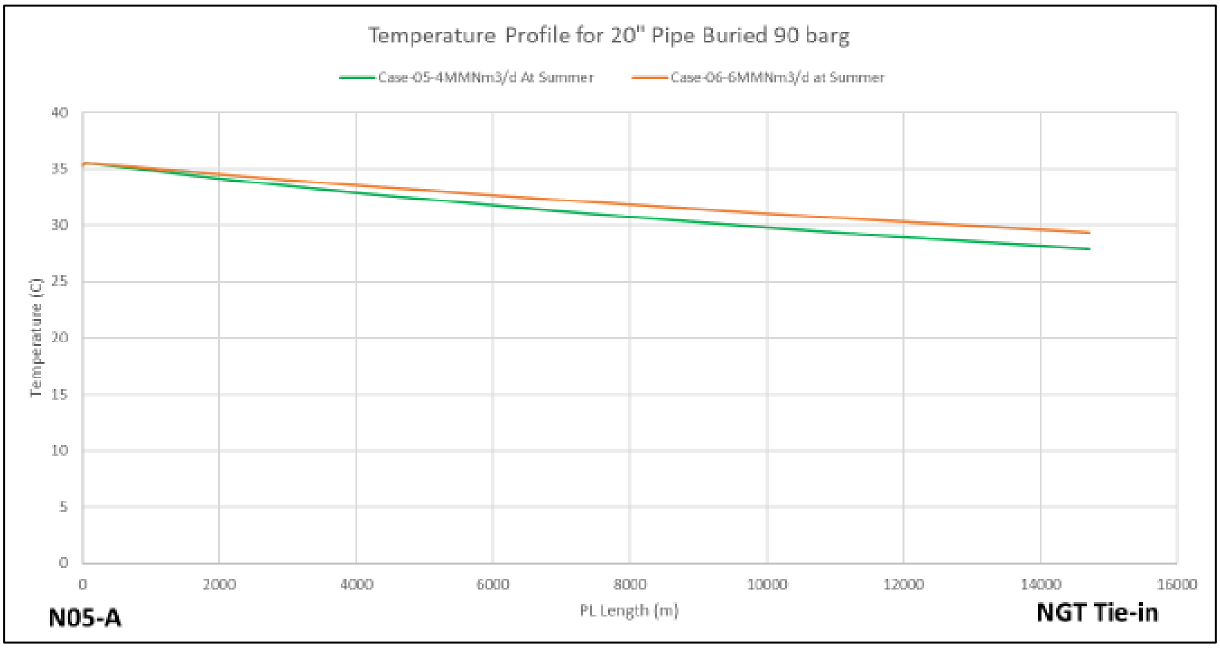


Figure 3-1 Operational thermal profile, nominal operation in summer

3.3. Coating Material Properties

Typical material properties of the coating are given in Table 3-4.

Property	Value
Anti-corrosion material type	3LPP
Anti-corrosion coating density	930 kg/m³
Anti-corrosion coating thermal conductivity	0.22 W/m°C
Anti-corrosion coating specific heat capacity	2000 J/kg°C

Table 3-4 Steel pipe coating material properties

3.4. Flange Properties

Table 3-5 presents the flange classes and main characteristics. The flange loads will be checked by using the ASME BPVC [10] flange integrity check. Note that table 3-5 is applicable to all flanges on the flowline and spool pieces.

Property	Export gas line
Flange rating	ANSI/ASME Class 1500
Flange type	RTJ Swivel / Weld Neck
Weld end thickness	20.62mm

Table 3-5 Flange properties

3.5. Environmental data

For the design of the pipeline, environmental data has been taken from Ref. [II] and [III]. Where Ref [II] contains the metocean data for the platform (water depth 26 m); Ref [III] contains the Metocean data for the NGT side tap tie-in (water depth 8 m) target box. Tables 3-6 to 3-11 present the relevant metocean data for the 1 and 100 year design conditions for the applicable locations.

Property	1-year return period	100-year return period
Positive surge (m) @26m	1.58	3.04
Negative surge (m)	-1.02	-1.79
LAT with respect to MSL (m)	-1.41	
HAT with respect to MSL (m)	1.31	

Table 3-6 Near platform extreme water level data [ref. II]

Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								OMNI
	N	NE	E	SE	S	SW	W	NW	
1-year									
Near-surface	0.36	0.94	0.98	0.70	0.42	0.77	0.98	0.59	0.98
Mid-Depth	0.40	0.89	0.90	0.53	0.27	0.62	0.90	0.51	0.90
Near-bed	0.38	0.74	0.74	0.42	0.25	0.56	0.74	0.43	0.74
100-years									
Near-surface	0.46	1.21	1.27	0.91	0.55	1.00	1.27	0.76	1.27
Mid-Depth	0.51	1.15	1.16	0.68	0.35	0.79	1.16	0.66	1.16
Near-bed	0.49	0.95	0.96	0.55	0.32	0.72	0.96	0.55	0.96

Table 3-7- Near platform design current data [ref. II]

Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	5.3	9.2	11.7	5.9	9.3	9.5	1.67
North-east	3.8	6.8	8.3	4.3	6.7	8.5	1.04
East	2.6	5.2	6.6	3.0	4.7	7.5	0.55
South-east	2.1	4.6	5.2	2.3	3.6	6.9	0.34
South	2.4	4.7	5.2	2.8	4.3	7.3	0.48
South-west	3.2	5.6	6.2	3.6	5.6	8.0	0.78
West	4.7	8.0	10.5	5.3	8.3	9.1	1.43
North-west	6.5	9.9	12.4	7.3	11.4	10.1	2.19
100-years							
North	8.1	11.5	14.3	9.1	13.8	10.8	2.73
North-east	5.9	8.1	10.4	6.6	10.0	9.7	1.84
East	4.0	5.9	8.2	4.5	6.9	8.6	1.07
South-east	3.1	4.9	6.0	3.5	5.4	7.9	0.71
South	3.7	5.0	6.0	4.2	6.4	8.4	0.95
South-west	4.9	6.4	7.3	5.5	8.3	9.1	1.43
West	7.2	9.8	12.9	8.1	12.3	10.4	2.40
North-west	9.9	12.3	14.9	11.1	16.9	11.5	3.20

Table 3-8 Near platform design wave data [ref. II]

Property	1-year return period	100-year return period
Positive surge (m) @26m	1.48	2.72
Negative surge (m)	-0.90	-1.26
LAT with respect to MSL (m)	-1.89	
HAT with respect to MSL (m)	1.61	

Table 3-9 Near tie-in extreme water level data [ref. III]

Return Period Depth Level	Extreme Cs [m/s] Direction [towards]								Omni
	N	NE	E	SE	S	SW	W	NW	
1-year									
Surface	0.31	0.52	1.04	0.51	0.27	0.50	1.04	0.59	1.04
Mid-depth	0.30	0.50	1.01	0.44	0.25	0.43	1.00	0.55	1.01
Near-bed	0.26	0.45	0.89	0.23	0.10	0.19	0.61	0.39	0.89
100-years									
Surface	0.37	0.63	1.25	0.62	0.32	0.60	1.25	0.71	1.25
Mid-depth	0.36	0.60	1.21	0.53	0.31	0.52	1.20	0.66	1.21
Near-bed	0.33	0.57	1.12	0.29	0.13	0.23	0.77	0.49	1.12

Table 3-10 Near side tap tie-in design current data [ref. III]

Return Period Direction [from]	Hs [m]	Tz [s]	Tp [s]	Cmax [m]	Hmax [m]	THmax [s]	U_{1m} [m/s]
1-year							
North	3.6	6.2	10.3	3.3	4.8	7.5	1.2
North-east	2.2	4.9	7.7	2.0	2.9	6.5	0.6
East	1.6	3.9	5.0	1.5	2.2	5.9	0.4
South-east	1.5	3.6	3.7	1.4	2.0	5.8	0.3
South	1.4	3.5	3.9	1.3	1.9	5.7	0.3
South-west	2.0	4.1	4.5	1.9	2.7	6.3	0.5
West	3.0	5.7	10.2	2.8	4.1	7.2	0.9
North-west	3.9	6.4	12.1	3.6	5.2	7.7	1.3
100-years							
North	3.9	6.4	10.6	4.2	5.7	7.9	1.5
North-east	2.4	5.1	7.9	2.6	3.5	6.8	0.8
East	1.7	4.1	5.2	1.9	2.6	6.2	0.5
South-east	1.6	3.7	3.8	1.8	2.4	6.1	0.4
South	1.6	3.7	4.1	1.7	2.3	6.0	0.4
South-west	2.2	4.3	4.6	2.4	3.2	6.7	0.7
West	3.3	6.0	10.7	3.6	4.9	7.5	1.2
North-west	4.2	6.6	12.6	4.5	6.2	8.1	1.6

Table 3-11 Near side tap tie-in design wave data [ref. III]

3.6. Marine growth

The following marine growth has been assumed, in accordance with NEN 3656 [1]

From	To	Thickness	Density
+2m LAT	Seabed	50mm	1300 kg/m3

Table 3-12 Assumed marine growth properties

3.7. Geotechnical data

The survey report – N5A to NGT side tap tie-in[ref. IV] indicates the soil along the route as ‘fine to medium Sand, with occasional areas of coarse Sand and Clay with gravel and shell fragments. Three lab result reports [ref XI – XII] present the soil parameters for the sand in the trajectory. The soil properties are listed in Table 3-13, data has been taken from ref. X-XIII and recommended values as per NEN3656 table H.1 ref[1] based on the soil description as presented in [ref X]. A SBP data example of the north end of the proposed route is presented in figure 3-14.

Soil type	Applicable area	Submerged Unit Weight (kN/m³)	Angle of internal friction (°)
Medium sand (measured)		10.2-10.5	32.5-34.9
Medium sand	Pipe on surface	10	32.5
	Trench backfill	8.5	28
Rock dump	Crossing / Tie-in	10	40

Table 3-13 Assumed soil geotechnical properties

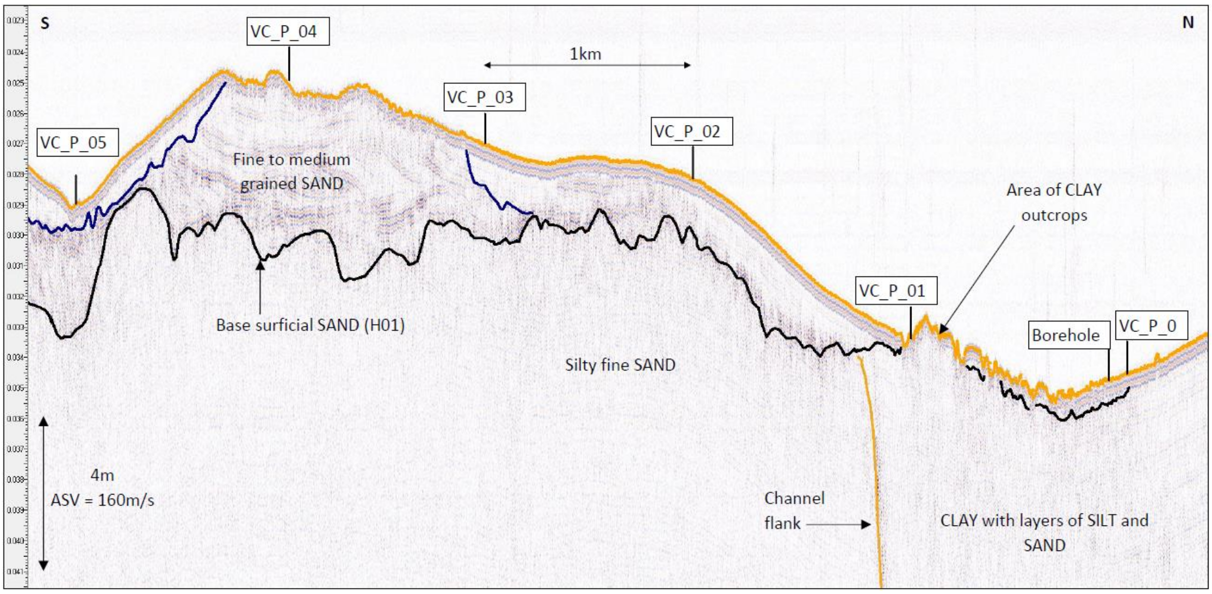


Figure 3-2 Soil profile from KP 0.0 to KP 6.0

4. Pipeline route data

This chapter deals with the pipeline route data describing the starting and end point of the pipeline, the used coordinate system, pipeline route coordinates and key facilities as well as the route bathymetry and contacts detected along the pipeline route. Based on this info the most optimal pipeline routing has been selected (ref. [IX].

4.1. General

The new pipeline to be installed originates at the new N05-A Platform and terminates at the NGT side tap via an existing connection. The pipeline length is approx. 14.6 km.

An installation of the pipeline on top of the seabed has been indicated as an opportunity. The final cover height or required concrete coating thickness will be determined based on the results of a risk assessment study, the on-bottom stability analysis and the upheaval buckling analysis.

Two pipeline/cable crossings are foreseen along the route. An overview of the field lay out is given in Figure 4-1.

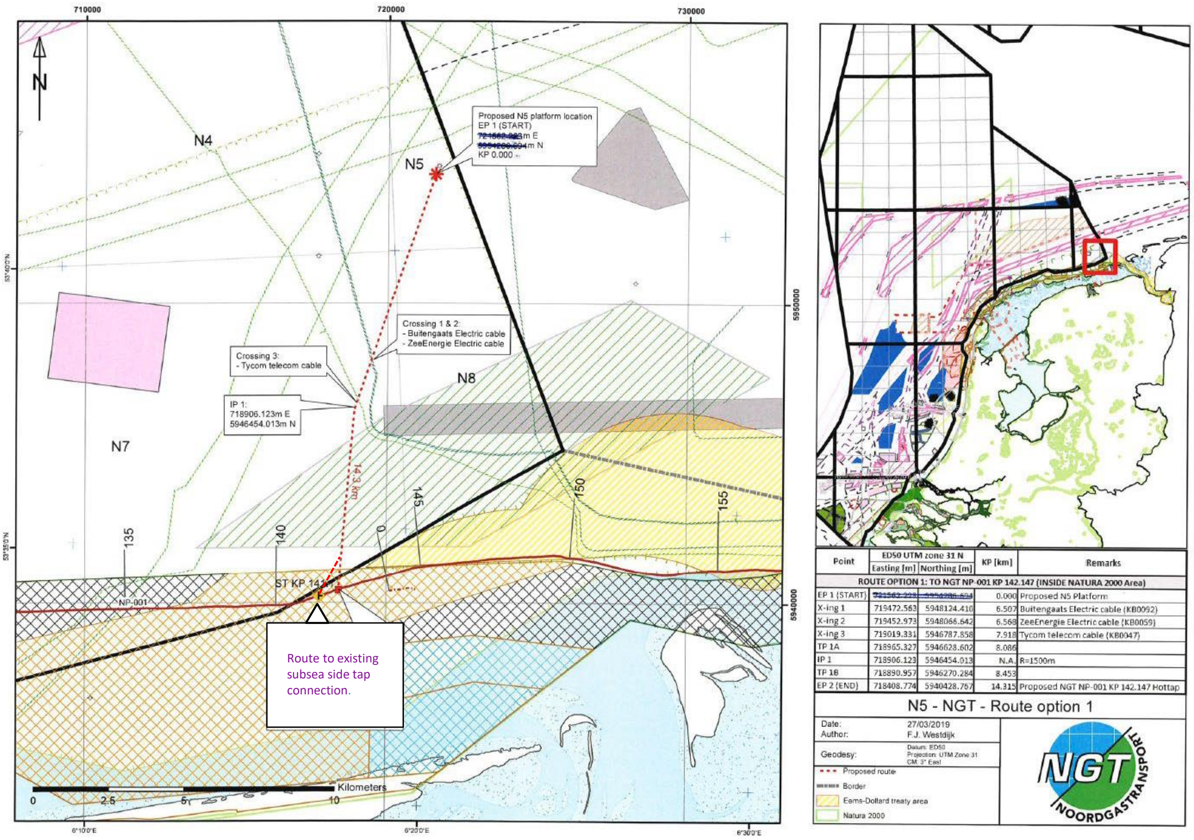


Figure 4-1 Overview N05A platform to the existing side tap tie-in location (left)

4.2. Coordinate system

The parameters of the geodetic system to be used for horizontal positions are listed in Table 4-1.

Item	Value
Datum	European Datum 1950 (ED50)
Projection	ED50 / UTM zone 31 N
Ellipsoid name	International 1924
Semi major axis	6 378 388 m
Inverse flattening	297.000
Central Meridian	03º00"00' E
Latitude of Origin	00º00"00' N
False Northing	0 mN
False Easting	500 000 mE
Scale Factor	0.9996

Table 4-1: Geodetic parameters

The vertical position is given relative to the Lowest Astronomical Tide (LAT).

4.3. Key facility coordinates

The following platform and tie in locations have been derived from Ref. [V] and are presented in Table 4-2.

Item	Northing (m)	Easting (m)
N05A Platform target box	5 953 858	721 896
NGT target box	5 940 213	717 687
NGT side tap location KP141.4	5 940 197	717 698
Water depth at N05A Platform	25.3 m LAT	
Water depth at NGT hot tap	9.8 m LAT	

Table 4-2 Key Facility coordinates

4.4. Bathymetry

Figure 4-3 shows the bathymetry along the surveyed flowline route. The water depths recorded during survey along the proposed N05-A platform and the NGT pipeline side tap location ranges between 9.8 m LAT and 25.3 m LAT.

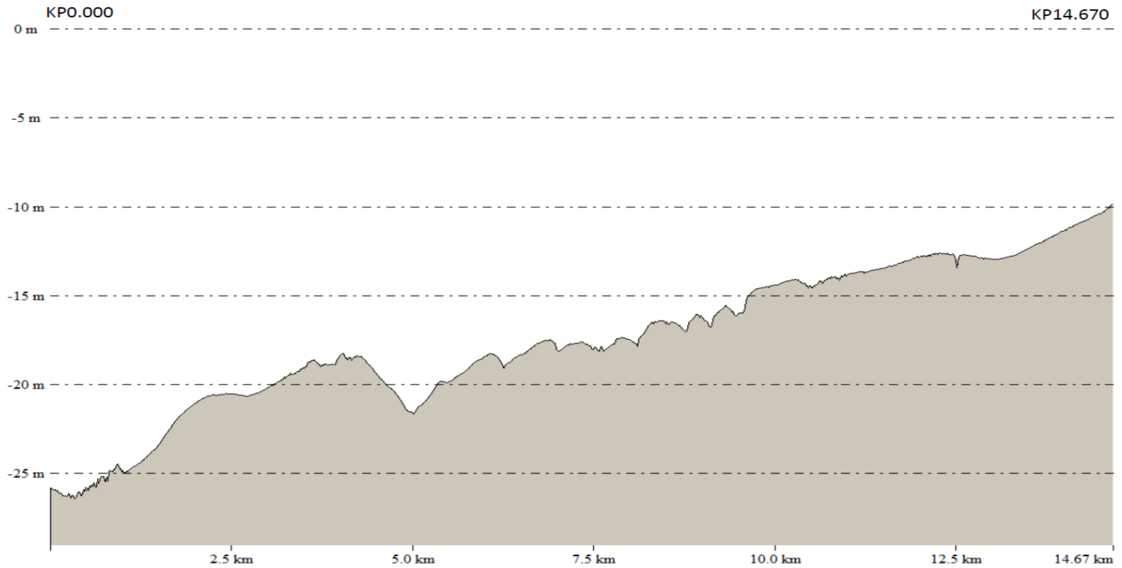


Figure 4-3 Seabed profile along pipeline route from N05-A Platform to NGT side tap connection

4.5. Side Scan Sonar Contacts & Magnetometer Anomalies

Ref. [5] describes the seafloor sediments across the N05-A to the proposed NGT side tap location survey area to consist of a top layer of fine to coarse sand, with occasional areas of coarse sand and clay with gravel and shell fragments. Photographs taken along the proposed route show the presence of small ripples covering the majority of the seabed within the survey corridor area.

Numerous boulders and items of debris are observed in the survey area. Most of the boulders occur in the north of the survey area and coincide with areas of clay exposure.

4.5.1. Magnetometer Contacts

A total of 241 magnetic anomalies (appendix A) were picked within the surveyed N05-A platform to the 36" NGT Tie-in and N05-A platform to Riffgat Tie-in route corridor. Most of these anomalies can be attributed to unknown identified seabed features the following seabed infrastructures are known, one (1) pipeline and four (4) cables. However, one (1) unknown linear feature.

The following existing pipelines and cables are detected:

- 36" Pipeline from L10-AR to Uithuizen
- Tycom Telecom cable
- Buitengaats Power cable
- Zeeenergie Power cable
- Norned Power cable

4.5.2. Geophysical Data

Eight-Hundred-Thirty (830) side scan sonar contacts were observed within the route survey. Most of the contacts are boulders located around the N05-A platform and stretching to the east side to Riffgat, besides the bolders the following contacts are found, twenty-six (26) debris items, two (2) wrecks. Side scan sonar data can be found in Appendix A.

4.6. Cable & Pipeline Crossings

The following crossings along the pipeline route are envisaged:

Infrastructure Name	KP	Northing (m)	Easting (m)
Buitengaats Electric cable	5.956	5.948.587	719.395
ZeeEnergie Electric cable	6.036	5.948.510	719.373
Tycom Telecom Cable Hunmanby GAP - Eemshaven	7.629	5.946.979	718.931

*) The N05A Pipeline will be connected to the NGT Pipeline with a side tap. This side tap is not part of the scope of the design report.

4.7. Approach

Near the platform a T-piece will be installed including 2 ball valves for the purpose of a future pipeline connection. At the NGT tie-in location 2 ball valves and a check valve will be placed for tie-in purposes. Figures 4-4 and 4-5 present an overview of respectively the platform and the tie-in location.

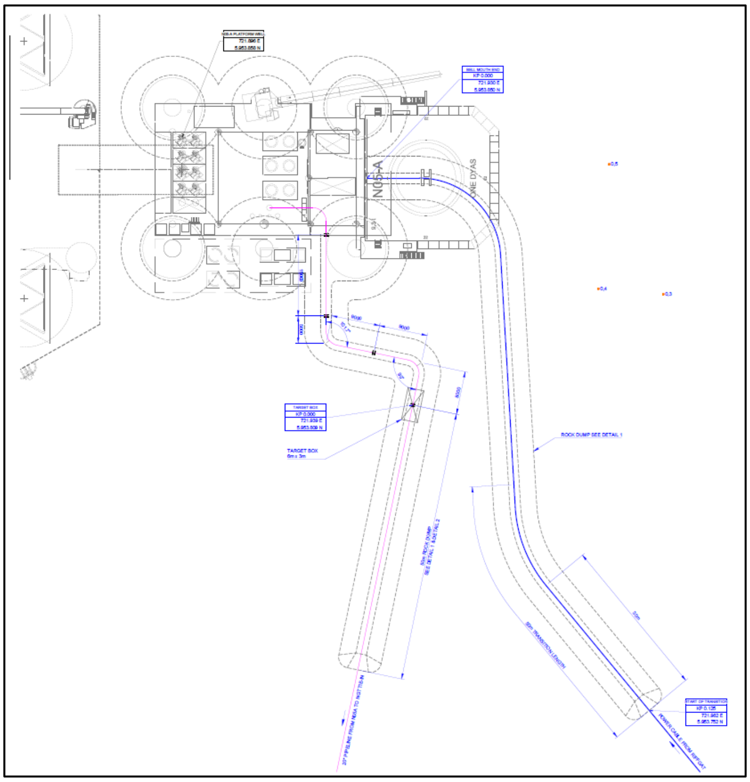


Figure 4-4 approach layout near the platform

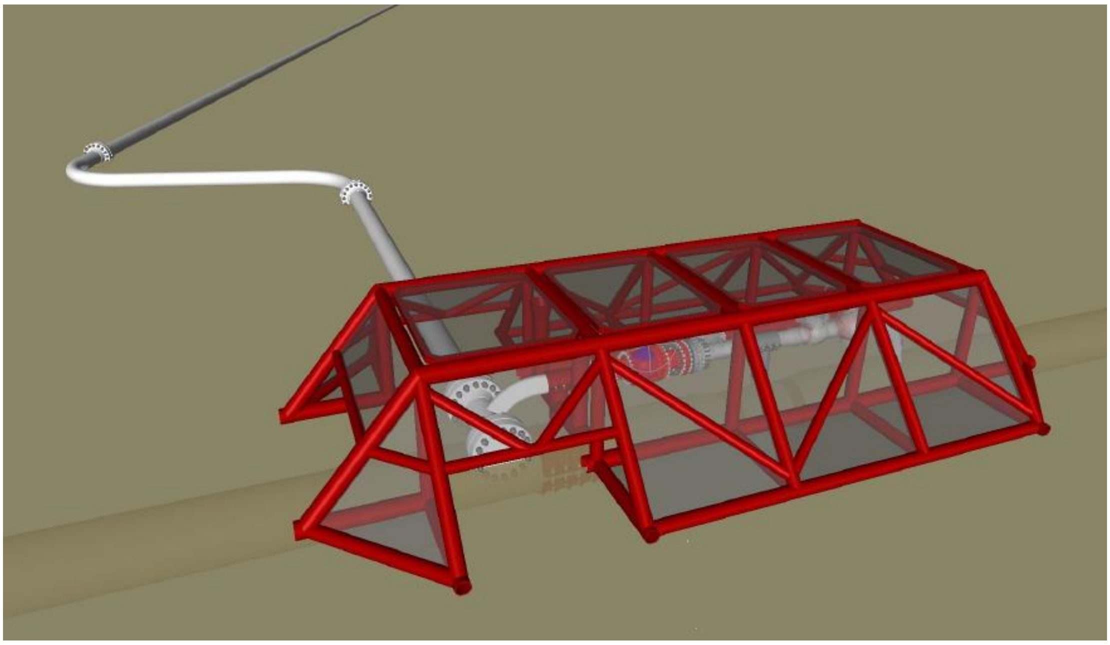


Figure 4-5 approach layout near the NGT Side tap tie-in

5. Riser and Spool piece analysis

The purpose of the riser and expansion spool analysis at the N05A platform is to determine the combined effect of functional and environmental loads on the structural integrity of the system. The analysis consists of the stress analysis of the spool pieces on both ends of the pipeline, carried out in accordance with NEN 3656:2015 (Nederlands Normalisatie-instituut, 2012).

5.1. Stress Criteria

Stresses in the riser and tie-in spool pieces will be assessed by using the finite element software ANSYS. The analysis ensures the structural integrity of the riser/spool system by NEN 3656 (Ref. [1])

The analysis will account for the load history of the pipe over the design life by considering the following four load cases:

- Installation
- Hydrotest
- Operational – Nominal
- Operational – Corroded

Considering the design cases listed above the following design loads will be considered when performing the stress analysis, see Table 5-1.

Load	Installation	Hydrotest	Operation
Pressure	N/A	Hydrotest Pressure	Design Pressure
Temperature	Seawater Temperature	Seawater Temperature	Design Temperature
Internal Fluid	Seawater	Seawater	Product Filled
Wall Thickness	Nominal	Nominal	Nominal / Fully corroded
Hydrodynamic Loads	1-year wave + 1-year current	1-year wave + 1-year current	100-year wave + 100 year current
Pipeline End Expansion	N/A	Expansion Under Hydrotest Pressure	Expansion under design temperature and pressure

Table 5-1 Design loads

Calculated equivalent stresses for the various design conditions will be checked against the allowable stress values, as per NEN3656 (Ref. [1]), see Table 5-2.

Case	Load Combination As Per NEN3656 Table 3.	Limit Stress	Allowable Equivalent Stress (LB360)
Installation	LC1	$R_{e(\theta)} / \gamma_m$	327 MPa
Hydrotest	LC4	$0.85\ (R_e + R_{e(\theta)}) / \gamma_m$	556 MPa
Operation (Nominal / Corroded)	LC4	$0.85\ (R_e + R_{e(\theta)}) / \gamma_m$	556 MPa

Table 5-2 Applied stress limits

Where:

Re = specified minimum yield strength at 20ºC (N/mm^2).

$R_{e(\theta)}$ = the yield strength of the material at design temperature.

γ_m = material factor (for steel 1.1).

All design loads applied will be factored as per the requirements of NEN 3656 (Ref. [1]), see Table 5-3.

Loads	**Load factors for load combinations (a)**								
Load combinations	LC 1	LC 2	LC 3	LC 4	LC 5	LC 6	LC 7a	LC 7b	LC 8
Internal pressure (design pressure)	-	1.25	-	-	-	-	1.0		1.0
Internal pressure (In combination)	-	-	-	1.15	1.15	-	-	1.0	1.15
Internal pressure (max. Incidental pressure)	-	1.10	-	-	-	-	-		1.1
Temperature differences (c g)	1.0	-	-	1.10	1.10	-	1.0	1.0	-
Soil parameters (d)	-	-	(d)	(d)	(d)	-	-	Low	-
Forced deformation (e)	-	-	1.1	1.1	1.1	1.1	-		-
Own weight	1.1	-	1.1	1.1	1.1	1.1	1.0		1.0
(Possible) coating (h)	1.2	-	1.2	1.2	1.2	1.2	1.0	1.2	1.0
Pipe contents (h)	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	1.0
Installation loads (f)	1.1	-	1.10	-	-	1.1	-		-
Hydrostatic pressure	1.1	-	1.1	1.1	1.1	1.1	1.0	1.1	
Marine growth (h)	-	-	1.2	1.2	1.1	-	1.0	1.0	1.0
Hydrodynamic forces	1.1	-	1.2	1.2	1.1	1.1	1.0	1.2	1.0
(a)	If a load has a favorable influence on the considered case this will not be considered if the load is variable and for a permanent load a multiplication factor of 0.9 is applied.								
(b)	The maximum incidental pressure does not need to be checked separately however must be ascertained by the pressure control system.								
(c)	During calculations of stress variations caused by temperature differences the highest and lowest occurring operation temperature should be considered. The displacements loads and moments exerting on connected equipment and/or structures are to be considered based on the design temperatures i.e. the temperature difference between the installation temperature and the maximum operational temperature.								
(d)	Reference is made to ref. [1] – K.4 to determine load spreading factors								
(e)	Forced deformations can be caused by: settling differences trench roughness execution sacking differences deformations due to prevented thermal expansion distortions in horizontal drilling and bottom-tow installation.								
(f)	Examples of installation loads are those applied during pipelay tie-ins trenching landfalls and HDD etc.								
(g)	Combined with measurements.								
(h)	In the stability check (BC 7b) the most unfavorable combination must be chosen. If necessary divide by the relevant factor.								

Table 5-3 Load factors

A description of the load combinations is shown below;

LC 1: Installation

LC 2: Only internal pressure, operating pressure, incidental pressure

LC 3: External load with zero internal pressure

LC 4: External load with internal pressure and temperature difference

LC 5: Variable load (primarily static load, e.g., temperature changes and pressure)

LC 6:a External pressure, external load and internal pressure zero

LC 7a: Incidental load (other than internal pressure)

LC 7b: Incidental load (meteorological)

LC 8: Dynamic loading

5.2. Model description

The riser and spool pieces will be modelled by using ANSYS dedicated submerged pipe element “PIPE59”. This element is a uniaxial element with tension-compression, torsion, and bending capabilities and can account for internal pressure effects. The element is a 3D element with six degrees of freedom, translations in the x, y and z directions and rotations about the x, y and z axes. In addition the element accounts for buoyancy, wave and current loads, and is capable of large deflections and rotations.

Hot bends are modelled by using “PIPE18” elements which are elastic bend pipe elements with similar properties as the straight “PIPE59” elements described previously.

At riser clamp locations pipe nodal translation and/or rotations shall be constrained appropriately based on the physical constraints provided by the clamps (guide clamps / anchor clamps).

To incorporate pipeline end expansion into the spool pieces a representative pipeline length (greater than the anchor length) will be modelled. Note that conservatively seabed undulations are neglected while modelling these pipeline sections as this provides the greatest end expansion into the spool pieces.

Pipe-soil interaction is simulated using three independent non-linear spring elements (COMBIN39) attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction. As the spool piece will be rock dumped after the hydrostatic testing, additional non-linear springs representing the uplift resistance of the rockdump / trenched backfill material, are attached to the pipe elements for the “operational” load cases. A detailed description of how the pipe soil interaction will be modelled is provided separately in section 5.3.

5.3. Pipe-soil interaction

The characteristics of the springs, which simulated the pipe-soil interaction, are defined through non-linear force-deflection curves. The force-deflection curves describe the frictional restraint provided by the soil to the pipeline in the axial and lateral direction and the soil’s bearing capacity / upwards resistance in the vertical direction. The upcoming sections describe how the force-deflection curves of the springs are generated.

5.3.1. Exposed pipeline – axial soil resistance

The axial soil resistance for a pipeline / spool piece resting on the seabed, per meter pipe-length, is a function of the pipe submerged weight (vertical load) and the axial Coulomb friction coefficient. The axial friction is determined as follows:

$$F_{axial} = \mu_{Coulomb} w_s$$

Where:

- F_{axial} = Peak axial soil resistance [N/m]
- $\mu_{Coulomb}$ = Coulomb friction coefficient [-]
- w_s = Pipe submerged weight [N/m]

The axial restraint will be described through a bi-linear force-displacement relationship, as shown in Figure 5-1. The stiffness of the springs varies along the pipeline route and between load steps to account for variations in the pipe submerged weight and soil conditions.

The axial spring mobilization displacement is assumed to be 1.25 mm.

Figure 5-1 Axial resistance Force-Displacement curve

5.3.2. Exposed pipeline – lateral soil resistance

Lateral soil resistance is composed of two parts:

- Coulomb friction.
- Passive soil resistance due to the build-up of soil penetration (and hence a soil berm, as the pipe moves laterally).

To account for both components of resistance, an equivalent friction coefficient shall be used, which is defined as:

$$\mu_{equivalent} = \mu_{Coulomb} + \mu_{passive}$$

Where:

- μ_{eqv} = Equivalent lateral friction coefficient [-]
- $\mu_{Coulomb}$ = Coulomb friction coefficient [-]
- $\mu_{passive}$ = Passive soil resistance coefficient [-]

The passive soil resistance model proposed in DNV's Recommended Practice, DNV-RP-F109 (rev. [5]) will be used.

The passive soil resistance coefficient, for a pipeline resting on a sandy seabed, depends on the pipe penetration depth into the soil and can be determined by the formulation:

- $\mu_{passive} = \frac{F_R}{F_C} = (5\kappa_s - 0.15{\kappa_s}^2)\left(\frac{z_p}{D}\right)^{1.25}$ if $\kappa_s \leq 26.7$
- $\mu_{passive} = \frac{F_R}{F_C} = \kappa_s\left(\frac{z_p}{D}\right)^{1.25}$ if $\kappa_s > 26.7$

Where:

- F_R = Passive resistance force [N/m]
- F_C = Vertical contact force between pipe and soil [N/m]
- D = Pipe outside diameter, including all coatings [m]
- z_p = Total pipe penetration [m]
- κ_s = Soil parameter for sandy soils [-]
- γ'_s = Submerged unit soil weight [N/m^3]

The soil parameter for sand, κ_s, is determined as:

$$\kappa_s = \frac{\gamma'_s D^2}{F_C}$$

The total pipe penetration is taken as the sum of:

- Initial penetration due to self-weight.
- Penetration due to dynamics during laying.
- Penetration due to pipe movement under the action of waves and current.

The pipe static/initial penetration due to self-weight for pipelines resting on sandy soil will be determined using the following formula taken from DNV-RP-F109 (rev. [5]):

$$\frac{z_{pi}}{D} = 0.037 {\kappa_s}^{-0.67}$$

Just as for the axial restraint, the lateral soil resistance will be described through a bi-linear force-displacement relationship as presented in Figure 5-1. The friction forces are increased monotonically to a maximum value calculated as the product of the pipe submerged weight (w_s) and the equivalent friction coefficient (μ_{eqv}), at a mobilisation distance of 2mm.

5.3.3. Vertical soil bearing capacity (Downward resistance)

The static vertical soil reaction per unit length can be determined based on bearing capacity formulas for ideal 2-D strip foundations, as per DNV-RP-F105 (rev. [3]):

$$R_V = \gamma'_{soil} B (N_q v_{eff} + 0.5 N_\gamma B)$$

Where:

- R_V = Vertical soil reaction [N/m]
- N_q & N_γ = Bearing capacity factors [-]
- v_{eff} = Effective penetration [m] (The larger of $v - D/4$ and 0)
- v = Vertical penetration [m]
- B = Contact width for pipe-soil load transfer [m]

The bearing capacity factors are determined as follows:

$$N_q = e^{\pi \tan \varphi_s} \tan^2 \left(45 + \frac{\varphi_s}{2}\right)$$

Where:

φ_s = Angle of internal friction [°]

$N_\gamma = 1.5(N_q - 1) \tan \varphi_s$

The contact width for pipe-soil load transfer, B, is given by:

- $B = 2\sqrt{(D - v)v}$ if $v \leq D/2$
- $B = D$ if $v > D/2$

5.3.4. Buried pipeline – axial soil resistance

Soil resistance forces for buried pipeline sections are based on ASCE's "Guidelines for the Design of Buried Steel Pipe" [9].

The maximum axial soil force that can be transmitted to the pipe per unit length is given by:

$$T_u = \pi D\alpha c + \pi DH\gamma'_s \frac{1+K_0}{2} \tan\delta$$

Where:

- c = Soil cohesion representative of soil backfill material [N/m^2] (c=0 for sand)
- H = Depth to the pipeline centreline [m]
- K_0 = Coefficient of earth pressure at rest [-] $(1 - \sin\varphi_s)$
- α = Adhesion factor [-]
- δ = Interface angle of friction for pipe and soil [°] $(f\varphi_s)$
- f = Coating dependent factor relating the internal friction angle of the soil to the friction angle at the pipe soil interface.

The axial resistance mobilisation displacement, Δ_t, is determined considering the soil type as follows:

- Δ_t = 3mm for dense sand
- Δ_t = 5mm for loose sand
- Δ_t = 8mm for stiff clay
- Δ_t = 10mm for soft sand

5.3.5. Buried pipeline – lateral soil resistance

The maximum lateral force that the soil can transmit per unit pipe length is given by:

$$P_u = N_{ch} cD + N_{qh} \gamma'_s HD$$

Where:

- N_{ch} = Horizontal bearing capacity for clay (0 for c=0).
- N_{qh} = Horizontal bearing capacity factor for sand (0 for $\varphi_s = 0$)

The bearing capacity factors are taken from figure 5-2

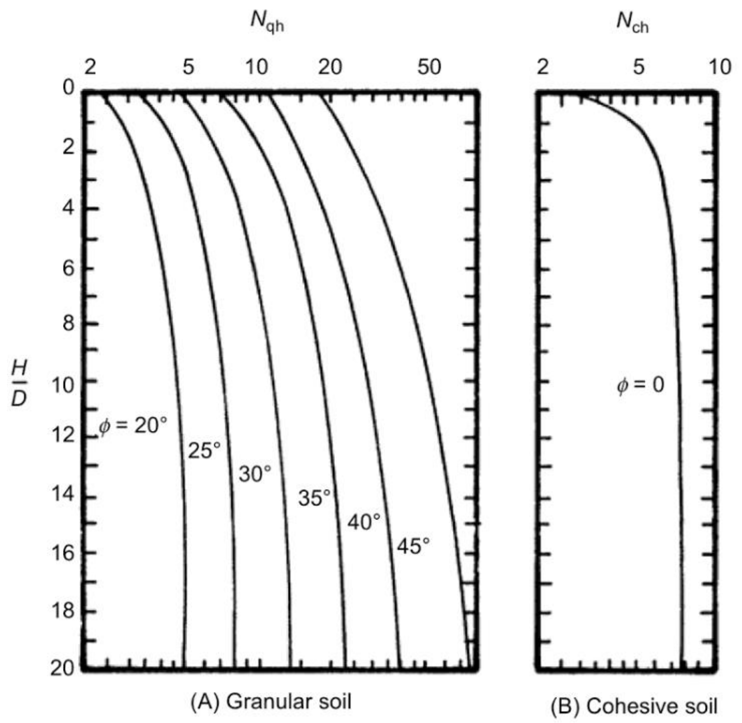


Figure 5-2 Horizontal bearing capacity factors

The lateral soil resistance mobilization displacement is given by:

$$\Delta_p = 0.04\left(H + \frac{D}{2}\right) \leq 0.10D \text{ to } 0.15D.$$

5.3.6. Buried pipeline – vertical upward soil resistance

The uplift resistance R_{max} of a pipe in sand consists of two components, viz. a component owing to the weight of the soil above the pipe and a component owing to soil friction as per DNV-RP-F110 (rev. [6]). The uplift resistance can therefore be expressed as:

$$R_{max} = \left(1 + f\frac{H}{D}\right)(\gamma'_s HD)$$

The uplift resistance factor, f, is:

- $f = 0.1$ for loose sand (backfill)
- $f = 0.5$ for rockdump

The non-linear force-displacement response of a buried pipe is represented by a tri-linear curve as shown in figure 5-3.

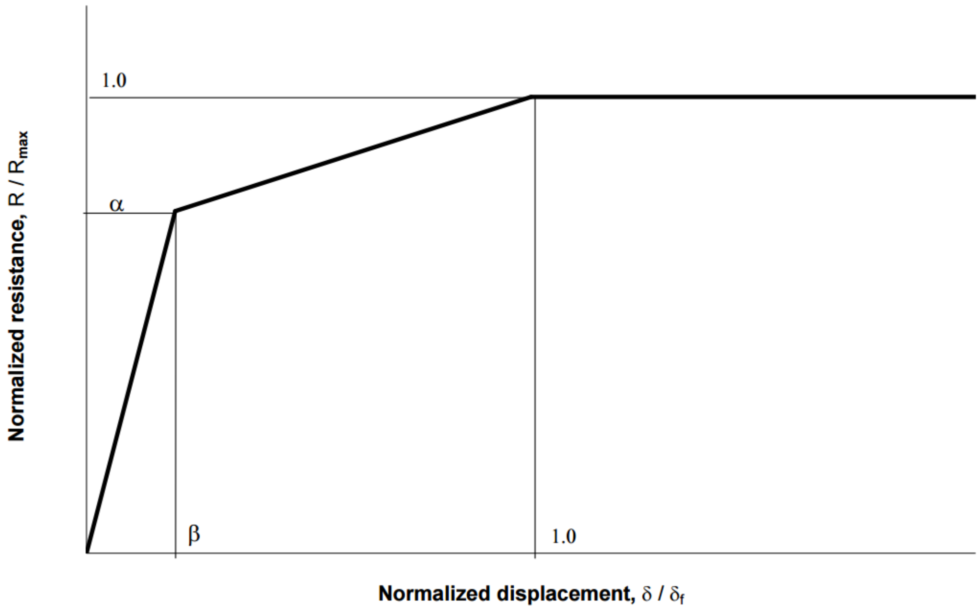


Figure 5-3 Uplift resistance Force-Deflection curve

Where:

- δ_f = Failure displacement (=0.0065H for loose sand backfill) (=20mm for rock dump)
- $\alpha = 0.8$ for loose sand (backfill) and $\alpha = 0.7$ for rock dump
- $\beta = 0.2$

5.4. Fatigue analysis

Fatigue is caused by time varying stresses resulting from applied loads to the riser and parts of the spool piece system which are exposed to hydrodynamic loads.

