RAPPORT

Geluidsmodellering compressorstation Porthos

MER Aramis CO2 transportinfrastructuur

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2022

Status: Definitief/01

Datum: 9 februari 2024

ARAMIS	CCS-ARAMIS Project
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2022 Document title Noise report compressor station Revision Final 4.0

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV NEDERLAND B.V.

Laan 1914 no.35
3818 EX Amersfoort
Netherlands
Industry & Buildings
Trade register number: 56515154

+31 88 348 20 00 **T**
+31 33 463 36 52 **F**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

Titel document:	Geluidsmodellering compressorstation Porthos
Sub titel:	MER Aramis CO2 transportinfrastructuur
Referentie:	ARM-PFE-B10-ENV-EIA-2022
Status:	01/Definitief
Datum:	9 februari 2024
Projectnaam:	Aramis CCS
Projectnummer:	BH8744-106-101

Classificatie
Projectgerelateerd

Inhoud

Bijlagen

1 Inleiding

Voor u ligt het deelrapport over de geluidsuitstraling van het compressorstation, onderdeel van het MER voor het Aramis initiatief.

Dit deelrapport bevat een gedetailleerde beschrijving en beoordeling van de effecten van alle onderdelen van het Aramis initiatief, en een globale beschrijving en beoordeling van de effecten van onderdelen die niet tot het Aramis initiatief behoren, maar wel tot de CCS-keten.

1.1 Korte introductie van het Aramis initiatief

Integrale Aramis CCS-keten

Om de klimaatdoelstellingen te behalen, is er behoefte aan additionele transportinfrastructuur voor CO_2, waarmee meerdere opslaglocaties op zee worden ontsloten voor verschillende industriële emissiebronnen. Het Aramis initiatief speelt in op die behoefte door een nieuwe integrale en open CCS-keten mogelijk te maken. Het Aramis initiatief vormt een onderdeel van deze CCS-keten en bestaat uit de aanleg en exploitatie van een open CO_2-transportinfrastructuur. Het Aramis initiatief wordt in de rapportage dan ook wel aangeduid als Aramis CO_2-transportinfrastructuur. Samen met de afvanginfrastructuur en opslaginfrastructuur vormt dit de integrale CCS keten met onderstaande samenhangende onderdelen (zie figuur 1-1).

CO_2-afvanginfrastructuur

1 CO_2-afvang bij industrie, en geschikt maken voor transport;

2 CO_2-transport naar het verzamelpunt op de Maasvlakte, middels de Porthos landleiding of per schip;

CO_2-transportinfrastructuur (Aramis initiatief)

3 CO_2-verzamelpunt op de Maasvlakte met een compressorstation en een terminal.

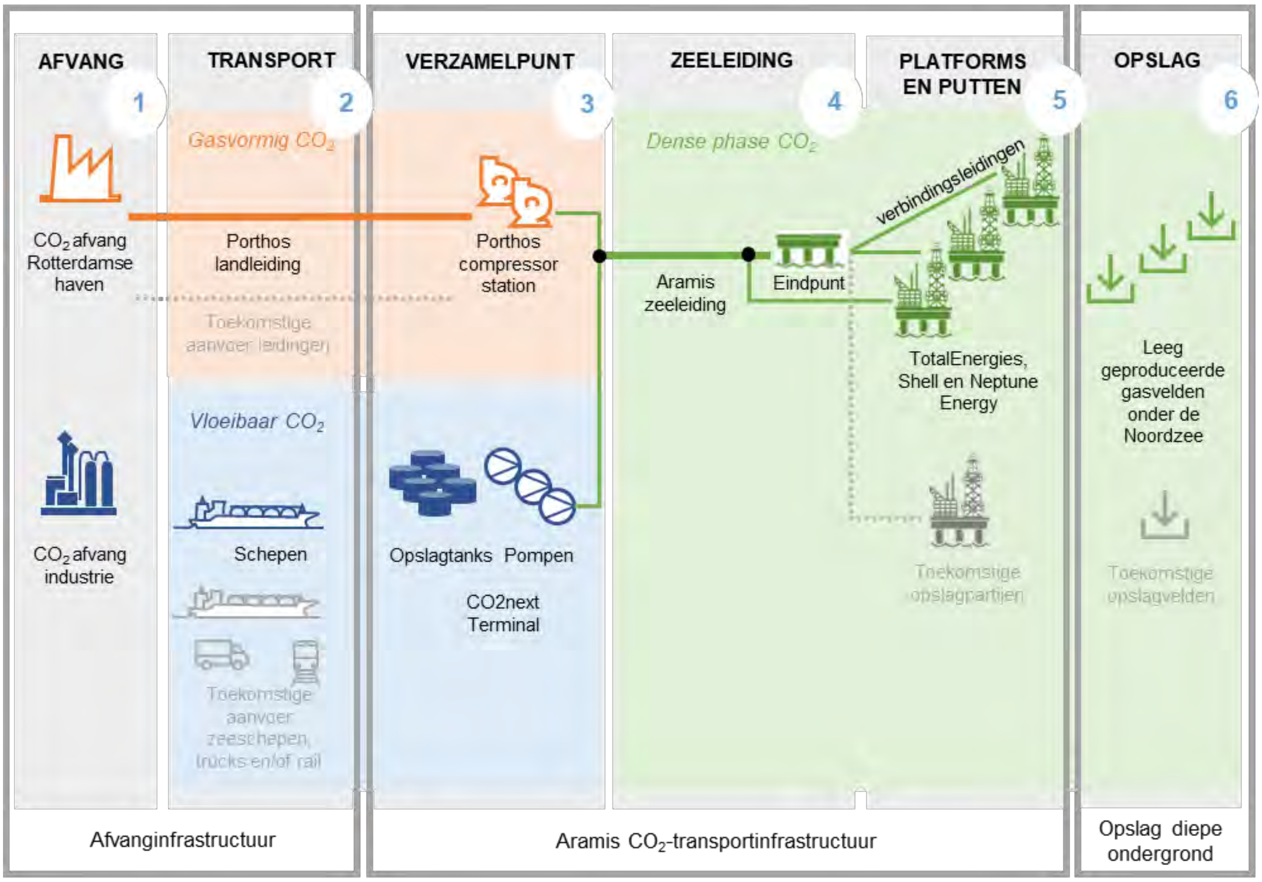
- Het compressorstation ontvangt gasvormig CO_2 dat aangevoerd wordt per landleiding (via de Porthos-landleiding) en brengt het op druk voor het transport per zeeleiding;
- De terminal ontvangt vloeibaar CO_2 aangevoerd per schip. De terminal locatie bevat steigers, opslagtanks voor tijdelijke opslag van CO_2 en hogedrukpompen voor levering aan de zeeleiding. CO_2 uit het compressorstation en vanaf de terminal komen samen in de CO_2-zeeleiding;

4 CO_2-transport door de centrale CO_2-zeeleiding naar het distributieplatform op de Noordzee. Dit platform is uitgerust met een verdeelstation voor toevoer van CO_2 naar de verschillende platforms. Er zijn tevens connectiepunten in de zeeleing waar vandaan CO_2 aan platforms geleverd kan worden;

5 CO_2-injectie: via verbindingsleidingen komt de CO_2 vanaf de zeeleiding bij injectieplatform. Middels putten bij deze platforms wordt CO_2 geïnjecteerd in leeg geproduceerde gasvelden in de diepe ondergrond van de Noordzee.

CO_2-opslag diepe ondergrond

6 CO_2-opslag: permanente CO_2 opslag in de diepe ondergrond.



Figuur 1-1. Overzicht van de integrale CCS-keten met daarin de componenten die onderdeel zijn van de voorgenomen activiteit, namelijk: transport per schip, terminal CO2next, uitbreiding compressorstation Porthos, zeeleiding met eindpunt en connectiepunten, aansluitleidingen en platforms

Het Aramis initiatief

Het Aramis initiatief heeft als doel het verzamelpunt (onderdeel 3), de zeeleiding (onderdeel 4) en de injectie (onderdeel 5) te realiseren. Hiervoor wordt door het Aramis consortium (bestaande uit Shell, TotalEnergies, Gasunie en EBN) samengewerkt met CO2next (voor de terminal) en Porthos (voor het compressorstation). De opslag vindt plaats vanaf de platforms van Shell, TotalEnergies en Neptune Energy.

De afvang (onderdeel 1) en transport van CO_2 naar het verzamelpunt (onderdeel 2) vallen buiten het Aramis initiatief[1]. In het MER worden deze aspecten wel benoemd en op hoofdlijnen beschreven, omdat ze integraal onderdeel uitmaken van de integrale Aramis CCS keten.

De opslag in de diepe ondergrond (onderdeel 6) valt eveneens buiten het initiatief. Voor de diepe ondergrond gelden geen milieuregels. De mogelijke gevolgen van opslag in de diepe ondergrond wordt echter wel apart beschreven in het MER middels de deelrapporten opslag diepe ondergrond.

Bij de aanleg van Aramis wordt rekening gehouden met toekomstige uitbreiding met meer leveranciers van CO_2 en meer opslagpartijen. In eerste instantie wordt vergunning aangevraagd voor een startsituatie en de eerste uitbreidingssituatie. Dit wordt in het MER getoetst. Toekomstige initiatieven *na* de eerste uitbreidingssituatie behoren niet tot de vergunningaanvraag maar worden in het MER wel (globaal) beschreven.

---

[1] *Een deel van de schepen die CO_2 leveren aan de terminal is afkomstig van Aramis-initiatiefnemers.*

De ingebruikname verwachten de Aramis initiatiefnemers in 2028, waarbij tegelijk al de eerste activiteiten zoals beschreven in de eerste uitbreidingsituatie kunnen starten. Voor het bereiken van de maximale doorvoercapaciteit is enkele jaren later als uitgangspunt in het MER aangehouden.

Een uitgebreide beschrijving van het Aramis initiatief is opgenomen in het deelrapport technische beschrijving en het samenvattend hoofdrapport MER (zie figuur 1-2).

1.2 Korte introductie op het thema geluid

In het kader van het MER zijn de effecten van het Aramis initiatief op het thema geluid onderzocht en beoordeeld.

In de eerste fase van de m.e.r.-procedure voor het Aramis initiatief is afgebakend welke onderwerpen binnen dit thema relevant zijn om te onderzoeken en hoe. Dit is beschreven in de Notitie Reikwijdte en Detailniveau die 2 december 2022 definitief is vastgesteld door de Minister voor Klimaat en Energie. In de NRD is opgenomen dat in het MER ingegaan moet worden op:

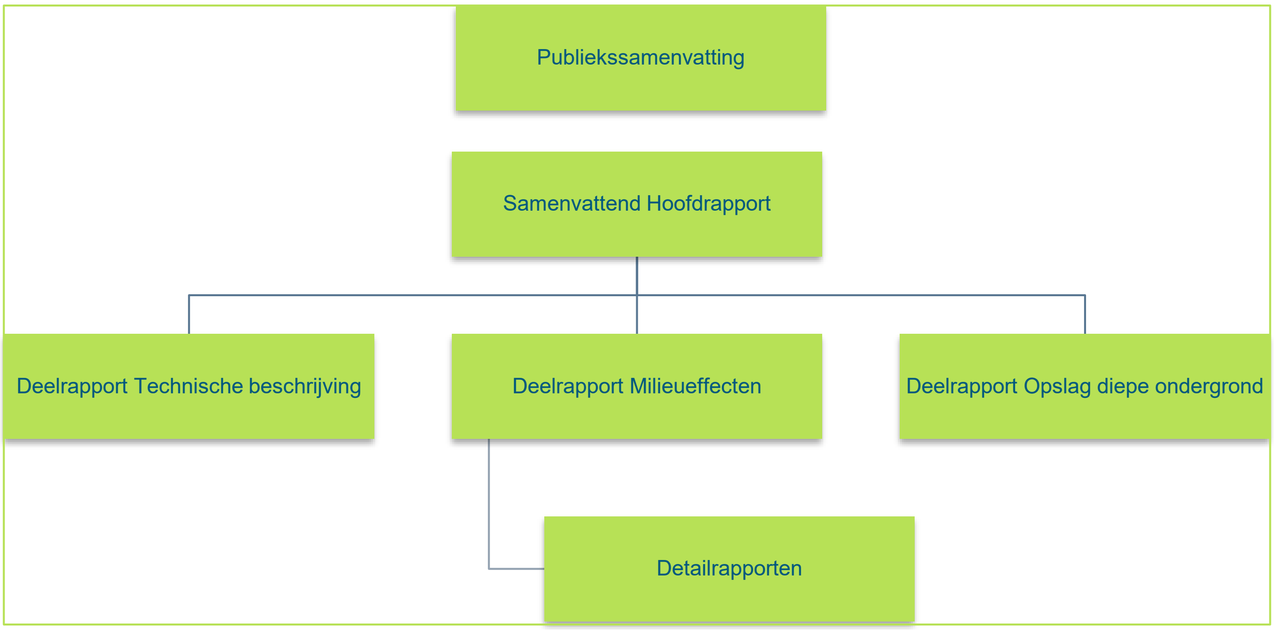
- geluid ten gevolge van de installaties (compressorstation en terminal) tijdens de gebruiksfase;
- geluid ten gevolge van de bouw en aanleg van de installaties.

Dit deelrapport behandelt genoemde onderwerpen in relatie tot het compressorstation. De terminal valt buiten de akoestische invloedssfeer van het compressorstation. De geluidsuitstraling van de terminal wordt behandeld in een ander deelrapport.

1.3 Opbouw van het MER en dit deelrapport

Voor het Aramis initiatief is een gecombineerd Plan-/ProjectMER opgesteld. Figuur 1-2 geeft de rapportagestructuur van het MER Aramis. Het MER bestaat uit een Samenvattend Hoofdrapport, voorzien van een Publiekssamenvatting. Ter onderbouwing van het Samenvattend Hoofdrapport zijn deelrapporten opgesteld. Dit betreft het deelrapport Technische beschrijving van Aramis, het deelrapport Milieueffecten met daarbij de onderliggende technische detailstudies en de deelrapporten Opslag diepe ondergrond. Doordat CO_2 in meerdere geologische voorkomens wordt opgeslagen, zijn er voor de opslag diepe ondergrond meerdere deelrapporten opgesteld.

Het voorliggende rapport is het detailrapport geluid compressorstation. De bevindingen uit dit detailrapport zijn opgenomen in het Deelrapport Milieueffecten, en op hoofdlijnen in het Samenvattend Hoofdrapport.



Figuur 1-2 - Overzicht rapportagestructuur MER Aramis

Opbouw van dit deelrapport

Dit deelrapport beschrijft in het volgende hoofdstuk allereerst welk kader van beleid, wet- en regelgeving van toepassing is voor het thema geluid. Nadat in hoofdstuk 3 is toegelicht hoe het onderzoek is uitgevoerd en hoe de effecten zijn beoordeeld, beschrijft hoofdstuk 4 de referentiesituatie. De referentiesituatie is de situatie die ontstaat op grond van de huidige situatie en alle relevante autonomie ontwikkelingen die verwacht worden in het studiegebied. Het dient veelal als vergelijkingsbasis voor het bepalen van de milieueffecten. In de dan volgende hoofdstukken (5, 6 en 7) worden de milieueffecten beschreven en beoordeeld, voor de gebruiksfase, tijdens de aanleg en ontmanteling, en tijdens onderhoudswerkzaamheden en onvoorziene situaties. Hoofdstuk 8 gaat op globaal niveau in op de effecten van alle ketenonderdelen die niet binnen de scope vallen van het Aramis initiatief, maar hier wel mee samenhangen. Tot slot geeft hoofdstuk 9 inzicht in de ontbrekende informatie voor het thema geluid.

2 Beleid, wet- en regelgeving

Dit hoofdstuk beschrijft welk beleid en welke wet- en regelgeving relevant is voor het Aramis initiatief voor het thema geluid. Dit maakt duidelijk binnen welke randvoorwaarden het Aramis initiatief tot stand moet komen.

Wet geluidhinder
Het initiatief wordt gerealiseerd op het ingevolge de Wet geluidhinder gezoneerde industrieterrein Maasvlakte. De door dit industrieterrein en het aangrenzende industrieterrein Europoort veroorzaakte geluidsbelasting in de omgeving is begrensd als gevolg van een geluidszone die om deze industrieterreinen is vastgesteld. Per 1 januari 2024 is dit geregeld in de Aanvullingswet geluid Omgevingswet (artikel 3.6), aangezien voor deze industrieterreinen op dat moment nog geen geluidsproductieplafonds van kracht zijn.

Het door het initiatief veroorzaakte geluid kan op meerdere manieren worden getoetst:

- toetsing van de geluidsbelasting ten gevolge van het volledige industrieterrein, inclusief het nieuwe compressorstation, aan de grenswaarden ter plaatse van de zonegrens en binnen de zone gelegen geluidsgevoelige gebouwen;
- toetsing van de geluidsemissie van het compressorstation aan de reservering die is gemaakt voor de kavel(s) waarop het compressorstation is gelegen;
- toetsing van de geluidsbelasting ten gevolge van het compressorstation aan de grenswaarden ter plaatse van de zonegrens en binnen de zone gelegen beoordelingspunten op basis van het voor het compressorstation beschikbare emissiebudget (zie vorig punt).

Het Geluidconvenant Rijnmond-West (1992) noemt kengetallen voor diverse industriële activiteiten. Gezien de aard van de relevante installaties (compressoren, transformatoren en leidingsystemen) is het compressorstation het best te vergelijken met procesindustrie. Hiervoor moet rekening worden gehouden met een benodigd geluidsbudget van circa 65 dB(A)/m^2. Op grond van de Beleidsregel zonebeheerplan industrielawaai Rijnmond-West (2005) is voor het compressorstation een emissiebudget van 65 dB(A)/m^2 beschikbaar.

Hoewel de Wet geluidhinder geen eisen stelt aan de optredende niveaus ten gevolge van piekgeluiden (‘maximale geluidsniveaus’), kunnen deze geluidsniveaus wel aan grenswaarden worden gebonden. Voor het voornemen is dit aspect niet relevant, gelet op de grote afstand (circa 3,5 km) tot de dichtstbijzijnde geluidsgevoelige gebouwen.

Besluit bouwwerken leefomgeving
Het Besluit bouwwerken leefomgeving verbindt grenswaarden aan de geluidsniveaus ten gevolge van bouw- en sloopwerkzaamheden in relatie tot het aantal dagen dat deze niveaus optreden. Een langtijdgemiddeld beoordelingsniveau van ten hoogste 60 dB(A) is in beginsel onbeperkt toelaatbaar.

De grenswaarden gelden ter plaatse van de gevels van woningen en andere geluidsgevoelige gebouwen, zoals scholen en ziekenhuizen. Uitgangspunt is dat de werkzaamheden plaatsvinden op doordeweekse dagen en zaterdagen, niet zijnde feestdagen, tussen 07:00 en 19:00 uur.

Indien buiten de voorgeschreven werktijden wordt gebouwd of gesloopt of indien niet aan de grenswaarden kan worden voldaan, is een ontheffing nodig om de werkzaamheden te kunnen uitvoeren.

3 Beschrijving onderzoeks- en beoordelingsmethodiek

Dit hoofdstuk beschrijft de aanpak waarmee de milieueffecten worden bepaald en beoordeeld.

3.1 Onderzoeksmethodiek

Er zijn aannames gedaan met betrekking tot de geluidsbronnen die worden toegevoegd als gevolg van de realisatie van het compressorstation. Leverancier MAN heeft gegevens van de compressoren beschikbaar gesteld. De bronnen zijn verwerkt in een uitsnede van het actuele zonebeheermodel die is aangeleverd door de DCMR Milieudienst Rijnmond. De werking van dit model is in overeenstemming met methode II.8 uit de Handleiding meten en rekenen Industrielawaai (ministerie van VROM, 1999).

Porthos

Op de beoogde kavel is reeds een compressorstation met bijbehorende installaties voorzien in het kader van het Porthos-project (zie paragraaf 1.1 en Figuur 3-1). Omdat beide ontwikkelingen deel uitmaken van dezelfde activiteit, is de bijdrage van het Porthos-project in de modelberekeningen meegenomen. Daarbij is gebruikgemaakt van het bij de vergunningaanvraag behorende geluidsonderzoek (rapport van Royal HaskoningDHV met referentie BF8260IBR001D3.0 d.d. 6 mei 2020).[2] Ook de gegevens van de toegevoegde geluidsbronnen zijn grotendeels ontleend aan dat onderzoek. Tenzij hierna anders vermeld, is daarbij als uitgangspunt het worstcasescenario gehanteerd dat de voor het Aramis initiatief toe te voegen akoestisch relevante voorzieningen overeenkomen met die welke reeds aanwezig zijn. Het ligt voor de hand dat een deel van de bestaande voorzieningen voor beide projecten kan worden ingezet.

Figuur 3-1: Verbeelding deel omgevingsplan Maasvlakte 1– Het blauwe vlak markeert de beoogde locatie van het compressorstation.

Aramis

Binnen het Aramis initiatief wordt aanvankelijk **één compressor, inclusief randapparatuur**, gebruikt voor het op druk brengen van CO_2 dat vervolgens wordt getransporteerd naar platforms in de Noordzee. Verwacht wordt dat er bij de eerste uitbreiding **twee extra compressoren worden geplaatst (totaal drie**

[2] *Op het moment van schrijven is de betreffende informatie nog niet verwerkt in het zonebeheermodel.*

stuks). In Bijlage 4 is een constructietekening van het compressorstation inclusief de uitbreiding weergegeven. In deze studie wordt aangenomen dat dit gevolgen heeft voor de geluidsuitstraling van de gebouwen (compressorgebouw, hoogspanningsgebouw, warmtewisselaargebouw) en het leidingwerk.

Als basis voor het rekenmodel is de situatie na de eerste uitbreiding aangehouden. Deze wordt in de volgende alinea's beschreven, evenals de belangrijkste toegevoegde geluidsbronnen per onderdeel. In de startfase wordt op de geluidsuitstraling van het compressorgebouw, het warmtewisselaargebouw, het leidingwerk en de kleppen een reductie van 5 dB(A) toegepast, terwijl voor de geluidsuitstraling van het hoogspanningsgebouw en de transformatoren een 3 dB(A) lagere waarde wordt gehanteerd.

De **compressoren en bijbehorende installaties** worden geplaatst in een gebouw met geluiddempende ventilatieroosters. Elke compressor staat in een afzonderlijke ruimte en heeft een bronsterkte van circa 121 dB(A)[3], wat aan de binnenzijde van de gevels en het dak een geluidsniveau van circa 102 dB(A) zal opleveren. Relevante geluidsuitstraling is te verwachten via de ventilatieroosters. We houden rekening met een geluidsvermogen van 96 dB(A) per rooster op basis van een oppervlakte van 12 m^2:

f [Hz]	63	125	250	500	1000	2000	4000	8000
L_p [dB(A)]	75	87	92	90	92	93	98	91
10 lg S [dB]	11	11	11	11	11	11	11	11
R [dB]	7	12	16	10	13	14	12	12
C_d [dB]	4	4	4	4	4	4	4	4
L_W [dB(A)]	75	82	83	87	86	86	93	86

De stroomvoorziening bestaat uit **twee transformatoren** en een hoogspanningsgebouw. De transformatoren hebben een bronsterkte van 83 dB(A) per stuk. Deze waarde is gebaseerd op metingen bij andere inrichtingen en wordt als uitgangspunt gehanteerd bij de keuze voor de installatie.

Het voor de koeling van de compressoren benodigde water is afkomstig uit de haven en wordt verplaatst met behulp van **vijf koelwaterpompen** die worden opgesteld in een gebouw op de kade. Uitgangspunt is dat deze pompen worden geplaatst in hetzelfde gebouw als de koelwaterpompen van het Porthos-project. De oppervlakte van het betreffende gebouw is in het model verdubbeld en het geluidsvermogen van de bijbehorende bronnen (dakventilator en gevelroosters) verhoogd met 3 dB(A). De pompen zelf worden ver onder het maaiveld opgesteld en zijn voor de geluidsuitstraling niet relevant.

Het secundaire koelsysteem, dat zorgt voor de feitelijke koeling van de compressoren, bestaat onder andere uit zes koelwaterpompen die worden opgesteld in een separaat gebouw (warmtewisselaar-gebouw). Voor deze pompen wordt een bronsterkte van 95 dB(A) per stuk aangehouden en voor de overige installaties een totale bronsterkte van 98 dB(A). Het resulterende geluidsniveau aan de binnenzijde van de gevels en het dak zal circa 85 dB(A) bedragen. Dit leidt per gevel tot een via de ventilatieroosters afgestraald geluidsvermogen van 94 dB(A), uitgaande van een totale roosteroppervlakte van 20 m^2 per gevel:

[3] *Conform opgave leverancier; zie bijlage 2.*

f [Hz]	63	125	250	500	1000	2000	4000	8000
L_p [dB(A)]	46	57	67	81	78	80	73	64
10 lg S [dB]	13	13	13	13	13	13	13	13
R [dB]	0	0	0	0	0	0	0	0
C_d [dB]	4	4	4	4	4	4	4	4
L_W [dB(A)]	55	66	76	90	87	89	82	73

Op het terrein zal een groot aantal **leidingen** worden aangelegd. De totale lengte van het leidingwerk zal circa 400 m bedragen. Het hierdoor afgestraalde stromingsgeluid is meegenomen in het onderzoek op basis van een gemiddelde bronsterkte van 65 dB(A)/m^1.

Uitgangspunt is dat ondersteunende (kantoor)activiteiten zonder akoestische gevolgen kunnen worden gehuisvest in het hoofdgebouw en regelgebouw, die onderdeel vormen van het Porthos-project. Verkeersbewegingen zullen beperkt zijn tot enkele voertuigen per dag en zijn daarmee akoestisch te verwaarlozen.

Een overzicht van het rekenmodel met de belangrijkste invoergegevens is opgenomen in bijlage 1.

3.2 Beoordelingsmethodiek

In een milieueffectrapportage worden de milieueffecten van een voornemen in beeld gebracht en beoordeeld. De effecten bepalen we veelal door de toekomstige situatie die ontstaat door het voornemen te vergelijken met de situatie die ontstaat zonder het voornemen, ook wel de referentiesituatie genoemd. Aan het verschil tussen die twee situaties, het effect, wordt een kwalitatief oordeel toegekend. Op die manier worden de effecten voor alle relevante milieuthema’s bepaald en beoordeeld.

Voor de realisatie van het compressorstation geldt dat de geluidsniveaus in de omgeving per definitie zullen toenemen ten opzichte van de situatie zonder het compressorstation. Anderzijds zijn deze geluidsniveaus (tot op zekere hoogte) reeds ingecalculeerd ten tijde van de vaststelling van de geluidszone om het industrieterrein. Dit betekent dat de toename kan worden gezien als de omzetting van een reservering in een feitelijke invulling, die ook zonder het voornemen zou (kunnen) plaatsvinden in het kader van een andere ontwikkeling op het industrieterrein; zie verder paragaaf 4.2.

Voorwaarde bij het toelaten van nieuwe ontwikkelingen op het industrieterrein is dat de grenswaarden ten gevolge van het totale industrieterrein worden gerespecteerd, en bij voorkeur tevens de grenswaarden op basis van het voor de betrokken ontwikkeling beschikbare emissiebudget. Toetsing van de inpasbaarheid van de aangevraagde activiteiten binnen de geluidszone is een taak van het bevoegd gezag en vindt plaats ten tijde van de vergunningverlening. De grenswaarden op basis van het emissiebudget hebben we indicatief bepaald door het aangeleverde model door te rekenen met een emissiebudget van 65 dB(A)/m^2 voor de kavel waarop het compressorstation is gelegen.

In het licht van de tweede alinea hierboven wordt het voornemen als neutraal gewaardeerd indien aan genoemde grenswaarden wordt voldaan en negatief als dat niet het geval is.

4 Beschrijving referentiesituatie

In een milieueffectrapportage worden de milieueffecten van een voornemen in beeld gebracht en beoordeeld. De effecten bepalen we veelal door de toekomstige situatie die ontstaat door het voornemen te vergelijken met de situatie die ontstaat zonder het voornemen, ook wel de referentiesituatie genoemd. Aan het verschil tussen die twee situaties, het effect, wordt een kwalitatief oordeel toegekend. Dit hoofdstuk beschrijft allereerst de huidige situatie voor het thema geluid. Vervolgens beschrijft het welke situatie ontstaat als gevolg van alle autonome ontwikkelingen; de referentiesituatie.

4.1 Huidige situatie

De bij de DCMR Milieudienst Rijnmond bekende (vergunde) bedrijfsvoering van de op het industrieterrein aanwezige bedrijven is opgenomen in het zonebeheermodel. Hiermee wordt de beschikbare geluidsruimte binnen de zone bewaakt. Zolang er ruimte beschikbaar is, zijn nieuwe ontwikkelingen uit akoestisch oogpunt in beginsel toelaatbaar.

4.2 Autonome ontwikkelingen

De invulling van het industrieterrein wijzigt continu als gevolg van wat autonome ontwikkelingen genoemd kunnen worden. Bedrijven vertrekken, vestigen zich of voeren veranderingen door in hun bedrijfsvoering. Hoewel deze ontwikkelingen slechts in algemene zin zijn te duiden, staat vast dat ze alleen kunnen worden toegestaan met inachtneming van de beschikbare geluidsruimte. Er is dus een ‘eindsituatie’ denkbaar, waarin het industrieterrein akoestisch volledig is gevuld en autonome ontwikkelingen (tijdelijk) tot stilstand komen.

Als autonome ontwikkeling is het Porthos compressorstation gerealiseerd en zijn er twee compressoren operationeel voor de compressie van CO_2 voor Porthos.

5 Milieueffecten gebruiksfase

Dit hoofdstuk gaat in op de effecten op het thema geluid, zoals die verwacht worden tijdens het gebruik van het compressorstation. Daarbij wordt onderscheid gemaakt naar de startfase en eerste uitbreidingsfase, die alle twee onderdeel zijn van het Aramis initiatief. Tevens bevat het hoofdstuk een doorkijk naar de effecten die verwacht worden in de eindfase, hoewel dit strikt gezien niet tot het Aramis initiatief behoort.

5.1 Effecten voorgenomen activiteit (vka)

In deze paragraaf worden de langtijdgemiddelde beoordelingsniveaus op de 'meest relevante rekenpunten' gepresenteerd. Hiermee worden de rekenpunten bedoeld waar in de situatie na de eerste uitbreiding het verschil tussen de berekende waarde en de grenswaarde op basis van het emissiebudget het kleinst is. Naar aanleiding van vragen van de DCMR Milieudienst Rijnmond is hieraan het rekenpunt toegevoegd waar de hoogste langtijdgemiddelde beoordelingsniveaus in Hoek van Holland optreden (nummer 101). Voor een volledig overzicht van de resultaten wordt verwezen naar bijlage 3.

Startfase

De berekende langtijdgemiddelde beoordelingsniveaus op de meest relevante rekenpunten zijn weergegeven in tabel 5.1. Hieruit blijkt dat het compressorstation past binnen de beschikbare geluidsruimte. Opgemerkt wordt dat de tabel vooral een signaleringsfunctie heeft: de vermelde waarden zijn uitermate laag en in vergelijking met de toelaatbare geluidsbelasting ten gevolge van het volledige industrieterrein is de bijdrage van het compressorstation verwaarloosbaar klein.

Tabel 5.1. Berekende langtijdgemiddelde beoordelingsniveaus in de startfase, met tussen haakjes het verschil ten opzichte van de grenswaarde op basis van het emissiebudget

rekenpunt	omschrijving	hoogte in m	langtijdgemiddeld beoordelingsniveau in dB(A)		
			07:00–19:00 uur	19:00–23:00 uur	23:00–07:00 uur
— ZONEBEWAKINGSPUNTEN —					
612z	Noordzee (zonegrens)	5	11,3 (–1,2)	11,3 (–1,2)	11,3 (–1,2)
613z	Noordzee (zonegrens)	5	7,6 (–2,0)	7,6 (–2,0)	7,6 (–2,0)
— OVERIGE PUNTEN —					
101	HvH Rivierkant	15	7,8 (–3,1)	7,8 (–3,1)	7,8 (–3,1)
102	HvH K.Emmablvd	15	6,0 (–2,3)	6,0 (–2,3)	6,0 (–2,3)
103	HvH Berghaven	15	4,8 (–2,4)	4,8 (–2,4)	4,8 (–2,4)
107	HvH Maeslandkeringweg(1)	15	0,4 (–3,3)	0,4 (–3,3)	0,4 (–3,3)

Eerste uitbreiding

De berekende langtijdgemiddelde beoordelingsniveaus op de meest relevante rekenpunten zijn weergegeven in tabel 5.2 op pagina 11. Hieruit blijkt dat het compressorstation ook na de eerste uitbreiding past binnen de beschikbare geluidsruimte.

Eindsituatie

Met betrekking tot het aspect geluid zijn in de eindsituatie geen andere effecten ten gevolge van het compressorstation te verwachten dan in de situatie na de eerste uitbreiding.

Tabel 5.2. Berekende langtijdgemiddelde beoordelingsniveaus na de eerste uitbreiding, met tussen haakjes het verschil ten opzichte van de grenswaarde op basis van het emissiebudget

rekenpunt	omschrijving	hoogte in m	langtijdgemiddeld beoordelingsniveau in dB(A)		
			07:00–19:00 uur	19:00–23:00 uur	23:00–07:00 uur
— ZONEBEWAKINGSPUNTEN —					
612z	Noordzee (zonegrens)	5	12,4 (–0,1)	12,4 (–0,1)	12,4 (–0,1)
613z	Noordzee (zonegrens)	5	9,2 (–0,4)	9,2 (–0,4)	9,2 (–0,4)
— OVERIGE PUNTEN —					
101	HvH Rivierkant	15	9,3 (–1,6)	9,3 (–1,6)	9,3 (–1,6)
102	HvH K.Emmablvd	15	8,0 (–0,3)	8,0 (–0,3)	8,0 (–0,3)
103	HvH Berghaven	15	7,2 (0,0)	7,2 (0,0)	7,2 (0,0)
107	HvH Maeslandkeringweg(1)	15	3,1 (–0,6)	3,1 (–0,6)	3,1 (–0,6)

5.2 Effectbeoordeling

De door het compressorstation veroorzaakte langtijdgemiddelde beoordelingsniveaus voldoen zowel in de startfase als na de eerste uitbreiding aan de grenswaarden.

6 Milieueffecten aanleg en ontmanteling

Dit hoofdstuk gaat in op de effecten op het thema geluid, zoals die verwacht worden tijdens de aanleg en de ontmanteling van het compressorstation.

De uit akoestisch oogpunt maatgevende activiteiten in verband met de aanleg en ontmanteling van het compressorstation betreffen heiwerkzaamheden in de aanlegfase. Deze werkzaamheden zouden aan de orde kunnen zijn bij het oprichten van bijgebouwen (o.a. warmtewisselaar). Een traditionele heistelling heeft een bronsterkte van circa 135 dB(A). De aanleg van de fundering is echter al onderdeel van de Porthos ontwikkeling en wordt gezien als een autonome ontwikkeling. Deze heeft zodoende geen effect voor Aramis.

7 Milieueffecten tijdens onderhoud en onvoorziene situaties

Dit hoofdstuk gaat in op de effecten die te verwachten zijn tijdens onderhoudswerkzaamheden en onvoorziene situaties.

Voor zover onderhoudswerkzaamheden en onvoorziene situaties — of andere afwijkende situaties — niet kunnen worden geschaard onder de zogenoemde representatieve bedrijfssituatie, worden de hierdoor veroorzaakte langtijdgemiddelde beoordelingsniveaus niet getoetst aan de binnen de zone beschikbare geluidsruimte.

Tijdens het opstarten of uit bedrijf nemen van het compressorstation zijn geen afwijkende geluidsniveaus te verwachten. Wel kunnen kortstondige verhogingen van de door het compressorstation veroorzaakte geluidsniveaus optreden wanneer de noodstroomgenerator wordt getest (eens per maand) of de compressoren door een storing uitvallen en druk wordt afgelaten via het drukaflaatsysteem. Alleen dit laatste geluid zou bij de dichtstbijzijnde woningen waarneembaar kunnen zijn.

8 Milieueffecten buiten Aramis scope

Zoals eerder beschreven behoren sommige CCS-ketenonderdelen niet tot het Aramis initiatief. Het is belangrijk om van deze onderdelen op hoofdlijnen wel de milieugevolgen in beeld te brengen. Het betreft immers effecten die mede via het Aramis initiatief ontstaan. Door de effecten van deze onderdelen ook te beschouwen ontstaat een beeld van de gevolgen van de totale CCS keten. Omdat deze onderdelen niet door de Aramis initiatiefnemers worden ondernomen en omdat hierover slechts beperkt informatie beschikbaar is, worden deze milieugevolgen slechts op globaal niveau beschouwd.

8.1 Afvang CO_2 voor Aramis initiatief

De bedrijven die CO_2 gaan leveren in het kader van het Aramis initiatief hebben waarschijnlijk een omgevingsvergunning nodig voor de verandering van hun bedrijfsvoering (uitbreiding met een afvanginstallatie en een compressor). Het effect hiervan op de geluidsuitstraling is niet op voorhand te kwantificeren en is sterk afhankelijk van de gebruikte afvangtechniek alsmede bedrijfs- en locatiespecifieke omstandigheden.

8.2 Transport landleiding

Hiervan is alleen de aanleg potentieel akoestisch relevant. De belangrijkste activiteit is het ingraven van de leiding, waarbij mobiele kranen met graafbakken en boormotoren de meest relevante geluidsbronnen zijn. De als gevolg hiervan optredende langtijdgemiddelde beoordelingsniveaus zullen naar verwachting voldoen aan de van toepassing zijnde grenswaarde uit de Circulaire bouwlawaai (2010).

Het is onduidelijk of er ergens damwanden moeten worden aangebracht. Zo ja, dan ligt het voor de hand dat daarvoor één of meerdere kra(a)n(en) met trilblok wordt/worden ingezet. Als we ervan uitgaan dat deze activiteit per locatie niet meer dan enkele dagen in beslag neemt, zullen ook de als gevolg hiervan optredende langtijdgemiddelde beoordelingsniveaus naar verwachting voldoen aan de van toepassing zijnde grenswaarde uit de Circulaire bouwlawaai.

Volledigheidshalve wordt opgemerkt dat de werkzaamheden niet zonder ontheffing mogen plaatsvinden (Algemene plaatselijke verordening Rotterdam 2012, artikel 4:6).

9 Leemten in kennis

Dit beschrijft of en zo ja welke leemten in kennis er zijn voor de besluitvorming over het Aramis initiatief.

Over de onderdelen van het Aramis initiatief is in dit stadium geen gedetailleerde akoestische informatie voorhanden. De gebruikte gegevens zijn daarom gebaseerd op kengetallen en eigen ervaring. De aangehouden terreinindeling en installaties moeten worden beschouwd als een goede benadering van de te realiseren situatie.

10 Samenvatting bevindingen en toetsing wet- en regelgeving

Het compressorstation past binnen de geluidsruimte die standaard beschikbaar is op grond van de Beleidsregel zonebeheerplan industrielawaai Rijnmond-West. Daarnaast zijn de door het compressorstation veroorzaakte geluidsniveaus zeer laag en, in vergelijking met de toelaatbare geluidsbelasting ten gevolge van het volledige industrieterrein, te verwaarlozen.

Het hoogste berekende langtijdgemiddelde beoordelingsniveau na de eerste uitbreiding van het compressorstation is 12 dB(A) ter plaatse van de zonegrens en 9 dB(A) langs de kust van Hoek van Holland (niet ter plaatse van geluidsgevoelige gebouwen). Genoemde waarden doen zich voor in elke etmaalperiode.

Aangezien het voor het compressorstation benodigde emissiebudget niet hoger is dan de standaard geluidsruimte conform de Beleidsregel zonebeheerplan industrielawaai Rijnmond-West, wordt het voornemen als neutraal gewaardeerd.

Het geluidsniveau ten gevolge van bouwactiviteiten is alleen potentieel relevant voor zover dit samenhangt met de aanleg van de fundering. De betreffende (hei)werkzaamheden maken echter deel uit van de Porthos ontwikkeling en vallen daarmee buiten de reikwijdte van deze studie.

Bijlage

1. Overzicht rekenmodel

Bijlage

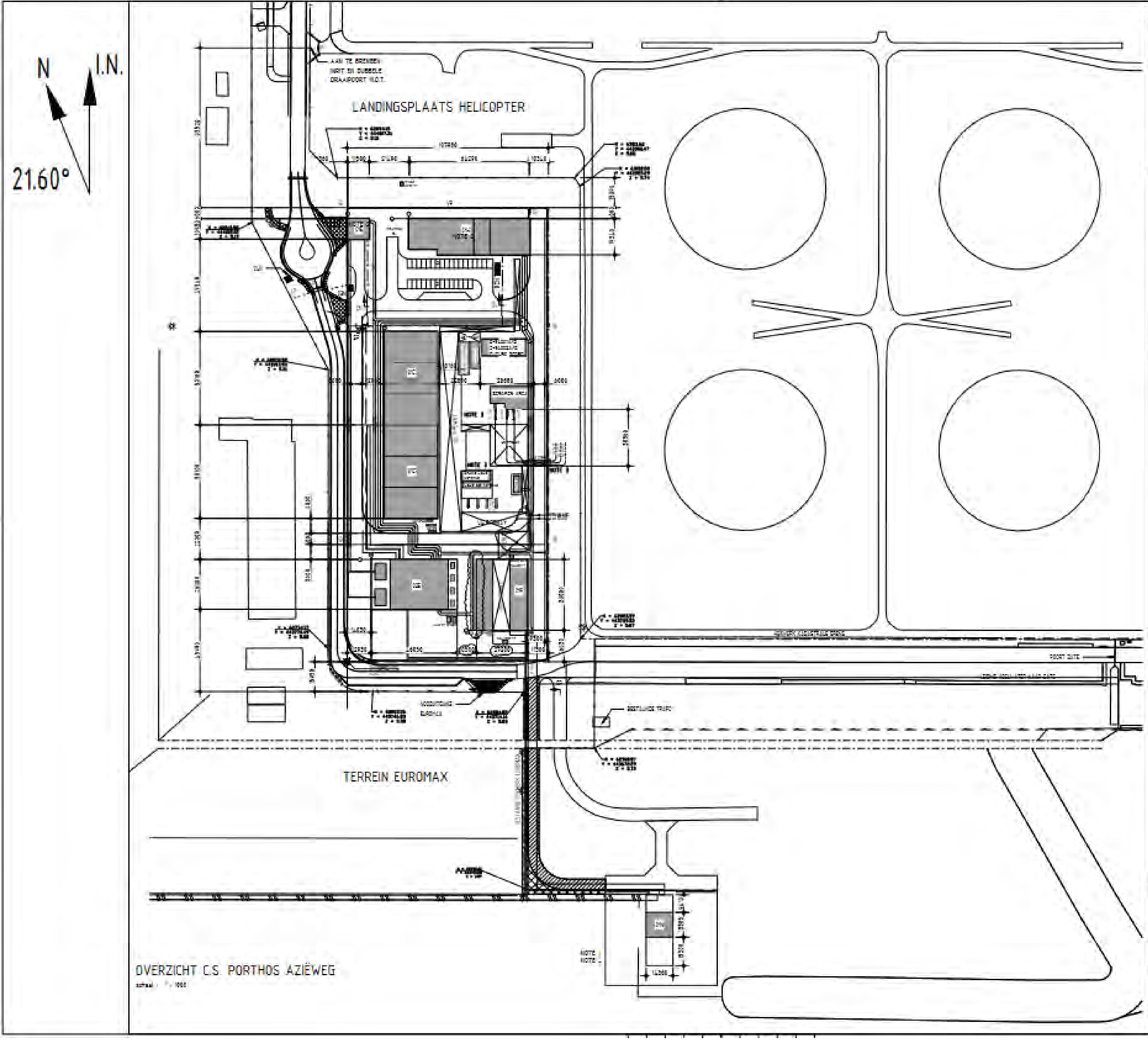
2. Technische informatie compressoren

Bijlage

3. Rekenresultaten

Bijlage

4. Constructietekening



OPMERKINGEN

- MATEN IN mm TENZIJ ANDERS VERMELD
- LOCATIEPEIL = 100.000 = NADER TE BEPALEN
- HOOGTE AFGEWERKT MAAIVELD = ca. 100.000

HOLD FOR APPROVAL AND AGREEMENT WITH GATE, HbR, Euromax and DTH

NOTE:
1. VERWIJZEN TRCS-ENG-MEC-RHD-SOW-0001 KOELWATERINLAATGEBOUW
2. VERWIJZEN TRCS-ENG-PEN-TEB-SOW-0001 VOOR TEBODIN PAKKET
3. GREEN CLOUD INDICATES ARAMIS SCOPE
4. COORDINATES AND GEBOUW FENCE IN DETAIL ENGINEERING TE BEPALEN

REFERENCE DRAWINGS:

TRCS-ENG-PIP-FLR-PLN-0003 UNIT PLOT PLAN CS PORTHOS AREA1
TRCS-ENG-PIP-FLR-PLN-0004 UNIT PLOT PLAN CS PORTHOS AREA2
TRCS-ENG-PIP-FLR-PLN-0005 UNIT PLOT PLAN CS PORTHOS AREA3
TRCS-ENG-PIP-FLR-PLN-0006 UNIT PLOT PLAN CS PORTHOS AREA4
TRCS-ENG-PIP-FLR-PLN-0007 UNIT PLOT PLAN CS PORTHOS AREA5

RENVOOI

GEBOUWNUMMERS

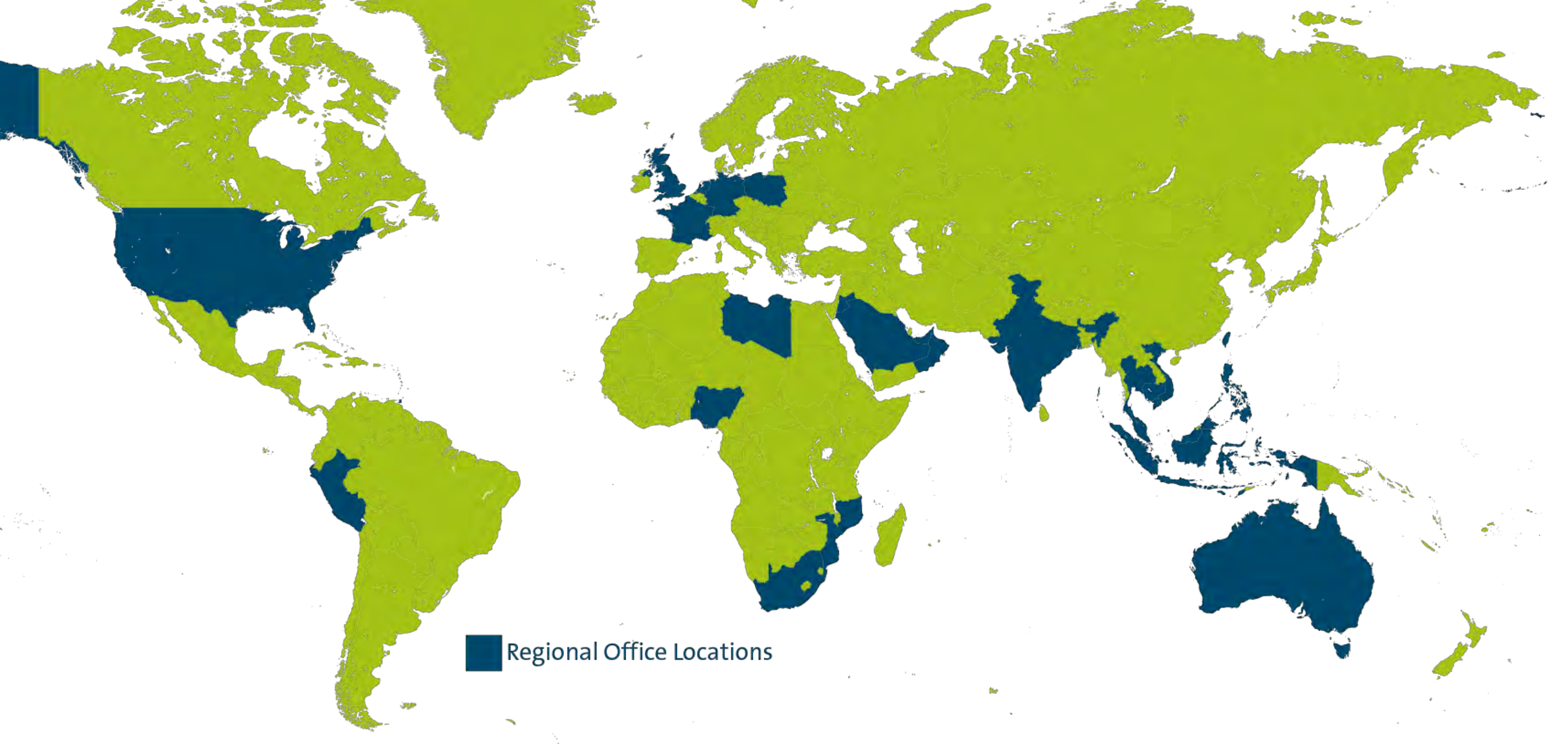
01A = ANALYSEGEBOUW
01C = COMPRESSORGEBOUW
01E = KLANTSTATIONGEBOUW
02E = ELEKTROGEBOUW
01H = HOOFDGEBOUW
01N = KOELWATERPOMPGEBOUW
02N = RIJWIELSTALLING
03N = ABRI
04N = ABRI
01P = WARMTEWISSELAARGEBOUW

REV.	DATE	DESCRIPTION	BY	department	checked	approved
3.0	2025-04-11	ISSUED FOR DESIGN	[illegible]		[illegible]	[illegible]
2.2	2025-02-18	ISSUED FOR CLIENT REVIEW	[illegible]		[illegible]	[illegible]
2.1	2022-12-01	ISSUED FOR CLIENT REVIEW	[illegible]		[illegible]	[illegible]
2.0	2022-03-03	ISSUED FOR DESIGN	[illegible]		JVV	FL
1.0	2020-09-11	ISSUED FOR CLIENT REVIEW	[illegible]		JVV	FL

OVERALL PLOT PLAN
C.S. PORTHOS

N.V. NEDERLANDSE GASUNIE

A1 TRCS-ENG-PIP-FLR-PLN-0002 3.0



Royal HaskoningDHV is een onafhankelijk internationaal advies- en ingenieursbureau. We combineren 140 jaar engineering- en ontwerpexpertise met consultancy, software en technology diensten. We leveren hiermee toegevoegde waarde voor klanten en hebben een positieve impact op mensen en onze leefomgeving. Dat is onze drijfveer: Enhancing Society Together. Daar hoort bij dat we onszelf en anderen voortdurend uitdagen om bij te dragen aan duurzame oplossingen voor lokale en wereldwijde vraagstukken in de gebouwde omgeving en de industrie.

In onze snel veranderende wereld wordt de agenda bepaalt door onder meer klimaatverandering, de digitale transformatie, een veranderende consumentenvraag en hybride werken. Met onze geïntegreerde duurzame oplossingen willen we bijdragen aan het bredere technologische en maatschappelijke plaatje.

Gesteund door de kennis en ervaring van meer dan 6.000 collega's werken we vanuit kantoren in meer dan 20 landen. We ondersteunen klanten om de transitie te maken naar een slimme en duurzame organisatie. We koppelen onze engineering- en ontwerpexpertise aan onze software- en technologische diensten om toegevoegde waarde te leveren voor onze klanten en de lifecycle van hun assets.

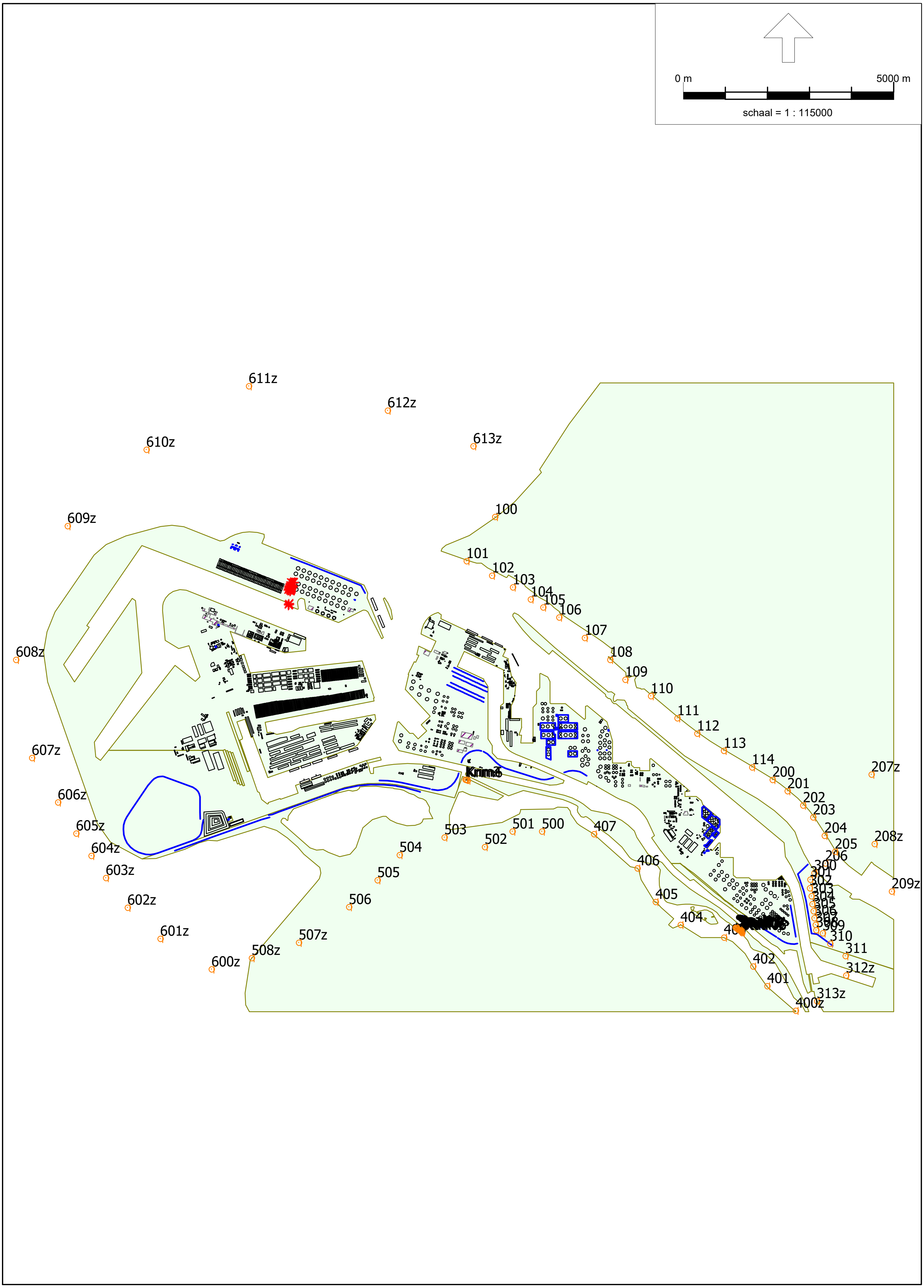
We zijn oprecht, handelen integer en transparant in al onze activiteiten, ook onze bedrijfsvoering Ons team is divers en inclusief. De veiligheid en het welzijn van mensen, in ons team en daarbuiten, staat onder alle omstandigheden voorop.

In projecten en initiatieven werken we actief samen met overheden en het bedrijfsleven, partners en stakeholders. We zien een belangrijke rol voor onszelf in innovatieve duurzame ontwikkeling en willen bijdragen aan een betere leefomgeving, nu en in de toekomst.

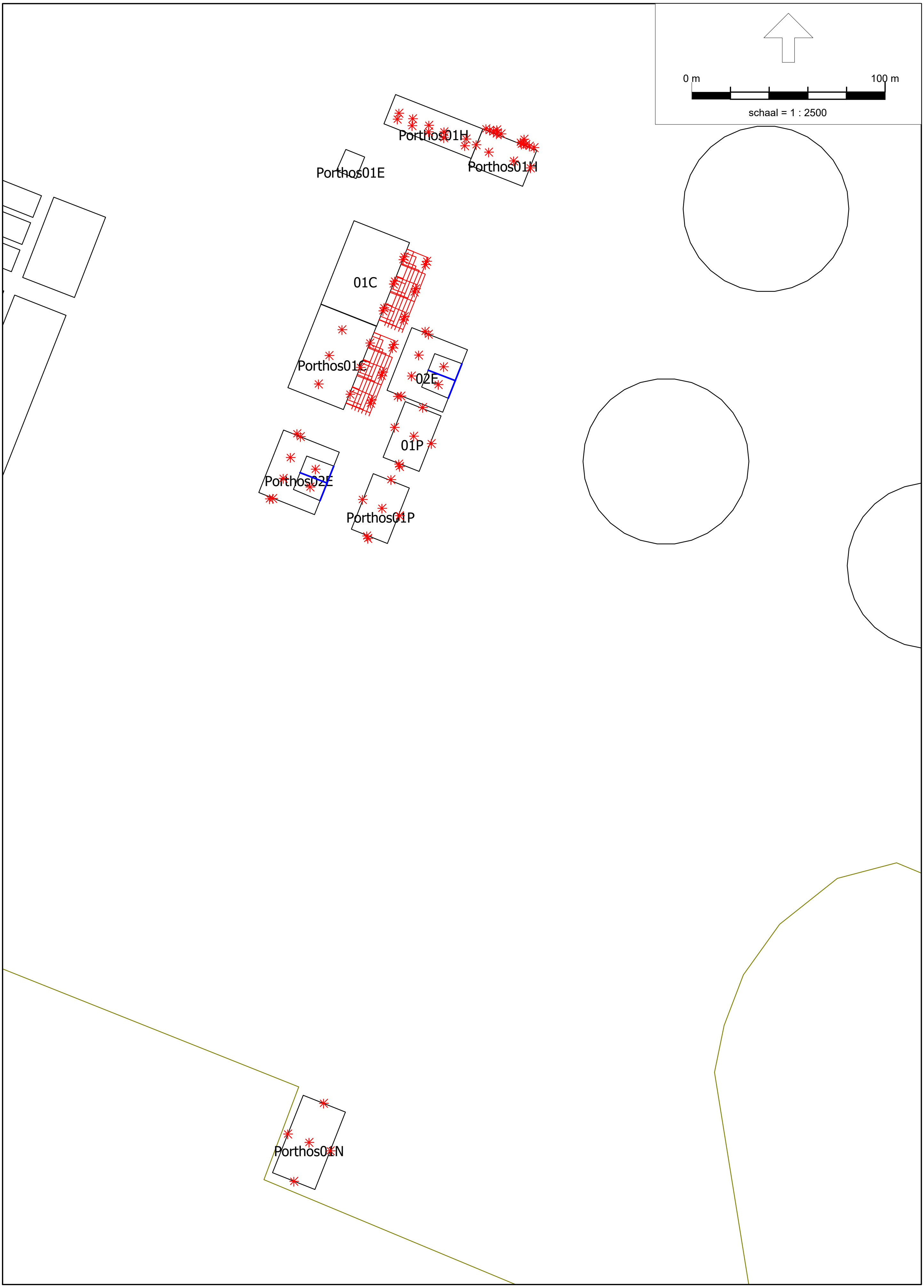
Ons hoofkantoor is gevestigd in Nederland en we hebben kantoren in Europa, Azie, Afrika, Australie en Amerika.

euroCompliance certification ISO 37001 — euroCompliance certification ISO 37301

royalhaskoningdhv.com

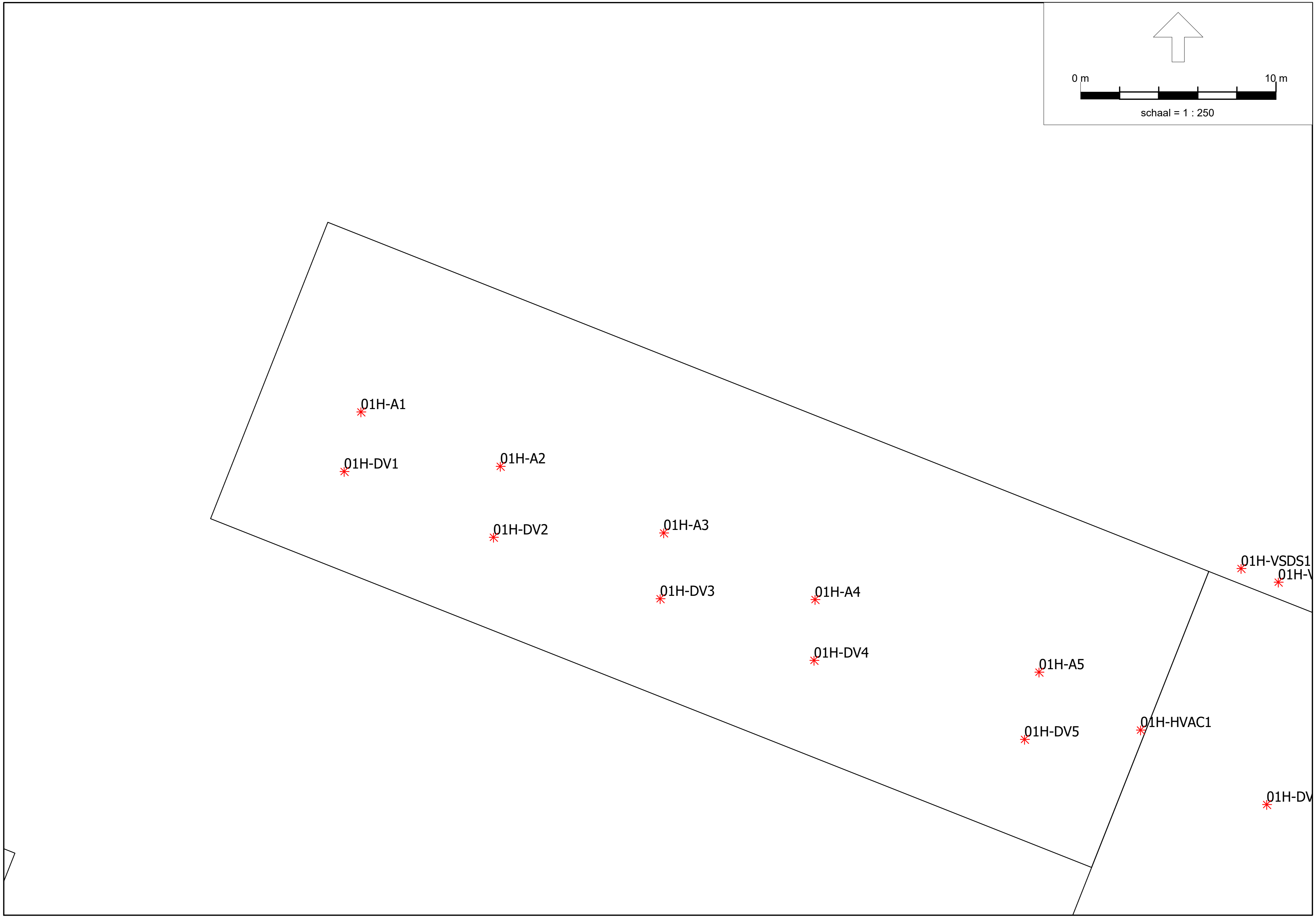

0 m
5000 m
schaal = 1 : 115000
611z
612z
610z
613z
609z
608z
607z
606z
605z
604z
603z
602z
601z
600z
508z
507z
506
505
504
503
502
501
500
407
406
405
404
402
401
400z
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
200
201
202
203
204
205
206
207z
208z
209z
300
301
302
303
304
310
311
312z
313z

Bijlage 1
Overzicht rekenmodel (detail)



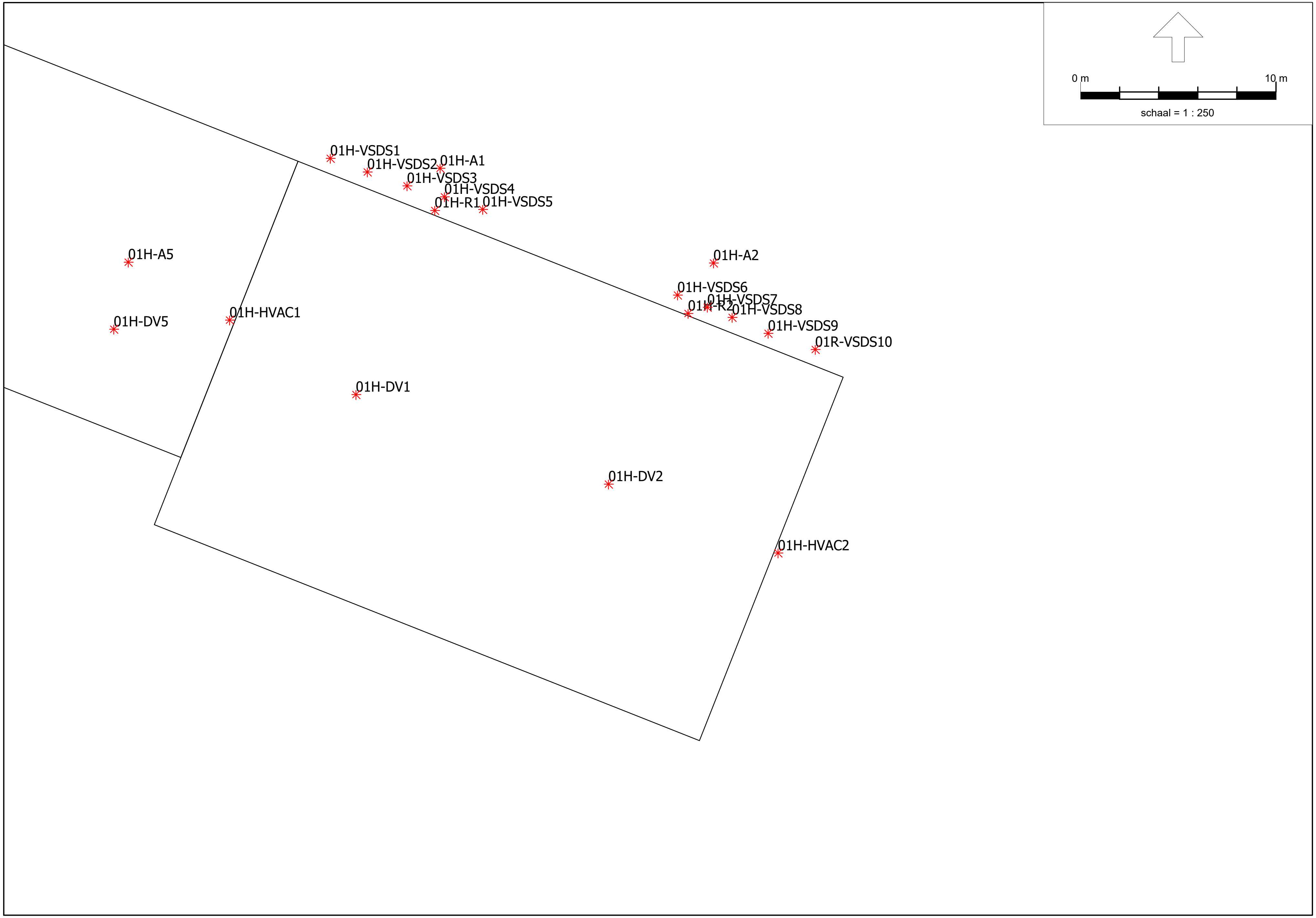
Royal HaskoningDHV

Aramis compressorstation (BH8744)



Overzicht rekenmodel (detail)

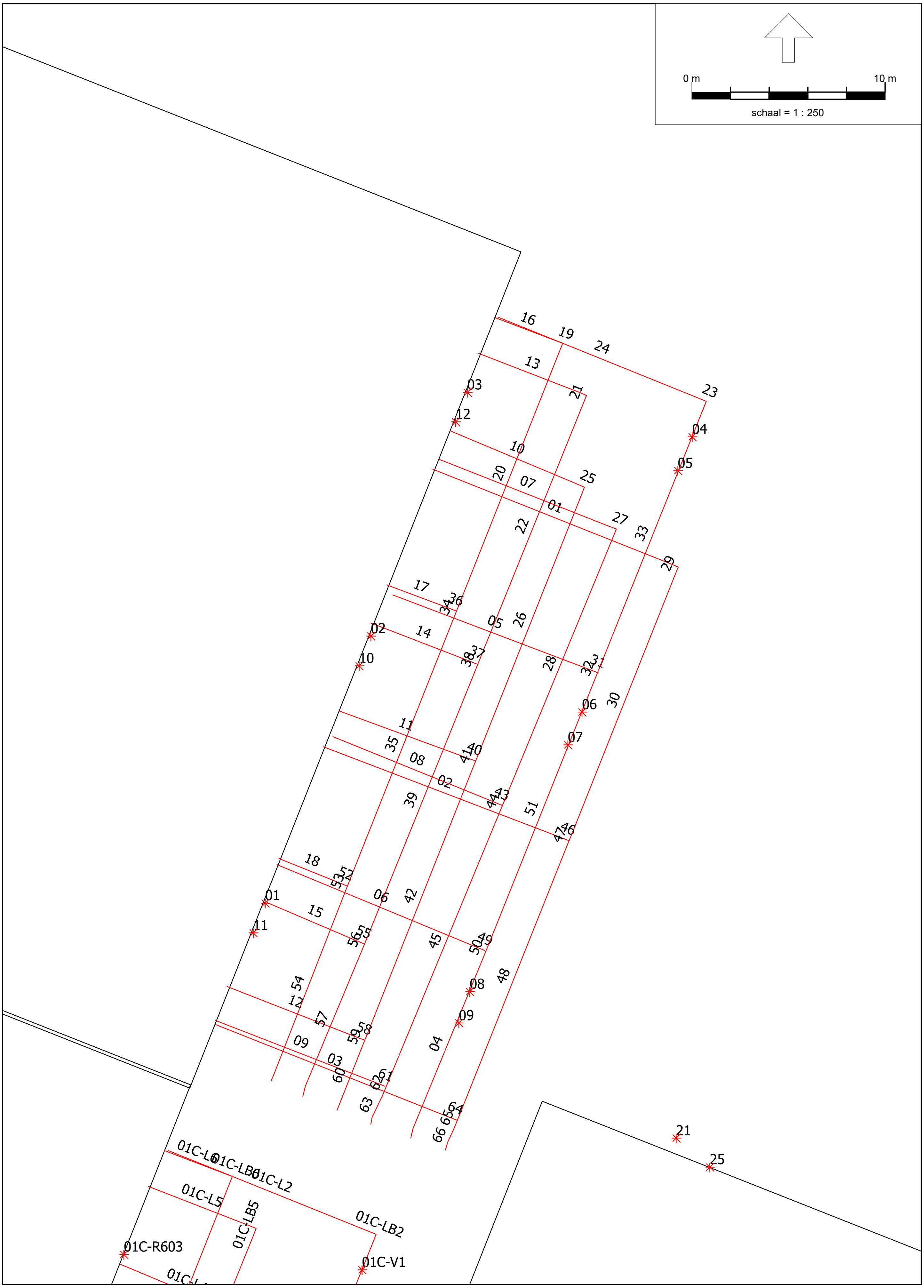
Bijlage 1

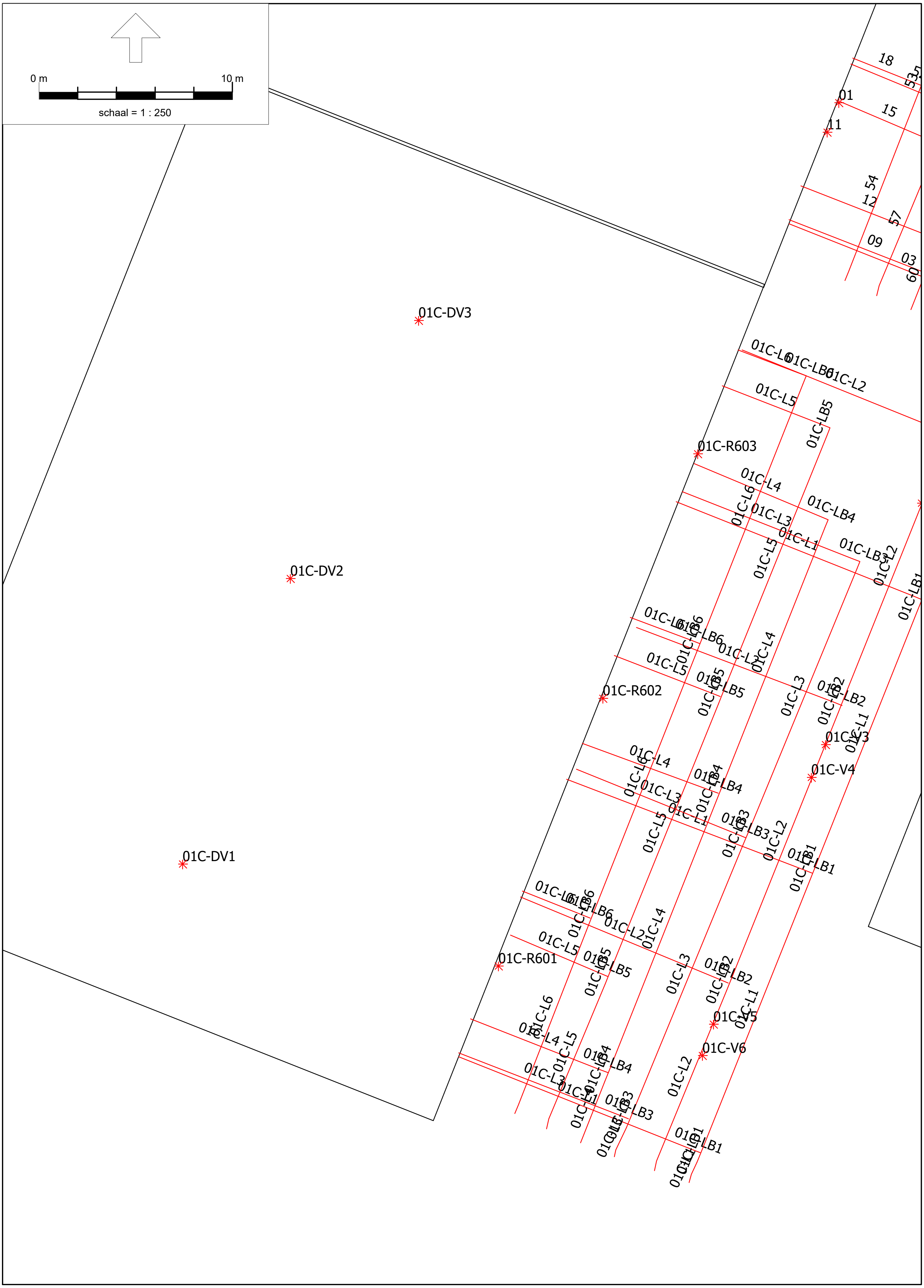


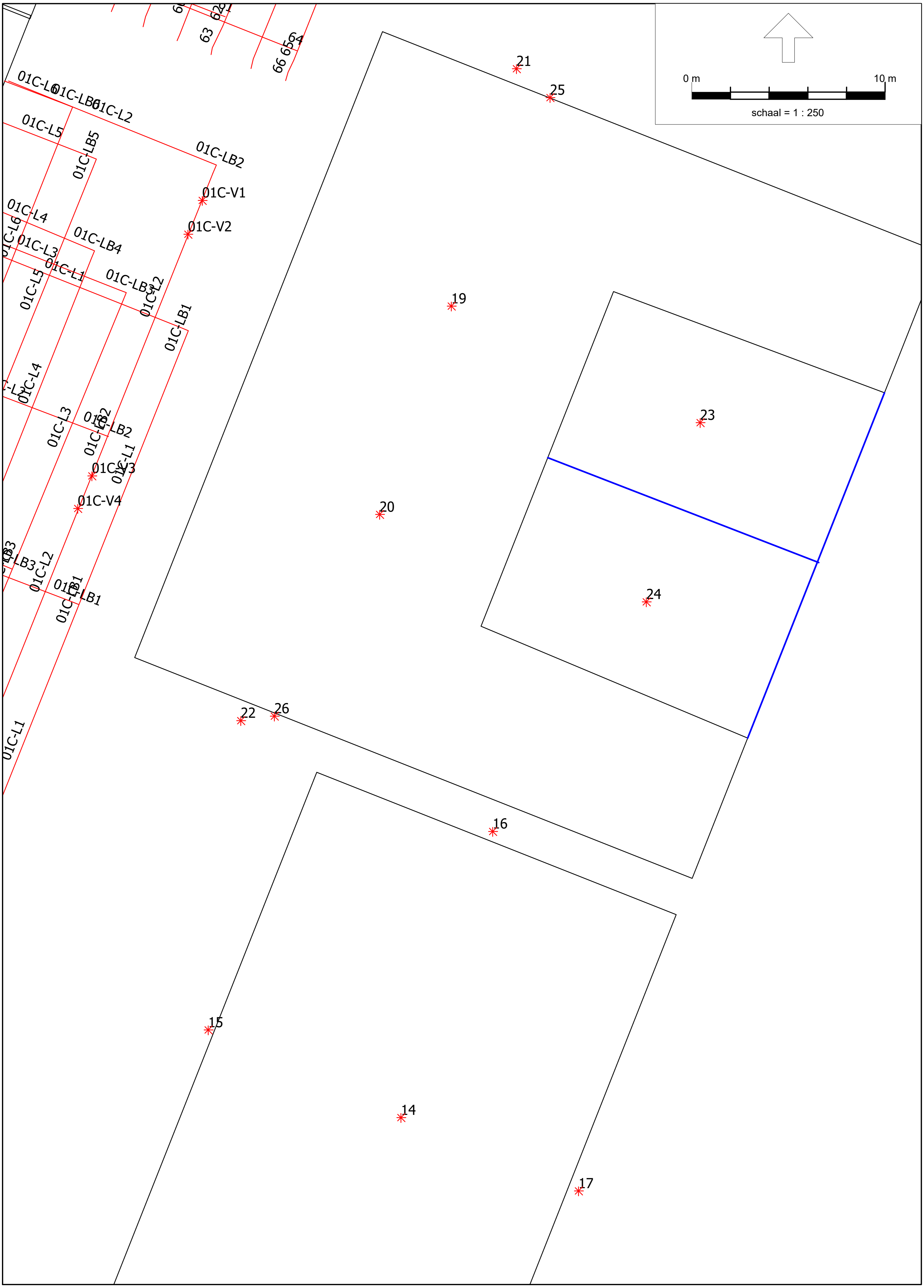
Royal HaskoningDHV
Aramis compressorstation (BH8744)

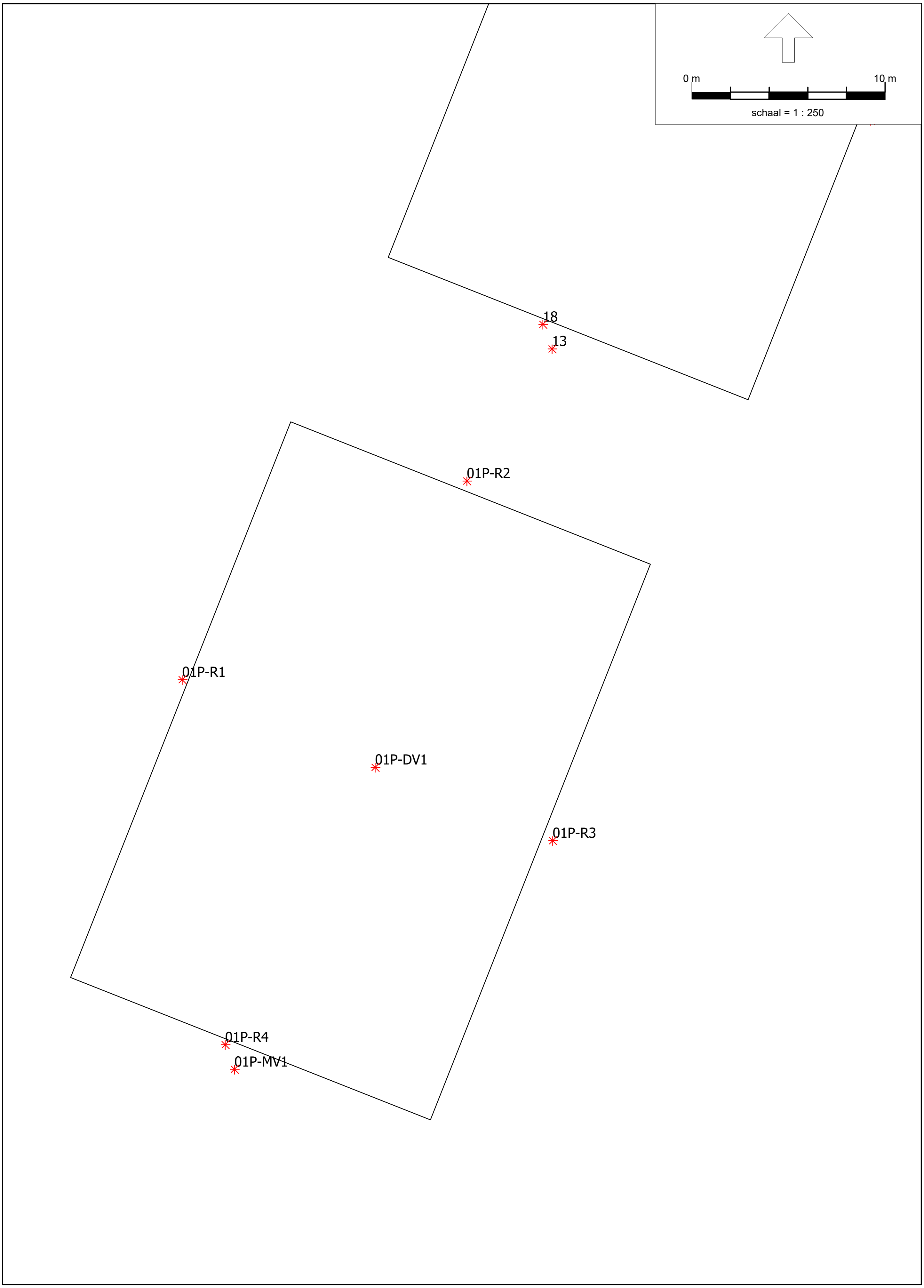
Bijlage 1
Overzicht rekenmodel (detail)

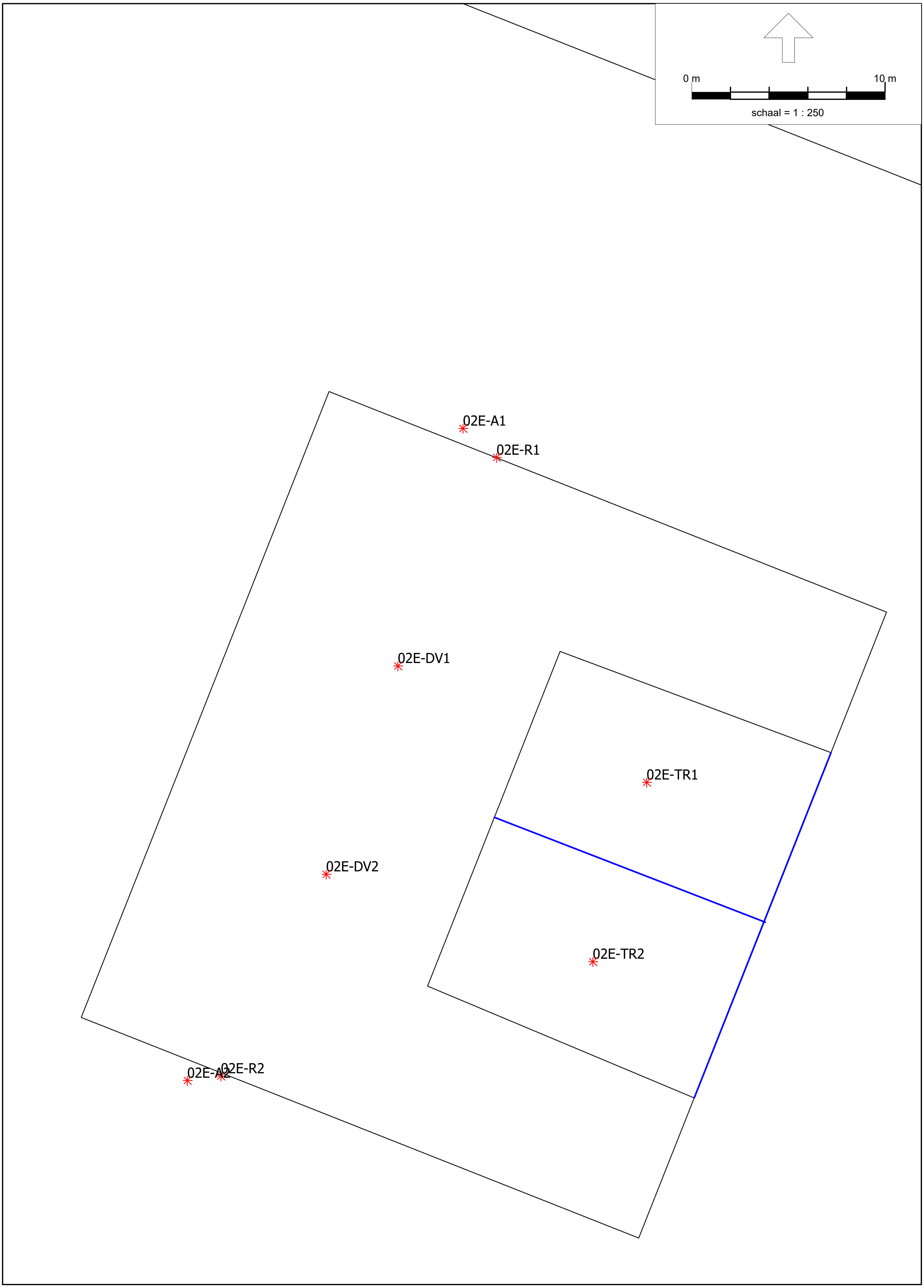
Bijlage 1
Overzicht rekenmodel (detail)




0 m
10 m
schaal = 1 : 250
01C-DV3
01C-DV2
01C-DV1
01C-R603
01C-R602
01C-R601
01C-V4
01C-V6


0 m
10 m
schaal = 1 : 250
21
25
19
20
23
24
22
26
16
15
14
17
01C-V1
01C-V2
01C-V3
01C-V4
01C-LB2
01C-LB4
01C-LB3
01C-LB1
01C-LB5
01C-L2
01C-L5
01C-L4
01C-L3
01C-L1
63
66


0 m
10 m
schaal = 1 : 250
18
13
01P-R2
01P-R1
01P-DV1
01P-R3
01P-R4
01P-MV1


0 m
10 m
schaal = 1 : 250
02E-A1
02E-R1
02E-DV1
02E-TR1
02E-DV2
02E-TR2
02E-A2
02E-R2

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Gebouwen, voor rekenmethode Industrielawaai - IL

Naam	Omschr.	Hoogte	Maaiveld	Hdef.	Cp	Refl. 31	Refl. 63	Refl. 125	Refl. 250	Refl. 500	Refl. 1k	Refl. 2k	Refl. 4k	Refl. 8k
01C	Compressorgebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
01P	Warmtewisselaargebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
02E	Electrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01C	Compressorgebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01E	Klantstationgebouw	3,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01H	Regelgebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01H	Hoofdgebouw	9,50	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01N	Koelwaterpompgebouw	4,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos01P	Warmtewisselaargebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos02E	Electrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Schermen, voor rekenmethode Industrielawaai - IL

Naam	Omschr.	H-1	M-1	Hdef.	Cp	Refl.L 31	Refl.L 63	Refl.L 4k	Refl.L 8k	Refl.R 31	Refl.R 63	Refl.R 4k	Refl.R 8k
02E	Elektrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
02E	Elektrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos02E	Elektrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80
Porthos02E	Elektrogebouw	12,00	5,50	Eigen waarde	0 dB	0,80	0,80	0,80	0,80	0,80	0,80	0,80	0,80

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	X	Y	Hoogte	Maaiveld	Hdef.	Type	GeenRefl.	GeenDemping
01C-DV1	01C	Dakventilator compressorgebouw	62863,27	443830,59	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-DV2	01C	Dakventilator compressorgebouw	62868,84	443845,35	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-DV3	01C	Dakventilator compressorgebouw	62875,47	443858,69	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-R601	01C	Rooster compressorgebouw	62879,60	443825,32	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01C-R602	01C	Rooster compressorgebouw	62885,00	443839,16	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01C-R603	01C	Rooster compressorgebouw	62889,90	443851,80	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01C-V1	01C	Klep ingaand CO2	62902,21	443851,00	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-V2	01C	Klep ingaand CO2	62901,47	443849,25	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-V3	01C	Klep ingaand CO2	62896,51	443836,76	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-V4	01C	Klep ingaand CO2	62895,78	443835,07	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-V5	01C	Klep ingaand CO2	62890,71	443822,31	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01C-V6	01C	Klep ingaand CO2	62890,14	443820,69	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A1	01H	Airco regelgebouw	62955,56	443962,02	1,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A1	01H	Airco hoofdgebouw	62904,90	443970,54	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A2	01H	Airco regelgebouw	62969,55	443957,18	1,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A2	01H	Airco hoofdgebouw	62912,03	443967,75	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A3	01H	Airco hoofdgebouw	62920,39	443964,35	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A4	01H	Airco hoofdgebouw	62928,14	443960,94	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-A5	01H	Airco hoofdgebouw	62939,60	443957,22	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV1	01H	Dakventilator Hoofdgebouw	62904,04	443967,49	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV1	01H	Dakventilator regelgebouw	62951,25	443950,45	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV2	01H	Dakventilator Hoofdgebouw	62911,68	443964,12	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV2	01H	Dakventilator regelgebouw	62964,17	443945,87	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV3	01H	Dakventilator Hoofdgebouw	62920,21	443960,98	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV4	01H	Dakventilator Hoofdgebouw	62928,08	443957,83	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-DV5	01H	Dakventilator Hoofdgebouw	62938,86	443953,79	10,50	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-HVAC1	01H	Rooster HVAC	62944,79	443954,26	10,75	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01H-HVAC2	01H	Rooster HVAC	62972,85	443942,34	10,75	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01H-R1	01H	Rooster regelgebouw	62955,29	443959,87	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01H-R2	01H	Rooster regelgebouw	62968,25	443954,60	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01H-VSDS1	01H	Airco VSDS	62949,94	443962,53	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS2	01H	Airco VSDS	62951,84	443961,83	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS3	01H	Airco VSDS	62953,87	443961,13	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS4	01H	Airco VSDS	62955,78	443960,56	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS5	01H	Airco VSDS	62957,74	443959,92	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS6	01H	Airco VSDS	62967,71	443955,54	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS7	01H	Airco VSDS	62969,23	443954,91	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS8	01H	Airco VSDS	62970,50	443954,40	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01H-VSDS9	01H	Airco VSDS	62972,34	443953,58	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01N-DV1	01N	Dakventilator koelwaterpompengebouw	62858,38	443438,50	5,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01N-R1	01N	Rooster Koelwaterpompen gebouw	62847,37	443442,79	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01N-R2	01N	Rooster Koelwaterpompen gebouw	62865,98	443458,74	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01N-R3	01N	Rooster Koelwaterpompen gebouw	62869,42	443434,09	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01N-R4	01N	Rooster Koelwaterpompen gebouw	62850,60	443418,36	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Naam	Richt.	Hoek	Cb(D)	Cb(A)	Cb(N)	Lwr 31	Lwr 63	Lwr 125	Lwr 250	Lwr 500	Lwr 1k	Lwr 2k	Lwr 4k	Lwr 8k	Lwr Totaal
01C-DV1	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01C-DV2	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01C-DV3	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01C-R601	0,00	360,00	0,00	0,00	0,00	60,76	67,67	78,11	84,28	90,35	96,06	97,69	100,77	90,22	103,86
01C-R602	0,00	360,00	0,00	0,00	0,00	60,76	67,67	78,11	84,28	90,35	96,06	97,69	100,77	90,22	103,86
01C-R603	0,00	360,00	0,00	0,00	0,00	60,76	67,67	78,11	84,28	90,35	96,06	97,69	100,77	90,22	103,86
01C-V1	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01C-V2	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01C-V3	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01C-V4	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01C-V5	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01C-V6	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
01H-A1	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A1	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A2	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A2	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A3	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A4	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-A5	0,00	360,00	0,00	0,00	0,00	48,80	57,90	65,60	69,20	71,50	73,40	69,20	67,40	60,50	78,03
01H-DV1	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV1	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV2	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV2	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV3	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV4	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-DV5	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
01H-HVAC1	0,00	360,00	0,00	0,00	0,00	51,63	61,83	73,91	68,36	69,46	60,15	58,59	57,05	52,91	76,48
01H-HVAC2	0,00	360,00	0,00	0,00	0,00	51,63	61,83	73,91	68,36	69,46	60,15	58,59	57,05	52,91	76,48
01H-R1	0,00	360,00	0,00	0,00	0,00	45,70	56,30	66,80	70,50	80,20	82,60	76,60	68,30	58,00	85,52
01H-R2	0,00	360,00	0,00	0,00	0,00	45,70	56,30	66,80	70,50	80,20	82,60	76,60	68,30	58,00	85,52
01H-VSDS1	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS2	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS3	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS4	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS5	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS6	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS7	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS8	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01H-VSDS9	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01N-DV1	0,00	360,00	0,00	0,00	0,00	53,20	62,10	69,10	65,70	61,90	60,00	59,20	57,60	54,80	72,54
01N-R1	0,00	360,00	0,00	0,00	0,00	42,20	53,60	65,10	74,90	88,70	85,70	87,70	80,60	71,60	92,71
01N-R2	0,00	360,00	0,00	0,00	0,00	42,20	53,60	65,10	74,90	88,70	85,70	87,70	80,60	71,60	92,71
01N-R3	0,00	360,00	0,00	0,00	0,00	42,20	53,60	65,10	74,90	88,70	85,70	87,70	80,60	71,60	92,71
01N-R4	0,00	360,00	0,00	0,00	0,00	42,20	53,60	65,10	74,90	88,70	85,70	87,70	80,60	71,60	92,71

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	X	Y	Hoogte	Maaiveld	Hdef.	Type	GeenRefl.	GeenDemping
01P-DV1	01P	Dakventilator warmtewisselaargebouw	62896,07	443766,34	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01P-MV1	01P	Muurairco warmtewisselaargebouw	62888,80	443750,73	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01P-R1	01P	Rooster warmtewisselaargebouw	62886,10	443770,87	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01P-R2	01P	Rooster warmtewisselaargebouw	62900,81	443781,14	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01P-R3	01P	Rooster warmtewisselaargebouw	62905,25	443762,55	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01P-R4	01P	Rooster warmtewisselaargebouw	62888,32	443752,00	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
01R-VSDS10	01H	Airco VSDS	62974,76	443952,75	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-A1	02E	Muurairco elektrogebouw	62852,18	443804,88	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-A2	02E	Muurairco elektrogebouw	62837,93	443771,17	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-DV1	02E	Dakventilator elektrogebouw	62848,82	443792,60	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-DV2	02E	Dakventilator elektrogebouw	62845,11	443781,83	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-R1	02E	Rooster elektrogebouw	62853,92	443803,38	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
02E-R2	02E	Rooster elektrogebouw	62839,67	443771,40	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
02E-TR1	02E	Trafo + schakelaar elektrogebouw	62861,68	443786,58	8,70	5,50	Eigen waarde	Normale puntbron	Nee	Nee
02E-TR2	02E	Trafo + schakelaar elektrogebouw	62858,90	443777,31	8,70	5,50	Eigen waarde	Normale puntbron	Nee	Nee
01	startsituatie 01C	gevelventilator compressorgebouw	62897,20	443869,95	9,00	5,50	Eigen waarde	Normale puntbron	Ja	Nee
02	startsituatie 01C	gevelventilator compressorgebouw	62902,67	443883,76	9,00	5,50	Eigen waarde	Normale puntbron	Ja	Nee
03	startsituatie 01C	gevelventilator compressorgebouw	62907,66	443896,36	9,00	5,50	Eigen waarde	Normale puntbron	Ja	Nee
04	startsituatie 01C	Klep ingaand CO2	62919,29	443894,07	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
05	startsituatie 01C	Klep ingaand CO2	62918,55	443892,32	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
06	startsituatie 01C	Klep ingaand CO2	62913,59	443879,83	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
07	startsituatie 01C	Klep ingaand CO2	62912,86	443878,14	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
08	startsituatie 01C	Klep ingaand CO2	62907,79	443865,38	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
09	startsituatie 01C	Klep ingaand CO2	62907,22	443863,76	6,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
10	startsituatie 01C	Rooster compressorgebouw	62902,06	443882,23	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
11	startsituatie 01C	Rooster compressorgebouw	62896,60	443868,43	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
12	startsituatie 01C	Rooster compressorgebouw	62907,05	443894,84	9,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
13	Aramis	Muurairco warmtewisselaargebouw	62905,22	443787,97	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
14	Aramis	Dakventilator warmtewisselaargebouw	62912,49	443803,58	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
15	startsituatie 01P	Rooster warmtewisselaargebouw	62902,52	443808,11	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
16	startsituatie 01P	Rooster warmtewisselaargebouw	62917,23	443818,38	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
17	startsituatie 01P	Rooster warmtewisselaargebouw	62921,67	443799,79	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
18	startsituatie 01P	Rooster warmtewisselaargebouw	62904,74	443789,24	2,50	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
19	Aramis	Dakventilator elektrogebouw	62915,09	443845,53	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
20	Aramis	Dakventilator elektrogebouw	62911,38	443834,76	13,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
21	Aramis	Muurairco elektrogebouw	62918,45	443857,81	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
22	Aramis	Muurairco elektrogebouw	62904,20	443824,10	1,00	5,50	Eigen waarde	Normale puntbron	Nee	Nee
23	startsituatie 01E	Trafo + schakelaar elektrogebouw	62927,95	443839,51	8,70	5,50	Eigen waarde	Normale puntbron	Nee	Nee
24	startsituatie 01E	Trafo + schakelaar elektrogebouw	62925,17	443830,24	8,70	5,50	Eigen waarde	Normale puntbron	Nee	Nee
25	startsituatie 01E	Rooster elektrogebouw	62920,19	443856,31	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee
26	startsituatie 01E	Rooster elektrogebouw	62905,94	443824,33	6,00	5,50	Eigen waarde	Uitstralende gevel	Ja	Nee

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Puntbronnen, voor rekenmethode Industrielawaai - IL

Naam	Richt.	Hoek	Cb(D)	Cb(A)	Cb(N)	Lwr 31	Lwr 63	Lwr 125	Lwr 250	Lwr 500	Lwr 1k	Lwr 2k	Lwr 4k	Lwr 8k	Lwr Totaal
01P-DV1	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01P-MV1	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
01P-R1	0,00	360,00	0,00	0,00	0,00	39,20	50,60	62,10	71,90	85,70	82,70	84,70	77,60	68,60	89,71
01P-R2	0,00	360,00	0,00	0,00	0,00	39,20	50,60	62,10	71,90	85,70	82,70	84,70	77,60	68,60	89,71
01P-R3	0,00	360,00	0,00	0,00	0,00	39,20	50,60	62,10	71,90	85,70	82,70	84,70	77,60	68,60	89,71
01P-R4	0,00	360,00	0,00	0,00	0,00	39,20	50,60	62,10	71,90	85,70	82,70	84,70	77,60	68,60	89,71
01R-VSDS10	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
02E-A1	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
02E-A2	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
02E-DV1	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
02E-DV2	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
02E-R1	0,00	360,00	0,00	0,00	0,00	42,20	47,20	53,40	58,90	75,20	63,00	58,00	56,70	47,50	75,72
02E-R2	0,00	360,00	0,00	0,00	0,00	42,20	47,20	53,40	58,90	75,20	63,00	58,00	56,70	47,50	75,72
02E-TR1	0,00	360,00	0,00	0,00	0,00	47,60	60,40	68,80	73,70	72,20	77,30	75,50	75,20	68,40	82,50
02E-TR2	0,00	360,00	0,00	0,00	0,00	47,60	60,40	68,80	73,70	72,20	77,30	75,50	75,20	68,40	82,50
01	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
02	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
03	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
04	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
05	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
06	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
07	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
08	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
09	0,00	360,00	0,00	0,00	0,00	29,20	34,90	43,50	49,10	56,10	58,40	57,10	71,40	71,30	74,63
10	0,00	360,00	0,00	0,00	0,00	61,90	74,60	81,70	83,20	86,60	85,80	86,00	92,80	85,70	95,91
11	0,00	360,00	0,00	0,00	0,00	61,90	74,60	81,70	83,20	86,60	85,80	86,00	92,80	85,70	95,91
12	0,00	360,00	0,00	0,00	0,00	61,90	74,60	81,70	83,20	86,60	85,80	86,00	92,80	85,70	95,91
13	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
14	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
15	0,00	360,00	0,00	0,00	0,00	43,20	54,60	66,10	75,90	89,70	86,70	88,70	81,60	72,60	93,71
16	0,00	360,00	0,00	0,00	0,00	43,20	54,60	66,10	75,90	89,70	86,70	88,70	81,60	72,60	93,71
17	0,00	360,00	0,00	0,00	0,00	43,20	54,60	66,10	75,90	89,70	86,70	88,70	81,60	72,60	93,71
18	0,00	360,00	0,00	0,00	0,00	43,20	54,60	66,10	75,90	89,70	86,70	88,70	81,60	72,60	93,71
19	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
20	0,00	360,00	0,00	0,00	0,00	50,20	59,10	66,10	62,70	58,90	57,00	56,20	54,60	51,80	69,54
21	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
22	0,00	360,00	0,00	0,00	0,00	35,80	44,90	52,60	56,20	58,50	60,40	56,20	54,40	47,50	65,03
23	0,00	360,00	0,00	0,00	0,00	47,60	60,40	68,80	73,70	72,20	77,30	75,50	75,20	68,40	82,50
24	0,00	360,00	0,00	0,00	0,00	47,60	60,40	68,80	73,70	72,20	77,30	75,50	75,20	68,40	82,50
25	0,00	360,00	0,00	0,00	0,00	42,20	47,20	53,40	58,90	75,20	63,00	58,00	56,70	47,50	75,72
26	0,00	360,00	0,00	0,00	0,00	42,20	47,20	53,40	58,90	75,20	63,00	58,00	56,70	47,50	75,72

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	H-1	M-1	Hdef.	Lengte	Cb(D)	Cb(A)	Cb(N)	LwrM 31	LwrM 63	LwrM 125
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	14,22	0,00	0,00	0,00	25,73	30,17	35,17
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	14,88	0,00	0,00	0,00	25,53	29,97	34,97
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	1,14	0,00	0,00	0,00	28,99	33,43	38,43
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	13,09	0,00	0,00	0,00	26,09	30,53	35,53
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	12,88	0,00	0,00	0,00	26,16	30,60	35,60
01C-L1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	13,20	0,00	0,00	0,00	26,05	30,49	35,49
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	11,11	0,00	0,00	0,00	26,80	31,24	36,24
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	14,21	0,00	0,00	0,00	25,73	30,17	35,17
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	10,04	0,00	0,00	0,00	27,06	31,50	36,50
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	10,90	0,00	0,00	0,00	26,89	31,33	36,33
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	11,18	0,00	0,00	0,00	26,78	31,22	36,22
01C-L2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	14,75	0,00	0,00	0,00	25,57	30,01	35,01
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	14,83	0,00	0,00	0,00	25,55	29,99	34,99
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	1,63	0,00	0,00	0,00	34,50	38,94	43,94
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	9,09	0,00	0,00	0,00	27,68	32,12	37,12
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	8,95	0,00	0,00	0,00	27,74	32,18	37,18
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	9,45	0,00	0,00	0,00	27,51	31,95	36,95
01C-L3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	14,61	0,00	0,00	0,00	25,61	30,05	35,05
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	14,37	0,00	0,00	0,00	25,69	30,13	35,13
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	14,79	0,00	0,00	0,00	25,56	30,00	35,00
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	3,43	0,00	0,00	0,00	31,59	36,03	41,03
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,18	0,00	0,00	0,00	28,70	33,14	38,14
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,04	0,00	0,00	0,00	28,78	33,22	38,22
01C-L4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,01	0,00	0,00	0,00	28,80	33,24	38,24
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	5,52	0,00	0,00	0,00	29,84	34,28	39,28
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,76	0,00	0,00	0,00	25,57	30,01	35,01
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,08	0,00	0,00	0,00	25,77	30,21	35,21
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	8,11	0,00	0,00	0,00	28,07	32,51	37,51
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	5,44	0,00	0,00	0,00	29,91	34,35	39,35
01C-L5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	4,95	0,00	0,00	0,00	30,32	34,76	39,76
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	10,43	0,00	0,00	0,00	26,99	31,43	36,43
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,30	0,00	0,00	0,00	25,71	30,15	35,15
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,38	0,00	0,00	0,00	31,98	36,42	41,42
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,23	0,00	0,00	0,00	32,17	36,61	41,61
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	13,96	0,00	0,00	0,00	25,81	30,25	35,25
01C-L6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,31	0,00	0,00	0,00	32,06	36,50	41,50
01C-LB1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,83	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,49	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,97	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,56	0,00	0,00	0,00	64,31	66,91	66,51

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	LwrM 250	LwrM 500	LwrM 1k	LwrM 2k	LwrM 4k	LwrM 8k	LwrM Totaal
01C-L1	44,33	55,54	58,32	54,96	50,86	40,27	61,80
01C-L1	44,13	55,34	58,12	54,76	50,66	40,07	61,60
01C-L1	47,59	58,80	61,58	58,22	54,12	43,53	65,06
01C-L1	44,69	55,90	58,68	55,32	51,22	40,63	62,16
01C-L1	44,76	55,97	58,75	55,39	51,29	40,70	62,23
01C-L1	44,65	55,86	58,64	55,28	51,18	40,59	62,12
01C-L2	45,40	56,61	59,39	56,03	51,93	41,34	62,87
01C-L2	44,33	55,54	58,32	54,96	50,86	40,27	61,80
01C-L2	45,66	56,87	59,65	56,29	52,19	41,60	63,13
01C-L2	45,49	56,70	59,48	56,12	52,02	41,43	62,96
01C-L2	45,38	56,59	59,37	56,01	51,91	41,32	62,85
01C-L2	44,17	55,38	58,16	54,80	50,70	40,11	61,64
01C-L3	44,15	55,36	58,14	54,78	50,68	40,09	61,62
01C-L3	53,10	64,31	67,09	63,73	59,63	49,04	70,57
01C-L3	46,28	57,49	60,27	56,91	52,81	42,22	63,75
01C-L3	46,34	57,55	60,33	56,97	52,87	42,28	63,81
01C-L3	46,11	57,32	60,10	56,74	52,64	42,05	63,58
01C-L3	44,21	55,42	58,20	54,84	50,74	40,15	61,68
01C-L4	44,29	55,50	58,28	54,92	50,82	40,23	61,76
01C-L4	44,16	55,37	58,15	54,79	50,69	40,10	61,63
01C-L4	50,19	61,40	64,18	60,82	56,72	46,13	67,66
01C-L4	47,30	58,51	61,29	57,93	53,83	43,24	64,77
01C-L4	47,38	58,59	61,37	58,01	53,91	43,32	64,85
01C-L4	47,40	58,61	61,39	58,03	53,93	43,34	64,87
01C-L5	48,44	59,65	62,43	59,07	54,97	44,38	65,91
01C-L5	44,17	55,38	58,16	54,80	50,70	40,11	61,64
01C-L5	44,37	55,58	58,36	55,00	50,90	40,31	61,84
01C-L5	46,67	57,88	60,66	57,30	53,20	42,61	64,14
01C-L5	48,51	59,72	62,50	59,14	55,04	44,45	65,98
01C-L5	48,92	60,13	62,91	59,55	55,45	44,86	66,39
01C-L6	45,59	56,80	59,58	56,22	52,12	41,53	63,06
01C-L6	44,31	55,52	58,30	54,94	50,84	40,25	61,78
01C-L6	50,58	61,79	64,57	61,21	57,11	46,52	68,05
01C-L6	50,77	61,98	64,76	61,40	57,30	46,71	68,24
01C-L6	44,41	55,62	58,40	55,04	50,94	40,35	61,88
01C-L6	50,66	61,87	64,65	61,29	57,19	46,60	68,13
01C-LB1	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB1	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB1	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB1	69,61	81,71	89,81	91,11	86,31	74,11	94,58

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	H-1	M-1	Hdef.	Lengte	Cb(D)	Cb(A)	Cb(N)	LwrM 31	LwrM 63	LwrM 125
01C-LB1	01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,87	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,93	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,44	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,76	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,47	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB2	01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,84	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,82	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,33	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,97	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,85	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB3	01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,50	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,87	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,46	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,44	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,79	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB4	01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,90	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,43	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,86	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,52	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,92	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB5	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,83	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,54	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,95	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,91	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,92	0,00	0,00	0,00	64,31	66,91	66,51
01C-LB6	01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,47	0,00	0,00	0,00	64,31	66,91	66,51
01	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	13,20	0,00	0,00	0,00	28,93	33,37	38,37
02	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	13,09	0,00	0,00	0,00	28,93	33,37	38,37
03	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	12,88	0,00	0,00	0,00	28,93	33,37	38,37
04	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	10,04	0,00	0,00	0,00	28,93	33,37	38,37
05	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	10,90	0,00	0,00	0,00	28,93	33,37	38,37
06	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	11,18	0,00	0,00	0,00	28,93	33,37	38,37
07	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	9,45	0,00	0,00	0,00	28,93	33,37	38,37
08	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	8,95	0,00	0,00	0,00	28,93	33,37	38,37
09	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	9,09	0,00	0,00	0,00	28,93	33,37	38,37
10	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,01	0,00	0,00	0,00	28,93	33,37	38,37
11	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,04	0,00	0,00	0,00	28,93	33,37	38,37
12	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	7,18	0,00	0,00	0,00	28,93	33,37	38,37
13	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	5,52	0,00	0,00	0,00	28,93	33,37	38,37
14	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	5,44	0,00	0,00	0,00	28,93	33,37	38,37

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	LwrM 250	LwrM 500	LwrM 1k	LwrM 2k	LwrM 4k	LwrM 8k	LwrM Totaal
01C-LB1	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB2	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB2	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB2	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB2	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB2	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB3	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB3	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB3	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB3	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB3	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB4	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB4	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB4	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB4	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB4	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB5	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB5	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB5	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB5	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB5	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB6	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB6	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB6	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB6	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01C-LB6	69,61	81,71	89,81	91,11	86,31	74,11	94,58
01	47,53	58,74	61,52	58,16	54,06	43,47	65,00
02	47,53	58,74	61,52	58,16	54,06	43,47	65,00
03	47,53	58,74	61,52	58,16	54,06	43,47	65,00
04	47,53	58,74	61,52	58,16	54,06	43,47	65,00
05	47,53	58,74	61,52	58,16	54,06	43,47	65,00
06	47,53	58,74	61,52	58,16	54,06	43,47	65,00
07	47,53	58,74	61,52	58,16	54,06	43,47	65,00
08	47,53	58,74	61,52	58,16	54,06	43,47	65,00
09	47,53	58,74	61,52	58,16	54,06	43,47	65,00
10	47,53	58,74	61,52	58,16	54,06	43,47	65,00
11	47,53	58,74	61,52	58,16	54,06	43,47	65,00
12	47,53	58,74	61,52	58,16	54,06	43,47	65,00
13	47,53	58,74	61,52	58,16	54,06	43,47	65,00
14	47,53	58,74	61,52	58,16	54,06	43,47	65,00

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	H-1	M-1	Hdef.	Lengte	Cb(D)	Cb(A)	Cb(N)	LwrM 31	LwrM 63	LwrM 125
15	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	4,95	0,00	0,00	0,00	28,93	33,37	38,37
16	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,31	0,00	0,00	0,00	28,93	33,37	38,37
17	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,38	0,00	0,00	0,00	28,93	33,37	38,37
18	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	3,23	0,00	0,00	0,00	28,93	33,37	38,37
19	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,91	0,00	0,00	0,00	28,93	33,37	38,37
20	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	13,96	0,00	0,00	0,00	28,93	33,37	38,37
21	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,92	0,00	0,00	0,00	28,93	33,37	38,37
22	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,08	0,00	0,00	0,00	28,93	33,37	38,37
23	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,93	0,00	0,00	0,00	28,93	33,37	38,37
24	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	11,11	0,00	0,00	0,00	28,93	33,37	38,37
25	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,90	0,00	0,00	0,00	28,93	33,37	38,37
26	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	14,37	0,00	0,00	0,00	28,93	33,37	38,37
27	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,85	0,00	0,00	0,00	28,93	33,37	38,37
28	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	14,61	0,00	0,00	0,00	28,93	33,37	38,37
29	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,97	0,00	0,00	0,00	28,93	33,37	38,37
30	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	14,22	0,00	0,00	0,00	28,93	33,37	38,37
31	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,47	0,00	0,00	0,00	28,93	33,37	38,37
32	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,84	0,00	0,00	0,00	28,93	33,37	38,37
33	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	14,21	0,00	0,00	0,00	28,93	33,37	38,37
34	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,95	0,00	0,00	0,00	28,93	33,37	38,37
35	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,30	0,00	0,00	0,00	28,93	33,37	38,37
36	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,47	0,00	0,00	0,00	28,93	33,37	38,37
37	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,43	0,00	0,00	0,00	28,93	33,37	38,37
38	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,86	0,00	0,00	0,00	28,93	33,37	38,37
39	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	14,76	0,00	0,00	0,00	28,93	33,37	38,37
40	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,44	0,00	0,00	0,00	28,93	33,37	38,37
41	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,79	0,00	0,00	0,00	28,93	33,37	38,37
42	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	14,79	0,00	0,00	0,00	28,93	33,37	38,37
43	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,50	0,00	0,00	0,00	28,93	33,37	38,37
44	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,82	0,00	0,00	0,00	28,93	33,37	38,37
45	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	14,83	0,00	0,00	0,00	28,93	33,37	38,37
46	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,49	0,00	0,00	0,00	28,93	33,37	38,37
47	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,83	0,00	0,00	0,00	28,93	33,37	38,37
48	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	14,88	0,00	0,00	0,00	28,93	33,37	38,37
49	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,44	0,00	0,00	0,00	28,93	33,37	38,37
50	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	0,76	0,00	0,00	0,00	28,93	33,37	38,37
51	startsituatie 01C	Ingaande CO2 leiding	3,00	5,50	Eigen waarde	14,75	0,00	0,00	0,00	28,93	33,37	38,37
52	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,54	0,00	0,00	0,00	28,93	33,37	38,37
53	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,92	0,00	0,00	0,00	28,93	33,37	38,37
54	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	10,43	0,00	0,00	0,00	28,93	33,37	38,37

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	LwrM 250	LwrM 500	LwrM 1k	LwrM 2k	LwrM 4k	LwrM 8k	LwrM Totaal
15	47,53	58,74	61,52	58,16	54,06	43,47	65,00
16	47,53	58,74	61,52	58,16	54,06	43,47	65,00
17	47,53	58,74	61,52	58,16	54,06	43,47	65,00
18	47,53	58,74	61,52	58,16	54,06	43,47	65,00
19	47,53	58,74	61,52	58,16	54,06	43,47	65,00
20	47,53	58,74	61,52	58,16	54,06	43,47	65,00
21	47,53	58,74	61,52	58,16	54,06	43,47	65,00
22	47,53	58,74	61,52	58,16	54,06	43,47	65,00
23	47,53	58,74	61,52	58,16	54,06	43,47	65,00
24	47,53	58,74	61,52	58,16	54,06	43,47	65,00
25	47,53	58,74	61,52	58,16	54,06	43,47	65,00
26	47,53	58,74	61,52	58,16	54,06	43,47	65,00
27	47,53	58,74	61,52	58,16	54,06	43,47	65,00
28	47,53	58,74	61,52	58,16	54,06	43,47	65,00
29	47,53	58,74	61,52	58,16	54,06	43,47	65,00
30	47,53	58,74	61,52	58,16	54,06	43,47	65,00
31	47,53	58,74	61,52	58,16	54,06	43,47	65,00
32	47,53	58,74	61,52	58,16	54,06	43,47	65,00
33	47,53	58,74	61,52	58,16	54,06	43,47	65,00
34	47,53	58,74	61,52	58,16	54,06	43,47	65,00
35	47,53	58,74	61,52	58,16	54,06	43,47	65,00
36	47,53	58,74	61,52	58,16	54,06	43,47	65,00
37	47,53	58,74	61,52	58,16	54,06	43,47	65,00
38	47,53	58,74	61,52	58,16	54,06	43,47	65,00
39	47,53	58,74	61,52	58,16	54,06	43,47	65,00
40	47,53	58,74	61,52	58,16	54,06	43,47	65,00
41	47,53	58,74	61,52	58,16	54,06	43,47	65,00
42	47,53	58,74	61,52	58,16	54,06	43,47	65,00
43	47,53	58,74	61,52	58,16	54,06	43,47	65,00
44	47,53	58,74	61,52	58,16	54,06	43,47	65,00
45	47,53	58,74	61,52	58,16	54,06	43,47	65,00
46	47,53	58,74	61,52	58,16	54,06	43,47	65,00
47	47,53	58,74	61,52	58,16	54,06	43,47	65,00
48	47,53	58,74	61,52	58,16	54,06	43,47	65,00
49	47,53	58,74	61,52	58,16	54,06	43,47	65,00
50	47,53	58,74	61,52	58,16	54,06	43,47	65,00
51	47,53	58,74	61,52	58,16	54,06	43,47	65,00
52	47,53	58,74	61,52	58,16	54,06	43,47	65,00
53	47,53	58,74	61,52	58,16	54,06	43,47	65,00
54	47,53	58,74	61,52	58,16	54,06	43,47	65,00

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	Groep	Omschr.	H-1	M-1	Hdef.	Lengte	Cb(D)	Cb(A)	Cb(N)	LwrM 31	LwrM 63	LwrM 125
55	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,52	0,00	0,00	0,00	28,93	33,37	38,37
56	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	0,83	0,00	0,00	0,00	28,93	33,37	38,37
57	startsituatie 01C	Coolerleiding e-motor/smeerolie	0,50	5,50	Eigen waarde	8,11	0,00	0,00	0,00	28,93	33,37	38,37
58	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,46	0,00	0,00	0,00	28,93	33,37	38,37
59	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	0,87	0,00	0,00	0,00	28,93	33,37	38,37
60	startsituatie 01C	Ingaande coolerleiding	0,50	5,50	Eigen waarde	3,43	0,00	0,00	0,00	28,93	33,37	38,37
61	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,33	0,00	0,00	0,00	28,93	33,37	38,37
62	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	0,97	0,00	0,00	0,00	28,93	33,37	38,37
63	startsituatie 01C	Uigaande coolerleiding	0,50	5,50	Eigen waarde	1,63	0,00	0,00	0,00	28,93	33,37	38,37
64	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,56	0,00	0,00	0,00	28,93	33,37	38,37
65	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	0,87	0,00	0,00	0,00	28,93	33,37	38,37
66	startsituatie 01C	Uitgaande CO2 leiding	6,00	5,50	Eigen waarde	1,14	0,00	0,00	0,00	28,93	33,37	38,37

Model: Kopie van VRY-2306739 (Aramis CCS)
Groep: compressorstation
Lijst van Lijnbronnen, voor rekenmethode Industrielawaai - IL

Naam	LwrM 250	LwrM 500	LwrM 1k	LwrM 2k	LwrM 4k	LwrM 8k	LwrM Totaal
55	47,53	58,74	61,52	58,16	54,06	43,47	65,00
56	47,53	58,74	61,52	58,16	54,06	43,47	65,00
57	47,53	58,74	61,52	58,16	54,06	43,47	65,00
58	47,53	58,74	61,52	58,16	54,06	43,47	65,00
59	47,53	58,74	61,52	58,16	54,06	43,47	65,00
60	47,53	58,74	61,52	58,16	54,06	43,47	65,00
61	47,53	58,74	61,52	58,16	54,06	43,47	65,00
62	47,53	58,74	61,52	58,16	54,06	43,47	65,00
63	47,53	58,74	61,52	58,16	54,06	43,47	65,00
64	47,53	58,74	61,52	58,16	54,06	43,47	65,00
65	47,53	58,74	61,52	58,16	54,06	43,47	65,00
66	47,53	58,74	61,52	58,16	54,06	43,47	65,00

EQUIPMENT NOISE DATE SHEET

Notes

Acoustical definitions, methods in accordance with **ISO 9614, ISO 11203**

[1]Data Source Codes: A) Noise Test identical equipment B) Ncise Test similar equipment C) Estimation VDI 2159 / VDI 3731 or similar
[2]The reference surface is typically a cuboid enclosing the component in 1m distance from the machine surface or base frame, see layout. Dimensions are given in length, width, height (L x W x H). If the component is located inside a noise control enclosure the size of the enclosure is given.
[3]Octave band values are un-weighted levels at the given center frequencies.
[4]The sum value is the A-weighted overall level.
Lw is Sound Power Level in decibels re 1E-12 Watts according to ISO 9614.
Lp is Sound Pressure Level in decibels re 20 μPa on a measurement surface fully enclosing the component according to ISO 11203. Sound pressure level is a geometric mean value under free-field conditions.
Octave band levels are in un-weighted decibels. Noise test according to MAN Noise Test Specification 10001026174.
Upper tolerance is 3.0 dB, uncertainly of measurement due to measuring procedure in accordance to EN ISO 9614-2.
Connected piping (incl. silencers) with noise control insulation, insertion loss Class C according to ISO 15665.
Noise control insulation of the connected piping (incl. silencers) is not within the scope of MAN Energy Solutions.

Train Configuration

Component	Operation Point	Power [kW]	Inside Enclosure	Data Source[1]	Distance	Size[2] L x W x H [m]
E-Motor typical	Normal	8600	no	B	1.0	3.6 x 2.8 x 2.8
Compressor RG28-6 incl. insulated pipes and coolers	Rated	7803	no	B	1.0	11.0 x 13.2 x 7.5
Lube Oil System	Normal	-	no	B	1.0	3.0 x 5.8 x 4.7
Train	-	-	-	-	1.0	20.4 x 14.4 x 7.5

Components		dB/Hz[3]	63	125	250	500	1k	2k	4k	8k	Sum dB(A)[4]
E-Motor (preliminary)	Casing	Lw	101	106	98	98	95	102	83	74	**105**
		Lp	81	86	78	78	75	83	63	54	**85**
RG28-6 incl. insulated pipes and coolers	Casing	Lw	120	122	120	111	111	110	116	110	**120**
		Lp	92	93	91	83	83	81	87	82	**92**
Lube Oil System (preliminary)	Casing	Lw	68	70	78	86	93	96	105	102	**108**
		Lp	45	47	55	63	70	73	82	79	**85**

Train		dB/Hz[3]	63	125	250	500	1k	2k	4k	8k	Sum dB(A)[4]
Train	With insulated pipes	Lw	120	122	120	112	111	111	116	111	**121**
		Lp	90	92	89	82	81	81	86	81	**90**
Measuring procedure in accordance to ISO 9614-2. Uncertainly of measurement is +/- 3dB, refer to ISO 9614-2 chapter 4.3											

Rapport: Resultatentabel
Model: Kopie van VRY-2306739 (Aramis CCS)
LAeq totaalresultaten voor toetspunten
Groep: compressorstation
Groepsreductie: Ja

Naam Toetspunt	Omschrijving	Hoogte	Dag	Avond	Nacht	Etmaal	Li
100_A	HvH duin	5,00	5,46	5,46	5,46	15,46	12,10
101_A	HvH Rivierkant	15,00	7,81	7,81	7,81	17,81	14,07
102_A	HvH K.Emmablvd	15,00	6,00	6,00	6,00	16,00	12,79
103_A	HvH Berghaven	15,00	4,79	4,79	4,79	14,79	11,94
104_A	HvH Pastoor Onderwaterstraat	15,00	3,46	3,46	3,46	13,46	10,59
105_A	HvH Pastoor Onderwaterstraat	15,00	2,68	2,68	2,68	12,68	9,99
106_A	HvH Krimsloot	15,00	2,03	2,03	2,03	12,03	9,46
107_A	HvH Maeslandkeringweg(1)	15,00	0,36	0,36	0,36	10,36	7,93
108_A	HvH Maeslandkeringweg(2)	15,00	-1,06	-1,06	-1,06	8,94	6,55
109_A	HvH Maeslandkering	15,00	-2,67	-2,67	-2,67	7,33	4,97
110_A	HvH Nieuw Oranjekanaal	15,00	-3,80	-3,80	-3,80	6,20	3,69
111_A	Oranjebuitenpolder(1)	15,00	-5,08	-5,08	-5,08	4,92	2,08
112_A	Oranjebuitenpolder(2)	15,00	-5,80	-5,80	-5,80	4,20	1,26
113_A	Oranjebuitenpolder(3)	15,00	-6,60	-6,60	-6,60	3,40	0,38
114_A	Oranjebuitenpolder(4)	15,00	-7,49	-7,49	-7,49	2,51	-0,56
200_A	Maassluis Schenkeldijk	15,00	-8,23	-8,23	-8,23	1,77	-1,29
201_A	Maassluis KWA Boulevard(1)	15,00	-8,77	-8,77	-8,77	1,23	-1,85
202_A	Maassluis Kwartellaan	15,00	-9,53	-9,53	-9,53	0,47	-2,95
203_A	Maassluis Nachtegaallaan	15,00	-9,99	-9,99	-9,99	0,01	-3,47
204_A	Maassluis Hoekwant	15,00	-10,67	-10,67	-10,67	-0,67	-4,24
205_A	Maassluis Vuurbaak	15,00	-11,02	-11,02	-11,02	-1,02	-4,67
206_A	Maassluis Het Scheur	15,00	-10,84	-10,84	-10,84	-0,84	-4,60
207z_A	Maasland Parallelweg (zonegrens)	5,00	-11,58	-11,58	-11,58	-1,58	-4,26
208z_A	Maassluis Geerkade (zonegrens)	5,00	-12,39	-12,39	-12,39	-2,39	-5,92
209z_A	Maassluis (zonegrens, 5m boven wal)	5,00	-12,47	-12,47	-12,47	-2,47	-6,19
300_A	Rozenburg Boulevard (fietspad)	10,00	-11,02	-11,02	-11,02	-1,02	-4,86
301_A	Rozenburg Vinkseweg	15,00	-10,98	-10,98	-10,98	-0,98	-4,85
302_A	Rozenburg Zandweg 14	15,00	-10,93	-10,93	-10,93	-0,93	-4,82
303_A	Rozenburg volkstuinen	15,00	-11,05	-11,05	-11,05	-1,05	-4,95
304_A	Rozenburg De Noordbank	15,00	-11,16	-11,16	-11,16	-1,16	-5,06
305_A	Rozenburg De Krabbe	15,00	-11,11	-11,11	-11,11	-1,11	-5,06
306_A	Rozenburg De Bongerd	15,00	-11,19	-11,19	-11,19	-1,19	-5,13
307_A	Rozenburg Balsemien	15,00	-11,32	-11,32	-11,32	-1,32	-5,26
308_A	Rozenburg Vinkseweg	15,00	-11,33	-11,33	-11,33	-1,33	-5,28
309_A	Rozenburg De Bieslook	15,00	-11,62	-11,62	-11,62	-1,62	-5,57
310_A	Rozenburg Droespolderweg	15,00	-11,58	-11,58	-11,58	-1,58	-5,59
311_A	Rozenburg A15	10,00	-11,98	-11,98	-11,98	-1,98	-5,97
312z_A	Botlek (zonegrens, 5m boven kade)	5,00	-11,92	-11,92	-11,92	-1,92	-5,90
313z_A	Botlek (zonegrens, 5m boven wal)	5,00	-11,94	-11,94	-11,94	-1,94	-5,88
400z_A	Zwartewaal Zalmlaan (zonegrens, 5m boven wal)	5,00	-11,98	-11,98	-11,98	-1,98	-5,90
401_A	Zwartewaal Buitengronden	5,00	-11,67	-11,67	-11,67	-1,67	-5,62
402_A	Brielle Buitengronden	10,00	-10,80	-10,80	-10,80	-0,80	-4,75
403_A	Brielle Geuzenkreek	10,00	-9,26	-9,26	-9,26	0,74	-3,23
404_A	Brielle Vierpolders	10,00	-8,47	-8,47	-8,47	1,53	-2,42
405_A	Brielle Veer	10,00	-7,72	-7,72	-7,72	2,28	-1,69
406_A	Brielle Oosterlandsedijk	10,00	-5,91	-5,91	-5,91	4,09	0,09
407_A	Brielle Oosterlandseweg	10,00	-3,97	-3,97	-3,97	6,03	1,98
500_A	Oostvoorne, Bollaarsdijk	10,00	-2,40	-2,40	-2,40	7,60	3,80
501_A	Oostvoorne Maasweg	10,00	-1,10	-1,10	-1,10	8,90	5,17
502_A	Oostvoorne Kamplaan	10,00	-0,93	-0,93	-0,93	9,07	5,70
503_A	Oostvoorne Koepelweg	10,00	0,87	0,87	0,87	10,87	7,10
504_A	Oostvoorne Zwartelaan	10,00	1,01	1,01	1,01	11,01	6,99
505_A	Oostvoorne, Zandweg	10,00	0,24	0,24	0,24	10,24	6,18
506_A	Oostvoorne Duinen	10,00	-0,25	-0,25	-0,25	9,75	5,75
507z_A	Oostvoorne Breede Water (zonegrens)	5,00	-0,93	-0,93	-0,93	9,07	5,12
508z_A	Oostvoorne zeewering (zonegrens)	5,00	1,01	1,01	1,01	11,01	7,19
600z_A	Noordzee (zonegrens)	5,00	0,32	0,32	0,32	10,32	6,66
601z_A	Noordzee (zonegrens)	5,00	0,41	0,41	0,41	10,41	6,74
602z_A	Noordzee (zonegrens)	5,00	-1,72	-1,72	-1,72	8,28	4,20
603z_A	Noordzee (zonegrens)	5,00	-2,75	-2,75	-2,75	7,25	3,16
604z_A	Noordzee (zonegrens)	5,00	-1,62	-1,62	-1,62	8,38	3,95

Alle getoonde dB-waarden zijn A-gewogen

Rapport: Resultatentabel
Model: Kopie van VRY-2306739 (Aramis CCS)
LAeq totaalresultaten voor toetspunten
Groep: compressorstation
Groepsreductie: Ja

Naam Toetspunt	Omschrijving	Hoogte	Dag	Avond	Nacht	Etmaal	Li
605z_A	Noordzee (zonegrens)	5,00	-1,61	-1,61	-1,61	8,39	3,91
606z_A	Noordzee (zonegrens)	5,00	-0,29	-0,29	-0,29	9,71	6,46
607z_A	Noordzee (zonegrens)	5,00	-0,03	-0,03	-0,03	9,97	6,12
608z_A	Noordzee (zonegrens)	5,00	1,91	1,91	1,91	11,91	7,23
609z_A	Noordzee (zonegrens)	5,00	4,39	4,39	4,39	14,39	9,87
610z_A	Noordzee (zonegrens)	5,00	4,60	4,60	4,60	14,60	9,75
611z_A	Noordzee (zonegrens)	5,00	6,64	6,64	6,64	16,64	11,79
612z_A	Noordzee (zonegrens)	5,00	11,33	11,33	11,33	21,33	17,23
613z_A	Noordzee (zonegrens)	5,00	7,56	7,56	7,56	17,56	14,11
Krim2_A	Krimweg 2 Oostvoorne (woning)	1,50	-0,21	-0,21	-0,21	9,79	6,07
Krim4_A	Krimweg 4 Oostvoorne (woning)	1,50	-0,25	-0,25	-0,25	9,75	6,03
Krim6_A	Krimweg 6 Oostvoorne (woning)	1,50	-0,55	-0,55	-0,55	9,45	5,79
Staal05_A	Staaldiepseweg 5 Brielle (woning)	5,00	-10,45	-10,45	-10,45	-0,45	-4,40
Staal06_A	Staaldiepseweg 6 Brielle (woning)	5,00	-10,45	-10,45	-10,45	-0,45	-4,40
Staal07_A	Staaldiepseweg 7 Brielle (woning)	5,00	-10,43	-10,43	-10,43	-0,43	-4,38
Staal08_A	Staaldiepseweg 8 Brielle (woning)	5,00	-10,39	-10,39	-10,39	-0,39	-4,34
Staal09_A	Staaldiepseweg 9 Brielle (woning)	5,00	-10,37	-10,37	-10,37	-0,37	-4,32
Staal10_A	Staaldiepseweg 10 Brielle (woning)	5,00	-10,38	-10,38	-10,38	-0,38	-4,32
Staal11_A	Staaldiepseweg 11 Brielle (woning)	5,00	-10,33	-10,33	-10,33	-0,33	-4,28
Staal12_A	Staaldiepseweg 12 Brielle (woning)	5,00	-10,29	-10,29	-10,29	-0,29	-4,24
Staal13_A	Staaldiepseweg 13 Brielle (woning)	5,00	-10,27	-10,27	-10,27	-0,27	-4,22
Staal14_A	Staaldiepseweg 14 Brielle (woning)	5,00	-10,24	-10,24	-10,24	-0,24	-4,19

Alle getoonde dB-waarden zijn A-gewogen

Rapport: Resultatentabel
Model: Kopie van VRY-2306739 (Aramis CCS)
LAeq totaalresultaten voor toetspunten
Groep: compressorstation
Groepsreductie: Nee

Naam Toetspunt	Omschrijving	Hoogte	Dag	Avond	Nacht	Etmaal	Li
100_A	HvH duin	5,00	7,21	7,21	7,21	17,21	12,10
101_A	HvH Rivierkant	15,00	9,33	9,33	9,33	19,33	14,07
102_A	HvH K.Emmablvd	15,00	8,02	8,02	8,02	18,02	12,79
103_A	HvH Berghaven	15,00	7,15	7,15	7,15	17,15	11,94
104_A	HvH Pastoor Onderwaterstraat	15,00	5,79	5,79	5,79	15,79	10,59
105_A	HvH Pastoor Onderwaterstraat	15,00	5,17	5,17	5,17	15,17	9,99
106_A	HvH Krimsloot	15,00	4,63	4,63	4,63	14,63	9,46
107_A	HvH Maeslandkeringweg(1)	15,00	3,09	3,09	3,09	13,09	7,93
108_A	HvH Maeslandkeringweg(2)	15,00	1,70	1,70	1,70	11,70	6,55
109_A	HvH Maeslandkering	15,00	0,10	0,10	0,10	10,10	4,97
110_A	HvH Nieuw Oranjekanaal	15,00	-1,18	-1,18	-1,18	8,82	3,69
111_A	Oranjebuitenpolder(1)	15,00	-2,80	-2,80	-2,80	7,20	2,08
112_A	Oranjebuitenpolder(2)	15,00	-3,63	-3,63	-3,63	6,37	1,26
113_A	Oranjebuitenpolder(3)	15,00	-4,52	-4,52	-4,52	5,48	0,38
114_A	Oranjebuitenpolder(4)	15,00	-5,46	-5,46	-5,46	4,54	-0,56
200_A	Maassluis Schenkeldijk	15,00	-6,20	-6,20	-6,20	3,80	-1,29
201_A	Maassluis KWA Boulevard(1)	15,00	-6,77	-6,77	-6,77	3,23	-1,85
202_A	Maassluis Kwartellaan	15,00	-7,87	-7,87	-7,87	2,13	-2,95
203_A	Maassluis Nachtegaallaan	15,00	-8,39	-8,39	-8,39	1,61	-3,47
204_A	Maassluis Hoekwant	15,00	-9,16	-9,16	-9,16	0,84	-4,24
205_A	Maassluis Vuurbaak	15,00	-9,59	-9,59	-9,59	0,41	-4,67
206_A	Maassluis Het Scheur	15,00	-9,53	-9,53	-9,53	0,47	-4,60
207z_A	Maasland Parallelweg (zonegrens)	5,00	-9,22	-9,22	-9,22	0,78	-4,26
208z_A	Maassluis Geerkade (zonegrens)	5,00	-10,88	-10,88	-10,88	-0,88	-5,92
209z_A	Maassluis (zonegrens, 5m boven wal)	5,00	-11,15	-11,15	-11,15	-1,15	-6,19
300_A	Rozenburg Boulevard (fietspad)	10,00	-9,80	-9,80	-9,80	0,20	-4,86
301_A	Rozenburg Vinkseweg	15,00	-9,78	-9,78	-9,78	0,22	-4,85
302_A	Rozenburg Zandweg 14	15,00	-9,75	-9,75	-9,75	0,25	-4,82
303_A	Rozenburg volkstuinen	15,00	-9,87	-9,87	-9,87	0,13	-4,95
304_A	Rozenburg De Noordbank	15,00	-9,99	-9,99	-9,99	0,01	-5,06
305_A	Rozenburg De Krabbe	15,00	-9,98	-9,98	-9,98	0,02	-5,06
306_A	Rozenburg De Bongerd	15,00	-10,06	-10,06	-10,06	-0,06	-5,13
307_A	Rozenburg Balsemien	15,00	-10,19	-10,19	-10,19	-0,19	-5,26
308_A	Rozenburg Vinkseweg	15,00	-10,21	-10,21	-10,21	-0,21	-5,28
309_A	Rozenburg De Bieslook	15,00	-10,51	-10,51	-10,51	-0,51	-5,57
310_A	Rozenburg Droespolderweg	15,00	-10,52	-10,52	-10,52	-0,52	-5,59
311_A	Rozenburg A15	10,00	-10,92	-10,92	-10,92	-0,92	-5,97
312z_A	Botlek (zonegrens, 5m boven kade)	5,00	-10,86	-10,86	-10,86	-0,86	-5,90
313z_A	Botlek (zonegrens, 5m boven wal)	5,00	-10,85	-10,85	-10,85	-0,85	-5,88
400z_A	Zwartewaal Zalmlaan (zonegrens, 5m boven wal)	5,00	-10,86	-10,86	-10,86	-0,86	-5,90
401_A	Zwartewaal Buitengronden	5,00	-10,58	-10,58	-10,58	-0,58	-5,62
402_A	Brielle Buitengronden	10,00	-9,69	-9,69	-9,69	0,31	-4,75
403_A	Brielle Geuzenkreek	10,00	-8,16	-8,16	-8,16	1,84	-3,23
404_A	Brielle Vierpolders	10,00	-7,35	-7,35	-7,35	2,65	-2,42
405_A	Brielle Veer	10,00	-6,62	-6,62	-6,62	3,38	-1,69
406_A	Brielle Oosterlandsedijk	10,00	-4,84	-4,84	-4,84	5,16	0,09
407_A	Brielle Oosterlandseweg	10,00	-2,93	-2,93	-2,93	7,07	1,98
500_A	Oostvoorne, Bollaarsdijk	10,00	-1,11	-1,11	-1,11	8,89	3,80
501_A	Oostvoorne Maasweg	10,00	0,27	0,27	0,27	10,27	5,17
502_A	Oostvoorne Kamplaan	10,00	0,81	0,81	0,81	10,81	5,70
503_A	Oostvoorne Koepelweg	10,00	2,21	2,21	2,21	12,21	7,10
504_A	Oostvoorne Zwartelaan	10,00	2,11	2,11	2,11	12,11	6,99
505_A	Oostvoorne, Zandweg	10,00	1,29	1,29	1,29	11,29	6,18
506_A	Oostvoorne Duinen	10,00	0,85	0,85	0,85	10,85	5,75
507z_A	Oostvoorne Breede Water (zonegrens)	5,00	0,19	0,19	0,19	10,19	5,12
508z_A	Oostvoorne zeewering (zonegrens)	5,00	2,25	2,25	2,25	12,25	7,19
600z_A	Noordzee (zonegrens)	5,00	1,72	1,72	1,72	11,72	6,66
601z_A	Noordzee (zonegrens)	5,00	1,80	1,80	1,80	11,80	6,74
602z_A	Noordzee (zonegrens)	5,00	-0,74	-0,74	-0,74	9,26	4,20
603z_A	Noordzee (zonegrens)	5,00	-1,78	-1,78	-1,78	8,22	3,16
604z_A	Noordzee (zonegrens)	5,00	-0,99	-0,99	-0,99	9,01	3,95

Alle getoonde dB-waarden zijn A-gewogen

Rapport: Resultatentabel
Model: Kopie van VRY-2306739 (Aramis CCS)
LAeq totaalresultaten voor toetspunten
Groep: compressorstation
Groepsreductie: Nee

Naam Toetspunt	Omschrijving	Hoogte	Dag	Avond	Nacht	Etmaal	Li
605z_A	Noordzee (zonegrens)	5,00	-1,03	-1,03	-1,03	8,97	3,91
606z_A	Noordzee (zonegrens)	5,00	1,54	1,54	1,54	11,54	6,46
607z_A	Noordzee (zonegrens)	5,00	1,20	1,20	1,20	11,20	6,12
608z_A	Noordzee (zonegrens)	5,00	2,32	2,32	2,32	12,32	7,23
609z_A	Noordzee (zonegrens)	5,00	4,97	4,97	4,97	14,97	9,87
610z_A	Noordzee (zonegrens)	5,00	4,86	4,86	4,86	14,86	9,75
611z_A	Noordzee (zonegrens)	5,00	6,91	6,91	6,91	16,91	11,79
612z_A	Noordzee (zonegrens)	5,00	12,36	12,36	12,36	22,36	17,23
613z_A	Noordzee (zonegrens)	5,00	9,22	9,22	9,22	19,22	14,11
Krim2_A	Krimweg 2 Oostvoorne (woning)	1,50	1,12	1,12	1,12	11,12	6,07
Krim4_A	Krimweg 4 Oostvoorne (woning)	1,50	1,09	1,09	1,09	11,09	6,03
Krim6_A	Krimweg 6 Oostvoorne (woning)	1,50	0,85	0,85	0,85	10,85	5,79
Staal05_A	Staaldiepseweg 5 Brielle (woning)	5,00	-9,36	-9,36	-9,36	0,64	-4,40
Staal06_A	Staaldiepseweg 6 Brielle (woning)	5,00	-9,36	-9,36	-9,36	0,64	-4,40
Staal07_A	Staaldiepseweg 7 Brielle (woning)	5,00	-9,34	-9,34	-9,34	0,66	-4,38
Staal08_A	Staaldiepseweg 8 Brielle (woning)	5,00	-9,30	-9,30	-9,30	0,70	-4,34
Staal09_A	Staaldiepseweg 9 Brielle (woning)	5,00	-9,28	-9,28	-9,28	0,72	-4,32
Staal10_A	Staaldiepseweg 10 Brielle (woning)	5,00	-9,28	-9,28	-9,28	0,72	-4,32
Staal11_A	Staaldiepseweg 11 Brielle (woning)	5,00	-9,24	-9,24	-9,24	0,76	-4,28
Staal12_A	Staaldiepseweg 12 Brielle (woning)	5,00	-9,20	-9,20	-9,20	0,80	-4,24
Staal13_A	Staaldiepseweg 13 Brielle (woning)	5,00	-9,18	-9,18	-9,18	0,82	-4,22
Staal14_A	Staaldiepseweg 14 Brielle (woning)	5,00	-9,15	-9,15	-9,15	0,85	-4,19

Alle getoonde dB-waarden zijn A-gewogen

RAPPORT

Laagfrequent geluid

MER Aramis CO2-transportinfrastructuur

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2023

Status: Definitief/01

Datum: 9 februari 2024

ARAMIS	CCS-ARAMIS Project
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2023 Document title Low frequency noise report Revision Final 4.0

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV NEDERLAND B.V.

Laan 1914 no.35
3818 EX Amersfoort
Netherlands
Industry & Buildings
Trade register number: 56515154

+31 88 348 20 00 **T**
+31 33 463 36 52 **F**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

Titel document:	Laagfrequent geluid
Sub titel:	MER Aramis CO2-transportinfrastructuur
Referentie:	ARM-PFE-B10-ENV-EIA-2023
Status:	01/Definitief
Datum:	9 februari 2024
Projectnaam:	MER CCS Aramis
Projectnummer:	BH8744-106-101

Classificatie
Projectgerelateerd

Inhoud

1 Inleiding

Voor u ligt het detailrapport over laagfrequent geluid, onderdeel van het MER voor het Aramis initiatief.

Dit detailrapport heeft betrekking op het milieuthema laagfrequent geluid. De effecten van onder- en bovenwater geluid zullen elk in hun eigen detailrapport beschreven worden.

Dit detailrapport bevat een gedetailleerde beschrijving en beoordeling van de effecten van alle onderdelen van het Aramis initiatief, en een globale beschrijving en beoordeling van de effecten van onderdelen die niet tot het Aramis initiatief behoren, maar wel tot de CCS-keten.

1.1 Korte introductie van het Aramis initiatief

Integrale Aramis CCS-keten

Om de klimaatdoelstellingen te behalen, is er behoefte aan additionele transportinfrastructuur voor CO_2, waarmee meerdere opslaglocaties op zee worden ontsloten voor verschillende industriële emissiebronnen. Het Aramis initiatief speelt in op die behoefte door een nieuwe integrale en open CCS-keten mogelijk te maken. Het Aramis initiatief vormt een onderdeel van deze CCS-keten en bestaat uit de aanleg en exploitatie van een open CO_2-transportinfrastructuur. Het Aramis initiatief wordt in de rapportage dan ook wel aangeduid als Aramis CO_2-transportinfrastructuur. Samen met de afvanginfrastructuur en opslaginfrastructuur vormt dit de integrale CCS keten met onderstaande samenhangende onderdelen (zie figuur 1-1).

CO_2-afvanginfrastructuur

1 CO_2-afvang bij industrie, en geschikt maken voor transport;

2 CO_2-transport naar het verzamelpunt op de Maasvlakte, middels de Porthos landleiding of per schip;

CO_2-transportinfrastructuur (Aramis initiatief)

3 CO_2-verzamelpunt op de Maasvlakte met een compressorstation en een terminal.

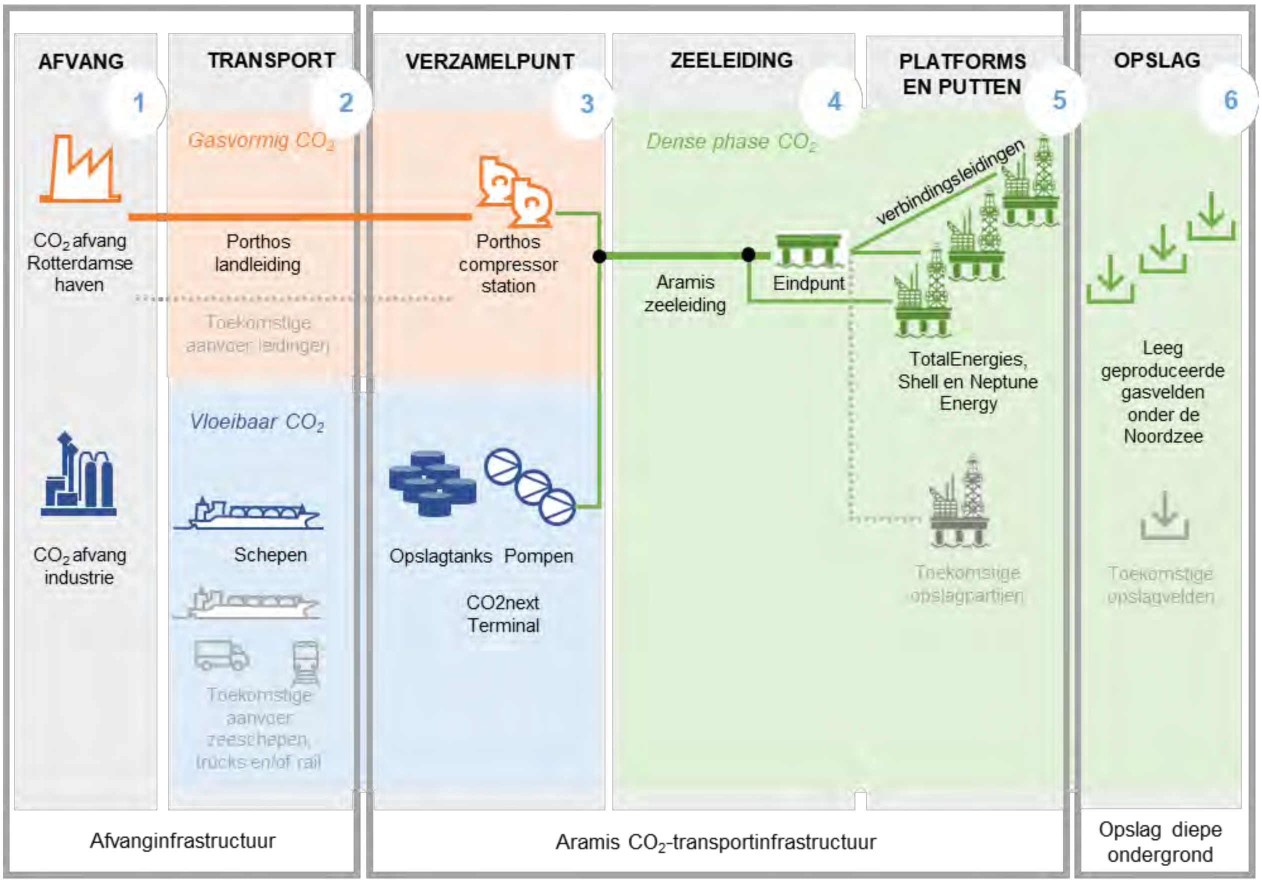
- Het compressorstation ontvangt gasvormig CO_2 dat aangevoerd wordt per landleiding (via de Porthos-landleiding) en brengt het op druk voor het transport per zeeleiding;
- De terminal ontvangt vloeibaar CO_2 aangevoerd per schip. De terminal locatie bevat steigers, opslagtanks voor tijdelijke opslag van CO_2 en hogedrukpompen voor levering aan de zeeleiding. CO_2 uit het compressorstation en vanaf de terminal komen samen in de CO_2-zeeleiding;

4 CO_2-transport door de centrale CO_2-zeeleiding naar het distributieplatform op de Noordzee. Dit platform is uitgerust met een verdeelstation voor toevoer van CO_2 naar de verschillende platforms. Er zijn tevens connectiepunten in de zeeleing waar vandaan CO_2 aan platforms geleverd kan worden;

5 CO_2-injectie: via verbindingsleidingen komt de CO_2 vanaf de zeeleiding bij injectieplatform. Middels putten bij deze platforms wordt CO_2 geïnjecteerd in leeg geproduceerde gasvelden in de diepe ondergrond van de Noordzee.

CO_2-opslag diepe ondergrond

6 CO_2-opslag: permanente CO_2 opslag in de diepe ondergrond.



Figuur 1-1. Overzicht van de integrale CCS-keten met daarin de componenten die onderdeel zijn van de voorgenomen activiteit, namelijk: transport per schip, terminal CO2next, uitbreiding compressorstation Porthos, zeeleiding met eindpunt en connectiepunten, aansluitleidingen en platforms

Het Aramis initiatief
Het Aramis initiatief heeft als doel het verzamelpunt (onderdeel 3), de zeeleiding (onderdeel 4) en de injectie (onderdeel 5) te realiseren. Hiervoor wordt door het Aramis consortium (bestaande uit Shell, TotalEnergies, Gasunie en EBN) samengewerkt met CO2next (voor de terminal) en Porthos (voor het compressorstation). De opslag vindt plaats vanaf de platforms van Shell, TotalEnergies en Neptune Energy.

De afvang (onderdeel 1) en transport van CO_2 naar het verzamelpunt (onderdeel 2) vallen buiten het Aramis initiatief[1]. In het MER worden deze aspecten wel benoemd en op hoofdlijnen beschreven, omdat ze integraal onderdeel uitmaken van de integrale Aramis CCS keten.

De opslag in de diepe ondergrond (onderdeel 6) valt eveneens buiten het initiatief. Voor de diepe ondergrond gelden geen milieuregels. De mogelijke gevolgen van opslag in de diepe ondergrond wordt echter wel apart beschreven in het MER middels de deelrapporten opslag diepe ondergrond.

Bij de aanleg van Aramis wordt rekening gehouden met toekomstige uitbreiding met meer leveranciers van CO_2 en meer opslagpartijen. In eerste instantie wordt vergunning aangevraagd voor een startsituatie en de eerste uitbreidingssituatie. Dit wordt in het MER getoetst. Toekomstige initiatieven *na* de eerste uitbreidingssituatie behoren niet tot de vergunningaanvraag maar worden in het MER wel (globaal) beschreven.

[1] *Een deel van de schepen die CO_2 leveren aan de terminal is afkomstig van Aramis-initiatiefnemers.*

De ingebruikname verwachten de Aramis initiatiefnemers in 2028, waarbij tegelijk al de eerste activiteiten zoals beschreven in de eerste uitbreidingsituatie kunnen starten. Voor het bereiken van de maximale doorvoercapaciteit is enkele jaren later als uitgangspunt in het MER aangehouden.

Een uitgebreide beschrijving van het Aramis initiatief is opgenomen in het deelrapport technische beschrijving en het samenvattend hoofdrapport MER (zie figuur 1-2).

1.2 Korte introductie op het milieuthema laagfrequent geluid

1.2.1 Laagfrequent geluid

Effecten van laagfrequent geluid treden op als gevolg van activiteiten tijdens de aanleg van de terminal en het compressorstations. Deze effecten kunnen ook optreden tijdens de gebruiksfase of bij calamiteiten. Beoordelingen van het laagfrequent geluid zijn uitgevoerd via een bureauonderzoek, waarbij gebruik is gemaakt van bestaande informatie.

1.2.2 Relevante fases

Het MER bestudeert die aspecten van een activiteit die de fysieke leefomgeving kunnen beïnvloeden. De milieueffecten van de alternatieven en varianten voor het milieuthema laagfrequent geluid worden beschreven. Daarbij wordt onderscheid gemaakt tussen de aanlegfase en gebruiksfase, en worden de mogelijke effecten van een incident beschreven; namelijk:

- Laagfrequent geluid ten gevolge van de installaties tijdens de gebruiksfase. Het onderzoek richt zich op het compressorstation en de terminal, op basis van ervaringen is geen laagfrequent geluid te verwachten dat afkomstig is van de platforms;
- Laagfrequent geluid ten gevolge van de bouw en aanleg van de zeeleiding en de installaties.

In de eerste fase van de m.e.r.-procedure voor het Aramis initiatief is afgebakend welke onderwerpen binnen dit thema relevant zijn om te onderzoeken en hoe. Dit is beschreven in de Notitie Reikwijdte en Detailniveau die 2 december 2022 definitief is vastgesteld door de Minister voor Klimaat en Energie.

1.2.3 Relevante milieuaspecten

Enkele voorgenomen activiteiten veroorzaken laagfrequent geluid. Na een beschrijving van het verschijnsel laagfrequent geluid en de bijbehorende normering komen deze activiteiten aan bod.

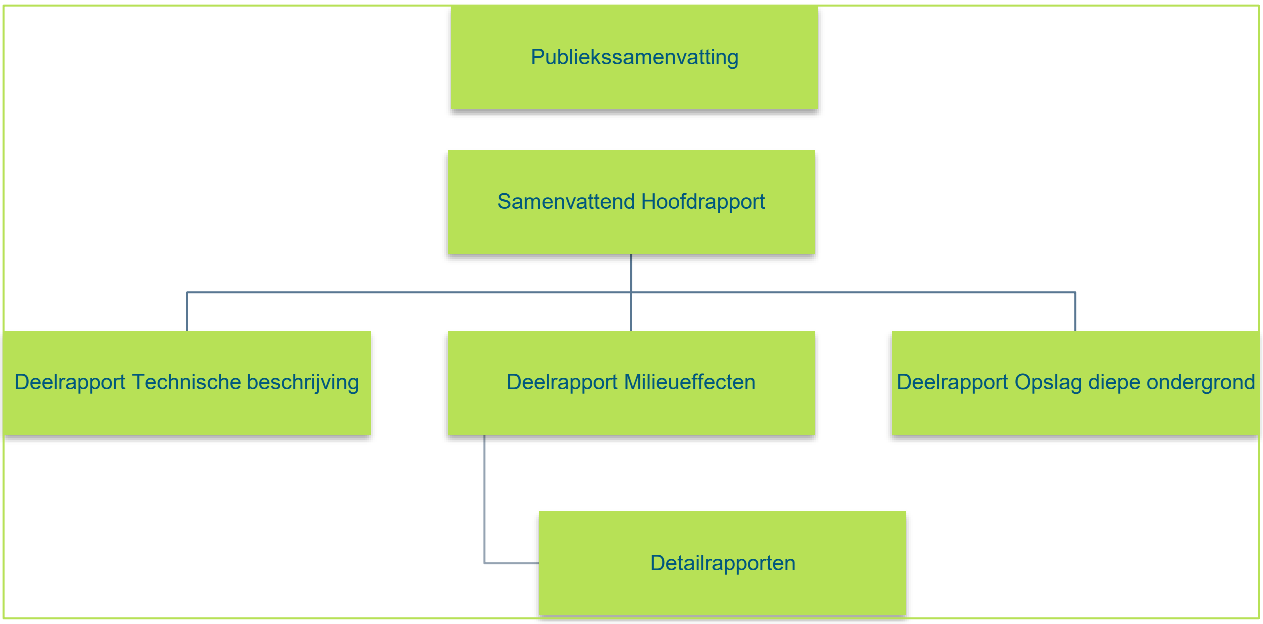
Laagfrequent geluid en normering

Het door de mens hoorbare geluid zijn luchttrillingen met een frequentie tussen circa 20 en 20.000 Hz. In het algemeen wordt onder laagfrequent geluid het geluid verstaan met een frequentie lager dan 125 Hz. Beneden 20 Hz spreekt men dan meestal over infrageluid. De gehoordrempel van de mens (de grens tussen het wel of niet horen van een geluid) is afhankelijk van de frequentie van het geluid. Des te lager de frequentie des te hoger de drempelwaarde. Infrageluid wordt door het grootste deel der mensen niet meer gehoord, maar het kan wel worden waargenomen. De wijze waarop verschilt van individu tot individu. Laagfrequent geluid wijkt qua eigenschappen en qua ervaren tot op zekere hoogte af van het 'normale geluid'. Zo wordt het horen van laagfrequent geluid al snel als hinderlijk ervaren. Om hinder te voorkomen zou men als grenswaarde de gehoordrempel kunnen gebruiken. Echter deze gehoordrempel verschilt nogal van individu tot individu. Sommige mensen horen voortdurend laagfrequent geluid terwijl andere mensen op dezelfde plaats niet weten waar men het over heeft. Ze horen het betreffende geluid niet. Ook fysisch verschilt laagfrequent geluid van het 'normale geluid'. Luchtdemping en bodemabsorptie vinden nauwelijks plaats; geluidwallen en -schermen hebben veel minder effect.

1.3 Opbouw van het MER en dit deelrapport

Voor het Aramis initiatief is een gecombineerd Plan-/ProjectMER opgesteld. Figuur 1-2 geeft de rapportagestructuur van het MER Aramis. Het MER bestaat uit een Samenvattend Hoofdrapport, voorzien van een Publiekssamenvatting. Ter onderbouwing van het Samenvattend Hoofdrapport zijn deelrapporten opgesteld. Dit betreft het deelrapport Technische beschrijving van Aramis, het deelrapport Milieueffecten met daarbij de onderliggende technische detailstudies en de deelrapporten Opslag diepe ondergrond. Doordat CO_2 in meerdere geologische voorkomens wordt opgeslagen, zijn er voor de opslag diepe ondergrond meerdere deelrapporten opgesteld.

Het voorliggende rapport is het detailrapport laagfrequent geluid. De bevindingen uit dit detailrapport zijn opgenomen in het Deelrapport Milieueffecten, en op hoofdlijnen in het Samenvattend Hoofdrapport.



Figuur 1-2 - Overzicht rapportagestructuur MER Aramis

Opbouw van dit detailrapport

Dit detailrapport beschrijft in het volgende hoofdstuk allereerst welk kader van beleid, wet- en regelgeving van toepassing is voor het thema laagfrequent geluid. Nadat in hoofdstuk 3 is toegelicht hoe het onderzoek is uitgevoerd en hoe de effecten zijn beoordeeld, beschrijft hoofdstuk 4 de referentiesituatie. De referentiesituatie is de situatie die ontstaat op grond van de huidige situatie en alle relevante autonome ontwikkelingen die verwacht worden in het studiegebied. Het dient veelal als vergelijkingsbasis voor het bepalen van de milieueffecten. In de dan volgende hoofdstukken (5, 6 en 7) worden de milieueffecten beschreven en beoordeeld, voor de gebruiksfase, tijdens de aanleg en ontmanteling, en tijdens onderhoudswerkzaamheden en onvoorziene situaties. Hoofdstuk 8 gaat op globaal niveau in op de effecten van alle ketenonderdelen die niet binnen de scope vallen van het Aramis initiatief, maar hier wel mee samenhangen. Hoofdstuk 9 geeft inzicht in de ontbrekende informatie voor het thema laagfrequent geluid. Tot slot bevat hoofdstuk 10 de samenvatting van bevindingen en de toetsing aan de wet- en regelgeving.

2 Beleid, wet- en regelgeving

Dit hoofdstuk beschrijft welk beleid en welke wet- en regelgeving relevant is voor het Aramis initiatief voor het thema laagfrequent geluid. Dit maakt duidelijk binnen welke randvoorwaarden het Aramis initiatief tot stand moet komen.

2.1 Vercammencurve en NSG-curve

Er is in Nederland geen algemeen geaccepteerd normstelsel voorhanden waarmee laagfrequente geluidhinder kan worden bestreden. Ook de Omgevingswet bevat geen normstelsel voor laagfrequent geluid.

In 1990 is er in opdracht van het ministerie van VROM een rapport samengesteld waarin normen worden voorgesteld die gehanteerd zouden kunnen worden bij vergunningverlening. In dit rapport werd door Vercammen een grenswaarde voorgesteld waarbij 3 tot 10% van de doorsnee bevolking hinder zou kunnen ondervinden. In het vervolg van dit hoofdstuk wordt de aan deze waarden gerelateerde curve de Vercammen 3-10%-curve genoemd [Vercammen, ‘Criteria for low frequency noise’, 19th International congress on Acoustics, Madrid, 2007]. Tot op heden heeft het ministerie geen standpunt bekend gemaakt met betrekking tot de voorgestelde normering. Althans niet zodanig dat dit geresulteerd heeft in een richtlijn.

In dit onderzoek vindt de beoordeling plaats aan de hand van de Vercammen 3-10%-curve, ter informatie hanteren we tevens de NSG-curve. De NSG-richtlijn is gebaseerd op de 90% gehoordrempel van doorsnee 55-jarigen. 90% van deze groep hoort de geluiden onder deze drempel niet. In deze richtlijn is geen relatie gelegd met de hinderbeleving.

2.2 Besluit bouwwerken leefomgeving

Het Besluit bouwwerken leefomgeving (Bbl) bevat in afdeling 7.1 regels over het uitvoeren van bouw- en sloopwerkzaamheden. De geluidimmissies op de gevels van geluidgevoelige bestemmingen vanwege bedrijfsmatige bouw- en sloopwerkzaamheden dienen te voldoen aan de dagwaarden en de bijbehorende maximale blootstellingsduur volgens artikel 7.17 (geluidhinder). Middels een maatwerkvoorschrift kan van (onder andere) de dagwaarden en de blootstellingsduur worden afgeweken als gebruik wordt gemaakt van de beste beschikbare stille technieken.

3 Beschrijving onderzoeks- en beoordelingsmethodiek

Dit hoofdstuk beschrijft de aanpak waarmee de milieueffecten worden bepaald en beoordeeld.

3.1 Onderzoeksmethodiek

Algemeen

Wat betreft de geprognosticeerde geluidniveaus ter plaatse van geluidgevoelige bestemmingen richten we ons uitsluitend op de dichtstbij gelegen bebouwing. Waarneembaarheid van laagfrequent geluid relateren we aan de NSG-curve (Nederlandse Stichting Geluidshinder), hinderlijkheid door laagfrequent geluid inclusief de bijbehorende beoordeling beschouwen we ten opzichte van de genoemde Vercammencurve.

Normstelsel

In het eerdergenoemde rapport van het Ministerie van VROM heeft Vercammen een grenswaarde voorgesteld waarbij 3 tot 10% van de doorsnee bevolking hinder zou kunnen ondervinden. In het vervolg van dit hoofdstuk wordt de aan deze waarden gerelateerde curve de Vercammen 3-10%-curve genoemd. De NSG-richtlijn is gebaseerd op de 90% gehoordrempel van doorsnee 55-jarigen. 90% van deze groep hoort de geluiden onder deze drempel niet. In deze richtlijn is geen relatie gelegd met de hinderbeleving. Vandaar dat er in het hogere deel van het laagfrequente gebied heel lage waarden voorkomen. Bij hogere frequenties leidt het kunnen waarnemen van het geluid minder snel tot hinder dan in het lagere deel van het laagfrequente geluidgebied.

De referentiewaarden volgens de curven voor hinderlijkheid en waarneembaarheid van laagfrequent geluid zijn in de tabellen 3-1 en 3-2 weergegeven. De bovenste rijen van de tabellen geven de middenfrequenties aan van het geluid uitgedrukt in tertsbanden. De tweede rijen bevatten de geluidniveaus die de curves voorstellen. De geluidwering standaard gevel geeft aan in welke mate de gevel de binnenruimte tegen geluid beschermt. Ten slotte geven de onderste rijen de (maximaal te verwachten) geluidniveaus aan de buitenzijde van de gevel bij geluidniveaus volgens de curves ofwel de 2e rijen.

Tabel 3-1:Referentiecurve voor laagfrequent geluid, Vercammen 3-10%-curve (continu geluid)

	10	12,5	16	20	25	31,5	40	50	63	80	100	125	Hz
Vercammen 3-10% (binnen)	86	82	77	70	65	59	55	50	46	42	39	36	dB
Geluidwering standaard gevel	5	6	7	8	9	10	11	12	13	14	15	17	dB
Vercammen 3-10% vertaald naar buiten voor de gevel	91	88	84	78	74	69	66	62	59	56	54	53	dB

Tabel 3-2: Referentiecurve voor laagfrequent geluid, NSG (continu geluid)

	20	25	31,5	40	50	63	80	100	Hz
NSG (binnen)	74	62	55	46	39	33	27	22	dB
Geluidwering standaard gevel	8	9	10	11	12	13	14	15	dB
NSG vertaald naar buiten voor de gevel	82	71	65	57	51	46	41	37	dB

In de berekeningen is uitgegaan van de gestandaardiseerde isolatiewaarde conform Vercammen. Deze gehanteerde geluidisolatie is gebaseerd op enerzijds metingen [Vercammen MLS, Heringa PH. Laagfrequent geluid; grenswaarden, overdracht en meten. Nijmegen: Adviesbureau Peutz & ass., 1990. Rapport R 548-13.1990] en anderzijds een theoretische benadering waarbij wordt uitgegaan van een 15 dB reductie van de standaard gevel bij 100 Hz en aflopend met 3 dB/octaaf naar de lagere frequentiebanden.

3.2 Beoordelingsmethodiek

In een milieueffectrapportage worden de milieueffecten van een voornemen in beeld gebracht en beoordeeld. De effecten bepalen we veelal door de toekomstige situatie die ontstaat door het voornemen te vergelijken met de situatie die ontstaat zonder het voornemen, ook wel de referentiesituatie genoemd. Aan het verschil tussen die twee situaties, het effect, wordt een kwalitatief oordeel toegekend. Op die manier worden de effecten voor alle relevante milieuthema's bepaald en beoordeeld.

Voor de realisatie van het compressorstation en de terminal geldt dat geluid in zowel de hoge frequenties als de lage frequenties in de omgeving per definitie zullen toenemen ten opzichte van de situatie zonder het compressorstation. Anderzijds zijn deze geluidsniveaus (tot op zekere hoogte) reeds ingecalculeerd ten tijde van de vaststelling van de geluidszone om het industrieterrein. Dit betekent dat de toename kan worden gezien als de omzetting van een reservering in een feitelijke invulling, die ook zonder het voornemen zou (kunnen) plaatsvinden in het kader van een andere ontwikkeling op het industrieterrein; zie verder paragaaf 4.2.

In het licht van de tweede alinea hierboven wordt het voornemen als licht negatief gewaardeerd indien het laagfrequente geluid toeneemt maar voldoet aan de genoemde Vercammen 3-10%-curve. De waardering is negatief als dat niet het geval is.

Algemene aanpak

Tabel 3-3 geeft de maatlat weer voor de effectbeoordeling van het Milieuthema Laagfrequent geluid.

Tabel 3-3 Maatlat effectbeoordeling laagfrequent geluid

Effect	Omschrijving	Operationalisering effectscores
+ + +	Sterk positief effect, groot van omvang en zodanig dat een overschrijding van normen wordt opgeheven	Permanente sterke afname geluid.
+ +	Positief effect, relatief groot of in een kritische periode of gebied	Permanente beperkte afname geluid.
+	Licht positief effect, relatief beperkt, tijdelijk of lokaal	Beperkte tijdelijke afname geluid.
0	Geen effect	Geen toename geluid
-	Licht negatief effect, relatief beperkt, tijdelijk of lokaal	Beperkte toename geluid binnen de Vercammen 3-10%-curve
- -	Negatief effect, relatief groot of in een kritische periode of gebied, onderzoek mitigerende maateregelen nodig	Toename geluid deels buiten de Vercammen 3-10%-curve
- - -	Zeer negatief effect, zodanig dat milieueffect zonder mitigerende maatregelen buiten de normen van regelgeving en beleid valt	Teveel toename geluid
Nvt	Niet van toepassing	

4 Beschrijving referentiesituatie

In een milieueffectrapportage worden de milieueffecten van een voornemen in beeld gebracht en beoordeeld. De effecten bepalen we veelal voor de toekomstige situatie die ontstaat door het voornemen te vergelijken met de situatie die ontstaat zonder het voornemen, ook wel de referentiesituatie genoemd. Aan het verschil tussen die twee situaties, het effect, wordt een kwalitatief oordeel toegekend. Dit hoofdstuk beschrijft allereerst de huidige situatie voor het thema geluid. Vervolgens beschrijft het welke situatie ontstaat als gevolg van alle autonome ontwikkelingen; de referentiesituatie.

4.1 Huidige situatie

De huidige situatie is de situatie zonder de voorgenomen activiteit. De voorgenomen locaties van het compressorstation en de terminal liggen nog deels braak. Nabij de terminal bevinden zich al meerdere steigers. Bij een steiger bestaat een kans dat losactiviteiten laagfrequent geluid richting de omgeving veroorzaken. Afhankelijk van de vergunningensituatie wordt op korte termijn gestart met de bouw van het compressorstation ten behoeve van Porthos.

4.2 Referentiesituatie

In de referentiesituatie veroorzaken de volgende activiteiten en ontwikkelingen mogelijk een laagfrequente geluidemissie:

1. Afgemeerde (zee-)schepen;
2. Het manoeuvreren van (zee-)schepen ten behoeve van het afmeren;
3. Installaties samenhangend met het compressorstation van Porthos en de losactiviteiten bij de bestaande steigers nabij de toekomstige terminal.

Ad 1. Afgemeerde (zee-)schepen
De aan de kades gelegen schepen zijn vrijwel hun volledige ligduur aan het lossen. Hierbij is een lospomp in bedrijf die zich meestal onder in het schip bevindt. Deze lospomp heeft dan geen relevante geluidemissie richting de omgeving. De pomp zelf heeft een beperkt geluidvermogen. Veel belangrijker dan het boven- of benedendeks aanwezig zijn van pompen is het type aandrijving. Bij de schepen worden de pompen elektrisch aangedreven. Eén of meerdere generatoren verzorgen de stroomvoorziening van afgemeerde schepen, het elektrisch vermogen ten behoeve van de pompen is klein ten opzichte van de totale stroombehoefte van een afgemeerd schip. Dit betekent dat de geluidemissie vanwege in bedrijf zijnde generatoren ten behoeve van het lossen beperkt is. We beschouwen de generatoren inclusief de uitlaat als de meest relevante laagfrequente bron van een afgemeerd schip.

Naast elektrisch aangedreven pompen kunnen pompen in theorie ook zijn voorzien van een hydraulische aandrijving. De hydraulische aandrijving heeft een hogere geluidemissie. Onze ervaringen met geluidmetingen aan schepen is dat zeeschepen zowel breedbandig als laagfrequent, een hogere geluidemissie bezitten dan binnenvaartschepen. Bij het onderzoek naar laagfrequent geluid bij (de dichtstbij gelegen) woningen aan de rand van Hoek van Holland richten we ons dan ook op zeeschepen met multi-megawatt systemen. Rekentechnisch gaan we uit van een afgemeerd zeeschip met generatoren van in totaal 17 MW, het bijbehorende geluidvermogen is 138 dB in de tertsbanden van 40 en 50 Hertz.

Ad 2. Het manoeuvreren van (zee-)schepen ten behoeve van het afmeren
Het geluid van de scheepsmotoren behoort tot 'scheepsgeluid' en is niet toe te kennen aan de terminal locatie. Dit geluid wordt getoetst als indirecte hinder. Hierbij merken we op dat de duur van het manoeuvreren significant korter is dan de losduur en dat de onder punt 1 genoemde generatoren (geheel of grotendeels) ook tijdens het manoeuvreren in werking zijn.

Dit onderzoek naar laagfrequent geluid is gebaseerd op situaties waarin door DCMR-geluidmetingen zijn verricht aan meerdere afgemeerde schepen met generatoren tot 17 MW. Voor de omgeving was ten tijde van de geluidmetingen sprake van overmatige overlast door laagfrequent geluid. De uitlaat van de hoofdmotor is bij moderne schepen voorzien van een geluiddemper. Tijdens manoeuvreren is het geluidvermogen van de uitlaat van de hoofdmotor lager dan het geluidvermogen van de 17 MW-generatoren. Een en ander volgens de publicatie 'Noise from ships in ports, Possibilities for noise reduction' Environmental Project No. 1330 2010 Miljøprojekt. Het is daarom reëel om ervan uit te gaan dat de activiteiten van Aramis nooit leiden tot meer laagfrequent geluid dan onder punt 1 is beschreven.

Ad 3. Installaties
Door TNO is uitgebreid onderzoek gedaan naar de overdracht van laagfrequent geluid van classeerinstallaties op een ponton ten behoeve van grindwinning (ook grindwinschepen genoemd).

Het voornoemde onderzoek gaat om classeerinstallaties. De installaties in de referentiesituatie betreffen het compressorstation van Porthos en de installaties samenhangend met de (los-)activiteiten bij de bestaande steigers nabij de terminal. Het bronniveau van de classeerinstallaties kan als bovengrens worden gezien voor de laagfrequente geluidemissie van de genoemde gezamenlijke installaties in de referentiesituatie. Gegevens over de geluidemissie zijn ontleend aan de rapportage 'LF-geluid en trillingen in woningen ten gevolge van grindwinning door grindwinschepen' rapportnr. 2003-CI-R0001. Het geluidvermogen in de tertsband van 12,5 Hertz is hierin vastgesteld op 132 dB, ook treden boventonen op bij onder andere 25 en 50 Hz. De laagfrequente bron bevindt zich rekentechnisch bezien aan de oostzijde van de terminal. Uitgaande van deze oostelijke bronpositie is door ons de laagfrequente bijdrage te Hoek van Holland berekend, zie paragraaf 5.2 voor de rekenresultaten.

We achten het onderzoeken van laagfrequent geluid op basis van de resultaten van het door TNO verrichte onderzoek, gezien de overeenkomsten in laagfrequente bijdragen, zinvol.

5 Milieueffecten gebruiksfase

Dit hoofdstuk gaat in op de effecten op het thema laagfrequent geluid, zoals die verwacht wordt tijdens het gebruik van het compressorstation en de terminal. Voor het milieuthema laagfrequent geluid zijn de maatgevende effecten bij de startfase en de eerste uitbreidingsfase identiek. Tevens bevat het hoofdstuk een doorkijk naar de effecten die verwacht worden bij de uiteindelijke maximale doorvoercapaciteit.

5.1 Uitgangspunten

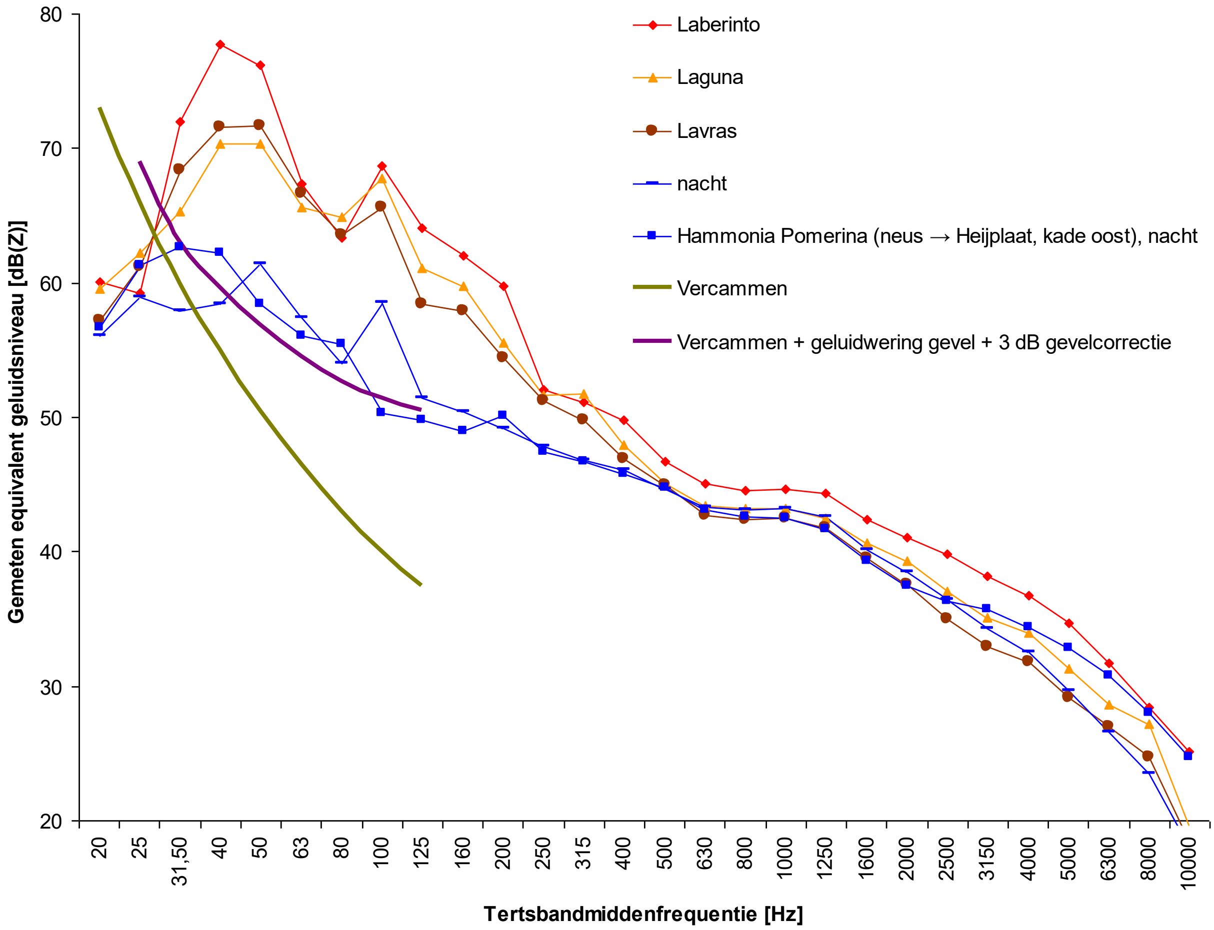
In de gebruiksfase kan laagfrequent geluid worden veroorzaakt door het compressorstation en de terminal. Als uitgangspunt geldt dat de (zee-)schepen bij de terminal als bron potentieel luider zijn dan het deels inpandig opgestelde zestal compressoren (5 stuks compressoren in werking en 1 compressor als backup). De kans op laagfrequente geluiduitstraling naar de omgeving is bij de terminal dan ook groter dan bij het compressorstation.

De worst case situatie in de gebruiksfase is daarom gebaseerd op afgemeerde (zee-)schepen. Als maat voor laagfrequent geluid van afgemeerde (zee-)schepen hanteren we een bijzonder luide situatie die in het verleden in het Rijnmondgebied is opgetreden. Het betrof een overlast veroorzakend afgemeerd containerschip waaraan laagfrequent geluidmetingen zijn verricht. De kans dat een afgemeerd (zee-)schip laagfrequent geluid produceert, is klein. De kans dat tegelijkertijd twee of meer (zee-)schepen bijzonder luid en tevens vergelijkbaar luid zijn, zodat cumulatie van geluid kan optreden, is verwaarloosbaar klein. De worst case situatie Aramis, die de terminal en het compressorstation representeert, bestaat daarom uit één afgemeerd (zee-)schip dat is beladen met een groot aantal koelcontainers, dat zeer veel laagfrequent geluid uitstraalt. De worst case situatie voor laagfrequent geluid is daarmee in de startfase en in de eerste uitbreidingsfase identiek.

Maatgevende situatie
In 2014 is door de milieudienst DCMR een onderzoek uitgevoerd naar het geluid van containerschepen die regelmatig in de Rotterdamse haven liggen afgemeerd. Zie het meetrapport d.d. 8 dec. 2014 met nr. 21855890 (verder genoemd de meetrapportage). Het gaat hierbij om geluidmetingen aan containerschepen met afmetingen van globaal 300 x 45 meter. Deze meetresultaten hanteren we ter berekening van de worst case situatie Aramis.

De notitie 21919473 ‘Laagfrequent geluid van containerschepen in de Waalhaven’ d.d. 4 maart 2015 verwijst naar de meetrapportage en stelt dat: ‘Uit het meetrapport blijkt dat overmatige overlast wordt ondervonden in de situatie dat de uitlaat op circa 500 meter afstand van de woning ligt (schip omgekeerd, westelijk afgemeerd). En dat de aanwezigheid van een overlastgevend schip niet is opgemerkt toen de uitlaat op 900 meter afstand van de woning lag (schip omgekeerd, oostelijk afgemeerd)’. In de onderstaande figuur zijn de gemeten geluidniveaus in tertsen bij de woning Heysedijk 19 opgenomen.

Overmatige overlast door laagfrequent geluid werd ondervonden bij de zeeschepen de Laberinto, de Laguna en de Lavras. De spectra van het voornoemde drietal zeeschepen hanteren we in het onderhavige onderzoek om laagfrequent geluid aan de rand van Hoek van Holland op minimaal 2.500 meter van het initiatief te onderzoeken. De genoemde 2.500 meter betreft de afstand tussen de mogelijk laagfrequente bron oostelijk op de terminal en het adres Zeekant 241 te Hoek van Holland. Dit doen we door met een inverse overdrachtsberekening het geluidvermogen in tertsen aan de bronzijde te berekenen gevolgd door een berekening van de overdrachtsweg tussen bron en ontvanger (te Hoek van Holland). Hierbij maken we gebruik van het Geomilieu-rekenmodel, dat ook voor de realisatie- en gebruiksfase van de terminal is gehanteerd.

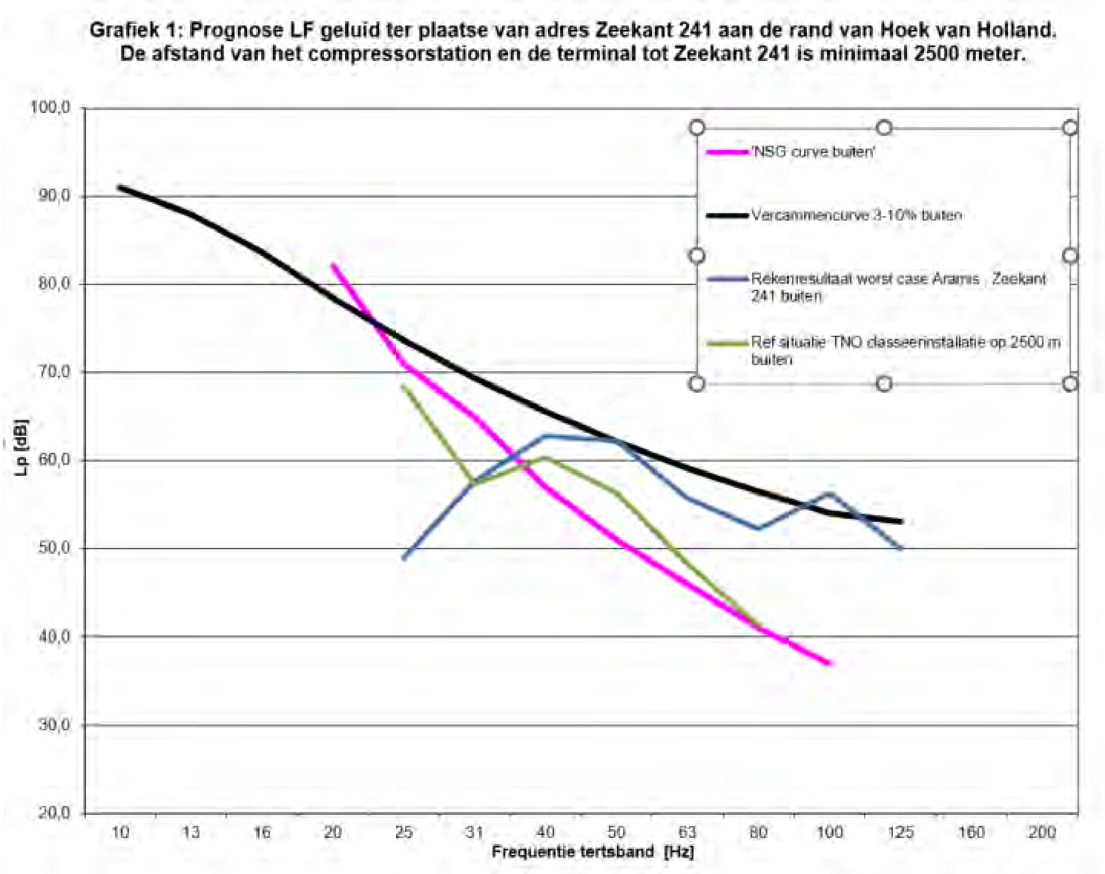


Figuur 5-1 Geluidniveaus gemeten 2 meter voor de gevel Heysedijk 19 op 5 meter hoogte

Aanname
Als worst case uitgangspunt kiezen we op grond van de bovenstaande feiten voor het hanteren van de meetresultaten volgens de meetrapportage in combinatie met een afstand (tot de dichtstbij gelegen woning) van 500 meter.

5.2 Berekeningen

Bij het berekenen van de te verwachten laagfrequente geluidniveaus in de referentiesituatie en de worst case situatie Aramis is onder andere gebruik gemaakt van de meetresultaten van DCMR die inclusief gevelreflectie zijn verricht. Om een uitspraak te kunnen doen over woningen in algemene zin op afstanden van 2.500 meter hebben we gekozen voor het berekenen en beoordelen van LF-geluid buiten voor de gevel. De NSG-curve en de Vercammencurve zijn daarom bewerkt voor het gebruik in posities voor de gevel. Figuur 5-2 geeft de rekenresultaten van de referentiesituatie (groene lijn) en de worst case situatie Aramis (blauwe lijn) ten opzichte van de genoemde curves.



Figuur 5-2 Prognose LF-geluid ter plaatse van Zeekant aan de rand van Hoek van Holland.
De kortste afstand van een mogelijke LFG bron tot de woning Zeekant 241 is ca. 2.500 meter.

In de inleiding noemden we het door TNO verrichte onderzoek naar laagfrequent geluid vanwege de classeerinstallaties bij grindwinning. Door de bron, die wordt beschreven in de TNO-studie, op de kortst mogelijke afstand tot woonbestemmingen te projecteren is de laagfrequente bijdrage te Hoek van Holland berekend, zie ook bijlage 1.

De voornoemde rapportage 'LF-geluid en trillingen in woningen ten gevolge van grindwinning door grindwinschepen' nr. 2003-CI-R0001 geeft op de pagina's 76 t/m 80 de vastgestelde geluidniveaus binnen een woning. De gepresenteerde geluiddrukniveaus betreffen woningen gelegen op een afstand van 150 tot 1.200 meter van de geluidbron. We merken op dat grotere afstanden dan 1.200 meter vanaf de bron niet in de rapportage nr. 2003-CI-R0001 voorkomen. In Hoek van Holland is de afstand tot de bron echter groter, namelijk 2.500 meter. Ter berekening van de afname in het bereik van 1.200 tot 2.500 meter hanteren we het rekenprogramma Geomilieu. Dit programma verschaft informatie in de octaafbanden van 31,5 en 63 Hz. De bijbehorende afname is circa 5 á 6 dB over het genoemde frequentiebereik. We benutten deze informatie ter berekening van de afname in de tertsen van 25 tot en met 80 Hz, zie bijlage 1. Na sommatie met de geluidwering van de gevel volgens paragraaf 3.2 leidt dit tot het geluidniveau in tertsen buiten voor de gevel op 2500 meter van de bron. Het rekenresultaat is in groen in figuur 5-2 weergegeven.

5.3 Effecten voorgenomen activiteit

Wat betreft de geprognosticeerde geluidniveaus ter plaatse van geluidgevoelige bestemmingen richten we ons uitsluitend op de woonbebouwing die zich in noordelijke richting van de terminal bevindt in de gemeente Hoek van Holland. Waarneembaarheid van laagfrequent geluid relateren we aan de NSG-curve, de beoordeling betreft uitsluitend de hinderlijkheid door laagfrequent geluid, hiervoor hanteren we de Vercammencurve 3-10%.

De onderzochte situatie bestaat uit de zogenoemde 'worst case situatie Aramis' conform paragraaf 5.1. Uitgaande van de geformuleerde uitgangspunten, behorend bij bronnen met extreem grote laagfrequente bijdragen, wordt de 3-10%-hindercurve van Vercammen (nagenoeg) gerespecteerd. De NSG-referentiecurve wordt alleen boven de 40 Hz tertsband overschreden.

De voorgenomen activiteiten van Aramis veroorzaken nooit meer laagfrequent geluid dan de bovengenoemde onderzochte worst case situatie. Dat de verwachte laagfrequente bijdragen in de gemeente Hoek van Holland lager zullen zijn dan de berekende curve (in blauw) in figuur 5-2 komt omdat:

- De kortste afstand van de bedrijfsoppervlakte van het compressorstation en de terminal tot Hoek van Holland is in de berekeningen gehanteerd, de overige posities binnen deze bedrijfsoppervlakte bevinden zich verder van de woonomgeving. Dit geldt ook voor het alternatief waarin de gehele terminal meer westelijk en dus verder van woonbebouwing af is geprojecteerd;
- Het aantal gelijktijdig afgemeerde (zee-)schepen is beperkt tot enkele stuks, het gezamenlijke aanwezige generatorenvermogen van afgemeerde zeeschepen zal in de praktijk lager zijn dan 17 MW behorend bij de worst case situatie Aramis. Een lager wattage leidt normaliter tot minder laagfrequent geluid.

Conclusie
De rekenresultaten laten zien dat het laagfrequent geluid van alle voorgenomen installaties en de (zee-)schepen die bij de CO2Next terminal afmeren in de woningen van Hoek van Holland hoorbaar kan zijn. Enige geluidhinder is hierdoor niet uit te sluiten. Omdat de worst case rekenresultaten vrijwel geheel voldoen aan de Vercammencurve en de verwachte bijdragen van laagfrequent geluid vanwege het initiatief lager zullen zijn dan de berekende worst case situatie, stellen we dat de omvang van de hinder voldoende beperkt blijft.

5.4 Effectbeoordeling

Het verschil tussen laagfrequent geluid in de referentiesituatie en de gebruiksfase is klein. Zowel de referentiesituatie als de gebruiksfase voldoen aan de grenswaarden (Vercammencurve). Het voornemen wordt als licht negatief gewaardeerd.

6 Milieueffecten aanleg en ontmanteling

Dit hoofdstuk gaat in op de effecten op het thema laagfrequent geluid, zoals die verwacht worden tijdens de aanleg en de ontmanteling van het compressorstation en de terminal. Op basis van ervaringen zijn platforms en het aanleggen van de pijpleiding geen relevante bronnen.

De uit akoestisch oogpunt maatgevende activiteiten in verband met de aanleg en ontmanteling van het compressorstation en de terminal betreffen heiwerkzaamheden van palen en damwanden in de aanlegfase. Een traditionele heistelling heeft een bronsterkte van circa 135 dB(A), daarmee is de heistelling de luidste geluidbron ten tijde van de aanleg en ontmanteling. Tijdens de aanlegfase van de transportleiding valt er ook een paar dagen tot weken laagfrequent geluid te verwachten van de tijdelijke mobiele compressoren.

De dichtstbijzijnde woningen bevinden zich op een afstand van circa 3,5 km van het compressorstation. Dit betekent dat door geometrische uitbreiding van geluid en luchtabsorptie het bij de betreffende woningen optredende langtijdgemiddelde beoordelingsniveau lager zal zijn dan 60 dB(A), ook indien er meerdere heistellingen worden ingezet en rekening wordt gehouden met het impulsachtige karakter van het geluid.

Hieruit kan worden geconcludeerd dat het langtijdgemiddelde beoordelingsniveau ten gevolge van alle bouw- en sloopactiviteiten (ruimschoots) zal voldoen aan de grenswaarde van 60 dB(A) uit het Besluit bouwwerken leefomgeving (Bbl). Wel is maatwerk op grond van het Bbl nodig indien de betreffende activiteiten plaatsvinden tussen 19:00 en 07:00 uur en/of op zondag dan wel op feestdagen. In dat geval kan, afhankelijk van de aard van de werkzaamheden, een nadere akoestische onderbouwing noodzakelijk zijn.

Ten tijde van de aanleg, testen en ontmanteling zijn het compressorstation en de terminal niet in gebruik. De maatgevende bronnen bestaan dan uit bouwmachines en tijdens testen uit onder meer een mobiele compressor. We veronderstellen op grond van ervaringen met grootschalige bouwprojecten dat laagfrequent geluid dan geen rol van betekenis speelt.

7 Milieueffecten tijdens onderhoud en onvoorziene situaties

Dit hoofdstuk gaat in op de effecten die te verwachten zijn tijdens onderhoudswerkzaamheden en onvoorziene situaties.

Tijdens het opstarten of uit bedrijf nemen van de installaties zijn geen afwijkende geluidsniveaus te verwachten. Wel kunnen kortstondige verhogingen van de door de installaties veroorzaakte geluidsniveaus optreden wanneer de noodstroomgenerator van de CO2Next terminal wordt getest (eens per maand) of de compressoren door een storing uitvallen en druk wordt afgelaten via het drukaflaatsysteem. Alleen dit laatste geluid zou bij de dichtstbijzijnde woningen waarneembaar kunnen zijn.

8 Milieueffecten buiten Aramis scope

Zoals eerder beschreven behoren sommige CCS-ketenonderdelen niet tot het Aramis initiatief. Het is belangrijk om van deze onderdelen op hoofdlijnen wel de milieugevolgen in beeld te brengen. Het betreft immers effecten die mede via het Aramis initiatief ontstaan. Door de effecten van deze onderdelen ook te beschouwen ontstaat een beeld van de gevolgen van de totale CCS keten. Omdat deze onderdelen niet door de Aramis initiatiefnemers worden ondernomen en omdat hierover slechts beperkt informatie beschikbaar is, worden deze milieugevolgen slechts op globaal niveau beschouwd.

8.1 Afvang CO_2 voor Aramis initiatief

De bedrijven die CO_2 gaan leveren in het kader van het Aramis initiatief hebben waarschijnlijk een omgevingsvergunning nodig voor de verandering van hun inrichting (uitbreiding met een afvanginstallatie en een compressor). Het effect hiervan op de geluidsuitstraling is niet op voorhand te kwantificeren en is sterk afhankelijk van de gebruikte afvangtechniek alsmede bedrijfs- en locatiespecifieke omstandigheden.

8.2 Aansluiting op Porthos-leiding en aanpassen kade

We gaan ervan uit dat emitters of aansluiten op de Porthos landleiding of via schepen hun CO_2 naar CO2next transporteren.

Aansluiten op Porthos leiding
Voor aansluitleidingen is in dit kader alleen de aanleg potentieel akoestisch relevant. De belangrijkste activiteit is het ingraven van de leiding, waarbij mobiele kranen met graafbakken en boormotoren de meest relevante geluidsbronnen zijn. De als gevolg hiervan optredende langtijdgemiddelde beoordelingsniveaus zullen naar verwachting voldoen aan de van toepassing zijnde grenswaarden uit het Besluit bouwwerken leefomgeving (Bbl).

Aanpassen kade
Bij de leveranciers worden mogelijk damwanden aangebracht. Hierbij kan gedacht worden aan het verstevigen van een kade bij een emitter en aan damwanden samenhangend met het plaatsen van een nieuwe steiger. Een kraan met trilblok en hulpkraan worden dan ingezet. Als we ervan uitgaan dat deze activiteit per locatie niet meer dan enkele dagen in beslag neemt, zullen ook de als gevolg hiervan optredende langtijdgemiddelde beoordelingsniveaus in de omgeving naar verwachting voldoen aan de van toepassing zijnde grenswaarde volgens het Besluit bouwwerken leefomgeving (Bbl).

Volledigheidshalve wordt hierbij aangetekend dat bouw- en sloopwerkzaamheden niet zonder maatwerkvoorschrift mogen plaatsvinden tussen 19:00 en 07:00 uur en/of op zondagen dan wel op feestdagen.

8.3 Periode na startfase en eerste uitbreiding

Toekomstige initiatieven na de eerste uitbreiding kunnen extra pompen op de terminal en extra aanlegsteigers betekenen. De kans dat afgemeerde (zee-)schepen laagfrequent geluid produceren is klein. De kans dat meerdere (zee-)schepen vergelijkbaar luid laagfrequent geluid veroorzaken, met relevante cumulatie tot gevolg, is verwaarloosbaar klein. Verder zijn schepen qua eventuele laagfrequente geluiduitstraling veel luider dan bijvoorbeeld kleinere installaties met geringere elektrische vermogens (al dan niet omkast of inpandig opgesteld). Extra pompen zijn voor het aspect laagfrequent geluid dan ook niet bepalend. De onderzochte worst case situatie samenhangend met de startfase en de eerste uitbreiding is daarom ook geschikt als maatgevende situatie in de periode na de vergunning.

9 Leemten in kennis

Dit beschrijft de leemten in kennis voor de besluitvorming over het Aramis initiatief.

De voor deze studie aangehouden terreinindeling en installaties geven een indicatie van de te realiseren situatie. De gebruikte gegevens zijn gebaseerd op kengetallen, eigen ervaring en informatie van leveranciers. Hoewel de onderdelen van het Aramis initiatief in dit stadium onvoldoende zijn uitgewerkt om een betere inschatting te maken, zijn de betreffende gegevens op zichzelf realistisch.

10 Samenvatting bevindingen en toetsing wet- en regelgeving

Gebruiksfase
Het verschil tussen laagfrequent geluid in de referentiesituatie en de gebruiksfase is klein. Zowel de referentiesituatie als de gebruiksfase voldoen aan de grenswaarden (Vercammencurve). Een toename van activiteiten leidt tot (een grotere kans op) meer laagfrequent geluid. Het voornemen wordt als licht negatief gewaardeerd.

Aanleg en ontmanteling
Ten tijde van de aanleg, testen en ontmanteling zijn het compressorstation en de terminal niet in gebruik. De maatgevende bronnen bestaan dan uit bouwmachines en tijdens testen uit onder meer een mobiele compressor. We veronderstellen op grond van ervaringen met grootschalige bouwprojecten dat laagfrequent geluid dan geen rol van betekenis speelt.

Onderhoud en onvoorziene situaties
Tijdens het opstarten of uit bedrijf nemen van de installaties zijn geen afwijkende geluidsniveaus te verwachten. Wel kunnen kortstondige verhogingen van de door de installaties veroorzaakte geluidsniveaus optreden wanneer de noodstroomgenerator van de CO2Next terminal wordt getest (eens per maand) of de compressoren door een storing uitvallen en druk wordt afgelaten via het drukaflaatsysteem. Alleen dit laatste geluid zou bij de dichtstbijzijnde woningen waarneembaar kunnen zijn.

Werkzaamheden buiten de Aramis scope
De bedrijven die CO_2 gaan leveren in het kader van het Aramis initiatief zullen een afvanginstallatie en een compressor gaan installeren. Het effect hiervan op de geluidsuitstraling is niet op voorhand te kwantificeren en is sterk afhankelijk van de afvangtechniek alsmede bedrijfs- en locatiespecifieke omstandigheden. Het aansluiten op de Porthosleiding en het eventueel aanpassen van kades vereist bouwmaterieel, zoals kranen en een trilblok ter realisatie van damwanden. Deze werkzaamheden zijn kortdurend. Als we ervan uitgaan dat deze activiteit per locatie niet meer dan enkele dagen in beslag neemt, zullen ook de als gevolg hiervan optredende geluidniveaus in de omgeving naar verwachting voldoen aan de van toepassing zijnde grenswaarde volgens het Besluit bouwwerken leefomgeving (Bbl).

11 Literatuur

- ‘LF-geluid en trillingen in woningen ten gevolge van grindwinning door grindwinschepen’ rapportnr. 2003-CI-R0001
- meetrapport d.d. 8 dec. 2014, notitie 21855890
- ‘Laagfrequent geluid van containerschepen in de Waalhaven’ d.d. 4 maart 2015, notitie 21919473

Appendix 1

Berekeningen LFG, worst case situaties

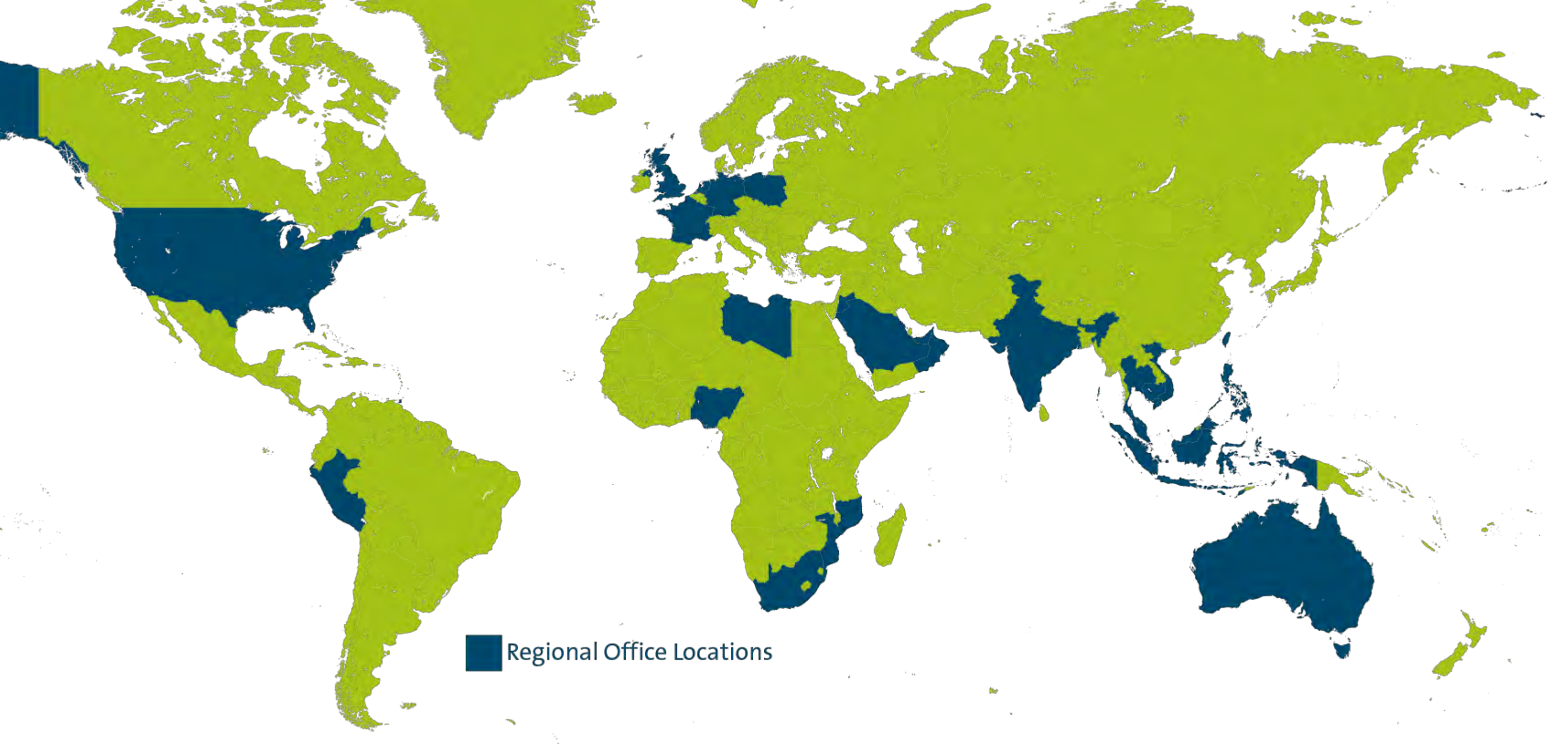
Royal HaskoningDHV

1.1 Worst case situatie

Meetresultaten DCMR 2014 op 500 m van zeekade						Geo-milieu		Worst case situatie					Resultaat
	Worst case overmatige overlast			Gemid-delde	Gemid-delde	Overdrachts-verlies				dBlin	AFNAME	AFNAME	**TERTS**
Tertsen	Laberinto	Lavras	Laguna	Immis-sie	immissie	obv 500m in		**Bron-spectrum**	Logsum	**Resul-taat**	OCTAAF	TERTS	**2500 m**
Freq in Hz	dB	dB	dB	Worst case	dB octaaf	dB octaaf	dB	dB terts	octaaf	**2500 m**	dB	dB	**dB**
20	60	58	60	59,4									
25	59	61	62	60,8			63,6	124,4				75,4	49,0
31,5	72	69	65	69,5	75,9	63,6	63,6	133,1	139,5	64,1	75,4	75,4	57,7
40	78	71	70	74,6			63,6	138,2				75,4	62,8
50	76	72	70	73,4			64,7	138,1				75,8	62,3
63	68	67	65	66,8	74,6	64,7	64,7	131,5	139,3	63,5	75,8	75,8	55,7
80	63	63	64	63,4			64,7	128,1				75,8	52,3
100	69	65	68	67,6			72,7	140,3				84	56,3
125	63	59	61	61,3	68,5	72,7	72,7	134,0	141,3	57,3	84,0	84	50,0
							72,7	122,0					

1.2 TNO studie

Geomilieu afname 1200-2500m: 31,5Hz -5 dB en bij hogere tertsen -6 dB			
M.b.v. TNO-studie 2003-CI_R0001 & HMRI			
Lp binnen [dB]		-5 dB HMRI 1200->2500m	
1200m	2500m	Gevelwering in [dB]	**Lp 2500m buiten [dB]**
65 (25 Hz)	59,4	9	68,4
53 (31,5 Hz)	47,4	10	57,4
55 (40 Hz)	49,4	11	60,4
50 (50 Hz)	44,3	12	56,3
41 (63 Hz)	35,3	13	48,3
33 (80 Hz)	27,3	14	41,3



Royal HaskoningDHV is een onafhankelijk internationaal advies- en ingenieursbureau. We combineren 140 jaar engineering- en ontwerpexpertise met consultancy, software en technology diensten. We leveren hiermee toegevoegde waarde voor klanten en hebben een positieve impact op mensen en onze leefomgeving. Dat is onze drijfveer: Enhancing Society Together. Daar hoort bij dat we onszelf en anderen voortdurend uitdagen om bij te dragen aan duurzame oplossingen voor lokale en wereldwijde vraagstukken in de gebouwde omgeving en de industrie.

In onze snel veranderende wereld wordt de agenda bepaalt door onder meer klimaatverandering, de digitale transformatie, een veranderende consumentenvraag en hybride werken. Met onze geïntegreerde duurzame oplossingen willen we bijdragen aan het bredere technologische en maatschappelijke plaatje.

Gesteund door de kennis en ervaring van meer dan 6.000 collega's werken we vanuit kantoren in meer dan 20 landen. We ondersteunen klanten om de transitie te maken naar een slimme en duurzame organisatie. We koppelen onze engineering- en ontwerpexpertise aan onze software- en technologische diensten om toegevoegde waarde te leveren voor onze klanten en de lifecycle van hun assets.

We zijn oprecht, handelen integer en transparant in al onze activiteiten, ook onze bedrijfsvoering Ons team is divers en inclusief. De veiligheid en het welzijn van mensen, in ons team en daarbuiten, staat onder alle omstandigheden voorop.

In projecten en initiatieven werken we actief samen met overheden en het bedrijfsleven, partners en stakeholders. We zien een belangrijke rol voor onszelf in innovatieve duurzame ontwikkeling en willen bijdragen aan een betere leefomgeving, nu en in de toekomst.

Ons hoofkantoor is gevestigd in Nederland en we hebben kantoren in Europa, Azie, Afrika, Australie en Amerika.

euroCompliance certification ISO 37001 euroCompliance certification ISO 37301

royalhaskoningdhv.com

RAPPORT

Onderwatergeluid

MER Aramis CO2 transportinfrastructuur

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2008

Status: Definitief/01

Datum: 9 februari 2024

ARAMIS	CCS-ARAMIS Project
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2008 Document title Underwater noise report Revision Final 4.0

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV NEDERLAND B.V.

Jonkerbosplein 52
6534 AB Nijmegen
Industry & Buildings
Trade register number: 56515154

+31 88 348 70 00 **T**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

Titel document:	Onderwatergeluid
Sub titel:	MER Aramis CO2 transportinfrastructuur
Referentie:	ARM-PFE-B10-ENV-EIA-2008
Status:	01/Definitief
Datum:	9 februari 2024
Projectnaam:	MER Aramis
Projectnummer:	BH8744

Classificatie
Projectgerelateerd

Inhoud

Bijlagen

Afkortingenlijst

CCS	:	Carbon Capture and Storage
CO_2	:	Koolstofdioxide
HF	:	High-Frequency cetaceans
KEC	:	Kader Ecologie en Cumulatie
LBBR	:	LNG Break Bulk terminal Rotterdam
LF	:	Low-Frequency cetaceans
LNG	:	Liquefied Natural Gas
MER	:	Milieueffectrapport
MF	:	Mid-Frequency cetaceans
NCP	:	Nederlands Continentaal Plat
NMFS	:	National Marine Fisheries Service
NOAA	:	National Oceanic and Atmospheric Administration
OW	:	Otariid pinnipeds in water
PTS	:	Permanent Threshold Shift
PW	:	Phocid Pinnipeds in water
RMS	:	Root Mean Square of effectieve waarde van een signaal
ROAD	:	Rotterdam Opslag en Afvang Demonstratieproject
SEL1	:	Single Strike Sound Exposure Level ook afgekort met SEL_{SS}
SEL	:	Sound Exposure Level of geluiddosis
SPL	:	Sound Pressure Level of geluiddrukniveau
TTS	:	Temporary Threshold Shift

Royal HaskoningDHV

1 Inleiding

Voor u ligt het detailrapport over onderwatergeluid, onderdeel van het bij het MER voor het Aramis initiatief

Dit detailrapport heeft betrekking op het milieuthema onderwatergeluid. De eigenschappen van het onderwatergeluid zoals de bron, het niveau van geluid met geluidfrequentie, de duur van geluidproductie en jaargetijden zijn bepalend voor de mogelijke effecten. De effecten worden beoordeeld onder het thema natuur en gerapporteerd in de natuurtoets Passende beoordeling.

Dit detailrapport bevat een gedetailleerde beschrijving en beoordeling van de effecten van alle onderdelen van het Aramis initiatief, en een globale beschrijving en beoordeling van de effecten van onderdelen die niet tot het Aramis initiatief behoren, maar wel tot de CCS-keten.

1.1 Korte introductie van het Aramis initiatief

Integrale Aramis CCS-keten

Om de klimaatdoelstellingen te behalen, is er behoefte aan additionele transportinfrastructuur voor CO_2, waarmee meerdere opslaglocaties op zee worden ontsloten voor verschillende industriële emissiebronnen. Het Aramis initiatief speelt in op die behoefte door een nieuwe integrale en open CCS-keten mogelijk te maken. Het Aramis initiatief vormt een onderdeel van deze CCS-keten en bestaat uit de aanleg en exploitatie van een open CO_2-transportinfrastructuur. Het Aramis initiatief wordt in de rapportage dan ook wel aangeduid als Aramis CO_2-transportinfrastructuur. Samen met de afvanginfrastructuur en opslaginfrastructuur vormt dit de integrale CCS keten met onderstaande samenhangende onderdelen (zie figuur 1-1).

CO_2-afvanginfrastructuur

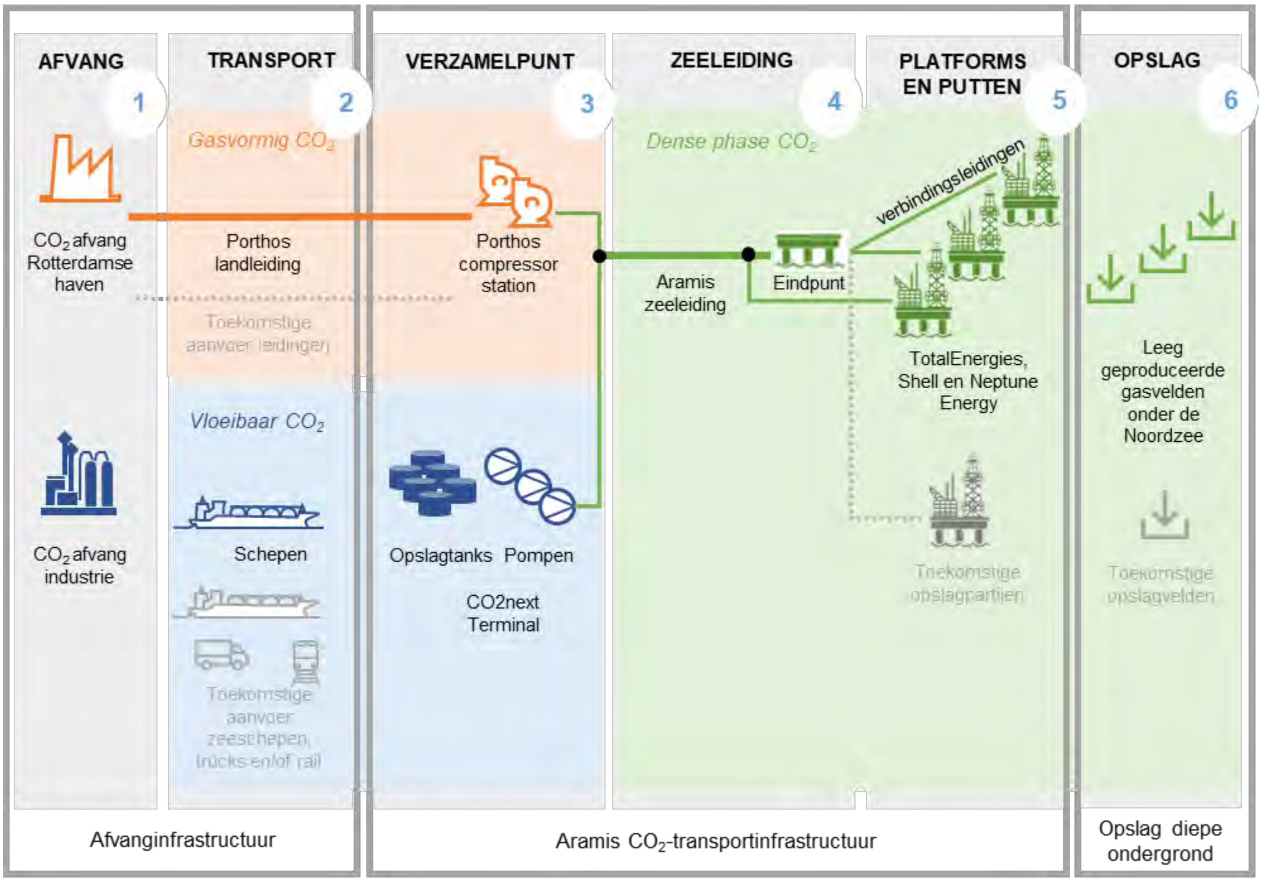
1. CO_2-afvang bij industrie, en geschikt maken voor transport;
2. CO_2-transport naar het verzamelpunt op de Maasvlakte, middels de Porthos landleiding of per schip;

CO_2-transportinfrastructuur (Aramis initiatief)

3. CO_2-verzamelpunt op de Maasvlakte met een compressorstation en een terminal.
   - Het compressorstation ontvangt gasvormig CO_2 dat aangevoerd wordt per landleiding (via de Porthos-landleiding) en brengt het op druk voor het transport per zeeleiding;
   - De terminal ontvangt vloeibaar CO_2 aangevoerd per schip. De terminal locatie bevat steigers, opslagtanks voor tijdelijke opslag van CO_2 en hogedrukpompen voor levering aan de zeeleiding. CO_2 uit het compressorstation en vanaf de terminal komen samen in de CO_2-zeeleiding;
4. CO_2-transport door de centrale CO_2-zeeleiding naar het distributieplatform op de Noordzee. Dit platform is uitgerust met een verdeelstation voor toevoer van CO_2 naar de verschillende platforms. Er zijn tevens connectiepunten in de zeeleiding waar vandaan CO_2 aan platforms geleverd kan worden;
5. CO_2-injectie: via verbindingsleidingen komt de CO_2 vanaf de zeeleiding bij injectieplatform. Middels putten bij deze platforms wordt CO_2 geïnjecteerd in leeg geproduceerde gasvelden in de diepe ondergrond van de Noordzee.

CO_2-opslag diepe ondergrond

6. CO_2-opslag: permanente CO_2 opslag in de diepe ondergrond.



Figuur 1-1: Overzicht van de integrale CCS-keten met daarin de componenten die onderdeel zijn van de voorgenomen activiteit, namelijk: transport per schip, terminal CO2next, uitbreiding compressorstation Porthos, zeeleiding met eindpunt en connectiepunten, aansluitleidingen en platforms

Het Aramis initiatief

Het Aramis initiatief heeft als doel het verzamelpunt (onderdeel 3), de zeeleiding (onderdeel 4) en de injectie (onderdeel 5) te realiseren. Hiervoor wordt door het Aramis consortium (bestaande uit Shell, TotalEnergies, Gasunie en EBN) samengewerkt met CO2next (voor de terminal) en Porthos (voor het compressorstation). De opslag vindt plaats vanaf de platforms van Shell, TotalEnergies en Neptune Energy.

De afvang (onderdeel 1) en transport van CO_2 naar het verzamelpunt (onderdeel 2) vallen buiten het Aramis initiatief[1]. In het MER worden deze aspecten wel benoemd en op hoofdlijnen beschreven, omdat ze integraal onderdeel uitmaken van de integrale Aramis CCS keten.

De opslag in de diepe ondergrond (onderdeel 6) valt eveneens buiten het initiatief. Voor de diepe ondergrond gelden geen milieuregels. De mogelijke gevolgen van opslag in de diepe ondergrond wordt echter wel apart beschreven in het MER middels de deelrapporten opslag diepe ondergrond.

Bij de aanleg van Aramis wordt rekening gehouden met toekomstige uitbreiding met meer leveranciers van CO_2 en meer opslagpartijen. In eerste instantie wordt vergunning aangevraagd voor een startsituatie en de eerste uitbreidingssituatie. Dit wordt in het MER getoetst. Toekomstige initiatieven *na* de eerste

[1] *Een deel van de schepen die CO_2 leveren aan de terminal is afkomstig van Aramis-initiatiefnemers.*

uitbreidingssituatie behoren niet tot de vergunningaanvraag maar worden in het MER wel (globaal) beschreven.

De ingebruikname verwachten de Aramis initiatiefnemers in 2028, waarbij tegelijk al de eerste activiteiten zoals beschreven in de eerste uitbreidingsituatie kunnen starten. Voor het bereiken van de maximale doorvoercapaciteit is enkele jaren later als uitgangspunt in het MER aangehouden.

Een uitgebreide beschrijving van het Aramis initiatief is opgenomen in het deelrapport technische beschrijving en het samenvattend hoofdrapport MER (zie figuur 1-2).

1.2 Korte introductie op het milieuthema onderwatergeluid

1.2.1 Onderwatergeluid

Effecten van onderwatergeluid treden op als gevolg van activiteiten in wateromgevingen tijdens de aanleg van de terminal, compressorstations, platforms en de transportleiding op zee. Deze effecten kunnen ook optreden tijdens de gebruiksfase of bij calamiteiten. Beoordelingen van het onderwatergeluidseffect zijn uitgevoerd via een bureauonderzoek, waarbij gebruik is gemaakt van bestaande informatie.

1.2.2 Relevante fases

Het MER bestudeert die aspecten van een activiteit die de fysieke leefomgeving kunnen beïnvloeden. De milieueffecten van de alternatieven en varianten voor het milieuthema onderwatergeluid worden beschreven. Daarbij wordt onderscheid gemaakt tussen de aanlegfase en gebruiksfase, en worden de mogelijke effecten van een incident beschreven, namelijk:

- De aanlegfase bestaat uit de aanleg van de terminal, het aanpassen van het compressorstation en plaatsen van de buisleiding op land en op zee en aanpassing en/of installatie van platforms en boorputten.
- De gebruiksfase bestaat uit de start-up en shutdown van de buisleiding waarbij de druk en temperatuur van CO_2 in de buisleiding zal toenemen en afnemen. Gedurende de normale gebruiksfase wordt een constante druk en temperatuur aangenomen.

In hoofdstuk 3 is nader gespecificeerd welke geluidbronnen onderwater van belang zijn in de bouwfase, de gebruiksfase en in onvoorziene situaties oftewel calamiteiten.

In de eerste fase van de m.e.r.-procedure voor het Aramis initiatief is afgebakend welke onderwerpen binnen dit thema relevant zijn om te onderzoeken en hoe. Dit is beschreven in de Notitie Reikwijdte en Detailniveau die 18 november 2022 definitief is vastgesteld door de Minister voor Klimaat en Energie.

1.2.3 Relevante milieuaspecten

De geluiduitstraling onderwater veroorzaakt effecten op het marine ecosysteem. De studie naar onderwatergeluid is input voor de effectbepaling bij het thema natuur. De geluiduitstraling wordt bepaald aan de hand van hinderafstanden voor het in te zetten materieel. In de studie naar onderwatergeluid wordt betrokken:

- Effecten van onderwatergeluid door bouwwerkzaamheden bij het compressorstation, de terminal, de pijpleiding en de platforms;
- Geluidemissies van materieel en activiteiten tijdens de ontmanteling van installaties en platforms;
- Geluidemissies van schepen, zowel van vaarbewegingen als van aangemeerde schepen. Naast varende schepen veroorzaken aangemeerde schepen met inwerking zijnde generatoren eveneens geluid onderwater. Vaarbewegingen met een relatief lage intensiteit op zee komen niet aan bod. Dit

in tegenstelling tot een hoge vaarintensiteit in de haven in de omgeving van de terminal en langdurig verblijf van een schip in een beperkt gebied op zee met relevantie voor onderwatergeluid. Onderzochte activiteiten in het kader van een langdurig verblijf bestaan uit de inzet van een pijplegschip en seismisch onderzoek;

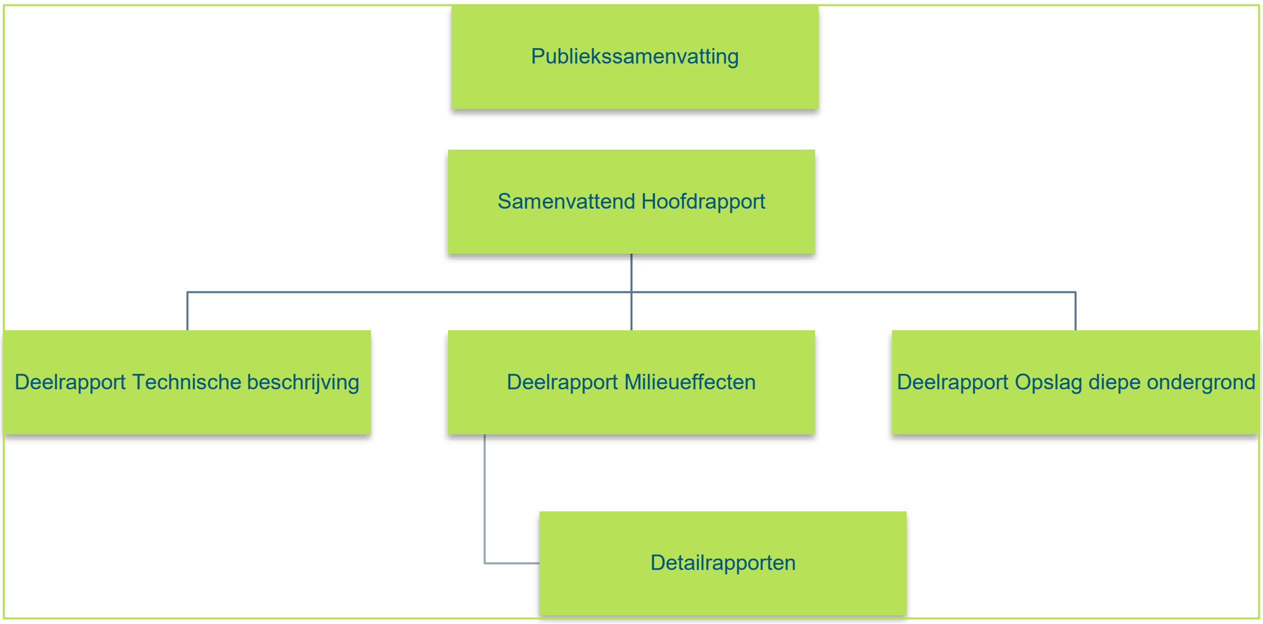
- Geluid tijdens bijzondere situaties bij transport.

Voor onderwatergeluid is vooral het effect op mariene ecologie van belang. De geluidbronnen, het niveau van geluid met geluidfrequentie, de duur van geluidproductie en jaargetijden zijn bepalend voor de mogelijke effecten. Dit detailrapport beschrijft de milieueffecten van de milieuaspecten.

1.3 Opbouw van het MER en dit deelrapport

Voor het Aramis initiatief is een gecombineerd Plan-/ProjectMER opgesteld. Figuur 1-2 geeft de rapportagestructuur van het MER Aramis. Het MER bestaat uit een Samenvattend Hoofdrapport, voorzien van een Publiekssamenvatting. Ter onderbouwing van het Samenvattend Hoofdrapport zijn deelrapporten opgesteld. Dit betreft het deelrapport Technische beschrijving van Aramis, het deelrapport Milieueffecten met daarbij de onderliggende technische detailstudies en de deelrapporten Opslag diepe ondergrond. Doordat CO_2 in meerdere geologische voorkomens wordt opgeslagen, zijn er voor de opslag diepe ondergrond meerdere deelrapporten opgesteld.

Het voorliggende rapport is het detailrapport Onderwatergeluid. De bevindingen uit dit detailrapport zijn opgenomen in het Deelrapport Milieueffecten, en op hoofdlijnen in het Samenvattend Hoofdrapport.



Figuur 1-2: Overzicht rapportagestructuur MER Aramis

Opbouw van dit detailrapport

In dit ondersteunende deelrapport wordt in hoofdstuk 3 een overzicht gegeven van de relevante werkzaamheden en activiteiten die plaatsvinden binnen het kader van het onderwatergeluids-thema, en hoe deze worden beoordeeld. De daaropvolgende hoofdstukken, 4 en 5, belichten respectievelijk het onderwatergeluid tijdens de bouwfase en de gebruiksfase in detail. Hoofdstuk 6 presenteert een beschrijving van het seismisch onderzoek, terwijl hoofdstuk 7 de milieueffecten in onvoorziene situaties behandelt. Uiteindelijk biedt hoofdstuk 8 een samenvatting van de bevindingen en inzichten rondom het thema onderwatergeluid.

2 Beleid, wet- en regelgeving

Geluidnorm heiwerk Noordzee

De standaard voor activiteiten die samenhangen met het Noordzeeakkoord betreft momenteel een geluidnorm onderwater van 164 dB re 1 μPa^2s op 750 meter van een heilocatie. Deze norm behoort bij het ontwerpkavelbesluit IJmuiden Ver en betreft de bouw van windturbineparken en niet de bijbehorende Net Op Zee platforms. De voornoemde norm vervangt de geluidnorm van 168 dB re 1 μPa^2s op 750 meter van de heilocatie.

Met de gekozen strengere geluidsnorm van 164 dB re 1 μPa^2s is een balans gezocht tussen enerzijds het beperken van de toename van het aantal bruinvisverstoringsdagen en anderzijds het rekening houden met de uitvoerbaarheid van de aanlegwerkzaamheden. Hiermee blijft er onverminderd een prikkel bestaan om te investeren in onderzoek naar en ontwikkeling van geluidsarmere funderingstechnieken, terwijl negatieve effecten op de staat van instandhouding van de bruinvis kunnen worden uitgesloten. Voor nadere informatie over de normering zie het ‘Ontwerpkavelbesluit kavel Alpha windenergiegebied IJmuiden Ver’, paragraaf 7.3.3 Bruinvis.

3 Inleiding onderwatergeluid

De onderwerpen genoemd in de introductie op het milieuthema onderwatergeluid komen aan bod tijdens de bouwfase en/of de gebruiksfase of samenhangend met een onvoorziene situatie.

Ten aanzien van de bouwfase (ook aangeduid als 'B') bestaan de te onderzoeken aspecten uit:

B1 Onderwatergeluid door de inzet van het pijplegschip en werkzaamheden aan de zeebodem;

B2 Heiwerk ten behoeve van het centrale eindpunt;

B3 Plaatsen van jacket en topside van het centrale eindpunt en andere platforms met heavy lift schip;

B4 Onderwatergeluid door de ontmanteling van installaties en platforms;

B5 De inzet van helikopters.

B6 Onderwatergeluid door activiteiten op land, zoals het realiseren van de fundering van het compressorstation en de terminal opslagtanks;

B7 Jetties, het met een heihamer realiseren van de fundering van de aanlegsteigers;

B8 (Hei- en boor-)werkzaamheden aan en vanaf de platforms;

B9 Boring ten behoeve van aanlanding buisleiding.

De te onderzoeken aspecten in de gebruiksfase (ook aangeduid als 'G') bestaan uit:

G1 Varende en lossende schepen in de haven en bij de platforms;

G2 Risers.

Een aspect dat in de bouwfase en tevens in de gebruiksfase speelt is:
BG1 Seismisch onderzoek (ondiep en diep).

De onvoorziene situatie betreft ten slotte een defect aan de pijpleiding en/of riser.

In het MER worden drie ruimtelijke alternatieven onderzocht, die betrekking hebben op de locatie van de terminal, de route van de zeeleiding en de kruising met de Maasgeul. Slechts de route van de zeeleiding kan een effect hebben op de mariene ecologie, de effecten van de verschillende routes zijn beschreven in de natuurtoets. De alternatieven hebben geen invloed op de berekende geluidniveaus dan wel de berekende veilige afstanden vanuit de werkzaamheden en bedrijfssituaties.

Door RHDHV zijn meerdere berekeningen uitgevoerd om inzicht te verkrijgen in de te verwachten verstoringseffecten voor vissen, bruinvissen en zeehonden. Hierbij is rekening gehouden met de waterdiepte, de uitbreiding en de frequentie van geluid. De overige omgevingsparameters, zoals bodem en wateroppervlak waar geluid wordt verstrooid en geabsorbeerd, zijn niet in onze berekeningen betrokken omdat hiervoor geen gevalideerde rekenprogrammatuur beschikbaar is. De rekenresultaten, bijvoorbeeld in de vorm van afstanden, zijn door het ontbreken van absorptie tot eerder een overschatting van de effecten. Zo zijn afstanden tot enkele kilometers voldoende nauwkeurig te berekenen, bij grote afstanden vanaf meerdere kilometers bestaat de kans dat de afstand significant (met factor 1,5 tot 2) wordt overschat. In de voorliggende rapportage wordt diverse malen verwezen naar door TNO uitgevoerde berekeningen. Hierin zijn meer variabelen verwerkt wat de nauwkeurigheid ten goede komt. De rekenresultaten van TNO hebben betrekking op andere projecten dan Aramis en worden indien nodig door RHDHV gecorrigeerd indien het schaalniveau van Aramis afwijkt.

Om de verwachte hoeveelheden onderwatergeluid in verband te brengen met de invloed ervan op de zeedieren, wordt uitgegaan van het begrip PTS (permanent threshold shift) oftewel gehoorschade door een permanente verhoging van de gehoordrempel. Naast PTS komt gedragsbeïnvloeding aan bod, bijvoorbeeld het mijden van een bepaald gebied waardoor eventueel minder mogelijkheden bestaan om te foerageren.

4 Onderwatergeluid in de bouwfase

De in de inleiding vermelde onderwerpen zijn onderstaand uitgewerkt, het gaat dan om 9 situaties (B1 t/m B9).

4.1 Inzet pijplegschip en werkzaamheden aan de zeebodem (B1)

4.1.1 Inzet pijplegschip

Bij de aanleg van de buisleidingen bestaande uit de hoofdleiding en de vertakkingen wordt een zogenoemd pijplegschip ingezet. Van het pijplegschip de ‘Solitaire’ zijn geluidgegevens voorhanden. We ontlenen de voornoemde gegevens aan het onderzoek dat door TNO is uitgevoerd in opdracht van RoyalHaskoningDHV met referentie TNO-MEM-2011-00473 ‘Onderwatergeluid bij de aanleg en het in bedrijf zijn van de CO_2 opslag in het kader van het ROAD project’ d.d. 5 april 2011. Een pijplegschip produceert vooral onderwatergeluid in het frequentiebereik van 125 Hz tot 1 kHz. Ten behoeve van het dynamic positioning system beschikt de Solitaire over thrusters met een totaal vermogen van ca. 50 MW. Thrusters zijn schroeven die zich in een behuizing onder het schip bevinden, de behuizing kan 360 graden roteren. De Solitaire produceert onderwatergeluid en heeft een door TNO geschat bronniveau van 188 dB re 1 $\mu Pa^2 m^2$. Op 100 meter afstand en bij een waterdiepte van 25 meter leidt dit bronniveau van 188 dB re 1 $\mu Pa^2 m^2$ tot een geluiddrukniveau (SPL) van 154 dB re 1 μPa. Het bijbehorende sound exposure level over 24 uren op 100 meter afstand is hiermee 203 dB re 1 $\mu Pa^2 s$.

Aramis maakt gebruik van de schepen Subsea 7 Borealis, de Allseas Lorelay of een vergelijkbaar pijplegschip. De pijplegschepen hebben een maximaal geïnstalleerd vermogen van 35 MW en maken gebruik van een positioneringssysteem DP2 of DP3. In verband met bedrijfszekerheid en veiligheid mag bij DP2 en DP3 slechts 50% van het vermogen tijdens de gangbare werking worden benut. Een voor Aramis representatief in werking zijnde pijplegschip heeft daarmee een vermogen van 18 MW, dat betekent een geluiddrukniveau (SPL) van maximaal 149,5 dB re 1 μPa. Gelet daarop achten we een geluiddrukniveau (SPL) van 149,5 dB re 1 μPa representatief voor alle typen mogelijk in te zetten pijplegschepen en andere grote multipurpose constructie schepen. De laatstgenoemde schepen houden zich plaatselijk bezig met bijbehorend installatiewerk (bij kruisingen of platforms) en duikactiviteiten. Zie de navolgende afbeelding voor het pijplegschip, de Subsea 7 Borealis, met een lengte van 182 meter.

Royal HaskoningDHV

We merken ten slotte op dat een pijplegschip kan worden ondersteund door één of incidenteel enkele schepen in verband met monitoring en de aanvoer van materialen. Akoestisch bezien zijn de ondersteunende schepen door de relatief beperkte motorvermogens niet relevant.

Gehoorschade bij vissen en zeezoogdieren in de vorm van een verhoging van de gehoordrempel kan tijdelijk of permanent zijn. Een tijdelijke verhoging wordt aangeduid als TTS (*temporary threshold shift*) en een permanente verhoging als PTS (*permanent threshold shift*). De veilige afstand en veilige verblijfstijd voor vissen en zeezoogdieren zijn berekend voor het pijplegschip. De drempels 'PTS SEL' betreffen ongewogen waarden.

Toepassing M-weging

In de veilige afstand en de veilige verblijfstijd is bij bruinvissen en zeehonden een (M-)weging toegepast. De M-weging, volgens Southall et al. (2007) ‘Marine mammal noise exposure criteria’, zorgt dat in berekeningen het feit wordt meegewogen dat elk dier een specifiek gehoor heeft en dus niet voor alle frequenties even gevoelig is. De gehanteerde drempels zijn afkomstig van:

- NOAA’s National Marine Fisheries Service (NMFS), ‘2018 Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0) - Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts’, zie bijlage 1;
- Voor vissen geldt in het kader van gedragsverandering (het mijden van een gebied) een geluiddrukniveau van 150 dB re 1 µPa (effectieve waarde). De bron hiervoor is Stadler en Woodbury (2009);
- Voor vissen hanteren we als drempel voor PTS (*permanent threshold shift*), oftewel gehoorschade door een permanente gehoordrempelverhoging, de waarde van 207 dB re 1 µPa^{2}s, zie tabel 4-1.

Tabel 4-1. Drempelwaarden TTS en PTS voor vissen

Species	Acoustic range	TTS	PTS
Fish*			
General [1],[2],[3]	30-1000 Hz	187 dB 1 re µPa2s	207 dB 1 re µPa2s
* The PTS is assumed to be 20 dB higher than TTS 15			

1 Weir CR, Dolman SJ (2007) Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. J Int Wildl Law Policy 10:1-27

2 DeRuiter SL (2010) Marine animal acoustics. In: Lurton X (ed) An introduction to underwater acoustics: principles and applications (2nd edn). Praxis Publishing, Chichester, p 425-474

3 Oestman, R., Buehler, D., Reyff, J. A., & Rodkin, R. (2009). Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish. Prepared for California Department of Transportation.

De berekende veilige afstanden en verblijfstijden zijn in de tabellen 4-2 en 4-3 vermeld. De drempels PTS SEL in tabel 4-2 betreffen ongewogen waarden. In de veilige verblijfstijd en alle afstanden in de tabellen 4-2 en 4-3 is bij bruinvissen en zeehonden de hiervoor reeds aangehaalde M-weging verwerkt. Het verschil in de eigenschappen tussen de bruinvis en zeehond (uitgedrukt in de weegfactoren) is significant, als gevolg daarvan treedt bijvoorbeeld in tabel 4-3 bij een identieke drempel een groot verschil in mijdingsafstand op.

Tabel 4-2. Afstand en verblijftijd samenhangend met PTS vanwege een pijplegschip, representatieve situatie

Bron van onderwater geluid	PTS gerelateerd					
	Diersoort	Drempel PTS SEL in dB re 1 μPa²s	SEL op 100m 1 μPa²s (24u)	Veilige afstand in m bij verblijf van 24 uur	Veilige afstand in m bij verblijf van 3 uur	Veilige verblijf-tijd op 100m afstand in uren
Pijpen leggen	Bruinvis	173	199	7	1	(>) 24
	Grote vis	207	199	16	2	(>) 24
	Kleine vis	207	199	16	2	(>) 24
	Zeehond	201	199	16	2	(>) 24

Tabel 4-3. Afstand samenhangend met mijding vanwege een pijplegschip, representatieve situatie

Bron van onderwater geluid	**Mijding gerelateerd**				
	Diersoort	**Drempel mijding SPL in dB re 1 μPa**	**Drempel mijding* SPL in dB re 1 μPa verhoogde achtergrond**	**Mijding op afstand in m**	**Mijding op afstand in m mits verhoogde achtergrond**
Pijpen leggen	Bruinvis	120	130	16	2
	Grote vis	150	n.v.t.	89	n.v.t.
	Kleine vis	150	n.v.t.	89	n.v.t.
	Zeehond	120	130	22909	2291

*NOAA stelt dat de drempel van 120 dB mag worden verhoogd bij achtergrondgeluidniveaus ≥ 120 dB re 1 μPa

4.2 Heiwerk ten behoeve van het centrale eindpunt (B2)

De jacket van het centrale eindpunt wordt aan de zeebodem verankerd. Hiervoor worden stalen buispalen gebruikt met een diameter van 78 inch (ca. 2 meter). De diameter en lengte van deze palen komen globaal overeen met de verankeringspalen voor de nieuwe platforms en lijken sterk op de palen van het ONE-Dyas gasboringsproject dat wordt beschreven in paragraaf 4.8.2. We veronderstellen dat de slagenergie, als relevante factor voor de representatieve geluidafstraling, ook maximaal 1000 kJ is. Gezien de voornoemde analogie verwijzen we voor de berekende geluiddosis SEL_{SS} en de verstoringsoppervlakte naar paragraaf 4.8.2. In deze fase voorafgaand aan de FEED zijn de specifieke geotechnische waarden van de ondiepe ondergrond nog niet bekend. De aannamen en bevindingen zijn daarom onder voorbehoud en dienen te zijner tijd, na afronding van het nadere geotechnisch onderzoek, te worden gecontroleerd en eventueel aangepast.

4.3 Heavy lift schip (B3)

Middels een heavy lift schip of kraanschip worden de jacket en de topside van het centrale eindpunt en andere Aramis platforms geplaatst. Ten behoeve van varen en het dynamic positioning system beschikt een heavy lift schip over meerdere thrusters. Voor het pijplegschip is gerekend met een totaal opgesteld motorvermogen van 18 MW. Onder representatieve omstandigheden zal het heavy lift schip eveneens kunnen volstaan met globaal 18 MW. Onder representatief wordt verstaan de situatie waarbij de voor de geluidproductie relevante omstandigheden kenmerkend zijn voor een bedrijfsvoering bij volledige capaciteit. Hogere vermogens dan 18 MW zijn niet voorzien.

De in de tabellen 4-2 en 4-3 genoemde afstanden kunnen als representatief worden aangehouden voor een varend en op locatie werkend heavy lift schip. De inzet van het heavy lift schip is verder kortdurend, het gaat in totaal om ongeveer 6 etmalen per platform.

4.4 Ontmanteling van installaties/ platforms (B4)

De ontmanteling van installaties en platforms veronderstellen we akoestisch bezien gelijkwaardig aan onderwatergeluid gedurende de (om-)bouwfase. In de bouwfase komen onder punt B8, paragraaf 4.8.1, machinegeluiden en het wegboren van pluggen aan bod. Het gehanteerde breedbandige geluidniveau voor machinegeluiden op het boorplatform en het wegboren van pluggen is 150 dB re 1 μPa op een afstand van 100 meter, overeenkomend met een significant sound exposure level van 199 dB re 1 μPa2s. Conform tabel 4-6 gaan we ervan uit dat zeehonden en bruinvissen deze werkzaamheden zullen mijden tot op een afstand van globaal 10 kilometer van een platform. Het in paragraaf 4.3 genoemde heavy lift schip wordt bij ontmanteling ook 6 etmalen ingezet.

4.5 Helikoptergeluid (B5)

Het helikoptergeluid dat vanuit de lucht doordringt tot in het water is zeer gering. Bij loodrechte inval reflecteert meer dan 99,9% van het geluid aan het wateroppervlak en blijft dus in de lucht. Bij een hoek van 13 graden en groter dringt het geluid helemaal niet meer door in het water en reflecteert het volledig. De te verwachten frequenties bevinden zich beneden 50 Hz. Als gevolg hiervan heeft helikoptergeluid weinig invloed onderwater. Daarnaast treedt het slechts in beperkt aantal gevallen op en is kortstondig. Door het verplaatsen van de helikopter is ook geen sprake van langdurige blootstelling van zeedieren aan geluid. De totale blootstelling is als verwaarloosbaar aan te merken.

4.6 Realiseren fundering op land (B6)

Het realiseren van funderingen op land ten behoeve van de terminal veroorzaakt geen significante geluidniveaus in het nabijgelegen water. We baseren ons hierbij op een in 2014 door RoyalHaskoningDHV verricht onderzoek naar de (onderwater-)geluidaspecten die samenhangen met de destijds te realiseren kade ten behoeve van de LNG terminal (ook genoemd LBBR) aan het Yangtzekanaal. In dit onderzoek en de bijbehorende notitie met referentie BC8918-126-100/N001/408255/Nijm d.d. 1 augustus 2014 zijn de volgende uitgangspunten gehanteerd.

De geluidrelevante werkzaamheden bestonden uit in de bodem op minimaal 45 meter afstand van de waterlijn te plaatsen buispalen. Het ging bij het plaatsen van buispalen deels om intrillen en deels om heien met de volgende gegevens:

- De maximale energie van het heiblok is ca. 300 kJ (bijvoorbeeld heihamer D100);
- Het trilblok geeft maximaal 110 kJ (bijvoorbeeld trilblok PvE 110M);
- De trilduur per buispaal is ca. 10 minuten (opgave Havenbedrijf Rotterdam), inbrengen tot -20m NAP;
- De heiduur per buispaal is variabel, we veronderstellen de duur op ca. 30 minuten, inbrengen tot -30m NAP;
- Energie door het heiblok aan water overgedragen is 16 W (Acoustic Watt);
- Energie door het trilblok aan water overgedragen is 13 W (Acoustic Watt).

Voor de fundering van de terminal wordt aangesloten bij de conclusie van het onderzoek naar de LNG terminal. Deze conclusie luidt als volgt:

"*Vanwege scheepvaartbewegingen en overige havenactiviteiten schatten we het achtergrondniveau nabij de geplande insteekhaven op 130 á 140 dB re 1 µPa. Op 100 meter afstand uit de waterlijn verwachten we onderwatergeluidniveaus van 135 tot 138 dB re 1 µPa. De rekenmethode is door de omvang van de bron minder geschikt om op kortere afstanden dan 100 meter uit de waterlijn te rekenen. We verwachten dat geluidniveaus onderwater bij kortere afstanden dan 100 meter uit de waterlijn niet significant zullen toenemen en een waarde van 140 dB re 1 µPa niet zullen overschrijden.*

Uit de kwantitatieve analyse blijkt dat de werkzaamheden ten behoeve van LBBR voor vissen en zeezoogdieren geen relevante onderwatergeluidniveaus opleveren. Dit geldt voor zowel trillen als heien in- én exclusief slow-start. Van effecten op de vissen en zeezoogdieren is dan ook geen sprake."

Het materieel om de opslagvoorzieningen van de terminal te bouwen is vergelijkbaar met het materieel dat is gebruikt voor de aanleg van de LNG terminal aan het Yangtzekanaal. Ook is de afstand van de bouwwerkzaamheden tot de waterlijn niet kleiner. De berekende geluidniveaus onderwater bij de LNG terminal worden daarom als maatgevend gebruikt voor de te verwachten geluidniveaus vanwege het voornemen.

4.7 Jetties en damwanden in de haven (B7)

Jetties
De fundering van de te bouwen aanlegsteigers in de haven bestaat uit stalen buispalen. We veronderstellen dat deze buispalen met uitsluitend een heihamer op diepte worden gebracht. De uitgangspunten van de berekeningen, de normstelling en de afstanden vanaf de heilocatie behorend bij PTS en mijding zijn als volgt. Mochten de buispalen (deels) trillend worden geplaatst, dan is sprake van overschatting van de geluidimmissies en de bijbehorende berekende afstanden onderwater want trillen leidt tot minder geluidproductie. Ook als het aantal slagen per seconde in de berekeningen wordt betrokken, dan levert een trilblok een duidelijk lager geluidvermogen (acoustic power) op dan de heihamer. Als trilblokken en heihamers gelijktijdig worden ingezet, dan veroorzaken trilblokken nagenoeg geen toename van de gecumuleerde geluidniveaus onderwater.

Het uitgangspunt voor brongeluid is ontleend aan tabel A.1 van de publicatie ‘Review on Existing Data on Underwater Sounds from Pile Driving Activities’ d.d. september 2018 van Guillermo Jiménez-Arranz, Rachel Glanfield, Nikhil Banda and Roy Wyatt. Van een stalen buispaal met een diameter van 1,2 meter is op basis van geluidmetingen gebruik makend van een diesel impact hammer D80-42 met slagenergie ≤270 kJ bij een waterdiepte van 11 meter vastgesteld:

- SEL_1 is 183 dB re 1 µPa @ 10 m;
- SPL_{rms} is 198 dB re 1 $\mu Pa^2 s$ @ 10m.

De rekenresultaten zijn opgenomen in bijlage 2 en 3, rekening houdend met de weegfactoren bij een maatgevende frequentie van 2 kHz.

Volgens de methodiek van het Kader Ecologie en Cumulatie (Heinis et al, 2019) worden bruinvissen en zeehonden verstoord bij blootstelling aan heigeluid dat de in tabel 4-4 aangegeven drempelwaarden overschrijdt. Voor detailberekeningen kan gebruik worden gemaakt van KEC 4.0. Voor deze situatie volstaat een berekening met KEC 3.0 aangezien daarmee voldoende inzicht wordt verkregen in de effecten op de populatie van bruinvissen.

Tabel 4-4 is gebaseerd op de systematiek KEC 3.0. Inmiddels is deze systematiek op onderdelen verfijnd, zo is onder andere de discrete drempelwaarde van SEL_{SS} > 140 dB re 1µPa^{2}s vervangen door een dosis-responsrelatie. Met respons wordt een significante gedragsrespons bedoeld zoals een verandering in zwemgedrag. Een kans van 50% op verstoring van bruinvissen binnen één etmaal treedt op bij een geluiddosis groter dan 144 dB re 1µPa^{2}s. De norm van SEL_{SS} > 140 dB re 1µPa^{2}s blijft echter geschikt ter indicatie van het aantal verstoorde bruinvissen. De normen voor PTS afkomstig van NMFS zijn eveneens in tabel 4-4 opgenomen.

Tabel 4-4. Drempelwaarden voor mijding en PTS van impulsachtig onderwatergeluid door bruinvissen en zeehonden.

	Bruinvis	Zeehond
Mijding/verstoring Heinis et al. 2019	SEL_{SS} > 140 dB re 1µPa^{2}s	$SEL_{SS,W}$ > 145 dB re 1µPa^{2}s
PTS-onset (NMFS, impact pile driving 2 kHz)	SEL_{CUM} > 155 dB re 1µPa^{2}s	$SEL_{CUM,W}$ > 185 dB re 1µPa^{2}s

Bij impact pile driving is volgens NMFS de maatgevende frequentie 2 kHz, de weegfactoren zijn dan voor bruinvissen en zeehonden achtereenvolgens -26,87 dB en -2,08 dB, zie ook bijlage 2.

De berekende afstanden vanaf de heilocatie, zie bijlage 2, in verband met PTS zijn voor:

- Bruinvissen ca. 3000 meter;
- Zeehonden ca. 1350 meter.

De berekende afstanden vanaf de heilocatie, zie bijlage 3, in verband met mijding zijn voor:

- Bruinvissen ca. 20 km;
- Zeehonden ca. 3900 meter.

Met de genoemde berekende afstanden wordt in de natuurtoets rekening gehouden. In de berekende afstanden is de geometrie van de haven niet betrokken omdat, geluid zich daar veelal niet ongehinderd rechtlijnig over afstanden van meerdere kilometers kan verplaatsen. In de praktijk zal verstrooiing en reflectie aan de diverse kades leiden tot kortere afstanden voor PTS en mijding. Door de genoemde geometrie van de haven is het rechtlijnig voortplanten van geluidgolven van bron tot oever of kademuur dus slechts over korte afstanden mogelijk. Verder leidt het meervoudig reflecteren van geluidgolven in oevers en kademuren tot veel energieverlies. Het hanteren van een beperkte mijdingsoppervlakte van globaal maximaal 9 km^2 is om de genoemde redenen reëel. Deze oppervlakte betreft het Yangtzekanaal, het Beerkanaal en de Europahaven.

Damwanden
De maximale slagenergie van trilblokken is in orde van grootte van 100 kJ en daarmee significant lager dan bij heihamers. Ook als het aantal slagen per seconde in de berekeningen wordt betrokken, dan levert een trilblok een duidelijk lager geluidvermogen (acoustic power) op dan de heihamer. Als trilblokken en heihamers gelijktijdig worden ingezet, dan veroorzaken trilblokken nagenoeg geen toename van de gecumuleerde geluidniveaus onderwater. Op basis van onze ervaringen en berekeningen met betrekking tot heiwerk voor de realisatie van de HES Hartel Tank Terminal concluderen we dat het plaatsen van damwanden in en nabij de waterlijn geen significant effect heeft op bruinvissen, zeehonden en vissen.

4.8 (Hei- en boor-)werkzaamheden aan en vanaf de platforms (B8)

4.8.1 Machinegeluid en wegboren plug

Het gehanteerde breedbandige geluidniveau voor machinegeluiden op het boorplatform en het wegboren van pluggen is 150 dB re 1 µPa op een afstand van 100 meter, overeenkomend met een *sound exposure level* van 199 dB re 1 µPa²s. Machinegeluid en het geluid van het wegboren van een plug zijn aan te merken als geluiden die continu van karakter zijn. We veronderstellen verder dat het boorwerk van injectieputten van nieuwe platforms evenveel onderwatergeluid veroorzaakt als het wegboren van pluggen. De boor staat hierbij steeds in rechtstreeks contact met het water. De duur van het wegboren van pluggen is globaal 5 dagen per plug. Wat de pluggen betreft veroorzaken alleen de ondiepe pluggen (hooguit enkele honderden meters diep) onderwatergeluid in de omgeving. We gaan per locatie uit van het wegboren van 3 ondiepe pluggen. Het wegboren van pluggen behoort formeel bij ontmanteling.

Het genoemde geluidniveau op een afstand van 100 meter ontlenen we aan het TNO onderzoek, 'Bijlage 1, Onderwatergeluid bij de aanleg en het in bedrijf zijn van de CO_2 opslag in het kader van het ROAD project' d.d. 5 april 2011. De rekenresultaten in de TNO memo die behoren bij het onderwatergeluid tijdens wegboren pluggen en boren van putten moeten niet gezien worden als absoluut, maar als orde van grootte. De omstandigheden van de literatuurstudie volgens de memo komen niet volledig overeenkomen met de verwachte werkzaamheden. Bijvoorbeeld staat de boor bij Aramis niet rechtstreeks in contact met water, want de boor zit altijd binnenin de conductor. De TNO memo schat de geluiduitstraling van machinegeluid en het wegboren van pluggen voor de situatie Aramis (te) hoog in.

Uitgaande van een *sound exposure level* van 199 dB re 1 µPa²s zijn de berekende afstanden ter voorkoming van PTS in tabel 4-5 opgenomen. Tabel 4-6 bevat de afstanden behorend bij mijding vanwege werkzaamheden aan een platform. De rekenresultaten in de tabellen 4-5 en 4-6 zijn gebaseerd op geometrische uitbreiding (10log(R/Rref)) zonder absorptie.

Tabel 4-5. Afstand en verblijftijd samenhangend met PTS vanwege werkzaamheden aan een platform

Bron van onderwater geluid	PTS gerelateerd				
	Diersoort	Drempel PTS SEL in dB re 1 µPa²s	SEL op 100m 1 µPa²s (24u)	SPL op 100m 1 µPa	Veilige afstand in m bij verblijf van 24 uur
Machinegeluid en wegboren plug	Bruinvis	173	199	150	<100
	Grote vis	207	199	150	<100
	Kleine vis	207	199	150	<100
	Zeehond	201	199	150	<100

De drempels 'PTS SEL' volgens NMFS betreffen ongewogen waarden, in de veilige afstand en de veilige verblijfstijd is bij bruinvissen en zeehonden een (M-)weging toegepast. Voor het boren is 62 Hz de bepalende frequentie, voor machinegeluid is dat 1 kHz. In tabel 4-6 worden veiligheidshalve voor de beide bronnen van onderwatergeluid identieke weegfactoren gebruikt. De gehanteerde (kleinste) weegfactoren behoren bij 1 kHz en bedragen voor bruinvissen en zeehonden respectievelijk -37,55 dB en -5,90 dB.

Tabel 4-6. Afstand samenhangend met mijding vanwege werkzaamheden aan een platform

Bron van onderwater geluid	Mijding gerelateerd				
	Diersoort	Drempel mijding SPL in dB re 1 µPa	Drempel mijding* SPL in dB re 1 µPa verhoogde achtergrond	Mijding op afstand in m	Mijding op afstand in m mits verhoogde achtergrond
Machinegeluid en wegboren plug	Bruinvis	120	130	100000	10000
	Grote vis	150	n.v.t.	100	n.v.t.
	Kleine vis	150	n.v.t.	100	n.v.t.
	Zeehond	120	130	100000	10000

*NOAA stelt dat de drempel van 120 dB mag worden verhoogd als de achtergrondgeluidniveaus gelijk of hoger zijn dan 120 dB re 1 µPa

In de zuidelijke delen van de Noordzee (Nederlands deel) zijn geluidniveaus door scheepvaart van globaal 130 dB re 1 µPa niet ongewoon. In tabel 4-6 is dit aangeduid als een zogenoemde verhoogde achtergrond.

4.8.2 Realiseren van verankeringspalen voor nieuwe platforms

Shell en Neptune Energy gaan ten behoeve van het onderhavige project nieuwe platforms plaatsen. Hierbij worden per platform verankeringspalen (ook platformpalen of jacketpalen genoemd) in de zeebodem geheid. De uitgangspunten liggen nog niet definitief vast, het realiseren van de verankeringspalen zal echter naar verwachting overeenkomen met de in 2014 geplaatste palen van dit type bij het Leman AC platform (Block 49/26 UK sector Noordzee). Daaruit volgen de volgende uitgangspunten.

Het aantal te plaatsen verankeringspalen is bij het Leman AC platform 4 stuks, de diameter van de palen is 1,5 meter en de realisatie neemt 2 etmalen in beslag. De hei-energie is voor globaal de helft van de slagen 250 kJ en voor de andere helft 1000 kJ.

RHDHV heeft TNO gevraagd om een onderzoek uit te voeren van de te verwachten geluidniveaus bij het ONE-Dyas gasboringsproject. Hiertoe zijn door TNO berekeningen verricht en is een memorandum opgesteld TNO 2020 M10542A ‘Onderwatergeluidsberekeningen voor gasboringsproject ONE-Dyas' d.d. 23 september 2020 (verder genoemd de TNO-rapportage). Dit onderzoek is uitgevoerd in het kader van het MER en de passende beoordeling. Een geluidrelevante activiteit bestond hier uit het plaatsen van verankeringspalen voor het platform N05-A dat ca. 20 km ten noorden van Schiermonnikoog ligt. De TNO-rapportage bevat rekenresultaten van het TNO model Aquarius 4 die nu wederom worden benut voor de verankeringspalen van de nieuwe platforms van Shell en Neptune Energy. De verankeringspalen bij het Leman platform zijn kleiner dan in het ONE-Dyas project waardoor de geluiduitstraling in de berekeningen van het voornemen waarschijnlijk enigszins wordt overschat. De palen van het centrale eindpunt en het ONE-Dyas project zijn (nagenoeg) identiek. Totdat informatie in meer detail beschikbaar is, veronderstellen we dat de geluiduitstraling van alle Aramis gerelateerde verankeringspalen overeenkomt met het ONE-Dyas project. Dit levert de meest conservatieve resultaten op.

Het ONE-Dyas gasboringsproject gaat uit van 6 te plaatsen verankeringspalen met een paaldiameter van 2,7 meter die in een tijdsbestek van 2 etmalen worden geplaatst. De hei-energie is hier constant verondersteld en bedraagt 600 kJ.

We merken op dat het TNO rekenmodel de maximaal optredende geluidniveaus berekent (*worst case*). Omdat propagatieverlies toeneemt bij toenemende windsnelheid en golfhoogte, is door TNO alleen gerekend aan de situatie zonder wind. Verder is sprake van een beperkte modelvalidatie waardoor onzekerheid bestaat in de berekende geluidverspreiding.

We achten de *worst case*-rekenresultaten van het ONE-Dyas project desondanks geschikt als maat voor de geluidverspreiding van het Aramis project. De berekeningen betreffen onder andere de dosismaat (SEL_{SS}) en de verstoringsoppervlakte, de rekenresultaten zijn in de navolgende paragrafen vermeld.

4.8.2.1 Ongewogen breedband single strike exposure level

Het berekende ongewogen breedbandige *single strike exposure level* (SEL_{SS}) is bij de soortgelijke verankeringspalen van ONE-Dyas 171 dB re 1 $\mu Pa^2 s$. Dat is met 7 dB beperkt hoger dan de te hanteren norm van 164 dB re 1 $\mu Pa^2 s$ voor het heien van turbinefundaties voor offshore windparken.

Hierbij moet worden bedacht dat de berekende SEL_{SS} is gebaseerd op *worst case* aannamen en de rekenmethodiek onzekerheden bevat. Onzeker zijn enerzijds de uitgangspunten en anderzijds de validatie van het rekenmodel. Uitgangspunten zoals de hei-energie worden maximaal gekozen ter voorkoming van het onderschatten van het rekenresultaat. Ook is onzeker of de verrichte validaties voldoende representatief zijn voor de betreffende omgeving. De onzekerheden leiden er toe dat de berekende geluidniveaus veelal hoger zijn dan de in de praktijk optredende geluidniveaus. In deze fase voorafgaand aan de FEED zijn de specifieke geotechnische waarden van de ondiepe ondergrond nog niet bekend. De aannamen en bevindingen zijn daarom onder voorbehoud en dienen te zijner tijd, na afronding van het nadere geotechnisch onderzoek, te worden gecontroleerd en eventueel aangepast.

4.8.2.2 Alternatieve heimethoden verankeringspalen

De onderbouw van de platforms wordt in de zeebodem verankerd met heipalen die verticaal in de zeebodem worden geheid. In dit stadium van het project zijn de dimensies (diameter, wanddikte en diepte) nog niet bekend. Voor het ontwerp van de fundering zijn de gegevens van de ondergrond op de locatie van het platform noodzakelijk. De grondgegevens zijn in de volgende projectfase beschikbaar.

Als gevolg van het onderwatergeluid van het heien kunnen met name zeezoogdieren en vissen worden verstoord en hun gehoor- en sonarorganen worden beschadigd. Alternatieve technieken voor het heien, bijvoorbeeld boren, trillen of zuigpalen (*suction piling*), zouden de verstoring kunnen beperken. In het project zijn de onderstaande alternatieve technieken voor de fundering van de constructie geëvalueerd.

1. *Fundatie door middel van boren of trillen van conventionele heipalen*

Bij constructies die gefundeerd worden door middel van conventionele palen worden palen in de poten van het jacket, of in zogenaamde *pile sleeves* die aan het jacket zijn gelast, gestoken. Deze palen kunnen vervolgens in principe door middel van heien, trillen of boren op de gewenste diepte worden gebracht.

De gebruikelijke techniek op het Nederlands Continentaal Plat (NCP) is om de palen in de zeebodem te heien en dit is ook het voorkeursalternatief.

Alternatief zouden de palen in de zeebodem kunnen worden geboord. Een geboorde paal wordt toegepast als de zeebodem uit rots of steen bestaat. Er wordt dan een overmaats gat geboord in de zeebodem waarin de paal wordt geplaatst. De holte tussen rots en paal wordt gevuld met beton om krachten over te dragen. Op het NCP bestaat de ondergrond uit (een combinatie van) zand, silt en/of klei. Het toepassen van de met beton omhulde geboorde paal is technisch moeilijk uitvoerbaar en vereist grote wijzigingen in ontwerp en installatie. Het toepassen van een niet met beton omhulde geboorde paal is niet mogelijk vanwege de lagere draagcapaciteit in met name trekkracht. Geboorde palen zullen dus langer moeten zijn met de gevolgen van dien voor realisatie?, materiaalgebruik, transport- en plaatsingswerkzaamheden en kosten.

In principe zouden de palen ook in de zeebodem kunnen worden getrild en is dit ook uitgevoerd voor kleinere diameters palen. Maar door het gebrek aan gegevens over het effect van de plaatsingsmethode op de draagcapaciteit van de paal, wordt deze methode niet aanbevolen voor axiaal belaste palen (ISO 19901-4).

2. *Fundatie door middel van zuigpalen (suction piling)*
Bij constructies gefundeerd middels zuigpalen worden aan de poten van het jacket zuigpalen gelast. De jacket met zuigpalen wordt geïnstalleerd door deze op de zeebodem te plaatsen en vervolgens een pomp te activeren die water uit de zuigpaal verwijderd. Hierdoor wordt een drukverschil opgewekt wat resulteert in een neerwaartse kracht, die de zuigpaal in de zeebodem drukt. Door de geringe waterdiepte in de K- en L- blokken is de beschikbare inzuigkracht gelimiteerd. Verder zijn er tijdens het installeren van zuigpalen diverse additionele risico's in vergelijking met heipalen.

De draagcapaciteit van de zuigpaal wordt gegenereerd door wandwrijving en druk op de onderrand van de zuigpaal. De afmetingen van de zuigpaal worden bepaald door de uitwendige krachten die op het platform aangrijpen en de condities van de grond. Een ruwe schatting gaat uit van een benodigde diameter van 8-12m en inzuigdiepte van 8-12m voor zuigpalen voor dit type platform. Het gebruik van zuigpalen zal het gewicht en de afmetingen van het jacket aanzienlijk vergroten, met gevolgen voor materiaalgebruik, transport- en plaatsingswerkzaamheden en kosten.

Op basis van bovenstaande evaluatie wordt er vooralsnog vanuit gegaan dat er geen alternatieve heimethodieken zijn, met een veel lager geluidsniveau. Zodoende wordt er in het onderzoek uit gegaan van de standaard waarden en de toepassing van de benodigde mitigerende maateregelen. Mitigatie bestaat uit het gebruik maken van afschrikmethodes, *soft start*, bellenschermen (zie ook bijlage 4) en/of geluidwerende mantels. Indien voorafgaand aan de werkzaamheden blijkt dat er andere geluidsarmere methoden beschikbaar zijn, is het wellicht niet nodig deze mitigerende maatregelen toe te passen.

4.8.2.3 Verstoringsoppervlakte

Bij het voldoen aan voornoemde norm van 164 dB re 1 μPa^{2}s is sprake van een beperkte mate van verstoring van zeezoogdieren. De verstoringsoppervlakte is naast de luidheid van de bron onder andere ook afhankelijk van de waterdiepte en de gesteldheid van de zeebodem. De door TNO berekende verstoringsoppervlakte in km^2 rond de verankeringspalen van ONE-Dyas is per etmaal 610 km^2 voor bruinvissen en 231 km^2 voor zeehonden. De verstoringsoppervlakte is het gebied waarbinnen het heigeluid de drempelwaarde voor verstoring van bruinvissen (SEL_{SS} = 140 dB re 1 μPa^{2}s) en zeehonden (Mpw-gewogen SEL_{SS} = 145 dB re 1 μPa^{2}s) overschrijdt. Hierbij verwijst de term 'Mpw-gewogen' naar het toepassen van een frequentieweging volgens het door Southall et al (2007) gedefinieerde filter voor zeehonden. Deze oppervlakten gelden per etmaal. De norm van 164 dB re 1 μPa^{2}s zal naar verwachting met 7 dB wordt overschreden. De genoemde oppervlakten van 610 km^2 en 231 km^2 behoren bij een situatie zonder mitigatie. Om aan de norm te voldoen zal gemitigeerd moeten worden zoals is beschreven in paragraaf 4.8.2.2. Na het treffen van de mitigerende maatregel zullen de genoemde oppervlakten daarom afnemen. Als vuistregel bij overdracht van geluid geldt dat als de verstoringsafstand in de situatie met maatregel (ten minste) halveert, de verstoringsoppervlakte tot een kwart afneemt. De input voor de natuurtoets is dan een verstoringsoppervlakte van 153 km^2 voor bruinvissen en 58 km^2 voor zeehonden.

4.8.3 Installatie conductorpijpen

Het voornoemde memorandum TNO 2020 M10542A 'Onderwatergeluidsberekeningen voor gasboringsproject ONE-Dyas' d.d. 23 september 2020 (verder genoemd de TNO-rapportage) is ook richtinggevend voor de te verwachten geluidsemissies onderwater door het plaatsen van conductorpijpen. De conductorpijpen zijn nieuw te plaatsen of hangen samen met de *re-drill* van putten.

Royal HaskoningDHV

De TNO-rapportage betrof het platform N05-A dat ca. 20 km ten noorden van Schiermonnikoog ligt. De rekenresultaten volgend uit het TNO model Aquarius 4 worden wederom benut voor de conductorpijpen van de nieuwe platforms van Shell en Neptune Energy.

Het ONE-Dyas gasboringsproject gaat uit van 12 te plaatsen conductorpijpen met een diameter van 0,76 meter die in een tijdsbestek van (maximaal) 6 etmalen worden geplaatst. De hei-energie is constant verondersteld en bedraagt 90 kJ, hetgeen significant lager is dan bij het heien van verankeringspalen. De nieuwe K14 en L10 injectieplatforms betreffen elk 4 of 6 conductorpijpen, het bestaande L4-A injectieplatform is 1 conductorpijp gepland met een identieke diameter (0,76 meter). We nemen aan dat de conductorpijpen steeds met circa 90 kJ energie en in een tijdsbestek van maximaal 3 dagen per platform worden gerealiseerd.

We merken op dat het TNO-rekenmodel de maximaal optredende geluidniveaus berekent (*worst case*). Omdat propagatieverlies toeneemt bij toenemende windsnelheid en golfhoogte, is door TNO alleen gerekend aan de situatie zonder wind. Verder is sprake van een beperkte modelvalidatie waardoor onzekerheid bestaat in de berekende geluidverspreiding. We achten de *worst case* rekenresultaten van het ONE-Dyas project desondanks geschikt als maat voor de geluidverspreiding van het Aramis project. De berekeningen betreffen onder andere de dosismaat (SEL_{SS}) en de verstoringsoppervlakte, de rekenresultaten zijn in de navolgende paragrafen vermeld.

4.8.3.1 Ongewogen breedband single strike exposure level

Het berekende ongewogen breedbandige *single strike exposure level* (SEL_{SS}) is bij de soortgelijke conductorpijpen van ONE-Dyas 164 dB re 1 μPa^2s. Dat is gelijk aan de te hanteren norm van 164 dB re 1 μPa^2s voor het heien van turbinefundaties voor offshore windparken. Hierbij moet worden bedacht dat de berekeningen, analoog aan de verankeringspalen, zijn gebaseerd op *worst case* aannamen en de rekenmethodiek onzekerheden bevat. Gelet op de berekeningen wordt aan de genoemde norm voldaan.

4.8.3.2 Verstoringsoppervlakte

De door TNO berekende verstoringsoppervlakte in km^2 rond de conductorpijpen is per platform en per dag 94 km^2 voor bruinvissen en 54 km^2 voor zeehonden. De verstoringsoppervlakte is het gebied waarbinnen het heigeluid de drempelwaarde voor verstoring van bruinvissen (SEL_{SS} = 140 dB re 1 μPa^2s) en zeehonden (Mpw-gewogen SEL_{SS} = 145 dB re 1 μPa^2s) overschrijdt. Hierbij verwijst de term ‘Mpw-gewogen’ naar het toepassen van een frequentieweging volgens het door Southall et al (2007) gedefinieerde filter voor zeehonden. Deze oppervlakten gelden per etmaal en zijn input voor de in de natuurtoets opgenomen berekeningen, zoals over het aantal verstoorde bruinvissen en het effect op de bruinvispopulatie. Mitigatie is niet aan de orde, de genoemde oppervlakten van 94 en 54 km^2 behoren dan ook bij de uitgangssituatie.

4.9 Boring ten behoeve van aanlanding buisleiding (B9)

De buisleiding kruist de Maasgeul. De boormethode ligt nog niet vast maar betreft *direct piping* of *microtunneling*. Beide methoden vereisen baggeren in de Maasgeul bij het eindpunt van de boring. Het maken van een kofferdam in het water is bij beide methoden overigens niet aan de orde.

Bij de boring is slechts één geluidbron potentieel relevant, het gaat dan om het baggeren. De verwachting is dat het baggerschip een geluiddrukniveau (SPL) van 151 dB re 1 µPa op 100 meter afstand veroorzaakt. De veilige afstand en de mijdingsafstand vanaf een baggerschip zijn daarmee vergelijkbaar met de afstanden volgens de tabellen 4-2 en 4-3.

5 Onderwatergeluid in de gebruiksfase

De in de inleiding vermelde onderwerpen zijn onderstaand uitgewerkt, het gaat dan om twee situaties, genoemd G1 en G2.

5.1 Varende en lossende schepen in de haven en bij de platforms (G1)

Schepen in de haven en op zee veroorzaken geluid onderwater tijdens varen, lossen en aanmeren. Vaarbewegingen met een relatief lage intensiteit op zee, zoals is aangegeven in paragraaf 1.2.3, worden niet onderzocht. Dit in tegenstelling tot een hoge vaarintensiteit in de haven in de omgeving van de terminal en langdurig verblijf van een schip in een beperkt gebied op zee met relevantie voor onderwatergeluid.

De volgende activiteiten zijn voorzien:

1. Het lossen van een barge met een volume (cargo tank gross volume 100%) tot 16.000 m^3;
2. Het nestgeluid van een afgemeerde barge;
3. Het varen van schepen met een motorvermogen van 2 MW.

Het varen van de barge ad 3 is hierbij het luidst, het bijbehorende totaal geïnstalleerde mechanische vermogen is (1500 tot) 2000 kW. Informatie van CO2next geeft voor het vermogen van een 16k schip dat de terminal van CO2next zal aandoen bij 8 knopen 1774 kW. De genoemde 2000 kW is ook gebaseerd op schepen klasse CEM T-klasse Va ‘Groot Rijnschip’ volgens de publicatie ‘Classificatie en kenmerken van de Europese vloot en de actieve vloot in Nederland’ d.d. december 2002 door Rijkswaterstaat, Adviesdienst Verkeer en Vervoer. De overige activiteiten ad 1 en 2 zijn beduidend minder luid en gaan gepaard met mechanische vermogens van veelal ca. 1000 kW. Voor alle geplande werkzaamheden en transporten geldt dat ze zich 24 uur per etmaal en 7 dagen per week kunnen voordoen.

In de luidste situatie hanteren we als bronniveau voor de barges (middelgrote schepen) volgens Richardson et al. (1995) 171 dB re 1 µPa op 1 m. Uitgedrukt in acoustic Watt is dit 1W. De minder luide situatie betreft 0,5 acoustic Watt.

De afstanden tot het bereiken van een achtergrondgeluidniveau van 130 dB re 1 µPa en daarmee mijding door zeezoogdieren van de (werk-)locatie zijn weergegeven in tabel 5-1 en 5-2. Hierbij gaan we uit van brongeluid dat zich in de tertsbanden van 250 Hz t/m 1 kHz bevindt. We gaan uit van een sferische uitbreiding ($20\log(R/R_{ref})$) nabij de bron gevolgd door een cilindrische uitbreiding ($10\log(R/R_{ref})$) op afstanden uit de bron die groter zijn dan de waterdiepte.

Tabel 5-1. Berekening afstand in [m] tot het achtergrondgeluidniveau, luidste situatie ‘varende barge’

PREDICTION OF MAXIMUM LIKELY UNDERWATER NOISE LEVELS					
using a dual red/white spectrum source				Estimate maximum transmission limit	
Enter source data		S1	S2	(only spreading and water losses)	
Transition Frequency Hz		500	0	Enter range (m)	300
Broadband acoustic power watts		1	0	Water depth (m)	20
				Water temp degC	10
Broadband noise at receptor		Lower	Upper		
130,5	dB//mPa between	250	1000	Hz bands (inclusive)	

Royal HaskoningDHV

Tabel 5-2. Berekening afstand in [m] tot het achtergrondgeluidniveau, minder luide situaties 'lossende barge en nestgeluid'

PREDICTION OF MAXIMUM LIKELY UNDERWATER NOISE LEVELS					
using a dual red/white spectrum source				Estimate maximum transmission limit	
Enter source data		S1	S2	(only spreading and water losses)	
Transition Frequency Hz		500	0	Enter range (m)	150
Broadband acoustic power watts		0,5	0	Water depth (m)	20
				Water temp degC	10
Broadband noise at receptor		Lower	Upper		
130,5	dB//mPa between	250	1000	Hz bands (inclusive)	

De globaal berekende afstanden zijn in de luidste situatie 300 meter (tabel 5-1) en in de minder luide situaties 150 meter (tabel 5-2). Een geluiddrukniveau van 150 dB re 1 µPa, van belang voor mijding van de activiteit door vissen, wordt op een afstand van enkele tientallen meters uit de bron bereikt.
Een toename van de intensiteit van scheepvaart veroorzaakt een toename van geluid onderwater. Dit betekent overigens niet dat de geluidniveaus onderwater bij afzonderlijke passages toenemen. Hoe de fauna reageert op de gewijzigde intensiteit is niet evident.

5.2 Risers (G2)

Een riser transporteert gassen of vloeistoffen tussen de zeebodem en faciliteiten boven het wateroppervlak. Een riser is daarmee een pijpleiding die dient voor het verticaal transporteren van materiaal.

Bij de aanvraag van vergunningen in het kader van het ROAD project voor CO_2 opslag speelde onderwatergeluid een rol. In opdracht van RHDHV is in 2011 door TNO een onderzoek uitgevoerd naar onderwatergeluid bij de aanleg en het gebruik van de hiermee samenhangende installaties. Het onderzoek betrof onder andere het aanpassen van het satelliet-productieplatform P18-A om dit geschikt te maken voor CO_2 injectie. Het onderzoek 'Bijlage 2' heeft referentie TNO-MEM-2011-00560 'CO_2 injectie P-18A: onderwatergeluid afstraling' d.d. 5 april 2011 van TNO. Het onderzoek 'Bijlage 2' betreft de volgende bronnen:

1 Turbulente stroming in de CO_2 riser naar P18A en;

2 Aardgas risers van P18A naar P-15.

De onderstaande tekst bevat de aanpak en enkele uitgangspunten van het TNO-onderzoek evenals de bijbehorende bevindingen.

Omdat de bepaling van de geluidafstraling beperkt nauwkeurig is en de input data niet definitief vastlag, wordt geluid van CO_2 injectie (injectiescenario) in het TNO-onderzoek vergeleken met geluid van aardgasproductie (productiescenario). Het injectiescenario is nog verdeeld in 4 cases die variëren in pijpleiding druk en temperatuur.

De upstream CO_2 riser en de downstream aardgasproductieriser zijn potentieel relevant, hebben een lengte van 20 meter, een buitendiameter van ca. 400 mm en een wanddikte van 20 mm. De overige risers bestaan uit meerdere concentrisch geplaatste buizen die gevuld zijn met vloeistof. Omdat de geluidisolatie van de laatstgenoemde risers zeer goed is kan onderzoek naar de geluiduitstraling buiten beschouwing worden gelaten.

Klepgeluid is niet relevant en stromings-geïnduceerd geluid wordt door de lage stroomsnelheid van het CO_2 niet verwacht. Ten slotte is afstraling van de geïsoleerde CO_2 leiding onder de zeebodem verwaarloosbaar. Daarom zijn als geluidbron van de zeeleiding uitsluitend de risers potentieel relevant.

Het afgestraalde geluidvermogen L_{WO} uitgedrukt in dB re 1 pW (1 picowatt) is:

- 2 tot 41 dB voor CO_2 injectie;
- 27 tot 75 dB voor gasproductie.

De geluidafstraling tijdens CO_2 injectie geeft in de luidste case een geluiddrukniveau van ca. 91 dB re 1 μPa^2m^2.

Bevindingen TNO:

- Zowel voor de productie- als de injectiescenario's ligt het maximum van het afgestraalde spectrum rond 4 kHz;
- Stromingsgeluid door CO_2 injectie is voor de meeste cases minder dan bij aardgasproductie;
- Het geprognosticeerde geluiddrukniveau is tijdens CO_2 injectie ca. 91 dB re 1 μPa^2m^2. Op 100 meter afstand (en bij 25 meter waterdiepte) is dit een geluiddrukniveau ofwel SPL van ca. 56 dB re 1 μPa. Dit is een zeer laag geluidniveau dat beneden het TTS niveau (tijdelijke verhoging van de gehoordrempel) blijft.

Zeezoogdieren en vissen mijden gebieden waarin de geluiddrukniveaus hoger dan achtereenvolgens 120 á 130 dB en 150 dB re 1 μPa zijn. Het genoemde geluiddrukniveau van 56 dB re 1 μPa is significant lager. Aanvullend op de bevinding dat een zeer laag geluiddrukniveau door stromingsgeluid wordt verwacht, concluderen we dat ook geen sprake is van mijding van de CO_2-riser(-s) door vissen en zeezoogdieren.

Royal HaskoningDHV

6 Seismisch onderzoek

6.1 Inleiding

Bij onderzoek met akoestische signalen onderscheiden we drie onderdelen, namelijk het zogenoemde *shallow* seismisch onderzoek nabij platforms, 3D/4D onderzoek en onderzoek met behulp van een ROV (*Remotely Operated underwater Vehicle* oftewel een op afstand bestuurbaar onderwatervoertuig).

Shallow seismic survey en *3D/4D survey* dienen verschillende doelen. *Shallow survey* dient om de stabiliteit van de zeebodem en eventuele onregelmatigheden in de ondiepe ondergrond (tot een paar honderd meter) in kaart te brengen en levert informatie voor het ontwerp en de plaatsing van buisleidingen en platforms. 3D/4D onderzoek vindt plaats om de diepere geologische structuren en eventuele aan- of afwezigheid c.q. migratie van CO_2 tot op ca. 3 km diepte inzichtelijk te krijgen. Het gebied voor monitoring omvat de injectiefaciliteiten, het opslagcomplex (inclusief waar mogelijk de CO_2 pluim) en de omringende omgeving. 4D onderzoek bestaat uit herhaald 3D onderzoek met (zoveel mogelijk) identieke onderzoeksparameters. 3D/4D onderzoek duiden we verder aan als 3D onderzoek.

Shallow survey is relevant voor de nieuwe platforms en putten van Shell. Shell en TotalEnergies voeren (ook) 3D onderzoek uit.

Qua gebied zullen de 3D survey gebieden het grootst zijn (orde van grootte 100 vierkante kilometer). Voor de omgeving is 3D daarom het meest relevant, Aan bod komen de bevindingen van drie 3D onderzoeken bij de velden N4, N05 en blok 41 nabij Whitby U.K.

De onderzoekslocaties voor 3D seismisch onderzoek zijn in de onderstaande figuren weergegeven. Het monitoringsgebied Shell (roze rechthoek), de groene stip is de geplande locatie van het nieuwe platform.

Royal HaskoningDHV

Het monitoringsgebied TotalEnergies (paars gearceerde rechthoek), het witte vierkant is de locatie van het platform dat wordt hergebruikt.

The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

Bij het vermoeden van een lekkage of bij een geplande inspectie wordt een onderzoek naar afwijkingen (op de zeebodem) getriggerd. Dit kan gaan om gegevensverzameling via bemonstering of neerlaatbare camera's waarbij een ROV wordt ingezet. Eventueel worden hierbij ook akoestische signalen gebruikt.

De uitvoering van seismisch onderzoek, de normering en 3D onderzoeken worden achtereenvolgens behandeld. Ten slotte volgen de bevindingen.

6.2 Uitvoering 3D seismisch onderzoek

Bij alle seismische onderzoeken wordt een bron gebruikt om geluidsgolven te genereren, aangesloten op een configuratie van ontvangers of sensoren om de gereflecteerde geluidsgolven op te nemen. De geluidsgolven worden gegenereerd door luchtbronnen met perslucht (luchtbron-arrays). Voor de gesleepte *streamer setup* worden de hydrofoons in *streamers* geplaatst die achter een bewegend onderzoeksvaartuig worden gesleept of ‘gestreamd’. *Streamers* zijn vuistdikke, kilometerslange slangen met ingebouwde hydrofoons (onderwatermicrofoons) die het geluid opvangen. Deze streamers zijn doorgaans 3 tot 8 kilometer lang. Voor 3D-onderzoeken worden over het algemeen twee of drie luchtbronnen-arrays en meerdere *streamers* (6 á 8) ingezet. De *streamers* hebben een onderlinge afstand in de breedte van ongeveer 100 meter. Buiten het onderzoeksgebied bevindt zich een zone waarin het onderzoeksvaartuig kan keren en waarin de *airguns* niet actief zijn, deze zone heeft een breedte van enkele kilometers (3 tot 5 kilometer).

Een andere methode voor opvang van de gereflecteerde geluidsgolven zijn '*Ocean Bottom Node* (*OBN*)', sensors die tijdelijk op de zeebodem liggen in lange, parallelle rijen.

6.3 Normering

Nederland Noordzeeakkoord
Op 19 juni 2021 is het “Onderhandelaarsakkoord voor de Noordzee” (Noordzeeakkoord) aangeboden aan de Tweede Kamer. Dit akkoord omvat afspraken tussen het Rijk en stakeholderpartijen over keuzes en beleid gericht op de balans in activiteiten en ecologie op de Noordzee tot en met 2030. De volgende afspraken zijn gemaakt met betrekking tot 3D seismisch onderzoek op de Noordzee (punt 5.15 van het Noordzee-akkoord):

- Bij het eerstvolgende 3D seismisch onderzoek wordt gelijktijdig een gezamenlijk onderzoeksprogramma opgezet voor het verzamelen van informatie over de minimale geluidsniveaus die nodig zijn om de benodigde informatie over de opsporing en winnen van koolwaterstoffen te verkrijgen, op kosten van de olie- en gassector.
- De bruinvissen zijn extra kwetsbaar voor verstoring tijdens het voortplantingsseizoen, ongeveer tussen 1 mei en 1 september. Partijen spreken af dat de olie-en gassector voorlopig zoveel mogelijk buiten deze voortplantingsperiode de 3D seismische onderzoeken laat uitvoeren.
- De *airguns* die weinig hoge frequenties uitzenden worden waar mogelijk gebruikt voor 3D seismisch onderzoek.

Richtlijnen NMFS & KEC
De drempelwaarden voor de verstoring van bruinvissen en zeehonden volgen uit de richtlijn van NMFS (*National Marine Fisheries Service*) of het KEC (Kader Ecologie en Cumulatie) opgesteld door Rijkswaterstaat. Het KEC dient ter bepaling van mogelijke cumulatie effecten op de populaties van te beschermen soorten gedurende de bouw en exploitatie van de windparken op de Noordzee tot 2030.

Zoals is vermeld, richt het KEC zich in eerste instantie niet op geluid vanwege seismisch onderzoek. Ten opzichte van heiwerk onderscheidt seismisch onderzoek zich door het mobiele karakter van de bron, het aantal pulsen en de luidheid van de pulsen.

Omdat zeezoogdieren niet bij alle frequenties van onderwatergeluid waaraan ze worden blootgesteld gevoelig zijn voor TTS en PTS wordt door zowel TNO als NMFS geadviseerd om een soortafhankelijke frequentieweging toe te passen, zoals het door Southall et al (2007) gedefinieerde filter voor zeehonden.

6.4 Onderzoek N4

ONE-Dyas heeft in 2022 een verkennend seismisch onderzoek laten uitvoeren in het gebied N4 in het zuidoostelijke deel van de Nederlandse Noordzee. De bijbehorende rapportage is WP1266-2_R2r0 'The propagation of underwater sound from eSource seismic airgun configurations, pre-survey verification measurements in the Dutch North Sea' d.d. 15 augustus 2022 (Draft) door Waterproof Marine Consultancy & Services BV.

Het doel van het onderzoek is het in kaart brengen van de geologische samenstelling van de ondergrond. Hierbij zijn verschillende *airgun* configuraties als geluidbron en *streamers* als ontvangers toegepast met verschillende volumes, namelijk gezamenlijke volumes van 1049, 720 en 360 *cubic inches*.

Voor het gebied N4 zijn diverse geluidnormen aan de orde. De maatgevende normen bestaan uit de geluiddoses (of *sound exposure levels* L_E) van 140 en 145 dB voor verstoring van achtereenvolgens de bruinvis en de zeehond volgens het KEC 3.0.

Om er zeker van te zijn dat de genoemde normen niet worden overschreden, is voor N4 een rekenmodel (Brinkkemper en Snoek, 2019; 2022) vervaardigd. Uit de rekenresultaten bleek dat conventionele *airguns* te luid waren en de genoemde normen zouden overschrijden. Daarom is het verkennend onderzoek in maart 2022 uitgevoerd met zogenoemde *eSource airguns* die beduidend minder geluidenergie produceren (vooral in de hogere frequenties boven 100 Hz). Voor seismisch onderzoek zijn de frequenties boven 100 Hz niet relevant. Het verkennend seismisch onderzoek dient ter kalibratie van het voornoemde rekenmodel.

Uit de kalibratie (de metingen) bleek dat de afstanden van de geluidbron tot de geluiddosis van 140 en 145 dB deels afweken van de rekenresultaten. De verwachting is echter dat de bij de kalibratie gevonden afstanden representatief zijn voor het gehele N4 gebied, ondanks de verschillen in bodemabsorptie en waterdiepte binnen N4.

De bevindingen zijn in de onderstaande tabel opgenomen.

Table 5.1 Distances to the L_E=140 dB and L_E=145 dB sound levels based on the measurements.

	eSource 1049 cu in	eSource 720 cu in	eSource 360 cu in
L_E = 140 dB	11.2 km	8.7 km	5.9 km
L_E = 145 dB	7.5 km	5.3 km	3.1 km

Royal HaskoningDHV

6.5 Onderzoek N05

One-Dyas heeft in het kader van de ontwikkeling van het gasveld N05-A onderwatergeluidsberekeningen laten uitvoeren, vastgelegd in TNO onderzoek ‘Onderwatergeluidsberekeningen voor gasboringsproject ONE-Dyas’ d.d. 28 januari 2020. Het onderzoek betrof het heien van conductorpijpen, jacketpalen en seismisch onderzoek. Het seismisch onderzoek gaat uit van 2 stuks Sercel G-gun II met een volume van elk 250 *cubic inch* en een druk van 2000 Psi. De berekende verstoringsoppervlakte in km^2 rond het VSP onderzoek waarbij de KEC drempelwaarden voor verstoring van bruinvissen en zeehonden wordt overschreden, is respectievelijk ten hoogste 41 en 3 km^2. Het heiwerk en seismisch onderzoek leiden gezamenlijk tot een extra afname van bruinvissen met 2 individuen. Door de gezamenlijke werkzaamheden ten behoeve van N05-A in combinatie met de aanleg van windparken blijft de afname van de bruinvispopulatie ruim beneden de door het Rijk gehanteerde grens. De grens is het met 95% zekerheid niet verder afnemen van de populatie dan tot 95% van de totale Nederlandse bruinvispopulatie (geschat op 51.000 dieren).

6.6 Onderzoek UK, Whitby

Egdon Resources U.K. Limited heeft een 3D seismisch onderzoek uitgevoerd te Whitby in de zuidelijk Noordzee (blok UKCS 41). Het onderzoeksgebied heeft een omvang van 438 vierkante kilometer en een waterdiepte van 30 meter oplopend tot maximaal 60 meter. Voorafgaand aan het seismisch onderzoek is een geluidstudie uitgevoerd waarbij een rekenmodel voor deze specifieke locatie is opgesteld. Het rekenmodel is opgesteld om de risico’s op gehoorschade en gedragsverandering op het zeeleven, met name op zoogdieren zoals bruinvissen en zeehonden in en nabij het onderzoeksgebied, vast te stellen.

De bron bestaat uit een enkele air gun reeks met een gezamenlijk volume van 2.495 *cubic inches* (*cu. in.*) Deze bron is werkzaam op een diepte 6 meter en wordt om de 5 seconden geactiveerd. Verder worden de opnamen verzorgd door 6 streamers. De snelheid van het onderzoeksschip is 4,7 knopen ofwel 8,7 kilometer per uur. De duur van het onderzoek is 23 dagen. De airgun is van het type Boltgun 1900LLXT/1500LL en bestaat uit 22 actieve delen, de werkdruk is ten slotte 2000 pounds per square inch (PSI).

Het rekenmodel betreft het Gundalf Designer software pakket (2018) en maakt gebruik van de NOAA technische richtlijn (NMFS, 2018) met weegfactoren voor zeezoogdieren volgens Finneran (2015, 2016). De rekenresultaten worden beoordeeld op:

- NMFS (2018) Tijdelijke verschuiving van de gehoordrempel ‘TTS onset’ voor impulsachtig geluid middels piekgeluiddruk (*Peak SPL*) en 24 uurs geluiddosis (*SEL24hr*);
- NMFS (2018) Permante verschuiving van de gehoordrempel ‘PTS onset’ voor impulsachtig geluid middels piekgeluiddruk (*Peak SPL*) en 24 uurs geluiddosis (*SEL24hr*);
- NMFS (2013) Gedragsverandering voor impulsachtig geluid op basis van de effectieve waarde van de geluiddruk (*RMS*) SPL van 160 dB re 1 µPa.

De geluidnormen voor TTS en PTS verschillen voor elke groep zeezoogdieren. De norm voor gedragsverandering van 160 dB re 1 µPa is echter identiek voor alle groepen zeezoogdieren. De groepen LF (*Low-frequency cetaceans*), MF (*Mid-frequency cetaceans*) en HF (*High-frequency cetaceans*) betreffen ter indicatie achtereenvolgens balein walvissen, dolfijnen en bruinvissen. Zeehonden vormen de groep PW (Phocid pinnipeds in Water).

De afstanden tot TTS, PTS en gedragsverandering zijn opgenomen in tabel 4-9 van de rapportage ref: 425.09284.00001 versie 02 ‘Whitby 3D Seismic Survey, prepared for: Egdon Resources U.K. Limited’ d.d. juli 2019 door SLR Consulting Limited.

Table 4-9 Zones of impact – marine mammals

Seismic survey impacts on marine mammals	Marine mammal hearing group	Zones of impact – distances from the array source to relevant threshold levels			
		Criteria - Pk SPL, dB re 1µPa	Zones of impact, m	Criteria - Weighted SEL_{24hr}, dB re $1µPa^2·S$	Zones of impact, m
PTS on-set	LF	219	250	183	3,500
	MF	230	50	185	<10
	HF	202	2,000	155	200
	PW	218	300	185	200
	OW	232	40	203	<10
TTS on-set	LF	213	600	168	20,000
	MF	224	120	170	80
	HF	196	4,000	140	4,000
	PW	212	700	170	4,000
	OW	226	100	188	150
Behavioural changes	All hearing groups	160 (RMS SPL, dB re 1µPa)	12,000	N/A	N/A

De impact van seismisch onderzoek op zeezoogdieren wordt gekwalificeerd als ‘laag’. In deze kwalificatie zijn de volgende factoren doorslaggevend.

- de beperkte onderzoeksduur van 23 dagen. Volgens Southall et al. (2007) is het onwaarschijnlijk dat een kortdurende verstoring van normaal gedrag de populatie beïnvloedt;
- de periode van het jaar (de maand oktober) waarin de meest zeezoogdieren met slechts een lage dichtheid in het onderzoeksgebied (blok 41) aanwezig zijn.

Om risico’s te minimaliseren zijn de onderstaande maatregelen in principe mogelijk:

- de aanwezigheid van een opgeleide waarnemer aan boord van het onderzoeksschip. Deze waarnemer zal het uur voorafgaand aan het seismisch onderzoek een gebied met een straal van 500 meter vanaf het schip visueel onderzoeken. Als zeezoogdieren binnen de straal van 500 meter worden waargenomen, zal een zogenoemde softstart worden toegepast;
- Monitoring van onderwatergeluid veroorzaakt door zeezoogdieren, de interpretatie van de geluiden vereist een opgeleide operator. Dit systeem wordt ook aangeduid als PAM, Passive Acoustic Monitoring.

Ten slotte wordt geconcludeerd dat bij vissen fysieke schade op korte afstanden van de bron kan optreden. Het meest gevoelig voor PTS zijn vissen met zwemblaas, PTS treedt op tot 150 meter uit de geluidbron. TTS bij vissen met en zonder zwemblaas treedt tot globaal 1000 meter uit de geluidbron op.

6.7 Bevindingen

De bevindingen ten aanzien van onderwatergeluid vanwege seismisch onderzoek zijn als volgt.

- Door seismisch onderzoek zullen de tijdelijke en permanente verschuiving van de gehoordrempel TTS en PTS bij zeezoogdieren niet op grote schaal optreden, desondanks is het toepassen van maatregelen aan de orde. Deze maatregelen hebben als doel om alle zeezoogdieren die in de nabijheid van het schip zijn te verjagen en te voorkomen dat de bronnen op vol vermogen zijn als er nog zeezoogdieren in de omgeving van het schip worden waargenomen. De standaardmaatregelen bestaan uit de aanwezigheid van een opgeleide waarnemer (*MMO*) en de monitoring van onderwatergeluid (*PAM*).
- Gedragsverandering door mijding van het onderzoeksgebied is door 3D seismisch onderzoek te verwachten op een afstand van globaal 12 kilometer. Bij shallow seismisch onderzoek is deze afstand beduidend korter. De vuistregel leidt tot de verwachting van een halvering van de genoemde afstand. Naast dat shallow seismisch onderzoek slechts een klein gebied van veelal enkele vierkante kilometers betreft, is het onderzoek ook korter en is de geluidbron minder krachtig dan bij 3D seismisch onderzoek.
- Op grond van het Nederlands Noordzeeakkoord bestaan twee voorwaarden voor 3D seismisch onderzoek. Ten eerste dient 3D onderzoek zoveel mogelijk buiten de voortplantingsperiode van bruinvissen plaats te vinden. Dit is de periode van 1 mei tot 1 september. Ten tweede worden, indien mogelijk, de minst luide airguns ingezet. Deze bronmaatregel betreft airguns die weinig hoge frequenties veroorzaken, zoals eSource airguns.
- De inzet van een ROV ten behoeve van Aramis behoort tot de mogelijkheden. Eventueel worden door ROV’s ook akoestische signalen gebruikt, naar verwachting met een verwaarloosbare impact op de omgeving. Belangrijker is dat een ROV inspectie kan leiden tot verdere metingen van de zeebodem en/of metingen naar gasdoorsijpeling met behulp van 3D seismisch onderzoek.

7 Milieueffecten tijdens onvoorziene situaties

Als de pijpleiding en/of riser het begeeft en leidt tot een sterke uitstroom van CO_2, veroorzaakt dit onderwatergeluid. Het ontwerp en onderhoud van de zeeleiding en risers is er op gericht dat het optreden van een eventuele lekkage vrijwel onmogelijk is. Mocht toch een lekkage optreden, dan zal dit tijdelijk en lokaal tot een intensieve uitstroom kunnen leiden, met aanzienlijke geluidsniveaus tot gevolg.

Royal HaskoningDHV

8 Samenvatting

De geluiduitstraling onderwater ten gevolge van Aramis veroorzaakt mogelijk effecten op het marine ecosysteem. De voorliggende studie naar onderwatergeluid is input voor de effectbepaling bij het thema natuur. In de natuurtoets komen de eventuele effecten van de in de voorliggende rapportage genoemde activiteiten aan bod, tabel 8-1 geeft een overzicht van de mijdingsafstanden voor bruinvissen en zeehonden.

Tabel 8-1. Overzicht potentieel relevante activiteiten voor onderwatergeluid met mijdingsafstand in kilometer

Activiteit	**Mijdingsafstand in kilometer**		
	Bruinvis	**Zeehond**	**Opmerking**
Aanlegfase			
Pijpleiding leggen	Verwaarloosbaar klein	2,3	Weging bij bruinvis toegepast. Schip 18 MW
Aansluitleidingen aanleggen	Verwaarloosbaar klein	2,3	Weging bij bruinvis toegepast. Schip 18 MW
Machinegeluid platform en wegboren pluggen	10	10	Deze activiteit speelt ook bij ontmanteling
Jetties heien	(20)	(3,9)	N.B. De verstoringsoppervlakte is kleiner namelijk ca. 9 km^2 i.v.m. de geometrie van de haven
Heien verankeringspalen	7	4,3	Op basis van de norm van 164 dB re 1 $\mu Pa^2 s$ op 750 meter van de heilocatie
Heien conductorpijpen	5,5	4,1	
Baggeren	Verwaarloosbaar klein	2,3	Vergelijkbaar met de mijdingsafstand van het leggen van de pijpleiding
Gebruiksfase			
Varen middelgroot schip	0,3	0,3	
Nestgeluid en lossen barge	0,15	0,15	
Seismiek			
Seismisch onderzoek 3D/4D	12	12	
Shallow seismisch onderzoek	6	6	Halve mijdingsafstand van het seismisch onderzoek 3D/4D

Tijdens de gebruiksfase van de CO_2 injectie-installaties treden onderwater geen geluidniveaus op die een relevante invloed hebben op vissen en zeezoogdieren. De bouwfase is duidelijk luider, geluidrelevant zijn dan vooral de bedrijfssituaties met de inzet van een pijplegschip, (hei- en boor-) werkzaamheden aan de platforms en heiwerk ter realisatie van de aanlegsteigers in de haven.

Uit indicatieve berekeningen blijkt dat het pijplegschip en de situatie tijdens werkzaamheden aan de platforms worden gemeden door bruinvissen en zeehonden tot op afstanden van respectievelijk maximaal ca. 2 en 10 kilometer. De bruinvissen en zeehonden zullen het heiwerk eveneens mijden en er zal mogelijk ook PTS optreden. De berekende afstand voor PTS bij bruinvissen en zeehonden door heiwerk in de haven is achtereenvolgens 3 kilometer en ruim één kilometer. Bruinvissen en zeehonden zullen het heiwerk in de haven in theorie mijden tot op een afstand van meer dan 3 kilometer, hierbij moeten we vermelden dat alle berekende waarden behoren bij situaties waarin geluid zich vrij kan uitbreiden in alle richtingen. In de haven is hier zeker geen sprake van en zijn de berekende grote afstanden als minder reëel te beschouwen. In de natuurtoets hanteren we voor verstoring in de haven een reële afstand van globaal 3.300 meter.

Het heien van conductorpijpen past net binnen de bandbreedte. Gelet op de berekeningen wordt aan de norm voldaan. Verankeringspalen vergen echter een mitigerende maatregel. Mitigatie bestaat uit het gebruik maken van afschrikmethodes, *soft start*, bellenschermen (zie ook bijlage 4) en/of geluidwerende mantels. Indien voorafgaand aan de werkzaamheden blijkt dat er andere geluidsarmere methoden beschikbaar zijn, is het wellicht niet nodig deze mitigerende maatregelen toe te passen.

Seismisch onderzoek is geen onderdeel van het MER. Echter, er is bekeken in hoeverre seismisch onderzoek in het verlengde van de ontwikkeling van Aramis mogelijk is. Gedragsverandering door mijding van het onderzoeksgebied is door 3D/4D seismisch onderzoek te verwachten op een afstand van globaal 12 kilometer. Bij shallow seismisch onderzoek is deze afstand beduidend korter, naar verwachting een halvering van de genoemde afstand. Naast dat shallow seismisch onderzoek slechts een klein gebied van veelal enkele vierkante kilometers betreft, is de geluidbron ook minder krachtig dan bij 3D seismisch onderzoek. Met de benodigde mitigerende maatregelen en aanpassingen is seismisch onderzoek uitvoerbaar.

Bijlage

1. NOAA Fisheries Acoustic Thresholds

NOAA Fisheries Acoustic Thresholds

Feburary 2023

Onset of Permanent Threshold Shift (PTS) (NMFS 2018)

	PTS Onset Thresholds*	
Hearing Group	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{p,\text{0-pk,flat}}$: 219 dB $L_{E,p,\text{ LF,24h}}$: 183 dB	*Cell 2* $L_{E,p,\text{ LF,24h}}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{p,\text{0-pk,flat}}$: 230 dB $L_{E,p,\text{ MF,24h}}$: 185 dB	*Cell 4* $L_{E,p,\text{ MF,24h}}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{p,\text{0-pk,flat}}$: 202 dB $L_{E,p,\text{HF,24h}}$: 155 dB	*Cell 6* $L_{E,p,\text{ HF,24h}}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{p,\text{0-pk.flat}}$: 218 dB $L_{E,p,\text{PW,24h}}$: 185 dB	*Cell 8* $L_{E,p,\text{PW,24h}}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{p,\text{0-pk,flat}}$: 232 dB $L_{E,p,\text{OW,24h}}$: 203 dB	*Cell 10* + $L_{E,p,\text{OW,24h}}$: 219 dB

February 2023

Underwater Level B Harassment Acoustic Thresholds (NOAA 2005)

Source type	**Threshold**
Continuous	$L_{p,\text{RMS,flat}}$: 120 dB re 1 µPa
Non-explosive impulsive or intermittent	$L_{p,\text{RMS,flat}}$: 160 dB re 1 µPa

For in-air sounds, NMFS predicts that harbor seals exposed to RMS received levels ≥90 dB re 20 µPa will be behaviorally harassed, and other pinnipeds will be harassed when exposed to RMS received levels ≥100 dB re 20 µPa.

In-Air Level B Harassment Acoustic Thresholds (Southall et al. 2007; NOAA 2009)

Species/Group	**Threshold***
Harbor seal	$L_{p,\text{RMS,flat}}$: 90 dB re 20 µPa
All other pinnipeds	$L_{p,\text{RMS,flat}}$: 100 dB re 20 µPa

* A cumulative sound exposure level threshold of 100 dB re 20 µPa (DoN 2017) has been used for Navy military readiness activities. NMFS is currently in the process of re-evaluating the Navy's threshold.

Bijlage

2. Jetties (B7a)

Schatting effectafstanden PTS door heiwerk aan de aanlegsteigers

Royal HaskoningDHV

Jetties (B7a), schatting effectafstanden PTS door heiwerk aan de aanlegsteigers

Rekentool NMFS d.d. 2018 'Technical Guidance For Assessing the Effects of Anthropogenic Noise on Marine Mammal Hearing: Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts (Version 2.0)'

E.1-2: ALTERNATIVE METHOD TO CALCULATE PK AND SEL_{cum} (SINGLE STRIKE EQUIVALENT)		
Unweighted SEL_{cum} (at measured distance) = SEL_{ss} + 10 Log (# strikes)	**219,0**	
SEL_{cum}		
Source Level (Single Strike SEL)	183	
Number of strikes per pile	2000	
Number of piles per day	2	
Propagation (xLogR)	15	
Distance of single strike SEL measurement (meters)⁺	10	
⁺Unless otherwise specified, source levels are referenced 1 m from the source.		

Weging bij impulsachtig (hei-)geluid

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
a	1	1,6	1,8	1	2
b	2	2	2	2	2
f_1	0,2	8,8	12	1,9	0,94
f_2	19	110	140	30	25
C	0,13	1,2	1,36	0,75	0,64
Adjustment (dB)†	**-0,01**	**-19,74**	**-26,87**	**-2,08**	**-1,15**

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

Rekenresultaat rekening houdend met de weegfactoren:

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS Isopleth to threshold (meters)	**2.516,4**	**89,5**	**2.997,4**	**1.346,7**	**98,0**

Bijlage

3. Jetties (B7b)

Mijding bij heiwerk met heihamer aan de aanlegsteiger.
Impulsachtig geluid door 'impact pile driving'

Royal HaskoningDHV

Jetties (B7b), mijding bij heiwerk met heihamer aan de aanlegsteiger. Impulsachtig geluid door 'impact pile driving'

Bron van onderwater geluid	Mijding gerelateerd				
	Diersoort	Drempel mijding SEL1 in dB re 1 μPa²s	SEL1 op 10m	SEL1 op 100m**	Mijding*** op afstand in m
Heiwerk steiger	Bruinvis	140	183	163	ongewogen 19.953 (en gewogen 41)
	Zeehond*	145	183	163	3908
*drempel zeehond betreft in tegenstelling tot de bruinvis een (M-)gewogen waarde					
**site specific attenuation factor F voor ondiep water is 15 tot 30, gehanteerd is F=20					
***In de berekening van de mijdingsafstand is voor zeehonden een (M-)weging toegepast					

Bijlage

4. Geluidreducerende maatregelen bij heiwerk verankeringspalen centrale eindpunt en nieuwe platforms (B2, B8)

Royal HaskoningDHV

Geluidreducerende maatregelen bij heiwerk verankeringspalen centrale eindpunt en nieuwe platforms (B2, B8)

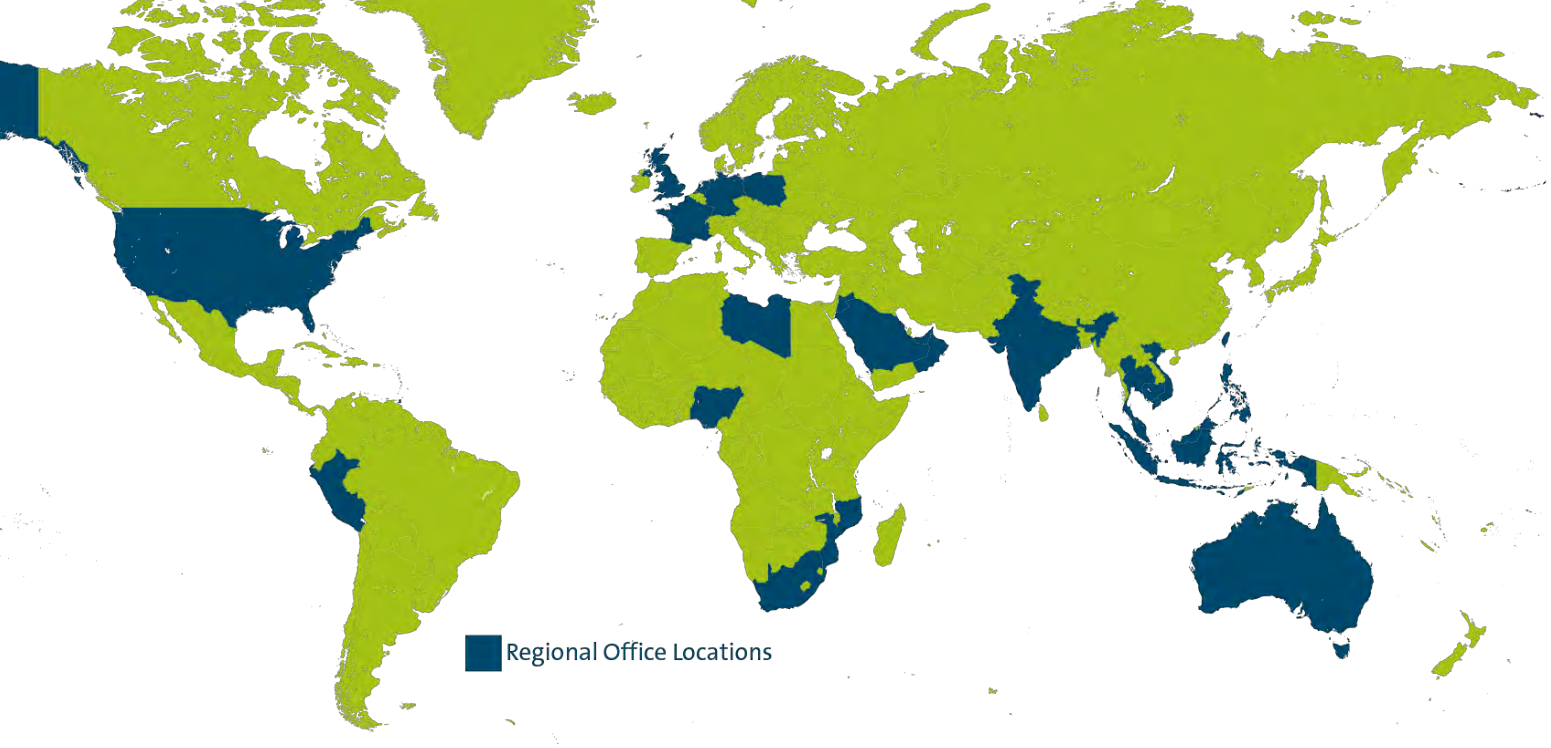
De onderstaande lijst met maatregelen is afkomstig van memorandum TNO 2020 M10542A 'Onderwatergeluidsberekeningen voor gasboringsproject ONE-Dyas' d.d. 23 september 2020.

De berekende overschrijdingen van de norm kunnen met behulp van in de markt beschikbare maatregelen gemitigeerd worden, zie bijvoorbeeld het overzicht in Tabel 7. De speciaal voor windturbinefundaties ontwikkelde maatregelen in deze tabel (NMS en HSD) zijn niet direct toepasbaar voor de platformpalen.

Tabel 7: overzicht van de bandbreedte aan geluidreducties die eerder zijn behaald met diverse maatregelen (NAS = underwater noise abatement systems; BBC = big bubble curtain; DBBC = double big bubble curtain; NMS = (IHC) noise mitigation system; HSD = hydro sound damper), uit (Verfuss et al, 2019)

NAS	Water depth	Noise reduction Δ SEL_{ss} (dB)
$BBC_{(>0.3m^3/(min*m))}$	~ 40 m	7 - 11
$DBBC_{(>0.3m^3/(min*m))}$	~ 40 m	8 - 13
$DBBC_{(>0.4m^3/(min*m))}$	~ 40 m	12 - 18
$DBBC_{(>0.5m^3/(min*m))}$	> 40 m	~ 15-16 (based on 1 pile)
NMS	Up to 40 m	13 - 16
HSD	Up to 40 m	10 - 12
NMS + optimised $BBC_{(>0.4m^3/(min*m))}$	~ 40 m	17-18
NMS + optimised $BBC_{(>0.5m^3/(min*m))}$	~ 40 m	18-20
HSD + optimised $BBC_{(>0.4m^3/(min*m))}$	~ 30 m	15-20
HSD + optimised $DBBC_{(0.48m^3/(min*m))}$	20-40 m	15-28
HSD + optimised $DBBC_{(>0.5m^3/(min*m))}$	< 45 m	18-19

N.B. Volgens het memorandum zijn de specifiek voor windturbinefundaties ontwikkelde maatregelen NMS (pipe-in-pipe system) and HSD-Nets (Hydro-Sound-Damper) niet direct geschikt voor platformpalen.



Royal HaskoningDHV is een onafhankelijk internationaal advies- en ingenieursbureau. We combineren 140 jaar engineering- en ontwerpexpertise met consultancy, software en technology diensten. We leveren hiermee toegevoegde waarde voor klanten en hebben een positieve impact op mensen en onze leefomgeving. Dat is onze drijfveer: Enhancing Society Together. Daar hoort bij dat we onszelf en anderen voortdurend uitdagen om bij te dragen aan duurzame oplossingen voor lokale en wereldwijde vraagstukken in de gebouwde omgeving en de industrie.

In onze snel veranderende wereld wordt de agenda bepaalt door onder meer klimaatverandering, de digitale transformatie, een veranderende consumentenvraag en hybride werken. Met onze geïntegreerde duurzame oplossingen willen we bijdragen aan het bredere technologische en maatschappelijke plaatje.

Gesteund door de kennis en ervaring van meer dan 6.000 collega's werken we vanuit kantoren in meer dan 20 landen. We ondersteunen klanten om de transitie te maken naar een slimme en duurzame organisatie. We koppelen onze engineering- en ontwerpexpertise aan onze software- en technologische diensten om toegevoegde waarde te leveren voor onze klanten en de lifecycle van hun assets.

We zijn oprecht, handelen integer en transparant in al onze activiteiten, ook onze bedrijfsvoering Ons team is divers en inclusief. De veiligheid en het welzijn van mensen, in ons team en daarbuiten, staat onder alle omstandigheden voorop.

In projecten en initiatieven werken we actief samen met overheden en het bedrijfsleven, partners en stakeholders. We zien een belangrijke rol voor onszelf in innovatieve duurzame ontwikkeling en willen bijdragen aan een betere leefomgeving, nu en in de toekomst.

Ons hoofkantoor is gevestigd in Nederland en we hebben kantoren in Europa, Azie, Afrika, Australie en Amerika.

euroCompliance certification ISO 37001 — euroCompliance certification ISO 37301

royalhaskoningdhv.com

RAPPORT

Energieverbruik en CO2-balans

MER Aramis CO2 transportinfrastructuur

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2013

Status: Definitief/01

Datum: 9 februari 2024

ARAMIS	CCS-ARAMIS Project
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2013 Document title Energy and CO2 balance report Revision Final 4.0

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV NEDERLAND B.V.

Laan 1914 no.35
3818 EX Amersfoort
Netherlands
Industry & Buildings
Trade register number: 56515154

+31 88 348 20 00 **T**
+31 33 463 36 52 **F**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

Titel document:	Energieverbruik en CO2-balans
Sub titel:	MER Aramis CO2 transportinfrastructuur
Referentie:	ARM-PFE-B10-ENV-EIA-2013
Status:	01/Definitief
Datum:	9 februari 2024
Projectnaam:	MER CCS Aramis
Projectnummer:	BH8744-105-107

Classificatie
Projectgerelateerd

Inhoud

Royal HaskoningDHV

1 Inleiding

Voor u ligt het rapport over energiegebruik & CO_2 balans van het Aramis systeem bij het MER voor het Aramis initiatief (kortweg Aramis). Het Aramis initiatief bestaat uit de aanleg en exploitatie van een open CCS-infrastructuur. Met deze infrastructuur is het mogelijk om bij de industrie afgevangen CO_2 te vervoeren naar leeg geproduceerde gasvelden onder de Noordzee, om het daar permanent op te slaan. Hiermee leveren de Aramis initiatiefnemers een bijdrage aan het behalen van de Nederlandse klimaatdoelstellingen.

Dit detailrapport heeft betrekking op energiegebruik en de CO_2 balans. En geeft daarmee een beeld van de benodigde hoeveelheden energie en efficiëntie van het complete systeem.

Om een goed beeld te geven van de complete CO_2-balans moet er naast enkel het Aramis initiatief ook naar de overige delen van de CCS-keten gekeken worden. Om deze reden omvat voorliggend rapport een gedetailleerde beschrijving van alle onderdelen van het Aramis initiatief en de bijbehorende CCS-keten.

1.1 Korte introductie van het Aramis initiatief

Integrale Aramis CCS-keten

Om de klimaatdoelstellingen te behalen, is er behoefte aan additionele transportinfrastructuur voor CO_2, waarmee meerdere opslaglocaties op zee worden ontsloten voor verschillende industriële emissiebronnen. Het Aramis initiatief speelt in op die behoefte door een nieuwe integrale en open CCS-keten mogelijk te maken. Het Aramis initiatief vormt een onderdeel van deze CCS-keten en bestaat uit de aanleg en exploitatie van een open CO_2-transportinfrastructuur. Het Aramis initiatief wordt in de rapportage dan ook wel aangeduid als Aramis CO_2-transportinfrastructuur. Samen met de afvanginfrastructuur en opslaginfrastructuur vormt dit de integrale CCS keten met onderstaande samenhangende onderdelen (zie figuur 1-1).

CO_2-afvanginfrastructuur

1. CO_2-afvang bij industrie, en geschikt maken voor transport;
2. CO_2-transport naar het verzamelpunt op de Maasvlakte, middels de Porthos landleiding of per schip;

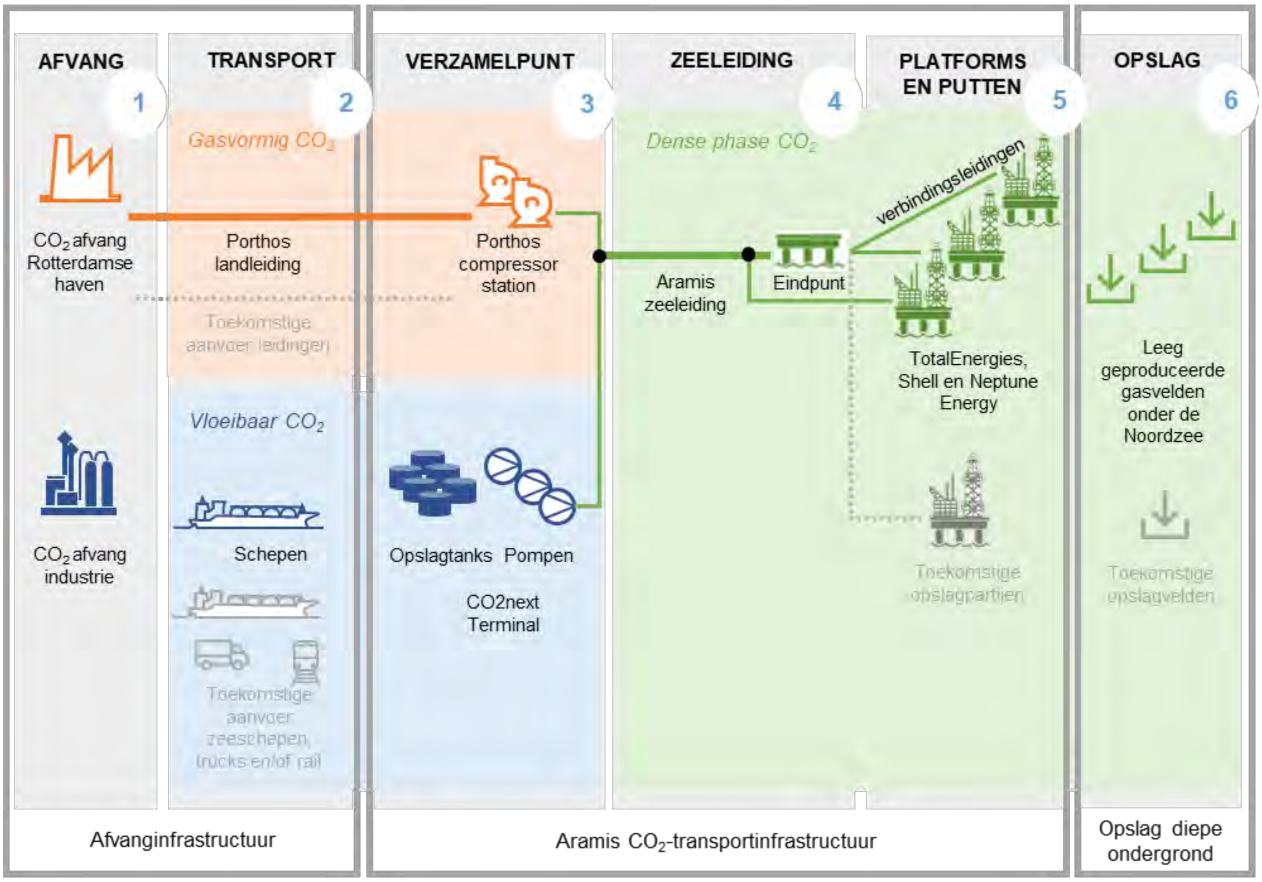
CO_2-transportinfrastructuur (Aramis initiatief)

3. CO_2-verzamelpunt op de Maasvlakte met een compressorstation en een terminal.
   - Het compressorstation ontvangt gasvormig CO_2 dat aangevoerd wordt per landleiding (via de Porthos-landleiding) en brengt het op druk voor het transport per zeeleiding;
   - De terminal ontvangt vloeibaar CO_2 aangevoerd per schip. De terminal locatie bevat steigers, opslagtanks voor tijdelijke opslag van CO_2 en hogedrukpompen voor levering aan de zeeleiding. CO_2 uit het compressorstation en vanaf de terminal komen samen in de CO_2-zeeleiding;
4. CO_2-transport door de centrale CO_2-zeeleiding naar het distributieplatform op de Noordzee. Dit platform is uitgerust met een verdeelstation voor toevoer van CO_2 naar de verschillende platforms. Er zijn tevens connectiepunten in de zeeleing waar vandaan CO_2 aan platforms geleverd kan worden;

5 CO_2-injectie: via verbindingsleidingen komt de CO_2 vanaf de zeeleiding bij injectieplatform. Middels putten bij deze platforms wordt CO_2 geïnjecteerd in leeg geproduceerde gasvelden in de diepe ondergrond van de Noordzee.

CO_2-opslag diepe ondergrond

6 CO_2-opslag: permanente CO_2 opslag in de diepe ondergrond.



Figuur 1-1. Overzicht van de integrale CCS-keten met daarin de componenten die onderdeel zijn van de voorgenomen activiteit, namelijk: transport per schip, terminal CO2next, uitbreiding compressorstation Porthos, zeeleiding met eindpunt en connectiepunten, aansluitleidingen en platforms

Het Aramis initiatief

Het Aramis initiatief heeft als doel het verzamelpunt (onderdeel 3), de zeeleiding (onderdeel 4) en de injectie (onderdeel 5) te realiseren. Hiervoor wordt door het Aramis consortium (bestaande uit Shell, TotalEnergies, Gasunie en EBN) samengewerkt met CO2next (voor de terminal) en Porthos (voor het compressorstation). De opslag vindt plaats vanaf de platforms van Shell, TotalEnergies en Neptune Energy.

De afvang (onderdeel 1) en transport van CO_2 naar het verzamelpunt (onderdeel 2) vallen buiten het Aramis initiatief[1]. In het MER worden deze aspecten wel benoemd en op hoofdlijnen beschreven, omdat ze integraal onderdeel uitmaken van de integrale Aramis CCS keten.

[1] *Een deel van de schepen die CO_2 leveren aan de terminal is afkomstig van Aramis-initiatiefnemers.*

De opslag in de diepe ondergrond (onderdeel 6) valt eveneens buiten het initiatief. Voor de diepe ondergrond gelden geen milieuregels. De mogelijke gevolgen van opslag in de diepe ondergrond wordt echter wel apart beschreven in het MER middels de deelrapporten opslag diepe ondergrond.

Bij de aanleg van Aramis wordt rekening gehouden met toekomstige uitbreiding met meer leveranciers van CO_2 en meer opslagpartijen. In eerste instantie wordt vergunning aangevraagd voor een startsituatie en de eerste uitbreidingssituatie. Dit wordt in het MER getoetst. Toekomstige initiatieven *na* de eerste uitbreidingssituatie behoren niet tot de vergunningaanvraag maar worden in het MER wel (globaal) beschreven.

De ingebruikname verwachten de Aramis initiatiefnemers in 2028, waarbij tegelijk al de eerste activiteiten zoals beschreven in de eerste uitbreidingsituatie kunnen starten. Voor het bereiken van de maximale doorvoercapaciteit is enkele jaren later als uitgangspunt in het MER aangehouden.

Een uitgebreide beschrijving van het Aramis initiatief is opgenomen in het deelrapport technische beschrijving en het samenvattend hoofdrapport MER (zie figuur 1-2).

1.2 Korte introductie op het milieuthema energie

1.2.1 Energiegebruik en CO_2-balans

Voor realisatie van het Aramis initiatief moet een uitgebreide infrastructuur voor CO_2-afvang, -transport en -opslag worden opgezet. Er is veel extra energie (stroom, warmte), chemicaliën en materialen nodig tijdens de constructiefase, in de operationele fase en de afsluitfase. Tijdens elk van deze fases zullen er zowel directe als indirecte emissies zijn. Directe emissies en indirecte emissies zijn concepten die worden gebruikt om de bronnen van broeikasgasuitstoot in verband met menselijke activiteiten te categoriseren. Het onderscheid tussen directe en indirecte emissies is van belang voor het begrijpen van de volledige impact van menselijke activiteiten op de uitstoot van broeikasgassen. Naast directe en indirecte emissies wordt er ook gekeken naar diffuse emissies.

Directe emissies:
Directe emissies verwijzen naar de uitstoot van broeikasgassen die rechtstreeks afkomstig zijn van specifieke bronnen die zich onder de controle van een individu, bedrijf of organisatie bevinden. Dit omvat emissies die ontstaan door verbranding van fossiele brandstoffen zoals benzine, diesel of aardgas voor transport, verwarming en industriële processen. Deze emissies zijn relatief gemakkelijk te meten en te kwantificeren, omdat ze afkomstig zijn van bronnen waar men direct invloed op kan uitoefenen.

Indirecte emissies:
Indirecte emissies verwijzen naar de uitstoot van broeikasgassen die niet rechtstreeks afkomstig zijn van de activiteiten van een individu, bedrijf of organisatie, maar eerder voortkomen uit de gehele levenscyclus van producten of diensten die zij gebruiken. Een voorbeeld van indirecte emissies is de uitstoot die ontstaat bij de productie van grondstoffen voor een product dat wordt gekocht, zelfs als de persoon of organisatie die het product koopt geen directe controle heeft over die productieprocessen.

Diffuse emissies:
Diffuse emissies verwijzen naar de uitstoot van broeikasgassen die niet als resultaat van het uitvoeren van een bepaalde activiteit plaatsvinden. Dit betreft voornamelijk onvermijdelijke lekkage en uitstoot van CO_2, wat realistischer wijs niet volledig kan worden voorkomen.

Om de doeltreffendheid van het CCS-systeem bij het verminderen van CO_2-emissies te evalueren wordt een analyse uitgevoerd van het energiegebruik en de CO_2-balans binnen het systeem. De CO_2-balans geeft een duidelijke indicatie van hoe de extra directe, indirecte en diffuse broeikasgasemissies van de hele CCS-keten zich verhouden tot de totale hoeveelheid verwijderde CO_2. Er is een spreadsheetmodel ontwikkeld om de netto jaarlijkse en cumulatieve reductie van broeikasgasemissies te bepalen die met het Aramis-project wordt bereikt.

De inhoud van dit rapport schetst het toegepaste model voor het berekenen van de saldi, waarbij tevens achtergrondinformatie wordt verstrekt met betrekking tot de gehanteerde kerncijfers. De bijlage van dit rapport omvat de gedetailleerde gegevens en informatiebronnen.

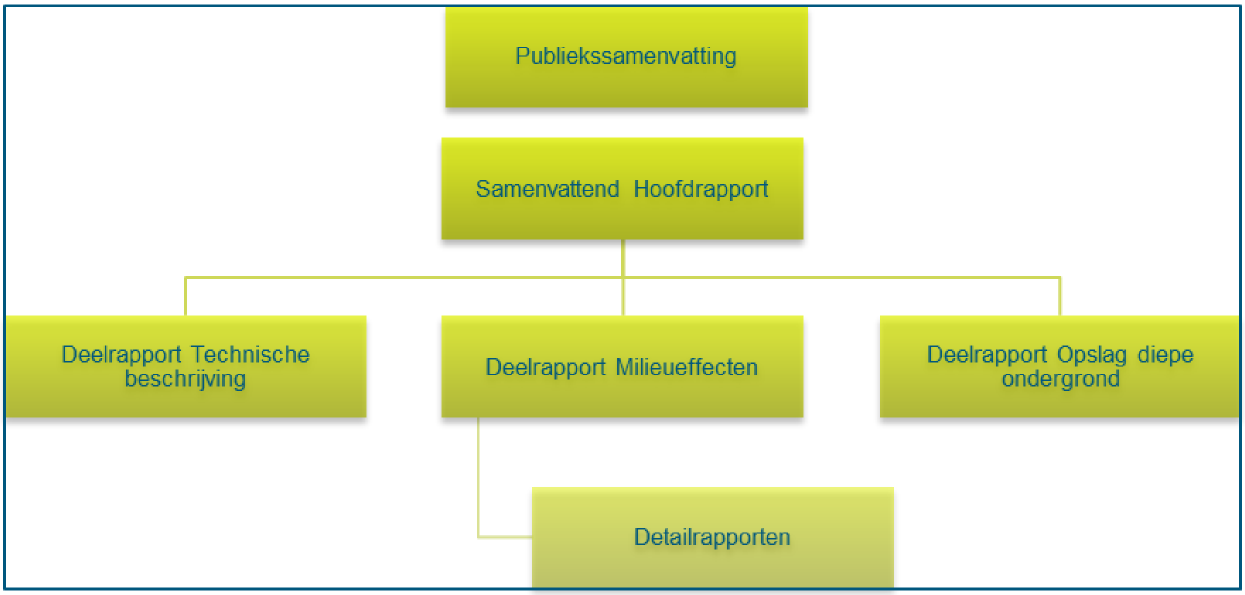
1.2.2 Relevante fases

Dit rapport omvat drie verschillende hoofdfases. In de eerste plaats wordt een differentiatie gemaakt tussen de constructiefase, operationele fase en de afsluitfase. Elk van deze fases behelst specifieke activiteiten die resulteren in energieverbruik en emissies. Bovendien wordt binnen het berekeningsmodel de operationele fase verder onderverdeeld in drie afzonderlijke periodes: opstartperiode, uitbreidingsperiode, en de vollastperiode. Deze drie periodes representeren opbouwende capaciteitsniveaus van het Aramis systeem.

1.3 Opbouw van het MER en dit detailrapport

Voor het Aramis initiatief is een gecombineerd Plan-/ProjectMER opgesteld. Figuur 1-2 geeft de rapportagestructuur van het MER Aramis. Het MER bestaat uit een Samenvattend Hoofdrapport, voorzien van een Publiekssamenvatting. Ter onderbouwing van het Samenvattend Hoofdrapport zijn deelrapporten opgesteld. Dit betreft het deelrapport Technische beschrijving van Aramis, het deelrapport Milieueffecten met daarbij de onderliggende technische detailstudies en de deelrapporten Opslag diepe ondergrond. Doordat CO_2 in meerdere geologische voorkomens wordt opgeslagen, zijn er voor de opslag diepe ondergrond meerdere deelrapporten opgesteld.

De bevindingen uit deze notitie energiegebruik en CO_2-balans zijn opgenomen in het Deelrapport Milieueffecten, en op hoofdlijnen in het Samenvattend Hoofdrapport.



Figuur 1-2 - Overzicht rapportagestructuur MER Aramis

Opbouw van dit rapport

Het rapport begint met een inleiding waarin het Aramis initiatief wordt geïntroduceerd, gevolgd door een korte introductie op energiegebruik en de CO_2-balans, evenals de relevante fases binnen dit thema.
Er wordt een beschrijving gegeven van de CCS-keten (Carbon Capture and Storage). Hierbij wordt de keten uiteen gesplitst in verschillende componenten en worden de verschillende projectfasen benoemd. Binnen de operationele fase worden verschillende aspecten van het CCS-project behandeld, zoals afvang bij emitters, conditionering bij afvang, scheepstransport, pijpleidingen en meer. Vervolgens worden de resultaten van het onderzoek, inclusief bevindingen over energiegebruik, directe, indirecte en diffuse CO_2-emissies, en de berekende CO_2-balans op basis van verschillende rekenscenario's gepresenteerd.

2 Beleid, wet- en regelgeving

Het Aramis initiatief is erop gericht om CO_2-emissies in de atmosfeer drastisch te verminderen. Tegelijkertijd is het onvermijdelijk dat de activiteiten ook tot nieuwe emissies leiden, veroorzaakt door de energieopwekking die nodig is om de installaties te laten werken. Het MER maakt daarom per onderdeel inzichtelijk hoeveel energie benodigd is en tot hoeveel nieuwe CO_2-emissies dit leidt. Ook wordt aandacht besteed aan mogelijkheden en maatregelen om het energieverbruik en de CO_2-emissies te beperken.

Naar aanleiding van de concept Notitie Reikwijdte en Detailniveau zijn door de Commissie voor de milieueffectrapportage enkele verplichtingen gesteld voor het MER van het Aramis initiatief. Voor het meewegen van het milieubelang in de besluiten over Aramis moet het MER in ieder geval onderstaande informatie bevatten:

- Aanleiding en beleid: opnemen in het MER wat de aanleiding is voor dit Carbon Capture and Storage (CCS) project, en hoe het zich verhoudt tot nationale en Europese afspraken voor CO_2-reductie. In het programma Noordzee 2022 -2027 wordt beschreven wat dit betekent voor het Aramis-initiatief[4] en de andere onderdelen van de CCS Aramis-keten.
- Afbakening van het Aramis initiatief en andere onderdelen CCS Aramis-keten: in het MER wordt een duidelijke beschrijving gegeven van het voornemen. Daarbij wordt ingegaan op de onderdelen van het Aramis initiatief maar ook de andere onderdelen van het CCS-proces (CO_2-afvang en CO_2-opslag). Dit is nodig om een goed beeld te geven van de te verwachten milieugevolgen.
- Alternatieven en varianten: een overzicht wordt gegeven van de alternatieven en varianten die worden onderzocht. Ook wordt voor het plaatsen van een platform een variant gemaakt (in het bijzonder met betrekking tot de funderingstechnieken) en een variant voor de aanleg van de zeeleiding.
- Doelbereik: Aangegeven wordt wat de netto CO_2-reductie is. Hierbij wordt de additioneel vrijgekomen CO_2 door de CCS Aramis-keten in mindering gebracht op de hoeveelheid opgeslagen CO_2 in de lege gasvelden.
- Milieugevolgen: de milieugevolgen (gebruiksfase en aanlegfase) van de alternatieven, varianten en het voorkeursalternatief worden vergeleken met de referentiesituatie. Daarbij wordt nadrukkelijk ingegaan op de effecten voor de bodem, water, natuur, archeologie en de emissies naar de lucht. Voor de onderdelen die nu nog niet concreet zijn gegeven, maar wel onderdeel zijn van de CCS Aramis-keten, wordt weergegeven wat de maximale ('worst-case') milieugevolgen zijn.

Voorliggend rapport geeft inzicht in de punten hierboven genoemd als 'Afbakening van het Aramis initiatief en andere delen CCS Aramis-keten' en 'Doelbereik'. Naast emissies binnen de grenzen van het Aramis initiatief worden namelijk ook emissies en energieverbruik gerelateerd aan CO_2-afvang en CO_2-opslag meegenomen in de balans. Dit is ook essentieel om een goed beeld te krijgen van wat de netto CO_2-reductie van het initiatief is.

Van de CCS-ketenonderdelen die geen deel zijn van het Aramis initiatief wordt een globale inschatting van de CO_2 emissies opgenomen in het MER. Gezamenlijk met de globale inschatting van de CO_2-emissies van buiten de huidige projectscope en de hoeveelheid op te slaan CO_2 kan een balans bepaald worden van hoeveel CO_2-emissies het Aramis initiatief per saldo terugbrengt. Dit geeft aan hoe effectief het voornemen is als klimaatmaatregel.

3 Beschrijving van de CCS-keten

3.1 Uitsplitsing van de CCS-keten

De CCS-keten bestaat uit meerdere schakels die elk hun eigen energiegebruik vergen en gepaard gaan met directe en indirecte emissies in verschillende mate. De reeks schakels tussen afvang bij de emitters en de uiteindelijke opslag in reservoirs onder de Noordzee omvat de volgende componenten:

- Afvang bij emitters;
- Conditionering van CO_2 voor transport bij emitters, zowel gasvormig als vloeibaar;
- Gasvormig transport over land via landleiding, of vloeibare CO_2 met scheepvaart;
- Terminal voor ontvangst en tijdelijke opslag van vloeibare CO_2;
- Pompen voor drukverhoging gevolgd door verwarming van vloeibare CO_2 afkomstig uit de terminal;
- Compressie van gasvormige CO_2, afkomstig uit de landleiding;
- Pijpleiding voor dense-mode transport offshore;
- Opslag van CO_2 in diep gelegen reservoirs onder de Noordzee.

3.2 Projectfasen

Voor het energieverbruik en de CO_2-balans worden de belangrijkste fasen in aanmerking genomen:

1. Constructiefase;
2. Operationele fase;
3. Afsluitfase.

3.3 Constructiefase

Voor de constructiefase wordt het energieverbruik bepaald dat benodigd is voor de constructie van afvanginstallaties, inclusief de compressoren van de leveranciers, en de uitbreiding van het compressorstation van Porthos. De aanleg van de transportleiding op zee en aansluiting op de installaties op land kost (veel) energie, net als de ombouw en constructie van injectieplatforms en het boren van nieuwe- of conversie van bestaande putten. Daarnaast wordt er relatief veel staal gebruikt voor pijpleidingen en de installaties, waaronder met name de putten en injectieplatforms, wat indirect energiegebruik en daarmee indirecte uitstoot van CO_2 met zich meebrengt. Bij de berekeningen is een verhouding van 1,4 ton uitgestoten CO_2 per ton staal aangehouden (IEA). Ander indirect energiegebruik, zoals productie van cement of andere bouwmaterialen, is naar verwachting relatief klein in vergelijking met de energie benodigd voor staal en wordt daarom niet in aanmerking genomen.

Naast indirecte emissies komen er ook directe emissies vrij in de bouwfase van het project. De eerste vulling met CO_2 van de pijpleiding vormt een fors CO_2 buffervolume, die gedurende de hele looptijd van het systeem aanwezig blijft in de pijpleidingen. Waarschijnlijk kan tijdens de afsluitfase niet alle CO_2 van deze buffer worden opgeslagen en komt daarmee na afronding van het project vrij, omdat het deels afgeblazen moet worden. Er wordt aangenomen dat 80% van de inhoud van de pijpleiding niet kan worden opgeslagen en afgeblazen moet worden. Daarnaast worden ook de directe emissies afkomstig van werktuigen met verbrandingsmotoren meegenomen.

3.4 Operationele fase

Type emissies

Voor alle componenten in de CCS-keten zijn tijdens de operationele fase drie emissietypen van belang:

1. Directe emissies: Directe emissies verwijzen naar de uitstoot van CO_2 rechtstreeks uit een puntbron. Deze puntbronnen zijn gemakkelijk te identificeren en kunnen worden toegeschreven aan specifieke activiteiten of processen. Enkele voorbeelden van directe emissies zijn uitlaatgassen van voertuigen en afblazen tijdens conditioneren.
2. Indirecte emissies: Indirecte emissies ontstaan niet rechtstreeks uit een puntbron, maar worden veroorzaakt door activiteiten die indirect bijdragen aan de emissie van CO_2. Dit type emissie ontstaat bij complexere chemische processen en de energie die daarvoor nodig is. De grootste bijdrager aan dit type emissies is afkomstig van gebruik van elektriciteit opgewekt in energiecentrales.
3. Diffuse emissies: Diffuse emissies zijn verspreide en niet-puntbronnen van CO_2. Het gaat hier over lekkages en slippage van CO_2 bij verschillende processtappen.

Periodes

Voor het bepalen van de cumulatieve effecten werden de volgende operationele fasen van de keten met bijbehorende gemiddelde hoeveelheden aan CO_2 opslag per jaar aangenomen:

1	Opstartperiode	10 MT CO_2/jaar	(5 jaar)
2	Uitbreidingsperiode	15 MT CO_2/jaar	(5 jaar)
3	Vollastperiode	20 MT CO_2/jaar	(20 jaar)

Dit betreft een schematische indeling. De dynamiek van de CCS keten zal in de praktijk hier ongetwijfeld van afwijken, maar dit geeft een zo realistisch mogelijke benadering om berekeningen over de levensduur van het initiatief zichtbaar te maken. Daarbij is nu uitgegaan van een levensduur van 30 jaar en een totale opslag van 525 Mton CO_2 in totaal. Dit zijn rekenkundige waarden, en moeten niet gezien worden als feitelijke begrenzing van CCS Aramis.

In de berekening wordt direct en indirect energiegebruik en CO_2 uitstoot tijdens de gebruiksfase beschreven voor de hele keten, vanaf het afvangen van de CO_2 tot en met die definitieve opslag in (lege) offshore aardgasvelden. In het model voor elk van deze ketenschakels wordt in kaart gebracht hoeveel energie (en in welke vorm) per ton aangeleverd CO_2 wordt verbruikt en welke percentages CO_2 ontsnappen door middel van procesemissies of diffuse emissies tijdens regulier bedrijf en onderhoud. Het CO_2 bestemd voor definitieve opslag gaat via de volgende ketenschakels:

3.4.1 Afvang bij emitters

Voor de afvang aan de bron wordt gebruik gemaakt van de data die in het kader van het Porthos-project zijn gegenereerd. (RHDHV, Porthos, 2019)

Diverse technieken kunnen worden ingezet voor de afvang van CO_2. De technieken die zijn geïntegreerd in het CO_2-balansmodel omvatten Op Spec, Cryocap, VPSA en chemische absorptie. Deze methodologieën hebben elk andere specifieke elektriciteits- en warmtevereisten, oplopend van laag naar hoog energieverbruik in volgorde van benoeming. De energieverbruiken per ton afgevangen CO_2 zijn terug te vinden in tabel 3-2. De praktische toepassing zal naar verwachting leiden tot een gemengde inzet van deze verschillende technieken. Onze analyse illustreert het bereik van directe en indirecte emissies aan de hand van een scenario met de laagste emissies, waarbij uitsluitend Op Spec wordt gebruikt voor afvang, en een scenario met de hoogste emissies dat volledig gebaseerd is op chemische absorptie als afvangtechniek.

Verder is binnen het model ook een samengesteld scenario berekend. Dit samengestelde scenario schetst een combinatie van afvangmethodes die als representatief worden beschouwd voor de toekomst. In deze context wordt verondersteld dat de verdeling van technieken overeenkomt met de samenstelling zoals uiteengezet in Tabel 3-1. Dit scenario wordt dan ook gebruikt om representatieve emissies, energieverbruiken en de algehele efficiëntie te berekenen. Deze verdeling is gemaakt op basis van bekende initiatieven binnen Nederland.

Techniek	Percentage
Op spec	50%
Cryocap	15%
VPSA	5%
Chemische absorptie	30%

Tabel 3-1:Verdeling afvangtechnieken op basis van bekende initiatieven.

3.4.2 Conditionering van CO_2 bij emitters

Voorafgaand aan transport moet CO_2 bepaalde behandelingen ondergaan. Deze behandelingen omvatten onder andere verwijderen van ongewenste verontreinigingen en aanpassing van de fysische condities, zoals temperatuur en druk. Een overzicht van de fysische condities per afvangtechniek is gegeven in tabel 3-2. De twee opties die beschouwd worden, zijn het transport van CO_2 door de pijpleiding en het transport van CO_2 door middel van scheepstransport. Beide routes vragen om andere fysieke condities van de CO_2.

Tabel 3-2: Energieverbruik voor verschillende afvangtechnieken.

Process type	Stroomverbruik vastleggen [GJ_e/ton]	Druk van het product [bar(a)]	Stroomverbruik voor compressie tot operationele druk of Porthos pijpleiding [GJ_e/ton]	Totaal stroomverbruik [GJ_e/ton]	Warmteverbruik [GJ_{th}/ton CO_2]
CO_2 op specificatie		20	0,041	0,041	
Cryocap	0,577	5,8	0,132	0,709	0,010
Vpsa	0,773	15	0,061	0,834	0,010
Membraan	0,957	1	0,270	1,227	
Oxybrandstof	1,395	1	0,270	1,665	
Chemische absorptie, hoge CO_2-concentratie	0,210	1	0,270	0,480	2,500
Chemische absorptie, lage CO_2-concentratie	0,210	1	0,270	0,480	3,000

A. Conditionering en compressie van CO_2 voor **pijpleiding transport**

Voor conditionering en compressie van CO_2 voor transport door de pijpleiding wordt een percentage aangenomen voor afblazen van CO_2 wat gepaard gaat bij de verwijdering van onzuiverheden uit het afgevangen CO_2. Deze waarde is 0% voor het lage scenario, 3% voor het mix scenario en 5% voor het hoge scenario. Vervolgens wordt het gas gecomprimeerd tot een druk van 35 bar waarna het in de pijpleiding vervoerd wordt richting het compressorstation op de Maasvlakte. Bij aankomst heeft het gas 2 bar aan druk verloren.

B. Conditionering en vloeibaarmaking van CO_2 voor **scheepstransport**

Voor conditionering en vervloeiing van CO_2 voor transport met schepen wordt aangenomen dat een gelijk percentage als bij het pijpleiding transport afgeblazen moet worden om onzuiverheden uit het afgevangen CO_2 te verwijderen. Vervolgens moet de CO_2 gecomprimeerd worden tot scheepstransportdruk. Hierbij wordt waterkoeling gebruikt om de gegenereerde warmte af te voeren. Wanneer scheepsdruk behaald is, moet de CO_2 vervloeid worden door het sterk af te koelen tot beneden de omgevingstemperatuur. Dit kan niet met waterkoeling gedaan worden en wordt daarom berekend analoog aan warmtepompkoeling. Nadat de CO_2 vloeibaar is gemaakt kan het tussentijds worden opgeslagen of verpompt worden naar het schip. De beschrijvingen van de initiatieven geven aan dat dampvormig CO_2, die ontstaat (‘boil-off gas’, BOG) uit tussentijdse opslag of tijdens scheepsopslag, teruggeleid wordt naar de installatie voor conditionering en vervloeiing (liquefactie). Er zijn dus geen andere verliezen in aanmerking genomen.

Gegevens voor conditionering en liquefactie van afgevangen CO_2 aan de bron zijn afgeleid van de MER voor Twence (van den Acker & al, 2019) en ReEnergy Roosendaal (RHDHV, MER CO2-afvang SUEZ ReEnergy Roosendaal , 2021) .

Energieverbruik tijdens het conditioneren

Conditionering en vervloeiing van de afgevangen CO_2 is cruciaal voor een veilige en efficiënte opslag en transport van CO_2. Het proces omvat verschillende stappen die hieronder verder uitgelegd worden.
Om de afgevangen CO_2 geschikt te maken voor opslag of transport, wordt het gas eerst gecomprimeerd. De mate van compressie is niet gelijk voor alle afvangtechnieken, aangezien de druk waarop de afgevangen CO_2 geleverd wordt onderling erg kan verschillen. Ook moet de CO_2 gekoeld worden tijdens het comprimeren, hier zijn meerdere redenen voor:

- Efficiëntie: Door tussentijdse koeling kan de compressie-energie-efficiëntie worden verbeterd, omdat koeler gas gemakkelijker gecomprimeerd kan worden dan warm gas.
- Condensatie van verontreinigingen: Tijdens het koelproces kunnen sommige verontreinigingen in de CO_2 condenseren, deze verontreinigingen kunnen vervolgens worden afgeblazen om een meer puur eindproduct te bewerkstelligen. Voorbeelden van verontreinigingen zijn CO, NOx, SOx, etc. De mate waarin deze stoffen voorkomen in de afgevangen CO_2 hebben direct invloed op de hoeveelheid die afgeblazen moet worden tijdens deze conditioneringsstap. Dit verschilt per afvangtechniek, en zelfs per afvanglocatie.
- Bescherming van apparatuur: Koeling helpt bij het voorkomen van oververhitting van de compressoreenheden, waardoor hun levensduur wordt verlengd.

Zodra de CO_2 de gewenste druk heeft behaald, wordt het verder gekoeld tot de transport temperatuur om een faseovergang naar vloeibaar CO_2 te bewerkstelligen. Het vloeibaar maken van CO_2 is van cruciaal belang voor transport en opslag, omdat vloeibare CO_2 een veel kleiner volume inneemt dan in gasvorm. Hierdoor is transport een stuk efficiënter.

Verschillende afvangtechnieken vereisen verschillende hoeveelheden energie voor het proces, dit wordt veroorzaakt door de variërende startdrukken. Tabel 3-3 hieronder geeft de benodigde energie per processtap weer voor twee verschillende afvangtechnieken, voor Op Spec is het drukverschil het kleinst, en voor chemische absorptie is het drukverschil het grootst. Het rendement van de compressor is hierbij aangenomen op 85%. Gedurende het comprimeren van de CO_2 wordt het gekoeld met water, waarbij vier keer zoveel warmte uit de CO_2 wordt onttrokken dan dat het energie kost om het water rond te pompen. Hierdoor is de energievraag voor dit onderdeel relatief laag.

Het vervloeien van de CO_2 kan echter niet worden gerealiseerd met slechts waterkoeling. In plaats daarvan wordt aangenomen dat de actieve koeling een rendement van 80% heeft. Uit tabel 3-3 blijkt dat deze vervloeiingsstap duidelijk de grootste energievraag heeft.

Tabel 3-3: Energievraag in MJe/ton per processtap voor op spec en chemische absorptie afvangtechnieken.

Processtap	Energievraag [MJe/ton]	
	Op Spec (laag)	Chemische absorptie (hoog)
Compressie naar scheepsdruk	15	242
Koeling tijdens compressie	3	42
Vervloeiing	393	457
Totaal	411	741

3.4.3 Transport

De afgevangen en geconditioneerde CO_2 kan getransporteerd worden naar het compressorstation via de Porthos buisleiding of middels scheepstransport. De verdeling tussen deze twee opties wordt is weergegeven in tabel 3-4.

	Landleiding	Scheepvaart
Opstartperiode	50%	50%
Uitbreidingsperiode	50%	50%
Vollastperiode	37,5%	62,5%

Tabel 3-4: Verdeling transport afgevangen CO_2 in de verschillende periodes van het project.

Landleiding:
Er wordt in het model rekening gehouden met diffuse emissies tijdens transport door pijpleidingen. Waarden die hiervoor in literatuur te vinden zijn variëren van 7,5 tot 282,0 kg CO_2/km/jaar (Batelle, 2020 en Batelle, 2022). De praktijkwaarde zal ergens tussen deze twee uitersten liggen, in het model is deze waarde aangenomen als zijnde 75,0 kg CO_2/km/jaar. Dezelfde waarden worden ook gebruikt om de diffuse emissies uit de zeeleiding te berekenen later in de keten.

Scheepvaart:
Data uit (Klein & al, 2022) worden gebruikt voor het energieverbruik en broeikasgasemissies in het scheepsvervoer. Aangenomen wordt dat LNG als brandstof wordt gebruikt. Conform (Klein & al, 2022) is hiervoor rekening gehouden met een 'toeslag' op het brandstofverbruik van 5% ten opzichte van diesel/gasolie. Daarnaast is rekening gehouden met een methaanslip van maximaal 3,5% en minimaal 0,15% van het verbruikte LNG (Comer, 2022); afhankelijk van het type motor. Deze zijn verrekend in de specifieke broeikasgasemissies en worden daarom niet nogmaals genoemd onder de diffuse emissies.

Tabel 3-5: Specifiek energieverbruik voor verschillende scheepstypen (MJ/tonne/km)

	CEMT Vb		Waal		Gebaseerd op referentie van (Klein & al, 2022)	
	max	min	max	min	Lading, [KtonNE/lading]	cdes
6k binnenvaart	0,36	0,35	0,30	0,29	5,046	Klasse Va + 1 Europa II binnenschip, breed
8.1k binnenvaart	0,36	0,35	0,30	0,29	8,1135	Gemiddelde van klasse Va + 1 Europa II barge, breed en 4-barge push konvooi
11.7k binnenvaart	0,18	0,18	0,24	0,23	11,181	4-barge duwkonvooi
16k-kustvaarder	0,25	0,24	0,20	0,19	16,481	6-barge duwkonvooi, breed

In tabel 3-5 worden voor verschillende groottes schepen het specifiek energieverbruik gegeven op waterwegen en kanalen in Europa (CEMT Vb) en op de Waal specifiek (Klein & al, 2022). De bijbehorende specifieke broeikasgasemissies per tonkilometer zijn gegeven in tabel 3-6. De laagste en hoogste waarde zijn gebruikt voor het berekenen van de laag en hoog scenario's respectievelijk, het mix scenario rekent met gemiddeldes van zowel de 8.1k als 11.7k binnenvaartschepen.

Tabel 3-6: Specifieke broeikasgasemissies voor verschillende scheepstypen (g CO_2-eq/ton/km)

	CEMT Vb		Waal	
	maximum	minimaal	maximum	minimaal
6k binnenvaart	26,1	19,3	22,1	16,4
8.1k binnenvaart	26,1	19,3	22,1	16,4
11.7k binnenvaart	13,4	10,0	17,4	12,9
16k-kustvaarder	18,2	13,5	14,2	10,6

3.4.4 Terminal opslag en pompen

Voor de overslag van schip van vloeibare CO_2, het op druk brengen van de vloeibare CO_2 en de afvoer / het transport van op superkritische druk gebrachte CO_2 via een pijpleiding, worden de volgende specifieke energieverbruiken gegeven (RINA, 2022):

- Energieverbruik bij het lossen: 1,5 MJ_e/ton CO_2 overgeslagen.
- Lagedruk- en hogedrukpompen: 20 MJ_e/ton CO_2 overgeslagen.
- BOG installatie: 0,4 MJ_e/ton CO_2 overgeslagen.

Er wordt van uitgegaan dat de energie die nodig is om de CO_2 onder druk op te warmen, wordt geleverd door de compressoren die operationeel zijn binnen het Aramis-initiatief en het Porthos-initiatief.

Royal HaskoningDHV

3.4.5 Compressie bij Aramis

De laatste stap alvorens injectie is het verhogen van de druk van de CO_2 naar 180 bar, zodat het via de Aramis zeeleiding naar de injectieplatforms getransporteerd kan worden. Het elektriciteitsverbruik voor de compressie van CO_2 dat via de Porthos-pijpleiding wordt aangeleverd en in het Aramis-initiatief tot 180 bar wordt gecomprimeerd, wordt geschat met behulp van de polytrope compressieformule.
Als diffuse emissies afkomstig van de compressoren wordt een hoeveelheid van 228 gram per uur per compressor aangehouden, een waarde afkomstig uit het handboek emissiefactoren van diffuse emissies en emissies bij op- en overslag.

3.4.6 Transport door trunk- en spurlines

Bij transport van de Aramis terminal naar de locaties voor eindberging komen geen directe of indirecte emissies vrij, aangezien het transport passief plaatsvindt door een drukverschil tussen de leiding na de compressor en het opslagreservoir.

Wel zijn er diffuse emissies die kunnen ontstaan tijdens het transport door de trunkline en spurlines. Er is een aanzienlijke bandbreedte aan emissiewaarden gevonden voor diffuse emissies tijdens het transport door pijpleidingen, zoals ook al eerder benoemd bij het transport door de landleiding. De waarden zijn hieronder gegeven in tabel 3-7.

Tabel 3-7: Diffuse emissiefactoren voor het vervoer via pijpleidingen in kg CO_2/km/jaar

Bron	Diffuse emissies in kg CO_2/km/jaar
Minimum	7,5
Verwachte, realistische waarde	75,0
Maximum	282,0

De door Batelle genoemde verwachtingswaarde betreft de uitstoot van een bestaande pijpleiding voor EOR in de VS (Niagaran Reefs CO2-EOR). (Sminchak, Webster, & Hawkins, 2022)

3.4.7 Platforms

De emissies vanaf de platforms hebben geen significante impact op de totale balans. Emissies zullen vooral optreden wanneer de druk van meters, putten en leidingwerk wordt afgelaten tijdens onderhoud of andere niet gebruikelijke situaties. De hoeveelheid wordt geschat op zo'n 10.000 m3 CO2 per jaar, of iets meer dan 18.300 kg CO2.

3.4.8 Aggregatie van componenten

Door de bovenstaande gegevens voor de verschillende koppelingen te combineren met de jaarlijkse hoeveelheden CO_2 die via de CCS-keten behorend bij het Aramis-systeem moeten worden verwijderd, produceert het model een massabalans van het Aramis-initiatief en een overzicht van het totale jaarlijkse energieverbruik en CO_2-verliezen.

De netto broeikasgasbalans wordt bepaald door het energieverbruik te vertalen naar de uitstoot van broeikasgassen door:

- Het combineren van CO_2-verliezen en aan energieverbruik gerelateerde directe- en indirecte emissies

- Het vergelijken van de som van verliezen en indirecte broeikasgasemissies met de hoeveelheid CO_2 die geologisch moet worden opgeslagen.

Gezien de onzekerheid in de veronderstelde kengetallen en herkomst van CO_2 bestemd voor geologische opslag wordt een bandbreedte berekend middels een laag en hoog scenario. Waar mogelijk worden hier respectievelijk lage en hoge aannames of indicatieve waarden gebruikt bij berekeningen. Werkelijke waarden liggen dus ergens in deze bandbreedte.

3.5 Afsluitfase

De afsluitfase van een project, hoewel een cruciale fase in de levenscyclus van een project, wordt in de verstrekte gegevens niet meegenomen. Dit kan worden toegeschreven aan de complexe en vaak onzekere aard van deze fase, die zich meestal ver in de toekomst bevindt. In de afsluitfase worden activiteiten ondernomen om een project of faciliteit veilig te ontmantelen, af te sluiten en de locatie te herstellen naar een staat die voldoet aan milieu- en gezondheidsnormen.

De besluitvorming en inschattingen met betrekking tot de afsluitfase worden bemoeilijkt door verschillende factoren:

- **Onzekerheid over technologie en wetgeving**: Tegen de tijd dat een project de afsluitfase bereikt, kunnen technologieën en regelgeving met betrekking tot demontage, afvalverwerking en milieubescherming aanzienlijk zijn veranderd. Dit kan leiden tot onzekerheid over de beste methoden en praktijken die moeten worden toegepast.
- **Economische en marktomstandigheden**: Economische omstandigheden en marktvraag kunnen aanzienlijk variëren over de lange termijn. Dit kan van invloed zijn op de beschikbare middelen voor de afsluitfase en de economische levensvatbaarheid van verschillende ontmantelingsopties.
- **Onvoorziene omstandigheden**: Na verloop van tijd kunnen onvoorziene omstandigheden, zoals technische problemen, natuurrampen of politieke veranderingen, de plannen voor de afsluitfase beïnvloeden.
- **Innovatie en ontwikkeling**: Nieuwe technologieën en benaderingen kunnen in de loop der jaren opkomen, wat mogelijk nieuwe mogelijkheden biedt voor de efficiënte en milieuvriendelijke afsluiting van projecten.

Vanwege deze onzekerheden en variabelen wordt de verlatingsfase vaak als te ver in de toekomst beschouwd om op dit moment een nauwkeurige inschatting te maken. Ook maakt het gebrek aan actuele en specifieke gegevens het moeilijk om de impact van de verlatingsfase op het project in deze fase te beoordelen. Daarbij is wel de verwachting dat de verlatingsfase ten opzichte van constructie en operationele fasen een zeer beperkte invloed heeft op de uitkomsten van de energie- en CO_2 balansen. Als voor de verlatingsfase dezelfde emissies worden aangenomen als voor de constructiefase exclusief de emissies verbonden aan staalproductie en opstart van het systeem zal de verlatingsfase slechts 2% van de constructie-emissies omvatten.

4 Resultaten

In dit hoofdstuk worden de resultaten van de energie en CO_2 balans gepresenteerd. De beschikbare informatie, in combinatie met een aantal aannames, is gebruikt om een uitgebreide spreadsheet op te zetten (zie Bijlage 1). Deze spreadsheet is ontworpen om de CO_2- en energiebalans te berekenen met als doel om een duidelijk en nauwkeurig beeld te krijgen van de milieu-impact en efficiëntie van het initiatief.

4.1 Directe en indirecte CO_2 emissies in de constructiefase

Tabel 4-1: Directe en indirecte emissies tijdens de constructiefase in tonnen.

Emissiebron		Direct (ton CO_2)	Indirect (ton CO_2)
Staalproductie	Pijpleidingen		511.851
	Platforms		5.919
	Putten		1.370
	Overige infrastructuur		28.000
Brandstof	Werktuigen	10.220	
Startup	Vullen pijpleiding	66.643	
Totaal *(ton CO_2)*			**624.003**

Bovenstaande resultaten in tabel 4-1 laten zien dat de staalproductie de grootste bron van CO_2-emissie is tijdens de constructiefase, met pijpleidingen als de voornaamste bijdrager. Het vullen van pijpleidingen draagt ook significant bij aan directe emissies, al zullen deze pas tijdens de afsluitfase vrijkomen. Brandstofgebruik in werktuigen heeft een relatief kleinere impact op de directe emissies.

4.2 Energiegebruik in de operationele fase

De resultaten worden gegeven in bandbreedtes en per projectfase. De bandbreedtes zijn berekend door voor elke processtap zowel het alternatief met de laagste als hoogste energievraag door te rekenen. De invloed van de fase van het project reikt niet verder dan de hoeveelheid CO_2 die afgevangen wordt en vervolgens via landleiding of scheeproute vervoerd wordt en de emissiefactoren die gepaard gaat met elektriciteitsverbruik.

Voor de operationele fase is het energiegebruik per jaar gegeven in de onderstaande tabel. Daarbij is in de operationele fase onderscheid gemaakt tussen:

- De opstartfase, met een duur van aangenomen 5 jaar;
- De uitbreidingsfase, met een duur van 5 jaar;
- De vollast fase met maximaal uitbreiding van het Aramis systeem, met een duur van 20 jaar.