The riser and spool piece section are from approx. LAT +6.000m to seabed level exposed to the environment and hence are subjected to time varying loads. Three sources of time varying loads, and hence fatigue damage to the riser, are identified:

1. Vortex Induced Vibrations (VIV)
2. Direct wave loading
3. Indirect loads resulting from platform deflections

Riser guide clamps will be spaced such that the maximum span length is below the critical span length at which VIV can occur. The methodology for determining the critical span lengths are described in chapter 7 of this report.

To assess fatigue damage due to direct and indirect wave loading, platform deflections are applied, and the exposed riser section will be subjected to hydrodynamic drag and inertia forces. The drag and inertia forces are determined using the wave induced velocities and accelerations as experienced by the riser section over the lifetime of the pipeline system considering the "Individual Wave Scatter Diagrams for Fatigue H-T" attached as appendix B.

To estimate the fatigue damage, due to direct and indirect wave loading, a detailed finite element assessment will be carried out considering the same finite element model of the riser spool system as described in Section 5.

In this case the H-T wave scatter diagram will be subdivided into a number of representative blocks, with a single sea-state selected to represent all waves in that block. For the wave height within a particular bin the mean wave height is selected and the corresponding wave period is based on the weighted average of the mean wave periods. This reduces the number of required finite element analyses. These wave blocks and the corresponding platform deflections based on the actual platform deflections will be applied to the model. The analyses will account for the directionality of the wave and the number of occurrences of the waves as per the scatter diagrams. The maximum longitudinal (= axial + bending) stress ranges are extracted from the riser elements as follows:

$$\Delta\sigma_{ax,max} = \Delta\sigma_{ax,pdeflect} + \Delta\sigma_{ax,wave} = 2 * \sigma_{ax,amplitude,pdeflect} + (\sigma_{ax,max,wave} - \sigma_{ax,min,wave})$$

Where:

- $\Delta\sigma_{ax,pdeflect}$ = Longitudinal stress range due to platform deflection [N/m^2]
- $\Delta\sigma_{ax,wave}$ = Longitudinal stress range due to wave [N/m^2]
- $\sigma_{ax,amplitude,pdeflect}$ = Single longitudinal stress amplitude due to platform deflection [N/m^2]
- $\sigma_{ax,max,wave}$ = Maximum longitudinal stress due to wave [N/m^2]
- $\sigma_{ax,min,wave}$ = Minimum longitudinal stress due to wave [N/m^2]

The allowable number of cycles will then be determined (N_p) in relation to the maximum longitudinal stress range in all riser elements ($\Delta\sigma_{ax,max}$) for each wave block given by:

$$\log N_p = \log a_n - m_n \log\left(\Delta\sigma_{ax,max}\left(t/t_{ref}\right)^k\right)$$

Where:

- N_p = Predicted number of cycles of failure for stress range [-]
- $\Delta\sigma_{eqv,max}$ = maximum stress range [N/m^2]
- $\log a_n$ = Constant valid in the range n (see Table 5-4)
- m_n = Constant valid in the range n (see Table 5-4)
- t = Wall thickness [m]
- t_{ref} = Reference wall thickness (16mm)
- k = Thickness component (see Table 5-4)

S-N curve designation	N<=10^6 cycles		N>10^6 cycles		Fatigue limit at 10^7 cycles	Thickness component (k)
	m_1	$\log(a_1)$	m_2	$\log(a_2)$		
F (seawater with cathodic protection)	3.0	11.455	5.0	15.091	41.52	0.00

Table 5-4. Fatigue curve parameters (ref. [6])

The design S-N curve (F-curve) is selected according to Table 2.5 of DNV-RP-C203, Ref [7] based on the expected maximum misalignment δ_m, see equation 2.10.5 of Ref [7]. The expected misalignment is calculated based on the pipe diameter/wall thickness and pipe tolerances (thickness and diameter) as given in Table 3.1.

The Stress Concentration Factor (SCF), to be used in the fatigue calculations for both the corroded and non-corroded wall thickness case, is shown in Table 5.5. They are calculated based on equations 2.10.4 and 2.10.1 of DNV-RP-C203, Ref [7].

Pipeline	Case	δ_m (mm)	SCF
20" Export Gas	Non corroded	2.12	1.25
20" Export Gas	Corroded	2.12	1.29

Table 5-5. Overview SCFs

The total fatigue damage due to direct wave loading and platform deflections is then determined, through summation using the Palmgren-Miner rule at each element in the riser as follows:

$$FD = \sum_1^k \left(\frac{n_i}{N_i}\right)$$

Where:

- k = Number of stress/wave blocks
- n_i = Number of stress cycles/wave occurrences in stress block i
- N_i = Number of cycles to failure at constant stress range in stress block i

The acceptability of the fatigue damage is then determined by comparison with the allowable fatigue damage (α_{fat}) ratio as given in Ref. [2]:

$$\alpha_{fat} \geq FD$$

Where:

α_{fat} = Allowable damage ratio = 0.1 [2]

5.5. Low cycle analysis

The riser and spool piece system will also be checked for low cycle fatigue, i.e. stress variations due to pressure and temperature fluctuations. During the pipeline's lifetime the following pressure/temperature fluctuations are anticipated:

- 1x strength test
- 3x leak tests (worst case)
- 25x shut down: Dp = 75 barg and temperature to ambient (annual shut down)

The allowable cycles for the resulting stress variations are to be determined from figure K.8 of ref. [1].

6. Wall Thickness Analysis

Several phenomena are to be investigated prior to finalising the selected wall thickness. Elements to be taken into account:

- pressure containment;
- on-bottom stability;
- implosion;
- progressive plastic collapse;
- local buckling;
- bar buckling;

6.1. Pressure containment

6.1.1. Design condition

NEN 3656, states that for every load combination the design resistance (R_d) must be greater than or equal to the loading effect (S_d) or:

$$R_d \geq S_d$$

R_d is defined as:

$$R_d = R_{e(\Theta)} / \gamma_m$$

Where:

$R_{e(\Theta)}$	=	yield strength of the material at design temperature (N/mm^2)
γ_m	=	material factor (1.1 for steel)

For load combination LC2 (internal pressure only), the equation for hoop stress can be expressed as:

$$\sigma_h = \frac{\gamma_p \cdot P_d \cdot (OD - t_{min})}{2 \cdot t_{min}}$$

Where:

s_h	=	hoop stress (N/mm^2)
γ_p	=	load factor as per Table 5-3 (-) => 1.25
Pd	=	design pressure (N/mm^2)
OD	=	outside diameter of steel pipe (mm)
t_{min}	=	minimum wall thickness (mm)

The selected wall thickness (t_{nom}) is then determined by:

$$t_{nom} = \left\{ \frac{t_{min} + CA}{1 - f_{tol}} \right\}$$

Where:

CA	=	applicable corrosion Allowance (mm)
f_{tol}	=	fabrication tolerance (%)

Further to this, NEN 3656 specifies additional requirements for bends with a bending radius R_b < 10 OD, to adjust the hoop stress of straight pipe (torus effect).

$$S_h(bi) = \frac{2R_b - \frac{1}{2}OD}{2R_b - OD} \cdot S_h \quad \text{(for inside bend)}$$

$$S_h(bo) = \frac{2R_b + \frac{1}{2}OD}{2R_b + OD} \cdot S_h \quad \text{(for outside bend)}$$

6.1.2. Hydrostatic Testing

The hydrostatic testing of pipeline / riser systems has two objectives:

- verify the strength of the system
- verify that there are no leaks from the system

The test pressure, P_t, will be determined as per as per Section 10.18.3 of NEN 3656 (Ref. [1]).

$$P_{t.\min} = C_p \cdot P_d \cdot \frac{R_e}{R_{ev}}$$

Where:

C_p	=	pressure test coefficient (-) => 1.30 for gas lines; 1.25 for others
P_d	=	design operating pressure (N/mm²)
R_e	=	minimum yield stress at 20 °C (N/mm²)
R_{ev}	=	minimum yield stress at design temperature (N/mm²)

The maximum hydrostatic test pressure is based on the weakest part of the pipeline/riser system to be tested. The pressure shall not exceed, $P_{t,max}$, which is defined by:

$$P_{t.\max} = \frac{2.R_e \cdot t_{\min}}{(OD - t_{\min})}$$

However, the maximum hydrotest pressure should not exceed the mill test pressure, which is given by:

$$P_{T,mill} = 0.9 \cdot \frac{2 \cdot R_e \cdot t_{nom}}{OD} \qquad \text{and}$$

$$t_{nom} = \left\{ \frac{t_{\min} + CA}{1 - f_{tol}} \right\}$$

Where:

t_{nom}	=	nominal wall thickness (mm)
t_{min}	=	minimum wall thickness (mm)
CA	=	applicable corrosion Allowance (mm)
f_{tol}	=	fabrication tolerance (%)

6.2. On-bottom Stability

6.2.1. Introduction

The aim of the stability analysis is to verify that the submerged weight of the pipeline ensures lateral stability against environmental loading. Depending on the pipeline being buried or not, the on-bottom stability analysis is carried out for the following condition(s):

- Installation – flooded
- Installation – empty
- Operation – product filled

The pipeline is to be laterally stable on the seabed for a 1 year resp. 100 year return period environmental conditions for a buried resp. unburied pipe. A buried pipeline will not be subject to any environmental loading during hydrostatic testing and operation.

6.2.2. Hydrodynamic loads

Hydrodynamic loads arise from the relative motions between pipe and seawater. They consist of drag, lift and inertia forces.

The drag force F_D is given by:

$$F_D = C_D \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V \cdot |V|$$

Where:

C_D	=	drag force coefficient (-)
OD_{tot}	=	total diameter of coated pipe (m)
ρ	=	mass density of surrounding fluid (kg/m^3)
V	=	velocity of the fluid normal to the pipe axis (m/s)

The lift force F_L is calculated by the following equation:

$$F_L = C_L \cdot OD_{tot} \cdot \frac{1}{2} \cdot \rho \cdot V^2$$

Where:

C_L	=	lift force coefficient (-)

The inertia force F_I is determined by the following equation:

$$F_I = \rho \cdot C_I \cdot \frac{\pi}{4} \cdot {OD_{tot}}^2 \cdot a$$

Where:

C_I	=	inertia force coefficient (-)
a	=	Fluid particle acceleration (m/s^2)

The recommended values of hydrodynamic coefficients for the on-bottom stability design as a function of the embedment of the pipeline are listed in Table 6-1.

Coefficient	Pipe embedment			Riser
	0%	**10%**	**20%**	
Drag	0.70	0.63	0.53	1.0
Lift	0.90	0.90	0.81	-
Inertia	3.29	2.80	2.30	2.0

Table 6-1 Overview hydrodynamic coefficients

The wave induced water particle velocities and accelerations will be determined using the appropriate wave theory for the design wave height, period and water depth. Phase shifts between horizontal and vertical water particle velocities will be considered.

6.2.3. Stability check

The stability of the pipelines is checked using the following relationship:

$$W_s > f_s \cdot \left(\frac{F_D + F_I}{f_w} + F_L \right) - \frac{F_P}{f_w}$$

Where:

W_s = pipeline submerged weight (N/m)

f_s = safety factor (-) => 1.1

F_D = drag force (N/m)

F_L = lift force (N/m)

f_w = friction factor (-)

F_I = inertia force (N/m)

F_P = passive soil resistance (N/m)

A safety factor (f_s) of 1.1 will be implemented. The above equation assumes absolute stability criteria. Note that the actual F_p is limited to the maximum of the combined drag and inertia forces.

The passive soil resistance is derived from:

$$F_p = 0.5 \cdot \rho_{soil} \cdot \varepsilon^2 \cdot K_p$$

Where:

ρ_{soil} = submerged soil density (kg/m^3)

ε = embedment of pipeline (m)

K_P = coefficient of passive soil resistance (-)

and K_P is calculated from :

$$K_P = \frac{1+\sin(\phi)}{1-\sin(\phi)} = \tan^2 \cdot \left(45 + \frac{\phi}{2} \right)$$

Where:

ϕ = angle of internal friction (°)

6.3. Implosion

6.3.1. External overpressure

The collapse pressure p_c causing implosion (radial instability) can be determined using:

$$(P_c - P_e) \cdot (P_c^{\ 2} - P_p^{\ 2}) = P_c \cdot P_e \cdot P_p \cdot 2 \cdot \delta_0 \cdot \frac{D_g}{t}$$

Where:

D_g	=	nominal diameter of pipe (mm)
P_c	=	critical external pressure for collapse (N/mm2)
P_e	=	critical external pressure for elastic deformation (N/mm^2)
P_p	=	critical external pressure for plastic deformation (N/mm^2)
P_L	=	allowable external pressure (N/mm^2)
δ_0	=	initial deformation (mm)
t	=	nominal wall thickness (mm)

$$D_g = \frac{1}{2} \cdot \{OD_{nom} - (OD_{nom} - 2 \cdot t_{min})\}$$

The critical external pressure for plastic deformation is calculated from:

$$P_p = \frac{2 \cdot R_e \cdot t}{D_{nom}}$$

The critical external pressure for elastic deformation is calculated from:

$$P_e = \frac{2 \cdot E}{1 - \nu^2} \cdot \left(\frac{t}{D_{nom}}\right)^3$$

Where:

ν	=	Poisson's ratio for elastic deformation (-) => 0.3

As a part of this the initial deformation is derived from:

$$\delta_0 = \frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}}$$

Where:

D_{max}	=	largest diameter of the ovalized pipe cross section
D_{min}	=	smallest diameter of the ovalized pipe cross section

The maximum allowable external pressure is defined as:

$$\gamma_{g,p} \cdot P_L \leq \frac{\gamma_M \cdot P_c}{\gamma_{m,p}}$$

Where:

$\gamma_{g,p}$	=	load factor (-) => 1.05
γ_M	=	model factor (-) => 0.93
$\gamma_{m,p}$	=	material factor (-) => 1.45

6.3.2. Bending moment

In case of a bending moment on the pipe, the moment which will cause buckling is calculated from the plastic moment of the pipe section.

$$M_c = D_{nom}^{\ 2} \cdot t \cdot R_e$$

The maximum allowable bending moment is defined as:

$$\gamma_{g,M} \cdot M_L \leq \frac{\gamma_M \cdot M_c}{\gamma_{m,M}}$$

Where:

$\gamma_{g,M}$	=	load factor (-) => 1.1
γ_M	=	model factor (-) => 1.0
$\gamma_{m,M}$	=	material factor (-) => 1.3
M_L	=	allowable bending moment for buckling (Nm)
M_c	=	critical bending moment for buckling (Nm)

6.3.3. Combined external pressure and bending moment

When external pressure exists in combination with a bending moment besides the checks above the condition for combined stresses as shown below shall be fulfilled.

$$\frac{\gamma_{g,p} \cdot P_L}{P_c / \gamma_{m,p}} + \left(\frac{\gamma_{g,m} \cdot M_L}{M_c / \gamma_{m,M}} \right)^n \leq \gamma_M$$

Where:

$$n = 1 + 300 \cdot \frac{t}{D_{nom}}$$

Where:

$\gamma_{g,p}$	=	load factor for pressure (-) => 1.05
$\gamma_{g,m}$	=	load factor for bending (-) => 1.55
γ_M	=	model factor (-) => 0.93
$\gamma_{m,p}$	=	material factor for pressure (-) => 1.25
$\gamma_{m,M}$	=	material factor for bending (-) =>1.15
M_L	=	allowable bending moment for buckling (Nm)
M_c	=	critical bending moment for buckling (Nm)

6.4. Progressive plastic collapse

Progressive plastic deformation load cycle will lead to extreme deformation, collapse and cracks initiation through the wall.

The condition for avoiding buckle propagation is:

$$\varepsilon_{\max} = \alpha \cdot \Delta T \leq \left[\frac{R_{ev}}{E} \cdot \sqrt{1 - \frac{3}{4}\left(\frac{\sigma_h}{R_{ev}}\right)^2} + \frac{R_e}{E}\sqrt{0.9 - \frac{3}{4}\left(\frac{\sigma_h}{R_e}\right)^2} \right]$$

Where:

α	=	coefficient of linear thermal expansion (m/ m/ ° C)
ΔT	=	temperature differential [° C] (design – installation)

Parameters have to be factored as defined in section 6.

6.5. Local buckling

In accordance with NEN 3656, if OD / t < 55, an assessment on local buckling can generally be omitted.

For this project it would mean that a local buckling check is required for a wall thickness of maximum 5.0 mm, which will be much smaller than the anticipated wall thickness based on internal pressure and on-bottom stability. This will be checked during detailed design.

6.6. Bar buckling

In a free span the pipeline will be susceptible to bar buckling. Bar buckling may occur due to an effective axial compressive force (N) in the pipeline. The compressive force in an axially restrained pipeline is based on the longitudinal stress:

$$N = A \cdot (\nu \cdot S_h - \gamma_t \cdot E \cdot \alpha \cdot \Delta T)$$

Where:

A	=	cross sectional area of steel (mm^2)
ν	=	Poisson's ratio for elastic deformation (-) => 0.3
S_h	=	factored hoop stress (N/mm^2)
γ_t	=	load factor as given in Table 5-3 (-)
α	=	coefficient of thermal expansion (m/m/°C)
ΔT	=	pipeline temperature differential (° C) (design – installation)

The factored hoop stress (S_h) is calculated from:

$$S_h = \gamma_P \cdot \sigma_h$$

and

$$\sigma_h = \frac{P_d \cdot (OD - t_{min})}{2 \cdot t_{min}}$$

Where:

P_d	=	design pressure (N/mm^2)
t_{min}	=	minimum pipe wall thickness (mm)
OD	=	outside diameter of steel pipe (mm)
γ_P	=	load factor as given in Table 5-3 (-)

The buckling length is based on the Euler buckling load definition, defined in Ref. [3]. Bar buckling is avoided if the span length fulfils:

$$L \leq \sqrt{4 \cdot \pi^2 \frac{E \cdot I}{|N|}}$$

Where:

L	=	allowable span length (mm)
I	=	moment of inertia (mm^4)

7. Free Span analysis

Spanning of a pipeline on the seabed causes forces and stresses in the pipe. The criterion for accepting a pipeline configuration is that the pipe should not be subjected to over-stressing, nor to excessive dynamic loading because of resonant oscillations of the pipe caused by the vortex shedding phenomenon during installation, testing and throughout its operating life.

The pipeline span assessment includes the following items:

- Static span analysis
- Dynamic span analysis.

The static analysis concerns the determination of the pipe stresses under functional- and static environmental loads for a given span length.

The dynamic span analysis is based on criteria for prevention of vortex induced vibrations (VIV) as outlined in NEN 3656 considering both current- and wave induced velocities.

In addition, operational limits of the trenching equipment, limits the span gap (distance between the pipe and the seabed).

Although the pipeline will be buried below the seabed prior to its operation, the pipeline must be checked for spanning for the period between installation and burial.

In the analysis, along with the seabed topography, both functional and environmental loads are taken into consideration to check pipeline structural integrity under the considered load cases.

7.1. Static span

Combining hoop, longitudinal and bending stresses in the pipeline, which shall satisfy criteria for equivalent stresses, gives the maximum allowable static span lengths. Checks are to be made for the installation, hydro test and operational load case.

The maximum bending moment is calculated from the (vector) combination of the pipelines' own weight and hydrodynamic forces for the maximum wave condition:

$$q = \sqrt{\gamma_W{}^2 \cdot W_S{}^2 + \gamma_H{}^2 \cdot (F_D + F_I)^2}$$

Where:

γ_W	=	load factor as per Table 5-3 (-)
γ_H	=	load factor as per Table 5-3 (-)

End fixity of an actual span is commonly assumed between fixed - fixed and fixed – pinned and the bending moment (M) calculated from:

$$M = \frac{q \cdot L^2}{10}$$

Where:

L	=	Maximum allowable span length [m]

The maximum allowable bending moment (M_{all}) is given by:

$$M_{all} = \frac{2 \cdot I \cdot \sigma_b}{OD}$$

Where:

I	=	moment of inertia (m^4)
OD	=	pipeline outside diameter (m)
s_b	=	maximum allowable bending stress

The maximum allowable static span can then be determined by:

$$L\max = \sqrt{\frac{20 \cdot \sigma_b \cdot I}{OD \cdot q}}$$

The maximum allowable span length follows from the condition that the equivalent stress (S_e) from the load combination satisfies the following conditions:

For the operational and hydrotest cases: $S_e \leq 0.85 \times (R_e + R_{ev}) / \gamma_m$

For the installation case: $S_e \leq R_e / \gamma_m$

Where:

R_e	=	minimum yield stress at 20 °C (N/mm^2)
R_{ev}	=	minimum yield stress at design temperature (N/mm^2)
γ_m	=	material factor (-) => 1.1

7.1.1. Load cases

The maximum static span will be determined for the load cases, and considering the environmental load return periods, as detailed in Table 7-1:

Condition	Wave Height Return Period	Current velocity Return Period
Installation	$H_{max,1yr}$	1 yr
Hydrotest	$H_{max,1yr}$	1 yr
Operational,1	$H_{max,100yr}$	10 yr
Operational,2	$H_{max,10yr}$	100 yr

Table 7-1 Load Cases for Span Assessment

7.2. Dynamic span

Flow of water particles induced by currents and waves perpendicular to a spanning pipeline or riser span can lead to vortices being shed. This will disrupt the flow around the pipe and thereby potentially cause periodic loads on the pipeline or riser, also known as Vortex Induced Vibration (VIV).

The natural frequency of a span being close to the vortex shedding frequency can result in a resonant oscillation, possibly resulting in fatigue failure of the pipeline or riser.

The oscillations of the span may occur in two directions:

- in line with the flow (parallel to the flow direction of the water particles)
- in cross flow direction (perpendicular to the flow direction of the water particles)

When assessing VIV, the span should be confirmed to be within acceptable limits set by either avoidance of VIV or an acceptable fatigue life for both the installation and operational condition.

Relevant dimensionless parameters governing the VIV phenomenon are the reduced velocity (V_r) and stability parameter (K_s).

The reduced velocity (V_r) parameter is defined by:

$$V_r = \frac{V_s}{f_{n \cdot OD_{tot}}}$$

Where,

V_s	=	water particle velocity due to current and significant wave (m/s)
f_n	=	1^{st} natural frequency of the pipe span (1/s)
OD_{tot}		total outside diameter of the pipe (m)

The 1st natural frequency can be calculated from:

$$f_n = \frac{a}{2\pi} \cdot \sqrt{\frac{E \cdot I}{m_e \cdot L^4}}$$

Where,

a	=	frequency factor (-) => 15.4 for a fixed-pinned beam, which is used for the pipe
E	=	Young's modulus (N/m^2)
I	=	moment of inertia (m^4)
L	=	length of span in pipeline / riser (m)

The effect of the CWC on the moment of inertia and the Young's modulus is not taken into account; this is a conservative approximation. The outer diameter is including the CWC.

The stability parameter (K_s) is defined by:

$$K_s = \frac{2 \cdot m_e \cdot \delta}{\rho_{sw} \cdot OD_{tot}^2}$$

Where,

m_e	=	effective mass of pipe (kg/m)
ρ_{sw}	=	density seawater (kg/m^3)
δ	=	logarithmic decrement of damping (-) => δ = 0.126 for steel

The effective mass of the pipe can be calculated as:

$$m_e = m + \pi/4 \cdot C_M \cdot \rho_{sw} \cdot OD_{tot}^{\ 2}$$

Where,

m	=	Pipeline / riser mass (kg/m)
Cm	=	added mass coefficient (-)

NEN 3656 states that In-line oscillations will occur if $K_s \leq 1.8$ and cross flow oscillations will occur if $K_s \leq 16$.

7.2.1. In-line VIV

NEN 3656 furthermore states that in-line oscillations of the span occur if the reduced velocity is within the range of: $1.0 \leq Vr \leq 3.5$

Vortices around a spanning pipe occur in a relatively steady state environment. The wave induced velocity varies from a maximum at t=0, to zero at t=1/4*Twave. Furthermore, the system does not respond instantaneously to the applied forcing. To ignore the wave induced velocity in assessing the allowable dynamic span length would be too optimistic, to account for the maximum induced value would be too conservative, therefore reference is made to DNV-RP-F105. “Free Spanning Pipelines.” (ref. [3]).

According to Ref. [3], fatigue damage due to in-line VIV can be neglected if the current flow velocity ratio α, as defined by the equation below is smaller than 0.8.

$$\alpha = \frac{v_{cur}}{v_{cur} + v_{wave}}$$

Where,

v_{cur}	=	Particle velocity due to current [m/s]
v_{wave}	=	Particle velocity due to waves [m/s]

7.2.2. Cross-flow VIV

The occurrence of cross flow oscillations depends on the magnitude of the Reynolds number, Re, and the reduced velocity as given in Figure 7-1.

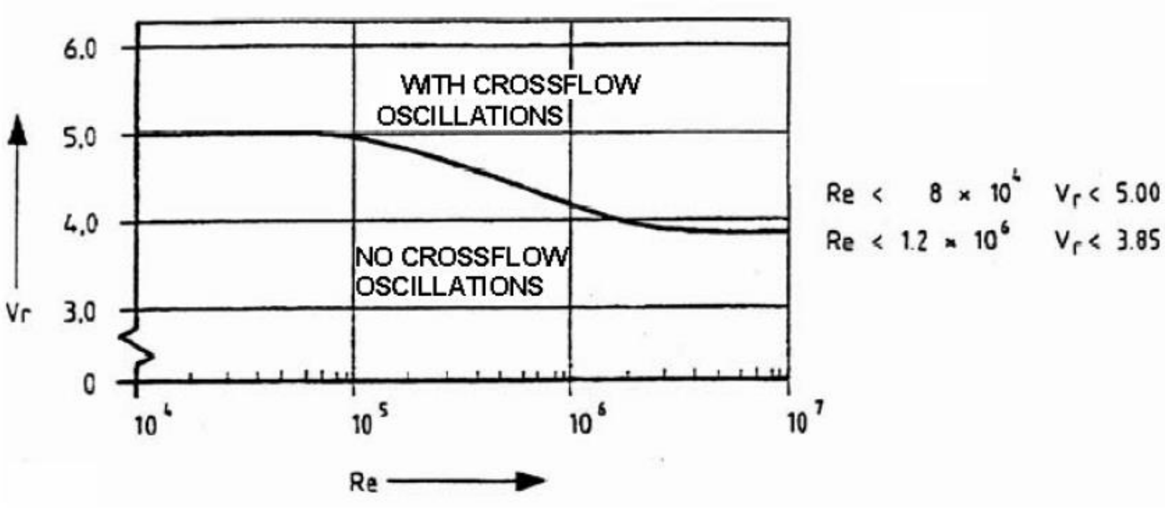


Figure 7-1 Reduced velocity for cross flow oscillations

$$\mathrm{Re} = \frac{\mathrm{v} \cdot OD_{tot}}{\nu}$$

Where,

v	=	particle velocity (m/s)
OD_{tot}	=	pipeline outside diameter (m)
n	=	Kinematic viscosity water (m^2/s) => 1,307 x 10^{-6} (at 10 °C)

8. Bottom roughness

8.1. General

To ensure the structural integrity of the pipeline over its entire design life finite element analyses will be carried out using industry proven software like Ansys or RFEM.

The analysis will assess the interaction between the pipeline and the supporting soil along the entire pipeline route and will be carried out in accordance with the requirements of NEN 3656 (Ref. [1]). The analysis will determine the number of spans exceeding the allowable span length and the subsequent pre-sweeping requirements. The design loads at the tie-in locations will be determined and in addition the analysis will assess the upheaval buckling response of the pipeline system under operating conditions.

The analysis will account for the load history of the pipelines over the design life by considering the following load cases:

- Installation (empty);
- Installation (flooded);
- Pipeline operation - nominal (nominal wall thickness content filling maximum operating pressure and temperature);
- Pipeline operation - corroded (corroded wall thickness content filling maximum operating pressure and temperature).

The pipeline will be modelled by uniaxial elements with tension-compression torsion and bending capabilities and can account for internal pressure effects. The element is a 3D element with six degrees of freedom translations in the x y and z directions and rotations about the x y and z axes. In addition, the element needs to account for buoyancy wave and current loads and to be capable of large deflections and rotations.

The pipeline is to be modelled with a maximum element length of 0.5 – 1.0 m and accounts for all curvatures in the horizontal plane and undulations in the vertical plane. Pipe-soil interaction is simulated using three independent non-linear spring elements attached to each pipe element. The springs represent the soil frictional resistance in the axial and lateral directions and the soils bearing capacity in the vertical direction.

For sections of the pipeline which are buried additional vertical non-linear springs representing the uplift resistance of the trench backfill material will be attached to the pipe elements.

Seabed roughness will be simulated by displacing the vertical springs representing the soil bearing capacity to the correct depth based on the bathymetric data and allowing the pipe to move and rest on the vertical springs.

When the depth of the pipeline at a certain point is less than the depth of the seabed a "free span" is identified. Similar succeeding joints indicate a larger span. The length of the free span is determined by subtracting the coordinates of the beginning of the span from the coordinates of the span end.

At pipeline termination points an additional axial spring will be attached to the pipeline ends to incorporate the structural response of the subsea tie-in spool/riser and supporting piping.

8.2. Pipe-soil interaction

The characteristics of the springs which simulate the pipe-soil interaction are defined through non-linear force deflection curves. These force-deflection curves describe the frictional restraint provided by the soil to the pipeline in the axial lateral direction and the soils bearing capacity /upwards resistance in the vertical direction.

2 situations can be distinguished:

- exposed pipeline
  - axial soil resistance;
  - lateral soil resistance;
  - vertical bearing capacity (downward resistance);

- buried pipeline
  - axial soil resistance;
  - lateral soil resistance;
  - vertical bearing capacity (downward resistance);
  - vertical upward soil resistance;

Table 8-1 gives an overview of the calculation basis of the mentioned soil resistances/capacities.

Direction	Exposed pipeline	Buried pipeline
Axial	Function of pipe submerged weight and axial Coulomb friction coefficient	Function of pipe diameter, burial depth and effective unit soil weight.
Lateral	Combination of Coulomb friction part and passive soil resistance due to build-up of soil penetration (ref. [5])	Based on horizontal bearing capacity factor (ref. [9])
Vertical bearing	Based on bearing capacity formulas for ideal 2-D strip foundations ref. [3]	Based on bearing capacity formulas for ideal 2-D strip foundations ref. [3]
Vertical upward	N/A	As per ref. [6] based on burial depth pipe diameter and submerged soil weight

Table 8-1 Overview soil resistance/capacity calculation basis

9. Upheaval Buckling

Buried pipelines exposed to compressive effective axial forces may get unstable beyond its anchor point and move vertically out of the seabed if the cover has insufficient resistance. An out-of-straightness configuration will result in forces acting on the cover perpendicular to the pipeline. In case these vertical forces exceed the cover resistance the pipeline will buckle upwards.

The relation between minimum required cover height and the imperfection height (out-of-straightness) will be established in accordance with ref. [11].

Parameters used in the assessment of upheaval buckling are the dimensionless imperfection length parameter (Φ_L):

$$\Phi_L = L \cdot \sqrt{\frac{N_e}{EI}}$$

Where:

L	=	exposure length (m)
N_e	=	effective axial compressive force (N)
EI	=	bending stiffness (N m^2)

And the dimensionless maximum download parameter (Φ_w):

$$\Phi_w = \frac{w \cdot E \cdot I}{\Delta_{calc} \cdot N_e^2}$$

Where:

w	=	required download [N/m]
Δ_{calc}	=	imperfection height [m]

Depending on the Φ_L value the required download is derived from Φ_w in accordance with:

$$\Phi_w = 0.0646 \text{ for } \Phi_L < 4.49$$

$$\Phi_w = \frac{5.68}{\phi_L^2} - \frac{88.35}{\phi_L^4} \text{ for } 4.49 < \Phi_L < 8.06$$

$$\Phi_w = \frac{9.6}{\phi_L^2} - \frac{343}{\phi_L^4} \text{ for } \Phi_L > 8.06$$

In cohesionless soils the uplift resistance (q) due to the cover of the pipe can be calculated from:

$$q = \gamma \cdot H \cdot OD \cdot \left(1 + f \cdot \frac{H}{OD}\right)$$

Where:

γ	=	effective under water weight of soil (N/m^3)
H	=	depth of cover (m)
OD	=	outside diameter of pipe (m)
f	=	uplift coefficient 0.5 for dense material 0.1 for loose material

The calculated required download (w) shall be smaller than the actual combination of the submerged weight and uplift resistance of the pipeline.

The simplified method from Reference [11] is conservative in that it does not model a number of mitigating factors such as:

- The finite axial stiffness of the pipeline which determines how rapidly the axial force diminishes as the pipeline moves upwards
- The pipeline resistance to axial movement through the soil determines how far the pipeline can slide towards a developing buckle.

Both the above factors may cause progressive upheaval buckling predicted by the analysis method in Reference [11] not to occur.

Further the sinusoidal imperfection profile assumed in the model is envisaged to yield conservative download requirements.

The results will be presented as a maximum imperfection length with respect to the cover depth and the imperfection height.

10. Cathodic Protection

As per NEN 3656 the cathodic protection system of the pipeline bundle will be designed as per ref. [12]. The characteristics of a typical anode element are given in Table 10-1.

Item	Value
Type	Half Shell Bracelet
Material	Aluminium
Cable connections	2 x @ 20" pipeline

Table 10-1 Typical anode characteristics

The cathodic protection will be designed to prevent external corrosion of the pipeline. The mass and spacing of the anodes will be such that the following criteria are met:

- Total anode mass to meet the mean and final current demand over the design life of the pipeline.
- Anode current output to meet the required current output at the end of the design life.
- Anode separation not to exceed a value of 300 m.

The pipeline will be divided in to sections where changes in conditions, such as water depth, operating temperature or burial, can give rise to variations in design current density.

From the pipeline dimensions and the coating selected, the mean current demand, I_{cm}, and the final demand, I_{cf}, shall be calculated separately as per the following:

$$I_c = A_c \cdot f_c \cdot i_c$$

Where:

I_c = the current demand for a specific pipeline section calculated for mean and final conditions (A)
A_c = the total surface area for a specific pipeline section (m^2)
f_c = the coating breakdown factor determined for mean and final conditions (-)
i_c = the current density selected for mean and final conditions (A/m^2)

For pipelines fully buried, a design current density (mean and final) of 20 mA/m^2 should be used irrespective of seawater temperature, oxygen content or depth as per Section 7.4.3 of Ref. [12].

The coating breakdown factors for mean and final conditions, f_c, taking into consideration the deign life of the pipeline, are calculated as follows.

The mean coating breakdown factor, $\overline{f_c}$, is determined by:

$$\overline{f_c} = f_i + (0.5\Delta f \cdot t_{dl})$$

And the mean coating breakdown factor, f_f , is determined by

$$f_f = f_i + (\Delta f \cdot t_{dl})$$

Where:

f_i = the initial coating breakdown factor at the start of pipeline operation (-)
Δf = the average yearly increase in the coating breakdown factor (-)
t_{dl} = the design life (yrs)

The initial coating breakdown factor and average yearly increase in breakdown factor are dependent on the anti-corrosion coating and field joint coating material. Values for various coating are taken from [12] and reported in Table 9-2.

Factory-applied coating type	Field joint coating type	f_i	Δf
Fusion-bonded epoxy (FBE)	Heat-shrinkable sleeves (HSS[a])	0,080	0,003 5
	FBE	0,060	0,003 0
Three-layer coating systems including epoxy, adhesive and polyethylene (3LPE)	HSS[a]	0,009	0,000 6
	FBE	0,008	0,005
	Multilayer coating including epoxy and PE (e.g. moulded, HSS[a] or flame spray)	0,007	0,000 5
Three-layer coating systems including epoxy, adhesive and polypropylene (3LPP)	HSS[a]	0,007	0,000 3
	FBE	0,006	0,000 2
	Multilayer coating including epoxy and PP (e.g. HSS[a], hot tapes, moulding or flame spray)	0,005	0,000 2
Heat insulation multilayer coating systems including epoxy, adhesive and/or PE, PP or PU	Thick multilayer coating systems including epoxy, adhesive and/or PE, PP, PU, HSS[a] or a combination of these products.	0,002	0,000 1
Thick coatings: elastomeric materials (e.g. polychloroprene or EPDM) or glassfibre-reinforced resins	Thick elastomeric materials or glassfibre-reinforced resins	0,002	0,000 1
Flexible pipelines	Not applicable (mechanical couplings)	0,002	0,000 1

[a] HSS can be used with or without primer.

Table 10-2 Coating breakdown factors [12]

Having established the mean current demand, the total required mass of anode material for a specific pipeline section is determined as follows:

$$m = I_{cm} \cdot t_{dl} \cdot \frac{8760}{\mu \cdot \varepsilon}$$

Where:

m = the total net anode mass, for the specific pipeline section (kg)

I_{cm} = the mean current demand for the specific pipeline section (A)

μ = is the utilization factor (-) = 0.8 for bracelet anodes as per Section 8.4 of Ref. [12].

ε = the electrochemical capacity of the anode material per kilogram (A/h)

The electrochemical capacity of the anode material is dependent on the surface temperature of the anode and its burial status. The applicable values are taken from Section 8.3 of Ref. [12] and reported in Table 9-3.

Having determined the total net anode mass required to meet the current demand, the minimum number of anodes required in a specific pipeline section, will be determined as follows:

$$n = \frac{m}{m_a}$$

Where:

n = the number of anodes to be installed on the specific pipeline section (-)

m_a = the individual net anode mass (kg)

The minimum number of anodes, n, shall be determined considering the maximum allowable anode spacing of 300m as reported in Section 8.1 of Ref. [12].

Anode type	Anode surface temperature[a]	Immersed in seawater		Buried in seawater sediments[d]	
		Potential	Electrochemical capacity	Potential	Electrochemical capacity
		Ag/AgCl/ seawater	ε	Ag/AgCl/ seawater	ε
	°C	mV	A·h/kg	mV	A·h/kg
Aluminium	< 30	– 1 050	2 000	– 1 000	1 500
	60	– 1 050	1 500	– 1 000	800
	80[b]	– 1 000	900	– 1 000	400
Zinc	< 30	– 1 030	780	– 980	750
	> 30 to 50[c]			– 980	580

Electrochemical capacity for a given alloy is a function of temperature and anode current density. Reference is made to Annex A for guidance on CP design for variations in anode current densities.

For non-buried pipelines, the anode surface temperature should be taken as the external pipeline temperature and not the internal fluid temperature. For buried pipelines, the anode surface temperature shall be taken as the internal fluid temperature.

[a] For anode surface temperatures between the limits stated, the electrochemical capacity shall be interpolated.

[b] For aluminium anodes, the anode surface temperature shall not exceed 80 °C unless the performance has been demonstrated in tests and has been documented.

[c] For zinc anodes, the anode surface temperature shall not exceed 50 °C unless satisfactory performance has been demonstrated in tests and has been documented.

[d] Pipelines which are rock-dumped shall be considered as buried in seawater sediments.

Table 10-3 Design values for galvanic anodes [12]

To provide the required current, the actual anode current output shall be greater than or equal to the required current output:

$$I_{af} \geq I_f$$

Where:

I_{af} = the actual end-of-life individual current output (A)

I_f = the required end-of-life individual anode current output (A)

The required end-of-life individual anode current output, I_f, shall be calculated from the following:

$$I_f = \frac{I_{cf}}{n}$$

Where:

I_{cf} = the total current demand for the protection of the specific pipeline section at the end of life (A)

For a given anode size and mass, the actual individual anode current output at the end of life, I_{af}, is calculated from the below equation:

$$I_{af} = \frac{E_c - E_a}{R_a}$$

Where:

E_c = the design protection potential (V)

E_a = the design closed-circuit potential of the anode (V)

R_a = the total circuit resistance, which is assumed to be equivalent to the anode resistance (ohms)

The anode resistance, R_a, shall be calculated as follows:

$$R_a = 0.315\frac{\rho}{\sqrt{A}}$$

Where:

ρ = the environmental resistivity (ohm.m)

A = the exposed surface area of the anode (m^2)

For determining the end-of-design-life anode-to-seawater resistance, the anodes shall be assumed to be consumed to an extent given by their utilization factor. The approximate anode dimensions (exposed surface area) corresponding to this degree of wastage shall be used in the anode resistance formula for R_a.

A. Environmental Data GEOxyz

Magnetic Contacts

MAG ID	Easting	Northing	Size nT
MAG_001	717953,7	5940271,5	1846
MAG_002	717991,0	5940276,5	2449
MAG_003	718039,9	5940290,0	1412
MAG_004	718041,2	5940299,0	88
MAG_005	718096,4	5940310,5	5750
MAG_006	718148,3	5942788,5	35
MAG_007	718149,5	5940331,0	2207
MAG_008	718198,9	5940350,5	4606
MAG_009	718247,8	5940365,0	878
MAG_010	718312,4	5940395,0	4218
MAG_011	718346,7	5940412,0	1847
MAG_012	718409,7	5940429,5	1254
MAG_013	718424,0	5944905,0	44
MAG_014	718444,3	5942692,5	828
MAG_015	718462,9	5941110,5	163
MAG_016	718472,4	5940453,5	1966
MAG_017	718484,8	5942724,5	4590
MAG_018	718491,8	5940449,0	962
MAG_019	718506,9	5942723,0	1900
MAG_020	718508,2	5942754,0	9330
MAG_021	718509,3	5940455,5	558
MAG_022	718516,3	5942748,5	5361
MAG_023	718534,0	5942694,0	1157
MAG_024	718548,1	5945123,5	32

MAG_025	718565,1	5940481,0	3279
MAG_026	718595,9	5942616,0	52
MAG_027	718617,5	5940493,0	5243
MAG_028	718662,3	5940506,0	613
MAG_029	718720,1	5940516,0	2386
MAG_030	718766,9	5940523,0	2963
MAG_031	718829,4	5940541,0	706
MAG_032	718856,6	5940558,0	9291
MAG_033	718875,8	5944329,5	23
MAG_034	718975,9	5941798,0	86
MAG_035	718995,8	5942736,5	67
MAG_036	719033,8	5946829,5	22
MAG_037	719274,9	5946749,5	136
MAG_038	719349,1	5948063,0	51
MAG_039	719395,2	5946438,0	14
MAG_040	719449,5	5948089,0	11
MAG_041	719489,0	5947981,0	40
MAG_042	719645,7	5947744,5	73
MAG_043	720080,7	5949053,0	11
MAG_044	720398,8	5952407,0	22
MAG_045	720432,3	5952500,5	428
MAG_046	720451,3	5952357,0	15
MAG_047	720452,1	5952553,0	197
MAG_048	720492,5	5952478,5	6757
MAG_049	720507,6	5952530,5	846
MAG_050	720589,2	5952492,5	539
MAG_051	720687,5	5951846,0	11
MAG_052	720733,6	5952469,5	17

MAG_053	720796,44	5954306,50	11
MAG_054	720823,9	5952486,5	38
MAG_055	720895,0	5952512,5	195
MAG_056	720896,6	5952528,5	258
MAG_057	720966,9	5952512,5	155
MAG_058	720972,6	5952521,0	30
MAG_059	720981,25	5955029,50	15
MAG_060	721006,69	5954892,50	18
MAG_061	721006,69	5954892,5	18
MAG_062	721043,6	5954396,5	50
MAG_063	721043,63	5954396,50	50
MAG_064	721043,6	5954396,5	50
MAG_065	721050,88	5954393,50	66
MAG_066	721050,9	5954393,5	66
MAG_067	721050,9	5954393,5	66
MAG_068	721097,9	5953584,0	8
MAG_069	721144,6	5952537,5	59
MAG_070	721224,2	5952542,0	88
MAG_071	721272	5954784,5	23
MAG_072	721272,00	5954784,50	23
MAG_073	721272,0	5954784,5	23
MAG_074	721395,3	5952547,0	97
MAG_075	721424,3	5952569,5	110
MAG_076	721424,88	5954616,50	285
MAG_077	721424,9	5954616,5	285
MAG_078	721424,88	5954616,5	285
MAG_079	721424,9	5954616,5	285
MAG_080	721430,5	5952680,5	22

MAG_081	721567,25	5954416,50	12
MAG_082	721567,3	5954416,5	12
MAG_083	721567,25	5954416,5	12
MAG_084	721567,3	5954416,5	12
MAG_085	721568,5	5954404,5	22
MAG_086	721568,50	5954404,50	22
MAG_087	721571,7	5954762,5	18
MAG_088	721571,69	5954762,50	18
MAG_089	721571,69	5954762,5	18
MAG_090	721571,7	5954762,5	18
MAG_091	721615,3	5954915,0	27
MAG_092	721615,25	5954915,00	27
MAG_093	721615,25	5954915	27
MAG_094	721615,3	5954915	27
MAG_095	721625,25	5954596,50	53
MAG_096	721625,3	5954596,5	53
MAG_097	721625,25	5954596,5	53
MAG_098	721625,3	5954596,5	53
MAG_099	721625,4	5954919,0	28
MAG_100	721625,38	5954919,00	28
MAG_101	721625,38	5954919	28
MAG_102	721625,4	5954919	28
MAG_103	721645,7	5954971,5	66
MAG_104	721645,69	5954971,50	66
MAG_105	721645,69	5954971,5	66
MAG_106	721645,7	5954971,5	66
MAG_107	721650,5	5954550	376
MAG_108	721650,50	5954550,00	376

MAG_109	721650,5	5954550,0	376
MAG_110	721657,8	5954589	358
MAG_111	721657,8	5954589,0	358
MAG_112	721657,81	5954589,00	358
MAG_113	721657,81	5954589	358
MAG_114	721658,0	5954624,0	45
MAG_115	721658,00	5954624,00	45
MAG_116	721658	5954624	45
MAG_117	721666,7	5954576,0	1100
MAG_118	721666,69	5954576,00	1100
MAG_119	721666,69	5954576	1100
MAG_120	721666,7	5954576	1100
MAG_121	721670,5	5954647,5	27
MAG_122	721670,50	5954647,50	27
MAG_123	721672,2	5954562,0	2733
MAG_124	721672,19	5954562,00	2733
MAG_125	721672,19	5954562	2733
MAG_126	721672,2	5954562	2733
MAG_127	721683,56	5954529,00	252
MAG_128	721683,6	5954529,0	252
MAG_129	721683,56	5954529	252
MAG_130	721683,6	5954529	252
MAG_131	721685,69	5954453,00	110
MAG_132	721685,7	5954453,0	110
MAG_133	721685,69	5954453	110
MAG_134	721685,7	5954453	110
MAG_135	721691,2	5954590,0	360
MAG_136	721691,19	5954590,00	360

MAG_137	721691,19	5954590	360
MAG_138	721691,2	5954590	360
MAG_139	721695,69	5954426,00	35
MAG_140	721695,7	5954426,0	35
MAG_141	721695,69	5954426	35
MAG_142	721695,7	5954426	35
MAG_143	721702,2	5954504,0	58
MAG_144	721702,19	5954504,00	58
MAG_145	721702,19	5954504	58
MAG_146	721702,2	5954504	58
MAG_147	721708,19	5954468,00	119
MAG_148	721708,2	5954468,0	119
MAG_149	721708,19	5954468	119
MAG_150	721708,2	5954468	119
MAG_151	721709,3	5954964,0	21
MAG_152	721709,25	5954964,00	21
MAG_153	721709,25	5954964	21
MAG_154	721709,3	5954964	21
MAG_155	721806,3	5954401,5	10
MAG_156	721806,3	5954401,5	10
MAG_157	721806,31	5954401,50	10
MAG_158	721806,31	5954401,5	10
MAG_159	722858,06	5954425,00	43
MAG_160	722858,1	5954425,0	43
MAG_161	722858,1	5954425	43
MAG_162	723840,1	5954855,5	31
MAG_163	723840,13	5954855,50	31
MAG_164	723843,06	5954772,50	17

MAG_165	723843,1	5954772,5	17
MAG_166	723868,19	5954698,50	23
MAG_167	723868,2	5954698,5	23
MAG_168	723879,8	5954617	25
MAG_169	723879,81	5954617,00	25
MAG_170	723905,06	5954389,00	15
MAG_171	723905,1	5954389,0	15
MAG_172	723905,1	5954389	15
MAG_173	723911,8	5954159	16
MAG_174	723911,81	5954159,00	16
MAG_175	723927,25	5954010,00	14
MAG_176	723927,3	5954010	14
MAG_177	723945,06	5953933,50	16
MAG_178	723945,1	5953933,5	16
MAG_179	724080,88	5954522,00	40
MAG_180	724080,9	5954522,0	40
MAG_181	724080,9	5954522	40
MAG_182	724147,19	5954742,00	61
MAG_183	724147,2	5954742	61
MAG_184	724181,8	5954587,5	57
MAG_185	724181,81	5954587,50	57
MAG_186	724182,56	5954368,00	43
MAG_187	724182,6	5954368,0	43
MAG_188	724182,6	5954368	43
MAG_189	724191,56	5954659,00	54
MAG_190	724191,6	5954659	54
MAG_191	724205	5954508,5	31
MAG_192	724205,00	5954508,50	31

MAG_193	724205,0	5954508,5	31
MAG_194	724223,6	5954348,5	27
MAG_195	724223,63	5954348,50	27
MAG_196	724223,6	5954348,5	27
MAG_197	724298,25	5954723,50	41
MAG_198	724298,3	5954723,5	41
MAG_199	724410,1	5954332	36
MAG_200	724410,13	5954332,00	36
MAG_201	724410,1	5954332,0	36
MAG_202	724420,9	5954339	38
MAG_203	724420,94	5954339,00	38
MAG_204	724420,9	5954339,0	38
MAG_205	724426,56	5954103,00	27
MAG_206	724426,6	5954103	27
MAG_207	724436,6	5954034	31
MAG_208	724436,63	5954034,00	31
MAG_209	724442,19	5954251,00	18
MAG_210	724442,2	5954251,0	18
MAG_211	724442,2	5954251	18
MAG_212	724449,06	5954180,50	16
MAG_213	724449,1	5954180,5	16
MAG_214	724449,1	5954180,5	16
MAG_215	724509,3	5953941,5	48
MAG_216	724509,31	5953941,50	48
MAG_217	724512,88	5954320,50	12
MAG_218	724512,9	5954320,5	12
MAG_219	724512,9	5954320,5	12
MAG_220	724611,8	5953854,5	26

MAG_221	724611,81	5953854,50	26
MAG_222	724706,25	5953751,50	26
MAG_223	724747,06	5953610,50	37
MAG_224	724772,75	5953676,00	29
MAG_225	725618,75	5953886,50	38
MAG_226	725618,8	5953886,5	38
MAG_227	726342,9	5953654	25
MAG_228	726342,94	5953654,00	25
MAG_229	727182,38	5954201,00	25
MAG_230	727182,4	5954201,0	25
MAG_231	727182,4	5954201	25
MAG_232	727518,9	5953952	5
MAG_233	727518,94	5953952,00	5
MAG_234	728994,88	5954791,50	14
MAG_235	728994,9	5954791,5	14
MAG_236	728994,9	5954791,5	14
MAG_237	729047,19	5955011,50	14
MAG_238	729047,2	5955011,5	14
MAG_239	729615,69	5955031,50	26
MAG_240	729615,7	5955031,5	26
MAG_241	729615,7	5955031,5	26

Side Sonar Scan Contacts

Contact ID	Easting	Northing	Height	Contact Type
DEB_001	718843,3	5945900,7	5.9x1.5x0.1	Debris
DEB_002	718696,2	5943976,4	3.0x0.3x0.1	Debris
DEB_003	718510,6	5942751,2	1.5x1.7xnmh	Debris
DEB_004	718689,5	5942724,0	3.0x0.5x0.3	Debris

DEB_005	718419,5	5942669,9	0.8x0.3x0.1	Debris
DEB_006	718479,3	5942653,2	2.5x1.2x0.1	Debris
DEB_007	718581,4	5942595,0	5.0x1.3x0.3	Debris
DEB_008	718582,9	5942591,3	4.1x1.0x0.6	Debris
DEB_009	718580,4	5942585,2	1.8x0.5x0.2	Debris
DEB_010	718589,2	5942584,2	5.1x2.4x0.3	Debris
DEB_011	718584,4	5942581,4	4.1x3.3x0.5	Debris
DEB_012	718550,1	5942539,3	1.4x0.8x0.2	Debris
DEB_013	718606,0	5942526,9	2.9x1.0x0.6	Debris
DEB_014	718630,6	5942524,1	2.0x0.5x0.1	Debris
DEB_015	720403,1	5952036,9	1.9x0.7x0.2	Wreck
DEB_016	718395,4	5945567,7	1.0x0.7x0.1	Wreck
DEB_017	718387,7	5945566,4	3.9x0.5x0.1	Debris
DEB_018	718282,9	5944250,1	1.6x0.7x0.3	Debris
DEB_019	718930,1	5944019,3	6.2x1.8x0.4	Debris
DEB_020	718995,4	5943832,0	2.0x0.6x0.2	Debris
DEB_021	718878,1	5943526,3	2.1x0.7x0.2	Debris
DEB_022	718167,1	5942830,6	2.2x0.8x0.2	Debris
DEB_023	718254,5	5942712,2	2.9x1.1x0.1	Debris
DEB_024	718142,1	5942390,0	3.4x1.6x0.8	Debris
DEB_025	718784,2	5941352,3	3.3x1.5xnmh	Debris
DEB_026	718687,6	5941281,5	1.4x0.6x0.1	Debris
SSS_001	720764,04	5955368,29	0,9	Debris
SSS_002	720829,13	5954453,20	0,6	Debris
SSS_003	720820,73	5954342,72	0,6	Object
SSS_004	720821,77	5954270,88	0,5	Object
SSS_005	720880,99	5954431,59	0,6	Object
SSS_006	720892,17	5954300,94	0,8	Object

SSS_007	720893,26	5954290,00	0,7	Object
SSS_008	720905,80	5954298,46	0,9	Object
SSS_009	720945,81	5954410,62	0,6	Object
SSS_010	720952,19	5954327,47	0,6	Object
SSS_011	720959,37	5954364,43	0,6	Object
SSS_012	720960,29	5954352,58	0,7	Object
SSS_013	720968,48	5954364,83	0,6	Object
SSS_014	720988,35	5954348,47	1	Object
SSS_015	720987,94	5954062,19	0,9	Object
SSS_016	721039,97	5954486,91	0,6	Object
SSS_017	720995,11	5954033,91	0,8	Object
SSS_018	721014,90	5954205,53	0,5	Object
SSS_019	721048,07	5954440,97	0,5	Object
SSS_020	721014,60	5954144,86	0,6	Object
SSS_021	721047,79	5954403,65	0,8	Object
SSS_022	721023,57	5954124,07	0,8	Object
SSS_023	721031,84	5954112,67	0,6	Object
SSS_024	721055,06	5954273,47	0,5	Object
SSS_025	721070,04	5954387,96	0,5	Object
SSS_026	721047,65	5954157,24	0,8	Object
SSS_027	721039,23	5954011,52	0,5	Object
SSS_028	721083,56	5954252,55	0,6	Object
SSS_029	721077,94	5954055,23	0,5	Object
SSS_030	721120,45	5954342,55	0,6	Object
SSS_031	721082,86	5953986,73	0,5	Object
SSS_032	721096,70	5954103,85	0,6	Object
SSS_033	721124,20	5954225,46	0,6	Object
SSS_034	721108,47	5954016,11	1	Object

SSS_035	721111,52	5954015,55	0,6	Object
SSS_036	721154,23	5954387,61	0,5	Object
SSS_037	721200,49	5954647,37	0,6	Object
SSS_038	721129,50	5954019,15	0,7	Object
SSS_039	721147,68	5954077,59	0,5	Object
SSS_040	721189,65	5954331,95	0,8	Object
SSS_041	721166,42	5954080,67	0,7	Object
SSS_042	721183,36	5954184,19	0,5	Object
SSS_043	721204,09	5954287,89	0,7	Object
SSS_044	721200,07	5954168,32	0,5	Object
SSS_045	721202,45	5954182,88	0,6	Object
SSS_046	721195,78	5953987,53	0,5	Object
SSS_047	721381,17	5955392,95	1,1	Object
SSS_048	721235,00	5954040,36	0,6	Object
SSS_049	721304,21	5954594,42	1	Object
SSS_050	721246,88	5953990,00	0,7	Object
SSS_051	721321,53	5954595,76	0,9	Object
SSS_052	721290,57	5954297,19	0,6	Object
SSS_053	721343,86	5954472,53	0,5	Object
SSS_054	721373,40	5954458,69	0,5	Object
SSS_055	721419,15	5954712,64	0,7	Object
SSS_056	721408,52	5954529,08	1,3	Object
SSS_057	721395,63	5954262,43	0,6	Object
SSS_058	721395,15	5954252,77	0,7	Object
SSS_059	721458,06	5954747,89	0,9	Object
SSS_060	721444,60	5954037,80	0,6	Object
SSS_061	721455,66	5954048,13	0,5	Object
SSS_062	721554,96	5954666,23	0,8	Object

SSS_063	721517,58	5954248,05	0,6	Object
SSS_064	721523,03	5954218,83	0,7	Object
SSS_065	721637,89	5954907,07	0,7	Object
SSS_066	721648,13	5954914,13	0,5	Object
SSS_067	721571,49	5954203,12	0,5	Object
SSS_068	721656,39	5954932,11	1	Object
SSS_069	721616,00	5954554,46	0,6	Object
SSS_070	721674,18	5955016,59	0,5	Object
SSS_071	721655,25	5954793,46	0,7	Object
SSS_072	721625,01	5954519,17	0,7	Object
SSS_073	721680,77	5955011,05	0,7	Object
SSS_074	721652,06	5954564,38	0,6	Object
SSS_075	721604,57	5954084,46	0,7	Object
SSS_076	721626,38	5954092,91	0,5	Object
SSS_077	721625,38	5954063,72	0,7	Object
SSS_078	721717,09	5954862,86	0,6	Object
SSS_079	721718,05	5954870,34	0,7	Object
SSS_080	721738,42	5955038,28	0,7	Object
SSS_081	721723,22	5954856,19	0,6	Object
SSS_082	721624,62	5953973,00	0,7	Object
SSS_083	721767,69	5955126,00	0,6	Object
SSS_084	721775,98	5955044,12	0,7	Object
SSS_085	721796,01	5955132,17	0,8	Object
SSS_086	721801,77	5955134,43	0,7	Object
SSS_087	721710,89	5954302,92	0,5	Object
SSS_088	721800,27	5955078,78	0,5	Object
SSS_089	721746,76	5954595,75	0,6	Object
SSS_090	721788,65	5954958,66	0,6	Object

SSS_091	721808,34	5955123,30	0,6	Object
SSS_092	721684,49	5953956,43	1,6	Object
SSS_093	721798,86	5954964,39	0,6	Object
SSS_094	721766,62	5954616,90	0,8	Object
SSS_095	721819,68	5955039,44	0,8	Object
SSS_096	721759,40	5954496,67	0,6	Object
SSS_097	721704,59	5954008,27	0,5	Object
SSS_098	721712,63	5954066,90	1	Object
SSS_099	721703,78	5953951,67	0,9	Object
SSS_100	721791,38	5954654,79	0,5	Object
SSS_101	721764,51	5954382,53	0,5	Object
SSS_102	721772,48	5954430,59	0,6	Object
SSS_103	721847,33	5954926,04	0,6	Object
SSS_104	721815,38	5954641,85	0,6	Object
SSS_105	721788,50	5954369,26	0,6	Object
SSS_106	721854,68	5954924,85	0,5	Object
SSS_107	721825,40	5954588,20	0,5	Object
SSS_108	721829,40	5954595,07	0,6	Object
SSS_109	721851,99	5954594,19	0,6	Object
SSS_110	721858,18	5954627,12	0,6	Object
SSS_111	721880,66	5954700,94	0,6	Object
SSS_112	721850,61	5954434,71	0,6	Object
SSS_113	721810,07	5953955,71	0,7	Object
SSS_114	721968,21	5955303,95	0,5	Object
SSS_115	721896,80	5954569,62	0,7	Object
SSS_116	721926,97	5954712,77	0,5	Object
SSS_117	721940,17	5954537,16	0,7	Object
SSS_118	721949,13	5954256,82	0,7	Object

SSS_119	722061,99	5954903,71	0,5	Object
SSS_120	722026,14	5954527,01	0,7	Object
SSS_121	721976,86	5953947,97	0,6	Object
SSS_122	722031,16	5954397,32	0,7	Object
SSS_123	722007,93	5954191,32	0,6	Object
SSS_124	722037,39	5954431,37	0,9	Object
SSS_125	722065,60	5954532,75	0,5	Object
SSS_126	722072,28	5954539,20	0,5	Object
SSS_127	722049,53	5954224,70	0,8	Object
SSS_128	722128,63	5954814,33	0,6	Object
SSS_129	722131,17	5954814,97	0,5	Object
SSS_130	722141,98	5954862,02	0,5	Object
SSS_131	722091,64	5954408,44	0,8	Object
SSS_132	722066,30	5954157,96	0,6	Object
SSS_133	722079,71	5954193,94	0,6	Object
SSS_134	722127,92	5954494,60	0,5	Object
SSS_135	722094,41	5954197,41	0,5	Object
SSS_136	722100,07	5954244,99	0,7	Object
SSS_137	722112,91	5954349,57	1	Object
SSS_138	722112,75	5954276,00	0,7	Object
SSS_139	722119,71	5954332,11	0,6	Object
SSS_140	722168,47	5954646,15	0,5	Object
SSS_141	722175,02	5954701,14	0,7	Object
SSS_142	722117,03	5954180,65	0,5	Object
SSS_143	722162,02	5954289,85	0,6	Object
SSS_144	722256,41	5954766,99	0,8	Object
SSS_145	722258,54	5954554,99	0,6	Object
SSS_146	722266,05	5954620,89	0,5	Object

SSS_147	722266,66	5954547,24	0,6	Object
SSS_148	722348,34	5955174,34	1	Object
SSS_149	722271,90	5954311,52	0,5	Object
SSS_150	722326,41	5954704,99	1,1	Object
SSS_151	722299,30	5954139,59	1	Object
SSS_152	722362,88	5954613,53	0,6	Object
SSS_153	722407,24	5954745,37	0,6	Object
SSS_154	722397,54	5954086,30	0,6	Object
SSS_155	722524,39	5954965,64	0,7	Object
SSS_156	722504,06	5954768,70	0,5	Object
SSS_157	722557,20	5954951,23	0,6	Object
SSS_158	722475,09	5954215,99	0,6	Object
SSS_159	722536,86	5954258,29	0,7	Object
SSS_160	722583,42	5954193,39	0,5	Object
SSS_161	722664,75	5954088,19	0,5	Object
SSS_162	722698,08	5954168,32	0,7	Object
SSS_163	722990,18	5955000,42	0,6	Object
SSS_164	723059,38	5954145,40	0,6	Object
SSS_165	723228,22	5954951,32	0,8	Object
SSS_166	723230,39	5954954,08	0,6	Object
SSS_167	723246,39	5954499,21	0,8	Object
SSS_168	723264,94	5954042,88	0,6	Object
SSS_169	723277,68	5953991,55	0,8	Object
SSS_170	723288,81	5953947,23	0,5	Object
SSS_171	723312,59	5954027,25	0,5	Object
SSS_172	723325,45	5954026,92	0,6	Object
SSS_173	723346,77	5954092,76	0,5	Object
SSS_174	723383,38	5954065,30	0,7	Object

SSS_175	723532,73	5954134,02	0,6	Object
SSS_176	723718,13	5954854,97	0,5	Object
SSS_177	723711,89	5954061,63	0,8	Object
SSS_178	723715,87	5954080,48	0,7	Object
SSS_179	723716,67	5954083,25	0,9	Object
SSS_180	723754,52	5953968,95	1,1	Object
SSS_181	723862,13	5954493,02	1	Object
SSS_182	723808,64	5953913,20	0,8	Object
SSS_183	723809,10	5953901,40	0,7	Object
SSS_184	723849,19	5954109,37	0,6	Object
SSS_185	723845,06	5953991,78	0,6	Object
SSS_186	723854,66	5954067,59	0,5	Object
SSS_187	723853,79	5954050,54	0,5	Object
SSS_188	723862,24	5954111,86	0,5	Object
SSS_189	723857,63	5954050,68	0,6	Object
SSS_190	723852,05	5953876,48	0,6	Object
SSS_191	723881,22	5953902,89	0,7	Object
SSS_192	723905,57	5954059,20	0,6	Object
SSS_193	723903,64	5953887,23	0,6	Object
SSS_194	723926,72	5954041,65	0,5	Object
SSS_195	723960,42	5954035,26	0,5	Object
SSS_196	723975,07	5954068,32	0,5	Object
SSS_197	724277,58	5954747,16	0,6	Object
SSS_198	724476,72	5953817,57	0,5	Object
SSS_199	724644,94	5954411,18	0,5	Object
SSS_200	724661,78	5954539,65	0,6	Object
SSS_201	724579,57	5953602,83	0,7	Object
SSS_202	724731,05	5954433,07	0,7	Object

SSS_203	724642,24	5953636,41	0,6	Object
SSS_204	724766,83	5954450,51	0,6	Object
SSS_205	724783,12	5954517,10	0,6	Object
SSS_206	724778,58	5954449,53	0,6	Object
SSS_207	724778,70	5954349,32	0,6	Object
SSS_208	724780,26	5953558,96	0,5	Object
SSS_209	724942,39	5954328,74	0,7	Object
SSS_210	724989,45	5954393,95	0,6	Object
SSS_211	725009,84	5954374,67	0,7	Object
SSS_212	725048,36	5954528,27	0,6	Object
SSS_213	724985,69	5953718,56	1,2	Object
SSS_214	725096,72	5954515,79	0,5	Object
SSS_215	725124,32	5954241,75	0,6	Object
SSS_216	725134,42	5954237,50	0,6	Object
SSS_217	725144,69	5954278,59	0,6	Object
SSS_218	725092,50	5953770,38	0,5	Object
SSS_219	725150,03	5954266,54	0,5	Object
SSS_220	725152,17	5954277,48	0,5	Object
SSS_221	725178,56	5954225,18	0,5	Object
SSS_222	725124,87	5953745,24	0,6	Object
SSS_223	725115,87	5953501,85	0,5	Object
SSS_224	725172,54	5953894,35	0,5	Object
SSS_225	725246,91	5954420,97	0,7	Object
SSS_226	725261,74	5954467,16	0,7	Object
SSS_227	725212,52	5953937,96	0,6	Object
SSS_228	725244,46	5954123,17	0,5	Object
SSS_229	725262,43	5954046,93	0,6	Object
SSS_230	725276,31	5954136,17	0,5	Object

SSS_231	725288,51	5954240,26	0,6	Object
SSS_232	725285,49	5954061,94	0,9	Object
SSS_233	725327,30	5954221,86	0,7	Object
SSS_234	725336,55	5954215,62	0,8	Object
SSS_235	725341,32	5954252,77	0,6	Object
SSS_236	725346,39	5954204,15	0,5	Object
SSS_237	725390,80	5954497,76	0,6	Object
SSS_238	725361,58	5954030,67	0,7	Object
SSS_239	725387,33	5954238,49	0,5	Object
SSS_240	725361,50	5953844,71	0,8	Object
SSS_241	725428,26	5954348,17	0,6	Object
SSS_242	725473,83	5954428,28	0,7	Object
SSS_243	725407,58	5953805,92	0,7	Object
SSS_244	725447,98	5953818,37	0,8	Object
SSS_245	725500,73	5954077,67	0,6	Object
SSS_246	725469,00	5953705,87	0,7	Object
SSS_247	725502,53	5953777,01	0,6	Object
SSS_248	725503,43	5953676,67	0,5	Object
SSS_249	725549,47	5953801,34	0,7	Object
SSS_250	725568,76	5953790,04	1,1	Object
SSS_251	725654,15	5954532,82	0,5	Object
SSS_252	725650,48	5954214,47	0,5	Object
SSS_253	725671,55	5954313,50	0,6	Object
SSS_254	725663,15	5954214,40	0,6	Object
SSS_255	725649,37	5953785,79	0,6	Object
SSS_256	725831,42	5954364,25	0,5	Object
SSS_257	725785,29	5953766,44	0,6	Object
SSS_258	725827,13	5953653,81	0,6	Object

SSS_259	725928,37	5954476,41	0,6	Object
SSS_260	725965,90	5954322,62	0,7	Object
SSS_261	725997,41	5953887,92	0,5	Object
SSS_262	726052,22	5954102,79	0,5	Object
SSS_263	726057,41	5954141,89	0,6	Object
SSS_264	726125,63	5954417,63	0,7	Object
SSS_265	726114,48	5954190,77	0,6	Object
SSS_266	726107,63	5954125,64	0,7	Object
SSS_267	726119,61	5954110,39	0,6	Object
SSS_268	726091,62	5953851,33	0,7	Object
SSS_269	726190,19	5954548,21	0,6	Object
SSS_270	726173,34	5954150,49	0,5	Object
SSS_271	726253,07	5954394,21	0,9	Object
SSS_272	726319,83	5954354,42	0,5	Object
SSS_273	726386,30	5954389,49	0,7	Object
SSS_274	726412,12	5954380,81	0,6	Object
SSS_275	726385,89	5954146,61	0,9	Object
SSS_276	726544,54	5954494,79	0,5	Object
SSS_277	726502,03	5954104,70	0,8	Object
SSS_278	726506,85	5954107,53	0,7	Object
SSS_279	726592,04	5954486,38	0,7	Object
SSS_280	726742,62	5954423,38	0,7	Object
SSS_281	726870,97	5954279,25	0,6	Object
SSS_282	726958,22	5954177,60	0,6	Object
SSS_283	726989,51	5954175,50	0,7	Object
SSS_284	727046,94	5954189,82	0,5	Object
SSS_285	727104,19	5954382,52	1,1	Object
SSS_286	729697,53	5955104,13	0,6	Object

SSS_287	729774,83	5955004,78	0,7	Object
SSS_288	729767,36	5955100,95	0,5	Object
SSS_289	729791,72	5955056,65	0,9	Object
SSS_290	729990,54	5955191,79	0,6	Object
SSS_291	730162,26	5955230,58	0,5	Object
SSS_292	730317,76	5955207,78	0,6	Object
SSS_293	730309,61	5955222,10	1,2	Object
SSS_294	730297,63	5955291,03	0,5	Object
SSS_295	730324,81	5955286,64	0,5	Object
SSS_296	730359,44	5955287,63	0,7	Object
SSS_297	730418,89	5955242,55	0,5	Object
SSS_298	730417,60	5955276,24	0,6	Object
SSS_299	730463,81	5955245,45	0,5	Object
SSS_300	730506,71	5955235,50	0,5	Object
SSS_301	730516,10	5955237,56	0,5	Object
SSS_302	730541,92	5955229,90	0,9	Object
SSS_303	730556,17	5955284,38	0,6	Object
SSS_304	730578,58	5955257,66	0,9	Object
SSS_305	730574,39	5955355,60	0,5	Object
SSS_306	721419,2	5954712,6	0,7	Object
SSS_307	721408,5	5954529,1	1,3	Object
SSS_308	721458,1	5954747,9	0,9	Object
SSS_309	721555,0	5954666,2	0,8	Object
SSS_310	721616,0	5954554,5	0,6	Object
SSS_311	721655,2	5954793,5	0,7	Object
SSS_312	721625,0	5954519,2	0,7	Object
SSS_313	721652,1	5954564,4	0,6	Object
SSS_314	721746,8	5954595,7	0,6	Object

SSS_315	721766,6	5954616,9	0,8	Object
SSS_316	721759,4	5954496,7	0,6	Object
SSS_317	721791,4	5954654,8	0,5	Object
SSS_318	721772,5	5954430,6	0,6	Object
SSS_319	721815,4	5954641,9	0,6	Object
SSS_320	721825,4	5954588,2	0,5	Object
SSS_321	721829,4	5954595,1	0,6	Object
SSS_322	721852,0	5954594,2	0,6	Object
SSS_323	721858,2	5954627,1	0,6	Object
SSS_324	721880,7	5954700,9	0,6	Object
SSS_325	721850,6	5954434,7	0,6	Object
SSS_326	721896,8	5954569,6	0,7	Object
SSS_327	721927,0	5954712,8	0,5	Object
SSS_328	721940,2	5954537,2	0,7	Object
SSS_329	722026,1	5954527,0	0,7	Object
SSS_330	722037,4	5954431,4	0,9	Object
SSS_331	722065,6	5954532,7	0,5	Object
SSS_332	722072,3	5954539,2	0,5	Object
SSS_333	722091,6	5954408,4	0,8	Object
SSS_334	722127,9	5954494,6	0,5	Object
SSS_335	722168,5	5954646,2	0,5	Object
SSS_336	722175,0	5954701,1	0,7	Object
SSS_337	722256,4	5954767,0	0,8	Object
SSS_338	722258,5	5954555,0	0,6	Object
SSS_339	722266,1	5954620,9	0,5	Object
SSS_340	722266,7	5954547,2	0,6	Object
SSS_341	722326,4	5954705,0	1,1	Object
SSS_342	722362,9	5954613,5	0,6	Object

SSS_343	722407,2	5954745,4	0,6	Object
SSS_344	723246,4	5954499,2	0,8	Object
SSS_345	723862,1	5954493,0	1	Object
SSS_346	724644,9	5954411,2	0,5	Object
SSS_347	724731,1	5954433,1	0,7	Object
SSS_348	724766,8	5954450,5	0,6	Object
SSS_349	724778,6	5954449,5	0,6	Object
SSS_350	724778,7	5954349,3	0,6	Object
SSS_351	724942,4	5954328,7	0,7	Object
SSS_352	724989,4	5954394,0	0,6	Object
SSS_353	725009,8	5954374,7	0,7	Object
SSS_354	725124,3	5954241,8	0,6	Object
SSS_355	725134,4	5954237,5	0,6	Object
SSS_356	725144,7	5954278,6	0,6	Object
SSS_357	725150,0	5954266,5	0,5	Object
SSS_358	725152,2	5954277,5	0,5	Object
SSS_359	725178,6	5954225,2	0,5	Object
SSS_360	725246,9	5954421,0	0,7	Object
SSS_361	725244,5	5954123,2	0,5	Object
SSS_362	725262,4	5954046,9	0,6	Object
SSS_363	725276,3	5954136,2	0,5	Object
SSS_364	725288,5	5954240,3	0,6	Object
SSS_365	725285,5	5954061,9	0,9	Object
SSS_366	725327,3	5954221,9	0,7	Object
SSS_367	725336,5	5954215,6	0,8	Object
SSS_368	725341,3	5954252,8	0,6	Object
SSS_369	725346,4	5954204,1	0,5	Object
SSS_370	725361,6	5954030,7	0,7	Object

SSS_371	725387,3	5954238,5	0,5	Object
SSS_372	725428,3	5954348,2	0,6	Object
SSS_373	725500,7	5954077,7	0,6	Object
SSS_374	725650,5	5954214,5	0,5	Object
SSS_375	725671,5	5954313,5	0,6	Object
SSS_376	725663,1	5954214,4	0,6	Object
SSS_377	725831,4	5954364,2	0,5	Object
SSS_378	725965,9	5954322,6	0,7	Object
SSS_379	726052,2	5954102,8	0,5	Object
SSS_380	726057,4	5954141,9	0,6	Object
SSS_381	726114,5	5954190,8	0,6	Object
SSS_382	726107,6	5954125,6	0,7	Object
SSS_383	726119,6	5954110,4	0,6	Object
SSS_384	726173,3	5954150,5	0,5	Object
SSS_385	726385,9	5954146,6	0,9	Object
SSS_386	726502,0	5954104,7	0,8	Object
SSS_387	726506,9	5954107,5	0,7	Object
SSS_388	726871,0	5954279,2	0,6	Object
SSS_389	726958,2	5954177,6	0,6	Object
SSS_390	726989,5	5954175,5	0,7	Object
SSS_391	727046,9	5954189,8	0,5	Object
SSS_392	727104,2	5954382,5	1,1	Object
SSS_393	729697,5	5955104,1	0,6	Object
SSS_394	729774,8	5955004,8	0,7	Object
SSS_395	729767,4	5955101,0	0,5	Object
SSS_396	729791,7	5955056,7	0,9	Object
SSS_397	729990,5	5955191,8	0,6	Object
SSS_398	721343,9	5954472,5	0,5	Object

SSS_399	721373,4	5954458,7	0,5	Object
SSS_400	721517,6	5954248,1	0,6	Object
SSS_401	721290,6	5954297,2	0,6	Object
SSS_402	721395,6	5954262,4	0,6	Object
SSS_403	721571,5	5954203,1	0,5	Object
SSS_404	721523,0	5954218,8	0,7	Object
SSS_405	721395,2	5954252,8	0,7	Object
SSS_406	721626,4	5954092,9	0,5	Object
SSS_407	721604,6	5954084,5	0,7	Object
SSS_408	721455,7	5954048,1	0,5	Object
SSS_409	721444,6	5954037,8	0,6	Object
SSS_410	721235,0	5954040,4	0,6	Object
SSS_411	721246,9	5953990,0	0,7	Object
SSS_412	721195,8	5953987,5	0,5	Object
SSS_413	721388,2	5953864,3	0,6	Object
SSS_414	721246,8	5953887,4	0,6	Object
SSS_415	721227,5	5953868,5	0,7	Object
SSS_416	721343,0	5953829,2	0,5	Object
SSS_417	721224,7	5953846,8	0,6	Object
SSS_418	721379,4	5953792,7	0,6	Object
SSS_419	721392,0	5953769,8	0,7	Object
SSS_420	721261,2	5953798,9	0,8	Object
SSS_421	721418,9	5953687,4	0,6	Object
SSS_422	721338,8	5953691,8	0,8	Object
SSS_423	721339,8	5953688,0	0,8	Object
SSS_424	721351,0	5953668,2	0,8	Object
SSS_425	721357,9	5953583,8	0,5	Object
SSS_426	721410,7	5953535,3	0,6	Object

SSS_427	718503,9	5942263,9	0,8	Object
SSS_428	720988,4	5954348,5	1	Object
SSS_429	721040	5954486,9	0,6	Object
SSS_430	721048,1	5954441	0,5	Object
SSS_431	721047,8	5954403,6	0,8	Object
SSS_432	721055,1	5954273,5	0,5	Object
SSS_433	721070	5954388	0,5	Object
SSS_434	721083,6	5954252,5	0,6	Object
SSS_435	721120,5	5954342,5	0,6	Object
SSS_436	721124,2	5954225,5	0,6	Object
SSS_437	721154,2	5954387,6	0,5	Object
SSS_438	721200,5	5954647,4	0,6	Object
SSS_439	721189,7	5954332	0,8	Object
SSS_440	721204,1	5954287,9	0,7	Object
SSS_441	721304,2	5954594,4	1	Object
SSS_442	721321,5	5954595,8	0,9	Object
SSS_443	721290,6	5954297,2	0,6	Object
SSS_444	721343,9	5954472,5	0,5	Object
SSS_445	721373,4	5954458,7	0,5	Object
SSS_446	721419,2	5954712,6	0,7	Object
SSS_447	721408,5	5954529,1	1,3	Object
SSS_448	721395,6	5954262,4	0,6	Object
SSS_449	721395,2	5954252,8	0,7	Object
SSS_450	721458,1	5954747,9	0,9	Object
SSS_451	721555	5954666,2	0,8	Object
SSS_452	721517,6	5954248,1	0,6	Object
SSS_453	721523	5954218,8	0,7	Object
SSS_454	721637,9	5954907,1	0,7	Object

SSS_455	721648,1	5954914,1	0,5	Object
SSS_456	721571,5	5954203,1	0,5	Object
SSS_457	721656,4	5954932,1	1	Object
SSS_458	721616	5954554,5	0,6	Object
SSS_459	721674,2	5955016,6	0,5	Object
SSS_460	721655,2	5954793,5	0,7	Object
SSS_461	721625	5954519,2	0,7	Object
SSS_462	721680,8	5955011	0,7	Object
SSS_463	721652,1	5954564,4	0,6	Object
SSS_464	721717,1	5954862,9	0,6	Object
SSS_465	721718,1	5954870,3	0,7	Object
SSS_466	721738,4	5955038,3	0,7	Object
SSS_467	721723,2	5954856,2	0,6	Object
SSS_468	721767,7	5955126	0,6	Object
SSS_469	721776	5955044,1	0,7	Object
SSS_470	721710,9	5954302,9	0,5	Object
SSS_471	721800,3	5955078,8	0,5	Object
SSS_472	721746,8	5954595,7	0,6	Object
SSS_473	721788,7	5954958,7	0,6	Object
SSS_474	721808,3	5955123,3	0,6	Object
SSS_475	721798,9	5954964,4	0,6	Object
SSS_476	721766,6	5954616,9	0,8	Object
SSS_477	721819,7	5955039,4	0,8	Object
SSS_478	721759,4	5954496,7	0,6	Object
SSS_479	721791,4	5954654,8	0,5	Object
SSS_480	721764,5	5954382,5	0,5	Object
SSS_481	721772,5	5954430,6	0,6	Object
SSS_482	721847,3	5954926	0,6	Object

SSS_483	721815,4	5954641,9	0,6	Object
SSS_484	721788,5	5954369,3	0,6	Object
SSS_485	721854,7	5954924,8	0,5	Object
SSS_486	721825,4	5954588,2	0,5	Object
SSS_487	721829,4	5954595,1	0,6	Object
SSS_488	721852	5954594,2	0,6	Object
SSS_489	721858,2	5954627,1	0,6	Object
SSS_490	721880,7	5954700,9	0,6	Object
SSS_491	721850,6	5954434,7	0,6	Object
SSS_492	721896,8	5954569,6	0,7	Object
SSS_493	721927	5954712,8	0,5	Object
SSS_494	721940,2	5954537,2	0,7	Object
SSS_495	721949,1	5954256,8	0,7	Object
SSS_496	722062	5954903,7	0,5	Object
SSS_497	722026,1	5954527	0,7	Object
SSS_498	722031,2	5954397,3	0,7	Object
SSS_499	722007,9	5954191,3	0,6	Object
SSS_500	722037,4	5954431,4	0,9	Object
SSS_501	722065,6	5954532,7	0,5	Object
SSS_502	722072,3	5954539,2	0,5	Object
SSS_503	722049,5	5954224,7	0,8	Object
SSS_504	722128,6	5954814,3	0,6	Object
SSS_505	722131,2	5954815	0,5	Object
SSS_506	722142	5954862	0,5	Object
SSS_507	722091,6	5954408,4	0,8	Object
SSS_508	722066,3	5954158	0,6	Object
SSS_509	722079,7	5954193,9	0,6	Object
SSS_510	722127,9	5954494,6	0,5	Object

SSS_511	722094,4	5954197,4	0,5	Object
SSS_512	722100,1	5954245	0,7	Object
SSS_513	722112,9	5954349,6	1	Object
SSS_514	722112,7	5954276	0,7	Object
SSS_515	722119,7	5954332,1	0,6	Object
SSS_516	722168,5	5954646,2	0,5	Object
SSS_517	722175	5954701,1	0,7	Object
SSS_518	722117	5954180,7	0,5	Object
SSS_519	722162	5954289,9	0,6	Object
SSS_520	722256,4	5954767	0,8	Object
SSS_521	722258,5	5954555	0,6	Object
SSS_522	722266,1	5954620,9	0,5	Object
SSS_523	722266,7	5954547,2	0,6	Object
SSS_524	722271,9	5954311,5	0,5	Object
SSS_525	722326,4	5954705	1,1	Object
SSS_526	722299,3	5954139,6	1	Object
SSS_527	722362,9	5954613,5	0,6	Object
SSS_528	722407,2	5954745,4	0,6	Object
SSS_529	722397,5	5954086,3	0,6	Object
SSS_530	722524,4	5954965,6	0,7	Object
SSS_531	722504,1	5954768,7	0,5	Object
SSS_532	722557,2	5954951,2	0,6	Object
SSS_533	722475,1	5954216	0,6	Object
SSS_534	722536,9	5954258,3	0,7	Object
SSS_535	722583,4	5954193,4	0,5	Object
SSS_536	722664,8	5954088,2	0,5	Object
SSS_537	722698,1	5954168,3	0,7	Object
SSS_538	723059,4	5954145,4	0,6	Object