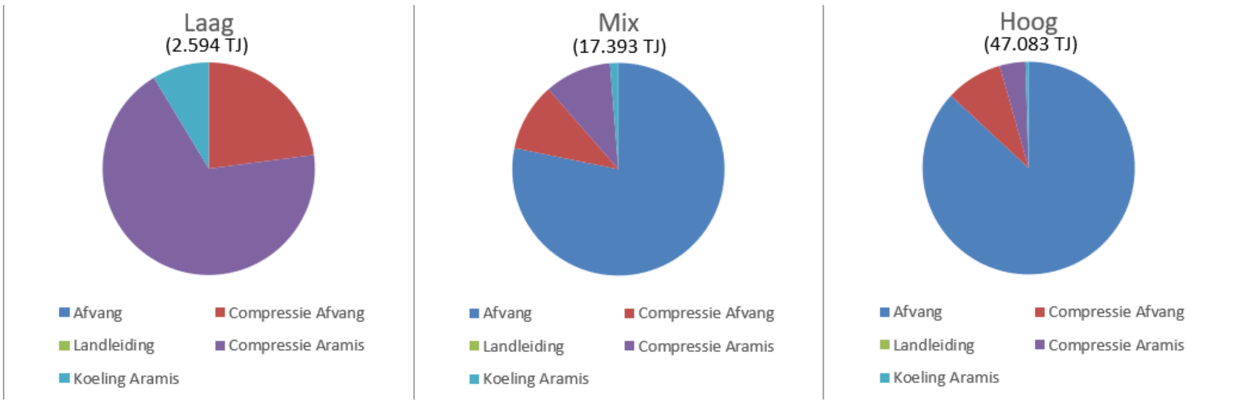
De totale duur voor het beschreven Aramis project met toekomstige aansluitingen is hier beperkt tot 30 jaar.

Voor elk van de bovenstaande fasen is de mix van toegeleverde CO_2 van belang. De details van de mix zijn beschreven onder hoofdstuk 3.

Tabel 4-2: Energievraag van het project in de verschillende periodes, berekent met de drie scenario's. (in TWh/jaar)

	Laag	Mix	Hoog
Opstart	0,48	3,23	8,72
Uitbreiding	0,72	4,83	13,08
Vollast	0,95	6,38	1

De bandbreedte voor het energieverbruik binnen elk van de verschillende periodes is erg groot zoals af te lezen is uit tabel 4-2. Dit wordt voornamelijk veroorzaakt door de grote invloed die de keuze van de afvangtechniek heeft op het geheel. In de taartdiagrammen is te zien hoe de scenario's van elkaar verschillen als het gaat om de verdeling van het energieverbruik. Koeling en compressie bij het compressorstation heeft in alle scenario's dezelfde energievraag per hoeveelheid CO2, enkel de energievraag van de afvangtechniek en de compressie naar landleiding druk bij de afvangers zorgt voor verschil in efficiëntie.



Figuur 4-1: Taartdiagrammen over de verdeling van de energievraag voor de verschillende scenario's. De totale hoeveelheid benodigde energie (gegeven voor de uitbreidingsfase van 15 MT/jaar) is in het laag scenario 20 keer kleiner dan in het hoog scenario.

Figuur 4-1 laat de verhoudingen zien van de energievraag per schakel in de keten. In absolute zin heeft het meest gunstige scenario, gebaseerd op alleen Op-Spec afvang technieken, een ongeveer 20 keer lager energieverbruik dan het meest ongunstige scenario, gebaseerd op alleen chemische absorptie. Een overgroot gedeelte van dit verschil stamt uit het energiegebruik door de afvang.

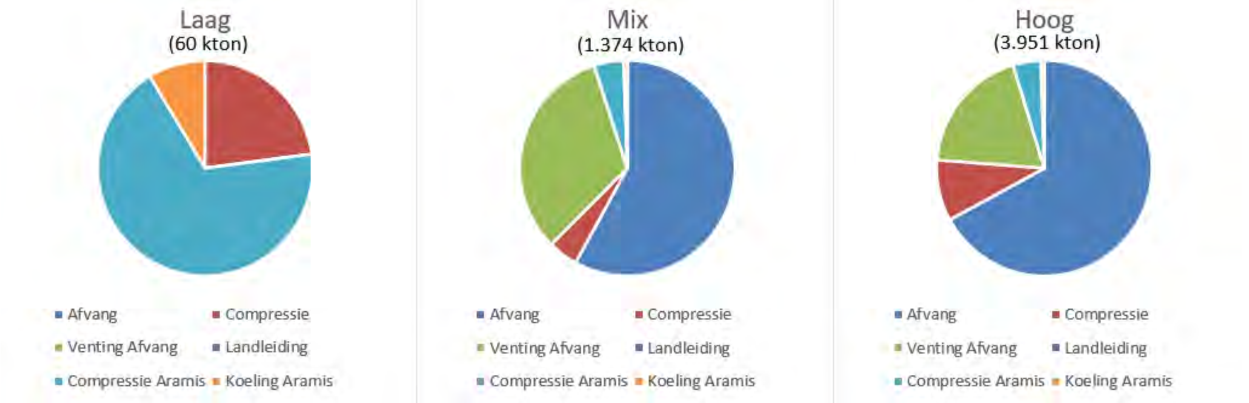
Uit deze grafieken blijkt de grote invloed die het type afvangtechniek heeft op het energieverbruik van de gehele keten. Deze observatie is terug te zien in alle uitbreidingsfasen van het project.

4.3 Directe en indirecte CO_2 emissie in de operationele fase

Tabel 4-3: Directe en indirecte CO_2 emissies van het project in de verschillende periodes, berekent met de drie scenario's. (in kton/jaar)

	Laag	Mix	Hoog
Opstart	67	919	2.813
Uitbreiding	60	1.374	3.951
Vollast	81	1.827	5.376

Ook de directe en indirecte CO_2-emissies zijn sterk afhankelijk van het type of mix van types afvangtechnieken die gebruikt worden zoals te zien in tabel 4-3 en figuur 4-2. Mede om deze reden zijn ook hier grote verschillen te zien tussen de verschillende berekende scenario's. Er zijn ook verschillen in het percentage CO_2 dat afgeblazen moet worden ten behoeve van conditionering van de afgevangen CO_2 stroom, deze percentages zijn respectievelijk 0%, 3% en 5% voor het laag, mix en hoog scenario.



Figuur 4-2: Taartdiagrammen over de verdeling van de emissies voor de verschillende scenario's. Voor elk van de scenario's zijn ook de totale directe en indirecte emissies gegeven voor de uitbreidingsfase (15 MT/jaar)

4.4 CO_2 balans

Hieronder wordt de CO_2 balans gegeven voor het mix scenario in de vollast periode. De vollast periode duurt relatief gezien het langst en weegt daarom het zwaarst mee voor de lifetime efficiency van het systeem. Er is gekozen om naar het mix scenario te kijken in tabel 4-4 omdat dit de meest realistische inschatting is van de werkelijke situatie.

Tabel 4-4: Overzicht van emissies per onderdeel van de keten voor het mix scenario in de vollast periode (in tonnen/jaar).

Component	Direct/indirect	Diffuus
Emitters afvang	1.069.648	
Emitters conditionering	677.614	12
Onshore pijpleidingtransport	-	4
Binnenvaart	34.644	-
Compressie	30.658	6
Terminal opslag & pompen	10.975	0
Offshore pijpleidingtransport	-	20
Platform opslag	-	18
Totaal emissies	1.827.316	1.911
Opslag per jaar	20.000.000	
% tov opslag	9,16%	

Op basis van deze data voor de verschillende scenario's en de verschillende periodes binnen de operationele fases is er een overzicht gemaakt zoals weergegeven in tabel 4-5.

Tabel 4-5: Overzicht van de emissies per fase, de totale opgeslagen emissies, en de lifetime efficiëntie voor de drie scenario's.

Lifetime	Laag emissies	Mix emissies	Hoog emissies
Constructie	624.003	624.003	624.003
Operationeel	2.314.973	48.067.530	141.393.611
Opslag	-525.000.000	-525.000.000	-525.000.000
Efficiency	99%	91%	73%

Wat deze tabel laat zien is dat de bandbreedte van de efficiëntie van het Aramis systeem loopt van 73% tot 99%. Het mix scenario is een inschatting van de werkelijke efficiëntie op basis van de aannames eerder besproken.

5 Conclusie

Tijdens de fase van constructie binnen het totale project vanaf afvang tot aan opslag zullen aanzienlijke initiële CO_2 emissies optreden, voornamelijk toe te schrijven aan de staalproductie voor de buisleidingen die een integraal onderdeel vormen van het project. De totale CO_2-emissies gedurende de constructiefase van het project belopen ongeveer 624 kiloton, maar deze hoeveelheid CO_2 emissie is niet significant in het licht van de verwachte hoeveelheid CO_2 die gedurende de levensduur van het project wordt opgeslagen.

In de operationele fase treden ook emissies op, waarbij de energievraag voor het vastleggen van CO_2 bij de uitstoters de voornaamste bron is. In werkelijkheid omvatten deze emissies ergens tussen de 1% en 29% van het totale opgeslagen emissievolume. Een benadering gebaseerd op bestaande initiatieven voor koolstofafvang suggereert dat een realistische levensduurefficiëntie van 91% haalbaar is.

Deze analyses laat niet alleen de dynamiek van emissies gedurende verschillende levensfasen van het project zien, maar zetten ook de emissies tijdens de constructiefase in perspectief, gezien hun geringe bijdrage aan de algehele opslag van CO_2 gedurende het gehele project. Een andere bevinding is dat de efficiëntie van het systeem grotendeels bepaald wordt door de afvangtechniek gekozen door de leveranciers van de CO_2. In dit licht is het voorspellen van de efficiëntie een uitdaging die een diepgaand begrip vereist van zowel technologische aspecten als bredere markt- en beleidstrends. Invloed op het type afvangtechniek is daarnaast ook beperkt, omdat het zich niet direct binnen de grenzen van het initiatief bevindt.

6 Verwijzingen

Comer, B. (2022). Methane slip: LNG's Achilles heel. *COP27* (p. 18). Sharm el-Sheikh: International Council on Clean Transportation.

Klein, A., & al, e. (2022). *STREAM Freight Transport 2020.* Delft: CE Delft.

RHDHV. (2019). *Porthos.* Amersfoort: Royal HaskoningDHV.

RHDHV. (2021). *MER CO2-afvang SUEZ ReEnergy Roosendaal .* Nijmegen: Royal HaskoningDHV.

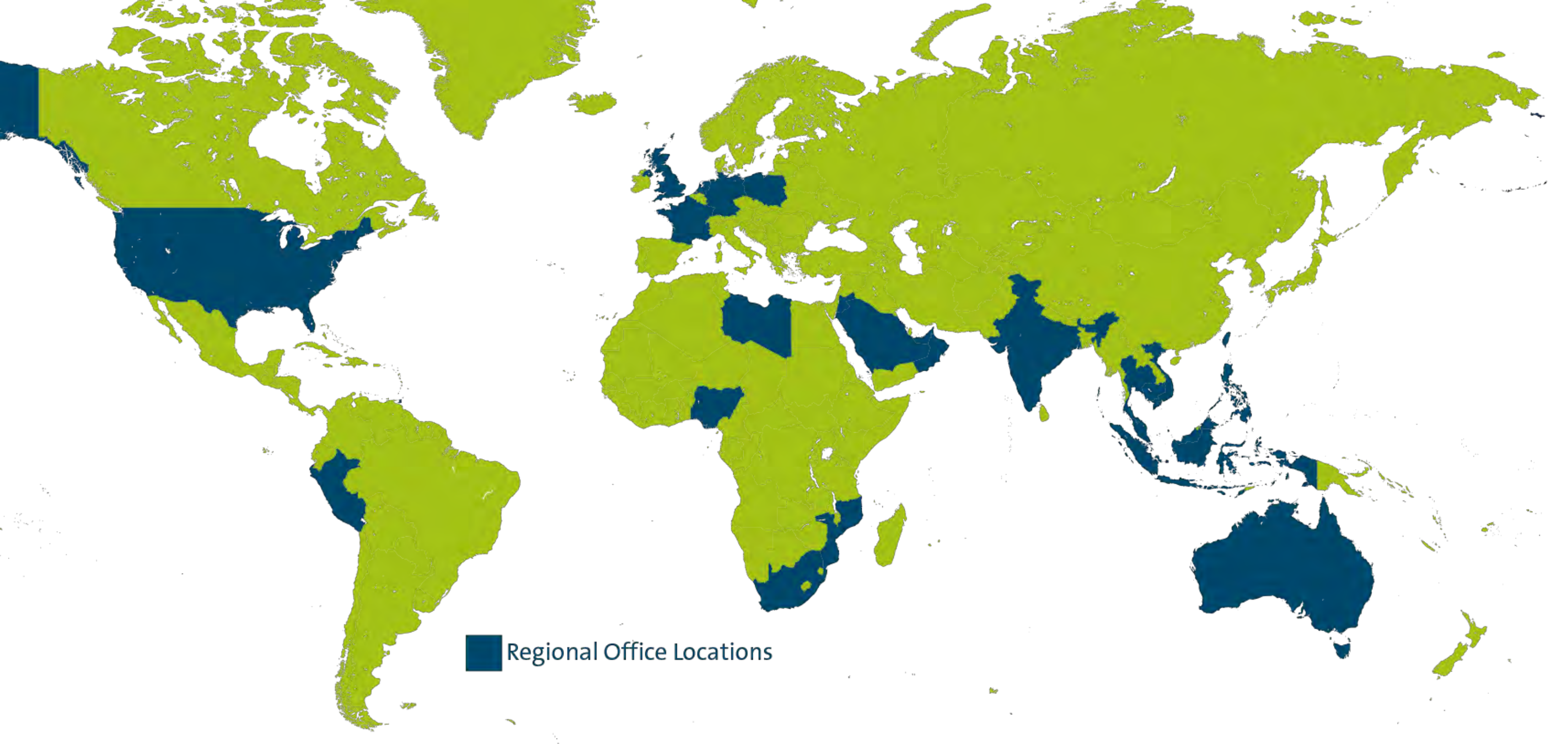
RINA. (2022). *CO2NNECT liquid CO2 terminal project - Heat & Material Balance (final issue 5/9/2022).* Genua: RINA Consulting S.p.A.

Sminchak, J., Webster, B., & Hawkins, J. (2022). *Greenhouse Gas Emissions Life Cycle Analysis of Carbon Capture and Storage for Industrial Sources in the Midwest-Northeast United States.* Columbus: Batelle.

van den Acker, J., & al, e. (2019). *Milieueffectrapport CO2-afvanginstallatie.* Deventer: Witteveen en Bos.

Bijlage

1. Energie en CO_2-balans spreadsheet



Royal HaskoningDHV is een onafhankelijk internationaal advies- en ingenieursbureau. We combineren 140 jaar engineering- en ontwerpexpertise met consultancy, software en technology diensten. We leveren hiermee toegevoegde waarde voor klanten en hebben een positieve impact op mensen en onze leefomgeving. Dat is onze drijfveer: Enhancing Society Together. Daar hoort bij dat we onszelf en anderen voortdurend uitdagen om bij te dragen aan duurzame oplossingen voor lokale en wereldwijde vraagstukken in de gebouwde omgeving en de industrie.

In onze snel veranderende wereld wordt de agenda bepaalt door onder meer klimaatverandering, de digitale transformatie, een veranderende consumentenvraag en hybride werken. Met onze geïntegreerde duurzame oplossingen willen we bijdragen aan het bredere technologische en maatschappelijke plaatje.

Gesteund door de kennis en ervaring van meer dan 6.000 collega's werken we vanuit kantoren in meer dan 20 landen. We ondersteunen klanten om de transitie te maken naar een slimme en duurzame organisatie. We koppelen onze engineering- en ontwerpexpertise aan onze software- en technologische diensten om toegevoegde waarde te leveren voor onze klanten en de lifecycle van hun assets.

We zijn oprecht, handelen integer en transparant in al onze activiteiten, ook onze bedrijfsvoering Ons team is divers en inclusief. De veiligheid en het welzijn van mensen, in ons team en daarbuiten, staat onder alle omstandigheden voorop.

In projecten en initiatieven werken we actief samen met overheden en het bedrijfsleven, partners en stakeholders. We zien een belangrijke rol voor onszelf in innovatieve duurzame ontwikkeling en willen bijdragen aan een betere leefomgeving, nu en in de toekomst.

Ons hoofkantoor is gevestigd in Nederland en we hebben kantoren in Europa, Azie, Afrika, Australie en Amerika.

euroCompliance certification ISO 37001

euroCompliance certification ISO 37301

royalhaskoningdhv.com

ARAMIS

Energie en CO2 balans

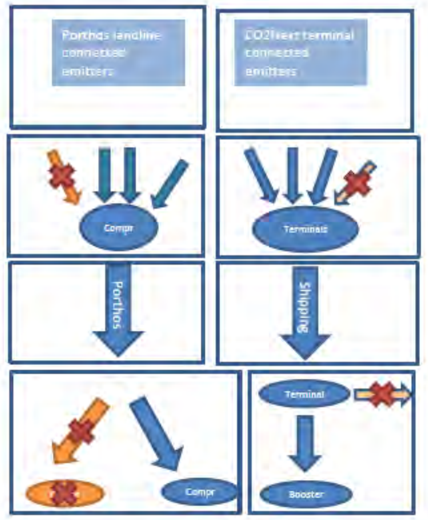
Laag: OP Spec & Emissiefactor integraal (KEV)

Mix: Combinatie van OP spec, Cryocap, VPSA en Chem Abs afvangtechnieken + SDE++ Emissiefactor + verdeling schipgroottes

Hoog: Chem Abs & Emissiefactor marginaal (KEV)

Gebruik onderstaande knoppen om te schakelen tussen de verschillende fases.
Weergegeven waarden zijn in Mton/jaar

Aramis
CO2Next
Porthos



Landleiding	CO2	Scheepsroute	CO2
Aramis	2,5	Aramis	3,50
Neptune	2,5	Neptune	2,50
Generiek	2,5	Generiek	1,50
Emitters	7,50	Emitters	7,50
Afvang	7,50	Afvang	7,50
Compressie	7,50	Vloeibaar en opslag	7,50
Landleiding	7,50	Scheepvaart	7,50
Compressie Aramis	7,50	Boosterpomp	7,50

Aramis ZL	15,00
Aramis opslag	15,00

aramis stores

Emissiefactoren tijdens deze fase		
SDE++	33	kg CO2/Gje
Integraal (KEV)	19	kg CO2/Gje
Marginaal (KEV)	89	kg CO2/Gje
Verscheping (Aramis)		
Energiegebruik	0,28	MJ/ton/km
Emissiefactor	17,77	g/ton/km

Energie

Landeiding	Laag	Mix	Hoog	Scheepsroute	Laag	Mix	Hoog
Afvang	00	7.052	20.325	Afvang	00	7.052	20.325
-electrisch	00	1.412	1.575	electrisch	00	1.412	1.575
-thermisch	00	5.640	18.750	thermisch	00	5.640	18.750
Compressie	307	933	2.027	Vloeibaar & Opslag	878	837	2.788
Landleiding	00	00	00	Scheepvaart	211	322	421
Compressie Aramis	917	917	917				
Koeling Aramis	116	116	116	Boosterpomp	164	164	164
				Aramis ZL	00	00	00
				Aramis opslag	00	00	00

	Laag	Mix	Hoog
Totaal (TJ/jaar)	2.594	17.393	47.083
-electrisch	2.594	11.753	28.333
-thermisch	0	5.640	18.750
=	=	=	
Totaal (TWh/jaar)	0,72	4,83	13,08
-electrisch	0,72	3,26	7,87
-thermisch	0,00	1,57	5,21

CO2 - Directe / Indirecte emissies

Landeiding	Laag	Mix	Hoog	Scheepsroute	Laag	Mix	Hoog
Afvang	00	401	1.317	Afvang	00	401	1.317
-electrisch	00	47	140	-electrisch	00	47	140
-thermisch	00	354	1.177	-thermisch	00	354	1.177
Compressie	06	31	180	Vervloeiing	17	28	248
Venting	00	225	375	Venting	00	225	375
Landleiding	00	00	00	Scheepvaart	12	21	31
Compressie Aramis	18	31	82	BOG venting	02	02	02
Koeling Aramis	02	04	10	Boosterpomp	03	05	15
				Aramis ZL	00	00	00
				Aramis opslag	00	00	00

	Laag	Mix	Hoog
Totaal	60	1.374	3.951
-electrisch	60	1.020	2.774
-thermisch	00	354	1.177
Totaal (ton/ton)	0,004	0,092	0,263
-electrisch	0,004	0,068	0,185
-thermisch	0,000	0,024	0,078

Initiele emissies	
Materialen	550
Machines (diesel)	10
Start-up	67
Totaal	627
Ton/ton (lifetime)	0,12%

CO2 - Diffuse emissies

Landeiding

Waardes in Ton CO2

	Laag	Mix	Hoog		Laag	Mix	Hoog
Afvang				Afvang			
Compressie	6,0	6,0	6,0	Vloeibaar & Opslag	6,0	6,0	6,0
Landleiding	0,4	4,4	16,6	Scheepvaart			
				Terminal	0	0	0
Compressie Aramis	6,0	6,0	6,0	Boosterpomp	0,2	0,2	0,2
				Aramis ZL	2	20	74
				Aramis opslag	0	0	0

	Laag	Mix	Hoog
Totaal (Ton)	1.871	1.892	1.959
+ indirecte emissies	61.757	1.375.686	3.952.916
percentage	3%	0%	0%
Totaal (ton/ton)	0,000	0,000	0,000
+ indirecte emissies	0,004	0,092	0,264

= geen data

CO2 - Ton/Ton

Landeiding	Laag	Mix	Hoog	Scheepsroute	Laag	Mix	Hoog
Afvang	0,000	0,053	0,176	Afvang	0,000	0,053	0,176
-electrisch	0,000	0,006	0,019	-electrisch	0,000	0,006	0,019
-thermisch	0,000	0,047	0,157	-thermisch	0,000	0,047	0,157
Compressie	0,001	0,004	0,024	Vervloeiing	0,002	0,004	0,033
Venting	0,000	0,030	0,050	Venting	0,000	0,030	0,050
Landleiding	0,000	0,000	0,000	Scheepvaart	0,002	0,003	0,004
Compressie Aramis	0,002	0,004	0,011	BOG venting	0,000	0,000	0,000
Koeling Aramis	0,000	0,001	0,001	Boosterpomp	0,000	0,001	0,002
				Aramis ZL	0,000	0,000	0,000
				Aramis opslag	0,000	0,000	0,000

2027/2028
Launch

Landleiding	CO2
Porthos	2,5
Aramis	2,5
Neptune	2,5
Generiek	0

Scheepsroute	CO2
Aramis	2,5
Neptune	2,5
Generiek	0
CO2next	1,95

Emissiefactor	
SDE++	33,33
Integraal (KEV)	36,11
Marginaal (KEV)	118,06
Schip	Launch
7,5K	100%
11,7K	0%
MJ/ton/km	0,325
g/ton/km	20,975

2035
Permit

Landleiding	CO2
Porthos	2,5
Aramis	2,5
Neptune	2,5
Generiek	2,5

Scheepsroute	CO2
Aramis	3,5
Neptune	2,5
Generiek	1,5
CO2next	4

Emissiefactor	
SDE++	33,33
Integraal (KEV)	19,44
Marginaal (KEV)	88,89
Schip	Permit
7,5K	58%
11,7K	43%
MJ/ton/km	0,275063
g/ton/km	17,76625

2040
Final

Landleiding	CO2
Porthos	2,5
Aramis	2,5
Neptune	2,5
Generiek	2,5

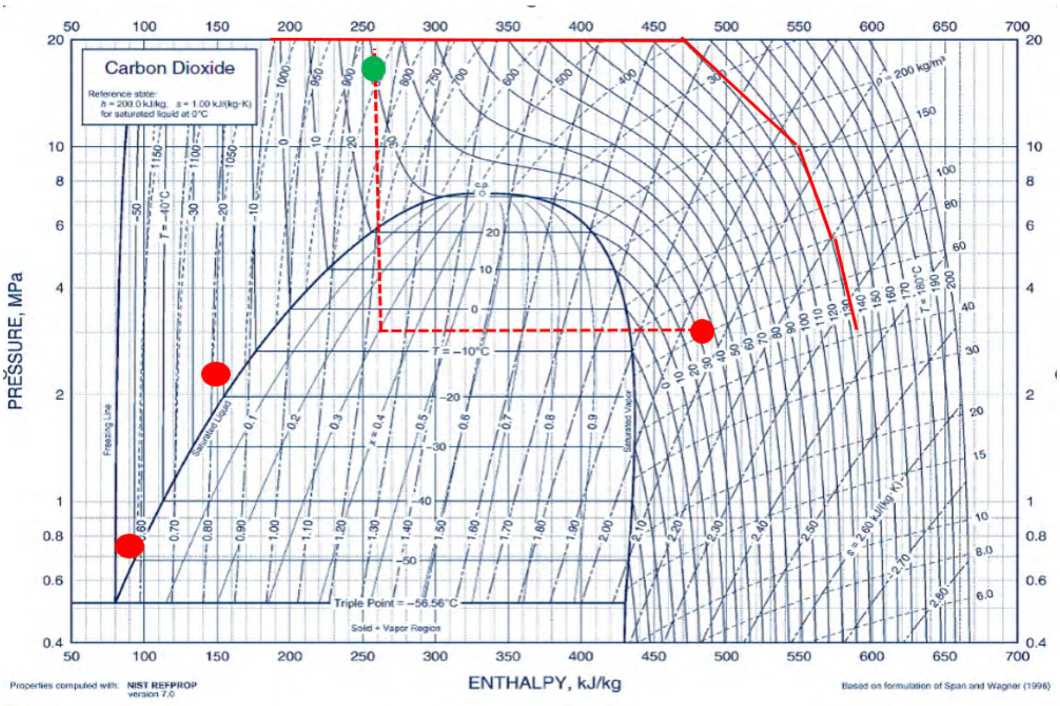
Scheepsroute	CO2
Aramis	3,5
Neptune	2,5
Generiek	6,5
CO2next	11

Emissiefactor	
SDE++	33,33333
Integraal (KEV)	19,44
Marginaal (KEV)	97,22
Schip	EIA
7,5K	58%
11,7K	43%
MJ/ton/km	0,275063
g/ton/km	17,76625

Emissiefactoren

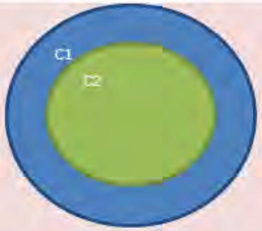
Van KEF	2025	2030	2040	
Marginaal	155,5556	80,55556	97,22222	kg CO2/Gje
Integraal	52,77778	19,44444	19,44444	kg CO2/Gje
Van SDE++		33,33333		

Koeling na compressie					
CO2 te koelen	225	MJ/ton			
Warmte capaciteit water	4,19	Kj/kg/°C			
Maximaal temperatuurverschil koelwater	5	°C			
Koelvermogen per kuub water	20,95	kJ/kg	=	20,95	MJ/m3
Kuub water per ton CO2 benodigd	10,739857	m3/ton		5,819444	
Energie waterpomp per m3	0,4	kwh/m3			
Energie waterpomp per ton gekoelde CO2	4,30	kwh/ton			
	0,0154654	GJ/ton			



Buisleiding (Trunk + Spurlines)

Staalproductie			
1 ton staal :	1,4	ton CO2	



Tonnen staal berekening:

	Spurlines			Trunkline				
	Lengte	58,8954 km		Lengte	203,2122 km			
	Hoogte	0,51 m		Hoogte	0,83 m			
	Wanddikte	25,4 mm		Wanddikte	39,6 mm			
	Oppervlak C1	0,202682992 m2		Oppervlak C1	0,543149 m2			
	Oppervlak C2	0,129717115 m2		Oppervlak C2	0,355941 m2	72331,57 m3	79971308,31	
	Oppervlak C1-C2	0,072965877 m2		Oppervlak C1-C2	0,187208 m2	13019682 m3 co2	79,97130831 kt	
	volume SL's	4297,35 m3		volume TL	38042,90 m3	26039364 kg co2	66642,75693 tonnes	
				volume P-ZL	28081,16 m3	26,03936 kt		
Aramis	totaal volume	42340,25 m3	Aramis	70421,42 m3				
	ton staal	332.371 ton	+ Porthos	552.808 ton				
	+10% onzekerheid	365.608 ton		608.089 ton	Aramis	CO2 Emissies van staalproductie:		511851 ton (A)
					Aram+Port			851325 ton (A+P)

Platforms

	Element	
	Topside - Primary steel	150 mT
	Topside - Secondary steel	100 mT
	Jacket - primary steel	500 mT
	Jacket - Anodes	50 mT
	Piles (42 inch, 75 meter)	442 mT
	Wells	685 mT
	Total steel Weight	1242 mT
	Contingency	15%
	Steel weight per platform	3644,35 mT
	Number of NEW platforms	2
	Total weight	7288,70
CO2 Emissies van staalproductie:		10204,18 ton
	*alleen nieuwe platforms aramis	

Overige infrastructuur bij Aramis, CO2NEXT & Porthos

	ruwe schatting
Totaal	20000 ton
CO2 Emissies van staalproductie:	28000 ton

1A West		
Trunkline (green):	194.337	
Spurline (yellow):		
D-HUBN to L10:	13999	
D-HUBN to L4:	28913	
L4 – K6:	15494	
1B West		
Trunkline:	223250	
Spurline:		
D-HUBN to L10:	13999	
L4 – K6:	15494	
2A		
Trunkline:	194623	
Spurline:		
D-HUBN to L10:	23521	
D-HUBN to L4:	26846	
L4 – K6):	15494	
2B		
Trunkline:	221469	
Spurline:		
D-HUBN to L10:	23521	
L4 – K6:	15494	
3 Centraal		
Trunkline:	182382	
Spurline:		
D-HUBN to L10:	23521	
D-HUBN to L4:	28846	
D-HUBN to K14:	33841	
L4 – K6:	15494	
Average:		
Trunkline	203.212	m
Spurlines	58895,4	m

		1. Benodigde informatie AERIUS	Type	Aantal (totaal)	Brandstof type	Vermogen (kW)	Inzet (uur/jaar)	kWh	**kg diesel**
		a. Activiteit 1							
Item		Activiteit	Excavator	2	Diesel	361	131	94582	25537,14
			Sandtruck	6	Diesel	249	133	199200	53784
Site preparation			Bulldozer	1	Diesel	461	130	59870,13	16164,94
	1	Construction of ring dike (optional/not necessary)						0	0
	2	Site excavating/preparations	Excavator	2	Diesel	361	21	15133,12	4085,942
			Sandtruck	6	Diesel	249	21	31872	8605,44
			Bulldozer	1	Diesel	461	21	9579,221	2586,39
Erecting construction site			Truck	2	Diesel	249	5	2490	672,3
	1	Construction of access road(s)	Mobile crane	1	Diesel	400	1	400	108
			Truck	3	Diesel	249	5	3735	1008,45
			Mobile crane	1	Diesel	400	1	400	108
	2	Laying temporary pipes (electricity, sewerage, etc)	Truck	3	Diesel	249	12	8964	2420,28
			Mobile crane	1	Diesel	400	12	4800	1296
	3	Install construction crane	Excavator	4	Diesel	361	66	94582	25537,14
			Truck	12	Diesel	249	67	199200	53784
	4	Install accommodations	Bulldozer	2	Diesel	461	65	59870,13	16164,94
			Mobile crane	1	Diesel	400	18	7200	1944
	5	Construction of bentonite reservoir	Excavator	4	Diesel	361	98	141873	38305,71
			Truck	12	Diesel	249	100	298800	80676
			Bulldozer	2	Diesel	461	97	89805,19	24247,4
			Mobile crane	1	Diesel	400	18	7200	1944
	6	Construction water reservoir	Excavator	4	Diesel	361	61	88250,02	23827,51
			Truck	12	Diesel	249	62	185864,2	50183,32
			Bulldozer	2	Diesel	461	61	55862,01	15082,74
			Mobile crane	1	Diesel	400	1	400	108
	7	Construction of soil/water/bentonite reservoir	Truck	2	Diesel	249	1	498	134,46
			Mobile crane	1	Diesel	400	1	400	108
			Tower crane	2	Diesel	400	1	800	216
			Truck	1	Diesel	249	2	498	134,46
	8	Install all supporting equipment tunnel boring machine	Mobile crane	1	Diesel	400	1	400	108
			Tower crane	1	Diesel	400	1	400	108
			Truck	2	Diesel	249	2	996	268,92
	9	Install cement mixer and other parts for diaphragm walls	Mobile crane	1	Diesel	400	4	1600	432
			Tower crane	1	Diesel	400	2	800	216
			Mobile crane	2	Diesel	400	7	5600	1512
	10	Supply reinforcement for shaft	Tower crane	1	Diesel	400	6	2400	648
								0	0
			Truck	60	Diesel	249	32	478080	129081,6
	11	Braiding reinforcement/making baskets	Excavator	8	Diesel	361	31	88250,02	23827,51
			Tower crane	1	Diesel	400	21	8400	2268
Construction Vertical Shaft			Concrete truck	17	Diesel	249	40	169320	45716,4
	1	Dig trenches for diaphragm walls shaft and fill with bentonite	Excavator	3	Diesel	361	87	94221	25439,67
			Sand truck	9	Diesel	249	89	199449	53851,23
	2	Placing reinforcement diaphragm walls	Tower crane	1	Diesel	400	95	38000	10260
	3	Pouring concrete diaphragm walls	Concrete trucks	6	Diesel	249	16	23904	6454,08
	4	Excavation of shaft	Tower crane	1	Diesel	400	3	1200	324
			Pump	1	Diesel	15	5	81,79361	22,08427
			Mobile crane	1	Diesel	400	1	400	108
	5	Install steel reinforcement and pour floor shaft with underwater concrete	Pump	2	Diesel	15	12	360	97,2
			Truck	3	Diesel	249	4	2988	806,76
			Tower crane	1	Diesel	400	12	4800	1296
	6	Dewatering of shaft	Mobile crane	1	Diesel	400	16	6400	1728
			Tower crane	1	Diesel	400	16	6400	1728
	7	Installation TBM installation platform and frame			Diesel			0	0
			Truck	1	Diesel	249	3	622,5	168,075
			Tower crane	1	Diesel	400	3	1200	324
	8	Installation all necessary items for drilling process	Trucks	1	Diesel	249	156	38810,4	10478,81
MT Construction			Tower crane	1	Diesel	400	78	31173,01	8416,713
	1	Placement of TBM in shaft on TBM frame	TBM	1	Diesel	2100	1870	3927800	1060506
			Pump	2	Diesel	15	1870	56111,42	15150,08
	2	Lowering MT elements into shaft	Pump	1	Diesel	15	1870	28055,71	7575,042
			Truck	1	Diesel	361	156	56267,29	15192,17
	3	Drill activities tunnel	Tower crane	1	Diesel	400	6	2400	648
	3	Discharge soil/bentonite/soil mixture from horizontal shaft	Truck	1	Diesel	249	2	498	134,46
	4	Soil/bentonite/soil mixture separation	Mobile crane	1	Diesel	400	1	400	108
	5	Soil discharge (Trucks/conveyor belt)	Tower crane	1	Diesel	400	1	400	108
	6	Installation of watertight bulkheads at KP 0.02 (20 m from entrance)	Pump	2	Diesel	15	90	2693,46	727,2343
	7	Installation of temporary drainage including pump to catch potential leakage	Offshore support v	1	Diesel	8750	8	70000	18900
			Offshore support v	1	Diesel	8750	4	35000	9450
					Diesel			0	0
	8	Switch on pump and continue pumping to control potential leakage	Truck	1	Diesel	249	2	498	134,46
	9	TBM excavated offshore	Tower crane	1	Diesel	400	1	400	108
	10	TBM lifting offshore	Crawling tool	1	Diesel	1,1	16	17,14516	4,629192
Pipeline Pull-in activities			Truck	2	Diesel	249	2	996	268,92
	1	Install messenger wire	Tower crane	1	Diesel	400	2	800	216
			Truck	4	Diesel	249	3	2988	806,76
			Tower crame	1	Diesel	400	4	1600	432
	2	Install vertical sheaves	Winch	1	Diesel	500	10	5195,502	1402,786
			Winch	1	Diesel	500	10	5195,502	1402,786
		Install winch and drum	Truck	3	Diesel	249	4	2988	806,76
	3		Mobile crane	1	Diesel	400	12	4800	1296
	4	Installing wire from offshore pipelay vessel	Tower crane	1	Diesel	400	16	6400	1728
	5	Pull in operations			Diesel			0	0
	6	Remove pull-in equipment	Truck	1	Diesel	249	2	498	134,46
			Tower crane	1	Diesel	400	1	400	108

			Truck	1	Diesel		249	2	498	134,46	
Pre-commissioning			Tower crane	1	Diesel		400	1	400	108	
	1	Remove pull head	Tower crane	1	Diesel		400	1	400	108	
			Offshore support v	1	Diesel		8750	1	8750	2362,5	
	2	Install test head	Offshore support v	1	Diesel		8750	1	8750	2362,5	
			CPS	1	Diesel		7500	4	30000	8100	
	3	Connect hoses lines on shore	CPS	1	Diesel		7500	4	30000	8100	
	4	Arrival offshore support vessel with water pump spread	Offshore support v	1	Diesel		8750	1	8750	2362,5	
	5	Connect hoses at sea	CPS	1	Diesel		7500	25	187500	50625	
	6	Send Run 1 Brush PIG from land to offshore	CDS	1	Diesel		18000	4	72000	19440	
	7	Send Run 2 Gauging PIG from land to offshore	CDS	1	Diesel		18000	8	144000	38880	
	8	Fill the installed pipe with water	Offshore support v	1	Diesel		8750	1	8750	2362,5	
	9	Hydro test 24 hours	Truck	1	Diesel		249	1	249	67,23	
	10	Run 3 drying PIG through installed pipe onshore to offshore	Tower crane	1	Diesel		400	1	400	108	
	11	Purging using Nitrogen	Truck	3	Diesel		249	4	2988	806,76	
	12	Offshore support vessel leaves field	Mobile crane	1	Diesel		400	3	1200	324	
	13	Remove test head on land	Tower crane	1	Diesel		400	3	1200	324	
									0	0	
	14	Remove equipment and platform	Truck	3	Diesel		249	2	1494	403,38	
			Mobile crane	1	Diesel		400	2	800	216	
			CPS/CDS	1	Diesel		25500	27	696660	188098,2	
Installation gooseneck for horizontal connection to CS			Tower crane	1	Diesel		400	1	400	108	
		Prefabricating gooseneck	Truck	1	Diesel		249	2	498	134,46	
	1		welding spread	1	Diesel		12	4	48	12,96	
	2	Pre-commissioning gooseneck	CDS	1	Diesel		18000	2	36000	9720	
	3	Lowering gooseneck into the shaft	Tower crane	1	Diesel		400	1	400	108	
	4	Make welded connection between the connecting piece and the pulled-in pipeline	Concrete trucks	50	Diesel		249	39	485338,1	131041,3	
			Pump	3	Diesel		15	37	1670,699	451,0887	
	5	Purging using Nitrogen	Mobile crane	1	Diesel		400	1	400	108	
	6	Stop dewatering and remove equipment from shaft							0	0	
	7	Grouting of annullus between shaft and pipeline	Excavator	2	Diesel		361	131	94582	25537,14	
			Sandtruck	6	Diesel		249	133	199200	53784	
			Bulldozer	1	Diesel		461	130	59870,13	16164,94	
Site reinstatement			Truck	3	Diesel		249	5	3735	1008,45	
	1	Cleaning up construction pit	Mobile crane	1	Diesel		400	1	400	108	
									Totaal	**2475391**	**kg Diesel**
										=	
	2	Deconstructing construction crane	diesel kg/L			0,84				2946895	L Diesel
			CO2 emissiefactor diesel (fossiel) WTW			3,468				=	
										10219,83	**ton CO2**

[Link naar bron]

Diffuse emissies

Apparaat	Emissiefactor	[g/uur]	Column1
	gas/damp	lichte vloeistof	zware vloeistof
Compressor	228		
Pomp		19,9	8,62
Roerwerk		19,9	19,9
Veiligheidsklep	104		
Klep, afsluiter	5,97	4,03	0,23
Open eindeleiding	1,7	1,7	1,7
Flenzen	1,83	1,83	1,83
Monsternamepur	15	15	15

Uren/jaar	8760	
Compressor	1	2,00 ton
Aantal compressoren A	3	5,99 ton
Aantal compressoren P	3	5,99 ton
Boosterpomp	1	0,17 ton

Buisleiding:	lengte (km)	
Landleiding	58,8954	
Zeeleiding Aram	262,1076	(spur- + trunklines)
Zeeleiding Porth	150	

Diffuse emissies buisleiding

bron	factor	eenheid
Batelle, 2020 en Batelle, 2022		
- minimum	7,5	kg CO2/km/jaar
- verwacht, praktijkwaarde	75,0	kg CO2/km/jaar
- maximaal	282,0	kg CO2/km/jaar

Diffuse emissies injectie 1 m3 = 1,78 kg

K14FA: 19 m3 CO2/year (mail Marcel Steenhoek, 8 March 2023).
L4A: 6,764 m3 CO2/year in phase 1 (mail Stephane Bernadeu, 17 April 2023)

*waarden worden niet meegenomen

Venting BOG units

Component	Mass Flow Rate (kg/h)
CO2	211,2
Yearly	1850,112 ton

Datum vandaag: 7-2-2024

A

Verdeling CO2 afvang technieken

Techniek Categorie	Techniek 1	Tech 2	Tech 3	Tech 4	Tech 5	Tech 6	Tech 7		
	Pre-Comb	Pre-Comb	Pre-Comb	Overig	Oxyfuel	Post-Comb	Post-Comb		
	Op spec vrijkomende CO2	Cryocap	VPSA	Membrane	Oxyfuel	Chem. Obs.	Chem. Abs. LJG		
Aandeel van de afvangsystemen									
Samenstelling van de afvang mix	2,80	3,50	3,50	0,00	0,00	7,70	0,00	17,50	Mton/j
Per type afvangstroom (% waarden)	16%	20%	20%	0%	0%	44%	0%	100%	

Indirecte CO2 emissies per techniek per type afvang stroom

		Techniek 1 Pre-Comb	Tech 2 Pre-Comb	Tech 3 Pre-Comb	Tech 4 Overig	Tech 5 Oxyfuel	Tech 6 Post-Comb	Tech 7 Post-Comb	Totaal per jaar		Looptijd	
Afvang + compressie, (1) en (2)												
- Lage emissie		Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j		Mton	
1. Afvang en conditionering		-	0,15	0,21	-	-	1,33	-	1,689		50,657	
2. CCS compressie		0,009	0,035	0,016	-	-	0,156	-	0,215		6,462	
											57,119	Checksum
- Hoge emissie												
1. Afvang en conditionering		-	0,32	0,42	-	-	1,46	-	2,196		65,880	
2. CCS compressie		0,018	0,072	0,033	-	-	0,323	-	0,445		13,354	
											79,234	checksum
									Per jaar	Periode	Looptijd	
Maasvlakte compressor, sectie (4)	jaren	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton/j	Mton	Mton	
Lage emissie, fase 1	2	0,006	0,008	0,008	-	-	0,018	-	0,040	0,080		
Lage emissie, fase 2	8	0,006	0,008	0,008	-	-	0,018	-	0,040	0,321		
Lage emissie, fase 3	20	0,006	0,008	0,008	-	-	0,018	-	0,040	0,802		
										Totaal	1,204	checksum
Maasvlakte compressor, sectie (4)												
Hoge emissie, fase 1	2	0,013	0,017	0,017	-	-	0,036	-	0,083	0,166		
Hoge emissie, fase 2	8	0,013	0,017	0,017	-	-	0,036	-	0,083	0,663		
Hoge emissie, fase 3	20	0,013	0,017	0,017	-	-	0,036	-	0,083	1,658		
										Totaal	2,488	checksum

B

Low - high scenario vergelijking

CCS equivalent ketenvermogen		Laag		Mix		hoog		
Equivalent keten vermogen (E+W)		3		150		351	MW	
Energieverbruik per jaar		553.298		26.197.738		61.439.101	GJ/j	
Project energieverbruik looptijd		Laag		Mix		Hoog		
Afvang	Elektriciteit	-	0%	190.284	23%	110.250	6%	TJ
	Warmte	-	0%	579.600	71%	1.575.000	85%	TJ
Compressie - afvang	Elektriciteit	21.504	57%	32.075	4%	141.875	8%	TJ
Compressie - Maasvlakte	Elektriciteit	16.048	43%	16.048	2%	16.048	1%	TJ
Totaal		37.553	100%	818.007	100%	1.843.173	100%	TJ
		38		818		1.843		PJ
Project indirecte CO2 emissies		Laag scenario		Mix		Hoog scenario		
Lage emissie								
Afvang		-	0%	50,66	87%	107,14	90%	Mton
Compressie - afvang		1,61	57%	6,46	11%	10,64	9%	Mton
Compressie - Maasvlakte		1,20	43%	1,20	2%	1,20	1%	Mton
Totaal		2,82	100%	58,32	100%	118,99	100%	Mton
Hoge emissie								
Afvang		-	0%	65,88	81%	115,96	83%	Mton
Compressie - afvang		3,33	57%	13,35	16%	21,99	16%	Mton
Compressie - Maasvlakte		2,49	43%	2,49	3%	2,49	2%	Mton
Totaal		5,82	100%	81,72	100%	140,44	100%	
Project CO2 opgeslagen		525,0		525,0		525,0		
Netto project CO2 reductie		522,2		443,3		384,6		Mton
CoP		90,20		6,42		3,74		Opslag / x-emissie
CO2 efficientie		99,5%		84,4%		73,2%		%
		99,5%		88,9%		77,3%		

C

1. CO2-afvang en conditionering

	Techniek 1	Tech 2	Tech 3	Tech 4	Tech 5	Tech 6	Tech 7	Totaal		
	2,80	3,50	3,50	0,00	0,00	7,70	0,00	17,50	Mton/j	
	16%	20%	20%	0%	0%	44%	0%	100%		
1. Energie voor afvang exclusief compressie afvang										
Gebruik elektriciteit per ton	-	0,577	0,773	0,957	1,395	0,210	0,210		GJe/ton	v
Idem	-	0,160	0,215	0,266	0,388	0,058	0,058		MWh/ton	v
Gebruik thermische energie per ton	-	0,010	0,010	-	-	2,500	3,000		GJ/ton	v
Idem	-	0,003	0,003	-	-	0,694	0,833		MWh/ton	v
Vermogen								Totaal		
elektrisch	-	12	15	-	-	9	-	36	MWe	v
thermisch	-	0	0	-	-	110	-	110	MWth	v
Verbruik										
a, elektriciteit, per jaar										
Totaal	-	2.019.317	2.706.474	-	-	1.617.000	-	6.342.791	GJe/j	v
Idem	-	560.921	751.798	-	-	449.167	-	1.761.886	MWh/j	v
b. warmte, per jaar										
Totaal	-	35.000	35.000	-	-	19.250.000	-	19.320.000	GJ-th/j	
Idem	-	9.722,22	9.722,22	-	-	5.347.222	-	5.366.667	MWh-th/j	
Verbruik looptijd project elek	-	60.579.503	81.194.223	-	-	48.510.000	-	190.283.726	GJe	
Verbruik looptijd project warmte	-	1.050.000	1.050.000	-	-	577.500.000	-	579.600.000	GJ-th	
2. Indirecte CO2 emissie factor exclusief compressie										
a) elektriciteit										
- lage emissiefactor	-	0,043	0,058	0,072	0,105	0,016	0,016		ton/ton	v
- hoge emissiefactor	-	0,089	0,120	0,148	0,216	0,033	0,033		ton/ton	v
b) warmte	-	0,001	0,001	-	-	0,157	0,188		ton/ton	
Totaal Indirecte emissies per jaar										
a) elektriciteit										
- lage emissie	-	0,151	0,203	-	-	0,121	-	0,476	Mton / j	v
- hoge emissie	-	0,313	0,420	-	-	0,251	-	0,983	Mton / j	v
b) warmte	-	0,002	0,002	-	-	1,208	-	1,213	Mton / j	v
Totaal CO2 emissies looptijd project								Totaal		
a) elektriciteit										
- lage emissie	-	4,54	6,09	-	-	3,64	-	14,271	Mton	v
- hoge emissie	-	9,39	12,59	-	-	7,52	-	29,494	Mton	v
b) warmte	-	0,07	0,07	-	-	36,25	-	36,386	Mton	v
Totaal CO2 emissies looptijd project										
Combinatie elek en warmte										
- lage emissie	-	4,609	6,155	-	-	39,892	-	50,657	Mton	
- hoge emissie	-	9,456	12,651	-	-	43,773	-	65,880	Mton	

2. CO2 compressie bij afvang

	Techniek 1	Tech 2	Tech 3	Tech 4	Tech 5	Tech 6	Tech 7	Totaal		
	2,80	3,50	3,50	0,00	0,00	7,70	0,00	17,50	Mton/j	
	16%	20%	20%	0%	0%	44%	0%	100%		
Uit proces aangeleverde druk	20	6	15	1	1	1	1		Bara	v
Pers druk	35	35	35	35	35	35	35		Bara	v
Compressie energie per ton	0,041	0,132	0,061	0,270	0,270	0,270	0,270		GJe/ton	v
Compressie vermogen afvang	0,10	0,53	0,24	-	-	5,23	-	6,11	MWe	v
E-verbruik per jaar	18.350	92.513	42.747	-	-	915.564	-	1.069.174	GJe/j	v
Idem	5.097	25.698	11.874	-	-	254.323	-	296.993	MWh/j	v
Verbruik elektriciteit looptijd project	550.514	2.775.382	1.282.404	-	-	27.466.921	-	32.075.221	GJe	
Indirecte CO2 emissies per ton CO2										
a) elektriciteit										
- *lage emissiefactor*	0,003	0,010	0,005	0,020	0,020	0,020	0,020		ton/ton	v
- *hoge emissiefactor*	0,006	0,020	0,009	0,042	0,042	0,042	0,042		ton/ton	v
Indirecte emissies per jaar										
a) elektriciteit										
- *lage emissie*	0,009	0,035	0,016	-	-	0,156	-	0,215	Mton/j	v
- *hoge emissie*	0,018	0,072	0,033	-	-	0,323	-	0,445	Mton/j	v
Totaal indirecte emissies looptijd project										
a) elektriciteit										
- *lage emissie*	0,258	1,041	0,481	-	-	4,682	-	6,462	Mton	v
- *hoge emissie*	0,533	2,151	0,994	-	-	9,676	-	13,354	Mton	v

3. Onshore pijplijn

Drukverlies transport 2 bar

4. Maasvlakte compressor

NEW

Condities compressie	Porthos Periode	Porthos Periode	Porthos Periode	**Aramis**	Totaal		
Lengte periode	2	8	20	10		jaren	v
CO2 stroom	17,50	17,50	17,50	17,50		Mton/j	
Zuigdruk	33	33	33	33		bara	v
Delta - druk	-5	23	93	143		bara	v
Persdruk	32	60	130	180		bara	v
Vermogen en energie	Periode 1	Periode 2	Periode 3	Periode 3			
Compressie vermogen	3,1	3,1	3,1	12,2		MWe	v
Energieverbruik per dag	73	73	73	293		MWh/d	v
Energieverbruik per dag	264	264	264	1.056		GJe/d	v
					Totaal		
Compressie-energie per ton CO2	0,031	0,031	0,031	0,122		Gje/ton	v
E-verbruik per jaar	534.948	534.948	534.948	2.139.791		GJe/j	v
E-verbruik per jaar	148.597	148.597	148.597	594.386		MWh/j	v
E-verbruik per periode	1.069.895	4.279.581	10.698.953	21.397.905	16.048.429	GJe	v
Indirecte CO2 emissies	Periode 1	Periode 2	Periode 3	Periode 3			
- lage emissiefactor	0,002	0,002	0,002	0,009		ton / ton	
- hoge emissiefactor	0,005	0,005	0,005	0,019		ton / ton	
							v
Totaal Indirecte emissies per jaar	Periode 1	Periode 2	Periode 3	Periode 3			v
- lage emissie	0,040	0,040	0,040	0,160		Mton/j	
- hoge emissie	0,083	0,083	0,083	0,332		Mton/j	
Totaal Indirecte emissies per periode					Totaal		
- lage emissie	0,080	0,321	0,802	1,605	1,204	Mton	checksum
- hoge emissie	0,166	0,663	1,658	3,317	2,488	Mton	checksum

5. Offshore pijplijn NVT

6. Offshore platform NVT

Compressie berekening Maasvlakte

NEW

	Jaren						
Periode	2	8	20	10			
kg/sec	1	1	1	1		v	1,5
druk start	33,0	50,4	77,0	117,7		v	
druk eind	50,4	77,0	117,7	180,0		v	
P2/P1 gem	1,53	1,53	1,53	1,53		v	
T1, °C	30	30	30	30		v	
Kappa van CO2	1,287	1,287	1,287	1,287		v	
(k-1)/k	0,22	0,22	0,22	0,22		v	
k/(k-1)	4,48	4,48	4,48	4,48		v	
kg/kmol	44,01	44,01	44,01	44,01		v	
polytroop rendement compr	85%	85%	85%	85%			
rendement e-motor	98%	98%	98%	98%			
Wcompress kJ/kg	0,031	0,031	0,031	0,031	**GJ/ton**	v	
Debiet	100	100	100	100	kg/sec	v	
Wcompress MW	**3,06**	**3,06**	**3,06**	**3,06**	MW	v	

T2, °C	60	60	60	60	
afkoelen tot °C	60	30	30	30	
Cp bij T2	0,86	0,86	0,86	0,86	
Cp na afkoelen	0,86	0,84	0,84	0,84	
wegkoelen, kJ/s per kg	0	27	27	27	
Koelvermogen	-	2,7	2,7	2,7	MW

Transport met schip:

Conditionering en vervloeiing vergen circa 85 kWh_e/ton vloeibare CO_2	85 kWhe/ton	=	306 MJe/ton
Transportafstand	156 km		
Verlading per jaar	2,7 Mton/jaar		

Tabel 1 *Specifieke energiegebruiken voor verschillende typen schepen (MJ/ton/km)*

	CEMT Vb		Waal		Gebaseerd op referentie uit (Klein & al, 2022)	
	maximaal	minimaal	maximaal	minimaal	load, kton/la	klase
6k-binnenvaa	0,36	0,35	0,3	0,29	5,046	Class Va + 1 Europa II barge, wide
8,1k-binnenva	0,36	0,35	0,3	0,29	8,1135	Gemiddelde van Class Va + 1 Europa II barge, wide en 4-barge push convoy
11,7k-binnenv	0,18	0,18	0,24	0,23	11,181	4-barge push convoy
16k-kustvaard	0,25	0,24	0,2	0,19	16,481	6-barge push convoy, wide

Tabel 2 *specifieke broeikasgasemissies, g/ton/km*

	CEMT Vb		Waal	
	maximaal	minimaal	maximaal	minimaal
6k-binnenvaa	26,1	19,3	22,1	16,4
8,1k-binnenva	26,1	19,3	22,1	16,4
11,7k-binnenv	13,4	10	17,4	12,9
16k-kustvaard	18,2	13,5	14,2	10,6

Lossen van schip en klaarmaken voor buisleiding druk:

▪ Energiegebruik bij lossen: 1,5 MJe/ton overgeslagen CO_2.	1,5 MJe/ton
▪ Lage druk en hoge druk pompen: 20 MJ_e/ton uitgezonden CO_2.	20 MJe/ton
▪ BOG-installatie: 0,4 MJe/ton overgeslagen CO_2.	0,4 MJe/ton
	21,9 MJe/ton

Verscheping CO2NEXT

	Launch		Permit		EIA	
Capaciteit Terminal	5.4 mtpa		10,0 mtpa		17,0 mtpa	
Capaciteit Aramis	3,45		6		6	
Non-Aramis	1,95		4		11	
Import quantity	Aramis	Non-Aramis	Aramis	Niet-Aramis	Aramis	Non-Aramis
2,1k-barge		0,2				
6k-barge						
7,5k-barge	3,45	1,755	3,45	1,755	3,45	3,3
8,1k-barge						
11,7k-barge			2,55	2,245	2,55	7,7
12,0-coaster						
16k-coaster						
Totaal	3,45	1,95	6	4	6	11

#vessel arrivals (laden)						
2,1k-barge		87				
6k-barge						
7,5k-barge	431	219	431	219	431	412
8,1k-barge						
11,7k-barge			204	180	204	616
12,0k-coaster						
16k-coaster						
Totaal	431	306	635	399	635	1028

Afvangtechniek specifieke conditionering en vervloeiing

Op Spec 0,50 LL 0,82 Schip
Van 20 naar 25 bar

					compressieverh	
kg/sec	1	1	1	1	20,0	
druk start	20,0	21,1	22,4	23,6	25,0	
druk eind	21,1	22,4	23,6	25,0	1,0574	
P2/P1 gem	1,06	1,06	1,06	1,06		
T1, °C	30	30	30	30	35	
Kappa van CO2	1,287	1,287	1,287	1,287		
(k-1)/k	0,22	0,22	0,22	0,22		
k/(k-1)	4,48	4,48	4,48	4,48		
kg/kmol	44,01	44,01	44,01	44,01		
rendement compressor	85%	85%	85%	85%		
rendement e-motor	98%	98%	98%	98%		
Wcompress kJ/kg	4	4	4	4	15	
T2, oC	34	34	34	34		
afkoelen tot oC	30	30	30	-20		
Cp bij T2	0,84	0,84	0,84	0,84		
Cp na afkoelen	0,84	0,84	0,84	0,79		
faseovergang kJ/kg					314	101
wegkoelen, kJ/kg	3	3	3	44	10	1

Totaal kJ/kg of MJ/ton 117

Cryocap 0,15 0,18 Schip
Van 5,8 naar 25 bar

					compressieverh	
kg/sec	1	1	1	1	5,8	
druk start	5,8	8,4	12,0	17,4	25,0	
druk eind	8,4	12,0	17,4	25,0	1,4409	
P2/P1 gem	1,44	1,44	1,44	1,44		
T1, °C	30	30	30	30	35	
Kappa van CO2	1,287	1,287	1,287	1,287		
(k-1)/k	0,22	0,22	0,22	0,22		
k/(k-1)	4,48	4,48	4,48	4,48		
kg/kmol	44,01	44,01	44,01	44,01		
rendement compressor	85%	85%	85%	85%		
rendement e-motor	98%	98%	98%	98%		
Wcompress kJ/kg	26	26	26	26	105	
T2, oC	56	56	56	56		
afkoelen tot oC	30	30	30	-20		
Cp bij T2	0,86	0,86	0,86	0,86		
Cp na afkoelen	0,84	0,84	0,84	0,79		
faseovergang kJ/kg					334	107
wegkoelen, kJ/kg	23	23	23	64	68	5

Totaal kJ/kg of MJ/ton 217

VPSA 0,05 0 Schip
Van 15 naar 25 bar

					compressieverh	
kg/sec	1	1	1	1	15,0	
druk start	15,0	17,0	19,4	22,0	25,0	
druk eind	17,0	19,4	22,0	25,0	1,1362	
P2/P1 gem	1,14	1,14	1,14	1,14		
T1, °C	30	30	30	30	35	
Kappa van CO2	1,287	1,287	1,287	1,287		
(k-1)/k	0,22	0,22	0,22	0,22		
k/(k-1)	4,48	4,48	4,48	4,48		
kg/kmol	44,01	44,01	44,01	44,01		
rendement compressor	85%	85%	85%	85%		
rendement e-motor	98%	98%	98%	98%		
Wcompress kJ/kg	9	9	9	9	36	
T2, oC	39	39	39	39		
afkoelen tot oC	30	30	30	30	-20	
Cp bij T2	0,84	0,84	0,84	0,84		
Cp na afkoelen	0,84	0,84	0,84	0,84		
faseovergang kJ/kg					278	89
wegkoelen, kJ/kg	8	8	8	8	23	2

Totaal kJ/kg of MJ/ton 127

Chem Abs 0,30 0 Schip
Van 1 naar 25 bar

					compressieverh	
kg/sec	1	1	1	1	1,0	
druk start	1,0	2,2	5,0	11,2	25,0	
druk eind	2,2	5,0	11,2	25,0	2,2361	
P2/P1 gem	2,24	2,24	2,24	2,24		
T1, °C	30	30	30	30	35	
Kappa van CO2	1,287	1,287	1,287	1,287		
(k-1)/k	0,22	0,22	0,22	0,22		
k/(k-1)	4,48	4,48	4,48	4,48		
kg/kmol	44,01	44,01	44,01	44,01		
rendement compressor	85%	85%	85%	85%		
rendement e-motor	98%	98%	98%	98%		
Wcompress kJ/kg	61	61	61	61	242	
T2, oC	90	90	90	90		
afkoelen tot oC	30	30	30	-20		
Cp bij T2	0,89	0,89	0,89	0,89		
Cp na afkoelen	0,84	0,84	0,84	0,79		
faseovergang kJ/kg					365	117
wegkoelen, kJ/kg	55	55	55	95	164	12

Totaal kJ/kg of MJ/ton 372

WC eff	14
CoP SC	4

Energie benodigd voor afvang + conditionering + compressie PER afgevangen ton CO2 (=output)

	Proces type	Elek. Behand. GJe/ton	bar Leverdruk	Elec. Compr. GJe/ton	bar Persdruk	Totaal Elec Gje/ton	Warmte GJth/ton	Totaal
1	CO2 op spec (samenstelling)		20	0,041	35	0,041		0,041
2	Cryocap	0,577	5,8	0,132	35	0,709	0,010	0,719
2	VPSA	0,773	15	0,061	35	0,834	0,010	0,844
2	Membrane	0,957	1	0,270	35	1,227		1,227
3	Oxyfuel	1,395	1	0,270	35	1,665		1,665
4	Chem abs BP	0,210	1	0,270	35	0,480	2,500	2,980
5	Chem Abs LJG	0,210	1	0,270	35	0,480	3,000	3,480

Transport verdeling

Landleiding factor landleidi	Schepen (NL) factor	Schepen NL (aangepast) factor	Type
0,50	0,82	0,50	pre-combustion
0,15	0,18	0,15	pre-comustion
0,05	0	0,05	pre-combustion
0,00	0	0,00	membrane (overig)
0,00	0	0,00	oxyfuel
0,30	0	0,30	post-combustion
0,00	0	0,00	post-combustion

	Lage emissie factor	Elek. Behand. ton / ton	Elec. Compr. ton / ton	Totaal Elec ton / ton	Warmte ton / ton	Totaal	Type
1	CO2 op spec (samenstelling)	0	0,003	0,003	-	0,003	pre-combustion
2	Cryocap	0,043	0,010	0,053	0,001	0,054	pre-comustion
2	VPSA	0,058	0,005	0,063	0,001	0,063	pre-combustion
2	Membrane	0,072	0,020	0,092	-	0,092	membrane (overig)
3	Oxyfuel	0,105	0,020	0,125	-	0,125	oxyfuel
4	Chem abs BP	0,016	0,020	0,036	0,157	0,193	post-combustion
5	Chem Abs LJG	0,016	0,020	0,036	0,188	0,224	post-combustion

	Hoge emissie factor	Elek. Behand. ton / ton	Elec. Compr. ton / ton	Totaal Elec ton / ton	Warmte ton / ton	Totaal	Type
1	CO2 op spec (samenstelling)	0	0,006	0,006	-	0,006	pre-combustion
2	Cryocap	0,089	0,020	0,110	0,001	0,111	pre-comustion
2	VPSA	0,120	0,009	0,129	0,001	0,130	pre-combustion
2	Membrane	0,148	0,042	0,190	-	0,190	membrane (overig)
3	Oxyfuel	0,216	0,042	0,258	-	0,258	oxyfuel
4	Chem abs BP	0,033	0,042	0,074	0,157	0,231	post-combustion
5	Chem Abs LJG	0,033	0,042	0,074	0,188	0,263	post-combustion

Rapport tabel

Verzamel ton / ton	Elek. Behand. ton / ton		Elek. Compr. ton / ton		Warmte ton / ton	Totaal	
	laag	hoog	laag	hoog		laag	hoog
CO2 op spec (samenstelling)	0,000	0,000	0,003	0,006	0,000	0,003	0,006
Cryocap	0,043	0,089	0,010	0,020	0,001	0,054	0,111
VPSA	0,058	0,120	0,005	0,009	0,001	0,063	0,130
Membrane	0,072	0,148	0,020	0,042	0,000	0,092	0,190
Oxyfuel	0,105	0,216	0,020	0,042	0,000	0,125	0,258
Chem abs BP	0,016	0,033	0,020	0,042	0,157	0,193	0,231
Chem Abs LJG	0,016	0,033	0,020	0,042	0,188	0,224	0,263

Aramis Pipeline Routing Desktop Study - Expected Site Conditions

Consultancy Report | Dutch Sector of the North Sea

R201644 03 | 10 February 2022

TotalEnergies

Document Control

Document Information

Project Title	Aramis Pipeline Routing
Document Title	Aramis Pipeline Routing Desktop Study - Expected Site Conditions
Fugro Project No.	P201644
Fugro Document No.	R201644
Issue Number	03
Fugro Legal Entity	Fugro France SAS
Issuing Office Address	Le Carillon – 5-6 Esplanade Charles de Gaulle – 92000 NANTERRE - FRANCE

Client Information

Client	TotalEnergies
Client Address	2 place Jean Millier, La Défense 6, 92078 Paris La Défense Cedex, France
Client Contact	[redacted]

Revision History

Issue	Date	Status	Comments on Content	Prepared By	Checked By	Approved By
01	21 January 2022	Draft	Awaiting client comments	[redacted]	[redacted]	[redacted]
02	07 February 2022	Final	Final report	[redacted]	[redacted]	[redacted]
03	10 February 2022	Final	Update of cables	[redacted]	[redacted]	[redacted]

Project Team

Initials	Name	Role
[redacted]	[redacted]	Engineering Geologist
[redacted]	[redacted]	Geologist
[redacted]	[redacted]	Principal Geologist – Project Lead
[redacted]	[redacted]	Principal Geologist – Project Reviewer
[redacted]	[redacted]	GIS Specialist
[redacted]	[redacted]	Manager Marine Geotechnics – Project Manager

FUGRO
Fugro France SAS
Le Carillon
5-6 Esplanade Charles de Gaulle
92000 Nanterre
France

TotalEnergies
La Coupole
2 place Jean Millier
92078 Paris La Défense Cedex
France

Nanterre, 10 February 2022

Dear [redacted],

Please find attached the final version of the Desktop Study performed as part of the ARAMIS Pipeline Routing project.

This report, referenced R201644 (03), was prepared by the joint efforts of [redacted], Engineering Geologist, [redacted] Geologist, [redacted], Principal Geologist. It was reviewed by [redacted], Principal Geologist, under the supervision of [redacted].

Thank you for giving us the opportunity to work for you.

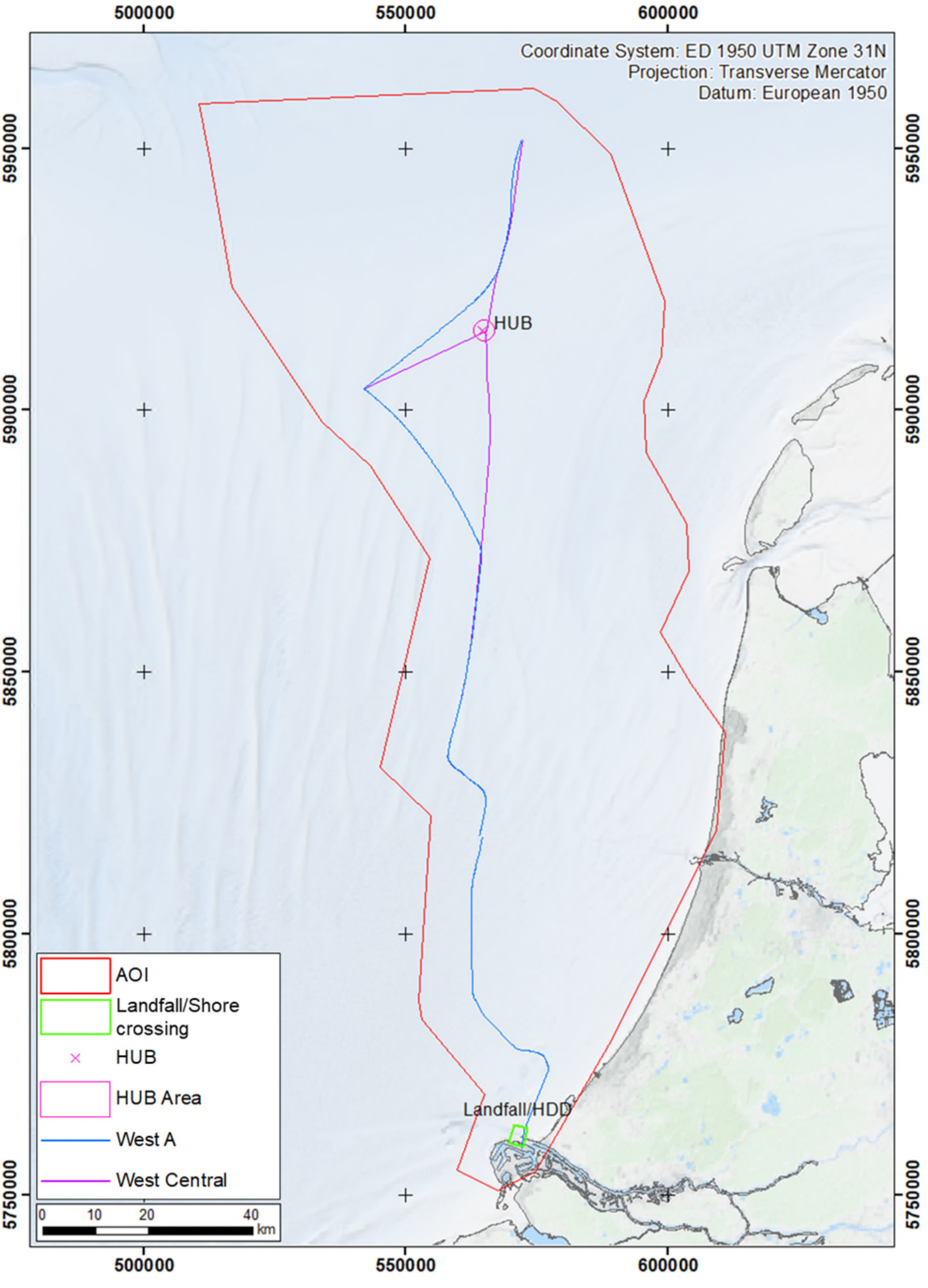
Please do not hesitate to contact us should you have any queries.

Yours faithfully,

[redacted]

[redacted]
Engineering Geologist

Frontispiece



Executive Summary

TotalEnergies requested Fugro to perform a desktop study (DTS) aimed at characterising soil conditions and site use based on publicly available data and Fugro experience over an area of 11,355 km^2 within the Dutch sector of the North Sea. Two areas of particular attention were differentiated within the general area of interest (AOI). These are the Landfall/Shore crossing Area and the Offshore Distribution HUB Area.

The main results of the DTS are summarised as follows:

- Information relating to site use, restricted areas, past or present activities, and any seafloor objects that may affect and constrain development of the proposed pipeline infrastructure was gathered and presented in the report in the form of text and maps;
- Water depths range from 0 m to a maximum of approximately 46 m relative to lowest astronomical tide (LAT). Seafloor gradients are generally less than 1°, but may be locally up to 30° and are related to anthropogenic features and crests of bedforms;
- Three zones with a distinct seafloor morphology were identified within the AOI: a coastal zone, a shallow continental shelf with low-angle topography covered by a complex compound of rhythmic bedforms, and a relatively deep low-energy zone with low-angle seafloor gradient;
- Three types of bedforms were observed within the AOI: sand banks, sand waves and megaripples;
- Sand waves are mobile over the lifetime of a pipeline and are considered to have a significant impact on pipeline foundation design and asset integrity;
- Six groups of surficial sediments were identified across the AOI: Sandy GRAVEL, (slightly) gravelly SAND, (slightly) gravelly muddy SAND, SAND, muddy SAND and sandy MUD. The main constituent is SAND;
- The AOI is characterised by variable soil conditions down to the depth of interest, which were grouped into geotechnical soil units based on the available data (geological, geophysical and geotechnical);
- Separate ground models are presented for the AOI, the Landfall/Shore crossing Area and the Offshore Distribution HUB Area. These ground models take into account the different depths of interest and site-specific site conditions;
- Eighteen soil profiles were generated to display the lateral and vertical variability across the AOI;
- In the Landfall/Shore crossing Area, the surficial sediments comprise predominantly sand to locally sandy gravel, and very soft clay in the Maasmond Kanaal. In the subsurface, the main units are the Naaldwijk Formation, comprising of interbedded sand and clay, with locally peat (laminae to thin beds), and the Kreftenheye, IJmuiden Ground and Winterton Shoal Formations, which comprise dense to very dense sand, with locally layers of silty sand and/or (laminated) clay in the lower part of the depth of interest.
- Three soil province maps were created to depict the spatial extent of each predicted soil profile within the AOI, Landfall/Shore crossing Area and Offshore Distribution HUB Area;
- A geohazards inventory list is provided, detailing (geo)hazards, soil and anthropogenic constraints and man-made obstructions identified across the AOI;

- Recommendations for site-specific geophysical and geotechnical surveys are detailed at the end of the report. These recommendations may aid in reducing uncertainties and aid decision making regarding the ARAMIS Pipeline routing.

Table of Contents

Table of Appendices

List of Figures

List of Tables

Abbreviations

AOI	Area of interest
BH	Borehole
bLAT	below Lowest Astronomical Tide
BP	Before Present
BSF	Below seafloor
CD	Chart datum
CM	Central meridian
CPT	Cone penetration test
DTM	Digital terrain model
DTS	Desktop study
ED	European Datum
Fm.	Geological formation
GIS	Geographic information system
ETRS	European terrestrial reference system
LAT	Lowest Astronomical Tide
ka	Period of thousand years
LGM	Last Glacial Maximum
Ma	Million years ago
Mb.	Geological formation member
MBES	Multibeam echosounder
MSL	Mean Sea Level
OWF	Offshore wind farm
SBP	Sub-bottom profiler
SHOM	Service Hydrographique et Océanographique de la Marine
SSS	Side Scan Sonar
UHR	Ultra High resolution
UTM	Universal Transverse Mercator
UXO	Unexploded ordnance
WFZ	Wind farm zone
WGS	World Geodetic System
WMS	Web Map Service

1. Introduction

1.1 Purpose

Fugro France SAS (Fugro) was contracted by TotalEnergies (client) to provide a desktop study to characterise the site conditions for the ARAMIS Pipeline Routing project.

This geological desktop study (DTS) aims to better understand the ground conditions along the future ARAMIS Pipeline located in the Dutch sector of the North Sea.

The final purpose is to provide the client with a geological and geotechnical model across area of interest (AOI), providing the necessary information to help decision making for the pipeline routing.

1.2 Study Areas

The AOI comprises an area of 11355 km² and is located in the southern North Sea, north-west off the coast of the Netherlands, within the Dutch administrative zone (Figure 1.1). Along the coastline, the AOI extends from Maasvlakte within the Port of Rotterdam in the south, to Egmond aan Zee in the north. The AOI extends over approximately 210 km in a north–south direction and 90 km in a west–east direction.

Within the AOI, two areas of particular attention were differentiated. These are:

- Landfall/Shore crossing Area: the first 3 km of the planned pipeline routing for horizontal directional drilling (HDD) and trenching at Maasvlakte;
- Offshore Distribution HUB Area: a 2 km radius area around the planned Offshore Distribution HUB location. This area is mentioned as HUB Area in maps throughout the report.

The depth of interest is 20 m below seafloor (BSF) for the entire AOI, except for the Landfall/Shore crossing Area, where it is 40 m to 50 m BSF and the Offshore Distribution HUB Area, where it is 100 m BSF.

Client provided preliminary offshore rigid pipeline routing (two options: West A and West Central). At this point the final pipeline routing is not defined.

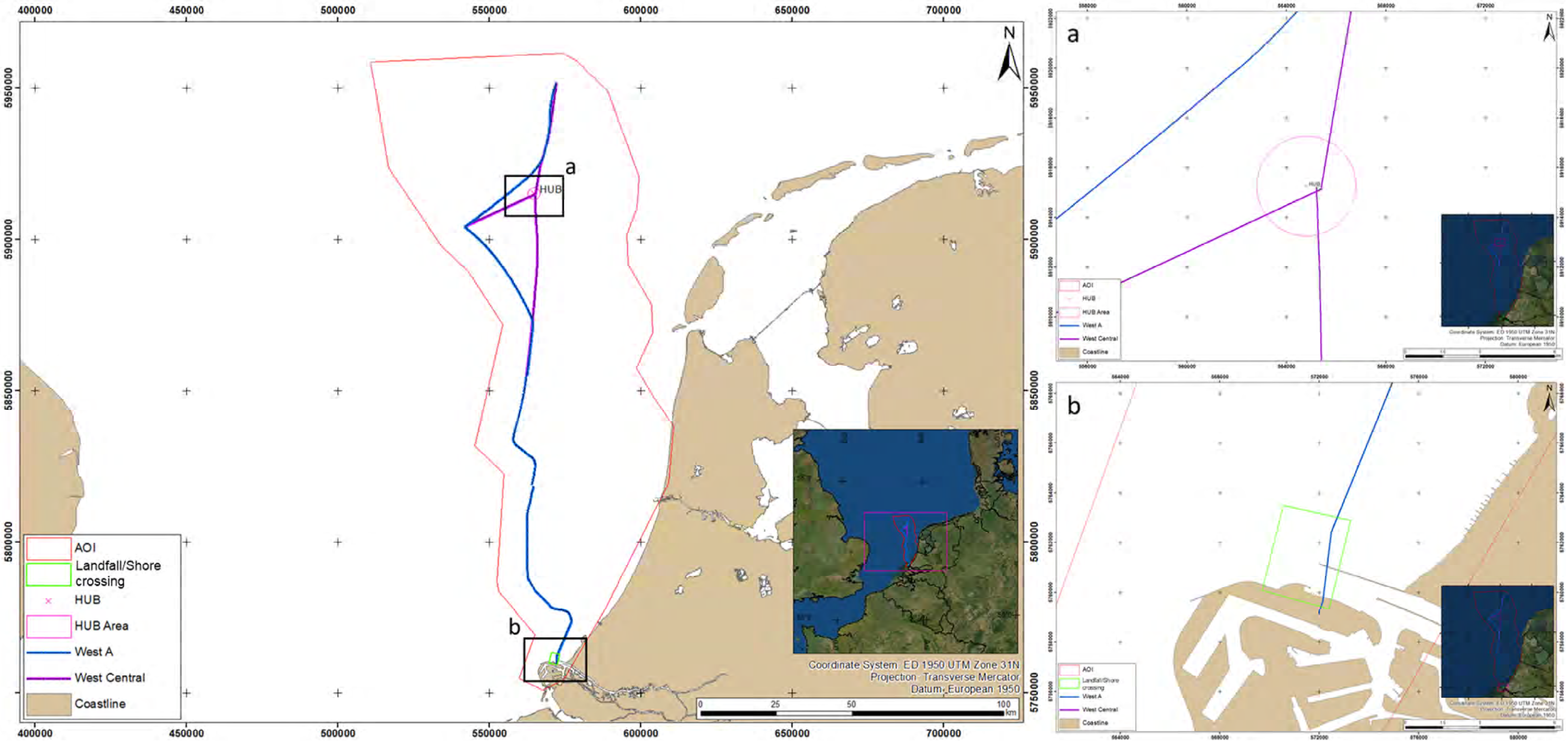


Figure 1.1: Extent of the AOI and definition of the Landfall/Shore crossing and Offshore Distribution HUB Areas

1.3 Scope of Work

The report presents the site-specific seafloor and sub-seafloor conditions derived from available data and the present understanding of the regional geology. These elements will be described across the AOI, Landfall/Shore crossing and Offshore Distribution HUB Areas.

This study includes comments on the site suitability considering a list of potential site-specific (geo)hazards, as well as soil and anthropogenic constraints across the AOI.

The UXO historical desktop study and archaeological desktop study were sub-contracted. Reports from sub-contractors are provided as Appendix B and Appendix C.

1.4 Study Limitations

This report does not cover the following topics:

- Metocean conditions;
- Environmental impact of foundations, if any;
- UXO risk assessment at the AOI.

The results of this study are dependent on the origin, quality, and quantity of available data. The presented ground model is preliminary and should only be used to help decision making during the bidding process.

Geotechnical parameters presented in this report are estimates, derived from Fugro experience over analogous representative areas within the AOI (e.g. planned wind farm sites). Future site-specific in situ measurements are required to confirm or adjust the presented geotechnical parameter ranges before any installation

1.5 Geodetic Parameters

Table 1.1 presents the coordinate reference system for this project. All illustrations in the report as well as the A3 maps are prepared using the ED50 datum and UTM Zone 31N projection.

Table 1.1: Geodetics parameters

Geodetic Datum	
Datum	International_1924
Spheroid	D_European_1950
Semi major axis	a = 6 378 137.0 m
Semi minor axis	b = 6 356 911.946127946 m
Inverse flattening	$^1/_f$ = 297.0
Map Projection	
Projection system	Transverse Mercator (UTM Zone 31N)
Central meridian	3°
Latitude of origin	0°

False easting	500 000 m
False northing	0 m
Linear unit	Metre

1.6 Data Use

Fugro understands that this report will be used for the purposes described in the 'Introduction' section. These purposes are a key factor in defining the scope and level of services offered.

It should also be noted that the geological and geotechnical data presented in this report are based on interpretations, correlations, and extrapolations, which implies a certain degree of uncertainty to be considered. This study will emphasise the level of confidence in the geological model and will detail the uncertainties related to stratigraphic conditions, the nature and thickness of the geological formations and geotechnical parameters.

However, the results of this report should not be used for purposes other than those for which this report was prepared, or if the original development or activity is modified by the client without prior control of their suitability.

1.7 Guidelines on Use of Report

Appendix A outlines the limitations of this report, in terms of a range of considerations including, but not limited to, its purpose, its scope, the data on which it is based, its use by third parties, possible future changes in design procedures and possible changes in the conditions at the site with time. It represents a clear description and explanation of the constraints which apply to all reports issued by Fugro. It should be noted that the Guidelines do not in any way supersede the terms and conditions of the contract between Fugro and TotalEnergies.

2. Approach and Data Review

2.1 Desktop Study Approach

The first step for the desktop study was to gather any relevant data, both public and internal, related to geological, geophysical and geotechnical features within the AOI but also covering a wider area. Based on these, the regional geological background was determined. This allowed for a better understanding and identification of potential or identified geological features or processes that may be expected across the AOI.

In addition, information relating to site use, restricted areas, past or present activities, and any seafloor objects that may affect and constrain development of the proposed pipeline infrastructure was gathered and presented in a number of maps.

These data were then reviewed and studied to characterise the different geological features, stratigraphic units, geotechnical parameters and constraints (geological and site-use) across the AOI, with a particular focus on the Landfall/Shore crossing Area and the Offshore Distribution HUB Area. Geotechnical parameters were derived mainly based on public information and Fugro experience. Note that no project names or locations are shared for confidentiality reasons. The data that were used are introduced in Section 2.2.

Attention is given to the identification of possible missing data or areas of uncertainties to establish recommendations for future geophysical and geotechnical site-specific surveys.

The ultimate result of the DTS is to provide a geotechnical ground model allowing to describe the soil variability, both vertically (soil profiles) and laterally (soil provinces), in the AOI (including Landfall/Shore crossing and Offshore Distribution HUB Areas).

The available data used for this study were compiled in a GIS (Geographic Information System) geodatabase. The maps were created using ArcGIS® software by Esri (version 10.8).

The final GIS project is delivered along with the final revision of the report.

2.2 Available Data

The main sources of information used in this study include:

- Client-supplied information (Table 2.1);
- Fugro internal databases;
- Digital public domain data (Table 2.2);
  - WMS
  - Freely downloadable GIS-compatible data
- Published literature.

For those sources that are not included in the GIS database deliverable, URL links are given to allow TotalEnergies to retrieve the relevant information.

2.2.1 Client-Supplied Information

Table 2.1: Project information

Data	Data Format	Date Provided
Boundaries of Area of Interest (AOI)	Shapefile	06 December 2021
WEST A and WEST CENTRAL Routings	Shapefile	07 December 2021
Offshore Distribution Area	Shapefile	04 November 2021
Outline of Landfall/Shore crossing Area	Coordinates	15 December 2021

2.2.2 Fugro Database

This report uses and summarises Fugro-held information:

- Information about regional geology;
- General geotechnical data;
- Previous geotechnical and geophysical investigation data applicable to development sites within the AOI.

2.2.3 Public Domain

Data from public sources have been gathered and reviewed. These data are accessible for consultation online, to download or using WMS servers. Table 2.2 presents the data sources used.

Table 2.2: Public domain data sources

Type	Source	Link
SITE USE		
Landing stations	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Telecommunication cables	EMODnet, SHOM, Rijkswaterstaat	https://www.emodnet-humanactivities.eu/view-data.php https://www.rijkswaterstaat.nl/en
Power cables	Rijkswaterstaat	https://www.rijkswaterstaat.nl/en
Buoys	Rijkswaterstaat	https://www.rijkswaterstaat.nl/en
Offshore facilities	NLOG	https://www.nlog.nl/index.php/en/files-interactive-map
Wells	NLOG	https://www.nlog.nl/index.php/en/files-interactive-map
Pipelines	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Active HC licenses	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Navigation channels	Noordzeeloket	https://www.noordzeeloket.nl/en/up-date-atlas/

Type	Source	Link
Anchoring areas	Noordzeeloket	https://www.noordzeeloket.nl/en/up-date-atlas/
Harbour approach areas	Noordzeeloket	https://www.noordzeeloket.nl/en/up-date-atlas/
Wind farm active areas	Noordzeeloket	https://www.noordzeeloket.nl/en/up-date-atlas/
Wind farm development areas	Noordzeeloket	https://www.noordzeeloket.nl/en/up-date-atlas/
Dredging areas	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Military areas	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Environment Natura 2000 areas	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
Dredging areas	Rijkswaterstaat	https://geo.rijkswaterstaat.nl/services/ogc/gdr/stort_loswal/ows?
Fishing and shipping activities	EMODnet	https://www.emodnet-humanactivities.eu/view-data.php
BATHYMETRY		
AOI	EMODnet (2020)	https://portal.emodnet-bathymetry.eu/
Rotterdam approach area	EMODnet (2020)	https://portal.emodnet-bathymetry.eu/
Landfall/Shore crossing Area	EMODnet (2018)	https://portal.emodnet-bathymetry.eu/
Hollandse Kust WFZs	RVO	https://offshorewind.rvo.nl/
SOIL		
Substrate type	EMODnet	https://www.emodnet-geology.eu/map-viewer/?p=seabed_substrate
Grab samples, vibrocores and boreholes	DINOloket	https://www.dinoloket.nl/en/subsurface-data
Hollandse Kust WFZs	RVO	https://offshorewind.rvo.nl/
GEOLOGICAL INFORMATION		
Southern Bight Fm.	Balson et al. (1991), NITG–TNO (2004b)	-
Urania Fm.	NITG–TNO (2004b)	-
Naaldwijk Fm.	Cameron et al. (1984), Harrison et al. (1987), Balson et al. (1991)	-
Boxtel (Twente) Fm.	NITG–TNO (2004d)	-
Eem Fm / Brown Bank Mb.	NITG–TNO (2004d)	-
Kreftenheye Fm.	NITG–TNO (2004d)	-
Eem Fm.	Cameron et al. (1984, 1986)	-
Drente (Borkum Riff) Fm.	Laban (1995)	-
Drente (Cleaver Bank) Fm.	Laban (1995), NITG–TNO (2004d)	-
Tea Kettle Hole Fm.	Laban (1995)	-

Type	Source	Link
Egmond Ground Fm.	Cameron et al. (1984, 1986), Laban (1995)	-
Peelo (Swarte Bank) Fm.	Cameron et al. (1986), Laban (1995), Laban & van der Meer (2011)	-
Yarmouth Roads Fm.	Cameron et al. (1984, 1986)	-
Ice sheet extents	Laban (1995)	-
Notes: Data was accessed between December 2021 and January 2022		

3. Regional Geology

3.1 Regional Geodynamics and Geological History

The large-scale tectonic setting of the Netherlands and adjacent areas is driven by the north–south collision of Gondwana and Laurussia during the Late Carboniferous to form Pangaea, and the subsequent rifting during the Triassic in the Arctic–North Atlantic and western Tethys domains. This formed, in conjunction with the anisotropic and thickened crust of the Variscan fold belt, a complex system of basins and rifts in Northwest Europe (Geluk, 2005). Alpine inversion of these basins took place during the Late Cretaceous and early Paleogene as a result of the collision of Iberia and Europe. This was followed by multiple phases of subsidence from the Eocene up to recent times (Wong et al., 2007).

3.2 Pre-Quaternary Geology

From the late Miocene onwards, a complex fan delta system developed, which gradually evolved into an alluvial plain prograding from the east. Until the end of the Neogene, deposition in the North Sea was dominated by sediment input from the Eridanos (Baltic) river system (Overeem, 2002; Knox et al., 2010; Rasmussen & Dybkjaer, 2014; Thöle et al., 2014).

3.3 Quaternary Geology

During the Pleistocene, the depositional evolution of the North Sea basin was strongly influenced by climatic variations, glaciations and associated sea level fluctuations (Funnell, 1996; Overeem et al., 2001; Kuhlmann & Wong, 2008; Thöle et al., 2014). This resulted in a complex interplay of glacial, glaciolacustrine, glaciofluvial, fluvial, aeolian, deltaic and (shallow) marine environments and deposits (Laban, 1995; Laban & Rijswijk, 2002; Joon et al., 1990; Peeters et al., 2015).

By the mid-Pleistocene (~1 Ma), the Rhine, Meuse and Scheldt rivers had become important contributors of sediment influx to the North Sea basin, as a result of uplift of highland areas in Germany (Laban and Rijsdijk, 2002). Subsidence decreased during this time and the basin had become largely filled with deltaic deposits.

The AOI has been affected by an alternating series of glacial and interglacial periods that has occurred since the Pleistocene and continues to the present day. Below follows a more detailed description of the three glacial and three interglacial periods that took place.

3.3.1 Elsterian Glaciation (Middle Pleistocene)

During the Elsterian glaciation (475 ka to 410 ka BP), the Scandinavian and British ice masses coalesced and spread in southern direction to cover the northern part of the Netherlands and the southern North Sea (Ehlers, 1990; De Gans, 2007). The northern half of the AOI has been affected by the Elsterian ice sheet, while the southern half was influenced by the Rhine and Meuse river systems (Figure 3.1a). The Aramis area was also influenced by the Eridanos river system, which was deflected south of the ice limit. Deposition of predominantly low energy open marine deltaic sediments consisting of siliceous sands and clays ensued, which are thought to belong to the Yarmouth Roads Formation (Laban, 1995; Laban & Rijsdijk, 2002; Rijsdijk et al., 2005). Elsterian tunnel valleys occur within the Yarmouth Roads Formation. The infill of these tunnel valleys comprises glaciofluvial, glaciolacustrine and proglacial clays and sands of the former Swarte Bank Formation (now part of the Peelo Formation; Praeg, 1996; Rijsdijk et al., 2005; Graham et al., 2011; Moreau et al., 2012).

3.3.2 Holsteinian Interglacial (Middle Pleistocene)

During the subsequent Holsteinian interglacial (410 ka to 370 ka BP), sea level rose because of climate amelioration and melting ice masses. This resulted in a transgression phase in the AOI.

Fluvial and marine deposits were prevalent in this period. The fluvial deposits have been defined as the onshore Urk Formation (Bosch et al., 2003), while the offshore equivalent comprises marine deposits belonging to the Egmond Ground Formation (Bosch et al., 2003; Rijsdijk et al., 2005). Laterally, the Urk Formation grades into the Egmond Ground Formation (Bosch et al., 2003). The Urk Formation can contain clay interbeds, while the Egmond Ground Formation can contain marine shells. The Urk Formation and Egmond Ground Formation may locally incise into the underlying Yarmouth Roads Formation.

3.3.3 Saalian Glaciation (Middle to Late Pleistocene)

During the Saalian glaciation (370 ka to 130 ka BP), the eastern half of the AOI was probably covered by the Saalian ice sheet while the western half was located in close proximity to the Saalian Ice Margin (Figure 3.1b). However, the exact limit of the ice sheet advance offshore remains uncertain.

Ice masses formed glacially scoured basins and several ice-pushed ridges (moraines). The ice-pushed ridges were recognised directly south of the Hollandse Kust (noord) wind farm zone (WFZ) (Laban & van der Meer, 2011; Peeters et al., 2015; Cartelle et al., 2021).

Numerous tunnel valleys were created during the Saalian in subglacial and proglacial settings. A major tunnel valley is present in the centre of the site, and more tunnel valleys may be present near the north-eastern boundary of the Aramis area (Cameron et al., 1984a; Joon et al., 1990; Laban, 1995; Stouthamer et al., 2015).

Fluvial erosion of underlying formations occurred. During the Saalian glaciation, the Rhine–Meuse river system merged with a proglacial river system south of the ice margin (Peeters et al, 2015). This setting implies variable soil conditions dominated by extensive areas of glaciofluvial sands and gravels (outwash plains/sandurs) deposited in front of the ice sheet, with clays deposited in glaciolacustrine environments. Local aeolian deposition took place near the Saalian Ice Margin. The glaciofluvial and aeolian sediments belong to the Drachten Formation (formerly Tea Kettle Hole Formation), while the glaciolacustrine sediments belong to the Uitdam Member of the Drenthe Formation (formerly Cleaver Bank Formation). The latter is mainly confined to the Saalian tunnel valleys (Laban, 1995).

Between the coast of the island of Texel to a position about 14 km to the west, a till plateau is present.

TILL is unsorted glacial sediment. Within the AOI the TILL is expected to comprise silty, sandy CLAY, with matrix-supported gravel to boulder-sized grains. It is present in the north-east of the AOI and belongs to the Drenthe Formation (Gieten Member). Glacial TILL may pose a risk to the installation of offshore structures due to its heterogenic grain size composition and overconsolidated nature.

The Saalian glaciation is associated with widespread glacial deformation both onshore and offshore. Large deformation structures have been reported within the AOI (Joon et al., 1990; Laban, 1995). Some indications of glacial deformation have been identified in the Hollandse Kust WFZs.

Saalian sediments in the southern North Sea have been largely eroded by the subsequent Eemian transgression but are still present in Saalian channels and valleys.

3.3.4 Eemian Interglacial (Late Pleistocene)

A major marine transgression affected AOI during the Eemian interglacial (130 ka to 115 ka BP). The AOI became part of the delta plain of the river Rhine. Shallow marine sands (Eem Formation), lagoonal and estuarine clays and sands, and fluvial sands (Kreftenheye Formation) were laid down in a complex depositional setting (Peeters et al., 2015). Existing glacial valleys and channels were inundated by the marine transgression (Figure 3.1c).

With the onset of the marine regression at the end of the Eemian and beginning of the Weichselian glaciation, brackish marine clays and lagoonal or lacustrine silty laminated clays, identified as the Brown Bank Member (part of Eem Formation), were deposited in a low-energy environment in the (north-)western part of the AOI (Figure 3.1d; Cameron et al., 1984a; Peeters et al., 2015; GDN, 2018).

3.3.5 Weichselian Glaciation (Late Pleistocene)

During the youngest glacial period, the Weichselian (115 ka to 18 ka BP), the limit of the ice sheet extent was just north-west of the AOI. At the time, deposition in the southern North Sea was dominated by periglacial conditions with temporary fluvial influences of the Rhine–Meuse river system (Figure 3.1e).

The periglacial deposits comprise sand, sandy loam, peat, thaw-lake deposits and aeolian sediments belonging to the Boxtel Formation. The aeolian deposits are considered to have little preservation potential in a dominantly (glacio)fluvial environment (NITG–TNO, 2004). The glaciofluvial deposits comprise sand, gravelly sand and clay of the Kreftenheye Formation. Erosion of underlying formations probably occurred.

3.3.6 Holocene (Recent)

With the transition from late glacial to early Holocene (11.6 ka BP to present), climatic amelioration resulted in sea level rise, and the North Sea basin became flooded. Deposition took place in a terrestrial periglacial environment, transitioning into tidal and lagoonal as the sea level rose. Sediments from this period belong to the Naaldwijk Formation and are preserved as (scattered) sands and clays that often infill channels. Locally, peat beds were deposited in shallow marsh settings (Nieuwkoop Formation). As transgression progressed, the AOI was overlain by sands of the Southern Bight Formation and muddy sands of the Urania Formation.

The North Sea Basin has remained essentially sediment starved since the start of the Holocene (Jacobs & De Batist, 1996), and deposits occur mainly in the form of sand banks and sand waves (Liu et al., 1993). Surficial sediments in the AOI mainly consist of sand with shell and shell fragments typical of a high energy, open marine environment. These sands are partially derived from reworking of the sediments from the underlying fluvial deposits. Sands with a higher mud fraction are present in a bathymetric depression in the northern part of the AOI. These sediments belong to the Urania Formation and are indicative of a low energy open marine environment.

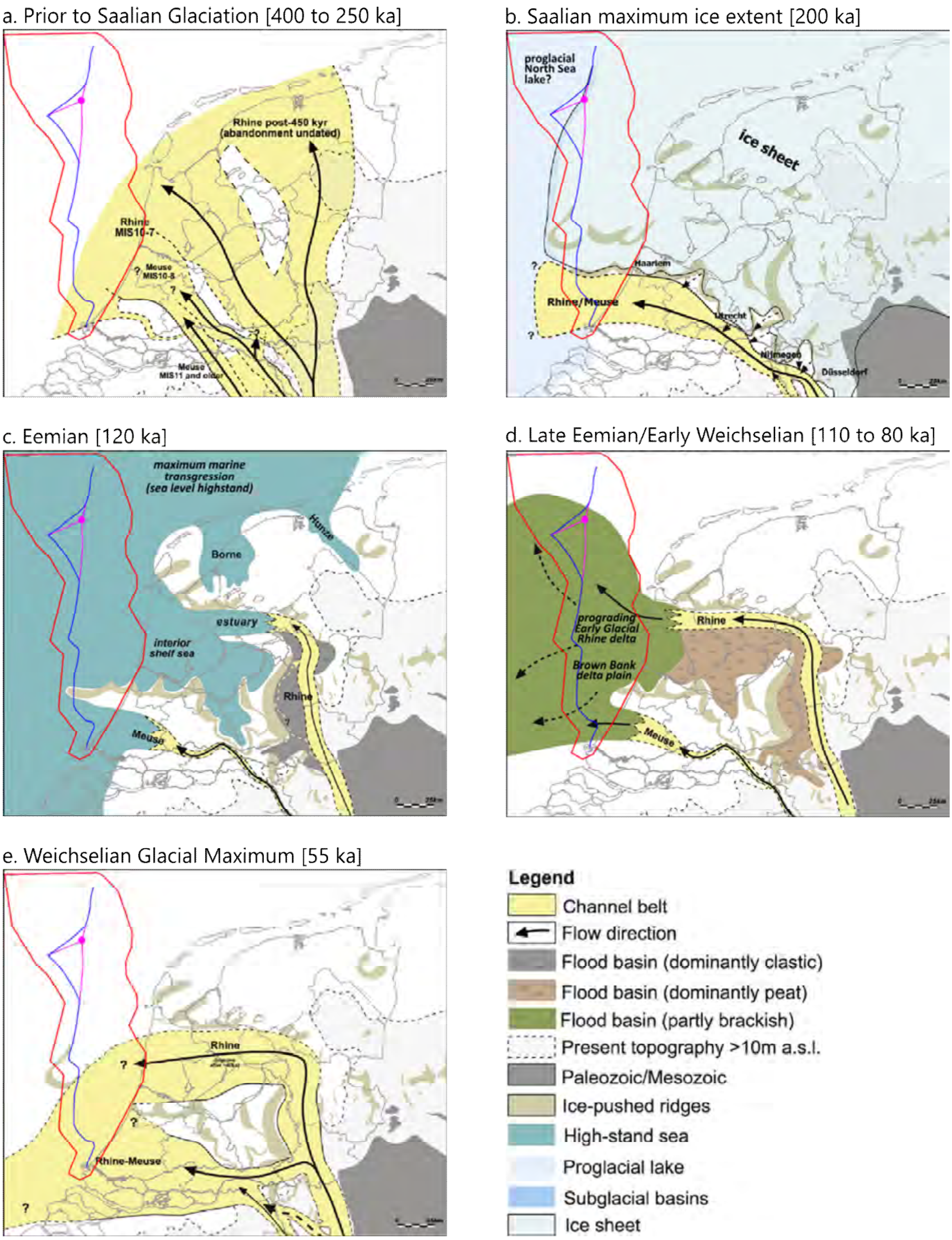


Figure 3.1: Paleo-geographical reconstructions of the Netherlands during the Middle to Late Pleistocene illustrated by five successive time frames. a) Rhine–Meuse drainage configuration prior to Saalian Glaciation. b) Maximum Saalian ice extent. c) Eemian interglacial maximum transgression during sea level highstand. d) Rhine delta prograding into lower-deltaic flood basin environment. e) Configuration of the Rhine and Meuse during the Weichselian glacial maximum (modified after Peeters et al., 2015).

3.4 Maximum Ice Sheet Extent and Subglacial Valleys

Three Pleistocene glaciations resulted in ice sheets covering large parts of the Dutch sector of the North Sea. From the oldest to the youngest, these glaciations are named Elsterian, Saalian and Weichselian. Figure 3.2 presents the maximum extent of the Pleistocene ice sheets and the location of the associated subglacial valleys.

The Elsterian valleys form a complex system of anastomosing, but mainly NNE–SSW trending, broad (approximately 1 km to 10 km wide) and deep (up to 400 m BSF) erosional features. They are present in the northern half of the AOI. These subglacial valleys were mainly filled with glaciofluvial SAND near the base and glaciolacustrine CLAY near the top, belonging to the Peelo Formation (Cameron et al., 1986; Laban, 1995).

A major Saalian subglacial valley runs in a N–S direction, along the margin of the maximum extent of the Saalian ice sheet, located in the centre of the AOI. It is approximately 10 km wide and up to 80 m deep. The infill consists locally of glaciolacustrine CLAY (Uitdam Member) near the base, covered with marine SAND of the Eem Formation (Laban, 1995, Fugro, 2020).

Weichselian subglacial valleys occur as close as 6 km north of the AOI (Laban, 1995).

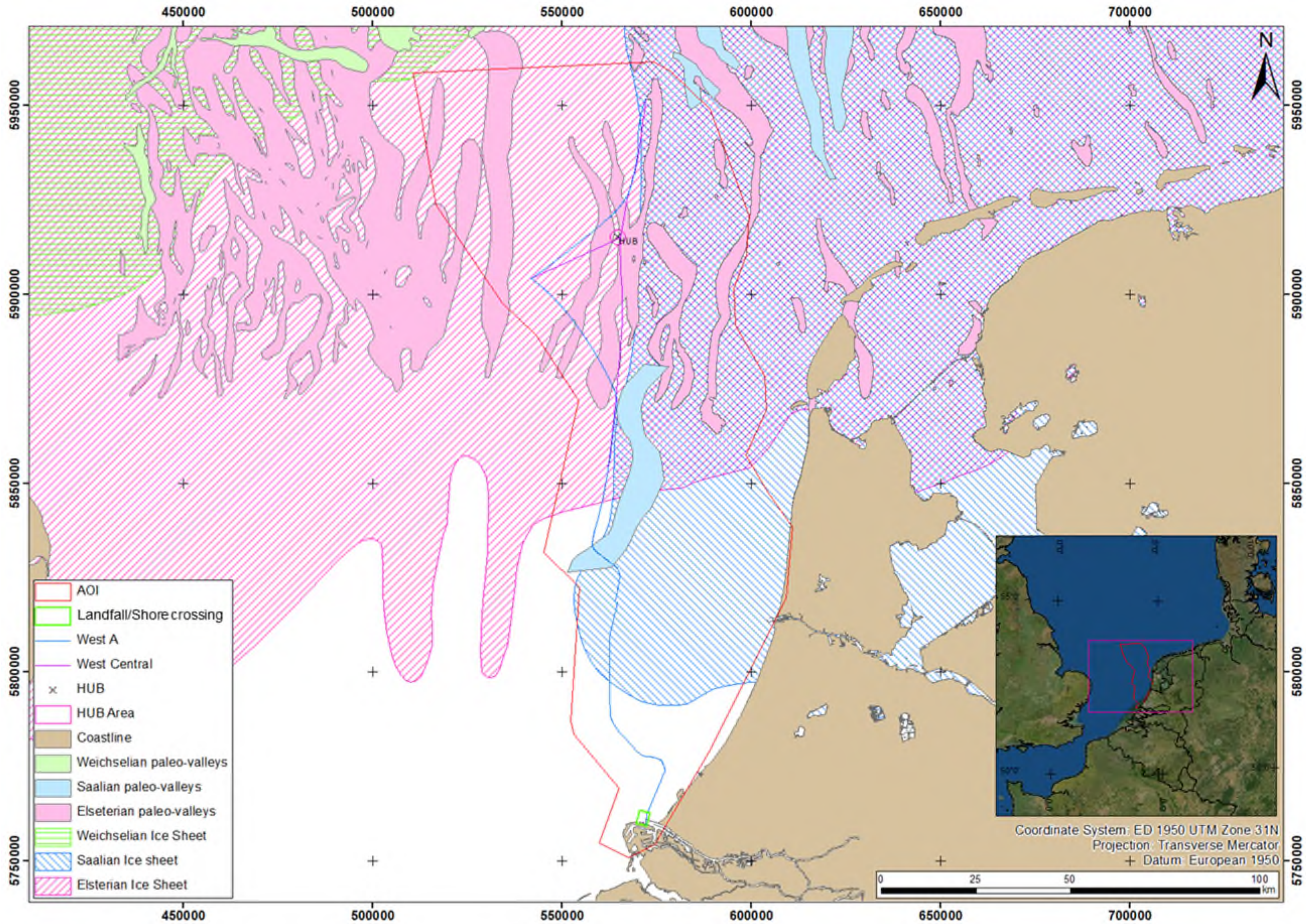


Figure 3.2: Maximum ice extent of the Pleistocene glaciations and associated paleo-valleys (Laban, 1995)

4. Site-Specific Conditions

4.1 Site Use

4.1.1 AOI

Past and/or present activities in the AOI can affect and constrain development of the pipeline infrastructure. Evidence of human activity and seafloor objects are documented in the Archaeological Desktop Study (Appendix B) and in the UXO Desktop Study (Appendix C).

Figure 4.1 presents navigation areas or infrastructure identified within the AOI:

- 197 navigation buoys;
- 7 navigation channels;
- 6 anchoring areas;
- 4 harbour approach areas.

Figure 4.2 presents restricted areas identified within the AOI:

- 7 navigation channels;
- 6 anchoring areas;
- 4 harbour approach areas;
- 3 wind farms in operation;
- 4 wind farms under development;
- 121 dredging areas;
- 11 dredge spoil areas;
- 4 military exercise areas;
- 7 natural protected areas.

Figure 4.3 presents seafloor oil and gas infrastructure identified within the AOI:

- 149 offshore facilities;
- 1153 wells;
- 227 pipelines.

Figure 4.4 presents seafloor cable and wind energy related infrastructure identified within the AOI:

- 1 cable landing station;
- 8 telecommunication cables;
- 139 wind turbine generators;
- 23 power cables.

Based on the currently available information, 36 cables and 35 pipeline crossings are to be expected in the AOI considering the current proposed pipeline routes.

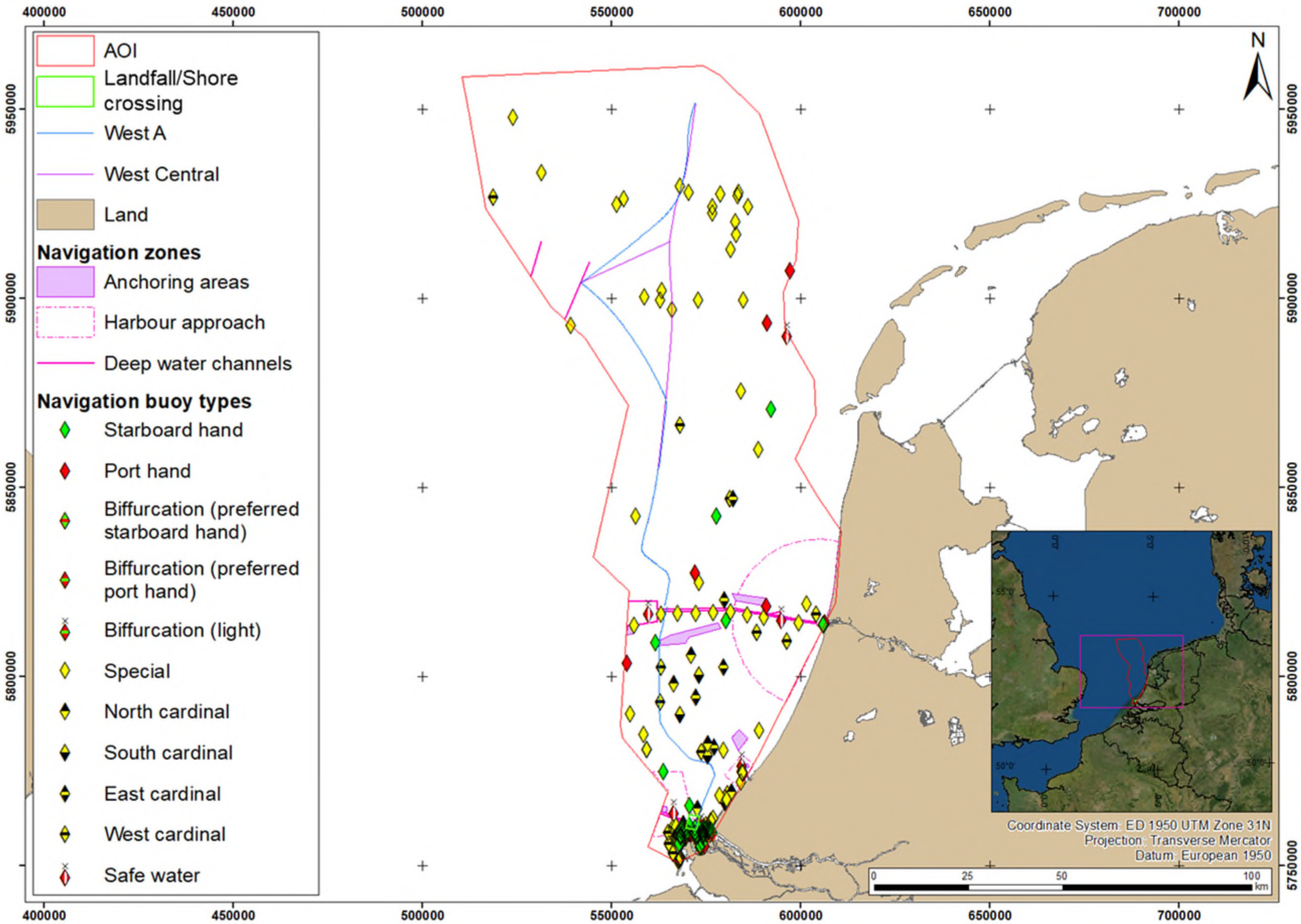


Figure 4.1: Navigation areas or infrastructures identified within the AOI

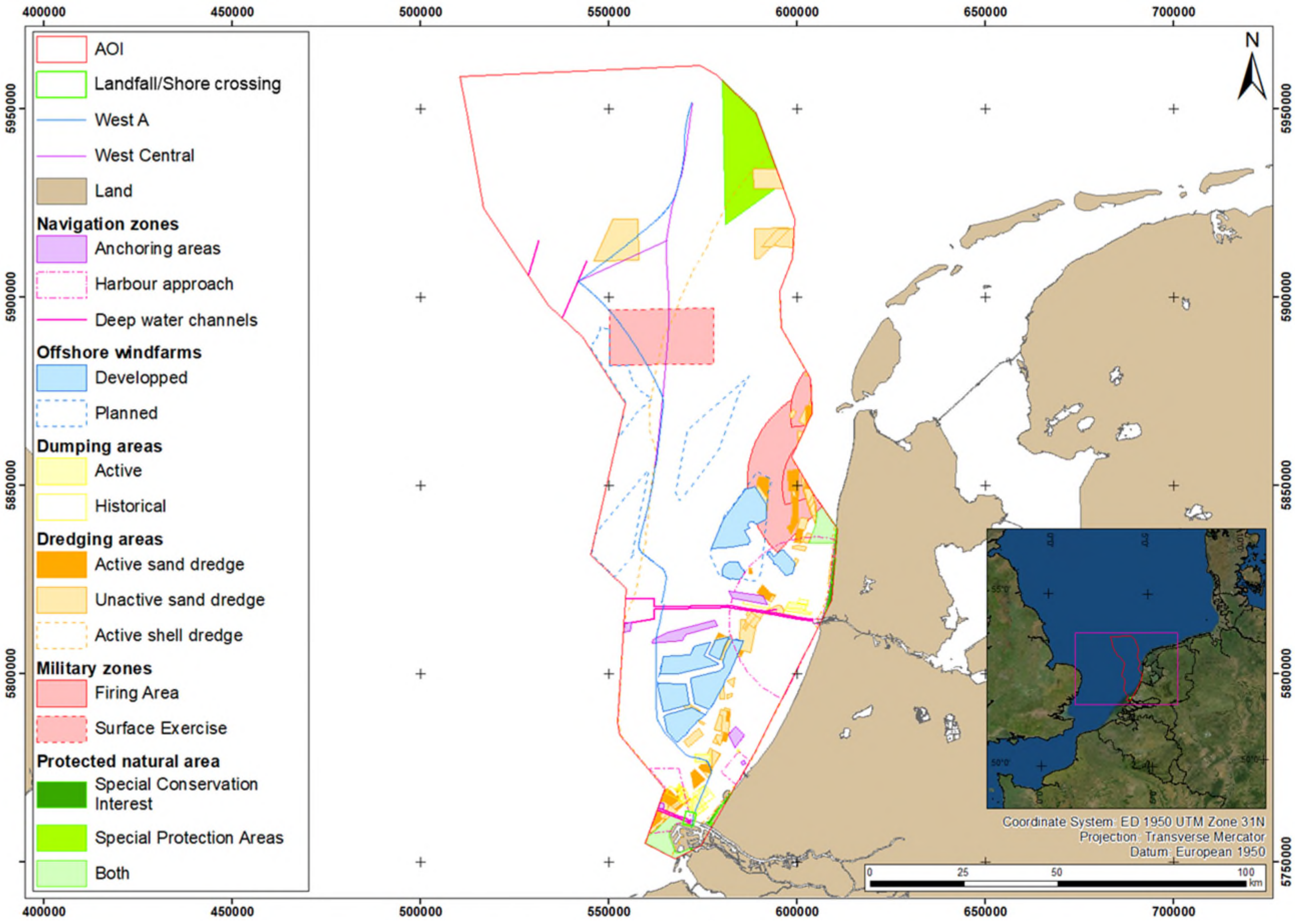


Figure 4.2: Restricted areas identified within the AOI

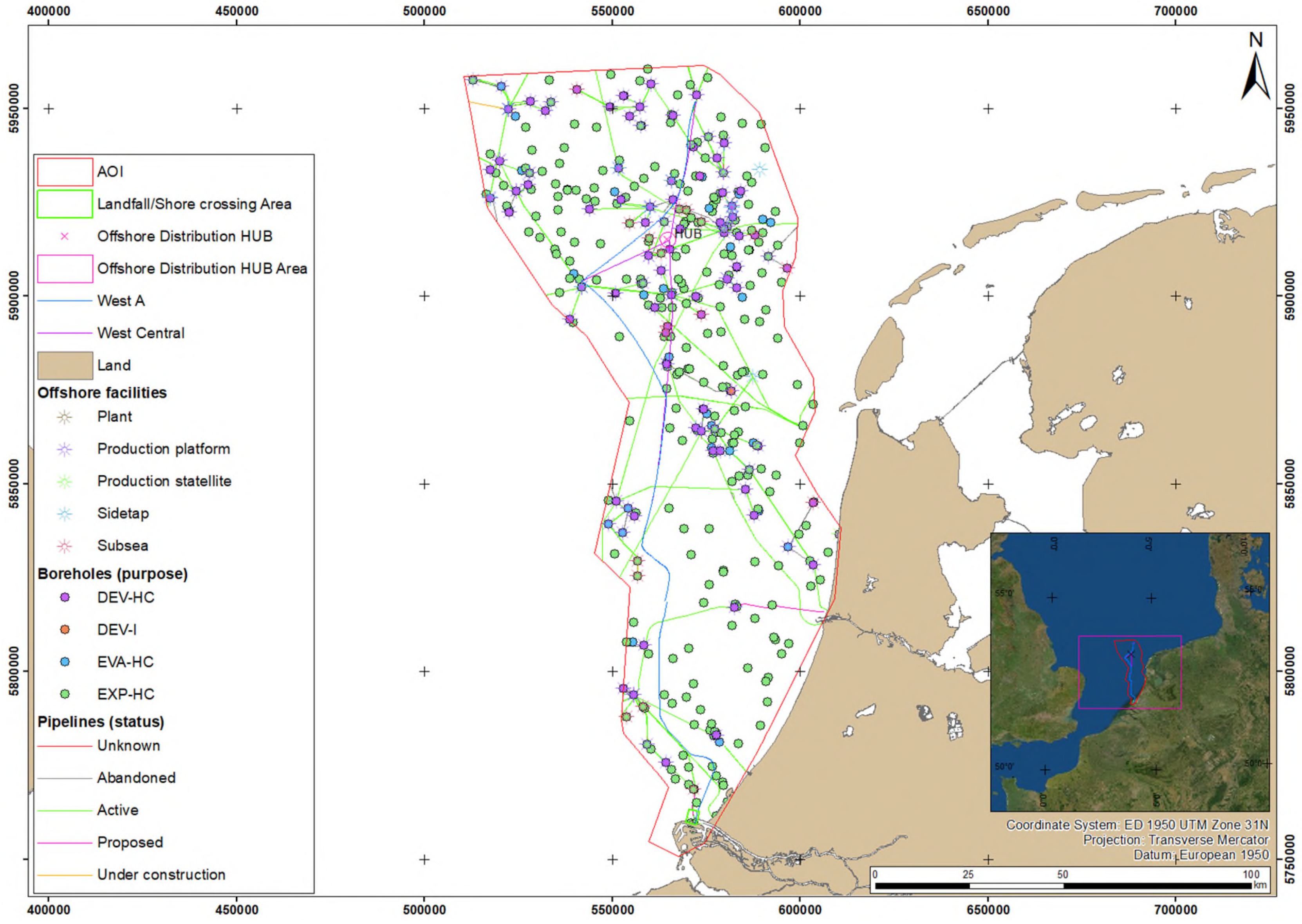


Figure 4.3: Oil and gas seafloor infrastructures identified within the AOI

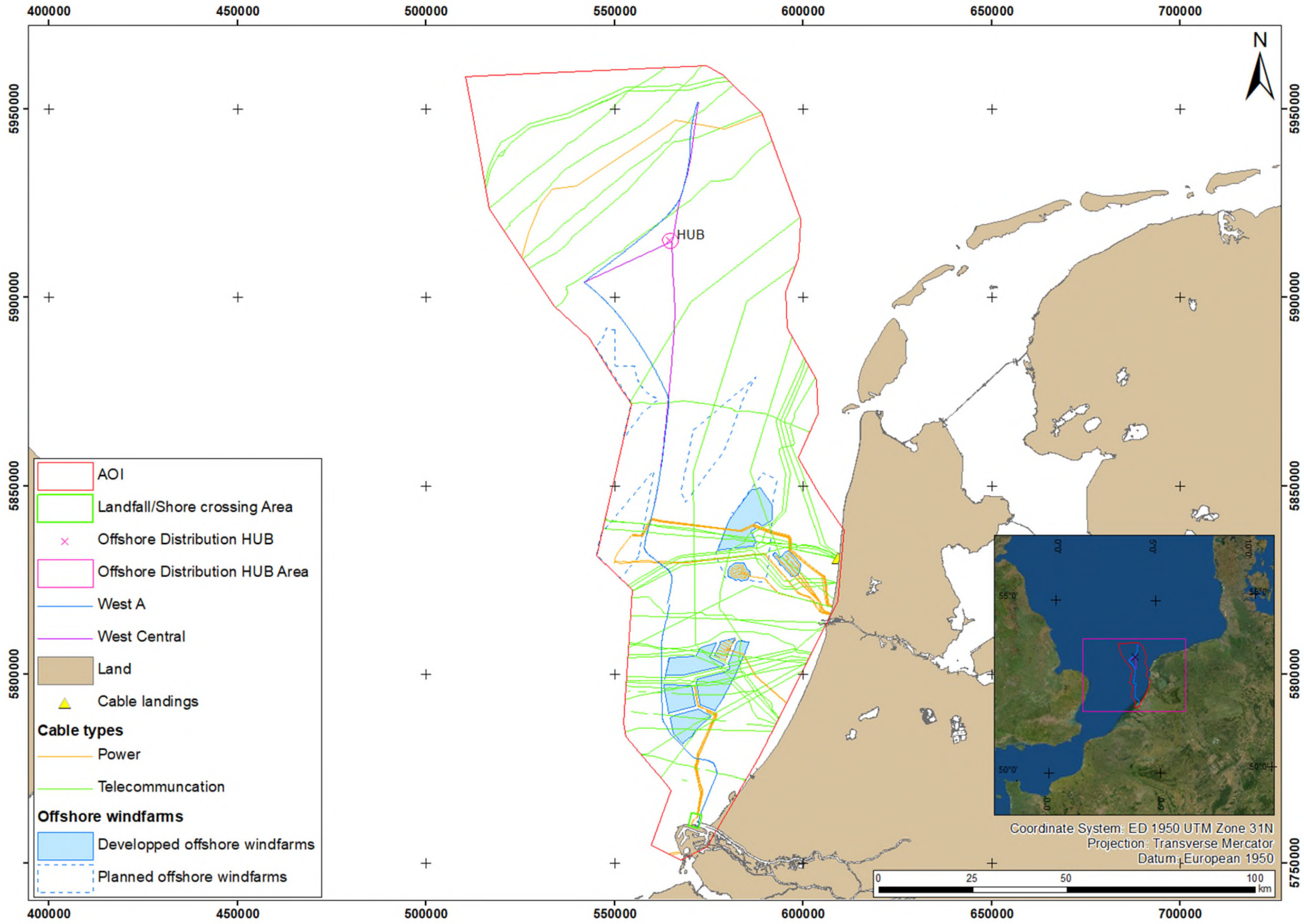


Figure 4.4: Cable and wind-energy related infrastructures identified within the AOI

Vessel route densities per type of vessels as well as vessel density per activity for 2020 were extracted from EMODnet.

Figure 4.5 present the total vessel route density for 2020 within and around the AOI, regardless of the types of boats. The main commercial routes are clearly visible as red lines, connecting the North Sea, Baltic Sea and English Channel as well as joining the main harbours (such as Rotterdam and IJmuiden). The present pipeline layout crosses three of the highest density routes. The Offshore Distribution HUB Area is within an area with medium density routes, probably corresponding mainly to small cargos, fishing, or leisure vessels.

Figure 4.6 presents the average fishing activity for 2020 within and around the AOI. Fishing activity is medium in the southern half of the AOI, and low within the northern half (and close to the Offshore Distribution HUB Area). Fishing activity is high within 20 km from the shore. However, within the Maasmond Kanaal, it is expected that fishing activity is low due to the presence of dense shipping traffic.

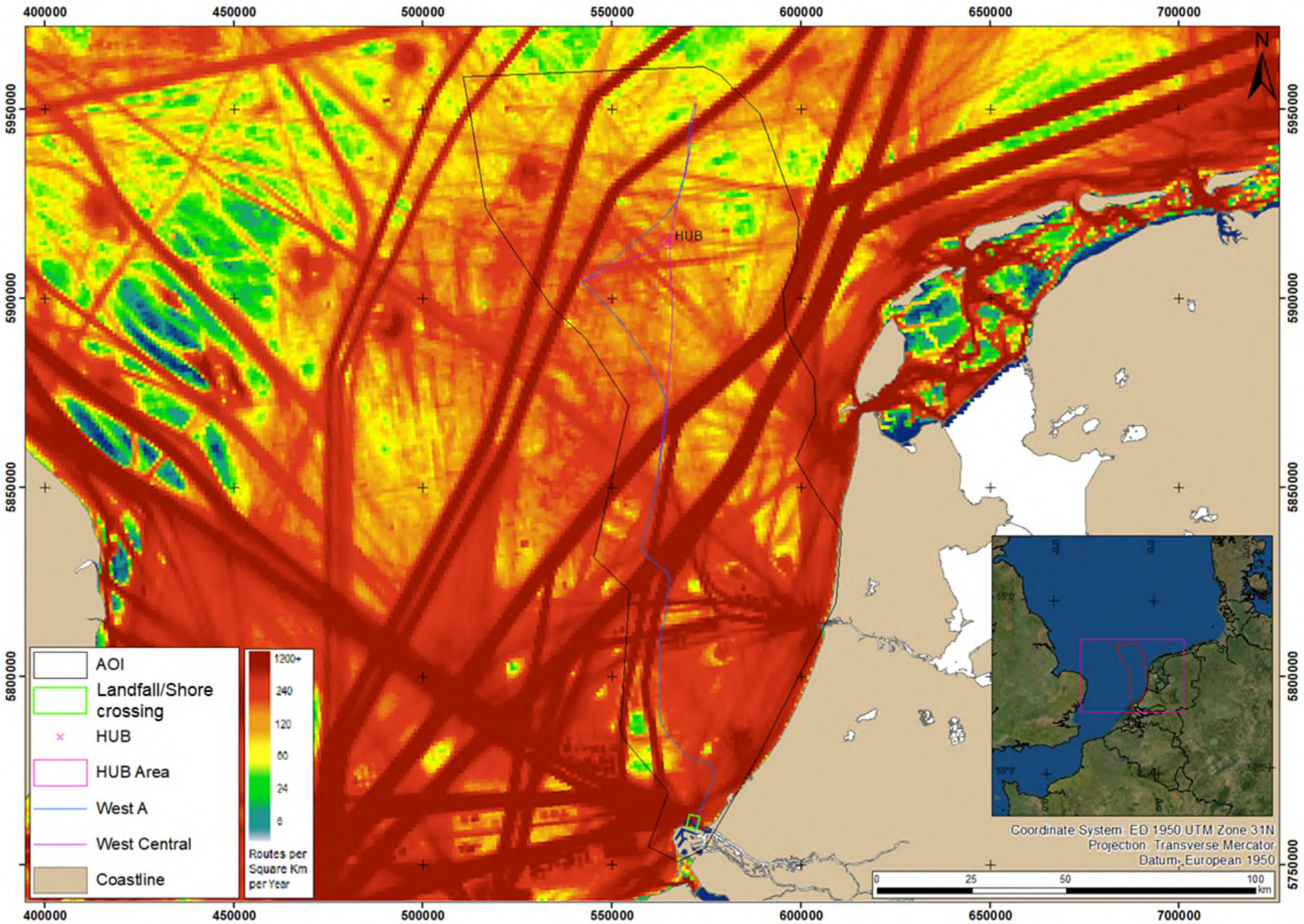


Figure 4.5: Total vessel routes density given as routes per km² per year for 2020 (EMODnet, 2022)

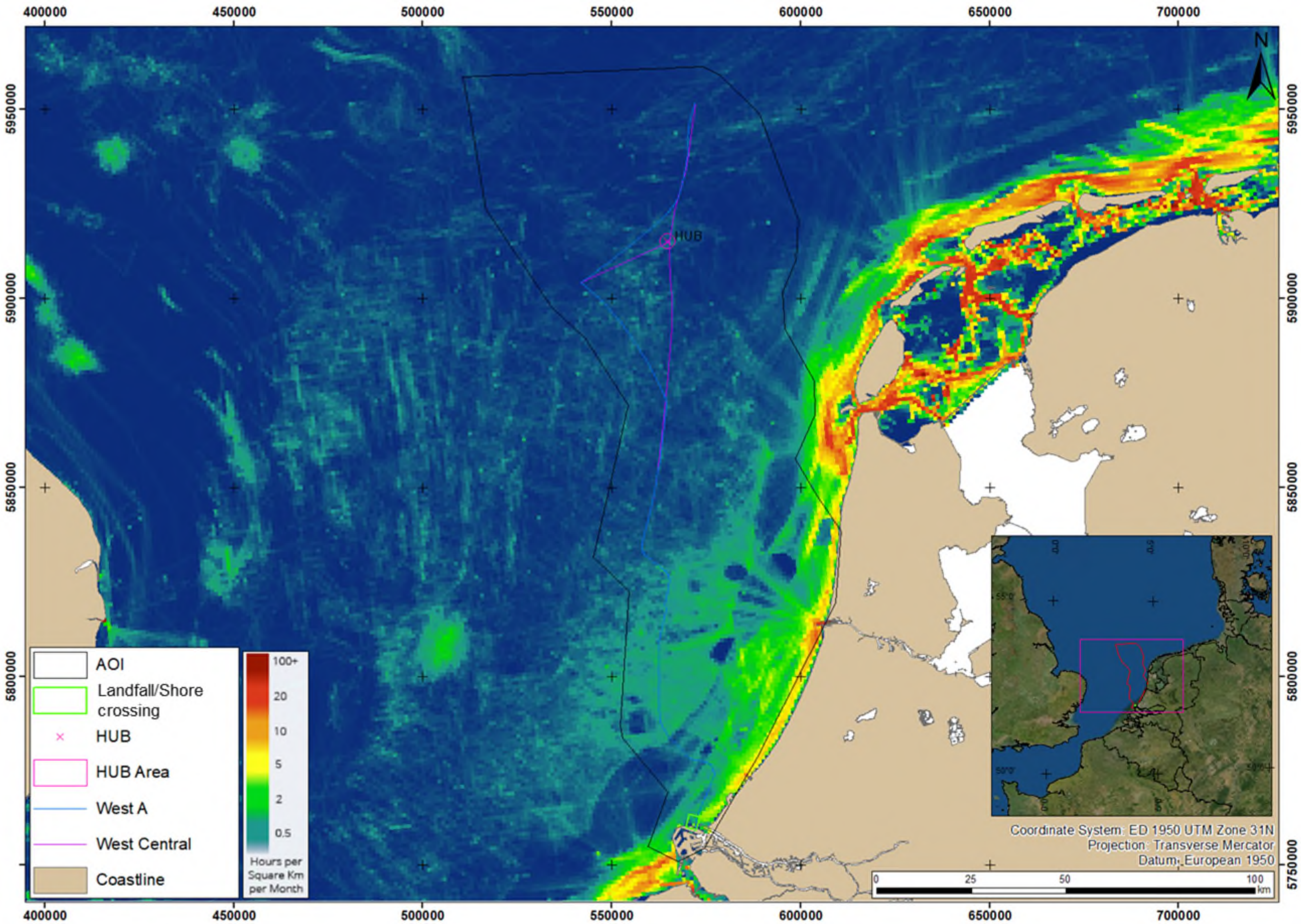


Figure 4.6: Average fishing activity density given in hours per km² per month for 2020 (EMODnet, 2022)

4.1.2 Landfall/Shore Crossing Area

Within the Landfall/Shore Crossing Area a number of restricted areas and infrastructure was identified.

Figure 4.7 presents the following:

- restricted areas and navigation infrastructures identified within the AOI:
  - 2 navigation buoys;
  - 1 (deep water) navigation channel;
  - 1 harbour approach area;
  - 1 dredge spoil area;
  - 1 natural protected area.
- seafloor oil and gas infrastructure identified within the AOI:
  - 1 production facility;
  - 4 wells;
  - 3 pipelines.
- power cables, related to wind energy infrastructure, identified within the AOI:
  - 4 power cables.

4.1.3 Offshore Distribution HUB Area

No specific site use or seafloor obstructions of any type are expected within the Offshore Distribution HUB Area, except for fishing activities and vessels crossing the area.

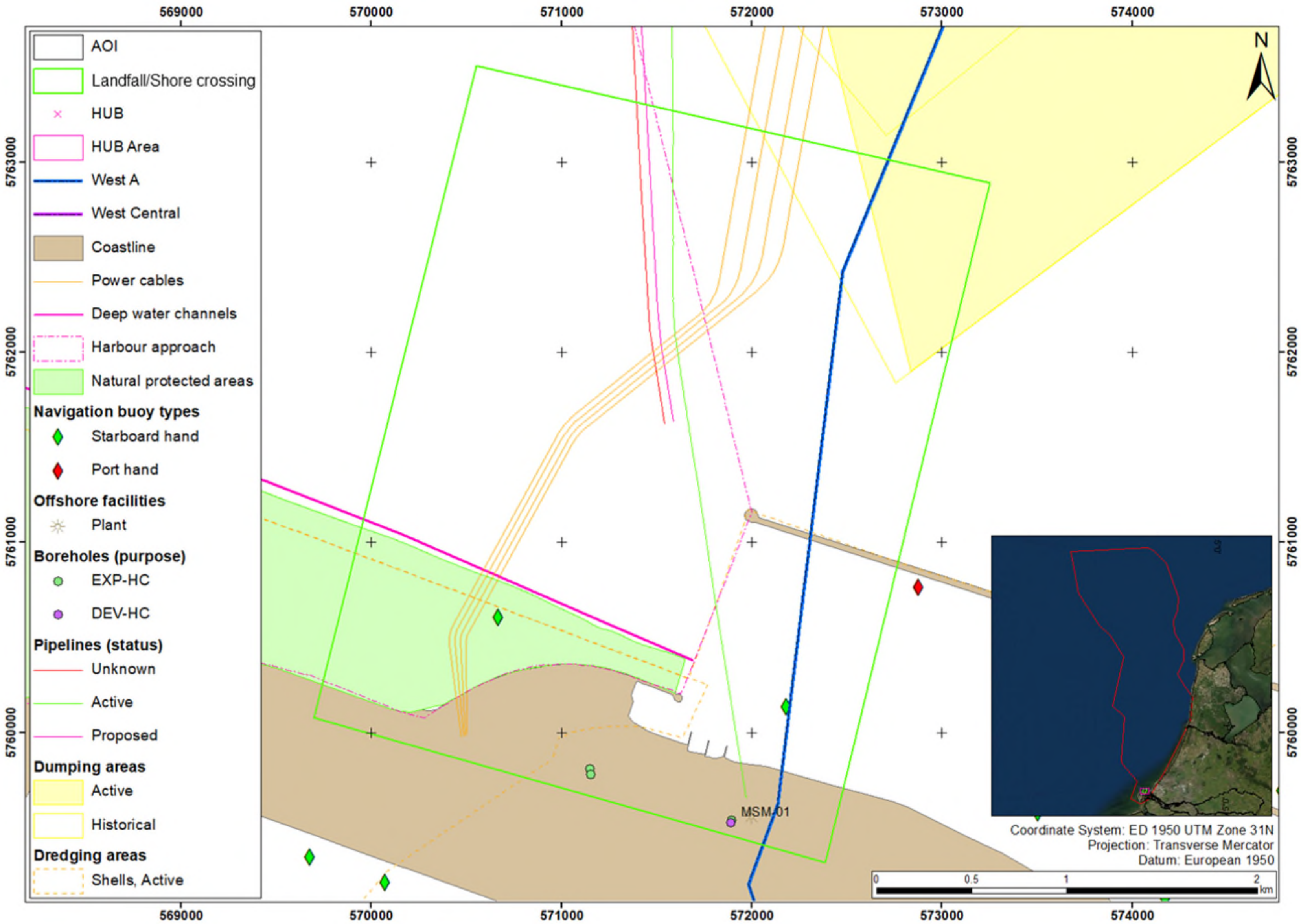


Figure 4.7: Site use across the Landfall/Shore crossing Area

4.2 Seafloor Conditions

4.2.1 Bathymetry and Seafloor Gradient

4.2.1.1 AOI

The Dutch offshore sector has been extensively surveyed by the Dutch Hydrographic Office, and historical data have been acquired and interpolated since 1979 (Deltares, 2016, 2020). This includes bathymetric data, which is publicly available on EMODnet.

Table 4.1 summarises the water depth and slope gradient values as observed in the individual bathymetry datasets available for the AOI. Included in the table is the resolution of the respective bathymetry datasets. Bathymetry and seafloor gradients of the AOI are presented in Figure 4.8. Close-ups for the Rotterdam approach, northern coastal, southern coastal, Hollandse Kust (noord), Hollandse Kust (west) and Hollandse Kust (zuid) WFZs are given in Figure 4.9 to Figure 4.14, respectively.

In general, the seafloor is gently dipping towards the west to west-north-west, perpendicular to the coast. The water depth in the AOI averages approximately 25 m below lowest astronomical tide (bLAT). Approximately 15 km north of the Offshore Distribution HUB Area, the seafloor deepens in a northern direction from approximately 20 m to 39 m bLAT over a distance of 20 km.

Most of the AOI is characterised by low seafloor gradients of less than 5°. Locally, higher seafloor gradients were observed and can have either a hydrodynamic (natural) or man-made origin.

The highest seafloor gradients associated with bedforms were observed on the lee side of sand waves (up to 30°). In the coastal area seafloor gradients up to approximately 19° were observed.

Man-made seafloor features resulting in higher seafloor gradients in the AOI include navigation channels, dredging areas, dumping areas, wrecks and other seafloor obstructions.

However, it should be noted that slope gradients are computed from bathymetry maps and therefore dependant on the data resolution. Where multibeam echosounder (MBES) data were acquired (WFZs), the calculated slope gradients are considered reliable and allow to visualise slope breaks linked to features as small as 2 m to 5 m. Outside of the wind farm sites, the grid resolution is either 30 m or 100 m and therefore smaller features cannot be imaged, and slope gradients are likely to be underestimated or overestimated locally.

Since the AOI covers a large area, Fugro does not recommend acquiring higher-resolution data at this stage. However, acquisition of MBES data along the final pipeline route will be paramount in order to assess and mitigate any seafloor hazards.

Table 4.1: Summary of water depths and seafloor gradients as observed in the different bathymetry datasets

Area	Maximum Water Depth [m LAT]	Minimum Water Depth [m LAT]	Average Slope Angle [°]	Maximum Slope Angle [°]	Minimum Slope Angle [°]	Bathymetry Grid Resolution [m]
AOI	-46.3	0	0.1	8	0	100
Hollandse Kust (noord) WFZ	-28.1	-14.9	1.7	29.9	0	2
Hollandse Kust (west) WFZ	-33.1	-22.5	2.2	20.6	0	2
Hollandse Kust (zuid) WFZ	-27.8	-16.1	0.6	14.9	0	5
Rotterdam approach area	-41.5	-13.5	0.3	9.5	0	30
Coastal area	-15.2	36.4	1.0	18.8	0	30
Notes: m LAT = metres relative to Lowest Astronomical Tide						

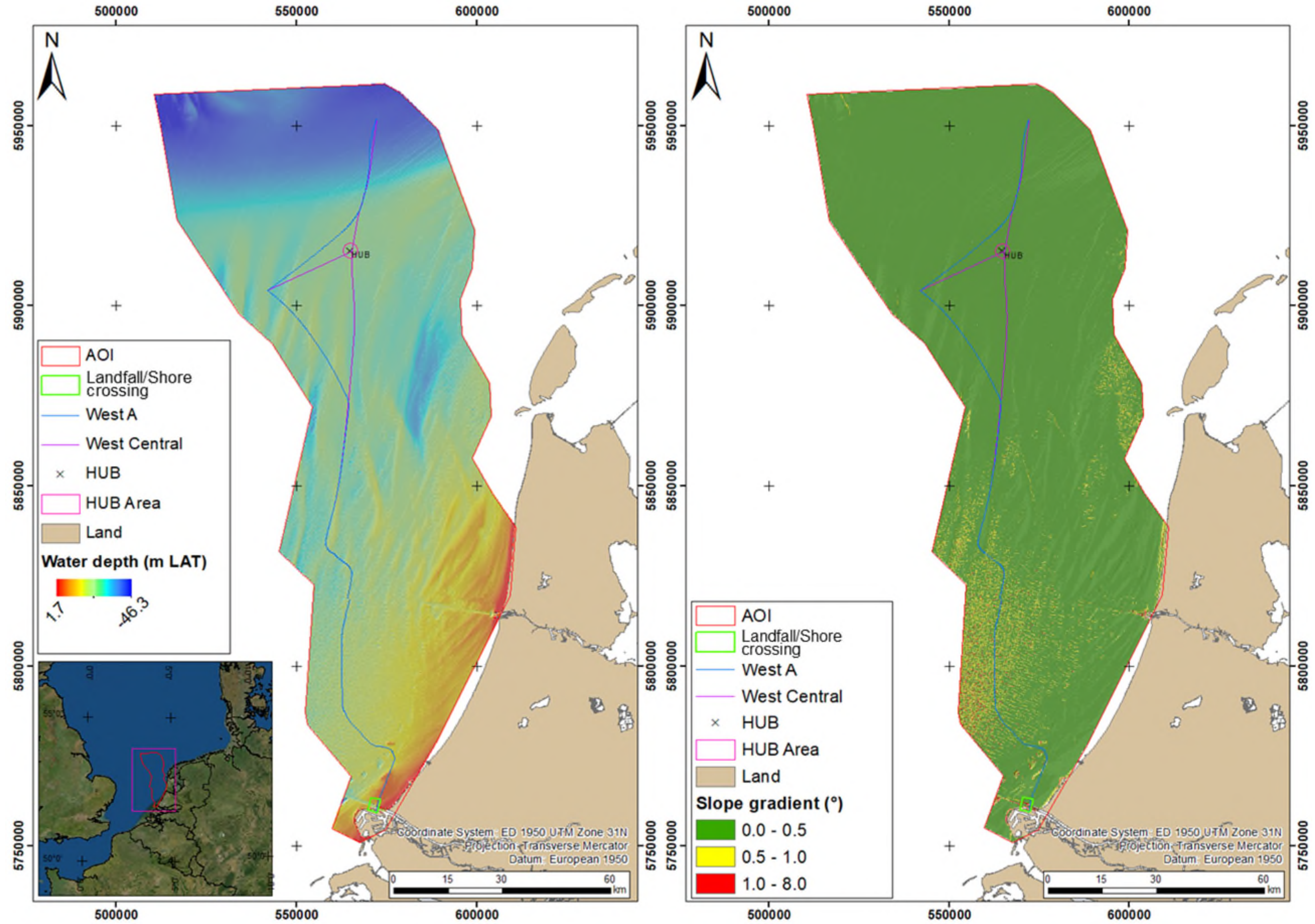


Figure 4.8: Left: bathymetric map and Right: slope gradient map of the entire AOI based on EMODnet 2020 data

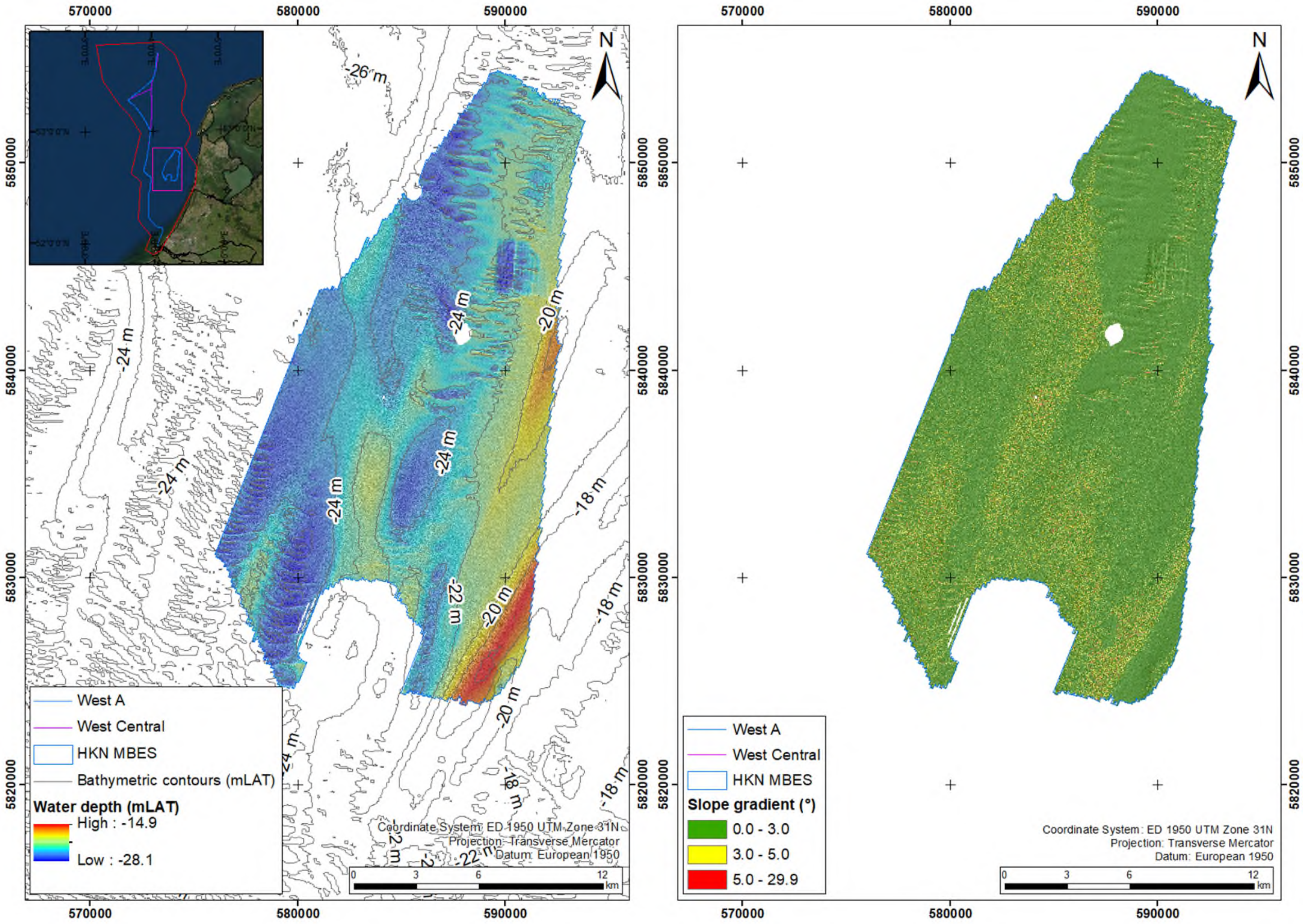


Figure 4.9: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (noord) WFZ area based on Fugro 2018 MBES data

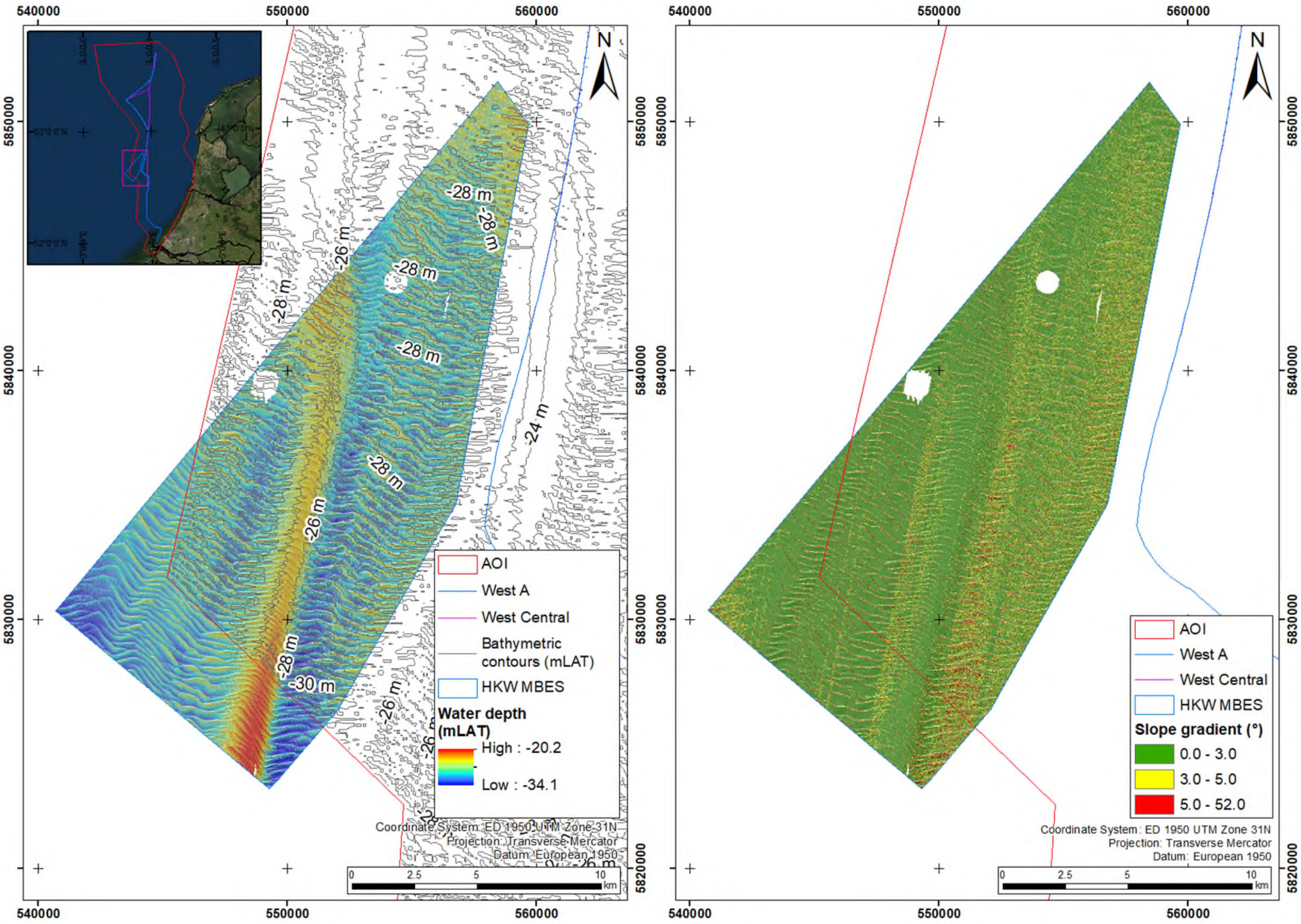


Figure 4.10: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (west) WFZ area based on Fugro 2019 MBES data

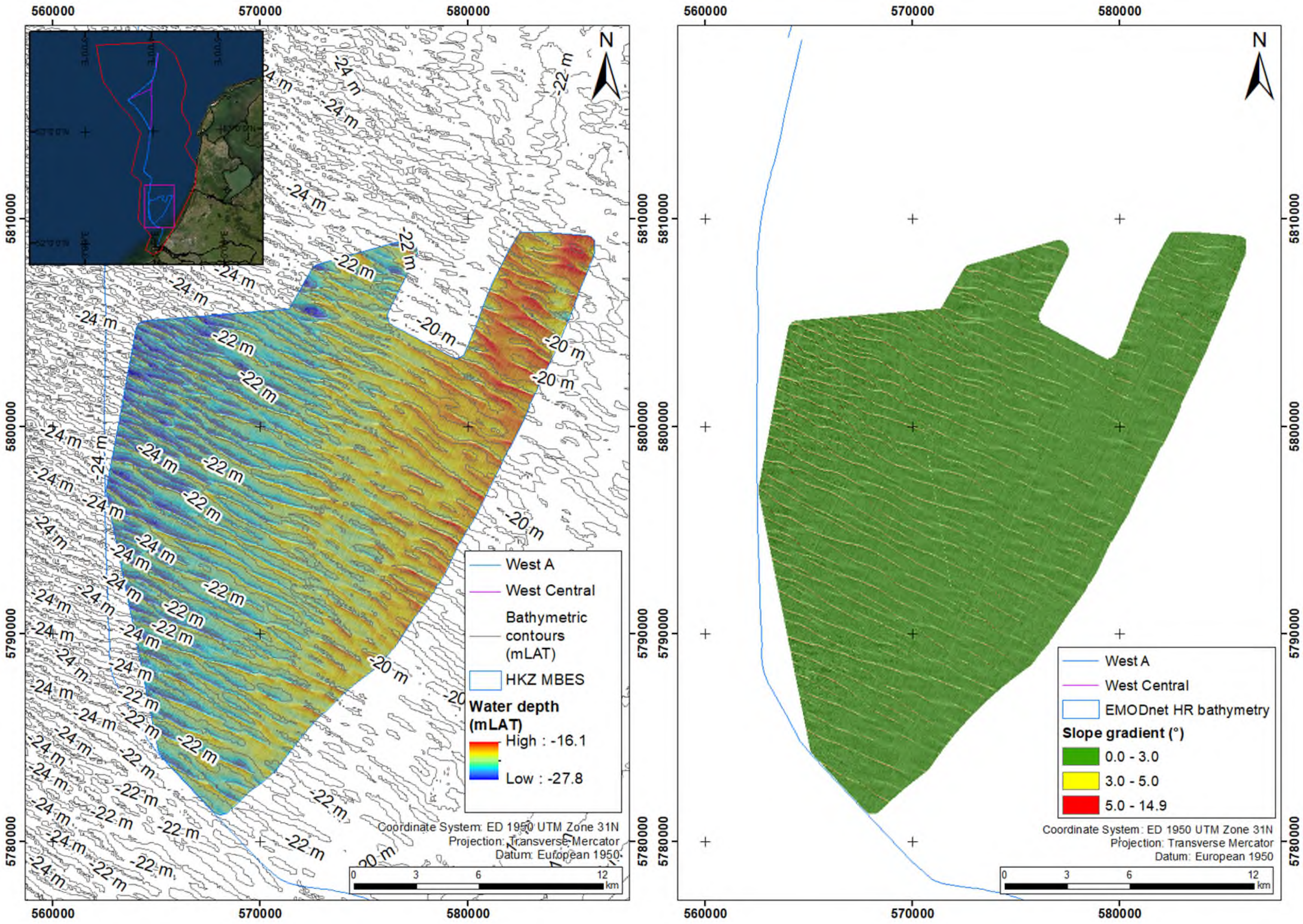


Figure 4.11: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (zuid) WFZ area based on Fugro 2016 MBES data

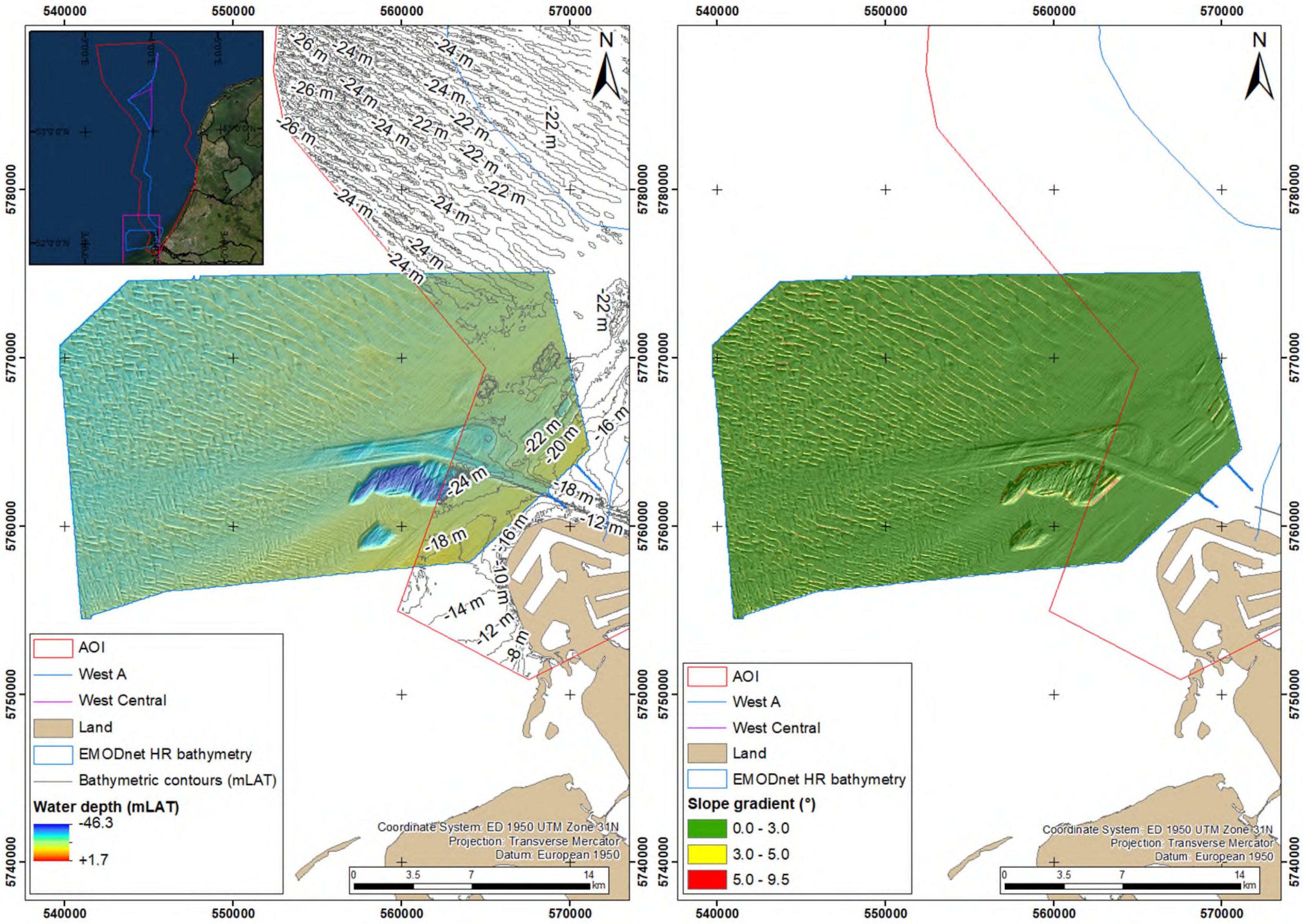


Figure 4.12: Left: bathymetric map and Right: slope gradient map of the Rotterdam approach area based on EMODnet 2020 high-resolution data

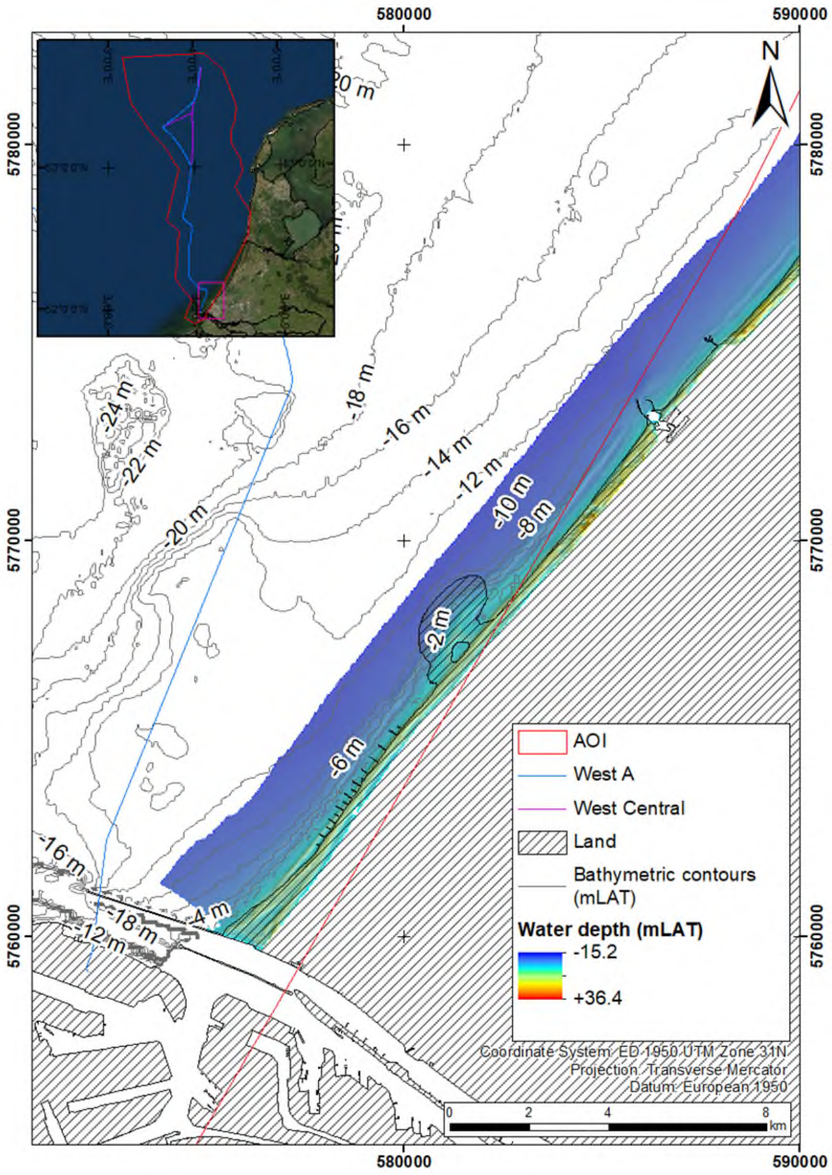


Figure 4.13: Left: bathymetric map and Right: slope gradient map of the southern coastal area based on EMODnet 2018 high-resolution data

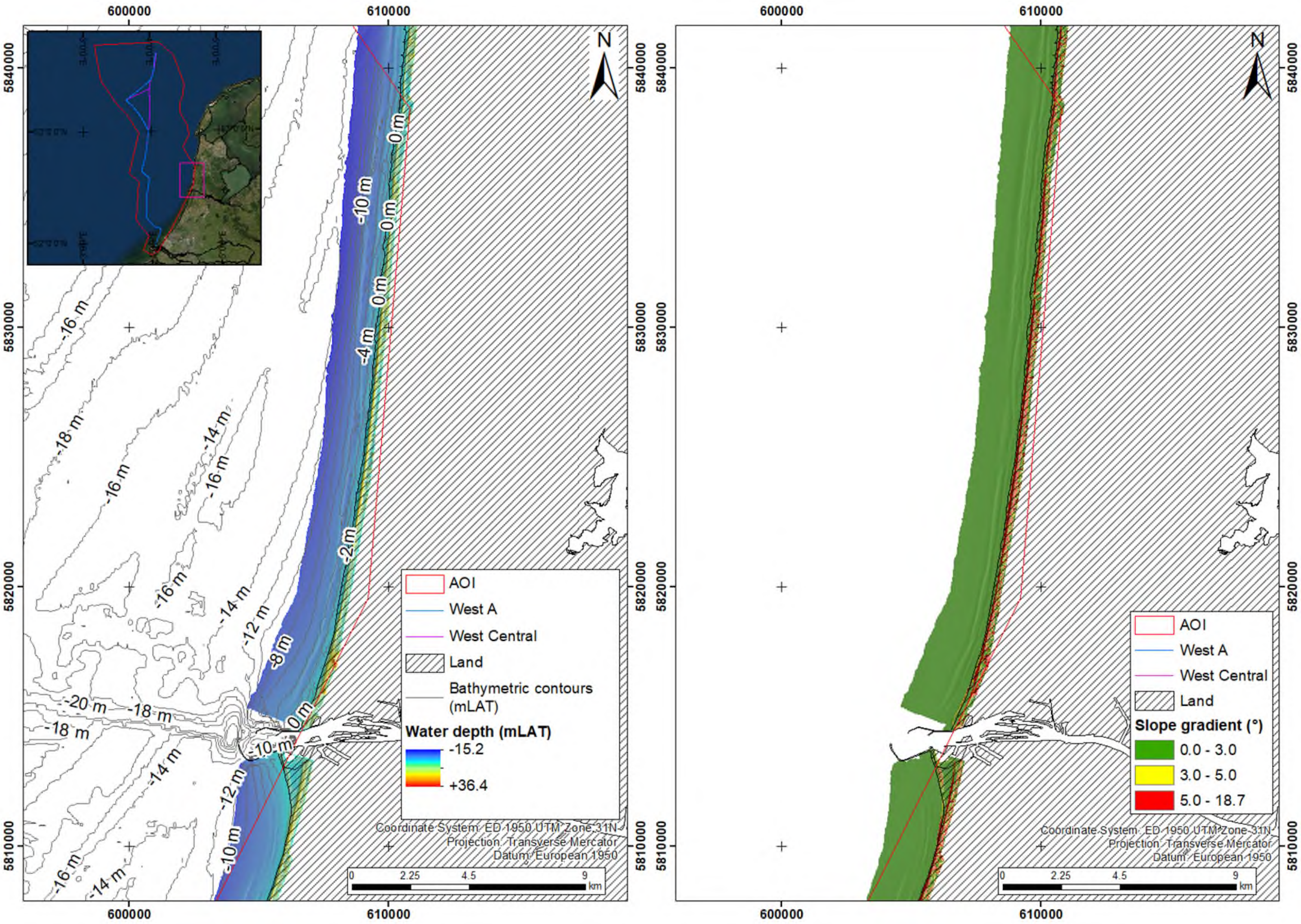


Figure 4.14: Left: bathymetric map and Right: slope gradient map of the northern coastal area based on EMODnet 2018 high-resolution data

4.2.1.2 Landfall/Shore Crossing Area

The Landfall/Shore crossing Area is covered by the EMODnet 2020 tile having a 100 m grid resolution.

Table 4.2 provides the water depth and slope gradient values for the Landfall/Shore crossing Area based on the available EMODnet data.

Table 4.2: Summary of water depths and seafloor gradients at the Landfall/Shore crossing Area

Area	Maximum Water Depth [m LAT]	Minimum Water Depth [m LAT]	Average Slope Angle [°]	Maximum Slope Angle [°]	Minimum Slope Angle [°]
Landfall/Shore crossing	-31.1	0	0.7	6.8	0
Notes: m LAT = metres Lowest Astronomical Tide Values derived from publicly available EMODnet (2020) bathymetry data, DTM with 100 m of grid resolution					

The bathymetric map for the Landfall/Shore crossing Area is given in Figure 4.15.

Water depth within the Landfall/Shore crossing Area varies between 0 m and 31.1 m bLAT. The major bathymetric feature in this area is the relatively deep navigation channel (Maasmond Kanaal). The navigation channel is well imaged by the EMODnet bathymetry data, forming a WNW–ESE oriented depression. The water depth at the edges of the Maasmond Kanaal is approximately 15 m bLAT, whereas in the navigation channel it is ranging between approximately 20 m 25 m bLAT. In local depressions within the Maasmond Kanaal water depths may exceed 30 m bLAT.

North of the navigation channel, no seafloor features are visible, and the seafloor gently dips from SE to NW ranging between 11 m to 18 m bLAT.

The slope gradients range from 0° to 7° with an average value of 0.7°. Slope gradients up to 20° are expected at the flanks of the navigation channel.

The southern flank of the Maasmond Kanaal appears regular, steep and narrow in the south-east and widens towards the south-west. The northern flank of the Maasmond Kanaal has locally an irregular shape, possibly as a result of slumping observed in this area. Seafloor gradients of up to 34° are related to these slumped areas (Fugro database).

A site-specific MBES survey across the entire Landfall/Shore crossing Area would allow to increase the resolution of these maps and highlight any features smaller than 100 m (which cannot be imaged based on the present data resolution).

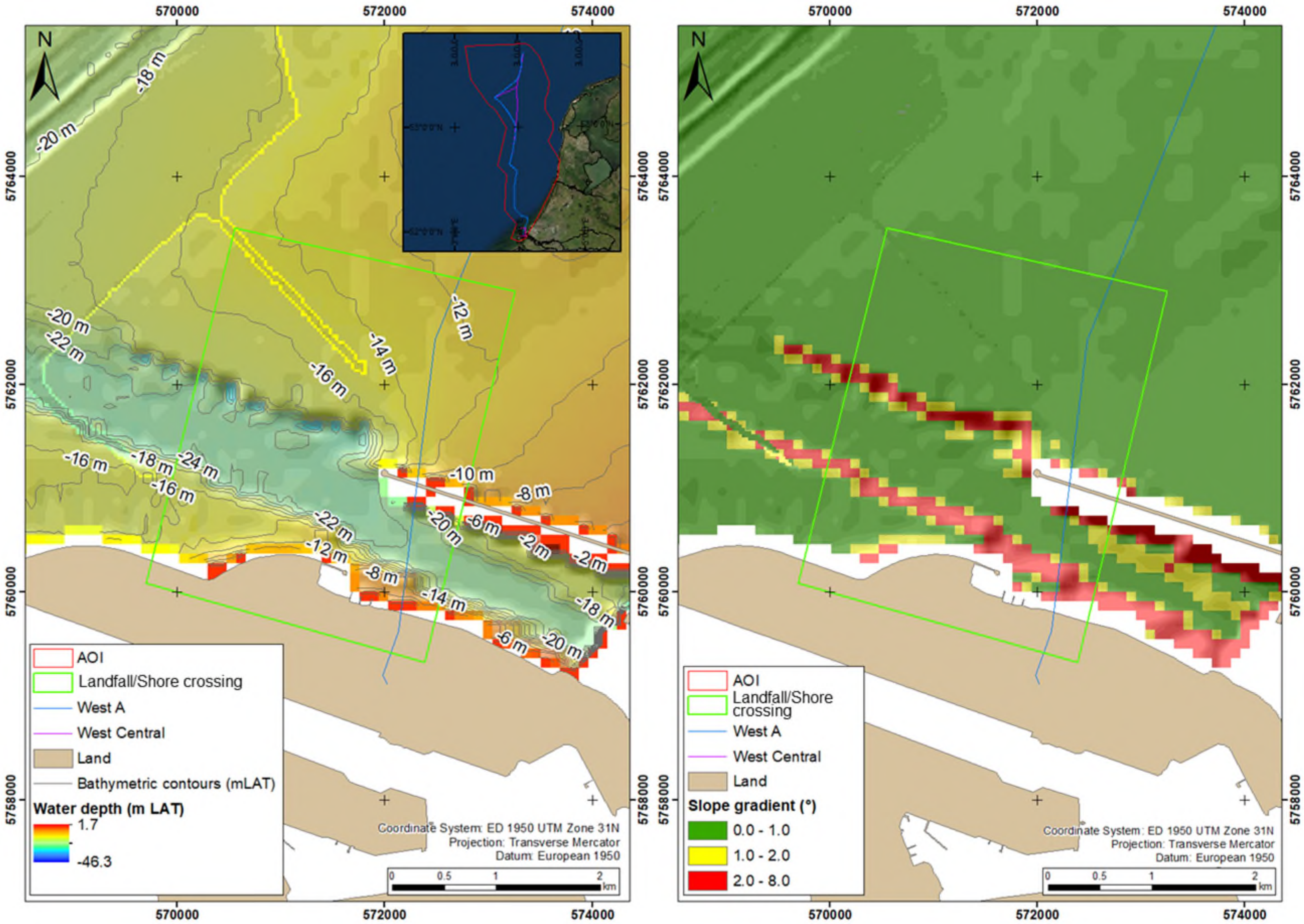


Figure 4.15: Left: bathymetric map and Right: Slope gradient map of the Landfall/Shore crossing Area based on the EMODnet 2020 data

4.2.1.3 Offshore Distribution HUB Area

The Offshore Distribution HUB Area is covered by the EMODnet 2020 tile having a 100 m grid resolution.

Table 4.3 provides the water depth and slope gradients values for the Offshore Distribution HUB Area based on the available EMODnet data.

Table 4.3: Summary of water depths and seafloor gradients at the Offshore Distribution HUB Area

Area	Maximum Water Depth [m LAT]	Minimum Water Depth [m LAT]	Average Slope Angle [°]	Maximum Slope Angle [°]	Minimum Slope Angle [°]
Offshore Distribution HUB Area	-26.2	-25.2	0.05	0.1	0

Notes:
m LAT = metres Lowest Astronomical Tide
Values derived from publicly available EMODnet (2020) bathymetry data, DTM with 100 m of grid resolution

Water depth within the Offshore Distribution HUB Area varies between 25.2 m and 26.2 m bLAT.

The bathymetric map for the Offshore Distribution HUB Area is given in Figure 4.16. The seafloor appears smooth, with a maximum water depth to the west of the Offshore Distribution HUB Area and minimum values to the north-east. No clear dipping trends can be noticed, except with bathymetric contours that tend to show that the Offshore Distribution HUB Area is crossed by a NE–SW oriented trough of less than 1 m deep (probably linked to a small seafloor bedform).

The slope gradients range from 0° to 0.1° confirming the presence of a flat and smooth seafloor. However, it has to be noted that slope gradients were computed based on the 100 m grid resolution bathymetry and that local features presenting higher seafloor gradients may occur.

A site-specific MBES survey across the entire Offshore Distribution HUB area would allow to increase the resolution of these maps and highlight any feature smaller than 100 m such as sand waves, megaripples and any other types of bedforms and seafloor obstructions that may occur.

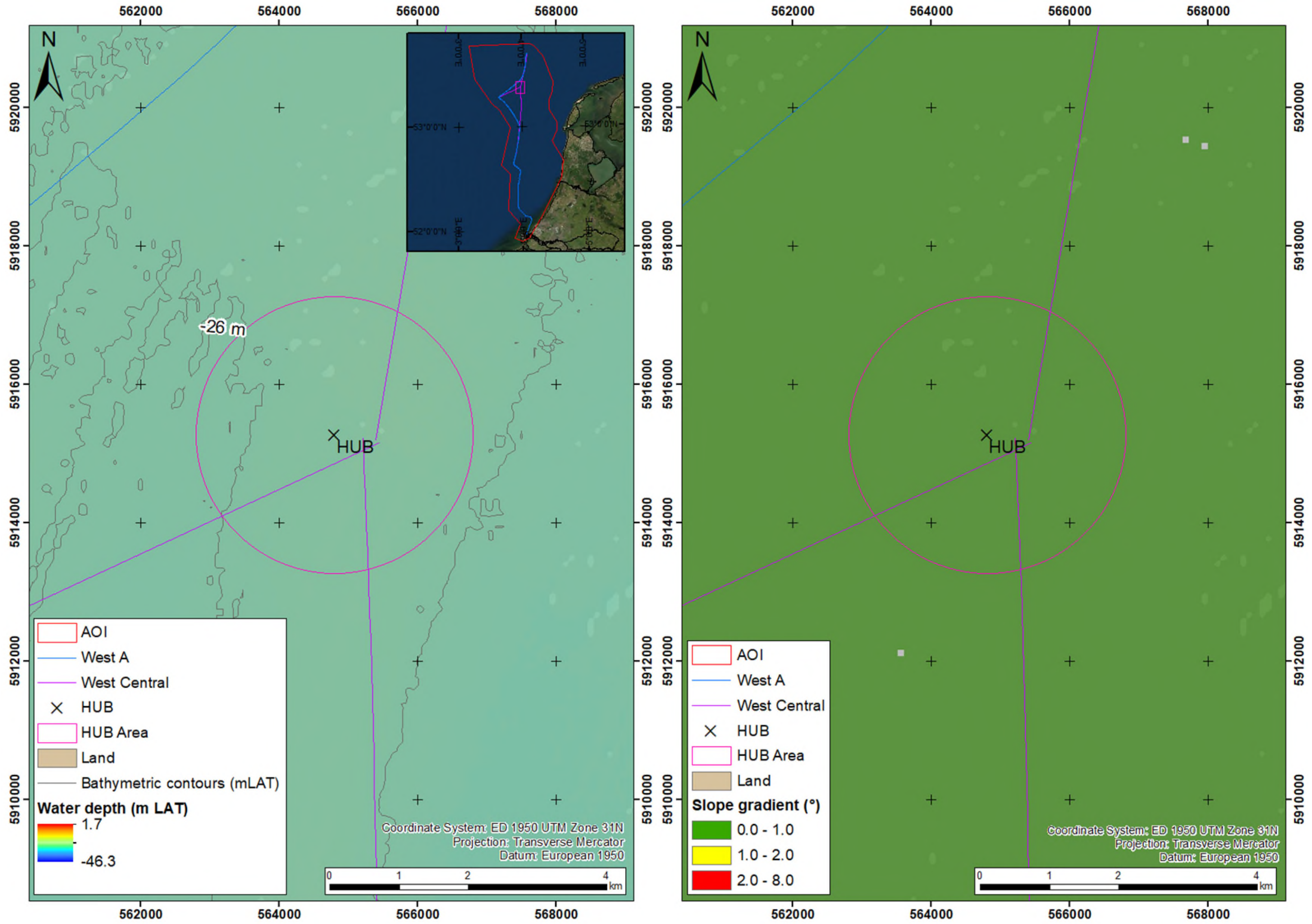


Figure 4.16: Left: bathymetric map and Right: slope gradient map of the Offshore Distribution HUB Area based on the EMODnet 2020 data

4.2.2 Seafloor Morphology

4.2.2.1 AOI

The seafloor morphology within the AOI can be divided into three distinct zones as illustrated in Figure 4.17: 1) a coastal zone covered by a complex compound of rhythmic bedforms, 2) a shallow continental shelf with low-angle topography covered by a complex compound of rhythmic bedforms, and 3) a relatively deep low-energy zone with low-angle topography (Figure 4.8).

The bedforms observed in Zones 1 and 2 include sand banks, sand waves, megaripples and ripples. These bedforms have been classified by Deltares (2016, 2019 and 2020), as part of morphodynamic desktop studies to aid development of the wind farms. The classification considers different parameters such as wavelength, wave height and mobility, which are the result of the complex interaction between hydrodynamics, sediment grain-size and character, sediment transport and morphology.

Below follows a more detailed description of the bedforms observed in the AOI. Table 4.4 summarises the characteristics of the different bedform types observed in the AOI.

Table 4.4: Bedform characteristics in the AOI

Type	Wavelength [m]	Wave Height [m]	Orientation
Sand bank	3000 to 10000	2.5 to 8	N–S to NNE–SSW
Sand wave	120 to 1750	0.5 to 6	NW–SE to WNW–ESE
Megaripple	4 to 20	0.1 to 0.4	NW–SE to WNW–ESE

Notes:
N: North S: South
E: East W: West

Bedforms across the AOI were mapped based on what is imaged on the EMODnet 100 m grid resolution data. Elements that were identified include sand banks, areas with sand waves as well as troughs and other depression features. Megaripples are below resolution of the EMODnet data. The resulting map is presented in Figure 4.8. The identified and expected bedforms across the AOI are further detailed hereafter.

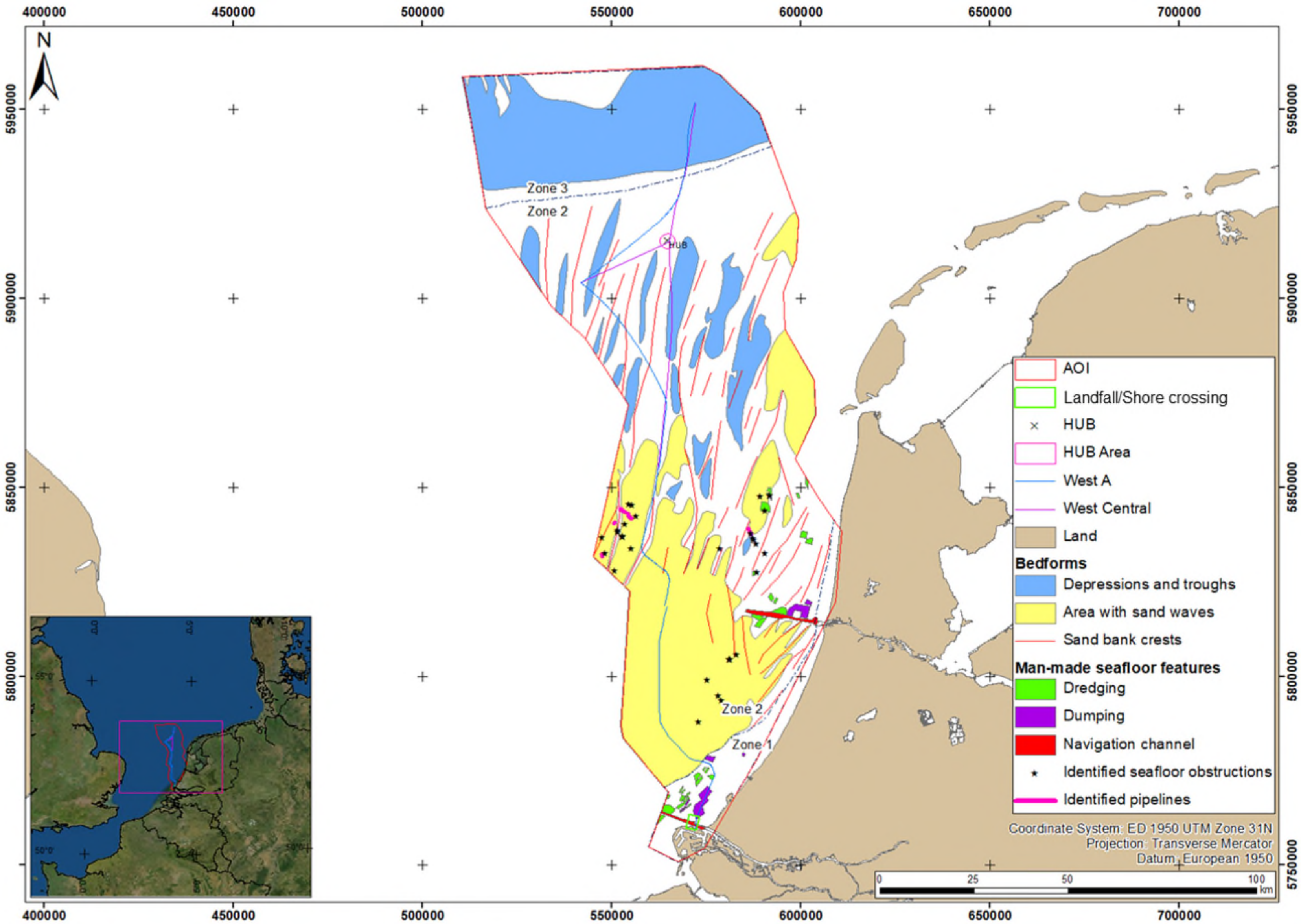


Figure 4.17: Map of the identified bedform and man-made seafloor features across the AOI

Sand Banks

The largest bedforms within the AOI are sand banks. They are present only in Zones 1 and 2 of the AOI (Figure 4.17). They form elongated ridges (sub-)parallel to the coast with a N–S to NNE–SSW orientation. The ridges are tens of kilometres long with a symmetric cross profile and lie several kilometres apart. They are on average 10 m high. An example of sand banks as imaged in Hollandse Kust (west) MBES data is given in Figure 4.18, with a bathymetric section perpendicular to the sand bank crest allowing to illustrate the morphology, height, and wavelength of sand banks in the AOI.