SSS_539	723228,2	5954951,3	0,8	Object
SSS_540	723230,4	5954954,1	0,6	Object
SSS_541	723246,4	5954499,2	0,8	Object
SSS_542	723264,9	5954042,9	0,6	Object
SSS_543	723277,7	5953991,5	0,8	Object
SSS_544	723312,6	5954027,2	0,5	Object
SSS_545	723325,5	5954026,9	0,6	Object
SSS_546	723346,8	5954092,8	0,5	Object
SSS_547	723383,4	5954065,3	0,7	Object
SSS_548	723532,7	5954134	0,6	Object
SSS_549	723718,1	5954855	0,5	Object
SSS_550	723711,9	5954061,6	0,8	Object
SSS_551	723715,9	5954080,5	0,7	Object
SSS_552	723716,7	5954083,2	0,9	Object
SSS_553	723754,5	5953969	1,1	Object
SSS_554	723862,1	5954493	1	Object
SSS_555	723808,6	5953913,2	0,8	Object
SSS_556	723809,1	5953901,4	0,7	Object
SSS_557	723849,2	5954109,4	0,6	Object
SSS_558	723845,1	5953991,8	0,6	Object
SSS_559	723854,7	5954067,6	0,5	Object
SSS_560	723853,8	5954050,5	0,5	Object
SSS_561	723862,2	5954111,9	0,5	Object
SSS_562	723857,6	5954050,7	0,6	Object
SSS_563	723881,2	5953902,9	0,7	Object
SSS_564	723905,6	5954059,2	0,6	Object
SSS_565	723903,6	5953887,2	0,6	Object
SSS_566	723926,7	5954041,6	0,5	Object

SSS_567	723960,4	5954035,3	0,5	Object
SSS_568	723975,1	5954068,3	0,5	Object
SSS_569	724277,6	5954747,2	0,6	Object
SSS_570	724644,9	5954411,2	0,5	Object
SSS_571	724661,8	5954539,6	0,6	Object
SSS_572	724731,1	5954433,1	0,7	Object
SSS_573	724766,8	5954450,5	0,6	Object
SSS_574	724783,1	5954517,1	0,6	Object
SSS_575	724778,6	5954449,5	0,6	Object
SSS_576	724778,7	5954349,3	0,6	Object
SSS_577	724942,4	5954328,7	0,7	Object
SSS_578	724989,4	5954394	0,6	Object
SSS_579	725009,8	5954374,7	0,7	Object
SSS_580	725048,4	5954528,3	0,6	Object
SSS_581	725096,7	5954515,8	0,5	Object
SSS_582	725124,3	5954241,8	0,6	Object
SSS_583	725134,4	5954237,5	0,6	Object
SSS_584	725144,7	5954278,6	0,6	Object
SSS_585	725092,5	5953770,4	0,5	Object
SSS_586	725150	5954266,5	0,5	Object
SSS_587	725152,2	5954277,5	0,5	Object
SSS_588	725178,6	5954225,2	0,5	Object
SSS_589	725172,5	5953894,4	0,5	Object
SSS_590	725246,9	5954421	0,7	Object
SSS_591	725261,7	5954467,2	0,7	Object
SSS_592	725212,5	5953938	0,6	Object
SSS_593	725244,5	5954123,2	0,5	Object
SSS_594	725262,4	5954046,9	0,6	Object

SSS_595	725276,3	5954136,2	0,5	Object
SSS_596	725288,5	5954240,3	0,6	Object
SSS_597	725285,5	5954061,9	0,9	Object
SSS_598	725327,3	5954221,9	0,7	Object
SSS_599	725336,5	5954215,6	0,8	Object
SSS_600	725341,3	5954252,8	0,6	Object
SSS_601	725346,4	5954204,1	0,5	Object
SSS_602	725390,8	5954497,8	0,6	Object
SSS_603	725361,6	5954030,7	0,7	Object
SSS_604	725387,3	5954238,5	0,5	Object
SSS_605	725361,5	5953844,7	0,8	Object
SSS_606	725428,3	5954348,2	0,6	Object
SSS_607	725473,8	5954428,3	0,7	Object
SSS_608	725407,6	5953805,9	0,7	Object
SSS_609	725448	5953818,4	0,8	Object
SSS_610	725500,7	5954077,7	0,6	Object
SSS_611	725502,5	5953777	0,6	Object
SSS_612	725549,5	5953801,3	0,7	Object
SSS_613	725568,8	5953790	1,1	Object
SSS_614	725654,1	5954532,8	0,5	Object
SSS_615	725650,5	5954214,5	0,5	Object
SSS_616	725671,5	5954313,5	0,6	Object
SSS_617	725663,1	5954214,4	0,6	Object
SSS_618	725649,4	5953785,8	0,6	Object
SSS_619	725831,4	5954364,2	0,5	Object
SSS_620	725785,3	5953766,4	0,6	Object
SSS_621	725928,4	5954476,4	0,6	Object
SSS_622	725965,9	5954322,6	0,7	Object

SSS_623	725997,4	5953887,9	0,5	Object
SSS_624	726052,2	5954102,8	0,5	Object
SSS_625	726057,4	5954141,9	0,6	Object
SSS_626	726125,6	5954417,6	0,7	Object
SSS_627	726114,5	5954190,8	0,6	Object
SSS_628	726107,6	5954125,6	0,7	Object
SSS_629	726119,6	5954110,4	0,6	Object
SSS_630	726091,6	5953851,3	0,7	Object
SSS_631	726190,2	5954548,2	0,6	Object
SSS_632	726173,3	5954150,5	0,5	Object
SSS_633	726253,1	5954394,2	0,9	Object
SSS_634	726319,8	5954354,4	0,5	Object
SSS_635	726386,3	5954389,5	0,7	Object
SSS_636	726412,1	5954380,8	0,6	Object
SSS_637	726385,9	5954146,6	0,9	Object
SSS_638	726544,5	5954494,8	0,5	Object
SSS_639	726502	5954104,7	0,8	Object
SSS_640	726506,9	5954107,5	0,7	Object
SSS_641	726592	5954486,4	0,7	Object
SSS_642	726742,6	5954423,4	0,7	Object
SSS_643	726871	5954279,2	0,6	Object
SSS_644	726958,2	5954177,6	0,6	Object
SSS_645	726989,5	5954175,5	0,7	Object
SSS_646	727046,9	5954189,8	0,5	Object
SSS_647	727104,2	5954382,5	1,1	Object
SSS_648	729697,5	5955104,1	0,6	Object
SSS_649	729774,8	5955004,8	0,7	Object
SSS_650	729767,4	5955101	0,5	Object

SSS_651	729791,7	5955056,7	0,9	Object
SSS_652	729990,5	5955191,8	0,6	Object
SSS_653	730162,3	5955230,6	0,5	Object
SSS_654	730317,8	5955207,8	0,6	Object
SSS_655	730309,6	5955222,1	1,2	Object
SSS_656	730297,6	5955291	0,5	Object
SSS_657	730324,8	5955286,6	0,5	Object
SSS_658	730359,4	5955287,6	0,7	Object
SSS_659	730418,9	5955242,5	0,5	Object
SSS_660	730417,6	5955276,2	0,6	Object
SSS_661	730463,8	5955245,5	0,5	Object
SSS_662	730506,7	5955235,5	0,5	Object
SSS_663	730516,1	5955237,6	0,5	Object
SSS_664	721968,2	5955304,0	0,5	Object
SSS_665	721381,2	5955392,9	1,1	Object
SSS_666	721801,8	5955134,4	0,7	Object
SSS_667	721796,0	5955132,2	0,8	Object
SSS_668	721808,3	5955123,3	0,6	Object
SSS_669	721767,7	5955126,0	0,6	Object
SSS_670	721800,3	5955078,8	0,5	Object
SSS_671	721819,7	5955039,4	0,8	Object
SSS_672	721776,0	5955044,1	0,7	Object
SSS_673	721738,4	5955038,3	0,7	Object
SSS_674	722062,0	5954903,7	0,5	Object
SSS_675	721674,2	5955016,6	0,5	Object
SSS_676	722142,0	5954862,0	0,5	Object
SSS_677	721680,8	5955011,0	0,7	Object
SSS_678	721798,9	5954964,4	0,6	Object

SSS_679	721788,7	5954958,7	0,6	Object
SSS_680	721854,7	5954924,8	0,5	Object
SSS_681	721847,3	5954926,0	0,6	Object
SSS_682	722131,2	5954815,0	0,5	Object
SSS_683	722128,6	5954814,3	0,6	Object
SSS_684	721656,4	5954932,1	1	Object
SSS_685	721648,1	5954914,1	0,5	Object
SSS_686	721637,9	5954907,1	0,7	Object
SSS_687	721718,1	5954870,3	0,7	Object
SSS_688	721717,1	5954862,9	0,6	Object
SSS_689	721723,2	5954856,2	0,6	Object
SSS_690	722031,2	5954397,3	0,7	Object
SSS_691	721200,5	5954647,4	0,6	Object
SSS_692	721321,5	5954595,8	0,9	Object
SSS_693	721304,2	5954594,4	1	Object
SSS_694	721764,5	5954382,5	0,5	Object
SSS_695	721788,5	5954369,3	0,6	Object
SSS_696	721949,1	5954256,8	0,7	Object
SSS_697	721710,9	5954302,9	0,5	Object
SSS_698	721040,0	5954486,9	0,6	Object
SSS_699	721048,1	5954441,0	0,5	Object
SSS_700	721154,2	5954387,6	0,5	Object
SSS_701	721047,8	5954403,6	0,8	Object
SSS_702	721070,0	5954388,0	0,5	Object
SSS_703	721189,7	5954332,0	0,8	Object
SSS_704	721120,5	5954342,5	0,6	Object
SSS_705	721204,1	5954287,9	0,7	Object
SSS_706	720988,4	5954348,5	1	Object

SSS_707	721712,6	5954066,9	1	Object
SSS_708	721055,1	5954273,5	0,5	Object
SSS_709	721083,6	5954252,5	0,6	Object
SSS_710	721625,4	5954063,7	0,7	Object
SSS_711	721124,2	5954225,5	0,6	Object
SSS_712	721202,4	5954182,9	0,6	Object
SSS_713	721183,4	5954184,2	0,5	Object
SSS_714	721704,6	5954008,3	0,5	Object
SSS_715	721200,1	5954168,3	0,5	Object
SSS_716	721810,1	5953955,7	0,7	Object
SSS_717	721014,9	5954205,5	0,5	Object
SSS_718	721703,8	5953951,7	0,9	Object
SSS_719	721684,5	5953956,4	1,6	Object
SSS_720	721624,6	5953973,0	0,7	Object
SSS_721	721047,7	5954157,2	0,8	Object
SSS_722	721014,6	5954144,9	0,6	Object
SSS_723	721096,7	5954103,8	0,6	Object
SSS_724	721166,4	5954080,7	0,7	Object
SSS_725	721023,6	5954124,1	0,8	Object
SSS_726	721147,7	5954077,6	0,5	Object
SSS_727	721031,8	5954112,7	0,6	Object
SSS_728	721077,9	5954055,2	0,5	Object
SSS_729	721129,5	5954019,2	0,7	Object
SSS_730	720987,9	5954062,2	0,9	Object
SSS_731	721567,9	5953867,9	0,6	Object
SSS_732	721111,5	5954015,6	0,6	Object
SSS_733	721108,5	5954016,1	1	Object
SSS_734	720995,1	5954033,9	0,8	Object

SSS_735	721039,2	5954011,5	0,5	Object
SSS_736	721082,9	5953986,7	0,5	Object
SSS_737	721072,1	5953895,1	0,6	Object
SSS_738	720316,0	5950031,5	0,9	Object
SSS_739	720114,5	5948971,1	0,8	Object
SSS_740	719671,1	5947933,0	0,6	Object
SSS_741	718851,9	5942574,8	0,5	Object
SSS_742	722065,602	5954532,748	0,5	Object
SSS_743	721847,333	5954926,036	0,6	Object
SSS_744	721718,052	5954870,335	0,7	Object
SSS_745	721723,219	5954856,189	0,6	Object
SSS_746	721523,033	5954218,829	0,7	Object
SSS_747	721517,576	5954248,052	0,6	Object
SSS_748	721717,093	5954862,856	0,6	Object
SSS_749	721395,154	5954252,774	0,7	Object
SSS_750	721395,633	5954262,425	0,6	Object
SSS_751	721321,532	5954595,757	0,9	Object
SSS_752	721738,417	5955038,276	0,7	Object
SSS_753	721767,685	5955125,998	0,6	Object
SSS_754	721800,267	5955078,779	0,5	Object
SSS_755	721200,485	5954647,373	0,6	Object
SSS_756	721710,894	5954302,916	0,5	Object
SSS_757	721759,398	5954496,665	0,6	Object
SSS_758	721815,378	5954641,854	0,6	Object
SSS_759	721940,171	5954537,155	0,7	Object
SSS_760	722072,284	5954539,197	0,5	Object
SSS_761	721571,489	5954203,118	0,5	Object
SSS_762	722031,163	5954397,323	0,7	Object

SSS_763	721764,507	5954382,525	0,5	Object
SSS_764	721788,498	5954369,264	0,6	Object
SSS_765	722112,914	5954349,566	1	Object
SSS_766	721656,392	5954932,107	1	Object
SSS_767	721788,653	5954958,655	0,6	Object
SSS_768	721896,799	5954569,624	0,7	Object
SSS_769	721819,678	5955039,442	0,8	Object
SSS_770	721775,982	5955044,12	0,7	Object
SSS_771	721808,335	5955123,298	0,6	Object
SSS_772	721458,055	5954747,893	0,9	Object
SSS_773	721880,655	5954700,943	0,6	Object
SSS_774	721554,962	5954666,225	0,8	Object
SSS_775	722119,708	5954332,113	0,6	Object
SSS_776	721637,887	5954907,072	0,7	Object
SSS_777	721625,005	5954519,167	0,7	Object
SSS_778	721419,153	5954712,644	0,7	Object
SSS_779	721746,755	5954595,746	0,6	Object
SSS_780	721766,615	5954616,901	0,8	Object
SSS_781	721825,401	5954588,196	0,5	Object
SSS_782	721851,994	5954594,191	0,6	Object
SSS_783	721854,677	5954924,845	0,5	Object
SSS_784	722037,385	5954431,371	0,9	Object
SSS_785	722026,142	5954527,01	0,7	Object
SSS_786	721290,573	5954297,188	0,6	Object
SSS_787	721343,864	5954472,532	0,5	Object
SSS_788	721373,402	5954458,692	0,5	Object
SSS_789	721408,521	5954529,082	1,3	Object
SSS_790	721829,398	5954595,074	0,6	Object

SSS_791	721652,063	5954564,38	0,6	Object
SSS_792	721791,384	5954654,785	0,5	Object
SSS_793	721798,859	5954964,393	0,6	Object
SSS_794	721648,134	5954914,129	0,5	Object
SSS_795	721796,007	5955132,171	0,8	Object
SSS_796	721655,249	5954793,462	0,7	Object
SSS_797	721304,212	5954594,415	1	Object
SSS_798	721674,177	5955016,59	0,5	Object
SSS_799	721949,132	5954256,82	0,7	Object
SSS_800	721850,605	5954434,709	0,6	Object
SSS_801	721680,772	5955011,048	0,7	Object
SSS_802	721858,183	5954627,117	0,6	Object
WRECK_001	720537,7	5952510,7	19.1x12.9x0.2	Wreck
WRECK_002	720467,1	5952450,6	40.1x12.8x1.1	Wreck

B. Directional wave scatter

Monthly and All-year Joint Frequency Distributions of Hs and Mdir

All-Year

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	22.27	10.00	2.97	1.81	1.75	3.29	17.18	40.73	100.00	
4.00								<0.01	<0.01	
3.75	<0.01							0.14	0.14	0.14
3.50	0.03							0.49	0.52	0.67
3.25	0.05							0.91	0.96	1.63
3.00	0.11						<0.01	1.31	1.42	3.05
2.75	0.18						<0.01	1.39	1.58	4.63
2.50	0.26						0.04	1.40	1.71	6.34
2.25	0.32	<0.01					0.12	1.78	2.22	8.56
2.00	0.43	0.03				<0.01	0.32	2.18	2.97	11.53
1.75	0.65	0.06				<0.01	0.57	2.70	3.99	15.51
1.50	1.16	0.22	0.01	<0.01	<0.01	0.04	1.23	3.48	6.14	21.65
1.25	1.94	0.54	0.04	<0.01	0.01	0.11	2.16	4.51	9.32	30.97
1.00	3.04	1.15	0.16	0.03	0.08	0.37	2.91	5.46	13.20	44.18
0.75	4.71	1.99	0.49	0.21	0.33	0.80	3.38	5.88	17.78	61.95
0.50	5.46	2.92	1.06	0.67	0.68	1.07	3.70	5.28	20.83	82.78
0.25	3.53	2.64	1.01	0.75	0.57	0.78	2.39	3.43	15.09	97.87
0.00	0.41	0.46	0.19	0.15	0.07	0.12	0.34	0.39	2.13	

Mean Wave Direction [°T From]
All-Year

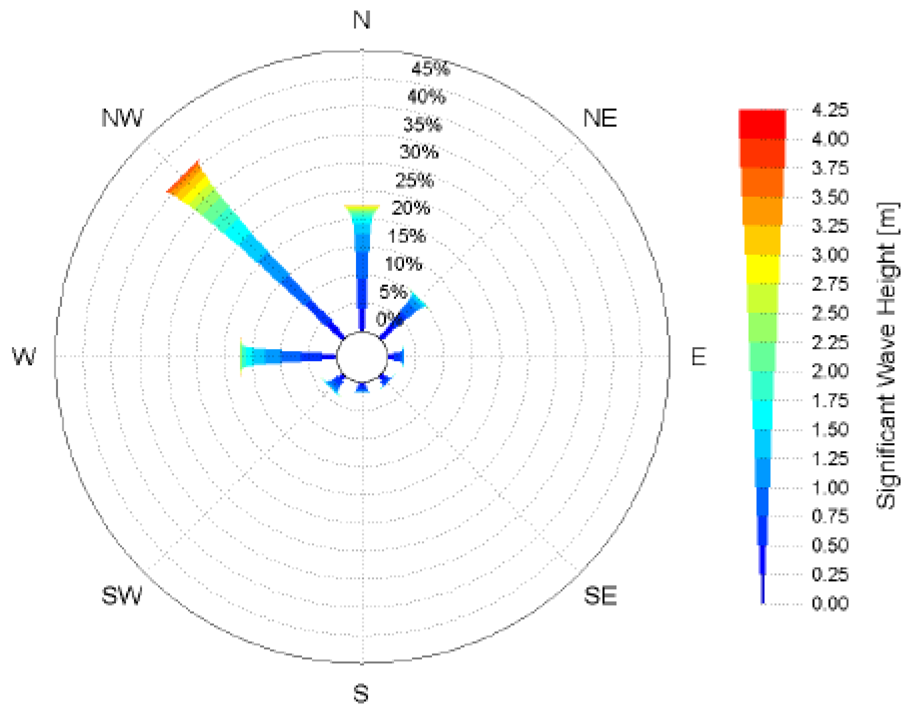


Figure B-1: Near platform wave scatter [ref II]

All-Year

Current Speed at 0m [m/s]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	2.05	3.60	44.83	1.01	0.30	0.60	41.81	5.80	100.00	
1.10			<0.01						<0.01	
1.05			<0.01				<0.01		<0.01	
1.00			0.02				<0.01		0.02	0.03
0.95			0.06				<0.01		0.06	0.10
0.90			0.16				<0.01		0.17	0.27
0.85			0.55				0.02		0.57	0.84
0.80			1.57				0.04		1.62	2.46
0.75			2.95				0.09		3.04	5.50
0.70			3.87				0.25		4.12	9.62
0.65			4.41				1.14		5.55	15.17
0.60			4.63				2.78		7.41	22.58
0.55			4.25				4.09	<0.01	8.34	30.93
0.50		<0.01	3.72	<0.01		<0.01	4.87	<0.01	8.59	39.52
0.45		<0.01	3.26	<0.01			5.18	0.02	8.46	47.98
0.40		<0.01	2.91	<0.01		<0.01	5.04	0.06	8.02	56.01
0.35		0.02	2.62	<0.01		<0.01	4.55	0.14	7.33	63.34
0.30	<0.01	0.05	2.38	0.02		<0.01	3.89	0.31	6.65	69.99
0.25	0.01	0.14	2.22	0.04	<0.01	<0.01	3.12	0.56	6.09	76.08
0.20	0.05	0.36	1.92	0.07	<0.01	0.02	2.42	0.94	5.78	81.86
0.15	0.18	0.82	1.48	0.12	<0.01	0.04	1.78	1.34	5.77	87.63
0.10	0.65	1.26	1.00	0.20	0.03	0.09	1.31	1.46	5.99	93.61
0.05	0.96	0.76	0.62	0.32	0.09	0.20	0.89	0.75	4.60	98.21
0.00	0.19	0.19	0.24	0.23	0.17	0.24	0.32	0.21	1.79	

Current Direction at 0m [°T Towards]

All-Year

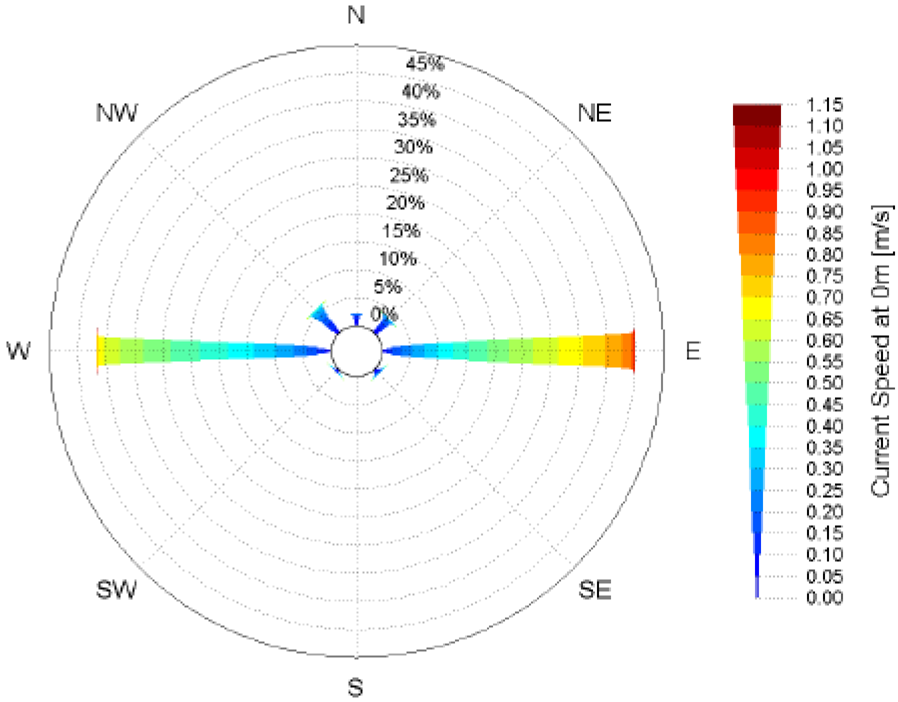
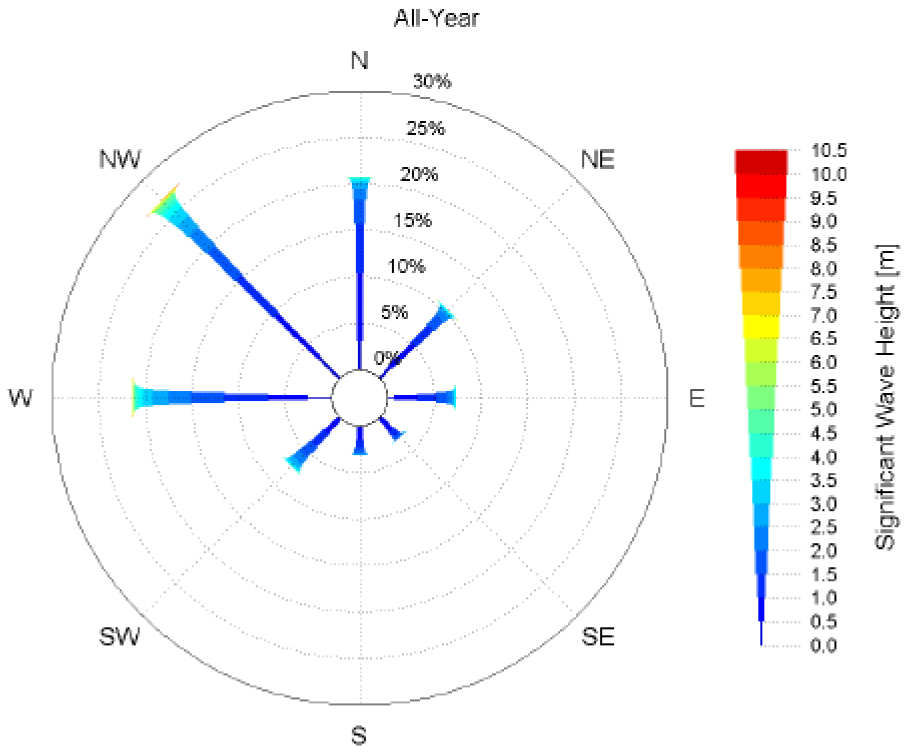


Figure B-2: Near platform current scatter [ref II]

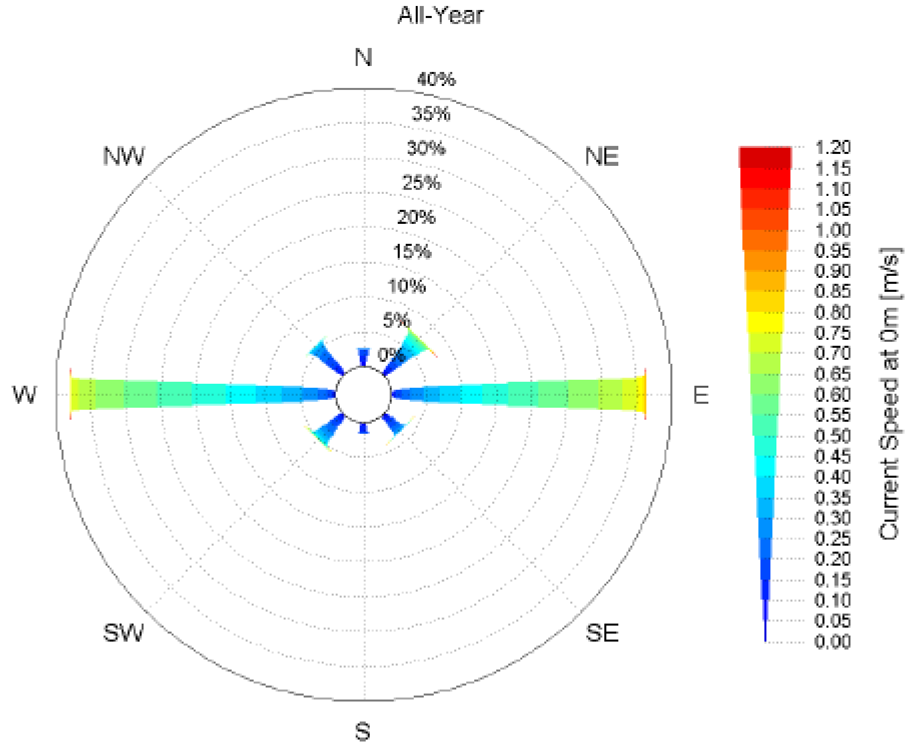


All-Year

Significant Wave Height [m]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	20.79	10.32	7.24	2.97	3.14	7.30	21.26	26.98	100.00	
> 10.0								<0.01	<0.01	
9.5–10.0										
9.0–9.5										
8.5–9.0								<0.01	<0.01	
8.0–8.5	<0.01							0.02	0.02	0.02
7.5–8.0	<0.01							0.01	0.01	0.04
7.0–7.5	<0.01						<0.01	0.02	0.03	0.06
6.5–7.0	<0.01						<0.01	0.04	0.05	0.11
6.0–6.5	0.01						<0.01	0.05	0.07	0.19
5.5–6.0	0.02	<0.01					0.02	0.11	0.15	0.34
5.0–5.5	0.04	<0.01					0.06	0.19	0.29	0.63
4.5–5.0	0.06	<0.01				<0.01	0.14	0.34	0.54	1.18
4.0–4.5	0.08	0.03	<0.01			0.02	0.26	0.47	0.86	2.03
3.5–4.0	0.19	0.08	0.03		<0.01	0.07	0.55	0.72	1.65	3.68
3.0–3.5	0.33	0.15	0.11	<0.01	0.01	0.24	1.03	1.12	3.00	6.68
2.5–3.0	0.62	0.28	0.24	0.01	0.04	0.52	1.66	1.68	5.05	11.73
2.0–2.5	1.18	0.63	0.55	0.09	0.19	0.93	2.39	2.66	8.62	20.35
1.5–2.0	2.50	1.47	1.10	0.30	0.44	1.51	3.59	4.22	15.13	35.48
1.0–1.5	5.38	2.57	2.00	0.79	0.87	1.95	4.64	5.78	23.97	59.45
0.5–1.0	7.29	3.44	2.46	1.54	1.43	1.87	4.29	6.30	28.62	88.07
0.0–0.5	3.08	1.64	0.75	0.25	0.17	0.19	2.61	3.24	11.93	

Mean Wave Direction [°T From]

Figure B-3: Near tie-in wave scatter [ref III]

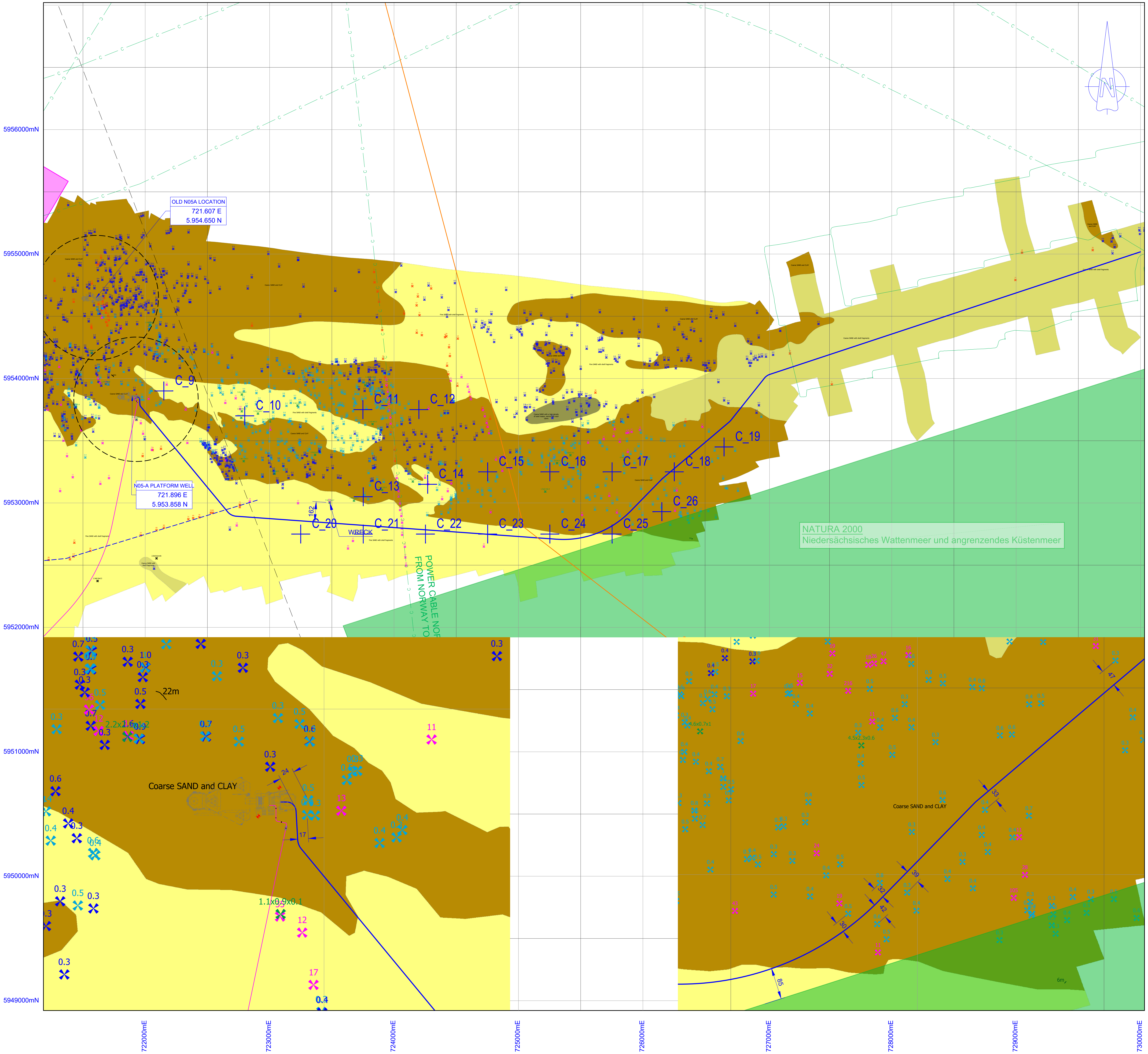


All-Year

Current Speed at 0m [m/s]	N	NE	E	SE	S	SW	W	NW	Total %	Exceed %
Total	2.56	7.29	36.34	3.37	1.69	5.05	37.96	5.75	100.00	
1.15			<0.01				<0.01		<0.01	
1.10		<0.01	<0.01				<0.01		<0.01	
1.05		<0.01	<0.01				<0.01		<0.01	
1.00		<0.01	<0.01				<0.01		<0.01	0.01
0.95		<0.01	0.01				<0.01		0.02	0.03
0.90		<0.01	0.03				0.01		0.05	0.08
0.85		<0.01	0.10				0.01		0.12	0.20
0.80		<0.01	0.30	<0.01			0.04		0.35	0.55
0.75		0.02	0.88	<0.01		<0.01	0.17		1.07	1.62
0.70		0.03	2.13	<0.01		<0.01	0.90		3.06	4.69
0.65		0.07	3.46	<0.01		<0.01	2.49		6.02	10.71
0.60		0.12	4.19	<0.01		<0.01	4.07		8.39	19.09
0.55		0.21	4.41	<0.01		<0.01	4.79	<0.01	9.42	28.51
0.50		0.32	4.20	<0.01		0.03	4.91	<0.01	9.46	37.98
0.45		0.43	3.73	<0.01	<0.01	0.07	4.80	<0.01	9.04	47.01
0.40		0.53	3.23	<0.01	<0.01	0.20	4.34	0.04	8.35	55.36
0.35	<0.01	0.61	2.81	0.04	<0.01	0.36	3.73	0.16	7.70	63.07
0.30	<0.01	0.72	2.35	0.14	<0.01	0.56	2.97	0.39	7.13	70.19
0.25	0.04	0.84	1.85	0.36	<0.01	0.78	2.13	0.78	6.78	76.98
0.20	0.24	0.97	1.31	0.70	0.03	0.97	1.36	1.22	6.81	83.79
0.15	0.71	0.99	0.78	0.98	0.36	1.05	0.72	1.49	7.09	90.88
0.10	0.89	0.87	0.38	0.80	0.85	0.72	0.33	1.13	5.97	96.85
0.05	0.59	0.47	0.14	0.28	0.38	0.25	0.14	0.46	2.72	99.57
0.00	0.09	0.07	0.03	0.04	0.05	0.04	0.03	0.07	0.43	

Current Direction at 0m [°T Towards]

Figure B-4: Near tie-in current scatter [ref III]



REFERENCES

LEGEND

0.3	Side scan sonnar contact from 2019 survey with height in metres
0.3	Side scan sonnar contact from 2021 survey with height in metres
16	Magnetic anomaly from 2019 survey with anomaly size in nanoTeslas
16	Magnetic anomaly from 2021 survey with anomaly size in nanoTeslas
1.4 x 0.5 x 0.3	Debris item from 2019 survey with dimensions (length x width x height) in meters
1.4 x 0.5 x 0.3	Debris item from 2021 survey with dimensions (length x width x height) in meters
	Infralittoral fine sand (A5.23)
	Infralittoral coarse sediment (A5.13)
	Infralittoral coarse sediment (A5.13) with scattered areas of Infralittoral mixed sediment (A5.43)
	Infralittoral mixed sediment (A5.43)

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name:
European Datum 1950 North Sea -UKCS

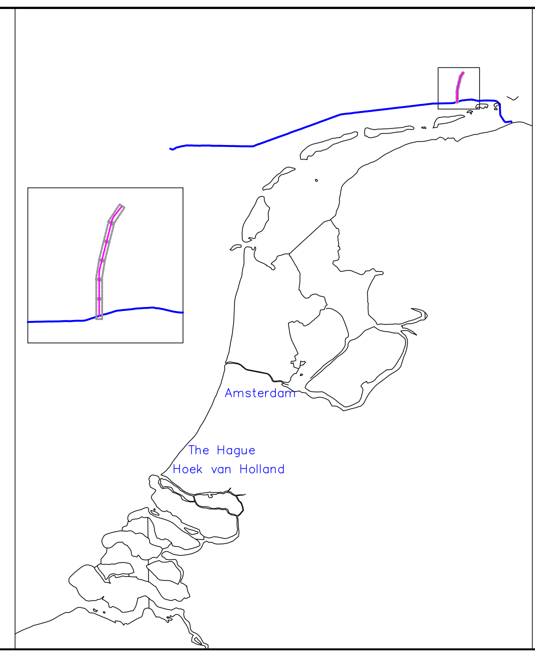
Projection Name:
Universal Transverse Mercator

Ellipsoid:
International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone :	=	North 31
Central meridian :	=	3° East
Latitude of origin :	=	Equator
False Easting :	=	500 000.00 m
False Northing :	=	0.00 m
Scale factor on C.M.:	=	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	NATURA 2000 ADDED	SvdV	-	-	DK	
01	10-12-2021	FOR COMMENTS	SvdV	-	-	DK	

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info@enersea.nl

Client
ONEDyas B.V.

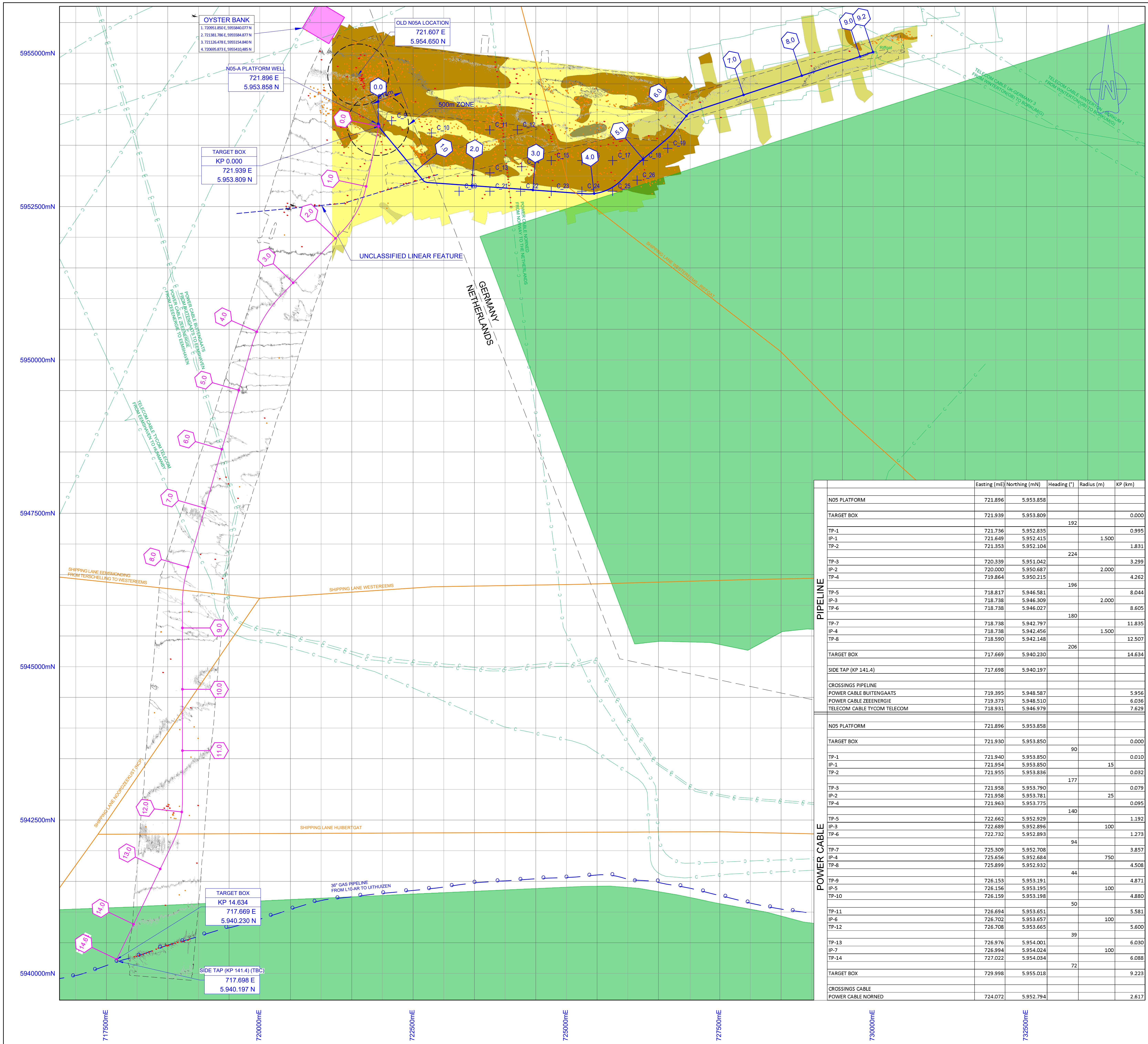
Project
N05-A TO NGT PIPELINE

Document
Cable routing Riffgat to N05A
2021 Layout with Bolders and Magnetics

Scale: 1:15000
Size: A1

Project number: 19018

Document Number: N05A-7-50-0-72048-01



		Easting (mE)	Northing (mN)	Heading (°)	Radius (m)	KP (km)
PIPELINE						
	N05 PLATFORM	721.896	5.953.858			
	TARGET BOX	721.939	5.953.809			0.000
				192		
	TP-1	721.736	5.952.835			0.995
	IP-1	721.649	5.952.415		1.500	
	TP-2	721.353	5.952.104			1.831
				224		
	TP-3	720.339	5.951.042			3.299
	IP-2	720.000	5.950.687		2.000	
	TP-4	719.864	5.950.215			4.262
				196		
	TP-5	718.817	5.946.581			8.044
	IP-3	718.738	5.946.309		2.000	
	TP-6	718.738	5.946.027			8.605
				180		
	TP-7	718.738	5.942.797			11.835
	IP-4	718.738	5.942.456		1.500	
	TP-8	718.590	5.942.148			12.507
				206		
	TARGET BOX	717.669	5.940.230			14.634
	SIDE TAP (KP 141.4)	717.698	5.940.197			
	CROSSINGS PIPELINE					
	POWER CABLE BUITENGAATS	719.395	5.948.587			5.956
	POWER CABLE ZEEENERGIE	719.373	5.948.510			6.036
	TELECOM CABLE TYCOM TELECOM	718.931	5.946.979			7.629
POWER CABLE						
	N05 PLATFORM	721.896	5.953.858			
	TARGET BOX	721.930	5.953.850			0.000
				90		
	TP-1	721.940	5.953.850			0.010
	IP-1	721.954	5.953.850		15	
	TP-2	721.955	5.953.836			0.032
				177		
	TP-3	721.958	5.953.790			0.079
	IP-2	721.958	5.953.781		25	
	TP-4	721.963	5.953.775			0.095
				140		
	TP-5	722.662	5.952.929			1.192
	IP-3	722.689	5.952.896		100	
	TP-6	722.732	5.952.893			1.273
				94		
	TP-7	725.309	5.952.708			3.857
	IP-4	725.656	5.952.684		750	
	TP-8	725.899	5.952.932			4.508
				44		
	TP-9	726.153	5.953.191			4.871
	IP-5	726.156	5.953.195		100	
	TP-10	726.159	5.953.198			4.880
				50		
	TP-11	726.694	5.953.651			5.581
	IP-6	726.702	5.953.657		100	
	TP-12	726.708	5.953.665			5.600
				39		
	TP-13	726.976	5.954.001			6.030
	IP-7	726.994	5.954.024		100	
	TP-14	727.022	5.954.034			6.088
				72		
	TARGET BOX	729.998	5.955.018			9.223
	CROSSINGS CABLE					
	POWER CABLE NORNED	724.072	5.952.794			2.617

REFERENCES

N05A-7-50-0-72050-01/06 — Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01-06
N05A-7-50-0-72051-01 — Alternative platform location - Approach drawing @ N05A
N05A-7-50-0-75052-01 — Alternative platform location - Approach drawing @ NGT

GEOxyz
LU0022H-553_A1_1905_UTM31-ED50_LAT_MB_#0.5
LU0022H-553_A2_1905_UTM31-ED50_LAT_MB_#0.5 + EXTRA POLYGON
LU0022H-553_A3_1905_UTM31-ED50_LAT_MB_#0.5 + EXTRA POLYGON
LU0022H-553_A4_1905_UTM31-ED50_LAT_MB_#0.5
LU0022H-553_A5_1905_UTM31-ED50_LAT_MB_#0.5
N05A-7-50-0-72039-01-02 Seabed Features - N05a - Riffgat OWF

LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK
- Infralittoral fine sand (A5.23)
- Infralittoral coarse sediment (A5.13)
- Infralittoral coarse sediment (A5.13) with scattered areas of Infralittoral mixed sediment (A5.43)
- Infralittoral mixed sediment (A5.43)

BATHYMETRY AND SEABED FEATURES

- CONTOUR LINE AT 1m INTERVAL
- SONAR CONTACT
- DEPRESSION
- MOUND
- AS-FOUND WELLHEAD
- CONE PENETRATION TEST
- VIBRE CORE
- MAGNETIC ANOMALY
- WRECK

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name:
European Datum 1950 North Sea -UKCS

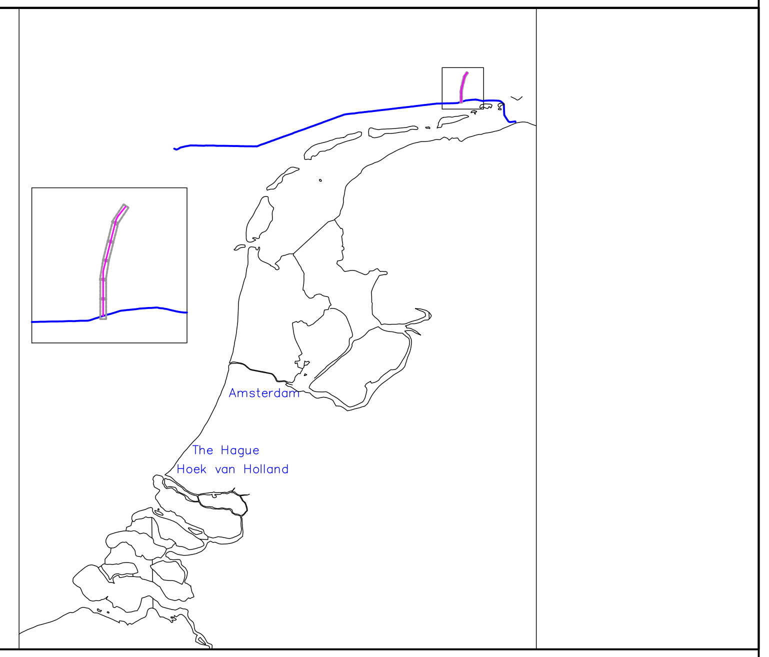
Projection Name:
Universal Transverse Mercator

Ellipsoid:
International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone :	=	North 31
Central meridian :	=	3° East
Latitude of origin :	=	Equator
False Easting :	=	500 000.00 m
False Northing :	=	0.00 m
Scale factor on C.M.:	=	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
07	21-12-2021	NATURA 2000 ADDED	SvdV	-	-	DK	
06	15-12-2021	KP NUMBERS ADDED + COORDINATES	SvdV	-	-	DK	
05	14-12-2021	PIPELINE AND CABLE REROUTED	SvdV	-	-	DK	
04	22-09-2021	CPT AND VC ADDED/ PLT RELOC.	SvdV	-	-	DK	
03	15-09-2021	PLATFORM LOCATION D ADDED	SvdV	-	-	DK	

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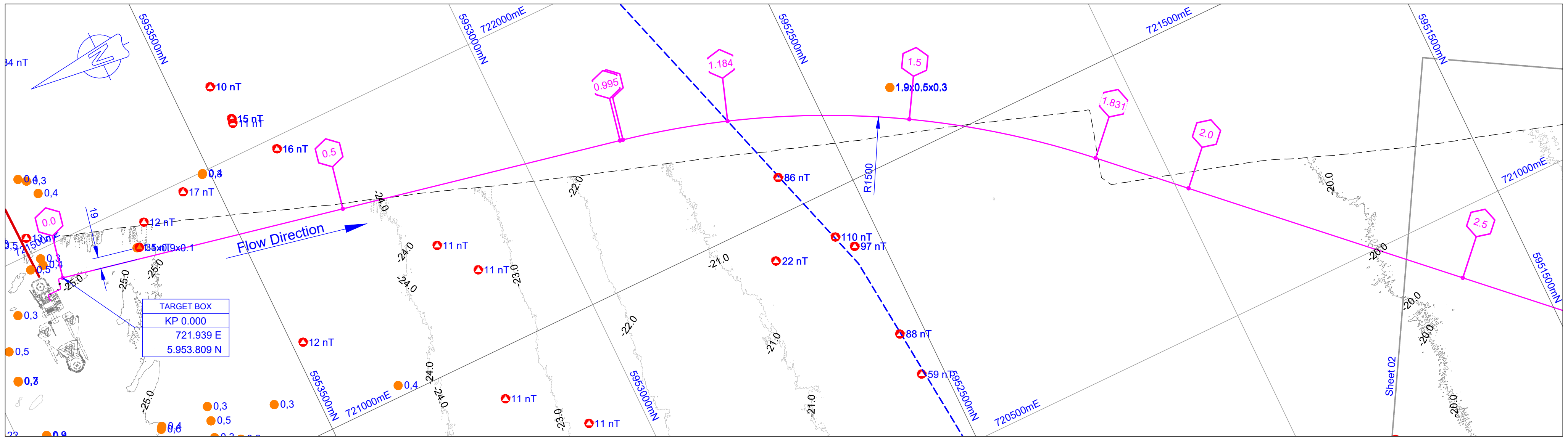
Client
ONEDyas B.V.

Project
N05-A TO NGT PIPELINE

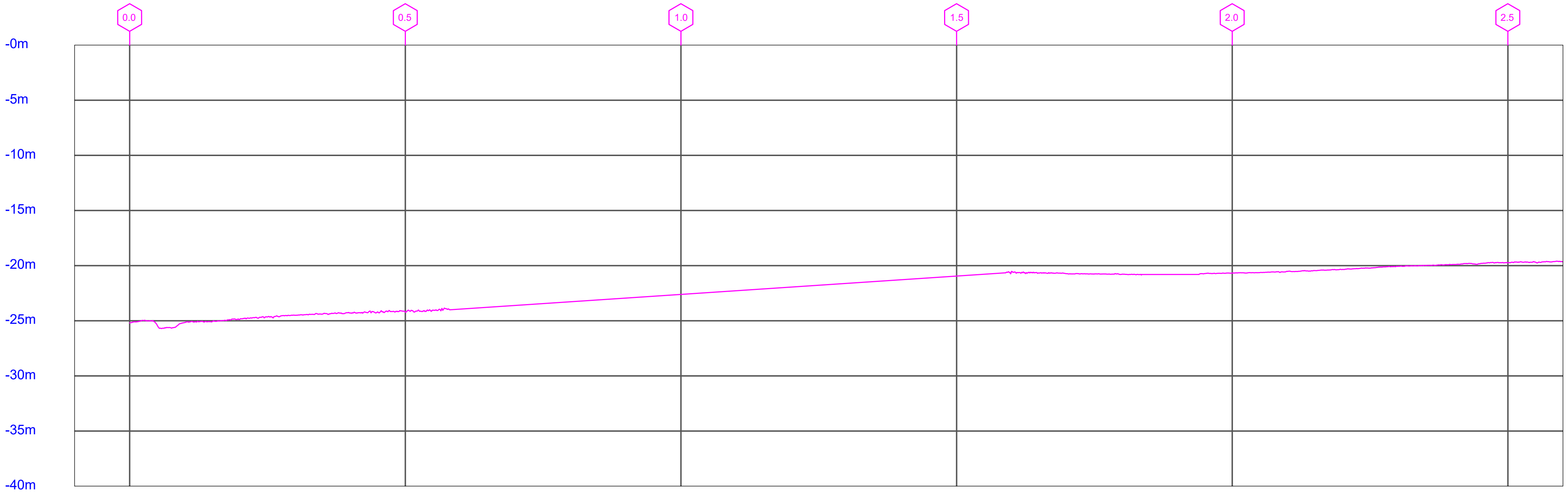
Document
Pipeline Route - Overall Field Layout
Alternative platform location

Scale: 1:30000
Size: A1

Project number: 19018
Document Number: N05A-7-51-0-72510-02



PLAN VIEW



PROFILE

Vertical scale 1:250
Horizontal scale 1:5000

START | MATCHLINE

PIPELINE	KP 0.0 / KP 0.05 / KP 0.5 / KP 0.995 / KP 1.0 / KP 1.184 / KP 1.5 / KP 1.831 / KP 2.0 / KP 2.5
PIPE SIZE O.D./W.T./GRADE	20" NB 20.62mm L450 HFIW
ANTI CORROSION COATING/THICKNESS(mm)	3LPE 2.8mm / 2.1mm FJC HEAT SHRINK SLEEVE
CONCRETE WEIGHT COATING THICKNESS(mm) / DENSITY KG/M3	40mm CWC, 3300 KG/m3 (TBC)
ANODE TYPE/SPACING/WEIGHT(kg)	20" HALF SHELL SACRIFICIAL ANODE / 1 EVERY TBD JOINTS / TBD
PIPE WEIGHT IN AIR(kg/m)/SUBMERGED EMPTY(kg/m)/ SUBMERGED FILLED(kg/m)	481.9 / 197.9 / 373.3 (TBC)
ALLOWABLE FREE SPAN LENGTHS(m) (INSTALLATION / OPERATION)	21.9 / 20.9 (WD 8m) / 22.9 / 21.6 (WD 17m) / 25.2 / 23.7 (WD 26m)
HEADING	191.7° (KP 0.0 – KP 0.995); 223.7° (KP 1.831 – KP 2.5)
SPECIAL ITEMS	ROCK DUMP (KP 0.05 – KP 0.995); CROSSING (KP 0.995 – KP 1.184)
PRESSURE(barg) DESIGN/HYDROTEST	111.1 / 138.9
TRENCHING	50m TRANSITION (ROCK DUMPED); 0.8m MINIMUM COVER OVER TOP OF PIPELINE

GENERAL NOTES

\- -

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06
N05A-7-50-0-72051-01	Alternative platform location - Approach drawing @ N05A

LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

BATHYMETRY AND SEABED FEATURES

- 0.5 CONTOUR LINE AT 1m INTERVAL
- LxWxH SONAR CONTACT
- LxWxH DEPRESSION
- LxWxH MOUND
- AS-FOUND WELLHEAD
- CPT05 CONE PENETRATION TEST
- VC05 VIBRE CORE
- 65nT MAGNETIC ANOMALY
- WRECK

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

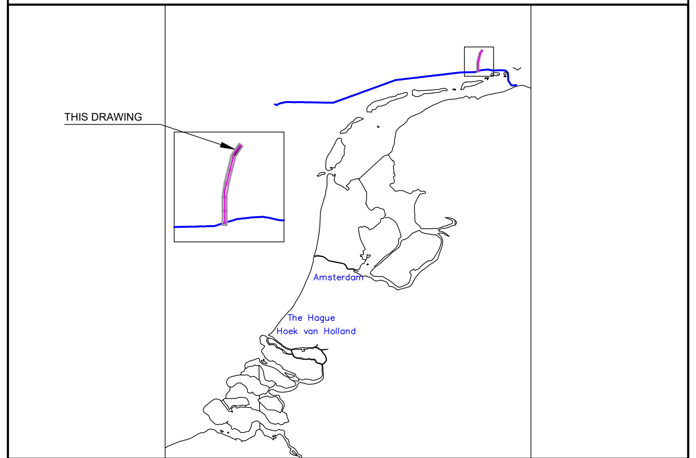
Horizontal Datum Name:
European Datum 1950 North Sea -UKCS

Projection Name:
Universal Transverse Mercator

Ellipsoid:
International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000	Zone :	= North 31
Semi minor axis	b	=	6 356 911.946	Central meridian :	= 3° East
Inverse ELattening	1/f	=	297.000	Latitude of origin :	= Equator
Excentricity squared	e	=	0.006 722 670	False Easting :	= 500 000.00 m
				False Northing :	= 0.00 m
				Scale factor on C.M.:	= 0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV	-	PF	PF	

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onedyas

Client
ONEDyas B.V.

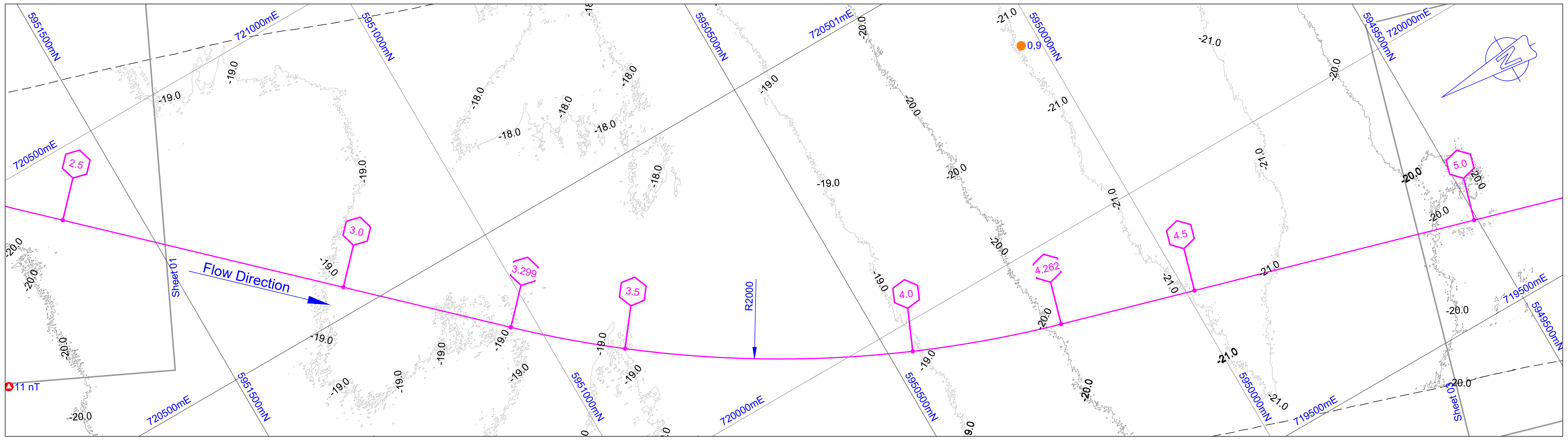
Project
N05-A TO NGT PIPELINE

Document
Pipeline alignment sheet
Alternative platform location - Buried option
Sheet 01

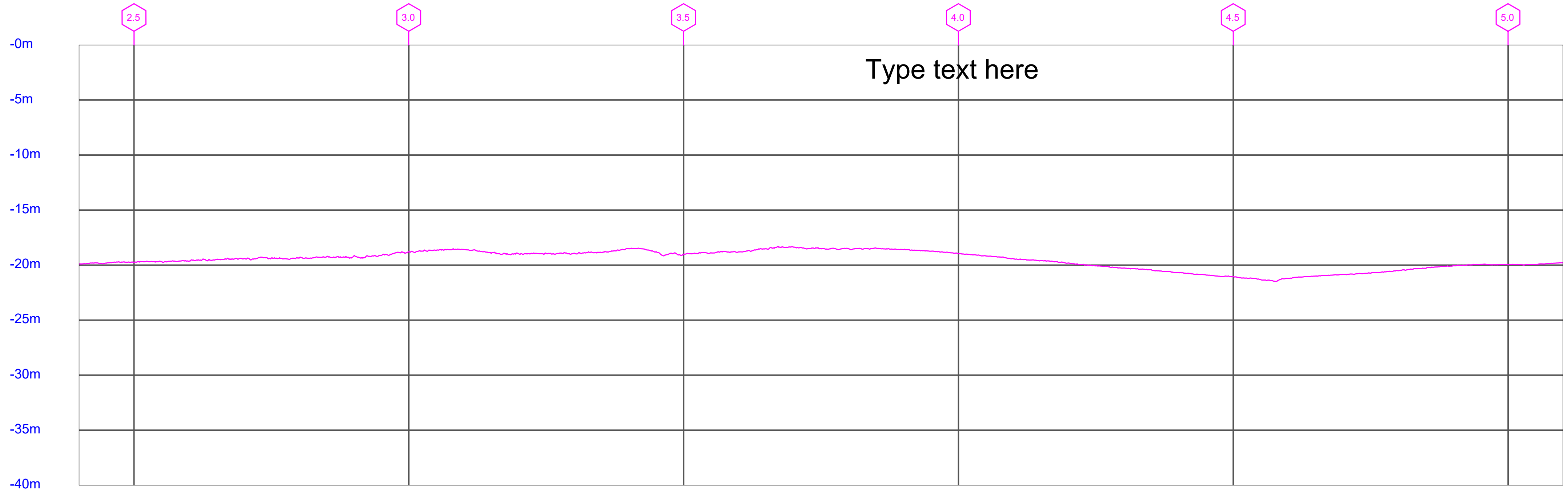
Scale: 1:5000
Size: A1

Project number: **19018**

Document Number **N05A-7-50-0-72050-01**



PLAN VIEW



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Horizontal scale 1:5000

PROFILE

MATCHLINE MATCHLINE

PIPELINE

PIPELINE	KP 2.5 – KP 3.0 – KP 3.299 – KP 3.5 – KP 4.0 – KP 4.262 – KP 4.5 – KP 5.0
PIPE SIZE O.D./W.T./GRADE	20" NB 20.62mm L450 HFIW
ANTI CORROSION COATING/THICKNESS(mm)	3LPE 2.8mm / 2.1mm FJC HEAT SHRINK SLEEVE
CONCRETE WEIGHT COATING THICKNESS(mm) / DENSITY KG/M3	40mm CWC, 3300 KG/m3 (TBC)
ANODE TYPE/SPACING/WEIGHT(kg)	20" HALF SHELL SACRIFICIAL ANODE / 1 EVERY TBD JOINTS / TBD
PIPE WEIGHT IN AIR(kg/m)/SUBMERGED EMPTY(kg/m)/ SUBMERGED FILLED(kg/m)	481.9 / 197.9 / 373.3 (TBC)
ALLOWABLE FREE SPAN LENGTHS(m) (INSTALLATION / OPERATION)	21.9 / 20.9 (WD 8m) / 22.9 / 21.6 (WD 17m) / 25.2 / 23.7 (WD 26m)
HEADING	223.7° (KP 2.5 – KP 3.299); 196.1° (KP 4.262 – KP 5.0)
SPECIAL ITEMS	
PRESSURE(barg) DESIGN/HYDROTEST	111.1 / 138.9
TRENCHING	0.8m MINIMUM COVER OVER TOP OF PIPELINE

GENERAL NOTES

- -

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06

LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

BATHYMETRY AND SEABED FEATURES

- CONTOUR LINE AT 1m INTERVAL
- SONAR CONTACT
- DEPRESSION
- MOUND
- AS-FOUND WELLHEAD
- CONE PENETRATION TEST
- VIBRE CORE
- MAGNETIC ANOMALY
- WRECK

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name: European Datum 1950 North Sea -UKCS

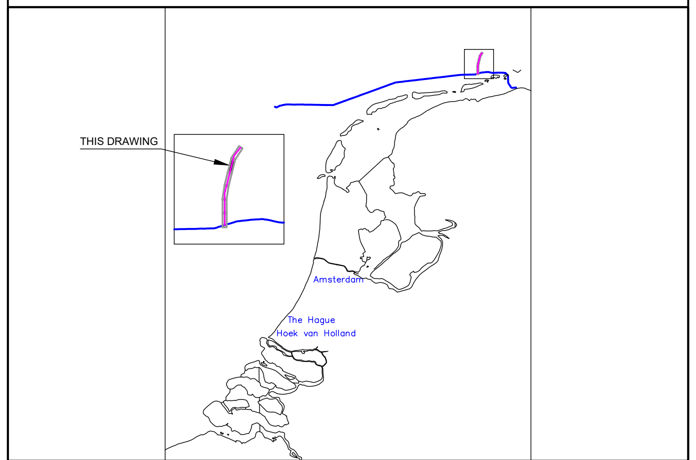
Projection Name: Universal Transverse Mercator

Ellipsoid: International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone	North 31
Central meridian	3° East
Latitude of origin	Equator
False Easting	500 000.00 m
False Northing	0.00 m
Scale factor on C.M.	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV	-	PF	PF	

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Project
N05-A TO NGT PIPELINE

Document
Pipeline alignment sheet
Alternative platform location - Buried option
Sheet 02

Scale: 1:5000
Size: A1

Project number: **19018**
Document Number **N05A-7-50-0-72050-02**

GENERAL NOTES

- -

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06

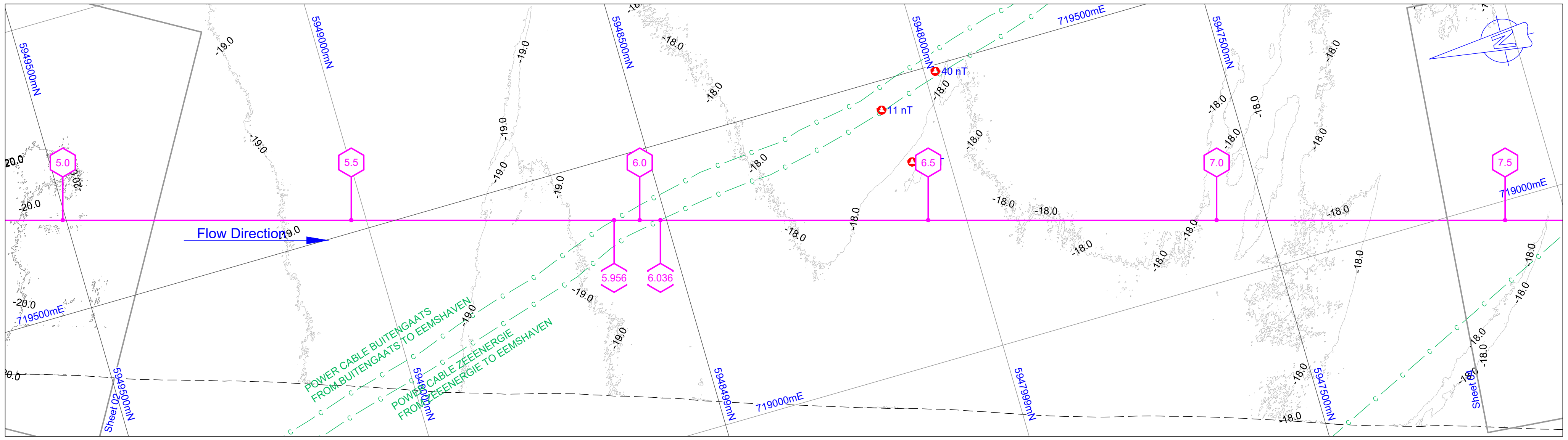
LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

BATHYMETRY AND SEABED FEATURES

- CONTOUR LINE AT 1m INTERVAL
- SONAR CONTACT
- DEPRESSION
- MOUND
- AS-FOUND WELLHEAD
- CONE PENETRATION TEST
- VIBRE CORE
- MAGNETIC ANOMALY
- WRECK



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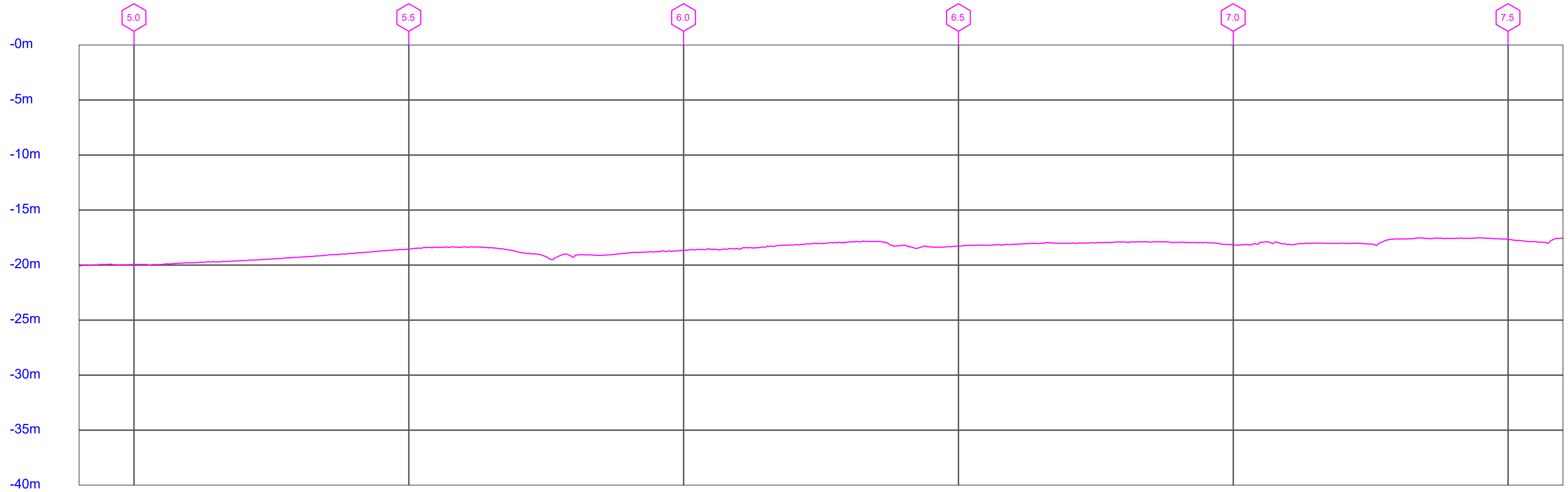

PROFILE

Vertical scale 1:250
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MATCHLINE — MATCHLINE

PIPELINE

	KP 5.0 – KP 7.5 (KP 5.5, KP 5.956, KP 6.0, KP 6.036, KP 6.5, KP 7.0)
PIPE SIZE O.D./W.T./GRADE	20" NB 20.62mm L450 HFIW
ANTI CORROSION COATING/THICKNESS(mm)	3LPE 2.8mm / 2.1mm FJC HEAT SHRINK SLEEVE
CONCRETE WEIGHT COATING THICKNESS(mm) / DENSITY KG/M3	40mm CWC, 3300 KG/m3 (TBC)
ANODE TYPE/SPACING/WEIGHT(kg)	20" HALF SHELL SACRIFICIAL ANODE / 1 EVERY TBD JOINTS / TBD
PIPE WEIGHT IN AIR(kg/m)/SUBMERGED EMPTY(kg/m)/ SUBMERGED FILLED(kg/m)	481.9 / 197.9 / 373.3 (TBC)
ALLOWABLE FREE SPAN LENGTHS(m) (INSTALLATION / OPERATION)	21.9 / 20.9 (WD 8m) / 22.9 / 21.6 (WD 17m) / 25.2 / 23.7 (WD 26m)
HEADING	196.1°
SPECIAL ITEMS	CROSSING (KP 5.956) / CROSSING (KP 6.036)
PRESSURE(barg) DESIGN/HYDROTEST	111.1 / 138.9
TRENCHING	0.8m MINIMUM COVER OVER TOP OF PIPELINE

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name: European Datum 1950 North Sea -UKCS

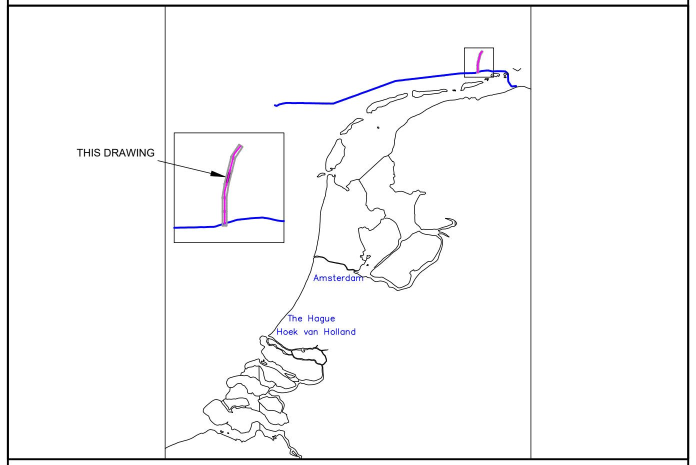
Projection Name: Universal Transverse Mercator

Ellipsoid: International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone	North 31
Central meridian	3° East
Latitude of origin	Equator
False Easting	500 000.00 m
False Northing	0.00 m
Scale factor on C.M.	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

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02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV	-	PF	PF	

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Project
N05-A TO NGT PIPELINE

Document
Pipeline alignment sheet
Alternative platform location - Buried option
Sheet 03

Scale: 1:5000
Size: A1

Project number: **19018**

Document Number **N05A-7-50-0-72050-03**

GENERAL NOTES

- -

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06

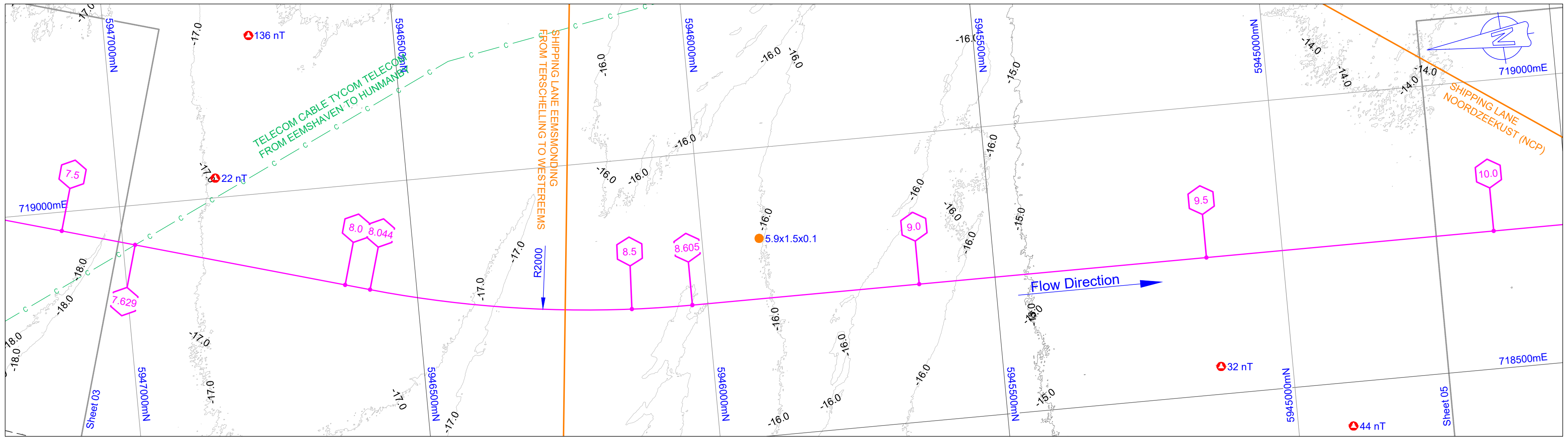
LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

BATHYMETRY AND SEABED FEATURES

- CONTOUR LINE AT 1m INTERVAL
- SONAR CONTACT
- DEPRESSION
- MOUND
- AS-FOUND WELLHEAD
- CONE PENETRATION TEST
- VIBRE CORE
- MAGNETIC ANOMALY
- WRECK



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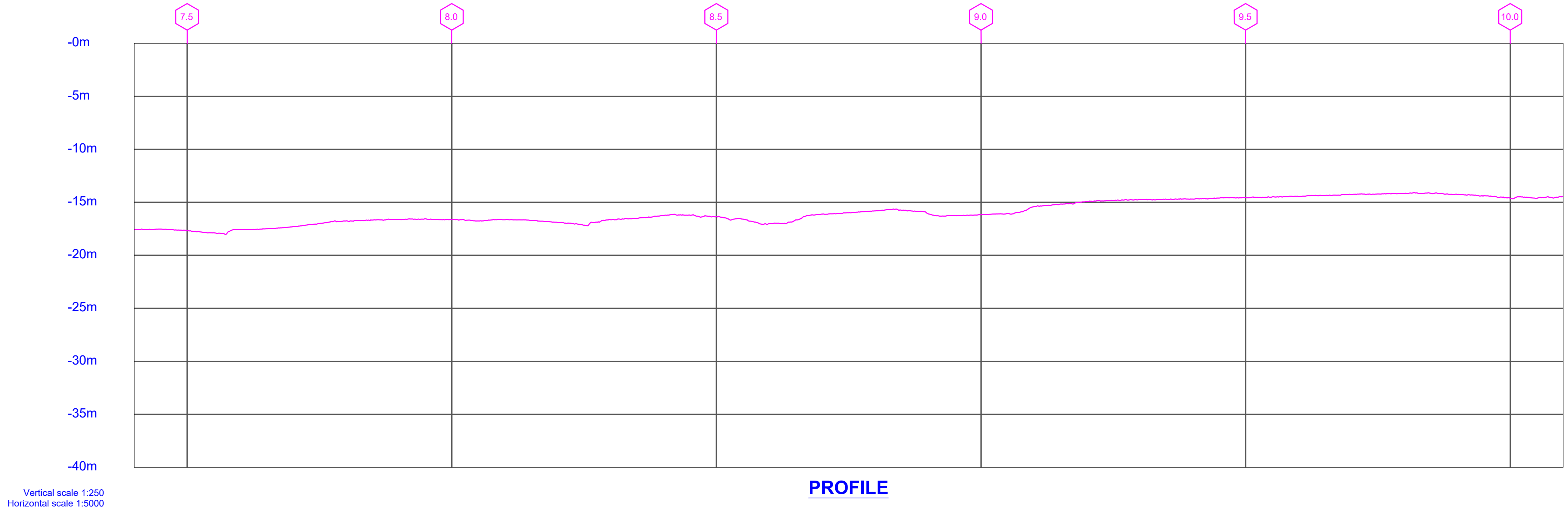


PROFILE

MATCHLINE | MATCHLINE

PIPELINE	KP 7.5 – KP 7.629 – KP 8.0 – KP 8.044 – KP 8.5 – KP 8.605 – KP 9.0 – KP 9.5 – KP 10.0
PIPE SIZE O.D./W.T./GRADE	20" NB 20.62mm L450 HFIW
ANTI CORROSION COATING/THICKNESS(mm)	3LPE 2.8mm / 2.1mm FJC HEAT SHRINK SLEEVE
CONCRETE WEIGHT COATING THICKNESS(mm) / DENSITY KG/M3	40mm CWC, 3300 KG/m3 (TBC)
ANODE TYPE/SPACING/WEIGHT(kg)	20" HALF SHELL SACRIFICIAL ANODE / 1 EVERY TBD JOINTS / TBD
PIPE WEIGHT IN AIR(kg/m)/SUBMERGED EMPTY(kg/m)/ SUBMERGED FILLED(kg/m)	481.9 / 197.9 / 373.3 (TBC)
ALLOWABLE FREE SPAN LENGTHS(m) (INSTALLATION / OPERATION)	21.9 / 20.9 (WD 8m) / 22.9 / 21.6 (WD 17m) / 25.2 / 23.7 (WD 26m)
HEADING	196.1° (KP 7.5 – KP 8.044); 180.0° (KP 8.605 – KP 10.0)
SPECIAL ITEMS	CROSSING (KP 7.629)
PRESSURE(barg) DESIGN/HYDROTEST	111.1 / 138.9
TRENCHING	0.8m MINIMUM COVER OVER TOP OF PIPELINE

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name: European Datum 1950 North Sea -UKCS

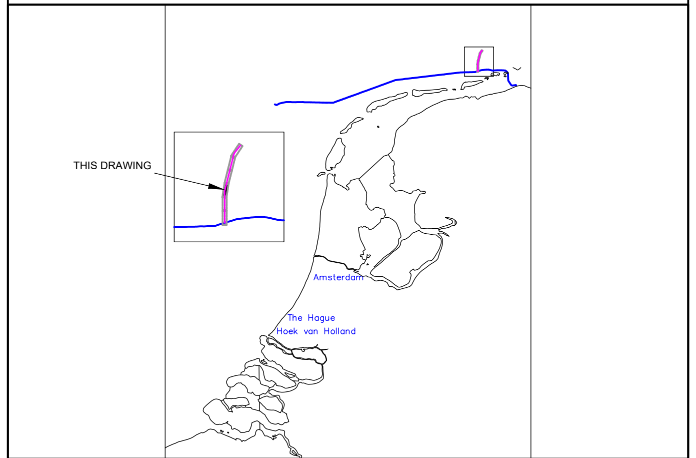
Projection Name: Universal Transverse Mercator

Ellipsoid: International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone	North 31
Central meridian	3° East
Latitude of origin	Equator
False Easting	500 000.00 m
False Northing	0.00 m
Scale factor on C.M.	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



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Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV	-	PF	PF	

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Client: ONEDyas B.V.