The sand banks are orientated roughly parallel to the main current direction (Hulscher et al., 1993). Near the coast they may be orientated more obliquely to the tidal current (Calvete et al., 2001). The sand banks closer to the shore are classified as tidal ridges (van Dijk et al., 2012). The formation of sand banks can broadly be divided into two categories (Dyer and Huntley, 1999):

- relict features, remaining after postglacial sea level rise;
- newly formed, in the present hydrodynamic regime.

The offshore sand banks may have formed during the early Holocene and the tidal ridges have been possibly formed more recently. Formation of tidal ridges is related to tidal currents in a tide-dominated coastal embayment (Ashley, 1990).

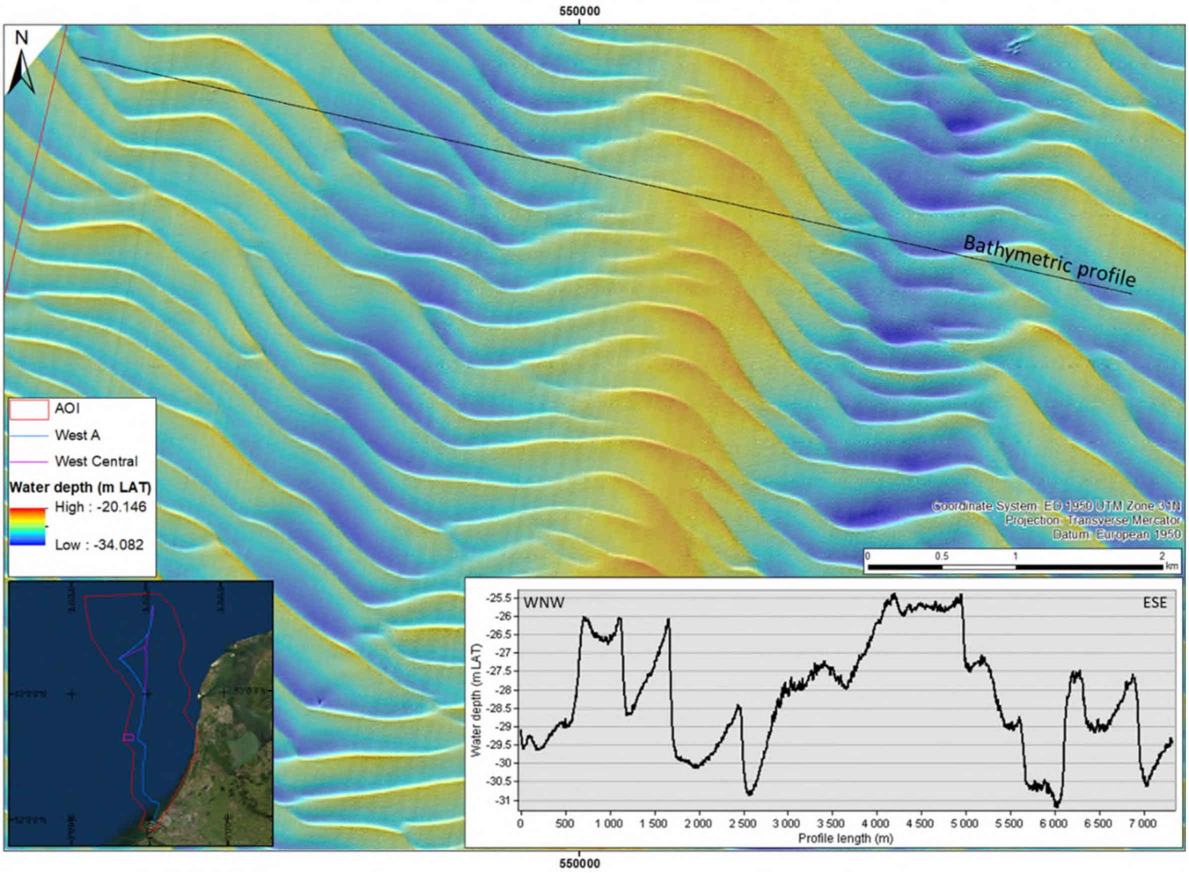


Figure 4.18: Example of sand banks with superimposed sand waves in the Hollandse Kust (west) WFZ as imaged on MBES bathymetry data. A bathymetric profile is given in a perpendicular direction to the sand banks.

Sand Waves

Sand waves are superimposed on the sand banks. They are observed in water depths of approximately 20 m to 28 m bLAT within Zones 1 and 2 of the AOI (Figure 4.17). The crests of the sand waves are orientated NW–SE to WNW–ESE, roughly perpendicular to the sand banks (see Figure 4.18). Their wavelength ranges between approximately 120 m and 1750 m, while wave height varies between 0.5 m and 4 m. The sand waves typically have an asymmetric profile with a lower angle stoss side and a steep lee side facing the direction of propagation. This morphology implies that the dominant migration direction is north to north-north-east (for sediment mobility refer to Section 4.3).

Sand waves are created due to tidal flow and may be as high as 25% of the water depth (McCave, 1971), and have wavelengths in the order of hundreds of metres (Ashley, 1990; van Dijk & Kleinhans, 2005; Deltares, 2016).

An example of sand waves as imaged in Hollandse Kust (west) MBES data is given in Figure 4.19, with a bathymetric section perpendicular to their direction, allowing to illustrate the morphology, height, and wavelength of sand waves in the AOI. Sand waves are also visible in Figure 4.18, perpendicular to the sand banks.

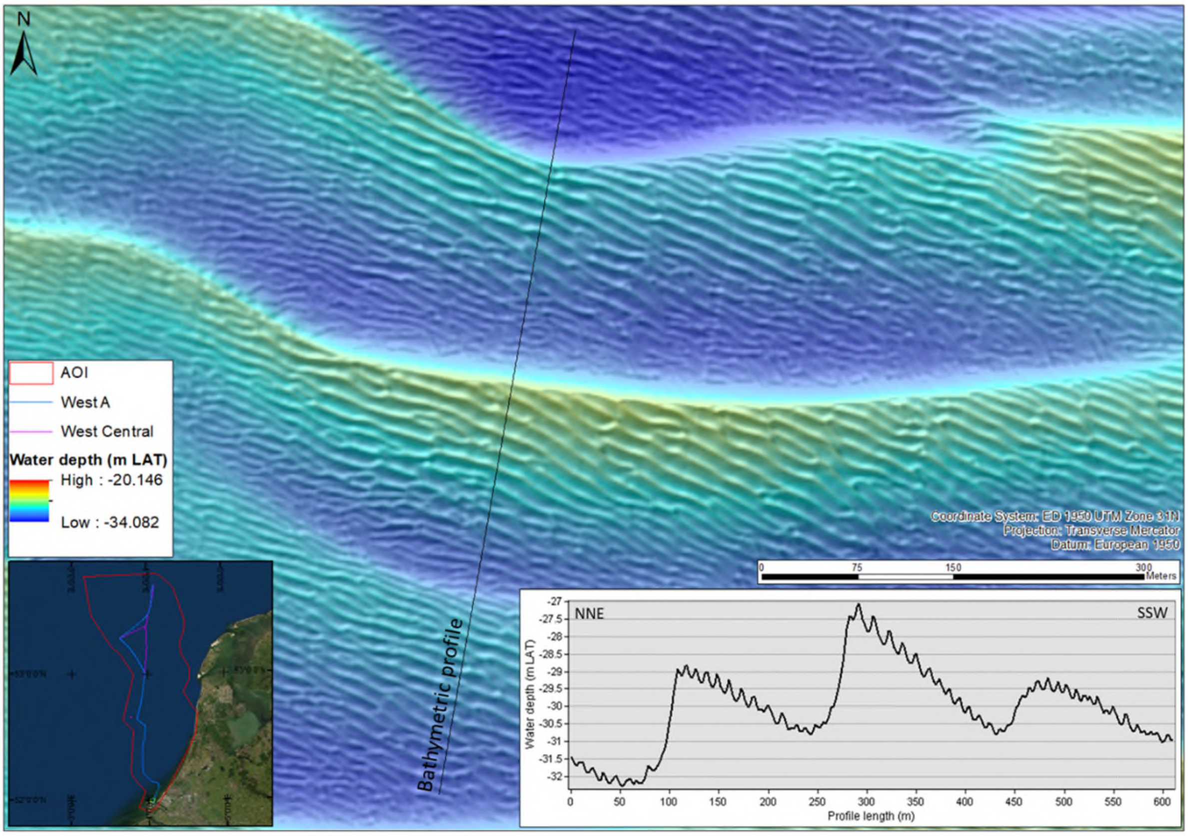


Figure 4.19: Example of sand waves with superimposed megaripples in the Hollandse Kust (west) WFZ as imaged on MBES bathymetry data. A bathymetric profile is given in a perpendicular direction to the sand waves.

Megaripples

High resolution bathymetry datasets for the wind farm sites located within the AOI allowed to capture the presence of megaripples. Megaripples are ubiquitous, superimposed on the stoss side of sand waves and are similarly orientated (Figure 4.19). They have wavelengths of approximately 4 m to 20 m, with heights between 0.1 m and 0.4 m.

An example of megaripples as imaged in Hollandse Kust (west) MBES data is given in Figure 4.19, with a bathymetric section perpendicular to their direction allowing to illustrate their morphology, height, and wavelength in the AOI.

Ripples

Ripples are the smallest bedforms, with dimensions in the order of centimetres. Because of their limited size, they cannot be observed in bathymetry data. They are superimposed on the megaripples and are similarly orientated. Because of their small size, ripples are not a concern for offshore pipeline design. They are, however, relevant for the seafloor roughness and sediment transport in the area (Deltares, 2020).

Troughs and Depressions

Troughs are linked to the presence of the sand banks in areas that are not affected by sand waves (deeper than 28 m bLAT). These troughs can be 4 m to 6 m deep and are elongated in a N–S direction (parallel to the sand banks). Where sand waves are present, these troughs were probably subsequently filled by sediments through the formation and evolution of the sand waves. Seafloor within the troughs appears to be smooth and regular on the EMODnet bathymetry. Troughs are only found in Zone 2 of the AOI as mapped in Figure 4.17.

Moreover, the northern depression (Zone 3) is characterised by a smooth seafloor and no bedform is imaged at the resolution of the EMODnet bathymetry. This is probably linked to the sudden increase of water depth (from 30 m bLAT to 42 m bLAT).

4.2.2.2 Landfall/Shore crossing Area

No bedforms were imaged at the EMODnet 2020 grid resolution of 100 m in the Landfall/Shore crossing Area. A site-specific MBES survey will provide a higher resolution, potentially imaging small-scale bedforms such as megaripples or ripples.

4.2.2.3 Offshore Distribution HUB Area

No bedforms were imaged at the EMODnet 2020 grid resolution of 100 m in the Offshore Distribution HUB Area. However, the Offshore Distribution HUB Area is located within an area containing sand banks (Zone 2), to the north of a trough (Figure 4.17). As the sand banks are the largest expected bedforms in the AOI (Table 4.4), it is likely that the Offshore Distribution HUB Area is too small to capture the typical sand bank morphology entirely. A site-specific MBES survey will provide a higher resolution, potentially imaging small-scale bedforms such as sand waves and/or megaripples.

4.2.3 Seafloor Sediments

4.2.3.1 AOI

An overview of the substrate type classification (Folk, 1954) is presented in Figure 4.20 (EMODnet). The seafloor sediments map is corroborated by information contained in the DINOloket (2021) database, which includes grab sample data, vibrocore data and sampling borehole data. In addition, seafloor sediments were mapped in high detail at the Hollandse Kust (noord), Hollandse kust (west) and Hollandse Kust (zuid) WFZs.

The following seafloor sediments are present in the AOI:

- Sandy GRAVEL
- (Slightly) gravelly SAND
- (Slightly) gravelly muddy SAND
- SAND
- Muddy SAND
- Sandy MUD

MUD is defined in the geological maps as the fraction composed of clay-sized to silt-sized sediments.

The AOI is covered by predominantly SAND with numerous patches of (slightly) gravelly SAND. North of the Offshore Distribution HUB Area, the seafloor comprises mainly muddy SAND with some patches of (slightly) gravelly muddy SAND and sandy MUD. This area with a higher MUD fraction coincides with the deeper low-energy marine environment as described in Section 4.2.2.1. Areas of (slightly) gravelly SAND correspond to areas where sand banks and sand waves are expected based on Figure 4.17 and Figure 4.20.

In terms of expected stratigraphy at the seafloor, three main Holocene units were mapped (Figure 4.21):

- Southern Bight Formation, deposited in a high-energy open-marine environment, mainly composed of SAND to (slightly) gravelly SAND, distributed in Zone 2 of the AOI;
- Urania Formation, deposited in a low-energy open-marine environment mainly composed of sandy MUD to muddy SAND, covering Zone 3 entirely;
- Naaldwijk Formation, deposited in a coastal to tidal-dominated environment and is mainly composed of (slightly) gravelly SAND, covering Zone 1 (not completely mapped).

Fugro recommends acquiring site-specific geotechnical data along the final pipeline layout prior to pipe installation in order to verify and refine the seafloor sediment types.

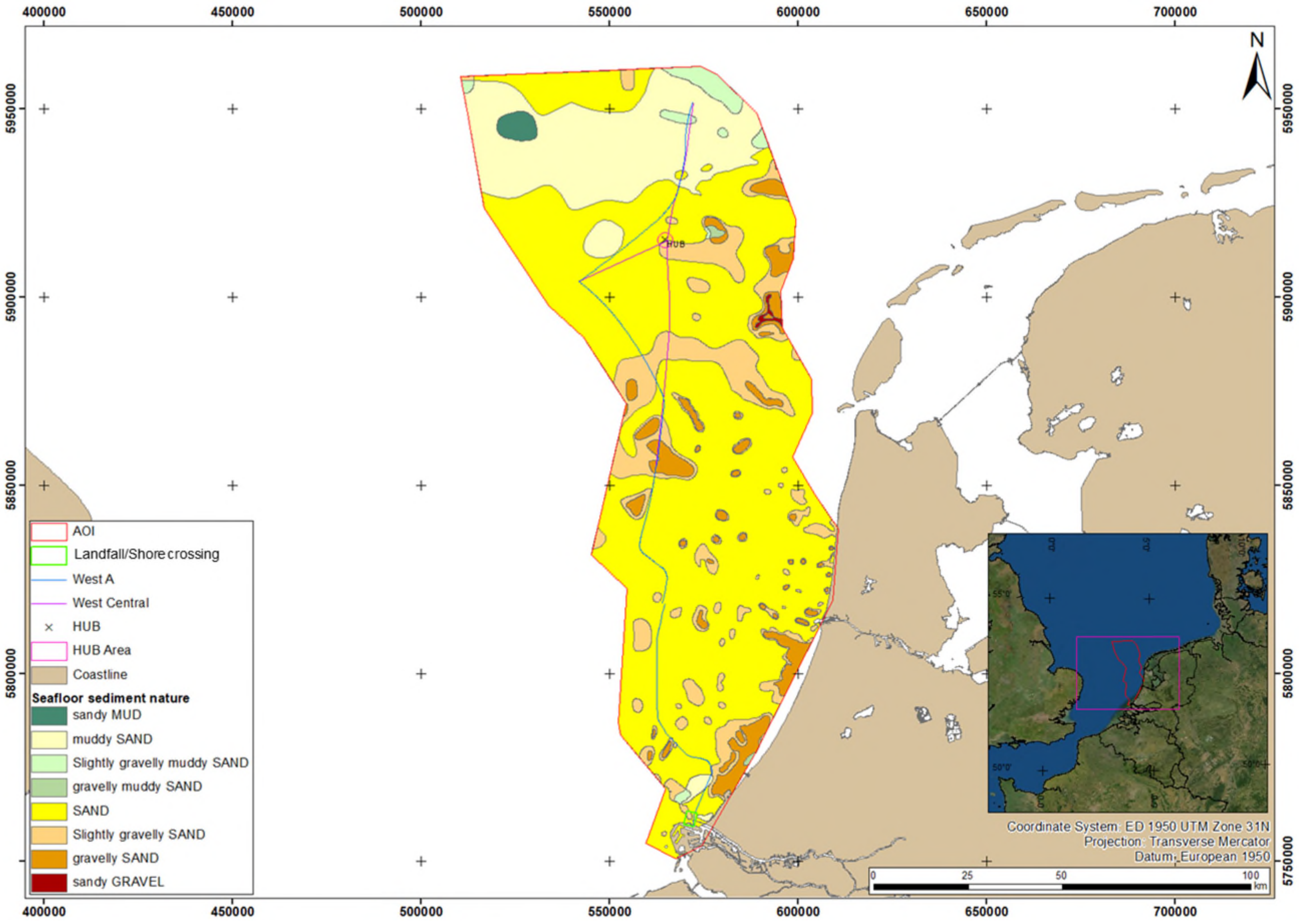


Figure 4.20: Surficial sediments across the AOI

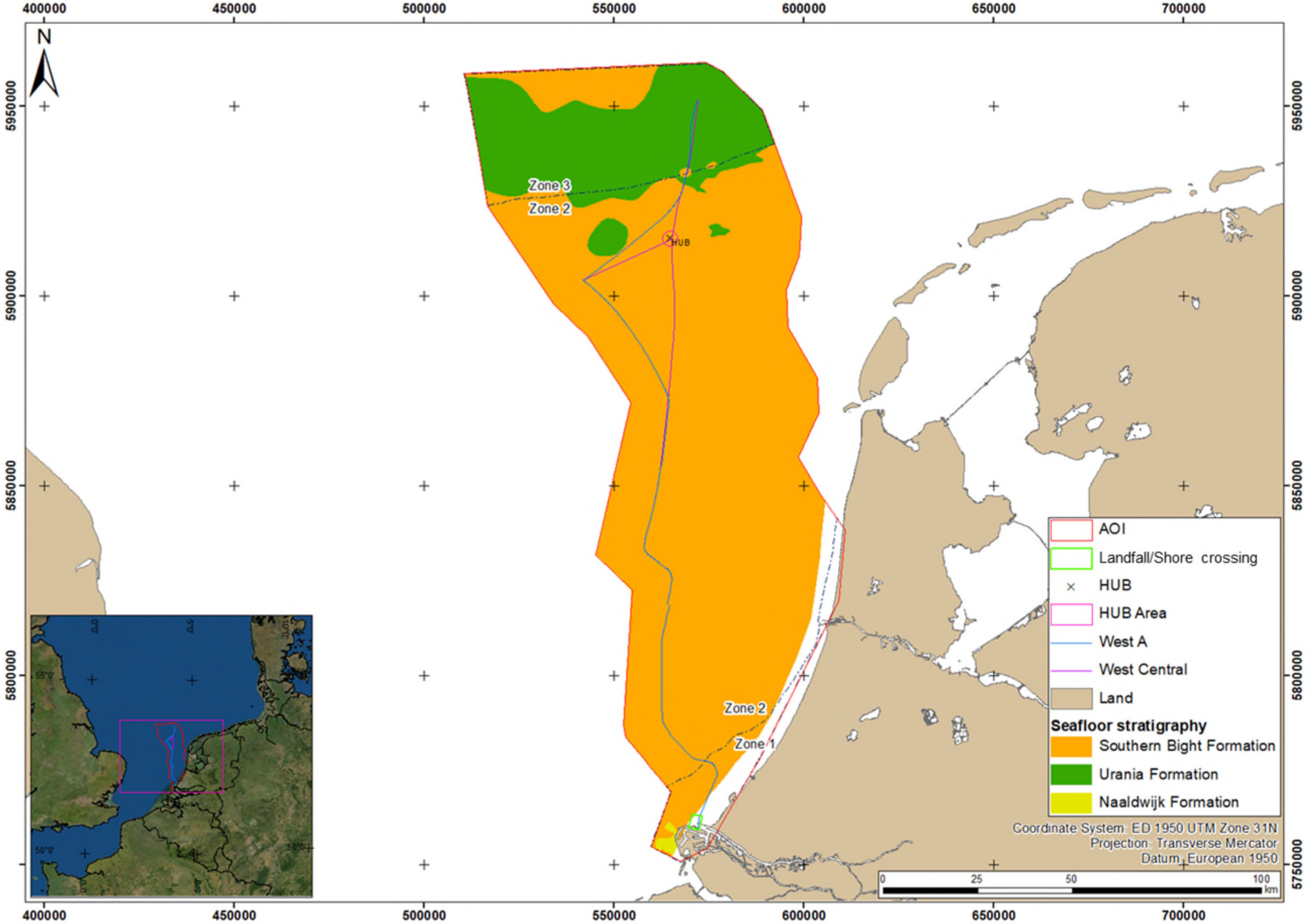


Figure 4.21: Surficial sediment stratigraphy across the AOI. Coverage is missing along the coastal area. In this area the Naaldwijk Formation is expected

4.2.3.2 Landfall/Shore Crossing Area

Two main seafloor sediment types are to be expected in the Landfall/Shore crossing Area (Figure 4.22):

- SAND;
- Slightly gravelly SAND, in the north-west corner.

Based on Fugro experience, clayey or silty SAND, locally slightly gravelly dominates at seafloor in areas outside the Maasmond Kanaal. In the Maasmond Kanaal very soft to soft CLAY dominates, with localised patches of clayey SAND.

Site-specific geotechnical surveys would allow to refine the sediment nature within the Landfall/Shore crossing Area.

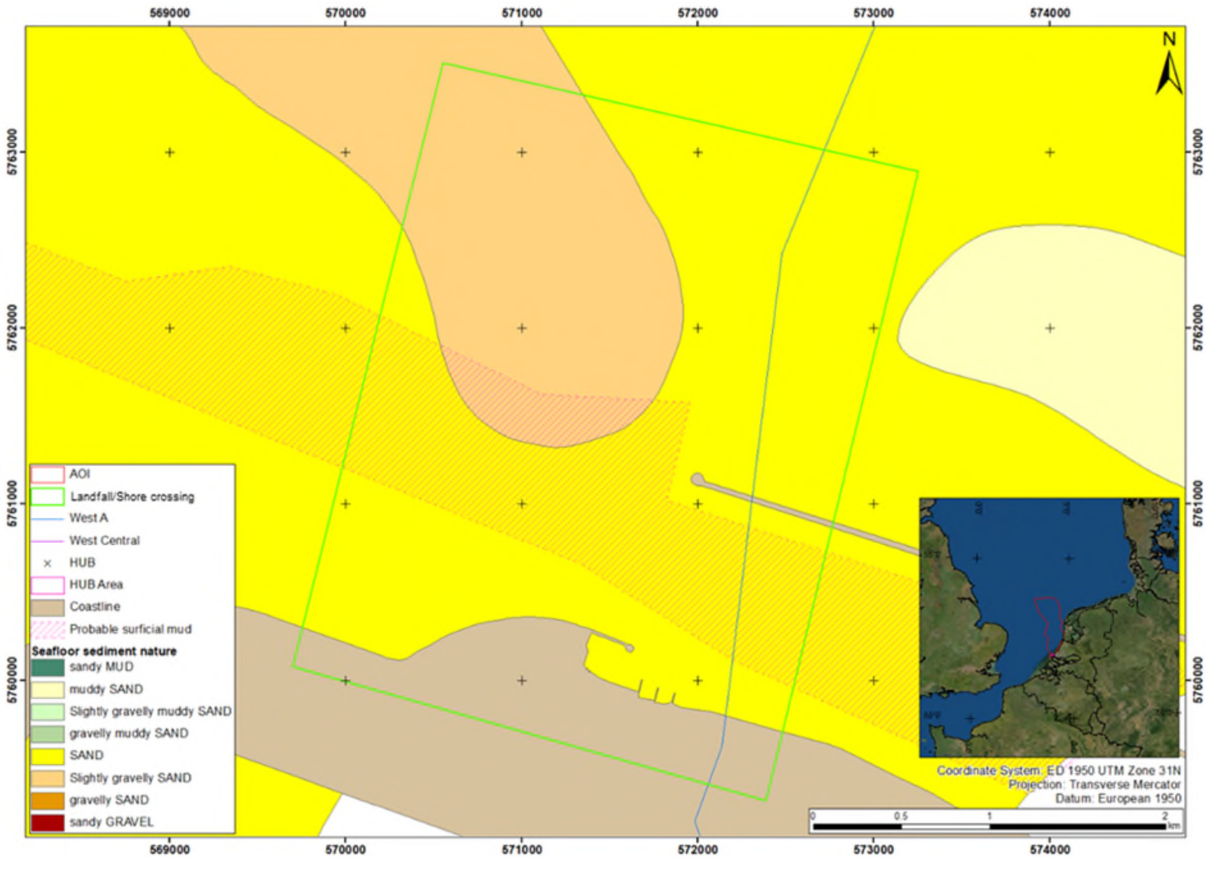


Figure 4.22: Surficial sediment nature across the Landfall/Shore crossing Area

4.2.3.3 Offshore Distribution HUB Area

The Offshore Distribution HUB Area comprises two main seafloor sediment types that are presented in Figure 4.23:

- SAND;
- Slightly gravelly SAND, in the south.

Site-specific geotechnical surveys would allow to refine the sediment nature within the Offshore Distribution HUB Area.

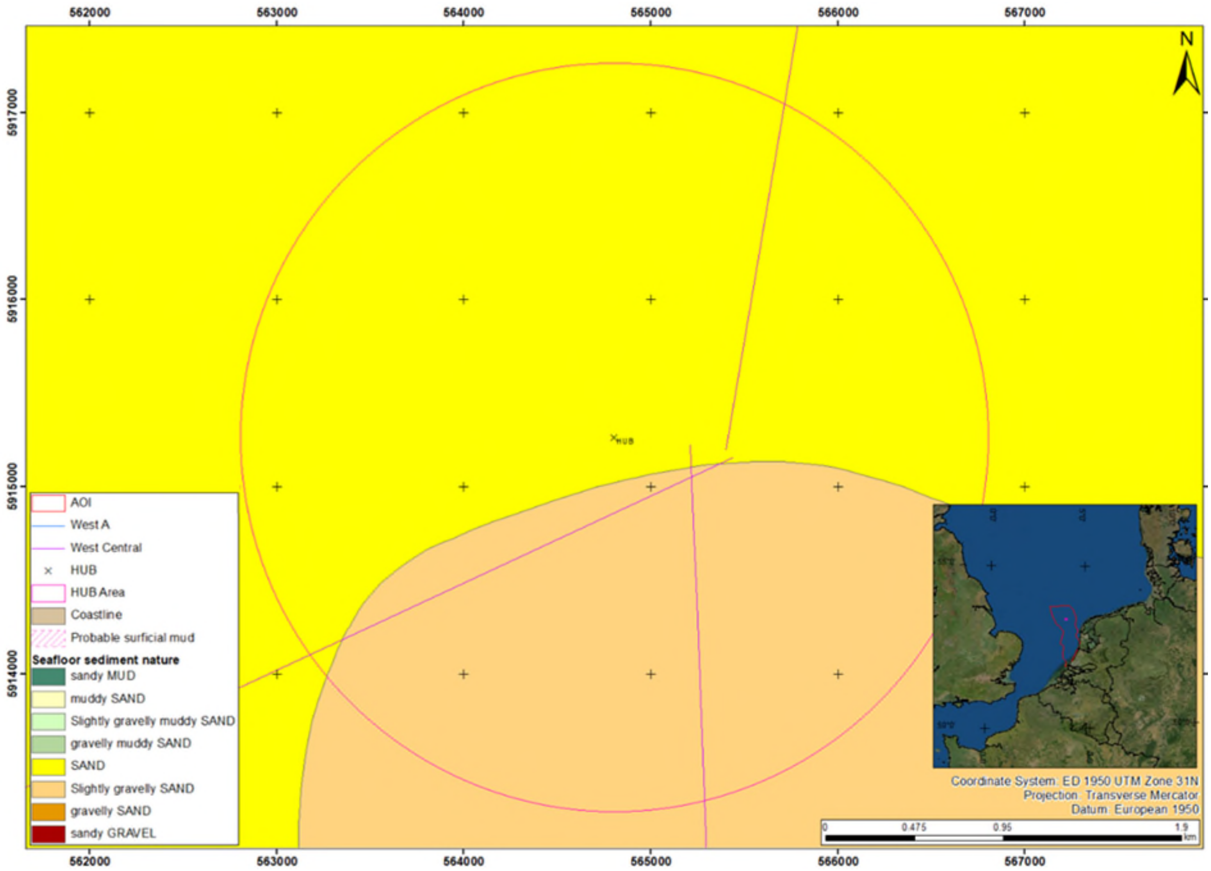


Figure 4.23: Surficial sediment nature across the Offshore Distribution HUB Area

4.2.4 Man-Made Seafloor Features

4.2.4.1 AOI

Man-made seafloor features were identified in the different bathymetric data. These features include:

- Unidentified seafloor obstructions (including probably several wrecks and wellheads);
- Pipelines;
- Dredged areas;
- Dumped material;
- Navigation channels.

These elements were mapped and are displayed in Figure 4.17. The man-made obstructions could only be mapped on the high-resolution MBES data. More details on the man-made obstructions are provided in the UXO and Archaeological DTS reports (Appendix C and Appendix B).

4.2.4.2 Landfall/Shore Crossing Area

The Maasmond Kanaal navigation channel and a dumping area were recognised within the Landfall/Shore crossing Area as mapped in Figure 4.24. In addition, ROCK dumps related to coastal defence structures are present on the shores of the Maasmond Kanaal as well as numerous seafloor scars related to dredging operations (Fugro database).

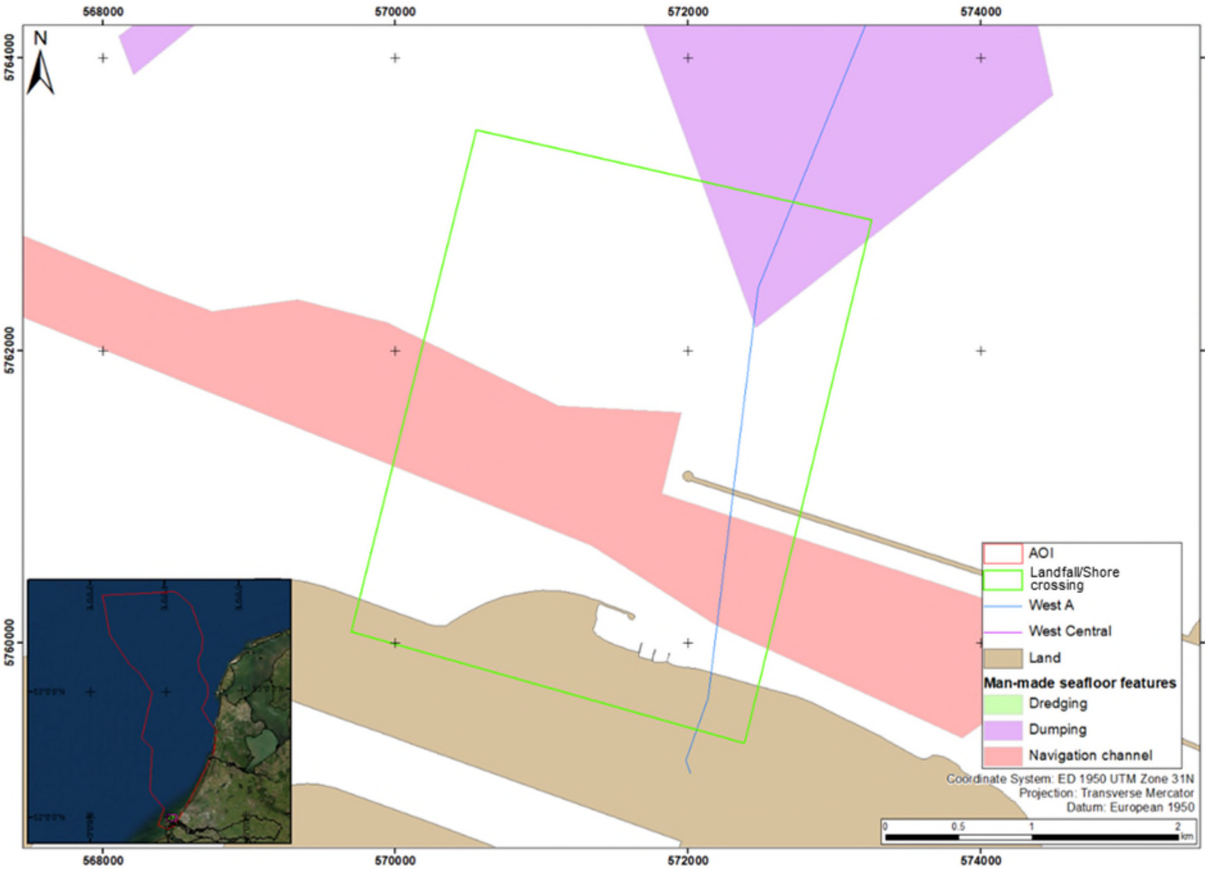


Figure 4.24: Surficial sediment nature across the Landfall/Shore crossing Area

4.2.4.3 Offshore Distribution HUB Area

No man-made seafloor features were recognised within the Offshore Distribution HUB Area.

4.3 Seafloor Mobility

The high availability of sand at seafloor facilitates the formation of dynamic bedforms (refer to Section 4.2.2 for description of bedforms), which are mobile in response to (tidal) currents.

Sand waves and sand banks have dimensions that are significant for pipeline foundation design, while megaripples and ripples are perceived as not having a significant impact. The sand banks are considered stationary over the lifetime of a pipeline, whereas the sand waves may migrate at a speed up to tens of metres per year (van Dijk & Kleinhans, 2005; Dorst et al., 2009; van Santen et al., 2011) and cause metres-scale vertical seafloor variations over the lifetime of a pipeline.

If sand waves are removed by dredging, they may regenerate within a period of years (Knaapen and Hulscher, 2002). This is illustrated in Figure 4.25, where sand waves appear to be building back within a former dredging area.

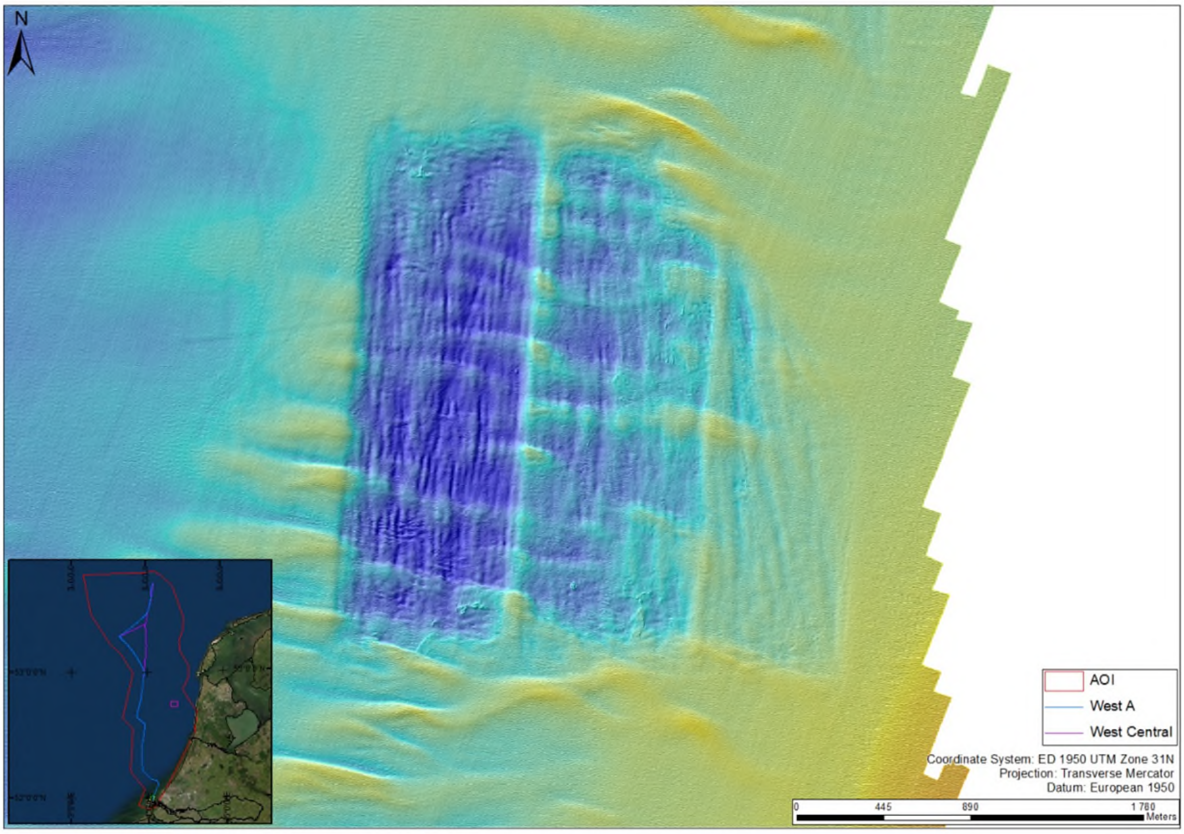


Figure 4.25: Former dredging area where sand waves are building back , as imaged in Hollandse Kust (noord) MBES bathymetry

Table 4.5 provides a summary of sand wave migration rates based on a selection of studies performed in the southern North Sea.

Table 4.5: Sand wave migration rates in the southern North Sea

Location	Average Migration Rate [m/year]	Source
Hollandse Kust (noord) WFZ	1.9 to 5.4	Deltares (2019)
Hollandse Kust (west) WFZ	1 to 3.9	Deltares (2020)
Hollandse Kust (zuid) WFZ	1 to 2.6	Deltares (2016)
Prinses Amalia OWF	4	Deltares (2017)
Luchterduinen OWF	2 to 3	Deltares (2017)
Texel	> 20	Van der Meulen et al. (2004)
Rotterdam Harbour	0	Van der Meulen et al. (2004)
Belgian Sector	1 to 4	Fugro database
UK Sector – east of Norfolk Banks	0 to 4	Fugro database

Typical sand wave migration rates in the southern North Sea are between 1 m/year to 10 m/year and in exceptional cases, as for example coastal zones, up to 20 m/year (Deltares, 2020). The sand wave morphology indicates that the dominant migration direction in the North Sea is to the north-north-east.

The migration rates of sand waves vary spatially and over time. In general sand waves in shallower water depths, e.g., on top of the sand banks migrate faster than in the deeper parts and locally migration speeds as high as 9.0 m/year are observed (Deltares, 2019).

The migration distance may increase in the event of storms or exceptional weather surge. Winter storm events can change the morphology of sand waves. For example, sediment can be transported from crest to trough, decreasing the height of bedforms. Additionally, megaripples and ripples may be smoothened. These small-scale bedforms will reappear once the rhythmic currents' regime is re-established (Deltares, 2016).

Van der Meulen et al. (2004) reported a migration rate of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 m/year) field near the Rotterdam harbour. Migration rates in the Prinses Amalia offshore wind farm (OWF) and Luchterduinen OWF, located in the centre of the AOI, were assessed to be in the order of 4 m/year and 2 m to 3 m per year, respectively.

Fugro performed several seafloor mobility studies in the North Sea, which included comparison of MBES data between different years. For example, in the Belgian sector, MBES data acquired 3 years apart revealed sand wave migration rates in the order of 1 m to 4 m per year. In the UK sector, east of Norfolk Banks, the MBES data between consecutive years revealed sand waves migration rates from 0 m to 4 m per year.

4.4 Sub-seafloor Conditions

Section 3 provides background information on the regional geological setting. The following sections provide project-specific results on sub-seafloor conditions. The Stratigraphic

Nomenclature by TNO – the Geological Survey of the Netherlands is used and is available on the DINOloket website (TNO-GDN, 2022).

4.4.1 AOI

The expected geological formations that occur in the AOI and description of the lithologies associated with these formations are summarised in Table 4.6. Included are the expected thickness ranges and distribution of the formations across the AOI. The expected thickness values are based on Cameron et al. (1984; 1986), Laban et al. (1992), Laban (1995), Fugro (2019a, 2020) and DINOloket (2022). The distribution of the geological formations was compiled from maps by Cameron et al. (1984, 1986), Harrison et al. (1987), Balson et al. (1991), Laban (1995), NITG–TNO (2004b, 2004d) and Laban & van der Meer (2011), which are stored in the GIS database for easy access.

To illustrate the subsurface stratigraphy a schematic profile from northern part of the AOI is provided on Figure 4.27. Figure 4.26 shows a detailed interpreted seismic profile taken from the Hollandse Kust (west) WFZ (Fugro, 2020) situated in the central-west part of the AOI.

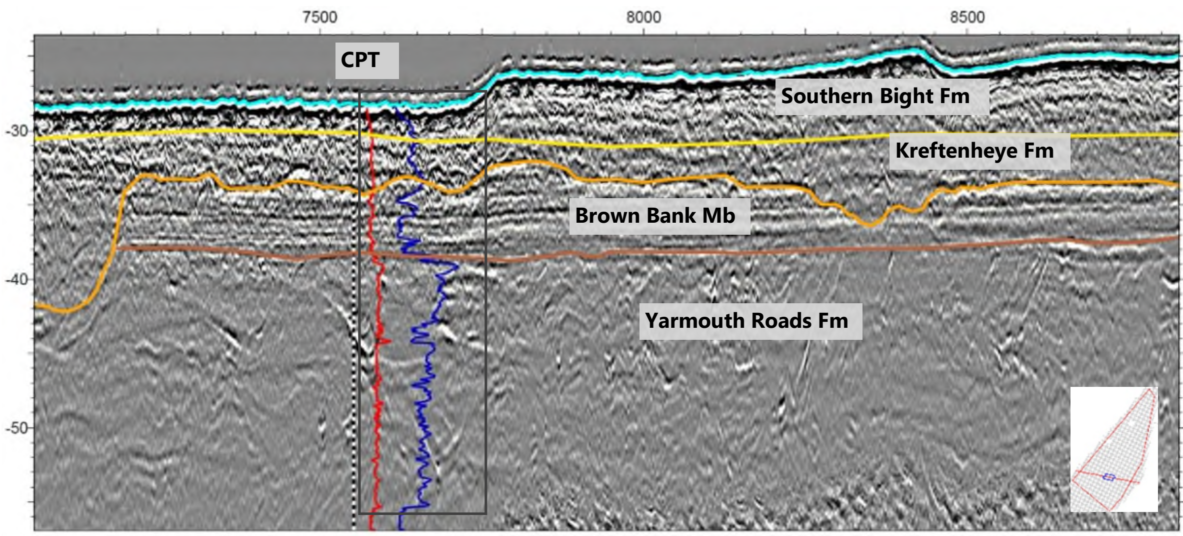


Figure 4.26: Example seismic reflection (2DUHR) cross section within the Hollandse Kust (west) WFZ (modified from Fugro, 2020). *Vertical scale is in metres reduced to LAT. The horizontal scale shows relative distance in metres along the seismic line. Width of the Cone Penetration Test (CPT) box shows cone resistance values (blue curve) within range of 0 to 60 MPa and sleeve friction values (red curve) from 0 to 1 MPa*

Maps showing distribution of the geological formations are provided in the following figures:

- Figure 4.21 shows the geological formations occurring at the seafloor;
- Figure 4.28 shows the thickness of the Holocene;
- Figure 4.29 shows distribution of the Late Pleistocene formations (directly below Holocene sediments);
- Figure 4.30 shows distribution of the Early to Middle Pleistocene formations, from the Drente Formation (Gieten Member) down to the Yarmouth Roads Formation;
- Figure 4.31 shows the distribution of the Early Pleistocene formations, comprising the Peelo Formation and the Yarmouth Roads Formation.

Note that the formations may have a larger extent than indicated on these figures (display effect—younger formation may partially cover the older formation). Refer to the GIS database for their full extents.

Table 4.6: Overview of the stratigraphy in the AOI specifying the geological units present

Age	Geological Formation / *Member**	Expected Thickness Range [m]	Soil Type†	Depositional Environment	Distribution and Comments
Holocene	Southern Bight	0 to 25	Very loose to very dense, fine to coarse SAND with shells and shell fragments, locally silty	High energy open marine	Present across the entire AOI, except the depression in the north and locally in the south The unit is thicker at the crests of the sand waves and thinner in the troughs between them. The maximum thickness is approximately 10 m. The extreme values are reached locally in the coastal area
Holocene	Urania	0 to 7	Very soft to soft (sandy) CLAY or very loose to medium dense (clayey) SAND	Low energy open marine	Present in the depression in the north
Early Holocene	Naaldwijk	0 to 15	Medium dense to very dense fine to medium (clayey) SAND and/or loose to medium dense (sandy) SILT or soft (low strength) CLAY, locally with beds of PEAT, locally thin beds of gravelly sand	Coastal to tidal	Present locally across the entire AOI, mostly as infill in shallow paleo-channels, which are highly variable in lateral and vertical extent. In general, the unit is more extensive and increase in thickness towards the coastline.
Weichselian	Boxtel (Twente)	0 to 5	Medium dense to very dense fine SAND, with minor intercalations of clay, silt, gravel and/or peat	Periglacial, aeolian	Patchy distribution across the AOI
Weichselian	Kreftenheye	0 to 25	Dense to very dense fine to medium SAND, with locally beds of gravelly sand, silty clay, clayey peat	Glaciofluvial to fluvial	Mainly present in the southern half of the AOI. Reaches maximum thickness in the southern part (Landfall/Shore crossing Area) and is absent in the northern part of the AOI
Late Eemian to Early Weichselian	Eem / *Brown Bank* (Brown Bank)	0 to 20	Firm to very stiff calcareous CLAY or SILT, with extremely closely to very closely spaced laminae to thick beds of sand	Brackish marine lagoonal to lacustrine	Present in the north-western part of the AOI. The unit reaches largest thickness (>10 m) very locally, where it forms infill of channelling features
Eemian	Eem	0 to 15	Medium dense to very dense fine SAND with shells and shell fragments; locally clay and silt beds	Shallow to open marine, locally glaciofluvial	Present in the most of the AOI, can be locally absent. Absent in the southernmost part of the AOI
Saalian	Drente / *Gieten* (Borkum Riff)2)	0 to 5	Very stiff to hard silty sandy gravelly CLAY (glacial TILL)	Glacial	Locally present only in the north-eastern part of the AOI
Saalian	Drente / *Uitdam* (Cleaver Bank)2)	0 to 25	Stiff to hard CLAY, locally with silt, sand, and gravel beds	Periglacial, glaciolacustrine	Mainly confined to Saalian tunnel valleys in the northern half of the AOI. The unit thickness is typically <10 m, larger thickness observed only very locally
Saalian	Drachten (Tea Kettle Hole)	0 to 10	Medium dense to dense, fine to medium SAND, with locally laminae of silt or/and clay	Periglacial, glaciofluvial, aeolian	Present locally in the northern half of the AOI
Holsteinian	Egmond Ground	0 to 40	Medium dense to very dense fine SAND with shells and shell fragments, with thin clay and silt interbeds	Open marine	Present across the northern half of the AOI
Elsterian	Peelo (Swarte Bank)	0 to > 100	Interbedded medium dense to very dense (silty) SAND and very stiff to hard (sandy) CLAY	Glacial, glaciofluvial (infill of valleys) to glaciolacustrine	Present across northern half of AOI, thickness significantly increases in (deep) tunnel valleys
Early to Middle Pleistocene	Yarmouth Roads	0 to > 100	Interbedded medium dense to very dense, slightly silty to very silty, fine to medium SAND, and stiff to very stiff CLAY or SILT with laminae of sand; locally laminae to thin beds of PEAT	Fluvio-deltaic to marine	Present across the AOI, except in the most south-eastern part
Early Pleistocene	Winterton Shoal / IJmuiden Ground	0 to > 100	Interbedded medium dense to very dense, silty, fine to medium SAND, with laminae to thick beds of (organic) clay and stiff to hard CLAY or SILT with laminae of sand; locally laminae of PEAT	Fluvio-deltaic to marine	Present in the south-eastern part of the AOI (Landfall/Shore crossing Area)

Notes:

Information is presented for depth range of interest (to 100 m BSF)
'Greater than' sign ('>') indicates minimum observed thickness

* = BGS naming convention between brackets
† = May contain boulders

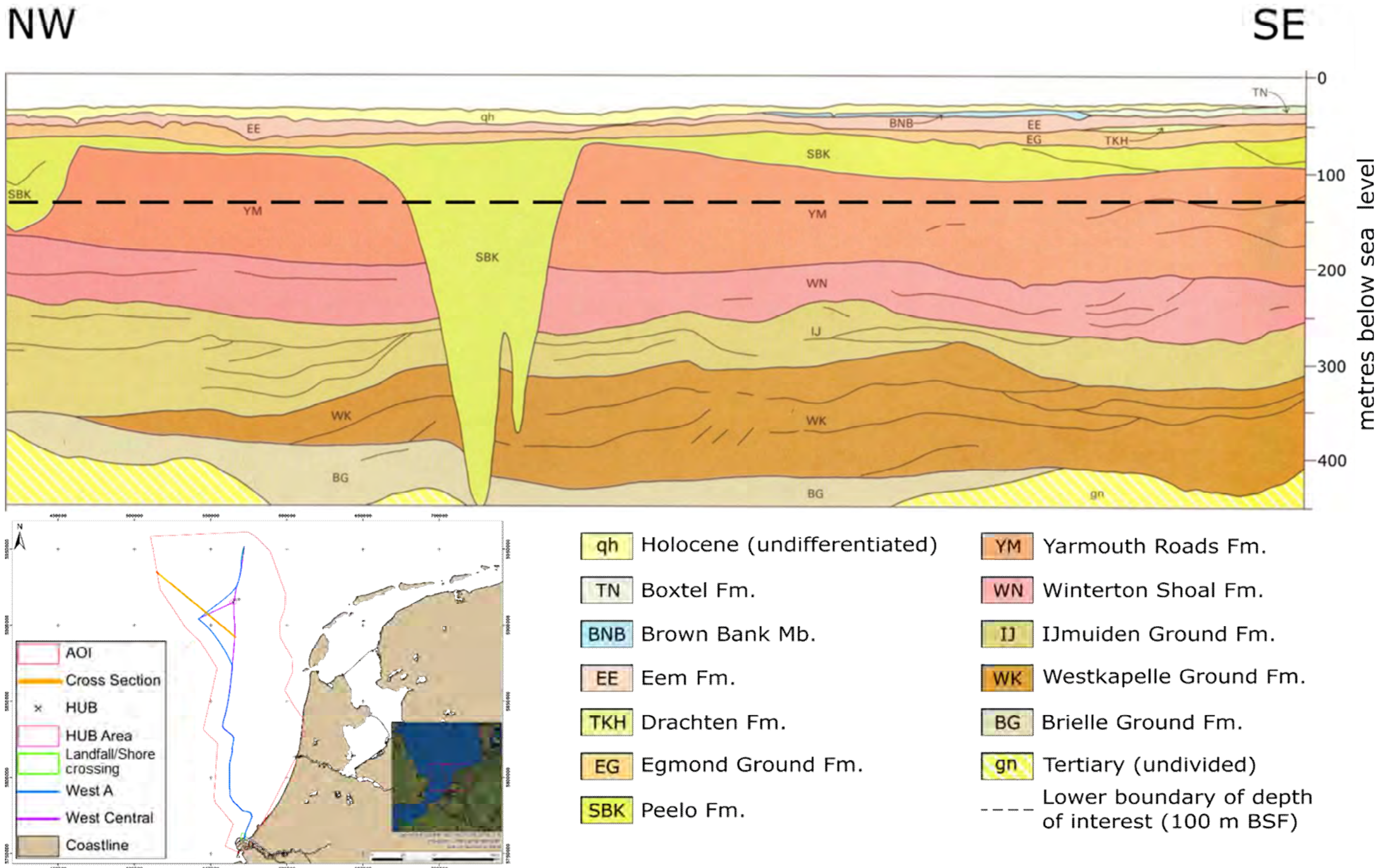


Figure 4.27: Schematic profile (with 50x vertical exaggeration) of the north-west part of the AOI. See the inset in the bottom left-hand corner for the location of the cross section (in orange). Modified after Cameron et al. (1986)

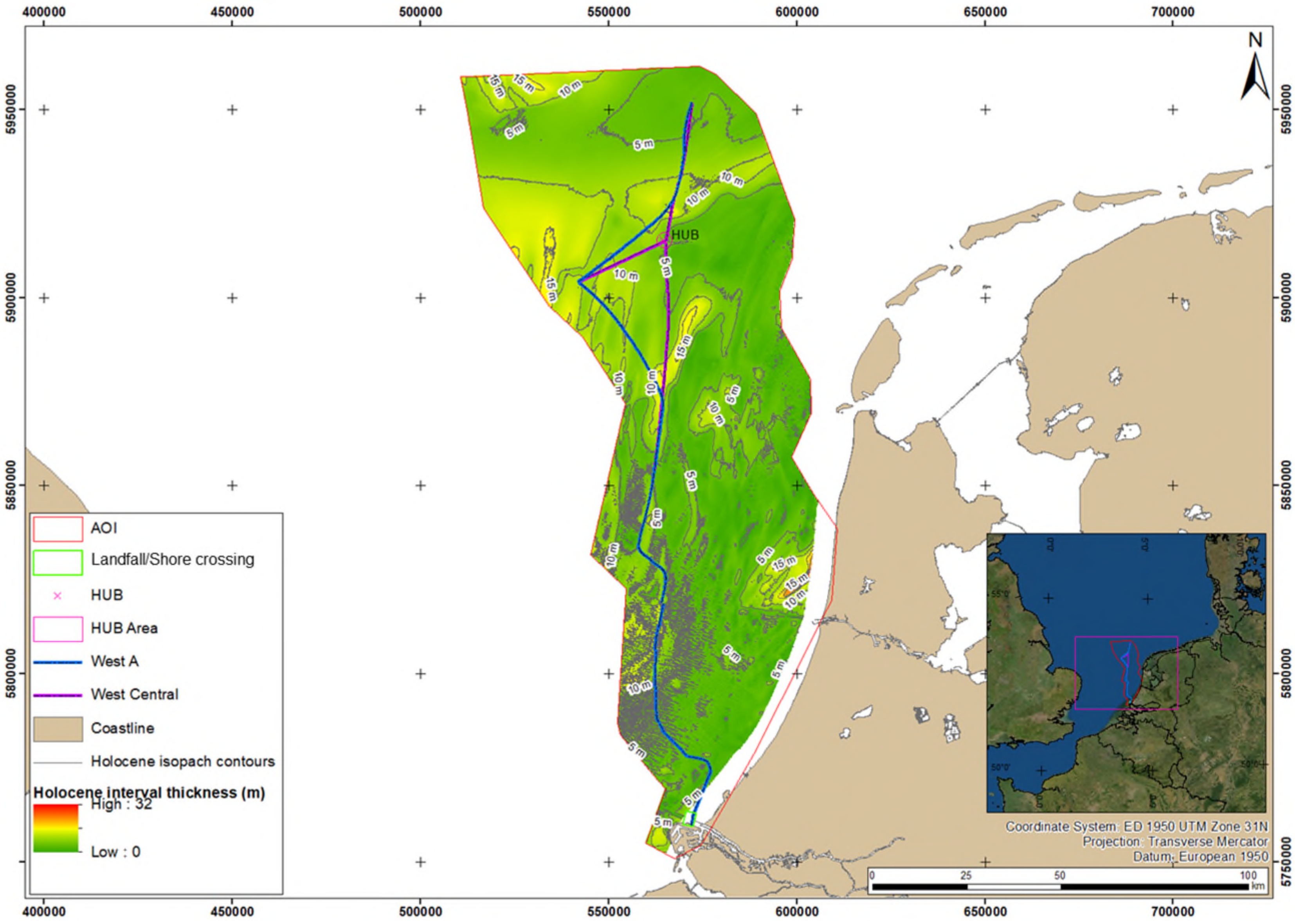


Figure 4.28: Expected thickness of the Holocene in the AOI

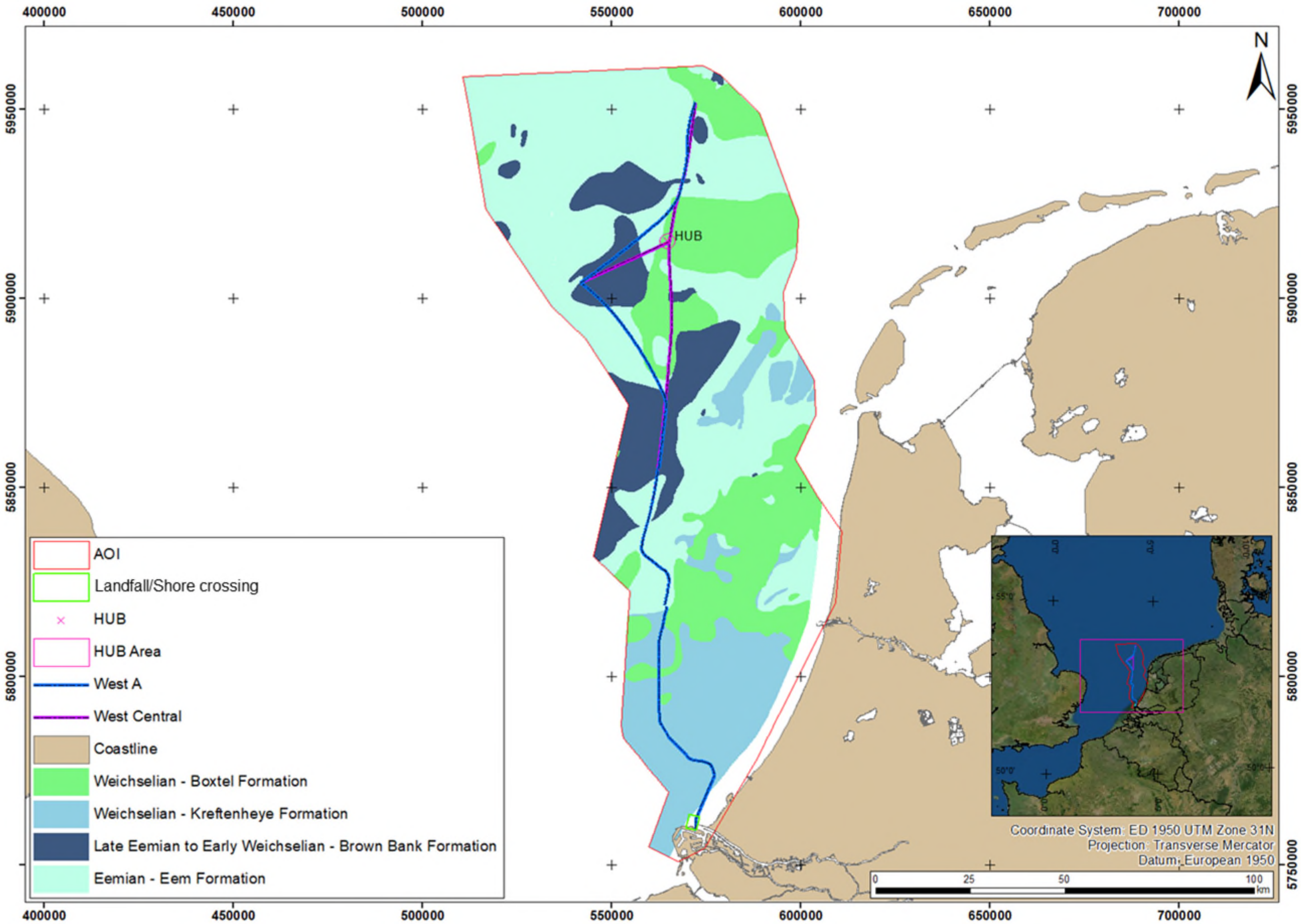


Figure 4.29: Distribution of the Late Pleistocene formations and members

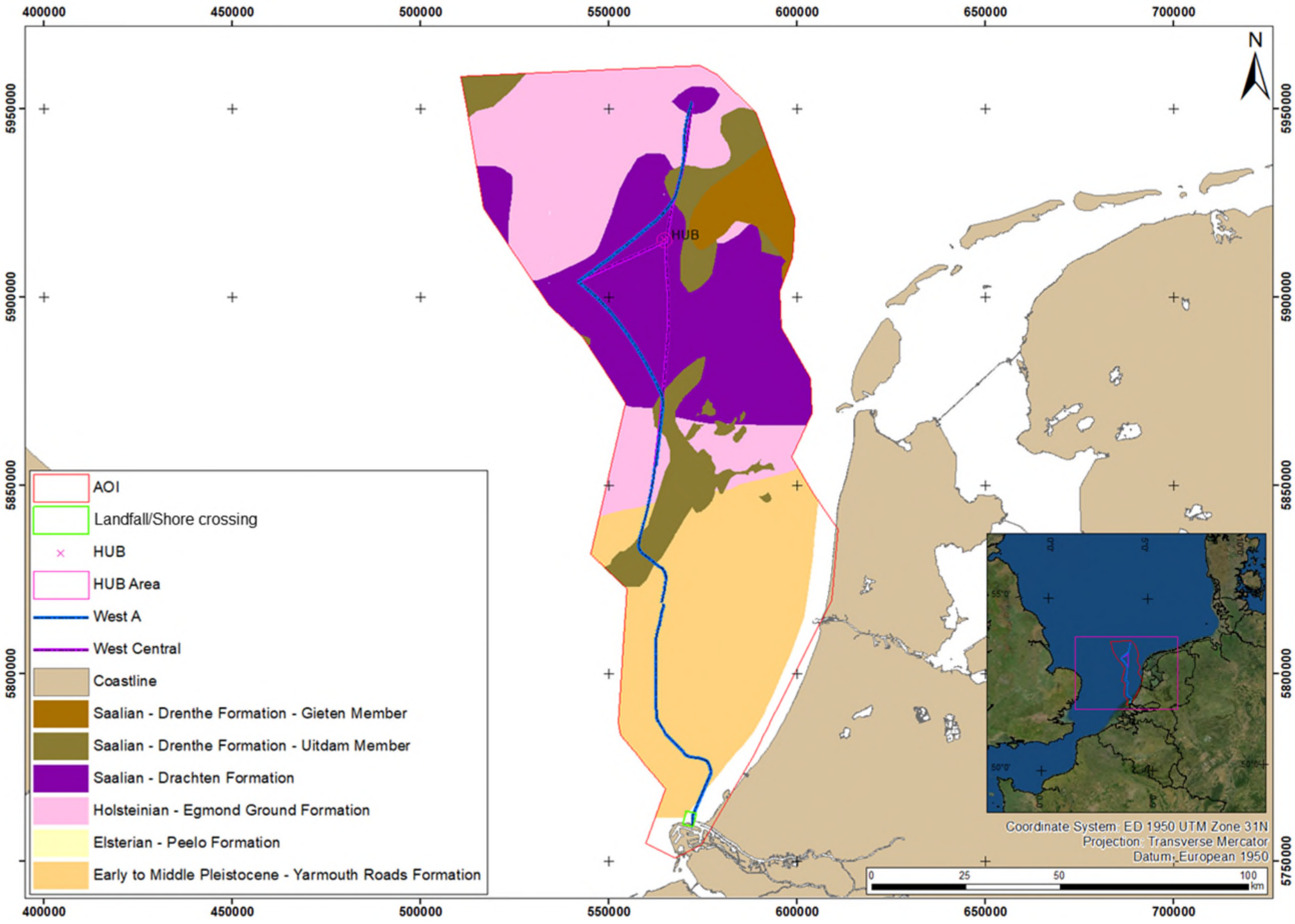


Figure 4.30: Distribution of the Early to Middle Pleistocene formations and members

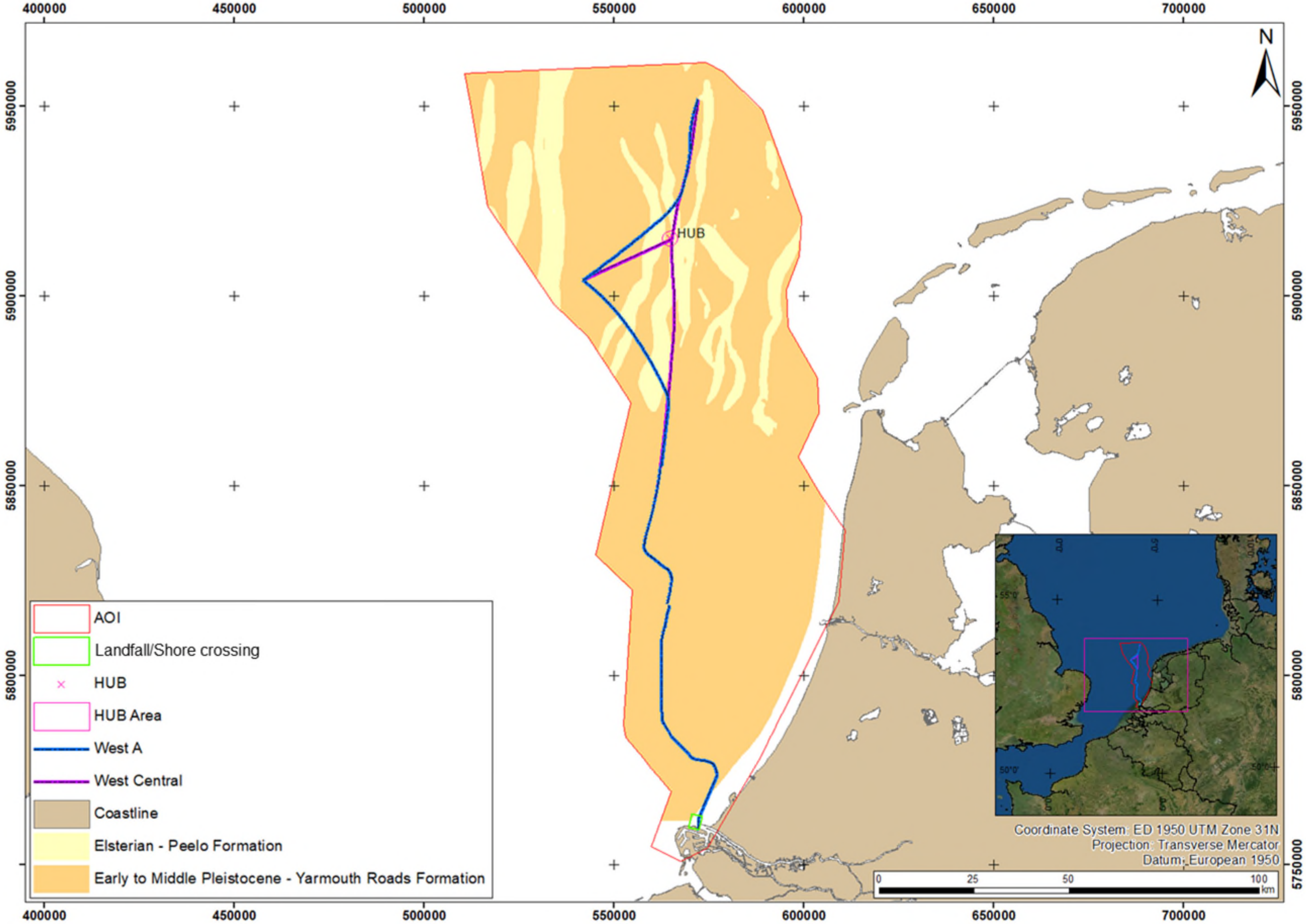


Figure 4.31: Distribution of the Early Pleistocene formations

4.4.2 Landfall/Shore Crossing Area

The expected stratigraphy and lithologies in the Landfall/Shore crossing Area, based on the information from DINOloket is presented in Figure 4.32.

There are three main units/geological formations to be expected, from top: Naaldwijk, Kreftenheye and Early Pleistocene formations, which comprise the Winterton Shoal and/or IJmuiden Ground Formations. The Naaldwijk Formation is internally very variable with dominant clay and locally some inclusions of peat. Kreftenhaye Formation is dominated by SAND and the Early Pleistocene deposits by SAND mixed with CLAY.

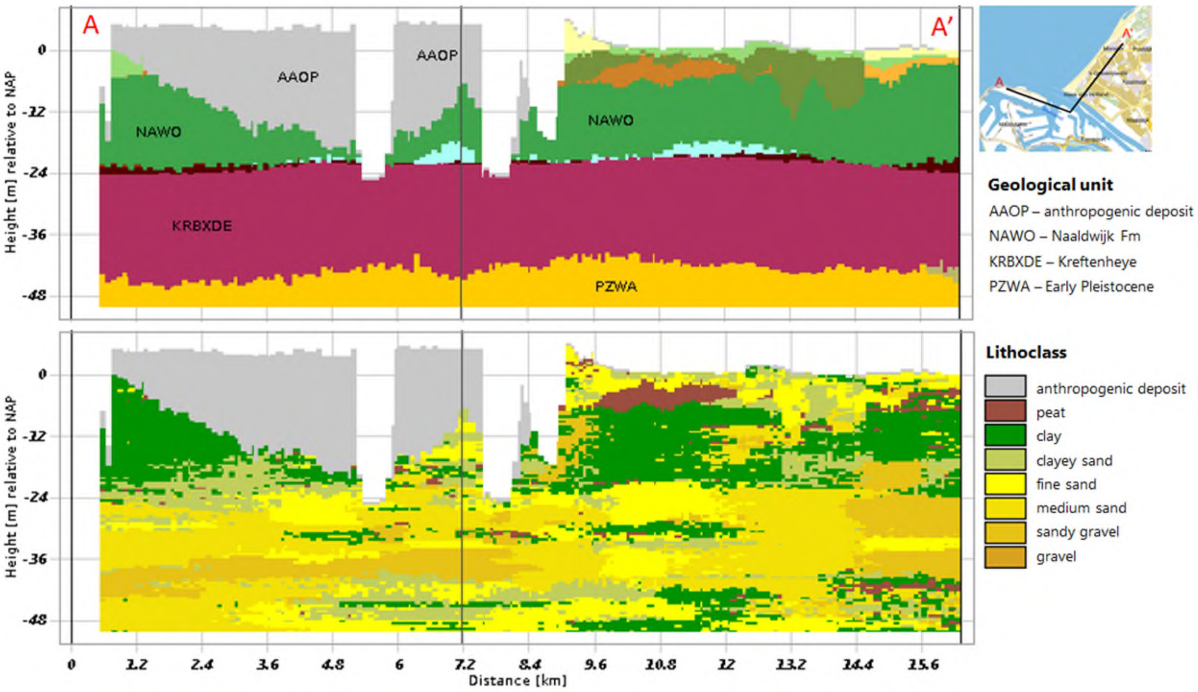


Figure 4.32: Synthetic ground models showing geological units (top image) and most probable lithologies (bottom image) in the vicinity of the Landfall/Shore crossing Area (source: DINOloket)

Table 4.7 presents the expected stratigraphy and spatial soil variability at the Landfall/Shore crossing Area. The information presented is based on (1) three geotechnical boreholes with penetration depth from approximately 17 m to 35 m BSF (Fugro, 2019c); (2) numerous geotechnical sampling and CPT testing locations from Fugro database, with various penetration depths from a few metres to approximately 40 m BSF. The geotechnical borehole data are within the boundaries of the Landfall/Shore crossing Area, located mainly in the western part.

Particularly, the presented depth and thickness values for the identified stratigraphic units/geological formations, as well as the spatial soil variability are based on previous geotechnical and geophysical investigation data performed by Fugro in the area. Figure 4.33 presents a schematic cross section along the first 3 km of the proposed pipeline route based on the interpretation of these data.

Table 4.7: Expected stratigraphy for the Landfall/Shore crossing Area

Geological Formation	Depositional Environment	Expected Thickness [m]	Soil Type	Distribution and Spatial Variability*
Disturbed Soil (DS)	Recent accumulation	0 to 5	Very soft to soft CLAY, locally sandy, locally gravelly	Present in the Maasmond Kanaal
Southern Bight	Marine	0 to 1	Very loose to dense, medium SAND with frequent shells and shell fragments	Locally present as a thin cover or in form of possible localised small-scale bedforms; can be present especially in the northern part of the area
Naaldwijk	Coastal, tidal channel and tidal flat	0 to 13	Medium dense to very dense, fine and medium SAND and soft to firm (sandy) CLAY, locally PEAT interlayers	Present across the entire area. Locally this unit might be removed due to dredging activities (i.e., in the Maasmond Kanaal) The unit is characterised by very high spatial soil variability. The unit locally forms infill of paleo-channels, where it reaches maximum thickness. More extensive paleo-channels are expected in the northern part of the area (Figure 4.34)
Kreftenheye	Fluvial	10 to 25	Very dense fine to medium SAND, locally slightly gravelly to gravelly, locally with traces to few gravels; locally with laminae to thin beds of clay	Present across the entire area. Relatively homogenous unit, with minor localised laminae to thin beds of clay
IJmuiden Ground/ Winterton Shoal	Deltaic to fluvial	> 20	Medium dense to very dense (slightly) silty SAND, locally beds of laminated CLAY, locally with thin to thick beds of very stiff to hard CLAY	The entire area; high variability in relative density of sand or an alternation of sand and clay; beds of laminated sandy clay can be (locally) present
Notes: Information is presented for depth range of interest (to 40 m BSF) 'Greater than' sign ('>') indicates minimum observed thickness * = refer to Figure 4.33 for schematic cross section				

Comments are as follows:

- The base of the Maasmond Kanaal has been dredged up to 10 m depth. As a result, the upper strata (i.e., the Naaldwijk Formation) were likely removed or reduced to thickness of occasionally less than 1 m.
- In the Maasmond Kanaal the top comprises very soft to soft clay or medium dense (clayey or silty) sand laminated with clay. This top relatively weak layer can be a recent deposit in the channel and/or partly a remnant or of the Naaldwijk Formation. Thickness of this layer is on average between 1 m and 3 m, but locally can be up to 6 m.

- Peat/organic clay layers (laminae to thin beds) can be present locally within the Naaldwijk Formation outside of the Maasmond Kanaal, and within the top layer in the Maasmond Kanaal. On seismic reflection data, localised areas of acoustic blanking were observed in and outside of the Maasmond Kanaal, which can be related to the peat and/or possible accumulations of gas as a result of decomposition of the organic material.
- Localised gravel beds may be present in the subsurface. A thick bed of very sandy gravel was encountered at a depth of approximately 5 m BSF at a single location south of the Maasmond Kanaal.
- Rock dumps made of gravel, cobbles and boulders (as part of the flood-defence structure) are present in the coastal zones. Side scan sonar (SSS) data indicated that submerged rock dump extent from several metres to tens of metres from the shoreline. No information on the thickness of this layer is available. In boreholes located onshore 2 m to 6 m-thick layers of gravel/cobbles were encountered.
- Seafloor depressions associated with objects interpreted as possible boulders were observed sporadically on the MBES data in the Landfall/Shore crossing Area. Boulders were not encountered or reported in the subsurface, based on the available information.

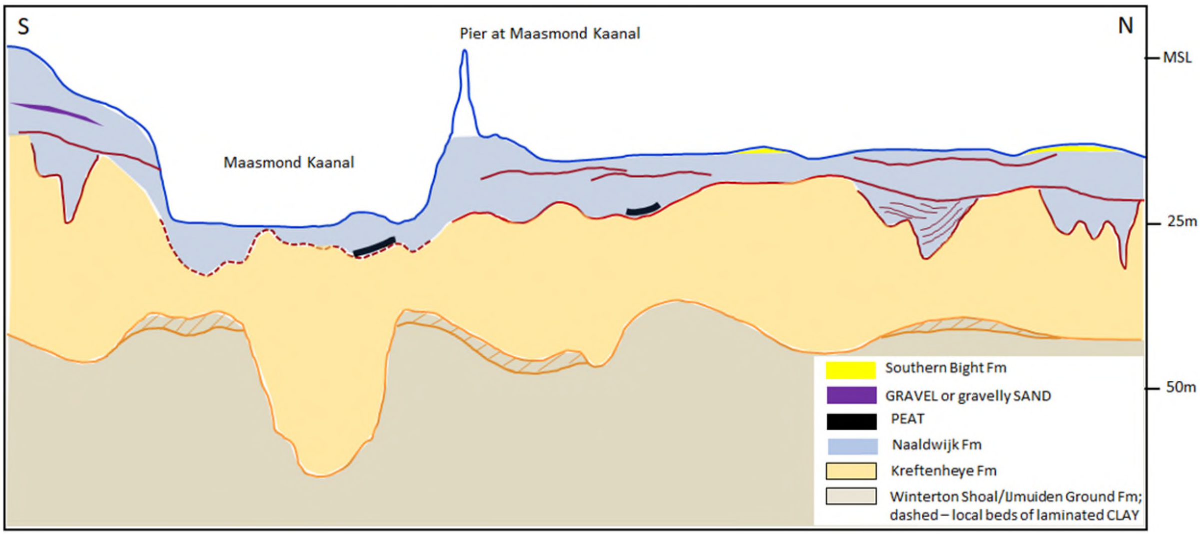


Figure 4.33: Schematic simplified cross section across the Maasmond Kanaal (based on geotechnical Fugro experience). Refer to Table 4.7 for detailed description of the units/geological formations

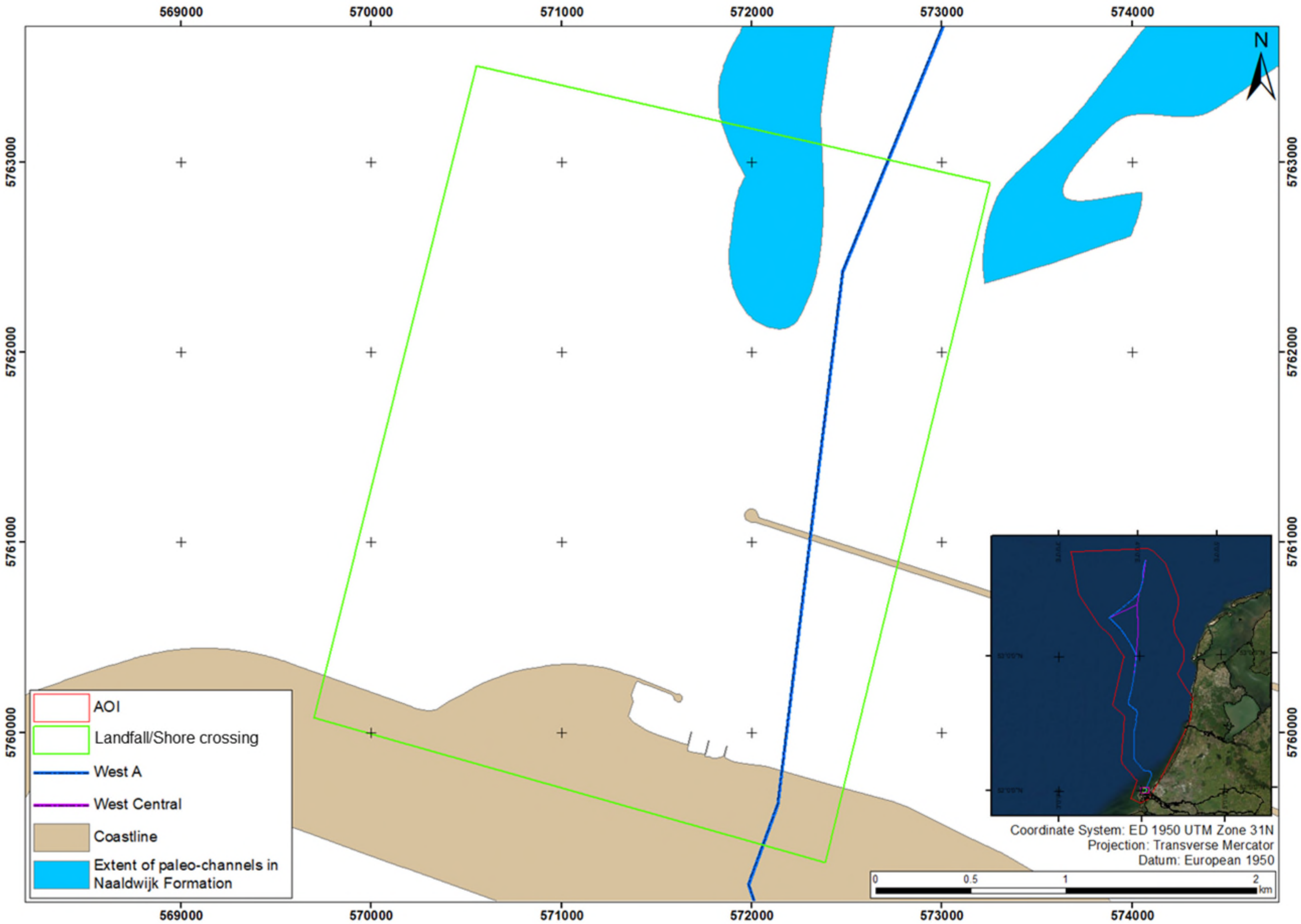


Figure 4.34: Distribution of the early Holocene (Naaldwijk Formation) paleo-channels in the Landfall/Shore crossing Area

4.4.3 Offshore Distribution HUB Area

Table 4.8 presents the general stratigraphy and spatial soil variability at the Offshore Distribution HUB Area. The information presented is based on geological maps and three geotechnical boreholes located approximately 3 km from the Offshore Distribution HUB Area boundary (Fugro confidential experience). No borehole information is available within the Offshore Distribution HUB Area.

Table 4.8: Expected stratigraphy for the Offshore Distribution HUB Area

Geological Formation / *Member*	Depositional Environment	Expected Thickness [m]	Soil Type	Distribution and Spatial Variability
Southern Bight	Marine	2 to 10	Very loose to very dense SAND with shells and shell fragments, locally silty	Present across the entire area
Naaldwijk	Coastal to tidal	0 to 5	Highly variable; generally soft CLAY, with silt, sand and peat beds	May be present (locally)
Boxtel	Periglacial, aeolian	0 to 5	Medium dense to very dense fine SAND	May be present (locally)
Eem / *Brown Bank*	Brackish marine lagoonal to lacustrine	0 to 10	Firm to very stiff calcareous CLAY or SILT, with extremely closely to very closely spaced laminae to thick beds of sand	May be present (locally)
Eem	Marine	5 to 15	Medium dense to very dense SAND with shells and shell fragments, locally silty and with peat beds	Expected to be present
Drente / *Uitdam*	Periglacial, glaciolacustrine	0 to 5	Stiff to hard CLAY, locally with silt, sand, and gravel beds	May be present (locally)
Drachten	Periglacial, aeolian	0 to 5	Medium dense to dense, fine to medium silty SAND	Expected to be present
Egmond Ground	Marine	10 to 40	Medium dense to very dense SAND with shells and shell fragments and beds of clay and silt	Expected to be present
Peelo	Glacial, glaciofluvial to glaciolacustrine	> 20	Interbedded medium dense to very dense SAND and very stiff to hard sandy CLAY	Expected to be present, although thickness may vary within the area
Yarmouth Roads	Fluvio-deltaic to marine	> 40	Dense to very dense SAND with shells and shell fragments, locally slightly silty	Expected to be present, although thickness may vary within the area

Notes:
Information is presented for depth range of interest (to 100 m BSF)
'Greater than' sign ('>') indicates minimum observed thickness

Comments are as follows:

- Based on the available geological maps, the Naaldwijk Formation and the Brown Bank Member may be (partly) present in the Offshore Distribution HUB Area. Based on information from the nearby boreholes it is not possible to distinguish between these formations and member. However, CLAY with a thickness of 0.5 m to 5 m between the Southern Bight Formation and the Eem Formation was observed. Therefore, either Naaldwijk or Brown Bank is expected to be (locally) present.

- Beds of PEAT may be present locally and belong to either the Naaldwijk, or the Brown Bank Member.
- Stratigraphy descriptions for the nearby geotechnical boreholes incorporated the Drachten Formation and Uitdam Member into the Eem Formation and/or Egmond Ground Formation. Therefore, it is not possible to confirm the presence of these strata. The geological maps suggest that the Drachten Formation should be present, while the Uitdam Member might be (locally) present. The expected thickness of each of these formations is up to 5 m.
- The thickness of the Peelo Formation as observed in the nearby boreholes is approximately 22 m and 29 m. Regional geophysical and geotechnical information suggests that the formation is present throughout the area (Figure 4.27; Cameron et al., 1986; Laban, 1995).
- The base of the Yarmouth Roads Formation was not encountered in the nearby geotechnical boreholes. However, regional geophysical and geotechnical information suggests the formation is present throughout the wider area and has a thickness of at least 40 m (Figure 4.27; Cameron et al., 1986; Laban, 1995).

4.5 Ground Models

One ground model per study area is presented in this report, allowing to capture site-specific details and the different depth of interest for each site.

4.5.1 AOI

4.5.1.1 Predicted Soil Units and Geotechnical Parameters

To predict soil units across the AOI, the seafloor and sub-seafloor features identified in the available geological, geophysical and geotechnical data and literature were reviewed and summarised (Sections 4.2 and 4.4). Predicting soil units enables soil profiles and associated soil province map(s) to be generated.

Soil units were defined by grouping together stratigraphic formations expected to have similar lithologies (e.g., principal soil type). A geotechnical description is given allowing to encompass the possible variability and change in lithology within each of the soil units.

Eight soil units were predicted to be present across the AOI and within the depth of interest. Table 4.9 presents the predicted soil units and the associated preliminary geotechnical parameters defined for each unit.

The geotechnical description of soil units, detailed below, are applicable for the complete AOI as well as on the specific Landfall/Shore crossing and Offshore Distribution HUB Areas:

- Soil unit i, comprising the Holocene surficial sediments:
  - ia: sandy very soft MUD to muddy loose SAND;
  - ib: very loose to very dense SAND;
  - ic: slightly gravelly loose SAND to sandy GRAVEL;
- Soil unit ii, comprising tidal and coastal deposits of Early Holocene: interbedded very thin to thick beds of CLAY and SAND;
- Soil unit iii, grouping the Pleistocene formations dominated by SAND: SAND, locally (slightly) silty, with locally (and minor) beds of CLAY, SILT, GRAVEL and PEAT;
- Soil unit iv, grouping the Pleistocene formations dominated by CLAY, subdivided based on age (strength):
  - iva: overconsolidated (firm to stiff) CLAY with SAND laminae/thin beds;
  - ivb: overconsolidated (stiff to hard) CLAY, with beds of SILT to SAND;
- Soil unit v, corresponding to glacial TILL: very stiff to hard silty sandy gravelly CLAY.

Geotechnical parameters are derived from Fugro experience comprising numerous geotechnical sampling and CPT boreholes across the AOI. Thicknesses given are based on the same experience as well as on geological maps used in this report. The AOI being very large, the geotechnical parameters values cannot be detailed precisely, and ranges given in Table 4.9 allow to encompass potential range of values across the AOI.

Fugro recommends geotechnical sample data and CPTs along the final pipeline route to refine parameter ranges, and precise the expected thicknesses of the different units along the pipeline route. It is also recommended that the siting of the sampling and CPT locations is performed once geophysical data has been acquired to ensure areas of variability are sufficiently characterised and consistent areas only collect the required information. Based on these future geophysical and geotechnical surveys, the soil units may be discriminated further along the pipeline route.

Table 4.9: Predicted preliminary geotechnical parameters for the AOI

Stratigraphic Unit (Geological Formation)	Soil Unit	Description	Soil Type	Thickness [m]	γ′ [kN/m³]	D_r [%]	s_u [kPa]	S_t [-]	Φ′ [°]	q_c [MPa]
Surficial Sediments (Southern Bight and Urania)	**ia**	sandy very soft MUD to muddy loose SAND	CLAY	0 to 5	18 to 19	N/A	5 to 50	-	N/A	<2
	ib	very loose to very dense SAND	SAND	0 to 10	18 to 19.5	<35 to >100		N/A	25 to 45	2 to 20
	ic	slightly gravelly loose SAND to sandy GRAVEL	SAND	0 to 5	19 to 20	<35		N/A	25 to 30	4 to 20
Naaldwijk	**ii**	interbedded very thin to thick beds of CLAY and SAND	CLAY	0 to 15	18 to 19.5	N/A	20 to 100	1 to 3	N/A	1 to 3
			SAND			25 to 85		N/A	25 to 35	2 to 10
Boxtel (Twente) Kreftenheye, Eem Drachten (Tea Kettle Hole) Egmond Ground Yarmouth Roads	**iii**	SAND, locally slightly silty, with locally beds of CLAY, SILT, GRAVEL and PEAT	CLAY	0 to >20	18.5 to 20.5	N/A	100 to 200	~1 to 3	N/A	2 to 4
			SAND			65 to >100		N/A	30 to 45	15 to 90
Brown Bank	**iva**	overconsolidated firm to stiff CLAY with SAND laminae/thin beds	CLAY	0 to 10	18.5 to 19.5	N/A	50 to 200	1 to 3	N/A	1 to 4
			SAND			25 to 75		N/A	30 to 40	2 to 10
Drenthe (Cleaver Bank) Peelo (Swarte Bank)	**ivb**	overconsolidated stiff to hard CLAY, with beds of SILT to SAND	CLAY	0 to >20	19.5 to 21	N/A	200 to 400	~1 to 2	N/A	4 to 8
			SAND			65 to >100		N/A	35 to 45	15 to 90
Drenthe (Borkum Riff)	**v**	sandy, gravelly CLAY (glacial TILL)	CLAY	0 to 5	20 to 22	N/A	200 to 600	~1 to 2	N/A	4 to 12

Notes:
N/A = not applicable
- = no information available
γ′ = total unit weight
s_u = undrained shear strength
S_t = sensitivity
Dr = relative density
Φ′ = drained peak effective friction angle
q_c = CPT cone resistance

4.5.1.2 Geotechnical Profiles

Nine soil profiles were generated for the AOI based on available data. These soil profiles describe the possible lateral and vertical variability of soil units predicted to be present to 20 m BSF across the AOI. Soil profiles are presented in Figure 4.35. They were designed to discriminate areas with presence of:

- glacial TILL (profiles numbered 2);
- firm to stiff CLAY from the Brown Bank Formation (profiles numbered 3);
- neither glacial TILL or Brown Bank CLAY (soil profiles numbered 1).

The other criteria differentiating between the soil profiles are the types of surficial sediments: (a) mud-rich, (b) sand and (c) gravel-rich.

Bedforms were considered as positive features relatively to the mean seafloor level and are shown as positive triangles at the top of the profiles.

4.5.1.3 Soil Provinces

A soil province map, presented in Figure 4.36, was generated for entire AOI to depict the spatial extent of each predicted soil profile (Figure 4.35). The soil province map allows the lateral variability in soil units to be better understood and pictured.

Areas covered by each soil province are given in Table 4.10 along with the percentage of the total AOI surface area they represent. From this table, it appears that over 84 % of the AOI is characterised by the normal soil profiles (profiles numbered 1 in Figure 4.35). Less than 4% of the AOI is likely to present glacial TILL (unit v) within the depth of interest (profiles numbered 2), while 12% of the AOI present firm to stiff CLAY of the Brown Bank Formation (unit iva) within the depth of interest (profiles numbered 3). 65% of the area is covered by SAND rich surficial sediments (profiles numbered ‘b’), less than 19% is covered by MUD-rich sediments (profiles numbered ‘a’) and 16% is covered by GRAVEL-rich surficial sediments (profiles numbered ‘c’).

Table 4.10: Area covered by each soil province

Soil Province	Area (km^2)	% of AOI
AOI - 1a	1920.2	16
AOI - 1b	6455.9	56
AOI - 1c	1395.2	12
AOI - 2a	18.6	<1
AOI - 2b	321.7	2
AOI - 2c	123.8	1
AOI - 3a	235.3	2
AOI - 3b	807.3	7
AOI - 3c	347.1	3

Figure 4.36 presents the maximum extent of units consisting of stiff to hard CLAY (unit ivb) as hatched areas. However, the stiff to hard CLAY is in general likely to occur below the depth of interest of the AOI.

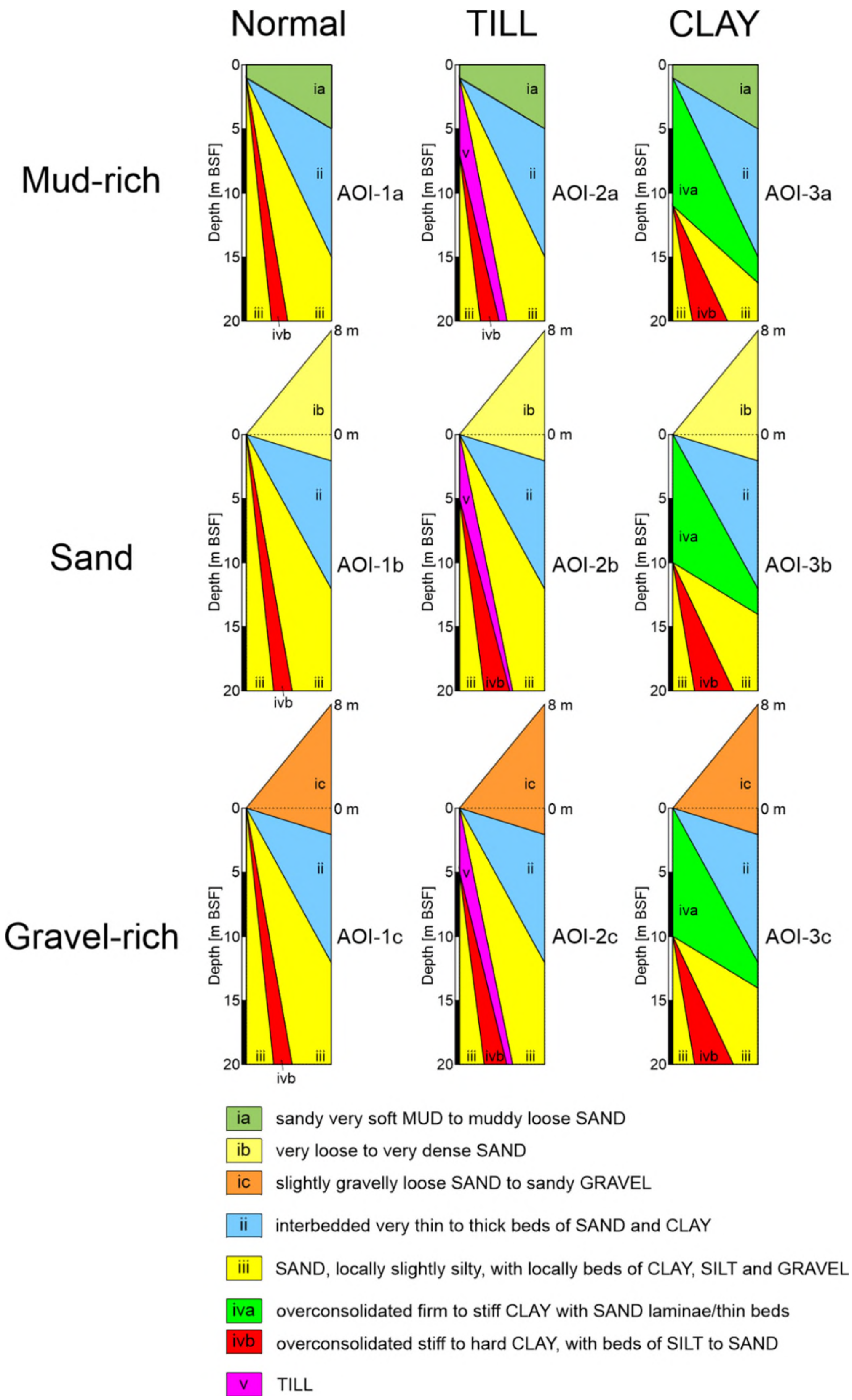


Figure 4.35: Predicted soil profiles across the AOI

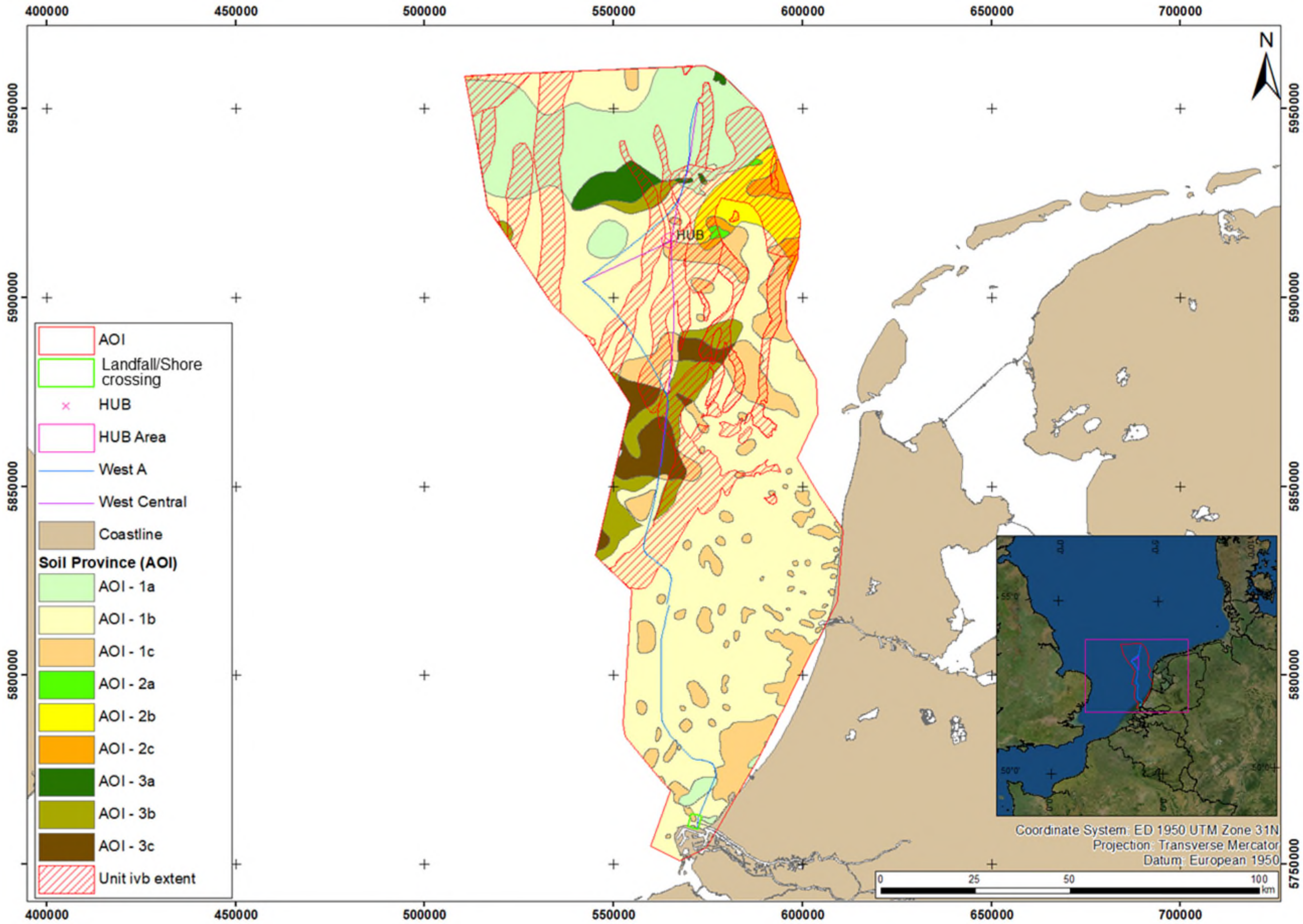


Figure 4.36: Soil province map across the AOI

4.5.2 Landfall/Shore Crossing Area

4.5.2.1 Predicted Soil Units and Geotechnical Parameters

Five soil units were predicted to be present in the Landfall/Shore crossing Area and within the depth of interest (40 m to 50 m BSF). Table 4.11 presents the predicted soil units and the associated preliminary geotechnical parameters defined for each unit.

Geotechnical descriptions and soil units are the same as those defined for the AOI (Section 4.5.1.1), with the addition of unit 'ds' corresponding to disturbed soil/recent accumulation consisting of very soft CLAY or very loose to medium dense SAND. This unit is limited to the Maasmond Kanaal and probably comprises residues of dredging operations.

Unit iii also includes the Early Pleistocene Winterton Shoal/IJmuiden Ground Formations, which are lateral equivalents of the Yarmouth Road Formation.

GRAVEL beds may be present locally in the subsurface. In the coastal zones there are gravel/cobbles/boulders accumulations (as part of rock dumps of the flood-defence structure). These deposits extent laterally from metres to several tens of metres from the shoreline. The thickness is unknown but may be up to several metres. No boulders were encountered in the subsurface, however presence of boulders cannot be entirely excluded (see also Section 4.4.2).

Geotechnical parameter values and thickness ranges are specific to the Landfall/Shore crossing Area and were derived from geotechnical Fugro experience in the Landfall/Shore crossing Area.

Fugro recommends acquisition and interpretation of site-specific geophysical data (sub-bottom profiler (SBP), MBES and SSS) across the Landfall/Shore crossing Area in order to confirm or refine the pipeline routing. Once the final routing is agreed, a site-specific survey should be planned depending on the expected soil variability. This would then allow to confirm and further refine geotechnical parameters and soil unit vertical and lateral variability. An update of the ground model may be subsequently considered based on any new findings.

Table 4.11: Predicted preliminary geotechnical parameters for the Landfall/Shore crossing Area

Stratigraphic Unit (Geological Formation)	Soil Unit	Description	Soil Type	Thickness [m]	γ' [kN/m^3]	D_r [%]	s_u [kPa]	S_t [-]	Φ' [°]	q_c [MPa]
Disturbed Soil	**ds**	very soft CLAY	CLAY	0 to 5	15 to 19	N/A	< 2	-	N/A	< 2
		very loose to medium dense SAND	SAND			<35 to 65		N/A	25 to 35	2 to 10
Surficial Sediments (Southern Bight and Urania)	**ib**	very loose to very dense SAND	SAND	0 to 5	18 to 19.5	<35 to 100		N/A	25 to 35	2 to 20
	ic	slightly gravelly loose SAND to sandy GRAVEL	SAND	0 to 5	18 to 19	<35		N/A	25 to 35	4 to 10
Naaldwijk	**ii**	interbedded very thin to thick beds of CLAY, SAND and locally PEAT	CLAY	0 to 13	18 to 19.5	N/A	2 to 100	1 to 3	N/A	1 to 4
			SAND			25 to 100		N/A	25 to 45	2 to 20
Kreftenheye,	**iii**	Dense to very dense SAND	SAND	10-25	18.5 to 20.5	80 to >100		N/A	25 to 45	20 to 60
Winterton Shoal / IJmuiden Ver		SAND, silty, with locally beds of CLAY and/or SILT	CLAY	>40		N/A	100 to 300	~1 to 3	N/A	2 to 6
			SAND			35 to >100		N/A	25 to 45	15 to 90

Notes:

N/A = not applicable
- = no information available
γ' = total unit weight
s_u = undrained shear strength
S_t = sensitivity
Dr = relative density
Φ' = drained peak effective friction angle
q_c = CPT cone resistance

4.5.2.2 Geotechnical Profiles

Four soil profiles were drawn for the Landfall/Shore crossing Area based on available data. These soil profiles describe the possible lateral and vertical variability of soil units predicted to be present to 40 m BSF across the Landfall/Shore crossing Area.

Soil profiles are presented in Figure 4.37. They were designed to discriminate areas with different surficial sediment types (GRAVEL and MUD above SAND), as well as areas with anthropogenic reworked material. Profile 1 was subdivided to discriminate areas where unit ii may be thicker (up to 14 m) due to the presence of paleo-channels from the Early Holocene.

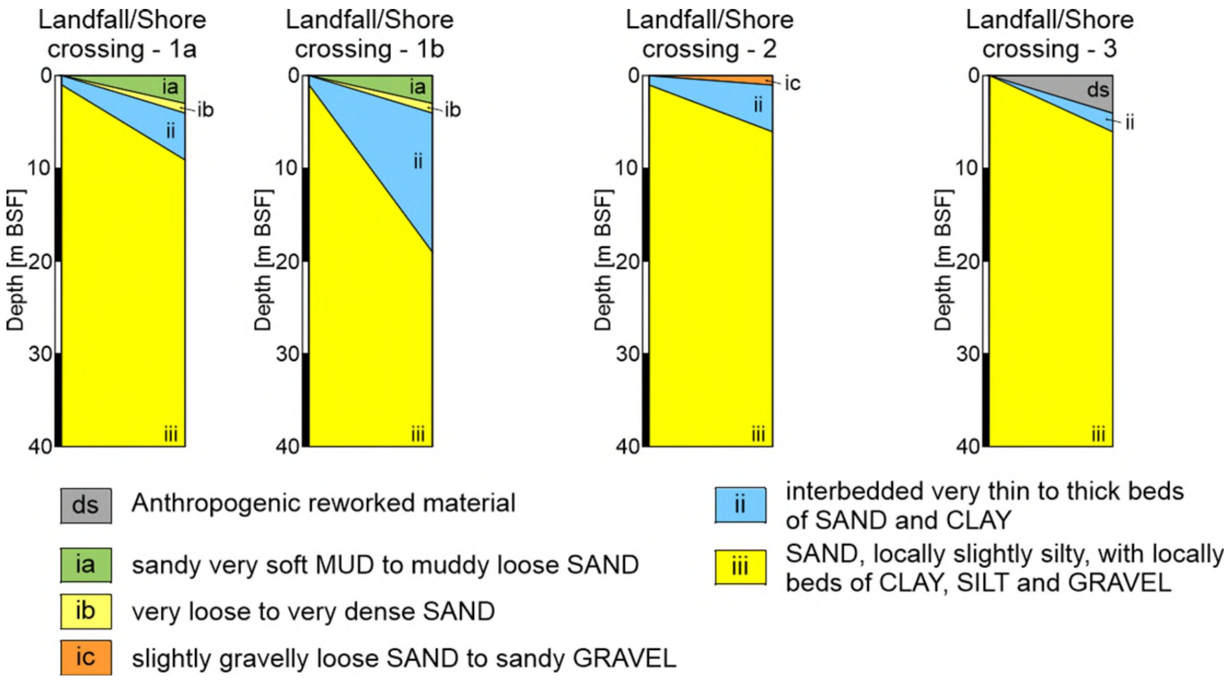


Figure 4.37: Predicted soil profiles across the Landfall/Shore crossing Area

4.5.2.3 Soil Provinces

A soil province map presented in Figure 4.38 was generated for the entire Landfall/Shore crossing Area to depict the spatial extent of each predicted soil profile (Figure 4.37). The soil province map allows the lateral variability in soil units to be better understood and pictured.

Areas covered by each soil province are given in Table 4.12 along with the percentage of the total Landfall/Shore crossing Area they represent. From this table, it appears that 38% of the area is characterised by mud-rich and muddy SAND surficial sediments (units ia and ib) with thin unit ii. 25% of the area, to the north-eastern corner, is expected to be covered by GRAVEL-rich sediments (unit ic). 21% of the area corresponds to the Maasmond Kanaal, potentially covered by disturbed/reworked deposits. Finally, only 4% of the area corresponds to the potential extent of paleo-channels (Naaldwijk Formation) based on geological maps (Figure 4.34).

About 12% of the Landfall/Shore crossing Area is covered by land and is not covered by any soil province.

Table 4.12: Area covered by each soil province across the Landfall/Shore crossing Area

Soil Province	Area (km^2)	% of AOI
Landfall/Shore crossing - 1a	3.8	38.3
Landfall/Shore crossing - 1b	0.4	4.4
Landfall/Shore crossing - 2	2.5	24.9
Landfall/Shore crossing - 3	2.1	20.8
Notes: 11.6% of the Landfall/Shore crossing Area is covered by land		

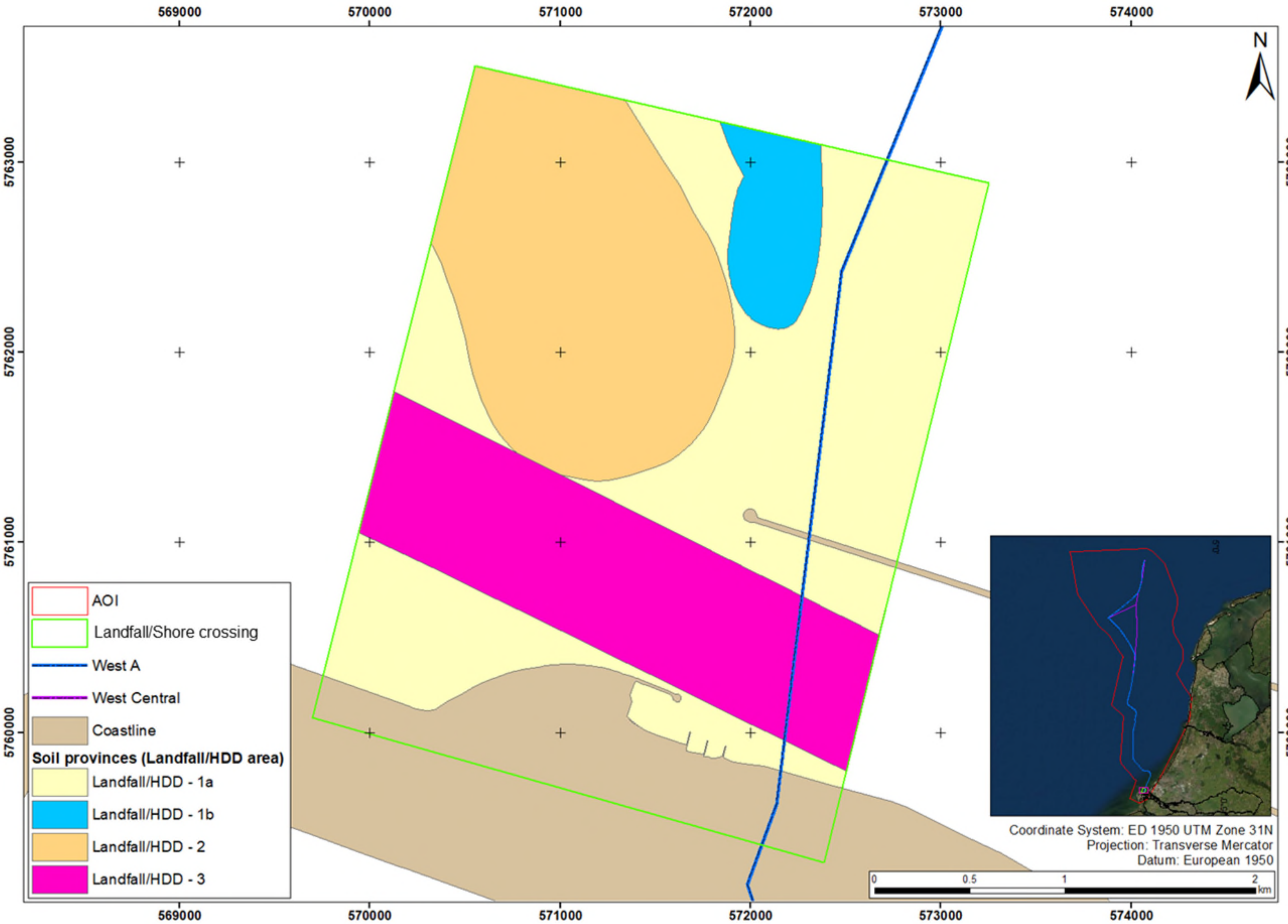


Figure 4.38: Soil province map across the Landfall/Shore crossing Area

4.5.3 Offshore Distribution HUB Area

4.5.3.1 Predicted Soil Units and Geotechnical Parameters

Five soil units were predicted to be present across the Offshore Distribution HUB Area and within the depth of interest (e.g., 100 m BSF). Table 4.13 presents the predicted soil units and the associated preliminary geotechnical parameters defined for each unit.

Geotechnical descriptions and soil units are the same as those defined for the AOI (Section 4.5.1.1).

Geotechnical parameters are the same as those presented for the entire AOI (Section 4.5.1.1). Fugro experience does not cover the Offshore Distribution HUB Area specifically, but the geotechnical parameter ranges for the AOI are likely to apply for the Offshore Distribution HUB Area to a depth of 100 m BSF. Expected thicknesses were adapted based on information from publicly available data and three geotechnical boreholes (Fugro experience) within 3 km of the Offshore Distribution HUB Area boundary.

Fugro recommends acquisition and interpretation of site-specific geophysical data (SBP, MBES and SSS) across the Offshore Distribution HUB Area to confirm or refine the pipeline routing. Once the final routing is agreed, a site-specific survey should be planned depending on the expected soil variability. This would then allow to confirm and further refine geotechnical parameters and soil unit vertical and lateral variability. An update of the ground model may be subsequently considered based on any new findings.

Table 4.13: Predicted preliminary geotechnical parameters for the Offshore Distribution HUB Area

Stratigraphic Unit (Geological Formation)	Soil Unit	Description	Soil Type	Thickness [m]	γ' [kN/m^3]	D_r [%]	s_u [kPa]	S_t [-]	Φ' [°]	q_c [MPa]
Surficial Sediments (Southern Bight and Urania)	**ib**	very loose to very dense SAND	SAND	4 to 9	18 to 19.5	<35 to >100		N/A	25 to 45	2 to 20
	ic	slightly gravelly loose SAND to sandy GRAVEL	SAND	4 to 9	19 to 20	<35		N/A	25 to 30	4 to 20
Naaldwijk	**ii**	interbedded very thin to thick beds of CLAY and SAND	CLAY	0 to 1	18 to 19.5	N/A	20 to 100	1 to 3	N/A	1 to 3
			SAND			25 to 85		N/A	25 to 35	2 to 10
Boxtel (Twente) Kreftenheye, Eem Drachten (Tea Kettle Hole) Egmond Ground Yarmouth Roads	**iii**	SAND, locally slightly silty, with locally beds of CLAY, SILT, GRAVEL and PEAT	CLAY	40 to >100	18.5 to 20.5	N/A	100 to 200	~1 to 3	N/A	2 to 4
			SAND			65 to >100		N/A	30 to 45	15 to 90
Drenthe (Cleaver Bank) Peelo (Swarte Bank)	**ivb**	overconsolidated stiff to hard CLAY, with beds of SILT to SAND	CLAY	0 to 30	19.5 to 21	N/A	200 to 400	~1 to 2	N/A	4 to 8
			SAND			65 to >100		N/A	35 to 45	15 to 90

Notes:
N/A = not applicable
\- = no information available
γ' = total unit weight
s_u = undrained shear strength
S_t = sensitivity
Dr = relative density
Φ' = drained peak effective friction angle
q_c = CPT cone resistance

4.5.3.2 Geotechnical Profiles

Four soil profiles were drawn for the Offshore Distribution HUB Area based on available data. These soil profiles describe the possible lateral and vertical variability of soil units predicted to be present to 100 m BSF across the Offshore Distribution HUB Area.

Soil profiles are presented in Figure 4.39. They were designed to discriminate areas with overconsolidated stiff to hard CLAY (unit ivb) at depth from the Peelo Formation. A subdivision was made to differentiate areas where SAND (ib) is expected at the seafloor from areas where GRAVEL-rich sediments (unit ic) are mapped.

The Offshore Distribution HUB Area is localised in-between two sand banks and therefore positive features of 1 m have been drawn to encompass the presence of the flanks of these bedforms.

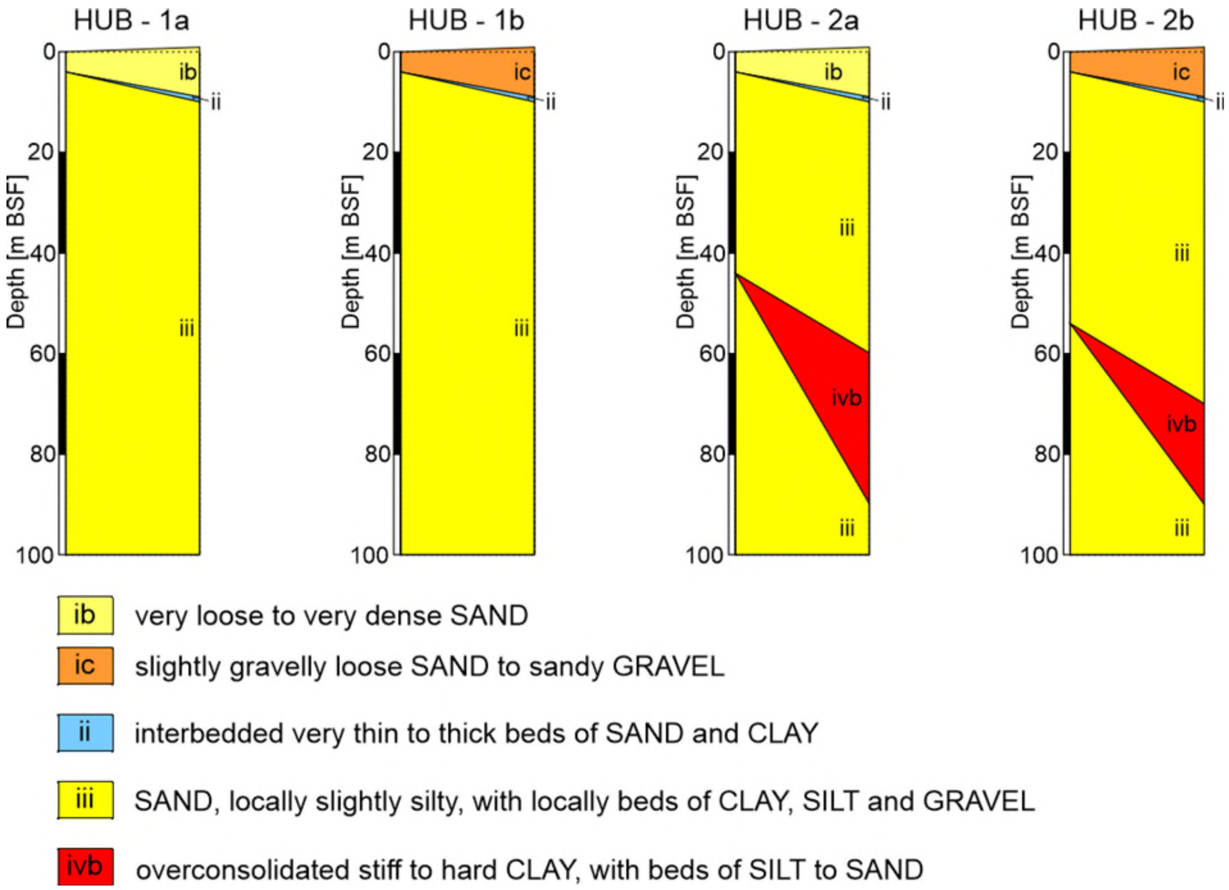


Figure 4.39: Predicted soil profiles across the Offshore Distribution HUB Area

4.5.3.3 Soil Provinces

A soil province map presented in Figure 4.40 was generated for the entire Offshore Distribution HUB Area to depict the spatial extent of each predicted soil profiles (Figure 4.37). The soil province map allows the lateral variability in soil units to be better understood and pictured.

Areas covered by each soil province are given in Table 4.14 along with the percentage of the total Offshore Distribution HUB Area they represent. From this table, it appears that 54% of the area is characterised by the potential presence of stiff to hard CLAY (unit ivb) within the depth of interest. This surface is divided within two distinct areas covering the western and eastern sides of the Offshore Distribution HUB Area. The areas correspond to two distinct paleo-channels from the Peelo Formation orientated north–south. More than 60% of the area is expected to be covered by SAND, while the southern part (40%) is expected to be composed of GRAVEL-rich material.

Table 4.14: Area covered by each soil province across the Offshore Distribution HUB Area

Soil Province	Area (km^2)	% of AOI
HUB - 1a	3.6	28
HUB - 1b	2.3	18
HUB – 2a	4.4	35
HUB – 2b	2.3	19

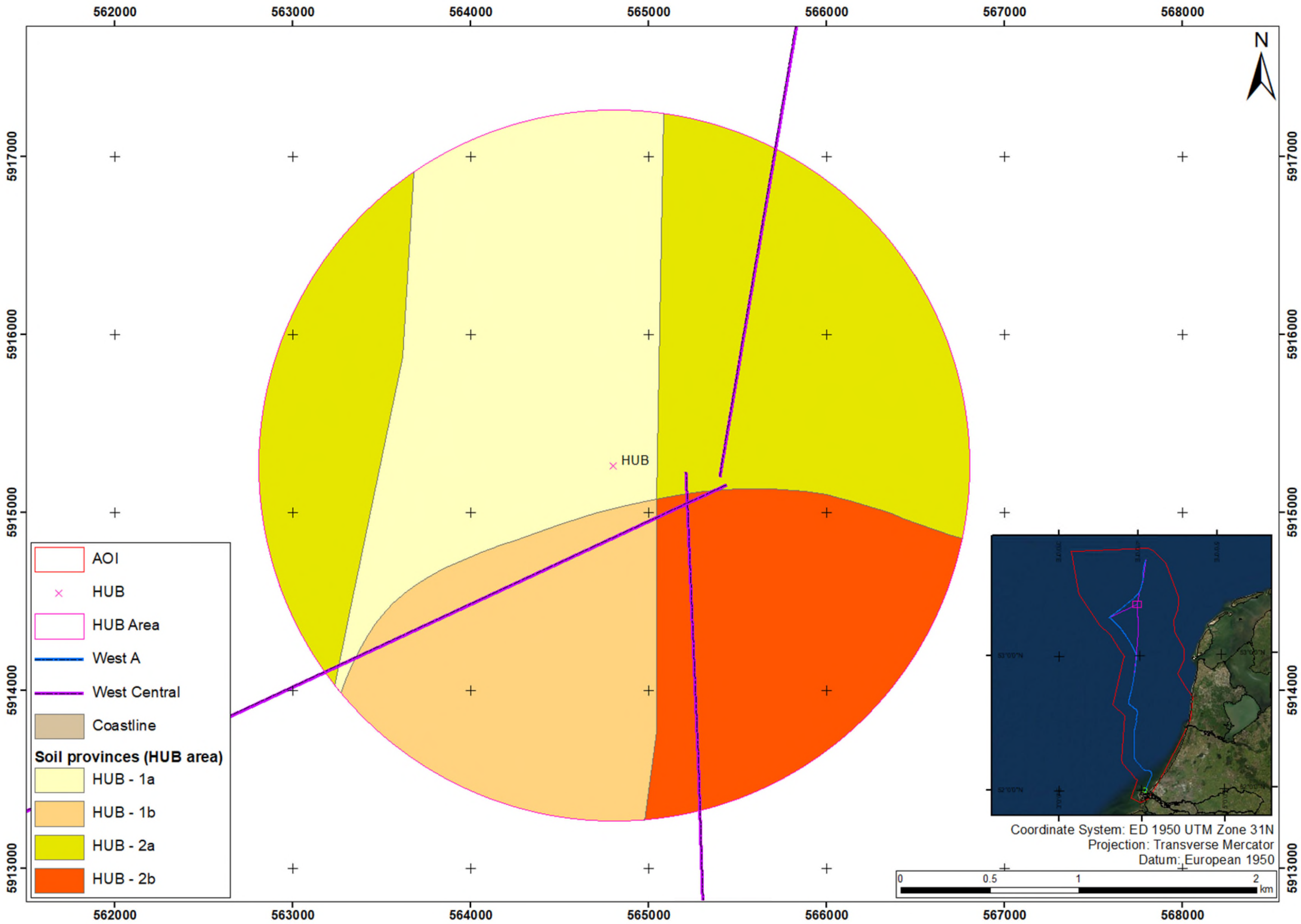


Figure 4.40: Soil province map across the Offshore Distribution HUB Area

5. Geohazards, Hazards and Site Constraints

5.1 General

Table 5.1 presents potential and identified geohazards and soil constraints for pipeline and other offshore infrastructures as well as for their installation. The information provides screening-level hazard characterisation (i.e. indicative) and may not be complete or comprehensive. Mitigation measures are proposed to reduce associated risks.

Table 5.2 presents potential and identified man-made related hazards, obstructions and site constraints for a pipeline and other offshore infrastructures. The information provides screening-level hazard characterisation (i.e. indicative) and may not be complete or comprehensive. Mitigation measures are proposed to reduce associated risks.

Table 5.1: Summary of potential and identified geohazards and soil constraints across the AOI

Constraint / Geohazard	Location / Distribution	Impact on Structure	Possible Mitigation
(Migrating) bedforms	Entire AOI, except northern part (Zone 3)	• Exposure or burial of structure; leading to snagging from trawling or anchoring, scour affecting structure stability • Spanning leading to uneven support of structure, critical stresses on structure • Temperature variations may lead to expansion / contraction of pipeline (increased susceptibility to walking in areas of exposure)	• Detailed mapping of bedforms through MBES data acquisition along pipeline route and within specific areas (Landfall/Shore crossing, Offshore Distribution HUB Areas) • Sediment mobility assessment, morphodynamic assessment and specific site survey works in areas of high risk • Meteocean site-specific desktop study to precisely assess migration/stability of bedforms • Avoid where possible areas with sand waves • Trenching to a certain depth (depending on bedform amplitude)
Storm events / wave action	Entire AOI. Probably lower impact within the areas deeper than 30 m LAT (northern AOI)	• Dynamic and cyclic loading • Burial or exposure, leading to loss of support, instability and damage	• Meteocean site-specific desktop study • Scouring site-specific study • Trenching to a certain depth (depending on estimated wave action depth)
Steep slopes / irregular topography	Flanks of Maasmond Kanaal Steep slopes also associated with bedforms, seafloor objects and dredging areas	• Uneven support of structure • Critical stresses on structure • Non-uniform penetration	• Avoidance • Trenching within bedforms

Constraint / Geohazard	Location / Distribution	Impact on Structure	Possible Mitigation
		• Slope failure • Lateral displacement of structure • Trenching difficulties	
Slumping	Northern flank of Maasmond Kanaal	• Slope instability and failure • Critical stresses • Scour and spanning or burial and loading • Rupture or failure of pipeline	HDD solution
Very soft clays	In Maasmond Kanaal and locally across the entire AOI, especially in paleo-channels	• Potential plough sinkage • Non-uniform penetration	• Jetting to install pipeline in soft sediments • Geophysical survey data to perform precise mapping of paleo-channels using UHR seismic or SBP data
Interbedded sand and clay sediments	Offshore Distribution HUB Area	Punch-through risk for foundation	Geotechnical survey at Offshore Distribution HUB location to refine geotechnical unitisation and parameters
Very dense sand	Entire AOI	• Trenching difficulties • Early refusal/limited penetration with plough	Selection of tools for pipeline emplacement suitable to deal with geotechnical properties
Gravel, cobbles and / or boulders	Localised areas across the AOI, particularly close to shore in the Landfall/Shore Crossing Area (in rock dumps of the flood-defence structure) and in deposits of Drente Formation	• Obstruction, trenching difficulties, possible early refusal or damage to structure • Gravel layers may impact HDD operations	• Detailed mapping of seafloor sediments along pipeline routing and across Offshore Distribution HUB area (MBES, SSS) • Detailed mapping of boulders expected at depth in UHR seismic and SBP data • Avoid areas with boulders
Peat / organic material	Locally present across AOI	• High compressibility, non-uniform support • chemical reaction between soil and steel • shallow gas	Geophysical and geotechnical survey in order to map and avoid areas where peat is expected
Pockmarks / shallow gas (peat)	Locally present in the Landfall/Shore crossing Area. Can be locally present in the AOI	• Laterally variable soil strength, steel corrosion, spanning of pipeline • Masking of acoustic signal • Risk of blowout and gas release during drilling and piling operations	• Geophysical survey data to detect shallow gas accumulations within seismic data • Map related seafloor features (pockmarks) • Avoid areas with shallow gas or identified markers (pockmarks)

Constraint / Geohazard	Location / Distribution	Impact on Structure	Possible Mitigation
Glacial TILL / boulder clay	Present locally in NE of AOI (Gieten Member)	• Spatially variable soil conditions • Heterogenous soil • Cobbles and boulders leading to challenging installation conditions	• Geophysical survey data to perform precise mapping and identification of these type of deposits using UHR seismic or SBP data • Geotechnical data collection to characterise conditions • Selection of pipeline emplacement method that can cope with variable soil conditions
Glaciotectonic deformation features	Present locally in NE and centre of AOI, related to the Gieten Member and Drachten Formation	• Variable soil conditions • Lower lateral resistance	• Geophysical survey data to perform precise mapping and identification of these type of deposits using UHR seismic or SBP data • Geotechnical data collection to characterise conditions
Regional subsidence / (historic) oil and gas extraction	Entire AOI	• Time-dependent reduction of freeboard of pipeline • Damage to structure	Monitoring during ongoing pipeline inspection surveys

Table 5.2: Summary of identified man-made obstructions and constraints across the AOI

Constraint / hazard	Location / Distribution	Impact on Structure	Possible Mitigation
Existing and planned future structures	Across AOI	• Obstruction • Potentially disturbed ground • Potential interruption in hydraulic flow regime affecting scour and soil deposition processes	• Relocation • Design pipeline/cable crossing • Collection of specific geophysical survey data at crossing locations
Rock dump / fill	Shorelines in the Landfall/Shore crossing Area related to coastal defence structures	• Disturbed soil / variable soil conditions • Potential interruption in hydraulic flow regime affecting scour and soil deposition processes • Pipeline abrasion • Installation problems	• Identify and map • Avoidance and relocation
Artificial soil / contaminated soil	Landfall/Shore crossing Area and dumping areas	• Variable soil conditions • Contamination	Avoidance and relocation
Wellheads	Across AOI	• Obstruction • Potentially pressurised shallow gas in soil	Avoidance and relocation

Unexploded ordnance (UXO)	See Appendix C	• Obstruction • Damage to structures • Uneven seafloor, disturbed soil	• UXO precise identification along pipeline route via magnetometer survey • UXO hazard risk assessment • Relocation • UXO clearance processes
Shipwrecks / dropped objects	See Appendix B and Appendix C	Obstruction	• Archaeological study and identification along pipeline route • Relocation • Investigate and remove if required
Potential archaeological targets	See Appendix B	• No / limited access • Project delay	• Archaeological study and identification along pipeline route • Relocation • Investigate and remove if required
Restricted areas (nature reserve, military exercise)	Across AOI	No / limited access	• Relocation • Permission requirements
Dredging and dumping areas	Across AOI	• Uneven seafloor • Disturbed soil • Variable soil conditions • Lateral displacement • No / limited access	• Damage to structures • Relocation • Permission requirements
Fishing activity (anchor and / or trawl scars)	Throughout most of AOI	• Disturbed soil / variable soil conditions • Entanglement of fishing gear • Damage to structure and offshore equipment • Lateral displacement	• Clearance operations before any site surveys, fishing liaison officer during survey works • Trenching to avoid damage from anchors or trawls
High level of shipping activity and anchorage areas	• Near Rotterdam and IJmuiden harbours • Navigation Channels	• Entanglement of anchor(line) • Damage to structure • Lateral displacement	• Clearance operations before any site surveys • Trenching to avoid damage from anchors or trawls

Figure 5.1 displays the extent of some mapped and identified soil constraints and geohazards. These includes:

- Glacial TILL;
- Areas with expected boulders;
- Areas with very soft surficial sediments;
- Expected paleo-channels;
- Extent of unit ivb, composed of stiff to hard CLAY.

Bedforms are mapped and highlighted as part of Figure 4.17, while steep slopes are highlighted in Figure 4.8 to Figure 4.16.

Most of the identified man-made seafloor obstructions and constraints are listed and mapped within Sections 4.1 and 4.2.4 of the report. More details on UXO and archaeological related features are provided within specific reports (see Appendix B and Appendix C).

Soils containing the mineral glauconite and/or carbonate soils are not expected to be present in the AOI (including the Landfall/Shore crossing Area) within the depth of interest based on available data.

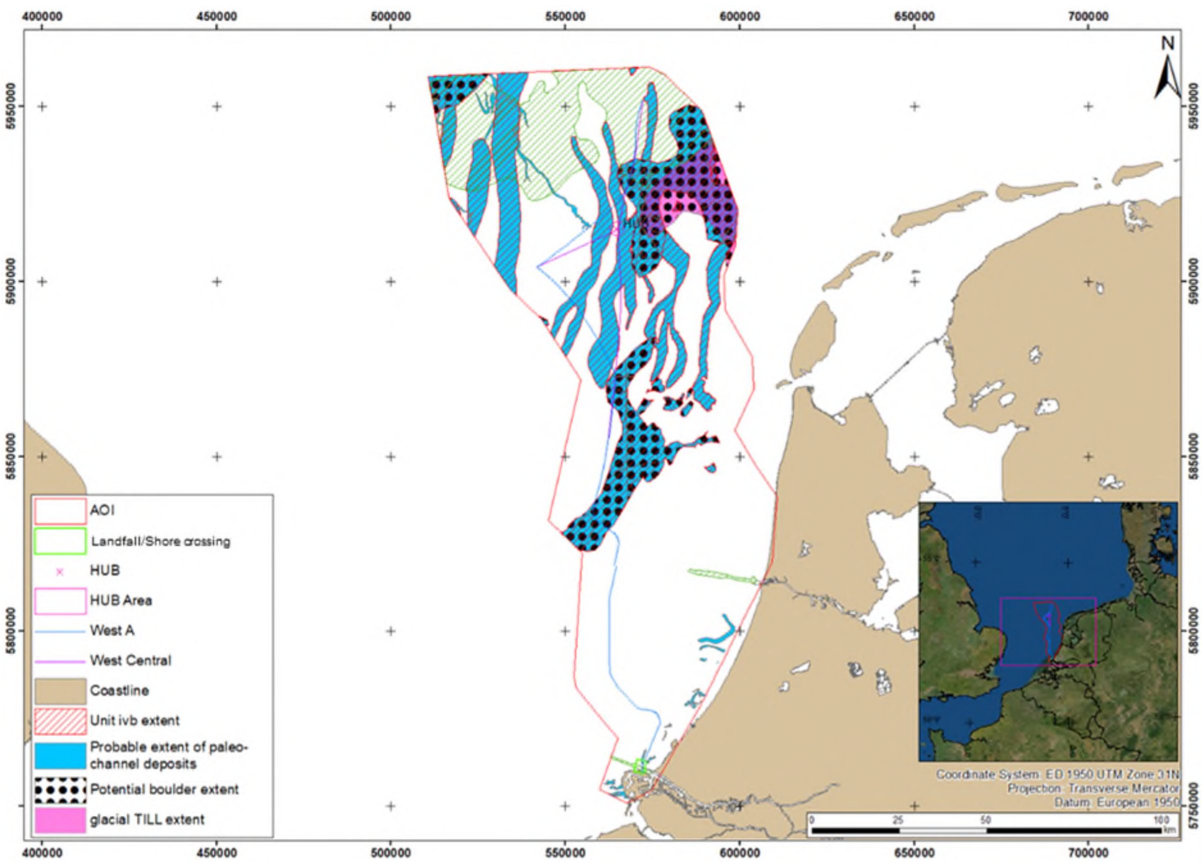


Figure 5.1: Map of identified soil constraints and potential geohazards across the AOI

5.2 Seismicity

Natural seismicity is mainly restricted to the southern (onshore) part of the Netherlands, where earthquakes with magnitudes of 2.5 to 6.0 are possible. The AOI lies within a tectonic region known as the West Netherlands Basin, which has been seismically quiet since the Neogene (Deltares, 2017).

The extraction of natural gas is known to produce induced seismicity. A total of 186 oil and gas fields are located in the AOI. Several induced seismic events related to these fields were recorded. These earthquakes had a magnitude between 2 and 4 (Deltares, 2017; Arcadis, 2018).

It is recommended that a probabilistic seismic hazard assessment is performed for the gas fields that are within a 5 km radius of the Landfall/Shore crossing Area and Offshore Distribution HUB Area to confirm the actual seismic hazard.

6. Conclusions and Recommendations

6.1 Conclusions

This desktop study aimed at characterising the soil conditions based on available public data and Fugro experience over an area of 11355 km² within the southern North Sea, Dutch sector. The ultimate purpose of the report is to provide information to help TotalEnergies in decision making regarding the ARAMIS Pipeline routing and provide recommendations regarding future site-specific surveys.

Based on available data, three preliminary geotechnical ground models focusing on three different areas are provided. These allow to picture the soil conditions and vertical and lateral variability to depth of interest. Geotechnical parameters were derived based on Fugro experience across the southern North Sea. The data review and analysis also allowed to list potential (geo)hazards, soil and anthropogenic constraints and man-made obstructions within the AOI.

The results provided within this desktop study are dependent on the available data and on data quality. Due to the large surface covered by the AOI, approximations and simplifications were made to create a comprehensive ground model allowing to capture the expected range of soil conditions. Variability within the defined soil units is expected, arising from varying depositional environments captured within independent units.

Site-specific data acquisition should be considered to refine and confirm the findings of the present study, once a more precise pipeline routing has been decided. Some recommendations are provided hereafter to help reducing uncertainties and mitigate identified (geo)hazards in the AOI.

6.2 Recommendations

Possible mitigation of identified or potential (geo)hazards and anthropogenic or soil constraints, including relocation of pipeline, engineering solutions or avoidance of certain features are already detailed in Table 5.1 and Table 5.2. These elements should help TotalEnergies in the decision making for the final pipeline route.

To better capture site conditions and soil variability along the future pipeline route and at specific areas (Offshore Distribution HUB and Landfall/Shore crossing Areas), several recommendations on further specific studies, geophysical and geotechnical site surveys are listed in this section. Most of these recommendations, in particular geophysical and geotechnical surveys will have to be considered once the pipeline route is decided.

6.2.1 Further Specific Studies

To better characterise some elements that are highlighted or identified within the present DTS, Fugro recommends performing specific studies including, but not limited to:

- Metocean site-specific desktop study to better understand mobility of bedforms and sediments due to currents, waves and tides;
- A sediment mobility assessment and study based on bathymetric data acquired at different dates across the area. This could be accompanied by specific site surveys in areas of identified high risks;
- UXO risk assessment study as defined in the conclusions of the UXO historical DTS (Appendix C) allowing to set fitting mitigation strategies.

6.2.2 Geophysical Site Surveys

Once the pipeline route corridor is agreed on, a number of geophysical methods should be considered to refine the mapping and identification of seafloor features and better define the variability of sub-seafloor soil units. They will in turn allow to better mitigate soil constraints and (geo)hazard-relatedrisks. Data acquired during these geophysical site surveys may include:

- MBES data to be acquired along the pipeline route with a typical corridor of 2 km allowing any re-routing if avoidance of any identified feature is required. MBES data will provide a high-resolution bathymetry along the route allowing to compute precise slope maps. Reflectivity may also be acquired during MBES operations giving a detailed representation of the seafloor rugosity. MBES should also be acquired around the planned Offshore Distribution HUB Area;
- SSS data to be acquired along the pipeline corridor with a typical corridor of 2 km and around the Offshore Distribution HUB location. SSS data helps identifying seafloor features and sediment types;
- SBP data to be acquired along the pipeline corridor. This will better characterise the sub-seafloor variability at the pipeline location, helping in the planning of the geotechnical site survey. At the Offshore Distribution HUB location and along the planned Landfall/Shore crossing Area, SBP grids should be acquired before any operations to identify potential sub-seafloor soil constraints and estimate soil variability. SBP can also provide valuable information when identifying preserved paleo-landscapes and potential prehistorical archaeological sites (Appendix B);
- UHR seismic data can be planned locally where specific designs are needed (such as HDD, piling at the Offshore Distribution HUB Area, trenching, tunnelling). UHR seismic data will provide a better penetration within deeper dense/hard units;
- A magnetometer survey must be performed along the entire pipeline corridor to identify any wrecks and UXOs at or close to the seafloor.

6.2.3 Geotechnical Site Surveys

Soil sampling and in situ testing (CPTs) are paramount to refine the geotechnical soil conditions and variability with depth. A geotechnical survey should be designed after geophysical data are acquired and interpreted to optimise the sampling and locations (both distribution and quantities). Where variable conditions or specific risks are identified, more locations may be required to better constrain them. Where more homogeneous conditions are expected, less locations could be planned. Geotechnical surveys should include:

- Sediment sampling to identify, log and test soil types. Sampling methods include gravity corers, box corers, grab samples and vibrocorers. A variety of laboratory testing can be considered, including geological testing (Multi-Sensor Core Logging, mineralogy, or dating) or geotechnical testing (water content, P-wave velocity, electrical resistivity, thermal conductivity, shear vane and oedometer tests). Specific geotechnical testing could be considered in order to measure the clay sensitivity;
- CPT allows to capture the site-specific soil conditions through a variety of measurements such as cone resistance and sleeve friction. It allows to identify soil units at depth and measure in situ mechanical properties such as sediment undrained shear strength (s_u) for clay or relative density for sand.

Along the pipeline route the depth of geotechnical locations can be limited to the first 5 m to 6 m BSF, while geotechnical locations within the Landfall/Shore crossing Area and at the Offshore Distribution HUB location should have greater penetration depths. For these deeper locations Fugro recommends downhole sampling and testing from a dedicated drilling platform (e.g. geotechnical drilling vessel or jack-up platform).

7. References

Arcadis (2018). *Geological Desk Study, Hollandse Kust (west) Wind Farm Zone* (Document No. WOZ2180087, dated 6 June 2018 to RVO). Arcadis Germany GmbH.

Ashley, G. M. (1990). Classification of large-scale subaqueous bedforms; a new look at an old problem. *Journal of Sedimentary Research, 60*(1), 160–172. https://doi.org/10.2110/jsr.60.160

Bosch, J.H.A., Weerts, H.J.T. & Busschers, F.S. (2003). Formatie van Urk. In *Lithostratigrafische Nomenclator van de Ondiepe Ondergrond*. Retrieved 18 October 2016 from https://www.dinoloket.nl/formatie-van-urk

Calvete, D., Walgreen, M., De Swart, H. E., & Falqués, A. (2001). A model for sand ridges on the shelf: Effect of tidal and steady currents. *Journal of Geophysical Research: Oceans*, *106*(C5), 9311–9325. https://doi.org/10.1029/2001JC900001

Cameron, T.D.J., Laban, C. & Schüttenhelm, R.T.E. (1984). *Flemish Bight, Sheet 52˚N–02˚E, Quaternary Geology (1:250.000 Series).* British Geological Survey & Rijks Geologische Dienst.

Cameron, T.D.J., Laban, C., Mesdag, C.S. & Schüttenhelm, R.T.E. (1986). *Indefatigable, Sheet 53˚N–02˚E, Quaternary Geology (1:250.000 Series).* British Geological & Survey Rijks Geologische Dienst.

Deltares (2016). *Morphodynamics of Hollandse Kust (zuid) Wind Farm Zone* (Document No. CR-SC-DNVGL-SE-0190-02453-2_Morphodynamics, issue 2, dated 24 December 2016 to RVO).

Deltares (2017). *Geological Study Hollandse Kust (noord) Wind Farm Zone* (Document No. 11200513-002-BGS-0001, issue 2, dated 23 March 2017 to RVO).

Deltares (2019). *Morphodynamics and Scour Mitigations for Hollandse Kust (noord) Wind Farm Zone* (Document No. 11202796-000-HYE-0002, issue 1, dated 15 March 2019 to RVO).

Deltares (2020). *Morphodynamics of Hollandse Kust (west) Wind Farm Zone* (Document No. 11204811-002-HYE-0001, issue 1, dated 6 July 2020 to RVO).

DINOloket, Data and Information of the Dutch Subsurface. (offshore dataset received on 29 December 2021). TNO, Geological Survey of the Netherlands. https://www.dinoloket.nl/en

Dorst, L. L., Roos, P. C., Hulscher, S. J., & Lindenbergh, R. C. (2009). The estimation of sea floor dynamics from bathymetric surveys of a sand wave area. *De Gruyter, 3*(2), 97–120. https://doi.org/10.1515/JAG.2009.011

Dyer, K. R., & Huntley, D. A. (1999). The origin, classification and modelling of sand banks and ridges. *Continental Shelf Research*, *19*(10), 1285–1330. https://doi.org/10.1016/S0278-4343(99)00028-X

Ehlers, J. (1990). Reconstructing the dynamics of the north-west European Pleistocene ice sheets. *Quaternary Science Reviews, 9*(1), 71–83. https://doi.org/10.1016/0277-3791(90)90005-U

Folk, R. L. (1954). The distinction between grain size and mineral composition in sedimentary-rock nomenclature. *The Journal of Geology*, 62(4), 344-359. https://doi.org/10.1086/626171

Fugro (2018). *Geophysical Site Investigation Survey, Dutch Continental Shelf, North Sea, Hollandse Kust (noord) Wind Farm Zone Survey 2017* (Document No. GH216-R3, issue 3, dated 18 May 2018 to RVO).

Fugro (2019a). *Geological Ground Model, Hollandse Kust (noord) Wind Farm Zone, Dutch Sector, North Sea* (Document No. P903749(03), issue 5, dated 1 May 2019 to RVO).

Fugro (2019b). *Geophysical Results Report, Hollandse Kust (west) Wind Farm Zone Survey 2018, Dutch Continental Shelf, North Sea* (Document No. P904162(03), issue 4, dated 19 August 2019 to RVO).

Fugro (2019c). *Project Porthos Maasgeul Crossing Dutch Sector North Sea* Investigation Results Geotecnics (Document No. P905721/01, issue 2, dated 4 September 2019 to Port of Rotterdam).

Fugro (2020). Geological Ground Model, Hollandse Kust (west) Wind Farm Zone, Dutch Sector, North Sea (Document No. P904711(06), issue 3, dated 12 May 2020 to RVO).

Funnell, B.M. (1996). Plio-Pleistocene palaeogeography of the southern North Sea basin (3.75–0.60 Ma). *Quaternary Science Reviews, 15*(5–6), 391–405. https://doi.org/10.1016/0277-3791(96)00022-4

De Gans, W. 2007. Quaternary. In Wong, T.E., Batjes, D.A.J. & De Jager, J. (Eds.) *Geology of the Netherlands* (pp. 173–195). Royal Netherlands Academy of Arts and Sciences.

GDN (2018). *Geological Overview Map of the Kingdom of the Netherlands 1:600,000 (centennial edition)*, Utrecht: TNO–Geological Survey of the Netherlands, 1 map sheet.

Geluk, M. C (2005). *Stratigraphy and tectonics of Permo–Triassic basins in the Netherlands and surrounding areas*. [PhD Thesis, Utrecht University].

Graham, A. G., Stoker, M. S., Lonergan, L., Bradwell, T., & Stewart, M. A. (2011). The Pleistocene glaciations of the North Sea basin. In Ehlers J., Gibbard, P.L. & Hughes, P.D. (Eds.) *Developments in Quaternary Sciences* (Vol. 15, pp. 261–278). Elsevier. https://doi.org/10.1016/B978-0-444-53447-7.00021-0

Hulscher, S. J., de Swart, H. E., & de Vriend, H. J. (1993). The generation of offshore tidal sand banks and sand waves. *Continental Shelf Research*, *13*(11), 1183–1204. https://doi.org/10.1016/0278-4343(93)90048-3

Jacobs, P. & De Batist, N. (1996). Sequence stratigraphy and architecture on a ramp-type continental shelf: the Belgian Palaeogene. In De Batist, N. & Jacobs, P. (Eds.) *Geology of Siliciclastic Shelf Seas* (pp. 23–48). Geological Society Special Publications, 117. https://doi.org/10.1144/GSL.SP.1996.117.01.03

Joon, B., Laban, C. & Van der Meer, J.J.M. (1990). The Saalian Glaciation in the Dutch part of the North Sea. *Geologie en Mijnbouw, 69*(2), 151–158.

Knaapen, M. A. F., & Hulscher, S. J. (2002). Regeneration of sand waves after dredging. *Coastal Engineering*, *46*(4), 277–289. https://doi.org/10.1016/S0378-3839(02)00090-X

Knox, R.W.O'B., Bosch, J.H.A., Rasmussen, E.S., Heilmann-Clausen, C., Hiss, M., De Lugt, I.R., Kasińksi, J., King, C., Köthe, A., Słodkowska, B., Standke, G. & Vandenberghe, N. (2010). Cenozoic. In Doornenbal, J.C. & Stevenson, A.G. (Eds.) *Petroleum geological atlas of the Southern Permian Basin area* (pp. 211–223). EAGE Publications B.V., Houten.

Kuhlmann, G. & Wong, T.E. (2008). Pliocene paleoenvironment evolution as interpreted from 3D-seismic data in the southern North Sea, Dutch offshore sector. *Marine and Petroleum Geology, 25*(2), 173–189. https://doi.org/10.1016/j.marpetgeo.2007.05.009

Laban, C., Schüttenhelm, R.T.E., Balson, P.S., Baeteman, C. & Paepe, R. (1992). *Ostend, Sheet 51˚N–02˚E, Quaternary Geology (1:250.000 Series).* British Geological & Survey Rijks Geologische Dienst & Belgische Geologische Dienst.

Laban, C. (1995). *The Pleistocene glaciations in the Dutch sector of the North Sea: a synthesis of sedimentary and seismic data*. [PhD Thesis, University of Amsterdam].

Laban, C. & Rijsdijk, K.F. (2002). De Rijn–Maasdelta's in de Noordzee. *Grondboor & Hamer 56*(3/4), 60–65.

Laban, C., & van der Meer, J. J. (2011). Pleistocene glaciation in the Netherlands. In Ehlers J., Gibbard, P.L. & Hughes, P.D. (Eds.) *Developments in Quaternary Sciences* (Vol. 15, pp. 247–260). Elsevier. https://doi.org/10.1016/B978-0-444-53447-7.00020-9

Liu, A. C., De Batist, M., Henriet, J. P., & Missiaen, T. (1993). Plio–Pleistocene scour hollows in the Southern Bight of the North Sea. *Geologie en Mijnbouw, 71*(3), 195–204.

McCave, I. N. (1971). Sand waves in the North Sea off the coast of Holland. *Marine geology, 10*(3), 199–225. https://doi.org/10.1016/0025-3227(71)90063-6

Moreau, J., Huuse, M., Janszen, A., van der Vegt, P., Gibbard, P. L., & Moscariello, A. (2012). The glaciogenic unconformity of the southern North Sea. *Geological Society, London, Special Publications, 368*(1), 99–110. https://doi.org/10.1144/SP368.5

NITG–TNO (2004d). *Top Pleistocene Formations*. Scale 1:750.000.

NITG–TNO (2004b). *Distribution of Holocene Formations at Seafloor*. Scale 1:750.000.

Overeem, I., Weltje, G.J., Bishop-Kay, C. & Kroonenberg, S.B. (2001). The Late Cenozoic Eridanos delta system in the southern North Sea basin: a climate signal in sediment supply? *Basin Research*,*13*(3), 293–312. https://doi.org/10.1046/j.1365-2117.2001.00151.x

Overeem, I. (2002). *Process–response simulation of fluvio–deltaic stratigraphy*. [PhD Thesis, Delft University of Technology, Department of Applied Earth Sciences].

Peeters, J., Busschers, F.S. & Stouthamer, E. (2015). Fluvial evolution of the Rhine during the last interglacial–glacial cycle in southern North Sea basin: a review and look forward. *Quaternary International, 357*, 176–188. https://doi.org/10.1016/j.quaint.2014.03.024

Praeg, D. (1996). *Morphology, stratigraphy and genesis of buried Mid-Pleistocene tunnel-valleys in the southern North Sea basin*. [PhD Thesis, University of Edinburgh]. http://hdl.handle.net/1842/15659

Rasmussen, E.S. & Dybkjær, K. (2014). Patterns of Cenozoic sediment flux from western Scandinavia: discussion. *Basin Research, 26*(2), 338–346. https://doi.org/10.1111/bre.12024

Rijsdijk, K.F., Passchier, S., Weerts, H.J.T., Laban, C., Van Leeuwen, R.J.W. & Ebbing, J.H.J. (2005). Revised Upper Cenozoic stratigraphy of the Dutch sector of the North Sea basin: towards an integrated lithostratigraphic, seismostratigraphic and allostratigraphic approach. *Netherlands Journal of Geosciences, 84*(2), 129–146. https://doi.org/10.1017/S0016774600023015

Stouthamer, E., Cohen, K., & Hoek, W. (2015). De vorming van het land. *Geologie en geomorfologie*. Perspectief Uitgevers, ISBN 978 94 91269 11 0.

Thöle, H., Gaedicke, C., Kuhlmann, G. & Reinhardt, L. (2014). Late Cenozoic sedimentary evolution of the German North Sea – a seismic stratigraphic approach. *Newsletters on Stratigraphy, 47*, 299–329. https://doi.org/10.1127/0078-0421/2014/0049

TNO-GDN (2022). Upper North Sea Group. In: *Stratigraphic Nomenclature of the Netherlands*, TNO – Geological Survey of the Netherlands. Accessed during December 2021 and January 2022 from https://www.dinoloket.nl/en/stratigraphic-nomenclature.

Van der Meulen, M.J., van Gessel, S.F., Tiemersma, J.J. & van Dijk, T.A. (2004). Grind en stenen voor de kust van Texel en de winbare voorraad suppletiezand (Document No. NITG 04-236-B1299). TNO–NITG.

Van Dijk, T. A., & Kleinhans, M. G. (2005). Processes controlling the dynamics of compound sand waves in the North Sea, Netherlands. *Journal of Geophysical Research: Earth Surface*, *110*(F4). https://doi.org/10.1029/2004JF000173

Van Dijk, T. A., van Dalfsen, J. A., Van Lancker, V., van Overmeeren, R. A., van Heteren, S., & Doornenbal, P. J. (2012). Benthic habitat variations over tidal ridges, North Sea, the Netherlands. In *Seafloor geomorphology as benthic habitat* (pp. 241–249). Elsevier. https://doi.org/10.1016/B978-0-12-385140-6.00013-X

Van Heteren, S (2010). *Analyses of seabed and soil quality required for wind farms*. Final report We@Sea Project 2005-005, dated April 2010.

Van Santen, R. B., De Swart, H. E., & van Dijk, T. A. G. P. (2011). Sensitivity of tidal sand wavelength to environmental parameters: A combined data analysis and modelling approach. *Continental Shelf Research*, *31*(9), 966–978. https://doi.org/10.1016/j.csr.2011.03.003

Wong, T.E., Batjes, D.A. & de Jager, J. (2007). *Geology of the Netherlands*. Royal Netherlands Academy of Arts and Sciences, Amsterdam.

Appendix A

Guidelines on Use of Report

A.1 Guidelines on Use of Report

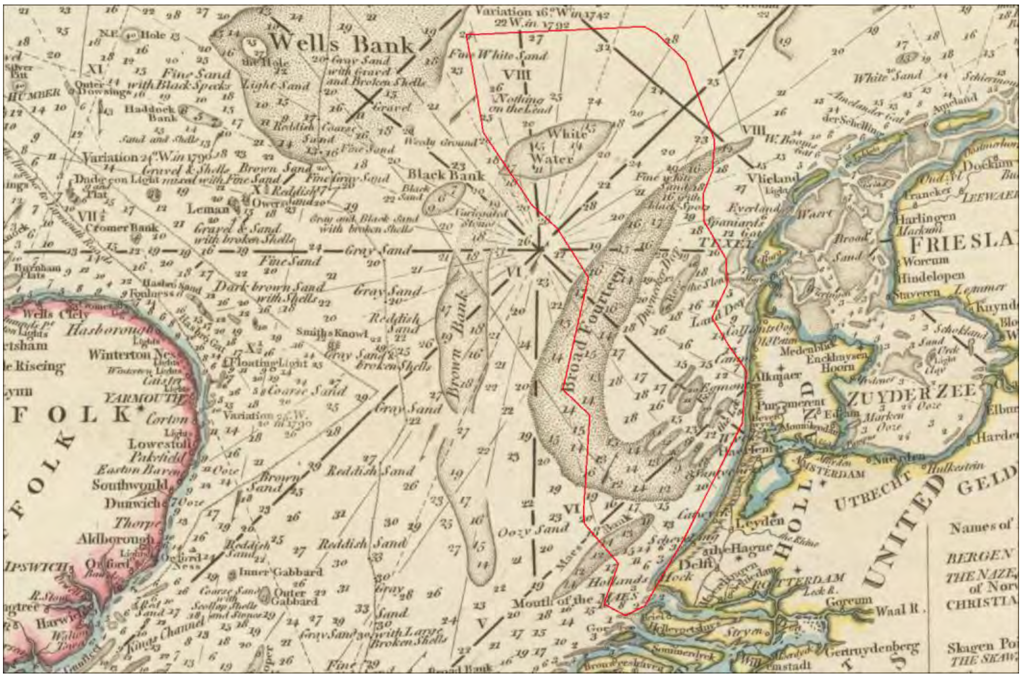
This report (the “Report”) was prepared as part of the services (the “Services”) provided by Fugro France SAS (”Fugro”) for its client (the “Client”) under the terms of the relevant contract between the two parties (the “Contract”). The Services were performed by Fugro based on requirements of the Client set out in the Contract or otherwise made known by the Client to Fugro at the time. Fugro’s obligations and liabilities to the Client or any other party in respect of the Services and this Report are limited in time and value as defined in Contract (or in the absence of any express provision in the Contract as implied by the law of the Contract) and Fugro provides no other representation or warranty whether express or implied, in relation to the Services or for the use of this Report for any other purpose. Furthermore, Fugro has no obligation to update or revise this Report based on changes in conditions or information which emerge following issue of this Report unless expressly required by the Contract.
The Services were performed by Fugro exclusively for the Client and any other party identified in the Contract for the purpose set out therein. Any use and/or reliance on the Report or the Services for purposes not expressly stated in the Contract, by the Client or any other party, is at that party’s risk and Fugro accepts no liability whatsoever for any such use and/or reliance.

Appendix B

Archaeological Desktop Study

Periplus Archeomare

Archaeological Desk Study
Area of interests
Aramis pipelines



Authors

[redacted] & [redacted]

At the request of

FUGRO

Document Control	
Revision	2.0
Date	February 04, 2022
Periplus Archeomare Reference	21A036-01
Client reference	Aramis

Reviewers	
Organization	Name
Fugro	[redacted]
Rijkswaterstaat	[redacted]
Rijksdienst voor het Cultureel Erfgoed	[redacted]
Gemeente Rotterdam	[redacted]

Colophon

Periplus Archeomare Report 21A036-01

Archaeological desk study area of interest Aramis pipelines
Authors: [redacted] and [redacted]
At the request of: Fugro
Contact: S. Po

ISSN 2352-9547

Revision details

Revision	Description	Authors	Checked by	Authorisation	Date
2.0	Final (comm. Inc.)	[redacted]	[redacted]	[redacted]	04-02-2022
1.0	Draft	[redacted]	[redacted]	[redacted]	15-01-2022

Authorization:

[redacted]

KNA Senior prospector waterbodems

Periplus Archeomare

Periplus Archeomare
Kraanspoor 14
1033 SE - Amsterdam
Tel: 020-6367891
Email: info@periplus.nl
Website: www.periplus.nl

Contents

Table 1. Dutch archaeological periods

Period	Time in Years				
Post-medieval / Modern Times	1500	A.D.	-	Present	
Late medieval period	1050	A.D.	-	1500	A.D.
Early medieval period	450	A.D.	-	1050	A.D.
Roman Times	12	B.C.	-	450	A.D.
Iron Age	800	B.C.	-	12	B.C.
Bronze Age	2000	B.C.	-	800	B.C.
Neolithic (New Stone Age)	5300	B.C.	-	2000	B.C.
Mesolithic (Stone Age)	8800	B.C.	-	4900	B.C.
Palaeolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Table 2. Administrative details

Location:	North Sea		
Toponym:	Aramis pipelines		
Chart:	1801-01		
Coordinates Geodetic datum: ED50 Projection: UTM31N	Centre:	E 560722	N 5856233
	NW	E 510577	N 5961562
	NE	E 610866	N 5961562
	SW	E 510577	N 5750904
	SE	E 610866	N 5750904
Depth (LAT):	0 to 46.1 meter, average 26.7 meter		
Surface investigation area	11,355 km^2		
Environment:	Tidal currents, salt water		
Area use:	Shipping , fishing, wind farm zones		
Area administrator:	Rijkswaterstaat Zee en Delta Municipality of Rotterdam		
ARCHIS number:	5144645100		
Periplus-project reference:	21A036-01		
Period of execution	January 2022		

Samenvatting (in Dutch)

Periplus Archeomare heeft in opdracht van Fugro een archeologisch bureauonderzoek uitgevoerd naar het plangebied voor de Aramis-leidingroutes. Het gebied van 11.355 km2 ligt in de Noordzee, voor de kust van Nederland.

Door de aanleg van de leidingen kunnen eventueel aanwezige archeologische resten in het gebied worden bedreigd. Volgens de Erfgoedwet (2016) is een wettelijke verplichting om archeologisch onderzoek te doen om archeologische resten te beschermen. Dit archeologische bureauonderzoek is de eerste stap in het archeologisch proces om vast te stellen of archeologische resten aanwezig zijn en of deze resten kunnen worden aangetast door de aanleg van de geplande pijpleidingen. De resultaten zijn hieronder samengevat.

Het gebied heeft hoge verwachtingen voor de aanwezigheid van (overblijfselen van) scheepswrakken en vliegtuigwrakken uit de Tweede Wereldoorlog. Intacte prehistorische landschappen en verwante in situ overblijfselen van paleolithische en vroeg-mesolithische campings en opgravingen kunnen op bepaalde plaatsen bewaard zijn gebleven. De voorlopige pijpleidingroutes zijn nog niet onderzocht door gedetailleerde geofysische onderzoeken. Deze gebieden bevatten mogelijk meer onontdekte scheepswrakken of overblijfselen van scheepswrakken dan nu bekend is.

Op dit moment is er nog weinig bekend over de integriteit van het Pleistoceen landschap. Door middel van seismiek kunnen hierin de voorkomende geologische eenheden (zowel horizontaal als verticaal) en archeologische niveaus in kaart worden gebracht. Het karakter van laaggrenzen (erosief of niet-erosief) kan worden geïnterpreteerd. Het is echter onwaarschijnlijk dat archeologische overblijfselen van paleolithische en mesolithische nederzettingsresten op basis van geofysisch en geotechnisch onderzoek met voldoende zekerheid kunnen worden geïdentificeerd om beperkingen op te leggen aan de aanleg van pijpleidingen. In dit stadium moet daarom niet worden geconcentreerd op het opsporen van prehistorische nederzettingsresten, maar op een pragmatische inzet geofysische technieken inzetten om een beter inzicht te krijgen in (de integriteit van) het Pleistoceen landschap. De verkregen inzichten zullen worden gebruikt om a) het archeologische verwachtingsmodel te verfijnen en b) gebieden met een hoge verwachting voor in situ prehistorische overblijfselen toe te wijzen.

Conform de AMZ-cyclus wordt geadviseerd om een inventariserend veldonderzoek uit te voeren om de archeologische verwachting. In het algemeen bestaan vergelijkbare onderzoeken uit een geofysisch onderzoek met side scan sonar, magnetometer en subbottom profiler en een geotechnisch onderzoek. De resulterende gegevens moeten worden geanalyseerd nadat de algemene verwerking, interpretatie en rapportage door de onderzoeksaannemer is uitgevoerd.

De archeologische beoordeling van de gegevens dient te worden uitgevoerd door een geofysisch specialist (KNA prospector Waterbodems). De datakwaliteit van de onderzoeken moet aansluiten bij de eisen voor deze archeologische beoordeling. Om de afstemming tussen het geofysisch onderzoek en de vereiste kwaliteit voor deze beoordeling te waarborgen, dient een Programma van Eisen opgesteld te worden conform de KNA (Kwaliteitsnorm Nederlandse Archeologie 4.1) dat door de bevoegde autoriteit wordt beoordeeld en goedgekeurd.

Summary

Periplus Archeomare was assigned by Fugro to conduct an archaeological desk study of the area of interest for the Aramis pipeline routes. The area of interest of 11.355 km^2 is located in the North Sea, off the coast of the Netherlands.

The installation of the pipelines may affect archaeological remains in the area, if present. According to the Law on Archaeological Heritage (Dutch: Erfgoedwet 2016) there is a statutory obligation to conduct archaeological research in order to protect the remains. This archaeological desk study is the first step in the archaeological process aiming to establish whether archaeological remains are, or are likely to be, present, and whether these remains could be effected by the development of the planned pipelines. The results are summarized below.

The area of interest has a high expectation for the presence of (remains of) ship wrecks and WWII plane wrecks. Intact prehistoric landscapes and related *in situ* remains of Palaeolithic and Early Mesolithic camp sites and inhumations are expected to have been preserved in places.

The proposed pipeline routes have not been investigated by detailed geophysical surveys yet. These areas may contain more undiscovered shipwrecks or remains of shipwrecks than currently known.

At this stage little is known about the integrity of the *Pleistocene* landscape. By means of subbottom profiling the occurrence geological units (both horizontal as vertical) and archaeological levels herein can be mapped. The character of layer boundaries (erosive or non-erosive) can be interpreted. It is unlikely however that archaeological remains of Palaeolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on pipeline development. At this stage focus should therefore not be put on tracing prehistoric camp sites but on a pragmatic employment of geophysical techniques in order to obtain a better insight in (the integrity of) the *Pleistocene* landscape. The insights gained shall be used to a) refine the archaeological expectancy model and b) allocate areas with a high expectancy for *in situ* prehistoric remains.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and preservation of ship wrecks, prehistoric landscapes and potential archaeological levels.

Archaeological Expectancy	**Method**		**Goal**	**Remarks**
Ship and aircraft wrecks	Geophysical	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
		Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
		Sub-bottom Profiler	detect buried objects including possible ship wrecks and remains of aircraft	nature of the buried object cannot be determined directly
		Magnetometer		
Prehistoric settlements		Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data

kiwa certified ISO 9001

Archaeological Expectancy	**Method**		**Goal**	**Remarks**
(camp sites)	Geotechnical	Geological Sampling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	designation of borehole and/or vibrocore locations for geo-archaeological research based on SBP data
		Cone Penetration Test	determine lithostratigraphy	correlate with drilling data

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler* and a geotechnical survey. The resulting data should be assessed after the general processing, interpretation and reporting has been performed by the survey contractor.

The archaeological assessment of the data shall to be conducted by a geophysical specialist (KNA prospector Waterbodems). The data quality from the surveys needs to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of Requirements (In Dutch: ‘Programma van Eisen’) in accordance with the ‘KNA’ (the Dutch quality standards for archaeological research), to be authorized by the competent authority.

1 Introduction

Periplus Archeomare was assigned by Fugro to conduct an archaeological desk study of the area of interest for the proposed Aramis pipeline routes. The area of interest of 11.355 km^2 is located in the North Sea off the coast of the Netherlands.

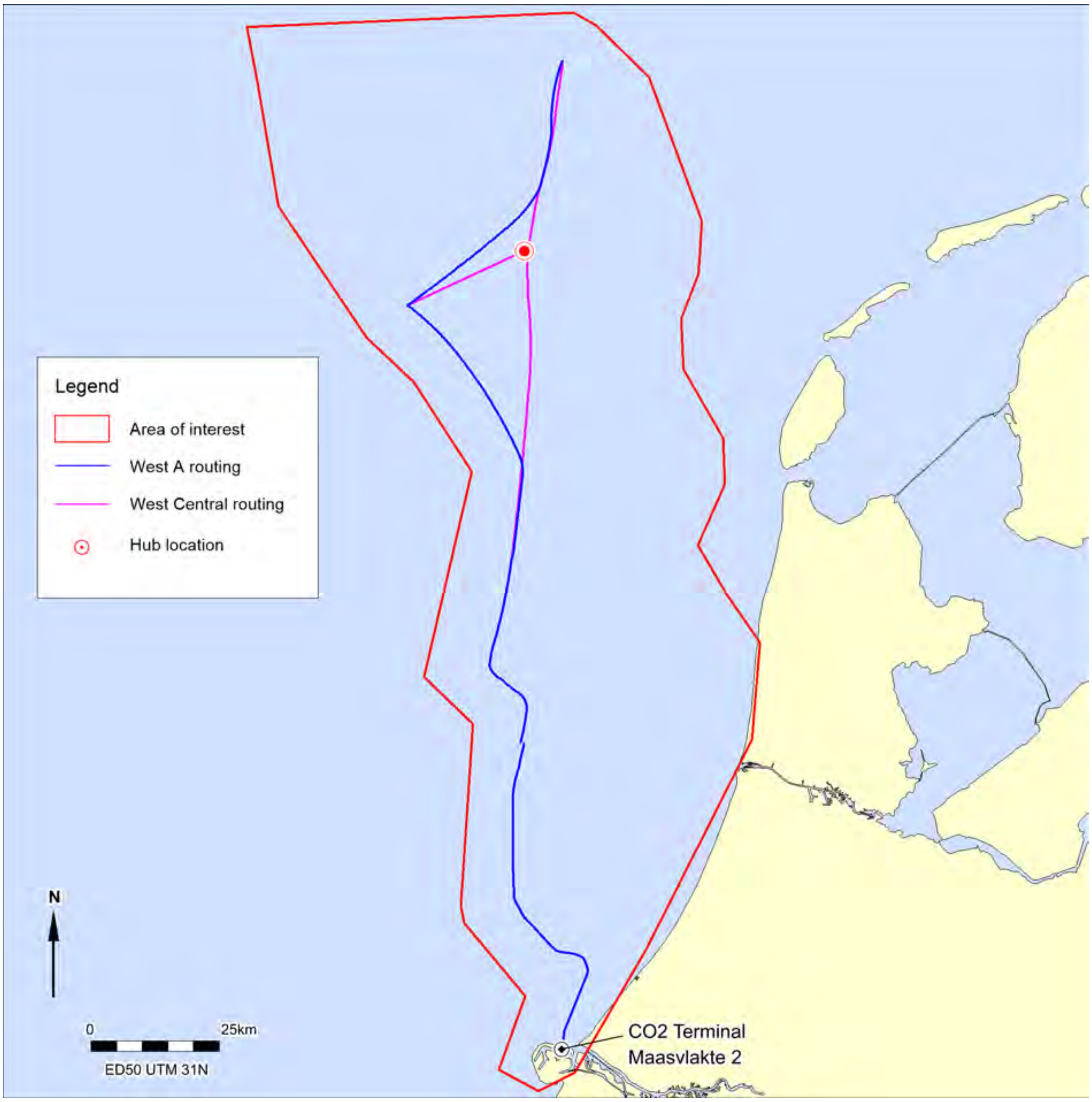


Figure 1. Location map of the area of interest

The desk study and reporting were carried out in accordance with the Dutch Quality Standard for archaeological research[1].

[1] Kwaliteitsnorm Nederlandse Archeologie (KNA waterbodems 4.1).

1.1 Background

TotalEnergies plans to build a new pipeline from Maasvlakte 2 to offshore blocks L4/K6 as part of the CCS Aramis project. The area to be investigated encompasses:

(1) the shore approach/Landfall pipeline routing for HDD and dredging part at Maasvlakte
(2) the offshore rigid pipeline routing from Maasvlakte to blocks L4/K6
(3) the offshore distribution hub.

As a preparation phase of the future surveys to be performed, TotalEnergies intends to conduct desktop studies of the area of interest. The final routing and the location of the distribution hub are not defined yet.

In the Law on Archaeological Heritage (Erfgoedwet 2016), emerged from the Malta Convention (1992), incorporated in the Monuments Act through the Archaeological Heritage Act, the protection of the archaeological heritage is regulated. Planned activities, such as the installation of pipelines in the North Sea, may affect the archaeological values if present. If effects on possible remains are expected, there is a statutory obligation to conduct archaeological research. This process is also outlined in the Water Decree (Dutch: Waterbesluit).

This archaeological desk study for the proposed Aramis pipeline is the first step in the archaeological process as part of the so-called *AMZ* cycle.

1.2 Objective

The purpose of an archaeological desk study in general is to specify the archaeological expectancy for a certain area. More in detail, the purpose of this desk study is to establish whether archaeological remains are, or are likely to be, present along the pipeline route, and whether these (possible) remains could be affected by the installation of the pipeline. Where possible, the desk study aims to give insight into the (possible) archaeological value of these remains in terms of their physical or scientific value, such as the overall quality of preservation and the rarity of the remains. Furthermore, this report aims to make recommendations regarding subsequent steps in dealing with known and expected archaeological remains along the pipeline route.

The archaeological management procedure (‘AMZ-cycle’) is a defined sequence of steps and decisions within archaeological heritage management in the Netherlands. The procedure is embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1) as the mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 1.

1.3 Research questions

For an archaeological desk study, the following research questions are applicable:

- Are there any known archaeological values present within the area of interest? If so, what is the nature, extent (depth) location and dating of these sites?
- Are there, in addition to any known values, archaeological remains to be expected? If so, what are the nature, extent (depth) location and date of the expected archaeological remains?
- Can the proposed activities affect known or expected archaeological values? If so, can an impact on archaeological assets be prevented or restricted by planning adaptation?
- If the archaeological values cannot be saved: What kind of further research is needed to determine the presence of archaeological values and their size, location, type and date to be determined enough to come to a selection decision?
- What are the possible effects of the installation of the pipeline on the areas with specific archaeological interest?
- What are the possibilities to mitigate the disturbance of areas with specific archaeological interests?
- Should further investigations be carried out from archaeological point of view and what are the recommendations on the scope and specifications of these investigations?

If, on the basis of this desk study, a connection can be made with other questions from the *NoaA* 2.0, then these must be answered. Given the nature of the research and the often limited possibilities for the identification of archaeological object, it is not possible to select all the questions in advance. As far as the possible find categories are concerned, there are also various ongoing research programs at universities, with which a relationship can be established.

1.4 Research and management framework

Our knowledge of the development of *Pleistocene* and Early *Holocene* landscapes and the plants, animals and humans who lived in the North Sea area is limited. This gap in geo-archaeological knowledge was recognized by the Dutch Cultural Heritage Agency (Rijksdienst voor het Cultureel Erfgoed). To provide tools to fill this gap the 'North Sea Prehistory Research and management Framework (NSPRMF)' was published, in which the foundation was laid for future research and management of the prehistoric heritage. The themes and topics of the NSPRMF are listed in table 3.

Theme	Topics
A. Stratigraphic and chronological frameworks	A.1: Lithostratigraphic classification and chronological anchoring A.2: Sea level change and glacio-isostacy A.3: Survival of deposits of archaeological significance A.4: Biostratigraphies and absolute dating
B. Palaeogeography and environment	B.1: Middle/Late Pleistocene reshaping of topography and river drainage B.2: Development of the Weichselian/Devensian landscape B.3: Palaeogeographic evolution after the Last Glacial Maximum (LGM) B.4: Quaternary palaeoecology
C. Global perspectives on intercontinental hominin dispersals	C.1: North Sea coastal dynamics and human uses of the coastal zone C.2: Pleistocene North Sea level oscillations and population of islands
D. Pleistocene hominin colonisations of northern Europe	D.1: Early human exploitation strategies in changing environments D.2: Natural barriers for hominin expansion
E. Reoccupation of northern Europe after the Last Glacial Maximum (LGM)	E.1: Post-LGM occupation flux E.2: Occupation strategies
F. Post-glacial land use dynamics in the context of a changing landscape	F.1: Changing landscape structure F.2: Behavioural diversity among hunter-gatherers F.3: Maritime archaeologies of the North Sea
G. Representation of prehistoric hunter-gatherer communities and lifeways	G.1: Spatial perspectives on North Sea palaeolandscapes G.2: The distributional nature of early hominin communities G.3: Enculturated hunter-gatherer landscapes

* Despite the fact that theme G primarily focusses on post-LGM hunter-gatherers, topic G.2 was broadly defined, and of equal relevance to theme D.

Table 3. NSPRMF - research themes and topics (Peeters 2009)

In 2019 the NSPRMF agenda was retuned based on the developments in the previous decade. This report contains the basis for policy in the years to come. The archaeological studies currently conducted in the context of wind farm development, pipeline and cable installation, sand extraction and exploration for oil and gas in the North Sea area, are conducted in accordance to the AMZ-cycle. These studies shall contribute to the goals set in the NSPRMF.

As described above little is known about the early *Holocene* inhabitants of the North Sea region, their settlements and the way in which they maintained themselves in the rapidly changing landscape. The information value of the expected settlements is therefore large. This is also stated in the National Research Agenda for Early Prehistory: *Locations and any surrounding phenomena that are located in paleo-landscape contexts that have not or have hardly been investigated have by definition a large information value.* For future investigations, reference shall therefor be made to the framework and the research questions in the *NOaA* in addition to the NSPRMF.

2 Methodology

The desk study was conducted in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1, Protocol 4002). This concerns in particular the specifications LS01, LS02, LS03, LS04 and LS05. The study is reported in accordance with specification LS06.

In order to comply with the main objectives and answer the research questions, the archaeological desk study is carried out according to the scope of Work as described in the following steps:

- Description of the Area of Interest and determination of the consequences for future use (LS01);
- Description of the current usage of the area of Interest (LS02);
- Description of the historical situation and possible disturbances (LS03);
- Description of the geological setting within which the archaeological objects are to be found (LS04);
- Description of the known archaeological features and objects (LS04);
- Definition of a specified archaeological expectation (LS05).

Based on these components a specified archaeological expectation is defined. It is expressed whether, and if so, which archaeological values can be expected. The properties of these values will be indicated in as much detail as possible. The results of the study are summarized in chapter 3. Based on the results the research questions are answered in chapter 4. The study concludes with a summary and recommendation in chapter 5.

The research and reporting were conducted by S. van den Brenk (senior marine archaeologist) and R. van Lil (senior marine prospector). The results were approved and authorized by B. van Mierlo (Senior marine prospector).

2.1 Sources

The following sources were consulted for the study:

- Archis III, archaeological database of the Dutch Cultural Heritage Agency
- Databases of Periplus Archeomare
- Dutch Federation for Aviation Archaeology (NFLA)
- Geological maps
- Geological publications
- Scope of Work NL DTS Aramis (Memo TotalEnergies)
- National Contact Number (NCN) database Rijkswaterstaat
- Rijkswaterstaat Zee en Delta
- The Hydrographic Service of the Royal Netherlands Navy
- *TNO-NITG*; geological borehole data and maps
- Various results from previous investigations in the area of interest
- Various sources from the Internet

For a complete overview of the sources and literature see references on page 51. Words in *italics* and abbreviations are explained in the glossary on page 50.

3 Results

3.1 Definition of the area of interest and consequences of future use (LS01)

The area of interest is located off the west coast of the Netherlands and stretches from Maasvlakte 2 to mining block L4, 75 km northwest of the island of Texel.

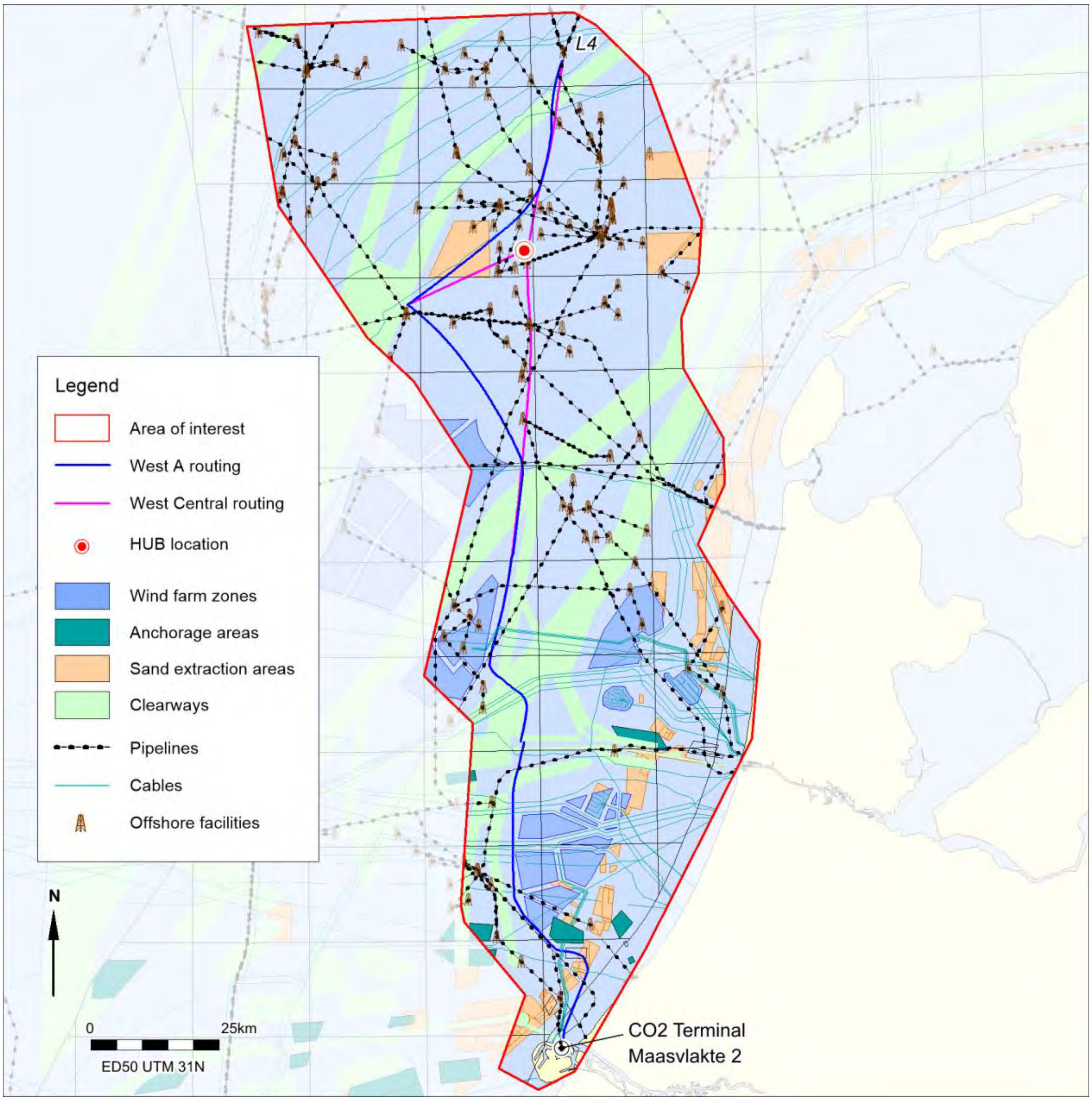


Figure 2. Overview of the area of interest in relation to other areas of use

The trenching of the pipelines has a direct impact on the seafloor, which might have an effect on the possible presence of cultural heritage. In the longer term, exposed pipelines can cause a change in seafloor morphology due to change of tidal currents. This may cause, in turn buried ship wrecks to emerge at the surface, exposing them to erosion.