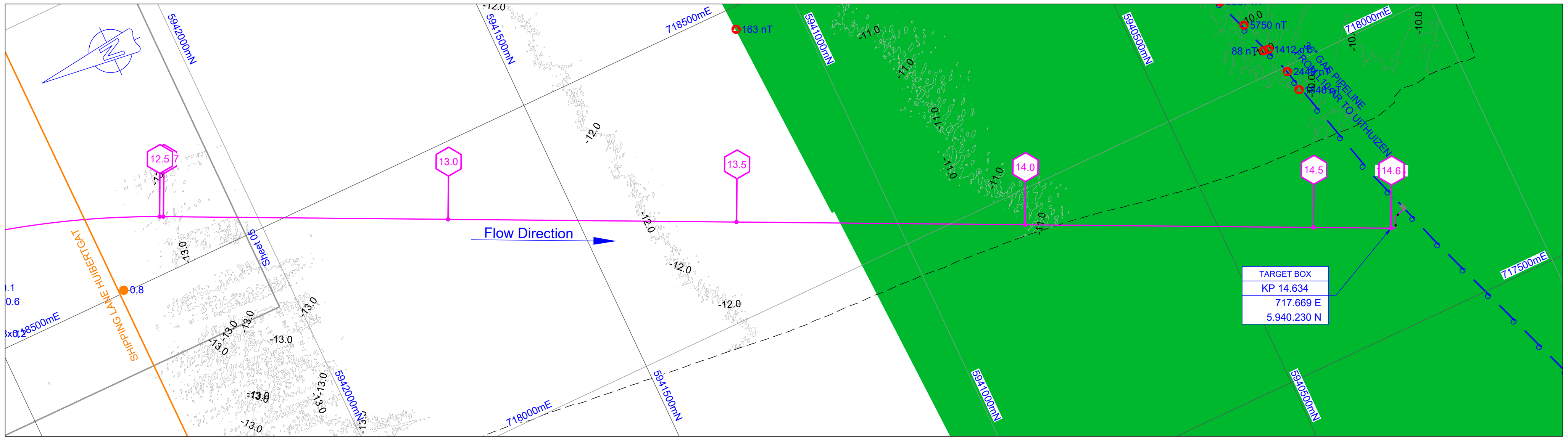
Project: N05-A TO NGT PIPELINE

Document: Pipeline alignment sheet
Alternative platform location - Buried option
Sheet 04

Scale: 1:5000
Size: A1

Project number: 19018

Document Number: N05A-7-50-0-72050-04



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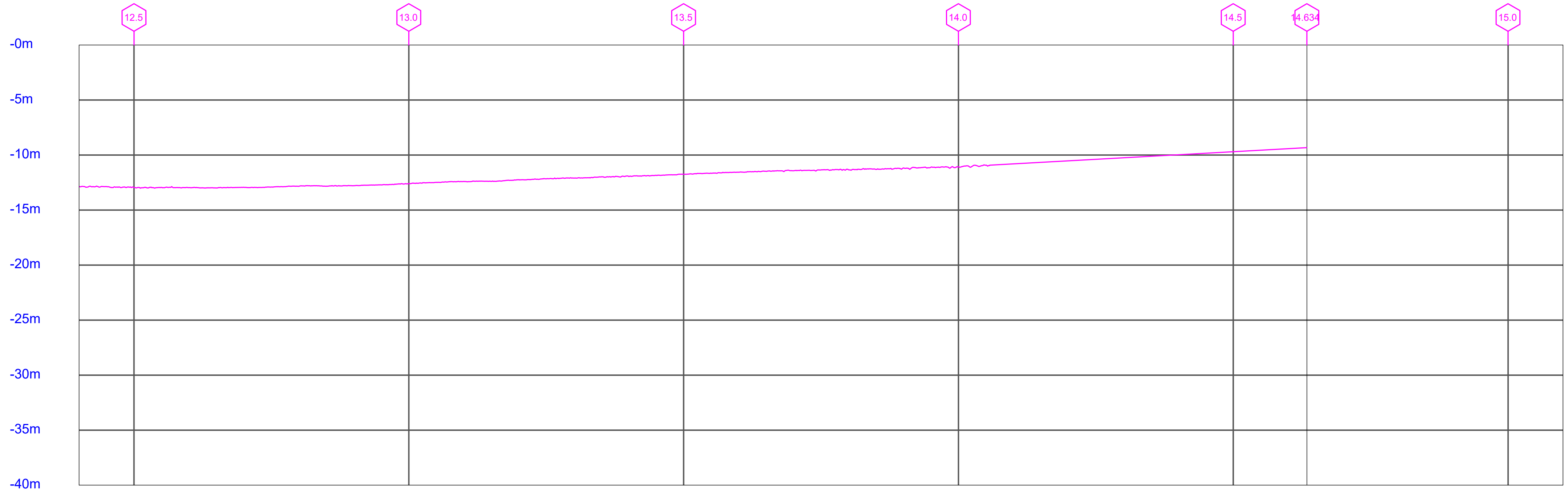

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Horizontal scale 1:5000

PROFILE

MATCHLINE — END POINT

PIPELINE	KP 12.507 / KP 12.5 — KP 13.0 — KP 13.5 — KP 14.0 — KP 14.5 — KP 14.584 — KP 14.634
PIPE SIZE O.D./W.T./GRADE	20" NB 20.62mm L450 HFIW
ANTI CORROSION COATING/THICKNESS(mm)	3LPE 2.8mm / 2.1mm FJC HEAT SHRINK SLEEVE
CONCRETE WEIGHT COATING THICKNESS(mm) / DENSITY KG/M3	40mm CWC, 3300 KG/m3 (TBC)
ANODE TYPE/SPACING/WEIGHT(kg)	20" HALF SHELL SACRIFICIAL ANODE / 1 EVERY TBD JOINTS / TBD
PIPE WEIGHT IN AIR(kg/m)/SUBMERGED EMPTY(kg/m)/ SUBMERGED FILLED(kg/m)	481.9 / 197.9 / 373.3 (TBC)
ALLOWABLE FREE SPAN LENGTHS(m) (INSTALLATION / OPERATION)	21.9 / 20.9 (WD 8m) / 22.9 / 21.6 (WD 17m) / 25.2 / 23.7 (WD 26m)
HEADING	205.7°
SPECIAL ITEMS	ROCK DUMP (KP 14.584 – KP 14.634)
PRESSURE(barg) DESIGN/HYDROTEST	111.1 / 138.9
TRENCHING	0.8m MINIMUM COVER OVER TOP OF PIPELINE; 50m TRANSITION (ROCK DUMPED)

GENERAL NOTES

- -

REFERENCES

N05A-7-51-0-72510-02	Pipeline Route - Overall Field Layout - Alternative platform location
N05A-7-50-0-72050-01/06	Pipeline alignment sheet - Alternative platform location - Buried option - sheet 01 to 06
N05A-7-10-0-72052-01	Alternative platform location - Approach drawing @ NGT

LEGEND

GENERAL

- KILOMETER MARKER
- PIPELINE: N05A - NGT
- CABLE: N05A - RIFFGAT
- BOUNDARY OF SURVEY AREA
- EXISTING PIPELINE
- EXISTING CABLE
- SHIPPING LANE RIJKSWATERSTAAT
- ROCKDUMP
- NATURA2000
- OYSTERBANK

BATHYMETRY AND SEABED FEATURES

- CONTOUR LINE AT 1m INTERVAL
- SONAR CONTACT
- DEPRESSION
- MOUND
- AS-FOUND WELLHEAD
- CONE PENETRATION TEST
- VIBRE CORE
- MAGNETIC ANOMALY
- WRECK

GEODETIC PARAMETERS

PROJECTED CRS: ED50/UTM zone 31N (EPSG: 23031)

Horizontal Datum Name: European Datum 1950 North Sea -UKCS

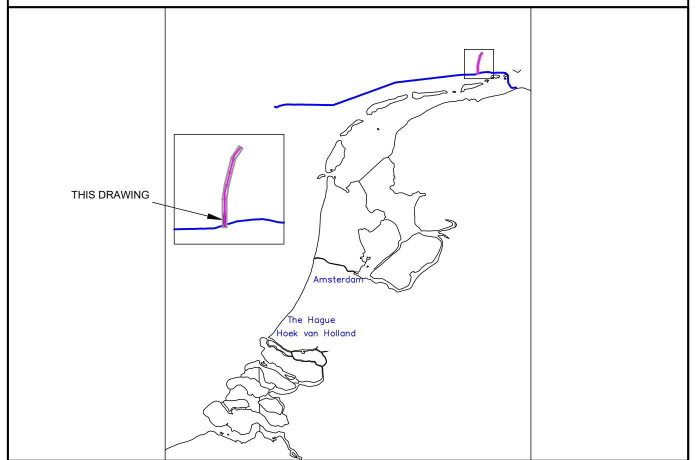
Projection Name: Universal Transverse Mercator

Ellipsoid: International 1924 (Hayford 1909)

Semi major axis	a	=	6 378 388.000
Semi minor axis	b	=	6 356 911.946
Inverse ELattening	1/f	=	297.000
Excentricity squared	e	=	0.006 722 670

Zone	North 31
Central meridian	3° East
Latitude of origin	Equator
False Easting	500 000.00 m
False Northing	0.00 m
Scale factor on C.M.	0.999 6

WGS84 to ED50 TRANSFORMATION: UKOAA (EPSG: 1311)



KEYPLAN

Rev	Date	Description	Drawn	Eng.	Check	Appr.	Client
02	21-12-2021	FOR APPROVAL	SvdV	-	DK	DK	
01	15-12-2021	FOR COMMENTS	SvdV		PF	PF	

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Client: ONEDyas B.V.

Project: N05-A TO NGT PIPELINE

Document: Pipeline alignment sheet
Alternative platform location - Buried option
Sheet 06

Scale: 1:5000
Size: A1

Project number: 19018

Document Number: N05A-7-50-0-72050-06

N05-A Pipeline design

Risk assessment & dropped object analysis

DOCUMENT NUMBER:

N05A-7-10-0-70030-01

22-12-2021

Rev.	Date	Description	Originator	Checker	Approver
01	02-01-2020	For Comments	JvdB	PF	PF
02	24-01-2020	For Approval	JvdB	PF	PF
03	12-10-2020	Extra CWC options	EvW	PF	PF
04	15.12.2021	Update for rerouted pipeline	PF	DK	DK
05	22.12.2022	Client comments incorporated	PF	DK	DK

Client

ONE-Dyas B.V.

Project

N05-A Pipeline Design

Document

Risk assessment & dropped object analysis

Project number	19018
Document number	N05A-7-10-0-70030-01
Client document number	N05A-7-10-0-70030-01
Revision	05
Date	22.12-2022

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Revision History

Revision	Description
01	For Client Comments
02	Client comments incorporated
03	Extra CWC options
04	Update for rerouted pipeline
05	Client comments incorporated (sections 1.1, 2 & 4.2)

Revision Status

Revision	Description	Issue date	Prepared	Checked	Enersea approval	Client approval
01	For Client Comments	02-01-2020	JvdB	PF	PF	
02	For Client Approval	24-01-2020	JvdB	PF	PF	
03	Extra CWC options	12-10-2020	EvW	PF	PF	
04	Updated for pipeline re-route	15-12-2021	PF	DK	DK	
05	Client comments incorporated	22-12-2022	PF	DK	DK	

Table of content

1. Introduction

1.1. Project Introduction

One-Dyas plans to develop a successfully drilled well in block N05-A of the North Sea Dutch Continental Shelf. More wells will be drilled at this location through the same jacket. It is planned to develop the wells by installing a platform and a gas export pipeline with a connection to the NGT pipeline @KP141.4. Approximate length of the pipeline is 14.6 km.

In addition, a power cable will be installed from the Riffgat Windpark to the N05-A platform.

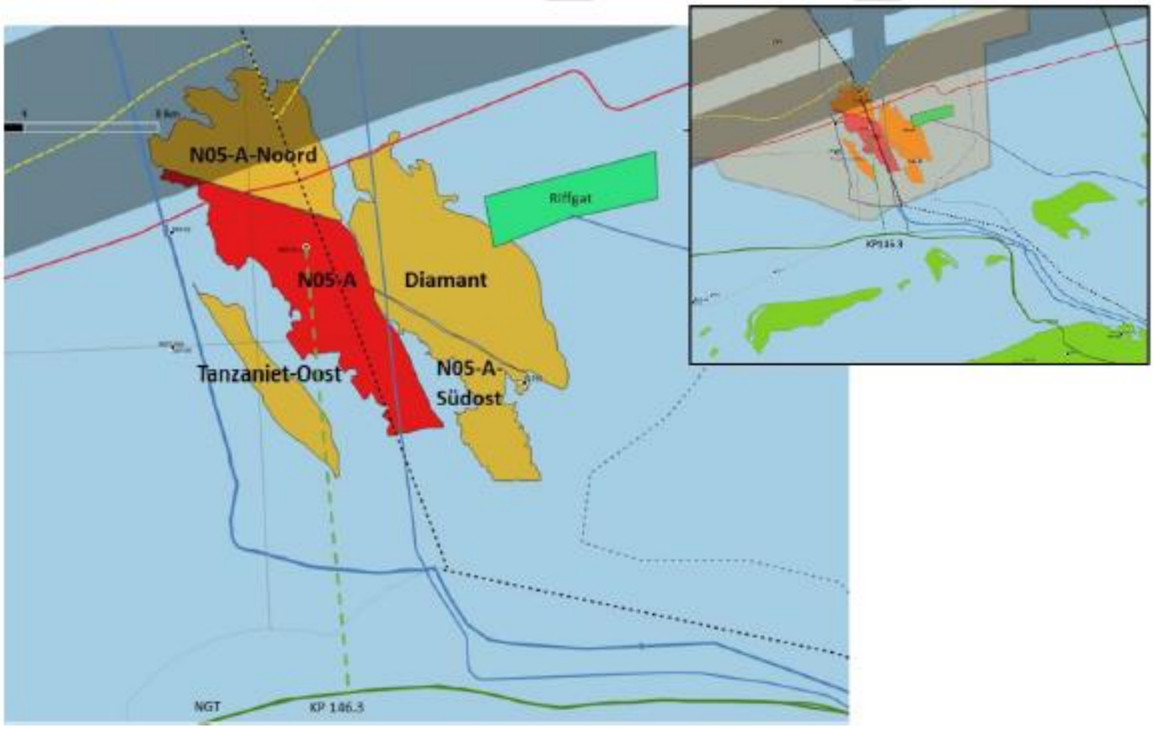


Figure 1, N05A Field layout

1.2. Purpose and scope of Document

This document fulfils the requirements for risk assessments for the 20" pipeline from the N05-A platform to the tie-in location on the NGT, and to comply with Dutch codes (ref [3]) and regulations. The report contains the outcome of the RIE workshop. The risk register is captured in Appendix B.

The quantitative risk assessment for the typical subsea Third Party threats are based on the general practice of industry, engineering judgements and AIS shipping data has been applied to determine the ships density.

The analyses presented, both contain the buried pipeline case and the un-buried pipeline case.

1.3. System of Units

All dimensions and calculations applied are based on the International System of Units (SI) unless noted otherwise.

1.4. Abbreviations

AIS	Automatic Identification System
ALARP	As Low As Practical Achievable
BoD	Basis of Design
CWC	Concrete Weight Coating
DWT	Dead Weight Tonnage
DFI	Design Fabrication and Installation
DNV	Det Norsk Veritas
DNVGL	Det Norsk Veritas &Germanisher Lloyds
DWT	Dead Weight Tonnage
ESDV	Emergency shutdown valve
NEN	Nederlands Normalisatie-Instituut
NGT	Noord-Gas-Transport B.V.
PIMS	Pipeline Integrity management System
RIE	Risk Inventarisation and Evaluation
ToP	Top of Pipe
TPI	Third Party Interference

1.5. References

[1] Overheidsbeleid inzake de aanleg van offshore pijpleidingen voor het transport van olie en/of gas, letter to NOGEPA from the Dutch Ministery of Economic Affairs, dated 03 November 1987;

[2] Risk analyses and burial requirements for Dutch Continental Shelf pipelines, D.Schaap a.o., 1987;

[3] Eisen voor Stalen Transportleidingsystemen, NEN 3656 (Requirement for Steel Pipeline Transportation Systems);

[4] Veiligheidsanalyse voor zeeleidingen, Rijkswaterstaat Directie Noordzee;

[5] -;

[6] Monitoring-nautische-veiligheid-2013-noordzee;

[7] Beleidsnota Scheepvaartverkeer Noordzee “Op Koers”, no 17408-26, Ministerie van Verkeer en Waterstaat, Januari 1987;

[8] Snelle reparatie Unocal-pijp volgens het boekje verlopen, Offshore Visie Magazine, Juni 1988;

[9] Mooring Anchors, The society of Naval Architects and Marine Engineers Transactions, Vol 67, 1959;

[10] Lloyd’s “Register of Ships”;

[11] DNV RP-F107 - Risk Assessment of Pipeline Protection - October 2010;

[12] DNV-RP-C204 – Design against accidental loads- November 2014;

[13] DNV-RP-F111 (2010)- Interference between trawl gear and pipelines;

[14] N05A-1-10-0-10001-01 FEED BOD platform facility;

[15] Marin Study, platform collision N05A, 32287-1-MO-rev0, November 2019;

[16] Geo XYZ, Surveys, 2019 LU0022H-553-RR-04-2.1, LU0022H-553-RR-05-1.1, LU0022H-553-RR-02;

[17] N05A-7-51-0-72510-02-06 - Overall field layout drawing;

[18] N05A-7-10-0-70031-01-01 – Route Selection Report;

2. Summary

This report presents the results of the pipeline risk assessments, for the export pipeline connecting the future ONE-Dyas platform N05A to NGT. Due to shipping traffic along the Southern shipping lanes and inbound and outbound traffic of the Eems-Dollard ports, the ship density in the whole area is high.

The pipeline Third Party shipping threats associated with high ship density, like dropped and dragging anchors, require additional measures to protect the pipeline and spools.

A pipeline RIE workshop was held on 3rd December 2019 and the following list contain in brief the outcome and highlights. Reference is also made to appendix A and B.

- Installation threats, due to installation, trenching and tie-in feasibilities;
- Third Party threats. Common subsea pipeline threats as dropped objects, dropped and dragging anchors and fishing gear impact;
- Natural hazards, related to on-bottom stability;

In this report the subsea pipeline third party threats are analysed in detail.

The dropped and dragging anchors are the most dominant threat. Table 1 shows the required minimal cover depth and probability of unacceptable damage per year per km of pipeline, as a function of ship traffic densities along the route and the applied CWC.

Table 1 Overview Pipeline leak probability (dropped and dragging anchors)

KP section	Ship density /1000 km²	No CWC		40 mm CWC		140 mm CWC	
		Cover ToP [m]	Probalility [10^{-6}]	Cover ToP [m]	Probalility [10^{-6}]	Cover ToP [m]	Probalility [10^{-6}]
0.0 - 2.0	45	0.7	0.97	0.6	0.97	0.5	0.90
2.0 – 7.5	15	0.0	0.74	0.0	0.54	0.0	0.52
7.5 - 12.2	45	0.7	0.97	0.6	0.97	0.5	0.90
12.2 – 14.6	27	0.3	0.89	0.0	0.97	0.0	0.93

*Note: calculated cover heights are excluding any potential natural sea bottom variations which might occur over the operational lifetime.

Within the shipping lane and for a pipeline without CWC, the pipeline Top of Pipe cover should be 0.7 m, to meet the acceptable risk level (≤ $1.00 \cdot 10^{-6}$ per year per km of pipeline). The minimum cover depth for shipping lane or anchor zone is 0.6 m when 40 mm of CWC is considered, and 0.5m when 140 mm of CWC is applied. In lower density traffic zones, pipeline burial may not be required if a CWC is applied.

The determined cover depth for 140mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

Fish gear interference for pipe diameters larger than 400 mm is negligible, according to NEN 3656 Section 9.4.2.6. Sinking ships are regarded as low risk due to the low probability of occurring in the vicinity of the pipeline.

The risk of dropped objects near the platform is fully mitigated with a rock berm height on top of pipe of 0.65 m. This risk is analyzed in section 8.

3. Dutch Authority Safety Criteria

The policy with regard to safety criteria for offshore pipelines is laid down in [1], effective 1987 and [3].

The Dutch Authorities require a minimum soil cover of 0.2 [m] for pipelines with a diameter smaller than 16-inch based on the maximum penetration depth of trawl gear into the sea bottom, consequently avoiding any contact between fishing gear and offshore pipelines. For areas denoted as shipping routes and anchor drop areas, a minimum cover depth of 0,6 [m] is required according to the 2015 edition in NEN 3656. In an update to this standard, expected to be in effect by the time of pipeline installation, the minimum required cover in shipping lanes is 0.2 m plus what is required to sufficiently reduce probability of failure.

Pipelines equal or larger than 400mm OD do not have to be buried according to NEN 3656 Section 9.4.2.6, as in practice they are not affected by fishing gear.

If natural sea bottom variations over the operational lifetime might occur, an appropriate extra cover is to be added to the minimum required cover.

In any case the following conditions must be fulfilled:

- The expected frequency of pipeline damage, due to third parties and resulting in a leak, should be less than 10^{-6} per km of pipeline per year;
- The resulting spillage of liquid hydrocarbons should be less than 100 m^3, 400 m^3, 700 m^3 for a pipeline located within respectively 12 nautical miles of shore, between 12 miles and 25 miles from shore and beyond 25 miles from shore,

3.1. NEN 3656

NEN 3656 provides guidance on the pipeline risk assessment, according the Dutch Authority regulations. The risk investigation and evaluation (RIE) methodology as suggested by NEN 3656 [3] has been applied. Reference is made to Appendix A and B.

4. Design data

All design data considered for the risk and safety calculations for the pipeline are presented in the following subsections and have been extracted from the Basis of Design ref [14]. It should be noted that the pipeline design is still on-going and the pipeline data may change.

4.1. Pipeline Data

The basic pipeline design data considered in the analysis are presented in the tables below. Table 2 presents the data of the pipeline, while Table 3 presents the material properties of the steel used.

Table 2, Pipeline data

Property	Value	
Product transported	Natural gas (dew-pointed gas and condensate)	
Design life	25 years	
Approximate length	14.637 km	
Steel material grade (ISO3183-NEN 3656)	L360 / X52	
Pipe outside diameter	20"/508 mm	
Wall thickness	20.62 mm	
Wall thickness tolerance	-/+ 1.5mm (HFI)	
Corrosion Allowance	5mm	
Minimum subsea hot bend radius	2540 mm (5D)	
Coatings and insulation		
Anti-corrosion coating	3 Layer Poly-Propylene	
Anti-corrosion coating thickness	3 mm	
Anti-corrosion coating density	900 kg/m3	
Heat insulation	NA	
	Un-buried	**Buried**
Outer coating type	Concrete Weight Coating	none
Outer coating thickness	140 mm	-
Outer coating density	3300 kg/m^3	-

Table 3, Material properties

Property	Value
Material (ISO 3183)	L360
Density (kg/m3)	7850
Specified Minimum Yield Strength at 20C (MPa)	360
Specified Minimum Yield Strength at 50C (MPa)	360
Specified Minimum Tensile Strength at (MPa)	460
Youngs Modulus (GPa)	207
Poisson ratio (-)	0.3
Thermal expansion coefficient (m/m C)	1.17 x 10^{-5}

Additional line pipe properties.

NEN 3656, requires a number of pipeline material mechanical properties. These un-quantified measures provide additional safety margins (plastically, ductility and cracking) to resist the pipeline against damages and prevent catastrophic ruptures. These measures are among others:

- Ratio Yield/tensile strength ≤ 0.90, to allow plasticity margin for installation purposes;
- Charpy-V-test additional to line pipe code, to prevent ductile propagation and brittle fracture;
- Low carbon equivalents in material composition and weld zones to prevent hardness and reducing cracking susceptibility;

4.2. Key facility coordinates

The following platform and target box locations have been derived from Ref. [17] and are presented in Table 4.

Table 4, Key Facility coordinates

Item	Northing (m)	Easting (m)
N05A Platform	5 953 858	721 896
NGT side tap location KP141.4	5 940 197	717 698
N05A Platform target box	5 953 809	721.939
NGT target box	5 940 230	717 669
Water depth at N05A Platform	25.3 m LAT	
Water depth at NGT hot tap	9.8 m LAT	

4.3. Pipeline Bathymetry and Route

The intended target boxes at the ONE-Dyas platform and the NGT hot tap are shown in Figure 2

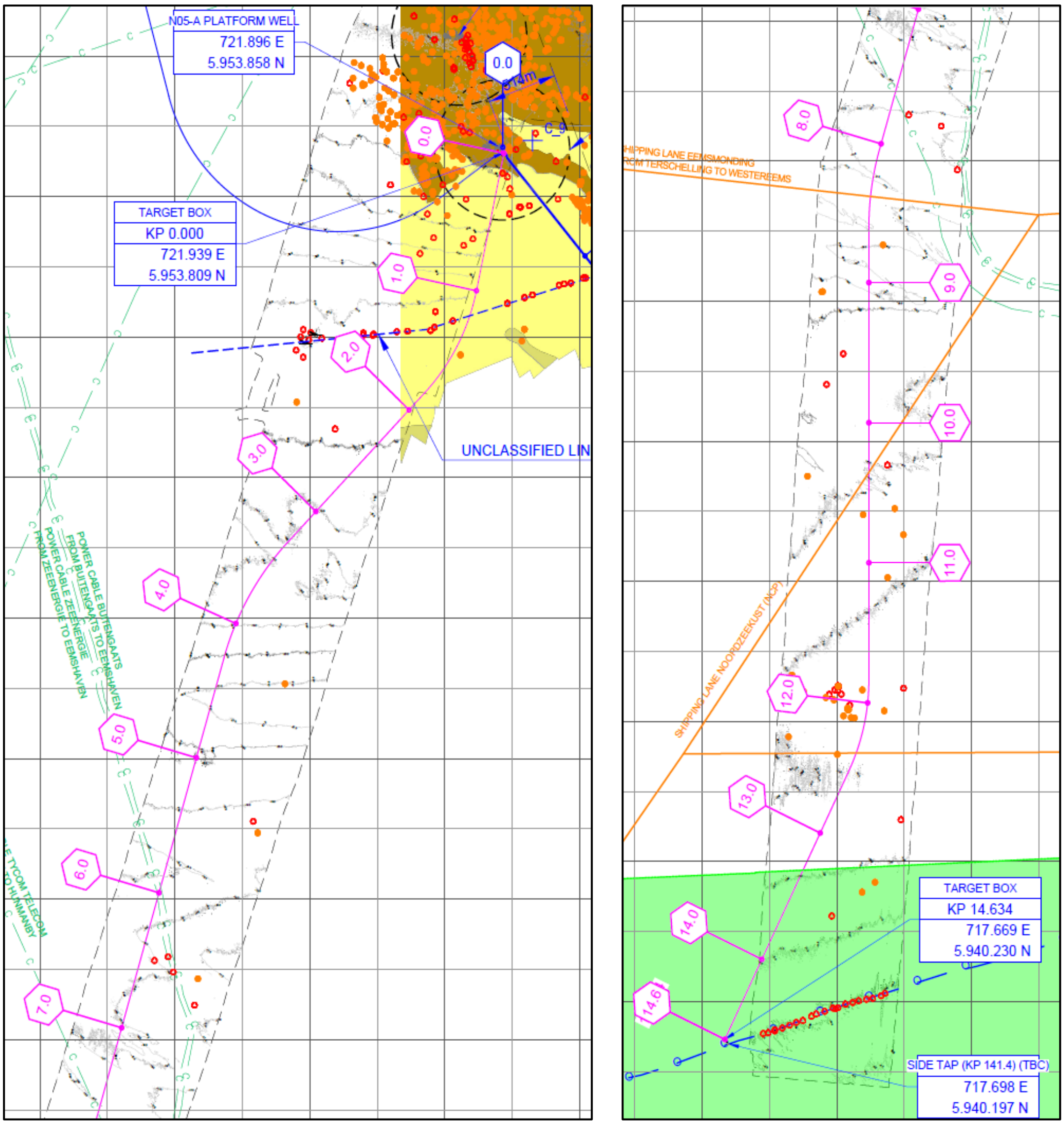


Figure 2, Pipeline route overview

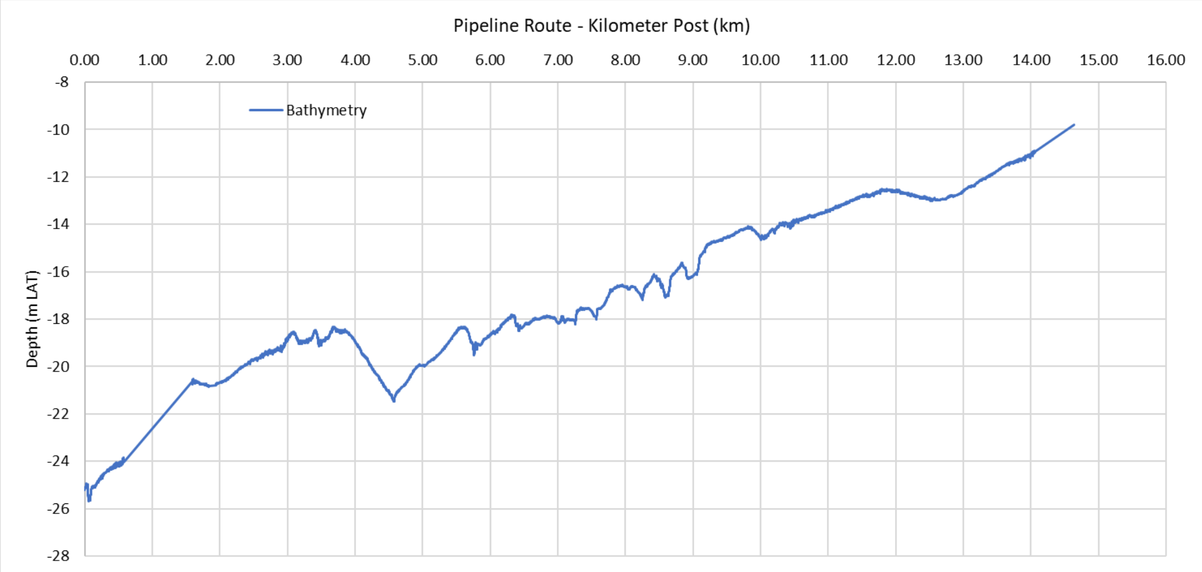


Figure 3, Bathymetric profile along the proposed pipeline route from platform N05A to NGT hot tap, ref [18].

4.4. Seabed Characteristics

The seabed is covered with fine to medium grained SAND generally thickening towards the South ref [16]. Sand was absent (or less than 0.5m thick) from KP 0.430 to KP 0.450, KP 0.757 to KP 1.045 and near KP 5.0 (channel), where the subsoil consists of sand with layers of clay. The soil properties are based on assumptions with reference to the geo-surveys reports, ref [16]. The 0.5 m top layer consists of mobile and loose sand properties. The clay outcrops are regarded as hard soil and to the South the subsoil sands are assumed to be medium.

4.5. Backfill and Rock berm properties

Backfill.

The natural backfilling of the trench is assumed to be loose sands.

Table 5, Properties of backfill material

Property	Value
Soil type	Sand
Submerged weight (kg/m3)	850
Angle of internal friction ϕ, [deg]	28

Rock Dump.

The following properties are considered for the rock dump, as given in Table 6.

Table 6, Rock dump properties

Property	Value
Rock Density [kg/m3]	2650
Porosity [%]	30
Submerged Weight γ, [kN/m³]	11.4
Angle of internal friction ϕ, [deg]	40

5. Hazards

The N05A pipeline hazards have been qualified in the risk assessment (RIE) workshop. Appendixes A and B presents the workshop attendees, Risk matrix, Risk register and Action list.

5.1. Hazards

Submarine pipelines are subject to various hazards, and are generally divided in the following categories:

- Design, Fabrication and Installation hazards;
- Natural hazards (slope instability, seismic activity, severe storm, erosion);
- Third Party damage (navigation, fishing);
- Corrosion threats;
- Structural threats;
- Operational and Process hazards;

During the workshop, all the threats were considered and assessed whether these are plausible, what potentially causes them and with what potential effects, which initial barriers are regarded in the design, assessing the risk being the combination of likelihood and severity and which controls and safeguards measures will be taken to mitigate the risk to an acceptable level or if an ALARP analysis is required.

It should be noted that this risk assessing is a “dynamic” process that requires updating, when the project is progressing into the following phases.

5.2. Classification of damage

The potential effect of hazards will be pipeline damage and ultimately loss of containment. The main topic of this report is Third Party damage and in order to perform analyses, damages are divided in four classes varying in severity according [11], see Figure 4.

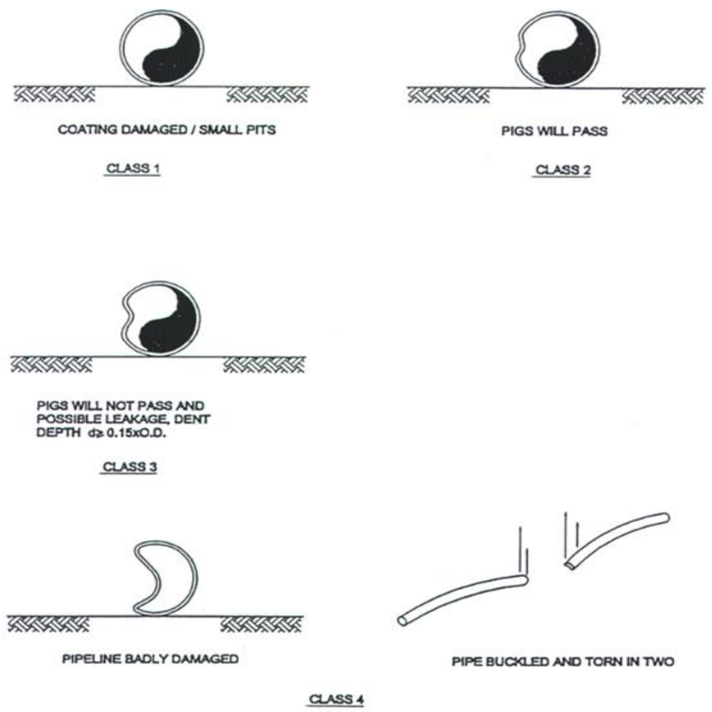


Figure 4, Damage classification

All consequences of third party threats like dropped objects and dropped and dragging anchors are modelled such that they will result in one of the damage classes.

CLASS 1:

Damage to the coating system is denoted as class 1 damage. This type of damage is not serious on the short term, basically limited to damage to the pipeline coating. On the long term, it may have serious consequences such as over-stressing or fatigue due to spanning, forced corrosion due to simultaneous damage of the corrosion coating or loss of anodes and pits in the steel. Such deficiencies, however, will be discovered in time during routine inspections of the pipeline.

CLASS 2:

Small plastic deformations with dents up to 15% of the pipe diameter, 76 mm for the 20-inch pipeline under consideration for this project is denoted as class 2 damage.

Dents up to 10% of the pipe diameter (50.8 mm) are hard to detect and require a caliper pig for detecting. Gauging pigs will pass such dents without being deformed.

Dents up to 15% of the pipe diameter can be nominated as small plastic deformations but are certainly not an immediate jeopardy for the pipeline operation and will not lead to pipeline damage resulting in a leak.

CLASS 3:

Plastic deformations with dents more than 76 mm (15 percent of the pipe diameter for the 20-inch pipeline) is denoted as class 3 damage.

This type of damage becomes serious for the operator, as pigs may not any longer pass the damaged section. Moreover, the possibility of a leak in the pipeline due to damage cannot be excluded. A study from Rijkswaterstaat, Directie Noordzee specifies that for deformations more than 15% of the outside diameter the probability of damage resulting in a leak by dropping anchors is 1.0.[1]

CLASS 4:

Class 4 damage refers to large pipeline deformations and total rupture of the pipeline.

Obviously, Class 4 damage is more serious than Class 3 damage for both operator and controlling agency. The occurrence of a leak in the pipeline is very likely.

Objective of the risk assessment is to determine likelihood of occurrence of Class 3 damage due to third parties and the probability of pipeline damage resulting in a leak.

The safety of the pipeline shall be in accordance with the rules stipulated by the Dutch Authorities as discussed in section 3.

5.3. Dropped object classification Methodology

Methodology and object classification of dropped objects is taken from Table 7, DNV RP-F107 [11]:

Table 7 Overview object classification

No	Description	Weight in air (mT)	Typical objects
1	Flat/Long shaped	< 2	Drill collar/casing/scaffolding
2		2 – 8	Drill collar/casing
3		> 8	Drill riser, crane boom
4	Box/Round shaped	< 2	Container (food, spare parts), basket, crane block
5		2 – 8	Container (spare parts), basket, crane block
6		> 8	Container (equipment), basket
7	Box/round shaped	>> 8	Massive objects, e.g. BOP, pipe reel etc.

With the hydrodynamic properties as specified in Table 8..

Table 8, Overview hydrodynamic coefficients

No	Description	Drag (Cd)	Inertia (Ci)	Added Mass (Ca)
1,2,3	Slender shape	0.7 – 1.5	1.0	0.1 – 1.0
4,5,6,7	Box shaped	1.2 – 1.3	1.0	0.6 – 1.5
All	Misc. shapes	0.6 – 2.0	1.0	1.0 – 2.0

The crane on the N05A platform is located on the North side of the platform, ref Appendix G. All load handling will take place at that side. However the crane can reach the other side, but with reduced lifting capacities of 5 mT. A low probability for dropped objects will remain.

Box shaped objects such as containers typically have a relatively large frontal area for its mass, resulting in a low impact velocity. The most probable objects to damage the spool are therefore pipe-shaped objects. A range of typical tubular and non tubular objects and the relevant properties are listed in Table 9.

Table 9, Dropped object properties

Object	Unit	1	2	3	4	5
Outside diameter, OD	[m]	0.47	0.54	0.6	0.64	2
Mass object in air, M	[kg]	650	1038	1495	5000	12000
Length	[m]	0.74	0.85	0.95	1	1.2
Volume steel, V_{steel}	[m^3]	0.083	0.132	0.190	0.637	1.6
Steel cross area, Ac	[m^2]	0.112	0.156	0.200	0.637	1.274
Wall thickness, WT	[m]	0.076	0.092	0.106	0.317	0.203
Internal diameter, ID	[m]	0.318	0.357	0.387	0.416	1.6
Added mass, M_a	[kg]	84.9	135.5	195.2	783.4	1880

5.4. Dropped and Dragging anchor methodology

All ships crossing the pipeline pose a threat that its anchor will be applied for emergency or for regular anchoring. The weight of the anchors has a more or less defined relation with ships DWT's. The damage is caused by dropping directly on the pipeline, similar to dropped objects. The damage is caused by dragging whereby the anchor is penetrating in the seabed and moved forward by ships kinetic energy and/or its propulsion.

Both damages may result in dents and follow the presented damage classes. Hooking anchors especially for exposed or shallow buried pipelines may get damaged by overstress, buckle and large displacements. The damage criteria is a maximum allowable strain of 5%. A hooked pipeline will display multiple damage features, e.g. dents and strain.

6. Risks analysis of other hazards

In this section the other than third Party interference hazards are briefly discussed.

For the detailed risk assessment reference is made to Appendix B.

During all pipeline phases, a pipeline integrity management system (PIMS) should be in-place. In general this is a risk-based system of inspecting and monitoring, whereby continuous enhancement keep the risk levels within the acceptance levels.

6.1. Design, Fabrication & Installation (DFI)

The pipeline design is based on the pipeline code, NEN 3656. By complying to a code all design aspects will be addressed and guidance is provided how the design analyses shall be made. The final design will result in a reliable pipeline, meeting its intended service life.

DFI threats should not result in pipeline damages if addressed in early stages. Main threats are related to project risks as schedule delay and increased costs.

6.2. Natural hazards

Natural hazards like liquefaction and scour require attention. Natural hazards to a pipeline are slope instability, seismic activity, severe storms, and erosion.

Main natural threats considered in this project are related to the wave-induced impact of the shallow water parts and the sand mobility of the Eems-Dollard Estuary. Impact of these dynamics need to be analyzed.

Typical natural hazard pipeline damages are buckling and ruptures as a result of large displacements. Fatigue can be an issue when pipeline get exposed due to scour.

6.3. Corrosion

The fluid in the pipeline is water dew-pointed wet gas, where liquids were separated, with only condensate added to the gas for export to shore. Corrosion inhibition is considered.

Pipeline corrosion in general comes with different corrosion morphologies and failure modes, from local and general metal loss to cracking.

External corrosion is mainly the exposure when third party damages occur that effects the pipeline coating and potentially lead to external corrosion threats.

6.4. Structural

Riser clamping is a common point of interest. Too much rock berm loads may lead to structural threats. Often structural threats originated from other root causes.

6.5. Operational/process error

Operational hazards will be managed by general company procedures, captured in PIMS.

Hydrate blockage might be a threat to consider.

7. Risk analysis of third party hazards

7.1. General

Potential damage to the pipeline by marine traffic can be caused by the following hazards:

- Riser damage caused by platform collision;
- Damage due to the fishing gear;
- Dropped and dragging anchors;
- Sinking of vessels;
- Damage of dropped objects near a platform;

The probability of these threats are related to the ship traffic density ate the location. The consequence of all of these impacts result in pipeline dents. Whereby a dent of ≥ 15% of the pipeline diameter has a consequence damage of class 3 and will lead to loss of containment.

The analyses are performed in this section. The analyses consider the pipeline protection by examining the resistance of a single barrier or combinations of bare steel of the pipe wall, CWC, sand cover and/or rock berm as protection measure.

7.2. Shipping traffic

Figure 5 indicates the density of sea traffic. The map originates from Marin report, ref [15] used for the platform collision study. The AIS data is collected over full 2017 of all ships equipped with (active) AIS transponder. Ships above 300 DWT and fishing vessels > 15 m, have a mandatory requirement for applying the AIS transponder.

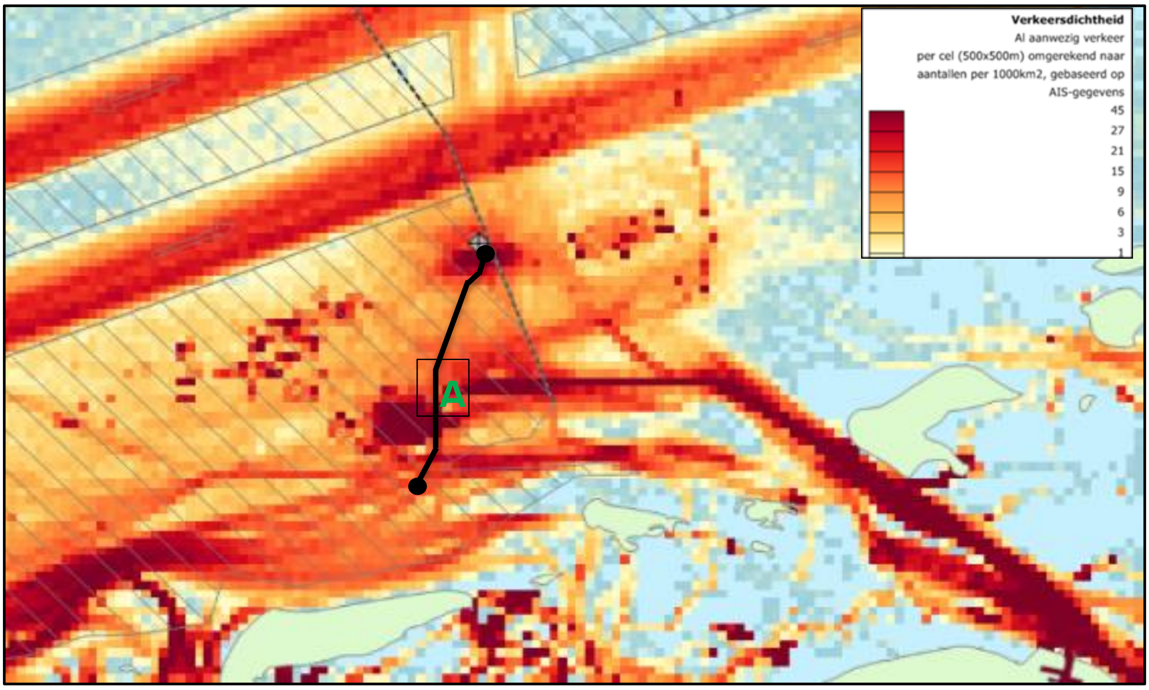


Figure 5, Vessel density maps, based on AIS over 2017 ref [15]], with platform and pipeline. All vessel sizes are shown.

For analyses performed in this report the density map of Figure 5 is applied, as the methodology is based on ships density and on a ship DWT composition typical for the Dutch sector of the North Sea. It should be noted that many of the smaller vessels do not pass this area. They will remain near shore or take the routes South of the Wadden islands.

The maximum ship density applied in this study is 45 per 1000 km^2. It is assumed that the average ship speed is 4.5 knots. Ships entering the anchor or fairway will have a reduced speed. Leaving vessels will be faster.

The N05A pipeline, from the platform in the North to the NGT hot tap in the South, is situated in the Eems-Dollard estuary, which has a fairway to Dutch and German ports. The fairway is a 200 m wide, dredged and maintained at approx. 14.5 m below LAT, channel. The fairway is a highly regulated corridor, where entering or leaving vessels are regulated by a traffic control centre. There is a requirement for pilotage and tug boat assistance from DWT ≥ 10.000. Whereby the rendez-vous point is at the point A (Figure 5) at the North Sea side of the fairway. This regulation results in ships waiting in the pilot waiting zone to get permission to enter the fairway.

The current projected pipeline route is outside the fairway, but it can be seen from the Figure 5 that ships wait at the entrance of the fairway.