Previous research

Parts of the area of interest have been investigated in the past for archaeological purposes:

- Several offshore drill locations
- Wind farm zones Hollandse Kust North, South and West
- Cable and pipeline corridors

The outlines of the investigated areas are shown in the figure below.

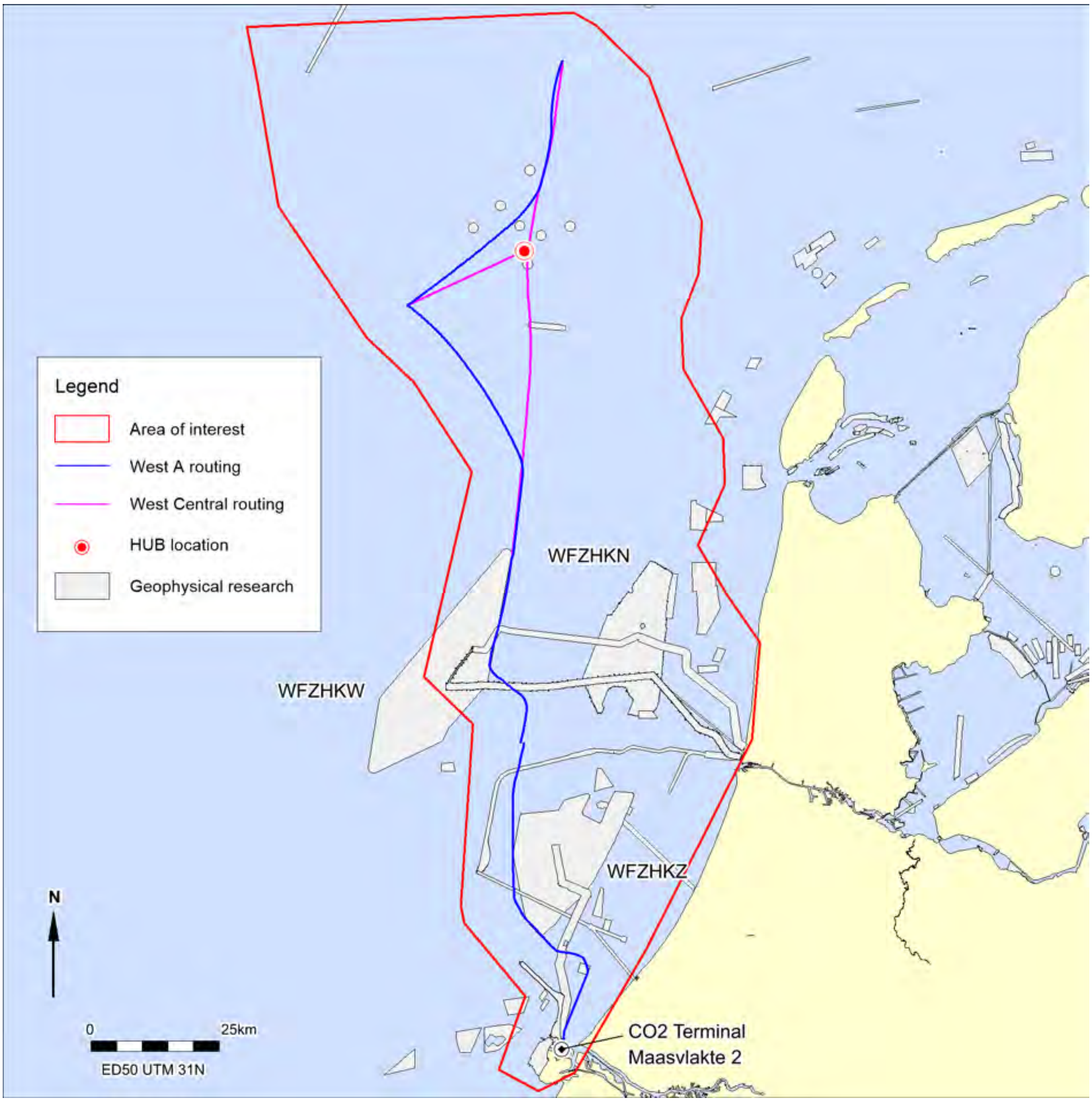


Figure 3 Previous conducted archaeological investigations in the area

The results of these investigations have been incorporated in paragraph 3.5, description of known archaeological values.

3.2 Description of the current situation (LS02)

The figure below shows a colour depth map based on composite data from the Hydrographic Service (25m grid, 2009) and data from various wind farm zones (5m, 2026-2020).

The water depth within the area of interest varies from 0 to 46.1 meter (LAT), with an average of 26.7 meter (LAT).

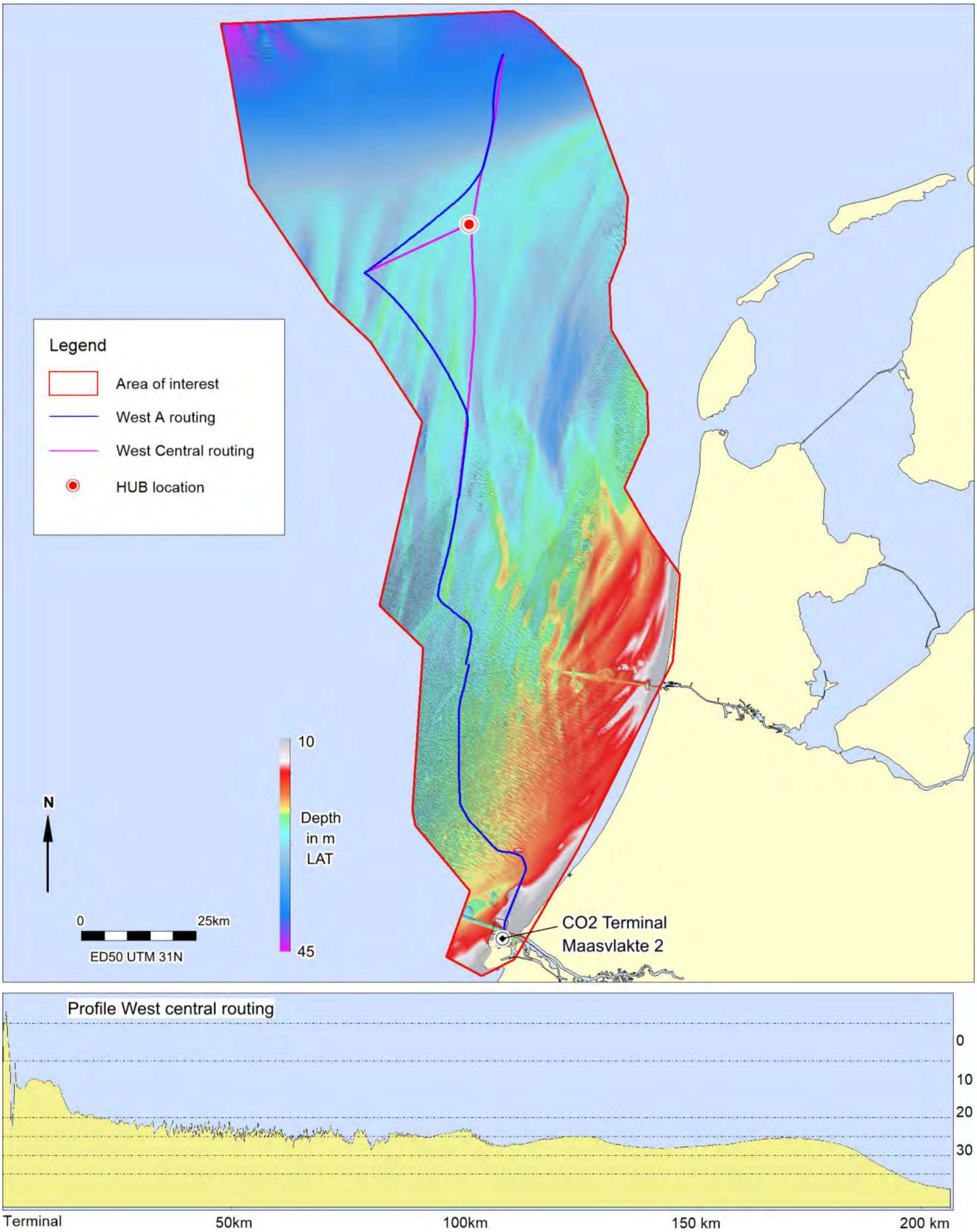


Figure 4. General bathymetry of the seabed and profile along the West central routing

The seabed is characterized by three types of morphological structures. The largest structures are north-south orientated ridges. The ridges vary in width from 1km to 4km and are generally up to 10m in height.
Superposed on the ridges sand waves have developed. The occurrence of sand waves is confined to the southwestern and central part of the area. The sand waves are up to 4m in height; the average distance between the crests is 300m. The crest heights tend to diminish towards the north. The sand wave crest orientation changes from west-east to northwest-southeast at the intersections with the large north-south orientated ridges.

Mega-current ripples which developed on top of the sand waves cannot be distinguished due to the grid-scale available (25m), but are nonetheless expected to be present. The ripple height is often less than a few dm; the distance between the current ripple crests is up to 10m.

The large ridges, sand dunes and current ripples have formed in the top layer of mobile sand. The ripples migrate along with tidal currents; the sand dunes typically migrate with a speed of 1 to 10 m/year. The migration rate of sand dunes in the Princes Amalia Wind Farm Zone was assessed to be in the order of 4 m/year[2].

[2] Laban 2004.

Landfall area

An overview of the recent bathymetry in the landfall area is constructed based on composite data from various surveys (Hydrographic service, Rijkswaterstaat and Tennet, with permission).

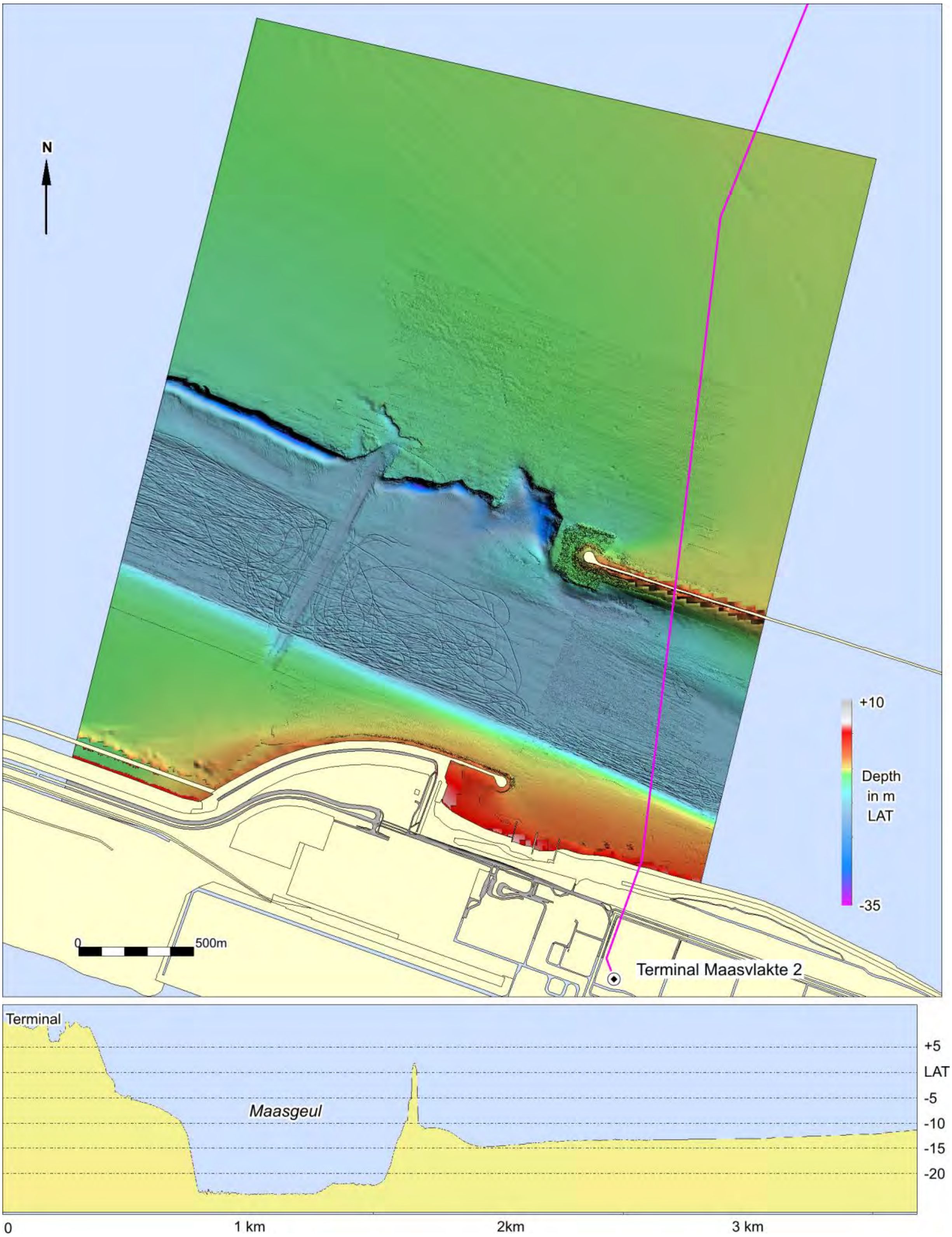


Figure 5. Bathymetry of the seabed in the landfall area

Seabed morphology

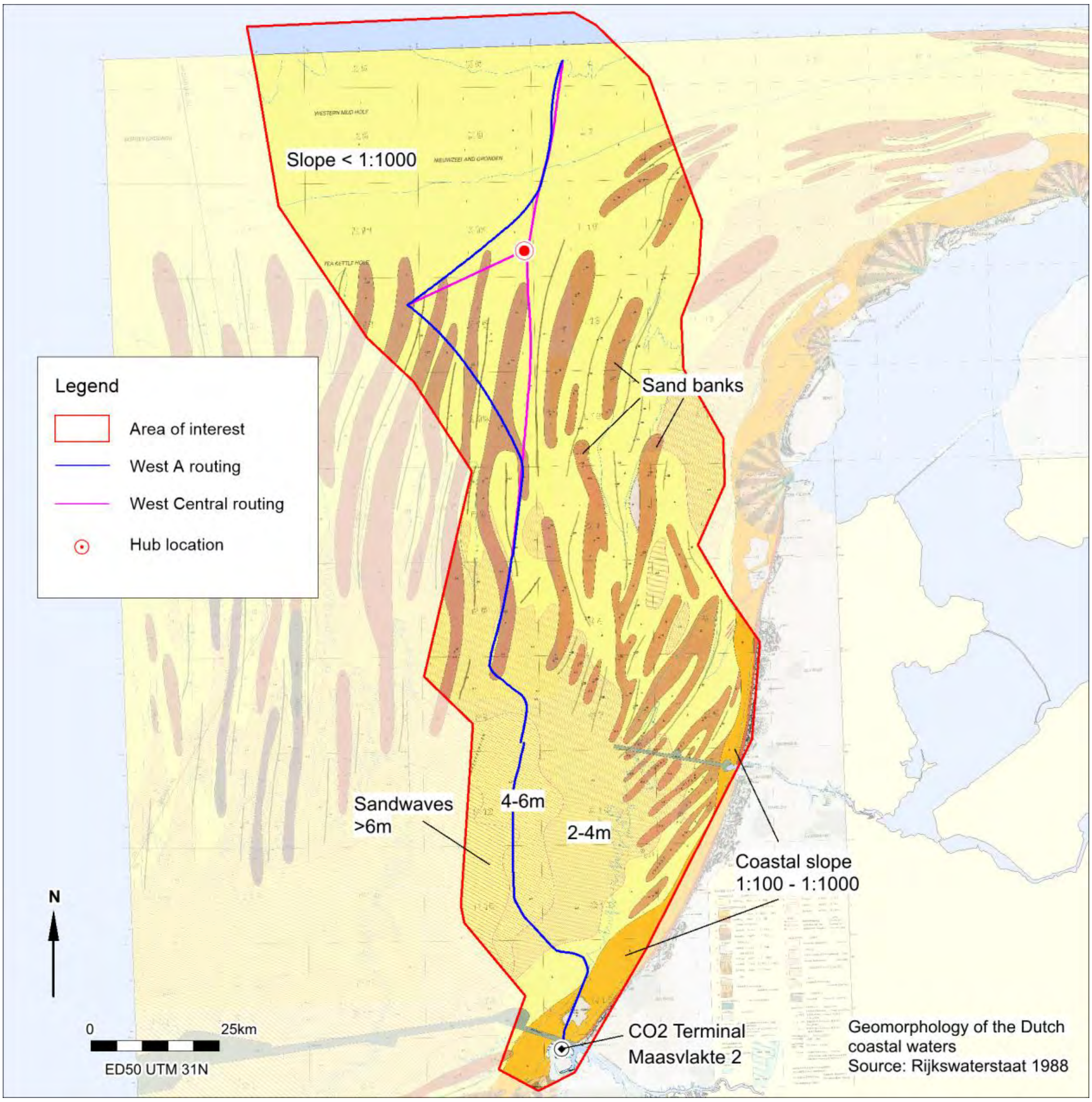


Figure 6. Geomorphology of the seabed

The southern part of the area of interest is dominated by sand waves with a northwest-southeast orientation and a height of 4 to 6 meters. The central area is dominated by large north-south oriented sand banks, superimposed by sand waves. The northern part is predominantly flat and featureless.

3.3 Historical situation and possible disturbances (LS03)

The North Sea basin formed about 12000 years ago as an extensive aeolian sand landscape with a tundra climate. At the end of the last Ice Age (ca 11500 years ago), the temperature rose as a result, the northern glaciers melted. The sea level rose and the North Sea basin was gradually filled. The filling of the North sea plains did occur over a period of 3500-5000 years. During this time the landscape changed, from freezing tundra to woodland where birch dominated the region, with some alder, hazel, juniper, and pine[3]. During this time, the North sea rose more rapidly than it does today, therefore, the residents of the area had to leave eventually for higher ground.[4]

Figure 7. Reconstruction of the historical coast lines in the North Sea basin (map by: McNulty, W.E. and J.N. Cookson in National Geographic Magazine)

The Dogger Bank in the North of the Dutch Continental Shelf is an example of an elevated area. Remnants of the tundra landscape and its inhabitants are regularly found in the nets of fishermen. However, all over the North Sea, remnants are found of hominin occupation of the region. For example, the only known Neanderthal from the Netherlands was found in the North sea. Moreover, multiple Palaeolithic and Mesolithic artefacts and even human remains have been found within the remains of the North Sea[12]. A number of artefacts have been found within the area of interest [5.] By 6000 years ago, the North sea plains were fully submerged, and the North sea looked very much as it does today.

[3] Van de Noort, 2011

[4] Gaffney e.a. 2005.

[5] Louwe Kooijmans 1970.

Due to the sea level rise the ancient landscapes drowned. These landscapes are depicted through geophysical and geotechnical engineering. Recently, for example, on the basis of seismic data from the oil industry a prehistoric landscape was reconstructed near the east coast of England[6]. Authors concluded that a large part of the Southern North Sea contains an in-situ prehistoric landscape.

Figure 8 shows the remains of mammal bones, among which many remains of mammoths which have been found in the nets of fishermen in the North Sea area. Among the finds is a well-preserved prehistoric human skull. Possibly the skull has been found near the Brown Bank area, but unfortunately the location of these finds is not known [7].

The finds are done by different fishermen, but given to fisherman Kommer Tanis who preserves and collects the finds. Tanis reports important finds, such as the human skull shown in figure 8 to scientists. In close cooperation with the scientists he makes the finds available for further analysis, such as DNA research.

Figure 8. Human skull found in the nets of fishermen in 'North sea/Doggerland' in November 2019

[6] Project 'North sea paleo-landscapes' of the University of Birmingham

[7] Pers. Comm. Fisherman and collector Kommer Tanis.

Figure 9. Prehistoric artefacts collected by fishermen and found at the beach (after Kooijmans 1970 en Armkreutz 2018).

Shipping

The earliest evidence of shipping in the North Sea dates from the Neolithic. For example, evidence of this can be found in prehistoric Rhineland burials. In this region the access of tin was limited and was therefore considered a luxury good. It had to be imported from other regions. One of such regions is South-West Britain[8]. It can be seen the other way around as well, Alpine jade axe heads have been sporadically found across the British Isles. Since this age, there is an increase of shipping in the North Sea with a few well-documented historical peaks. During Roman times, the North Sea and in particular the Channel served as connecting bridge for the empire. From the Early and High Middle Ages new centres of power arose along the North Sea coast. Furthermore, the raids of the Vikings should also be mentioned in this context. From the late Middle Ages, the international trade and the shipbuilding industry developed so that the North Sea was a stepping stone for global shipping routes. In all periods, ships were lost at sea. Ship wrecks are

[8] Van de Noort 2011.

the traces of the maritime past and this can be preserved under favourable storage conditions in sediment. Obviously, the possible existing wreck sites only occupy a very small area of the total area of interest.

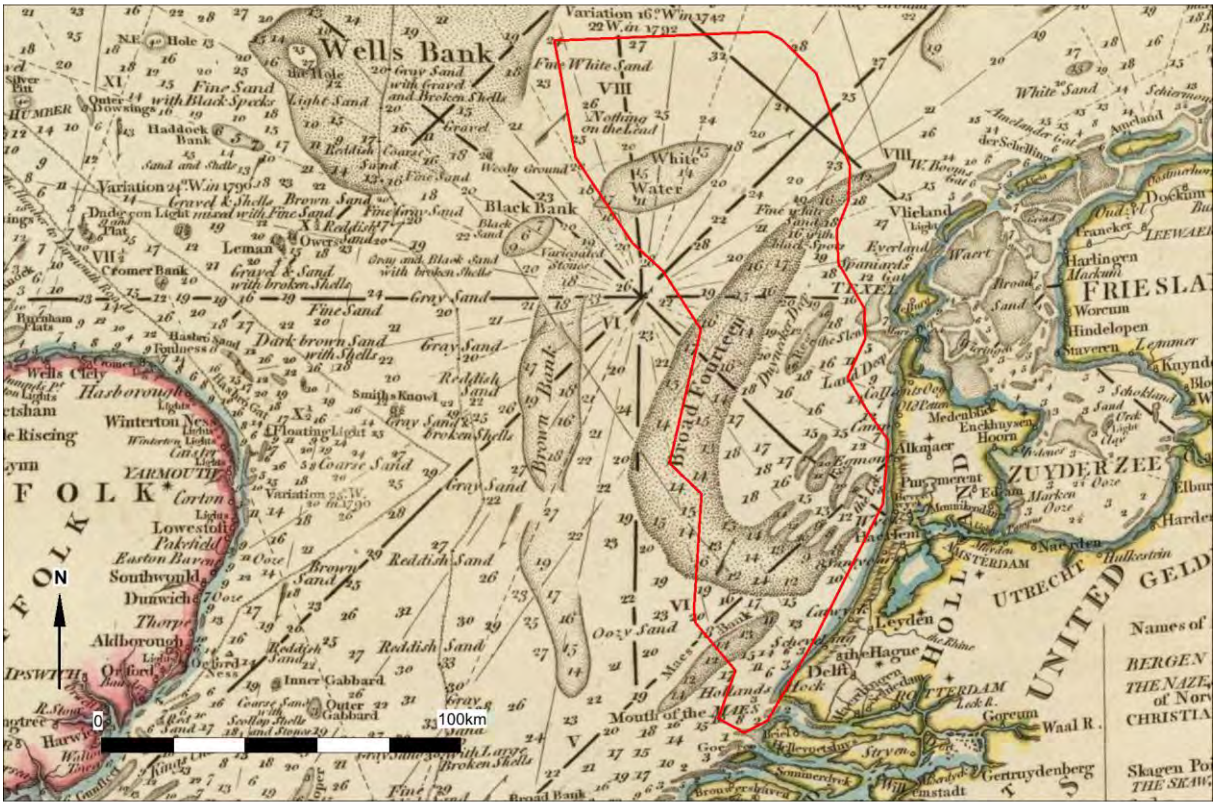


Figure 10. The area of interest on the historical map of 1777 (Faden)

Known disturbances of the seabed

In the past, parts of the seabed within the area of interest have been disturbed by trenches for cables and pipelines. The initial depth of burial of the cables is unknown, but should be a minimum of 1 meter according to the environmental permits. It is however expected that the cables are laid at a depth of 2 meters up to a maximum of 5 meters below the seabed. This also applies to the pipelines in the area.

Within the area of interest, more than 100 areas are known where sand is extracted, generally to a depth of 2 meters in relation to the seabed.

In general, large parts of the seabed have been disturbed by trawl nets of fishermen.

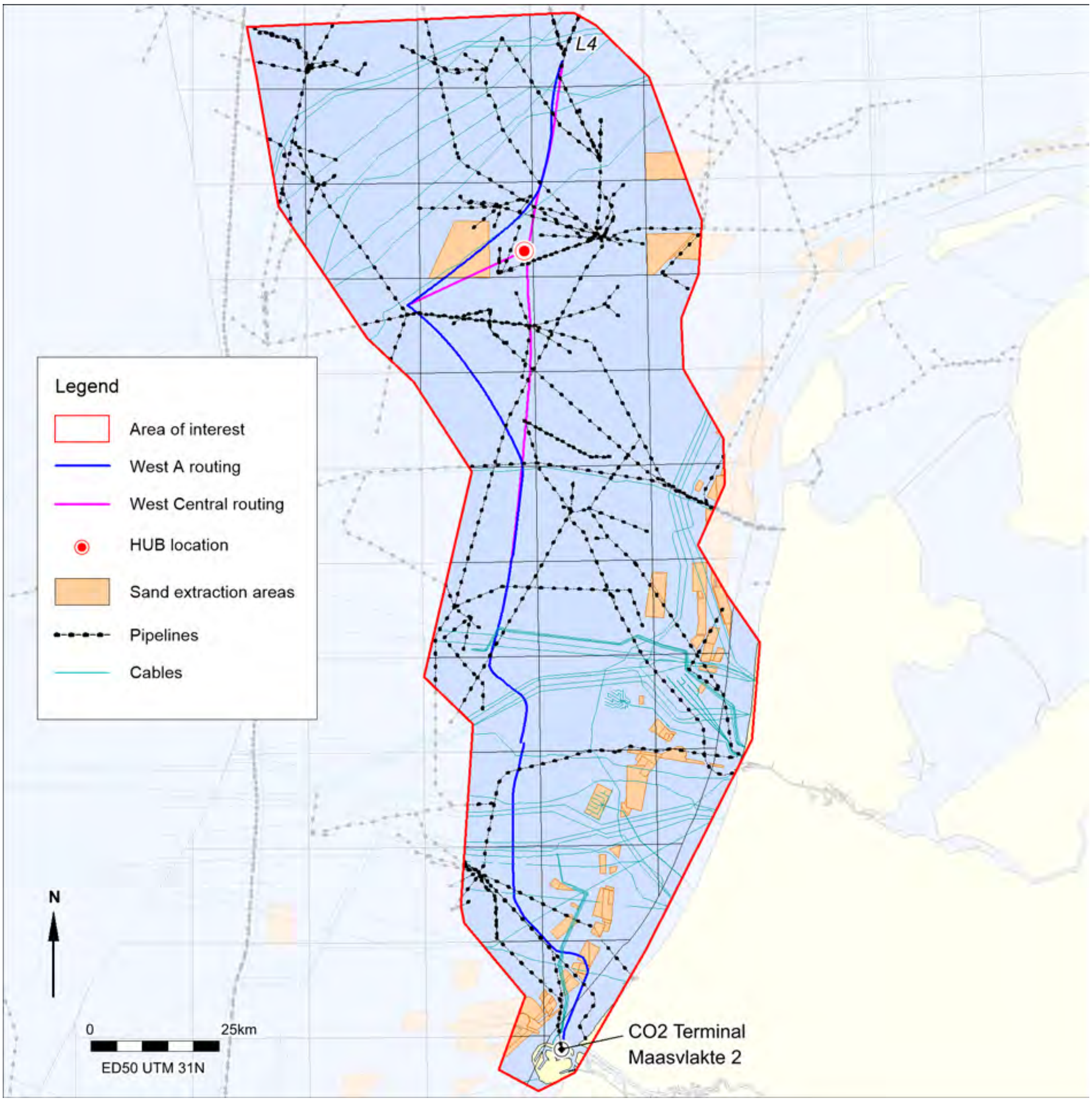


Figure 11. Pipelines, cables and sand extraction areas in the area

Locations and status of cables, pipeline and sand extraction areas are based on the database of Rijkswaterstaat (November 2021). This may differ from the as-built data from the operators.

3.4 Geological setting within which the archaeological objects are to be found (LS04)

The archaeological prospect for (pre)historic settlements is strongly related to the geogenesis of the plan area. The geogenesis is reflected by the lithostratigraphic units present, the character of layer boundaries (erosive vs non-erosive) and indications for the development of soils within the sediments in prehistoric times. Therefore geophysical and geological data are an important source to answer questions with respect to the nature, age, depth and location of occurrence, integrity and preservation of the archaeological remains which are to be expected within the area of interest.

Seabed sediments

The seabed sediments in the area of interest consist mainly of sand, with patches of gravelly sand in the southern and central area. In the northern part the sediments become finer (muddy sand).

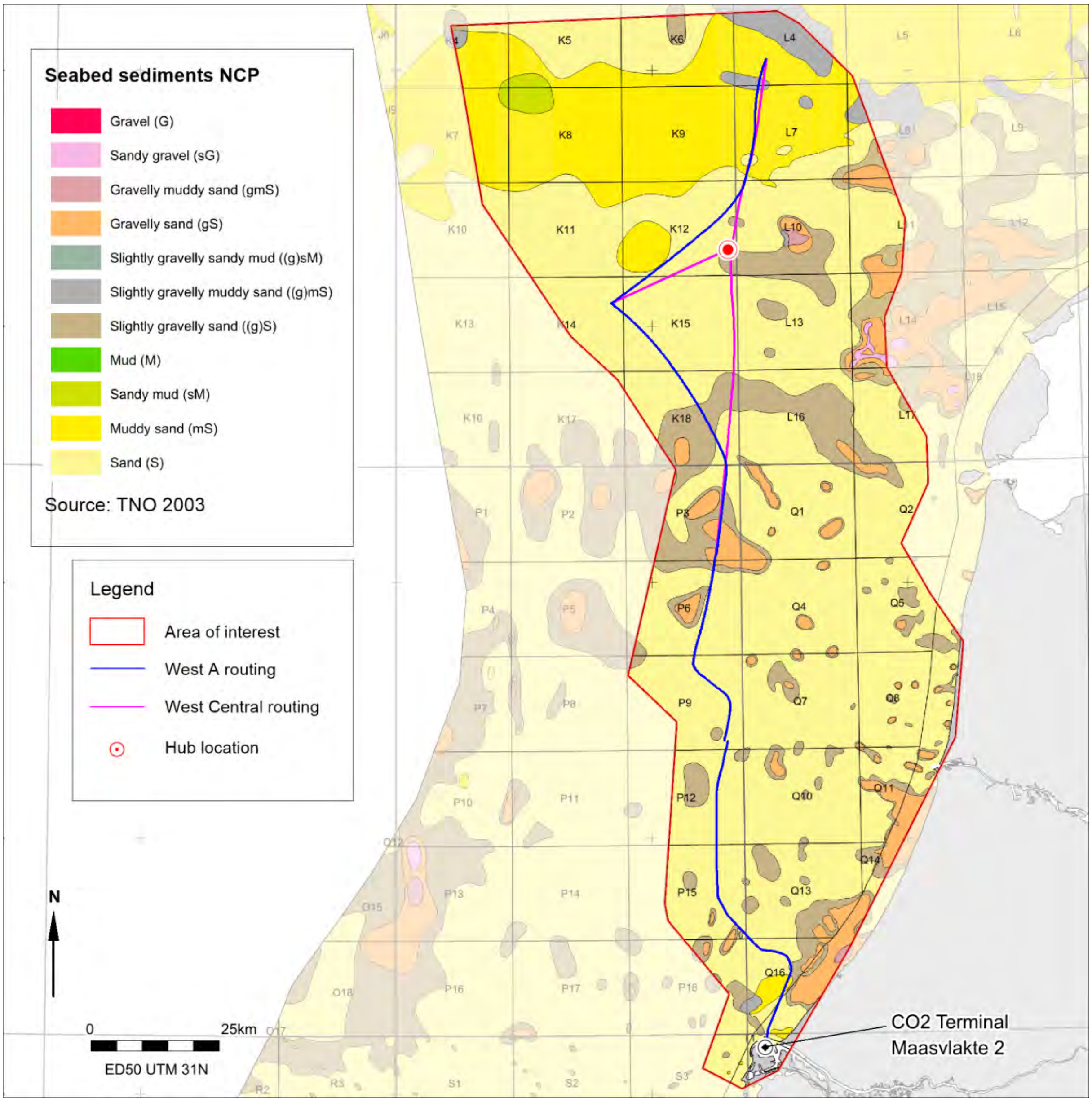


Figure 12. Seabed Sediments (Laban 2003)

Pleistocene Units

Figure 13 shows the different subcropping *Pleistocene* units in the area of interest[9].

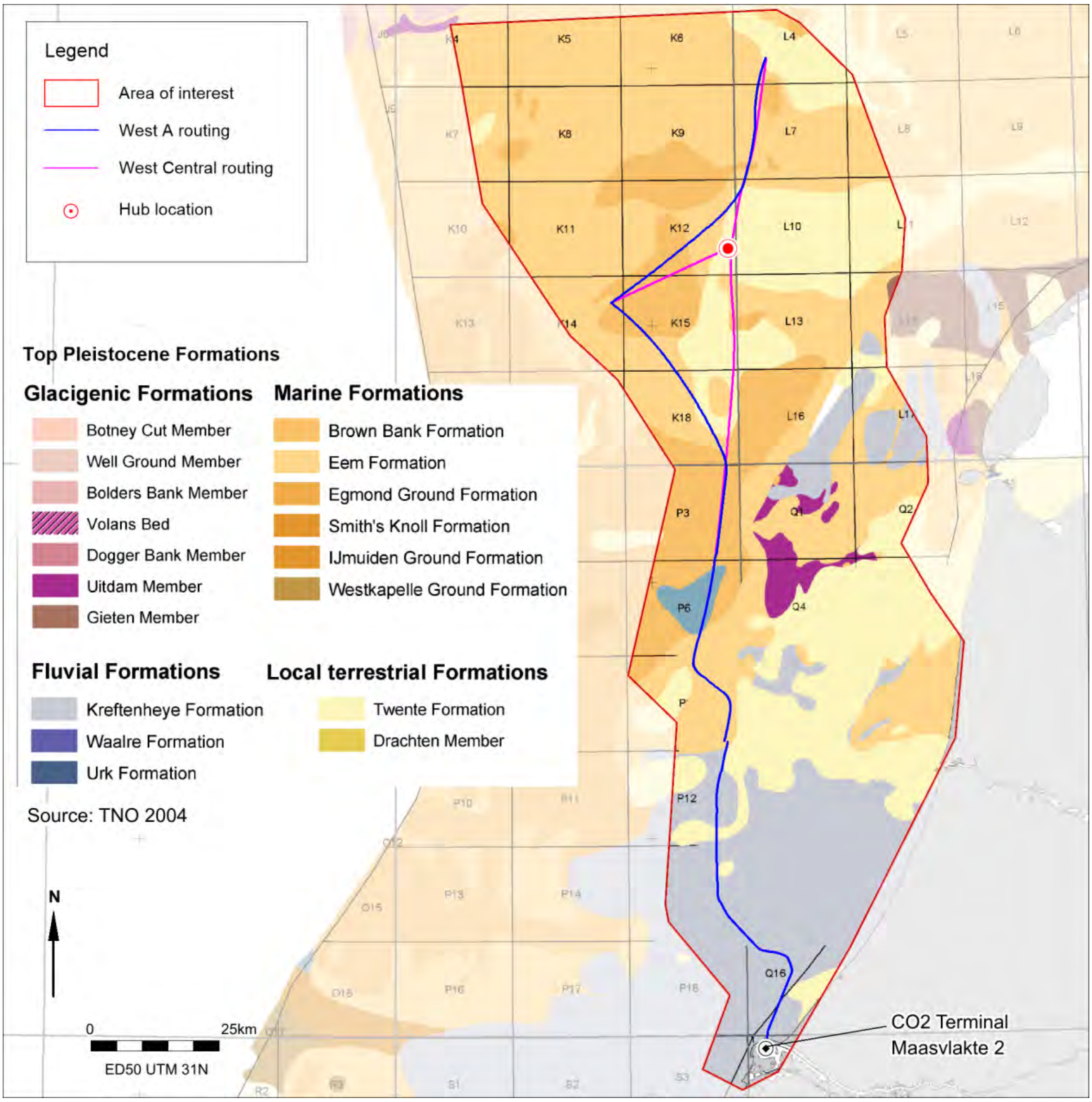


Figure 13. Subcropping Pleistocene formations

Within the boundaries of the area of interest several subcropping *Pleistocene* units have been mapped. The most relevant are described below.

<u>Yarmouth Roads Formation</u>

The Yarmouth Roads Formation consists of fine or medium-grained grey-green sands, typically non-calcareous, with variable clay lamination and local intercalations of reworked peat. According to the Lexicon of Named Rock Units of the British Geological Survey the depositional environment of the Yarmouth Roads Formation is interpreted to be 'mainly fluviatile, with possible shallow marine incursions'.[10]

[9] Laban 2004.

[10] https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=YM.

In the DINO nomenclature the depositional setting is described as 'predominantly low energy open-marine deltaic, delta top and fluvial'.[11] The Yarmouth Roads Formation is older than 500 kyr. The unit has been glacially deformed into ice-pushed ridges in the section that is crossed by the current Aramis route trajectory.

Egmond Ground Formation

The Egmond Ground Formation consists of fine-grained, sparsely shelly marine sands with clay interbeds. The amount of shells and shell fragments is markedly less than the overlying younger sands of the Eem Formation.[12] The marine deposits date from the Holsteinian interglacial period. The exact age of the deposit is uncertain, including both Marine Isotope Stage 11 (424 kyr – 374 kyr ago) and Marine Isotope Stage 11 (424 kyr – 374 kyr ago) and Marine Isotope Stage 9 (300 kyr – 337 kyr years ago). The deposits of the Egmond Ground Formation predate the Saalian glacial period and can therefore be part of the ice-pushed ridges.

Eem Formation

The Eem Formation predominantly consists of shell bearing fine sands deposited in an open marine environment during the Remain interglacial (warm) period.[13]

Brown Bank Member (Eem Formation)

At the end of the Eemian period brackish and fresh water clays were deposited in lagoons and lakes which remained in the glacial basins during regression of the Eemian Sea. These lake and lagoonal deposits have separately been classified as the Brown Bank Member within the Eem Formation. The Brown Bank Member was previously referred to as Brown Bank Bed or Brown Bank Formation.

Woudenberg Formation

In the Early Weichselian cooling climate peat was locally deposited on top of the clayey Brown Bank Member. At its base the peat is often rich in wood remains; at the top moss is a major constituent. The unit consists of firm, amorphous, clayey, non-calcareous, brown to black peat or gyttja. The peat has been deposited in a nutrient-poor (moss peat) to nutrient-rich (reed, sedge and woody peat) marsh or swamp. Occurrences of the Woudenberg Formation have been described in the Amersfoort Basin, not in the North Sea area. Formerly, this unit was part of the Eem Formation. As the Saalian glacial basins are present in the North Sea area which is crossed by the proposed Aramis pipeline routes, local occurrences of this unit could be crossed.

Kreftenheye Formation (Weichselian)

The Kreftenheye Formation consists of sands of the Rhine | Meuse fluvial system. The depositional environment includes braided and meandering stream, and braidplain and floodplain. The deposits consist of yellowish grey to greyish brown medium to very coarse sand. The sands are moderately to very gravelly. Locally, fine to coarse gravel lags occur. Occasional thin clay laminae and clay pebbles can be present intercalations in the predominantly sandy sequence. Characteristic of the Kreftenhye river deposits is a parallel layering on mm- to cm-scale which is related to small variations in grain size and composition. Offshore the coast of South Holland, small shallow channel incisions are observed in subbottom profiler data. These incisions occur in the top of the Kreftenheye Formation which is truncated by the Bligh Bank

[11] In accordance with Rijsdijk 2005.

[12] British Geological Survey: Lexicon of Named Rock Units.

[13] Eemien: interglacial period between 128.000 and 115.000 years ago.

Member. The channels are filled with fine sand. An impression of the stratigraphy that is to be expected in the southern part of the current Aramis route trajectory in the vicinity of sand extraction areas Q16H and Q16H is illustrated in figure 14 below.

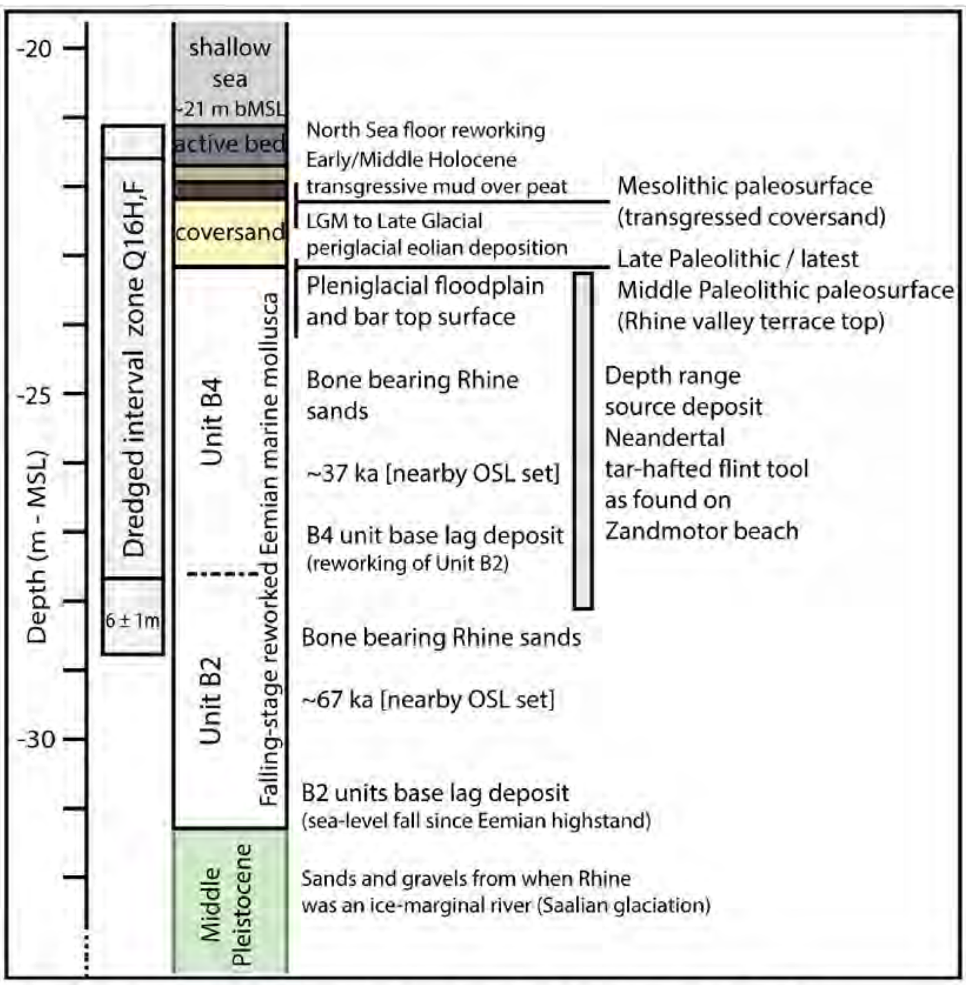


Fig. S2. Stratigraphy of the dredging area Q16. The upper 6-8 meters of the sedimentary column consist of: 1) a dynamic sheet of shelly sand of the active sea bed, 2) beds of Early-Middle Holocene transgressive tidal muds on basal peat, 3) Late Glacial eolian coversands containing Mesolithic materials (27, 28), and 4) medium to coarse grained fluvial sands of the Rhine-Meuse valley, Units B2 and B4, dating to 70-30 ka.

Figure 14. Stratigrafie van het zandwingebied Q16 (Niekus 2019).

During the installation of the Hollandse Kust (zuid) export cables mammoth bones were found on the trencher when the trencher emerged above water (see for site location figure 1). The very well preserved mammoth bones probably originate from an infilled channel.

The course of the river Rhine changed during the Weichselian. The extent and distribution of the Rhine - Meuse channel belts is shown in figure 15, below.

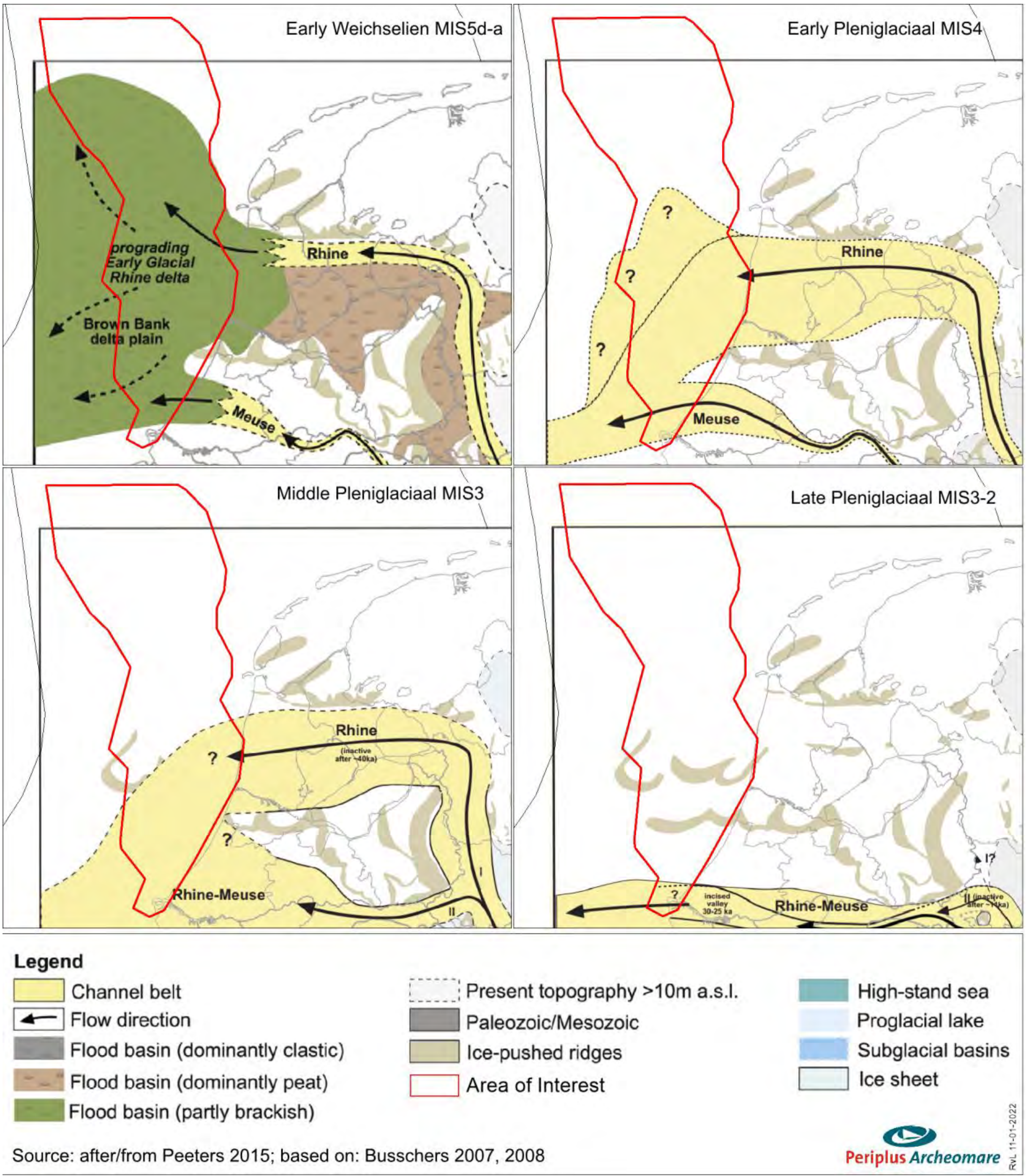


Figure 15. Paleogeographic maps of the Weichselian.

North and south of Maasgeul firm beds of clay and loam occur at the top of the Kreftenheye Formation. The firm clay dates from the Late Weichselian (Allerød interstadial) and Early *Holocene* and is separately classified as the Wijchen Bed. The Wijchen Bed has been deposited in meandering floodplain of the Rhine which is subject to frequent overbank flow.[14] The deposition of the Wijchen Bed is related to the evolution of the Rhine – Meuse river pattern from braided to meandering. The change to a meandering river pattern is triggered by a warming of the climate, which resulted in the development of a vegetation cover. The landscape morphology is more or less fixed by the vegetation, thus promoting incision of the river. This

[14] Törnqvist 1994; Makaske 1995; Busschers 2008.

also explains why the overbank clay of the Wijchen Bed is characterized as ‘humic and non-calcareous, especially at the organic-rich top, which may be marked by a palaeosol’.[15]

The Late Glacial fluvial evolution of the Niers–Rhine and Maas in relation to climate and vegetation changes is nicely illustrated by Kasse (see, below).[16]

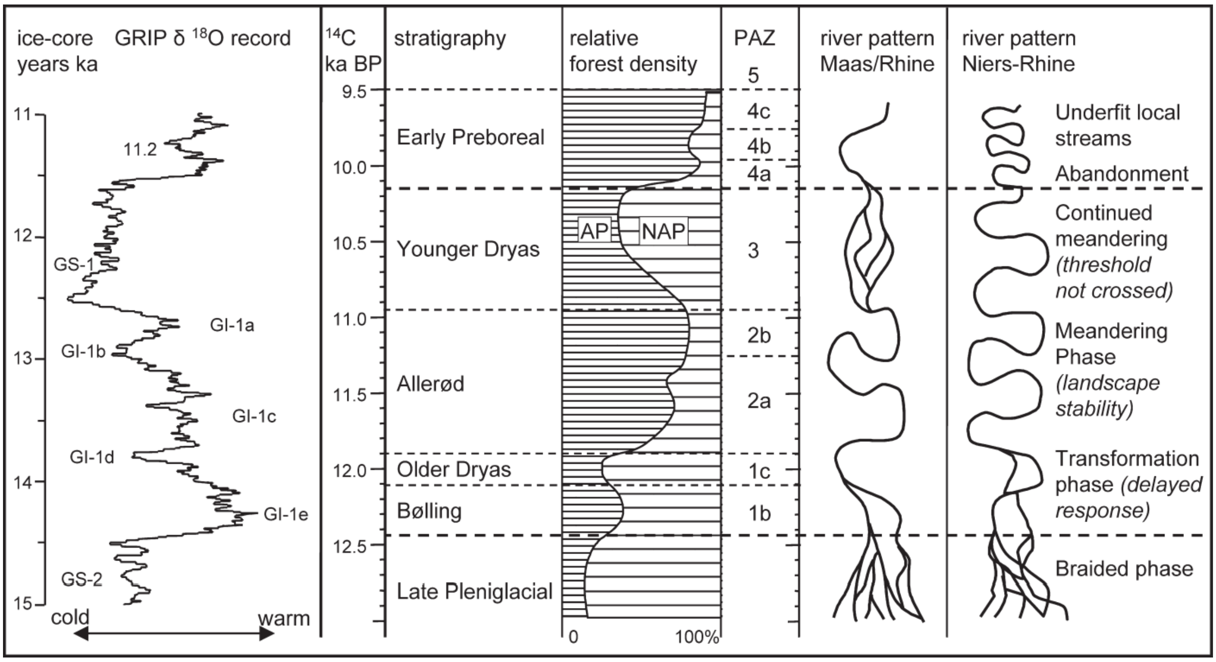


Figure 16. Late Glacial fluvial evolution of the Niers–Rhine and Maas in relation to climate and vegetation changes (from: Kasse 2005).

In the Yangtze area two separate beds are distinguished in the Wijchen Bed:[17] a lower bed that is described as ‘grey loam, sandy clay and clayey sand, and is internally stratified’, and an upper bed that is described as ‘moderately silty to strongly silty and humic (often humically stratified), and at the base sandy and mostly sandy-stratified.’ The lower bed was found between 23m and 22m – asl; the upper bed between 22m and 19m – asl. In the upper bed charcoal is found which is related to the archaeological sites that were found on the nearby river dunes.

Boxtel Formation (Weichselian and Early *Holocene*)

The Boxtel Formation consists of terrestrial deposits. The upper part of the unit subcrops below a cover of *Holocene* deposits in parts of the area of interest (figure 13). The subcrops of the Boxtel Formation shown in figure 13 date from the latest ice age, the Weichselian, and Early *Holocene*. This upper part of the unit most probably consists of aeolian deposits of the Wierden Member (cover sands) and loamy stream deposits of the Singraven Member. Apart from loam (=silt) the Singraven Member can contain sand, clay and peat. The Boxtel Formation overlies brackish to fresh water lagoonal and deposits or laminated fresh water lacustrine clays of the Brown Bank Member and peat of the Woudenberg Formation. The thickness of the Boxtel Formation is unknown.

---

[15] TNO-GDN (2022). Wijchen Bed. In: Stratigraphic Nomenclature of the Netherlands, TNO – Geological Survey of the Netherlands. Accessed on 13-01-2022 from http://www.dinoloket.nl/en/stratigraphic-nomenclature/wijchen-bed-0.

[16] Kasse 2005.

[17] Moree and Sier 2015; The Wijchen Bed is refered to as Wijchen Member.

During the Early *Holocene* aeolian sands were deposited within the floodplain bordering the dry bed of the river Rhine (these river deposits themselves are part of the Kreftenheye Formation; see above). The so-called river dunes are found in the subsurface of the route trajectory north and south of the Maasgeul. The river dune deposits are described as grey to brown, fine to medium, moderately sorted sand, mostly non-calcareous but calcareous near base, with sporadic silt layers or granule laminae. The river dune deposits are separately classified as the Delwijnen Member within the Boxtel Formation.

Drachten Formation

Terrestrial deposits can also occur at a deeper stratigraphic level. The Drachten Formation is located in between the Egmond Ground Formation and the Eem Formation. Formerly the Drachten Formation was onshore classified as the Eindhoven Formation and later as a member of the Boxtel Formation. Offshore the Drachten Formation was referred to as the Tea Kettle Hole Formation. The local terrestrial deposits date from the Saalian ice age and consist of fine grained periglacial aeolian, fluvial and lacustrine sands. The Drachten Formation predates the Saalian glaciation and is often deformed due to the overriding ice-sheet. Deposition took place during the Hoogeveen and Bantega interstadials (227 – 180 ka. ago), when the landscape was covered by temperate zone forests. In the 1980s, Neanderthal camps related to the Hoogeveen or Bantega interstadials were excavated in the Maastricht-Belvédère quarry in Limburg. Therefore, remains of Neanderthal camps may exist *in situ* if intact palaeosol are present.

Holocene Units

The *Pleistocene* units are - except from some local outcrops - covered in by a sequence of *Holocene* deposits. The overall thickness of the *Holocene* sediments ranges from 0m to 37m. The differences in thickness are for a major part related to the present-day seabed morphology, which is characterized by sand dunes, ridges and valleys. The occurrence of *Holocene* units which are exposed at the seabed is shown in figure 17. Because this map displays the exposed lithostratigraphic units, under these units older *Holocene* deposits can occur.

Nieuwkoop Formation (*Holocene*)

Fluvial deposits of the Kreftenheye Formation and terrestrial deposits of the Boxtel Formation are in places covered by peat. This Early *Holocene* peat layer is classified as the Basal Peat Bed within the Nieuwkoop Formation. Occurrences of the Basal Peat Bed could indicate that the underlying *Pleistocene* landscape has been preserved intact, provided that no erosion as taken place prior to the deposition of the peat. If the Basal Peat Bed is found in borehole or vibrocore samples, signs that the top of the underlying unit is intact can be found in the occurrence of palaeosol horizons. Known are the podzol soils which developed at the higher parts of the cover sand landscape during the Early *Holocene*. These cover sands are classified as the Wierden Member within Boxtel Formation (see text above).

Echteld Formation (*Holocene*)

Both north and south of the Maasgeul a bed of silty humic clay with silty laminae occurs. The presence of washed-in wood remains is characteristic.[18] The clay is deposited in a freshwater environment, with slight tidal influence. Presumably, sedimentation took place under water (subaquatic, subtidal). The bed of humic clay is classified by Hijma as Terbregge Member | Echteld Formation. The classification as a separate member has not been formalized in the DINO nomenclature, yet. The Terbregge Member covers the Early *Holocene* Basal Peat Bed and is itself covered by the Wormer Member | Naaldwijk Formation.

Naaldwijk Formation (*Holocene*)

Pleistocene units and the Early *Holocene* Basal Peat Bed are in places covered by *Holocene* tidal deposits (clay and fine sand). These layered and laminated tidal deposits are part of the Wormer Member within the Naaldwijk Formation. The earliest clastic deposits are those of the Velsen Bed. The Velsen Bed consists of firm to stiff humic clay, sometimes containing considerable amounts of Hydrobia shells. The lower boundary can be present as a gradual transition from peat deposits of the Basal Peat Bed to clastic lagoonal deposits of the Velsen Bed.

Southern Bight Formation (*Holocene*)

The Southern Bight Formation consists of reworked sediments. The Southern Bight Formation is exposed at the seabed surface in major part of the Aramis route trajectory (see figure 17). Along the route, three members of this formation have been mapped. The Bligh Bank Member is a mobile sand layer in which sand ridges, dunes and mega-ripples have developed. This unit predominantly consists of marine sands with variable admixtures of gravel. The formation often has a more gravelly structure towards the base. It should be noted that shell fragments over 4 mm are considered to be 'gravel'.

In the northern part of route, the Bligh Bank Member changes into the Terschellingerbank Member, which consists of reworked (peri-)glacial sand with a small amount (< 10%) of mud.[19]

---

[18] Moree and Sier 2015.

[19] Mud = clay (< 2µm) + silt (>2µm and <63µm)

Urania Formation (*Holocene*)

The Urania Formation is found in the northernmost of the route, where the Western Mudhole Member is mapped. Alike the Terschellingerbank Member, the Western Mudhole Member consists of reworked (peri-)glacial material, but the grain size of the sediments is smaller. The unit is described as very fine sand with a considerable admixture (> 10%) of mud.

Figure 17. Geological overview map (De Mulder 2003).

Only the total thickness of the *Holocene* sequence including the Basal Peat Bed, the Naaldwijk Formation, the Southern Bight Formation and Urania Formation is known. The total thickness of the *Holocene* layer ranges from less than 1 to over 10 meters in the area of interest (see figure below).

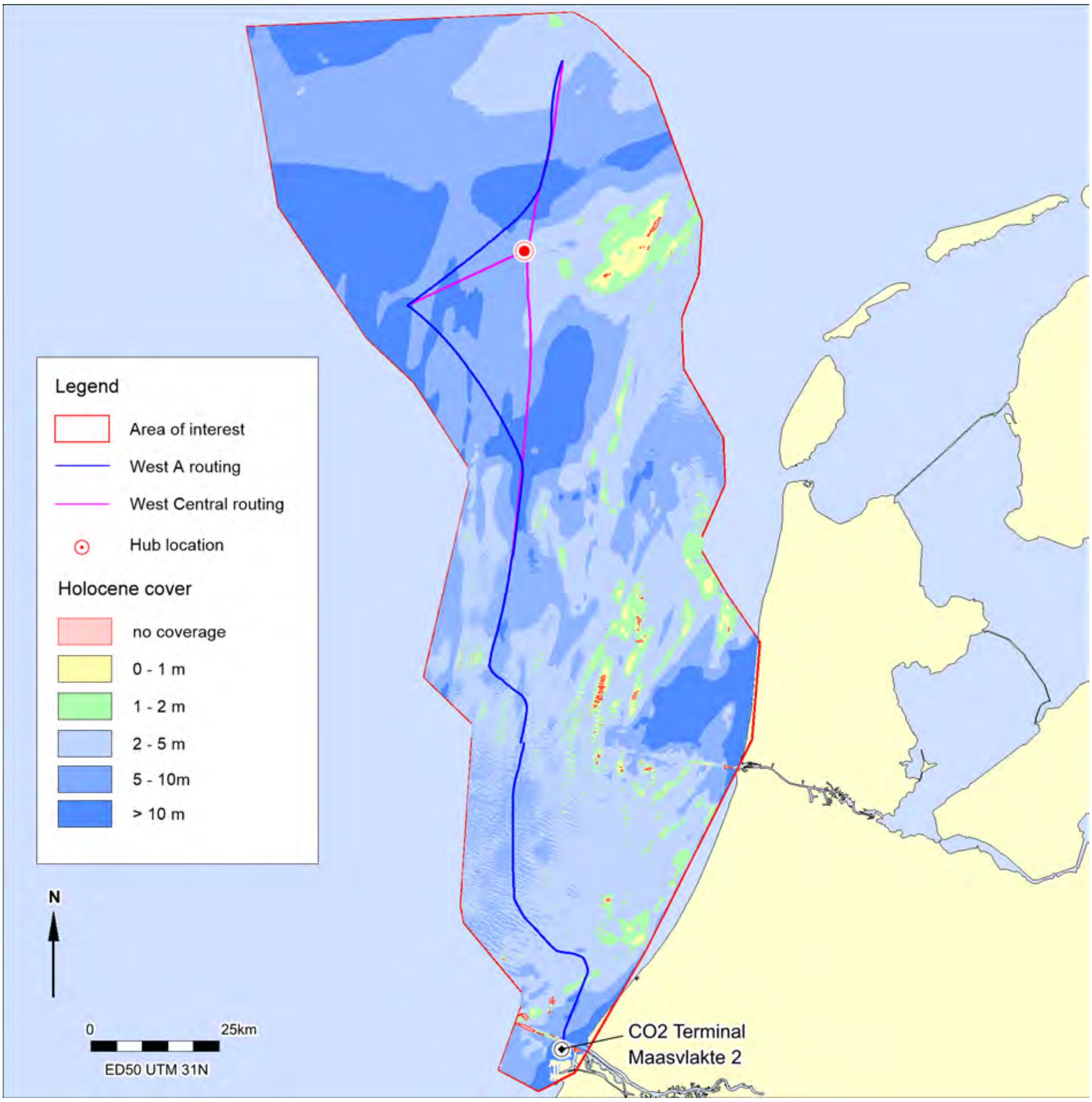


Figure 18. Thickness of Holocene cover

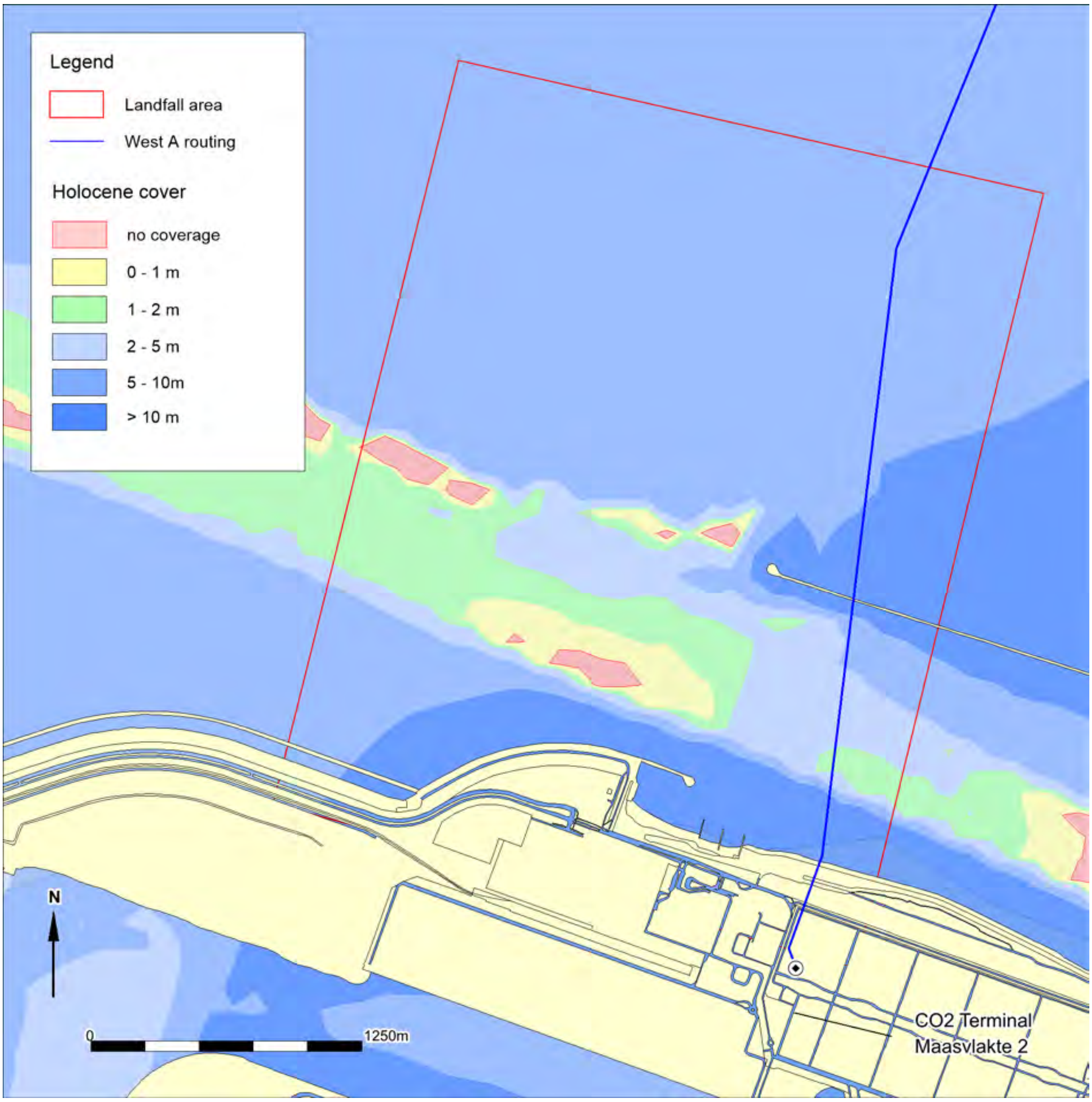


Figure 19. Holocene cover within the landfall area

3.5 Known archaeological values and other objects (LS04)

The former National Service for Archaeological Heritage (ROB, now Dutch Cultural Heritage Agency or RCE) in collaboration with Rijkswaterstaat and TNO NITG has developed a comprehensive archaeological map of the continental shelf based on geological and archaeological observations (see figure below)[20].

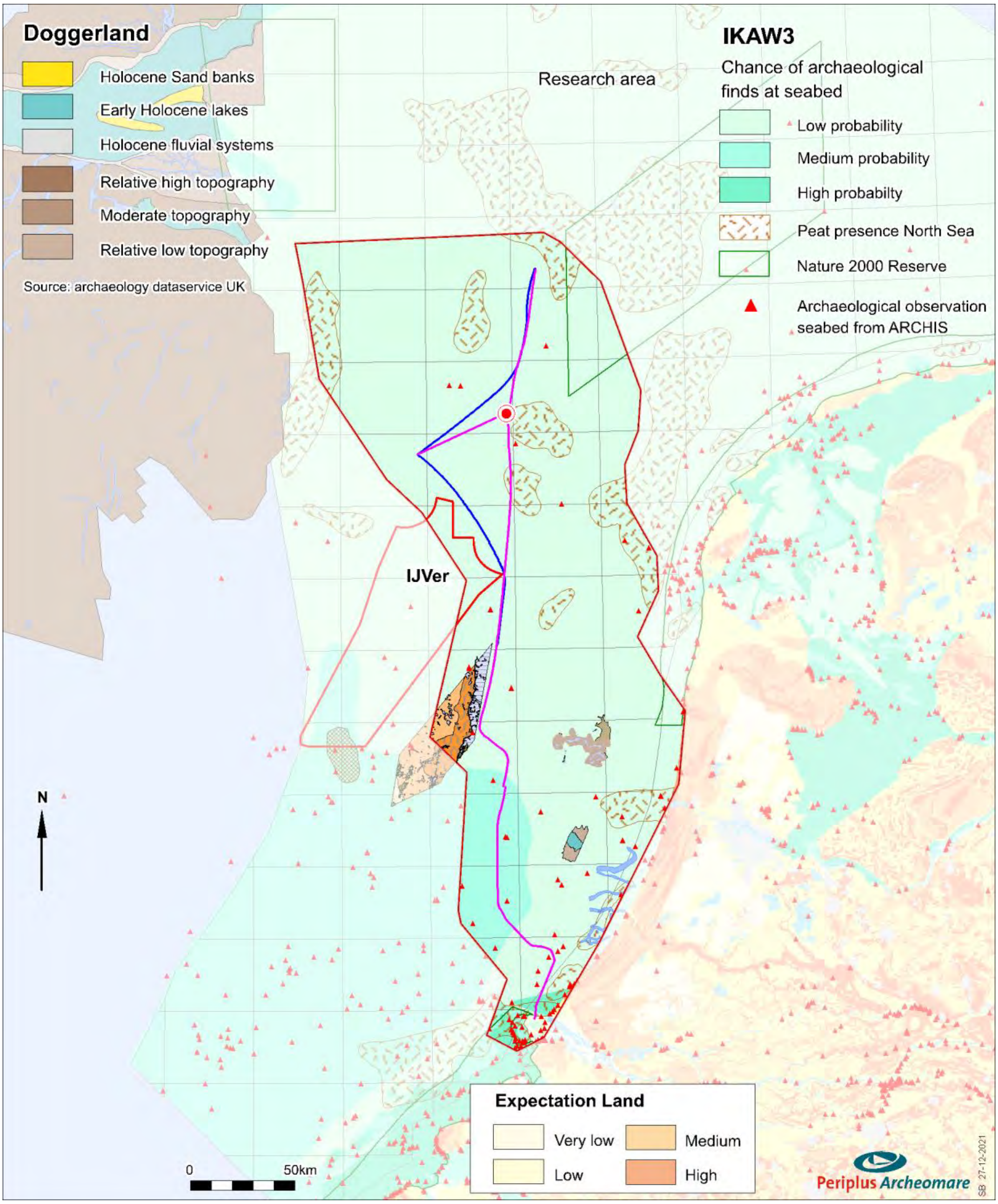


Figure 20. Overview indicative map of archaeological values (IKAW)

[20] IKAW 3e generatie, RCE 2008.

This global map presents the probability of well-preserved shipwrecks to be encountered (and often a ship's discovery of high archaeological value) in the Dutch part of the Continental Shelf, expanded with available palaeogeographic reconstructions.

However, this map is of very limited use. This is partly due to the large scale (1: 500,000). Further the map has become outdated, because it shows the state of knowledge 25 years ago. The degree of conservation of wreck remains is closely related to geology and morphology which has not been taking into account in the IKAW3 map. The idea here is that in channel deposits or regions with soft sediment, a wreck quickly sinks into the seabed and therefore remains in good condition. In other areas with harder top sediments the chance of a find is not necessarily lower, but the chance to find a well-preserved ship with the cargo and equipment still intact is considerably less.

Figure 20 also indicates areas where peat and clay have been preserved. This cover with clay / peat only refers to the possible location of *Pleistocene* deposits on / near the seabed. Where *Holocene* clay or peat is eroded *Pleistocene* layers with artefacts and fauna fossils may be present. The presence of early *Holocene* sediments could indicate the presence of a well preserved prehistoric landscape. West of the area of interest lies the nature reserve Brown Bank, a shoal known for its paleontological and prehistorical finds. At this archaeological hotspot rigid *Pleistocene* clays and silts of the Brown Bank Member are exposed at the seabed. These sediments contain the prehistoric remains which are found in the nets of fishermen.

Research in the last decade has shown that the probability of encountering prehistoric residues in the North Sea is much greater than originally thought. The archaeological map for the Dutch continental shelf is therefore being revised. In 2016, an indicative model of the archaeological potential of the North Sea was published by Deltares[21]. A detail of this map is shown in figure 21. The potential for prehistoric remains is closely related to the lithostratigraphic units which have been discussed and outlined in previous paragraphs. For instance the potential for Middle Palaeolithic remains indicated in red coincides with the occurrence of the Kreftenhye Formation and Brown Bank Member, the potential for residual Mesolithic and Late Palaeolithic remains indicated in beige coincides with the occurrence of the Boxtel Formation and the limited potential for prehistoric remains in areas indicated in grey relates to the occurrence of the marine deposits of the Egmond Ground Formation and the Eem Formation[22].

It should however be stressed that figure 21 offers a two dimensional view. The occurrences of the Eem Formation (grey), the Kreftenheye Formation and the Brown Bank Member (red) are not limited to the mapped areas but extend underneath the Boxtel Formation (beige). This means that Middle Palaeolithic remains are also to be expected in those areas.

It is important to bear in mind that the occurrences and boundaries of the lithostratigraphic units mapped are based on a limited amount of geological data. The occurrences and boundaries should therefore not be considered definite, but an indication of what is to be expected in the area and a framework for further research. Also morphological phenomena like the ice-pushed ridges have not been taken into account in this map.

[21] Vonhögen et al, 2016.

[22] Occurrence Naaldwijk Fm according to Deltares grids (2004).

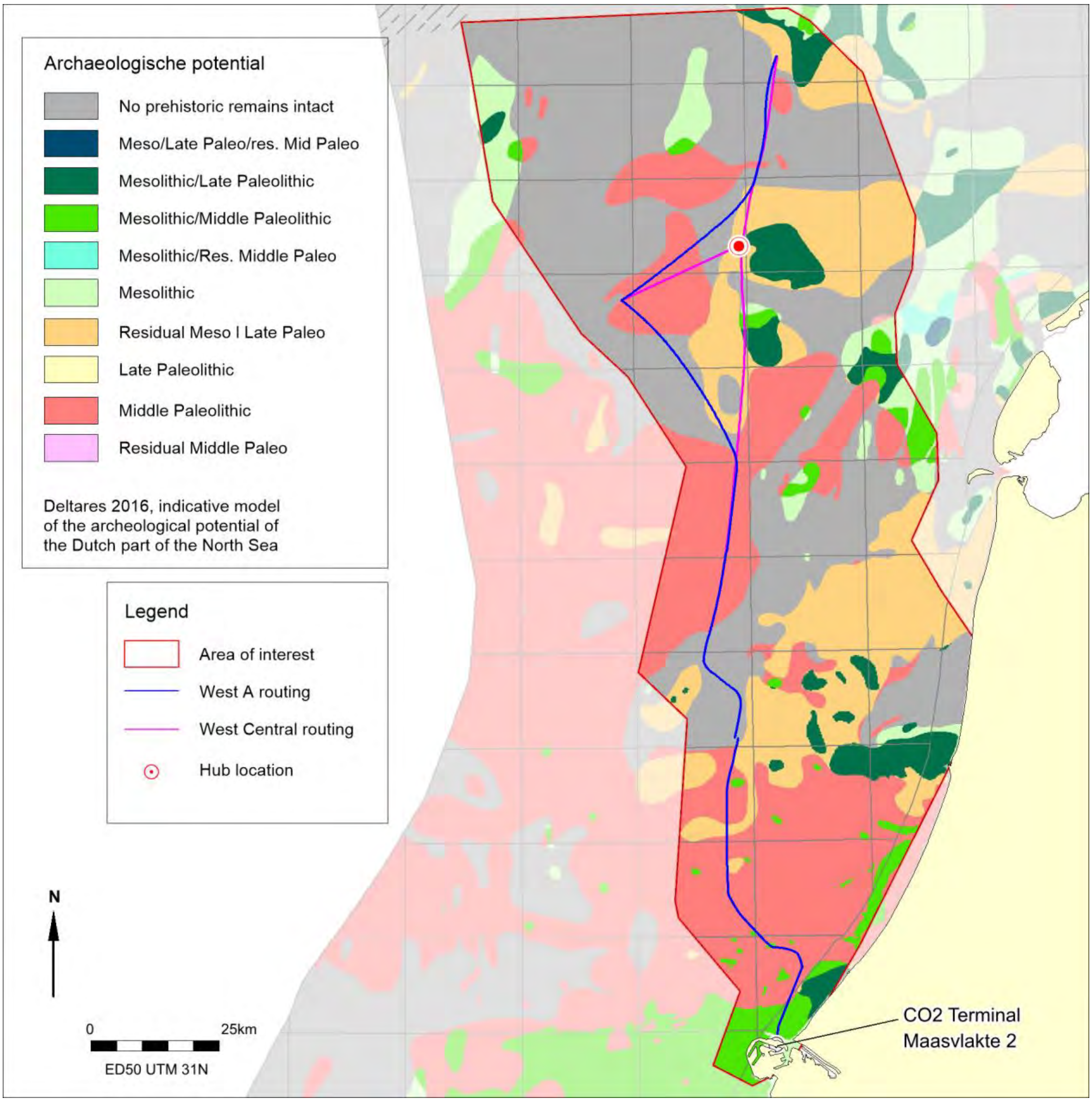


Figure 21. Archeological potential for prehistoric remains

Ice-pushed ridges

The ice-pushed ridges have been formed by Saadian glaciers which stretched into the North Sea area. pre-dates the Eemian, Weichselian and Early *Holocene* deposits. The ice-pushed river sands of the Yarmouth Roads Formation can contain reworked flint artefacts from Lower and Middle Palaeolithic times. At the top of the ice-pushed ridge in situ remains of camp sites and inhumations of Neanderthal and Late Palaeolithic and Mesolithic hunters and gatherers can be expected.

Open sea (Eemian)

The Eem Formation consists predominantly of marine sand deposited in the Eem Sea during the Eemian interglacial (warm) period.[23] Within the sandy marine deposits no *in situ* archaeological remains are expected.

[23] Eemien: interglacial which lasted from 130.000 till 115.000 years ago.

Lagoons, lakes and fens (Eemian to Early Weichselian)

The Brown Bank Member at the top of the Eem Formation consists of lacustrine fresh water and coastal marine brackish water deposits of silty clay. At the end of the Eemian the sea regressed and the Brown Bank clays were deposited. This layer can contain Middle Palaeolithic artefacts from, or remains of Neanderthals who in this period populated the Netherlands and the North Sea area. Little archaeological research has been done into this often deep-seated stratigraphical unit. Camp sites are expected to be intact and well preserved, especially when the remains are contained in a clayey context and covered by peat of the Woudenberg Formation and/or cover sands of the Wierden Member | Boxtel Formation. The Woudenberg Formation can contain dumps from close-by camps, lost hunting gear and intended depositions. The available geological information does not suffice to assess whether the Late Eemian to Early Weichselian facies of sandy lagoonal beaches and/or clayey shores of lakes and fens is present.

The top of the Brown Bank Member is expected at depths varying from 0m to 30m below the seabed.

River valley (Weichselian)

The Kreftenheye Formation consists of fluvial deposits of the Rhine and Rhine - Meuse system. The extent and distribution of the channel belts during the Pleniglacial (74 ka – 15 ka ago) is illustrated in Figure 15. Well-preserved finds prove that Neanderthal occupied the Rhine valley. Melt water discharged through the braided channels of the Rhine. Peak discharge occurred during the summer months, when temperatures rose above freezing point in the hinterland. Large mammals including woolly mammoths, woolly rhinoceros, musk ox and steppe wisent migrated over the steppe-tundra landscape. This landscape was vegetated with grasses, herbs and occasional dwarf birches. The water-intake of mammoths was immense, so the fresh-water-filled channels must have had a large attraction to these animals, thus offering Neanderthal the opportunity to hunt them. The change of encountering *in situ* remains in the residual infilled channels of the Kreftenheye Formation is considered to be relatively large. It is believed that the Neanderthal became extinct some 40 kyr to 35 kyr ago, prior to the Late Glacial Maximum, some 27 kyr to 19 kyr ago.

The Wijchen Bed at the top of the Kreftenheye Formation consists of firm, matured humic clays in which locally palaeosol developed. In the clayey context of this bed well-preserved Late Palaeolithic and Mesolithic remains could be encountered. These remains include lost hunting gear and waste of camp sites which are found on nearby river dunes. Also the presence of camp site relics on the overbanks deposits cannot fully be excluded.

Cover sand landscape (Late Weichselian and Early *Holocene*)

The camp sites of Late Palaeolithic and Mesolithic hunters and gatherers are found in a cover sand landscape with ridges and dunes and valleys formed by small streams. Stream valleys offered fresh water, a large variety of plant species and ample opportunities for hunting. Camps were installed along the borders of those valleys. The remains of sites can be encountered in the context of sandy, loamy, clayey or peaty beak deposits of the Singraven Member. The lithological context of settlements found at the dunes and ridges comprises well sorted non-calcareous fine cover sand of the Wierden Member. Both Singraven and Wierden Member are part of the Boxtel Formation.

Late Palaeolithic and Mesolithic remains are expected at two distinct levels within the cover sand sequence. The first is a palaeosol found in between two cover sand layers Late Palaeolithic remains of camp sites of reindeer hunters are to be expected. The palaeosol is a charcoal rich layer called the Usselo Bed, which has been formed during the Bølling and Allerød interstadials. The second level is the top of the cover sand sequence. The sandy dunes and ridges often display a well-developed podzol, if not eroded. Due to the low carbonate content presence of oxygen in the pores of the sand the preservation conditions for organic remains (wood, bone, et cetera) is a priori not so good in cover sands. The preservation of organic remains is therefore highly dependent on the timing of the water table rising above the archaeological level.

If the Boxtel Formation is covered by the Basal Peat Bed or the Velsen Bed the integrity and conservation of archaeological remains is expected to be high. Considering our limited knowledge of prehistoric sites in the North Sea area such well-preserved finds would *a priori* be worth preserving. Archaeological markers consist of flint and bone artefacts, burnt nuts and seeds and charcoal. Zones of interest are locations where the top of the cover sands and river dunes (if present) are not eroded. The presence of the Basal Peat Bed and Velsen Bed indicate that underlying Boxtel Formation and possible archaeological remains herein could be intact.

Peat and humic clays

The Basal Peat Bed and Velsen Bed themselves can also contain archaeological remains. These remains include dumped waste from nearby camp sites, lost hunting gear or intentional (e.g. ritual) depositions. Due to the low levels of oxygen and wet conditions both organic and inorganic remains might be very well preserved.

Site characteristics

The expected camp sites of hunters and gatherers are generally small (a few sqm), although larger settlements (up to approximately 2000 sqm) can occur in case the site repeatedly or for prolonged period of time was occupied. Sites are characterized by the presence of concentrations of charcoal, flint artefacts, bone remains, burnt seeds and nuts, natural stones and artefacts of bone or horn. Inhumations can occur. The density of finds (debris of flint processing) can vary from low to high.

Physical Quality

It is not known to what extent erosion has affected the integrity of the *Pleistocene* landscape and embedded remains of prehistoric settlements. The presence of the Basal Peat Bed, the Terbregge Member (Maasgeul area) and/or Velsen Bed provides an indication for an intact *Pleistocene* landscape, although it should be noted that erosion could have taken place prior to the deposition of peat and clay, leading to degradation or even annihilation of prehistoric remains. If the *in situ* prehistoric remains did not suffer from erosion, the very rapid Early *Holocene* 'drowning' of the *Pleistocene* landscape and local deposition of a peat and/or clay cover offered perfect conditions for the conservation of both organic and inorganic remains. In this situation well-preserved sites of high physical quality can occur.

Occurrence and spacial distribution

The occurrence and spacial distribution of Late Saalian ice pushed-ridges, Early Weichselian lagoons, lakes and fens, Pleniglacial river deposits and the Late Weichselian wind-blown dunes and stream valleys in the area of interest is not known in detail. Surely the available geological maps of the Flemish Bight Map (1984), the Indefatigable Map (1986), the Top *Pleistocene* Formation map and Deltares' grid data (2004) and palaeogeographic maps (2015) provide an indication, but the actual situation can only be established through subbottom profiling in combination with borehole sample analysis. The depth below the seabed of the *Pleistocene* landscape ranges from 0m (*Pleistocene* exposed) to nearly 30m.

Known objects and shipwrecks

For a listing of known objects and shipwrecks within the area of interest, the united NCN database is consulted[24].

The National Contact Number (NCN)

The NCN database combines the data from three governmental databases:

- The Dutch Continental Shelf and Westerschelde wrecks register from The Hydrographic Service of the Royal Netherlands Navy.
- The SonarReg92 object database of Rijkswaterstaat
- The ARCHIS database (the official archaeological database of the Ministry of Cultural Heritage)

The permission for the use of the NCN database was granted by the owner (Rijkswaterstaat Sea and Delta)

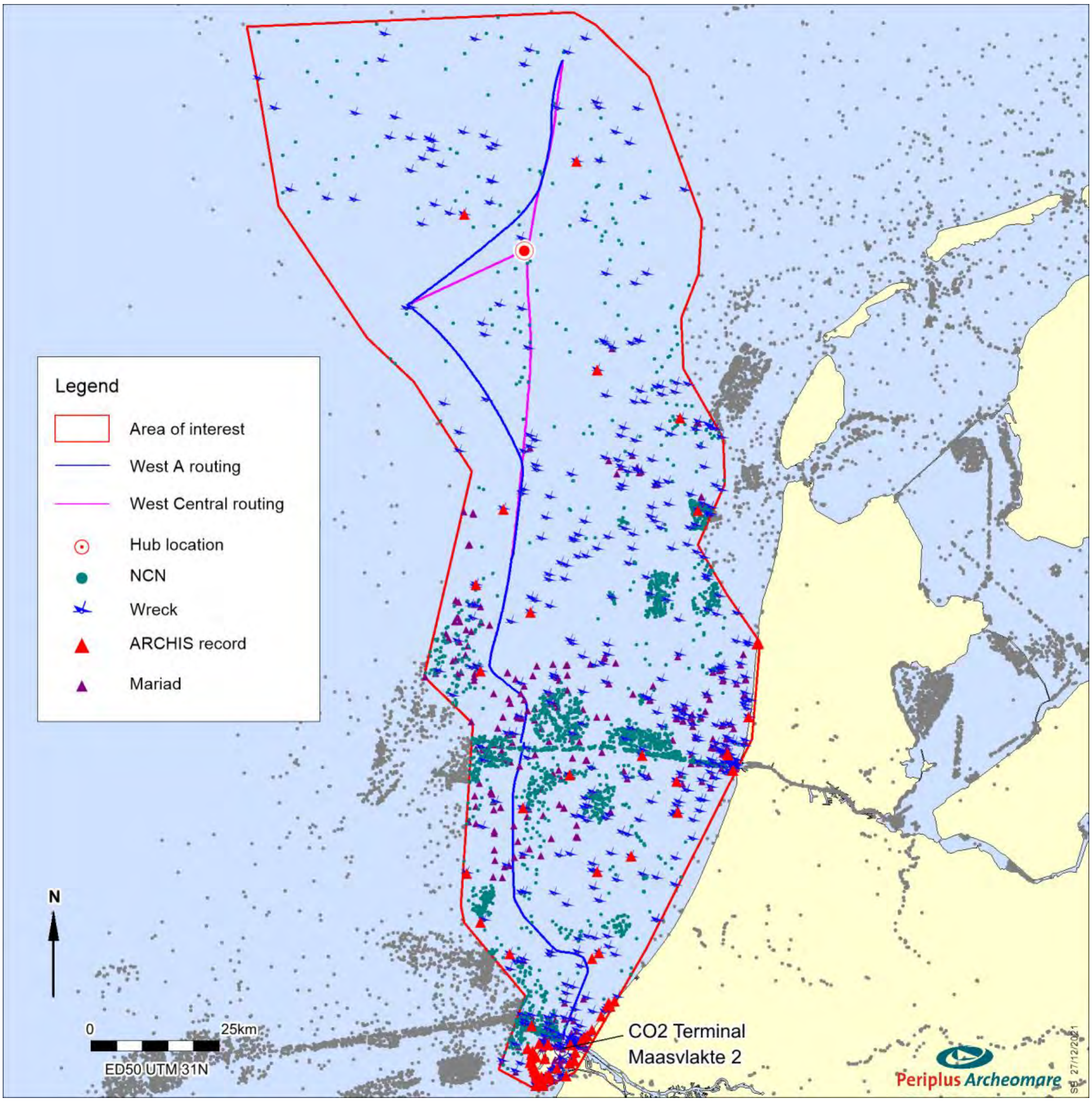


Figure 22. Overview of known objects and contacts in the area of interest

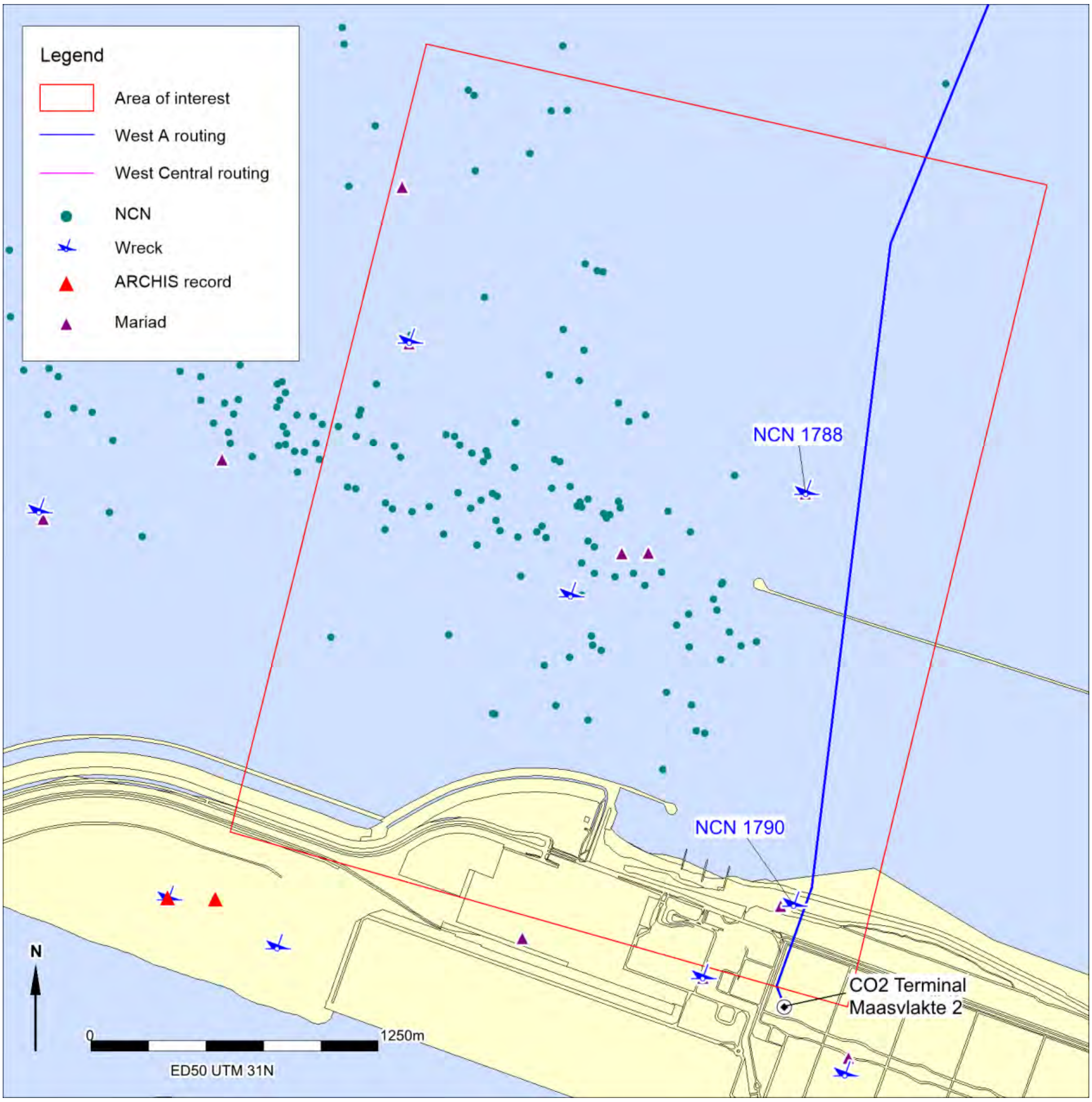


Figure 23. Overview of known objects and contacts in the landfall area

Archaeological records.

Within the area of interest, 316 records of archaeological finds are known with the ARCHIS 3 database. These vary from prehistoric artefacts (mainly concentrated around Maasvlakte 2) to remains of shipwrecks, (see next paragraph).

Shipwrecks

There are 458 known shipwrecks within the area of interest of which 38 are officially recorded in the ARCHIS database. 307 wrecks are identified and date from the 16th to the 21st century. The remaining 151 wrecks have not been identified and dated yet. Additional research is needed to determine the cultural-historical value.

Within the landfall area, two records of ship wrecks are known in the vicinity of the proposed route. NCN 1788 was the wreck of the *SS Ceres*, sunk in 1934, and was cleared away to a depth 0f 75 dm. Remains may still be present. NCN 1790 was the wreck of the *Hertha Engelina Frit, sunk in 1941.* It is now covered by sand in reclaimed area.

In general, when a sinking ship ends up on the seabed, the tidal currents will create scouring around the wreck, and bury it down to a level of a harder surface within the sedimentary sequence. The thicker the layer of loose material, the more the ship will be packaged therein and will be retained. Especially in areas where the sediments have high clay content the wreck remains will be sealed and well preserved. In more sandy areas this effect is much smaller. Uncovered wooden parts may be affected by a naval shipworm (Teredo Navalis).

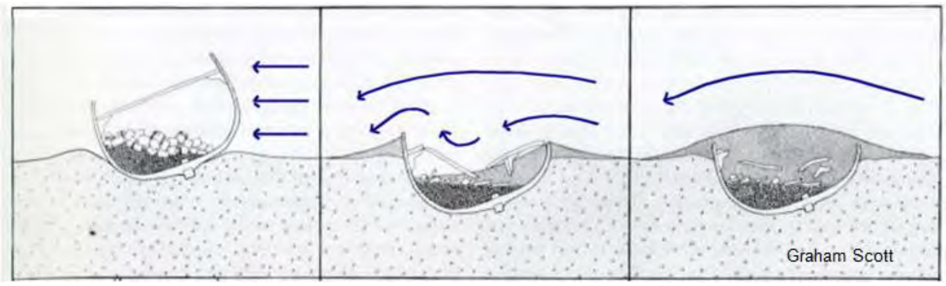


Figure 24. Example of wreck site formation (Graham Scott)

Other know objects

Besides wrecks, the SonarReg database contains records of 3494 other known objects within the area of interest. A summary is listed below.

Classification	Amount
Anchors	121
Boulders	77
Cables/Chains	304
Man-made objects	193
Natural phenomena	10
Seabed disturbances	226
Unidentified objects	2563
Total	**3494**

Table 4. Observations of known objects

Among the man-made objects and unidentified objects archaeological artefacts may be present.

Airplane wrecks

During World War II, many airplanes crashed into the North Sea. Several sources are ambiguous about the number of aircraft still missing. It is at least hundreds[25]. Remains are found on a regular basis by fishermen or during sand extraction or and beach protection projects. Within the area of interest, five locations with remains of aircrafts are known.

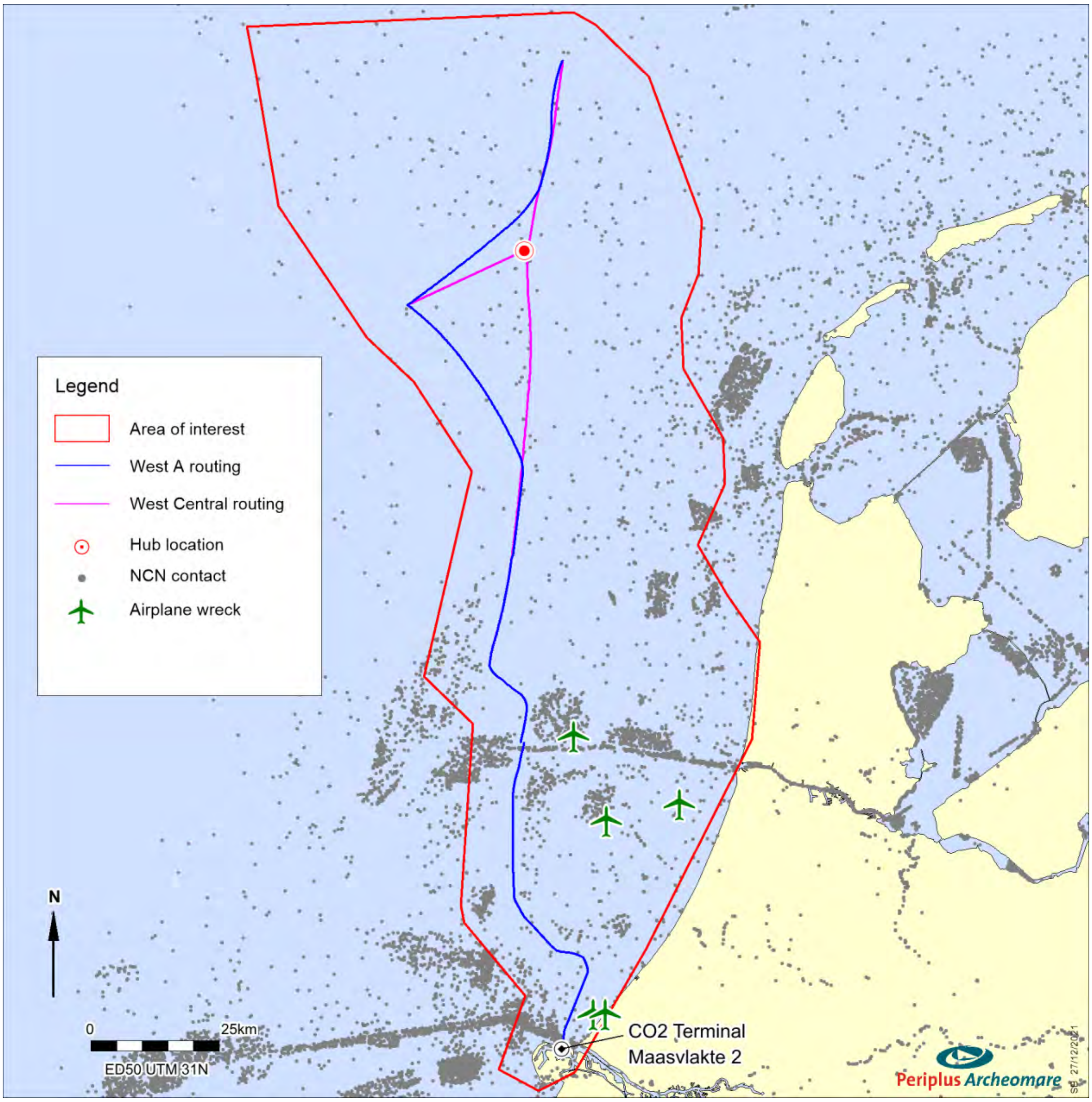


Figure 25. Known airplane wrecks within the area of interest

A complete listing of all known wrecks and objects within the area of interest can be made digitally available in consult with the administrator, Rijkswaterstaat Zee en Delta.

[25] Dutch Federation of Aviation Archaeology

3.6 Specified archaeological expectancy (LS05)

Shipwrecks

The area has a high expectation for shipwrecks from all periods. A total of 458 shipwrecks are known in the area, and more undiscovered wrecks can be expected. For some of the wrecks details like names, types and date of sinking are not known. Further research is needed to determine the cultural-historical value of these wrecks.

Plane wrecks

The area has a high expectation for plane wrecks from the Second World War. Several sources are ambiguous about the number of aircraft still missing. It is at least hundreds [26.] Within the area of interest, five locations with remains of aircrafts are known.

> **Current theme : wrecks from the First and Second World Wars**
> In addition to archaeological and cultural-historical value, ship and aircraft wrecks can also have a, memorial or emotional value. The commotion that arose as a result of the clearing of WWII wrecks in the Java Sea can be mentioned as an example. With regard to wrecks from the World Wars in Dutch waters, more and more voices are coming from society to deal with this respectfully.

Prehistory

During the last ice ages the area of interest was exposed due to very low sea levels. In those times the landscape was occupied by hunters and gatherers. Therefore camps sites are to be expected in the top of *Pleistocene* formations. The archaeological expectancy is discussed below by means of the geogenesis of the area and lithostratigraphic units present. As discussed in the section on ship wrecks, also for the *Pleistocene* landscape applies that our specific knowledge is limited, because a major part of the area has not been investigated by detailed geophysical surveys or the analysis of high quality borehole samples. As part of the Aramis pipeline development shall therefore be strived to gather additional information to broaden and deepen our geo-archaeological knowledge of the area, as outlined in the NSPRMF report.

[26] Dutch Federation of Aviation Archaeology.

Formation	Member / Bed		Lithology	Environment	Age	Arch. Potential*	Period
Southern Bight	Bligh bank		sand	open marine	Holocene	I, IV	Historical periods
Naaldwijk	Wormer		clay and sand	tidal		I	
		Velsen	humic clay	lagoon	Early Holocene	II	Meso
Echteld	Terbregge		humic clay with plant remains	freshwater tidal		II	
Nieuwkoop	Basal Peat		Peat	coast marsh		II	
Boxtel	Singraven		sand, loam, clay and peat	small-scale fluvial	Weichselian and Early Holocene	II and III	LPaleo + Meso
	Delwijnen		sand	river dune		III	
	Wierden		fine sand	cover sand		III	
Kreftenheye		Wijchen	clay and loam	overbank	Weichselian and Early Holocene	II and III	
			sand	bedding sand		II and III	MPaleo
Woudenberg			Peat	lakes	Eemian and Early Weichselian	II	
Eem	Brown Bank		humic clay and silt	lagoons and lakes	Eemian and Early Weichselian	II and III	
			sand and clay	open marine	Eemian	IV	
Boxtel | Drachten			gravel, sand, loam, peat	terrestrial	Late Saalian to Early Eemian	II and III	
Egmond Ground (ice-pushed)			sand with clay beds	open marine	Pre-Saalian deposition; Saalian (ice-push event)	II, III and IV	MPaleo - Meso
Yarmouth Roads (ice-pushed)			sand and clay	open-marine deltaic, delta top and fluvial	Pre-Saalian deposition; Elsterian/Saalian (ice-push event)	II, III and IV	Paleo - Meso

Table 5. Relation between lithostratigraphy and archaeological potential

*

Archaeological Expectancy	
I	Ship wrecks and shipping related objects; air planes from World War I and II
II	Lost or dumped objects including flint and bone hunting gear, fish weir, fish traps and dugout boats
III	Camp sites and inhumations
IV	Artefacts in reworked context

Archaeological levels are contained in the stacked sequence of *Pleistocene* and *Holocene* units. The relationship between the lithostratigraphic units and archaeological levels contained herein is summarized in table 5.

4 Synthesis

Based on the results of de data analysis the research questions are answered.

Are there any known archaeological values present within the area of interest? If so, what is the nature, extent (depth) location and dating of these sites?
Yes, within the area of interest, 316 records of archaeological finds are known with the ARCHIS 3 database. These vary from prehistoric artefacts (mainly concentrated around Maasvlakte 2) to remains of shipwrecks.

Are there, in addition to any known values, archaeological remains to be expected? If so, what are the nature, extent (depth) location and date of the expected archaeological remains?
Yes. There are 458 known shipwrecks within the area of interest of which only 38 are officially recorded in the ARCHIS database. 307 wrecks are identified and date from the 16th to the 21st century. The remaining 151 wrecks have not been identified and dated yet. Additional research is needed to determine the cultural-historical value.

The area may contain shipwrecks, remains of shipwrecks or remains of airplanes from the Second World War which have not been discovered to date. Apart from undiscovered ship and plane wrecks it is expected that locally prehistoric landscapes have been preserved intact. Related to these intact landscapes *in situ* prehistoric remains left behind by Palaeolithic and Mesolithic hunters and gatherers can be encountered.

Those *in situ* prehistoric remains include camp sites, burials, lost hunting gear, et cetera. Remains of camp sites are characterized by the presence of flint and bone artefacts, burnt nuts and seeds, charcoal and hunting gear.

Can the proposed activities affect known or expected archaeological values? If so, can an impact on archaeological assets be prevented or restricted by planning adaptation?
This question can only be answered once the area has been geophysically investigated and when the cultural historic value of the objects in the area has been determined.

If the archaeological values cannot be saved: What kind of further research is needed to determine the presence of archaeological values and their size, location, type and date to be determined enough to come to a selection decision?

Further research is to be performed within the framework of the standardized sequence of phases of maritime archaeological research as defined in the Dutch archaeological management procedure (Dutch: ‘AMZ Cycle’). The research strategy is further determined by the type of archaeological remains which, based on the archaeological expectancy outlined in section 3.6 of this report, are to be expected. In summary the expectancy is two-fold comprising plane and ship wrecks on one hand and prehistoric remains on the other. The first phase after the archaeological desk study is an inventory field research. This field research comprises a geophysical survey. The methods employed include multibeam echo sounder, side scan sonar and magnetometer to trace and map wrecks and shipping related objects. A subbottom profiler is used to assess the potential for prehistoric remains by mapping the top of the buried *Pleistocene* landscape, identify seismostratigraphic units and correlate those units with the expected lithostratigraphic units (and potential archaeological remains herein), and determine the locations at which archaeological levels have been affected by erosion.

What are the possible effects of the installation of the pipeline on the areas with specific archaeological interest?
Archaeological values can be affected by human activities which result in a disturbance of the seabed. Direct disturbances are caused by trenching operations. Scouring adjacent to the pipeline is considered to be an indirect disturbance which might lead to the exposure of wrecks and erosion of the prehistoric landscape.

What are the possibilities to mitigate the disturbance of areas with specific archaeological interests?
In general, a buffer or safety zone of 100 meters around an archaeological object or an object with an archaeological expectation is to be defined in which seabed disturbing activities are not allowed[27]. If additional research shows that the object has no archaeological value, the location and the buffer zone can be omitted. The identification and mapping of camp sites from the Palaeolithic and Mesolithic is, due to their limited size and depth of burial, in practice troublesome. Mitigating measures to preserve those sites can therefore only be effected by excluding areas in which prehistoric landscapes have been preserved intact and which are considered to have a high probability for containing those sites.

Should further investigations be carried out from archaeological point of view and what are the recommendations on the scope and specifications of these investigations?
Additional research in the form of a geophysical survey is standard in the process of archaeological investigations. (in Dutch: *Inventariserend veldonderzoek opwaterfase*). The scope and specifications for this geophysical survey are to be recorded in a mandatory Program of Requirements (PvE). Typical requirements include restrictions about the maximum range and minimum frequency of the side scan sonar, survey speed and line spacing.

[27] Beleidsregels ontgrondingen in Rijkswateren, see http://wetten.overheid.nl/BWBR0028498/

5 Summary and recommendations

The installation of the pipelines may affect archaeological remains in the area, if present. According to the Law on Archaeological Heritage (Dutch: Erfgoedwet 2016) there is a statutory obligation to conduct archaeological research in order to protect the remains. This archaeological desk study is the first step in the archaeological process aiming to establish whether archaeological remains are, or are likely to be, present, and whether these remains could be effected by the development of the planned pipelines. The results are summarized below.

The area of interest has a high expectation for the presence of (remains of) ship wrecks and WWII plane wrecks. Intact prehistoric landscapes and related *in situ* remains of Palaeolithic and Early Mesolithic camp sites and inhumations are expected to have been preserved in places.

The proposed pipeline routes have not been investigated by detailed geophysical surveys yet. These areas may contain more undiscovered shipwrecks or remains of shipwrecks than currently known.

At this stage little is known about the integrity of the *Pleistocene* and Early *Holocene* landscapes. By means of subbottom profiling the occurrence geological units (both horizontal as vertical) and archaeological levels herein can be mapped. The character of layer boundaries (erosive or non-erosive) can be interpreted. It is unlikely however that archaeological remains of Palaeolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on pipeline development. At this stage focus should therefore not be put on tracing prehistoric camp sites but on a pragmatic employment of geophysical techniques in order to obtain a better insight in (the integrity of) the *Pleistocene* landscape. The insights gained shall be used to a) refine the archaeological expectancy model and b) allocate areas with a high expectancy for *in situ* prehistoric remains.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and preservation of ship wrecks, prehistoric landscapes and potential archaeological levels.

Archaeological Expectancy	Method		Goal	Remarks
Ship and aircraft wrecks	Geophysical	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
		Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
		Sub-bottom Profiler	detect buried objects including possible ship wrecks and remains of aircraft	nature of the buried object cannot be determined directly
		Magnetometer		
Prehistoric settlements (camp sites)		Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data
	Geotechnical	Geological Drilling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	designation of borehole and/or vibrocore locations for geo-archaeological research based on SBP data
		Cone Penetration Test	determine lithostratigraphy	correlate with drilling data

Table 6. Testing of archaeological expectation with geophysical and geotechnical methods

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler* and a geotechnical survey. The resulting data should be assessed after the general processing, interpretation and reporting has been performed by the survey contractor.

The archaeological assessment of the data shall to be conducted by a geophysical specialist (KNA prospector Waterbodems). The data quality from the surveys needs to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of Requirements (In Dutch: 'Programma van Eisen') in accordance with the 'KNA' (the Dutch quality standards for archaeological research), to be authorized by the competent authority.

List of figures

List of tables

Glossary and abbreviations

Terminology	**Description**
AMZ	Archeologische Monumenten Zorg
CPT	Cone penetration test
Ferrous	Material which is magnetic or can be magnetized, and well known types are iron and nickel
Holocene	Youngest geological epoch (from the last Ice Age, around 10,000 BC. To the present)
In situ	At the original location in the original condition
KNA	Kwaliteitsnorm Nederlandse Archeologie
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
NoaA	Nationale Onderzoeksagenda Archeologie
NSPRMF	North Sea Prehistory Research and management Framework
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
PvE	Program of Requirements (Programma van Eisen)
RCE	Rijksdienst voor het Cultureel Erfgoed
ROV	Remotely Operated Vehicle
Side scan sonar	Acoustic instrument that registers the strength of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil
Current ripples	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side.
Subbottom profiler	Acoustic system used to create seismic profiles of the sub surface.
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	A special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place.

References

Literature

- Busschers, F.S. 2008. Unravelling the Rhine. Response of a fluvial system to climate change, sea-level oscillation and glaciation. PhD Thesis, Vrije Universiteit Amsterdam, 184 p.
- Busschers, F.S., C.W. Dubelaar, J. Stafleu en D. Maljers, 2010: Lithological and sand grain-size variability in the three-dimensional GeoTOP model of Zuid-Holland, Delft.
- De Mulder, E. e.a., 2003: *De ondergrond van Nederland*, Groningen.
- Deeben, J., D.P. Hallewas & Th.J. Maarleveld, 2002: Predictive modelling in Archaeological Heritage Management of the Netherlands: the Indicative Map of Archaeological Values (2nd Generation), Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 45, 9-56.
- Forzoni, A., Vermaas, T., Mesdag, C., Hijma, M., de Lange, G. and de Kleine, M., 2017. Geological study Hollandse Kust (West) Wind Farm Zone).
- Gaffney, V.L., K. Thomson en S. Fitch, 2005: The Archaeology and geomorphology of the North Sea, Kirkwall.
- Hessing, W.A.M., 2005: Het Nederlandse kustgebied, in: Bechert, T en W.J.H. Willems (red.), De Romeinse rijksgrens tussen Moezel en Noordzeekust, 89-102.
- Hijma, M., 2009: From river valley to estuary, The early-mid holocene transgression of the Rhine-Meuse valley, The Netherlands, Netherlands Geographical Studies 389, Utrecht.
- Huizer, J. en H.J.T. Weerts, 2003: Formatie van Maassluis, In: Lithostratigrafische Nomenclator van de Ondiepe Ondergrond, Geologische Dienst Nederland (DINOloket).
- IMAGO projectgroep, 2003: Eindrapportage IMAGO: Samenvatting en conclusies, RDIJ rapport 2003-13a.
- Kasse, C., W.Z. Hoek, S.J.P. Bohncke, M. Konert, J.W.H. Weijers, M.L. Cassee and R.M. van der Zee, 2005. Late Glacial fluvial response of the Niers-Rhine (western Germany) to climate and vegetation change. Journal of Quaternary Science 20 (4): 377-394.
- Kramer, E. e.a., 2003 (red.): Koningen van de Noordzee, 250-850, Leeuwarden / Nijmegen.
- Laban, C. 2004: Top Pleistocene Formations map. Netherlands Institute of Applied Geoscience TNO. Department of Geo Marine and Coast. Utrecht.
- Louwe Kooijmans, L.P., 1970-1971. *Mesolithic Bone and Antler Implements from the North Sea and from the Netherlands*.- Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek, 20-21: 69-70.
- Maarleveld, Th. J. en E.J. van Ginkel, 1990: Archeologie onder water, het verleden van een varend volk, Amsterdam.
- Maarleveld, TH.J. , Almere 1998: Archaeological heritage management in Dutch waters: exploratory studies.
- Makaske, B., NAP, R.L. 1995. A transition from a braided to a meandering channel facies, showing inclined heterolithic statification (Late Weichselian, central Netherlands). Geologie en Mijnbouw, 74, 1-8.
- Niekus, Marcel J. L. Th., Paul R. B. Kozowyk, Geeske H. J. Langejans, Dominique Ngan-Tillard, Henk van Keulen, Johannes van der Plicht, Kim M. Cohen, Willy van Wingerden, Bertil van Os, Bjørn I. Smit, Luc W. S. W. Amkreutz, Lykke Johansen, Annemieke Verbaas, Gerrit L. Dusseldorp, 2019: Middle Paleolithic complex technology and a Neandertal tar-backed tool from the Dutch North Sea. Proceedings of the National Academy of Sciences 116(44).
- Peeters J.H.M., L.W.S.W. Amkreutz, K.M. Cohen and M.P. Hijma, 2019. North Sea Prehistory Research and Management Framework (NSPRMF) 2019. Retuning the research and management agenda for prehistoric landscapes and archaeology in the Dutch sector of the continental shelf. Nederlandse Archeologische Rapporten (NAR) 63
- Rieu, R., van Heteren, S., van der Spek, J.F., and de Boer, P.L., 2005: Development and preservation of a Mid-holocene Tidal-Channel Network Offshore the Western Netherlands. Journal of Sedimentary Research, 75-3, p 409-419.

- Rijsdijk, K.F, S. Passchier, H.J.T. Weerts, C. Laban, R.J.W. van Leeuwen & J.H.J. Ebbing, 2005: Revised Upper Cenozoic stratigraphy of the Dutch sector of the North Sea Basin: towards an integrated lithostratigraphic, seismostratigraphic and allostratigraphic approach. Netherlands Journal of Geoscience 84-2, p 129-146
- Schüttenhelm, R.T.E.and Laban, C. 2005. Heavy minerals, provenance and large scale dynamics of seabed sands in the Southern North Sea.
- Thal, J., Socko, L., Feldmann, S, Brock, J. P. (2018). Geological Desk Study for the Hollandse Kust (west) Wind Farm Zone. Arcadis Nederland B.V. and Geo-Engineering.org GmbH, 180017. Netherlands Enterprise Agency. (RVO).
- Thal, J., Feldmann, S., Brock, J. P. (2019). Geological Desk Study for the IJmuiden Ver Wind Farm Zone. Arcadis Nederland B.V. and Geo-Engineering.org GmbH, 180017. Netherlands Enterprise Agency. (RVO).
- Törnqvist, T.E., Weerts, H.J.T., Berendsen, H.J.A. 1994. Definition of two new members in the upper Kreftenheye and Twente Formations (Quaternary, the Netherlands): a final solution to persistent confusion? Geologie en Mijnbouw, 72, 251-264.
- Van de Noort, R., 2011. North sea archeaeologies: A maritime biograph, 10,000 BC to AD1500. Oxford university press
- Van den Brenk, S., B.E.J.M. van Mierlo en W.B.Waldus, 2008. Archeologisch bureauonderzoek aanleg windturbinepark Tromp-Binnen en kabelroutes naar de Nederlandse kust. Periplus Archeomare rapport 08A014
- Van Lil, R. en van den Brenk, S., 2014. Windturbinepark Q4 en kabelroute naar de Nederlandse kust. Periplus Archeomare rapport 14A021
- Van Lil, R. en van den Brenk, S., 2018. Net op Zee Hollandse kust (Noord) and (west Alpha), offshore export cable routes. Periplus Archeomare report 18A013-01 (English)
- Verhart, L., 2005: Een verdronken land. Mesolithische vondsten uit de Noordzee, in: Louwe Kooijmans, L.P. e.a. (red.), de Prehistorie van Nederland, 157-160.
- Vonhögen-Peeters, L.M., S. van Heteren and J.H.M. Peeters, 2016. Indicatief model van het archeologische potentieel van de Noordzeebodem. Deltares rapport 209133-000
- Waasdorp, J.A., 1999: Van Romeinse soldaten en Cananefaten, Den Haag.
- Zijverden, W.K. van, 2017: After the deluge, a palaeogeographical reconstruction of bronze age West-Frisia (2000-800 BC), Leiden University dissertation, Leiden.

Atlases and Maps

- GeoTOP-model Laag van Wijchen en Hollandveen Laagpakket
- Globale Archeologische Kaart van het Continentale Plat

Sources from the Internet

- Dienst der Hydrografie (www.hydro.nl)
- Geologische Dienst Nederland - Data Informatie Nederlandse Ondergrond (www.dinoloket.nl)
- Noordzeeloket (www.noordzeeloket.nl)
- North sea paleolandscapes, University of Birmingham (http://www.iaa.bham.ac.uk)
- Olie en Gasportaal (www.nlog.nl)
- Stichting Aircraft recovery Group 40-45 (http://www.arg1940-1945.nl)
- Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB.nl)
- Stichting Maritiem Historische Databank (http://www.marhisdata.nl/)

Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- Databases Periplus Archeomare
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Zee en Delta

Appendix 1. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA waterbodems, version 4.1) describes all procedures and requirements for the archaeological research process. Below a brief description of the steps involved:

Desk study

The purpose of a desk study is to collect and report all available historical data, geological information and information about disturbances in the past. The result is an archaeological expectation map or model.
The desk study may be expanded with an analysis of sonar and multibeam data, if available.

IF the outcome of the desk study shows that there is a risk of occurrence of archaeology, then the next phase must be carried out:

Exploratory geophysical field research (opwaterfase)

In order to test the archaeological expectation, a geophysical survey is carried out. The type of survey depends on the type of expected objects, local geology and expected depth of the objects below the seafloor. In practice, the research usually consists of a side scan sonar survey, if necessary, supplemented with multibeam echo sounder recordings, subbottom profiling and magnetometer measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

IF potential archaeological objects are found, then the next phase must be carried out:

Exploratory field research under water (onderwaterfase verkennend)

The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

IF as site is identified as an archaeological object or structure then the next phase must be carried out:

Validating field research (onderwaterfase waarderend)

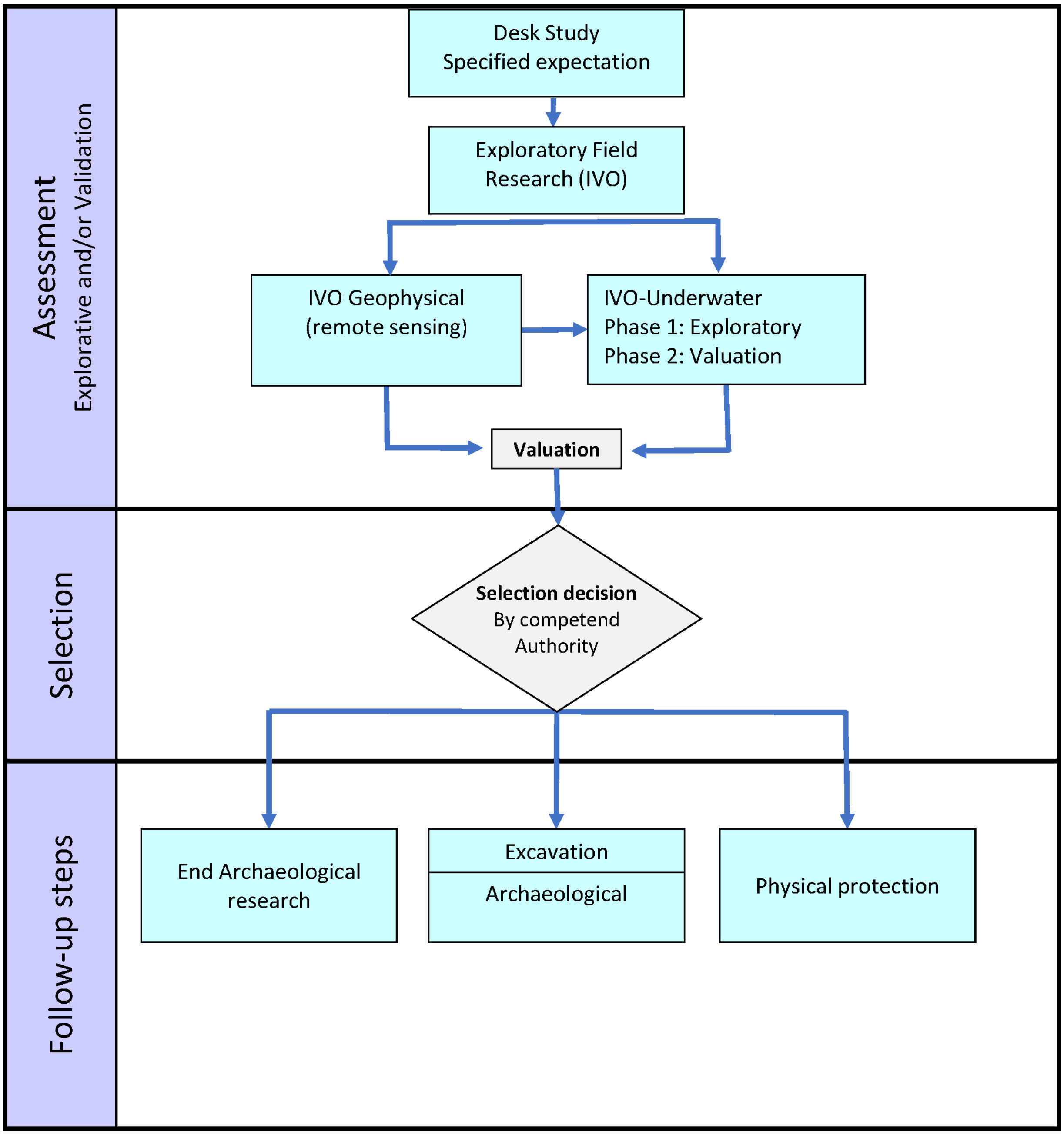
The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains are worth preserving. If the latter is the case, then there are two possibilities: either the remains can be preserved in situ (adjustment of plans) or the next phase will be conducted:

Archaeological excavation

The archaeological remains are excavated under supervision of a senior maritime archaeologist. All remains need to be documented, registered and conserved. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

The phases described above contain a number of decision points that are dependent on the detected archaeological objects and structures. The figure on the next page shows these moments schematically.

Schematic overview KNA Waterbodems version 4.1



Appendix 2. Archaeological and geological periods and time scale

Chronostratigrafie

Serie			Etage - Chronozone	Tijd
Holoceen			**Laat Subatlanticum**	**1150 n. Chr**
Holoceen			Vroeg Subatlanticum	0
Holoceen			Vroeg Subatlanticum	450 v. Chr
Holoceen			Subboreaal	3700
Holoceen			Atlanticum	7300
Holoceen			Boreaal	8700
Holoceen			Preboreaal	9700
Pleistoceen	Weichselien	Laat Glaciaal	Jonge Dryas	11.000
Pleistoceen	Weichselien	Laat Glaciaal	Allerød	12.000
Pleistoceen	Weichselien	Laat Glaciaal	Oude Dryas	12.100
Pleistoceen	Weichselien	Laat Glaciaal	Bølling	13.000
Pleistoceen	Weichselien	Pleniglaciaal L		17.000
Pleistoceen	Weichselien	Pleniglaciaal L	Late Glacial Max	20.000
Pleistoceen	Weichselien	Pleniglaciaal L		31.500
Pleistoceen	Weichselien	Pleniglaciaal L	Denekamp	34.000
Pleistoceen	Weichselien	Pleniglaciaal M		40.000
Pleistoceen	Weichselien	Pleniglaciaal M	Hengelo	41.500
Pleistoceen	Weichselien	Pleniglaciaal M		45.000
Pleistoceen	Weichselien	Pleniglaciaal V	Moershoofd	50.000
Pleistoceen	Weichselien	Pleniglaciaal V		71.000
Pleistoceen	Weichselien	Vroeg Glaciaal	Odderade	74.000
Pleistoceen	Weichselien	Vroeg Glaciaal		
Pleistoceen	Weichselien	Vroeg Glaciaal	Brørup	
Pleistoceen	Weichselien	Vroeg Glaciaal		
Pleistoceen	Weichselien	Vroeg Glaciaal	Amersfoort	
Pleistoceen	Weichselien	Vroeg Glaciaal		114.000
Pleistoceen			Eemien	126.000
Pleistoceen			Saalien	236.000
Pleistoceen			Oostermeer	241.000
Pleistoceen			onbenoemd	322.000
Pleistoceen			Belvédère	336.000
Pleistoceen			onbenoemd	384.000
Pleistoceen			Holsteinien	416.000
Pleistoceen			Elsterien	463.000

Archeologische periode

Tijdperk				Datering
		Nieuwe tijd	C	1850
		Nieuwe tijd	B	1650
		Nieuwe tijd	A	1500
		Middeleeuwen	Laat B	1250
		Middeleeuwen	Laat A	1050
		Middeleeuwen	Vroeg D	900
		Middeleeuwen	Vroeg C	725
		Middeleeuwen	Vroeg B	525
		Middeleeuwen	Vroeg A	450
		Romeinse tijd	Laat	270
		Romeinse tijd	Midden	70 n. Chr.
		Romeinse tijd	Vroeg	15 v. Chr.
Prehistorie	Metaaltijden	IJzertijd	Laat	250
Prehistorie	Metaaltijden	IJzertijd	Midden	500
Prehistorie	Metaaltijden	IJzertijd	Vroeg	800
Prehistorie	Metaaltijden	Bronstijd	Laat	1100
Prehistorie	Metaaltijden	Bronstijd	Midden	1800
Prehistorie	Metaaltijden	Bronstijd	Vroeg	2000
Prehistorie	Steentijd	Neolithicum	Laat	2850
Prehistorie	Steentijd	Neolithicum	Midden	4200
Prehistorie	Steentijd	Neolithicum	Vroeg	4900/5300
Prehistorie	Steentijd	Mesolithicum	Laat	6450
Prehistorie	Steentijd	Mesolithicum	Midden	8640
Prehistorie	Steentijd	Mesolithicum	Vroeg	9700
Prehistorie	Steentijd	Paleolithicum	Laat B	12.500
Prehistorie	Steentijd	Paleolithicum	Jong B	16.000
Prehistorie	Steentijd	Paleolithicum	Jong A	35.000
Prehistorie	Steentijd	Paleolithicum	Midden	250.000
Prehistorie	Steentijd	Paleolithicum	Oud	

Appendix C

UXO desktop Study

Historical Desktop Study

Unexploded Ordnance (UXO)

Maasvlakte Aramis CCS Project

RO-220005 Report version 1.0 (final)
9th February 2022

Riel Explosive Advice & Services Europe B.V. • Vijfhuizenbaan 1b 5133 NH Riel Nederland
Postbus 21 5133 ZG Riel Nederland • T +31 (0) 13 518 6076 • www.reaseuro.com • info@reaseuro.com

Historical Desktop Study

Unexploded Ordnance (UXO)

Maasvlakte Aramis CCS Project

Client	:	Fugro GB Marine Limited
Label	:	74497 / RO-220005 version 1.0 (final)
Place, Date	:	Riel, 9th February 2022

REASeuro			
	Name/Function	Signature	Date
Authors	[redacted] MA, Historian	[redacted]	9th February 2022
GIS-Assistance	[redacted] GIS-Specialist	[redacted]	9th February 2022
Checked by	[redacted] Historian	[redacted]	19th January 2022
	[redacted] Senior UXO expert	[redacted]	19th January 2022
Approved by	[redacted] Head of the Advice Department	[redacted]	9th February 2022
Fugro			
Accepted	[redacted] Manager Marine Geotechnics		

Front page image: Fragment of oblique aerial photograph showing Bristol Beaufighter's of the North Coates Strike Wing attacking a small enemy convoy off Terschelling, Holland. The nearest trawler is being attacked with cannon gunfire, and also with rocket projectiles fired by the aircraft from which the photograph was taken. Source: Imperial War Museum.

TABLE OF CONTENTS

Page

REASeuro

SUMMARY

Historical research

The Central North Sea was the scene of several war related events during World War I and II. Among these are the sinking of a large amount of vessels and aircraft, bombing by planes, naval battles and the presence of minefields, military exercise zones and munition dumping grounds. Due to these events UXO may be located within the area of interest. The UXO items considered most likely to be present within the investigation area are shown in the overview below. Note that the overview shows the likelihood of presence of generic UXO types within the site based on the evidence available in the REASeuro GIS-Database at the time of writing this report.

UXO type	Likelihood of presence	Subtype / calibre	Remarks
Naval mines (WWII)	Feasible	German E-Mine moored contact mines British Vickers / British Elia and H Mark II moored contact mines	The area of interest was situated between the British coast and Germany. During the First World War this area was a theatre of mine warfare. Multiple German and British minefields were laid within the area of investigation. This evidence supports a strong likelihood that naval mines are present within the boundaries of the known minefields. Outside these boundaries likelihood of presence is determined to be feasible.
	Probable		
Naval mines (WWII)	Probable	British Mk I-IV ground mines and British Mk VII- VIII and Mk XIV	During the Second World War the area of interest was situated between the British oast and the German occupied coasts of Europe. During the Second World War this area was once again a theatre of mine warfare. Multiple German and British minefields (filled with mines and sweeping obstructers) were laid within the area of investigation. Primary sources lead to the conclusion that within the boundaries of the known minefields, the likeliness of presence of naval mines is certain. Outside these boundaries likelihood of presence is determined to be probable.
	Certain	German EMB, EMC, EMD, UMA, RMA, KMA contact mines German LMB Ground mines German Exploding Floats (and also non explosive sweep obstructors) Dutch Model 1921 '2e soort'	
Aerial bombs	Certain	4 lbs, 25 lbs, 30 lbs, 100 lbs, 250 lbs, 260 lbs, 300 lbs, 500 lbs, 1.000 lbs, 4.000 lbs	During the Second World War, aerial warfare played a huge factor. Research shows that a large amount of allied airstrikes took place in the area of investigation. Depending on the target bombs, rockets, torpedoes and depth charges could be deployed. Besides airstrikes, allied aircraft often jettisoned bombs over the North Sea. At least one direct indication of jettisoning in the area of investigation has been derived from the historical sources. Indirect indications are plentiful. Due to the large amount of sources stating attacks near the convoy routes it is deemed certain that UXO as a result of aerial warfare might still be present near these convoy routes. In the rest of the area of investigation the likelihood of presence of UXO is deemed probable due to the large amount of jettisons in the North Sea.
	Probable		
Rockets	Certain	3 inch rocket with 25 lbs or 60 lbs (SAP) warhead	
	Probable		
Under water ammunition	Certain	18 inch torpedo Mk XV Depth charge	
	Probable		

UXO type	Likelihood of presence	Subtype / calibre	Remarks
Artillery Shells Small calibre ammunition (Naval weaponry)	Probable Remote	Small Calibre Ammunition .303 .50 13,2 mm 15 mm Artillery Shells 2 cm/20 mm 2 pr. pompom 3.7 cm 6 pr. 8.8 cm	As mentioned, German shipping was attacked regularly by Allied aircraft. As a countermeasure German ships were equipped with anti-air (machine)guns. Due to the deployment of these guns, UXO might be present near the commonly used German convoy routes. Outside of these convoy routes the likelihood of presence of UXO is deemed remote. This statement is further enhanced by the fact that British surface craft tried to infiltrate the German convoy routes and, in some instances, fought small scale naval battles with German ships.
Artillery Shells	Probable Negligible	Coastal guns: 5 cm 7,5 cm 9,4 cm 10,5 cm 12 cm 14,91 cm 15 cm 15,2 cm 24 cm 28 cm	After the German occupation coastal guns were installed along the Dutch coast as part of the *Atlanikwall*. The coastal guns covered the whole coast in order to repel a possible Allied attack. Due to exercises and combat UXO of artillery shells could be present within the area of investigation. However, UXO could only have reached as far as the range of the coastal guns. Within range of the coastal guns the likelihood of presence is deemed to be probable, outside of this range the likelihood of presence is deemed negligible.
Unknown (exercise) munition	Certain Negligible	Each military exercise zones had it's own purpose, it is outside the scope if this research to determine the munition used in each zone.	Within the area of investigation there were several military exercise zones. Some were already in use by German troops during the Second World War, others taken into use by the Dutch military after the war. It is deemed certain that UXO of (exercise) munition is still present within the boundaries of the military exercise zones, outside these zones the presence of UXO of (exercise) munition is deemed negligible.
Unknown dumped munition	Certain Probable Negligible	-	A total of three known munition dumping grounds overlap with the area of investigation. Sources state that fishermen found munition outside of the dumping grounds, therefore a buffer of three nautical miles was projected around dumping grounds. 'Fishing, intrusive, and seismographic activities' were deemed dangerous within this buffer. The presence of munition dumping grounds lead to the determination of a UXO Risk Area at the location of the dumping ground. The likelihood presence of UXO at this location is deemed certain. Within the buffer of three nautical miles this likelihood presence is deemed probable, in the rest of the area of investigation the likelihood presence is set to negligible.

Table 1: UXO items likely to be encountered in the area of interest.

1 GENERAL INFORMATION

This chapter describes the context and goal for the Historical Desktop Study–Unexploded Ordnance (HDTS-UXO). Furthermore the area of investigation, the area of interest, the purpose and methodology are described. The chapter concludes with a general structure of the report.

2.1 INTRODUCTION

Fugro has invited REASeuro to conduct an HDTS-UXO for the CCS Aramis project. The plans are to build a new pipeline from Maasvlakte (man-made westward extension of the Europoort port and industrial facility within the Port of Rotterdam) to offshore blocks L4/K6. To obtain insight in the possible chance of encountering UXO during this project, Fugro Survey B.V. has requested REASeuro to provide a HDST-UXO.

2.2 AREA OF INTEREST AND AREA OF INVESTIGATION

The area of interest is located off the Maasvlakte, Netherlands to offshore blocks L4/K6, located within the northwestern part of the North Sea. The area of investigation is the given radius, based on the inaccuracies inherent to conducting offshore desk research. The positions of naval minefields, air strikes, crashes and convoy routes in historical sources are given approximately only, since navigation equipment was not nearly as accurate as it is in modern systems. The most common method of marking locations during the World Wars was based on decimal degrees, which were accurate down to 1 naval mile (1,852 meters). Another way of positioning is found in German sources, which are based on the German Naval Grid (*Kriegsmarine Quadranten*), with a grid size of 6x6 nautical miles. Historical sources based on this grid thus position war related events in an area of 123 square kilometres.

Besides these inherent inaccuracies from historical sources, one must take into account the displacement of UXO on the seabed. Bottom trawling, tides and currents, and recent developmental activities may have caused this displacement. The area of interest and research area are shown in Figure 1.

Figure 1: Area of interest and area of investigation (Source of base map: ESRI).

2.3 PURPOSE AND MAIN OBJECTIVES

The HDTS-UXO will be performed with sources which are currently in the REASeuro-database and open sources in a short amount of time. Therefore, it provides an indication if UXO might be present in the Area of interest. By conducting the sources which are mentioned above, historical research will be conducted on the war-related events that took place within the Area of Interest. More specifically, the HDTS-UXO will provide historical research on:

- Aerial attacks on ships
- Airplane crashes
- Shipwrecks
- Laying of minefields (WWI, WWII)
- Dumping of UXO
- Military zones

The starting point of REASeuro is, that the presence of UXO cannot be excluded. In the HDTS-UXO REASeuro will examine whether this premise is true and if there are areas with an increased risk of UXO. Based on the historical sources, the possible calibres and type of UXO are determined which could be present within the Area of Interest.

The HDTS-UXO will provide historical research on:

1. The military events, battle activities, aerial attacks on ships, airplane crashes, shipwrecks, laying of minefields (WWI, WWII), dumping and submarine activities.
2. The possible calibres and type of expected UXO.

3 APPRAISAL OF HISTORICAL SOURCES

This chapter describes the consulted sources. Detailed information extracted from each source is included within the annexes. Information extracted from the sources, results in an overview of relevant war events. These events are the starting point for the review and analysis of sources in chapter 4 of this historical research.

3.1 METHODOLOGY OF HISTORICAL RESEARCH

This research report is conducted in accordance with the Dutch CS-OOO regulations for UXO research and REASeuro's internal standards for offshore desk top studies. War related events that took place in the area of investigation are derived from historical sources, and subsequently analysed. Based on this analysis a UXO risk area may be demarcated.

Due to several years of experience with offshore research, REASeuro has built up a substantial database regarding war related events in the North Sea. A multitude of sources are consulted for this report. All consulted sources are listed and explained in paragraph 2.2.

The research has been conducted by an historian. Page 1 of this report mentions the involved experts. ArcGIS Pro version 2.9.0[1] has been used as a tool to conduct this research. Historical maps and other information have been gathered and projected in this geographical information system for analysis[2]. GIS is also used to position and clarify the relevant war related events mentioned in the list of war related events in chapter 3.

3.2 SOURCES

For more than twenty years, REASeuro has collected historical sources regarding war-related events within the North Sea. Many of these sources have been made available for historical research through an internal database in our own Geographical Information System (GIS). This database contains a wide variety of sources. The following sources will be consulted for the HDTS-UXO:

Sources
Literature • Maps and charts regarding minefields
Nationaal Archief, The Hague, The Netherlands • Coastal guns
Noorzeeloket, The Netherlands • Military zones
Dienst der Hydrografie, Koninklijke Marine, The Netherlands • Wrecks • Military zones
Nederlands Instituut voor Militaire Historie, The Hague, The Netherlands • Minefields
Marinemuseum, Den Helder, The Netherlands • Coastal guns
Bundesarchiv-Militärarchiv, Freiburg, Germany • ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration) – mine-clearance operations
The National Archives, Richmond, United Kingdom • Bomber Command: aerial attacks and minelaying within the North Sea

[1] Mentioned as 'GIS' throughout this report.
[2] Historical charts are "georeferenced" in GIS and used for this report. Georeferencing is the name given to the process of transforming a scanned map or aerial photograph so it appears "in place" in GIS. By associating features on the scanned image with real world x and y coordinates, the software can progressively warp the image so it fits to other spatial datasets. For this research, historical charts have been georeferenced by distinguishing points of recognition on both the historical and present maps and placing 'those points together' so that both maps align. Since several of these charts are hand-drawn or lack exact coastlines, inaccuracies may occur and exact inaccuracies in meters could not be given.

• Coastal Command: aerial attacks and minelaying within the North Sea • Squadrons: Loss charts
National Archives and Records Administration, College Park (MD), United States • Documents from the US Army Air Forces (USAAF)
Beneficial Cooperation - The Royal Netherlands Navy and the Belgian Navy • UXO-clearance operations • Military zones
OSPAR-convention • UXO-clearance operations
Wrecksite • Locations of wrecks (airplanes/ships etc.) within the North Sea
UK Hydrographic Office • Charts regarding minefields • Charts regarding naval routes
Library of Congress • Charts regarding minefields

Literature

An overview of used literature can be found in Annex 2. Literature is consulted in order to get a general depiction of the war related events (especially the laying of minefields) within the area of investigation. The resulting events are shown in chronological order in tables. The references (book and page) for each event are included in the tables.

Nationaal Archief, The Hague, The Netherlands

The Dutch National Archives have been consulted for more information on the coastal guns on the Dutch Coast.

Noordzeeloket, The Netherlands

The Noordzeeloket is a comprehensive website, covering relevant Dutch maritime policy related North Sea information. On the website relevant information about the locations of Voormalige munitiestortplaatsen (Former munitions dump locations), Oefengebieden Mijnenruimen (Mine clearance training areas), (Laag)vlieggebieden ((Low) flying areas) and Schietterrein / onveilige zone (Shooting site / unsafe area) is available.

Dienst der Hydrografie, Koninklijke Marine, The Netherlands

Naval charts of the area of analysis have been acquired through the Hydrographic Service. Besides naval charts regarding military usage the HP39 (wreck registry) publication has been consulted to gain information on possible wrecks in the area of investigation.

Nederlands Instituut voor Militaire Historie, The Hague, The Netherlands

The 'Nederlands Instituut voor Militaire Historie' has been consulted on information about Dutch naval minefields.

Marinemuseum, Den Helder, The Netherlands

The map collection of the Marinemuseum (Navy Museum) in Den Helder has been consulted. NEMEDRI-maps were found in this collection. These maps offer information on minesweeping after the Second World War. The NEMEDRI maps show some information about mine clearance shortly after the war.

Bundesarchiv-Abteilung Militärarchiv (BAMA) in Freiburg

The German military archives were severely damaged during World War II. The remains of the archives are kept and maintained in the Bundesarchiv in Freiburg. The archives of the German navy (*Kriegsmarine*) survived the war relatively well compared to the other service branches. These have been consulted for this desktop study, as well as the German Air Force (*Luftwaffe*) archives, of which only 2% of the documents survived the war. Annex 4 contains the relevant information from the BAMA.

The National Archives (TNA) in Londen

The National Archives have been consulted for information on naval minefields, air strikes, naval combat, bomb jettisoning and other relevant war related events. The Admiralty, War Cabinet and Air Ministry archives have been consulted for this information. Annex 4 contains relevant results from TNA.

National Archives and Records Administration (NARA) in College Park (MD)

Research has been conducted in the US National Archives and Records Administration. The NARA has been consulted for documents from the US Army Air Forces (USAAF) and for the collection of captured German records. Annex 4 contains the relevant information from the NARA.

Beneficial Cooperation - The Royal Netherlands Navy and the Belgian Navy

The Dutch navy is working with the Belgian navy to keep the sea, coastal waters and harbour mouths free of mines. Therefore, the UXO-related interventions in the database of the Beneficial Cooperation is consulted.

Post-war UXO clearance: OSPAR

The area of interest is situated in the North Sea. Therefore, the UXO-related interventions in the database of the OSPAR Commission[3] were consulted. The results are shown in Annex 4.

Wrecksite

The wreck site is the world's largest online wreck database. The website has information about 205.740 wrecks around the world. When information about the reason for the sinking of a ship is known, it is mentioned on the website.

UK Hydrographic Office

The UK hydrographical office maintains a collection of historical naval charts, including charts that contain minefields and convoy routes. Naval charts showing the area of investigation have been consulted, but no map has been found with information regarding the area of interest.

Library of Congress

On the website of the Library of Congress, which is known as the national library of the United States, a chart has been consulted regarding minefields in the First World War. This chart is shown in Annex 5.

---

[3] The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR-convention) provides a framework for reporting encounters with conventional and chemical munitions in the OSPAR maritime area.

4 ANALYSIS OF WAR RELATED EVENTS

The consulted historical sources (see annexes) indicate several war related events within the area of interest. The war related events derived from the historical sources that are relevant for the area of interest are listed categorically in the tables underneath. The events are grouped into four categories: war at sea, the air war, naval mines, and other UXO-related events. Following these tables per category, the UXO type and likeliness of presence within the area of interest is determined. Before each category is analysed below, the method of defining UXO risk areas is explained.

Defining the UXO risk area

The UXO items considered most likely to be present within the area of interest are shown in each specified category. Note that the table at the end of each paragraph shows the probable presence of generic UXO types within the site based on the evidence gathered about potential UXO sources. It's important to recognise that the presence of a UXO type does not necessarily mean that it will be encountered. The likelihood of encounter (i.e. a positive interaction with the UXO during a specific project activity), will generally be less than the probability of items of that particular UXO type being present across the whole area of interest; given that the actual footprint of the anchor locations will be less than the total investigation area volume. In the following table the terminology used for the likely presence of UXO is shown.

"Presence" Term	Meaning
Negligible	No evidence pointing to the presence of this type of UXO within an area but it cannot be discounted completely.
Remote	Some evidence of this type of UXO in the wider region but it would be unusual for it to be present within the area of study.
Feasible	Evidence suggests that this type of UXO could be present within the area.
Probable	Strong evidence that this type of UXO is likely to be present within the area.
Certain	Indisputable evidence that this type of UXO is present within the area.

Table 2: Definitions of terminology used for the likely presence of UXO.

Condition of expected UXO

The majority of the expected UXO are likely to be in an armed condition. This means that the safety devices preventing the UXO from premature detonation, e.g. during handling, have been removed. Therefore, the explosive train, is in line.

The explosive train is a sequence of events that culminates in the detonation of explosives and can be different for each type of UXO:

- In the case of aerial bombs which were dropped by aircraft in distress situations, the bombs could have been dropped with safety features still in place, however they still present an explosive risk, e.g. as a result of corrosion of vital safety features.
- Some of the expected UXO, e.g. naval munitions, contain a large quantity of explosives and may be encountered in very poor condition as the thin metal casings may have severely eroded. In many cases, the explosive capability could remain more or less undiminished. Some explosive charges neither absorb nor dissolve in water, and some charges do. However, stability of the explosive charge may have deteriorated with age.
- Naval contact mines from the period of interest typically contained a dry cell battery with an electrical detonating circuit which was connected to external conventional switch horns. These batteries will have now deteriorated and no longer have the ability to supply sufficient power to function. However, the condition of the explosives can be unstable.
- Contact mines with Hertz Horns were also common from World War I and onwards. Each horn contains a container of acid. Heavy contact with the horn can brake the acid container within, which

subsequently energizes a battery and detonates the main charge. Therefore, this type of mine (like all other UXO) must be handled with extreme caution.

Although corrosion can make a UXO more sensitive, it can also make it less likely to detonate, as i.e. electrical wiring may have corroded resulting in a break in the explosive train. As a wide range of UXO can be expected, all UXO must be handled with extreme caution until the exact state is determined after positive identification by an EOD-expert.

4.1 NAVAL MINES

Naval mines were laid in the North Sea during the First and Second World War. The purpose was twofold. Mines were used in a defensive way to protect own waters and ports and to hold off enemy ships. At the same time, mines could be used to harass enemy shipping and obstruct military movements. Mines could be laid by surface ships, submarines and aircraft. During the First World War moored contact mines were used almost uniquely. Moored mines float beneath the water surface and are kept in position with an anchor and anchor cable. This technique was also used during the Second World War. Next to contact mines, the belligerent parties developed influence mines. These mines were laid on the sea bottom and would detonate if sensors in the mine detect a difference in pressure, sound, or magnetism caused by a passing ship.

The area of investigation has overlap with a suspected British minefield from the First World War and several German minefields from the Second World War. These minefields, the post-war clearance and UXO encounters are discussed in the next paragraphs. A conclusion is added in paragraph 4.1.4.

4.1.1 First World War

A map from the Library of Congress (see Annex 3) shows two minefields on relatively large distance from the area of investigation. It was a large German minefield (red, marked with a '3') lying along the Dutch coast. The map title (see subscript of Figure 2) explains that only the approximate position of the minefield is showed. The presence of the minefield is confirmed in the book *The Hidden Threat* (see Annex 2). According to this book 664 mines were laid in the field. No information about the exact type of mines was found, but the belligerent parties during the First World War used almost uniquely moored contact mines.

The second Minefield was British (bordered in red, northeast of the area of investigation). The border indicates an area in which multiple smaller minefields were laid. The mined area, the German Bight, was a major theatre of naval warfare during World War I. British forces laid 42.899 naval mines in the Bight. Only few German minefields can be found in the German Bight.

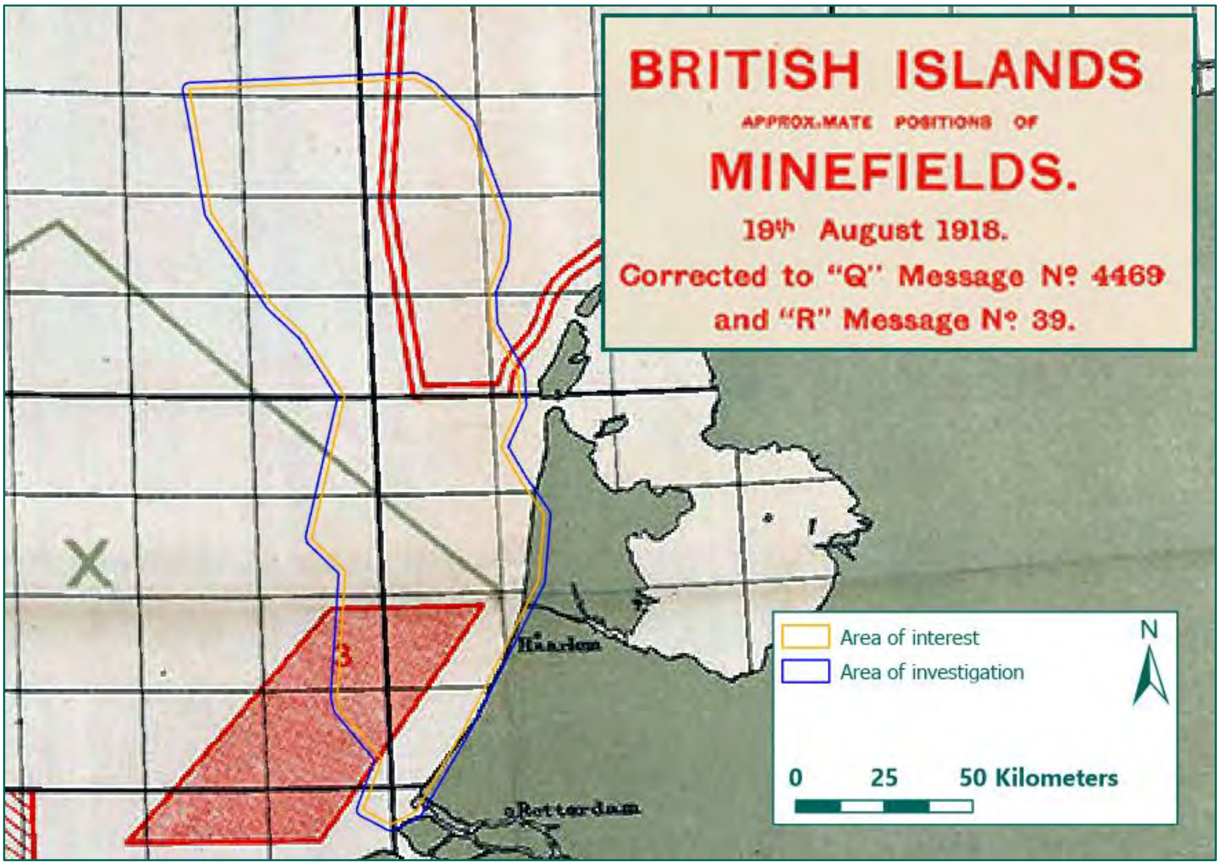


Figure 2: Cutout of the map *British Islands. Approximate position of minefields*, *19th August 1918,* showing minefields around the British Islands (Source: Library of Congress).

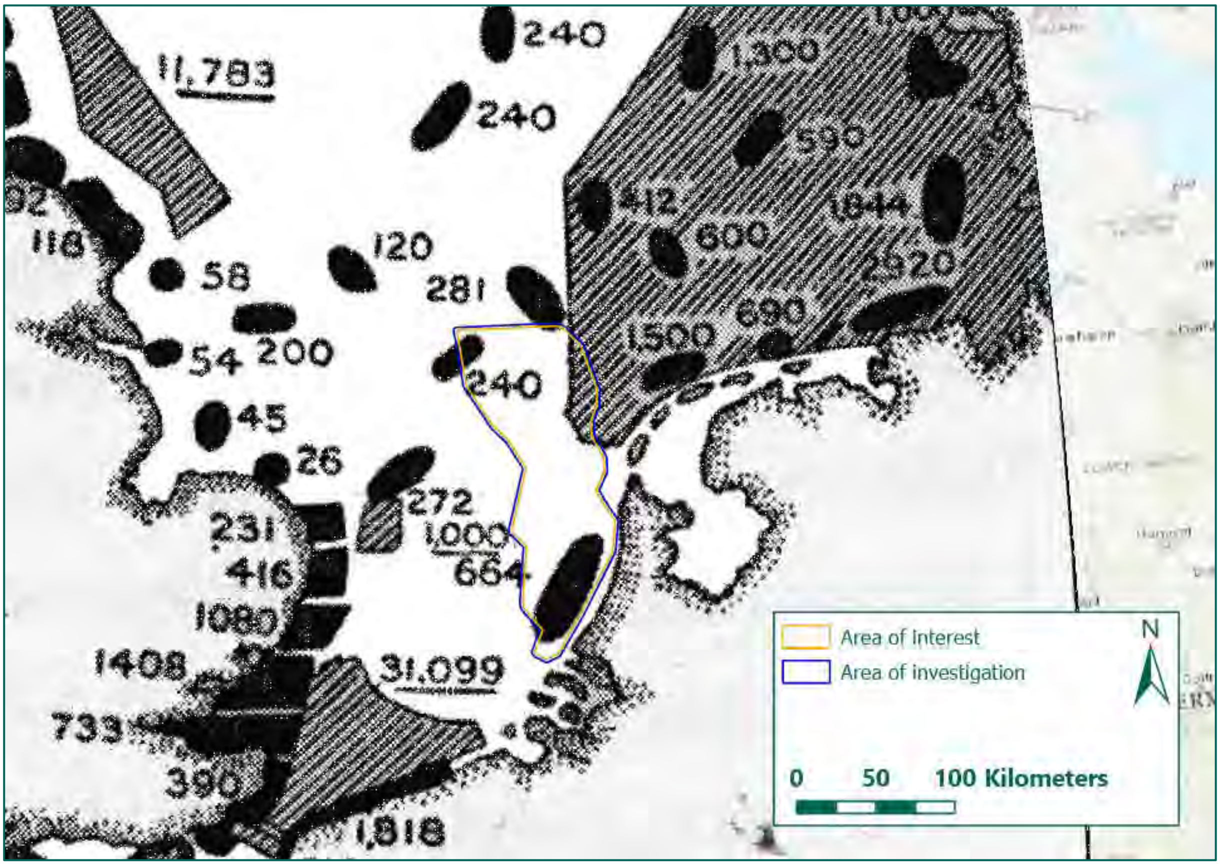


Figure 3: British, German and American mines laid during the First World War (Source: Literature CRO 62).

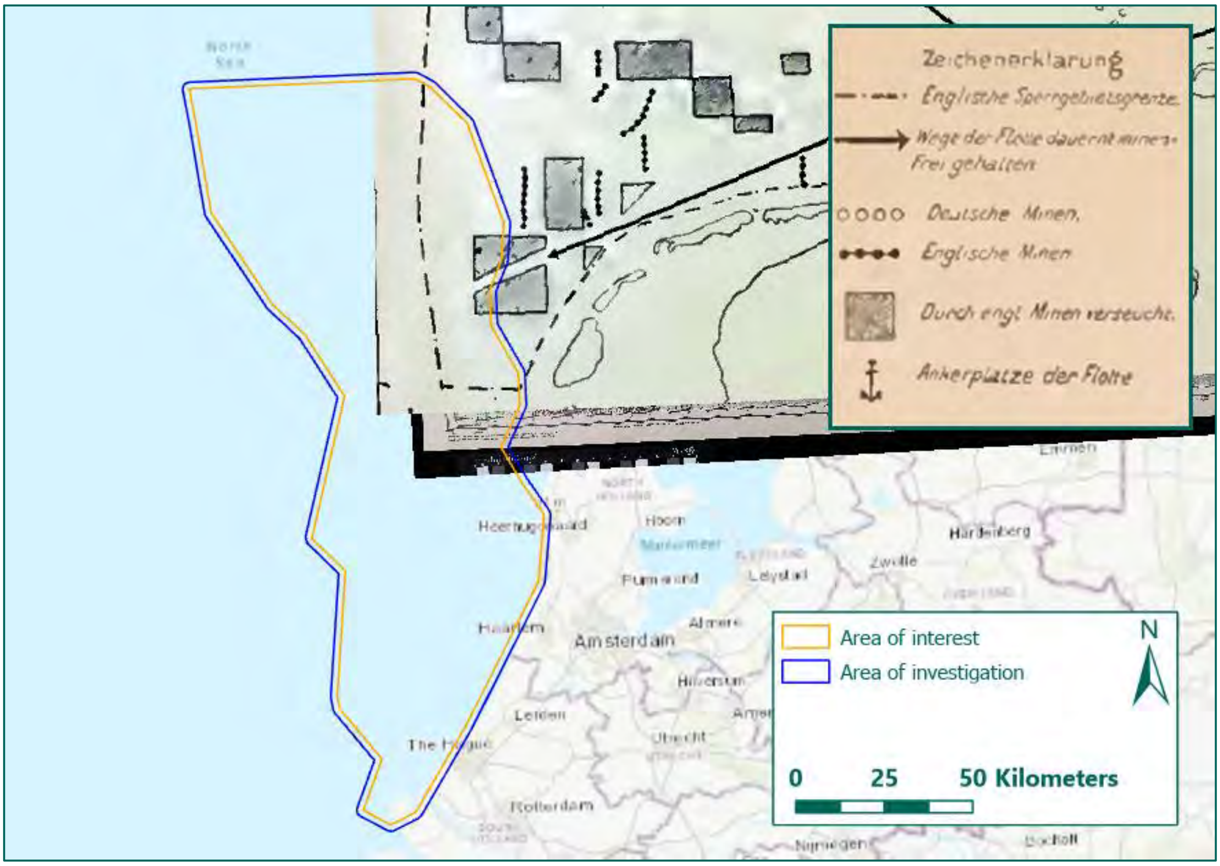


Figure 4: Details about minefields near the Dutch coast (Source: Literature SCH 288)

According to German sources derived from the Bundesarchiv, the area of investigation has overlap with an area which is suspected to have been mined. Reports from the *Kommando der Hochseestreitkräfte* (Command of the Naval Forces) contain a map showing the minefield. *Treibende Minen* (Contact mines) were laid on the Dutch Coast. Additional information about these minefields is not given.

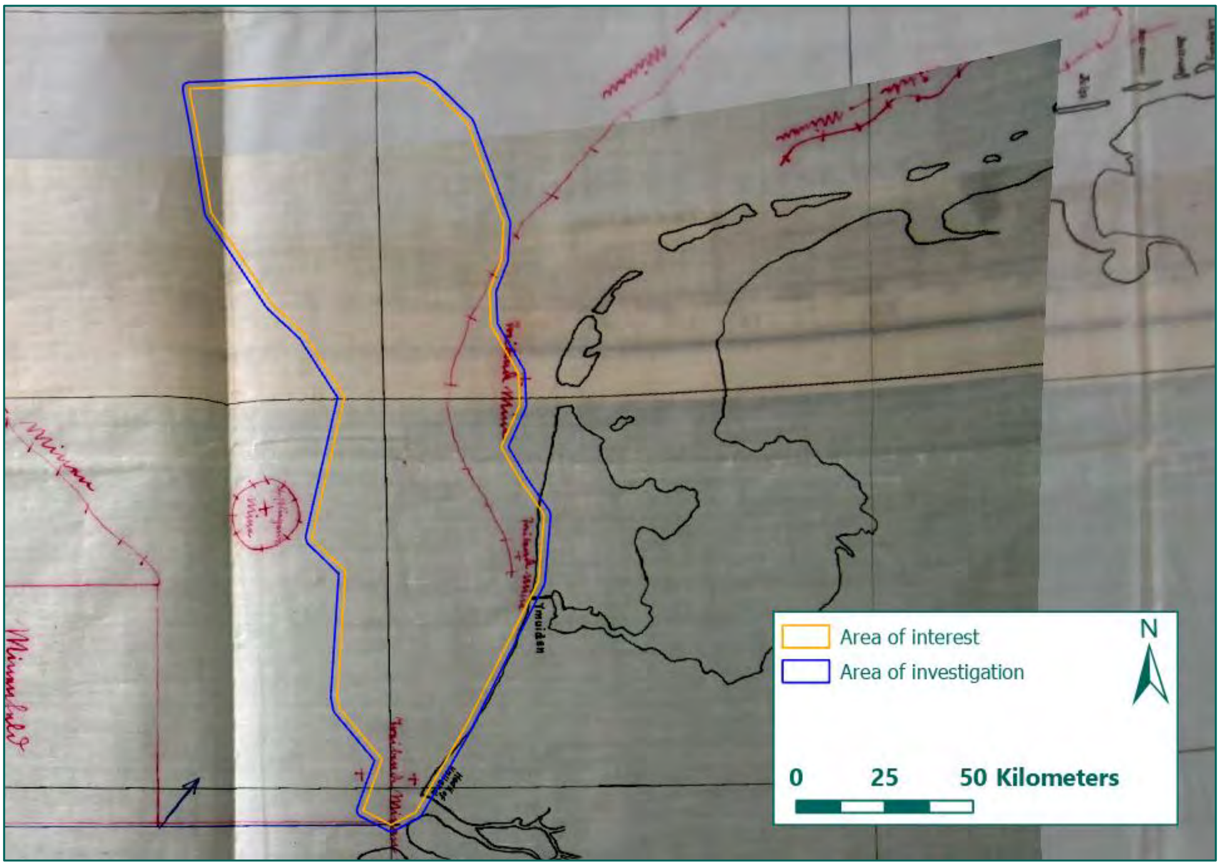


Figure 5: German map showing the suspected Allied minefield, according to the situation of March 1915 (Source: BaMa, RM 5/4721K).

During the First World War, a lot of mines broke loose from their anchor and drifted away. A total of 6.000 mines washed ashore on the Dutch beaches. Amongst those mines 4.981 were from British origin, 431 were German, 81 were French, and 500 mines were from other or unknown origins. It is estimated that no less than 240.000 mines have been spread out in the North Sea.

The information about minefields have been entered into our GIS-system. Relevant minefields within the area of investigation are shown below.

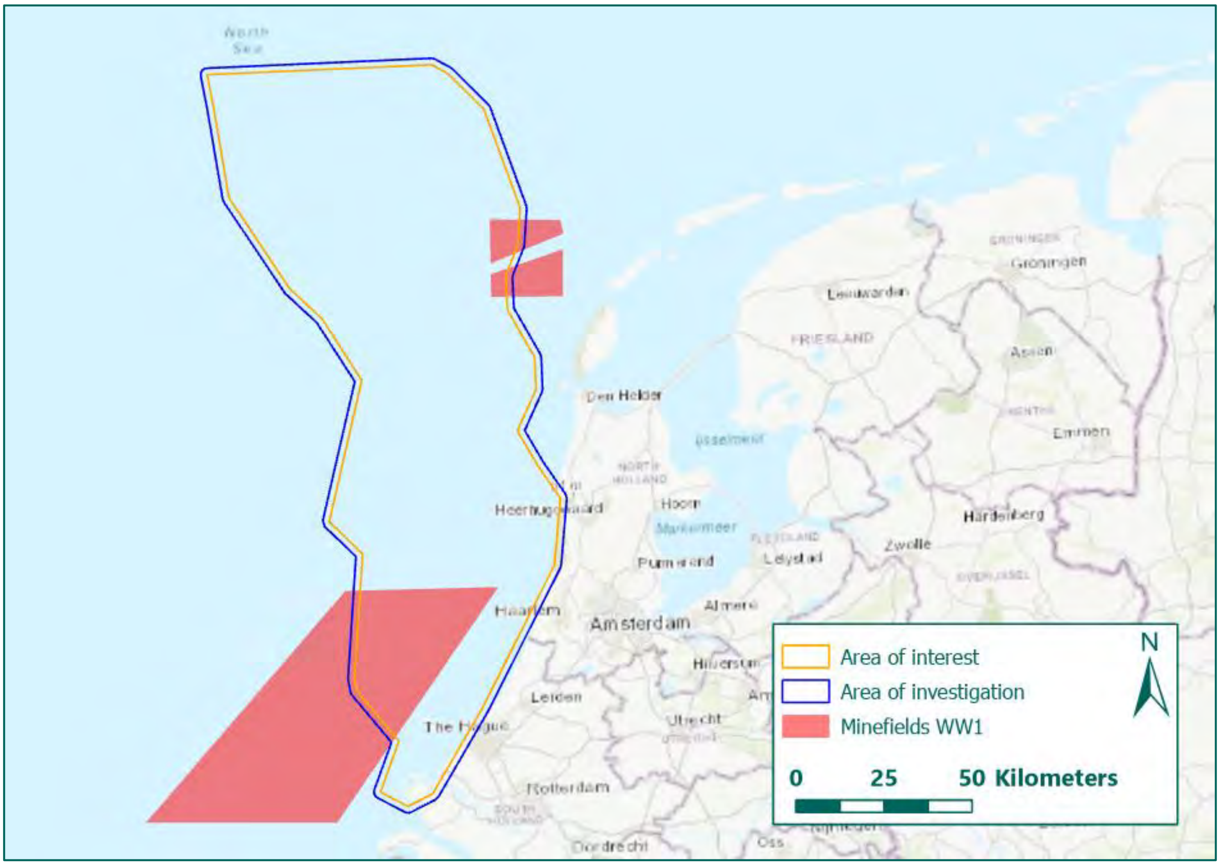


Figure 6: British and German minefields during WW1 (Source basemap: ESRI).

Records from The Dutch National Archives (see Annex 3) contain evidence that mines were present in the area of investigation during the First World War. On a map obtained in the "Nationaal Archief" (Dutch National Archives) it is shown that during 1914-1916 multiple Dutch ships ran onto mines. Most of these accidents happened outside of known minefields. One of these incidents occurred within the area of investigation. As can be seen in the figure below, the black dots indicate the locations where Dutch ships ran onto contact mines. Several black dots are visible within the area of investigation. However, no details have been provided about the ship that sunk at this location. Because there are no known minefields near the locations of the incidents, it is possible that the ships ran upon a contact mine that broke loose from the minefields seen in Figure 2, Figure 3, Figure 5.

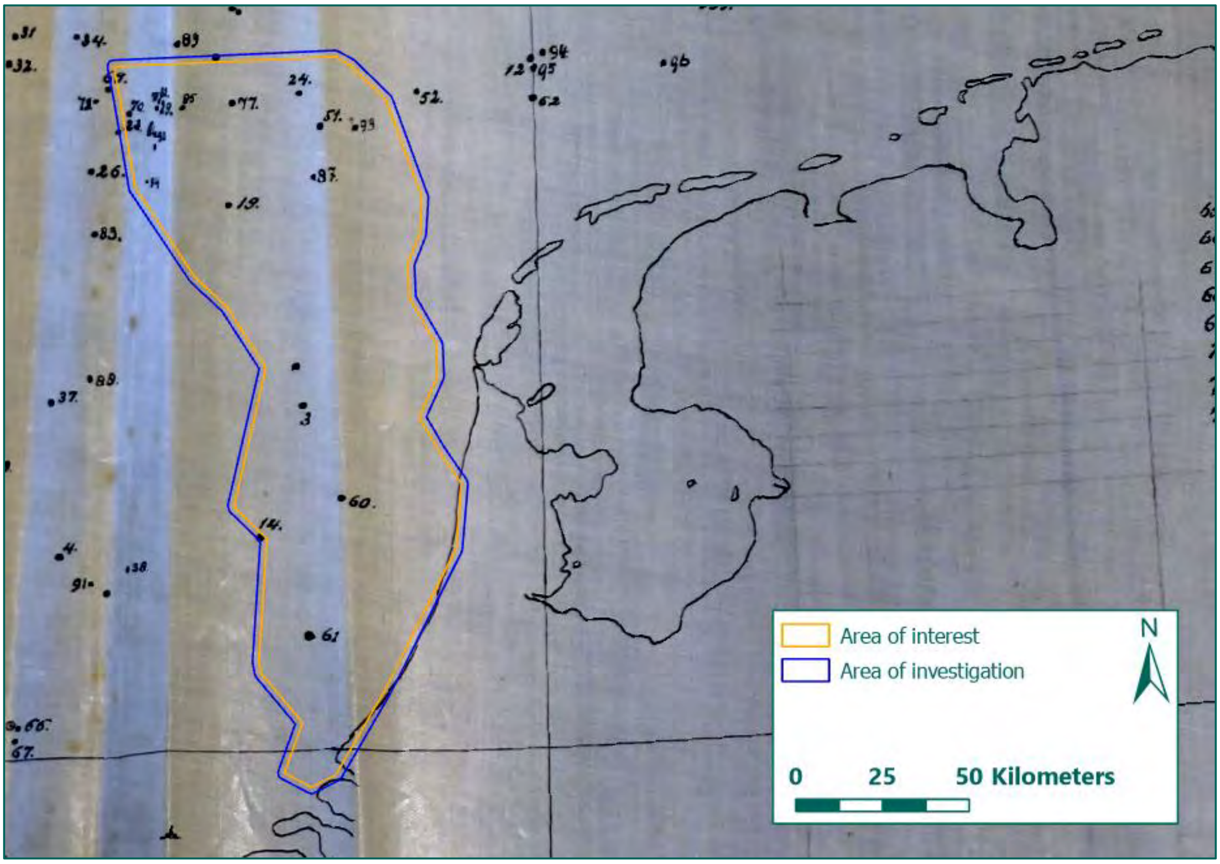


Figure 7: Map showing locations where Dutch ships ran onto mines during 1914-1916 (Source: NA, 2.05.32.09, file 44).

Wrecksite.eu also shows a lot of wrecks within the North Sea. A total of 39 ships were sunk due to mines laid in WW1 and WW2. Besides that a lot of ships were sunk due to unknown causes. The book 'HP39 Wrakkenregister, Nederlands Continentaal Plat en Westerschelde' (abbreviated to HP39), drawn up by the Dutch navy, show an abundance of wrecks (ships and aircraft) within the area of interest. In HP39 no details are given about the reason/cause of the sinking of the ships or aircraft. However. An overview of all wrecks according to this book is shown below.

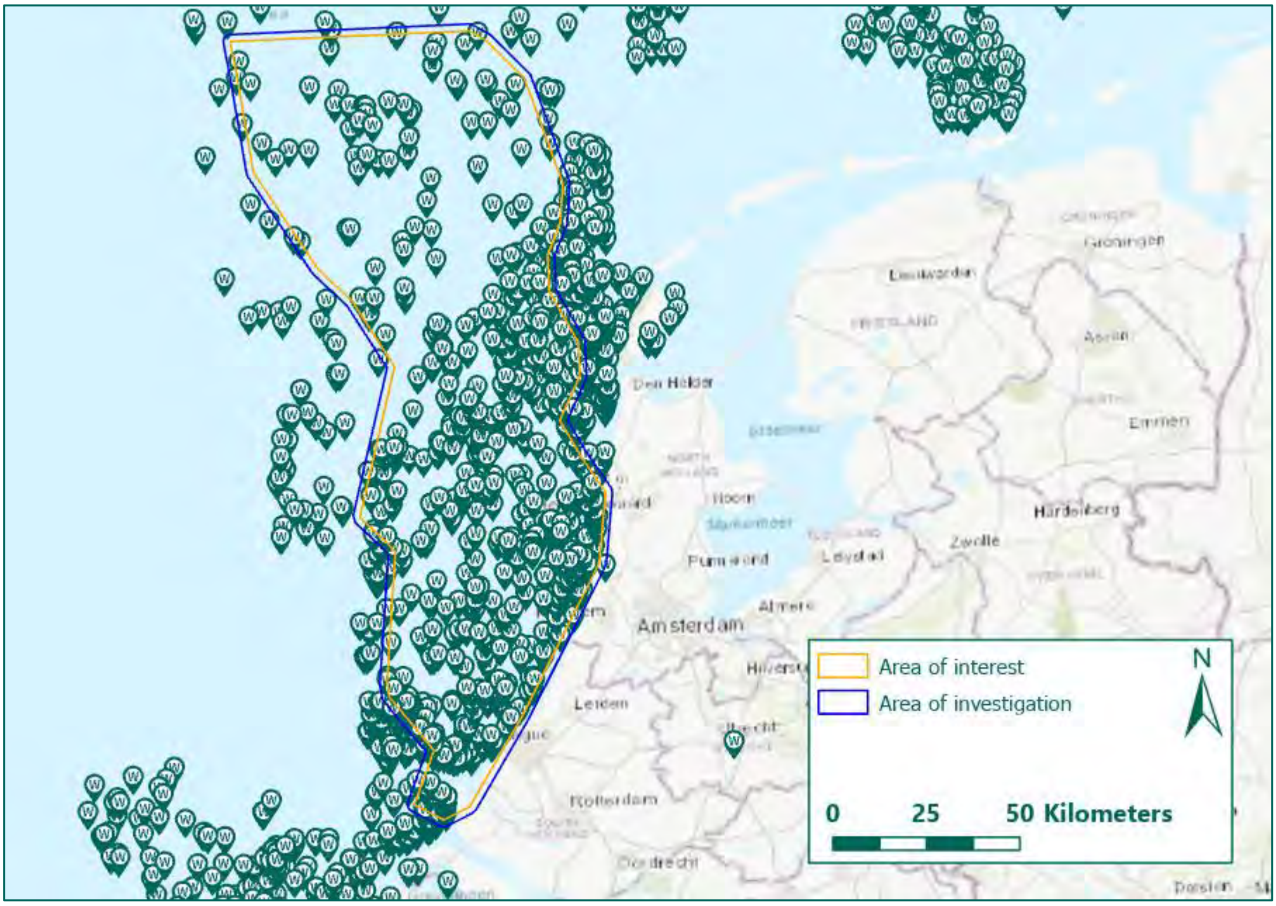


Figure 8: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

According to sources that were consulted by REASeuro British and German minefields overlapped the area of investigation during the First World War. Several ships were sunk due to mines laid within the Area of investigation.

Based upon the sources available, it is concluded that First World War German and British contact mines could be present in the area of investigation. Since no information is found about the precise types of the mines, it is presumed that the most common types of German and British mines could be present in the area of investigation, the German E-Mine and British Vickers / British Elia and H Mark II moored contact mines. Conclusions about the UXO Risk Area as a result of naval mines is given in paragraph 4.1.4.

4.1.2 Second World War

During the Second World War several German minefields were laid in the area of investigation. The German minefields were laid defensively, with the intention to hinder allied ships from approaching the Dutch Coast. British offensive minelaying was aimed against German convoy routes sailing by the Dutch Coast. Some of these British offensive minefields overlap the area of Investigation.

Different sources show maps and coordinates of German and British minefields within the area of investigation. The German minefields within the area of investigation are well documented. During the war the British authorities were quite aware of the locations of German minefields, as can be seen in Figure 9 several minefields overlapped with the area of investigation. The large minefield 404X consists of many smaller minefields. Detailed information about these, and other, minefields that overlap with the area of investigation can be found in the Bundesarchiv (see Figure 10). The German minefields were also littered with sweeping obstructers, suchs as Exploding floats, *Sprengboje* (with explosive load) and Static cutters/Static Conical Sweep Obstructor, *Reisboje* (without explosive load). It is also known that some Dutch minefields were laid in the beginning of WW2. Most Dutch and German mines were laid by surface crafts. Although the British used surface craft as well, they also deployed aircraft.

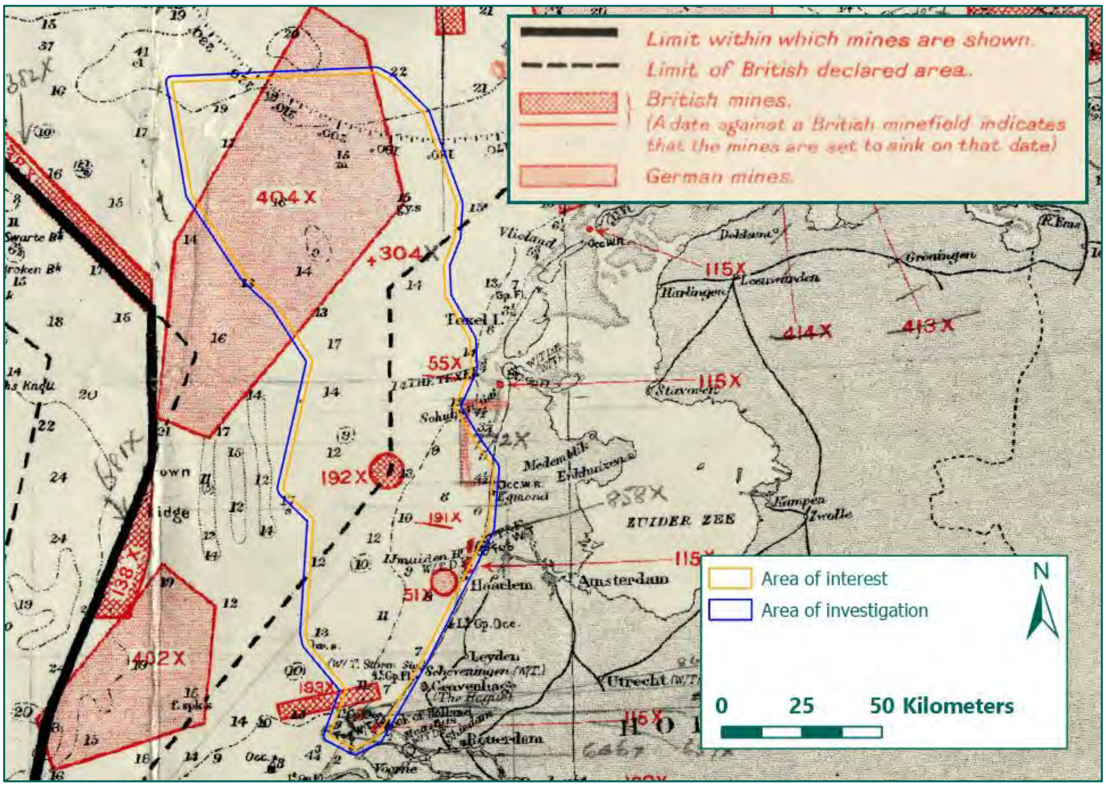


Figure 9: British map showing German and British minefields (Source: TNA, ADM 239/304).

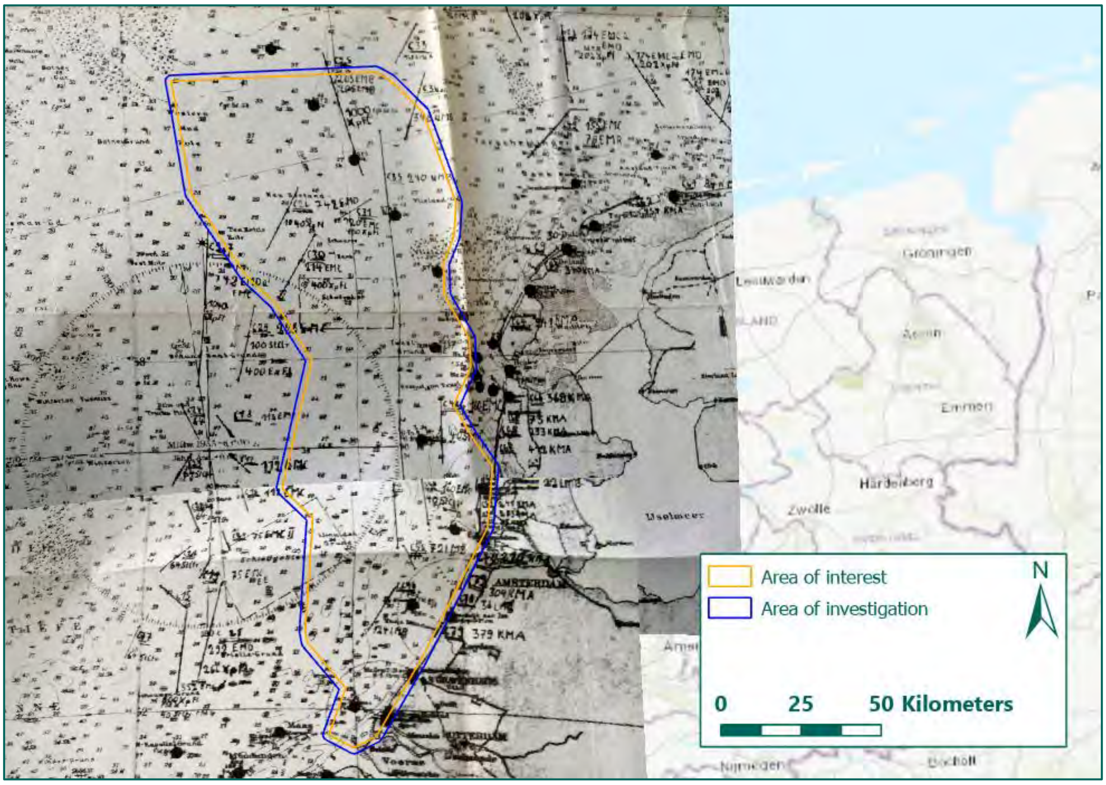


Figure 10: Naval chart showing numbered German minefields. Multiple minefields are present in the area of interest. (Source: BAMA, ZA 5/27).

Another means of minelaying were the "Gardening" operations. These operations were carried out by the Royal Air Force. Planes dropped mines into designated zones. Three zones laid in front of the Dutch coast. Two of these zones, "Whelks" and "Trefoil", have overlap with the area of investigation. The mines laid by planes were ground mines. Over 1200 mines were laid in these 'gardens'.

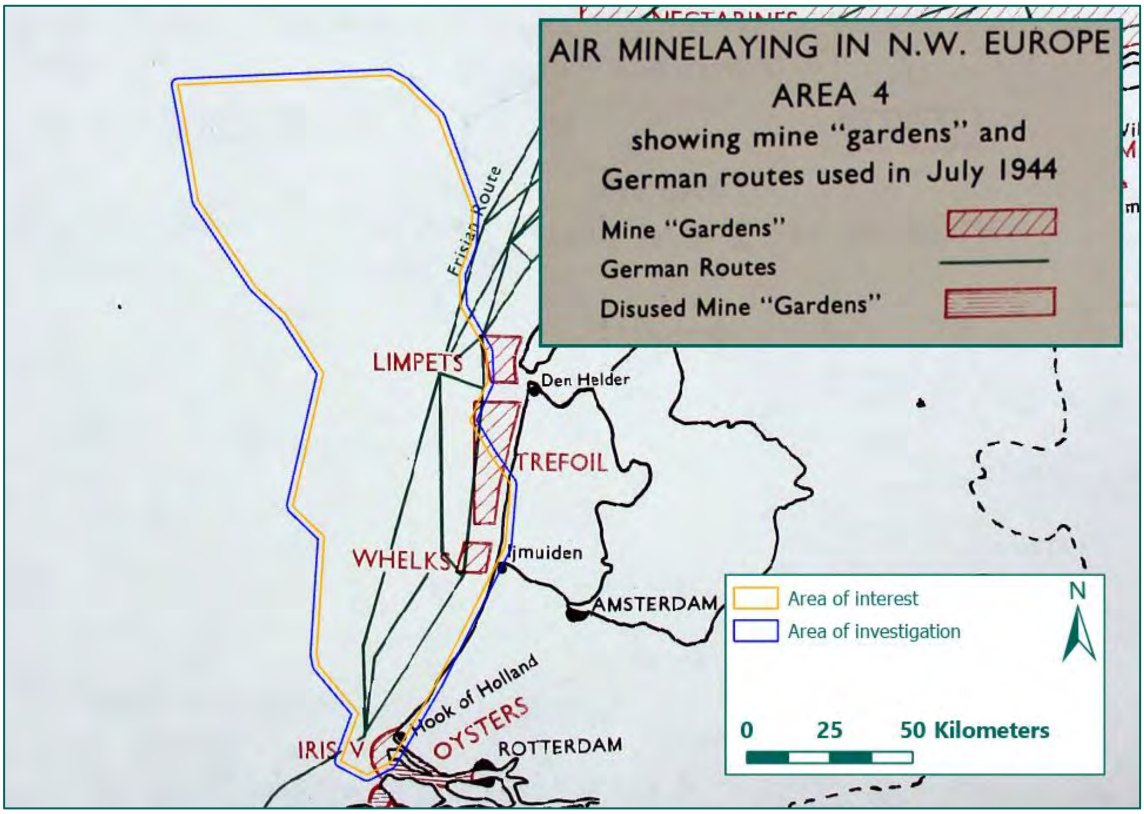


Figure 11: British 'Gardens' within the area of investigation (Source: TNA, ADM 234/561).

All minefields that were mentioned within the consulted sources have been incorporated in our GIS-system. In the figure below all these minefields are shown.

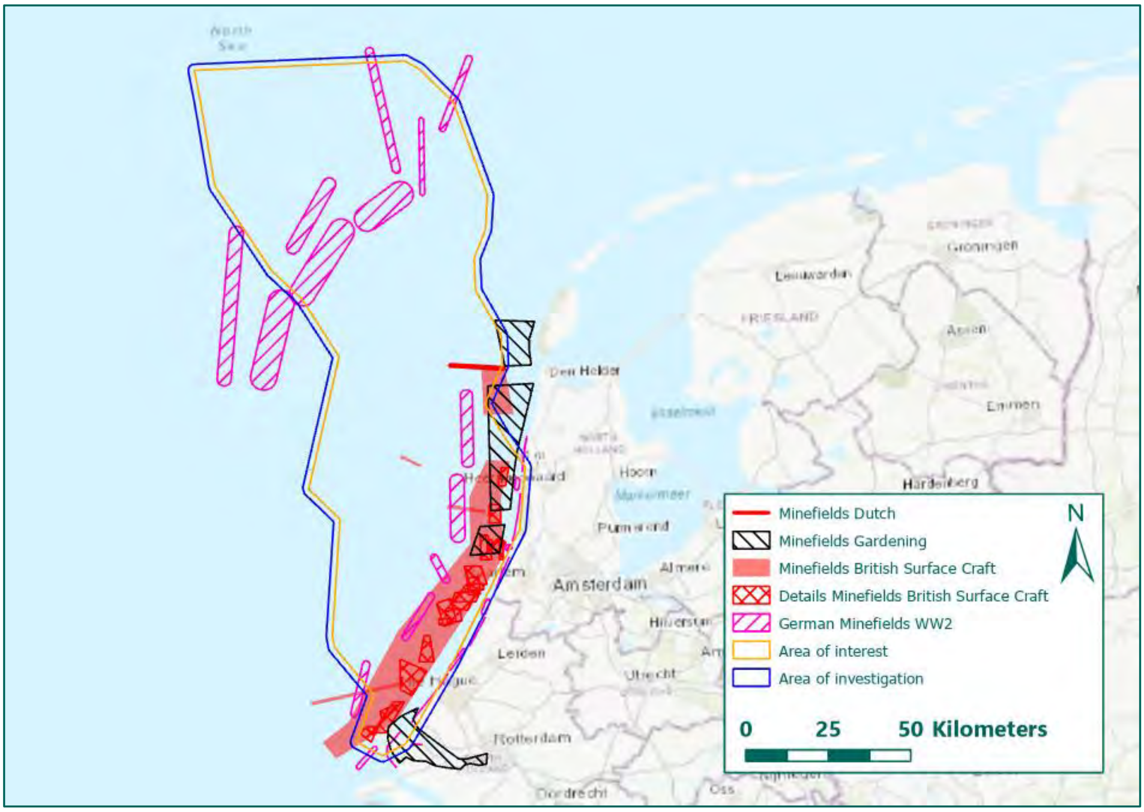


Figure 12: Minefields in WW2 (Source basemap: ESRI).

It is not known what kind of mines were laid in the Dutch and British minefields. Therefore, it is assumed that the most common types of mines were used within these minefields. In the Dutch minefields it is assumed that contact mines from the type 'Model 1921 2e soort' can be encountered. The British minefields consist of minefields laid by surface craft and aircraft. Mines dropped by aircraft were ground mines, mines laid by surface craft are either ground mines or contact mines. The most used types of British ground mines are Mk I-IV. The most common types of British contact mines are Mk VII- VIII and Mk XIV contact mines. The German mines used within the Area of investigation are EMB, EMC, EMD UBA and KMA contact mines, and LMB ground mines. Some German minefields were also fitted with German sweep obstructers: Exploding floats, *Sprengboje* (with explosive load) and Static cutters/Static Conical Sweep Obstructor, *Reisboje* (without explosive load).

4.1.3 Post-war mine clearance

After the First World War, a large effort was made to clear shipping lanes of naval mines. It took several months and a fleet of minesweepers to clear the minefields. Sweeping was carried out by sweeping a cable with anchors below the water surface. The cable was dragged by two ships (see Figure 13).

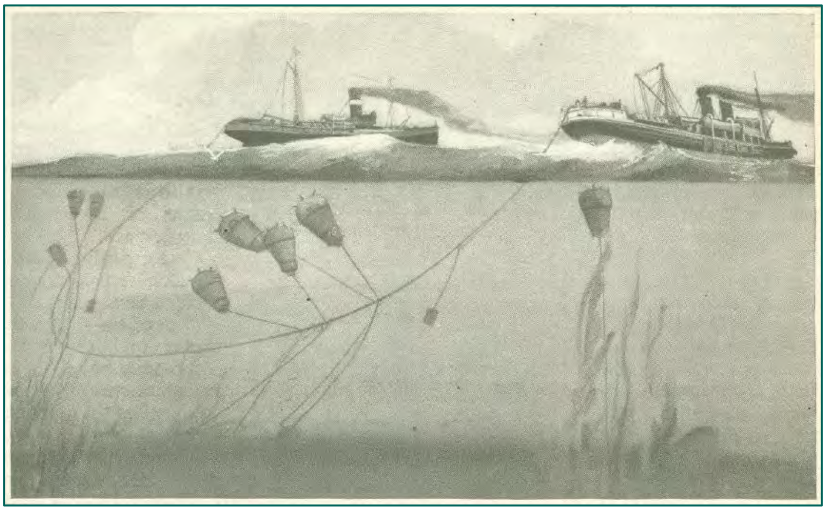


Figure 13: Post WWI-mine sweeping. (Source: http://www.digitalhistoryproject.com/2012/06/submarine-mines-in-world-war-i-byleland.html)

Mines also continued to pose a danger to shipping after the Second World War. In order to combat this threat, a large-scale minesweeping campaign was set up. The area of investigation was situated in the Dutch sweeping zone. Charts of the *Marinemuseum* (see Annex 3) show some details of minesweeping in the area of investigation. Details about minesweeping have not been found in the consulted sources. Minesweeping was conducted with a variety of methods. Moored mines were usually swept with Oropesa sweeping gear[4] (see Figure 14).

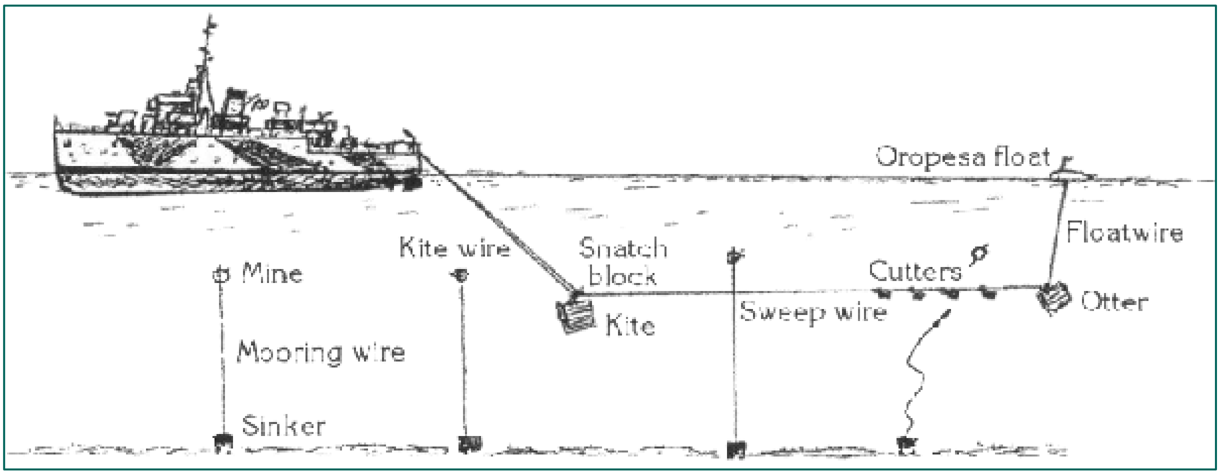


Figure 14: Oropesa sweeping (source: 'The 'Art' of Minesweeping', 27 May 2013, http://www.minesweepers.org.uk/sweeping.htm, consulted 2 August 2019).

The moorings of the mines were cut with cutters dragged on a wire behind a ship. Cutting the mooring wires/cables caused the mines to float to the surface, where the mines could easily be shot with cannon or rifle fire (see Figure 15). Shooting the mines caused them to sink or to detonate. Ground mines were swept with acoustic hammer boxes, triggering the acoustic mines, or by magnetic sweeping gear to trigger magnetic mines.

[4] So named after the World War I trawler in which the technique was first developed. Till then all sweeping was done using two ships joined by a single wire.

Figure 15: Mine disposal team preparing to fire on swept mines. (Source: TNA, ADM 199/154).

Minesweeping was not synonymous to mine clearance. Objective of the operations was to clear the shipping lanes for navigation. The sea bottom is still littered with unexploded mines, including swept and sunken moored mines, self-disarming mines and ground mines with empty batteries[5]. Nowadays, fishermen and dredging ships still encounter these naval mines on a regular basis.

As a result of clearance operations, tidal and other weather conditions, moored mines could break loose from their anchor and migrate. Furthermore, due to extensive pair and beam trawling there is often no clear relation between the positions of encountered mines and the locations of historical minefields. This observation is confirmed in the paragraphs 4.1.1 and 4.1.2. These paragraphs show mine incidents/ encounters outside known minefields. Clearance reports of the Dutch Coast Guard and the OSPAR Commission also show that mines can be found outside the boundaries of known minefields. In Figure 16 the locations of cleared mines are shown relative to the area of investigation.

[5] According to international laws, mines are obligated to include mechanisms to automatically disarm or 'self-sterilize' them after a set time. Moored mines were to sink to the seabed after a given time through, for example, a soluble plug, while ground mines disarmed automatically through a timing mechanism or simply at the end of their battery life. These mechanisms move the mine out of harm's way, but do not disable mechanical fusing mechanisms like *herz horns* and anti-handling devices.

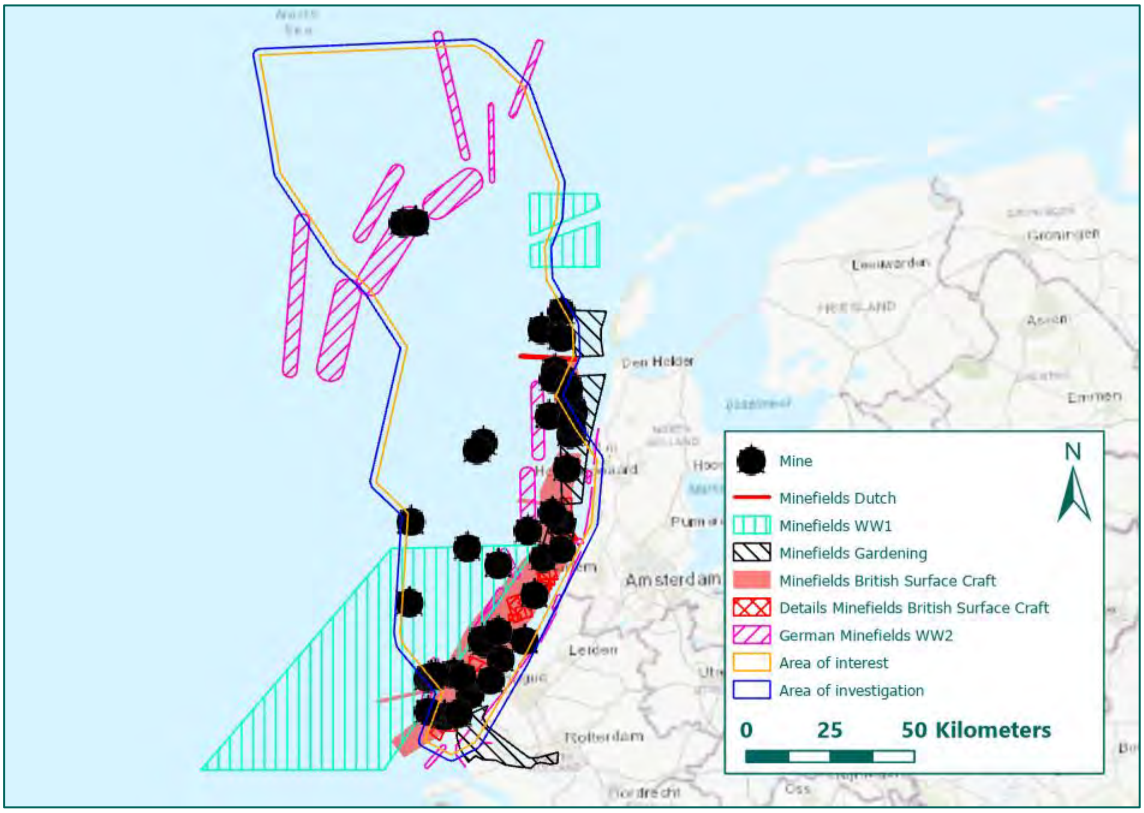


Figure 16: Locations of known minefields and locations where the Dutch Coastguard cleared mines (Source basemap: ESRI).

4.1.4 Conclusion

The area of investigation intersects several minefields. During World War I, British and German minefields overlapped the area of investigation. Within the area of investigation, several mine related incidents occurred during the First World War. Most of these incidents happened outside of known minefields.

During the Second World War the German navy laid 33 minefields that intersect with the area of investigation. No information about the clearance of these fields is known to REASeuro. Several British and two Dutch minefields also overlapped with the area of investigation. Information about the clearance of these fields is also unknown to REASeuro.

Post-war (both World War I and II) minesweeping succeeded in securing the shipping lanes, but did not manage to dispose of all mines. Many mines still litter the seabed, with fuzes still intact. Sweeping, trawling, tides and currents have caused these mines to migrate over the years, resulting in a situation in which there is no longer a clear link between the location of the original minefields and the current positions of the naval mines. As a result of this, it is possible that UXO is still encountered within the area of investigation.

A distinction needs to be made between the likelihood of encountering UXO related to World War I and to World War II. During World War II multiple minefields overlapped the area of investigation. A total of thousands of mines were laid by German surface craft and British surface craft and aircraft. Sweeping operations could have these mines and sweep obstructors (*Sprengboje*) to have sunken to the seabed within the area of investigation. The likelihood of encountering UXO related to World War II minefields is deemed certain within the borders of the minefields and, due to migration, probable outside of these borders.

During World War I the area of investigation only overlapped with a single suspected German minefield and some small British minefields. The consulted sources do not state the amount or types of mines laid in this field. However, factual evidence points out that multiple mine related incidents occurred within the area of investigation. Because of the relative sparse amount of information known about World War I minefields within the area of investigation the likelihood of encountering UXO related to World War I minefields is lower than the World War II minefields. Therefore encountering UXO of WW1 naval mines is deemed probable to within the borders of the WW1 minefields, and feasible outside of these minefields.

UXO type	Reference Nr.	Type/calibre	Condition
Naval Mines	1	German E-Mine moored contact mines	Armed
	2	British Vickers / British Elia and H Mark II moored contact mines	Armed
	Outside the borders of the known minefields all abovementioned types of naval mines can be encountered. The likelihood of presence outside the known minefields is set to feasible.		

Table 1: Expected UXO due to WW1 Minefields.

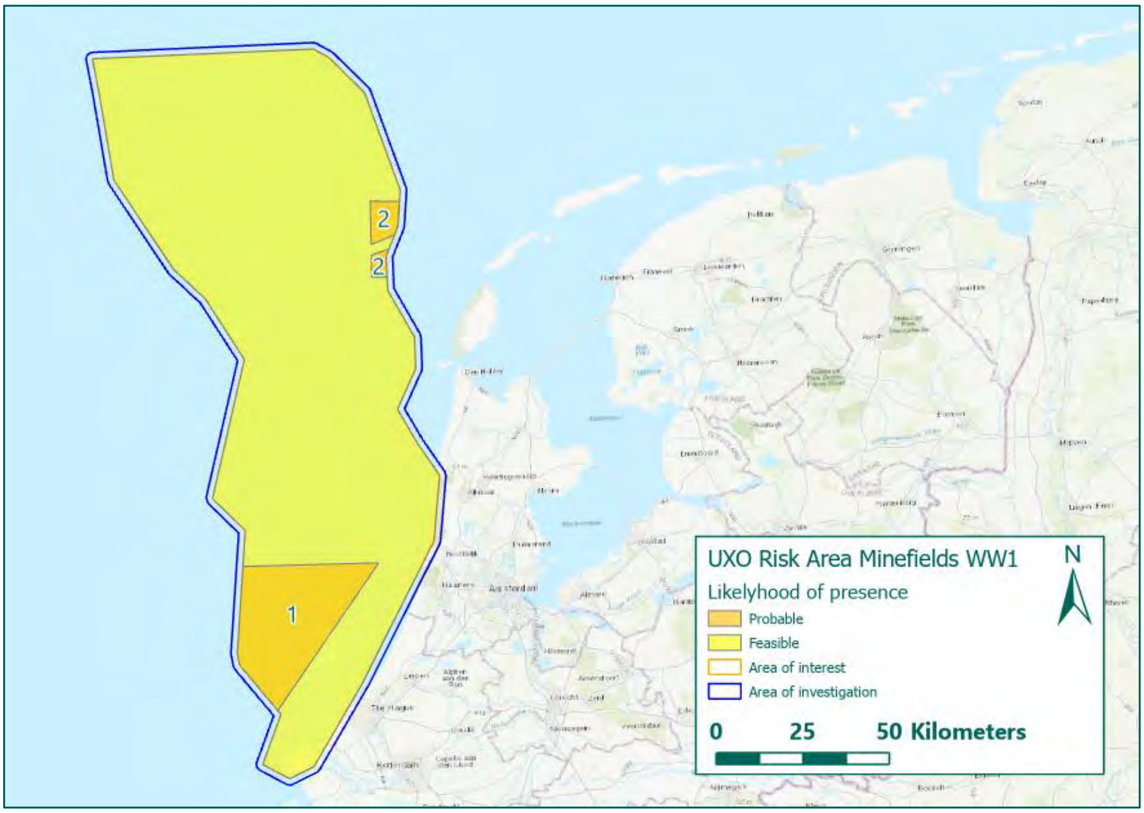


Figure 17: Likelihood of presence of UXO as result of the WW1 minefields. (Source basemap: ESRI).

UXO type	Reference Nr.	Type/calibre	Condition
Naval Mines	1	British ground mines Mk I-IV	Armed
	2	German EMB Contact mines and Exploding Floats	
	3	German EMC Contact mines (also non explosive sweep obstructors)	
	4	German EMC Contact mines and Exploding Floats	
	5	German EMD Contact mines and Exploding Floats	
	6	German KMA Contact mines	
	7	German LMB Ground mines	
	8	German LMB Ground mines and German EMC Contact mines	
	9	German UMB Contact mines	
	10	German RMA Contact mines	
	11	British Mk I-IV ground mines and British Mk VII-VIII and Mk XIV contact mines	
	12	Dutch Model 1921 '2e soort'	
	Outside the borders of the known minefields all abovementioned types of naval mines can be encountered. The likelihood of presence outside the known minefields is set to probable.		

Table 2: Expected UXO due to WW2 Minefields.

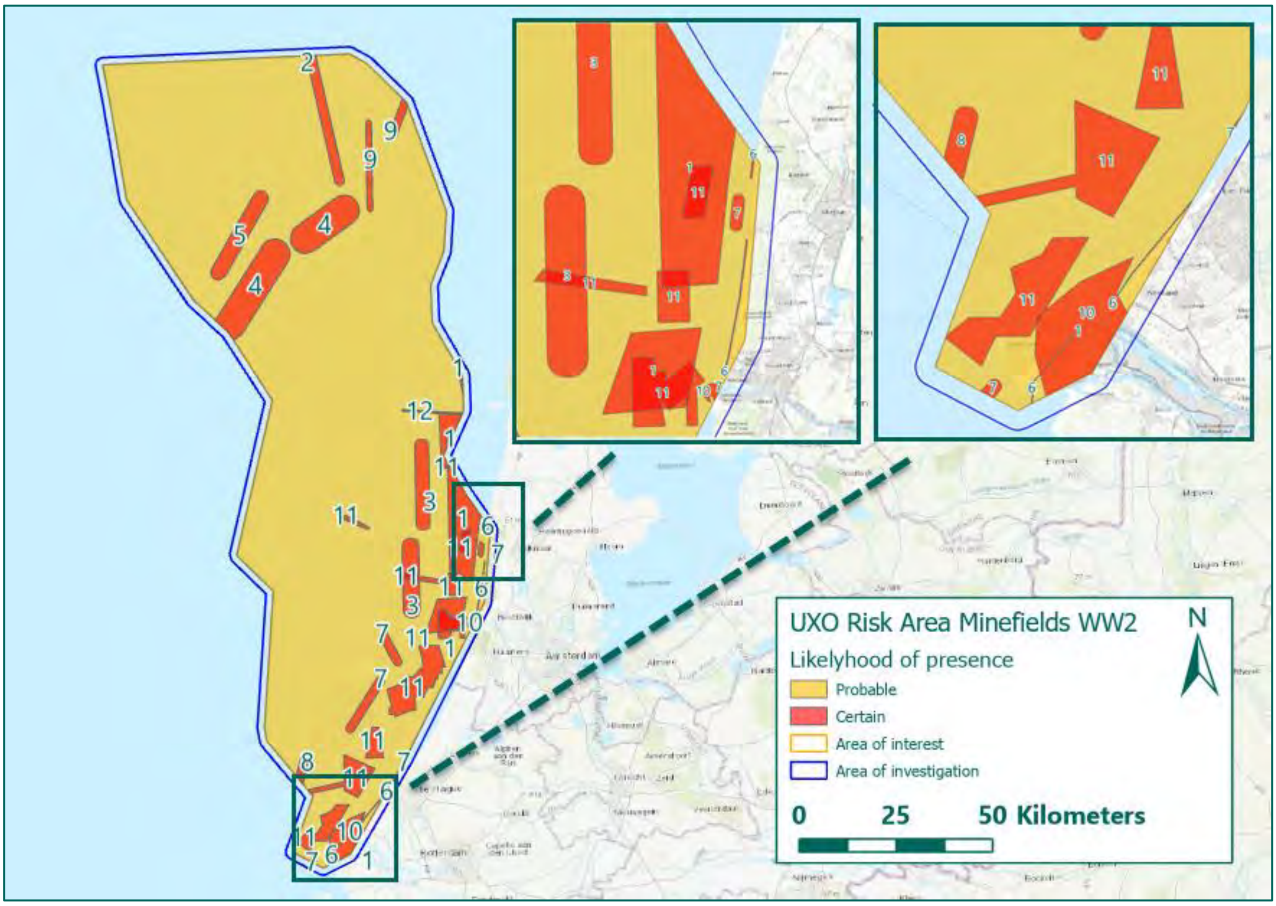


Figure 18: Likelihood of presence of UXO as result of the WW2 minefields. (Source basemap: ESRI).

4.2 AIR WAR

In and in the vicinity of the area of investigation many events relating to the air war did occur. This concerns air strikes on shipping, jettisons of bombs, and anti-aircraft gunfire.

4.2.1 Air strikes on surface vessels

A German convoy route crossed the area of analysis. During the Second World War the British Air Force almost continuously attacked the German convoys and other ships like minesweepers or the *Vorpostenboote*. From November 1944 onwards, attacks were also carried out on submarines and midget submarines (Anti-Seehund missions) which threatened the Allied convoys towards the harbour of Antwerp.

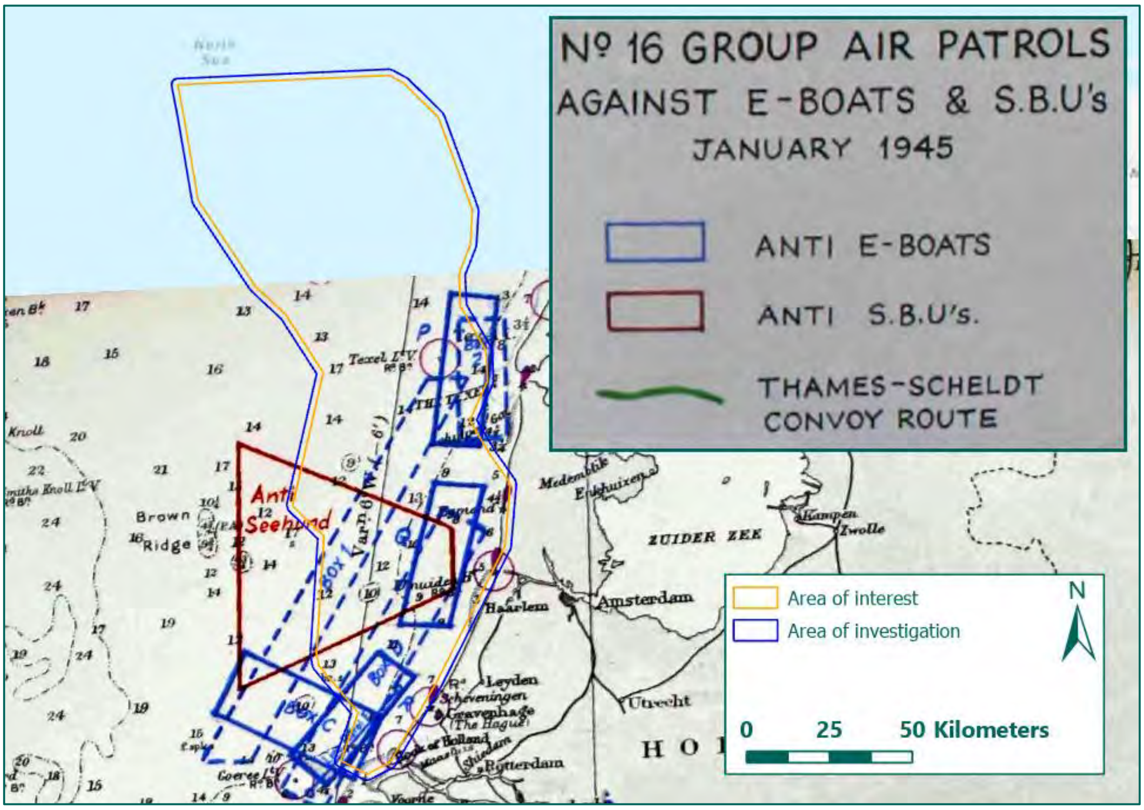


Figure 19: Coastal Command, No.16 Group, Air Patrols against E-Boats & S.B.U.'s January 1945 (Source: CAB 101/324).

The locations of the air strikes are seldom very accurate. Navigating above the sea was not an easy task. The consulted literature (see Annex 2) points out that a lot of ships were attacked along the Dutch coast. It started with the German invasion on 10 May 1940.

The air attacks by the British Bomber Command and Coastal Command are added in a geodatabase, if possible. Coastal Command used a code instead of decimal degrees. According to the information entered in the REASeuro database, a total of 508 attacks were made within the area of investigation by Coastal Command and Bomber Command. It is outside the scope of this research to examine the target and the results of each of these missions. Due to the large amount of attack locations near the known German routes, it is to be expected that a large amount of the attacks by the RAF was targeted at German shipping. In the figure below the relevant locations of attacks by Coastal Command and Bomber Command is shown. The locations of German convoy routes are also shown.

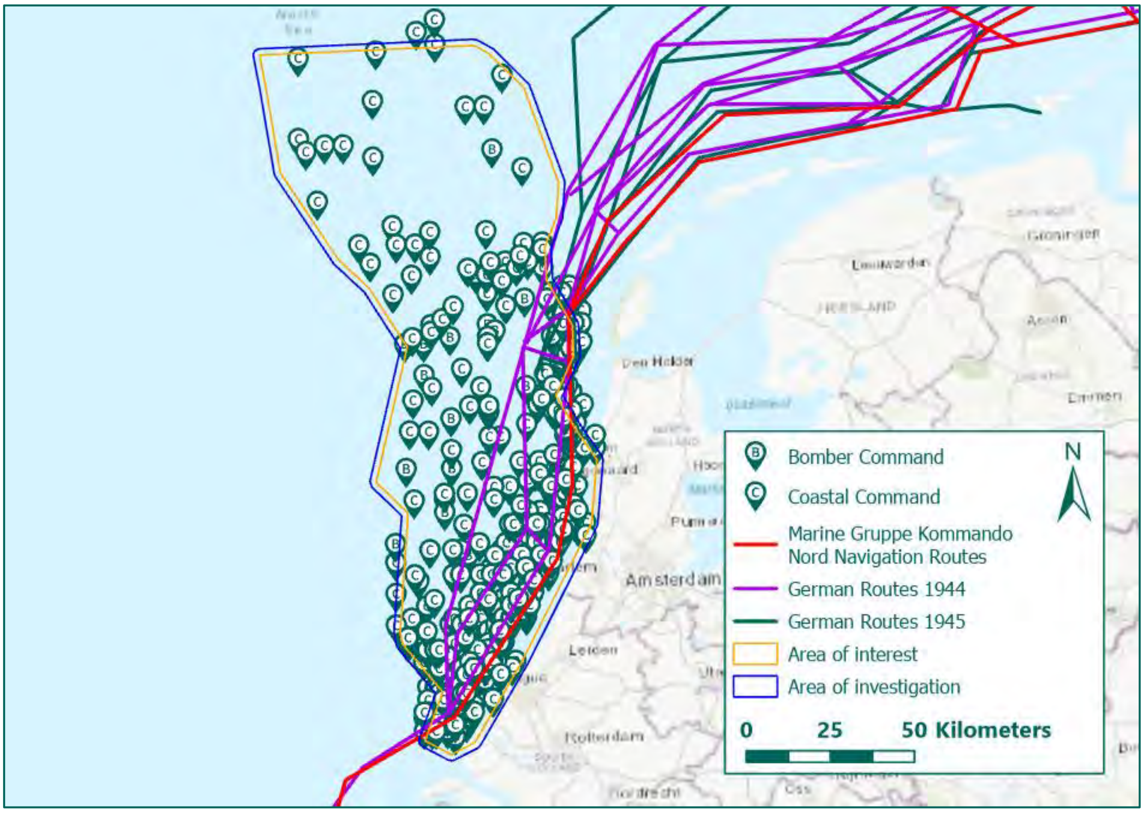


Figure 20: Attacks made by Coastal Command and Bomber Command, and relevant German convoy routes (Source basemap: ESRI).

Since more than 500 attacks took place in the area of investigation, it is expected that UXO remain. Air strikes on ships were carried out with aerial bombs, depth charges, torpedoes, and 3 inch rockets with a 60 lbs warhead semi armour piercing (SAP). The definition of the UXO risk area and the calibres is explained in paragraph 4.2.5.

4.2.2 Jettisoned bombs

During the Second World War groups varying from few to many British and American bombers flew almost on a daily basis (day and night) towards targets in Germany or German-occupied territory. The flight paths towards targets and back to base (in the United Kingdom) ran across the North Sea.

The Allied bombers were often attacked by German fighters in order to prevent the bombers from bombing their targets. Hundreds of planes were hit and/or shot down. When a bomber was involved in an air battle the procedure was to jettison the bombs. This would reduce the weight of the bomber enabling it to increase the speed and manoeuvrability, and thus the crew's chance to survive. Normally, bombs had to be jettisoned in a safe, thus unarmed, condition. This procedure is documented in a record from The National Archives (see annex 3).

Jettisons in the sea also happened when aircraft could not find a suitable target or in other cases when a crew could not drop their bombs. The reason to jettison the bombs was to avoid a landing with the bomb load, which was a risky event. Jettisons were seldom accurately documented. Furthermore, bombs were also jettisoned live, thus without their safety. An example of this is shown in the figure below.

![RFASeuro logo]

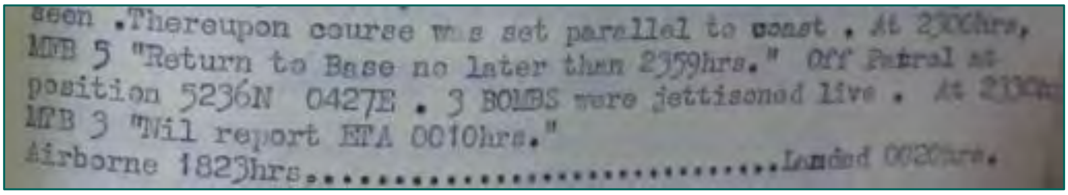

seen .Thereupon course was set parallel to coast . At 2300hrs,
MTB 5 "Return to Base no later than 2359hrs." Off Patrol at
position 5236N 0427E . 3 BOMBS were jettisoned live . At 2330hrs
MTB 3 "Nil report ETA 0010hrs."
Airborne 1823hrs.......................................Landed 0020hrs.

Figure 21: Example of a live jettison within the area of investigation, night 12/13 October 1944. (Source: TNA, AIR 25/367).

It is not clear how many times such jettisons occurred. The figure below gives an example of a flight path that crosses the area of analysis.

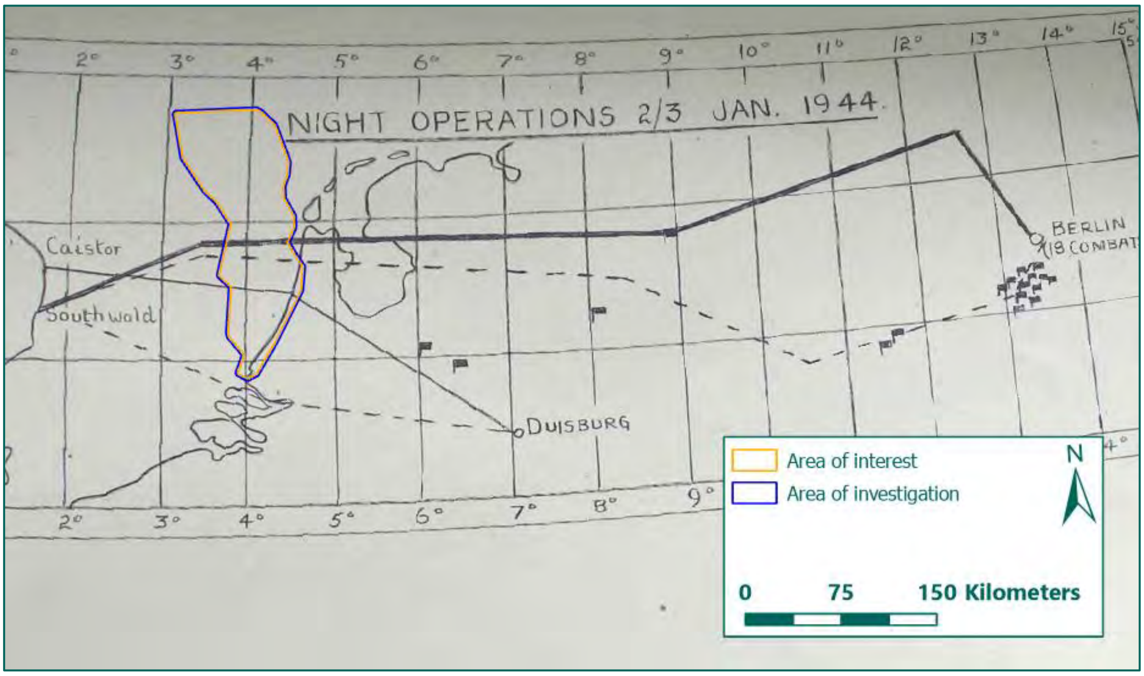


Figure 22: Example of a flight path over the area of investigation of bombers from Bomber Command, 2/3 January 1944 (Source, TNA, AIR 24/264).

Based upon the consulted sources, it is concluded that aerial bombs remain in the area of investigation as a result of jettisons. Because it is not possible to define the calibres specifically, the most common allied bombs are taken into account. The UXO risk area is specified in paragraph 4.2.5. Detailed information on the UXO is given in annex 10.

4.2.3 Anti-aircraft gunfire

The guns which were placed onto the German Vorpostenboote and escort ships were also used against enemy airplanes. The calibres of the guns vary from 2 cm to 8.8 cm. Machine guns (7.92 cm, 13,2 mm, 15 mm) completed the anti-aircraft weaponry on ships. Every time when ships and convoys were attacked, they opened fire.

Taking into account the large amount of air strikes on ships, UXO of anti-aircraft weapons are present in the area of investigation. Unexploded shells could come down and hit the sea level and sink to sea bottom. The UXO risk area is defined in paragraph 4.2.5

4.2.4 Post-war UXO encounters

As showed in annex 5, aerial bombs are encountered throughout the entire area of analysis. A total of 52 bombs have been encountered and disposed of since 2005. These bombs could originate from air strikes and/or jettisons. The Dutch Coastguard also encountered a lot of UXO that have not been specified. It is therefore unknown whether more bombs have been cleared. It is also unknown how many bombs have been encountered before 2005. Next to aerial bombs, torpedoes, depth charges and artillery shells have also been encountered. The latter were possibly caused by the use of anti-aircraft gunfire. A total of 130 artillery shells have been cleared by the Dutch Coastguard. In the figures below the locations of encountered UXO are specified. A combined total of 31 torpedoes and depth charges were encountered.

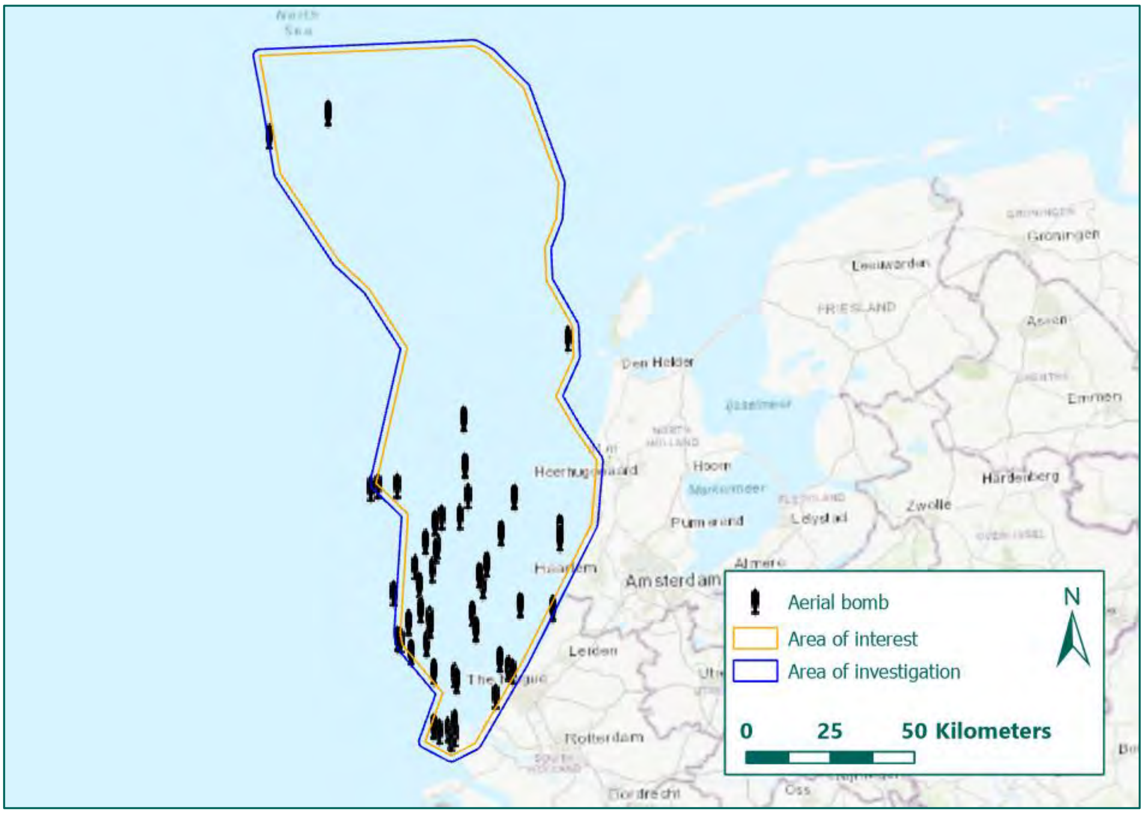


Figure 23: Cleared aerial bombs within the area of investigation (Source basemap: ESRI).

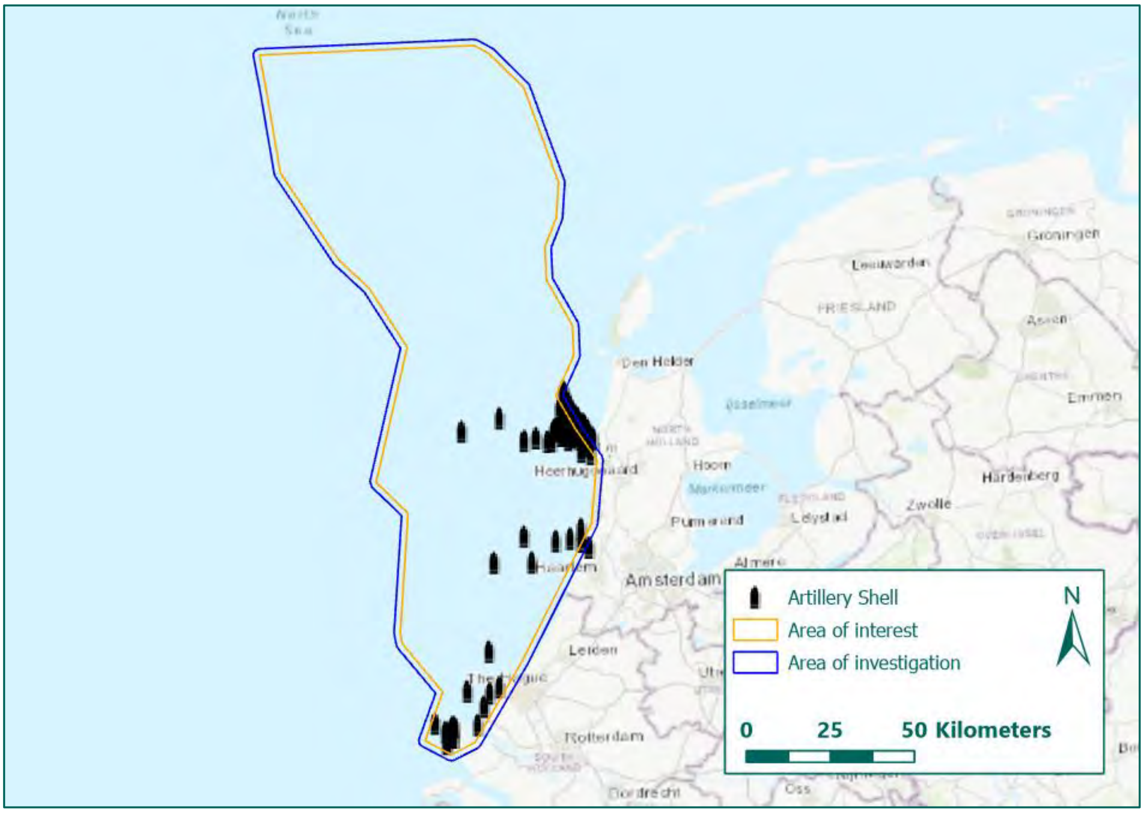


Figure 24: Cleared artillery shells within the area of investigation (Source basemap: ESRI).

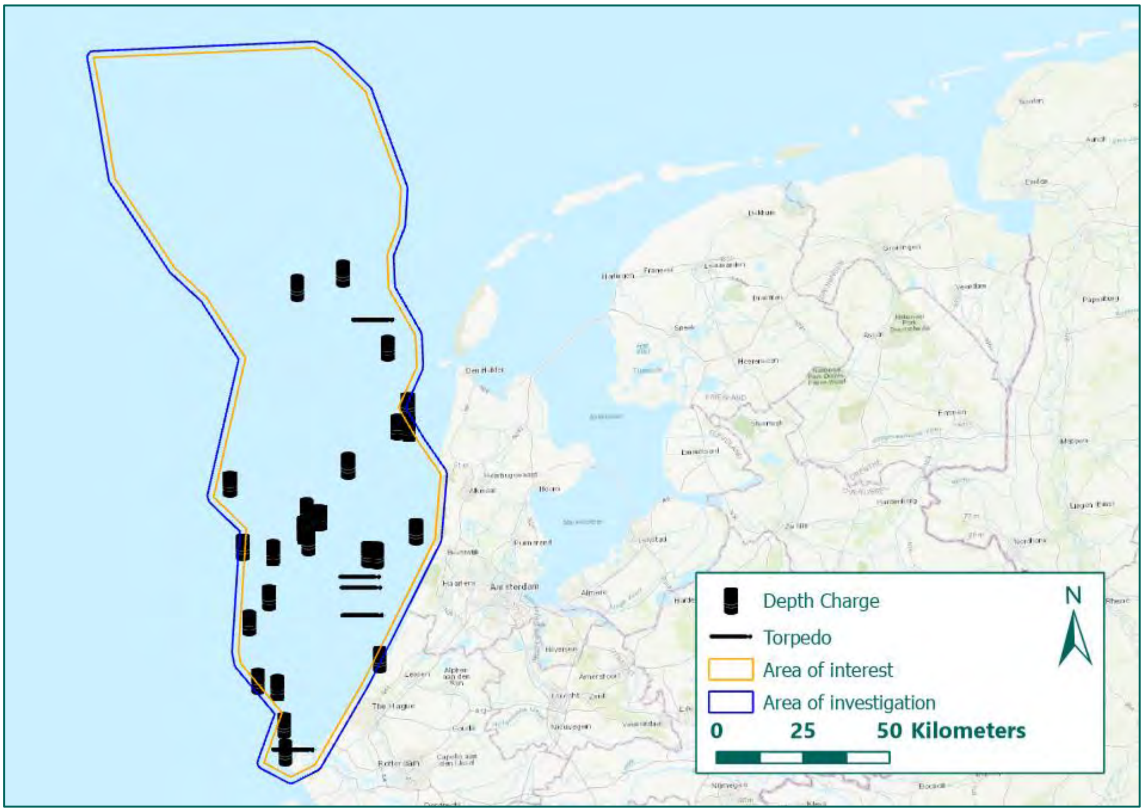


Figure 25: Cleared torpedoes and depth charges within the area of investigation (Source basemap: ESRI).

4.2.5 Conclusion

As a result of the various air strikes and jettisons UXO might still remain in the area of investigation. This is proved by the fact that since 2005 UXO have been encountered and disposed of in the area of investigation. Therefore, a UXO risk area is defined. The most probable locations of attacks are near the German convoy routes. This is confirmed by attack locations specified in the source material. Therefore the likelihood of presence of UXO regarding the air war is deemed certain along the convoy routes. The UXO risk area is projected between the most western route and the Dutch coast. A buffer of 1 nautical mile (1.852 meter) is taken into account for navigational inaccuracy of ships and aircraft. In the rest of the area of investigation the likelihood of presence of UXO is deemed probable due to the large amount of jettisons in the North Sea. In the figure and table below the UXO Risk Area regarding air war is shown. Details about calibres are also specified in the separately supplied shapefiles.

UXO type	Type/calibre	Condition
Aerial bombs	4 lbs, 25 lbs, 30 lbs, 100 lbs, 250 lbs, 260 lbs, 300 lbs, 500 lbs, 1.000 lbs, 4.000 lbs	Armed/not armed (safe)
Under water ammunition	18 inch torpedo Mk XV	Armed
	Depth charge	Armed
Rockets	3 inch rocket with 25 lbs or 60 lbs (SAP) warhead	Armed

Table 3: Expected UXO.

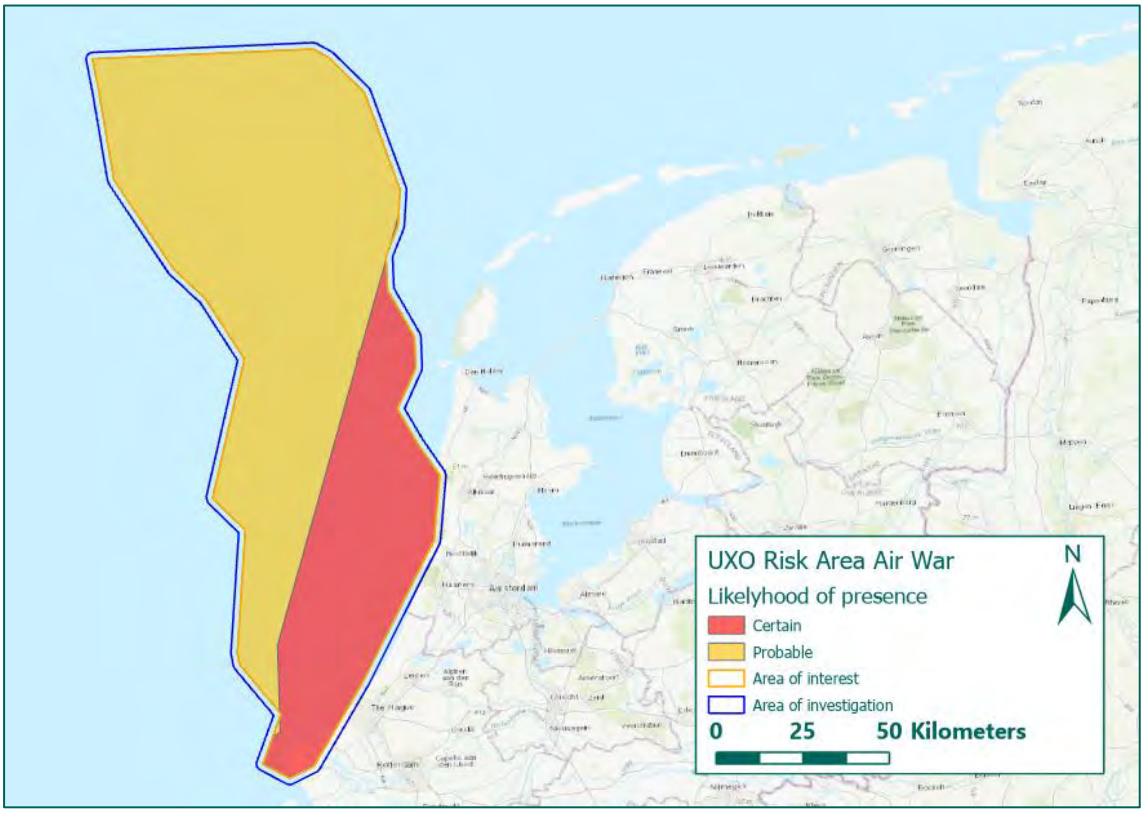


Figure 26: Likelihood of presence of UXO as result of the air war. (Source basemap: ESRI).

As on land, it is not possible to define a UXO risk area in response to the usage of anti-aircraft gunfire. The gunfire was aimed towards a moving target in the air. Unexploded shells could come down almost anywhere. It should be noted that probably most AA-projectiles came down between the shore and to the west of the convoy route. Part of this area was also covered by coastal guns. UXO of artillery shells that might be present in the coastal region will be further analysed in paragraph 4.3 and 4.4.

4.3 COASTAL GUNS

Coastal guns were traditionally used in strongpoints that had to defend harbours from enemy ships. At the start of WW2 some coastal guns were already installed on the Dutch Coast. After the German occupation of the Netherlands, a large amount of coastal guns were installed on the Dutch coast as part of the *Atlantikwall.* Source material shows that the German guns were used to stave off Allied ships nearing the Dutch Coast. Information from The National Archives (TNA) show that within the area of investigation shells fired by coastal guns exploded during an attack of the RAF. Below a strike photo is shown where the impact of a shell is highlighted.

Figure 27: Strike photo showing the impact of a shell, fired by a German coastal battery. 4 May 1942. (Source: TNA, AIR 28/595).

Various sources such as literature, records from the Dutch National Archives, the Bundesarchiv, maps and aerial photographs were used to determine the locations of coastal guns. These positions have been entered in the REASeuro GIS-database. The largest calibre that could strike the Area of investigation are 28 cm guns. They could hit targets at a range of 41100 meter. This range is extraordinary. Besides the 28 cm guns, guns from the calibres 17 cm and smaller were deployed along the coast. The maximum range of these 'smaller' calibre guns was 22000 meters. The known coastal guns near the area of investigation are shown in the figure below

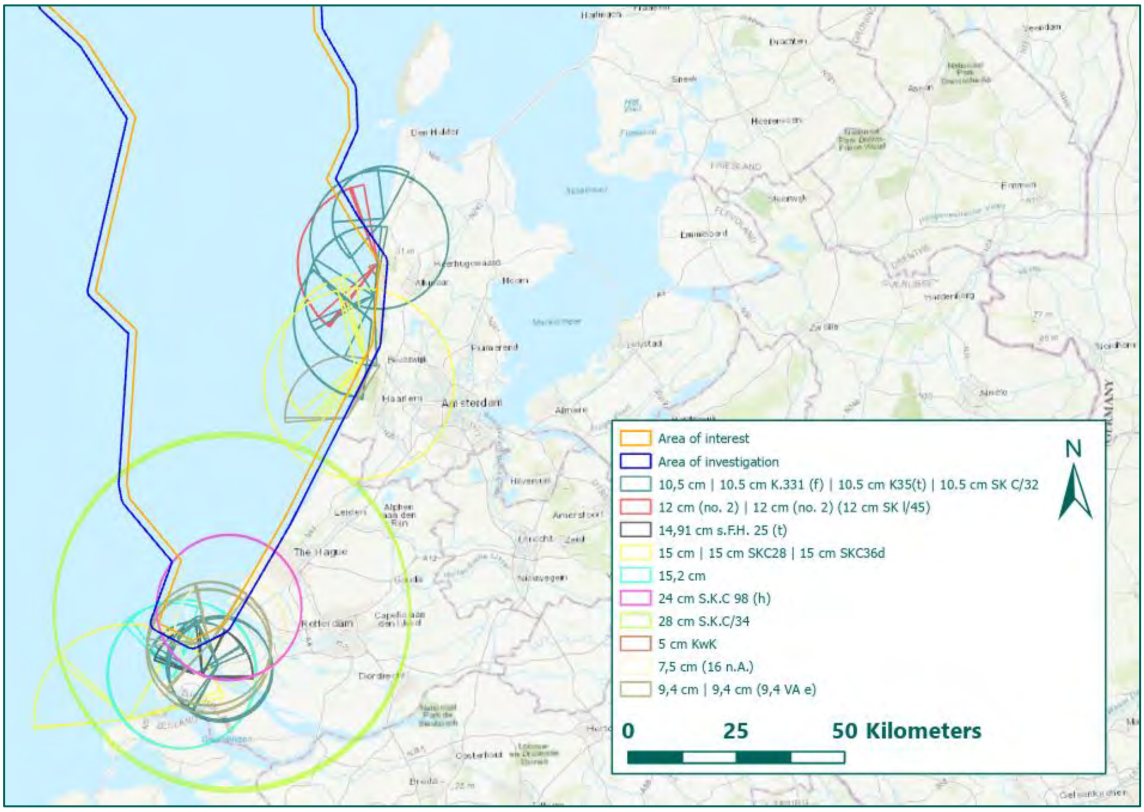


Figure 28: Locations and range of coastal guns near the area of investigation (Source basemap: ESRI).

Entering data in the REASeuro GIS-database is done on a project-by-project basis. Because REASeuro has not yet carried out Offshore Projects near the Dutch coast in the area between IJmuiden and Beverwijk, REASeuro does not yet have data on the coastal guns in this area. Consulting the Dutch 'Nationaal Archief' shows that strongpoints and military infrastructure were constructed on the Dutch coast. In order to find out the locations, calibres and range of the coastal guns on Texel and between IJmuiden and Beverwijk, REASeuro would need to visit the 'Nationaal Archief', analyse additional aerial photographs and consult literature and the internet. This is outside the scope of this research. As an example, a cutout of an 'Blokkaart' of the 'Nationaal Archief' is shown below. The map shows the contours of military infrastructure near Katwijk. Detailed information about the specific types of military infrastructure are not shown on these map, as is already mentioned, additional information is to be consulted separately.

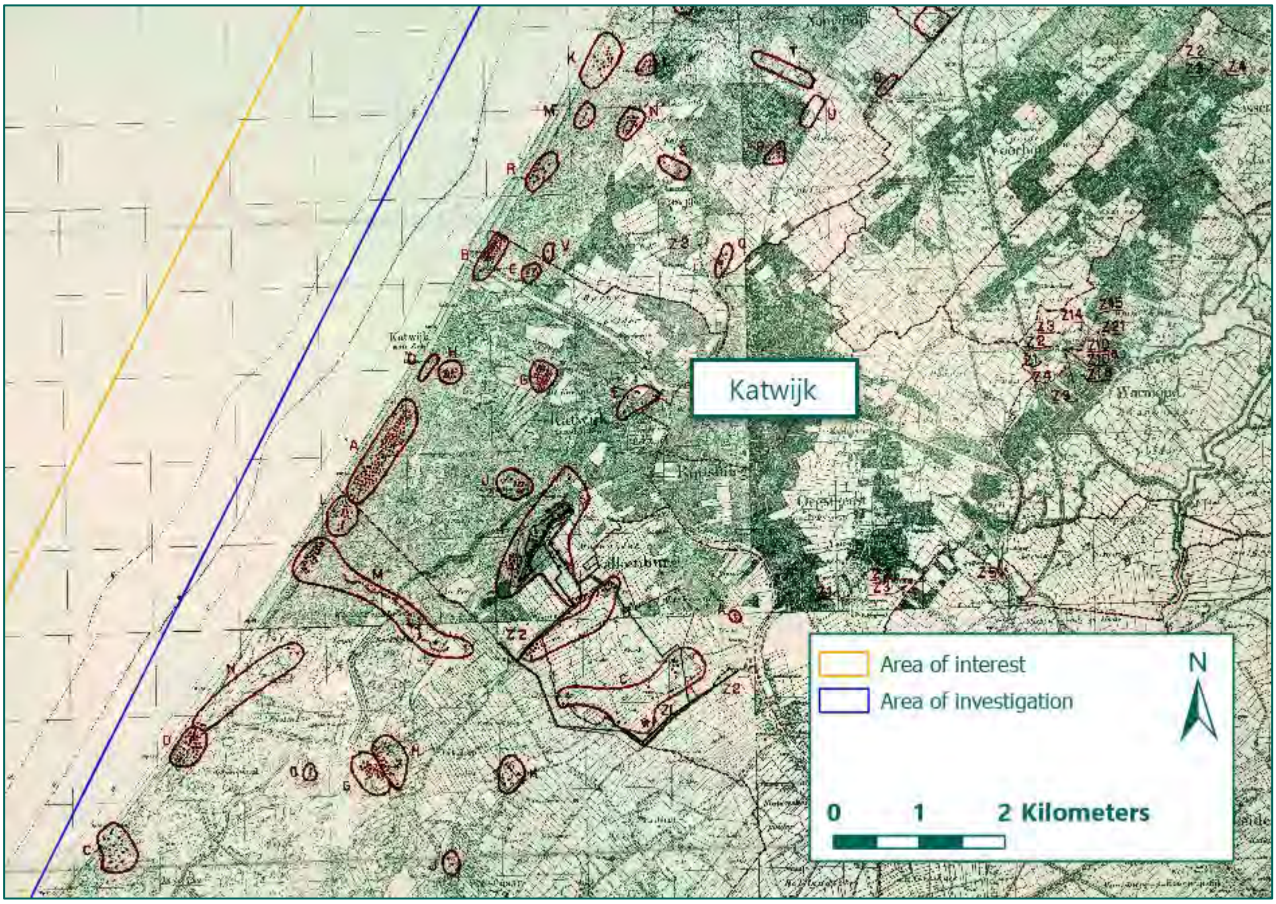


Figure 29: Cutout from a 'Blokkaart' showing the contours of military Infrastructure (Source: Nationaal Archief, 'Blokkaart' 275 3G).

4.3.1 Conclusion

Different guns could reach the area of investigation. Although the sources give only a few hints about the action of the coastal guns, it is estimated that all guns and crews had to practice from time to time. Due to the deployment of- and training with coastal guns it is probable that UXO of artillery shells are present in the area of investigation. These shells could possibly be encountered within, but no farther than, the maximum range of the coastal guns.

To cover the gap in knowledge about the coastal guns on Texel and between IJmuiden and Beverwijk the maximum range of coastal guns, not being 28 cm guns, is projected from the Dutch coast. This range is 22000 meters. Within the range of the known coastal guns and the range projected from the Dutch coast of Texel and between IJmuiden and Beverwijk an UXO Risk Area is projected. This UXO Risk area is shown in the figure below. Details about calibres are specified in the separately supplied shapefiles.

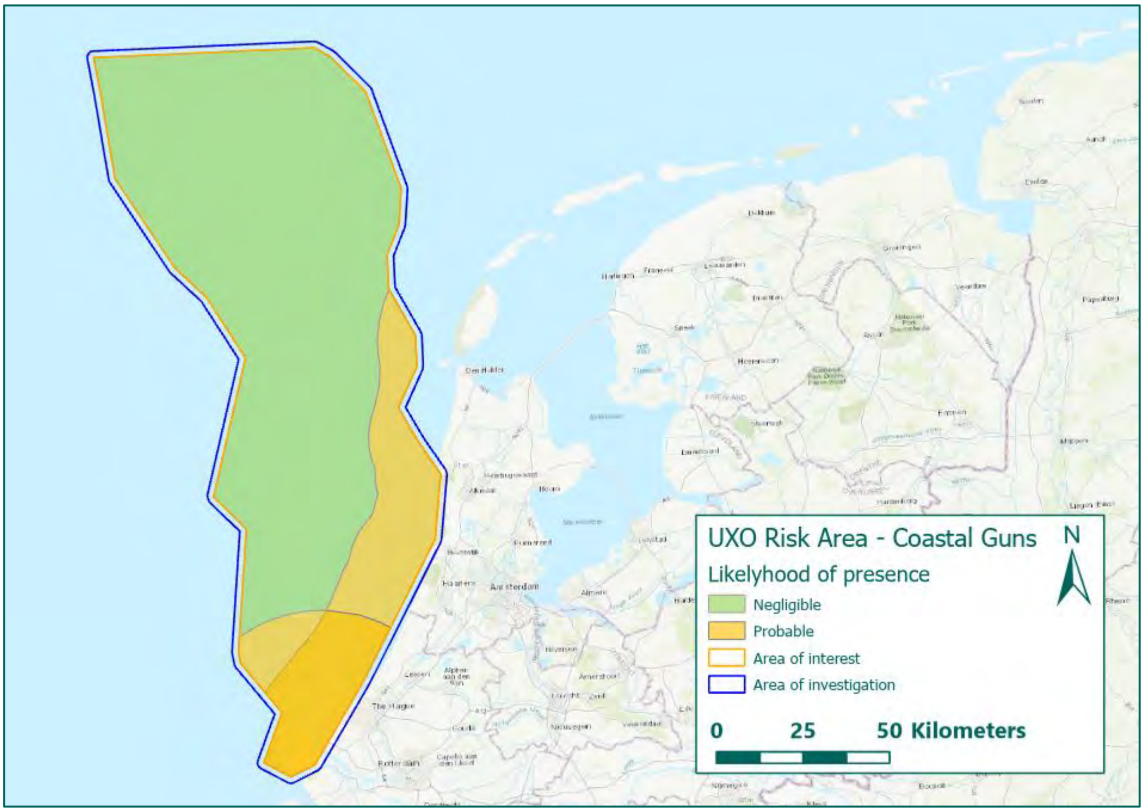


Figure 30: Likelihood of presence of UXO as result of the presence of coastal guns. (Source basemap: ESRI).

4.4 WAR AT SEA

Considering the surface craft battles, a large section of the area of investigation is situated on former German convoy routes. The convoys were accompanied with armed escort ships. Also, the convoy route itself was guarded by armed vessels and trawlers, the so-called "*Vorpostenboote*" that patrolled between checkpoints. The convoy routes are shown in Figure 31. Besides, IJmuiden and its harbour overlap the area of investigation. During the Second World War IJmuiden became an important base for the German fast attack boats (*Schnellboote*, S-Boats), for which a bunker was constructed. Later on, midget submarines also operated from IJmuiden.

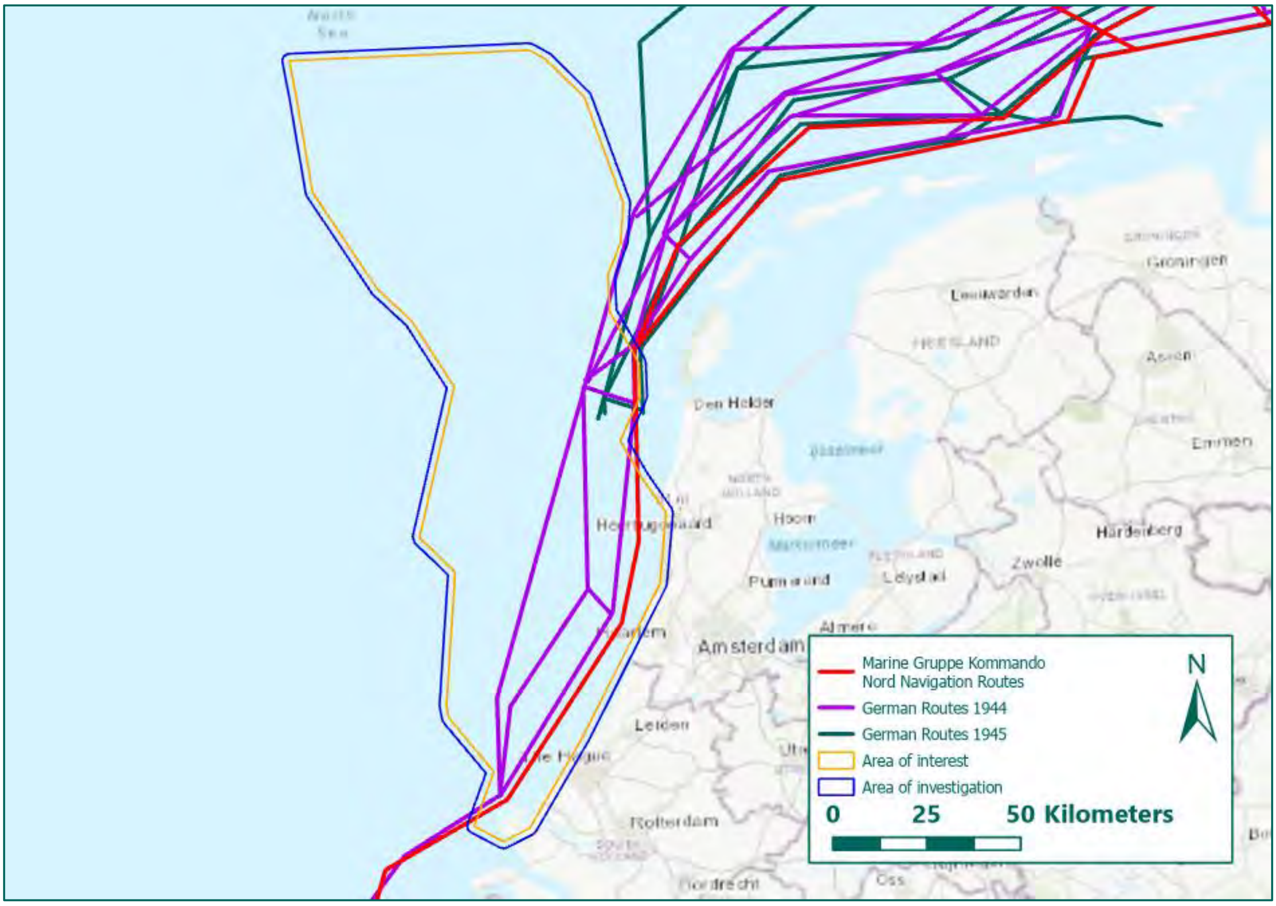


Figure 31: Convoy route “Weg Rot” and the quadrants used by the German navy. (Source basemap: ESRI).

The armed escorts and Vorpostenboote did not prevent the British Coastal Forces from attacking these ships and convoys. Detailed records about armed encounters between British and German ships can be found in German (BAMA), British (TNA) and American (NARA, Captured German Records) archives. Studying these records is outside the scope of this report. However, previously conducted studies by REASeuro (Amongst others 73556/RO-190149 Final Report DTS HKW Beta Export Cable Routes version 1.0) point out that near IJmuiden alone 36 confrontations between British and German vessels took place. The localisation is mainly based on the quadrants used by the German navy. The accuracy of these quadrants is not better than six to six nautical miles. For many of the surface craft battles only one source is available. Nevertheless, the German records show that most battles took place in a zone from the coast to the west of the convoy route.

4.4.1 Conclusion

Because of the large amount of naval battles that took place, an UXO risk area is defined. It is deemed probable that AA-shells and munition that could be used against enemy shipping might still be present in the area of investigation. UXO might be present near the convoy routes used by German ships. Therefore a UXO Risk Area is projected between the Dutch coast and the convoy routes. A buffer of 1 nautical mile (1.852 meter) is taken into account to mitigate the navigational inaccuracy. The likelihood of presence of UXO outside of the area between the Dutch coast and the convoy routes is deemed remote. In the table and figure below the UXO Risk Area is shown.

UXO type	Type	Condition
Small calibre ammunition	.303	Fired
	.50	
	13,2 mm	

	15 mm	
Artillery shells	2 cm/20 mm	
	2 pr. pompom	
	3.7 cm	
	6 pr.	
	8.8 cm	

Table 4: Expected UXO.

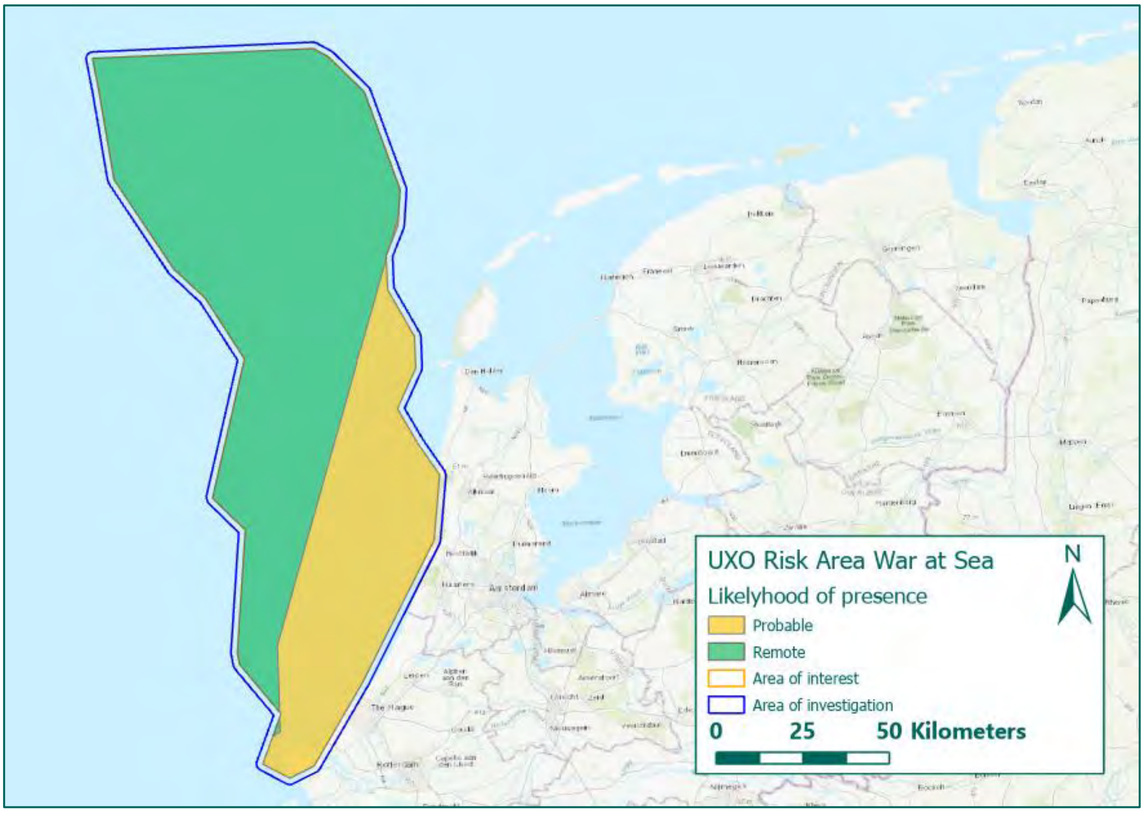


Figure 32: UXO risk area caused by surface craft battles. (Source basemap: ESRI).

4.5 MILITARY EXERCISE

On maps that show German minefields (used in paragraph 4.1.2) a German 'Schieβgebiet' ('Shooting area') can be seen that overlaps with the area of investigation. The 'Schieβgebiet' was drawn onto a map concerning German minefields in the North Sea. In the consulted sources there is no further mention about the 'Schieβgebiet'. It is therefore unclear what kind of exercising took place within this area. It could either be exercises carried out by the Kriegsmarine or the Luftwaffe. It is expected that within this area small arms calibres and artillery shells have been used. It is known that wartime exercises are often carried out with live ammunition, this in contrast to post-war exercises.

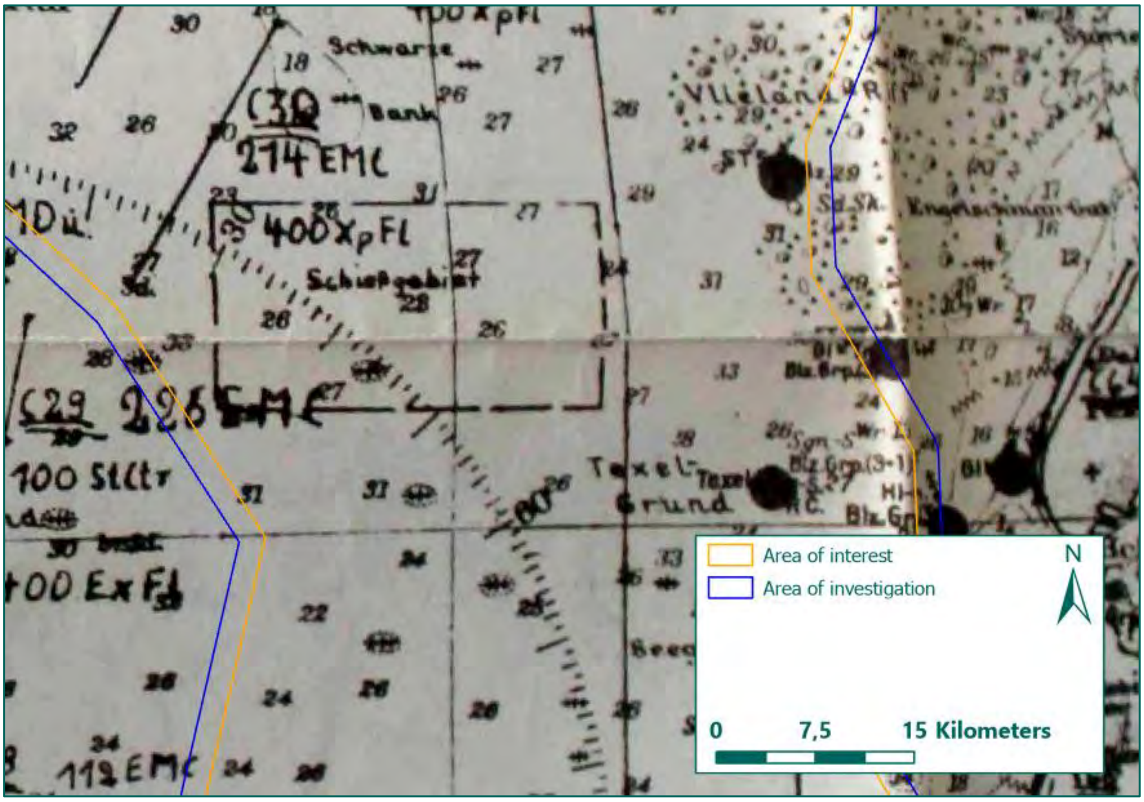


Figure 33: German map showing minefields and a 'Schieβgebiet' ('Shooting area') within the area of analysis (Source: BAMA, ZA 5/27).

Based upon information from the 'Nationaal Archief' in the Hague it is known that the above mentioned 'Schieβgebiet' was used by the Dutch Navy after World War II. The contours of the military exercise area appear to have an exact overlap with the contours of the German 'Schieβgebiet' discussed above. Sources from the Noordzeeloket (see Annex 3) show that this military exercise zone was used as a "laag vlieggebied" (low fly zone) where one of the activities carried out was 'gun fire'[6]. The map on which the military exercise area is drawn dates from 1965. It is not known for how long the Dutch Navy used the area for exercises and whether only 'gun fire' was carried out.

[6] It is expected that in this low fly zone exercises with both machine gun- and cannon fire were carried out with aircraft.

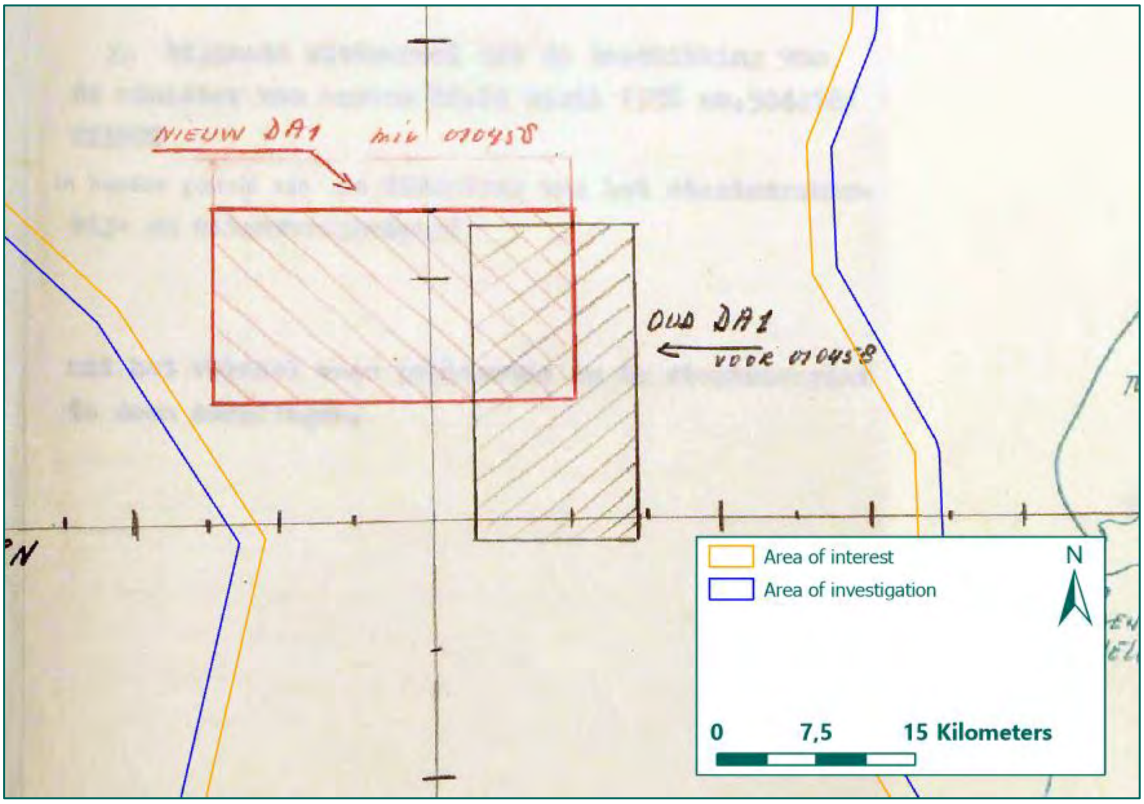


Figure 34: maps showing the location of a Dutch military exercise area within the area of investigation (Source: Nationaal Archief Toegang 2.12.56, folder 939).

Both during and after the war a military exercise area overlapped with the area of analysis. Normally, explosives are no part of exercise ammunition. However, as a result of German wartime practicing within the 'Schieβgebiet', UXO could be encountered within the 'Schieβgebiet' as wartime exercises were often carried out with live ammunition. It is to be expected that Dutch post-war exercises were carried out with small arms calibres and artillery shells. During peacetime military exercises would often be carried out with practice ammunition. Practice ammunition can incorporate devices to simulate the impact, like smoke markers or relatively small amounts of high explosives.

Besides the abovementioned 'Schieβgebiet', several other military exercise zones were located within the Area of investigation. It is known that some of these zones were in use during World War II. However, it is not clear whether this is the case for all exercise zones. It is outside the scope of this HDTS-UXO to conduct research in the usage of each of these zones. Because of the possible usage of live munition within the different exercise areas, it cannot be ruled out that UXO might still be present within the area of investigation.

The different military exercise zones as mentioned in the consulted sources are shown in the figure below.

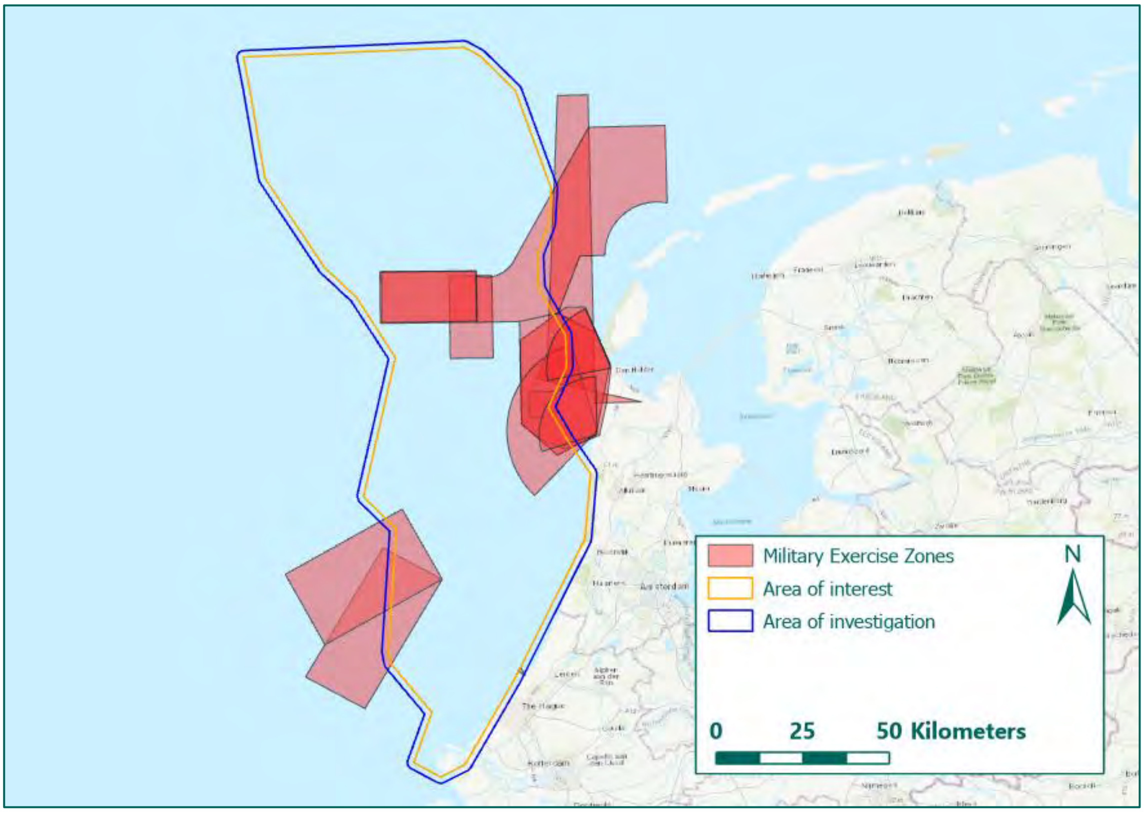


Figure 35: Military exercise zones within the area of investigation (Source basemap: ESRI)

4.5.1 Conclusion

The presence of several military exercise zones within the area of investigation, of which some were used during World War II, leads to the conclusion that UXO (either exercise ammunition or live ammunition) could still be present within the area of investigation. Additional research may be necessary to determine the type of munition used in each of the zones, and to determine whether or not live ammunition was used within the zones. This additional research is outside the scope of this research.

The sort, type, amount and condition of the munition used within the different military exercise zones can, at this time, not be determined. The consulted sources do not provide information about this. However, it cannot be ruled out that UXO might still be present within the area of investigation. Therefore, a UXO Risk Area is projected at the location of these military exercise zones. The likeliness of presence of UXO in these zones is deemed probable. The likeliness of presence of UXO in the other parts of the Area of investigation is deemed negligible.

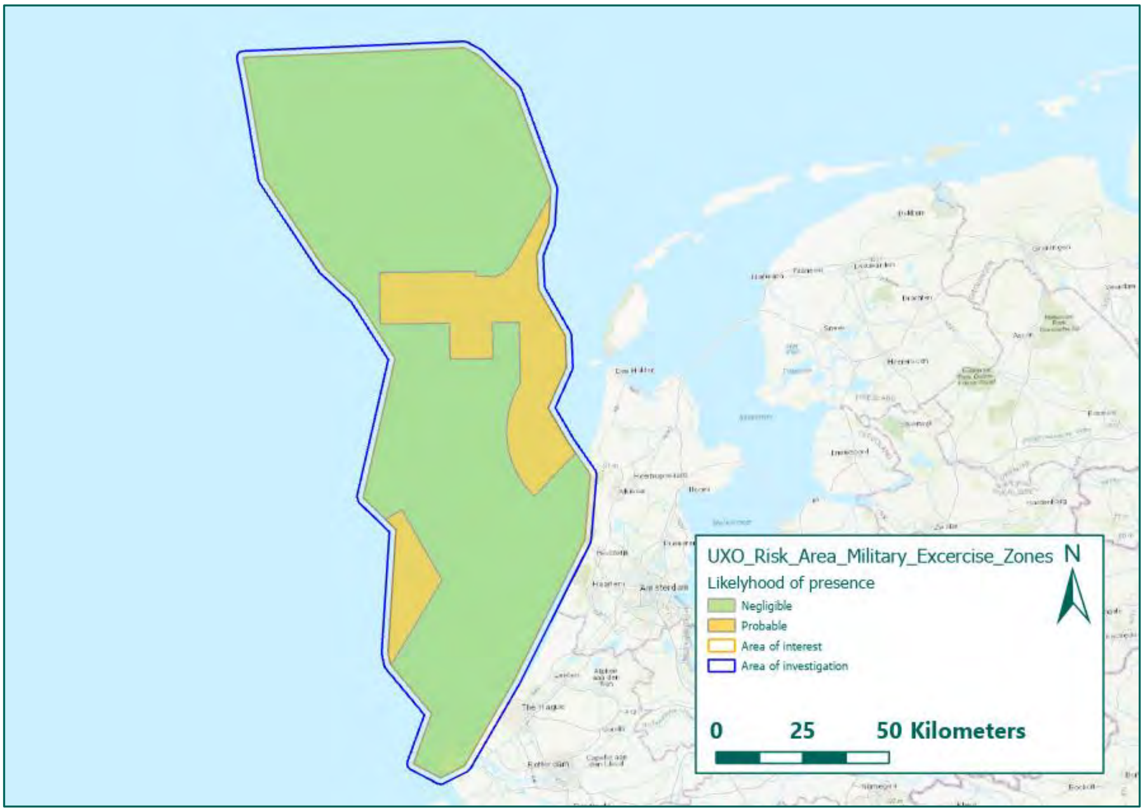


Figure 36: Likelihood of presence of UXO as result of the presence of coastal guns. (Source basemap: ESRI).

4.6 WRECKS

According to consulted sources (website of the Wrecksite and HP39 Wrakkenregister), various airplanes crashed into the area of investigation and boats sunk in the North Sea. For many crashes and shipwrecks the exact location is not known. Some wreck locations are therefore indicatively marked.

The wreck register (HP39 Wrakkenregister) shows 609 shipwrecks in the area of investigation (see annex 5). Detailed information about most wrecks are unknown. However, in some cases the name of the sunken vessel is known. It is possible to research whether or not these vessels sunk due to war related events. However, it is deemed outside the scope of this research to find additional information about 97 wrecks. Therefore, this additional research will not be conducted. In the figure below a total of all wrecks near the Area of investigation is shown.

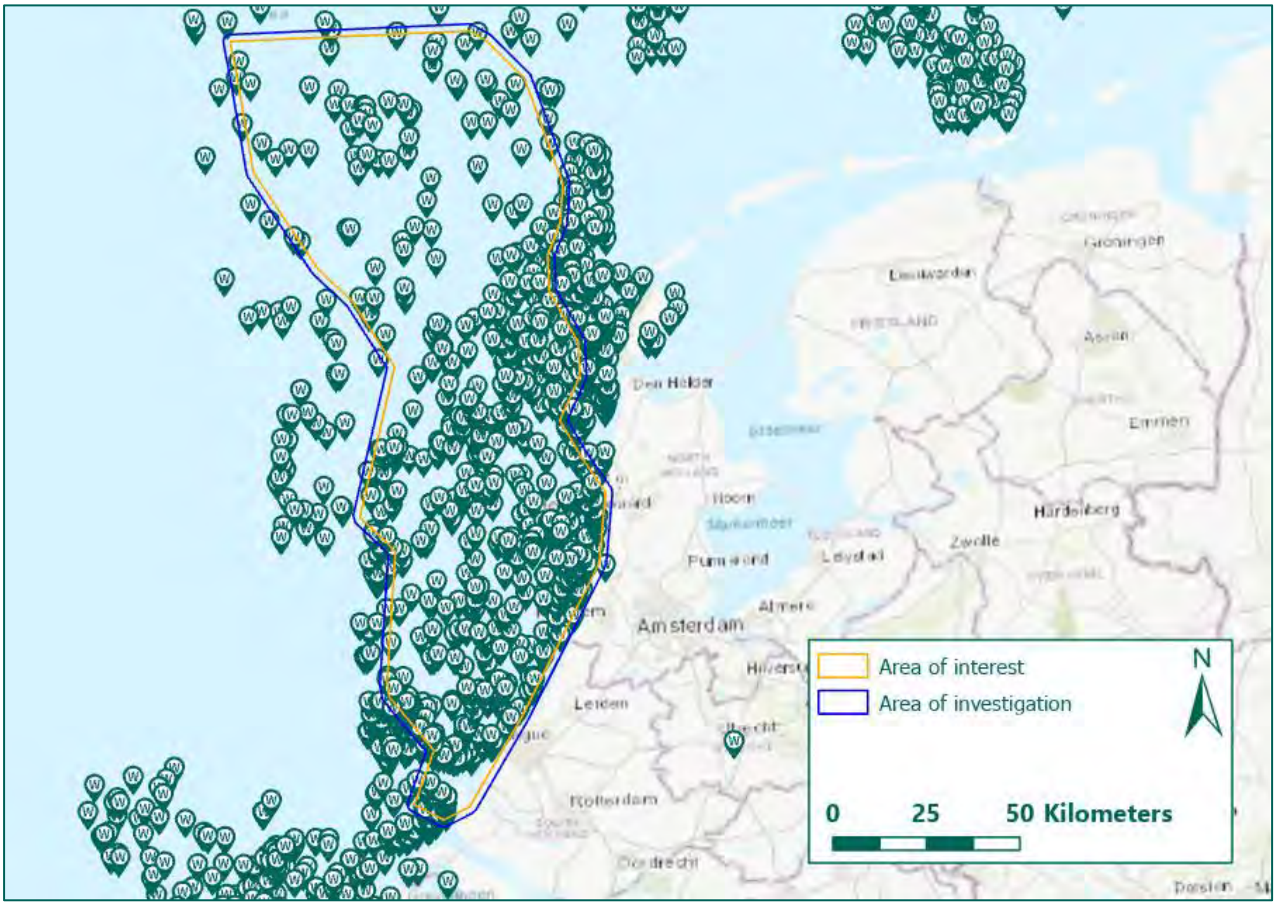


Figure 37: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

The website of 'Wrecksite' also provides a lot of information about wrecks. Near the area of investigation, a total of more than 1800 wrecks lay within and near the area of interest. Plotting all these wrecks in the GIS-system would be too comprehensive and falls outside the scope of this report. In the table below a list of war related causes of sinking of ships/aircraft within the area of interest is shown. It should be mentioned that in most cases, no cause of sinking was mentioned.

Cause of sinking	Total number sunk
Airplane crashes, WW2	75
Air raids, WW2	19
Charges/explosives, WW1 and WW2	8
Depth charges , WW2	2
Explosions, WW2 and after WW2	4
Gunfire – shelled, WW1 and WW2	152
Mine, WW1 and WW2	39
Naval battles, WW1 and WW2	10
Torpedo, WW1 and WW2	21
War loss (Not specified), WW1	1

Table 3: Listing of ships/aircraft sunk by war related events.

4.6.1 Conclusion

As can be seen, most of the wrecks mentioned in this table can be ascribed to war related events described in paragraphs 4.1-4.3. The demarcation of UXO Risk Areas resulting from these war related events is also described in these paragraphs. Additional UXO Risk Areas will not be demarcated because of the possible presence of wrecks of ships or aircraft. However, if a wreck is encountered during activities in the Maasvlakte the authorities are to be alerted. Wrecks can possibly still house the bodies of fallen troops or might be considered cultural heritage.

4.7 MUNITION DUMPING

As shown on the map of the Noordzeeloket (Figure 38) and the naval chart of the Royal Netherlands Navy Hydrographic service (Figure 39), ammunition dumping sites are situated within the area of investigation. According to archival documents, tons of German left behind ammunition were dumped into this zone shortly after World War II. In the 1960's, it appeared that fishermen encountered also ammunition outside the most northern dumping site, therefore a larger zone was marked as "*dangerous for fishing, intrusive, and seismographic activities*". The centre of the dump ground is marked with a buoy in position 52-33,5N, 04-03,6E. The dangerous area is defined by a radius of three nautical miles around this buoy. For the two southern dumping sites no such 'danger zones' were determined. In the figures below, the location of the dumping sites are indicated.

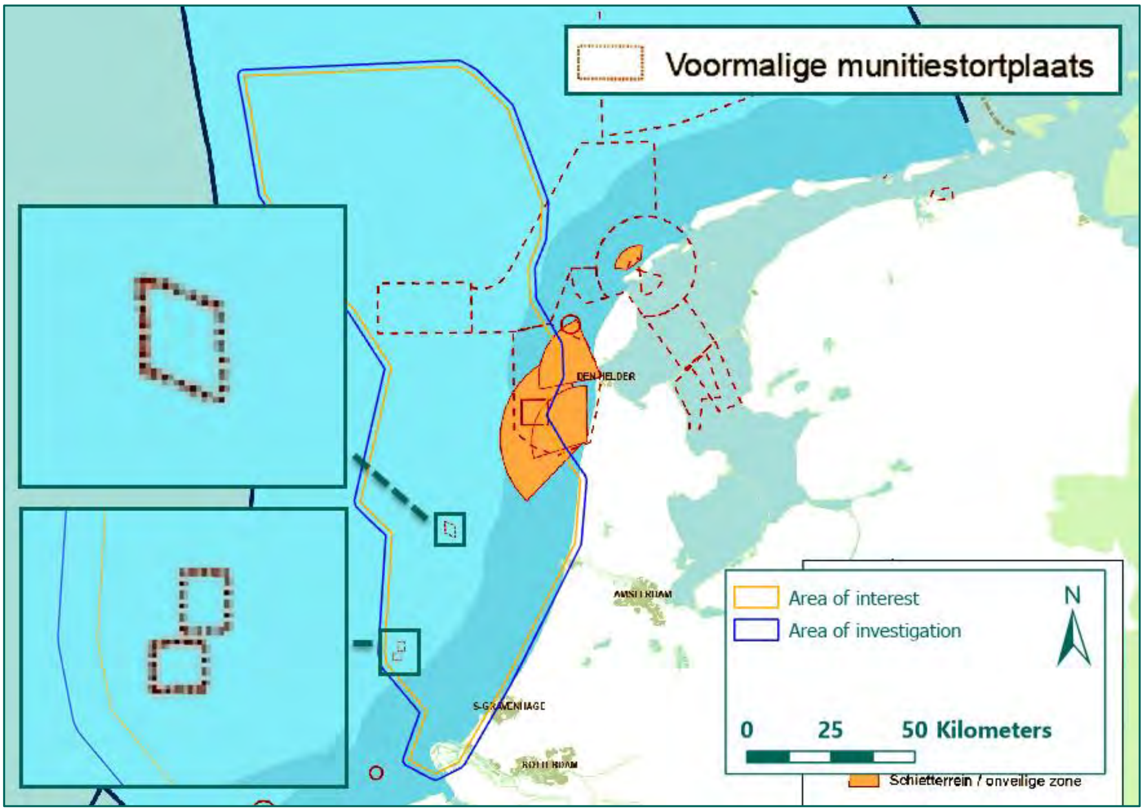


Figure 38: Map showing the military usage of parts of the North Sea, including munition dumping sites (Source: NZL).

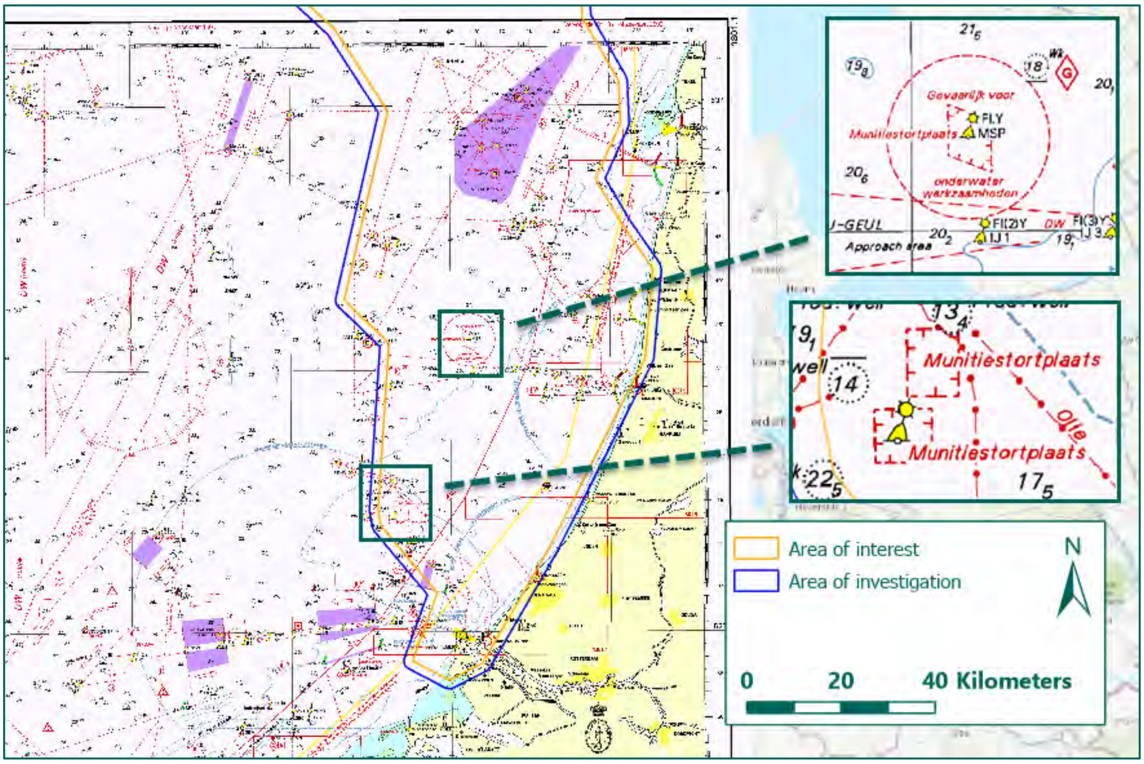


Figure 39: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

4.7.1 Conclusion

Because of the large amounts of munition dumped within these sites, it is certain that UXO is still present within the dumping sites. It is also probable that munition was dumped outside of the determined dumping sites, as was the case near the most northern dumping site. Therefore, a buffer of three nautical miles is projected around these two munition dumping sites as well. Within these buffer zones the likelihood of presence is deemed probable. No information is available on the exact amount and type of the ditched ammunition. Therefore, the sort, type, amount and condition cannot be determined.

The consulted sources do not provide information about munition dumping in other parts of the Area of investigation. Therefore, the likeliness of presence of dumped munition in the other parts of the Area of investigation is deemed negligible.

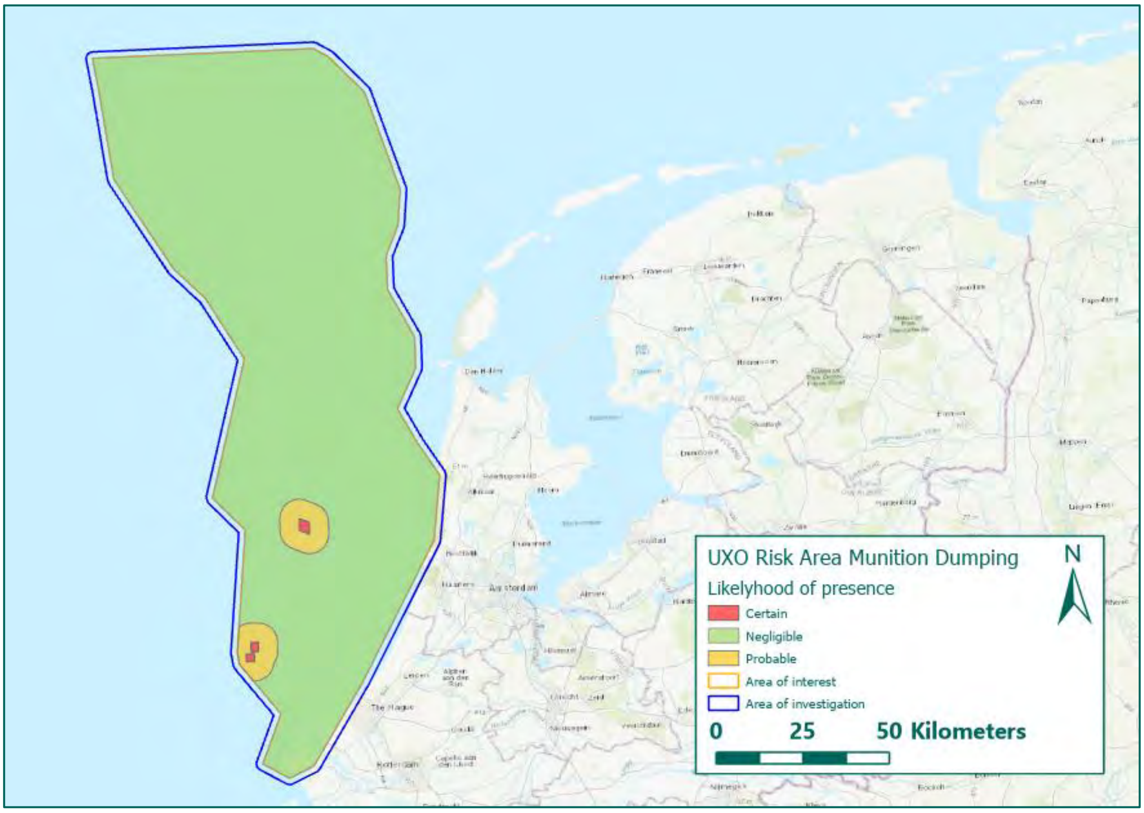


Figure 40: UXO risk area due to munition dumping. (Source basemap: ESRI).

4.8 V1 AND V2 BOMBS

During the last years of World War II, the German High Command started using new weapons with the hopes of stopping the Allied build-up and advance. These new weapons were the Vergeltungswaffe 1 (V1) and Vergeltungswaffe 2 (V2). The V1 was an early cruise missile with a pulsejet for power. The V2 was the world's first long-range guided ballistic missile. These weapons were targeted against, amongst others, Allied cities and harbours.


Figure 41: photographs of a V1 and V2 (Source: REASeuro-database).

V1 and V2 launch sites were constructed all over German-occupied territories. London was one of the main targets of the V1 and V2. Many of the V1s and V2s launched did not reach their target but landed prematurely or overshot their target due to navigational or technical errors. V1s and V2s were also vulnerable to Allied countermeasures such as anti-aircraft guns.

The consulted sources show that V1s and V2s could also land in the sea near the United Kingdom (see Figure 42). It is possible that, either through navigational or technical errors or through Allied countermeasures, UXO of V1s and V2s are left within the Area of investigation. However, in the consulted sources there are no indications that this has occurred.. A UXO Risk Area can therefore not be determined.

Figure 42: V1 and V2 bombs hitting targets in the United Kingdom (Source: V2, See Annex 2)

4.8.1 Conclusion

Although it is known that V1s and V2s could at times strike down at the sea, there are no indications in the consulted sources that this has occured within the area of investigation. It is therefore not possible to determine a UXO Risk Area within the Area of investigation.

5 GAPS IN KNOWLEDGE

During the analysis and review of historical sources some gaps in knowledge occurred that could not be filled in with the consulted sources:

- Knowledge of previous UXO clearance operations is often absent. Therefore, it is not fully known if during the period 1914-2016 UXO were encountered in and/or removed out of the area of investigation.
- It is unclear whether the source material concerning German convoy routes is complete. The consulted sources mention several attacks on convoys sailing outside the convoy routes that are known by REASeuro.
- Pinpointing the locations of all 1800 wrecks within and near the Area of Investigation was considered too comprehensive a task with regards of the scope of this research. Therefore, not all (approximate) locations of wrecks as mentioned in the consulted sources are pinpointed.
- The REASeuro-database did not contain detailed information about all individual coastal guns on the Dutch coast bordering the Area of investigation.
- Detailed records about armed encounters between British and German ships are not yet entered into REASeuro’s GIS-Database. Therefore, it was not possible to give an overview of all (approximate) locations of these encounters.
- The type and amount of ammunition used by German and allied submarines, planes and ships is not always known.
- The types, calibres and amounts of munition used in the different military exercise zones are not always known
- It is unclear which types, calibres and amounts of munition were dumped in the munition dumping ground within the area of investigation.
- The REASeuro database does not contain every sortie made by Coastal Command planes during the Second World War.

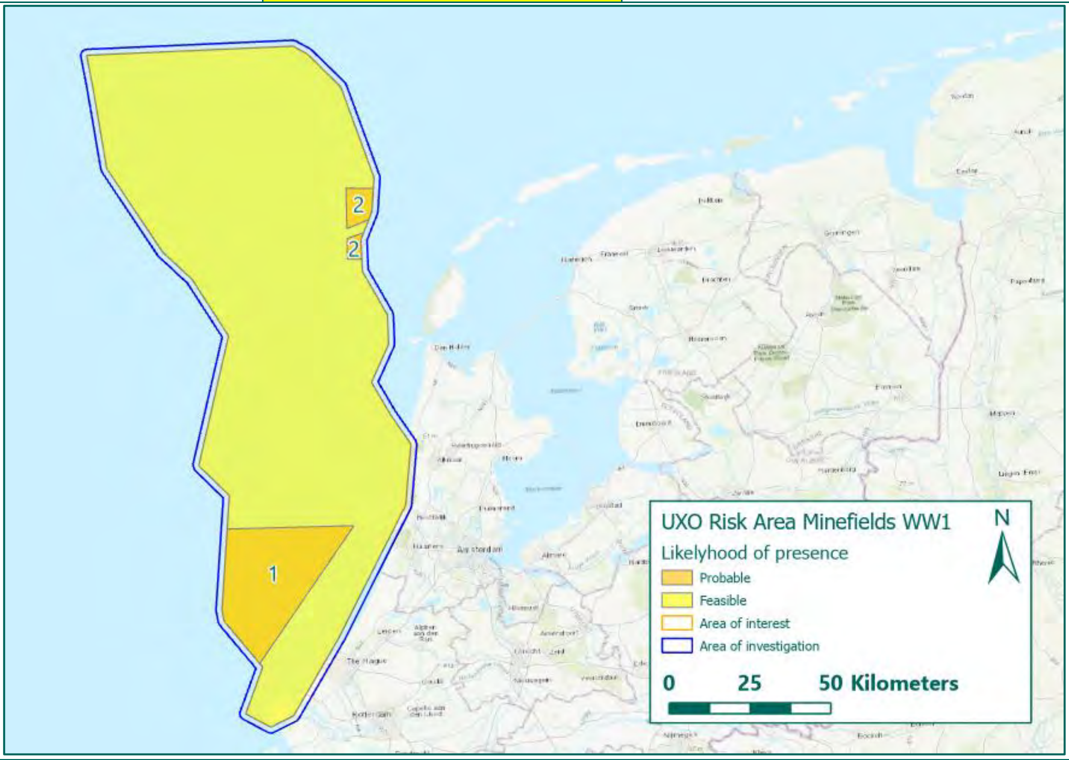
Besides these gaps of knowledge, there are also some uncertainties concerning source material relevant for this report:

- It is not possible to pinpoint exact locations of war-related events at sea. This problem is partly solved by defining a large area of investigation. Events that took place within this area could have led to a UXO risk area.
- Compared to land, the North Sea offers few reference points. Therefore, specific information about locations is often lacking. Furthermore, it must be noted that information can be inaccurate.
- Because of the systematic destruction of the *Luftwaffe* archives, there is only sporadic information available on German Air Force activity.
- Crash locations of planes during World War II are not exactly known. This is also the case for many shipwrecks, which are also unknown on Wrecksite.eu.
- There is no exact information about the locations, amounts, conditions and types of dropped bombs during aerial attacks or jettisoning above the North Sea.

6 OVERVIEW OF UXO RISK AREAS

Based on the assessment and analysis of the source material, several UXO Risk Areas have been identified within the area of investigation. The main types of UXO found in each UXO risk area are outlined in chapter 4. The horizontal demarcation of UXO Risk Areas is discussed per type of warfare in the conclusions of paragraph 4.1, 4.2, 4.3, 4.4, 4.5, 4.7 and are presented in tables below.

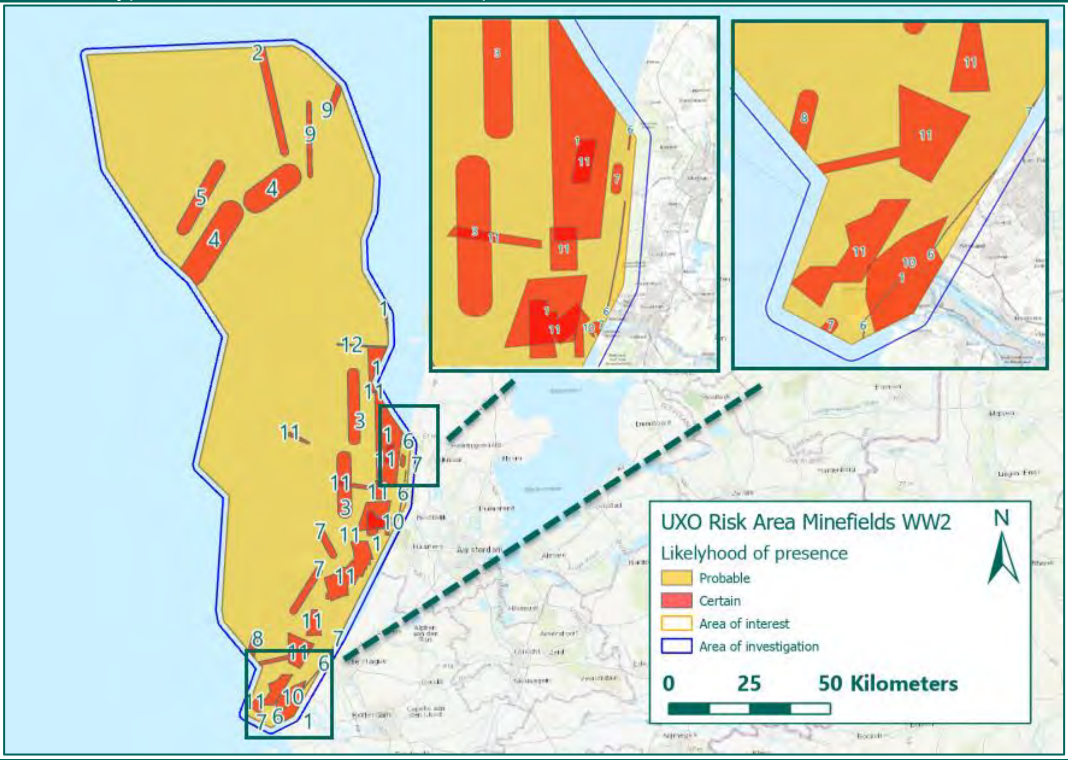
UXO Risk Area as a result of the naval mines (paragraph 4.1)

<table>
<tr><th>UXO (sub)type and calibre</th><th>Likelihood of presence</th><th>Demarcation</th></tr>
<tr><td rowspan="2">Naval Mines WW1: German E-Mine moored contact mines, British Vickers / British Elia and H Mark II moored contact mines</td><td>Probable</td><td>Within the boundaries of known minefields.</td></tr>
<tr><td>Feasible</td><td>Outside the boundaries of known minefields.</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td rowspan="2">Naval mines WWII: British Mk I-IV ground mines and British Mk VII- VIII and Mk XIV

German EMB, EMC, EMD, UMA, RMA, KMA contact mines
German LMB Ground mines
German Exploding Floats (and also non explosive sweep obstructors)

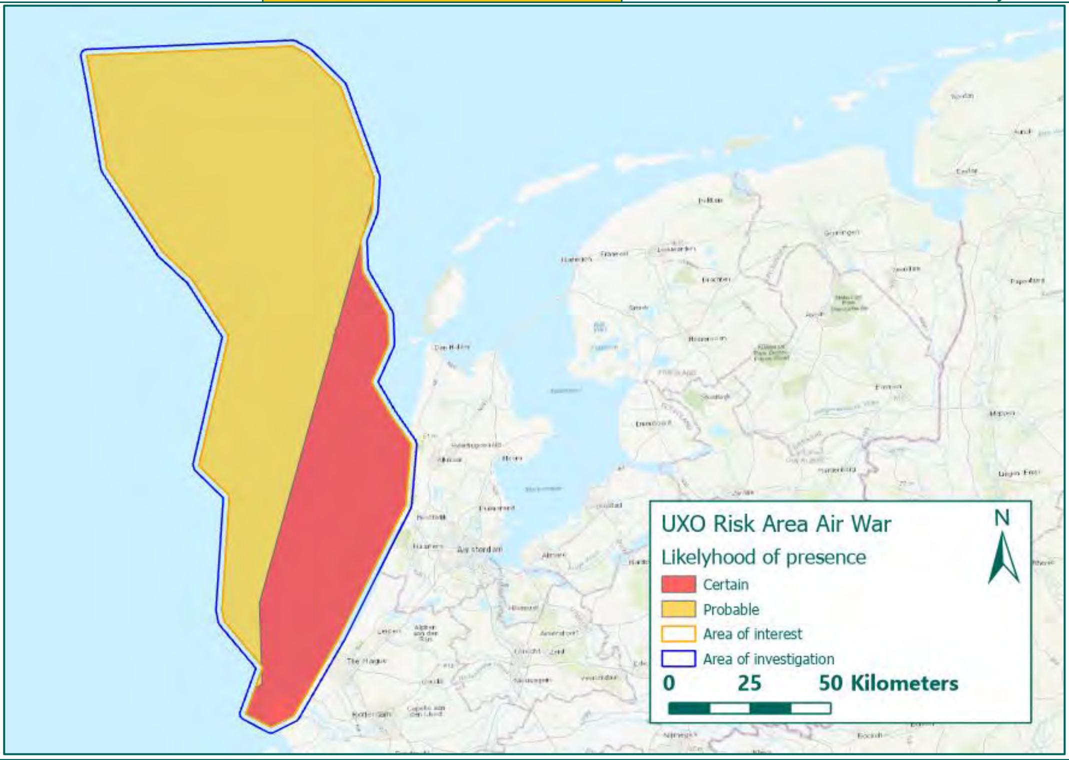
Dutch Model 1921 ‘2e soort’</td><td>Certain</td><td>Within the boundaries of known minefields.</td></tr>
<tr><td>Probable</td><td>Outside the boundaries of known minefields.</td></tr>
</table>

UXO (sub)type and calibre	Likelihood of presence	Demarcation



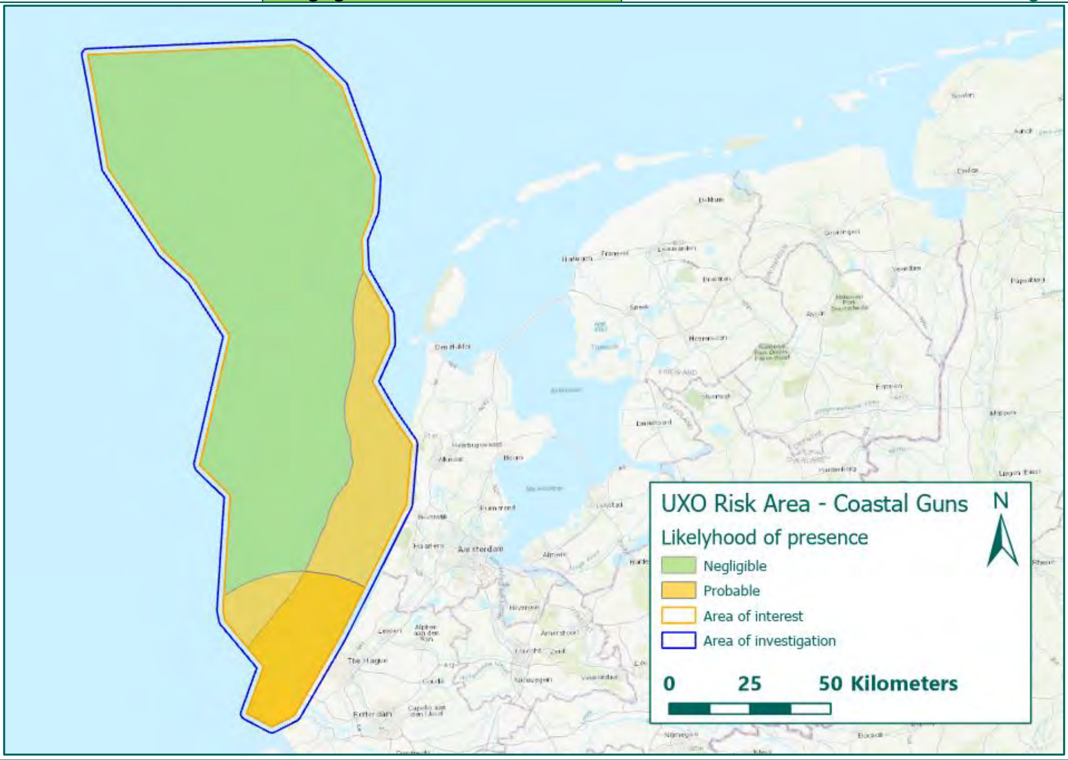
UXO Risk Area as a result of the air war (paragraph 4.2)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Aerial bombs: 4 lbs, 25 lbs, 30 lbs, 100 lbs, 250 lbs, 260 lbs, 300 lbs, 500 lbs, 1.000 lbs, 4.000 lbs	Certain	The UXO risk area is projected between the most western convoy route and the Dutch coast. A buffer of 1 nautical mile (1.852 meter) is taken into account for navigational inaccuracy of ships and aircraft.
	Probable	Areas outside of the known convoy routes.
Under water ammunition: 18 inch torpedo Mk XV Depth charge	Certain	The UXO risk area is projected between the most western convoy route and the Dutch coast. A buffer of 1 nautical mile (1.852 meter) is taken into account for navigational inaccuracy of ships and aircraft.
	Probable	Areas outside of the known convoy routes.
Rockets: 3 inch rocket with 25 lbs or 60 lbs (SAP) warhead	Certain	The UXO risk area is projected between the most western convoy route and the Dutch coast. A buffer of 1 nautical mile (1.852 meter) is taken into account for navigational inaccuracy of ships and aircraft.
	Probable	Areas outside of the known convoy routes.



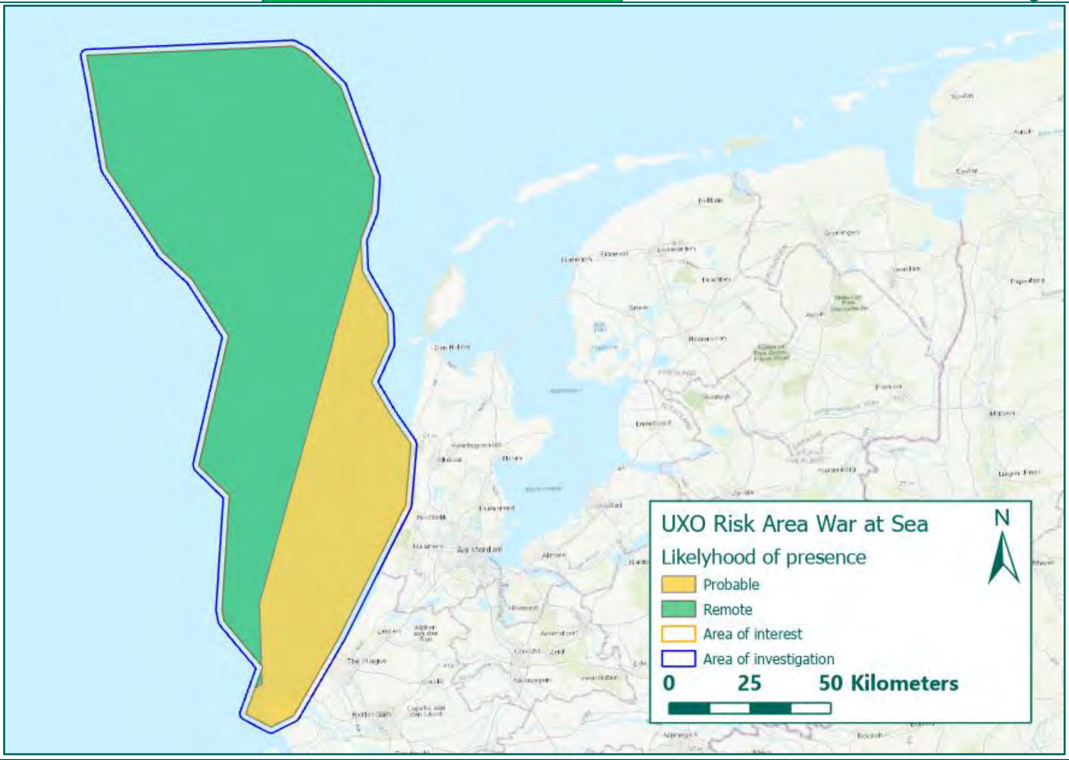
UXO Risk Area as a result of the coastal guns (paragraph 4.3)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Artillery shells: 5 cm, 7,5 cm, 9,4 cm, 10,5 cm, 12 cm, 14,91 cm, 15 cm, 15,2 cm, 24 cm, 28 cm	Probable	Within reach of the coastal guns. Where the REASeuro Database lacked information about coastal guns, the maximum range of coastal guns, not being 28 cm guns, is projected from the Dutch Coast.
	Negligible	Areas outside of reach of the coastal guns.



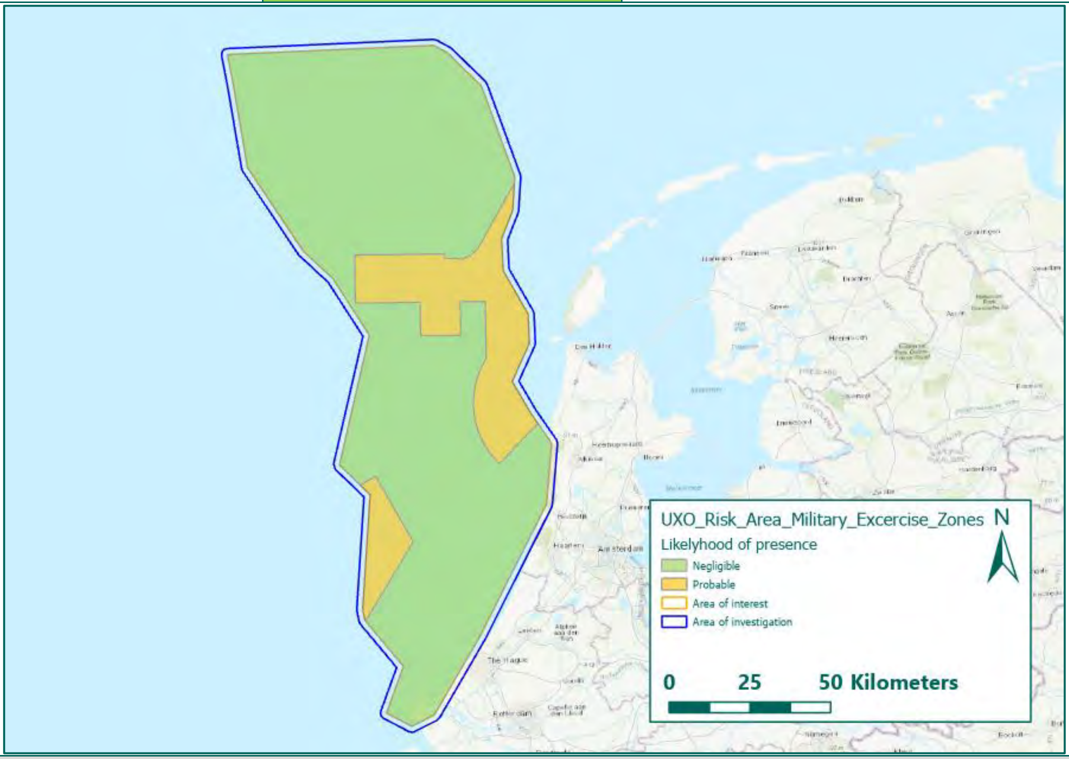
UXO Risk Area as a result of the war at sea (paragraph 4.4)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Small Calibre Ammunition: .303, .50, 13,2 mm, 15 mm Artillery Shells 2 cm/20 mm, 2 pr. Pompom, 3.7 cm, 6 pr., 8.8 cm	Probable	The UXO risk area is projected between the most western convoy route and the Dutch coast. A buffer of 1 nautical mile (1.852 meter) is taken into account for navigational inaccuracy of ships and aircraft.
	Remote	Areas outside of reach of the coastal guns.



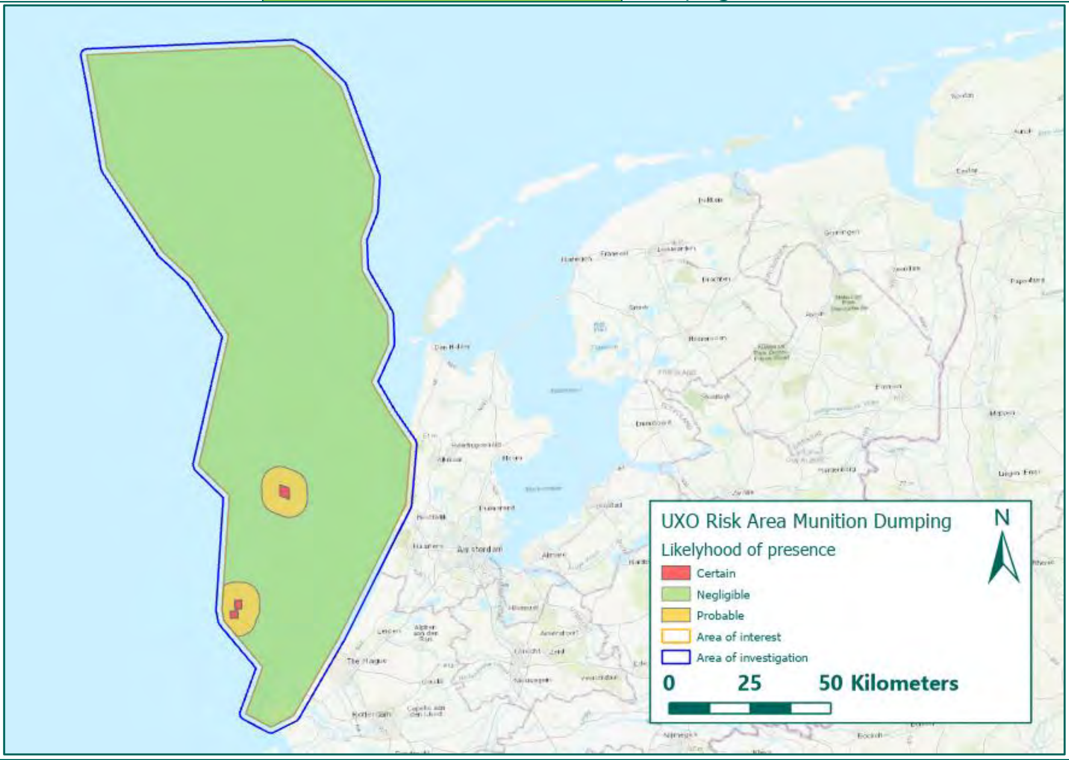
UXO Risk Area as a result of military exercises (paragraph 4.5)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Unknown (exercise) munition: Each military exercise zone had it's own purpose, it is outside the scope if this research to determine the munition used in each zone.	Probable	Within the boundaries of known military exercise zones.
	Negligible	Outside of the boundaries of known military exercise zones.



UXO Risk Area as a result of munition dumping (paragraph 4.7)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Unknown dumped munition	Certain	Within the boundaries of known munition dumping sites
	Probable	Three nautical miles around the munition dumping sites due to large amounts of munition being found outside the munition dumping sites
	Negligible	Outside of the boundaries of known munition dumping sites



7 CONCLUSION AND ADVICE

The Historical Desktop Study leads to the conclusion that the presence of UXO within the whole Area of interest ranges from certain to negligible, depending on the type of UXO involved. In particular, the presence of UXO resulting from minefields, aerial warfare and the dumping of munition is deemed certain. Therefore, there is a severe risk of encountering UXO within the Area of interest.

Only a few specific locations wherein certain types of UXO could be present can be demarcated in this HDTS-UXO. Performing a full Historical Research will produce some further results. REASeuro advises to implement an UXO Risk Assessment (RA) alongside full Historical Research. The purpose of the RA is defining the risk that UXO poses to the planned activities in the area of analysis. This risk is a function of the 'Likelihood of Occurrence' and the 'Hazard Severity'. The 'Likelihood of Occurrence' is the product of the 'Likelihood of Presence' as defined in this HDTS-UXO and the likelihood of initiation of an item of UXO, which will be assessed in a RA. Therefore, the likelihood of presence alone is not enough to define the risk of UXO to the planned activities.

Several factors like the burial of UXO, migration of UXO, the planned intrusive activities, hazards of UXO likely to be encountered and effects of detonation are analysed and assessed for use in a Semi Quantitative Risk Assessment (SQRA). The following matrix is used to quantify the risk. Each generic UXO hazard is assessed for severity and likelihood of occurrence. This model is generally considered best practice for assessing risk in the marine environment, although it has been modified where required to ensure it is UXO centric. The risk matrix is presented in Table 3.

Once the risks have been identified fitting mitigation strategies to bring the risk down to an acceptable level will be proposed. The mitigation strategies are focused on bringing the risk down to a level that is defined as 'As Low As Reasonably Practicable' (ALARP).

		Hazard Severity				
Likelihood of Occurrence		1 = Negligible	2 = Slight	3 = Moderate	4 = High	5 = Very High
	1 = Very Unlikely	1 LOW	2 LOW	3 LOW	4 LOW	5 LOW/MODERATE
	2 = Unlikely	2 LOW	4 LOW	6 LOW/MODERATE	8 MODERATE	10 MODERATE/HIGH
	3 = Possible	3 LOW	6 LOW/MODERATE	9 MODERATE	12 MODERATE/HIGH	15 HIGH
	4 = Likely	4 LOW	8 MODERATE	12 MODERATE/HIGH	16 HIGH	20 HIGH
	5 = Very Likely	5 LOW/MODERATE	10 MODERATE/HIGH	15 HIGH	20 HIGH	25 HIGH

(red)	Unacceptable
(orange)	ALARP with reduction measures
(yellow)	ALARP
(green)	Acceptable

Table 3: UXO Risk Assessment Matrix.

8 ANNEXES

ANNEX 1 GLOSSARY TERMS

Term	Definition
Historical Desk Study - UXO	Preliminary desk study in which war related events in the 1940-1945 period (including post-war detection and clearance) are being analysed. The aim is to determine whether there can be a UXO risk area in the area of interest. The historical desk study UXO consists of: - Reports. - Affirmative or negative recommendation. - In case of an affirmative recommendation: - Horizontal delimitation UXO-Risk area(s). - UXO risk map.
Historical Quick Scan - UXO	A narrower preliminary desk study than a Historical Desk Study – UXO. The aim of a HQS is to examine whether UXO cannot be excluded within the area of interest and if there are areas with an increased risk of UXO.
Unexploded ordnance (UXO)	- Unexploded ordnance (UXO) is explosive ordnance that has been primed fused, armed, or otherwise prepared for use and used in an armed conflict. It may have been fired, dropped, launched or projected, and should have exploded, but failed to do so. - For the purposes of this publication, the term UXO is used generically to also refer to explosive ordnance that has not been used during an armed conflict, which has been left behind or dumped by a party to an armed conflict, and is no longer under control of that party. Such UXO may or may not have been primed, fused, armed or otherwise prepared for use.
Area of interest	Area of focus for the historical desk study. The area of investigation is wider than the area of investigation in order to get a full view of any war related events which could be relevant.
Area of investigation	The area specified by the client in which regular work unrelated to UXO will be performed or in which a change of function will be implemented.
Detection area	The possibly contaminated area within the area of investigation where UXO detection is recommended prior to commencing regular work activities.
War related event	Events that could possibly have led to the presence of UXO. Examples of war related events are: - Aerial Bombardment - Artillery fire - Ammunition dumping or jettisoning - Ammunition related accidents - Aircraft crashes
UXO Risk map	Cartographic view of the UXO risk area(s).
UXO Investigation (Five phases policy)	REASeuro developed a five phases policy: the integral total approach to UXO related issues comprised of five separate phases. This allows the client to make a well-considered decision for each phase and to plan follow-up actions with the aim of keeping the client in control of the project. Five phases policy: 1. Historical research 2. Project risk assessment 3. Project management plan 4. Execution 5. Clearance certificate and final report
Risk assessment	The process of identifying potential threat and estimating the risks of harm and loss associated with that threat. A risk assessment also contains the evaluation of the acceptability of the assessed risk including the consequences of a materialised risk and identifies potential risk reduction and control measures.
Risk mitigation	Eliminating risk or reducing it from an identified unacceptable risk to an acceptable level.

Term	Definition
As low as reasonably practicable (ALARP)	A risk tolerability principle that has particular connotations in UK health and safety law. It requires a developer to reduce the risks from UXO until or unless the cost of implementing those measures is considered to be grossly disproportionate to the risk averted.
"CS-OOO"	The CS-OOO is the Dutch branch specific certification plan for the system certificate "detection of conventional explosives". This includes guidelines, process requirements and expertise standards. Since January 1st 2020, the CS-OOO has been the successor to the "*Werkveldspecifieke certificatieschema voor het Systeemcertificaat Opsporen Conventionele Explosieven*" (WSCS-OCE) and is legally anchored in the Working Conditions Act (Arbowet). In order to safeguard societal interests – health and safety in relation to work – the government has opted for a mandatory certification plan to guarantee the quality and safety of detecting conventional explosives.

ANNEX 2 LITERATURE

The scope of this research was to insight in the possible chance of encountering UXO within the area of investigation by consulting the REASeuro-Database. In addition several books have been consulted in order to get a clear depiction of war related events within the area of interest. In consulting literature the focus has been placed on the First World War to fill the gaps in the REASeuro-Database. For this research the following literary sources have been consulted:

Abbreviation	Author	Title	Relevant
AAS	Air and Space	*These Amateur Archaeologists Dig Up the Buzz Bombs That Fell on England in WW2* *Two brothers scour the English countryside for remnants of Hitler's vengeance weapons.*	Yes
CRO	Crossley, J.,	*The Hidden Threat. The story of mines and minesweeping by the Royal Navy in World War I* (South Yorkshire 2011).	Yes
SCH	Scheer, R.	*Germany's High Sea Fleet In The World War* (London 1920)	Yes
VER	Vergeltungswaffen	*http://www.vergeltungswaffen.nl/*	Yes
V2	V2 Rocket	*http://www.v2rocket.com*	Yes

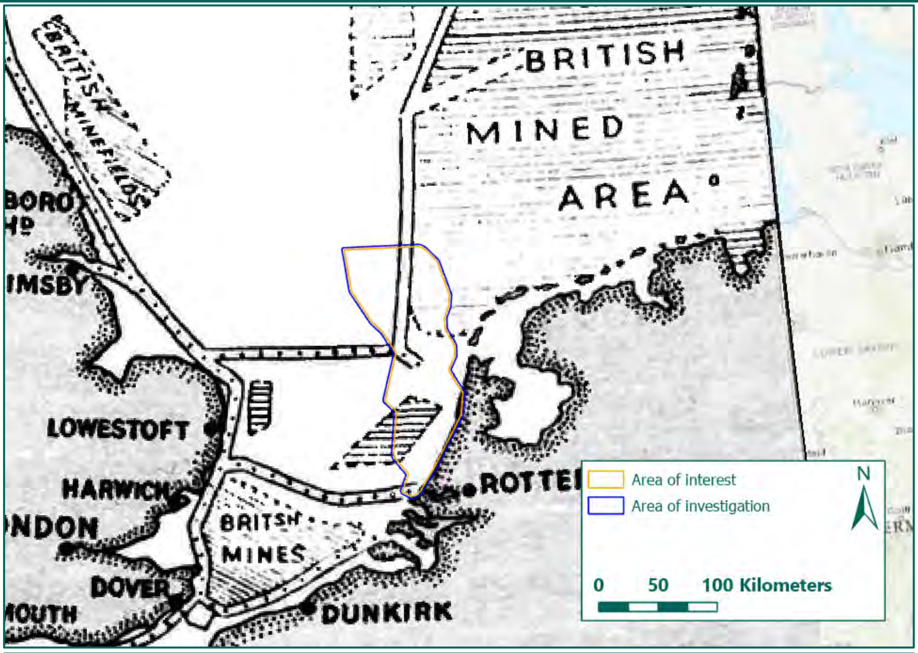
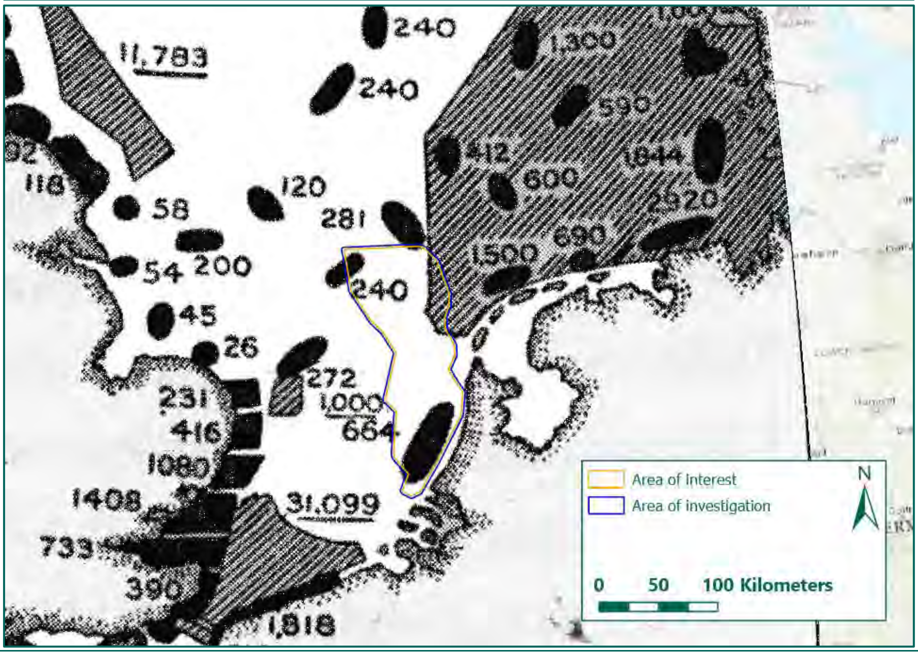
Table 4: Reference to literature.

The annex in this table contain the events that are considered relevant for the area of interest.

First World War mobilization and interbellum, 1914-1939

The First World War forced the armed forces of many nations to mobilize. Coastal guns were installed to protect strategic positions on the coast. Furthermore, shipping took considerable damage from mine and U-vessel warfare. Dozens of merchant vessels were sunk by the thousands of mines laid by the German and British navies. Large scale efforts to clear the minefields after the First World War did not succeed in clearing all these mines. The following literature is relevant for this period:

Date / year	Event	Source	Page
1914-1918	British, German and American mines laid during the war. The German minefields are in black, whereas the Allied fields are shaded. The underlined figures are numbers of Allied mines, and other figures are numbers of German mines. With their vastly greater resources, the Allies laid far more mines in the latter part of the war placing them strategically where they would effectively trap the maximum numbers of U-vessels. German mines were placed mainly close to headlands where ships would make landfalls and around the approach to major ports. From 1916 onwards, most of the German mines were laid by submarines, whereas the Allies were able to use surface ships, especially fast destroyer-minelayers, to operate close to enemy coasts. The chart gives an idea of how dangerous mine laying and minesweeping operations were as both enemy and friendly mines might be laid in the same areas. *Hatched areas in the figure below indicate allied minefields, solid areas indicate German minefields. No minefields are shown within the area of interest.*	CRO	55, 62

Date / year	Event	Source	Page
	 		
1918	Mines, of course, remain deadly irrespective of peace treaties or armistices. No fewer than 240,000 mines were scattered about the seas, some in their original position, some having dragged their moorings and settled in a new location, and some drifting freely. These constituted a major danger to shipping after the end of the war. To clear them up an international committee was formed, which included most belligerent and neutral countries, and was eventually joined by the defeated powers. This was called the International Mine Clearance Committee (IMCC) and was organized principally by the Royal Navy. All members carried out mine clearance activities and reported regularly to the IMCC, who issued regular charts and updates showing safe areas and known danger zones. The main part of the clearance work was divided between the maritime nations, Germany being responsible for sweeping Heligoland Bight, France the waters off the French and Belgian coasts, America the Northern Barrage and the UK, most of the rest, working through a new organization called the Mine Clearance Service. The service	CRO	149-160

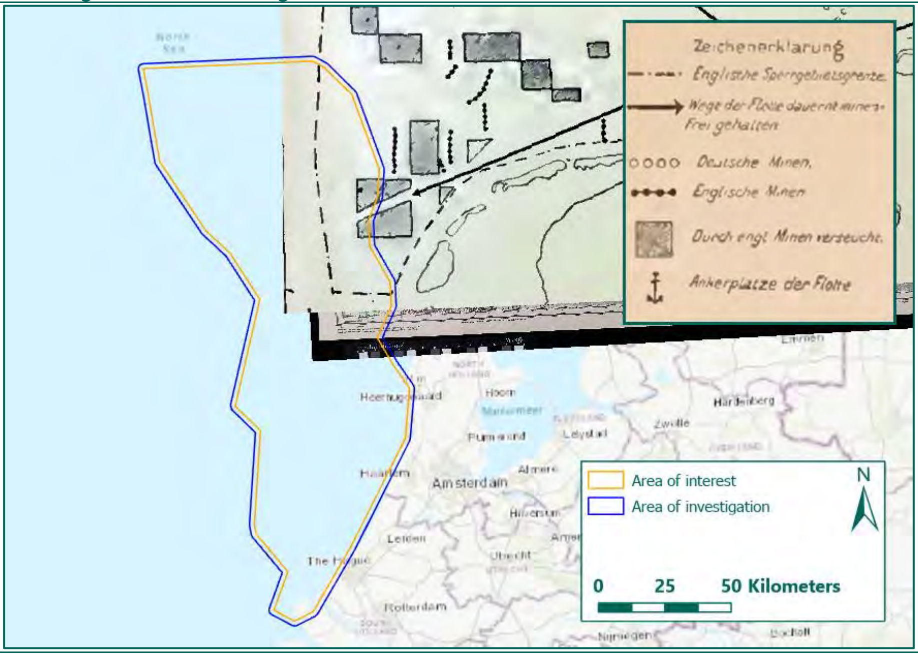
Date / year	Event	Source	Page
	was manned mainly by Royal Navy personnel and fishermen and consisted of 14,500 men and 700 officers at its peak. A particular danger when clearing dense fields was what was known as 'counter mining'. This occurred when exploding one mine would set off others in the vicinity – possibly dangerously close to the sweeper involved. Normally, deep minefields were left until last, as they did not constitute a serious danger to shipping, but sometimes some of the mines were laid incorrectly and finished up close to the surface. It was determined to skim of any of these shallow mines first, and the sweep began in the normal way. The intensive mining of the eastern North Sea also affected the German Navy to such an extent that it could not even undertake exercises safely, the British offensive mining campaign contributed to the collapse of fleet discipline and hence to the popular revolt against the Kaiser's government, which resulted in the Armistice.		
		SCH	288

Table 5: Overview of events World War 1 – Interbellum.

German invasion and subsequent occupation, 1939-1945 and Post-war period

When the inevitability of the Second World War became clear in August 1939, the allied and non-aligned armies of the countries surrounding Germany once again mobilized to prepare for an imminent attack. While serious naval threats were not foreseen, preparations also took place on the coast and the sea. Coastal guns were once again installed, and vital waterways were mined.

The North Sea became the frontline between Great-Britain and occupied mainland Europe. Fast attack craft from the Royal Navy coastal forces attacked German shipping close to the coast and laid mines to further hamper German navigation of the North Sea. Patrolling allied aircraft attacked convoys, submarines and surface vessels with all possible means, while heavy bombers dropped even more mines in the waters around de occupied European Coast. To make matters worse, thousands of aircraft flew over the North Sea on route to targets in Germany, jettisoning their bombs in the sea when they encountered German fighters or anti-air guns.

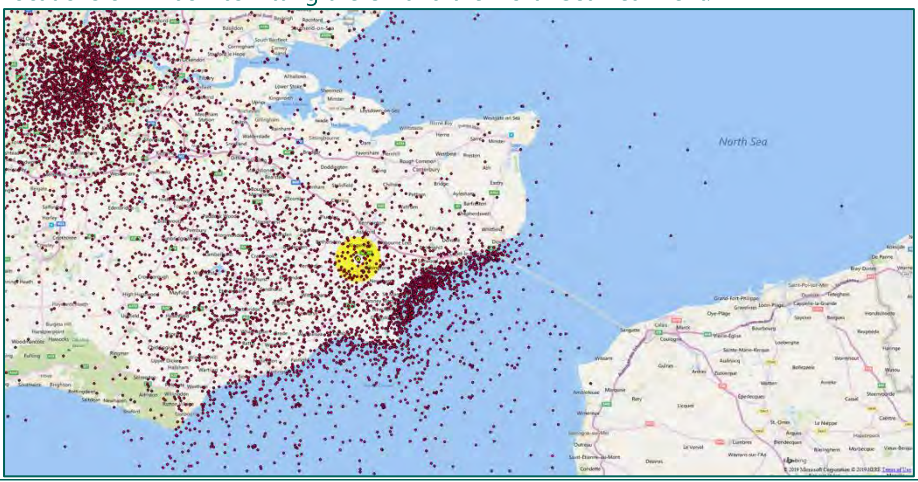
Immediately after the war, the reconstruction Europe began. Defensive works, bunkers and remaining UXO were cleaned up.

Literature about this period was not consulted for this report. The REASeuro-Database already contains a large quantity of sources about war related events within the North Sea. Moreover, consulting literature about this period is outside of the scope of this research.

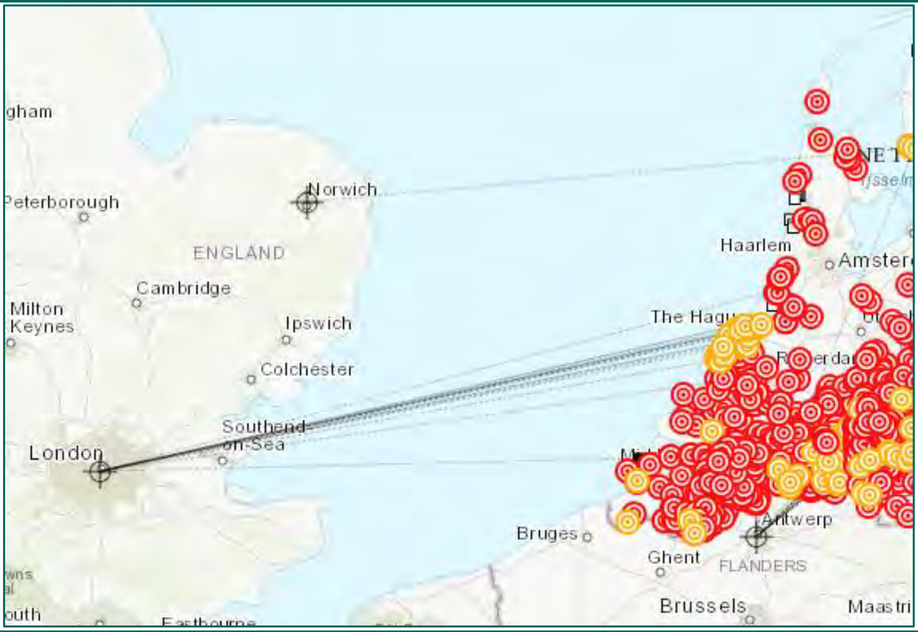
Some information about the locations of V1s and V2s was consulted:

<table>
<tr><th>Date / year</th><th>Event</th><th>Source</th><th>Page</th></tr>
<tr><td rowspan="3">1944-1945</td><td>V1 and V2 bombs hitting the UK

</td><td>V2</td><td>-</td></tr>
<tr><td>Locations of V1 bombs hitting the UK and the North Sea near Kent.



</td><td>AAS</td><td>-</td></tr>
<tr><td>V1s and V2s were also launched from the Netherlands to the UK. It is possible that bombs that did not reach the UK landed in the North Sea and possibly within the Area of interest.</td><td>VER</td><td>-</td></tr>
</table>

Date / year	Event	Source	Page
			

ANNEX 3 (INTERNATIONAL) ARCHIVES

Several international archives have been consulted in order to gain information on the war related events in the area of investigation. The REASeuro database contains a large quantity of documents from the British, American and German archives. The following international archives yielded relevant documents for this desk top study:

- Noordzeeloket, The Netherlands.
- Dienst der Hydrografie, Koninklijke Marine, The Netherlands
- Nationaal Archief, The Hague, The Netherlands
- Nederlands Instituut voor Militaire Historie, The Hague, The Netherlands
- Marinemuseum (Navy Museum), Den Helder, The Netherlands
- UK Hydrographic Office (UKHO), Taunton, Somerset, United Kingdom.
- Library of Congress (LOC), Washington D.C., United States.
- The National Archives (TNA) in London, United Kingdom.
- National Archives and Records Administration (NARA) in College Park (MD), United States.
- Bundesarchiv-Militärarchiv (BaMa) in Freiburg, Germany.

Noordzeeloket (NZL)

The Noordzeeloket is a comprehensive website, covering relevant Dutch maritime policy related North Sea information. On the Website relevant information about the locations of Voormalige munitiestortplaatsen (Former munitions dump locations), Oefengebieden Mijnenruimen (Mine clearance training areas), (Laag)vlieggebieden ((Low) flying areas) and Schietterrein / onveilige zone (Shooting site / unsafe area) is available

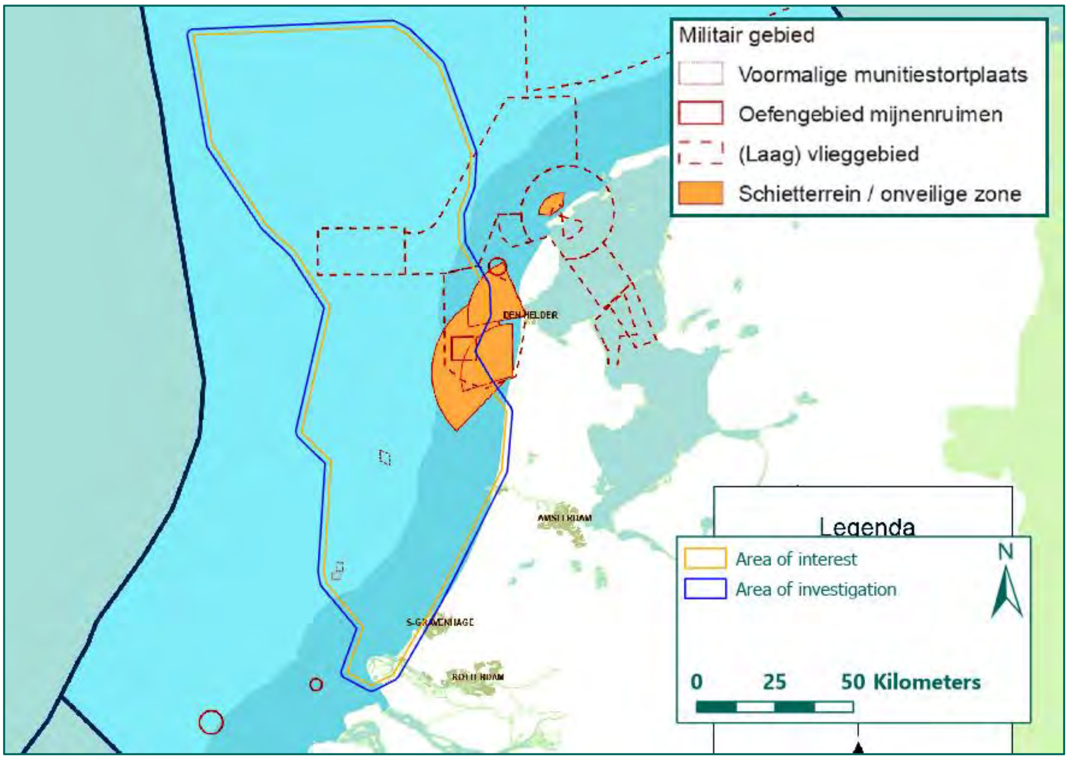


Figure 43: Map showing the military usage of parts of the North Sea (Source: NZL).

Dienst der Hydrografie, Koninklijke Marine (Royal Netherlands Navy Hydrographic service)

Naval charts of the area of analysis have been acquired through the Hydrographic Service. Besides naval charts the HP39 (wreck registry) publication has been consulted to gain information on possible wrecks in the area of investigation.

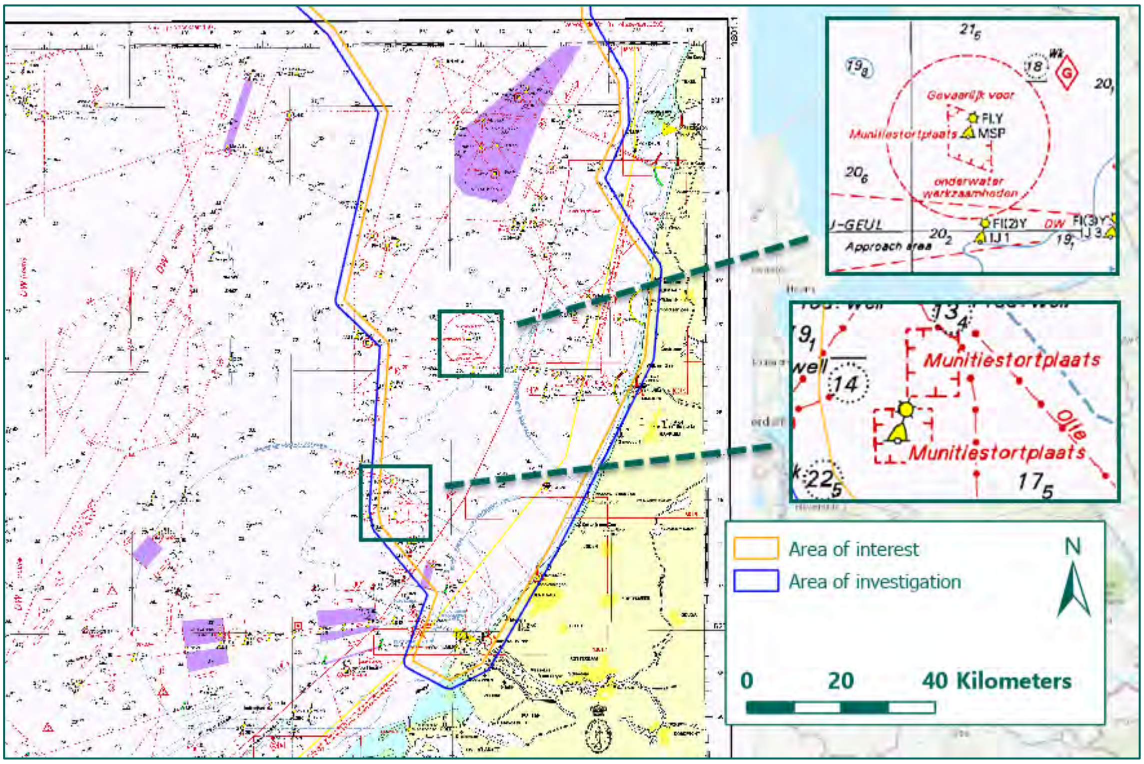


Figure 44: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

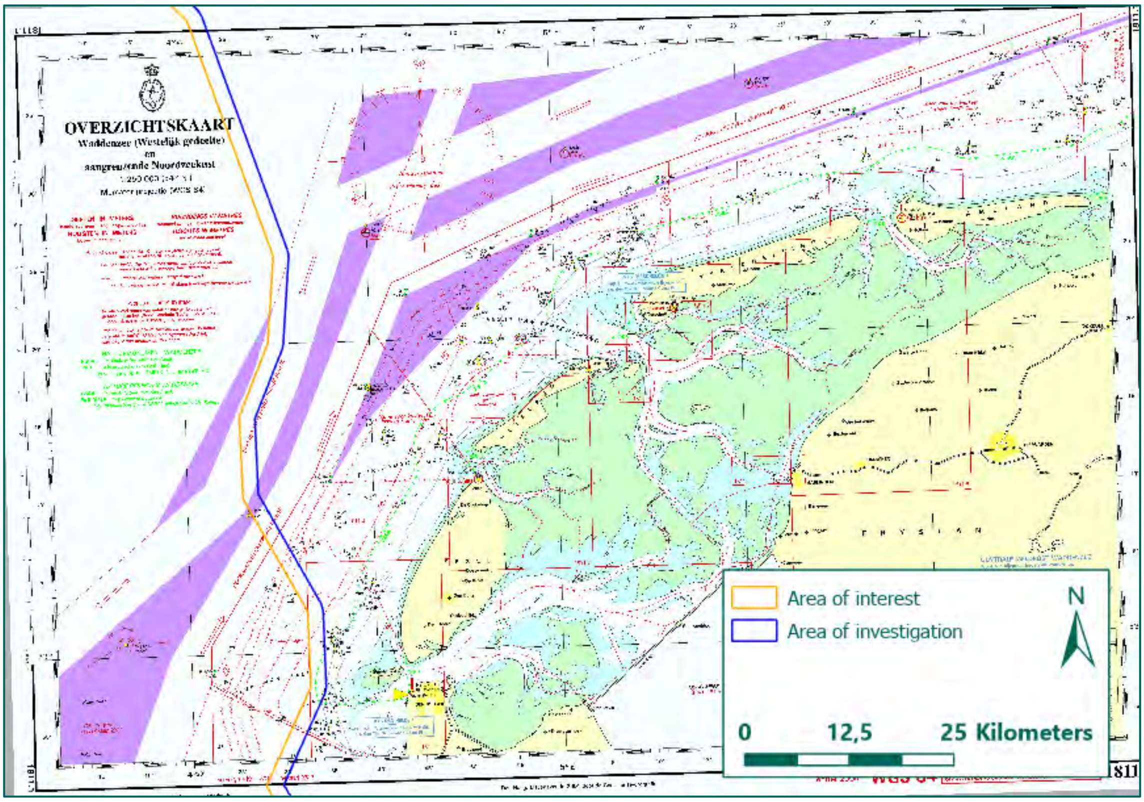


Figure 45: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

Nationaal Archief

The Dutch 'Nationaal Archief' (National Archives) has been consulted for more information on the dumping of explosives, naval minefields and minesweeping, shipwrecks and other relevant information for the area of investigation.

Toegang 2.12.18: Archief van de Koninklijke Marine: Chef van de Marinestaf te ''s-Gravenhage, 1886-1942	
Inventaris 162	Stukken betreffende verboden en gevaarlijke vaargebieden 1914-1939
Map showing area's that are 'gevaarlijk voor de visserij' (Dangerous for fishing activities):	

Onder verwijzing naar circulaire N°. 41 der Visscherij-Inspectie, vestigt de Hoofdinspecteur der Visscherijen de aandacht van belanghebbenden er op, dat vanaf 22 November 1917, het door Duitschland als gevaarlijk aangegeven gebied in de Noordzee, inzooverre is gewijzigd, dat als Oostgrens daarvan dient te worden aangenomen een lijn loopende van het einde der Nederlandsch-Belgische grens over het punt:

	51° 35′ N.B.	2° 57′ O.L.
naar	52° 2′ N.B.	3° 52′ O.L.
"	52° 28′ N.B.	4° 22′ O.L.
"	52° 40′ N.B.	4° 25′ O.L.
"	52° 40′ N.B.	3° 40′ O.L.
"	54° 45′ N.B.	3° 40′ O.L.
"	55° 10′ N.B.	4° 0′ O.L.
"	56° 0′ N.B.	4° 0′ O.L.
"	56° 0′ N.B.	4° 50′ O.L.

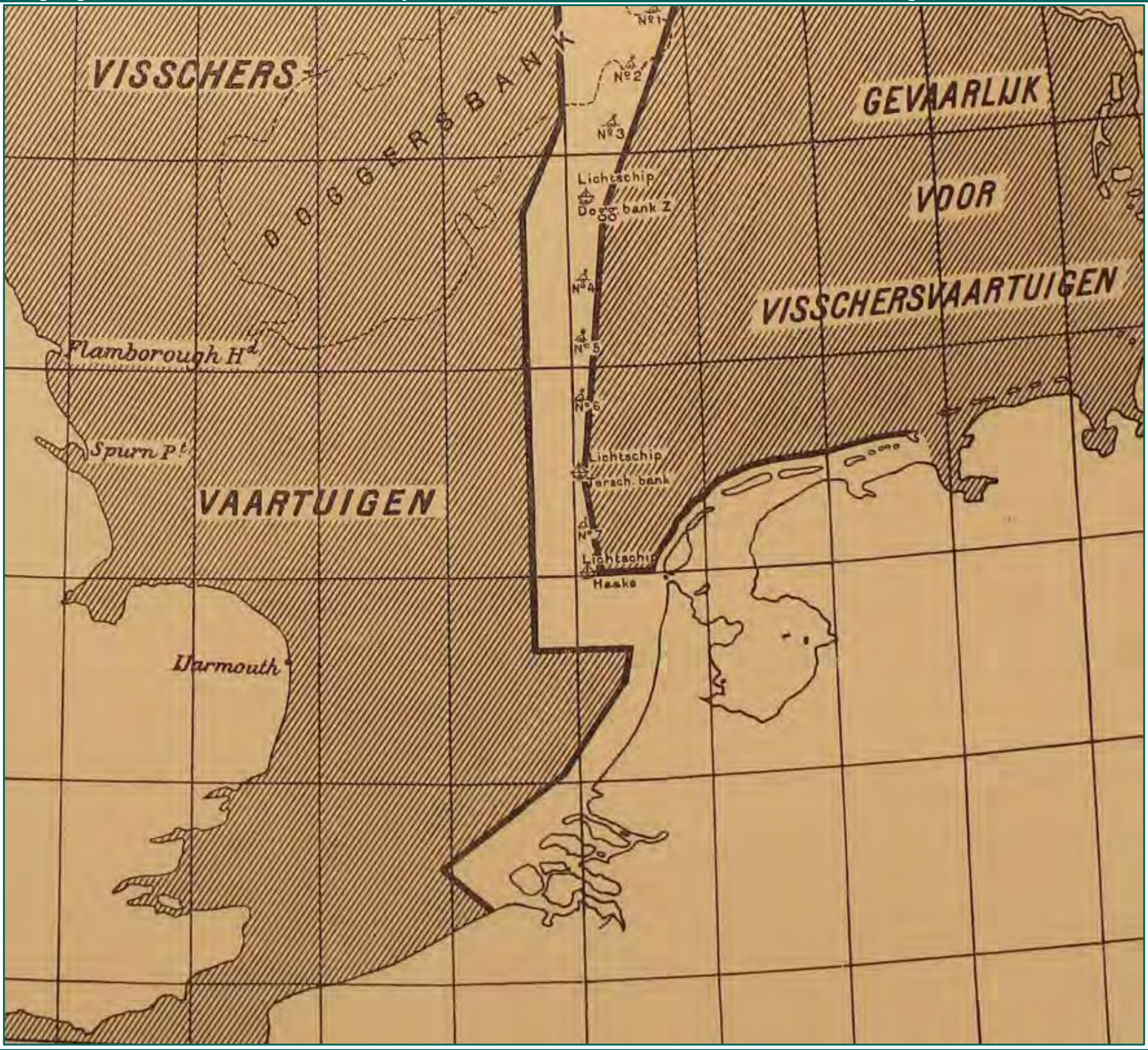
verder daarvandaan langs den lengtegraad 4° 50′ O. tot op een punt, dat 10 zeemijlen van den vuurtoren van Udsire af ligt.

Het thans voor de visscherij gevaarlijke gebied in de Noordzee, alsmede de ligging van lichtschepen en lichtbrulboeien, zijn op bijbehoorend kaartje aangegeven.

'S-GRAVENHAGE, 26 November 1917.

De Hoofdinspecteur voornoemd,
J. M. BOTTEMANNE.

Toegang 2.12.18: Archief van de Koninklijke Marine: Chef van de Marinestaf te ''s-Gravenhage, 1886-1942



Toegang 2.12.56: Marine na 1945

Inventaris 939	Vaststelling oefengebieden voor schietoefeningen. 1950-1975

Maps and information about Military training area's in the North Sea. Relevant maps and information regarding the area of investigation are shown below:

Training Ground Aircraft:

Toegang 2.12.56: Marine na 1945

B e p a a l t:

dat de navolgende gebieden, voorzover zij vallen onder het gebied des Rijks, gesloten worden verklaard voor de luchtvaart, en voorzover zij niet vallen onder het gebied des Rijks, worden bekend gesteld als terrein, waar regelmatig militaire schiet-oefeningen worden gehouden.

1. het luchtgebied gelegen binnen de volgende hoekpunten tot op een hoogte van 1000 m

$\frac{52^\circ - 05' \text{ N},}{03^\circ - 40' \text{ E}}$ $\frac{52^\circ - 25' \text{ N},}{04^\circ - 00' \text{ E}}$ $\frac{52^\circ - 10' \text{ N},}{03^\circ - 25' \text{ E}}$ $\frac{52^\circ - 30' \text{ N}}{03^\circ - 25' \text{ E}}$

Training Ground Cruisers

Ingevolge Uw telefonisch verzoek hierbij de dzz. voorgestelde onveilige gebieden i.v.m.schietoefeningen,nabij den Helder.

1. Kruiseroefenterrein
tussen meridianen $4^\circ - 16' - 20''$ en $4^\circ - 26' - 40''$
en parallellen $52^\circ - 52' - 0''$ en $53^\circ - 4' - 40''$

2. Vanaf Oostbatterij,sector tussen peilingen 276° en 308° tot afstand 6 mijl.

3. Erfprins vanaf Kaap Hoofd sector tussen peilingen 260° en 340° tot afstand 8 mijl.

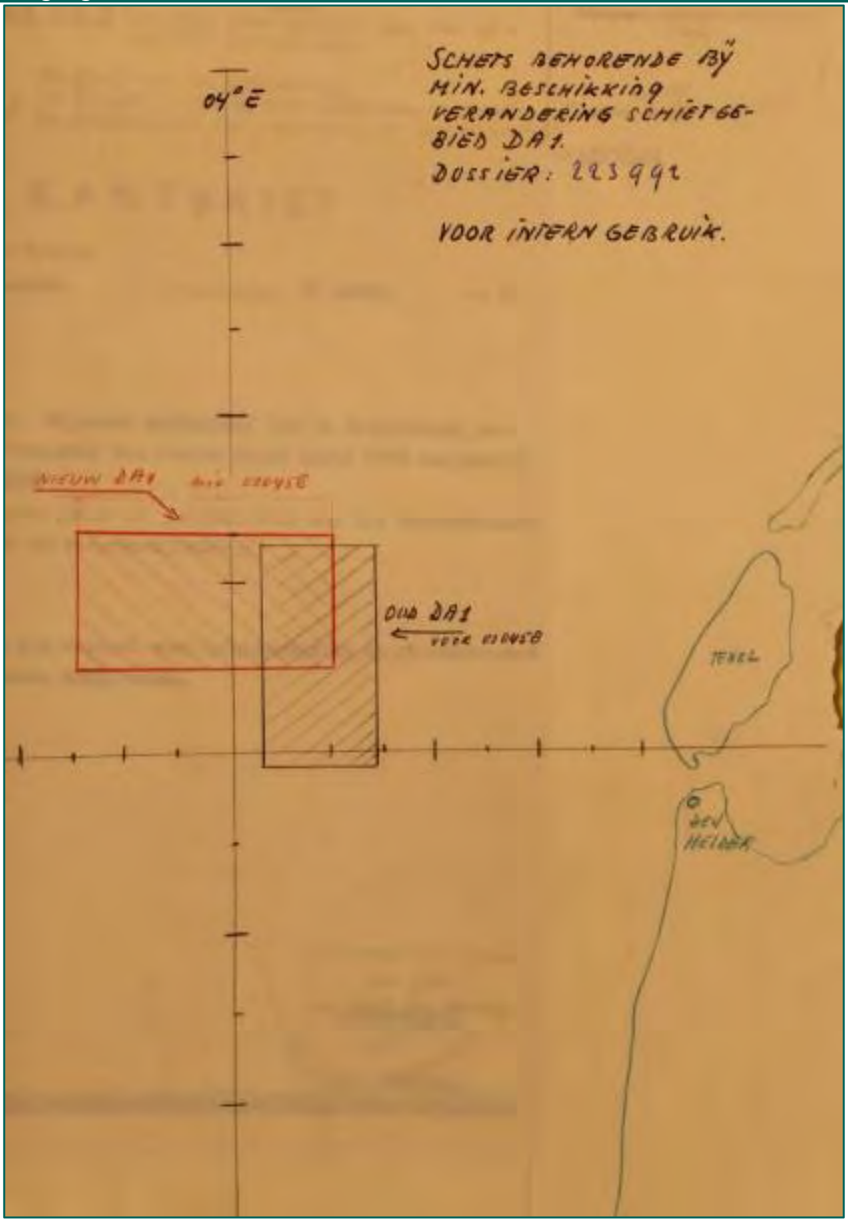
4. L.A.Schietoefeningen omgeving Haaks met gebruik "Stereomatr[illegible]lage Erfprins.
Gebied begrensd door Kaap Hoofd naar

$\frac{52^\circ - 52' \text{ N}}{4^\circ - 40' \text{ E}}$ naar $\frac{52 - 52 \text{ N}}{4^\circ - 52' \text{E}}$ naar $\frac{52 - 56 \text{ N}}{4^\circ - 28' \text{E}}$

naar $\frac{53^\circ - 0' \text{ N}}{4^\circ - 28' \text{E}}$ naar $\frac{53^\circ - 4' \text{ N}}{4 - 32' \text{ E}}$ naar $\frac{53^\circ - 4' \text{ N}}{4^\circ - 40' \text{ E}}$

naar Kaap Hoofd.

Old en new site of DA1:



Training Grounds in the North Sea:

Besluiten:

I.1. In de hieronder nader omschreven gebieden zijn de Commandant der Zeemacht in Nederland, de Chef van de Generale Staf en de Chef van de Luchtmachtstaf, ieder voor zover hem aangaat, bevoegd om in overleg met de Directeur Generaal van de Rijksluchtvaartdienst de uitoefening van de burgerlijke luchtvaart in verband met militaire oefeningen te beperken dan wel geheel te verbieden.

<u>DA 1 (Den Helder I)</u>

Het gebied, begrensd door een lijn, welke de volgende posities verbindt:
53.05.00 N — 03.45.00 O; 53.13.00 N — 03.45.00 O;
53.13.00 N — 04.10.00 O; 53.05.00 N — 04.10.00 O,
tot een hoogte van 9150 meter.

Toegang 2.12.56: Marine na 1945

DA 2 (Den Helder II)

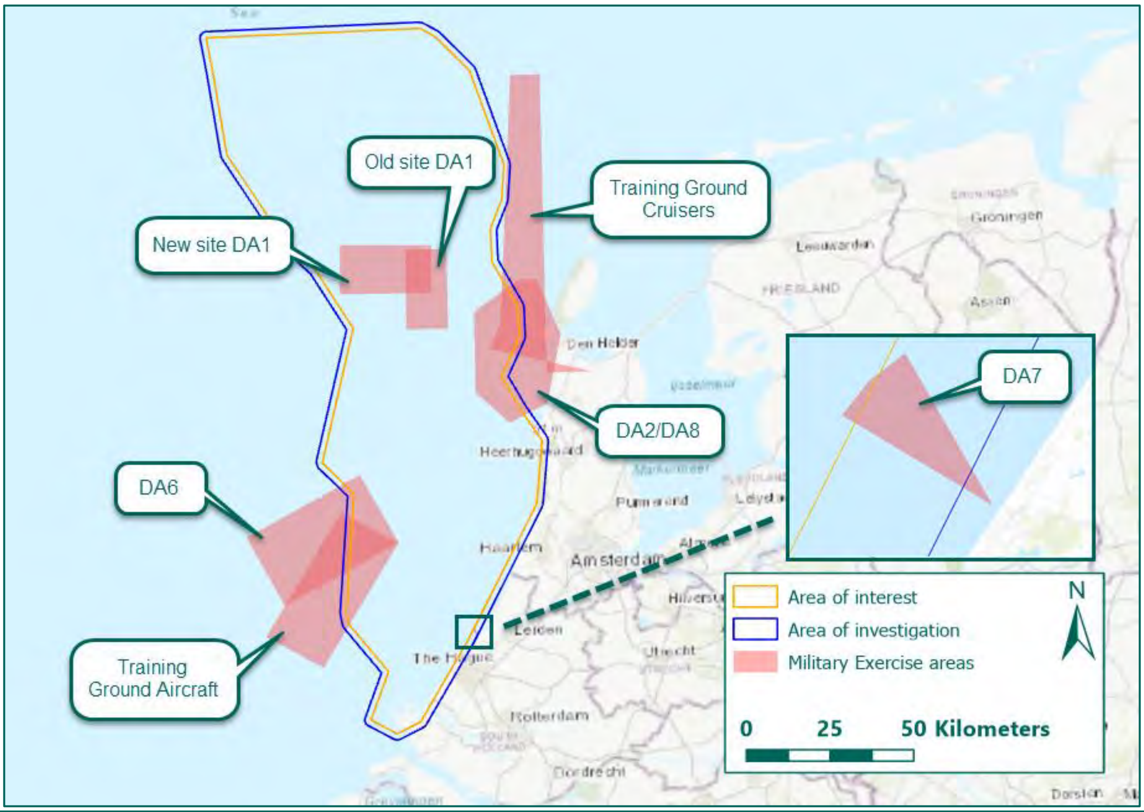
Het gebied, begrensd door een lijn, welke de volgende posities verbindt:
52.58.00 N — 04.44.00 O; 52.47.00 N — 04.40.00 O;
52.44.00 N — 04.30.00 O; 52.49.00 N — 04.21.00 O;
53.02.00 N — 04.21.00 O; 53.07.00 N — 04.33.00 O en
53.07.00 N — 04.38.00 O,
tot een hoogte van 10.000 meter.

DA 6 (Noordzee)

Het gebied, begrensd door een lijn, welke de volgende posities verbindt:
52.26.00 N — 03.20.00 O; 52.36.00 N —03.50.00 O;
52.25.00 N — 04.00.00 O; 52.15.00 N —03.30.00 O,
tot een grootste hoogte van 900 meter.

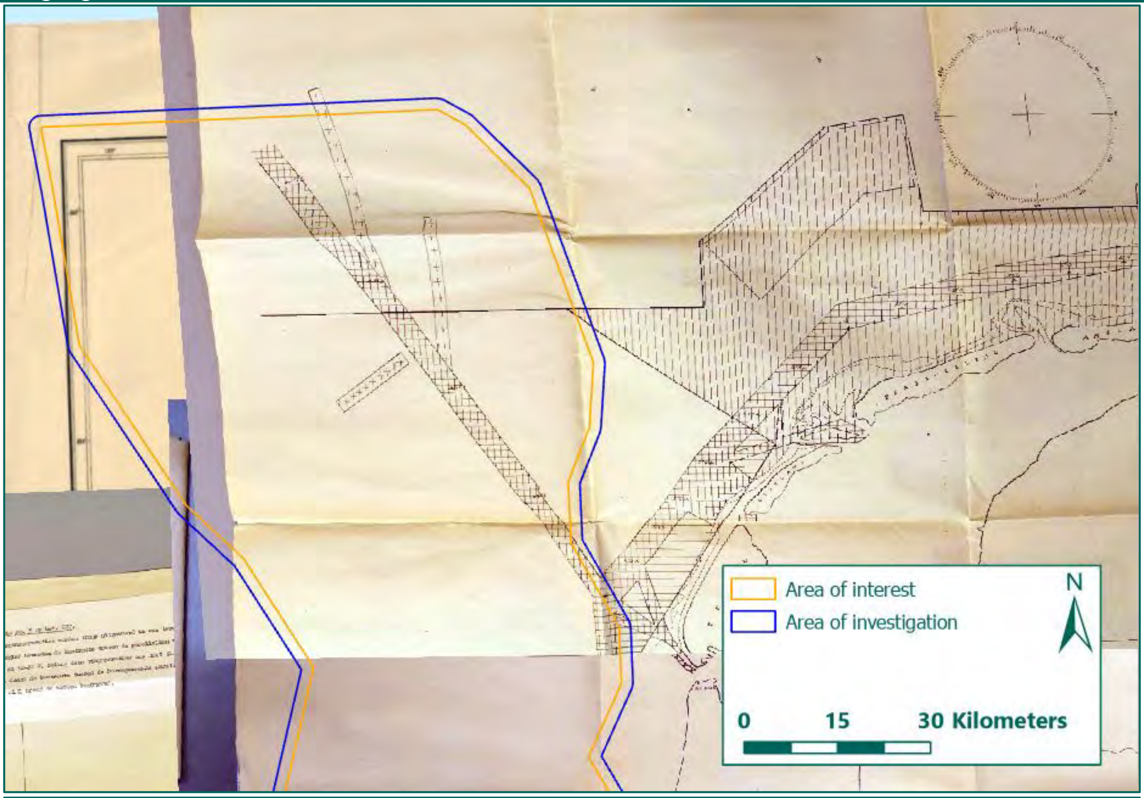
DA 7 (Wassenaarse slag)

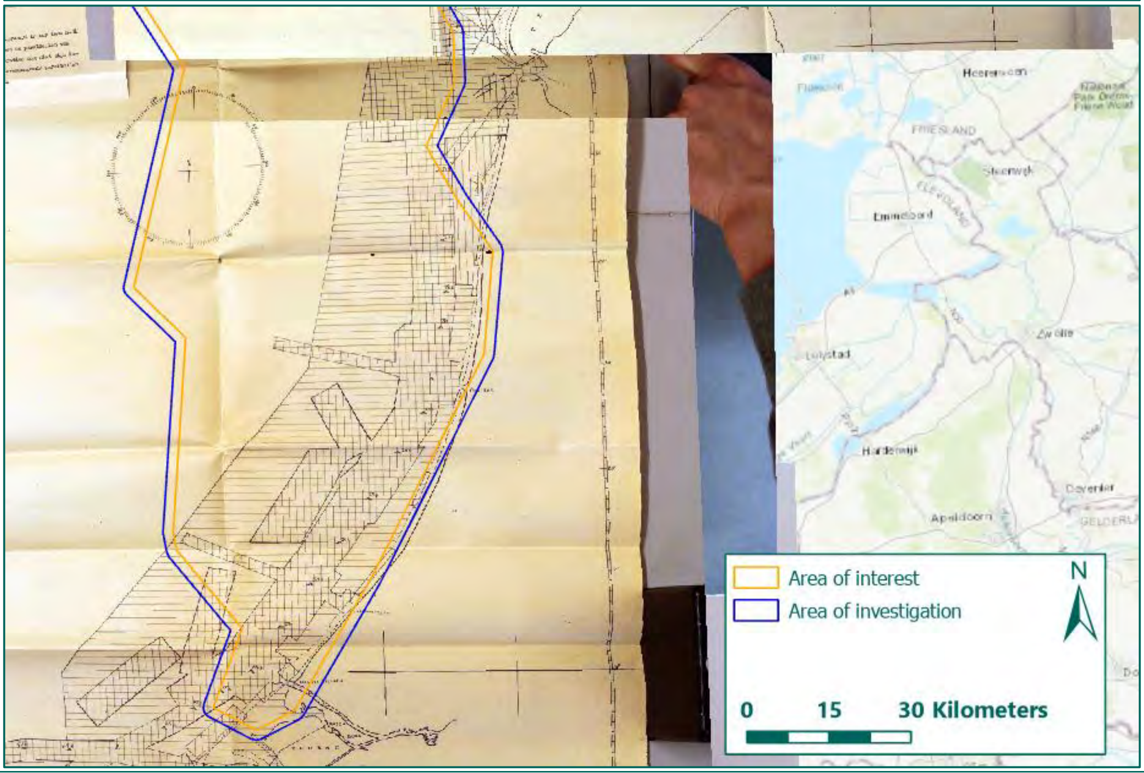
Een sector uit de positie 52.09.48 N — 04.20.45 O, in de richting 300° rechtwijzend door 315° naar 330° rechtwijzend, met een straal van 1,4 zeemijlen, tot een hoogte van 500 meter.