7.3. Ships classification data

Ships are divided by ship classification systems.

Table 10, ship composition

Vessel size	Anchor weight	Percentage
DWT ≤ 3.000	625 kg	74.0
3.000 < DWT ≤ 10.000	2000 kg	6.3
10.000 < DWT ≤ 100.000	13500 kg	18.2
DWT > 100.000	17000 kg	1.5
Total		100.0

In Table 10 the classes of ships and ship composition, considered to be representative for the North Sea and for this area, are given.

7.4. Ship accidents

Table 11 presents the numbers of incidents , relevant for the Dutch sector North Sea , Ref[6].

Table 11, incidents and emergency numbers

Incident	Number of incidents	
	2004-2012	per year
Total 2004 – 2012: Sea and delta	346	38,4
Number fishing + shipping + Ferries total Netherlands	534	59,3
Total number of shipping incidents	834	93
Number fishing + shipping + Ferries total sea and Delta	221,5	24,6
Sinking	1,0	0,1

7.5. Riser damage caused by platform collision

A platform collision study has been performed, by Marin [15]. This collision report has determined the collision frequency caused by passing ships. The high risk of collision is dominated by the large vessels passing at high speeds in the Southern main shipping lanes, North of the platform. The collision is determined on drifting and ramming ships hitting the platform, resulting in a total risk of 3.66 10^{-3}/year or once every 273 years.

The study has excluded the consequence of a collision, however stated that an energy impact of ≥200 MJ has a catastrophic impact on the platform. This occurs 1.04 10^{-3} or once every 961 years.

Risers follow the pipeline code, NEN 3656 and shall comply with the failure frequency of 10^{-6}/year.

Even if the risers are located inside the jacket and shielded from direct collision impact, it is likely that Class 3 damage will occur when 200 MJ energy impacts the platform.

The platform is subject to risk mitigation or ALARP assessments where the outcome is not yet available to implement in this report. It is assumed that the riser along with other pressure contained equipment is captured in these assessments.

7.6. Risk analysis fishing gear impact

Fishing gear impact is considered a third party threat to the un-buried pipeline and to the pipeline coating. It also presents a threat to the fishing gear, the vessel and its crew.

According to NEN3656 Section 9.4.2.6, pipelines larger than 400 mm in diameter are in practice not affected by fishing gear, which is applicable to the current pipeline with an outer diameter of the steel pipe of 508 mm plus possible additional CWC.

A further mitigating measure is that the pipeline will be unburied for a short period of time during installation and during this time the position will be clearly identified to marine traffic, including fishing boats. Guard vessel(s) will also be used to safeguard the pipeline from external impacts.

7.7. Sinking ships

The average number of sinking ships is 1 per 9 years according [6] and the total distance sailed by ships is 21.6 x 10^6 nautical miles, the frequency of ships sinking is 24.6/year. Consequently, the probability that a ship will sink is equal to $P_{accidental}$ = 5.14 x 10^{-9} per sailed nautical mile per year.

Approximately 85% of all sunken ships had a DWT of less than 500. Taking 500 DWT as an average, the characteristic length of the ships is 50m. The critical corridor in which a vessel can sink and hit the pipeline is 100m wide, with the pipeline in the center.

The course of a ship in an emergency has a random orientation, not all the ships which sink in the critical corridor, will hit the pipeline. Only a fraction of $1/\pi$ of the ships sinking in the critical area will hit the pipeline.

As stated section 7.2, a shipping density of 45 ships per 1000 km² is assumed within the area of the North Sea where the pipeline will be placed.

The average sailing speed is 4.5 nautical miles per hour, this means that an average vessel will sail 24 x 365 x 4.5 = 39420 nautical miles per year. The sailed distance (L_s) within the area of 1000 km² is therefore equal to the number of nautical miles per year multiplied by the shipping density:

$$L_s = 39420 \cdot 45 = 1.77 \cdot 10^6 \; nm$$

The distance sailed in the critical pipeline corridor of 100m per km pipeline length equals to

$$L_c = L_s \frac{0.1}{1000} = 177.4 \; nm$$

The probability of sinking ships on the pipeline (P_s) is equal to the frequency of sinking ships, $P_{accidental}$, multiplied by the sailed nautical miles in the critical pipeline corridor L_c.

Consequently, $P_s = P_{accidental} \cdot L_c = 5.14 \cdot 10^{-9} \cdot 177.4 = 9.13 \cdot 10^{-7}$ accidents per km per year in the critical pipeline corridor due to sinking ships. Taking the random directionality into account, the probability of a sinking ship on top of the pipeline is $\frac{P_s}{\pi} = 2.90 \cdot 10^{-7}$ per km per year and well below the NEN 3656 acceptance criterium of 1.0 x 10^{-6} /year.

When a ship sinks, it will eventually come to rest on the seabed. If this occurs just above the pipeline, it would depend on the local strength of the shell of the ship whether the pipeline would be dented or damaged with leakage.

Due to the relatively low vertical velocity of the sinking ship when hitting the pipeline, one can consider the loading on the pipeline as quasi static. The kinetic energy carried by a sinking ship of 3000 DWT (74% of the vessels) is in the order of 6kJ per m^2. The energy resistance capacity of the un-buried pipeline with CWC is indicative 120kJ, refer to section 7.10. A sunken ship will likely provide a more even load distribution.

To penetrate 0.2m cover approximately 30kJ of kinetic energy per m^2 contact area is required. It is unlikely that the buried pipeline with a depth of cover of 0.6 m will be affected by a sinking ship.

The un-buried pipeline with 140 mm CWC has a significant impact resistance. However impact cannot be excluded.

7.8. Frequency of dropped and dragging anchors

Dropping anchors near the pipeline pose a risk, as it can potentially hit and damage the pipeline.

Anchoring of work boats outside platform areas is not expected to be hazardous to the pipeline as the crews of such vessels are always fully aware of obstacles in their work sector and anchoring is consequently carefully planned. Furthermore, anchoring of a workboat is often done with assistance of a special anchor vessel.

Reasons for anchoring can be divided in two groups, including:

- Regular anchoring, to await the boarding of a pilot or permission for entering the harbor, waiting for further sailing orders of the owner or for cleaning and maintenance.
- Emergency anchoring, following an accident such as fire, engine failure or collision.

In case of regular anchoring, a ship's captain will inspect his sea charts, avoid obstacles and preferably choose an area assigned for anchoring. For that reason, regular anchoring is not considered to be a risk factor for the safe operation of a pipeline.

In the event of an emergency, it may be expected that most of the ship's captains will inspect their sea charts before dropping an anchor. In addition, many captains prefer not to anchor at all in emergency situations. However, it cannot entirely be ruled out that some of them decide to drop an anchor impulsively. Following this reasoning, it is assumed in this study that in 25 percent of emergency situations, anchors are dropped without prior inspection of the sea charts. In such case, the anchors are considered to be dropped at random; some of them will land in the vicinity of the pipeline and may create a critical situation for the pipeline.

The probability of anchor drops or dragging of the anchor near the pipeline is a function of the following factors:

- The chance that a ship faces an emergency.
- The width of the corridor, wherein anchor drop or drag becomes a risk factor for the pipeline.
- The length of the hazardous zone, this being a function of the angle between the vessels' course and pipeline.
- Traffic density and composition in the identified region.
- Critical ship DWT causing Class 3 damage in the case of drop/drag.
- Type and mass of anchor used

The traffic density/composition and the chance that a ship faces an emergency is a function of the registered accidents and emergency situations ref.[6] and listed in in section7.3 and 7.4.

The probability that a vessel will be involved in an accident or will face an emergency depends on the distance sailed by a vessel. Using the data presented in ref. [6], the cumulative distance sailed per day by all vessels is determined being 21.6 million nautical miles.

Considering the total number of ships involved minus the ships running aground 24.5/year (24.6/year–sinking 0.1 /year). The frequency of an accident or emergency is:

$P_{accidental} = \frac{24.6-0.1}{21.6 \cdot 10^6} = 1.13 \cdot 10^{-6}$ accidents per sailed nautical mile per year.

The maximum dragging distance of an anchor depends on the type, mass, and the soil conditions. For smaller anchors in sand the dragging distance is less than 10m, for heavier anchors it is 10–15m. In this study, the critical corridor is taken as 30m (15m each side of the pipeline) for all anchors.

When the anchor is dropped in the inner part of the critical zone it will hit the pipeline directly. The width of this anchor drop sector is a function of the anchor width. The width of a large anchor is taken as 2.5m (see also Appendix C for anchor sizes) resulting in a sector width for anchor drop of 5.0m.

The probability that an anchor, when dropped in the critical zone, will directly fall on top of the pipe is therefore 5/30. Consequently, the probability that dropping an anchor in the critical zone will result in anchor drag towards the pipeline is 25/30.

The frequency of accidents per year occurring in the critical zone is calculated as follows:

It is assumed that in 25 percent of the events that an accident occurs, an anchor will be dropped without first consulting any charts, as discussed above. Furthermore, it was shown that the probability that a dropped anchor within in the critical zone directly hits the pipeline is 5/30. The frequency directly hitting the pipeline per km per year can thus be calculated.

The direction of the dragging anchor is variable and the portion of dropped anchors that are dragged towards the pipeline is accounted by multiplying the total number by a factor 1/π.

The distance sailed per year in the critical pipeline corridor of 30m per km pipeline length is equal to:

$L_c = L_s \frac{0.03}{1000} = 53.2\, nm$

The probability of an accident due to emergency anchoring P_{anchor} per km per year in the corridor is equal to the probability of accidents per sailed nautical mile P_{acc} multiplied by the sailed nautical miles per year in the corridor L_c and apply the factors 0.25 and 5/30 to account for the probability of anchor drop and anchors directly falling on the pipe P_{drop}:

$P_{anchor} = P_{accidental} \cdot L_c = 6.04 \cdot 10^{-5}$ emergency anchoring per kilometer per year

$P_{drop} = P_{anchor} \cdot \frac{5}{30} \cdot 0.25 = 2.52 \cdot 10^{-6}$ anchors falling on the pipeline per kilometer per year.

The probability of an accident due to dragging anchors P_{drag} outside the shipping lane is equal to the probability of emergency anchoring multiplied by 25/30 accounting for the anchor drag length of 25m relative to the length of the critical area 30m. Further factors of $1/\pi$ and 0.25 are applied to account for the directionality and the probability of anchoring.

$P_{drag} = P_{anchor} \cdot \frac{25}{30} \cdot \frac{1}{\pi} \cdot 0.25 = 4.00 \cdot 10^{-6}$ accidents per km of pipe per year due to dragging anchors

7.9. Damage due to dropping and dragging anchors

Not all anchors dropped or dragged in the critical zone will result in leakage. There are two major factors contributing to this. First is the absorption of energy by the soil covering the pipeline, second is the allowable deformation of the pipeline before leakage occurs.

An anchor dropped from a ship first penetrates vertically into the seabed. The depth of penetration depends on the weight and shape of the anchor and characteristics of the seabed soils.

As the ship continues to move after the anchor has reached the seabed, the anchor chain tightens and pulls the anchor over until it reaches a horizontal position on the seabed. From this position the flukes gradually work down into the soil until the body of the anchor is either partly or wholly embedded in the seabed and the anchor attains its maximum holding power.

To represent the entire range of anchors, anchors with masses of respectively 1000kg, 5000kg, 10000kg, and 15000kg have been considered in this study. Typical anchor parameters are given in Appendices C. Based on published test results an average drag distance of 10m has been selected as appropriate for the sizes of anchors considered. [9]

The passive soil resistance determines the maximum holding power of an anchor. When this holding power is exceeded, some anchors drag horizontally through the soil, while others rotate and will break out and dig in again. When an anchor attains its maximum holding power at the end of dragging, it also has embedded a certain depth below the sea bottom.

A pipeline, which is resting in or on the seabed, is hit by an anchor either vertically when the anchor is dropped on top of it, or horizontally when the anchor is dragged towards the side of the pipeline.

Both types of loading deform the pipeline differently and are discussed below.

7.10. Damage due to anchor drop

The kinetic energy of the falling anchor is absorbed by the soil and by deformation of the pipeline. To visualize the plastic deformation energy, the model in Appendix D is used.

The energy required for plastic deformation is a function of the pipeline characteristics and extent of deformation in accordance with equation:

$$E_p = 2\,\sigma_t\,t_{EOL}^2\,\delta\,\sqrt{2},$$

in which:

$$t_{EOL} = (1 - wtt) \cdot wt - t_{cor},$$

where

- t_{EOL} is the wall thickness of the pipeline at the end of life;
- wtt is the wall thickness tolerance, as defined in Table 2 (50% taken into account)**;**
- t_{cor} is the internal corrosion allowance, as defined in Table 2 (50% taken into account)**;**
- δ is 15% of the pipeline OD, so 41 [mm];

For the given material properties and wall thickness, provided in section 4.1. This leads to a plastic energy of 20.16 [kJ]. It should be noted that the CWC of 40 and 140 mm provides an additional energy absorption resistance of 34 and 120 [kJ], respectively (indicative). This is based on linear extrapolation of concrete coating absorption energy, as indicated in section 4.6 of ref[11].

The maximum allowable deformation (δ) is 15 % of the pipeline diameter, further deformation is associated with leakage. To establish the impact velocity of the anchor it is necessary to determine the impact velocity of the anchor when it reaches the seabed. During its descend to the sea floor, the anchor is subjected to the forces of gravity and drag. Drag can be computed from:

$$F_d = \frac{1}{2}\rho V^2 C_d A$$

If the anchor is released from sufficient height, drag and gravity will be in balance at a certain speed of descend, known as terminal velocity. Terminal velocity can be calculated from:

$$v_T = \sqrt{\frac{2 \cdot g \cdot (m - V \cdot \rho_{water})}{\rho_{water} \cdot C_d \cdot A}},$$

in which:

- m is the mass of the dropped object;
- g is the gravitational constant;
- V is the volume of the object (the volume of the displaced water);
- ρ_{water} is the sea water density, 1025 [kg/m^3];
- Cd is the drag coefficient, which is a function of the dropped object shape;
- A is the projected area of the object in the flow direction;
- v_T is the terminal velocity;

The kinetic energy of the anchor is computed from

$$E_k = 0.5(M + M_a) \cdot v_T^2$$

With the added mass given by

$$m_a = \rho_{water} \cdot V \cdot C_a,$$

in which:

- C_a is the added mass coefficient, which is a function of the object shape;

The calculation of the kinetic energy as a function of the anchor mass is provided in Appendix E.

The absorption of energy (E_{pen}) by the seabed can be derived with the Brinch-Hansen method for the soil bearing capacity

$$E_{pen} = \int_0^{d_p} F(y)dy$$

Where:

y is the penetration depth [m]

d_p is the depth of the soil cover above the top of the pipeline [m]

$F(y)$ is the soil bearing capacity at a certain depth [N], given by:

$$F(y) = A \cdot \left(c\, N_c\, S_C\, D_c + q_0\, N_q\, S_q\, D_q + 0.5\, \gamma\, B\, N_\gamma\, S_\gamma\, D_\gamma\right)$$

Where:

A is the frontal area of the anchor [m^2]

c is the cohesion of the soil [N/m^2], for the project under consideration $c = 0$ (ref. [14]);

q_0 is the overburden load at depth y [N/m^2], $q_0 = \gamma\, g\, y$

γ is the submerged density of the soil [kg/m^3], as given in Table 5;

ϕ is the angle of soil internal friction [deg], as given in Table 5;

B is the width of the anchor frontal area [m];

L is the length of the anchor frontal area [m];

N, S and D are dimensionless factors related to the soil bearing capacity, shape of the frontal area, and the depth respectively

$$N_c = \frac{N_q - 1}{\tan\phi}$$

$$S_c = 1 + 0.2\frac{B}{L}$$

$$D_c = 1 + 0.4\,\text{atan}\frac{y}{B}$$

$$N_q = e^{\pi\tan\phi}\tan^2\left(45 + \frac{\phi}{2}\right)\text{F}$$

$$S_q = 1 + \sin\phi\frac{B}{L}$$

$$D_q = 1 + 2\tan\phi\ (1 - \sin\phi)^2\,\text{atan}\frac{y}{B}$$

$$N_\gamma = 2\left(N_q - 1\right)\tan\phi$$

$$S_\gamma = 1 - 0.4\frac{B}{L}$$

$$D_\gamma = 1$$

Damage will be beyond the 15 % acceptable deformation when:

$$E_k - E_{pen} > E_p$$

Appendix C shows a relation between anchor mass and the frontal area of the anchor.

The calculated absorption energy as a function of the cover height is provided in Appendix E.

Using a representative set of anchor masses, a relation between anchor mass and the required minimum soil cover was established, as presented in Figure 6.

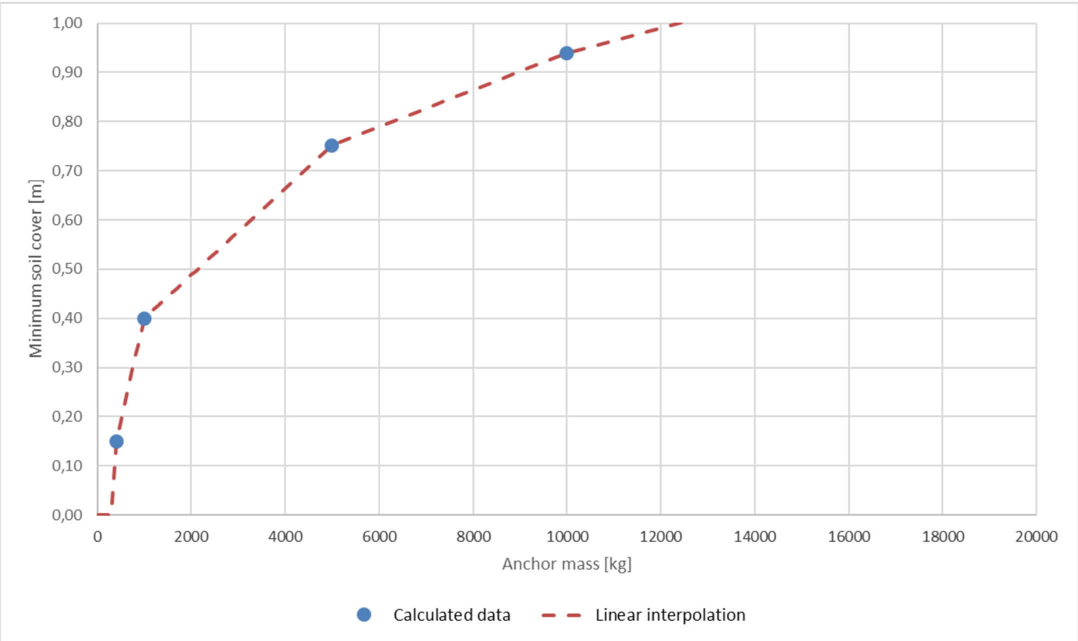


Figure 6 Required minimum soil cover as function of anchor mass (valid > 1200kg)

Impact from dropped anchors start at 1100 kg for pipeline without CWC and 4150 kg for pipelines with 140 mm CWC (this last figure is only indicative).

7.11. Damage due to anchor drag

If the pipeline is hit by a dragging anchor, it first experiences an impact load, followed by a sustained load when the anchor hooks behind the pipeline and the anchor chain/cable is straightened.

The impact loading and its consequence for the pipeline can be found from the results above. It is logical to expect that the velocity of the dragged anchor is very low and of the same order as the surface current velocity, which keeps the ship without engine power moving. With an anchor drag velocity of 1m/s the effect of the impact load is negligible due to the anchor velocity at the time of a direct drop.

For that reason, the pipeline damage assessment following an anchor drag is only done for the second phase of loading, when the anchor hooks and starts to drag the pipeline. The ultimate load to which the pipeline is exposed is assumed to be equal to the design load of the anchor chain.

If a pipeline has sufficient cover it is possible that the dragging anchor will not reach it. This cover depth is equal to the depth of anchor embedment after being dragged minus half of the pipe diameter, as an anchor which hits the pipe on its top half will be dragged over the pipeline without causing any serious damage.

The depth of penetration or embedment as a function of the anchor size is illustrated in Appendix C. This relationship is valid for sandy soils like those found along the considered pipeline route. To investigate the uniformly supported pipeline exposed to a concentrated load, a mechanical model is selected based on the following assumptions:

- The pipeline is supported by soil which will yield, and therefore, the soil resistance equals the ultimate soil resistance.
- Three plastic hinges represent the deflection pattern of the pipeline.
- The maximum load capacity of the pipeline is reached when the stress level in the fully plastic cross section reaches the breaking strength of steel.

Based on the above assumptions, the maximum load capacity can be determined by considering an energy balance.

The ultimate load bearing capacity due to energy absorbed by the plastic hinges and soil is equal to:

$$F = 4\sqrt{M_p R}$$

Where:

M_p is the plastic moment [Nm], $M_p = D^2\, t\, \sigma_t$

D is the outside pipe diameter [m]

t is the pipe wall thickness at end of life [m]

σ_t is tensile strength of steel [N/m^2]

R is the resistance of the soil behind the pipe [N/m],

$$R = \gamma\, g\, z\, N_q\, D$$

z is the depth of the centerline of the pipe

γ is the submerged density of the soil [kg/m^3], as given in Table 4

$$N_q = e^{\pi \tan\phi} \tan^2\left(45 + \frac{\phi}{2}\right)$$

The maximum anchor drag force to which the pipeline will be exposed is taken to be half of the breaking strength of the chain. According to Lloyd's register of Shipping, the mass of an anchor is related to the link breaking strength of the anchor chain. Appendix C shows a plot of this relationship.

The tension force in the chain is equal to the anchor drag force plus drag of the chain itself on the sea floor and the gravity component up to the ship anchor chain attachment point. To account for these forces the following approximate linear relation is used:

$$T = K \cdot F$$

The factor K depends on whether the pipeline is buried or not, and on the type of anchor considered. For anchors used on merchant vessels, K = 1.1 for an unburied pipeline and K = 1.3 for a buried pipeline. For this project a buried pipeline is considered.

7.12. Probability of damage due to anchor drop and drag

Accounting for the associated vessel Dead Weight Tonnage (DWT), the probability of a dropped anchor resulting in unacceptable damage has been determined. The distribution of marine traffic split into the four groups as discussed earlier in this chapter has been utilized to establish this probability (in percentage) according to:

$P(d) = 100 - \frac{DWT}{3000} P_{0,group1}$; valid for DWT<3,000 mT

$P(d) = 100 - \frac{DWT-3000}{7000} P_{0,group2} - P_{0,group1}$; valid for 3,000 mT < DWT < 10,000 mT

$P(d) = 100 - \frac{DWT-10000}{100000} P_{0,group3} - P_{0,group1} - P_{0,group2}$; valid for 10,000 mT < DWT < 100,000 mT

$P(d) = P_{0,group4}$; valid for DWT >100,000 mT

Dropped anchors

The DWT of the ships which anchors can cause Class 3 damage when directly dropped on top of the pipeline were calculated in section 7.9,. For the associated DWT ranges, the percentage of a group which causes damage by a dropped anchor can be determined, as given in Table 12 (calculation as per Appendix E)

Table 12, Probability of a leak as a function of the critical anchor mass and ToP cover

ToP cover [m]	Critical anchor mass [kg]	Critical DWT [mT]	Traffic > Crit. DWT [%]	Probability of leak $X10^{-6}$
No CWC				15/27/45 vessels /1000km^2
0.0	1000	4870	41.9	0.39 / 0.70 / 1.17
0.2	1300	6388	35.3	0.33 / 0.59 / 0.99
0.4	2000	10032	19.7	0.18 / 0.33 / 0.55
0.6	3500	18321	18.0	0.17 / 0.30 / 0.50
0.8	7500	44278	12.8	0.12 / 0.21 / 0.36
1.0	13000	95040	2.5	0.01 / 0.03 / 0.04
40 mm CWC				
0.0	2000	10032	19.7	0.18 / 0.33 / 0.55
0.2	3000	15483	18.6	0.17 / 0.31 / 0.52
0.4	4000	21237	17.4	0.16 / 0.29 / 0.49
0.6	5000	27322	16.2	0.15 / 0.27 / 0.45
0.8	8500	51920	11.2	0.10 / 0.19 / 0.31
1.0	14500	113631	1.5	0.04 / 0.04 / 0.04
140 mm CWC				
0.0	4000	21237	17.4	0.16 / 0.29 / 0.49
0.2	4500	24236	16.8	0.16 / 0.28 / 0.47
0.4	6000	33778	14.9	0.14 / 0.25 / 0.42
0.6	8000	48029	12.0	0.11 / 0.20 / 0.34
0.8	12000	83977	4.7	0.04 / 0.08 / 0.13
1.0	16500	142817	1.5	0.04 / 0.04 / 0.04

Dragging anchors

The DWT of the ships which anchors can cause Class 3 damage when directly dragged towards the pipeline were calculated in section 7.9. The relevant properties calculated for anchor drag, can be found in Appendix F. The contribution of the CWC on the resistance against anchor drag is not known, as such the calculation is conservatively performed for the steel pipeline only.

Table 13, Probability of a leak as a function of the critical anchor mass and cover depth

ToP cover [m]	Critical anchor mass [kg]	Critical DWT [mT]	Traffic > Crit. DWT [%]	Probability of leak $X10^{-6}$ 15/27/45 vessels /1000km²
0.0	1097	5358	39.8	0.35 / 0.64 / 1.06
0.2	1520	7520	30.4	0.27 / 0.49 / 0.81
0.4	1887	9435	22.1	0.20 / 0.35 / 0.59
0.6	2226	11235	19.5	0.17 / 0.31 / 0.52
0.8	2543	12955	19.1	0.17 / 0.31 / 0.51
1.0	2832	14547	18.8	0.17 / 0.30 / 0.50

7.13. Cumulated dropped and dragged anchor damage

The cumulated probability is shown in Table 14.

Table 14, Cumulative probability of anchor drop and drag for buried pipeline

ToP cover [m]	Probability of leak: anchor drop $x10^{-6}$	Probability of leak: anchor drag $x10^{-6}$	Total Probability of leak: (anchor drop + anchor drag) $x10^{-6}$
No CWC	15/27/45 vessels /1000km²	15/27/45 vessels /1000km²	15/27/45 vessels /1000km²
0.0	0.39 / 0.70 / 1.17	0.35 / 0.64 / 1.06	0.74 / 1.34 / 2.23
0.2	0.33 / 0.59 / 0.99	0.27 / 0.49 / 0.81	0.60 / 1.08 / 1.80
0.4	0.18 / 0.33 / 0.55	0.20 / 0.35 / 0.59	0.38 / 0.68 / 1.14
0.6	0.17 / 0.30 / 0.50	0.17 / 0.31 / 0.52	0.34 / 0.61 / 1.02
0.8	0.12 / 0.21 / 0.36	0.17 / 0.31 / 0.51	0.29 / 0.52 / 0.87
1.0	0.01 / 0.03 / 0.04	0.17 / 0.30 / 0.50	0.18 / 0.33 / 0.54
40 mm CWC			
0.0	0.18 / 0.33 / 0.55	0.35 / 0.64 / 1.06	0.54 / 0.97 / 1.61
0.2	0.17 / 0.31 / 0.52	0.27 / 0.49 / 0.81	0.44 / 0.80 / 1.33
0.4	0.16 / 0.29 / 0.49	0.20 / 0.35 / 0.59	0.36 / 0.65 / 1.08
0.6	0.15 / 0.27 / 0.45	0.17 / 0.31 / 0.52	0.32 / 0.58 / 0.97
0.8	0.10 / 0.19 / 0.31	0.17 / 0.31 / 0.51	0.27 / 0.49 / 0.82
1.0	0.04 / 0.04 / 0.04	0.17 / 0.30 / 0.50	0.21 / 0.34 / 0.54
140 mm CWC			
0.0	0.16 / 0.29 / 0.49	0.35 / 0.64 / 1.06	0.52 / 0.93 / 1.55
0.2	0.16 / 0.28 / 0.47	0.27 / 0.49 / 0.81	0.43 / 0.77 / 1.28
0.4	0.14 / 0.25 / 0.42	0.20 / 0.35 / 0.59	0.34 / 0.60 / 1.01
0.6	0.11 / 0.20 / 0.34	0.17 / 0.31 / 0.52	0.28 / 0.51 / 0.85
0.8	0.04 / 0.08 / 0.13	0.17 / 0.31 / 0.51	0.21 / 0.39 / 0.64
1.0	0.04 / 0.04 / 0.04	0.17 / 0.30 / 0.50	0.21 / 0.34 / 0.54

7.14. Shipping Densities

Along the selected pipeline route different shipping densities occur. The pipeline route has been divided into 4 sections for which the highest shipping density will be governing, see figure 7 below and table 15.

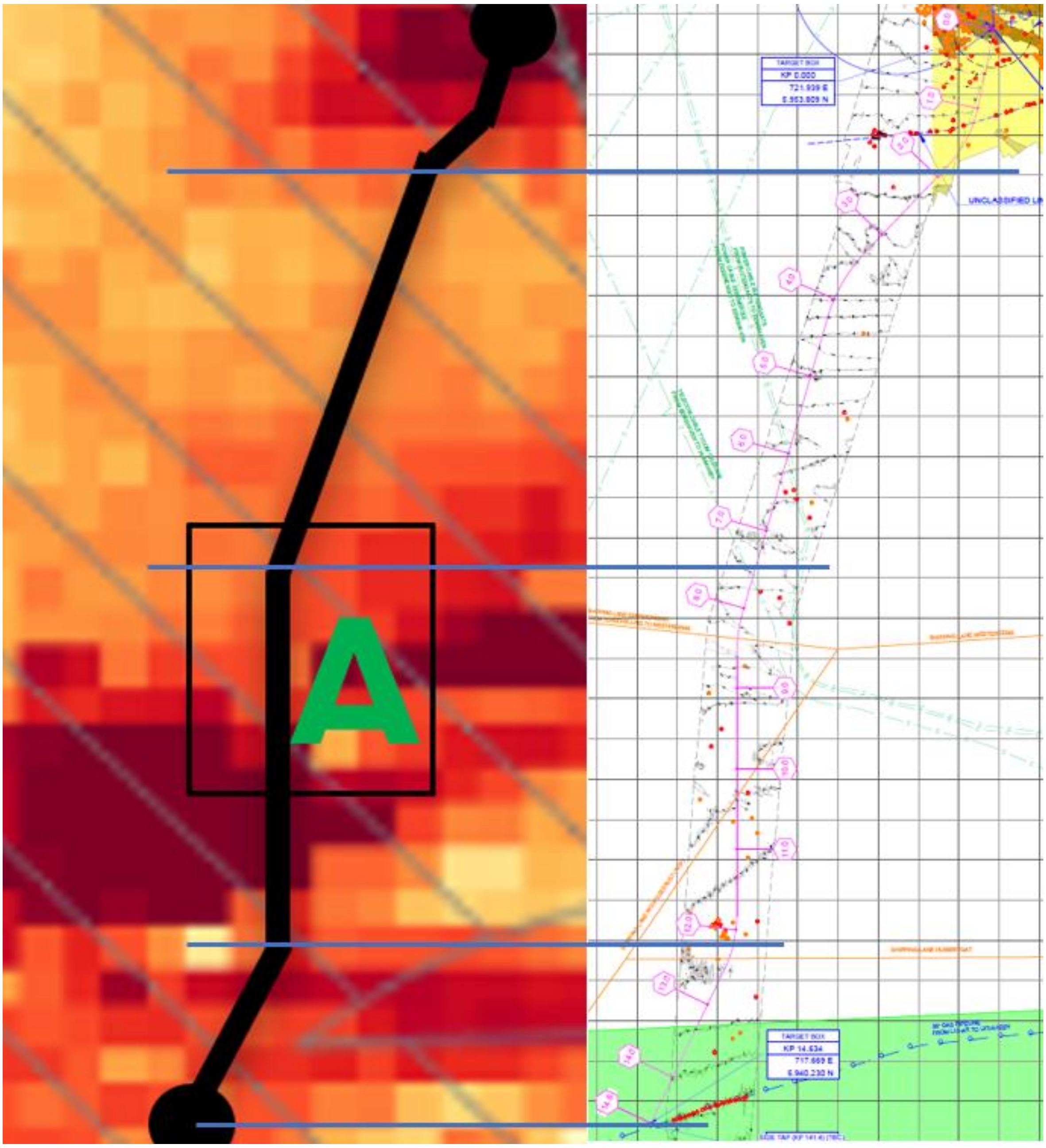


Figure 7 Shipping densities along the pipeline route

Table 15 Shipping densities along the pipeline route

From KP	To KP	Shipping density
0.0	2.0	45
2.0	7.5	15
7.5	12.2	45
12.2	14.6	27

The effect on the shipping density on the minimum burial depth is summarized in table 16.

It should be noted that the CWC thickness of 140 mm has already reached its maximum thickness from manufacturing, handling and installation perspective.

Table 16 Minimum required cover depth

Ship density /1000 km²	No CWC		40 mm CWC		140 mm CWC	
	Depth ToP [m]	Probability 10^{-6}	Depth ToP [m]	Probability 10^{-6}	Depth ToP [m]	Probability 10^{-6}
45	0.7	0.97	0.6	0.97	0.5**	0.90
27	0.3	0.89	0.0	0.97	0.0	0.93
15	0.0	0.74	0.0	0.54	0.0	0.52

Note **: The determined cover depth for 140 mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

8. Dropped object analysis

This section describes the used methodology for determining the impact energy due to the dropped objects and the amount of energy absorbed by the rock dump as a function of its height. This approach excludes probabilistic data and is merely a comparison between impact energy of the dropped object and absorbed energy by the cover layer. It is assumed that the spool has the same properties as the pipeline, as a result the same acceptable amount of plastic deformation energy has been used.

The required height of the rock dump near the platforms and tie-in, to withstand the impact energy generated by dropped objects because of crane handling from and on(to) the platform/supply vessel (containers, equipment, pipes etc.), is determined following DNV-RP-F107 [11].

8.1. Dropped object impact energy

Calculation of the kinetic energy (E_k) of a dropped object is performed using the same method as described in section 7.8. As discussed in chapter 5.3, the most likely objects to damage the pipeline are tubular objects such as pipe elements.

Using the data on typical dropped objects as presented in Table 9, the terminal velocity and kinetic energy upon impact are calculated and the results are presented in Table 17. The maximum drop height (Hd) in air is estimated not to exceed 50 [m].

The impact velocity at sea level can be determined using section 4 of ref. [12]:

$$v_{i,a} = \sqrt{2 \times g \times Hd}$$

The characteristic water depth is determine using 4 of ref. [12]:

$$sc = \frac{M + Ma}{\rho_w * C_d * A_p}$$

Knowing the minimum water depth of 28 [m], (s) and having determined the characteristic distance (s_c) and terminal velocity (v_t) for a specific object, the actual impact subsea velocity (v) and thus the impact energy can be calculated using above given 8.

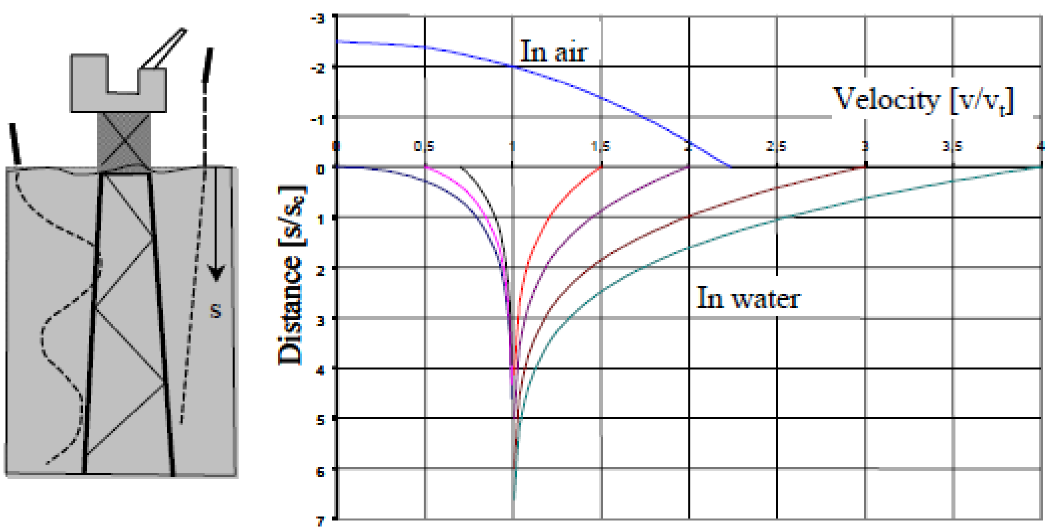


Figure 8, Velocity profile for objects falling in water [12]

Table 17 Kinetic impact energies for design dropped objects

Object	Unit	1	2	3	4	5
Impact vi,a at waterline. Sa=50 m	[m/s]	31.3	31.3	31.3	31.3	31.3
Terminal velocity in water, vt. S=26m	[m/s]	8.98	9.62	10.17	12.5	11.43
Kinetic impact energy, Ek	[kJ]	35.8	65.7	105.8	453.3	1097
Bearing capacity, p(h)	[tonnes/m^2]	41.8	65.7	58.7	108.6	108.2
Absorption energy Rock dump, (Epd)	[kJ]	36.4	65.2	105.0	443.1	1095.5
Absorption energy Rock spool, (Eps)	[kJ]	26.1	26.1	26.1	26.1	26.1
$h_{,critical}$	[m]	**0.24**	**0.28**	**0.32**	**0.65**	**0.43**

It should be noted that the absorption energy of the spool, is not contributing to the total absorption energy. The rockberm should provide all the absorption energy, such that the pipeline is fully protected and not contribution to the absorption.

8.2. Rock dump energy capacity

The properties of the rock dump as presented in Table 6, are used as input for the dropped object calculation.

The bearing force which can be taken by the rock dump is evaluated according the Brinch-Hansen method.

The energy absorption capacity of a rock dump is defined by:

$$E_p = \mathrm{p} \cdot g \cdot \left\{ \frac{1}{2} \cdot (B_r + B_o) \cdot \frac{1}{2} (L_r + L_o) \cdot h \right\}$$

Whereas, Br, Lr=breadth/length influence zone rock dump at top of pipe .

$$Br = Bo + 2 \cdot h \cdot \tan{(90 - \varphi)}$$

$$Lr = Lo + 2 \cdot h \cdot \tan{(90 - \varphi)}$$

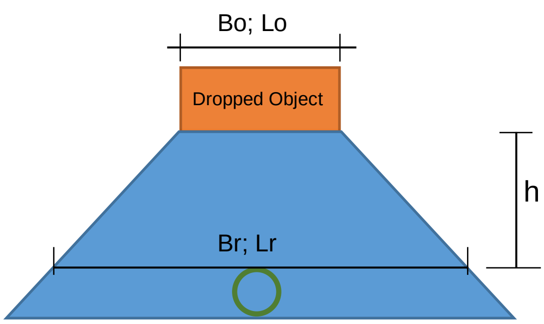


Figure 9 Rock dump geometric annotations

Where both Br and Lr are calculated per object, based on the rock dump properties as provided in Table 6 and the pipe diameter, which is equal to Bo and Lo.

Cylindrical objects will find a stable falling orientation in a horizontal position. As the longest object considered is 1.2 m in length and the width of the rock cover is typically 2 meters, it is assumed that the object contacts the rock cover along its full length. The contact area is then equal to the outer diameter times the length.

The absorption energy calculated for the objects dropped on the and 20" for both the rock dump and the spool is presented in Table 16, where the maximum value for the rock dump cover is highlighted. The absorption energy of the spool is identical to the absorption energy of the pipeline (Ep = 26.1 [kJ]), as calculated in section 7.10.

As can be seen, object 4 is most critical regarding the required rock dump height, above pipeline, which should be more than 0.65 m.

9. Conclusions

Conclusions.

The Eems-Dollard to North Sea area is busy ship traffic area with high ship densities. Generally high ship densities induces higher accidents rates for collision and sinking. Ship accidents result into the higher pipeline risks for dropped and dragging anchors.

The ships frequenting the Eems-Dollard ports are generally smaller ships, as the Eems-Dollard ports cannot receive the very large vessels (max draught approx. 14 m), all larger vessel arrival and departures are controlled by a traffic control centre. And will enter or leave the fairway with the mandatory pilotage and tug boat assistance.

The N05A pipeline has a relative large wall thickness and is for stability purposes provided with a combination of measures like rock berm, CWC and burying. These additional measures provide additional protection against third party interference.

Dropped and dragging anchors

Generally, dropped and dragging anchors are the dominant threat for the pipeline. Just because ships need to navigate in the narrow shipping lane, means that anchors are easily deployed in case of emergency. The minimum soil cover to achieve a failure probability of less than 10^{-6} per km per year is determined.

When no CWC is applied, a minimum burial depth of 0.7 m (ToP) is to be applied in ranges KP 0-2.0 and 7.5-12.2 with high density shipping, 0.3 m of cover is required for the section KP 12.2-14.6, in the remainder between KP2.0-7.5, no cover is required.

With 40 mm of CWC, the burial depth in the designated shipping lanes (KP 0-2.0 and 7.5-12.2) must be 0.6 m, outside the shipping lanes no cover is required in relation to protection of the pipeline against anchors.

Increasing the CWC to 140 mm requires a cover height of 0.5m in the shipping lane. The determined cover for 140 mm CWC in the shipping lane considers an update to NEN 3656, expected to be in effect by the time of pipeline installation, where the cover depth in a shipping lane is based on a risk assessment instead of the minimum requirement of 0.6m cover in the 2015 edition.

The energy absorption capabilities of the CWC referred in this document are just indicative and require confirmation.

Dropped Objects

The pipeline spools near platform N05A , require full protection against dropped objects. This is done by rock berm with a required rock berm height of 0.65 m above the spools.

Fishing gear and sinking ships

Fishing gear interference damage and sinking ships are both relative less critical pipeline risks. The un-buried pipeline case is more exposed but still the risk is below acceptance level.

Consequence of damage

The calculated probabilities are for damage 3 categories. This is a loss of containment of natural gas with a fraction condensate. With the maximum liquid hold-up of approximately 137 m^3 a part of this volume could be released.