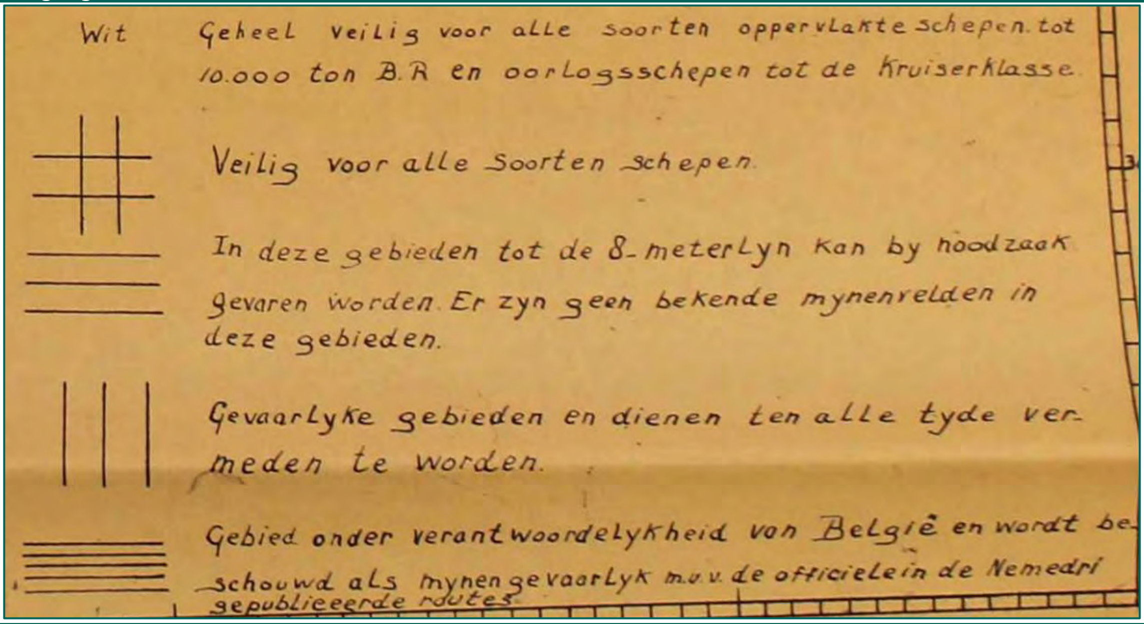
Inventaris 1882	Situatiekaarten van mijnen voor de Nederlandse kust. 1949-1950

Toegang 2.12.56: Marine na 1945



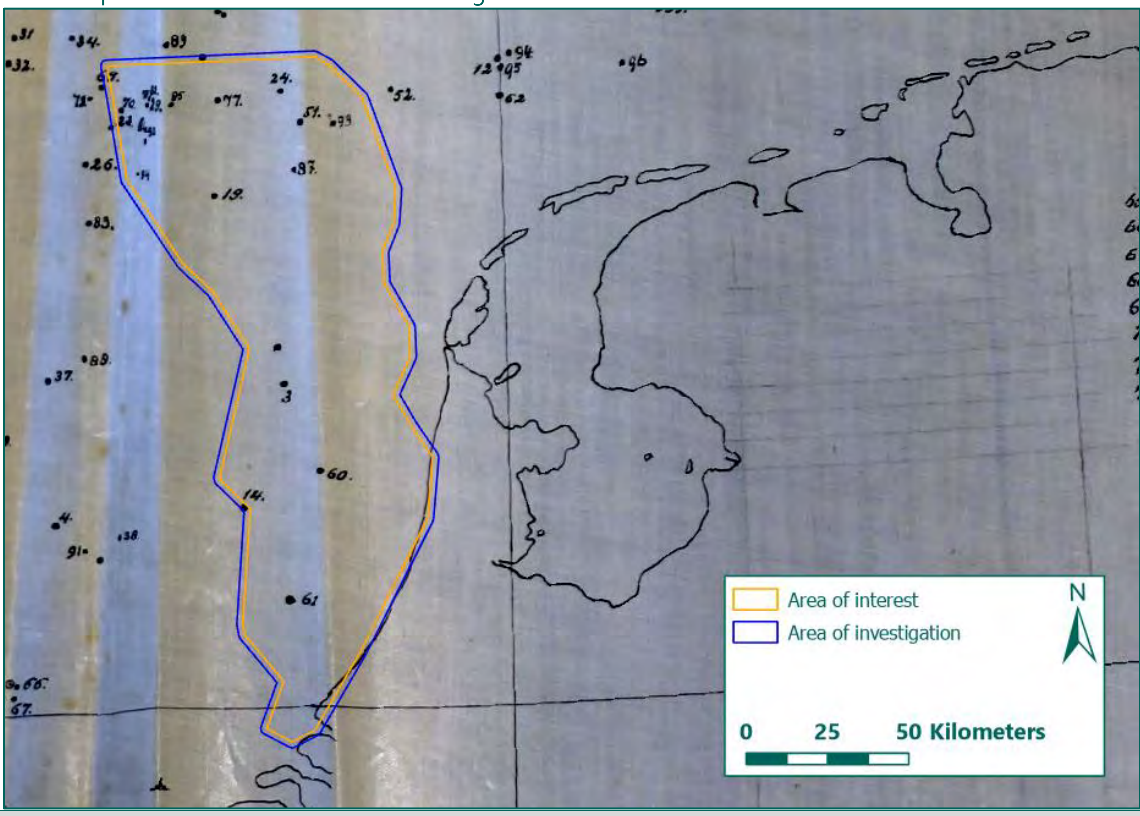


Toegang 2.12.56: Marine na 1945



Toegang 2.05.32.09 BuZa/Zeeoorlogschade	
Inventaris 44	Kaart van de Noordzee met opgave van de plaatsen waar verankerde mijnen lagen, waarop Nederlandse schepen zijn gevaren in de jaren 1914-1916, op linnen, zonder datum

Dutch ships sunk due to contact mines during WW1



Nederlands Instituut voor Militaire Historie (NIMH)

The NIMH is a knowledge and research centre in the field of Dutch military history. The institute houses, amongs others, information about Dutch minefields in the North Sea. Some minefields were laid within the area of investigation.

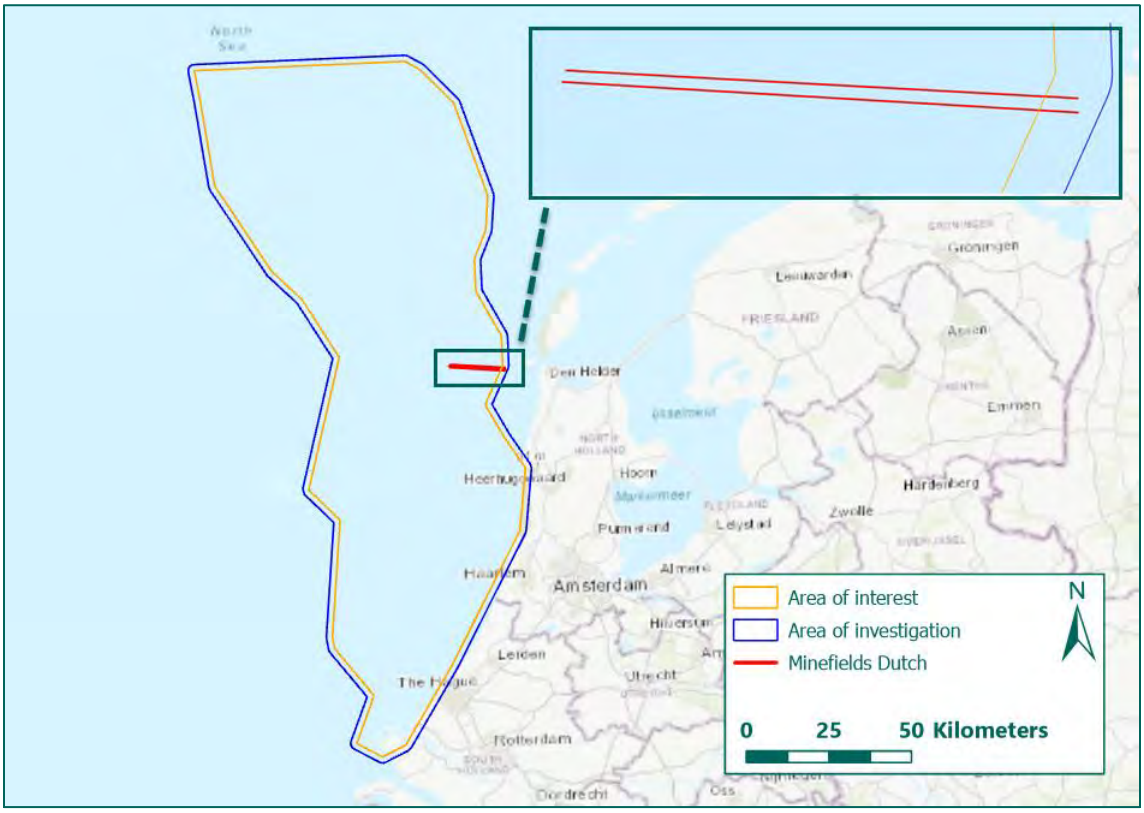
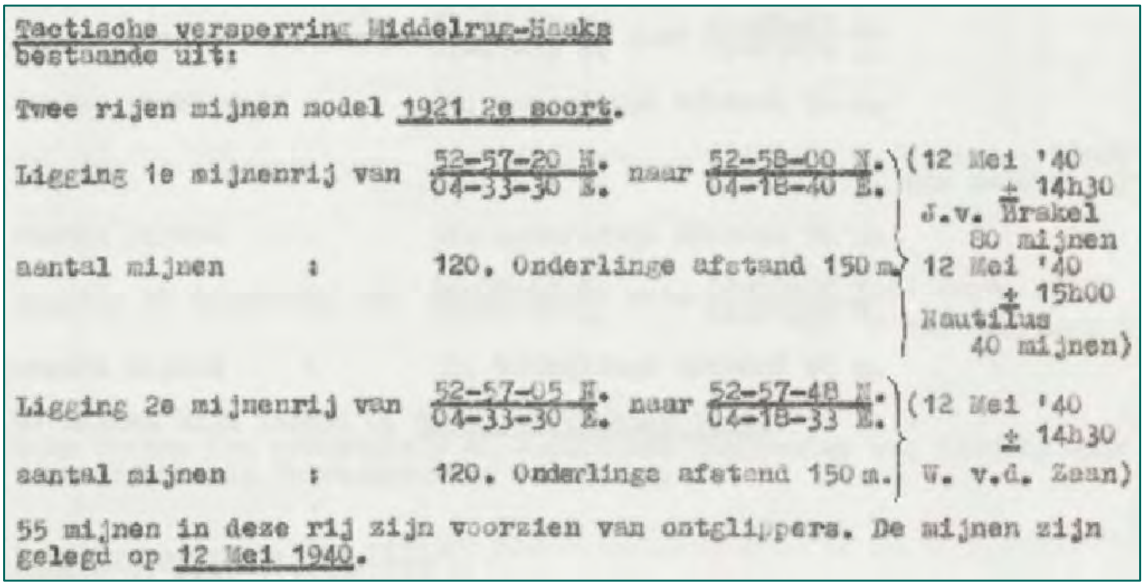


Figure 46: Dutch minefields within the Area of investigation (Source: NIMH 092).



Tactische versperring Middelrug-Haaks
bestaande uit:

Twee rijen mijnen model 1921 2e soort.

Ligging 1e mijnenrij van 52-57-20 N. / 04-33-30 E. naar 52-58-00 N. / 04-18-40 E. (12 Mei '40 ± 14h30 J.v. Brakel 80 mijnen

aantal mijnen : 120. Onderlinge afstand 150 m. 12 Mei '40 ± 15h00 Nautilus 40 mijnen)

Ligging 2e mijnenrij van 52-57-05 N. / 04-33-30 E. naar 52-57-48 N. / 04-18-33 E. (12 Mei '40 ± 14h30

aantal mijnen : 120. Onderlinge afstand 150 m. W. v.d. Zaan)

55 mijnen in deze rij zijn voorzien van ontglippers. De mijnen zijn gelegd op 12 Mei 1940.

Figure 47: information about relevant Dutch minefields (Source: NIMH 092).

Marinemuseum (Navy Museum), Den Helder

The map collection of the Marinemuseum (Navy Museum) in Den Helder has been consulted. NEMEDRI-maps were found in this collection. These maps offer information on minesweeping after the Second World War. The NEMEDRI maps show some locations some 'geveegde geulen' (shipping route in which minesweeping took place) within the area of investigation shortly after the war. The area of investigation is consequently shown in a ubiquitous Danger Area, owing to naval mines.

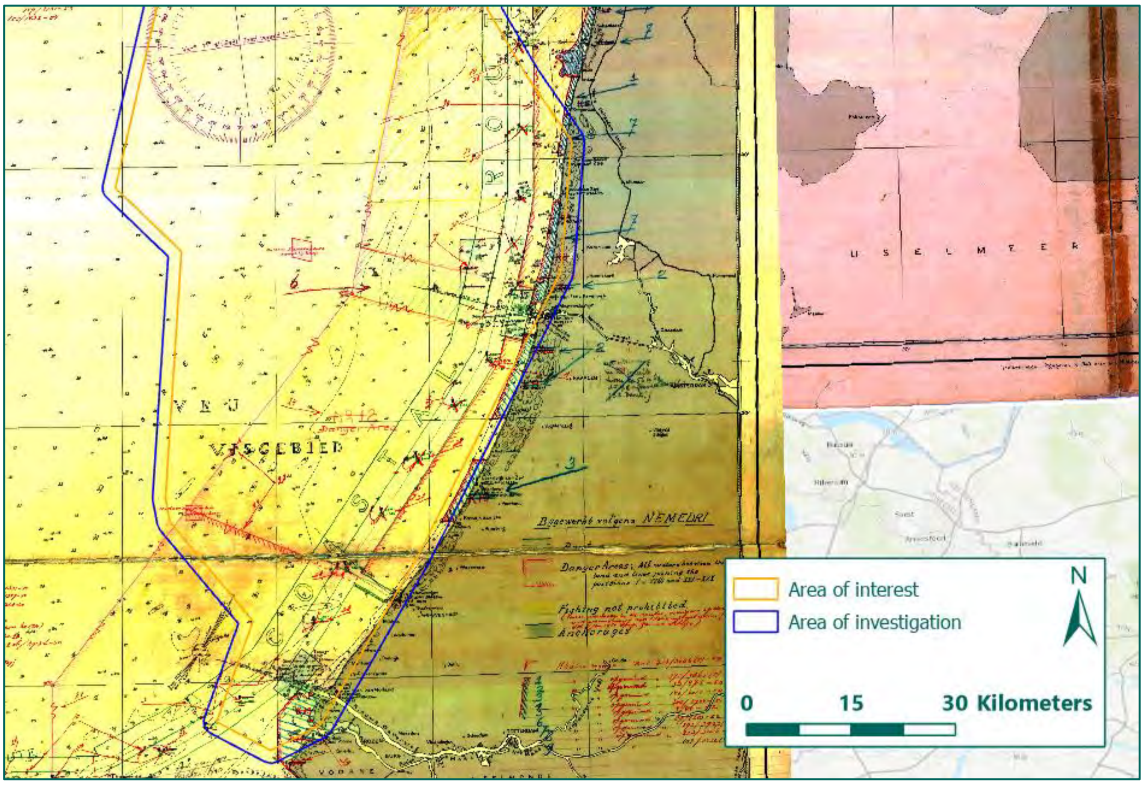


Figure 48: Map offer information on minesweeping after the Second World War (Source: Navy Museum NEMEDRI 227 West-Hinder tot Texel).

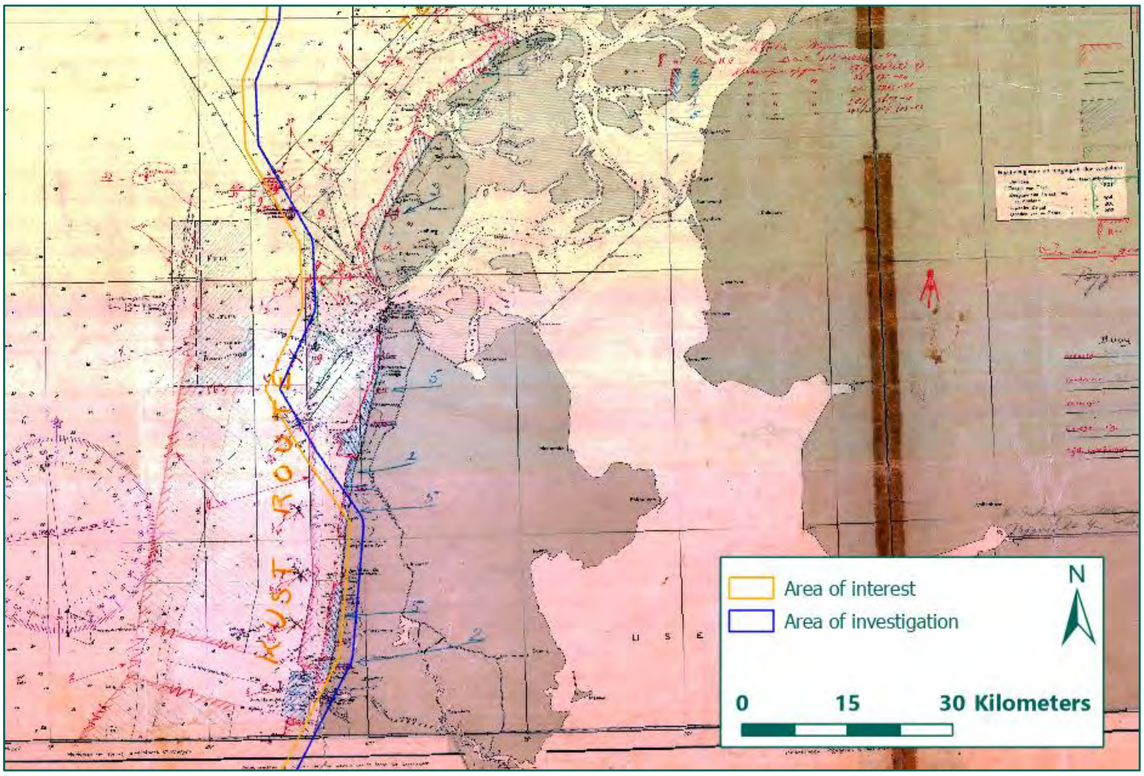


Figure 49: Map offer information on minesweeping after the Second World War (Source: Navy Museum NEMEDRI 226 IJmuiden tot de Weser).

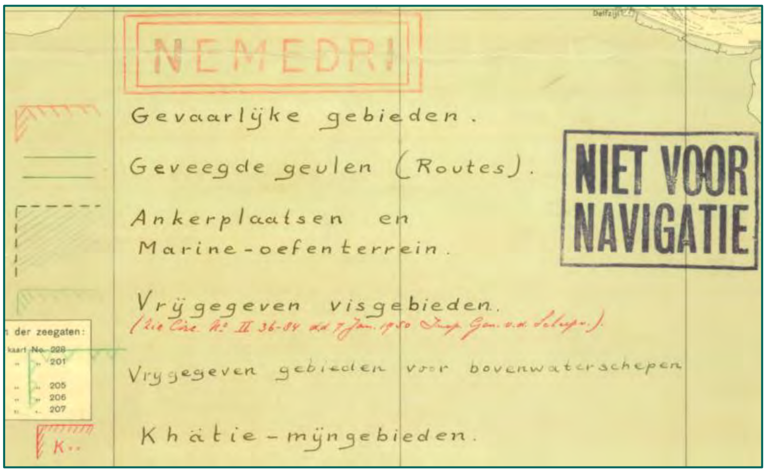


Figure 50: Legend of NEMERDI maps (Source: Navy Museum NEMEDRI 226 IJmuiden tot de Weser).

UK Hydrographic Office (UKHO)

The UK Hydrographic Office has a large amount of historical, maritime maps. This collection also includes maps showing the locations of minefields and shipping routes. These maps have been consulted.

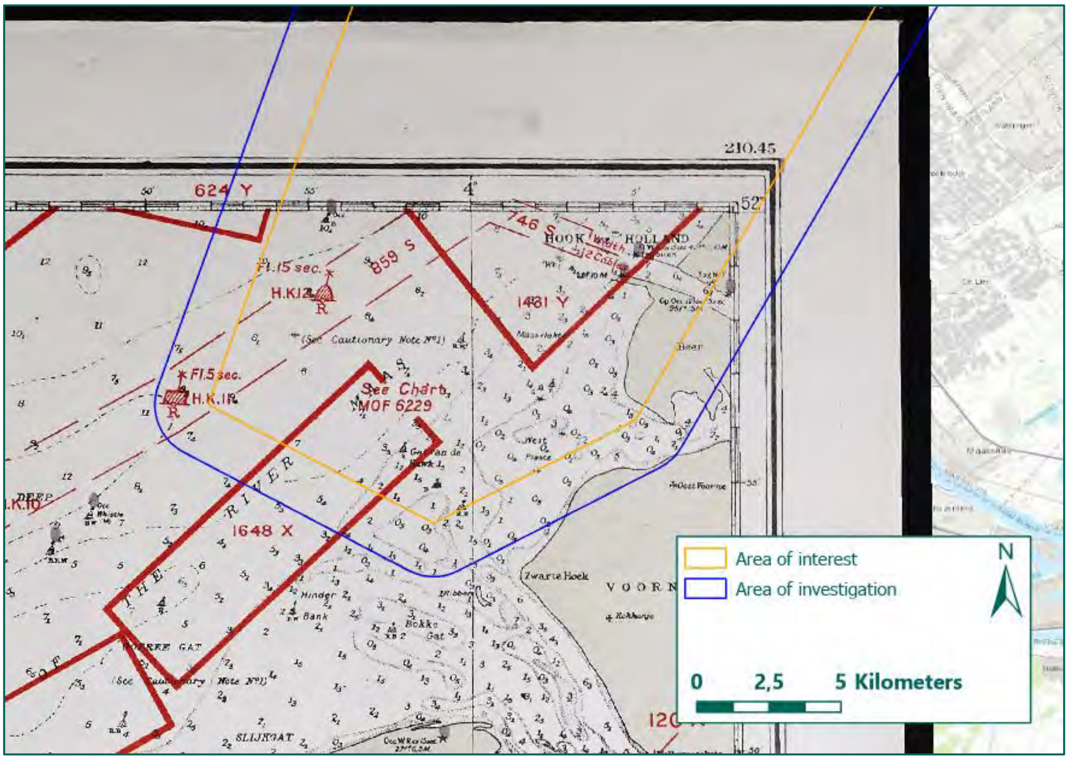


Figure 51: OCB MO F6550 Dunkerque to Hook of Holland, 1945. The red squares indicate minefields (Source: UKHO, Shelf 35).

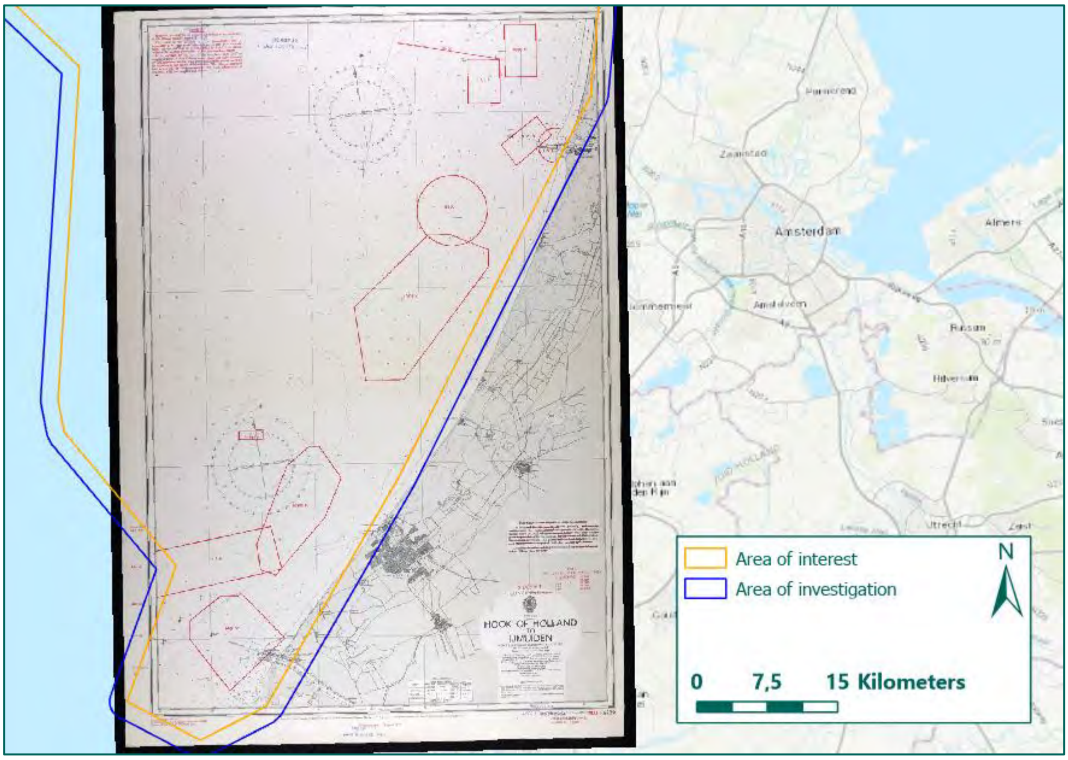


Figure 52: OCB MO F6229 Hook of Holland 1944. The red squares indicate minefields (Source: UKHO, Shelf 35).

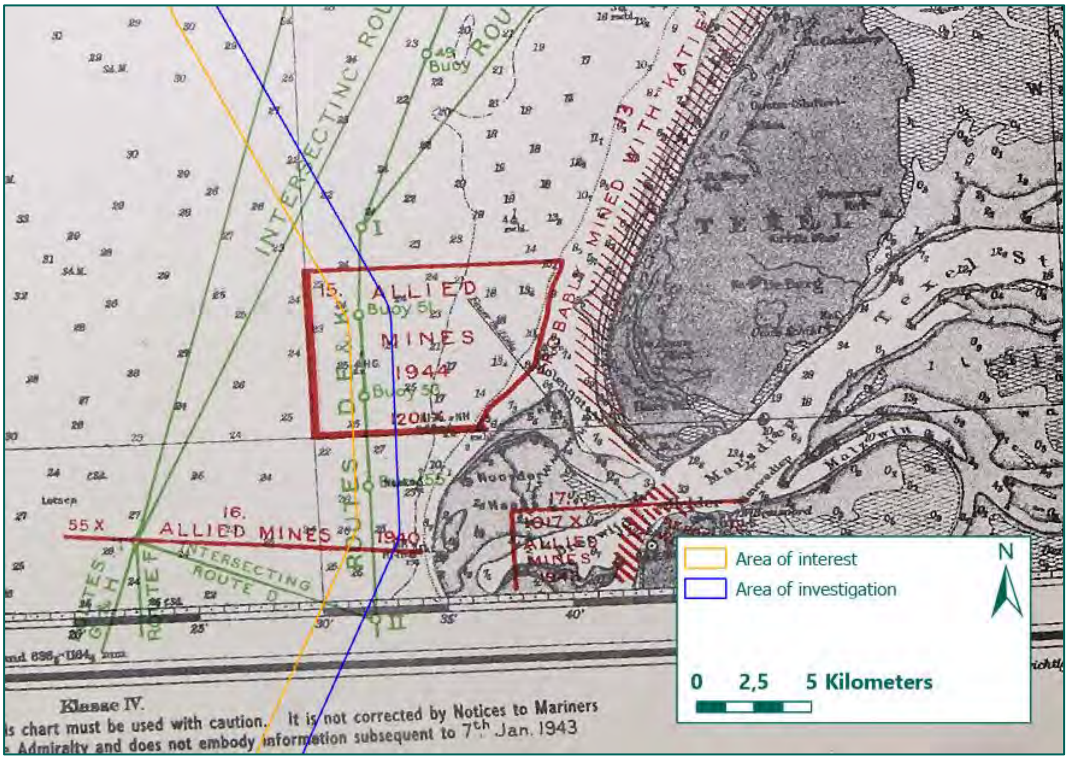


Figure 53: OCB MO 6590 Texel Bis Cuxhaven 1945. The red squares indicate minefields, green lines indicate convoy routes (Source: UKHO, Shelf 35).

Library of Congress

Library of Congress (LOC) has been consulted. Several maps about the First World War have been consulted in the LOC. Relevant maps are shown below.

Figure 54: locations of sunken ships due to submarine attacks between 1 February 1917 – 1 February 1918 (Source basemap: LOC).

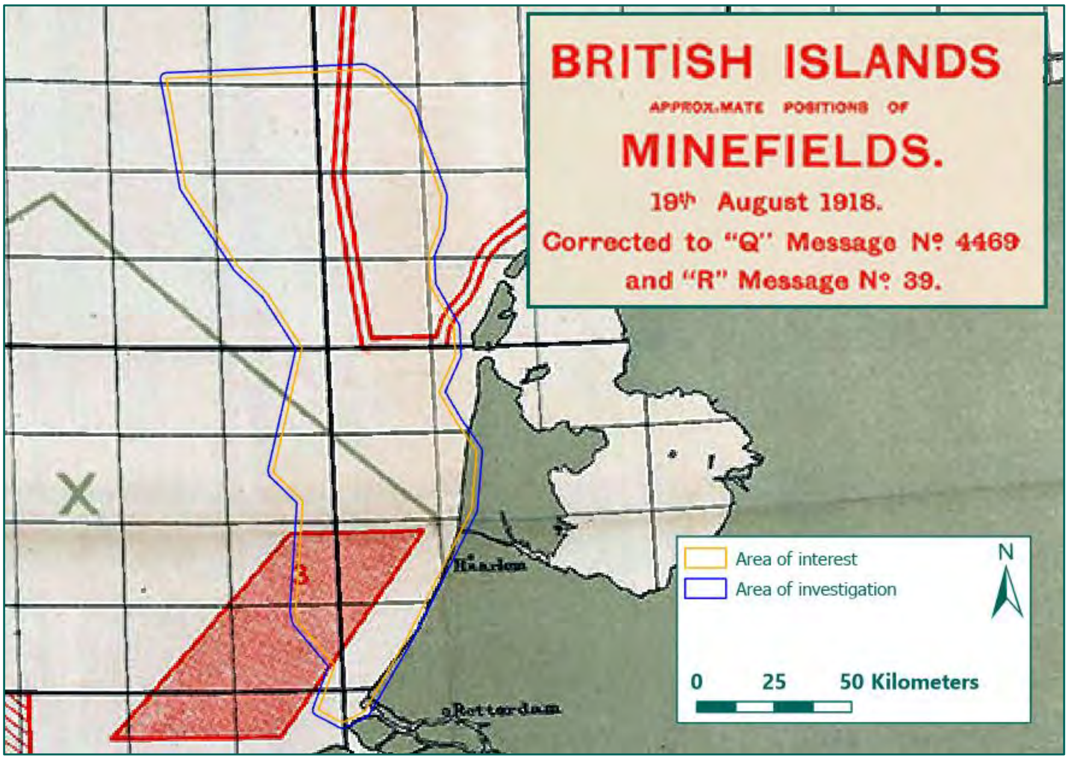


Figure 55: Minefields in the North Sea during 19 August 1918 (Source basemap: LOC).

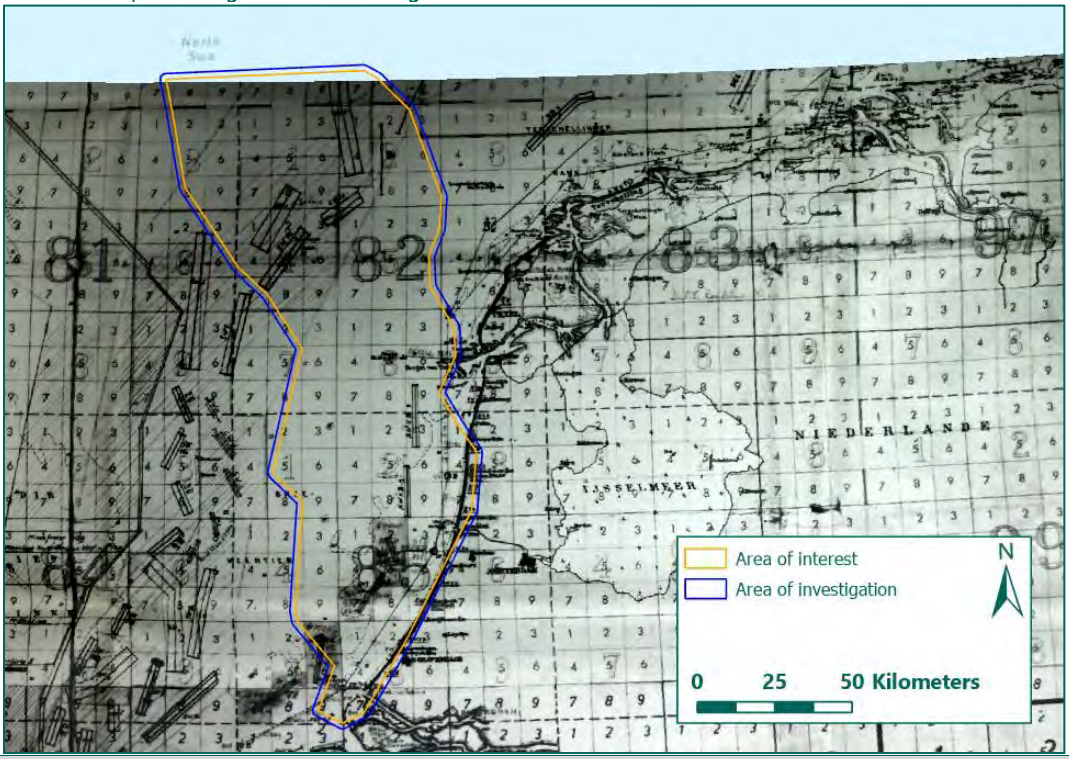
The National Archives

The National Archives (TNA) have been consulted for more information on maritime and aerial warfare in the area of investigation. This annex contains relevant information from TNA. Information regarding maritime and aerial warfare is mentioned consecutively.

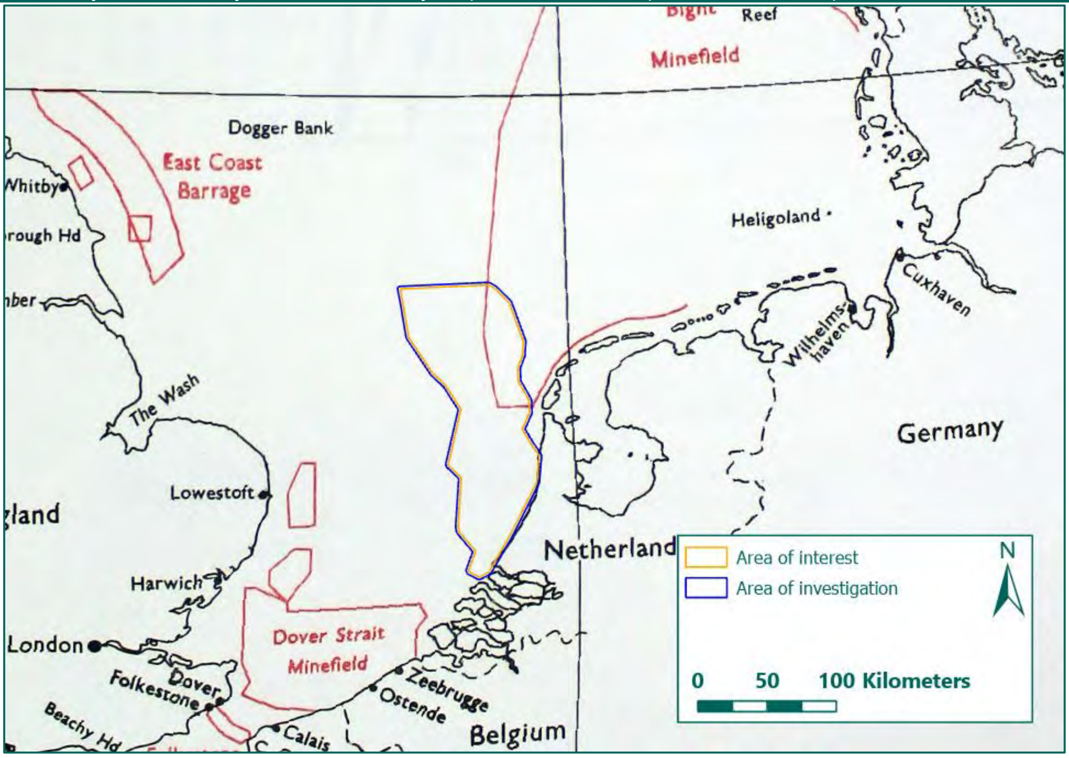
Admiralty series

The admiralty series (ADM) have been consulted for information concerning wrecks, naval combat, minefields and air strikes. Consulting these series yielded several files containing relevant information. These files are shown in the tables below.

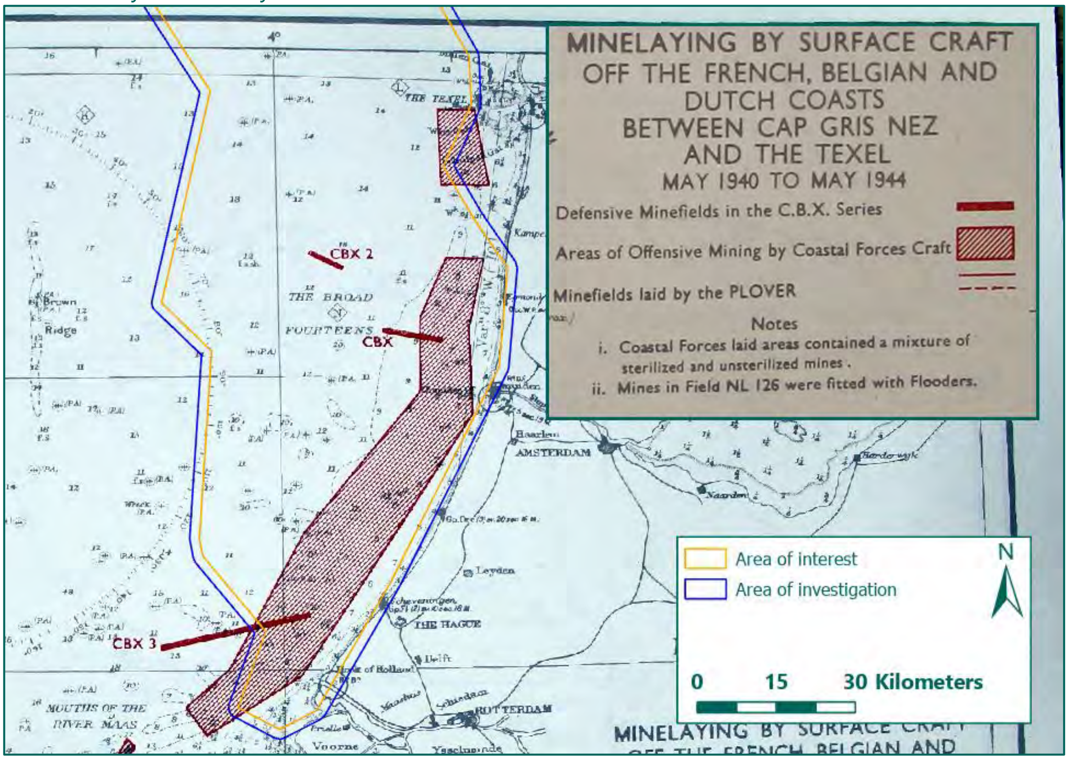
Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)	
ADM 1/18996	Results of British minelaying offensive.
General information about total amount of laid/dropped mines, 3rd September 1939 – 5th May 1945: MINES LAID IN ENEMY WATERS By Fast Minelayers and Destroyers 11,100 By M.T.Bs, M.Ls and M.G.Bs 6,450 By Submarines 3,000 By Aircraft 53,100 Total 73,650 Mines	
ADM 1/19745	Post-war mine clearance in European waters: first interim report of International Central Board. With charts, 1946-1947.
Relevant information: o Dangerous areas existing in March 1946.	

Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)	
	
ADM 199/154	British mining operations 1939-1945: Vol 1.
Relevant information: o Map showing minefields along the Dutch coast: 	
ADM 234/561	British mining operations 1939-1945: Vol 2.
Relevant information: o Map showing: British Minefields laid in the Chanel, North Sea and Kattegat 1914-1918. No minefields within area of interest.	

Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)

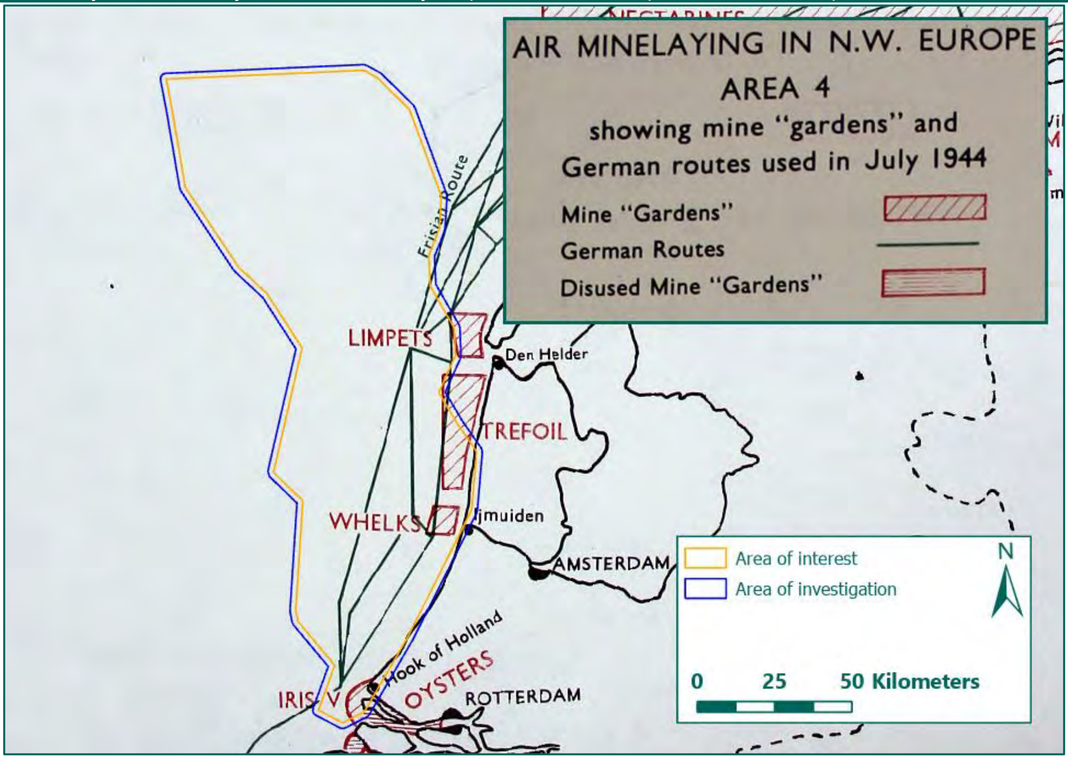


- Map showing:
  Minelaying by surface craft off the French, Belgian and Dutch Coasts between Cap Gris Nez and The Texel, May 1940 – May 1944:



- Map showing:
  Air Minelaying in NW Europe:

Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)



In ADM 234-560 it is stated that mines were laid within the Minefields limpets, Trefoil, Whelks, Iris V and Oyster:

AREA 4

ANALYSIS OF OPERATIONS

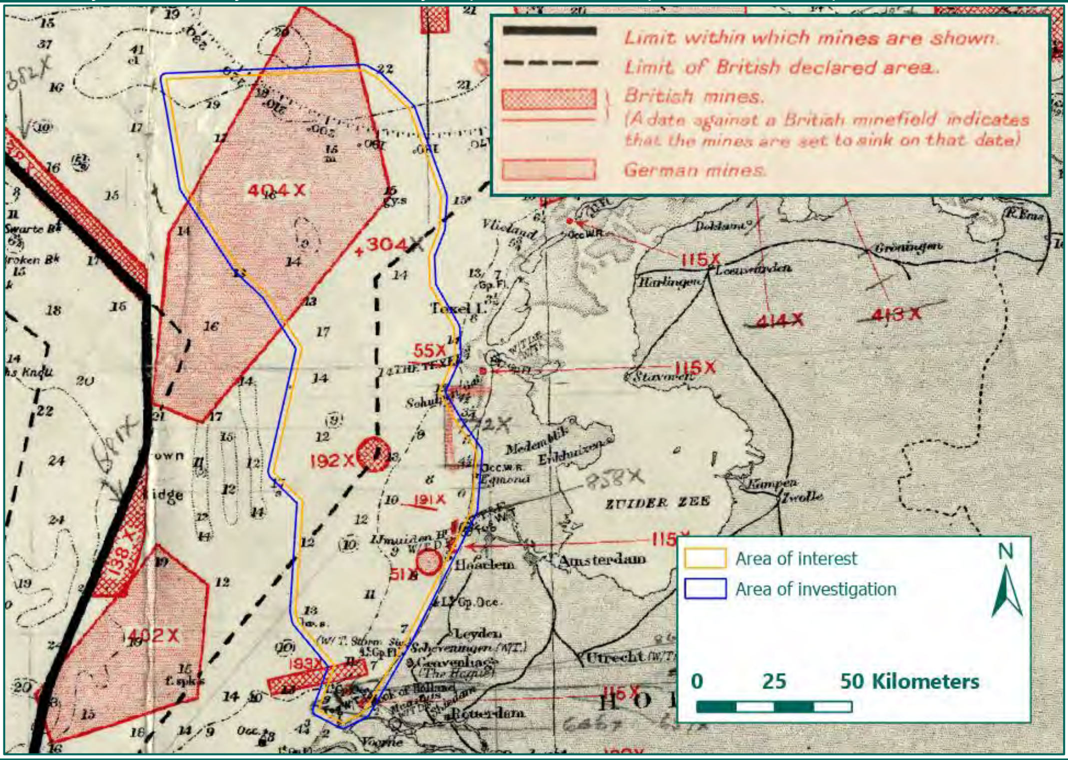
		DANISH COAST Hawthorn Rosemary	ELBE & WESER Eglantine Yams	GERMAN COAST & FRISIAN Is. Xeranthemum Zinnia Mussels Nectarine	DUTCH WEST COAST Limpets Whelks Trefoil	HOOK OF HOLLAND Oysters Iris V	SCHELDT Newts Juniper Iris II Flounders	ALL AREAS
1940	Mines	-	139	127	45	60	70	441
	Casualties	-	8	10	10	7	5	40
	Ratio	-	1:17	1:13	1:4.5	1:8.5	1:14	1:11
1941	Mines	37	116	268	-	2	-	423
	Casualties	1	11	18	4	2	-	36
	Ratio	1:37	1:10.5	1:15	∞	1:1	-	1:11.7
1942	Mines	698	133	3,921	170	-	-	4,922
	Casualties	18	10	67	4	-	-	99
	Ratio	1:39	1:13	1:58	1:42	-	-	1:49.5
1943	Mines	156	63	6,288	372	-	-	6,879
	Casualties	12	4	32	-	-	-	48
	Ratio	1:13	1:16	1:197	∞	-	-	1:143
1944	Mines	1,800	150	1,468	491	88	252	4,249
	Casualties	53	11	19	8	5	8	104
	Ratio	1:34	1:13.6	1:77	1:61	1:18	1:31	1:41
1945	Mines	296	361	-	-	-	-	657
	Casualties	1	14	-	2	-	-	17
	Ratio	1:296	1:26	-	∞	-	-	1:39
OVERALL	Mines	2,987	962	12,072	1,078	150	322	17,571
	Casualties	85	58	146	28	14	13	344
	Ratio	1:35	1:16.6	1:83	1:38.5	1:10.7	1:25	1:51

ADM 239/304	North Sea: chart 736 showing position of British and German minefields.

Relevant information:

- o British map showing German and British minefields. There are two German minefields within the area of interest:

Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)

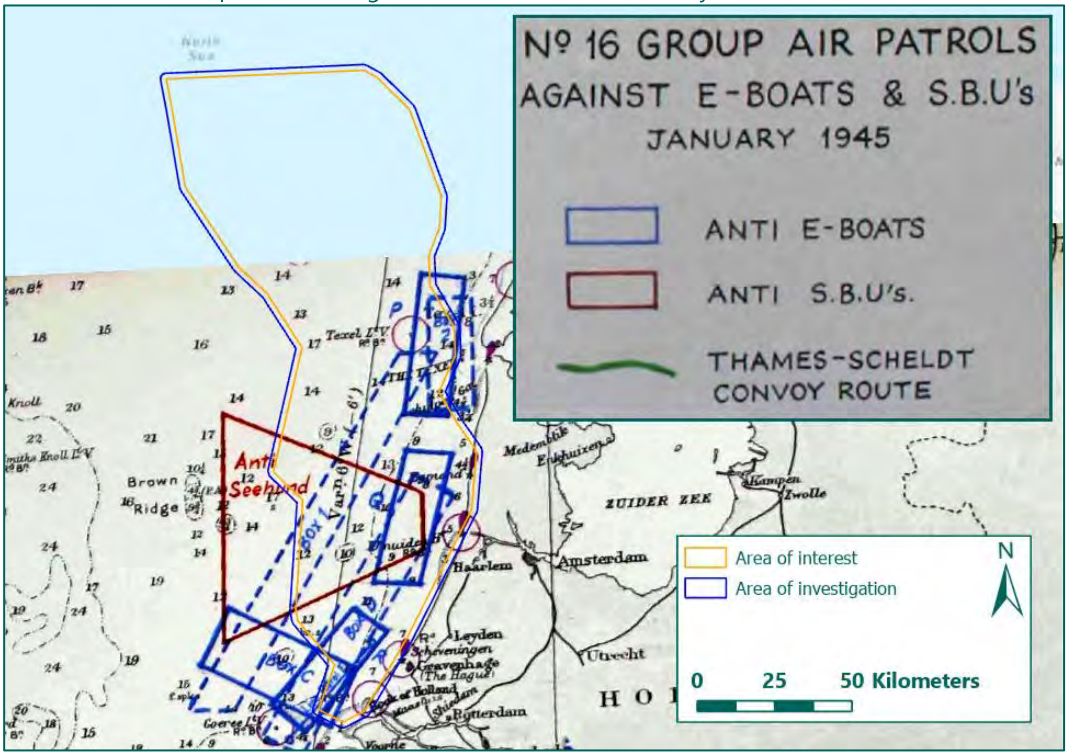


Cabinet and its committees (CAB)

Cabinet and its committees (CAB)	
CAB 101/324	Air Offensive Against Enemy Shipping and Bomber Command Minelaying Operations, 1 September 1944 - 5 May 1945

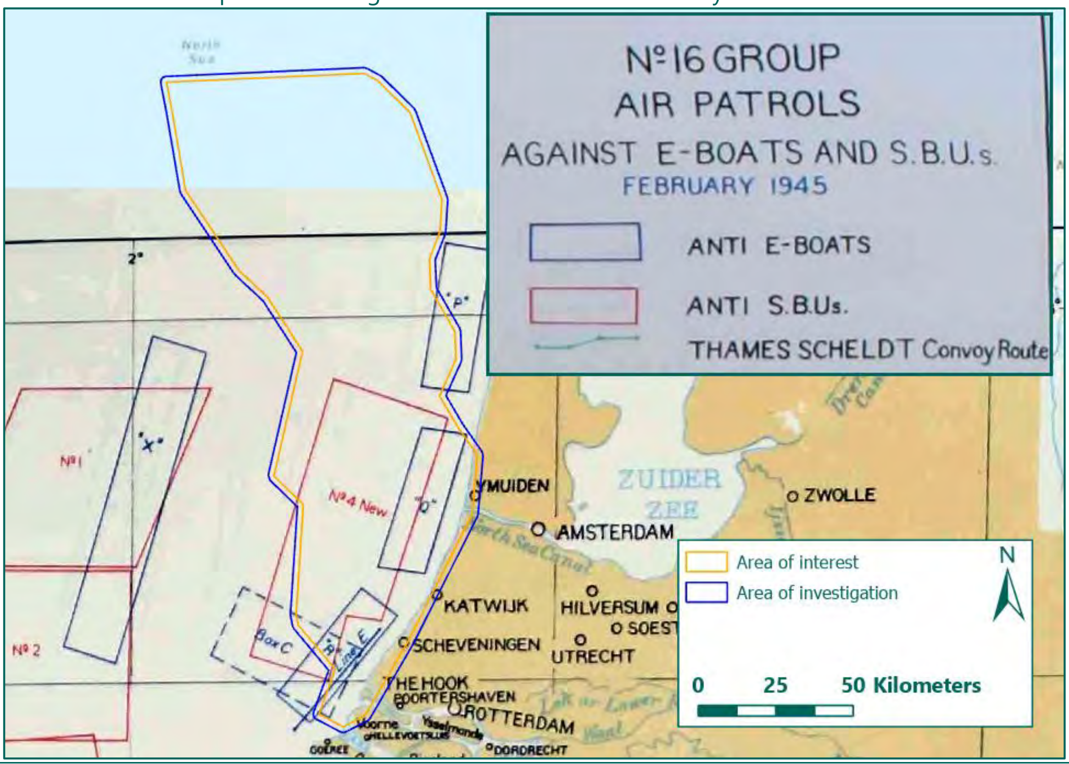
Relevant information:

- No.16 Group Air Patrols against E-Boats & S.B.U.'s January 1945.



Relevant information:

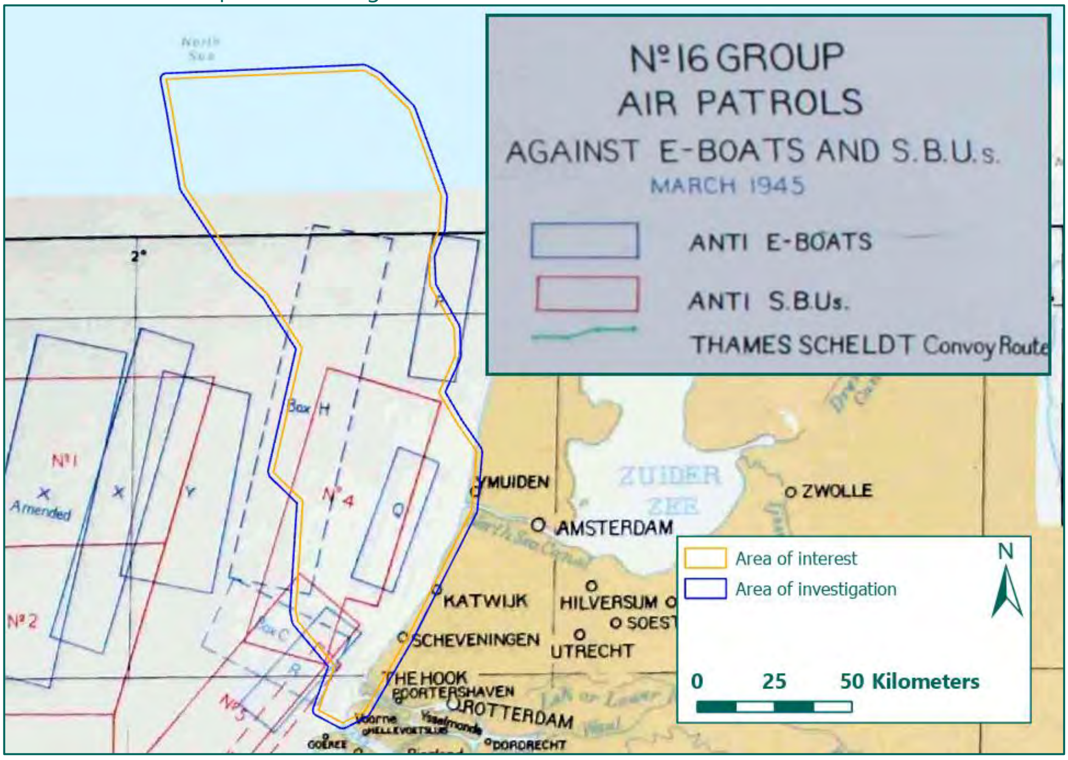
- No.16 Group Air Patrols against E-Boats & S.B.U.'s February 1945.



Cabinet and its committees (CAB)

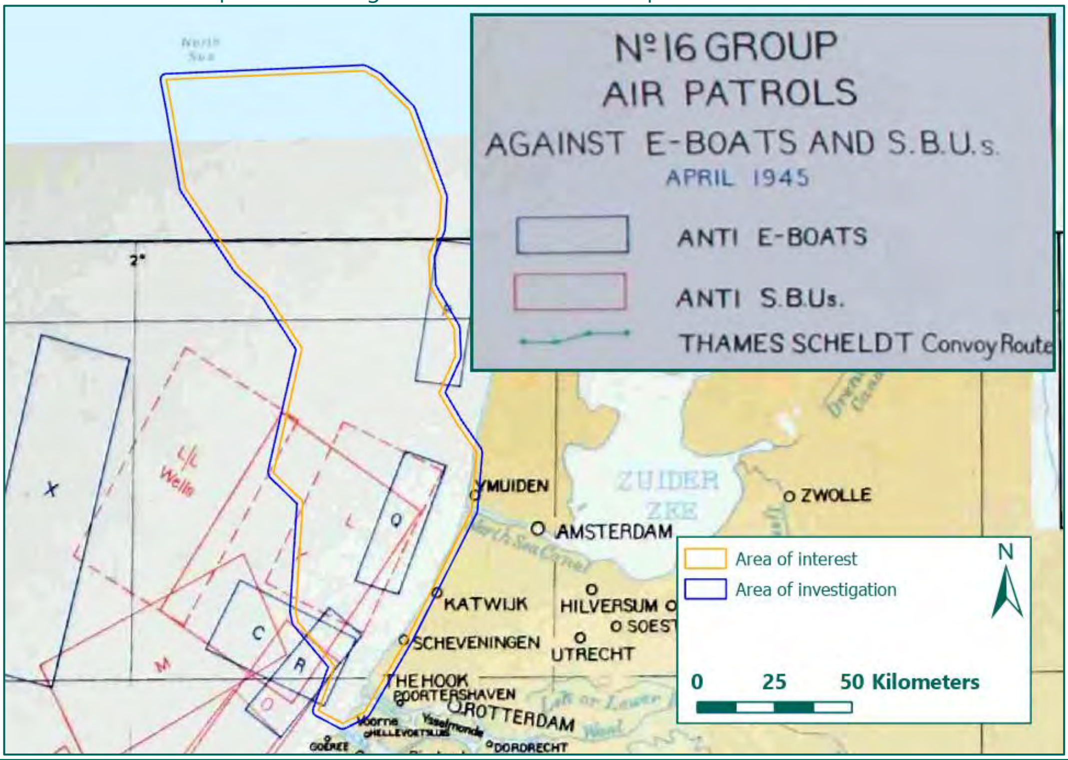
Relevant information:

- No.16 Group Air Patrols against E-Boats & S.B.U.'s March 1945.



Relevant information:

- No.16 Group Air Patrols against E-Boats & S.B.U.'s April 1945.



Air Ministry series
The Air Ministry series (AIR) contain information on aerial warfare during the Second World War. The Operations Record Books (ORBs) of units that operated in or near the area of investigation have been consulted:

- Headquarters Coastal Command, 1940-1945 (AIR 24/372 t/m AIR 24/427)
- 16 Group Coastal Command, 1940-1945 (AIR 25/313 t/m AIR 25/374)
- Headquarters Bomber Command, 1940-1945 (AIR 24/217 t/m AIR 24/319)
- Intelligence on USAAF missions (AIR 40)

16 Group Coastal Command patrolled the North Sea, attacking German shipping and conducting rescue operations. ORBs from this unit contain locations of air strikes, jettisoning, aircraft wreckages and Anti-Aircraft Artillery (AAA). Until halfway through 1942 the locations were noted in Coastal Command cypher which has only partially been decrypted by REASeuro. From 1942 onwards the ORBs mention locations in coordinates, based on decimal degrees. One must take into account that Coastal Command operated during the night as well, severely hampering navigational accuracy. When possible, war related events mentioned in the Coastal Command records have been coupled with records from the German point of view, resulting in more accurate positioning based on multiple sources.

Bomber Command, Coastal Command's famous land-based counterpart, was also active against German shipping during the first years of the war. Besides intentional bombing, Bomber Command aircraft also jettisoned bombs when in trouble. The jettisoning preferably took place over sea, since this dramatically reduced the chance of collateral damage.

In the figure below the attacks, jettisons, crashes and relevant observations from Bomber Command and Coastal Command are shown. Each feature refers to a passage of a primary source.

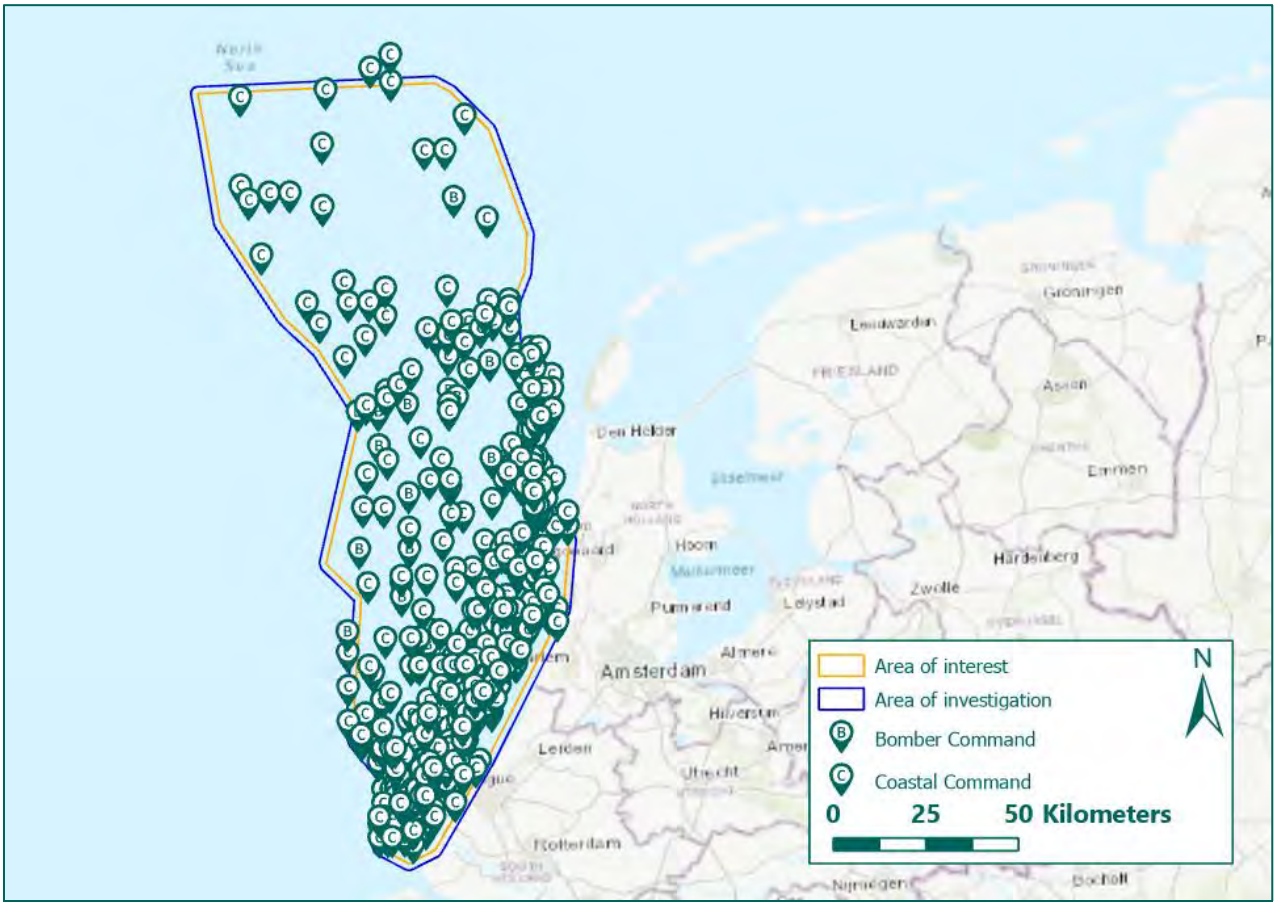


Figure 56: Locations of attacks, jettisons, crashes and relevant observations from Bomber Command and Coastal Command (Source basemap: ESRI).

The North Sea theatre of war saw also action of fighter planes of Fighter Command and 2nd Tactical Air Force (2TAF). Fighter Command patrolled the sea in order to intercept German planes heading for Britain and escorted bombers. From 1944 onward Fighter Command was involved in the war against the German V1 and V2 weapons. 2TAF mainly supported the ground forces by carrying out attacks on tactical ground targets, but also enemy shipping near the shores was attacked. No locations have been found of Fighter Command's and 2TAF's attacks within the area of interest.

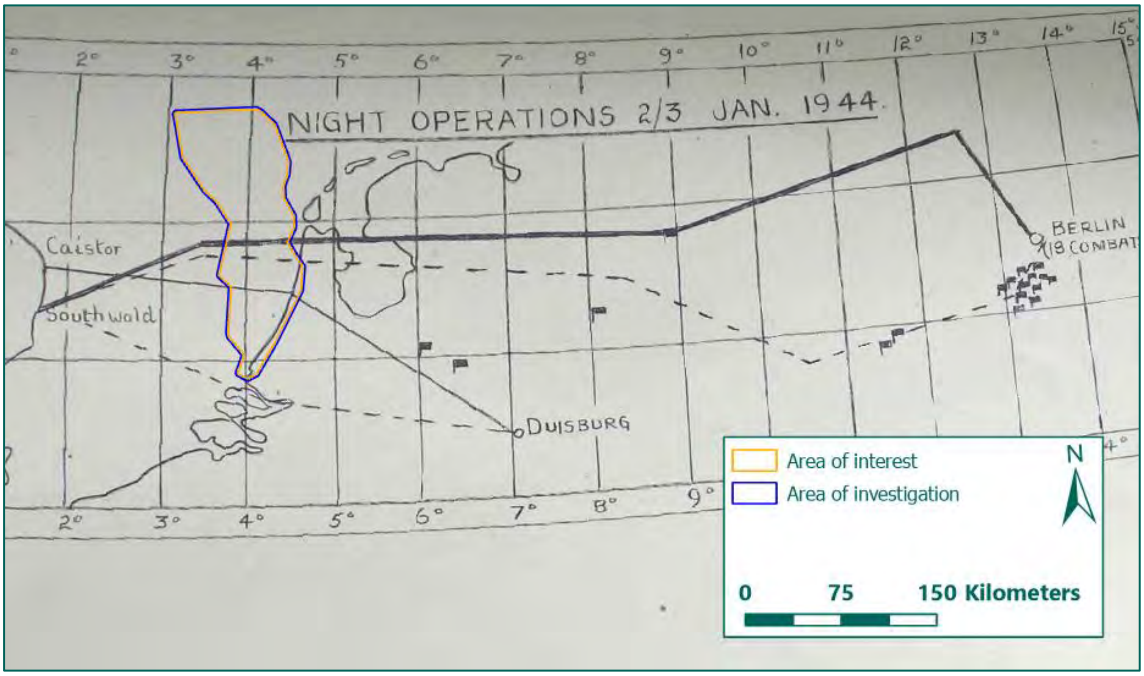
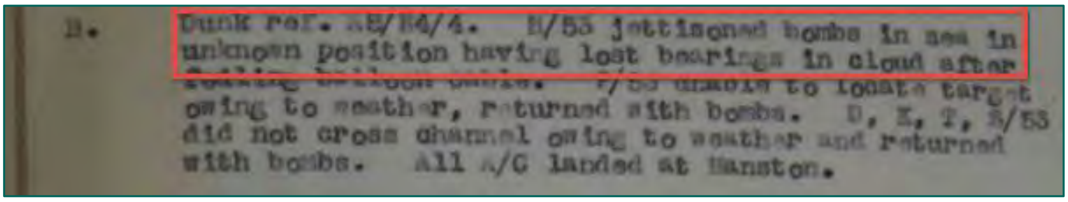


Figure 57: Example of a flight path over the area of investigation of bombers from Bomber Command, 2/3 January 1944 (Source, TNA, AIR 24/264).

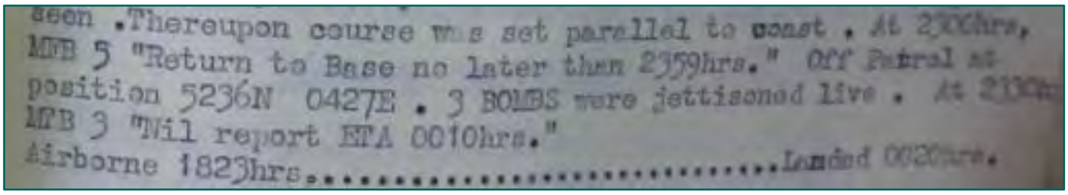
Remark on jettisoning and flight paths

Related to the air war are jettisoning of bombs and the numerous flight paths of incoming and outgoing bombers above the North Sea. During bombing raids, allied bombers followed certain routes towards their target and backwards to base. In case of emergency or to avoid landing with the bomb load, the bombs were often released above the North Sea. The figure underneath is a document from The National Archives (AIR 14/110 Disposal of bombs not dropped on allotted targets) that describes what to with the remaining bomb load. It is stated that a captain could decide where ever the bombs are dropped, as long as they are dropped in safe condition. Despite this document, the logs of Coastal and Bomber Command prove that bombs were also jettisoned in live condition.



B. Dunk ref. AB/B4/4. H/53 jettisoned bombs in sea in unknown position having lost bearings in cloud after [illegible] balloon cable. [illegible]/53 unable to locate target owing to weather, returned with bombs. D, E, [illegible], S/53 did not cross channel owing to weather and returned with bombs. All A/C landed at Manston.

Figure 1: Blenheim Bomber jettisoned its bombs at an unknown position in the Northsea (Bron: TNA, AIR 24/375).



seen .Thereupon course was set parallel to coast . At 2300hrs, MTB 5 "Return to Base no later than 2359hrs." Off Patrol at position 5236N 0427E . 3 BOMBS were jettisoned live . At 2300hrs MTB 3 "Nil report ETA 0010hrs." Airborne 1823hrs..................................Landed 0020hrs.

Figure 58: Example of a live jettison within the area of investigation, night 12/13 October 1944. (Source: TNA, AIR 25/367).

Spitfires found 10/10th cloud over target. 1 Sqdn jettisoned bombs in sea, 1 Sqdn brought bombs back.

Figure 2: A Squadron of Spitfires jettison their bombs in sea after being unable to locate the assigned target (Bron: TNA, AIR 37/713).

[redacted]
WELLINGTONS FROm Bircham Newton to be armed with 5 x 500lb bombs and 25 flares and to reconnoitre enemy inner convoy route from 5335N 0620E to 0800E and back to 5355N 0630E and to R/V with Beaus in this position at 0300. Wellington to be at 5335N 0620E at 0230. W/T Org 1a R/T Org 4 . TOrbeaus to be armed with torpedoes 10ft setting.
Patrol carried out. At 0250 MTB 1 'Nil sighting' and VHF MT Beaufighters 'Nothing'. At 0258 2 bombs were jettisoned safe but one exploded. [redacted]

Figure 3: Wellington bombers jettisoned two bombs at an undisclosed location at sea. Although the bombs are jettisoned "safe", one exploded (Bron: TNA, AIR25/363).

DISPOSAL OF BOMBS NOT DROPPED ON TARGETS.

1. In the event of Captains of Aircraft having to return from bombing missions without having dropped all bombs, discretion is left to the Captain of the Aircraft as to whether it is wise for him to land with

(i) all bombs
(ii) a portion of bombs
(iii) no bombs.

2. If the Captain of the Aircraft decides to drop his bombs in the sea, they are to be jettisoned "safe".

Figure 4: Extract from AIR 14/110 (Disposal of bombs not dropped on allotted targets) (Source: TNA).

Coastal guns

Coastal guns were traditionally used in strongpoints that had to defend harbours from enemy ships. Shortly before the beginning of World War II, more modern batteries were installed on the Dutch Coast. After the German Occupation the amount of Coastal Guns grew in order to strengthen the *Atlantikwall*. It is known that Coastal guns were active in the area of investigation. In the TNA a photograph showing an explosion of a shell from land battery was consulted. The photograph was dated 4 May 1942 and located at 52 36N, 04 22E (within the area of investigation).

Figure 59: Strike photo showing the impact of a shell, fired by a German coastal battery. 4 May 1942. (Source: TNA, AIR 28/595).

National Archives and Records Administration (NARA)

The following Record Groups have been consulted in the NARA:

- Record Group 18: Mission Reports.
  The mission reports contain detailed information on allied bombing raids, including height, air speed and the deployed munitions.
- Record Group 342: Records of U.S. Air Force Commands, Activities, and Organizations
  Record Group 342 contains additional details not mentioned in Record Group 18.

These Record Groups show several attacks by the USAAF on targets along the Dutch Coast. It is known that these aircraft operated above the area of investigation. No specific targets within the area of investigation were mentioned. It is possible that due to technical or navigational failures war related events took place within the area in investigation. In the figure below an example of a flight path over the area of investigation is shown.

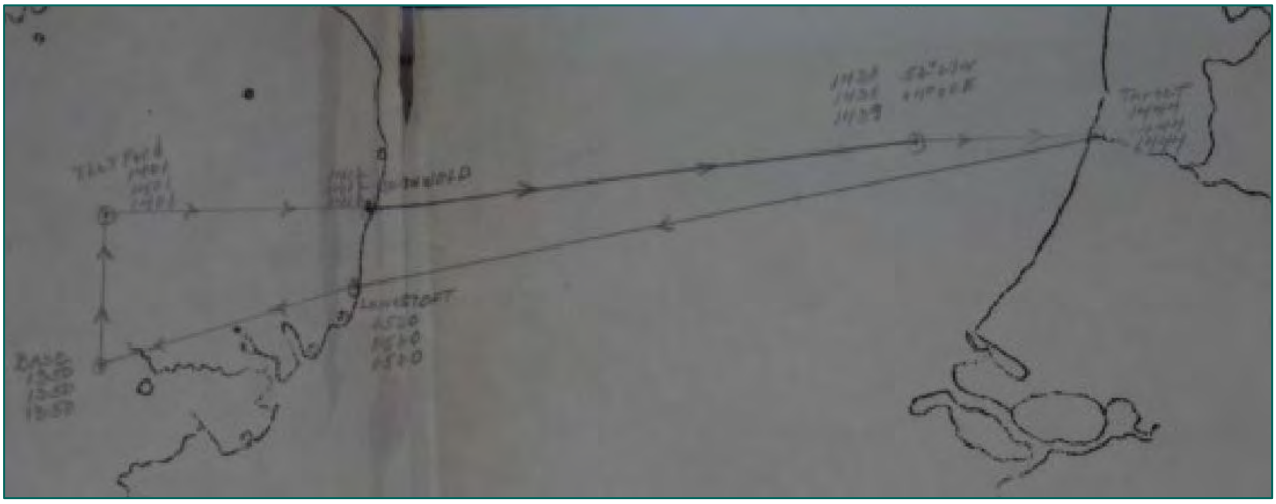


Figure 60: The flightpath of aircraft of USAAF on 26 March 1944 (Source: NARA Box RG18, Box 1388).

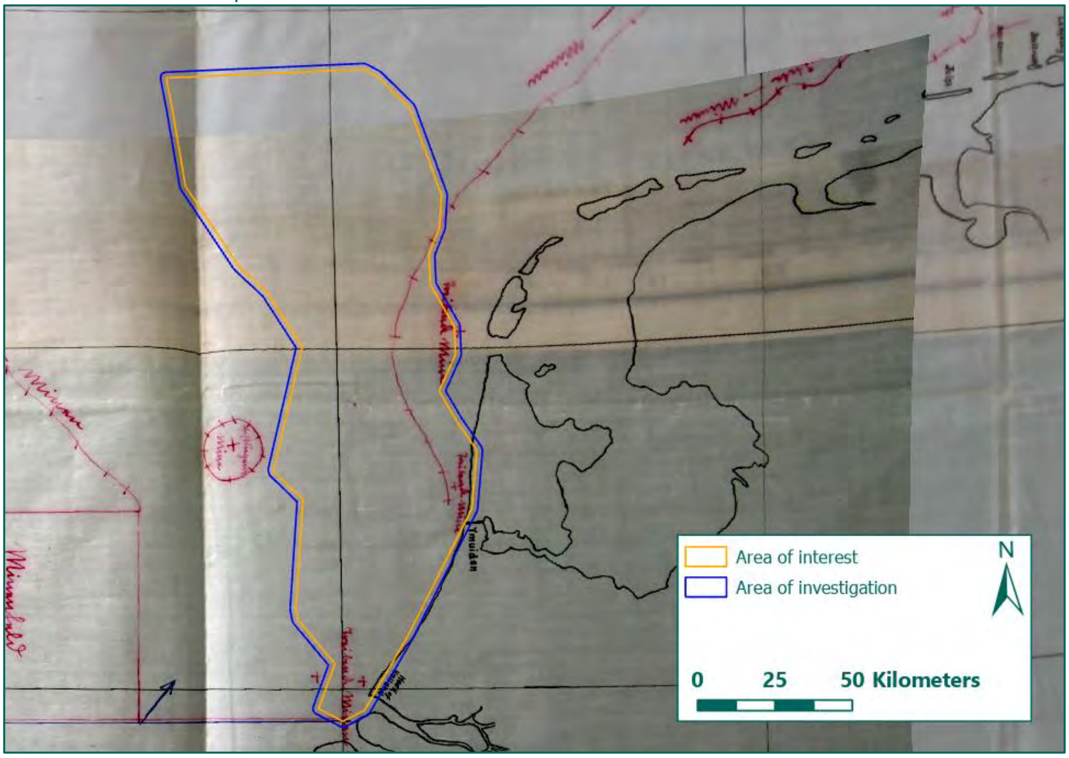
No further files have been consulted with regards of the area of investigation. Consulting these sources is outside the scope of this research.

Bundesarchiv-Militärarchiv (BAMA)

The German military archives have been consulted in the BAMA in Freiburg. This archive contains the documents from the German military in the Second World War. The following record groups have been consulted by REASeuro to gain more information about the German perspective of naval warfare in the area of investigation:

- RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.
- ZA 5: Deutscher Minenräumdienst (German Minesweeping Administration).

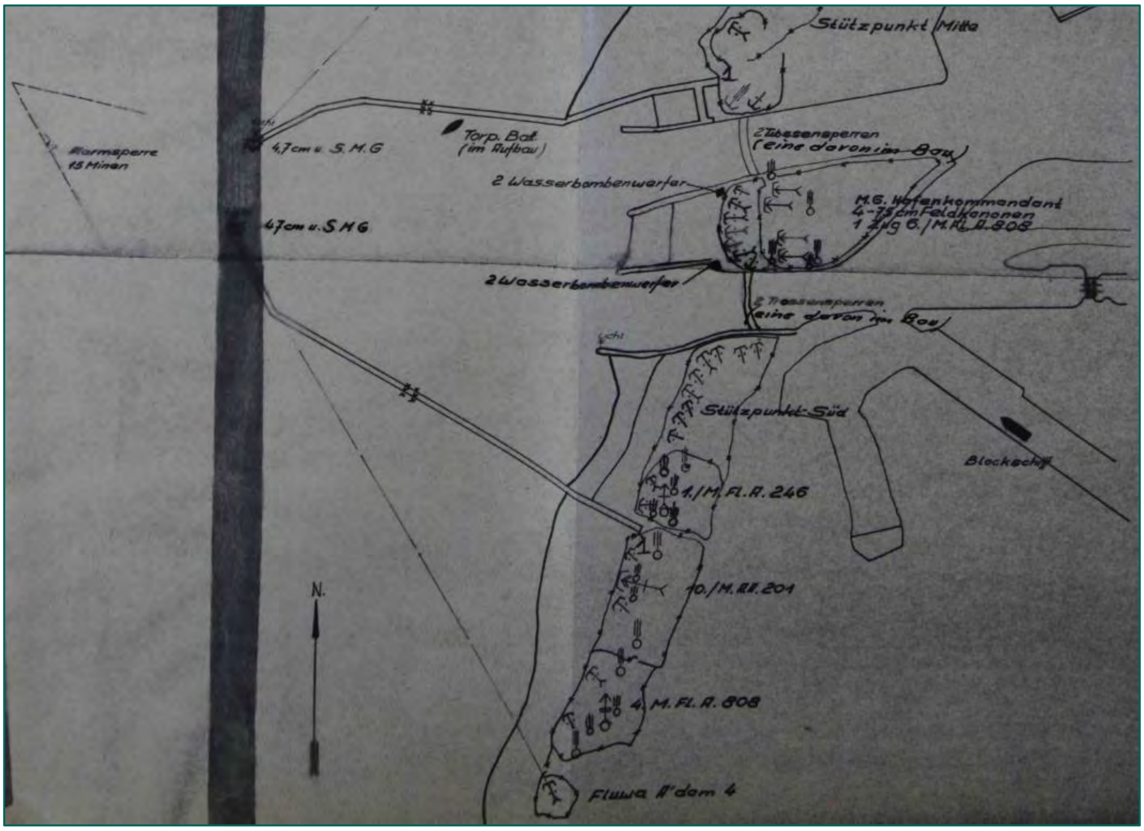
The following documents have been found relevant for the area of investigation:

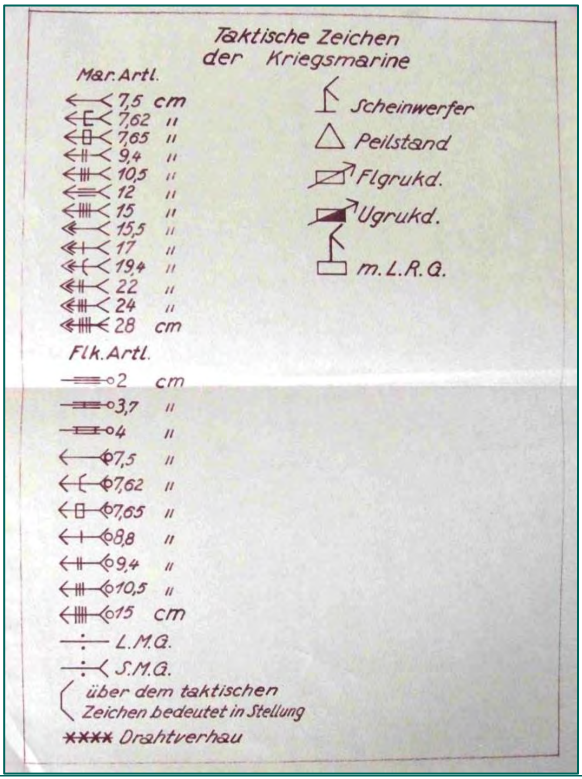
<table>
<tr><th colspan="2">RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.</th></tr>
<tr><td colspan="2">The Admiralty of the Imperial Navy was the highest level of command of the German Navy during the First World War. Record Group RM5 contains documents from the admiralty. The following documents are considered relevant for the area of investigation.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>RM 5/4721K</td><td>Kommando der Hochseestreitkräfte: "Zusammenstellung der bisher bekannten Minensperren und minenverdächtigen Gebiete". Druck, 3.3.1915</td></tr>
<tr><td colspan="2">Map showing known and suspected allied minefields, situation March 1915. The area of interest has no overlap with an area which was suspected to be mined.


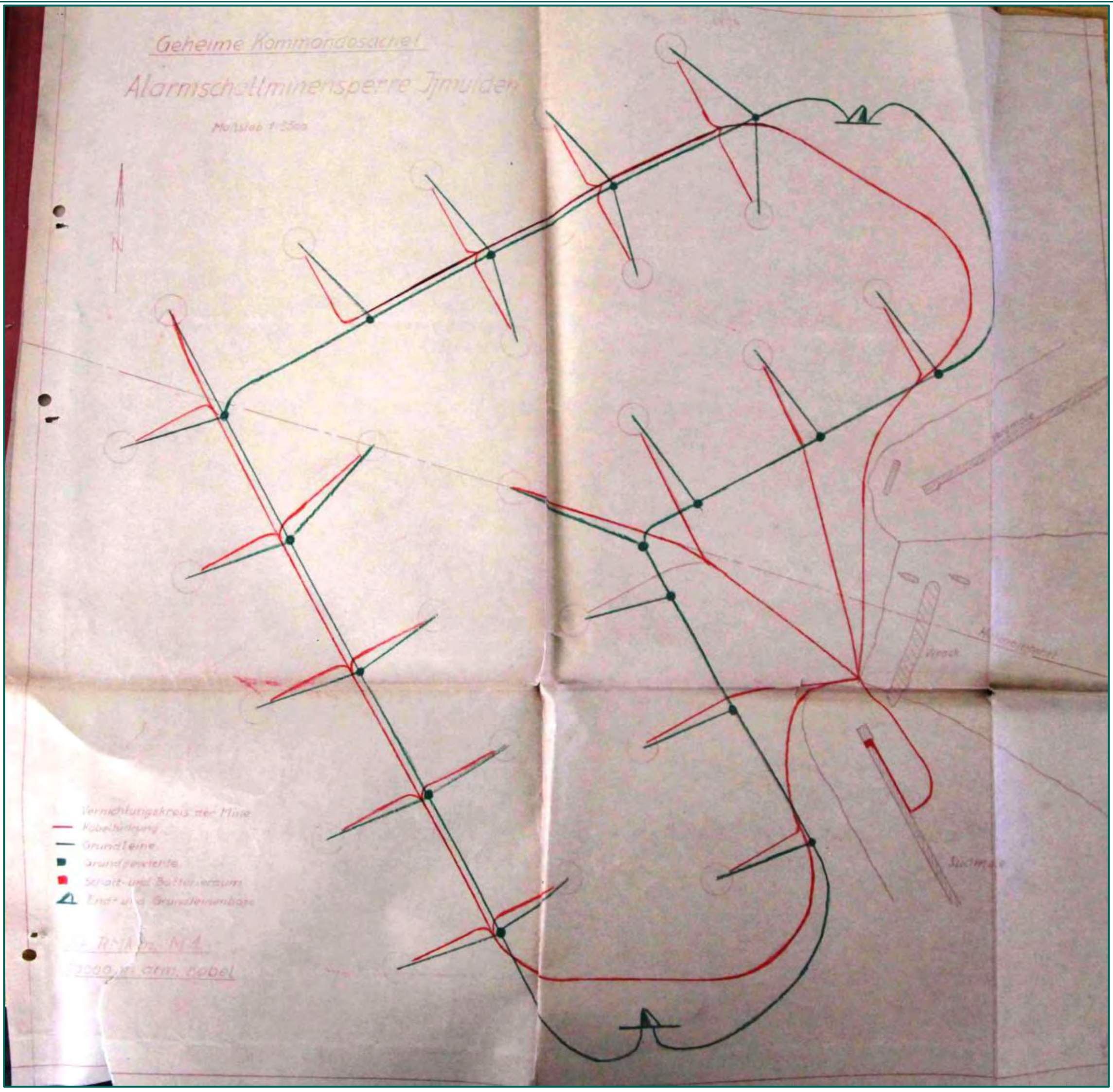
Within the area of investigation the map shows ‘Treibende Minen’ (Contact mines).</td></tr>
<tr><td colspan="2"></td></tr>
</table>

<table>
<tr><th colspan="2">RM 35-I: Marinegruppenkommando Ost – Nord der Kriegsmarine.</th></tr>
<tr><td colspan="2">The Marinegruppenkommando Ost – Nord operated as the commander of the units that had to secure the East and North Sea.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>RM 35-I/277</td><td>Minenlage Nord (M.L.N.)
1. Mai 1942 - 1. Okt. 1943</td></tr>
</table>

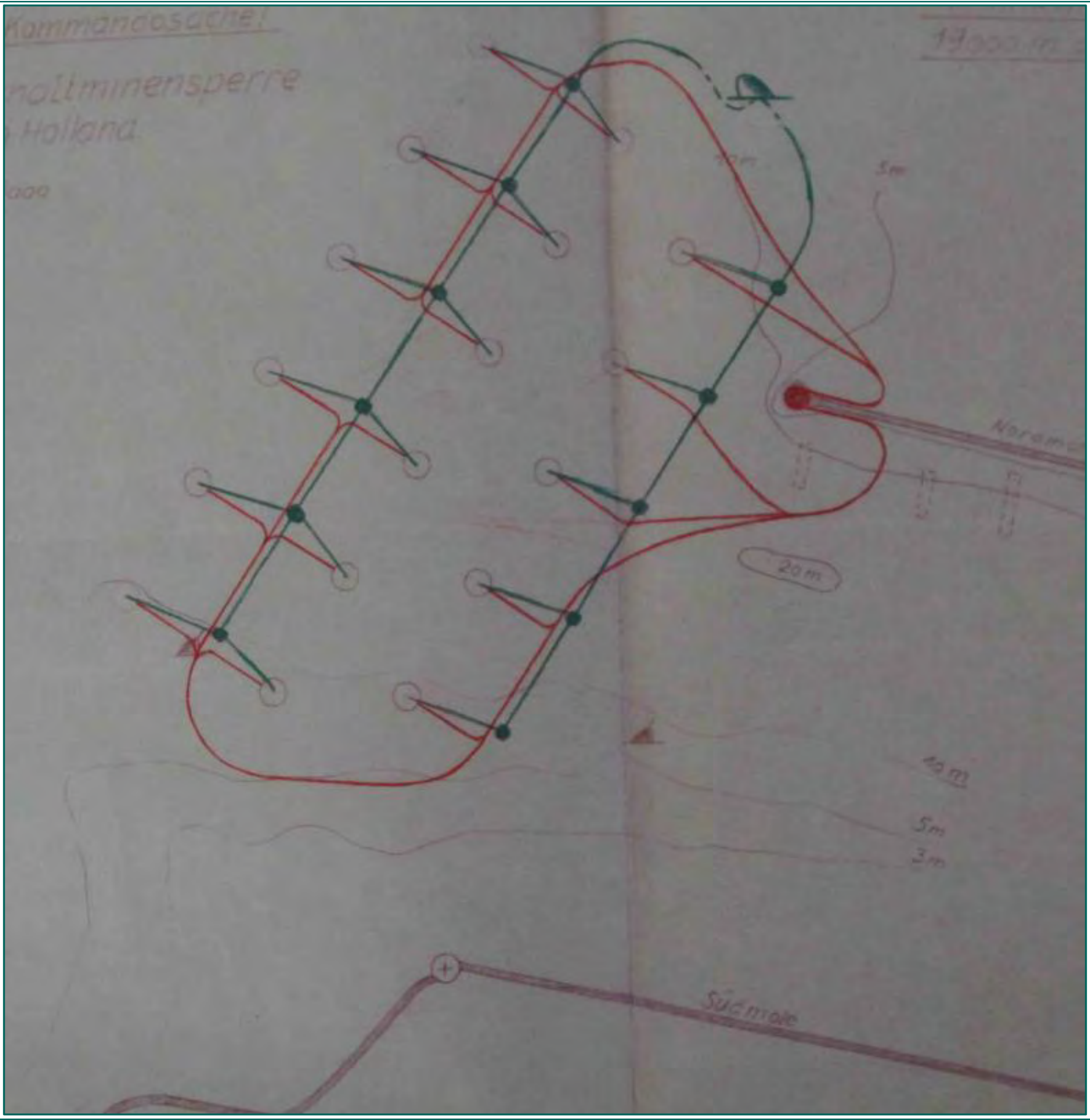
Map showing the defences of IJmuiden harbour. A warning minefield is situated in front of the port entrance. The minefield consisted of 24 RMA magnetic ground mines. The mines had a remote controlled detonator and each mine was coupled to a device on land. This gave the German defender the option to turn the mines on and off.



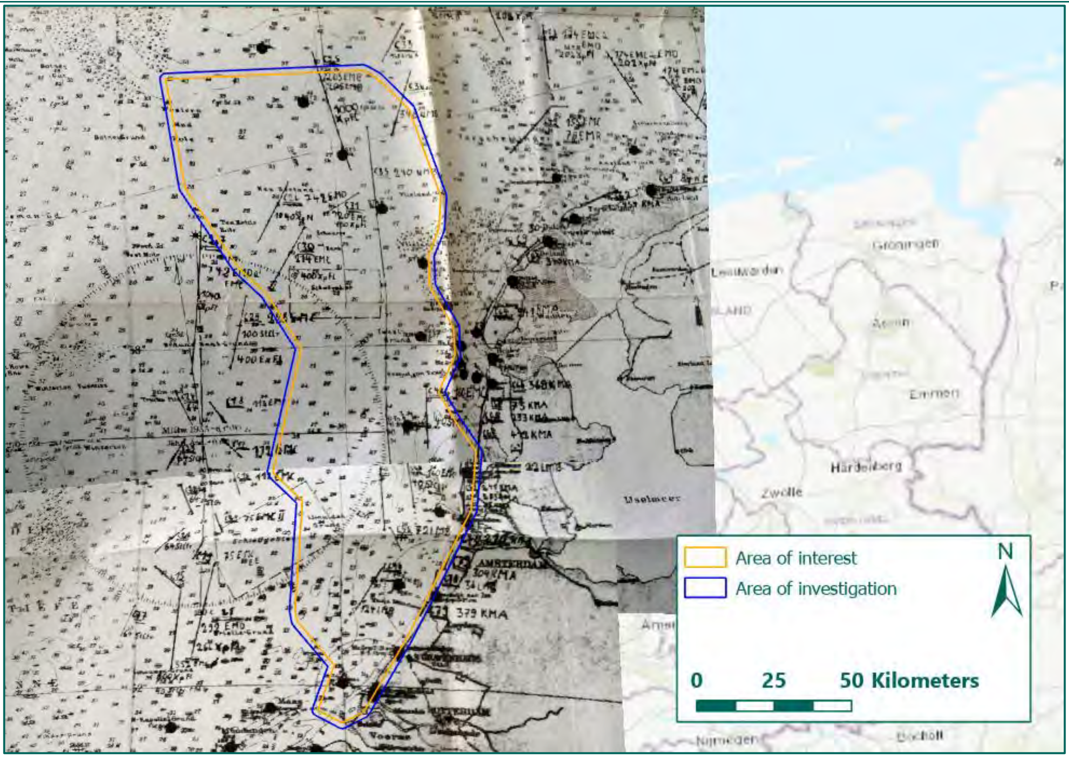




Map showing a minefield consisted of 17 RMA magnetic ground mines at the Hoek van Holland.



ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)	
The German Minesweeping Administration was responsible for post-war mine clearance of German waters. This administration also summarized and mapped all German minefields laid during the Second World War.	
ZA 5/27	Im Kriege geworfene Minensperren in der Ost- und Nordsee etc.
Naval chart showing numbered German minefields. Multiple minefields are present in the area of interest. For a more detailed map, see ZA 5/47.	



A large amount of minefields were present in the area of investigation:

- C25
- C26
- C27
- C29
- C30
- C31
- C35
- C36
- C44
- C45
- C46
- C47
- C48
- C67
- C69
- C70
- C71
- C72
- C73
- C78
- C79
- E25
- E26
- E38
- E41
- E42
- E43
- E44
- E45
- E46
- E47

- E69

ZA 5/44 | Chart B: The North Sea – Central Sheet

C25-C27

C25	SW-0	9/40	53 30.0 N 04 05.0 E 53 49.5 N 03 58.0 E	.5	205 EMB 205 EMB 1000 XpF1		M M M	8 8 17		1) 1))	220-(300(	With AE Switch. Without AE Switch. To west of mines. Considered safe.
C26	SW-1	8/40	53 27.8 N 03 46.5 E 53 17.5 N 03 36.5 E	1	742 EMD 1040 XpF1		M M	7 16	65	3	50	AE Switch "OFF" Considered safe.
C27	SW-2	8/40	53 20.0 N 03 21.0 E 52 56.0 N 03 17.5 E	1	742 EMD and EMC 1040 XpF1		M M	7 17	65 50	3		AE Switch "OFF" Considered safe.

C29-C31

C29	SW-9	7/42	53 08.5 N 03 33.1 E 52 56.3 N 03 28.2 E	2	226 EMC 100 StCtr 400 ExF1		M M M	10 20 20		2 1		With 50 feet lower antenna. The 400 Ex-Floats are for lines C.29, C.30 and C.31. They are in the space between the mine lines.
C30	SW10	7/42	53 20.0 N 03 49.7 E 53 10.0 N 03 38.9 E	2	214 EMC 400 XpF1		M M	10 20		2		With 50 feet lower antenna. The 400 Ex-Floats are for lines C.29, C.30 and C.31. They are in the space between the mine lines.
C31	SW11	7/42	53 26.0 N 04 06.0 E 53 22.1 N 03 56.8 E	2	120 EMC 400 XpF1		M M	8 20		2		With 50 feet lower antenna. The 400 Ex-Floats are for lines C.29, C.30 and C.31. They are in the space between the mine lines.

C35-C36

C35	4c	10/43	53 26.0 N 04 12.0 E 53 38.2 N 04 12.0 E	.25	240 UMB		M	12		3	160	(Comment-another version shows 240 UMB). With SNAG LINES. Eight mines are missing from S. end of centre row.
C36	4d	10/43	53 36.6 N 04 17.8 E 53 48.0 N 04 25.7 E	.4	348 UMB		M	12		3		With SNAG LINES.

C44-C48

C44	SWK3	6/44	52 37.5 N 04 36.0 E 52 39.0 N 04 36.3 E	.25	22 LMB		G	30	250	2	165	Mean MINE spacing 125 yds.
C45	SWKA-1b	9/44	52 26.5 N 04 13.5 E 52 22.8 N 04 16.6 E	.5	72 LMB	DM-1	G		240	2	165	Mean MINE spacing 120 yds. Arming delay 24 hours (?)
C46	SWKA-2	9/44	52 20.2 N 04 12.5 E 52 13.6 N 04 05.5 E	.5	124 LMB	DM-1	G		260	2	165	Mean MINE spacing 130 yds. Arming delay 24 hours.
C47	SWKB-1	11/44	52 30.0 N 04 20.0 E 52 39.0 N 04 20.0 E	1	160 EMC 40 StCtr		M) M)	10	270	3	220	With chain 4 mines to 1 obstructor. Mean spacing 135 yards.
C48	SWKB-2	11/44	52 42.0 N 04 23.0 E) 52 53.0 N 04 23.0 E)	½-1	160 EMC) 40 StCtr)		M	10	330	3	330	Mines with chain. Four mines to one obstructor. Mean spacing 150 yards.

C67

C67	K-6	5-7 1944	52 46.0 N 04 39.1 E 52 40.2 N 04 37.5 E	Fairly accur-ate	412 KMA		G		58	2	33-66	Mean mine spacing 29 yards.

C69-C73

C69	K-7	7-8 1944	52 33.4 N. 04 36.2 E 52 36.7 N 04 37.0 E	Fairly accur-ate	241 KMA		G	3-8ø	56	2	43-55	ø Below HIGH water springs Mean mine spacing 28 yards.
C70	K-8	5/44	52 28.9 N 04 34.5 E 52 29.9 N 04 35.0 E	Exact	75 KMA		G	7ø	55	2	43-55	ø Below HIGH water springs. Mean mine spacing 27.5 yards.
C71	K-8a	5-7 1944	52 29.9 N 04 35.0 E 52 33.4 N 04 36.2 E	Exact	285 KMA		G	5-11ø	52	2	43-66	ø Below mean HIGH water springs. Mean mine spacing 26 yards.
C72	K-9	5-8 1944	52 24.0 N 04 31.7 E 52 20.0 N 04 29.1 E	Fairly accur-ate	304 KMA		G	5-8ø	55	2	43-55	ø Below high water springs. Mean mine spacing 27.5 yards.
C73	K-9a	5/44	52 26.4 N 04 33.7 E 52 24.0 N 04 31.7 E	Exact	210 KMA		G		55	2	43	Mean mine spacing 27.5 yards.

C78-C79

C78	SWK-6	6/44	52 17.3 N 04 26.4 E 52 19.3 N 04 27.8 E	.25	36 LMB		G	28	246	2	165-190	Mean mine spacing 123 yards.
C79	K10	8/44	52 16.7 N 04 27.0 E 52 12.0 N 04 22.6 E	Fairly accurate	379 KMA		G	5-10	55		44-55	Mean mine spacing 27½ yards. Below HIGH water springs.

E25-E26

E25	SWK7	6/44	52 08.2 N 04 17.1 E 52 11.4 N 04 21.1 E	.125	78 LMB	M1	G	23-30	210	2	165	Mean mine spacing 105 yds.
E26	SWK9	4/44	51 55.5 N 03 57.1 E 51 52.4 N 03 52.5 E	.25	90 LMB	M1	G		190	2	220	Mean mine spacing 95 yds.

E38

E38	SWK A3	9/44	52 09.2 N 03 55.0 E 52 01.2 N 03 51.7 E	.5	90 LMB 90 EMC	DM3	G M	 10	180 180	1 1	165	Mean mine spacing 90 yds. Arming delay 24 hours. EMC with chain.

E41-E47

E41	K10	8/44	52 16.7 N 04 27.0 E 52 12.0 N 04 22.6 E	Fairly exact	739 KMA		G	5-10	55		44-55	Mean mine spacing 27½ yards. Below HIGH water springs.
E42	K11	5-8 1944	52 05.0 N 04 14.0 E 52 07.5 N 04 16.7 E	Exact	179 KMA		G	6-13	55		44	Mean mine spacing 27½ yards. Below HIGH WATER springs.
E43	K12	5/44	51 59.6 N 04 06.8 E 52 01.1 N 04 08.5 E	Exact	135 KMA		G		55	2	44	Mean mine spacing 27½ yards.
E44	K12A	4/44	52 01.1 N 04 08.5 E 52 04.8 N 04 13.6 E	Exact	334 KMA		G		55	2	44	Mean minespacing 27½ yards.
E45	K13	7-8 1944	51 58.4 N 04 04.2 E 51 56.7 N 04 01.8 E	Exact	134 KMA		G	6-8 below H.W.S.	66		44	Mean mine spacing 33 yards.
E46	K14	8/44	51 54.5 N 04 00.1 E 51 55.7 N 04 00.3 E 51 56.7 N 04 01.8 E	Exact	164 KMA		G	6-7 below H.W.S.	55	2	44	Mean mine spacing 27½ yards. (Comment: Alternative version gives 182 KMA).
E47	K15	8/44	51 54.3 N 04 00.1 E 51 52.3 N 04 02.5 E	Exact	162 KMA		G	6 below H.W.S.	55	2	44	Mean mine spacing 27½ yards.

E69

E69		11/44	Brielschegat from net barrage at Seeberg to 04 10E.	Exact	147 KMA	G	to 13 below H.W.S.	70	2	55	Mines scattered.

The information from ZA 5/27 and 5/44 is shown in the figure and table below.

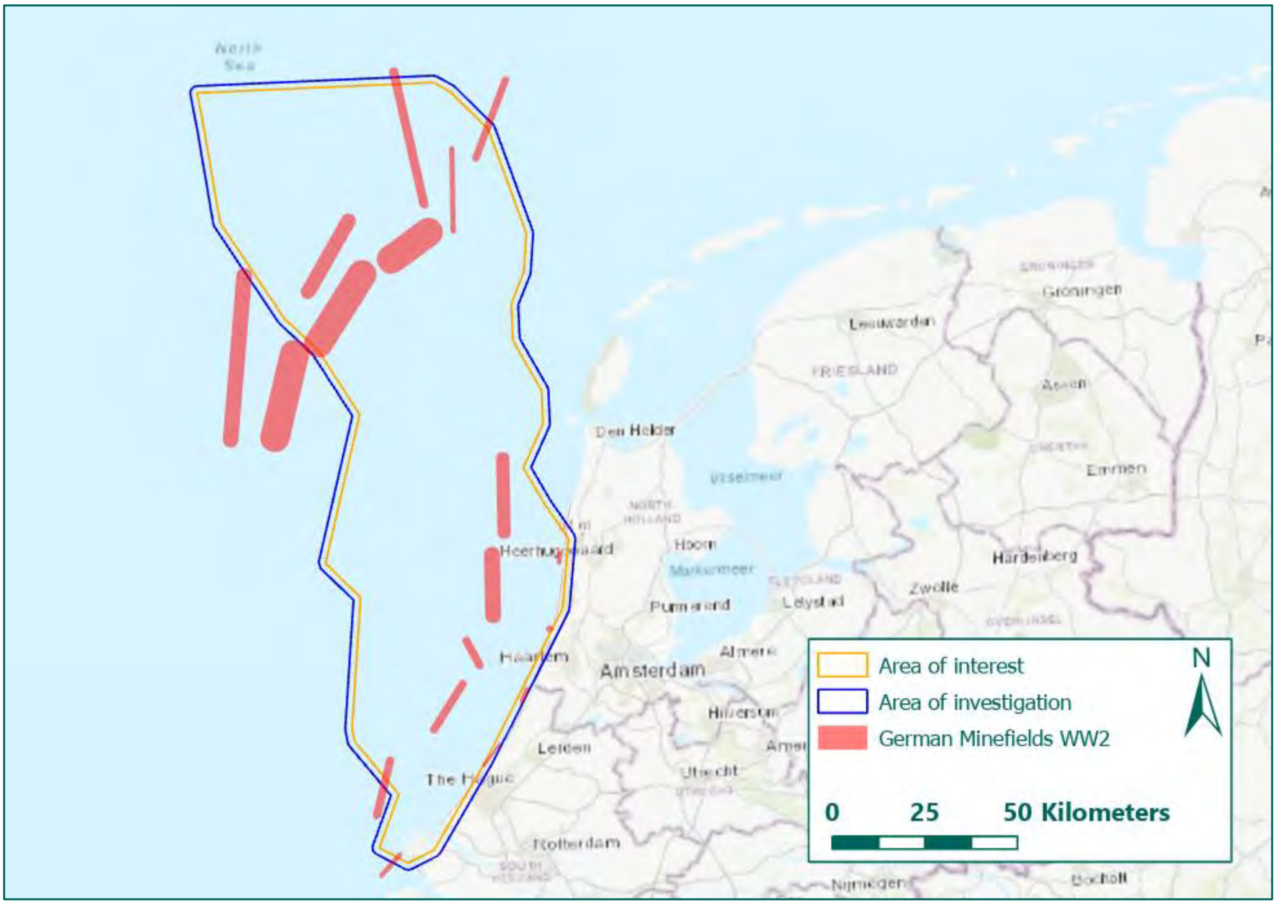


Figure 61: German Minefields within the Area of investigation (Source basemap: ESRI).

Number	Amount of mines	Rows	
		Amount	Spacing
C25	205 x EMB[7], 205 x EMB, 1000 x XpFl[8]	2	220/300 yards
C26	742x EMD[9], 1040 x XpFl	3	65 yards
C27	742 x EMD/EMC[10], 1040 x XpFl	3	65 yards
C29	226 x EMC, 100 x StCtr[11], 400 x XpFl	2, 1	Unknown
C30	214 x EMC, 400 x XpFl	2	Unknown
C31	120 x EMC, 400 x XpFl	2	Unknown
C35	240 x UMB[12]	3	Unknown
C36	348 x UMB	3	Unknown
C44	22 x LMB[13]	2	Unknown
C45	72 x LMB	2	Unknown

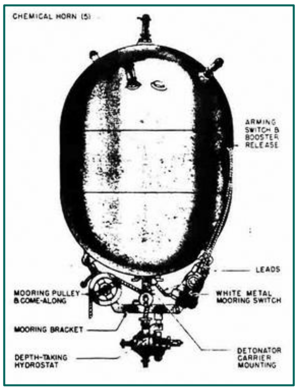
[7] *Einheidsmine* – Type B, Contact mine
[8] Exploding floats, *Sprengboje*
[9] *Einheidsmine* – Type D, Contact mine
[10] *Einheidsmine* – Type C, Contact mine
[11] Static cutters/Static Conical Sweep Obstructor, *Reisboje*
[12] *U-Bootabwehrmine* – Type B, Contact Mine
[13] *Luft Mine* – Type B, Influence Mine

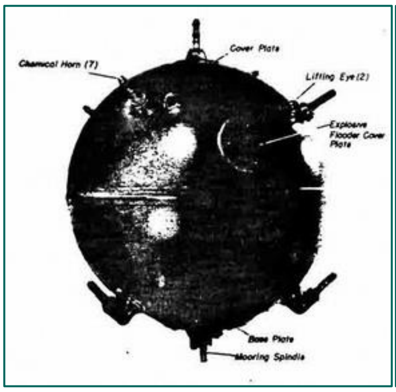
Number	Amount of mines	Rows	
		Amount	Spacing
C46	124 x LMB	2	Unknown
C47	160 x EMC, 40 x StCtr	3	Unknown
C48	160 x EMC, 40 x StCtr	3	Unknown
C67	412 x KMA[14]	2	Unknown
C69	KMA (unknown amount)	2	Unknown
C70	75 x KMA	2	Unknown
C71	285 x KMA	2	Unknown
C72	304 x KMA	2	Unknown
C73	210 x KMA	2	Unknown
C78	36 x LMB	2	Unknown
C79	379 x KMA	Unknown	Unknown
E25	78 x LMB	2	Unknown
E26	90 x LMB	2	Unknown
E38	90 x LMB, 90 x EMC	2	Unknown
E41	739 x KMA	Unknown	Unknown
E42	179 x KMA		Unknown
E43	135 x KMA	2	Unknown
E44	334 x KMA	2	Unknown
E45	134 x KMA	Unknown	Unknown
E46	164 x KMA	2	Unknown
E47	182 x KMA	2	Unknown
E69	147 x KMA	2	Unknown
Unknown, Harbour Hoek of Holland	17 x RMA[15]	-	-
Unknown, Harbour IJmuiden	24 x RMA	-	-
Unknown, Harbour IJmuiden	LMB (unknown amount)	Unknown	Unknown

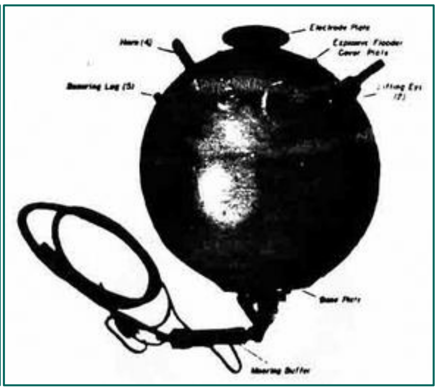
[14] Küstenmine – Type A, Contactmine
[15] Regulare Mine – Type A, Contactmine

German Mines (and sweep obstructors) within the area of investigation)

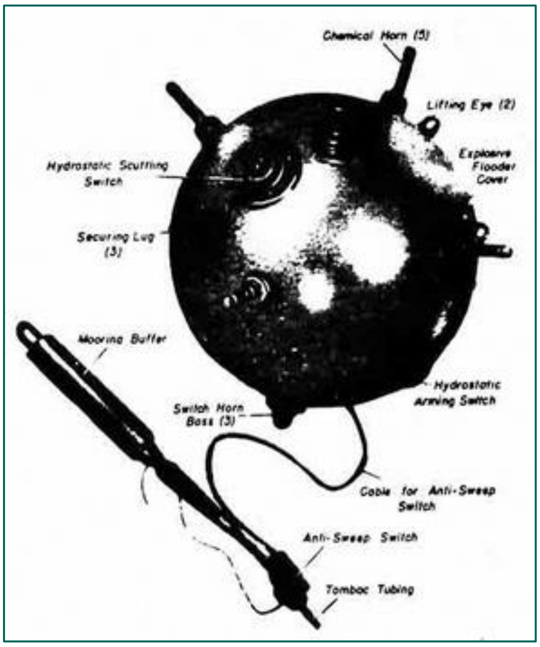
Einheidsmine – Type B, C and D Contact mine



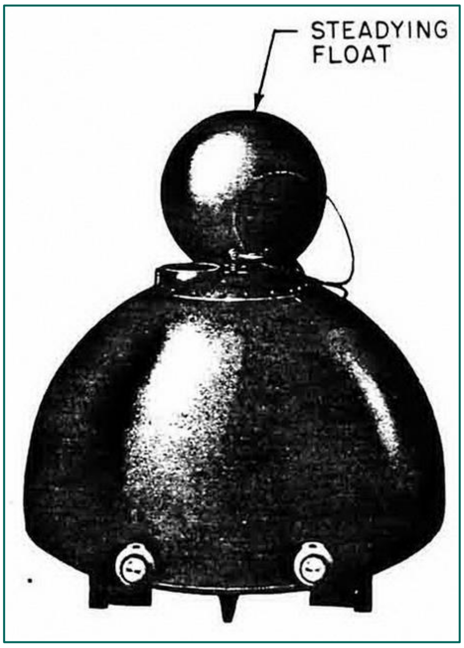




U-Bootabwehrmine – Type A, Contact Mine

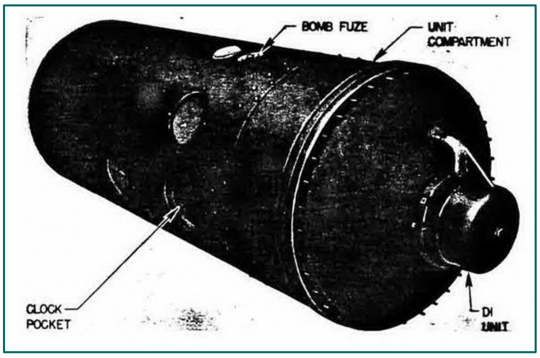


Regulare Mine – Type A, Contactmine

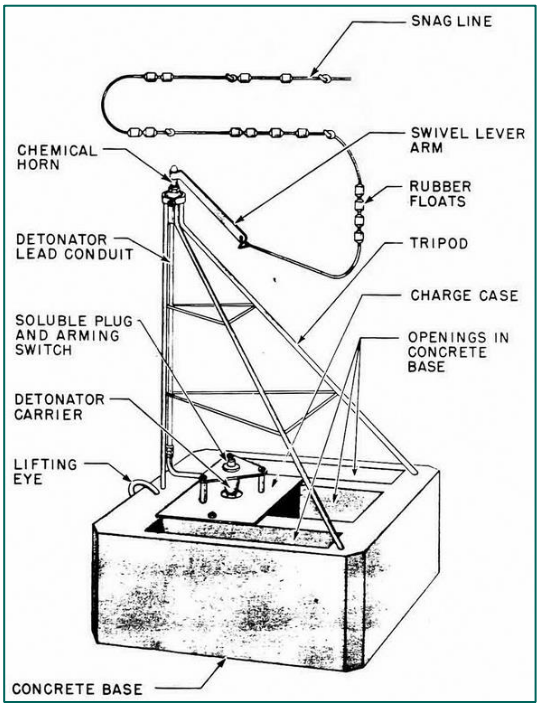


German Mines (and sweep obstructors) within the area of investigation

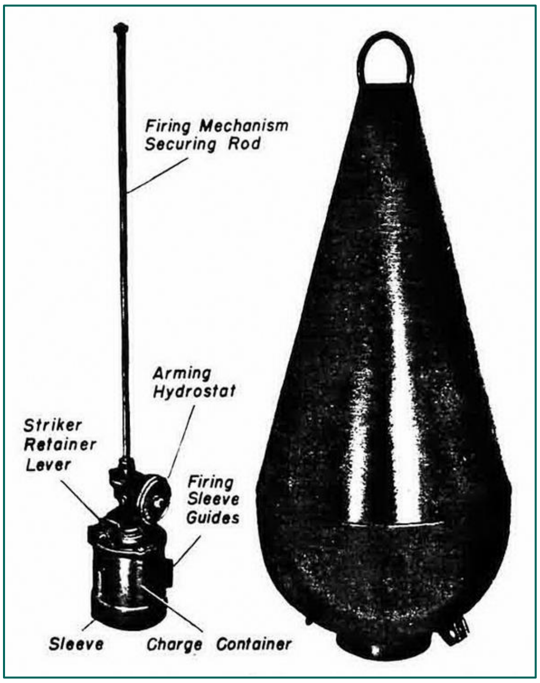
Luft Mine – Type B, Influence/Ground Mine



Küstenmine – Type A, Contactmine



Exploding floats, *Sprengboje* (Explosive)



Static cutters/Static Conical Sweep Obstructor, *Reisboje* (Non explosive)

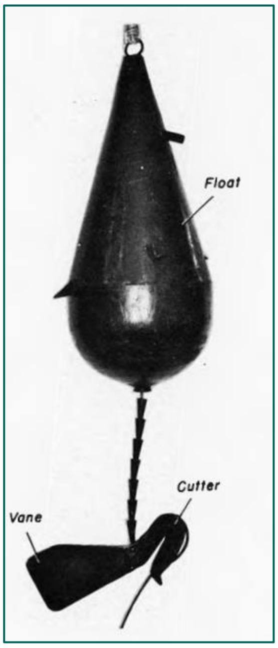


Table 6: German Mines (and sweep obstructors) within the area of investigation.

ANNEX 4 WRECKS WITHIN THE AREA OF INTEREST

The website 'Wrecksite' and the book 'HP39 Wrakkenregister, Nederlands Continentaal Plat en Westerschelde' (abbreviated to HP39), drawn up by the Dutch navy, show an abundance of wrecks (ships and aircraft) within the area of interest. In HP39 no details are given about the reason/cause of the sinking of the ships or aircraft. However. An overview of all wrecks according to this book is shown below.

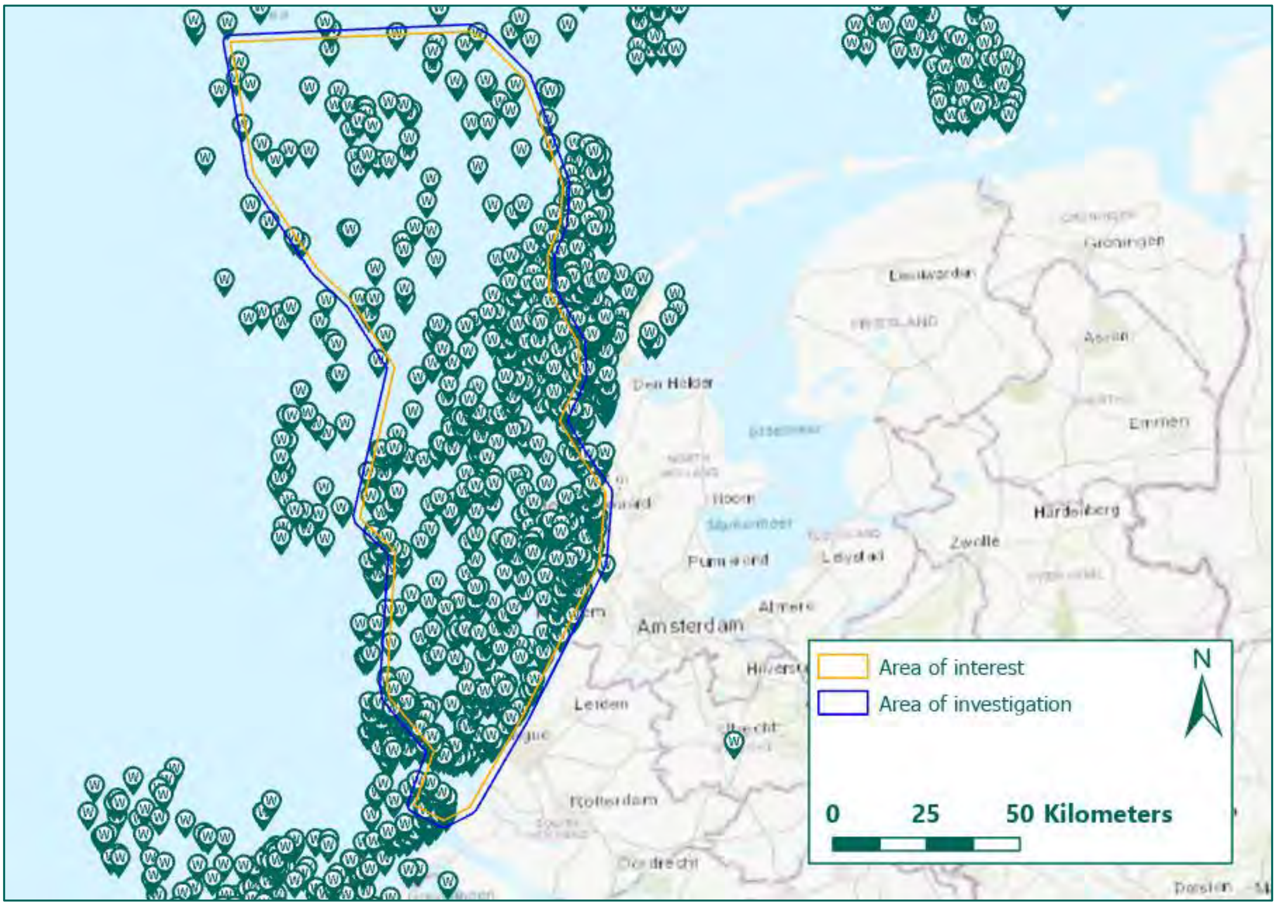


Figure 62: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

The Website 'Wrecksite' shows more details with regards to the wrecks in the North Sea. The website shows a total of more than 1800 wrecks within and near the area of interest. Plotting all these wrecks in the GIS-system would be too comprehensive and would outside the scope of this report. In the table below a list war related causes of sinking of ships/aircraft within the area of interest is shown.

Cause of sinking	Total number sunk
Airplane crashes, WW2	75
Air raids, WW2	19
Charges/explosives, WW1 and WW2	8
Depth charges , WW2	2
Explosions, WW2 and after WW2	4
Gunfire – shelled, WW1 and WW2	152
Mine, WW1 and WW2	39
Naval battles, WW1 and WW2	10
Torpedo, WW1 and WW2	21
War loss (Not specified), WW1	1

Table 7: Listing of ships/aircraft sunk by war related events.

ANNEX 5 POST-WAR UXO CLEARANCE

OSPAR Commission

OSPAR is the mechanism by which 15 governments and the European Union cooperate to protect the marine environment of the North-East Atlantic. Since 1972 the OSPAR Convention has worked to identify threats to the marine environment and has organised, across its maritime area, programmes and measures to ensure effective national action to combat them. One of the Policy Issues of the OSPAR Convention is to report encounters with conventional and chemical munitions in the OSPAR maritime area. These encounters are kept in a database[16]. The munition encounters from 1999 onwards within the area of interest are rendered in Figure 63. Multiple UXOs were lifted from the area of interest. The exact type of UXO lifted is not mentioned in all cases. However, it is known that several aerial bombs, flares, mines, torpedo's and shells were lifted.

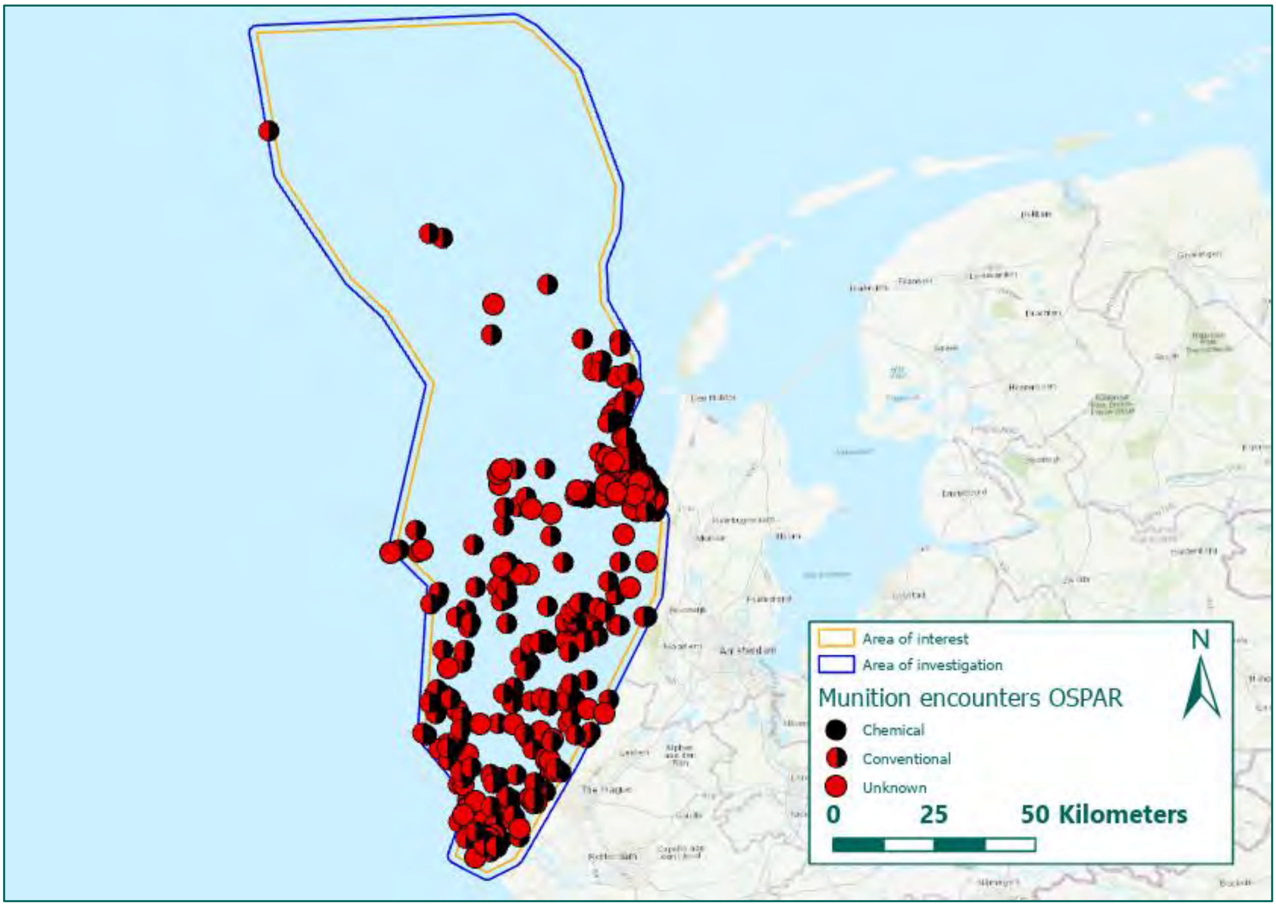


Figure 63: Overview OSPAR ammunition encounters within the area of interest (Source: OSPAR).

Dutch Coastguard (Nederlandse Kustwacht) and Beneficial Cooperation

The Dutch Coastguard (Nederlandse Kustwacht) cleared hundreds of UXO in the North Sea. Coordinates were used to keep track of the locations of encountered UXO. The Dutch Coastguard also cooperated with the Belgian Navy in clearing ammunition. This joint venture operates under the name Beneficial Cooperation.

The Dutch Coastguard manufactured lists that could help citizens (mainly citizens active in the fishing industry) identify any UXO found at sea. This additional information helped the Coastguard to be better prepared. These lists are shown at the end of this annex for clarification. When known, the numbers referring to the different types of UXO are shown in the GIS-shapefiles of the Dutch Coastguard and

[16] This database can be consulted at http://odims.ospar.org/layers/?limit=100&offset=0.

Beneficial Cooperation. The figures below respectively show cleared UXO reported by the Dutch Coastguard and Beneficial Cooperation.

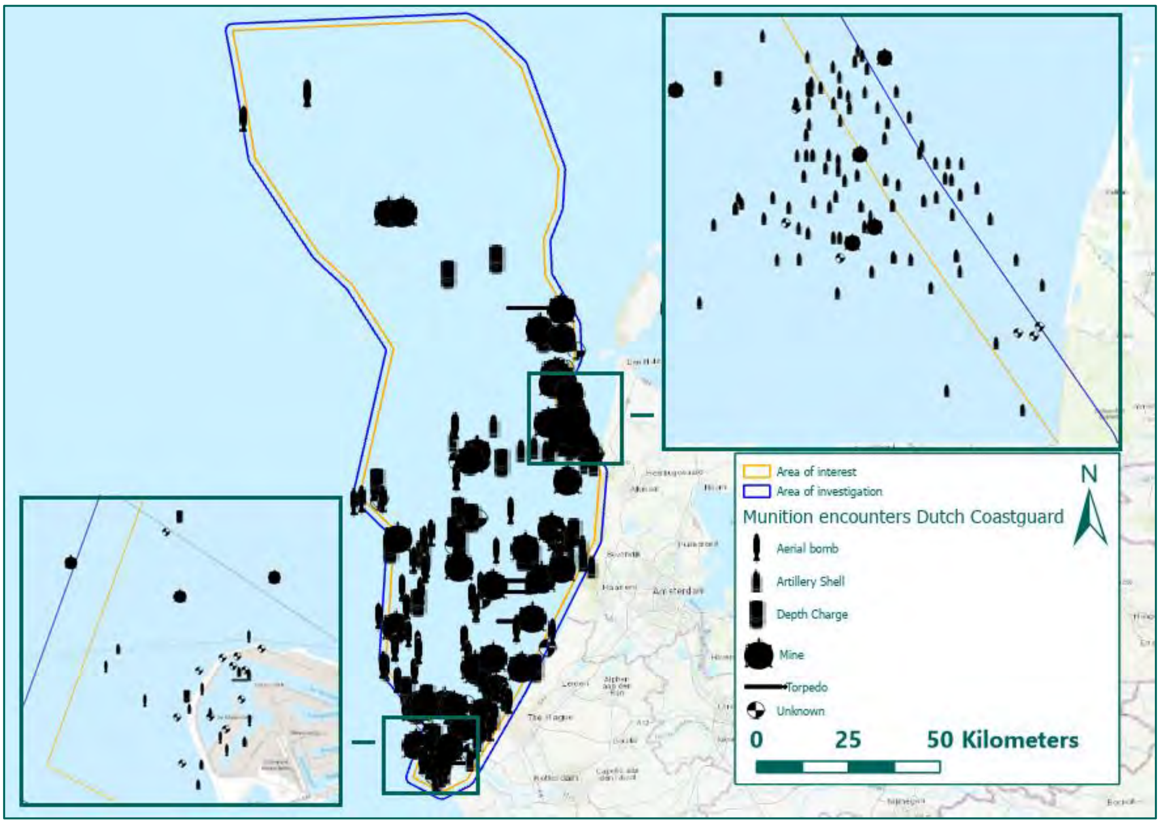


Figure 64: Overview of UXO lifted by the Dutch Coastguard (Source basemap: ESRI).

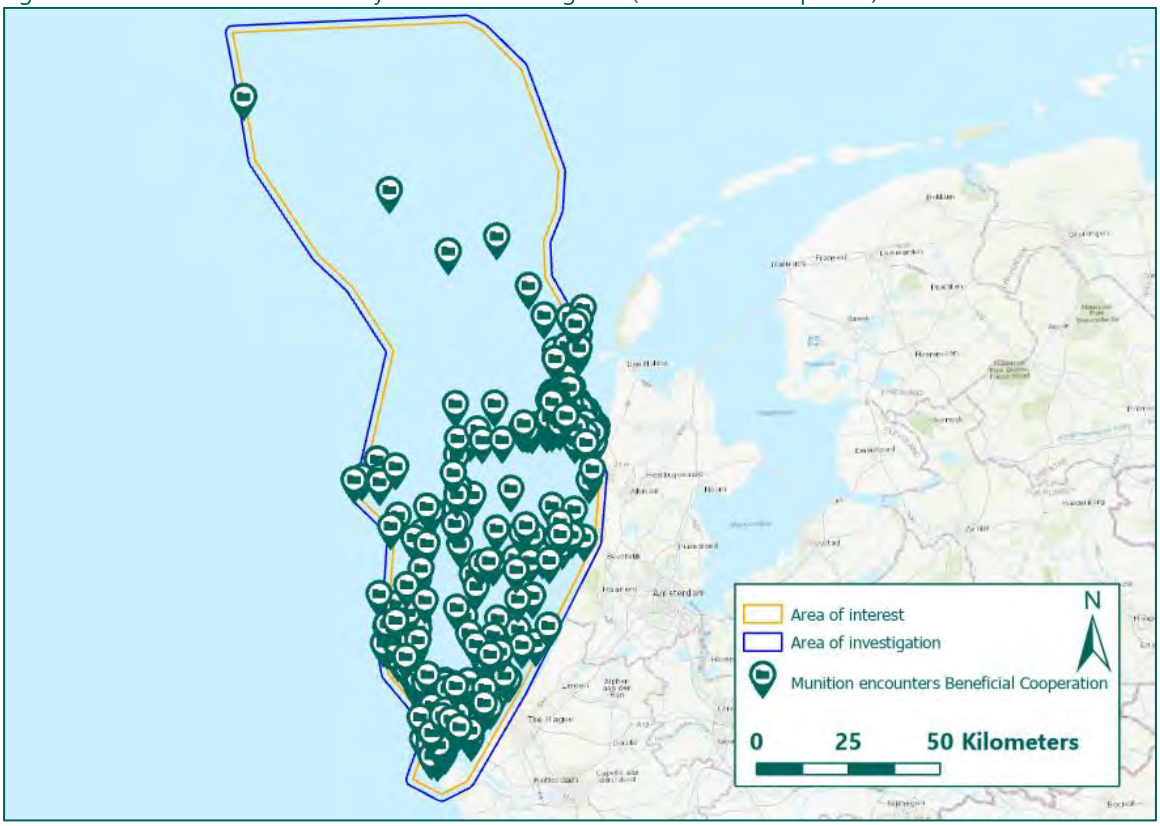
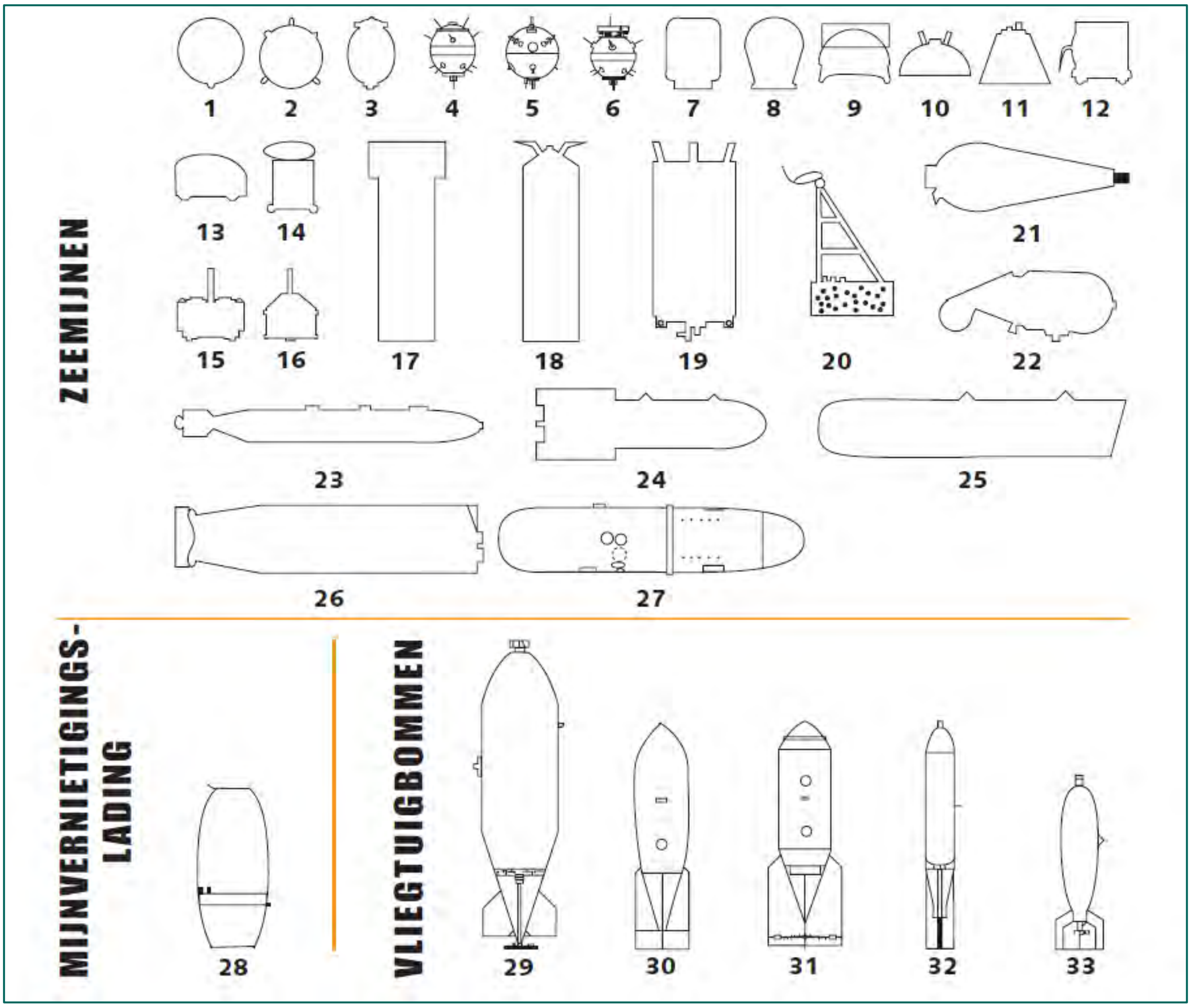


Figure 65: Overview of UXO lifted by the Beneficial Cooperation (Source basemap: ESRI).


ZEEMIJNEN
1
2
3
4
5
6
7
8
9
10
11
12
13
14
21
15
16
17
18
19
20
22
23
24
25
26
27
MIJNVERNIETIGINGS-
LADING
28
VLIEGTUIGBOMMEN
29
30
31
32
33

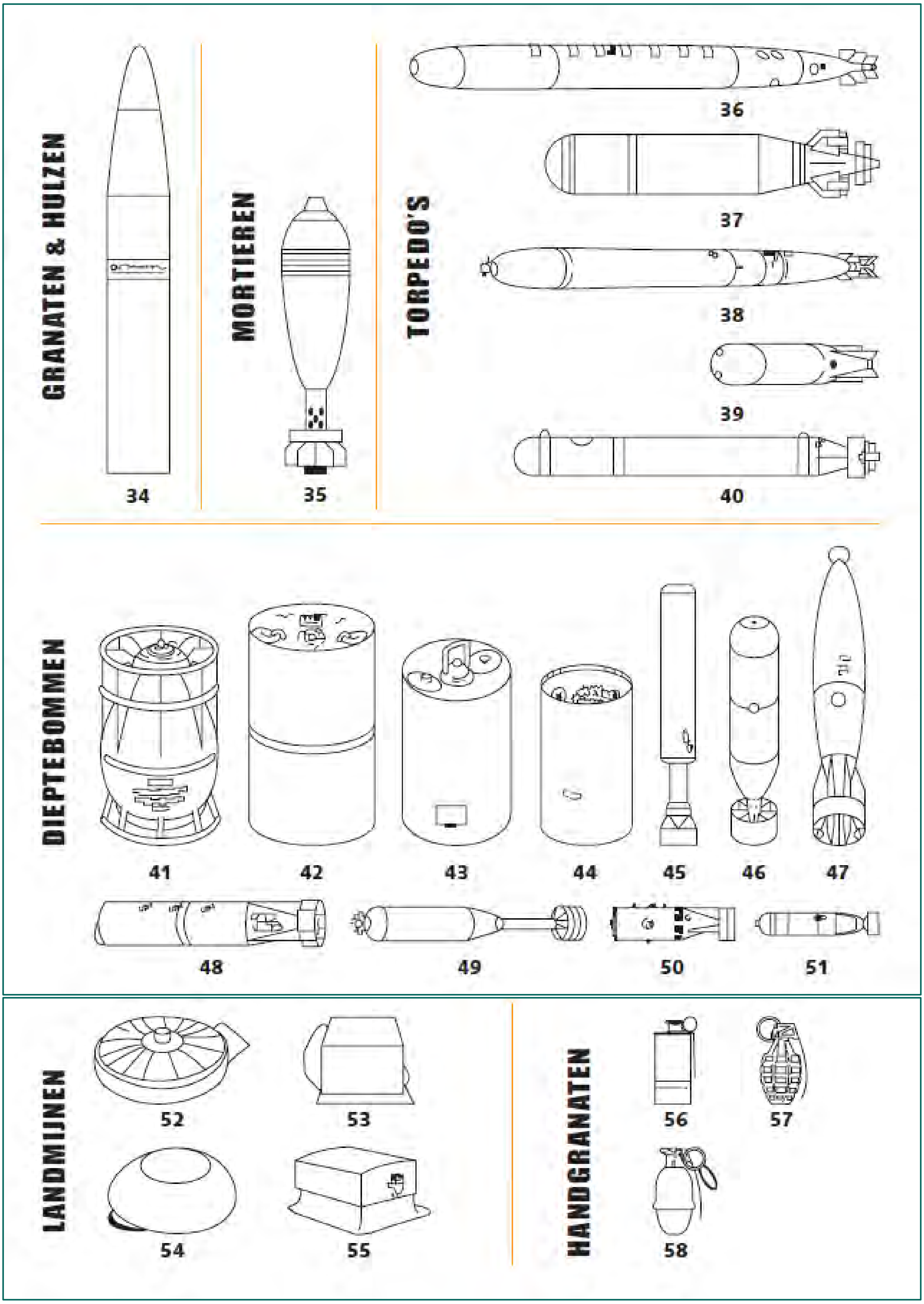


Figure 66: 'Explosievenkaart' (Explosives chart) of the Dutch Coastguard. This chart is used to help identify UXO (Source: Dutch Coastguard).

Dutch 'Explosieven Opruimingsdienst' (EOD)

Every year, the Dutch EOD clears an average of 2,500 explosives from the Second World War in the Netherlands. Most of these clearances take place onshore. However, the Dutch Navy does assist the Coastguard with offshore UXO encounters. In the figure below the locations of multiple UXO encounters are shown. The same 'Explosievenkaart' (Explosives chart) is used to identify these UXO. When known, the numbers referring to the different types of UXO are shown in the GIS-shapefiles of the EOD.

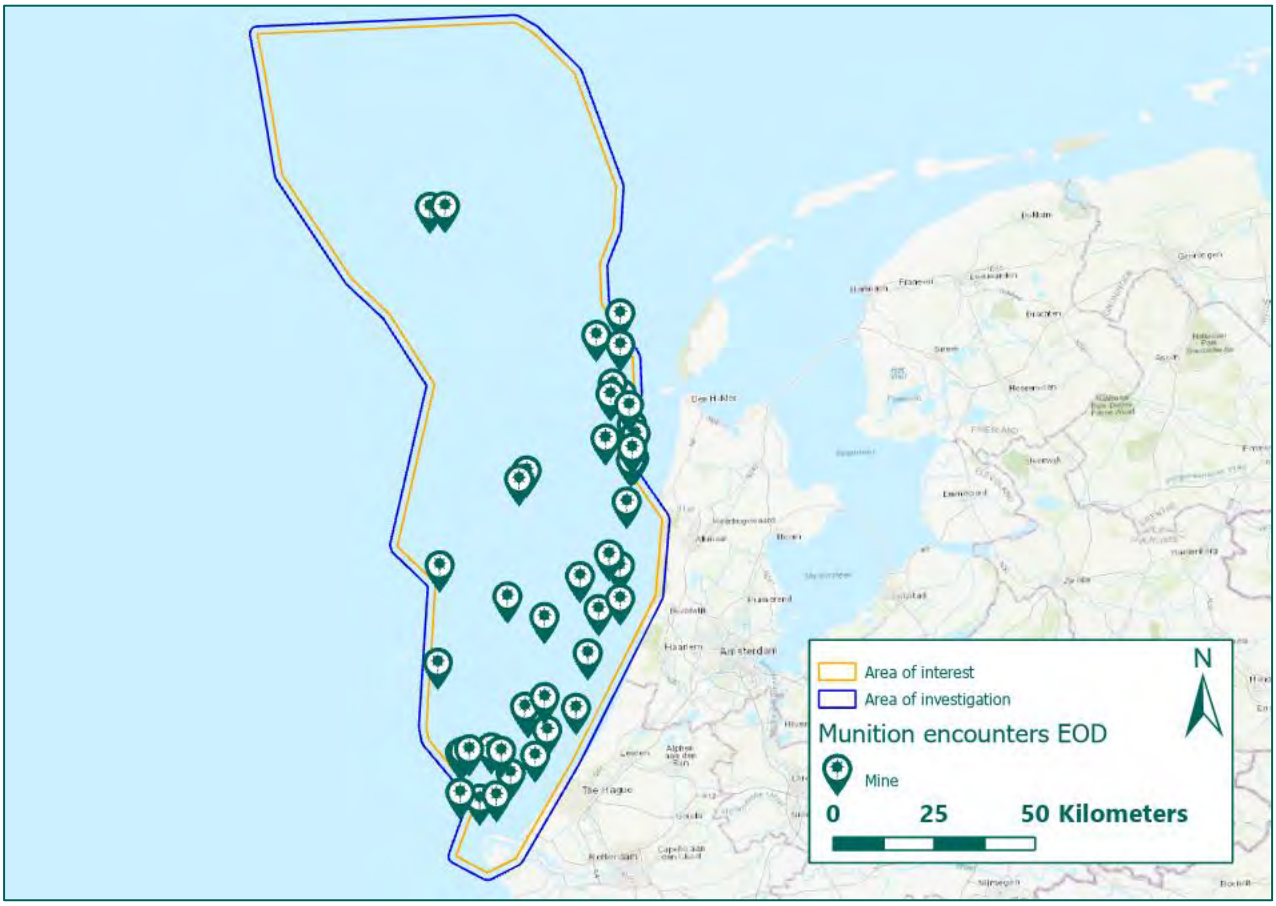


Figure 67: Overview of UXO lifted by the Dutch EOD (Source basemap: ESRI).

Aramis Pipeline

An archaeological assessment
Of geophysical survey results

Authors
[redacted], [redacted] and [redacted]

At the request of

TotalEnergies EP Nederland B.V.

Document Control	
Document 22A030-01 Aramis pipeline – An archaeological assessment of geophysical survey data	
Revision	3.0 (final)
Date	31-08-2023
Periplus Archeomare Reference	22A030-01
TotalEnergies reference	Aramis pipeline

Colophon

Periplus Archeomare Report 22A030-01
Aramis Pipeline – An archaeological assessment of geophysical survey results
Authors: [redacted] [redacted] and [redacted]

At the request of TotalEnergies Nederland B.V.
Contact: [redacted]

The report has been reviewed by the Cultural heritage Agency of the Netherlands

ISSN 2352-9547

Revision details

Rev.	Description	Authors	Checked	Authorization	Date
3.0	Final	[redacted]	[redacted]	[redacted]	31-08-2023
2.0	For Comments Authorities	[redacted]	[redacted]	[redacted]	03-08-2023
1.0	For Client Comments	[redacted]	[redacted]	[redacted]	27-06-2023

Authorization:

[redacted]

Periplus Archeomare
Kraanspoor 14
1033 SE – Amsterdam
Tel: 020-6367891
Email: info@periplus.nl
Website: www.periplus.nl

Table of contents

Table 1. Dutch archaeological periods

Period	Time in Years				
Post-medieval / Modern Times	1500	A.D.	-	Present	
Late medieval period	1050	A.D.	-	1500	A.D.
Early medieval period	450	A.D.	-	1050	A.D.
Roman Times	12	B.C.	-	450	A.D.
Iron Age	800	B.C.	-	12	B.C.
Bronze Age	2000	B.C.	-	800	B.C.
Neolithic (New Stone Age)	5300	B.C.	-	2000	B.C.
Mesolithic (Stone Age)	8800	B.C.	-	4900	B.C.
Paleolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Table 2. Administrative details

Location:	North Sea	
Province	Zuid-Holland	
Municipality	Rotterdam	
Toponym Dutch:	Aramis pipeline	
Chart:	1801-01, 1811-01	
Coordinates Geodetic datum: ETRS89 Projection: UTM31N	Geophysical survey area	
	Centre	E 564 944 - N 5 856 821
	Northwest	E 580 104 - N 5 953 697
	Northeast	E 542 599 - N 5 953 697
	Southwest	E 542 599 - N 5 759 945
	Southeast	E 580 104 - N 5 759 945
Depth (LAT):	4.8 to 39.6 meter, average 27.0 meter	
Area (km^2):	Survey area	243.25 km^2
Environment:	Tidal currents, salt water	
Area use:	Shipping, fishing, oil, and gas industry	
Area administrator:	Rijkswaterstaat Zee en Delta	
Competent authority	Rijkswaterstaat Zee en Delta	
Advising body	Cultural Heritage Agency of the Netherlands [redacted]	
ARCHIS-research report (CIS-code):	5330686100	
Periplus-project reference:	22A030-01	
Period	May - August 2023	

Samenvatting (Abstract in Dutch)

In opdracht van TotalEnergies Nederland B.V. heeft Periplus Archeomare een archeologische analyse uitgevoerd van de geofysische onderzoeksresultaten van het Aramis pijpleidingtracé.

Een grote hoeveelheid onderzoeksgegevens (*sidescan-sonar, magnetometer, multibeam echosounder* en *subbottom-profiler*) van een gebied met een totale oppervlakte van 243 km2 is geanalyseerd om een archeologische beoordeling uit te voeren.

Deze analyse van geofysische onderzoeksresultaten is de tweede stap in de AMZ-cyclus, na de bureaustudie. Het doel van deze analyse is het toetsen van de op de bureaustudie gebaseerde verwachting voor archeologische resten in het gebied. De verwachting omvat overblijfselen van scheepvaartgerelateerde resten (wrakken), vliegtuigen uit de Tweede Wereldoorlog en prehistorische nederzettingen.

Sidescan-sonar en multibeam-contacten
Binnen het onderzochte gebied is aan in totaal acht contacten een archeologische verwachting toegekend. In overeenstemming met de Nederlandse wet- en regelgeving mogen hier geen bodemverstoringen plaatsvinden. Indien er binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven.

Magnetische afwijkingen
In totaal zijn op 2748 locaties magnetische afwijkingen waargenomen. Op tien locaties zijn magnetische afwijkingen met een piek-tot-piekwaarde van meer dan 500 nT in kaart gebracht, die niet gerelateerd kunnen worden aan bekende objecten zoals pijpleidingen of kabels en die van potentieel archeologisch belang kunnen zijn. De objecten die deze afwijkingen veroorzaken, zijn niet zichtbaar op sidescan-sonar- of multibeam-beelden en worden daarom geacht in de zeebodem te zijn begraven. Deze objecten kunnen (naast archeologische objecten) onder meer puin, explosieven, verloren ankers, et cetera zijn. Zolang het karakter van deze objecten niet is vastgesteld, worden de objecten geacht van potentieel archeologisch belang te zijn. Negen van de tien contacten vallen binnen een straal van 100 meter van de voorgestelde route.

In overeenstemming met de Nederlandse wet- en regelgeving mogen geen bodemverstoringen plaatsvinden op deze locaties. Indien binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven. Alle locaties van potentieel archeologisch belang binnen een straal van 100 meter van de voorgestelde route zijn weergegeven in figuur 1.

Prehistorische resten
De fysieke kwaliteit, dat wil zeggen de integriteit en het behoud van prehistorische resten, is sterk afhankelijk van de mate waarin prehistorische landschappen en archeologische niveaus daarin zijn aangetast door erosie. De seismische gegevens geven aan dat een deel van het Pleistoceen-landschap is geërodeerd tijdens de mariene transgressie in het vroege Holoceen, waardoor de integriteit van mogelijke prehistorische nederzettingen is aangetast. Lokaal kunnen de geologische eenheden die zijn gedefinieerd

als potentiële lagen met prehistorische overblijfselen intact zijn gebleven, vooral in gebieden waar veen is gevonden. De interpretatie van lithostratigrafische eenheden en het karakter van de laaggrenzen (erosief versus niet-erosief) uit de seismische gegevens is gebaseerd op de beschikbare geologische gegevens en het oordeel van deskundigen. De seismische interpretatie moet worden geverifieerd door middel van vibrocore-bemonstering. De werkelijke geologische sequenties die in het gebied aanwezig zijn en de integriteit van de laaggrenzen zullen worden geverifieerd, wat een instrument zal bieden voor verdere analyse van de prehistorische landschappen en het specificeren en testen van het archeologische potentieel.

Advies prehistorie

Periplus Archeomare beveelt aan verder archeologisch onderzoek uit te voeren dat zich richt op het ontstaan en de integriteit van paleo-landschappen langs de Aramis-routetrajecten voor algemene archeologische onderzoeksdoeleinden. Dit onderzoek omvat een inventarisatie van veldonderzoek door middel van vibrocore-bemonstering conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1). Er wordt een geotechnische campagne uitgevoerd om een geologisch model te genereren van de ondergrond van de pijpleidingcorridor en om de fysische eigenschappen van de aanwezige sedimentlagen te bepalen. Wij adviseren om een aantal vibrocore-locaties aan te wijzen waar sedimentmonsters worden verzameld die gebruikt kunnen worden voor geo-archeologisch onderzoek.

De intacte monsters moeten door een (senior) prospector worden onderzocht en beschreven volgens de Standaard Boorbeschrijvingsmethode (SBB). Monsters worden geselecteerd en gestabiliseerd om te worden geanalyseerd door specialisten op het gebied van OSL- en radiokoolstofdatering, sedimentpetrografie, palynologie, micropaleontologie (foraminiferen, ostracoden, diatomeeën, et cetera), macroresten van planten en dieren en weekdieren om inzicht te krijgen in de ontwikkeling van landschappen in de loop van de tijd en de mate waarin deze paleolandschappen bewaard zijn gebleven.

Conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1) moet er een Programma van Eisen (PvE) en/of Plan van Aanpak (PvA) worden opgesteld. Dit PvE/PvA omvat de doelstelling, de onderzoeksstrategie en -methodiek, de kaders en de praktische uitvoering van het onderzoek, zodat het proces soepel verloopt en meervoudig gebruik van de op uniforme wijze verkregen data wordt bereikt. Geadviseerd wordt om deze PvE/PvA ter goedkeuring voor te leggen aan het Bevoegd Gezag en de RCE. Na afronding van het inventariserend veldonderzoek kunnen tijdens de aanleg van de pijpleiding gegevens worden verzameld die – vanuit archeologisch oogpunt – op gedetailleerd niveau waardevolle informatie opleveren. Het kan zeer nuttig zijn om deze informatie vanuit archeologisch oogpunt verder te onderzoeken. Het verdient aanbeveling om, nadat de plannen zijn uitgewerkt, in overleg met de RCE de mogelijkheden hiervoor te onderzoeken.

Tijdens de installatie van de leiding kunnen archeologische voorwerpen worden ontdekt die volledig zijn begraven of tijdens het geofysisch onderzoek niet als archeologisch object zijn herkend. Wij adviseren passieve archeologische begeleiding op basis van een goedgekeurd Programma van Eisen. Passieve archeologische begeleiding houdt in dat een archeoloog tijdens de uitvoering van de werkzaamheden niet aanwezig is, maar altijd op afroep beschikbaar is. Het opvolgen van deze aanbeveling voorkomt vertragingen tijdens de werkzaamheden wanneer er onverwacht archeologische resten worden aangetroffen. Op grond van de Erfgoedwet is het verplicht om deze bevindingen te melden aan de toezichthouder (Minister van OCW). Deze melding moet ook worden opgenomen in het bestek van het werk.

Summary

TotalEnergies Nederland B.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical survey results of the Aramis pipeline route survey.

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) covering a total area of 243 km^2 have been analyzed to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Side scan sonar and multibeam contacts

Within the surveyed area, an archaeological expectation was assigned to a total of 8 contacts. In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE).

Feature	NCN	Easting	Northing	Route section	Distance
BK_FSEA_SSS_0022	-	551288	5924521	D	**+50**
BK_FSEA_SSS_0179	-	555839	5929168	D	-240
BJ_FD_SSS_0015	-	548443	5894128	F	+230
BB_FS_SSS_0683	219	570384	5762003	East	-540
BH_FSEA_SSS_0104	531	559172	5935317	C	**+25**
BK_FSEA_SSS_0163	967	550165	5921956	D	**-56**
BN_FD_SSS_0025	945	576689	5920367	E Neptune	+220
BB_FS_SSS_0433	-	570711	5761481	East	-210

Three of the eight contacts fall within 100 meters of the proposed route.

Magnetic anomalies

A total of 2748 magnetic anomalies have been observed. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Target	E	N	nT	Section	Distance
BAB_FS_UXO_0010	570711	5761625	808	East	-210
BAB_FS_UXO_0599	570931	5761671	514	East	**+5**
BAB_FS_UXO_0603	570932	5761987	2312	East	**+8**
BAB_FS_UXO_0605	570933	5761957	1158	East	**+8**
BAB_FS_UXO_0618	570936	5761510	729	East	**+11**
BAB_FS_UXO_0657	570948	5761543	1348	East	**+22**
BC_FD_MAG_0121	571170	5763666	666	East	**+4**
BH_FSEA_MAG_0044	559169	5935057	578	C	**-2**
BJ_FD_MAG_0050	563642	5875159	2089	F	**-59**
BP_FD_MAG_0016	559490	5931390	591	B	**-60**

Table 3. Magnetic anomalies over 500 nT with an archaeological expectation.

Nine of the ten contacts fall within 100 meters of the proposed route.

In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). All locations of potential archaeological interest within 100 meters of the proposed route are shown in the next figure.

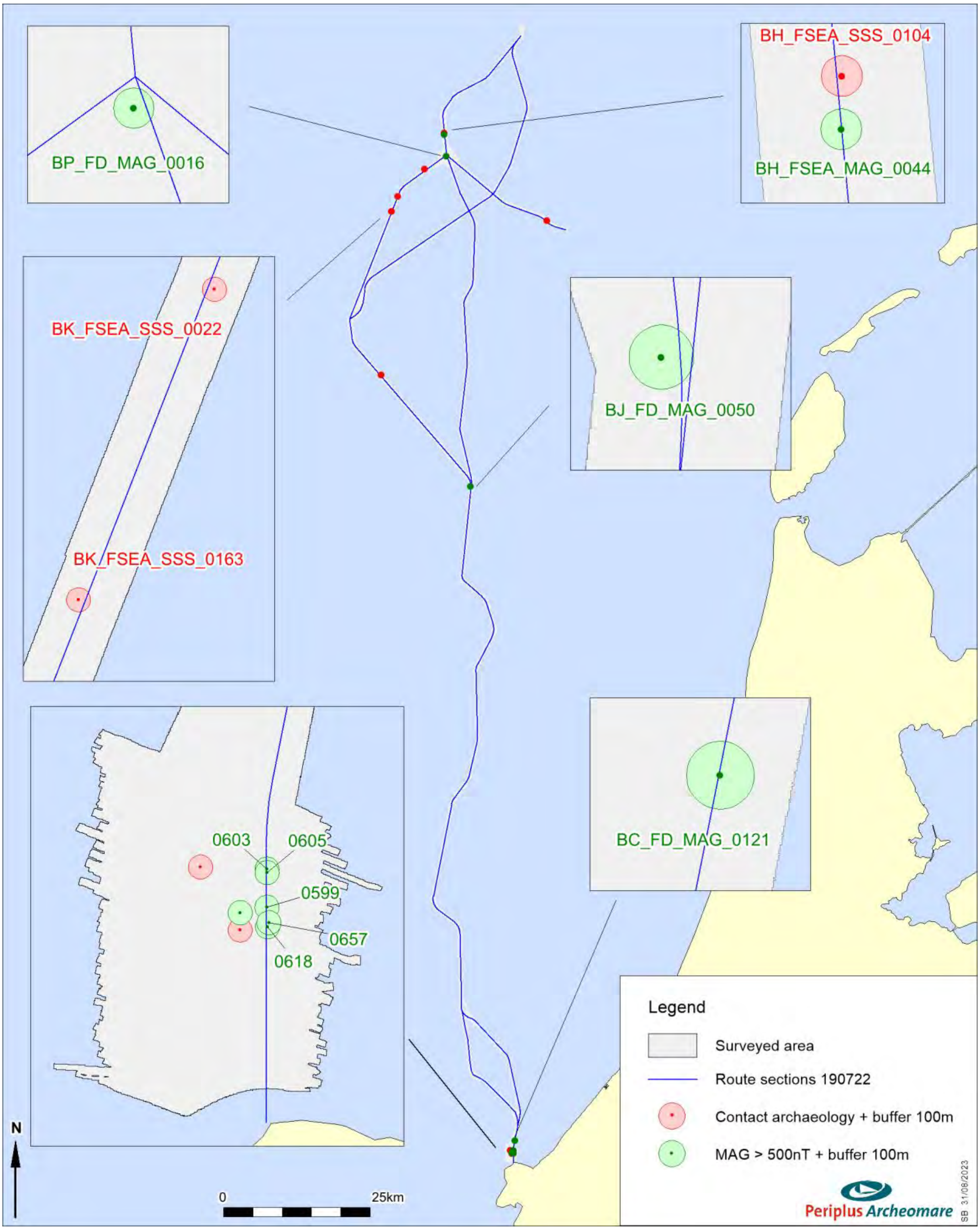


Figure 1. Overview of the potential archaeological targets within 100 meters of the proposed route

Prehistoric remains
Areas of potential archaeological interest listed below.

Depositional environment Areas of potential archaeological interest	Lithostratigraphic Unit	Time of deposition	Archaeological period
Peat-covered aeolian and small scale fluvial deposits	Boxtel Formation	*Late Glacial* and Early *Holocene*	Late Paleolithic and Early Mesolithic
Catchment of the Rhine	Kreftenheye Formation	Pleniglacial	Middle Paleolithic
Shores of lakes and lagoons	Brown Bank Member	Early *Weichselian*	Middle Paleolithic to Early Mesolithic

The physical quality, that is, the integrity and preservation of prehistoric remains is highly dependent on the extent to which prehistoric landscapes and archaeological levels herein have been affected by erosion. The seismic data indicate that part of the *Pleistocene* landscape has eroded during the Early *Holocene* marine ingression, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains may have been preserved intact, especially in areas where peat has been found. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by vibrocore sampling. The actual geological sequences present in the area and the integrity of layer boundaries will be verified, thus offering a tool for further analysis of the prehistoric landscapes and specify and test the archaeological potential.

Recommendation

Prehistory
Periplus Archeomare recommends conducting further archaeological research that focuses on the genesis and integrity of paleo-landscapes along the Aramis route trajectories for general archaeological research purposes. This research comprises an inventory of field research by means vibrocore sampling in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carried out to generate a geological model of the subsurface of the pipeline corridor and to determine the physical properties of the sediment layers present. We recommend designating a number of vibrocore locations where sediment samples are collected that can be used for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of OSL and radiocarbon age dating, sediment petrography, palynology, micropaleontology (foraminifera, ostracods, diatoms, et cetera), macro-remains of plants and animals and molluscs to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly, and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE. After completion of the inventory field research, during the construction of the pipeline, data can be collected that - from an archaeological point of view - provides valuable information at a detailed level. It can be very useful to investigate this information further from an archaeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.

During the installation of the pipeline, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Minister of OCW). This notification must also be included in the Scope of Work.

1 Introduction

TotalEnergies Nederland B.V. has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical survey results of the Aramis pipeline route survey.

The area of investigation (243 km^2) is located in the North Sea, and runs from Maasvlakte II to offshore block L4 over a distance of 192 km.

Figure 2. Location map of the area of investigation

1.1 Background

TotalEnergies plans to build a new pipeline from Maasvlakte 2 to offshore blocks L4/K6 as part of the Carbon Capture and Storage (CCS) project Aramis. The CCS system will consist of an onshore pipeline, the compressor station, an offshore pipeline and the storage of CO_2 in the deep subsoil of the North Sea (figure 3). The capture of CO_2 from the harbour's industries and the use of CO_2 of the storage of it underground is one of the measures to achieve the climate objectives. The area to be surveyed encompasses:

(1) the shore approach/Landfall pipeline routing for HDD and dredging part at Maasvlakte
(2) the offshore rigid pipeline routing from Maasvlakte to blocks L4/K6
(3) the offshore distribution hub[1].

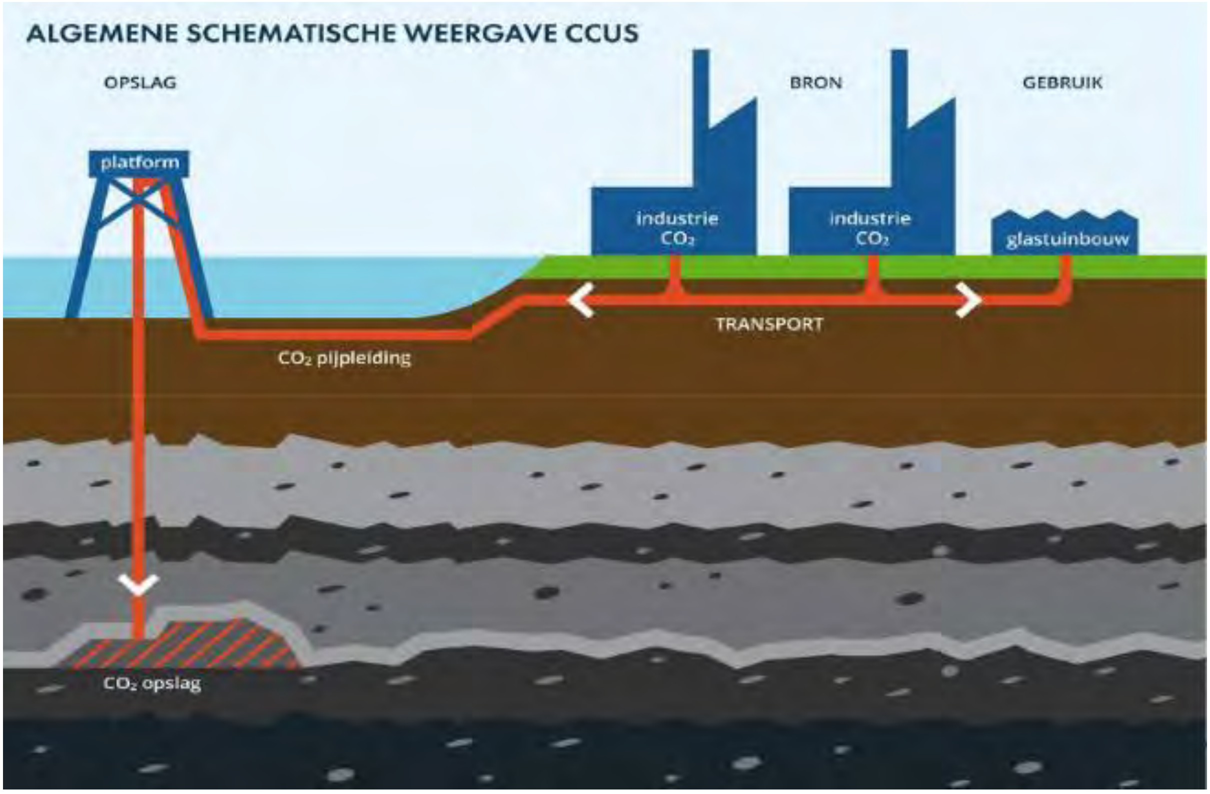


Figure 3: Schematic representation of the transport and storage system.

Offshore, the proposed 32 inch pipeline will be trenched into the seabed to a maximum depth of one meter[2].

In the Erfgoedwet[3] the protection of the archaeological heritage is embedded. Planned activities, such as the installation of a pipeline in the North Sea, may affect the archaeological values if present. If the remains are in jeopardy, there is a statutory obligation to conduct archaeological research. In line with this obligation an archaeological desk study has been carried out.

[1] Porthos project
[2] Concept Notitie Reikwijdte en Detailniveau Aramis CO2-transportinfrastructuur
[3] De Erfgoedwet became effective on the 1st of July 2016.

An archaeological desk study is the first step in the so-called *AMZ* cycle (Archeologische Monumenten Zorg). The *AMZ* cycle includes a description of procedures for subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands.

The second phase of the *AMZ* cycle is an inventory archaeological field study. As a rule, this field study comprises a geophysical survey of the seabed. The survey executed by Fugro was not primarily set to provide data to be used in the course of archaeological research. However, a scan of the survey data acquired, prove these data to be fit for an archaeological assessment.

The separate phases of the AMZ-cycle are embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). This standard dictates a mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 4.

1.2 Results desk study

In January 2022 an archaeological desk study has resulted in specific information on the archaeological remains which are to be expected within the entire area of interest of the Aramis pipeline[4]. The results of the desk study will be discussed below.

The area of interest has high expectations for the presence of (remains of) ship wrecks and WWII plane wrecks. Intact prehistoric landscapes and related *in situ* remains of Palaeolithic and Early Mesolithic camp sites and inhumations are expected to have been preserved in places.

The proposed pipeline routes have not been investigated by detailed geophysical surveys yet. These areas may contain more undiscovered shipwrecks or remains of shipwrecks than are currently known.

At this stage little is known about the integrity of the *Pleistocene* landscape. By means of subbottom profiling the occurrence geological units (both horizontal as vertical) and archaeological levels herein can be mapped. The character of layer boundaries (erosive or non-erosive) can be interpreted. It is unlikely however that archaeological remains of Paleolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on pipeline development. At this stage focus should therefore not be put on tracing prehistoric camp sites but on a pragmatic employment of geophysical techniques in order to obtain a better insight in (the integrity of) the *Pleistocene* landscape. The insights gained shall be used to a) refine the archaeological expectancy model and b) allocate areas with a high expectancy for *in situ* prehistoric remains.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to test the archaeological predictive model and further specify the type, vertical and lateral extent, age, integrity and preservation of shipwrecks, prehistoric landscapes and potential archaeological levels.

[4] Van den Brenk en van lil, 2022

Archaeological Expectancy	Method		Goal	Remarks
Ship and aircraft wrecks	Geophysical	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
		Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
		Sub-bottom Profiler	detect buried objects including possible shipwrecks and remains of aircraft	nature of the buried object cannot be determined directly
		Magnetometer		
Prehistoric settlements (camp sites)		Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data
	Geotechnical	Geological Sampling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	designation of borehole and/or vibrocore locations for geo-archaeological research based on SBP data
		Cone Penetration Test	determine lithostratigraphy	correlate with drilling data

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler* and a geotechnical survey. The resulting data should be assessed after the general processing, interpretation and reporting has been performed by the survey contractor.

The archaeological assessment of the data shall be conducted by a geophysical specialist (KNA prospector Waterbodems). The data quality from the surveys needs to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of Requirements (In Dutch: 'Programma van Eisen') in accordance with the 'KNA' (the Dutch quality standards for archaeological research), to be authorized by the competent authority.

1.3 Objective

The purpose of the archaeological assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

The goals set for this assessment are:

- To determine the historical or archaeological value of contacts found in the geophysical survey;
- To validate the locations of known wrecks;
- Assess the prehistoric landscape based on seismic data.

1.4 Research questions

For the inventory archaeological field study, the following research questions have been defined in the Program of Requirements[5].

Primary Question : Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?
With respect to side scan sonar, magnetometer and multibeam survey:
- Are there any phenomena visible on the seabed?

If so:
- What is the description of these phenomena?
- Do these phenomena have a man-made or natural origin?

If these phenomena can be designated to be man-made:
- What classification can be attached?

If these phenomena can be classified as archaeological:
- Is it possible to interpret the nature of the archaeological objects?

If these phenomena can be identified as natural:
- What is the nature of these natural phenomena?
- Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?

If so:
- How can these zones be interpreted?

General:
- What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?
- If no acoustic phenomena can be observed, are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?

With respect to the seismic data:
- What is the depth of the top of the Pleistocene and Holocene landscape(s) relative to a) LAT and b) the present seabed?
- What lithostratigraphic units can be distinguished along the pipeline routes?

The answer to this question shall include information on:
- the classification,
- the occurrence (lateral extent and depth),
- the lithologic and stratigraphic characteristics,
- the age and depositional environment,
- the character of the layer boundaries (gradual or instantaneous |erosive) of these units.

- Are channel-like features observed?

If so:
- What are the characteristics of the channel-like features in terms of spacial distribution (width, depth, shape, extent), channel infill composition, stratigraphic position and age.

- Are occurrences of peat and/or organic clay observed?

[5] Van den Brenk and van Lil, 2022.

If so:

- What is the spacial distribution (depth, extent) stratigraphic position and age of these deposits.
- Are intact prehistoric landscapes affected by the installation of the pipeline based on their vertical position related to the seabed?
- Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?

If so:

- Based on the presence of buried objects and their correlation with side scan sonar, magnetometer en multibeam data can something be said about the nature of these buried objects?

2 Methodology

2.1 Introduction

As part of the installation of the pipeline, a geophysical and geotechnical survey has been carried out by Fugro. The aim of the survey was to contribute to the bathymetrical, morphological, and geological understanding of area of interest, as defined in the scope of work. The results have been compiled in a survey report[6].

This geophysical survey provides the information needed for the planning and preparation of the geotechnical survey. The outcome of the geotechnical survey will be combined with the seismic data to create an Integrated Ground Model (IGM).

The following methods have been deployed:

- Side scan sonar (SSS)
- magnetometer (MAG)
- multibeam echo sounder (MBES)
- sub-bottom profiler (SBP)
- ultra-high resolution seismic (UHR)

The results of the survey and geotechnical activities have been recorded in reports, listings, drawings, and images. Prior to the execution of the archaeological assessment the quality and completeness of the delivered survey data have been judged. It is concluded that the data is of high quality and that the data are fit for the purpose of this archaeological assessment.

SSS	- event listings containing all contacts observed. - Geotiffs mosaics of all contacts listed
MAG	- event listings containing all anomalies observed
MBES	- validated *multibeam* XYZ point cloud dataset (grid 25x25cm)
SBP/UHR	- representative subbottom profiles
Report	- survey reports

Table 4. Data used for archaeological assessment.

[6] Fugro report F192961_REP_007 01, rev 00, 23 September 2022.

2.2 Geophysical survey

The geophysical survey was carried out by Fugro between July 2022 and April 2023. For the execution of the survey the vessels '*MV Fugro Discovery*', '*MV Fugro Seeker*', and the '*Fugro Searcher*' were employed. An overview of the survey campaign and the employed methods is presented in the table below.

Region	Survey Type	Vessel	Survey		Survey Methods
			Start	End	
Offshore	Geophysical	MV Fugro Discovery	11-11-2022	12-12-2022	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), Two-dimensional Ultra-heigh Resolution (2DUHR), and Magnetometer
Nearshore	Geophysical	MV Fugro Seeker	11-07-2022	22-09-2022	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), and Two-dimensional Ultra-heigh Resolution (2DUHR)
Offshore	Geophysical	MV Fugro Searcher	09-10-2022	23-01-2023	Multibeam (MBES), Sub Bottom Profiler (SBP), Side Scan Sonar (SSS), and Two-dimensional Ultra-heigh Resolution (2DUHR), and a Sparker
Offshore & Nearshore	Geotechnical	MV Normand Mermaid	11-11-2022	24-01-2023	CPT and Vibrocore
Offshore & Nearshore	Geotechnical	MV Kommandor Orca	02-12-2022	12-12-2022	CPT and Vibrocore

Table 5. Overview of the survey campaigns and the employed survey methods (source: Fugro report F197217-REP-001 | 01 | 18 April 2023).

77 geotechnical locations were investigated during the geotechnical surveys. All locations comprise of Vibrocore (VC) and Cone Penetration Test (CPT).

Details about the geophysical and geotechnical surveys can be found in the integrated Geophysical and Geotechnical reports in Appendix 3

2.3 Known objects.

Fugro has summarized the *side scan sonar* contacts and *magnetometer* anomalies encountered within the survey area in detailed event listings. From different databases the occurrence of a number of objects within the area is known, as described in the desk study[7]. The contacts included in the survey event listings are compared with the database objects in the area. For this comparison four different datasets are used:

- The Hydrographic Service database (hereafter referred to as NLhono database);
- The Rijkswaterstaat SonarReg database (hereafter referred to SR database);
- The Dutch Cultural Heritage Agency database ARCHIS;
- The Dutch Nationaal Contact Nummer database (hereafter referred to as NCN);
- The NCN database contains all basic information (E, N, and description) of the Nlhono, SR and Archis databases. More detailed information is gathered through the other datasets.

[7] Van den Brenk en van lil, 2022

The National Contact Number (NCN)

The NCN database combines the data from three governmental databases:

- The Dutch Continental Shelf and Westerschelde wrecks register from the Hydrographic Service of the Royal Netherlands Navy;
- The SonarReg object database of Rijkswaterstaat;
- The ARCHIS database (the official archaeological database of the Ministry of Cultural Heritage)

The permission for the use of the NCN database for the analysis was granted by the owner (Rijkswaterstaat Zee en Delta).

In addition to shipwrecks, information on contacts referred to as ‘foul’ or ‘obstruction’ are included. From these objects the origin is not always known, but information on the location, dimensions and other valuable information is listed. Besides the databases other sources containing information on wrecks and historic finds are consulted for comparison with the survey results.

All known data is combined and plotted in GIS. In this way an overview is made of the areas in which archaeological remains are present or to be expected. The known contacts are a reference framework for the assessment of data recorded during the route survey.

2.4 Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include *side scan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES), subbottom profiling (SBP) and ultra-high resolution multi-channel seismic (UHRS). The natures of those methods differ, with coherent strengths and weaknesses.

Table 6 provides a summary of the objective(s) the methods employed and the nature of those methods in terms of seabed penetration and coverage. Data are cross correlated because the methods are complementary. E.g., *multibeam* data can aid in the interpretation of a *side scan sonar* contact by providing information on its height with respect to the surrounding seabed, the occurrence of scouring next to the contact, and the accuracy and precision of the object. CPT's, borehole and vibrocore data will aid in the determination of geological units from seismic strata.

Method	**Objective**	**Seabed**		**Accuracy and Precision**	**Cross Correlation**
		Penetration	**Coverage**		
SSS	Identification of outcropping objects; seabed classification	No	Full	High	MBES / MAG
MBES	Charting of seabed morphology; identification of scours	No	Full	Very high	SSS
MAG	Identification of magnetic anomalies induced by ferromagnetic objects	Yes*1	Full*2	Accuracy = high Precision = poor*3	SSS
SBP/UHRS	Identification of seismic strata and buried objects such as pipelines, cables and boulders	Yes	No Profile data beneath sailed line	High	BH/VC/CPT*4 MAG
BH/VC	Determination physical properties of sediments and lithostratigraphy	Yes VC appr. 5 m bsb BH 60 to 80 m bsb	No Point location	High	CPT/ SBP/UHRS
CPT	Determination of physical properties of sediments and lithostratigraphy	Yes Up to 50 to 80 m bsb	No Point location	High	BH/VC/ SBP/UHRS

Table 6. Characteristics of geophysical and geotechnical methods employed.

NOTE:
*1 detection dependent on size of the ferromagnetic object, depth of burial, height of *magnetometer* above the seabed and distance cross course.
*2 distant and/or deeply buried objects can be missed.
*3 accuracy: perpendicular to ship heading = ½ * spacing of sailed lines; parallel to ship heading = approximately 1 m.
*4 interpretation of geology through correlation of seismic data with BH/VC/CPT-data.

With *side scan sonar* all objects and structures on the seabed can be made visible. Seabed sediment of different composition can be distinguished by their characteristic reflection. *Multibeam* images reveal the morphology of the seabed. Large objects and scouring can be mapped. Smaller objects, like thin cables, or flat objects lying on the seabed often are impossible to identify in *multibeam* images.

The strength of *side scan sonar* resides in the ability to visualize differences in reflectivity of seabed sediments and exposed objects. Variations in seabed composition cannot be observed in *multibeam* data, unless those variations are accompanied by morphological changes. This also applies for objects which are barely elevated above the seabed. Another strength of *side scan sonar* is the full coverage which is accomplished with a limited number of survey lines. A limitation of *side scan sonar* buried objects cannot be found with this technique.