A. Risk Investigation and Evaluation

The following attendees have participated in the pipeline RIE, held on 3 December 2019 at One-Dyas office Amsterdam

- Jan Willem in 't Anker — Engineering ManagerONEDyas
- Frits Gremmen — Pipeline EngineerONEDyas
- Michel van der Beek — HSE EngineerONEDyas
- Pascal Ferier — Project ManagerEnersea
- Jan van den Berg — Pipeline EngineerEnersea

Applied Risk Matrix

Risk assessment matrix									
Potential consequences									
Harm to People	Environmental Impact	Asset Damage	Reputation Impact		Never heard of in Industry	Heard of in Industry	Has occurred in NL or UK EP Industry	Happens several times per year in NL or UK EP Industry	Happens several times per year in own company
P	E	A	R		A	B	C	D	E
No injuries or health effect	No effect	No damage	No impact	0	Low	Low	Low	Low	Low
Slight injuries not effecting daily life	Slight impact	Slight damage <10K €	Slight impact	1	Low	Low	Low	Low	Low
Minor injuries or health effect, restriction in work or life for 5 days	Minor environmental damage, but self-reversible	Minor damage 10K-100K €	Minor impact	2	Low	Low	Low	Medium	Medium
Major injuries or health effect, lost time or effect for more than 5 days	Limited environmental damage that will persist or needs intervention	Moderate damage 100K-1000K €	Significant regional impact	3	Low	Low	Medium	Medium	High
Permanent total disability or up to 3 fatalities	Severe Environmental damage that will require extensive measures to restore	Major damage 1-10x10⁶ €	Major impact on national reputation	4	Low	Medium	Medium	High	High
More than 3 fatalities	Persistent severe Environmental damage that will lead to loss of use or natural resources over wide area	Massive damage over 10x10⁶ €	Major impact on Companywide reputation	5	Medium	Medium	High	High	High
Score P, E, A, R, on Consequences and Likelihood. The highest score is valid for the registration and investigation. Example an incident with a score for either P,E,A,R in 3E makes it a High for Registration and Investigation					An incident can score different on P,E,A,R. An incident can happen with damage several times per year (score E on Asset), but hardly ever with Environmental damage (score B on Environment)				

RIE Outcome, action list

The following actions were recorded during the workshop

	Action	response	Action holder	Date
Design based on faulty metocean and environmental data, or faulty application	Comparison with other locations		OneDyas	
Installation, tie-in NGT defect	separate evaluation of risk required		OneDyas	
Liquefaction	ALARP. Can we find similar projects	.. Email 04 dec 2019 to Frits Gremmen	Enersea	
Scour, loss of cover, exposure (freespan), buoyancy	Captured in MER		OneDyas	
Dropped and dragging anchor	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.		OneDyas	
Ship traffic	ALARP. To be performed for platform		OneDyas	
Dredging waterway	Contact RWS		OneDyas	

B. Risk Register

(3 pages)

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk S	Initial Risk L	Initial Risk RR	Control / Safeguard	Reference Document	Residual Risk S	Residual Risk L	Residual Risk RR	Action
DFI (design, fabrication and installation errors)														
	Design and material, specifying properties	**general**	Inadequate material properties to meet design requirements	Non-compliance to codes and regulations, delays, costs	Design Standards,	**2**	**C**	**L**	Design review, Verification by Certifier		**2**	**B**	**L**	
	Design and material, fracture control	**general**	Inadequate specified brittle and ductile toughness properties.	Non-compliance to codes and regulations, delays, costs	Design Standards,	**2**	**C**	**L**	Design review, Verification by Certifier		**2**	**B**	**L**	
	Design based on faulty process parameters	**general**	Process parameters and conditions are unconfirmed, not consistent	Non-compliance to codes and regulations, delays, costs	Design Standards,	**2**	**C**	**L**	Design (peer) review, Verification by Certifier		**2**	**B**	**L**	
	Design based on faulty metocean and environmental data, or faulty application	**general**	The water depth varies from 26.5 to 9.5 m with significant stability issue. Poor geotechnical interpretations	Pipeline stability at risk. Non-compliance to codes and regulations, delays, costs.	Design Standards, Design focusses specifically on stability, metocean data.	**3**	**C**	**M**	Design (peer) review, Verification by Certifier,		**3**	**B**	**L**	
	Design and material defects, design life	**general**	Fatigue, corrosion rates, material degradation.	Anticipated design life is not met. Non-compliance to codes and regulations, delays, costs.	Design Standards. Design incorporates fatigue life, corrosion rate, degradation predictions.	**2**	**C**	**L**	Design review, Verification by Certifier.		**2**	**B**	**L**	
	Fabrication material defects, wrong properties of materials	**general**	Manufacturing defects, inadequate material inspection and test procedures	Non-compliance to codes and regulations/company specs, delays, costs	Design Standards, QA/QC policy, Company Standards.	**2**	**C**	**L**	Inspection and Supervision		**2**	**B**	**L**	
	Installation, construction defects		Installation defects	Pipeline buckle, dents, any type of damage. Causing delays and costs.	Design Standards, installation design and procedures, QA/QC policy	**2**	**C**	**L**	Inspection and Supervision		**2**	**B**	**L**	
Buried	**Installation** trenching problem	**pipeline**	inadequate trench depth, boulders in trench, UHB risk, suitability of soil	Non-compliance to required burial depth, delays, costs	Design Standards, QA/QC policy, Site surveys: seabed objects, likeboulders, wrecks and magnetic objects are surveyed and incorpated in the routing design.	**3**	**C**	**M**	Perform trenching and installation feasibility determining suitable installation equipment.		**3**	**B**	**L**	
Unburied	**Installation** stability problem	**pipeline**	Insufficient submerged weight (steel wall thickness and / or CWC)	Non-compliance to stability requirements, delays, costs	Design Standards, QA/QC policy, Soil surveys and metocean data.	**3**	**B**	**L**			**3**	**B**	**L**	
	Installation (environmental restrictions)	**pipeline**	Unforeseen limitations	Delay and cost	Pipeline is part of the environmental assessment (MER)	**2**	**C**	**L**	Follow-up on MER outcome		**2**	**C**	**L**	
	Installation clash, error	**at platform**	Unforeseen SIMPOS, Loss of control, colission with platform, workover rig, Target box too close to platform. Magnetic contacts close to platform.	Delay, costs, safety	Planning, interface management. Design incorporates potential clashes or avoids obstacles.	**3**	**D**	**M**	Managing stakeholder and interfaces. Perform installation feasibility Manage contracts and installation contractor windows, to avoid clashes.		**3**	**C**	M	
	Installation, tie-in NGT defect	**at NGT Tie-in**	Not able to establish tie-in. Unforeseen issues, eg Reduced wall thickness at Hot tap location, etc.	Non-compliance to installation specs, delays, costs, loss of containment.	Planning, interface management.	**5**	**C**	**H**	Managing stakeholder and interfaces. Perform feasibility study. Will be executed by NGT. To be managed by contracting reputable contractor and will be risk assessed separately.		**5**	**B**	**M**	Separate evaluation of risk required
	Pre-commissioning error		Any failure related to pre-commission the pipeline. Inadequate cleaning and drying	Non-compliance, delays, costs.	Design Standards, QA/QC policy	**2**	**C**	**L**	Inspection and Supervision, as-laid information		**2**	**B**	**L**	
Natural Event/Hazards														
	Land slide, debris flow	**general**	Soil and slope instability. Not captured in geotech reports	pipeline rupture, pipeline large displacements, resulting in buckling and loss of containment	Geotech data interpreted and no significant exposure found	2	C	**L**	PIMS, perform event-based inspection. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		**2**	**C**	**L**	
	Seismic loading, fault lines	**general**	Seismic and fault movement	pipeline overstress, buckling resulting in loss of containment	Geotech data interpreted and no known seismic risks found	2	C	**L**	PIMS, perform event-based inspection		**2**	**C**	**L**	
	Subsidence	**platform**	Subsidence due to well drilling, historic sand extraction	unforeseen pipeline displacements, resulting in buckling and loss of containment	Geotech data interpreted and no subsidence expected	2	C	**L**	PIMS, perform event-based inspection. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		**2**	**C**	**L**	
Buried	Liquefaction	**pipeline**	Wave induced liquefaction	Floatation of pipeline, resulting in buckling. Interruption production	Trench right back-fill material. Apply high specific gravity.	3	C	**M**	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Perform trenching and backfill analyses. Remedial works (re-trenching, backfilling e.g. rock dumping)		**3**	**C**	M	ALARP

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk			Control / Safeguard	Reference Document	Residual Risk			Action
						S	L	RR			S	L	RR	
Buried	Uncontrolled Pipeline movement (vertical)	**pipeline**	Loss of cover, Loss of stability	Overstress, buckling, resulting in loss of containment	Design standards. Trenching providing controlled pipeline stability. Depth of cover.	3	C	M	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI), pipe tracking and seabed scanning (e.g. multibeam sonar). Perform trenching and backfill analyses. Remedial works (e.g. rock dumping)		3	B	L	
Un-buried	Uncontrolled Pipeline movement (vertical, lateral)	**pipeline**	Loss of stability	Excessive displacement, Overstress, buckling, resulting in loss of containment	Design standards. Concrete Weight coating =140 mm,	3	C	M	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Perform state-of-art stability analyses . Remedial works (e.g. rock dumping)		3	B	L	
Un-buried	Scour, loss of cover, exposure (free span), buoyancy	**pipeline**	Mobility of seabed	Developing free spans resulting in overstress, fatigue, hooking of fishing gear, excessive displacements	Design standards.	3	C	M	PIMS, perform inspections. Seek geotechnical/hydro-morphological advise. Remedial works (e.g. rock dumping)		3	B	L	MER states a requirement for morphological study
	Severe weather	**pipeline**	Unpredicted severe weather conditions	Any damage	Sufficient knowledge of weather and environmental data	2	C	L	PIMS, perform event-based inspection.		2	C	L	
Third party damage/interference														
	Dropped objects	**near platform**	Dropped Object from vessel/rig/platform	Damaging coating and pipeline. Dent, Loss of containment. (effect can extend to platform)	The rock berm is designed for full protection against dropped objects (and rig anchors) on spools. Lifting activities at North end of platform	**3**	**D**	M	PIMS, maintaining procedures for lifting, approaches and position of vessels and dril rig. Periodically visual inspect rock berm/protection or sidescan sonar. Remedial works (e.g. rock dumping). Procedure for platform abandonment.	Risk assessment study capturing dropped objects	3	B	L	
buried	Dropped and dragging anchor	**pipeline**	Dropped/dragging anchor Pipeline route crosses anchor zone.	Damaging coating and pipeline. Damage to pipeline, rupture. Loss of containment	Trenching and large diameter reduces risk of hooking. Depth of cover = 1m.	**4**	**D**	H	PIMS, periodic pipe tracking survey and active AIS monitoring. Regulations in fairway for marine traffic on Eems (pilotage and tug assistance). Remedial works (e.g. rock dumping). Regulatory restriction for anchoring outside designated anchor zones.	Risk assessment study capturing dropped and dragging anchors	4	C	M	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.
un-buried	Dropped and dragging anchor	**pipeline**	Dropped/dragging. Pipeline route crosses anchor zone.	Damaging coating and pipeline. Damage to pipeline, rupture. Loss of containment	Concrete weight coating (CWC=140 mm) reduces some impact of denting or hooking.	**4**	**D**	H	PIMS, periodic pipe tracking survey and active AIS monitoring. Regulations in fairway for marine traffic on Eems (pilotage and tug assistance). Remedial works (e.g. rock dumping). Regulatory restriction for anchoring outside designated anchor zones.	Risk assessment study capturing dropped and dragging anchors	4	C	M	Contact RWS to investigate legitimacy anchoring zone. ALARP. Assessing effcetiveness of measures.
buried	Foundering, ship sinking	**pipeline (shallow section)**	Sinking, stranding ship	damage to pipeline, likely only buckling	Trenching provide some minor protection	**3**	**C**	M	PIMS, and active AIS monitoring. Regulation for marine traffic on Eems (piloting and towing service (mandatory DWT >10.000)). Safeguard pipeline. Remedial works (e.g. rock dumping)	Risk assessment study capturing sinking ships	3	B	L	
unburied	Foundering, ship sinking	**pipeline (shallow section)**	Sinking, stranding ship	damage to pipeline, likely only buckling		**3**	**C**	M	PIMS, and active AIS monitoring. Regulation for marine traffic on Eems (piloting and towing service (mandatory DWT >10.000)). Safeguard pipeline. Remedial works (e.g. rock dumping)	Risk assessment study capturing sinking ships	3	B	L	
*buried /**unburied***	Dropped and dragging anchor	**riser**	Main cause are drifted ships from main shipping lane	Colission with platform, damaging riser. Damage to riser, loss of containment	Platform is projected near shipping lanes. Riser(s) situated within jacket	**5**	**C**	H	Managing exclusion zone, Navigation Aids, Active AIS monitoring with possibility to warn off ships, Subsea check valve near platform, platform abandonment procedure	32287-1-MO, Platform collision report	5	B	M	ALARP. To be performed for platform
buried	Fishing gear	**pipeline**	pulling and hooking of pipeline	Damage to pipeline, dents, displacements	Trenching provides adequate protection against fishing gear	**2**	**B**	L	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		2	B	L	
unburied	Fishing gear	**pipeline**	pulling and hooking of pipeline	Damage to pipeline, dents, displacements	Concrete weight coating = 140 mm. CWC provide protection against denting. (CWC damage)	**2**	**C**	L	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)	Risk assessment study capturing fishing interaction	2	B	L	
buried/unburied	Unexploded ordinance	**pipeline**	undetected UXO	damage to pipeline, loss of containment	Surveys contain magnetic anomalies and safety distance of 200 m is kept.	**2**	**C**	L	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)		2	B	L	
buried/unburied	Wrecks, boulders and obstructions	**pipeline**	Presence of anomalies.	Potential clash and damage to pipeline, non-compliance (ecological/archeological values)	Ship wrecks and other objects are identified and separation distances are maintained	**2**	**C**	L	PIMS. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar)	N05A-7-51-0-72510-01-01_Overall field layout drawing	2	B	L	
buried/unburied	Mining, sand extraction, dredging	**pipeline**	Mining, sand extraction or dredging activities.	Potential clash and damage to pipeline	No clashes are foreseen	**2**	**C**	L	Stakeholder and right of way management. PIMS, perform inspections		2	B	L	
buried/unburied	Dredging waterway	**pipeline vaargeul**	Future extension of port entrance, with dredging fairway	Non-compliance, loss of license to operate	Obtain and implement permit conditions for crossing fairway/shipping channel extention.	**4**	**C**	M	PIMS, Stakeholder and right of way management. Manage permits.	N05A-7-51-0-72510-01-01_Overall field layout drawing	4	B	M	Contact RWS
buried/unburied	Sabotage	**general**	Sabotage	damage to pipeline		**2**	**C**	L			2	C	L	
	Pipeline (future) crossing(s)	**pipeline**	unfavourable design	Additional/excessive loading onto pipeline system.	Design standards.	**2**	**C**	L	PIMS, Stakeholder and right of way management		2	B	L	
Corrosion														
	Internal corrosion	**general**	Changing composition of Production fluids. Water dewpoint too high	Higher corrosion rate than anticipated, not meeting service life, resulting in loss of containment	CA= 3mm, no corrosion is expected (treated and dew pointed fluids)	**2**	**C**	L	PIMS, perform inspections and monitoring. Periodic wall thickness measurements. Monitoring fluid properties , spec water content and dew point, inhibition rate.		2	B	L	

Generic Hazard	Specific Hazard	Pipeline section	Cause	Potential Effect	Initial Barriers	Initial Risk			Control / Safeguard	Reference Document	Residual Risk			Action
						S	L	RR			S	L	RR	
	Internal corrosion	general	Inadequate inhibition.	Inhibition not adequate result in higher corrosion rate than anticipated, not meeting service life	CA= 3mm	2	C	L	PIMS, perform inspections and monitoring. Monitoring fluid properties inhibition rate and periodic inhibition efficiency control.		2	B	L	
	Galvanic corrosion	general	Different materials in pipeline system.	Local corrosion near material changes, resulting in loss of containment	Transition by isolation between different metals.	2	C	L	PIMS, perform inspections and monitoring		2	B	L	
	External corrosion (coating damage)	pipeline	Coating damage (due to e.g. dropped objects, dragging anchors)	Local corrosion, resulting in loss of containment	CA= 3mm, 3LPE coating with anodes	3	C	M	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and CP stabbing.		3	B	L	
	External corrosion (coating damage)	riser	Coating damage (due to e.g. dropped objects, vessel impact)	High corrosion rate in splash zone, due to oxygen and seawater, resulting in loss of containment	CA= 3mm, neoprene (extra mechanical strength) in splash zone	2	C	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and CP stabbing.		2	B	L	
	External corrosion (CP failure)	general	Anode depletion, faulty contacts	Too low protection levels resulting in external corrosion, resulting in loss of containment	Anode design includes contingency.	2	C	L	PIMS, perform inspections and monitoring		2	B	L	
	Erosion	general	particles in production fluid	Loss of wall thickness, resulting in loss of containment	Design standards. CA= 3mm, sand particles and high fluid velocities are not foreseen. Peer review.	2	C	L	PIMS, perform inspections and monitoring . Wall thickness measurements and fluid properties (velocity and sand particles).	TR-19018-ONE002 FA Steady state analysis CRS Flow Assurance N05A Steady State PEER Review	2	B	L	
	Fatigue	pipeline	Unforeseen fatigue, free spans,	Cracking in material, resulting in loss of containment	Design standards. Fatigues analyses to be performed and acceptable span lengths determined.	2	C	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and side scan sonar		2	B	L	
	Fatigue	riser	Unforeseen fatigue, loose clamps/guides	Cracking in material, resulting in loss of containment	Design standards. Fatigues analyses to be performed.	2	C	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI).		2	B	L	
	Brittle fracture	general	During Cold-start-up or changing operation modes.	Brittle fracture results in rupture and loss of containment	Min. material design temperature set at - 20 C for Charpy value.	2	C	L	PIMS, monitoring operation modes. Procedures for changing operation modes (incl cold-starts)	TR-19018-ONE002 FA Steady state analysis CRS Flow Assurance N05A Steady State PEER Review	2	B	L	
Structural Threats														
	Uncontrolled riser movement	riser	Loss of clamp or guiding	Overloading, non-compliance to codes and regulations, loss of containment	Captured in design	3	C	M	PIMS, Procedures for monitoring and periodic inspections (specific for clamping). Visual inspections and incorporate (top rope) inspection of riser clamp tightness during platform inspection. Procedures for monitoring and periodic inspections (specific for clamping).		3	B		
	Excessive riser displacement / loads	general	Excessive temperature or pressure.	Overloading, non-compliance to operating design envelopes	Captured in design, spools take the expansion	2	B	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar). Monitor and analyse temperature and pressure excursion.		2	B	L	
	On bottom stability	general	Any cause. Malfunction of CWC	Large displacements, Overloading or buckling, non-compliant	Captured in design, pipeline is buried	2	B	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar).		2	B	L	
	Static Overload	general	Any cause. Excessive rockdump.	Overloading, non-compliance to design envelopes, loss of containment	Captured in design	2	B	L	PIMS, perform inspections. Periodic visual inspection subsea (general visual inspection (GVI) and seabed scanning (e.g. multibeam sonar).		2	B	L	
	Fatigue	general	Any cause. Excessive spans, scour.	Overloading, non-compliance to design envelopes, cracking, rupture. Loss of containment.	Captured in design	2	B	L	PIMS, perform inspections , Monitor and analyse pressure and temp cycles.		2	B	L	
Operational & Process errors														
	Export to NGT	general	Compliance or contractual issue	Non-compliance/non-conformity to agreements, problem with exporting gas	Implement contracting conditions	2	C	L	PIMS, Contract and stakeholder management. Develop procedure for periodic exchange of data.		2	B	L	
	Export to NGT	general	Off-spec gas, fluid in N05A pipeline.	Non-compliance/non-conformity to technical requirements	Defined export fluid properties	2	C	L	PIMS, Monitor fluids and develop off-spec fluid procedure. Assure that process envelopes are set in systems (DCS)		2	B	L	
	Process envelope	general	Process conditions (and operationing outside envelope)	Non-compliance/non-conformity to agreed process envelopes, higher corrosion rates than foreseen, hydrate blockage. Loss of containment	Defined process and operating conditions	3	C	M	PIMS, Monitor fluids and inhibition. Maintain operations procedures for applicable operation modes. Assure that process envelopes are set in systems (DCS)	TR-19018-ONE002 FA Steady state analysis. CRS Flow Assurance N05A Steady State PEER Review	3	B	L	
	Process parameters envelope	general	Exceeding design pressure (DP = 111 barg) and temperatures (DT = - 20 and 50 C)	non-compliance to design parameters, overstress, larger displacement than foreseen. Loss of containment	Defined process and operating conditions	2	C	L	PIMS, Monitor fluids and procedure. Maintain operations procedures. Assure that process envelopes are set in systems (DCS)		2	B	L	
	Operator errors	general	Unable to follow or inadequate procedures and systems of work	High risk, high costs and safety threat	Established operator	3	C	M	PIMS. Operational company standards & systems. Periodic check and update procedures, check lessons learned		3	B	L	
	Operator errors	pipeline	Inadequate and Incorrect IRM	High risk, high cost and safety threat	Established operator	3	C	M	PIMS. Operational company standards & systems. Periodic check and update procedures, check lessons learned		3	B	L	

C. Reference graphs for dropped and dragging anchors

Data was gathered on several types of anchor configurations (stockless and Baldt) in a mass range of 550 to 15400 kg. The length and width dimension projected to the oncoming flow during the descend to the sea floor were obtained. A polynomial curve has been fitted through the data and this was used to estimate the dimensions of an anchor for which only the mass was specified.

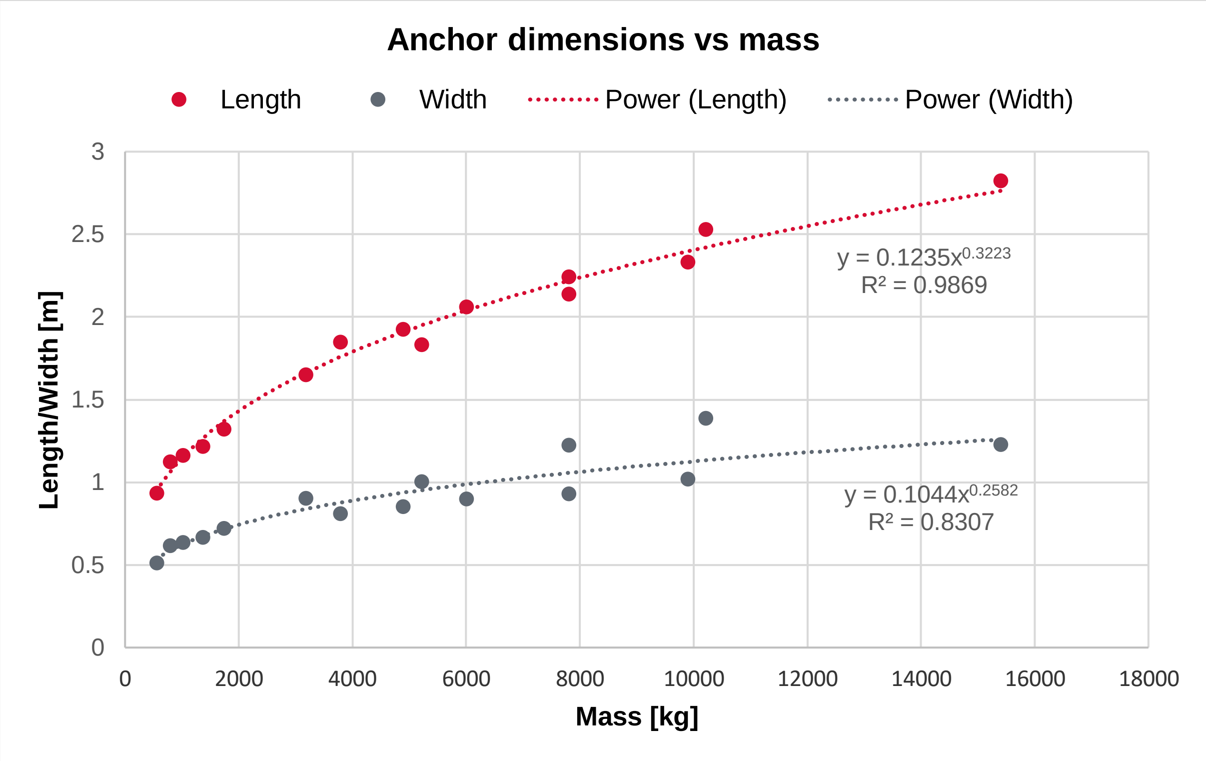


Figure 7, anchor size determination.

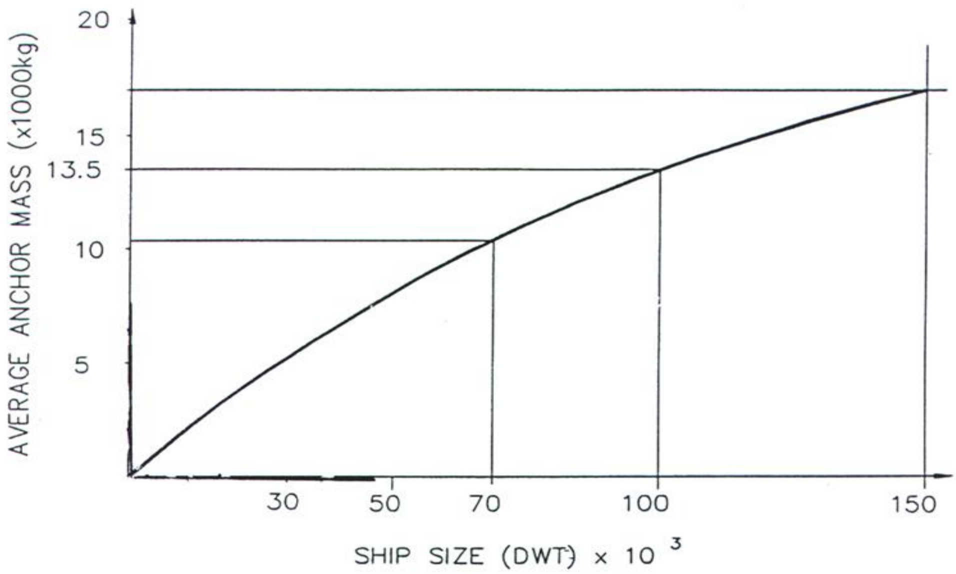


Figure 8, A.Ship size versus anchor mass

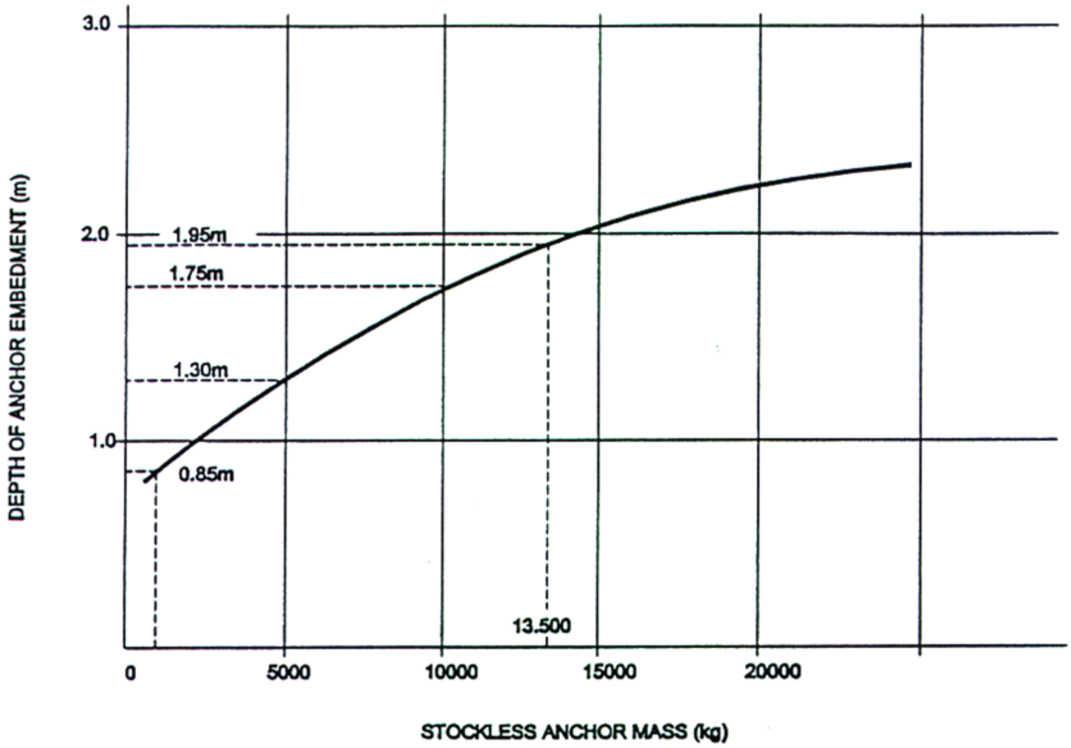


Figure 9, A.Penetration depths due to anchor drag versus anchor size

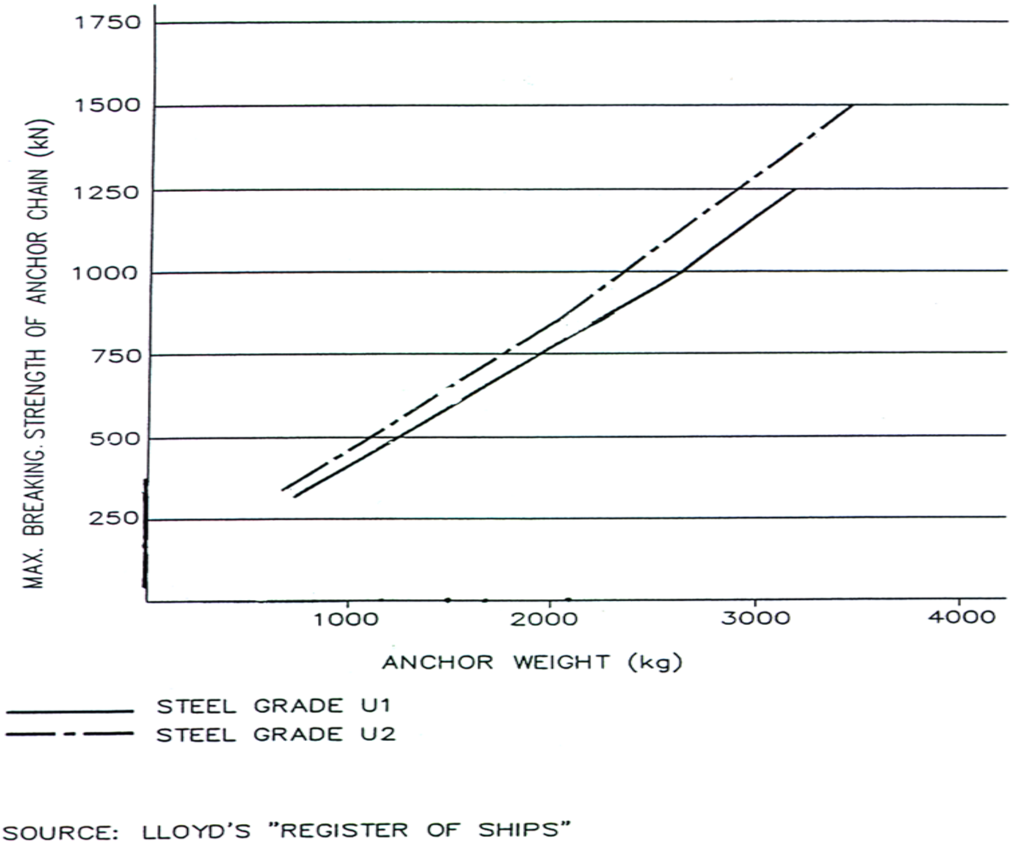
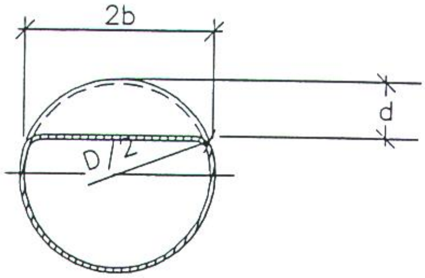
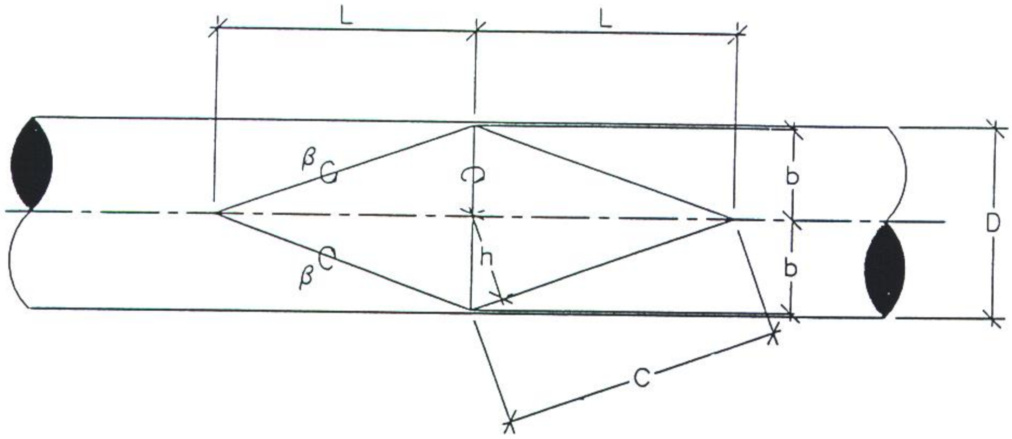


Figure 10, A.Anchor mass versus maximum breaking strength of anchor chain

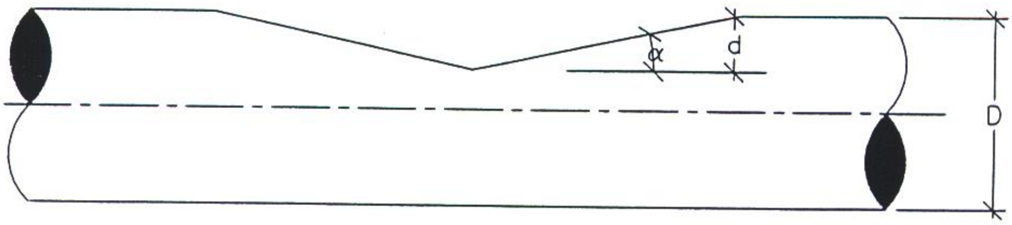
D. Plastic deformation model



A. PIPE CROSS-SECTION THROUGH DENT



B. PLAN VIEW OF SIMPLIFIED DENT SHAPE



C. SIDE VIEW OF SIMPLIFIED DENT SHAPE

$$\tan\alpha = d/L$$
$$\tan\beta = d/h$$

E. Dropped anchor calculations

The following calculations were performed for the no CWC situation

Table 18, Kinetic energy calculation per anchor mass group

Symbol	Description	unit	Anchor 1	Anchor 2	Anchor 3	Anchor 4	Anchor 5
g	grav. Acceleration	m/s^2	9,81	9,81	9,81	9,81	9,81
M	anchor mass	kg	1100	2000	4500	10000	15000
w	width frontal	m	0.64	0.74	0.92	1.13	1.25
L	length frontal	m	1.18	1.43	1.86	2.40	2.74
A	anchor frontal area	m2	0.75	1.06	1.70	2.71	3.43
V anchor	anchor volume	m3	0.14	0.25	0.57	1.27	1.91
vt	Terminal velocity	m/s	5.90	6.25	7.41	8.77	9.54
Ma	added mass	kg	143.63	261.15	587.58	1305.73	1958.60
Ek	kinetic energy total	kJ	21.6	44.2	139.8	434.3	772.3

Table 19, Calculation of the absorption energy as a function of the burial depth

Symbol	Description	unit	Anchor mass 1	Anchor mass 2	Anchor mass 3	Anchor mass 4	Anchor mass 5
Nq	Bearing capacity factor	[-]	14.72	14.72	14.72	14.72	14.72
Nc	Bearing capacity factor	[-]	25.80	25.80	25.80	25.80	25.80
Sc	Shape factor	[-]	1.27	1.37	1.46	1.57	1.63
Ng	Bearing capacity factor	[-]	10.94	10.94	10.94	10.94	10.94
Fy (z)	Force at sea bed (z=0,0m)	[N]	1.75E+04	4.13E+04	1.06E+05	2.67E+05	4.28E+05
Epen (z)	kinetic energy absorbed (z=0.0m)	[kJ]	3.49	8.25	21.15	53.46	85.61
	kinetic energy absorbed (z=0.2m)	[kJ]	12.13	24.08	54.92	128.10	198.90
	kinetic energy absorbed (z=0.4m)	[kJ]	25.91	47.49	101.31	223.90	339.89
	kinetic energy absorbed (z=0.6m)	[kJ]	44.83	78.48	160.32	340.88	508.56
	kinetic energy absorbed (z=0.8m)	[kJ]	68.90	117.05	231.94	479.03	704.92

Cover depth	Anchor mass	Critical DWT	P > Cr.DWT	Prob. Drop anchor
[m]	[kg]			x 10^{-6}
0.0	1000	4870	41.9	0.39
0.2	1300	6388	35.3	0.33
0.4	2000	10032	19.7	0.18
0.6	3500	18321	18.0	0.17
0.8	7500	44278	12.8	0.12
1.0	13000	95040	2.5	0.01

Notes:

- Z is the penetration depth and is assumed the thickness of backfill material in the trench.
- A 15% dent requires 20.16 kJ of energy
- The probability in the above table is determined for 15 ships per 1000 km2, the relationship between probability and traffic density is linear.

F. Anchor drag calculations

Table 20, Critical anchor weight as a function of the ToP cover

Cover depth [m]	z [m]	z/D [-]	Nq [-]	Qu [N/m²]	R [N/m]	Mp [N/m]	F [N]	F [kN]	T=K*F [kN]	Tbreaking (Tb=T) [kN]	Anchor weight [kg]	Crit. DWT [kg]	P>Cr.DWT [%]	Prob drag anchor x 10^{-6}
0.0	0.254	0.5	4.80	10156	5159	1.50E+06	3.52E+05	352	457	457	1097	5358	39.8%	0.64
0.2	0.454	0.9	5.15	19509	9910	1.50E+06	4.87E+05	487	633	633	1520	7520	30.4%	0.49
0.4	0.654	1.3	5.51	30056	15269	1.50E+06	6.05E+05	605	786	786	1887	9435	22.1%	0.35
0.6	0.854	1.7	5.87	41799	21234	1.50E+06	7.13E+05	713	927	927	2226	11235	19.5%	0.31
0.8	1.054	2.1	6.21	54579	27726	1.50E+06	8.15E+05	815	1060	1060	2543	12955	19.1%	0.31
1.0	1.254	2.5	6.47	67694	34389	1.50E+06	9.08E+05	908	1180	1180	2832	14547	18.8%	0.30

G. Platform approach

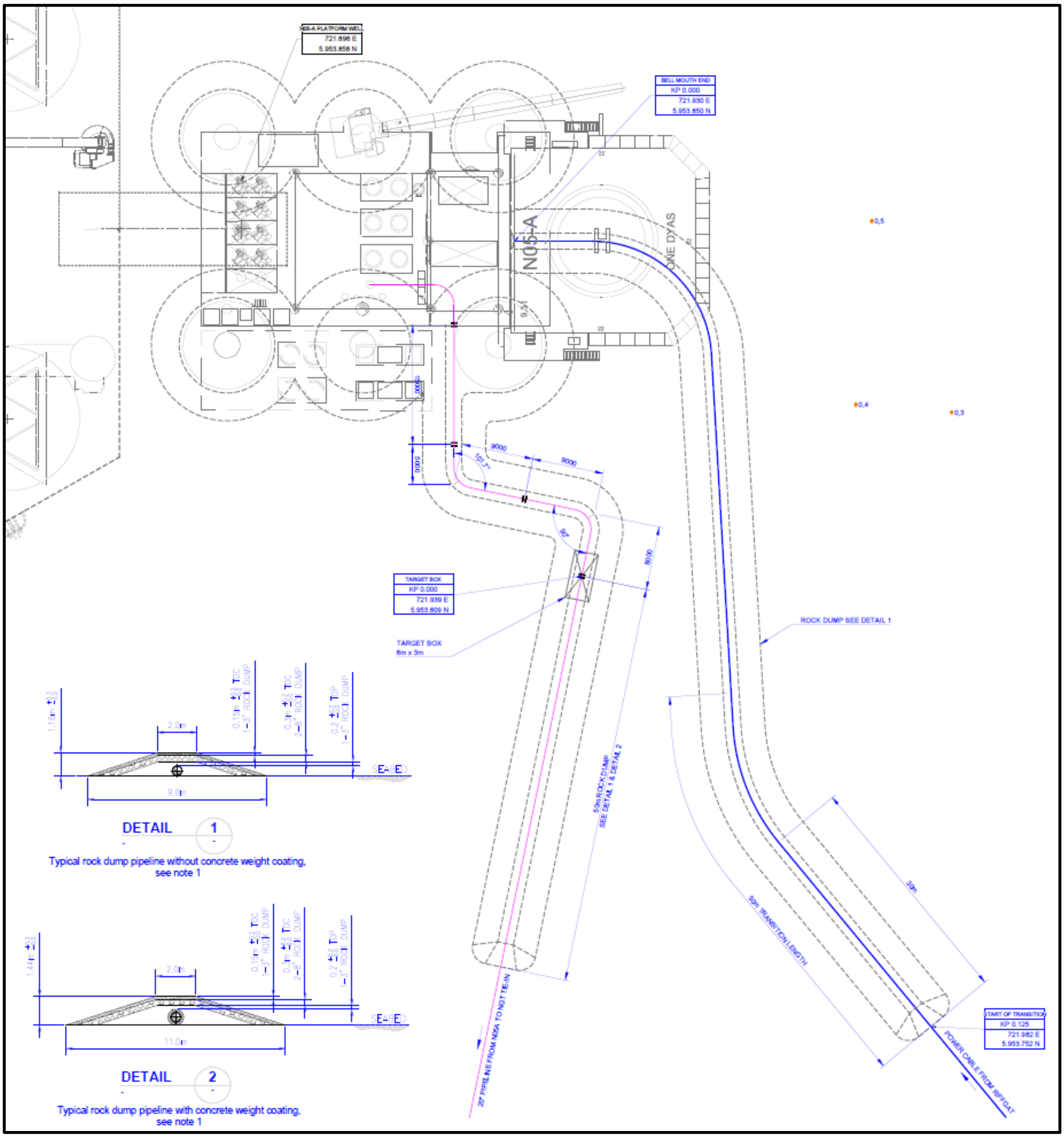


Figure 11, N05A-7-50-0-72051-01, Approach at N05A,