The strength of *multibeam* lies in the high accuracy and high precision images of the seabed morphology the technique provides. Sand waves and current ripples can clearly be observed in *side scan sonar* data, but the height of those sedimentary structures can far better be established by means of *multibeam*. However, buried objects generally cannot not be traced with *multibeam*, scours caused by shallowly buried objects can lead to the identification of buried objects.

In this study *side scan sonar* and *multibeam* data were combined in the identification of objects which are of potential archaeological interest. The listing of potential archaeological objects is considered to be complete as far as it concerns exposed objects, although the presence of buried non-ferro-magnetic archaeological objects or objects which erroneously have been labelled as non-archaeological, can never be fully excluded.

Magnetometer contacts are identified by the presence of ferro-metallic objects which induce an anomaly in the earth magnetic field. These objects can be buried or lying on the seabed. Unlike *side scan sonar* and *multibeam* the contacts are tagged at the sailed survey line. The actual object can be located at both sides of the survey line. Given the 70-meter spacing of the run lines the precision perpendicular to the line is in the order of 35 meter. The precision parallel to the run line is in the order of one meter.

The strength of a *magnetometer* lies in its ability to trace buried objects, if those objects are ferro-magnetic. The technique provides a strong tool in mapping continuous linear structures like buried cables and pipelines. Also, an indication of the presence and distribution of isolated ferro-magnetic objects in an area of investigation is obtained.

An important limitation of the *magnetometer* is the poor accuracy and precision of the positions, size and weight of the objects found. An object must be boxed in by sailing additional lines with a *magnetometer* to pinpoint the location of the object. The measured amplitude of a magnetic anomaly is determined by different parameters, such as the size of the object, the depth of burial, the height of the *magnetometer* above the seabed and the distance cross course. Because the measured anomaly is influenced by multiple unknown parameters it is a priori not possible to deduce the size | iron content of the object from the measured anomaly. Magnetic anomalies are in many cases induced by buried objects. From the character of the magnetic anomaly (monopole or dipole) it is not possible to identify the nature of this buried object.

The listing of *magnetometer* anomalies is expected to be complete as far as it concerns large ferro-magnetic objects. As the line spacing employed is 100 meters it cannot be excluded that especially small distant buried objects have been missed.

Fugro processed their survey data and produced detailed event listings of the *side scan sonar* and *magnetometer* contacts encountered within the survey areas. Like the known objects the locations of the contacts are plotted in a GIS.

In the course of this archaeological assessment a selection was made based on the dimensions of the reported contacts. All contacts have been assessed, and the fraction of contacts larger than or equal to four (4) meters is investigated in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. The purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

This is done by analyses of:
- *Side scan sonar* images included in the survey reports;
- raw *side scan sonar* data (XTF-files);
- raw *multibeam*-data (xyz-files);
- values of magnetic anomalies reported in the survey reports;
- comparison of *side scan sonar* and *magnetometer* contacts;

Apart from the survey data studied the geological constellation and seabed morphology of the area are considered as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

The *side scan sonar* images are scanned to define potential archaeological sites. A selection of contacts was made of contacts to be studied in detail. The interpretation and selection of *side scan sonar* contacts is based on best professional judgment. If desired or needed the exact nature of the contacts observed can be established with certainty through the execution of additional research by means of a ROV or divers in a following phase.

Fugro has acquired and processed shallow seismic data using a sub-bottom profiler (SBP) and an ultra-high resolution multi-channel sparker (UHR). The processing involved an analysis of seismic profiles which had a line spacing of 70 m for both the main lines and the cross lines. Observed seismic strata have been digitized and – based on known geological data from the area – lithostratigraphic units have been identified. The base of each lithostratigraphic unit has been interpolated into a grid. The results have been summarized and reported. In addition to the identification and occurrence of lithostratigraphic units, seismic anomalies which are expected to reflect potential hazardous phenomena have been identified.

2.5 Data Analysis

The first step in the data analysis is to cross-reference known objects within the surveyed area with the survey data. For the comparison the results of the desk study and the survey datasets were used. All the known objects were projected in a GIS together with the survey data.

For cross-reference it was assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. The raw data was used only to verify the description of found objects and anomalies as reported.

The positions of the interpreted contacts from the different surveys were compared with the positions of the known objects collected from the databases. Besides that, all the positions of both the survey contacts and the known objects were plotted on the high resolution *multibeam* grid to visualize the morphological influence of the presence of these objects. This assisted in the determination of possible archaeological value of the present remains. If an object had a potential archaeological value, the description of the object was finalized.

Besides the objects detected from the *side scan sonar* survey also the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. For the *magnetometer* contacts that corresponded with the *side scan sonar* contacts within 50 meters of each other, these contacts were related. When in the vicinity of a magnetic anomaly no visible object was found the size of the anomaly defines whether the buried object causing the magnetic anomaly is of potential archaeological interest. If the magnetic anomaly of a contact is more than 500 nT (nano-Tesla) then it is stated that the contact could possibly be of archaeological value[8]. All the *magnetometer* contacts above 500 nT but within 25 meters of the existing cable and pipeline routes are exempt for further investigation. It must be stressed that within this assessment no distinction can be made between anomalies related to possible archaeological objects or anomalies related to (for example) unexploded ordinance (UXO's).

An archaeological assessment has been undertaken for all visible contacts. This interpretation is based on the best 'professional judgment'.

The interpreted seismic data have been assessed to test the archaeological expectation with respect to remains of prehistoric settlements in the area. The archaeological desk study has resulted in the identification of lithostratigraphic units which could contain archaeological levels. The grids produced by Fugro have been used to get an insight in both the lateral and vertical distribution of the lithostratigraphic units and the expected archaeological levels herein. Thus, testing the desk study based archaeological expectation. An important factor included in the assessment is the integrity of layer boundaries, because erosion by natural processes poses a significant threat to archaeological levels. Based on the assessment, zones along the pipeline route which are expected to contain archaeological remains are mapped and presented. The results are reviewed in the context of the activities planned to predict possible influence on the potential archaeological remains.

The analysis was executed in June 2023 by R.W. Cassée (KNA Archaeologist Ma specialism Waterbodems), R. van Lil and S. van den Brenk (both KNA senior prospector). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.1; protocol 4103*).

[8] The designated value of 50 nT to discriminate between anomalies that are induced by objects of possible archaeological value (>50nT) and that are not (<50 nT) is arbitrary. Given the employed lines spacing of 70 m, an anomaly that solely is observed on one survey line could be located within 35 m on either side of this survey line. It is estimated that an iron mass of 1000 kg located at 10 m from the magnetometer will result in a 50 nT magnetic anomaly. On the other hand, an iron mass of 1 kg located within 3 m of the magnetometer will also result in a 50 nT anomaly, albeit that the anomaly with will be less. It is estimated that an iron mass of 100 kg that is located at 30 m from the magnetometer will result in an anomaly of less than 2 nT. This value is often below the limit of detection. If those small values were to be labelled as anomalies caused by objects of possible archaeological interest all magnetic anomalies found in the survey area were to be labelled as such. Therefore, the arbitrary value of 50 nT is chosen, given the current line spacing. If a closer line spacing is used a larger value shall be considered.

2.6 Used Sources

The following sources were used for the analysis:

- Survey data Fugro, original survey data and reported interpretations;
- Archaeological desk study Periplus (19A029-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- Nlhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN).

For a complete list of used sources and literature see the reference list at page 67.

Italic written words are explained in the glossary at page 65.

3 Results

3.1 Seabed bathymetry and morphology

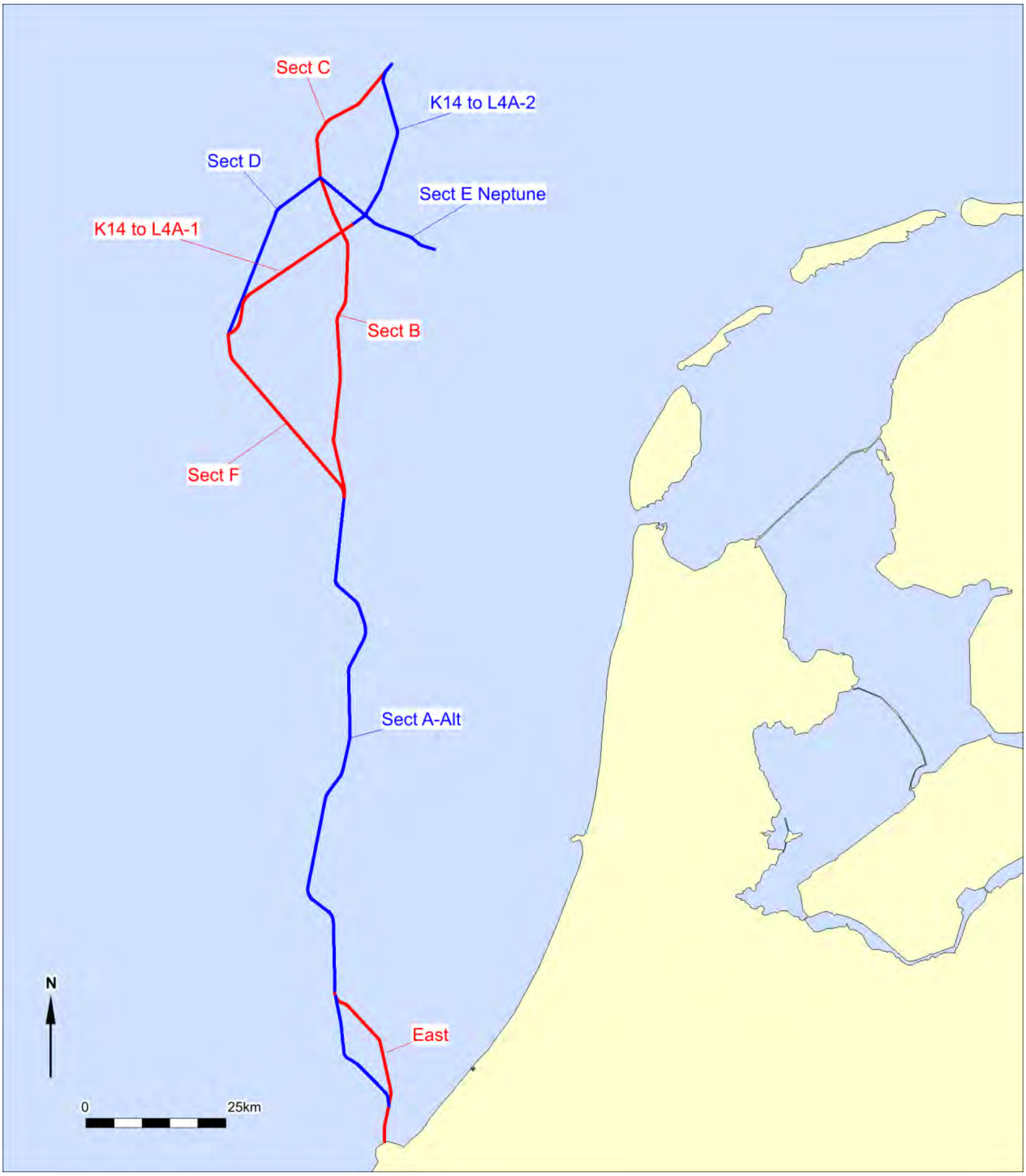


Figure 4. Sections bathymetric profiles based on the multibeam recordings (source data: Fugro 2022)

Based on the 2022 survey data the water depth within the survey corridor varies from 4.8 to 39.6 m, with an average depth of 27.0 m LAT. Bathymetric profiles along the different sections are presented in the next figure.

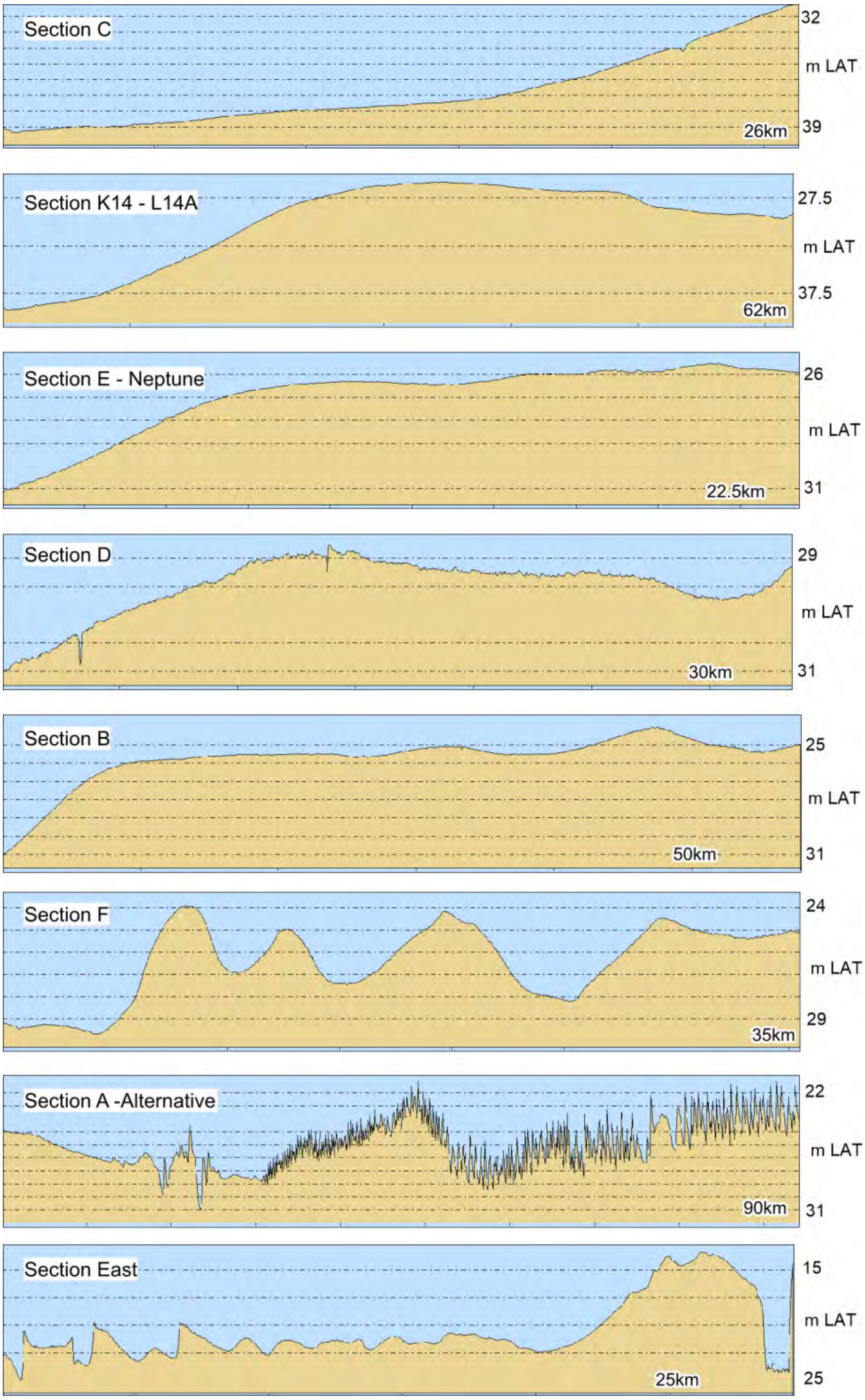


Figure 5. The seabed profiles along the different sections from north to south.

Seabed morphology

The seabed along the route is characterized by a complex pattern of bedforms of various orders. Those bedforms include very large ridges (hereafter sand banks), sand dunes, mega ripples and small ripples. The sand banks are some 2 to 2.5 km wide and stretch more or less north - south. The sand banks are separated by low-lying areas. The difference in height between the troughs and crests of the sand banks is up to 7.5 m. The wavelength of the sand dunes varies, the height of the ranges from 1 m to 3 m. Superimposed on the major sand dunes and sand banks lie mega ripples with an average wavelength of 20 m. The height of the mega ripples ranges from 0.2 m to 0.4 m. The mega ripple crests stretch west northwest - east.

Migration rate

The mobility of the seabed sediments imparts major implications to the prospection of archaeological remains in the area. Wreck remains can be covered by a layer of sandy seabed sediments, as a result the remains are not exposed to the seabed and cannot be traced with *side scan sonar.* Remains can become exposed at a later stage due to the ongoing migration of the sand dunes.

Each of the morphological features in the area has its typical migration rate. The position of the north-south oriented sand banks is fairly stable. Van der Meulen et al. (2004) reported a migration rate for sand dunes of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 – 3 m/year) field near the entrance of the Rotterdam Harbour[9]. Deltares studied the migration rate of sand dunes in the Prinses Amalia WFZ and concluded that the dunes in this area migrate some 4 m/year[10].

To assess the migration rate of sand dunes in the IJmuiden Ver wind farm zone a comparison of *multibeam* data acquired 30 days apart was made. Within this short period of time a sand dune had migrated two meters and the shape of the sand dune had altered[11].

---

[9] Meulen, M.J. van der, et al. 2004.

[10] Fugro survey report P904162, Volume 3.

[11] Van Lil et al. 2023

3.2 Known objects: As Found positions versus database positions.

In the archaeological desk study report a total of 316 archaeological records, 458 shipwrecks, and 3494 other known objects have been reported.

However, the survey area (243 km^2) is considerably smaller than the area which had been defined as area of investigation for the archaeological desk study (11.355 km^2). Additionally, since the finalization of the archaeological desk study, new objects have been added to the NCN-database. The known objects which, according to their database positions are located within the survey area are listed in the table below.

Type	amount
Anchor with chain	2
Seabed distortion	9
Cable or chain	27
Unidentified object	124
Boulder	1
Wreck and wreck remains	8
Total	**171**

Table 7. Known objects within the surveyed area.

The SSS and MBES contacts and the MAG anomalies encountered during this survey have been stored in event listings. The positions of the contacts and anomalies in these listings are compared with the theoretical positions of objects in the NCN database. To conduct this comparison all SSS contacts and MAG anomalies found within a range of 25 meters around the database locations are selected.

The outcome of this comparison can be:

- The As Found position of a shipwreck is in agreement with the database position of a known wreck;
- The As Found position of a contact is in agreement with the position of a contact listed in the database, but the interpretations do not match;
- The As Found position of a shipwreck is not in agreement with the database position of a known wreck;
- A wreck listed in the database has not been found;
- A new wreck has been found.

Known NCN objects found

A total of 37 out of 171 known NCN objects were found during the survey.

NCN	Contact type	E	N	Survey_ID
219	Wreck remains	570384	5762003	BB_FS_SSS_0683
531	Wreck	559172	5935317	BH_FSEA_SSS_0104
967	Wreck remains	550165	5921956	BK_FSEA_SSS_0163
4543	Unidentified object	571058	5762056	BB_FS_MAG_0458
4547	Unidentified object	570585	5761590	BB_FS_SSS_0483
4559	Unidentified object	570645	5763097	BC_FD_MAG_0089
4623	Unidentified object	571139	5761040	BB_FS_MAG_0080
8099	Unidentified object	570782	5761179	BB_FS_MAG_0083
8104	Cable / Chain	570716	5761482	BB_FS_SSS_0433

NCN	Contact type	E	N	Survey_ID
8111	Unidentified object	569849	5761781	BB_FS_MAG_0129
8120	Unidentified object	570177	5761705	BB_FS_MAG_0164
8121	Cable / Chain	570729	5761506	BAB_FS_UXO_0074
13434	Unidentified object	571042	5761479	BB_FS_SSS_0431
13881	Unidentified object	570170	5761683	BB_FS_MAG_0139
13882	Unidentified object	570722	5761528	BAB_FS_UXO_0033
17443	Cable / Chain	570751	5760384	BB_FS_SSS_0019
17446	Unidentified object	569970	5761679	BB_FS_SSS_0513
17852	Unidentified object	570668	5761516	BB_FS_MAG_0147
17863	Unidentified object	570285	5761300	BB_FS_SSS_0307
17866	Unidentified object	570283	5761184	BB_FS_SSS_0241
17870	Seabed distortion	569820	5761550	BB_FS_SSS_0465
17873	Cable / Chain	570079	5761633	BB_FS_MAG_0106
17883	Unidentified object	571009	5761365	BB_FS_SSS_0355
19203	Unidentified object	570846	5761183	BB_FS_MAG_0089
19214	Unidentified object	570608	5761553	BB_FS_SSS_0464
19222	Unidentified object	571021	5761490	BB_FS_SSS_0439
19585	Unidentified object	562818	5899439	BF_FD_SSS_0019
20270	Unidentified object	571246	5761234	BB_FS_MAG_0141
20279	Seabed distortion	570157	5761591	BB_FS_SSS_0481
20280	Unidentified object	570772	5761331	BB_FS_SSS_0328
20282	Unidentified object	570154	5761363	BB_FS_SSS_0374
20283	Seabed distortion	570757	5760383	BB_FS_SSS_0019
20288	Unidentified object	571165	5761318	BB_FS_MAG_0143
29706	Unidentified object	569875	5762289	BB_FS_SSS_0835
33006	Unidentified object	563254	5896797	BF_FD_SSS_0026
33416	Unidentified object	558944	5814439	BD_FD_SSS_0218
33993	Cable / Chain	570971	5761365	BB_FS_SSS_0363

Table 8. As Found NCN objects

Known wrecks found and not found

NCN	E	N	Description	Arch value	Survey_ID
219	570384	5762003	Fishing vessel reported lost in 1945	Unknown	BB_FS_SSS_0683
531	559172	5935317	Wreck reported in 2011. 24x11x2.5m	Unknown	BH_FSEA_SSS_0104
967	550165	5921956	HMS Ivanhoe, sunk 01-09-1940 (ARCHIS ID 4030384100)	Yes	BK_FSEA_SSS_0163
1133	564181	5917118	Wreck reported in 1941, not found during several surveys	No	(not found)
1822	571084	5760899	Sailing vessel Lindis Farne, sunk 03-01-1908. Wreck cleared away according to Hydrographic service	No	(not found)
1902	569952	5777662	Wreck reported in 1945, not found during several surveys	No	(not found)

NCN	E	N	Description	Arch value	Survey_ID
2113	566176	5846859	Steam ship Nipponia, sunk 13-10-1908. Wreck cleared away to a depth of 17 m in 1909. Remains not found during several surveys	No	(not found)
32851	570262	5762370	Motorvessel Clearwater, sunk 29-08-1968. Wreck raised in 1968 according to Hydrographic service	No	(not found)

Table 9. Known shipwrecks found and not found

The five shipwrecks that have not been found during the survey are probably in a different location or completely salvaged in the past, because they were also not found during previous surveys. If they were covered in the seabed, this would have resulted in magnetic anomalies at the locations.

Examples of the shipwrecks that have been found are presented below.

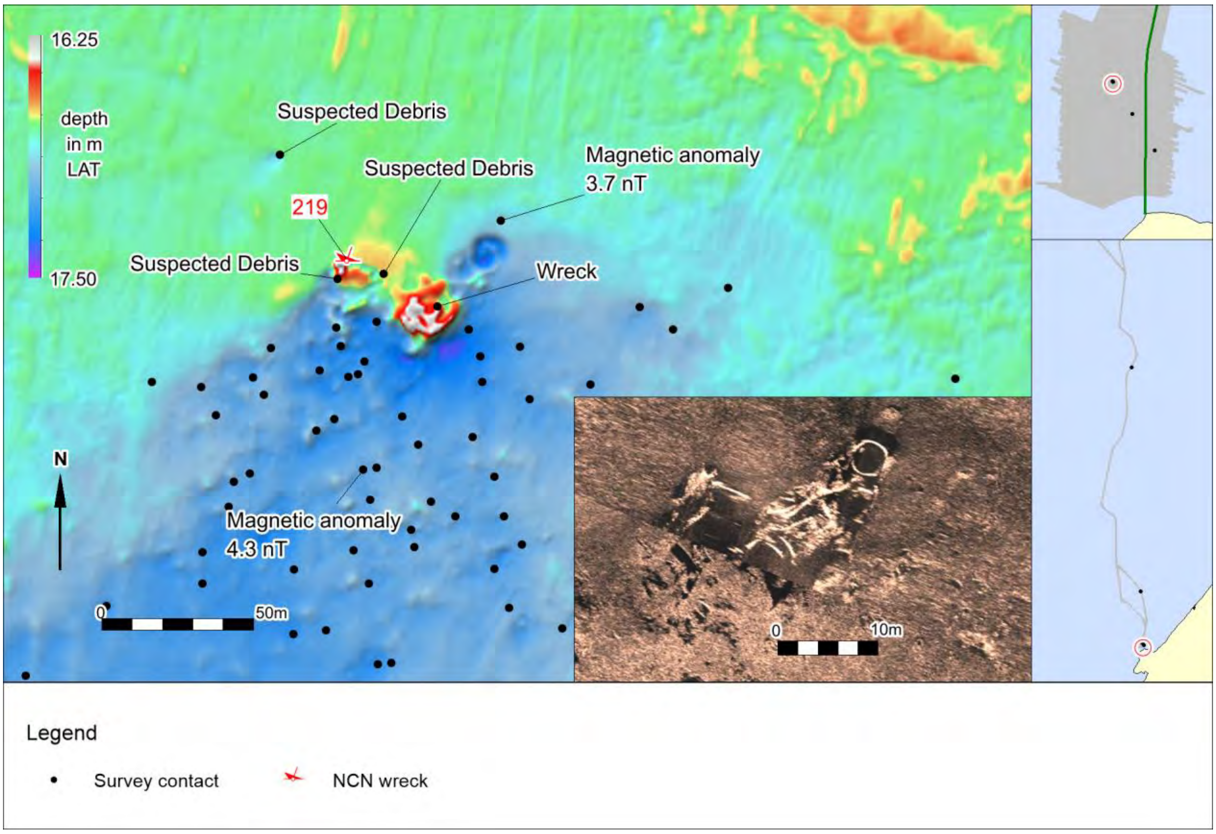


Figure 6. Multibeam image of NCN 219

NCN 219 represents the location of a fishing vessel reported lost in 1945. Both side scan sonar en multibeam images show an area of 22 x 20m scattered with debris at a depth of 17m LAT. Relatively small magnetic anomalies are observed in the surroundings of the area. The location is situated 544 meter west of the proposed route section C-East. The possible wreck remains have not been identified yet, so the archaeological value is not known. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

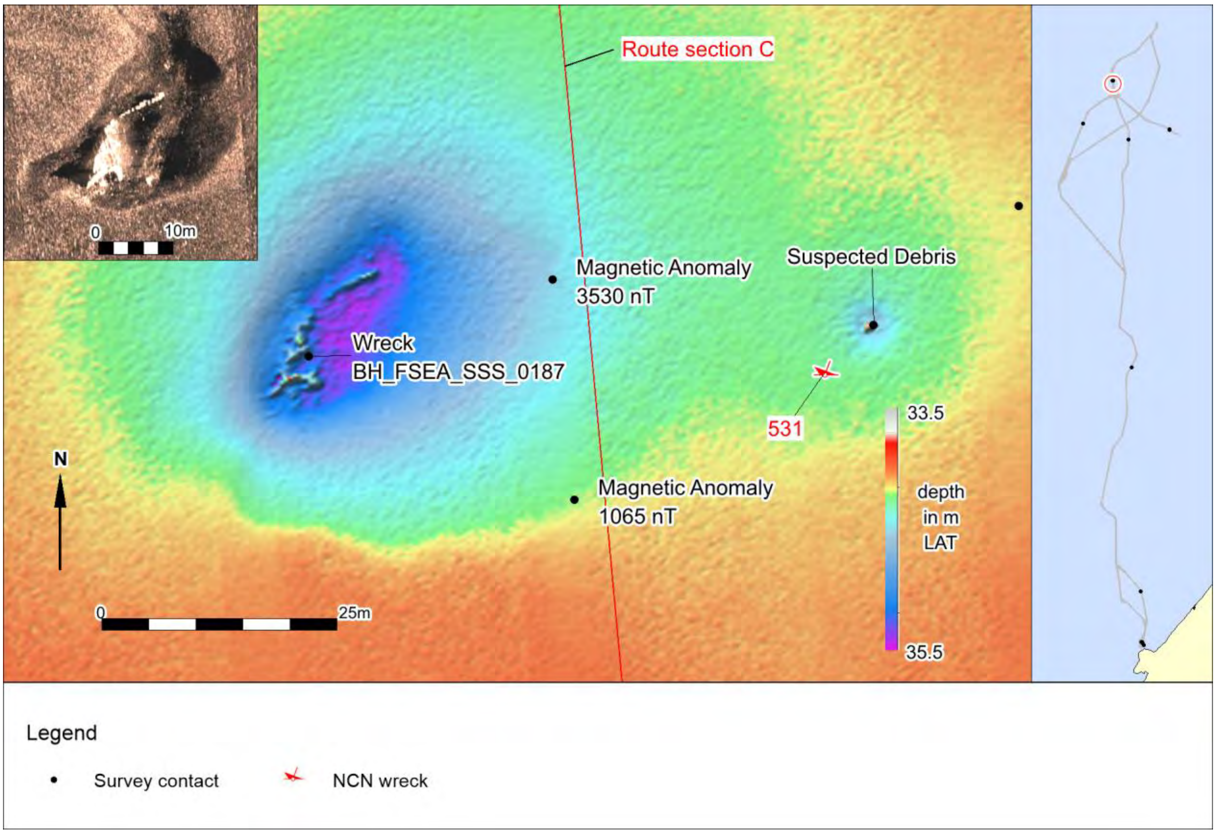


Figure 7. Sonar and multibeam image of NCN 531

NCN 531 is an unidentified wreck reported by the Hydrographic Office in 2011. Both side scan sonar en multibeam images show an area of 63 x 18m at the theoretical location of NCN 531 with a large structure in the west and a smaller object in the east at a depth of 34m LAT. Both locations lie within 30 meters of the proposed route (Section C) In between, very large magnetic anomalies are observed suggesting buried remains. The possible wreck remains have not been identified yet, so the archaeological value is not known. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

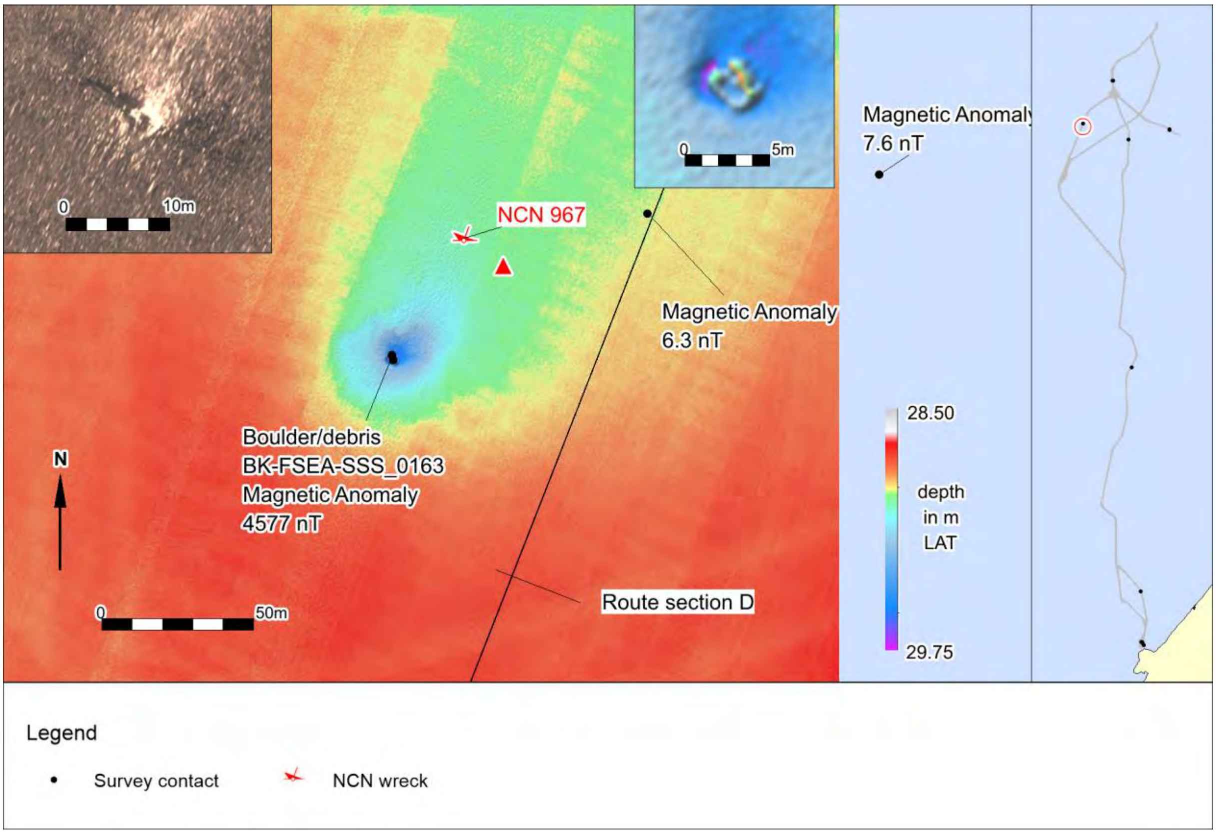


Figure 8. Sonar and multibeam image of NCN 967

Contact BK-FSEA-SSS-0163 is a square object of 2.9 x 2.6 m at a depth of 29m LAT surrounded by scouring. At the location, a very large magnetic anomaly of 4577 nT was observed. Smaller anomalies lie to the east of the object and may present buried wreck remains. The object is located within 50 meters of the theoretical position of NCN 967. This represents the wreck of the HMS *Ivanhoe*, a British destroyer built for the Royal Navy in the mid-1930's. Together with sistership HMS *Esk* it hit a mine on August 31, 1940 and sunk. The location of the wreck of the HMS ESk is confirmed and lies 2900m to the east.

The location is situated 63 meter west of the proposed route section D. If these are the remains of the HMS Ivanhoe, it is considered to be of archaeological value. It is advised to avoid this location including a buffer zone of 100 meters during pipeline construction.

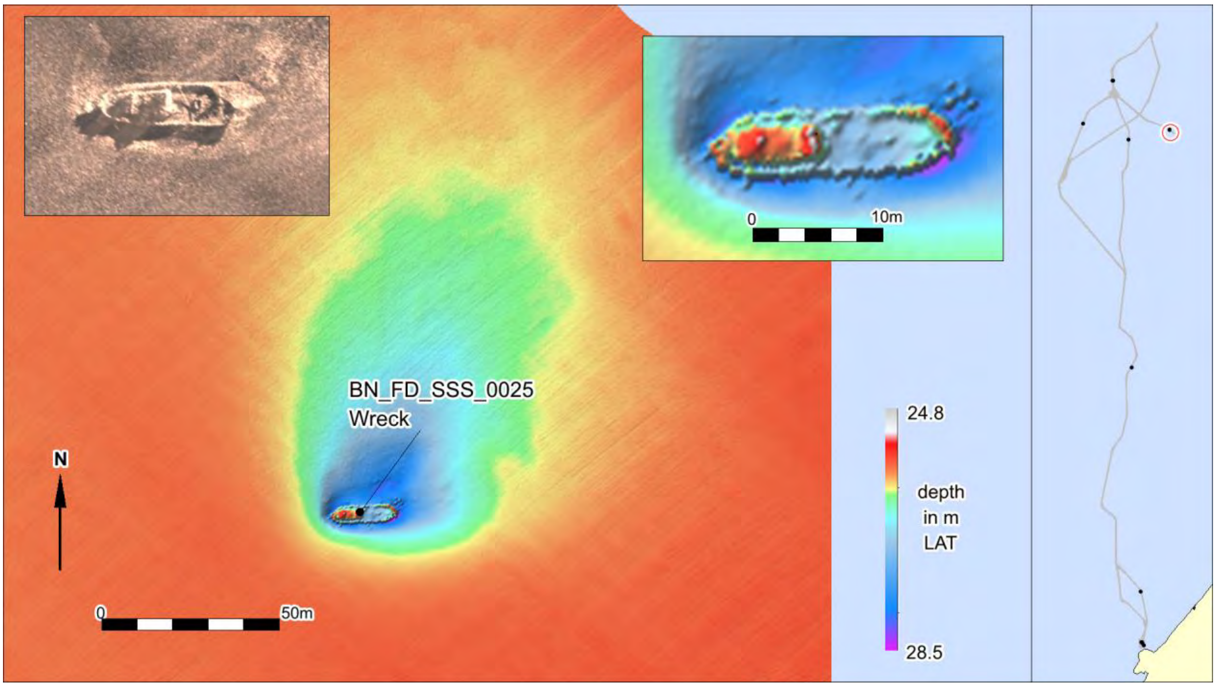


Figure 9. Sonar and multibeam image of contact BN_FD_SSS_0025

Contact BN-FD-SSS-0025 is an unidentified wreck. Both side scan sonar en multibeam images show a clear shipwreck with dimensions of 19.7 x 5.1 x 1.0 m at a depth of 25 m LAT. The location lies 220 m northeast of proposed pipeline section E.

The wreck has the characteristics of a fishing trawler. This might be a known wreck (NCN 945) which theoretical location is situated 200 meters to the north, just outside of the surveyed area. NCN 945 represents the fishing trawler *Stormvogel* (IJM 9) sunk at 7-04-1981 and has no archaeological value.

3.3 Side scan sonar

Fugro has identified 3806 *side scan sonar* contacts within the surveyed corridor. The classification of the contacts is listed below.

Classification	**Amount**
Boulder	3010
Debris	159
Depression Pockmark	5
Fishing Gear	7
Mattress	2
Pipeline	4
Seabed Mound	98
Suspected Debris	517
Wreck	4
Total	**3806**

Table 10. Side scan sonar contacts identified by Fugro

The objects classified as '*Boulder*' are found throughout the whole surveyed area. These probably also include clay boulders, because known stone boulders in the North Sea only occur north of the city of Den Helder.
All contacts which match known objects have been discussed in the previous paragraph. The remaining *side scan sonar* contacts and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Side scan sonar* geotiffs;
- *Multibeam* grids;
- Comparison of *side scan sonar* and *magnetometer* contacts.

Apart from the survey data studied, the geological constellation and seabed morphology of the area are taken into account, as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

All side scan sonar contacts greater than four meters in any dimension, 117 in total, have been examined in detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. The purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

A summary of the outcome of the detailed inspection of selected contacts larger than four meters is presented in the table below. It should be noted that the seven contacts that are classified as '*wreck*' refer to four different wrecks, which are already discussed in the previous paragraph. Appendix 3 contains a complete listing of the results of this assessment.

Category	Amount
Anchor	1
Buoy anchor	1
Cable/chain	10
Matress	3
Natural ridge	1
Pipeline	4
Seabed disturbance	11
Shell bed	1
Shipwreck	7
Spudcan depression	4
Unidentified object	74
Total	**117**

Table 11. Results of the assessment of selected side scan sonar contacts

At total of seven side scan sonar contacts larger than four meters are attributed to four different wreck sites (which have been discussed in section 3.2) and three possible new wreck sites. Additionally, one side scan sonar contact is attributed to a large anchor. The summary of the side scan sonar records with potential archaeological interest is listed below.

Feature	Easting	Northing	Fugro	L	W	H	Z	Interpretation PPA
BK_FSEA_SSS_0022	551288	5924521	Boulder	5.6	2.9	5.2	-29.8	Buried remains with magnetic anomalies - wreck remains
BK_FSEA_SSS_0179	555839	5929168	Boulder	6.7	5.7	1.0	-30.3	Large anchor shaft 3.2m arms 2.1m with scouring
BJ_FD_SSS_0015	548443	5894128	Debris	5.6	1.8	0.0	-26.4	Elongated object 5.6m - wreck remains
BB_FS_SSS_0433	570711	5761481	Wreck	4.3	2.4	0.3	-18.9	Oval contact, possibly wreck remains

Table 12. Listing of side scan sonar records with potential archaeological interest.

The results with examples of the four objects are discussed below.

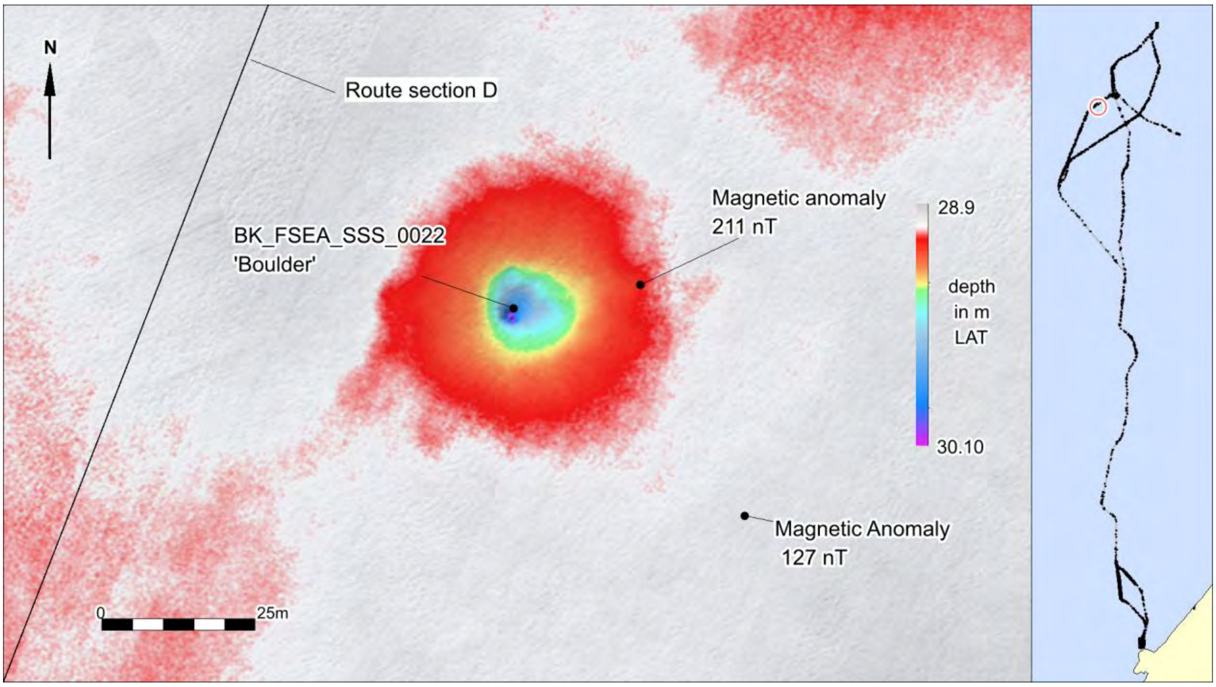


Figure 10. Multibeam image of survey contact BK-FSEA-SSS-022

Contact BK-FSEA-SSS-0022 was interpreted by Fugro as a '*boulder*'. The multibeam image shows an object surrounded by a round scour depression with a diameter of 30 meters and a relative depth of one meter.

Two large magnetic anomalies have been observed to the east of the contact. These might represent a buried structure; possibly unidentified wreck remains. The location lies 55 meters east of route section D.

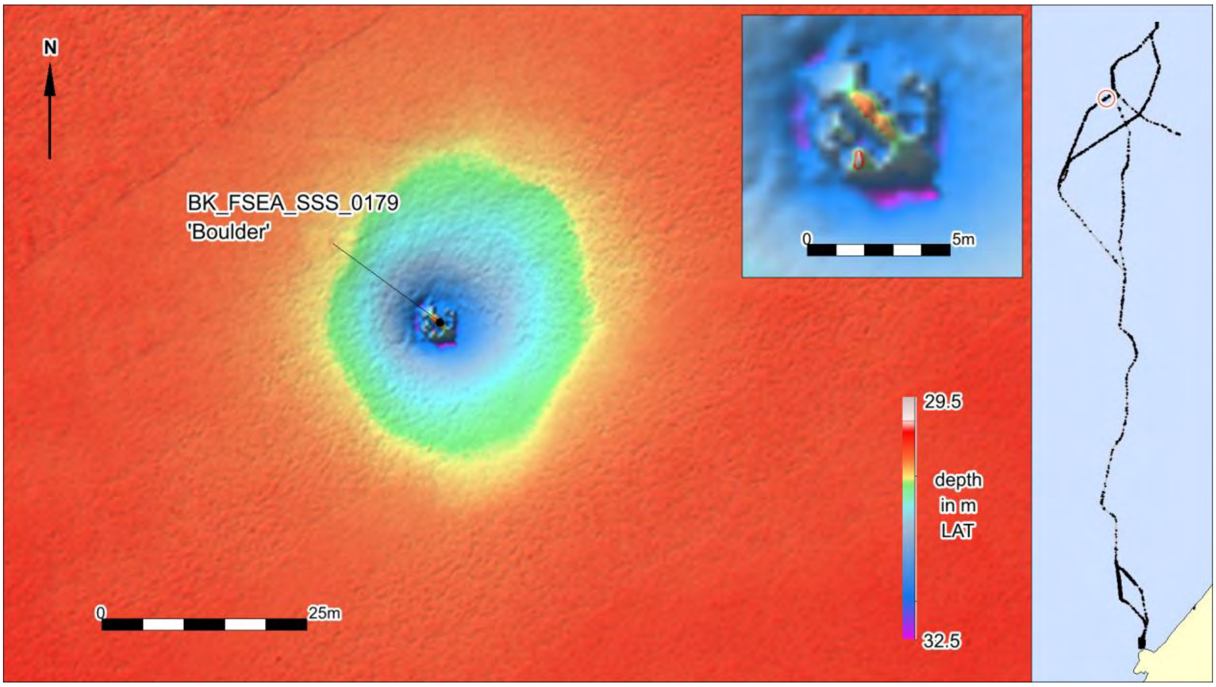


Figure 11. Multibeam image of survey contact BK-FSEA-SSS-0179

Contact BK-FSEA-SSS-0179 was interpreted by Fugro as a '*boulder*'. The multibeam image shows a triangular object surrounded by a round scour depression with a diameter of 20 meters and a relative depth of 1.5 meter. In more detail, the object resembles an anchor with a shaft length of 3.2 meters and arms of 2.1 meters. This might be an historical Admiralty Pattern anchor, or simply "Admiralty", commonly used in the 17th and 18th century. The location lies 240 meters west of route section D.

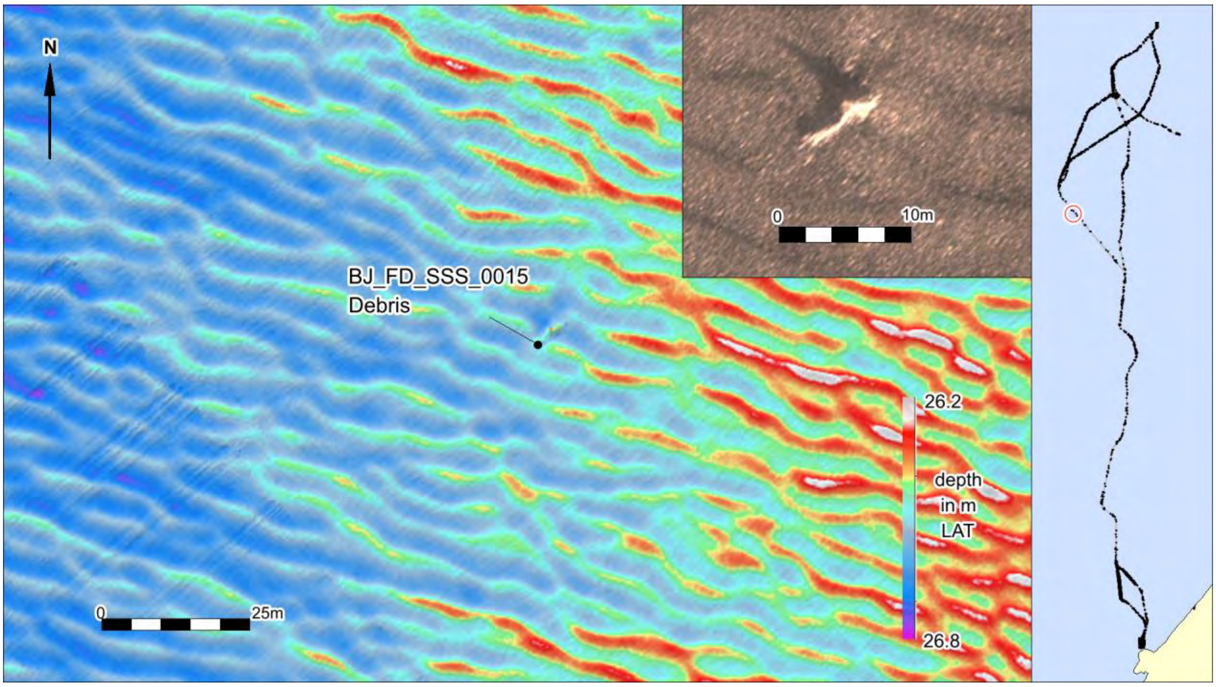


Figure 12. Sonar and multibeam image of survey contact BJ-FD-SSS-015

Contact BJ-FD-SSS-0015 was interpreted by Fugro as a '*debris*'. Both multibeam and side scan sonar images show an elongated irregular object of 5.6 x 1.5 x 1.0 meters perpendicular to the surrounding sand ripples. No magnetic anomalies have been observed in the surrounding area. The object might be the remains of a wreck. The location lies 232 meters east of route section F.

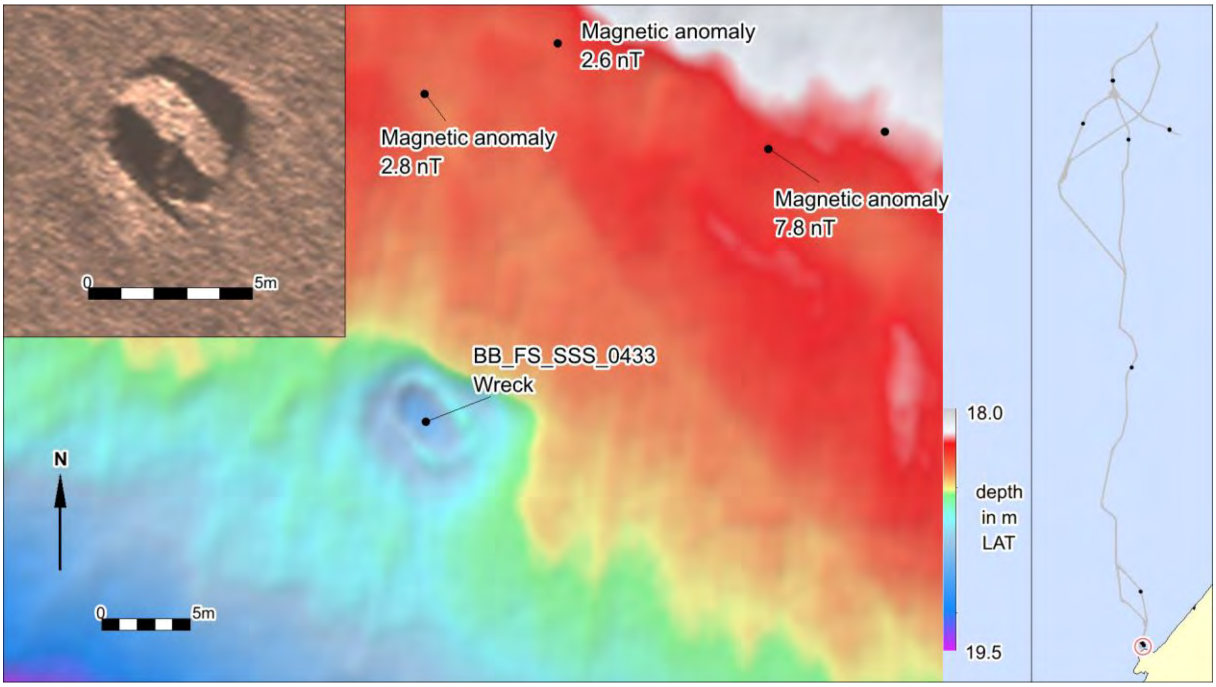


Figure 13. Multibeam image of survey contact BB-FS-SSS-0433

Contact BB-FS-SSS-0433 was interpreted by Fugro as a 'wreck'. Both multibeam and side scan sonar images show an oval object of 4.3 x 2.4 x 0.3 meters surrounded by (relatively small) magnetic anomalies. The object might be the remains of a wreck. The location lies 216 meters west of route section West.

Summary of side scan sonar / multibeam contacts

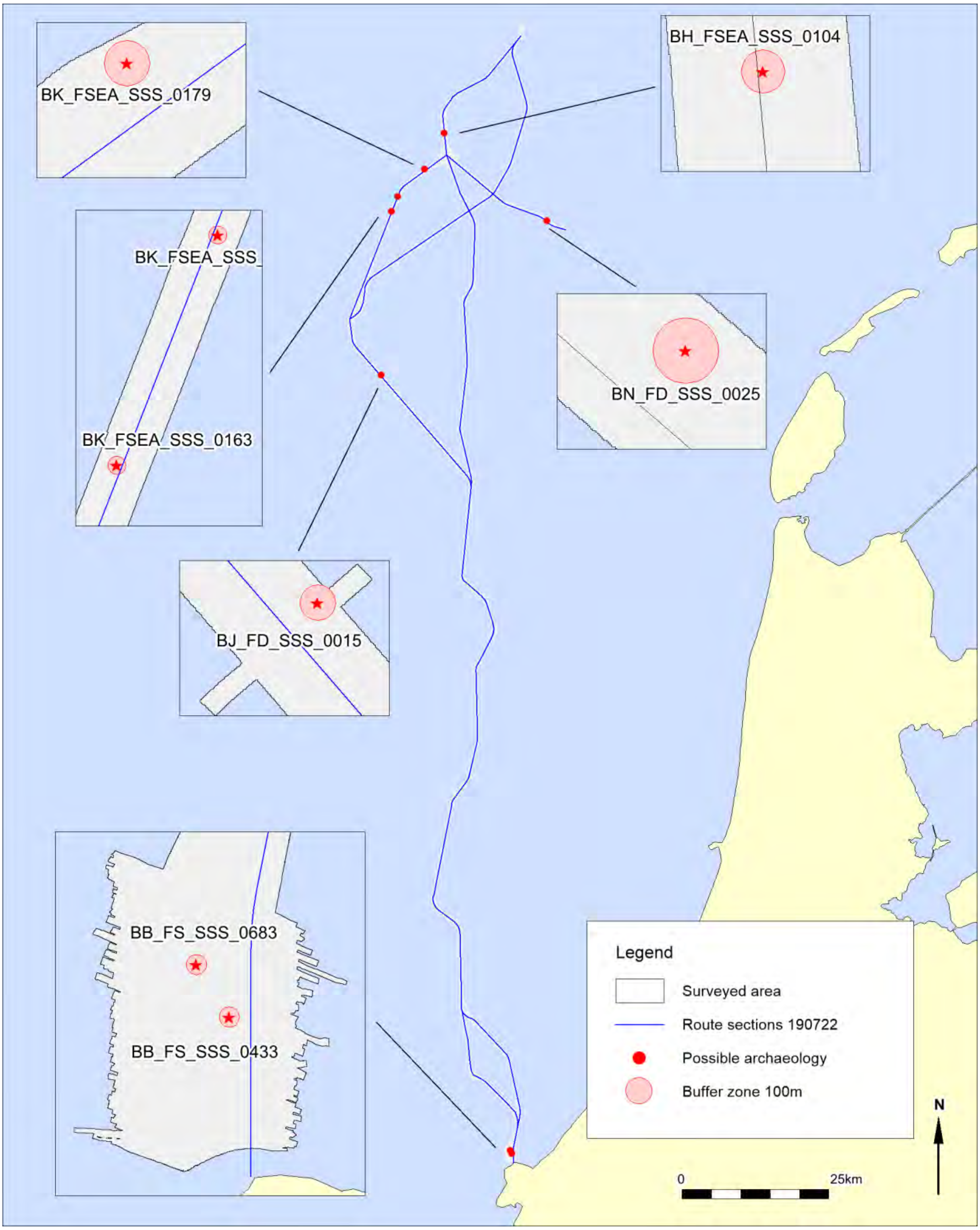


Figure 14. Overview of all side scan sonar / multibeam contacts with an archaeological expectation

3.4 Multibeam

Apart from the *multibeam* images discussed in the previous sections no *multibeam*-features have been observed outside the side scan sonar contacts which are interpreted to reflect the presence of archaeological objects or structures.

3.5 Magnetometer

A total of 2748 magnetic anomalies have been observed within the area of investigation. An overview is given in the next figure.

Figure 15. Spatial distribution of all magnetic anomalies

A number of these anomalies can be related to infrastructure (cables and pipelines), but the majority have an unknown origin. Although the nature of these objects is not known it is possible that the anomalies represent archaeological remains buried in the seabed, and therefore have to be taken into account within this assessment. The average line spacing for the magnetometer was 20 to 40 meters. A minimum value of 500 nT has been used to classify the objects as potentially archaeological targets.

Note on magnetic anomalies and value of 500 nT.
A magnetic anomaly is a local deviation from the natural magnetic field, expressed in nanoTesla. The measured value depends on the mass of the iron contained by an object, but also largely on the distance between magnetometer and the object. With a relatively large line spacing (>= 100m) chances are, that objects are missed or have an apparent lower reading on the magnetometer.

For example: a mass of 1000 kg iron results in a value of 50 nT at 12 meters, and 500 nt at 5 meters. The term 'large anomaly' is therefore subjective and depends mainly on the line spacing of the magnetometer survey.

For archaeological assessments, as a rule of thumb, the following minimum values for unidentified deviations are therefore considered to be of archeological interest:
Line spacing ~100 meters: 50 nT
Line spacing ~50 meters: 500 nT

According to Fugro, 212 anomalies with an unknown origin are larger than 500 nT. After re-examination, 202 anomalies can be associated with known present objects like pipelines and wellheads.

Association	Amount
Cable	1
Pipeline	194
Wellhead	2
Known NCN	5
Unknown	10
Total	**212**

Table 13. Magnetic anomalies over 500 nT

The remainder, a total of 10 magnetic anomalies, cannot be related to known pipelines and cables, or visible objects at the seabed surface. These anomalies are induced by unknown ferrous objects buried in the seabed, covered by sediments. These objects could consist of pieces of cable, chain, debris, lost anchors, UXO, iron parts of shipwrecks, et cetera. The 10 objects which induced anomalies of more than 500 nT are considered to be of potential archaeological interest, until proven differently.

An overview is presented in the figure below.

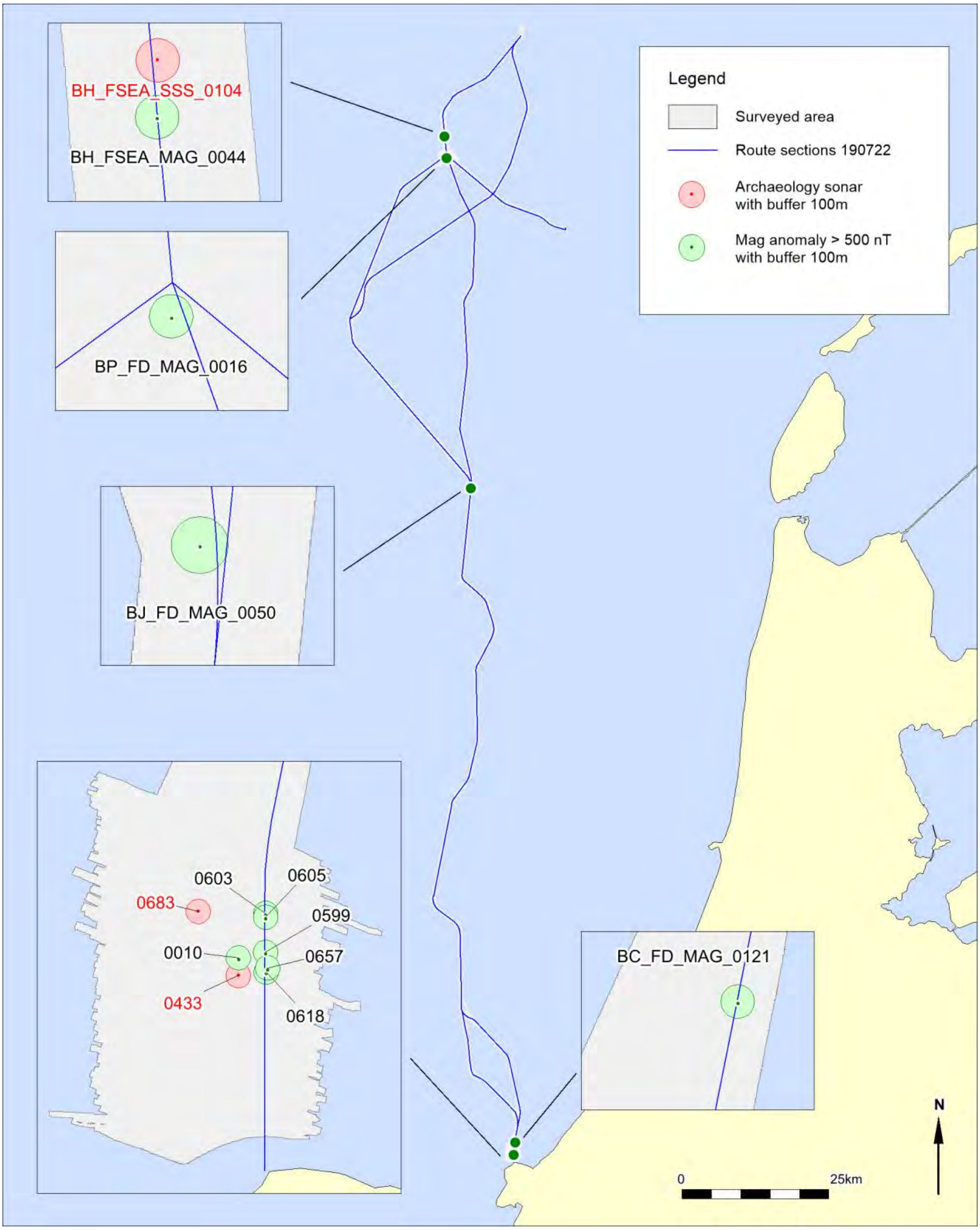


Figure 16. Magnetic anomalies larger than 500nT not related to known objects, infrastructure or objects found with side scan sonar.

3.6 Subbottom data

Desk study results

The archaeological desk study has indicated that the combined thickness of the *Holocene* sequence is expected to range from 0 to 30 meters in the area.

The variations in thickness are due to:

- lateral variations in water depth, mobility of the seabed, sediment supply and sedimentation rate from the onset of the Early Holocene till present day.
  general trend:
  a) near coastal shallow waters with high mobility of seabed in the southern part: high thickness of Holocene cover;
  b) distal parts of trajectories with deep waters and low mobility of seabed: thin Holocene cover;

- the morphology of the seabed
  a) in part of the trajectory sand ridges and sand waves occur (Pleistocene deep-seated), which alternate with:
  b) low-lying areas in between those ridges and sand waves (Pleistocene more roximate to seabed surface);

- the original morphology Pleistocene landscape which was present prior to the Holocene marine ingression in the area;

- the various extent to which the Pleistocene landscape has eroded during the Holocene marine ingression.

The *Holocene* units include the surface sediments of the Bligh Bank Member (south) and Terschellingerbank Member| Southern Bight Formation and the Urania Formation (north). Those units locally cover deposits of the Wormer Member | Velsen Bed | Naaldwijk Formation and/or the Basal Peat Bed | Nieuwkoop Formation.

Just north of the Maasgeul a more than one-meter-thick bed of stiff Early to Mid-Holocene river clay is present. This clay is part of the Echteld Formation and wedges out to the north. Stratigraphically this clay of the Echteld Formation is positioned in between the Basal Peat Bed and lagoonal and marine deposits of the Wormer Member | Naaldwijk formation. Further, in the Maasgeul area Early Holocene overbank deposits of the Rhine can be present. These stiff ripened clays and silts are classified as the Wijchen Bed | Kreftenheye Formation. On top of the Wijchen Member locally Early Holocene wind-blown deposits (river dunes) of the Delwijnen Member can be present. The flanks of these river dunes are covered by the Basal Peat bed and Echteld Formation.

The *Holocene* deposits cover *Pleistocene* units of:

- the Eem Formation (Eemian marine)
- the Brown Bank Member | Eem Formation (Early Weichselian lagoonal and shallow marine)
- the Kreftenheye Formation (Pleniglacial river), and
- the Boxtel Formation (Late Glacial terrestrial - stream deposits and aeolian).

To illustrate the variations in the subsurface geology we present in figure 17 the Top Pleistocene Map by TNO | Laban from 2004 and the Geological Map of the Netherlands produced by Geological Survey of The Netherlands in 2021. This image provides a reference framework for the interpretation of the subbottom profiler data.

In the left panel of figure 17 the 2004 Top Pleistocene map is displayed. This map shows the Pleistocene units that subcrop below a cover of Holocene deposits. Those Holocene deposits include the mobile sands of the Bligh Bank Member | Southern Bight Formation and towards the north the Terschellingerbank Member | Southern Bight Formation and Urania Formation which are exposed at the seabed over the full extent of the route. Locally these recent deposits cover Early Holocene deposits of the Basal Peat Bed | Naaldwijk Formation and Wormer Member | Naaldwijk Formation.

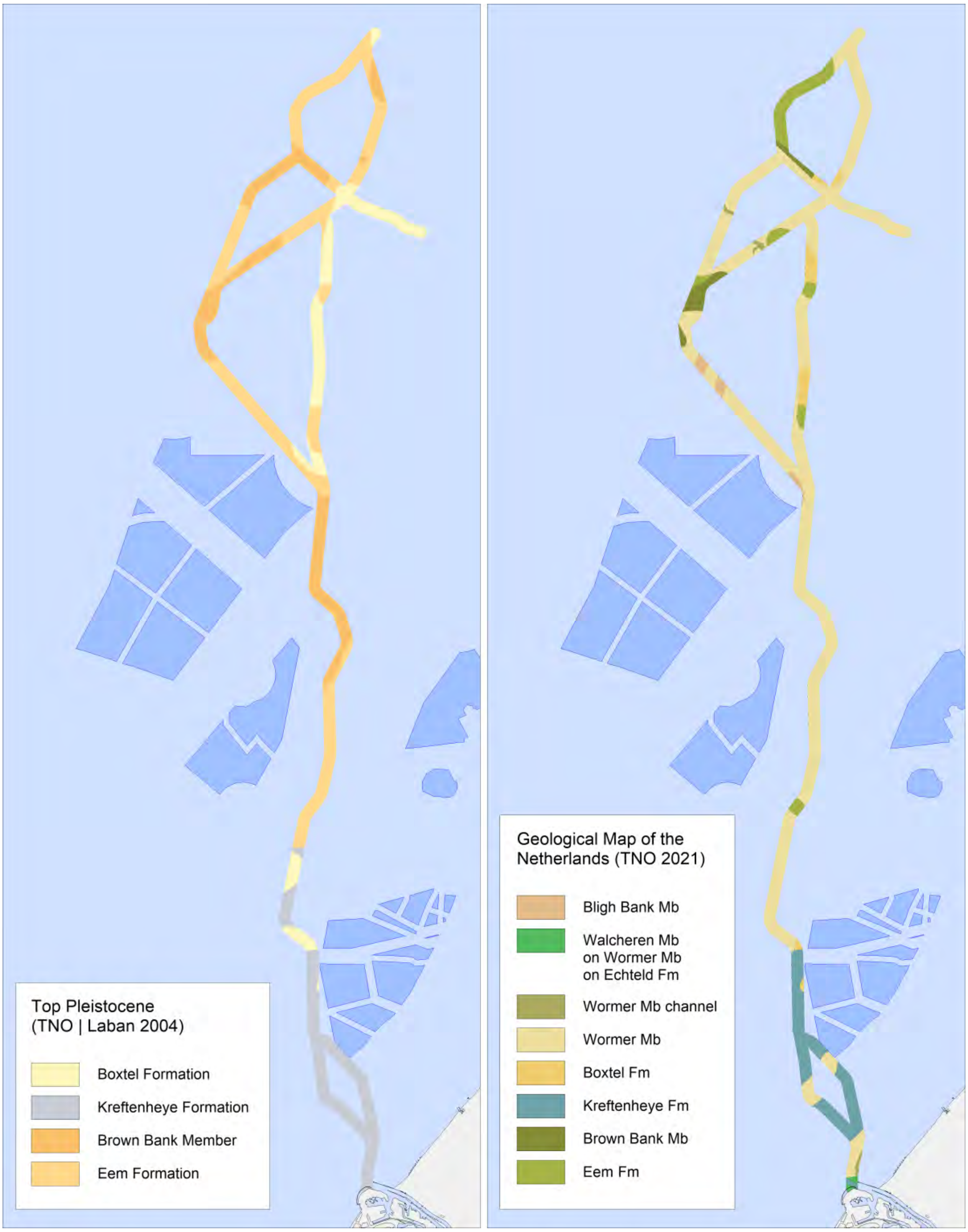


Figure 17. Subcropping Pleistocene units within 2000-meter corridor along the optional Aramis routes according to the 2004 Top Pleistocene Map and 2021 Geological map of the Netherlands; wind farm sites displayed to provide some spatial context.

As described above, in the Maasmond area Early to Middle Holocene fluvial clays of the Echteld Formation are present. Also, local occurrences of Early Holocene river dunes of the Delwijnen Member | Boxtel Formation and repined overbank clays of the Wijchen Member | Kreftenheye Formation could be encountered.

The Geological Map of the Netherlands is shown in the right panel of figure 17. This image shows the units that are subcropping below the Southern Bight Formation and Urania Formation. Contrary to TNO | Labans' map those subcropping deposits also include Holocene units.

In the online explanatory document that comes along with the Geological map the following is stated: '*Coversand (BX4: Boxtel Fm, Wierden Mb) and loess (BX5: Boxtel Fm, Schimmert Mb) are only shown if more than 2 m thick. The ubiquitous layer of actively transported open-marine sand (SB2: Bligh Bank Mb) is only shown if it is more than 7 m thick. Anthropogenic deposits are not shown on the map.*'

Occurrences of the Boxtel Formation are very often less than 2 meter thick. It should therefore be borne in mind that in areas where other units such as the Brown Bank Member are mapped the Boxtel Formation can still be present as a thin bed topping this unit.

Another important note is that recent research in the IJmuiden Ver Wind Farm Zone and personal communication with Cees Laban indicates that offshore deposits that in the past - based on seismic data - were classified as the Wormer Member[12] also include small-scale fluvial and aeolian deposits of the Late Glacial Boxtel Formation. The Boxtel Formation is often found offshore in stream valleys. Stream valleys were low-lying parts of the paleo-landscape. Because of this relative low-lying position and the presence of firm beds of the Early Holocene Basal Peat Bed and clayey Velsen Bed the Boxtel Formation was better protected against erosion in the stream valleys than in the surrounding landscape.[13]

[12] In the 20th Century the units that currently are classified as the Wormer Member and Basal peat Bed were mapped as the 'Elbow Formation'.
[13] Pers. Comm. F. Busschers 2023.

Assessment of seismic data

Table 14 shows the shallow seismic units which have been identified by Fugro along the Aramis route trajectories. The table contains an interpretation of the lithostratigraphic units that according to Fugro could be part of the identified seismic units.

Dataset	Unit	Horizon Top	Horizon Base	Seismic Signature and Character of the Base	Distribution	Lithology[1]	Geological Formation / *Member*	Depositional Environment
SBP	DS	H00	H_DS	Semi-transparent and chaotic. The basal reflector marks the change from chaotic to acoustically transparent or structured seismic facies.	Present in nearshore part only (Maaskanaal)	Clayey sand to sandy clay	-	-
	A	H00	H10	Acoustically transparent to chaotic, with locally high amplitude reflections. Base is marked by a medium to high amplitude, flat reflector.	Present across the entire route	Sand	Southern Bight	Marine
SBP, 2D-UHRS	B	H00, DS, H10	H15	Various; semi-transparent and structureless to locally bedded with low to medium amplitude parallel reflectors; locally, internal channels with high amplitude parallel reflectors observed; locally internal erosion surfaces observed. The base is locally channelised and the infill of these channels has typically chaotic or structured (layered) character with high amplitude reflections. The basal reflector has a medium to high amplitude; irregular to undulating. High amplitude (negative on the 2D-UHRS) reflectors may indicate layers/pockets of peat / organic clay frequently present in this unit.	Present basically across the entire route; locally absent in the southern part of the route	Sand, clay, locally laminated sand and clay, locally thin beds or laminae of peat	Naaldwijk Boxtel Kreftenheye	Coastal to tidal-flat, locally lagoonal; locally periglacial to fluvial
2D-UHRS	C	H15	H20	Mostly structured (layered) with low to medium-amplitude parallel reflectors. Locally, in the upper part of the unit, structureless, semi-transparent interval locally semi-transparent, structureless. In the north-eastern part of the route, the unit is characterised by overall semi-transparent seismic facies with local high amplitude negative reflectors of various extent. The high amplitude reflectors may indicate layers of pockets of peat and/or organic clay. Base forms a sub-horizontal erosional surface, locally forming broad channels/depressions.	Present in the central and large portion of the northern part of the route	Laminated sand and clay, locally sand, locally thin beds or laminae of peat	*Brown Bank*	Lagoonal, estuarine, tidal flat
	D	H15, H20	H25	Acoustically transparent to semi-transparent, structureless. Locally, layered intervals, internal erosion surfaces marked by strong undulating or inclined reflectors. Internal channelling features are locally present. The infill of these channels is various from chaotic to structured (layered). Base forms a sub-horizontal erosional surface, locally forming channels.	Present almost across the entire route, except small area in the centre and in the most southern part of the route	Sand	Eem Kreftenheye (nearshore)	Marine
	E	H25	H30	Acoustically transparent to semi-transparent, structureless; locally chaotic. Base forms a sub-horizontal erosional surface, locally forming channels.	Present in the northern part of the route	Sand	Egmond Ground	Marine
	F	H25, H30	H35	Semi-transparent infill with occasional amplitude anomalies. locally discontinuous, wavy and steeply inclined medium-amplitude reflectors. Internal channels near the top. The basal reflector forms U-shaped channel / valley.	Present locally in the northern and central part of the route	Sand with clay interbeds	Peelo	Fluvio-glacial, glacio-lacustrine (subglacial valley infill)
	G	H20, H25, H30, H35	H40 (internal) / BPD	Chaotic to acoustically semi-transparent, locally discontinuous, inclined medium-amplitude reflectors. Locally, internal erosion surfaces and internal channels / channelling features. Horizon H40 marks internal erosion surface, at which locally high amplitude negative reflectors are present, indicating a thin bed or laminae of peat /organic clay.	Present across the entire route	Sand with local clay interbeds	Yarmouth Roads	Fluvio-deltaic to marine

Notes:
DS = disturbed sediments
Hyphen = not applicable
BPD = below penetration depth of seismic reflection data
1) = predominant soil type; more detailed information will be provided in the Integrated Report F197217-REP-007, which will include data of the geotechnical investigation

Table 14. Overview of seismostratigraphic units (source: Fugro survey report F197217-REP-001)

The result of the assessment of the prehistoric landscapes from the subbottom profiler and UHRS data is described below. A geological x-section from south to north along the sections nearshore east, A, B, and C is included as Appendix 3 in this report. Focus is put on the upper 5 meters below the seabed plane that marks the base of the mobile seabed sediments, because the As Planned pipeline installation foresees a burial depth of 1 m below the seabed after a pre-sweep of sand waves have been carried out. This does not mean that geological units that occur at greater depths are fully disregarded. Phenomena of interest for the evolution of prehistoric landscapes are looked into.

Section Nearshore East

This x-section covers:

- the landfall of the pipeline at the Maasvlakte 2,
- the pipeline crossing of the Maasgeul,
- the shallow parts of the seabed with depths less than 15 meters north of the Maasgeul between KP 1.5 and KP 8.5 in a section that can be described as a bulge, and
- the trajectory between KP8.5 and KP 30.6 with depths varying from 20 to 30 meters.

Both on the southern and northern edge of the Maasgeul Pleistocene en Holocene units are exposed at the intersection of these layers and beds with the Maasgeul. North of the Maasgeul the top of Unit B likely consists of Mid-Holocene fresh-water fluvial tidal deposits of firm to stiff clay with plant remains. This bed of clay is part of the Echteld Formation.

To illustrate the different sediment beds and lithostratigraphic units that are contained in Unit B in the Maasgeul area we projected the lithological column of DINO borehole B37A0952 onto the x-section of the Nearshore East section. The borehole lies 46 m west of the route trajectory. No lithostratigraphic interpretation is given in DINO.

We interpret the sequence from bottom to top as:

- medium coarse sand of the Kreftenheye Formation,
- peat and organic clay of the Basal Peat Bed,
- very coarse sand with clay bed of Wormer Member (?),
- clay of the Echteld Formation.

Between KP 1.5 and KP 6.5 the Echteld Formation is covered by tidal deposits of the Wormer Member and the Walcheren Member | Naaldwijk Formation, and mobile sands of the Bligh Bank Member | Southern Bight Formation (Unit A). Within this KP 1.5 to KP 6.5 section the Echteld Formation wedges out towards the north.

Further north, around KP 5.0 foresets are observed in the upper part of Unit B (see figure 18 below). We interpret the upper part of Unit B as estuarine deposits of the Naaldwijk Formation. At the base Fugro mapped acoustic blanking. It is not known if the blanking is related to occurrences of peat in the subsurface.

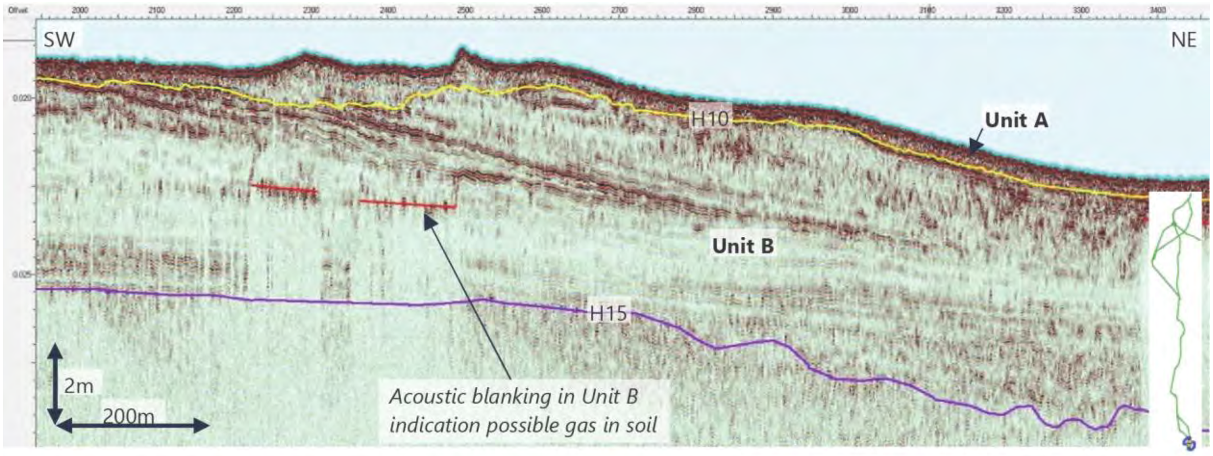


Figure 0.12: SBP data example of acoustic blanking in Unit B. (Line SBP_TA3C2020P1)

Figure 18. Wormer Member | Naaldwijk Formation in the upper part of Unit B around KP 5.0 of the Section Nearshore East

The section between KP 8.5 and the end of Section Nearshore East at KP 30.5 shows a gradual thickening of Unit A. The thickness of Unit B varies from 1 to 4 meters. Possibly Unit B represents tidal deposits of the Wormer Member. However, this is not certain. As can be seen in figure 19 Unit B has a (semi)transparent character, while the underlying Unit C has a more homogenous character with occasional anomalies. It might be possible that both Unit B and Unit C consist of Pleistocene deposits of the river Rhine that are classified as the Kreftenheye Formation, with H15 being an internal reflector.

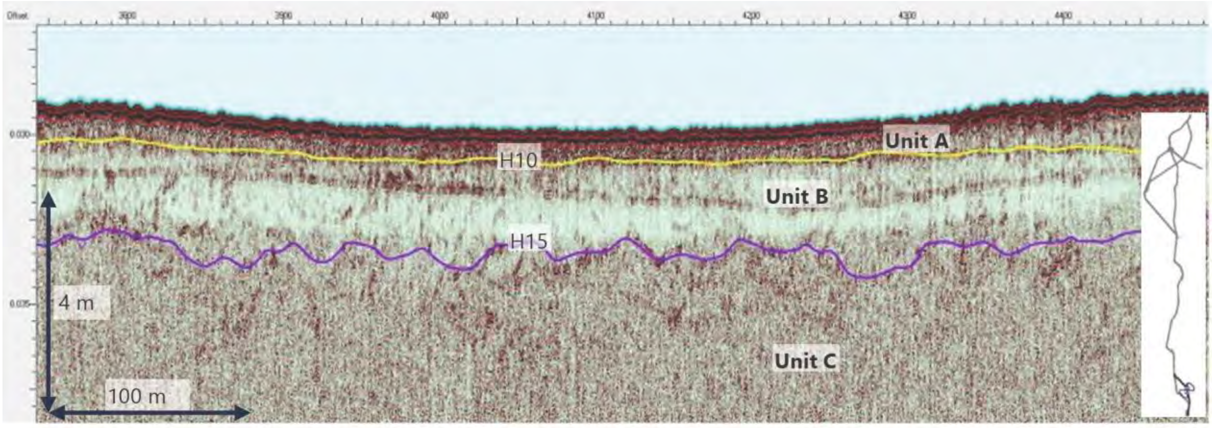


Figure 0.9: SBP data example of route section Export Route East MT. (Line SBP_TA3C2016P2)

Figure 19. River sands of the Kreftenheye Formation (Unit C). The interpretation of Unit B is uncertain. Unit B could also consist of the Kreftenheye Formation with H15 as an internal reflector or Unit B consists of Holocene tidal deposits of the Wormer Member.

Section A

In this section the seabed morphology is characterized by up sand dunes with elevations up to 5 meter relative to the surrounding seabed. The sand dune crests lie on average some 500 meters apart. The sands from which the dunes are built are classified as the Southern Bight Formation | Bligh Bank Member. The base of the Unit A (reflector H10) likely coincides with the base of the Bligh Bank Member. However, in places where the Bligh Bank Member covers sandy deposits of the Wormer Member, the layer boundary between those two lithostratigraphic units might not show as a reflector in the subbottom profile. Where a classic Early Holocene bottom to top sequence of the Nieuwkoop Formation | Basal Peat Bed, organic clay of the Naaldwijk Formation | Velsen Bed and coarsening upward fine sand of the Naaldwijk Formation | Wormer Member has been preserved intact, the transition from the generally thin layers of the Basal Peat Bed and Velsen Bed to underlying Pleistocene sands will show as a distinct reflector in the subbottom profile. Therefore, it is possible that Unit A also includes those Early Holocene organic and argillaceous deposits. Intermittent occurrences of peat and/or organic clay have been mapped at the transition from Unit A to Unit B. We interpret these occurrences of peat and organic clay as the Basal Peat Bed and Velsen Bed. An example is shown in figure 20.

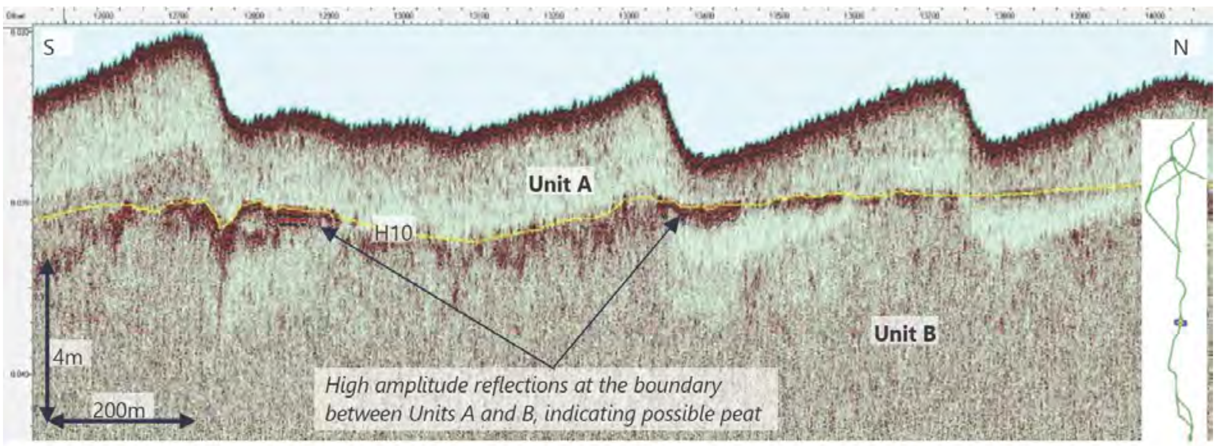


Figure 0.11: SBP data example of anomalies indicating possible peat in Unit B. (Line SBP_TA3E2134P1)

Figure 20. Possible peat the transition from Unit B to Unit A

As can be seen in x-section A in Appendix X, peat also occurs as beds covering the layered infills of channel features. Because of the stratigraphic position of the channels relative to the Basal Peat Bed we conclude that the channels are older than the Basal Peat Bed.[14] Because the channels incised the surrounding sediments that are part of the seismic Unit B, we also conclude that the channel infills are younger than the surrounding sediments. This age difference can be large or small. We interpret the channel features as Late Glacial (?) stream valleys that are infilled with fine sandy or loamy fluvial deposits of the Boxtel Formation | Singraven Member with possible intercalations or topping of fine well-sorted aeolian sand (cover sand) of the Boxtel Formation | Wierden Member. An example of a channel feature that incised Unit B is shown in figure 21. The seismic facies of Unit B in this part of the pipeline route trajectory is described as transparent and semi-transparent with rare high amplitude reflectors. This seismic facies points, together with the known geological constellation of the area, at the presence of fluvial deposits of the Kreftenheye Formation. These fluvial deposits consist of poorly sorted Early Pleniglacial river sands of the Rhine.

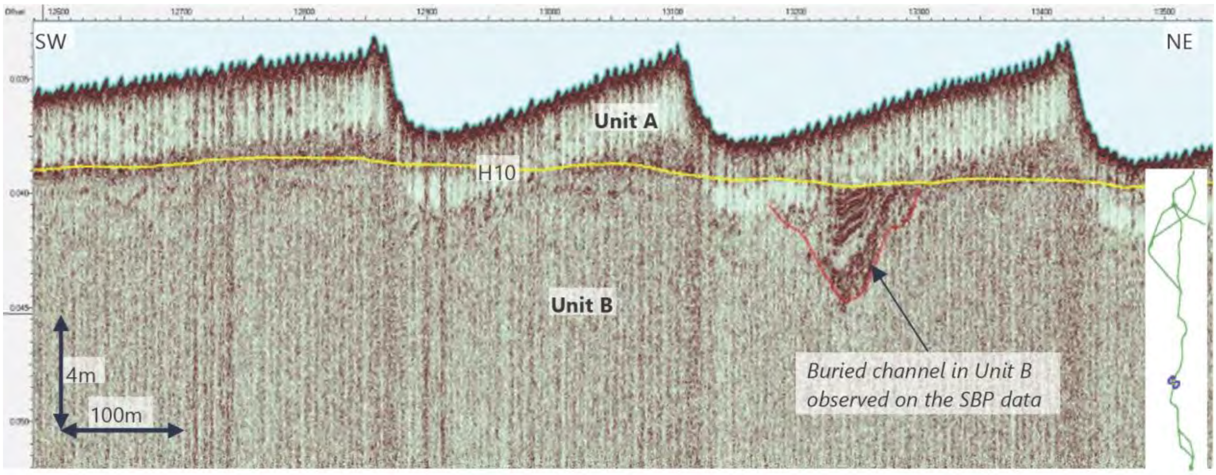


Figure 0.10: SBP data example of buried channels in Unit B. (Line SBP_TA3D2118P1)

Figure 21. Channel-like feature in top of Unit B (source: Fugro survey report F197217-REP-001)

At KP 63.2 a change in seabed morphology is observed. South of this point sand waves are present; north of this point the seabed is generally flat with few ridges. These ridges are elevated some 2.8 meters relative to the surrounding seabed. The fading sand dunes coincide with the appearance of high-amplitude parallel reflectors and high negative amplitude anomalies at relatively shallow depths in the seismic profile. For instance, at KP 67.9 the top of this sequence lies at approximately 1.3 m below the seabed. This coherent layered seismic facies is mapped as Unit C. We interpret Unit C as Early Weichselian layers and laminae of (organic) clay, silt, fine sand, and detritus of the Eem Formation | Brown Bank Member. The fine clastic layered sediments have been deposited in a brackish water lagoonal and shallow marine environment.

Between KP 67.5 and KP 81.0 the top of Unit C, the presumed Brown Bank Member, is found proximate to the seabed surface, and the overlying Unit B is very thin. According to the Geological Map of the Netherlands (2021) partly reworked Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation are present below the mobile deposits of the Bligh Bank Member. However, if a bed of peat and/or organic clay that was mapped by Fugro around KP 79.4 at the interface between Unit A and Unit B indeed is there, this bed of peat and/or organic clay likely comprise the Basal Peat Bed and/or Velsen Bed. This implies that - at this location - the deposits of Unit B cannot be part of the Wormer Member but shall

[14] In other words: the channel infill is covered by a layer of peat.

be classified as Late Glacial deposits of the Boxtel Formation or a veneer of Early Pleniglacial river deposits of the Kreftenheye Formation.

Between KP 80.7 and KP 87.3 the base of Unit B has a basin-like shape and reaches a thickness of 5 meters. The lithostratigraphic interpretation is uncertain. In this interval Unit C, that is the Brown Bank Member | Eem Formation, has eroded during the deposition of the sediments that are now contained in Unit B. Possibly, sedimentation took place during the Early Pleniglacial, when the catchment area of the Rhine reached far into North Sea area. At KP 87.3 a peat bed has been identified in the upper section of Unit B that probably is part of the Basal Peat Bed.

Between KP 80.7 and the end of section A around KP 94.0 the seabed surface is flat with minor decimeter high current ripples. Unit A has a very consistent thickness of 2.8 meters. If the pipeline is installed at 1 meter below the seabed, the seabed disturbance will be limited to the Holocene top layer. The underlying Pleistocene landscapes will not be affected.

Section B

Between KP 0.0 and KP 12.5 Unit A is 2.5 meters thick. The seabed morphology and thickness of Unit A form a continuation of what is observed in Section A.

Between KP 0.0 and KP 45.0 Unit B is present throughout. The thickness of Unit B varies from a few decimeters to nearly 3 meters. Between KP 30.0 and KP45.0 Unit A is thinner than in other parts of Section B. The interpretation of Unit B is not straightforward. According to the TNO | Laban 2004 Top Pleistocene map the Boxtel Formation occurs as subcropping unit in major part of Section B. On the 2021 Geological Map of the Netherlands the Wormer Member | Naaldwijk Formation is mapped as subcropping unit below the Bligh Bank Member. From KP 45.0 northward Unit B thickens to 8 meters around KP 50.0. Along with Unit B, Unit A also thickens to some 2.5 meters.

Fugro has mapped occurrences of peat at the top of Unit B, (around KP 42.2), as intraformational beds within Unit B (between KP 44.0 and 48.0), and at the base of Unit B (between KP 51.0 and 58.0). The peat that was identified at the base of Unit B lies around -37 m LAT. The seismostratigraphic position of this peat bed (base of Unit B) is different from the stratigraphic position of the peat in Section A (top of Unit B). The interpretation is therefore not straightforward. Possibly the peat bed is again the Basal Peat Bed, but now covered by a thick sequence of tidal deposits of the Wormer Member. Another, possibly more likely option, is that the peat bed was deposited during an interstadial period of the latest ice age, the Weichselian. The peat could be part of the Boxtel Formation or the Early Weichselian Woudenberg Formation.

Section C

The general trend in Section C is an overall deepening of the seabed surface from 31 meters in the south (KP 0.0) to 39 meters in the northern part of this section (KP 26.2). The combined thickness of Unit A and Unit B is less than 2 meters between KP 12.8 and the end of Section C.

Intermittent peat is found at the base of Unit B. As mentioned above the timing of deposition and the lithostratigraphic unit where these peat layers are part of is uncertain. The base of Unit B (= top of Unit C) is a straight plane that very gently dips from -39 m LAT at KP 0.0 to -41 m LAT at KP 26.2.

Distinct channel features have been mapped at the base of Unit B. The incision depth of these channels ranges from 2 to 4 meters. The intermittent peat beds at the base of Unit B cover the channel infills. The development of the channels and the later deposition of peat represent different phases in the development of the landscape. These phases could either be separated by a time hiatus or have followed shortly after each other.

Figure 22 shows a subbottom data example of section C including a channel feature and intermittent occurrences of peat at the base of the well-bedded sequence of Unit B (source: Fugro survey report F197217-REP-001). Clearly visible is the thinning of Unit B from south (left side of the image) to north (right side of the image. Figure 23 shows a subbottom data example of section K14-L4A in which channel features are visible that are also encountered in section C.

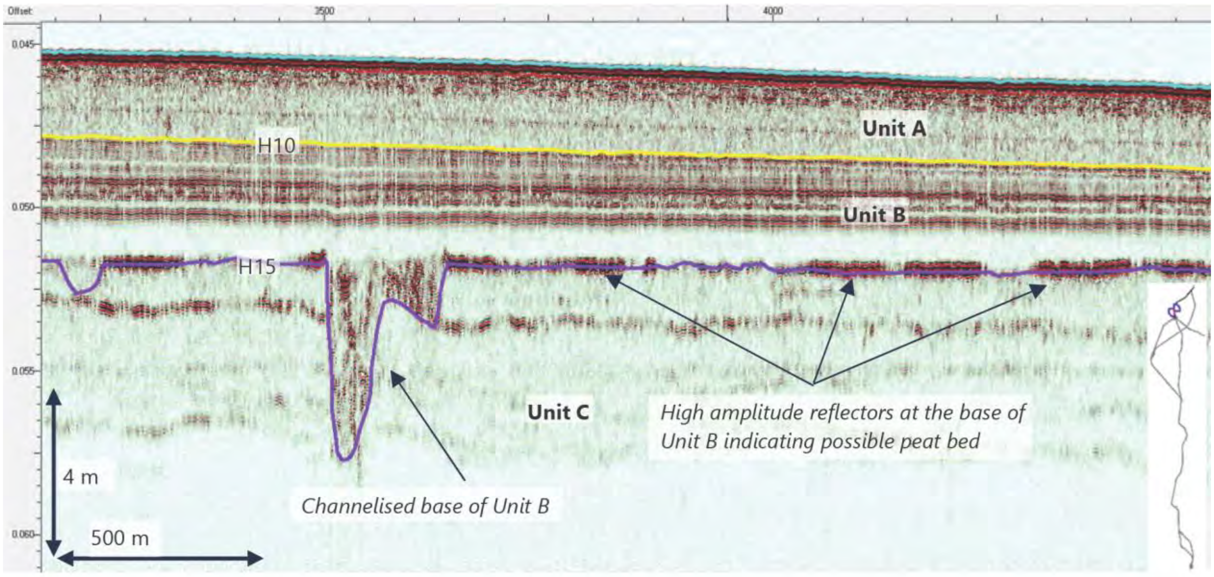


Figure 0.8: SBP data example of route section C. (Line SBP_TA3H23321P1_1)

Figure 22. Channel feature and intermittent occurrences of peat at the base of the parallel bedded sequence of Unit B (source: Fugro survey report F197217-REP-001)

The upper part of Unit C has a (semi)transparent character with a faint plan-parallel sub-horizontal bedding. Although the deposits within Unit C appear to be bedded, this bedding does not show as clear reflectors in the subbottom profile. The top of Unit C probably consists of sandy deposits with little difference and/or gradual changes in grain-size and composition. We interpret the top of Unit C as Eemian marine deposits of the Eem Formation.

The channels that incised Unit C have been infilled with sediments that, at least in figure 23, have not resulted in clear reflectors in the subbottom profile. Probably the absence of clear reflectors is due to limited variation in the lithological composition of the channel infills, which could point to an infill with predominantly (fine) sandy sediments.

The channel infills are truncated by discrete sub-horizontal plan-parallel reflectors at the base of Unit B. These clear reflectors relate to alternating beds with different acoustic impedances. Likely, these differences in acoustic impedance are caused by lithological variations such as alternating beds of fine sand, silt, clay, and peat.

If Unit B consists of Early Holocene tidal deposits of the Wormer Member | Naaldwijk Formation, the peat bed at the base is of Unit B is the Early Holocene Basal Peat Bed. The layered to laminated character of Unit B would fit an Early Holocene tidal setting. The truncated channel features could then represent Late Glacial stream valleys that are infilled with fine sandy or loamy sediment. However, it should be noted that the plan-parallel alternations of fine sand, silt, clay, and detritus also are characteristic of the Early Weichselian Brown Bank Member | Eem Formation. The option that Unit B represents the Brown Bank Member can therefore not be excluded.

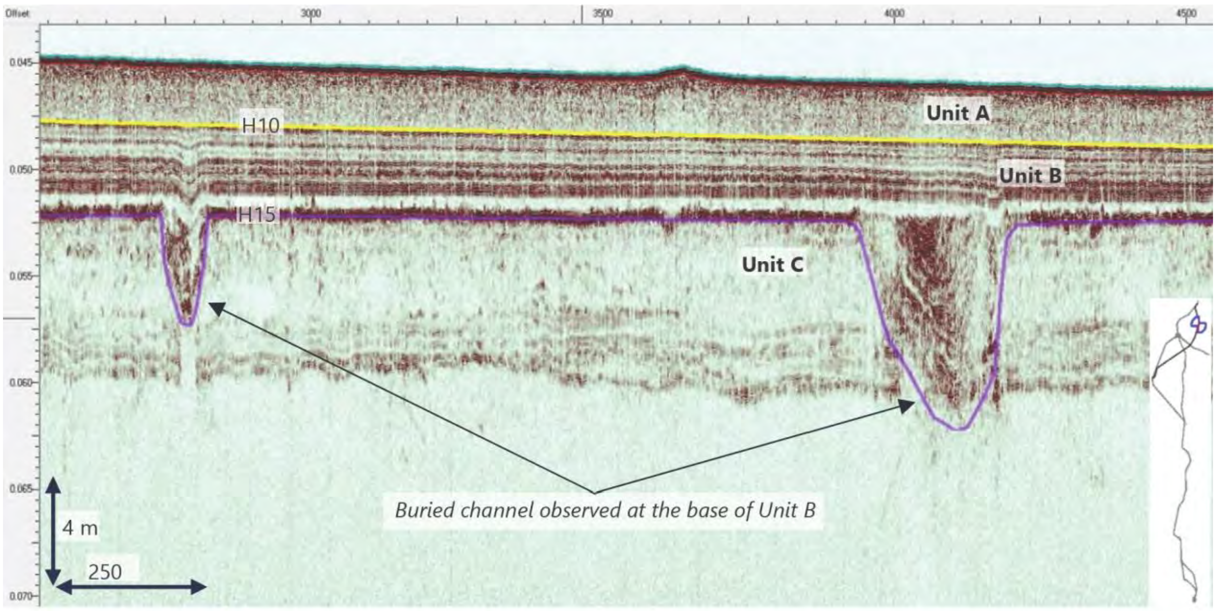


Figure 13.7: SBP data example of route section K14-L4A. (Line SBP_TA3M2321P1_1)

Figure 23. Channel features that are truncated by parallel beds of Unit B (source: Fugro survey report F197217-REP-001)

4 Synthesis

For this investigation different research questions are defined in the Program of Requirements[15]. Based on the results of de data analysis the research questions are answered.

Primary Question : Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

Yes. At 19 locations objects have been found with a possible archaeological value. Eight of these objects are related to visible contacts at the seabed and may represent shipwreck remains. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

With respect to side scan sonar, magnetometer and multibeam survey:
Are there any phenomena visible on the seabed?
Yes. With side scan sonar and multibeam a total of 3806 contacts have been mapped. With magnetometer, a total of 2748 magnetic anomalies have been observed within the area of investigation.

If so: What is the description of these phenomena?
Fugro has identified 3806 *side scan sonar* contacts within the surveyed corridor. The classification of the contacts is listed below.

Classification	**Amount**
Boulder	3010
Debris	159
Depression Pockmark	5
Fishing Gear	7
Mattress	2
Pipeline	4
Seabed Mound	98
Suspected Debris	517
Wreck	4
Total	**3806**

Do these phenomena have a man-made or natural origin?
The majority of the contacts have been classified as man-made.

If these phenomena can be designated to be man-made: What classification can be attached?
See the table above.

[15] Van Lil and van den Brenk, 2022

If these phenomena can be classified as archaeological: Is it possible to interpret the nature of the archaeological objects?
Eight of these objects are related to visible contacts at the seabed and may represent shipwreck remains. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

If these phenomena can be identified as natural: What is the nature of these natural phenomena?
Over 3000 contacts are classified as 'boulder'. These probably also include clay boulders, because known stone boulders in the North Sea only occur north of the city of Den Helder.

Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?
Along the route sand waves have been mapped which are known to migrate a few meters per year northwards. Sand ripples originated by tidal currents are present along the entire route.

General:
What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?
Larger objects like the shipwrecks show scouring but are largely embedded in the seabed sediments. This appears to be the case throughout the area. Therefore, it is not possible to mark risk-prone areas selectively.

If no acoustic phenomena can be observed, are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?
This question is given the results of the investigation not applicable.

With respect to the seismic data: What is the depth of the top of the Pleistocene and Holocene landscape(s) relative to a) LAT and b) the present seabed?
The depth of the Pleistocene landscapes relative to both LAT and the present seabed could not always be determined, because the boundaries of the identified seismic units do not always coincide with those of the lithostratigraphic units. The lithostratigraphic sequences along the routes cannot always be deduced from the seismic data. The presence of peat found by Fugro does help in determining the top of the Pleistocene. The Basal Peat Bed is a bed of peat that has been deposited throughout the North Sea area when groundwater levels rose in response to the rising of the sea level from the beginning of the Holocene to present. The timing of the deposition of the Basal Peat Bed differs with the elevation of the landscape at the moment of inundation.

We produced a south to north x-section utilizing the seismic data delivered by Fugro to provide a context of the geological constellation in the area. The x-section includes the sections Nearshore East, A, B and C. The findings for these sections are also applicable for the other route options.

Section Nearshore East

In the nearshore section, no occurrences of peat were reported. Based on the known geological constellation in this part of the route trajectory we expect the top of the Pleistocene landscape to be buried by tidal deposits of the Naaldwijk Formation, at multiple meters below the seabed. An exception is the Maasgeul where the top of the Pleistocene sequence is expected to intersect with edge of the Maasgeul at or below -20 m LAT.

Section A

In section A occasional peat has been mapped at the base of Unit A | top of Unit B. We interpret these beds of peat as the Basal Peat Bed that covers Pleistocene deposits that are contained in Unit B. The Basal Peat Bed has an intermittent character. The reason for this can be two-fold: 1) peat has never been deposited, and 2) peat has initially been deposited, but has eroded at a later stage. Yet, in between the peat occurrences we expect the top of the Pleistocene landscape in Section A to be located at the same stratigraphic level, that is the top of the seismic Unit B (= H10), albeit that the change that the top of these deposits has eroded is significantly larger than in areas where peat has been found. Along with the occurrence of peat, the top of the Pleistocene sequence has been found at 25 to 30 meters relative to LAT in Section A. The depth of the Pleistocene sequence relative to the seabed varies with the thickness of Unit A. This means that in between sand waves the top of the Pleistocene can be close to being exposed at the seabed or solely covered by a veneer of sand. At the locations of sand wave crests the top of the Pleistocene can be located up to 7 meters below the seabed.

Section B

Given the seismic character of Unit C, including clear subhorizontal subparallel reflectors we interpret Unit C as the Eem Formation, including the Brown Bank Member. The interpretation of Unit B is uncertain. Unit B can include Late Glacial terrestrial deposits of the Boxtel Formation, Early Holocene deposits of the Naaldwijk Formation and even also shallow marine deposits of the Eem Formation and Brown Bank Member. Beds of peat or organic clay are also identified in Section B. The amount and continuity of the peat increases from south to north. Most peat occurs at a different stratigraphic level than in Section A. In Section B peat is often found at the base of the seismic Unit B. This peat could either be the Basal Peat Bed or peat from a deeper stratigraphic level such as the Boxtel Formation or Woudenberg Formation. If the Pleistocene landscape coincides with the base of Unit A, the top of the Pleistocene lies -26.5 m to -34 m LAT and 1 to 3 meters below the seabed. If the Pleistocene landscape coincides with the base of Unit B, the top of the Pleistocene lies -28 m to -40 m LAT and 2.5 to 11 meters below the seabed. Ground truthing is necessary to make a better judgement.

Section C

The very flat seabed in Section C deepens to the north from -32 m LAT to -39 m LAT. Towards the north the combined thickness of Unit A and Unit B decreases to less than 2 meters. The base of Unit B gently dips towards the north from -39 m LAT in the south to -41 m LAT in the north. Intermittent peat is found in many locations at the base of Unit B. Discrete channel features have been mapped that incise Unit C. The peat beds cover these channel features. If the Pleistocene landscape coincides with the base of Unit A, the top of the Pleistocene lies -34 m to -40 m LAT and 0.7 to 3 meters below the seabed. If the Pleistocene landscape coincides with the base of Unit B, the top of the Pleistocene lies -39 m to -41 m LAT and 1.3 to 7.5 meters below the seabed. Ground truthing is necessary to make a better judgement.

What lithostratigraphic units can be distinguished along the pipeline routes?
It is not possible to distinguish lithostratigraphic units based on the seismic data alone. The dominant lithostratigraphic units that are expected to be present are listed in the table below.

Classification	**Occurrence Section**	**Lithology**	**Age**	**Environment**	**Layer boundary**
Naaldwijk Fm	Nearshore	sand and clay	holocene	tidal, estuarine	erosive
Basal Peat Bed Nieuwkoop Fm	Nearshore A, B and C	peat	holocene	Marsh, swamp	conformable
Boxtel Fm	Nearshore A, B and C	Homogeneous fine sand loam, peat, clay	Late Glacial	polar desert, small stream	erosive
Kreftenheye Fm	Nearshore A, poss. B	poorly sorted sand	Pleniglacial	braided river	erosive
Brown Bank Mb	A, B and C	layered and laminated fine sand, silt, clay, and detritus	Early Weichselian	lagoon, lake	conformable
Eem Fm	A, B and C	sand and clay	Eemian	marine	erosive

Table 15. Lithostratigraphic units along the pipeline routes

Have channel-like features been observed?
Yes.

If so: What are the characteristics of the channel-like features in terms of spatial distribution (width, depth, shape, extent), channel infill composition, stratigraphic position and age.
Channel features are observed at two seismostratigraphic levels:

1- As incisions into the top of Unit B
2- As incisions into the top of Unit C

The depth of incision is limited to a few meters or less. At both stratigraphic levels the channel features are covered by peat. From this we conclude that the channel infills are older than the peat depositions. We interpret the channels that incised the top of Unit B as Late Glacial stream valleys that are filled-in with fine sand or loam and later covered by Early Holocene peat of the Basal Peat Bed.

The channel features that incised Unit C could also be Late Glacial with a cover of the Basal Peat Bed, but the interpretation of the peat at this stratigraphic level is uncertain (possible Boxtel Fm or Woudenberg Fm?).

Are occurrences of peat and/or organic clay observed?
Yes.

If so: What is the spatial distribution (depth, extent) stratigraphic position and age of these deposits.
Please refer to the answers to the previous questions.

The Basal Peat Bed is expected to occur at the base of Unit A in Section A. The peat beds that are found at the base of Unit B could be the Basal Peat Bed, but older peat from the Boxtel Formation or Woudenberg Formation cannot be excluded.

Are intact prehistoric landscapes affected by the installation of the pipeline based on their vertical position related to the seabed?
Yes, even if the trenching depth is limited to one meter below the seabed intact prehistoric landscapes could be affected by the installation of the pipeline. Risk-prone areas are sections where peat beds occur proximate to the seabed surface. Those areas have been identified in Section A in where peat occurs in low-lying areas in between sand dunes and in the northern parts where peat occurrences a wide-spread and the combined thickness of Unit A and Unit B is less than two meters.

Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?
No.

If so: Based on the presence of buried objects and its correlation with side scan sonar, magnetometer en multibeam data can something be said about the nature of these buried objects?
This question is not applicable.

.

5 Summary and recommendations

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) covering a total area of 243 km^2 have been analyzed to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second and step in the AMZ-cycle, following the desk study. The purpose of this assessment is to test the desk study-based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

Side scan sonar and multibeam contacts

Within the surveyed area, an archaeological expectation was assigned to a total of 8 contacts. In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE).

Feature	NCN	Easting	Northing	Route section	Distance
BK_FSEA_SSS_0022	-	551288	5924521	D	**+50**
BK_FSEA_SSS_0179	-	555839	5929168	D	-240
BJ_FD_SSS_0015	-	548443	5894128	F	+230
BB_FS_SSS_0683	219	570384	5762003	East	-540
BH_FSEA_SSS_0104	531	559172	5935317	C	**+25**
BK_FSEA_SSS_0163	967	550165	5921956	D	**-56**
BN_FD_SSS_0025	945	576689	5920367	E Neptune	+220
BB_FS_SSS_0433	-	570711	5761481	East	-210

Table 16. Objects with an archaeological expectation.

Three of the eight contacts fall within 100 meters of the proposed route.

Magnetic anomalies

A total of 2748 magnetic anomalies have been observed. At 10 locations magnetic anomalies with a peak-to peak value over 500 nT have been mapped which cannot be related to known objects like pipelines or cables and may be of potential archaeological interest. The objects that cause these anomalies are not visible on side scan sonar or multibeam images and are therefore considered to be buried in the seabed. These objects could, apart from archaeological objects, include debris, UXO, lost anchors, et cetera. As long as the character of these objects has not been determined, the objects are considered to be of potential archaeological interest.

Target	E	N	nT	Section	Distance
BAB_FS_UXO_0010	570711	5761625	808	East	-210
BAB_FS_UXO_0599	570931	5761671	514	East	**+5**
BAB_FS_UXO_0603	570932	5761987	2312	East	**+8**
BAB_FS_UXO_0605	570933	5761957	1158	East	**+8**
BAB_FS_UXO_0618	570936	5761510	729	East	**+11**
BAB_FS_UXO_0657	570948	5761543	1348	East	**+22**
BC_FD_MAG_0121	571170	5763666	666	East	**+4**
BH_FSEA_MAG_0044	559169	5935057	578	C	**-2**
BJ_FD_MAG_0050	563642	5875159	2089	F	**-59**
BP_FD_MAG_0016	559490	5931390	591	B	**-60**

Table 17. Magnetic anomalies over 500 nT with an archaeological expectation.

Nine of the eleven contacts fall within 100 meters of the proposed route.

In accordance with Dutch Law and Legislation no seabed disturbances should be carried out within 100 meters of each of the marked locations. If any activities will take place within 100 meters of a potential archaeological location, it will be examined on a case-by-case basis whether the 100 meters should be maintained in consultation with the Cultural Heritage Agency of the Netherlands (RCE). All locations of potential archaeological interest within 100 meters of the proposed route are shown in the next figure.

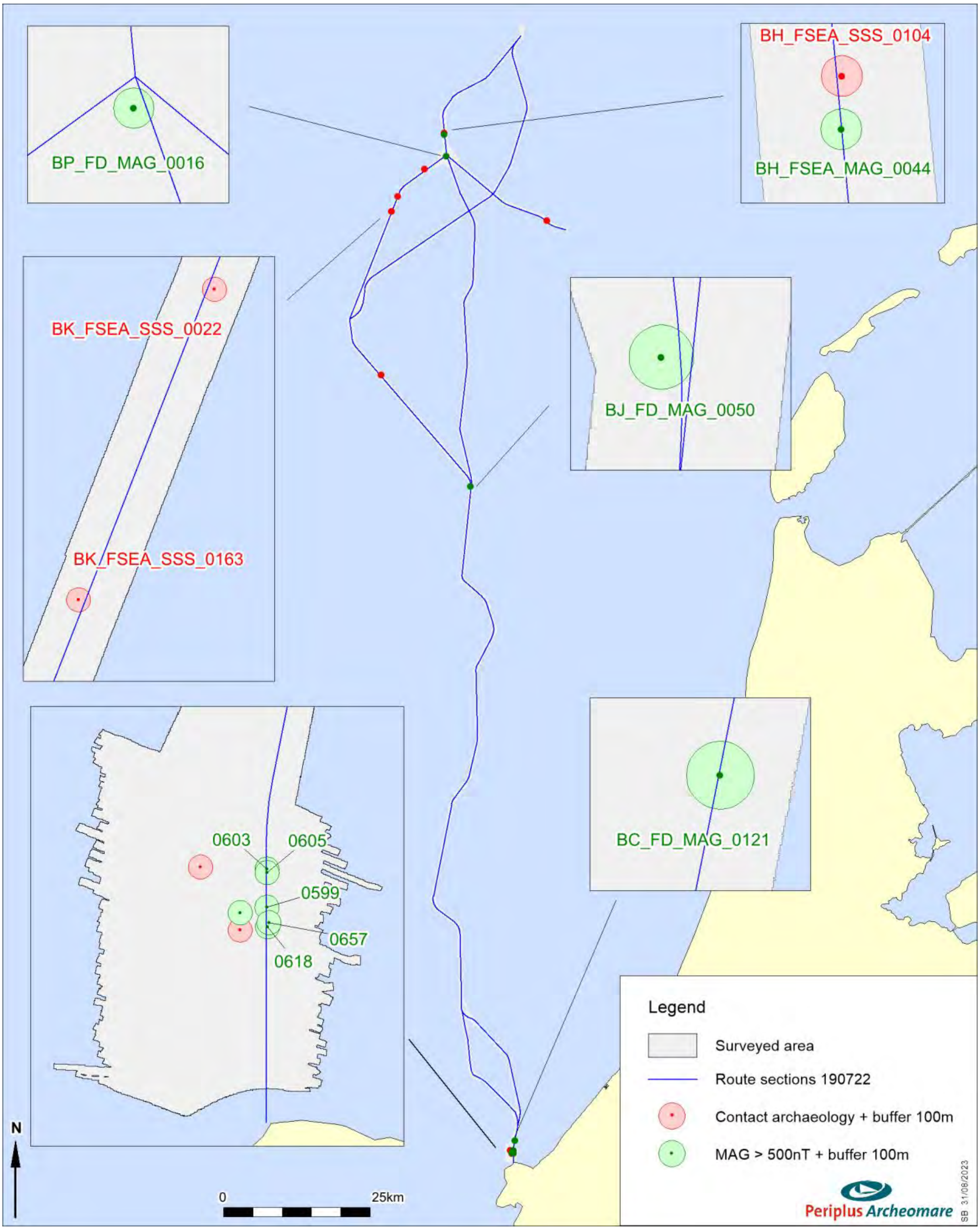


Figure 24. Overview of the potential archaeological targets within 100 meters of the proposed route

Prehistoric remains

Areas of potential archaeological interest listed below.

Depositional environment Areas of potential archaeological interest	**Lithostratigraphic Unit**	**Time of deposition**	**Archaeological period**
Peat-covered aeolian and small scale fluvial deposits	Boxtel Formation	*Late Glacial* and Early *Holocene*	Late Paleolithic and Early Mesolithic
Catchment of the Rhine	Kreftenheye Formation	Pleniglacial	Middle Paleolithic
Shores of lakes and lagoons	Brown Bank Member	Early *Weichselian*	Middle Paleolithic to Early Mesolithic

Table 18. Areas of potential archaeological interest

The physical quality, that is, the integrity and preservation of prehistoric remains is highly dependent on the extent to which prehistoric landscapes and archaeological levels herein have been affected by erosion. The seismic data indicate that part of the *Pleistocene* landscape has eroded during the Early *Holocene* marine ingression, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains may have been preserved intact, especially in areas where peat has been found. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by vibrocore sampling. The actual geological sequences present in the area and the integrity of layer boundaries will be verified, thus offering a tool for further analysis of the prehistoric landscapes and specify and test the archaeological potential.

Recommendation

Prehistory

Periplus Archeomare recommends conducting further archaeological research that focuses on the genesis and integrity of paleo-landscapes along the Aramis route trajectories for general archaeological research purposes. This research comprises an inventory of field research by means vibrocore sampling in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carried out to generate a geological model of the subsurface of the pipeline corridor and to determine the physical properties of the sediment layers present. We recommend designating a number of vibrocore locations where sediment samples are collected that can be used for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of OSL and radiocarbon age dating, sediment petrography, palynology, micropaleontology (foraminifera, ostracods, diatoms, et cetera), macro-remains of plants and animals and molluscs to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly, and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE. After completion of the inventory field research, during the construction of the pipeline, data can be collected that - from an archaeological point of view - provide valuable information at a detailed level. It can be very useful to investigate this information further from an archaeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.

During the installation of the pipeline, archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Erfgoedwet, it is required to report those findings to the enforcing authority (Minister of OCW). This notification must also be included in the scope of work.

List of Figures

List of tables

Glossary and abbreviations

Terminology	**Description**
AMZ	Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage
Allerød	Warm period (*interstadial*) within the *Late Glacial*, 13,900 to 12,900 cal years BP
Bioturbation	Disturbance of sediment layers by burrowing animals
Bølling	Warm period (*interstadial*) within the *Late Glacial*, 14,700 to 14,000 cal years BP
CPT	Cone penetration test
Cryoturbation	Disturbance of sediment layers due to freezing and thawing
Diffraction Hyperbola	Isolated point reflectors induced by e.g. boulders or pipelines show as hyperbola in a seismic profile, because the reflections of these objects are not only registered during the crossing of the object (top of hyperbola), but also before and after the crossing (arms of hyperbola)
Eemian	Warm period (*interglacial*) between *Saalian* and *Weichselian* from 130,000 to 115,000 years ago
Erratic	An (glacial) erratic is a piece of rock that differs from the size and type of rock native to the area in which it rests. These rocks are carried by glacial ice, often over distances of hundreds of kilometres. Erratics can range in size from pebbles to large boulders.
Ferrous	Material, which is magnetic or can be magnetized, and well-known types are iron and nickel
Glacial	Ice-age
Holocene	Youngest geological epoch (from the last Ice Age, around 10,000 BC. to the present)
In situ	At the original location in the original condition
Interglacial	Warm period in between two ice-ages
Interstadial	Warm period within an ice-age
Late Glacial	Last part of the Weichselian, 15,000 to 12,000 years ago
ka	Kiloanus or kiloyear, a period of 1,000 years
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
Odderade	Warm period (*interstadial*) within the Early *Weichselian*, 85,000 to 75,000 years ago
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
Pleniglacial	Coldest part of the *Weichselian*, 75,000 ka to 15,000 years ago
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
Saalian	Second last Ice age (glacial), 240,000 to 130,000 years ago
Sandr	Fan shaped outwash plain in front of a glacier

Terminology	Description
Side scan sonar	Acoustic instrument that registers the amplitude of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil
Current ripples	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side
Subbottom profiler	Acoustic system used to create seismic profiles of the subsurface
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	Vibrocore bore is a special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place
Weichselian	Last Ice Age (glacial) from 115,000 to 12,000 years ago

References

Literature

- Busschers, F. S., Kasse, C., Van Balen, R. T., Vandenberghe, J., Cohen, K. M., Weerts, H. J. T., Wallinga, J., Johns, C., Cleveringa, P. & Bunnik, F. P. M. 2007: Late Pleistocene evolution of the Rhine in the southern North-Sea Basin: imprints of climate change, sea-level oscillations and glacio-isostasy. Quaternary Science Reviews 26, 3216–3248.
- Cameron, T.D.J., Laban, C. and Schüttenhelm, R.T.E., 1984. Flemish Bight Kaartblad 52°N-02°E: Quaternary Geology, 1:250.000 series. British Geological Survey and Geological Survey of the Netherlands.
- Cameron, T.D.J., Laban, C., Mesdag, C.M. & Schuttenhelm, R.T.E. 1986: Indefatigable Sheet 53°N - 02°E. Quaternary Geology, 1:250.000 series. British Geological Survey and Geological Survey of the Netherlands.
- Cartelle, V., N.L.M. Barlow, D.M. Hodgson, F.S. Busschers, K. Cohen, B.M.L. Meijninger, & W.P. Kesteren, 2021: Sedimentary architecture and landforms of the late Saalian (MIS 6) ice sheet margin offshore of the Netherlands. Earth Surface Dynamics. 9.
- Fugro, 2019. Geophysical Results Report Hollandse Kust (West) Wind Farm Zone Survey 2018, Zone Survey 2018 Dutch Continental Shelf, North Sea. Fugro Document No.: P904162, volume 3 of 3.
- Fugro, 2022. Geophysical Survey at the IJmuiden Ver Wind Farm Sites V and VI (IJ56) | Dutch Sector, The Netherlands. Geophysical Results Report F192961_REP_007 01 | 23 September 2022. (Preliminary for review).
- GeoXYZ, 2019. Geophysical Results Report Hollandse Kust (West) Wind Farm Zone Survey 2018, Zone Survey 2018 Dutch Continental Shelf, North Sea. GeoXYZ Document No.: P904162, volume 3 of 3.
- Hart, J.K., Young, D.S., N.R. Baurley, B.A. Robson & K. Martinez, 2022: The seasonal evolution of subglacial drainage pathways beneath a soft-bedded glacier. Communications Earth Environ 3, 152 (2022).
- Van den Brenk, S. en van Lil, R., 2022. *Archaeological desk study area of interest Aramis pipelines.* Amsterdam (NL): Periplus Archeomare rapport 21A036-01.
- Lil, R. van, Brenk, S. van den en Cassée, R.W., 2022. *IJmuiden Ver Wind Farm Zone– An archaeological assessment of geophysical survey results.* Amsterdam (NL): Periplus Archeomare rapport 20A031-01. Netherlands Enterprise Agency (RVO).
- Van der Meulen, M. J., Van Gessel, S. F., Tiemersma, J. J. and Van Dijk, T. A. G. P. (2004). Grind en stenen voor de kust van Texel en de winbare voorraad suppletiezand. 25. Netherlands Institute of Applied Geosciences (TNO-NITG), Utrecht, NITG 04-236- B1299.
- Vink, A., Steffen, H., Reinhardt, L. en Kaufmann, G., 2007. Holocene relative sea-level change, isostatic subsidence and the radial viscosity structure of the mantle of northwest Europe (Beglium, The Netherlands, Germany, southern North Sea). *Quaternary Schience Reviews*, 26, pp. 3249-3275.
- Vonhögen-Peeters, L.M., Heteren, S. van and Peeters, J.H.M., 2016. *Indicatief model van het archeologische potentieel van de Noordzeebodem*. Deltares, 1209133-000.
- Van Lil, R., S. van den Brenk en R.W. Cassée, 2023. IJmuiden Ver Wind Farm Zone– An archaeological assessment of geophysical survey results. Periplus Archeomare report 20A034-01

Atlases and Maps

- GeoTOP-model Laag van Wijchen en Hollandveen Laagpakket
- Globale Archeologische Kaart van het Continentale Plat
- Noordzee atlas
-

Sources from the Internet

- Dienst der Hydrografie (www.hydro.nl)
- Dutch Federation of Aviation Archaeology (www.nfla.nl)
- Geologische Dienst Nederland – Data Informatie Nederlandse Ondergrond (www.dinoloket.nl)
- Noordzeeloket (www.noordzeeloket.nl)
- North Sea paleolandscapes, University of Birmingham (http://www.iaa.bham.ac.uk)
- Olie en Gasportaal (www.nlog.nl)
- Stichting Aircraft recovery Group 40-45 (http://www.arg1940-1945.nl)
- Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB.nl)
-

Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

Appendix 1. Listing of selected side scan sonar contacts

The table below contains a selection of 117 *side scan sonar* contacts with a possible archaeological expectation, based on the comparison with known objects (NCN), their size (larger than four meters) and characteristics.

After reviewing, an archaeological expectation has been assigned to 9 contacts marked with a light green colour, presented in the table below.

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BH_FSEA_SSS_0036	572394	5953350	Mattress	18.7	2.3	0.0	-32.8	Mattress
BH_FSEA_SSS_0003	572516	5953431	Depression Pockmark	7.7	6.6	0.0	-39.6	Spudcan depression
BH_FSEA_SSS_0007	572470	5953396	Depression Pockmark	8.2	6.2	0.0	-39.6	Spudcan depression
BH_FSEA_SSS_0004	572548	5953407	Depression Pockmark	6.1	5.9	0.0	-39.5	Spudcan depression
BH_FSEA_SSS_0005	572529	5953379	Depression Pockmark	7.0	6.1	0.0	-39.5	Spudcan depression
BH_FSEA_SSS_0016	572402	5952674	Depression Pockmark	4.3	4.1	0.0	-39.4	oval contact
BH_FSEA_SSS_0001	572373	5953287	Mattress	16.0	0.8	0.1	-39.3	mattress
BM_FSEA_SSS_0354	571321	5945854	Suspected Debris	4.4	0.3	0.0	-38.1	Elongated contact
BM_FSEA_SSS_0042	572235	5942929	Suspected Debris	4.3	0.9	0.2	-36.8	Oval contact, clustered with other oval contacts
BH_FSEA_SSS_0245	558780	5937355	Suspected Debris	12.7	3.1	0.0	-35.1	irregular contact, possibly a seabed disturbance
BM_FSEA_SSS_0030	573164	5939530	Seabed Mound	5.6	1.5	0.0	-34.7	Elongated thin contact, possible cable or chain
BH_FSEA_SSS_0117	558891	5936096	Suspected Debris	4.0	1.3	0.4	-34.2	Irregular contact in depression.
BM_FSEA_SSS_0078	572899	5938204	Suspected Debris	11.5	7.2	0.0	-33.8	Matrasses Pipeline Total L7-A to L7-P
BH_FSEA_SSS_0107	559378	5933267	Suspected Debris	4.3	0.3	0.4	-32.3	Elongated straight contact
BP_FD_SSS_0003	560054	5931344	Debris	5.7	1.0	0.0	-31	Seabed disturbance
BP_FD_SSS_0010	559575	5930614	Debris	7.5	3.2	0.0	-30.6	no contact visible
BK_FSEA_SSS_0290	543796	5905721	Boulder	4.3	4.7	0.0	-29.6	Seabed disturbance
BK_FSEA_SSS_0108	551298	5924649	Boulder	28.8	1.2	0.2	-29.4	buoy anchor with cable
BK_FSEA_SSS_0174	544378	5904424	Boulder	4.3	2.4	0.0	-29.4	elongated contact
BK_FSEA_SSS_0154	546697	5913055	Boulder	9.8	0.6	0.2	-29.3	Patch of shells
BK_FSEA_SSS_0044	547294	5914807	Boulder	4.5	2.2	0.0	-29.2	Nothing Visible on SSS and MBES
BK_FSEA_SSS_0120	547879	5915829	Boulder	6.8	0.8	0.0	-29.2	Nothing Visible on SSS and MBES
BK_FSEA_SSS_0196	545707	5909928	Boulder	4.3	3.1	0.0	-29.2	oval contact
BK_FSEA_SSS_0260	545890	5910411	Boulder	4.2	1.1	0.0	-29.2	oval contact
BK_FSEA_SSS_0274	547617	5914888	Boulder	5.2	5.6	0.0	-29.2	oval contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BK_FSEA_SSS_0075	549384	5919899	Boulder	6.0	3.3	0.0	-29.1	Elongated straight contact
BK_FSEA_SSS_0175	545656	5908303	Boulder	4.3	1.0	0.1	-29.1	oval contact
BM_FSEA_SSS_0086	570587	5931442	Suspected Debris	4.0	0.5	0.0	-29.1	Seabed disturbance
BE_FD_SSS_0003	561690	5822980	Suspected Debris	5.7	2.7	0.1	-28.9	oval contact
BN_FD_SSS_0039	562547	5929173	Debris	4.1	1.0	0.0	-28.9	no contact visible
BE_FD_SSS_0002	560603	5821138	Suspected Debris	8.3	4.3	0.4	-28.8	oval contact in depression
BM_FSEA_SSS_0292	546644	5910321	Suspected Debris	7.8	0.2	0.1	-28.8	Elongated contact
BK_FSEA_SSS_0286	542892	5903521	Boulder	9.8	0.5	0.0	-28.7	thin straight contact, possibly depression
BM_FSEA_SSS_0377	547318	5911315	Suspected Debris	6.4	0.3	0.0	-28.7	Elongated contact, cable or chain
BM_FSEA_SSS_0098	570182	5930164	Suspected Debris	4.6	0.6	0.0	-28.3	Elongated contact
BG_FD_SSS_0014	561067	5926853	Pipeline	25.1	0.8	0.1	-28.2	Pipeline
BG_FD_SSS_0021	561279	5926721	Pipeline	53.6	0.5	0.0	-28.1	Pipeline
BG_FD_SSS_0010	561476	5926599	Pipeline	87.8	0.6	0.0	-27.8	Pipeline
BG_FD_SSS_0017	561489	5926592	Pipeline	53.9	0.5	0.3	-27.6	Pipeline
BG_FD_SSS_0009	561534	5926360	Suspected Debris	5.7	3.4	0.0	-27.3	Nothing Visible on SSS and MBES
BN_FD_SSS_0025	576689	5920367	Wreck	17.5	5.2	1.5	-27	See NCN 945 / Contact bn_fd_sss_0025
BE_FD_SSS_0035	562830	5824316	Suspected Debris	24.6	1.0	0.0	-26.9	Elongated contact, possibly cable or chain
BJ_FD_SSS_0004	545175	5897731	Debris	4.5	2.3	0.0	-26.9	Nothing Visible on SSS and MBES
BE_FD_SSS_0015	561724	5823492	Suspected Debris	15.9	0.7	0.0	-26.8	Elongated contact, possibly cable or chain
BE_FD_SSS_0031	564689	5840888	Suspected Debris	6.0	1.1	0.0	-26.8	Elongated contact, possibly cable or chain
BM_FSEA_SSS_0082	567876	5925957	Suspected Debris	4.0	0.4	0.0	-26.6	Elongated contact
BG_FD_SSS_0020	562256	5924505	Suspected Debris	13.2	0.4	0.0	-26.4	Long Small Bended Contact, Nothing on Mbes, Possible Rope or Chain
BN_FD_SSS_0010	566548	5925589	Debris	5.7	3.1	0.0	-26.4	no contact visible
BM_FSEA_SSS_0014	566988	5924284	Suspected Debris	4.6	0.4	0.1	-26.3	no contact visible
BF_FD_SSS_0026	563257	5896796	Seabed Mound	6.6	3.2	0.7	-26.2	oval contact, possibly a stone
BM_FSEA_SSS_0130	559140	5919286	Suspected Debris	4.9	0.4	0.0	-26.2	cable/chain
BM_FSEA_SSS_0283	566066	5924076	Suspected Debris	4.3	0.7	0.0	-26.2	Elongated contact
BM_FSEA_SSS_0279	565452	5923640	Suspected Debris	10.1	0.8	0.0	-26.1	Elongated contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BN_FD_SSS_0017	571919	5922297	Debris	4.1	0.8	0.0	-26.1	elongated curved contact
BM_FSEA_SSS_0263	560640	5920327	Suspected Debris	5.7	0.6	0.0	-26	Elongated contact
BM_FSEA_SSS_0277	561266	5920672	Suspected Debris	4.7	0.8	0.0	-26	Elongated contact
BM_FSEA_SSS_0333	561394	5920909	Suspected Debris	5.3	0.7	0.0	-26	Elongated contact
BM_FSEA_SSS_0367	564897	5923160	Suspected Debris	4.9	0.6	0.0	-26	Elongated contact
BG_FD_SSS_0023	563609	5921710	Debris	5.7	0.5	0.0	-25.9	Cluster of small oval contacts
BM_FSEA_SSS_0221	562349	5921382	Suspected Debris	4.2	0.4	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0256	562509	5921591	Suspected Debris	6.1	0.4	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0273	562187	5921340	Suspected Debris	5.7	0.7	0.0	-25.9	Elongated contact
BM_FSEA_SSS_0317	563598	5922366	Suspected Debris	8.0	0.9	0.0	-25.9	Elongated contact
BN_FD_SSS_0034	574301	5921805	Debris	6.7	2.5	0.0	-25.9	Seabed disturbance
BF_FD_SSS_0002	562271	5906303	Seabed Mound	6.5	4.0	0.2	-25.8	oval contact
BF_FD_SSS_0004	562337	5906463	Debris	4.8	1.4	0.1	-25.8	oval contact
BF_FD_SSS_0005	562372	5906435	Seabed Mound	4.1	1.3	0.1	-25.8	oval contact
BF_FD_SSS_0009	562478	5906537	Seabed Mound	5.1	1.0	0.0	-25.8	oval contact
BE_FD_SSS_0033	564696	5841065	Suspected Debris	6.7	0.4	0.0	-25.7	Elongated contact, possibly cable or chain
BF_FD_SSS_0007	562431	5905891	Seabed Mound	11.9	3.3	0.3	-25.7	Elongated triangular contact, with a grinding channel
BF_FD_SSS_0008	562436	5905902	Seabed Mound	6.8	3.0	0.2	-25.7	oval contact, with a depression
BF_FD_SSS_0015	562631	5906896	Seabed Mound	4.3	2.2	0.1	-25.7	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0021	562712	5906802	Seabed Mound	5.6	1.4	0.1	-25.7	oval contact
BF_FD_SSS_0027	563122	5908014	Suspected Debris	13.3	2.4	0.2	-25.7	Elongated contact
BG_FD_SSS_0008	564555	5919314	Suspected Debris	5.3	0.5	0.0	-25.7	Elongated contact
BF_FD_SSS_0006	562395	5905025	Debris	4.7	1.2	0.2	-25.6	Two oval contacts, possibly stones
BF_FD_SSS_0013	562585	5906295	Seabed Mound	12.9	2.5	0.1	-25.6	Elongated, curved contact, possibly a depression
BF_FD_SSS_0023	562758	5906789	Seabed Mound	6.3	1.5	0.0	-25.6	Nothing Visible on SSS and MBES
BG_FD_SSS_0030	564078	5914876	Debris	16.5	5.2	0.0	-25.6	Nothing Visible on SSS and MBES

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BF_FD_SSS_0030	563476	5908191	Seabed Mound	13.6	2.8	0.1	-25.5	Elongated contact
BF_FD_SSS_0032	563600	5908415	Seabed Mound	5.3	1.9	0.1	-25.5	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0034	563664	5908420	Seabed Mound	4.0	2.6	0.0	-25.5	Oval contact in a cluster of smaller oval contacts
BF_FD_SSS_0035	563664	5908843	Seabed Mound	7.9	1.2	0.1	-25.5	Elongated contact
BF_FD_SSS_0038	563778	5908537	Seabed Mound	12.4	3.1	0.1	-25.5	Elongated, curved contact, possibly a depression
BF_FD_SSS_0041	563849	5908905	Seabed Mound	11.2	3.1	0.1	-25.5	Elongated contact in a cluster of smaller oval contacts
BF_FD_SSS_0042	563897	5908744	Seabed Mound	8.3	2.8	0.1	-25.5	Elongated contact
BF_FD_SSS_0049	564270	5910802	Seabed Mound	4.2	0.8	0.0	-25.5	no contact visible
BG_FD_SSS_0004	564261	5911517	Debris	8.2	1.4	0.0	-25.5	Nothing Visible on SSS and MBES
BJ_FD_SSS_0010	553035	5888675	Debris	4.3	0.7	0.0	-25.4	elongated curved contact
BF_FD_SSS_0025	562976	5899476	Fishing Gear	84.9	0.6	0.0	-25.3	Elongated contact, cable or chain
BJ_FD_SSS_0008	549409	5892980	Debris	4.0	1.6	0.0	-25	oval contact in depression
BE_FD_SSS_0026	564436	5829719	Suspected Debris	5.0	0.6	0.0	-24.2	Seabed disturbance
BB_FS_SSS_0147	569907	5761041	Suspected Debris	6.5	0.9	0.4	-24	Seabed disturbance
BE_FD_SSS_0009	564748	5833956	Suspected Debris	4.2	2.0	0.1	-23.9	oval contact lying on a sand wave
BE_FD_SSS_0028	564355	5830266	Suspected Debris	4.5	3.2	0.0	-23.9	Oval contact, possibly stone
BD_FD_SSS_0642	563132	5781065	Debris	5.1	0.8	0.1	-23.7	Nothing Visible on SSS and MBES
BB_FS_SSS_0481	570154	5761583	Suspected Debris	6.0	2.2	0.1	-23.2	Nothing Visible on SSS and MBES
BE_FD_SSS_0020	563657	5826463	Suspected Debris	11.0	2.7	0.0	-23.2	Seabed disturbance
BD_FD_SSS_0224	557171	5805022	Debris	4.1	1.0	0.0	-23.1	No contact on the SSS, in the Mbes an elongated contact parallel to the sand golf
BB_FS_SSS_0419	570165	5761433	Suspected Debris	8.9	0.6	0.4	-22.6	Elongated straighht contact, partially cut off by the mosaic
BE_FD_SSS_0008	564243	5829215	Suspected Debris	5.9	1.1	0.3	-20.7	No contact on the SSS, in the Mbes an elongated contact parallel to the sand golf
BB_FS_SSS_0433	570711	5761481	Wreck	4.3	2.4	0.3	-18.9	oval contact

Feature_name	Easting	Northing	Feature description Fugro	L	W	H	Z	Description PPA
BB_FS_SSS_0444	570947	5761501	Suspected Debris	4.4	0.5	0.1	-18.4	Natural Ridge
BB_FS_SSS_0025	570853	5760453	Suspected Debris	7.9	1.1	0.2	-18.1	Seabed disturbance
BB_FS_SSS_0705	569990	5762046	Suspected Debris	7.3	0.9	0.2	-17	Elongated contact, possibly cable or chain
BB_FS_SSS_0835	569874	5762289	Suspected Debris	4.1	1.2	0.3	-17	irregularly formed contact
BB_FS_SSS_0937	569719	5762832	Suspected Debris	7.2	0.6	0.2	-16.4	oval contacts, possibly stones
BB_FS_SSS_0019	570760	5760382	Suspected Debris	4.9	1.2	0.5	-14.9	NCN 20283, Seabed disturvance
BA_FS_SSS_0035	570150	5760234	Suspected Debris	4.8	0.5	0.3	-11.5	Elongated contact
BB_FS_SSS_0620	570364	5761961	Suspected Debris	4.1	0.4	0.3	-17	See Wreck NCN 219
BB_FS_SSS_0678	570397	5761996	Wreck	31.9	20.5	1.6	-17	See Wreck NCN 219
BB_FS_SSS_0684	570389	5762001	Suspected Debris	4.3	0.6	0.4	-17	See Wreck NCN 219
BH_FSEA_SSS_0187	559117	5935318	Wreck	17.1	3.9	1.7	-34	See Wreck NCN 531
BJ_FD_SSS_0015	548443	5894128	Debris	5.6	1.8	0.0	-26.4	Elongated object 5.6 perpendicular to sand waves
BK_FSEA_SSS_0022	551288	5924521	Boulder	5.6	2.9	5.2	-29.8	Buried Remains with Magnetic Anomalies
BK_FSEA_SSS_0163	550142	5921916	Boulder	0.0	2.5	2.5	-29	See NCN 967
BK_FSEA_SSS_0179	555839	5929168	Boulder	6.7	5.7	1.0	-30.3	Large Anchor Shaft 3.2 M Arms 2.1m With Scouring

Appendix 2. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA Waterbodems, version 4.1) describes all procedures and requirements for the archaeological research process. Below a brief description of the steps involved:

1. **Desk study**
   The purpose of a desk study is to collect and report all available historical data, geological information, and information about disturbances in the past. The result is an archaeological expectation map or model.
   The desk study may be expanded with an analysis of sonar and multibeam data, if available.

   IF the outcome of the desk study shows that there is a risk of occurrence of archaeology, then the next phase must be carried out:

2. **Exploratory field research (opwaterfase)**

   a. Geophysical survey
   In order to test the archaeological expectation, a geophysical survey is carried out. The type of survey depends on the type of expected objects, local geology and expected depth of the objects below the seafloor. In practice, the research usually consists of a side scan sonar survey, if necessary, supplemented with multibeam echo sounder recordings, subbottom profiling and magnetometer measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

   IF potential archaeological objects are found, then the next phase (**3**) must be carried out.

   b. Geotechnical survey
   In order to reconstruct prehistoric landscapes and refine and test the archaeological expectation related to those landscapes a geotechnical survey can be carried out. A geotechnical survey comprises penetration tests (CPT's) and/or bottom sampling (*vibrocore*, Acqualock, Begemann, grab sampling, etcetera). The sample strategy and sample locations are based on the geological constellation of the area and interpreted subbottom profiling data. The requirements of the survey shall be listed in a program of requirements which must be approved by the competent authorities.

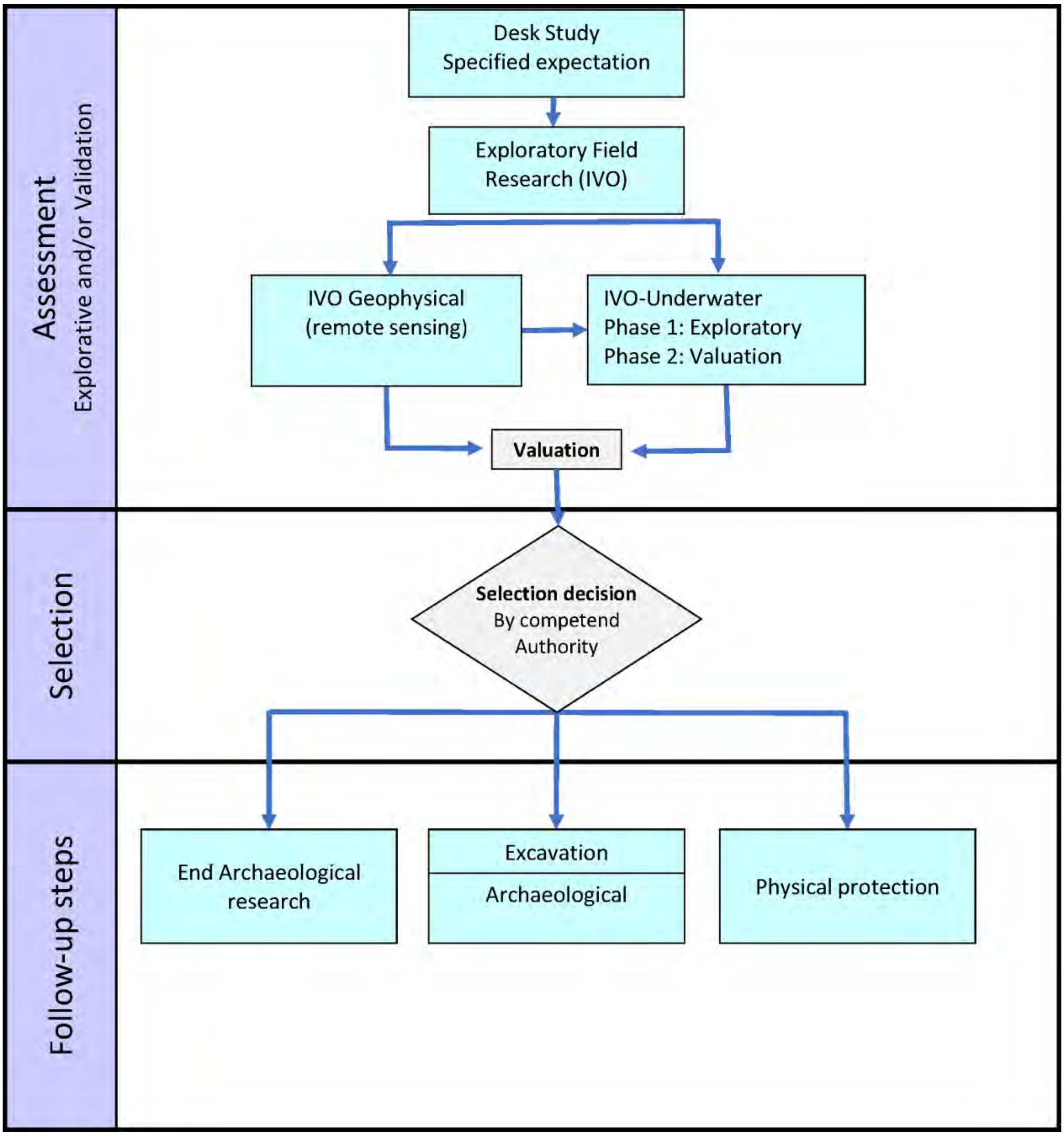
3. **Exploratory field research (onderwaterfase verkennend)**
   The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

   IF as site is identified as an archaeological object or structure then the next phase must be carried out:

4. **Appreciative field research (onderwaterfase waarderend)**
   The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains are worth preserving. If the latter is the case, then there are two possibilities: either the remains can be preserved in situ (adjustment of plans), or the next phase will be conducted:

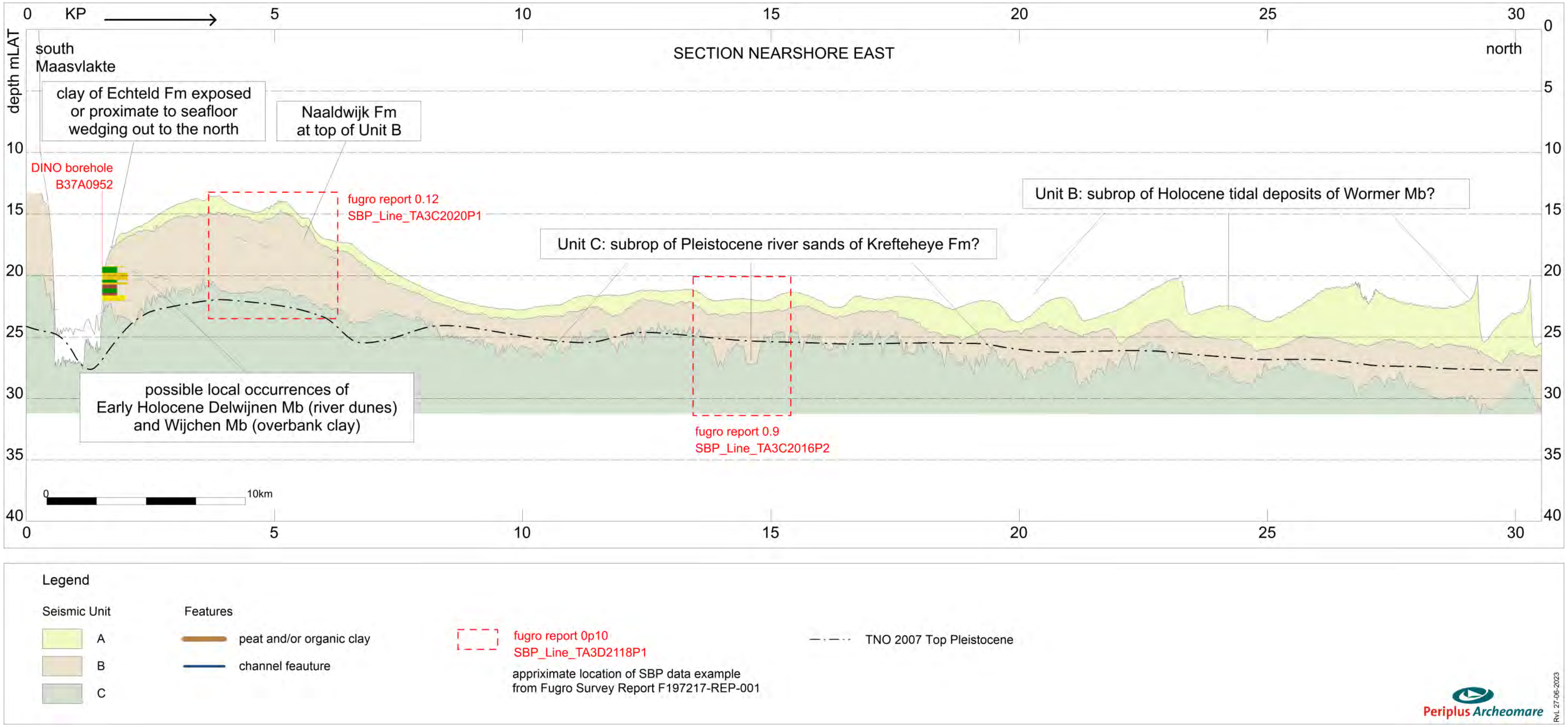
5. **Archaeological excavation**
   The archaeological remains are excavated under supervision of a senior maritime archaeologist. All remains need to be documented, registered, and conserved. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

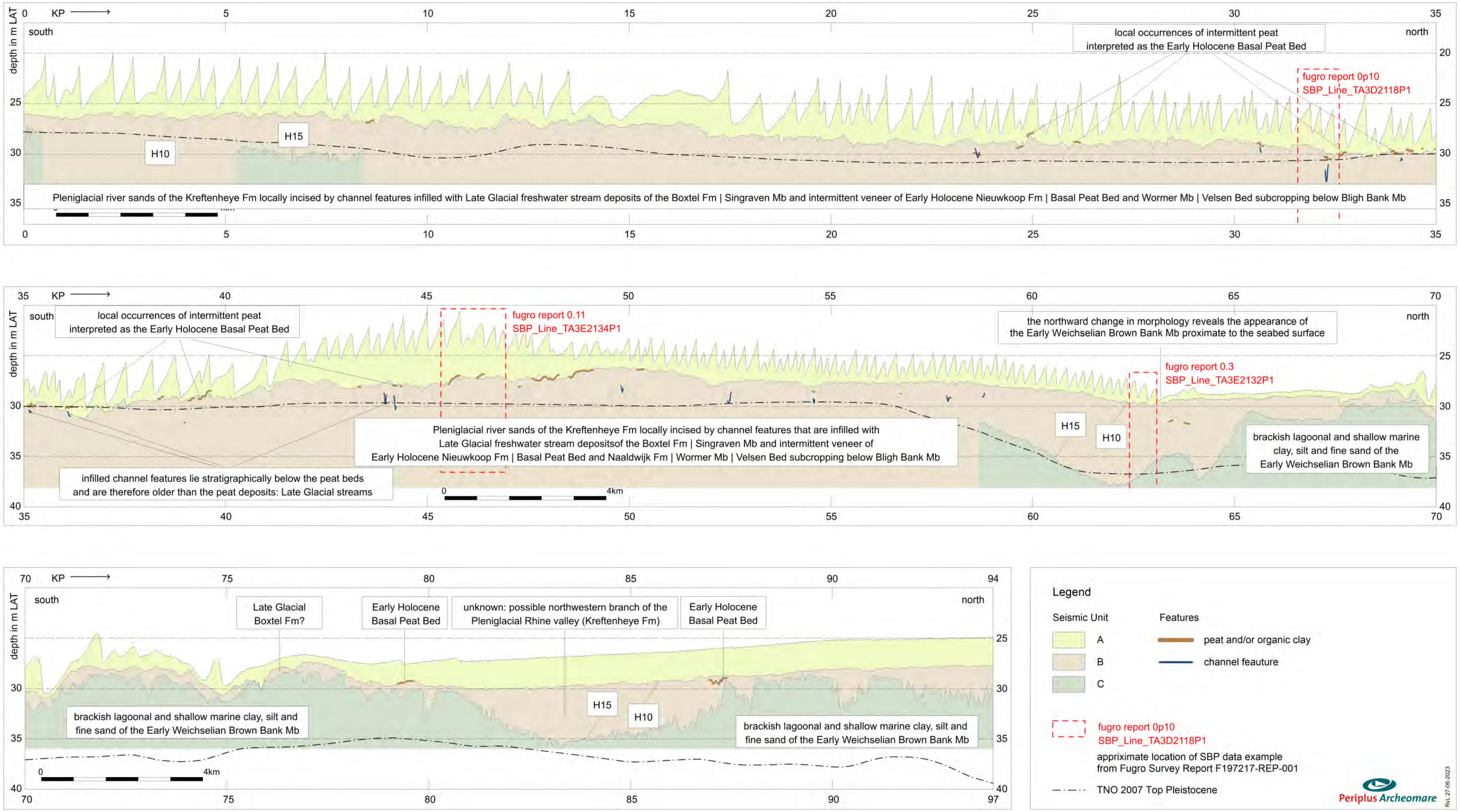
The phases described above contain a number of decision points that are dependent on the detected archaeological objects. The figure below shows these moments schematically.

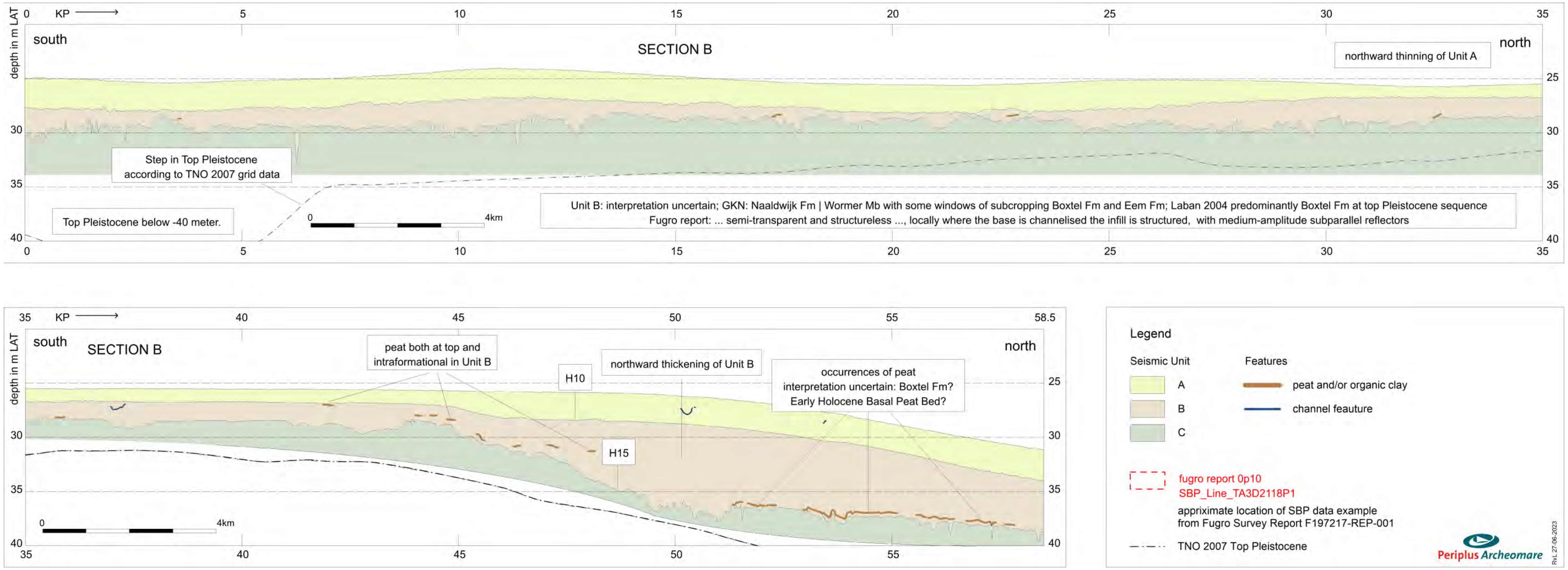


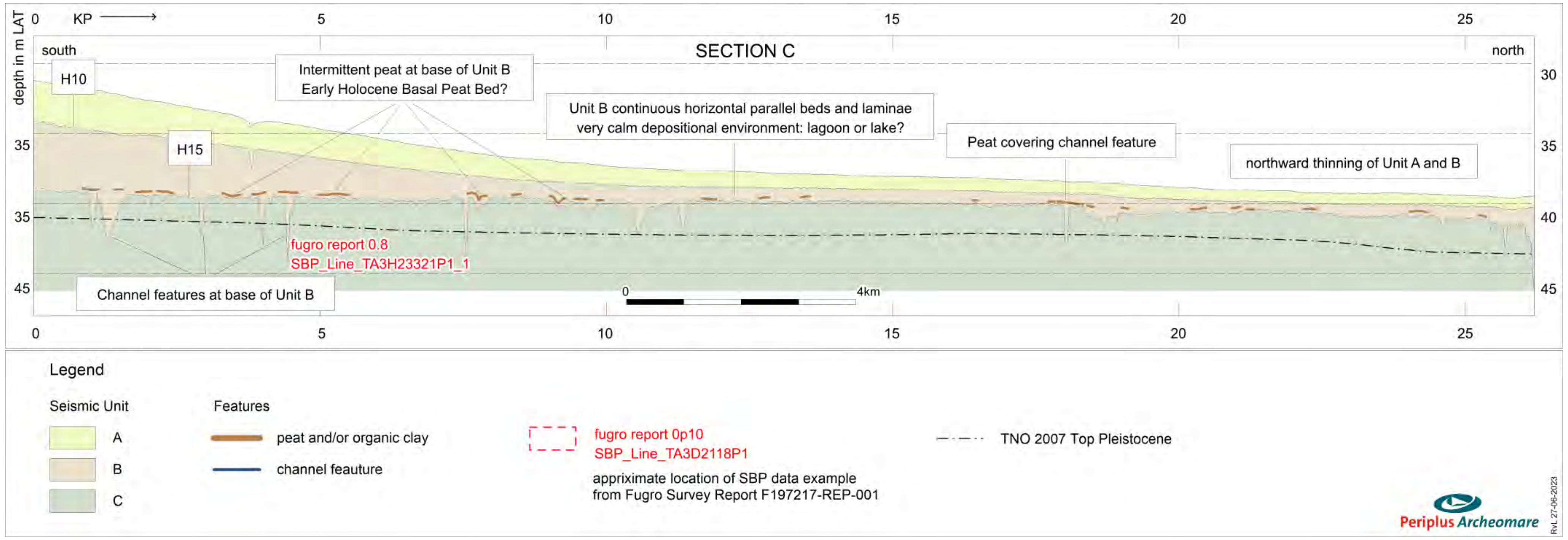
Appendix 3. X-sections

Section Nearshore East, A, B and C


0 KP 5 10 15 20 25 30
depth mLAT
south
Maasvlakte
SECTION NEARSHORE EAST
north
clay of Echteld Fm exposed or proximate to seafloor wedging out to the north
Naaldwijk Fm at top of Unit B
DINO borehole B37A0952
fugro report 0.12
SBP_Line_TA3C2020P1
Unit B: subrop of Holocene tidal deposits of Wormer Mb?
Unit C: subrop of Pleistocene river sands of Krefteheye Fm?
possible local occurrences of Early Holocene Delwijnen Mb (river dunes) and Wijchen Mb (overbank clay)
fugro report 0.9
SBP_Line_TA3C2016P2
0 10km
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
appriximate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
RvL 27-06-2023


KP
depth in m LAT
south
north
local occurrences of intermittent peat interpreted as the Early Holocene Basal Peat Bed
fugro report 0p10
SBP_Line_TA3D2118P1
H15
H10
Pleniglacial river sands of the Kreftenheye Fm locally incised by channel features infilled with Late Glacial freshwater stream deposits of the Boxtel Fm | Singraven Mb and intermittent veneer of Early Holocene Nieuwkoop Fm | Basal Peat Bed and Wormer Mb | Velsen Bed subcropping below Bligh Bank Mb
fugro report 0.11
SBP_Line_TA3E2134P1
the northward change in morphology reveals the appearance of the Early Weichselian Brown Bank Mb proximate to the seabed surface
fugro report 0.3
SBP_Line_TA3E2132P1
Pleniglacial river sands of the Kreftenheye Fm locally incised by channel features that are infilled with Late Glacial freshwater stream depositsof the Boxtel Fm | Singraven Mb and intermittent veneer of Early Holocene Nieuwkoop Fm | Basal Peat Bed and Naaldwijk Fm | Wormer Mb | Velsen Bed subcropping below Bligh Bank Mb
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
infilled channel features lie stratigraphically below the peat beds and are therefore older than the peat deposits: Late Glacial streams
0 4km
Late Glacial Boxtel Fm?
Early Holocene Basal Peat Bed
unknown: possible northwestern branch of the Pleniglacial Rhine valley (Kreftenheye Fm)
Early Holocene Basal Peat Bed
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
brackish lagoonal and shallow marine clay, silt and fine sand of the Early Weichselian Brown Bank Mb
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
appriximate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare
Rvl. 27-06-2023


SECTION B
depth in m LAT
KP
south
north
northward thinning of Unit A
Step in Top Pleistocene according to TNO 2007 grid data
Top Pleistocene below -40 meter.
0 4km
Unit B: interpretation uncertain; GKN: Naaldwijk Fm | Wormer Mb with some windows of subcropping Boxtel Fm and Eem Fm; Laban 2004 predominantly Boxtel Fm at top Pleistocene sequence
Fugro report: ... semi-transparent and structureless ..., locally where the base is channelised the infill is structured, with medium-amplitude subparallel reflectors
peat both at top and intraformational in Unit B
H10
northward thickening of Unit B
occurrences of peat interpretation uncertain: Boxtel Fm? Early Holocene Basal Peat Bed?
H15
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
apprixmate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare


SECTION C
depth in m LAT
KP
south
north
H10
H15
Intermittent peat at base of Unit B Early Holocene Basal Peat Bed?
Unit B continuous horizontal parallel beds and laminae very calm depositional environment: lagoon or lake?
Peat covering channel feature
northward thinning of Unit A and B
fugro report 0.8
SBP_Line_TA3H23321P1_1
Channel features at base of Unit B
0 4km
Legend
Seismic Unit
A
B
C
Features
peat and/or organic clay
channel feauture
fugro report 0p10
SBP_Line_TA3D2118P1
apprixmate location of SBP data example from Fugro Survey Report F197217-REP-001
TNO 2007 Top Pleistocene
Periplus Archeomare

Appendix 4. Integrated Geophysical and Geotechnical reports

F197217-REP-001_(01) Geophysical Results Report.pdf

By Fugro

Samenvatting (Abstract in Dutch)

In opdracht van TotalEnergies Nederland B.V. heeft Periplus Archeomare een archeologische analyse uitgevoerd van de geofysische onderzoeksresultaten van het Aramis pijpleidingtracé.

Een grote hoeveelheid onderzoeksgegevens (*sidescan-sonar, magnetometer, multibeam echosounder* en *subbottom-profiler*) van een gebied met een totale oppervlakte van 243 km2 is geanalyseerd om een archeologische beoordeling uit te voeren.

Deze analyse van geofysische onderzoeksresultaten is de tweede stap in de AMZ-cyclus, na de bureaustudie. Het doel van deze analyse is het toetsen van de op de bureaustudie gebaseerde verwachting voor archeologische resten in het gebied. De verwachting omvat overblijfselen van scheepvaartgerelateerde resten (wrakken), vliegtuigen uit de Tweede Wereldoorlog en prehistorische nederzettingen.

Sidescan-sonar en multibeam-contacten
Binnen het onderzochte gebied is aan in totaal acht contacten een archeologische verwachting toegekend. In overeenstemming met de Nederlandse wet- en regelgeving mogen hier geen bodemverstoringen plaatsvinden. Indien er binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven.

Feature	NCN	Easting	Northing	Route section	Distance
BK_FSEA_SSS_0022	-	551288	5924521	D	**+50**
BK_FSEA_SSS_0179	-	555839	5929168	D	-240
BJ_FD_SSS_0015	-	548443	5894128	F	+230
BB_FS_SSS_0683	219	570384	5762003	East	-540
BH_FSEA_SSS_0104	531	559172	5935317	C	**+25**
BK_FSEA_SSS_0163	967	550165	5921956	D	**-56**
BN_FD_SSS_0025	945	576689	5920367	E Neptune	+220
BB_FS_SSS_0433	-	570711	5761481	East	-210

Tabel 1. Side scan sonar contacten met een archeologische verwachting.

Drie van de acht contacten vallen binnen 100 meters van de geplande route.

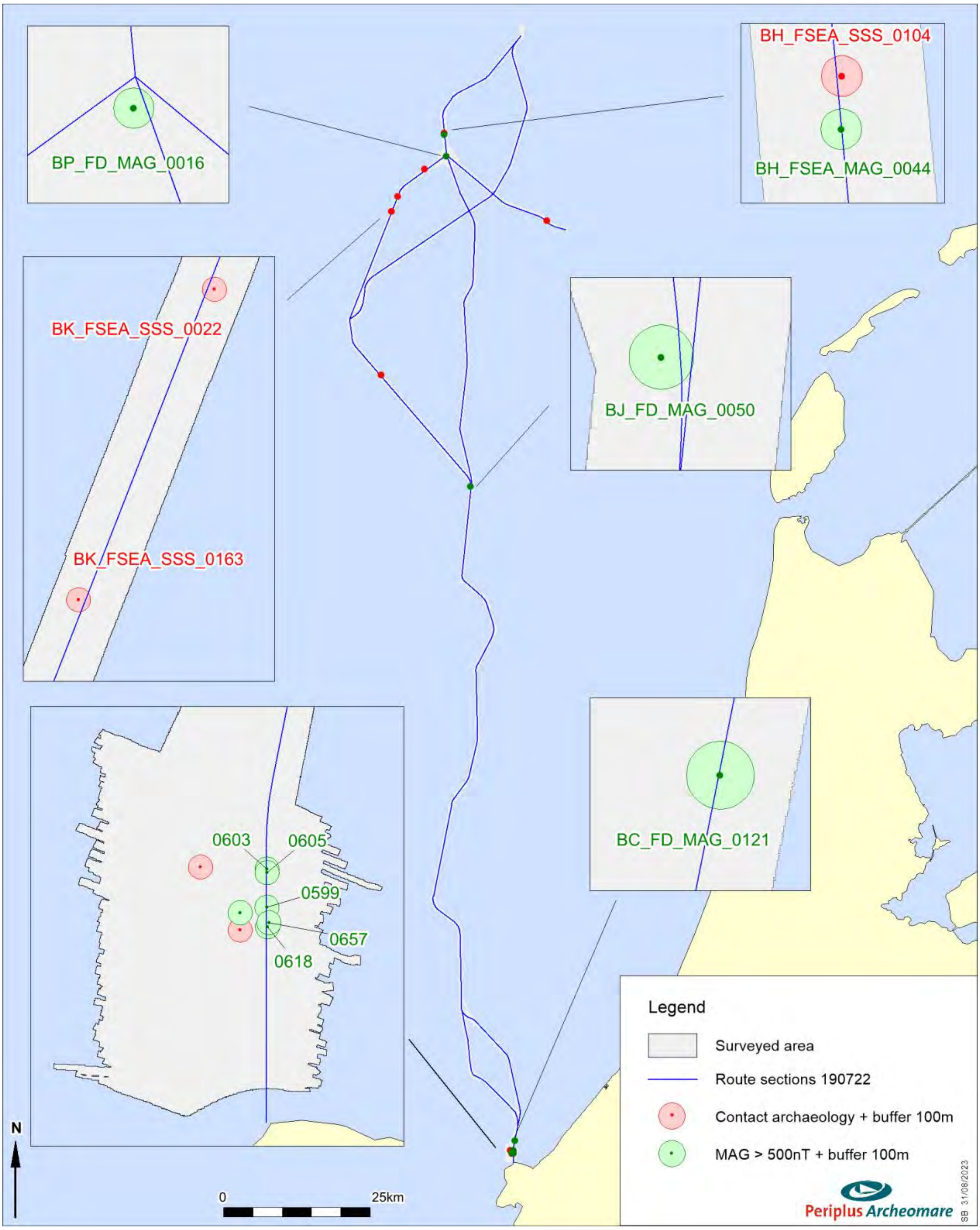
Magnetische afwijkingen

In totaal zijn op 2748 locaties magnetische afwijkingen waargenomen. Op tien locaties zijn magnetische afwijkingen met een piek-tot-piekwaarde van meer dan 500 nT in kaart gebracht, die niet gerelateerd kunnen worden aan bekende objecten zoals pijpleidingen of kabels en die van potentieel archeologisch belang kunnen zijn. De objecten die deze afwijkingen veroorzaken, zijn niet zichtbaar op sidescan-sonar- of multibeam-beelden en worden daarom geacht in de zeebodem te zijn begraven. Deze objecten kunnen (naast archeologische objecten) onder meer puin, explosieven, verloren ankers, et cetera zijn. Zolang het karakter van deze objecten niet is vastgesteld, worden de objecten geacht van potentieel archeologisch belang te zijn. Negen van de tien contacten vallen binnen een straal van 100 meter van de voorgestelde route.

Target	E	N	nT	Section	Distance
BAB_FS_UXO_0010	570711	5761625	808	East	-210
BAB_FS_UXO_0599	570931	5761671	514	East	**+5**
BAB_FS_UXO_0603	570932	5761987	2312	East	**+8**
BAB_FS_UXO_0605	570933	5761957	1158	East	**+8**
BAB_FS_UXO_0618	570936	5761510	729	East	**+11**
BAB_FS_UXO_0657	570948	5761543	1348	East	**+22**
BC_FD_MAG_0121	571170	5763666	666	East	**+4**
BH_FSEA_MAG_0044	559169	5935057	578	C	**-2**
BJ_FD_MAG_0050	563642	5875159	2089	F	**-59**
BP_FD_MAG_0016	559490	5931390	591	B	**-60**

Tabel 2. Magnetische anomalieën groter dan 500 nT met een archeologische verwachting.

Een overzicht van de contacten en magnetische anomalieën is weergegeven in de volgende figuur.



Figuur 1 Overzicht van de potentieel archeologische contacten binnen het onderzochte gebied.

In overeenstemming met de Nederlandse wet- en regelgeving mogen geen bodemverstoringen plaatsvinden op deze locaties. Indien binnen een straal van 100 meter van een potentiële archeologische locatie activiteiten plaatsvinden, wordt in overleg met de Rijksdienst voor het Cultureel Erfgoed (RCE) van geval tot geval bekeken of de 100 meter gehandhaafd moet blijven. Alle locaties van potentieel archeologisch belang binnen een straal van 100 meter van de voorgestelde route zijn weergegeven in figuur 1.

Prehistorische resten

Gebieden met een archeologische potentie voor prehistorische vondsten zijn hieronder samengevat

Depositional environment Areas of potential archaeological interest	**Lithostratigraphic Unit**	**Time of deposition**	**Archaeological period**
Peat-covered aeolian and small scale fluvial deposits	Boxtel Formation	*Late Glacial* and Early *Holocene*	Late Paleolithic and Early Mesolithic
Catchment of the Rhine	Kreftenheye Formation	Pleniglacial	Middle Paleolithic
Shores of lakes and lagoons	Brown Bank Member	Early *Weichselian*	Middle Paleolithic to Early Mesolithic

De fysieke kwaliteit, dat wil zeggen de integriteit en het behoud van prehistorische resten, is sterk afhankelijk van de mate waarin prehistorische landschappen en archeologische niveaus daarin zijn aangetast door erosie. De seismische gegevens geven aan dat een deel van het Pleistoceen-landschap is geërodeerd tijdens de mariene transgressie in het vroege Holoceen, waardoor de integriteit van mogelijke prehistorische nederzettingen is aangetast. Lokaal kunnen de geologische eenheden die zijn gedefinieerd als potentiële lagen met prehistorische overblijfselen intact zijn gebleven, vooral in gebieden waar veen is gevonden. De interpretatie van lithostratigrafische eenheden en het karakter van de laaggrenzen (erosief versus niet-erosief) uit de seismische gegevens is gebaseerd op de beschikbare geologische gegevens en het oordeel van deskundigen. De seismische interpretatie moet worden geverifieerd door middel van vibrocore-bemonstering. De werkelijke geologische sequenties die in het gebied aanwezig zijn en de integriteit van de laaggrenzen zullen worden geverifieerd, wat een instrument zal bieden voor verdere analyse van de prehistorische landschappen en het specificeren en testen van het archeologische potentieel.

Advies prehistorie

Periplus Archeomare beveelt aan verder archeologisch onderzoek uit te voeren dat zich richt op het ontstaan en de integriteit van paleo-landschappen langs de Aramis-routetrajecten voor algemene archeologische onderzoeksdoeleinden. Dit onderzoek omvat een inventarisatie van veldonderzoek door middel van vibrocore-bemonstering conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1). Er wordt een geotechnische campagne uitgevoerd om een geologisch model te genereren van de ondergrond van de pijpleidingcorridor en om de fysische eigenschappen van de aanwezige sedimentlagen te bepalen. Wij adviseren om een aantal vibrocore-locaties aan te wijzen waar sedimentmonsters worden verzameld die gebruikt kunnen worden voor geo-archeologisch onderzoek.

De intacte monsters moeten door een (senior) prospector worden onderzocht en beschreven volgens de Standaard Boorbeschrijvingsmethode (SBB). Monsters worden geselecteerd en gestabiliseerd om te worden geanalyseerd door specialisten op het gebied van OSL- en radiokoolstofdatering, sedimentpetrografie, palynologie, micropaleontologie (foraminiferen, ostracoden, diatomeeën, et cetera), macroresten van planten en dieren en weekdieren om inzicht te krijgen in de ontwikkeling van landschappen in de loop van de tijd en de mate waarin deze paleolandschappen bewaard zijn gebleven.

Conform de Nederlandse Kwaliteitsnorm voor Archeologie (KNA Waterbodems 4.1) moet er een Programma van Eisen (PvE) en/of Plan van Aanpak (PvA) worden opgesteld. Dit PvE/PvA omvat de doelstelling, de onderzoeksstrategie en -methodiek, de kaders en de praktische uitvoering van het onderzoek, zodat het proces soepel verloopt en meervoudig gebruik van de op uniforme wijze verkregen data wordt bereikt. Geadviseerd wordt om deze PvE/PvA ter goedkeuring voor te leggen aan het Bevoegd Gezag en de RCE. Na afronding van het inventariserend veldonderzoek kunnen tijdens de aanleg van de pijpleiding gegevens worden verzameld die – vanuit archeologisch oogpunt – op gedetailleerd niveau waardevolle informatie opleveren. Het kan zeer nuttig zijn om deze informatie vanuit archeologisch oogpunt verder te onderzoeken. Het verdient aanbeveling om, nadat de plannen zijn uitgewerkt, in overleg met de RCE de mogelijkheden hiervoor te onderzoeken.

Tijdens de installatie van de leiding kunnen archeologische voorwerpen worden ontdekt die volledig zijn begraven of tijdens het geofysisch onderzoek niet als archeologisch object zijn herkend. Wij adviseren passieve archeologische begeleiding op basis van een goedgekeurd Programma van Eisen. Passieve archeologische begeleiding houdt in dat een archeoloog tijdens de uitvoering van de werkzaamheden niet aanwezig is, maar altijd op afroep beschikbaar is. Het opvolgen van deze aanbeveling voorkomt vertragingen tijdens de werkzaamheden wanneer er onverwacht archeologische resten worden aangetroffen. Op grond van de Erfgoedwet is het verplicht om deze bevindingen te melden aan de toezichthouder (Minister van OCW). Deze melding moet ook worden opgenomen in het bestek van het werk.

Environmental Desk Top Study

Aramis Pipeline Route – Geophysical and Geotechnical Site Investigation
Netherlands

F197217-REP-ENV-001 02 | October 11, 2022

Final

Total Energies

Document Control

Document Information

Project Title	Aramis Pipeline Route – Geophysical and Geotechnical Site Investigation Netherlands
Document Title	Environmental Desk Top Study
Fugro Project No.	220677
Fugro Document No.	F197217-REP-ENV-001
Issue Number	02
Issue Status	Final
Fugro Legal Entity	Fugro GB Marine Ltd.
Issuing Office Address	Victory House, Trafalgar Wharf, Hamilton Road. Portchester, Hants, UK. PO6 4PX

Client Information

Client	Total Energies
Client Address	P.O. Box 93280, 2509 AG Den Haag, The Netherlands
Client Contact	[redacted]

Document History

Issue	Date	Status	Comments on Content	Prepared By	Checked By	Approved By
01	20 Sept 2022	Complete	Awaiting client comments	PE/TS/NK	JV	JV
02	07 Oct 2022	Final		PE/TS/NK		JF

Project Team

Initials	Name	Role
[redacted]	[redacted]	Project Director
[redacted]	[redacted]	Project Manager
[redacted]	[redacted]	Principal Consultant
[redacted]	[redacted]	Senior Consultant
[redacted]	[redacted]	Consultant
[redacted]	[redacted]	Consultant
[redacted]	[redacted]	Reporting & Deliverables Manager

Executive Summary

Total Energies plans to construct a new pipeline on the Dutch Continental Shelf between Maasvlakte and offshore oil and gas offshore blocks L4/K6 as part of the carbon capture and storage (CCS) Aramis project. To assess the potential environmental and social impacts of the plans, a detailed Environmental Baseline Survey (EBS) is required including a characterization of the environmental conditions and any sensitive receptors.

This document acts as a precursor to the EBS. It presents the results of a desk top study (DTS) of environmental information for the area of the proposals and wider region and is intended to be used to orientate the EBS appropriately. It collates environmental and human use information for the wider region surrounding the proposed EBS and describes the distributions of valued features in relation to the pipeline route. Recommendations for optimising the EBS are provided based on the information collated.

The Dutch Continental Shelf is subject to intensive development and human use including oil and gas, aggregate extraction, offshore renewables, shipping, commercial fishing, submarine cables and pipelines and military uses. Overlapping these activities are areas of high ecological value which support important populations of seabirds, marine mammals, fish and invertebrates. Where sufficient data exist, these areas are designated for protection under international and national statutes.

Given the level of activity and presence of valued ecological features, several recommendations for the conduct of the forthcoming EBS are proposed including;

1. Use of geophysical data to assist final EBS sample positioning;
2. Use of a sea camera to confirm the absence of potential seabed obstructions or sensitive seabed features prior to grab / core sampling particularly in nearshore areas affected by channel dredging and dredge spoil disposal at the Port of Rotterdam;
3. Advice on permit requirements for the exemption of EBS activities within the Voordelta Natura 2000 protected area should sought from the Netherlands Enterprise Agency (Rijksdient voor Ondernermend) (RVO);
4. A standard protocol for recording and handling any chance finds of cultural artefacts of value should be adopted.
5. Where data allows, the mapping of sand eel habitat should be undertaken as part of the EBS reporting;
6. Environmental DNA (eDNA) samples should include analysis for protected fish species including river lamprey, sea lamprey, allis shad and twaite shad as well as sand eels and marine mammals.
7. Reporting of any sightings of marine mammals and seabirds; and;
8. Compliance with the requirements of Convention on Marine Pollution (MARPOL) 73/78 as well as guidelines for hull fouling and ballast water management to minimise the risk of introduction and spreading of marine invasive species.

Contents

Figures in the Main Text

Tables in the Main Text

Abbreviations

AEWA	Agreement on the Conservation of African Eurasian Waterbirds
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North-east Atlantic, Irish and North Seas
BZK	Binnenlandse Zaken en Koninkrijksrelaties
CBD	Convention on Biological Diversity
CCS	Carbon capture and storage
CEMP	Coordinated Environmental Monitoring Programme
CMS	Convention on Migratory Species
CR	Client Representative
CVO	Coöperatieve Visserij Organisatie
DCS	Dutch Continental Shelf
DLO	Dienst Landbouwkundig Onderzoek
DTS	Desktop study
EBN	Energie Beheer Nederland
EBS	Environmental baseline survey
EEZ	Exclusive Economic Zone
ESAS	European Seabirds at Sea
EU	European Union
EZK	Rijksoverheid Ministerie van Economische Zaken en Klimaat
GON	Government of the Netherlands
IBA	Important bird areas
ICES	International Council for the Exploration of the Sea
ICONA	Interdepartmental Co-ordinating Committee for North Sea Affairs
IMO	International Maritime Organisation
INIPM	National Institute for Fisheries and Marine Research
IUCN	International Union for Conservation of Nature's Red List of Threatened Species
MEPC	Marine Environment Protection Committee
MBES	Multi-beam echo sounder
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NCC	Norwegian Coastal Current
NDFF	Nationale Databank Flora en Fauna
NEN	National Ecological Network
NIOO	Nederlands Instituut voor Ecologie

NIOZ	Nederlands Instituut voor Zeeonderzoek
OSCP	Oil Spill Contingency Plan
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polyaromatic hydrocarbons
PFA	Pelagic Freezer-trawler Association
RIVO	Netherlands Institute for Fisheries Research
RVO	Rijksdient voor Ondernermend
SAC	Special Areas of Conservation
SCI	Special Conservation Interest
SCP	Netherlands Institute for Social Research
SNS	Southern North Sea
SPA	Special Protection Areas
THC	Total hydrocarbons
TNO	Nederlandse Organisatie voor toegepastnatuurwetenschappelijk Onderzoek

1. Introduction

1.1 Project Background

Total Energies plans to build a new pipeline from Maasvlakte (man-made westward extension of the Europort port and industrial facility within the Port of Rotterdam) to offshore blocks L4/K6 as part of the carbon capture and storage (CCS) Aramis project. Currently, two pipeline route options are being considered including the WEST-A (293 km) and the WEST-CENTRAL (339 km). Figure 1.1 presents the two proposed pipeline routes.

In concert with the geotechnical and geophysical survey campaigns that are needed to collect geological data to inform the pipeline plans, an Environmental Baseline Survey (EBS) is also required to characterise the environmental conditions along the proposed routes and to inform an Environmental and Social Impact Assessment (ESIA) relating to the construction and operation of the CCS proposals.

This document presents the findings of a desk top study (DTS) of environmental information within and around the CCS proposals prior to the conduct of the EBS. The study is intended to inform and optimise the EBS, to ensure sufficient coverage of the characterising environmental conditions and that any potential ecologically sensitive and/or interest features are considered. Recommendations on the conduct and design of the EBS are given (see Chapter 9).

At present, the EBS is envisaged to comprise the following elements;

<u>Along the pipeline route:</u>

- sediment sampling (box core) and seabed video station every 10 km
- 1 water sampling station every 50 km, located about 3 km downstream,
- 1 plankton sampling station every 100 km located about 3 km downstream.

<u>On the nearshore area close to landfall (0 to 5 km from shore):</u>

- a sediment sampling and seabed video plan of about 6 stations is to follow a grid pattern,
- 2 water sampling stations to be positioned in the most relevant location.

Triplicate seabed sediment samples are proposed to be collected with the use of a 0.1 m^2 box corer or grab sampler at each sampling station and analysed for macrofaunal and microbiological content, particle size distribution and sediment chemistry.

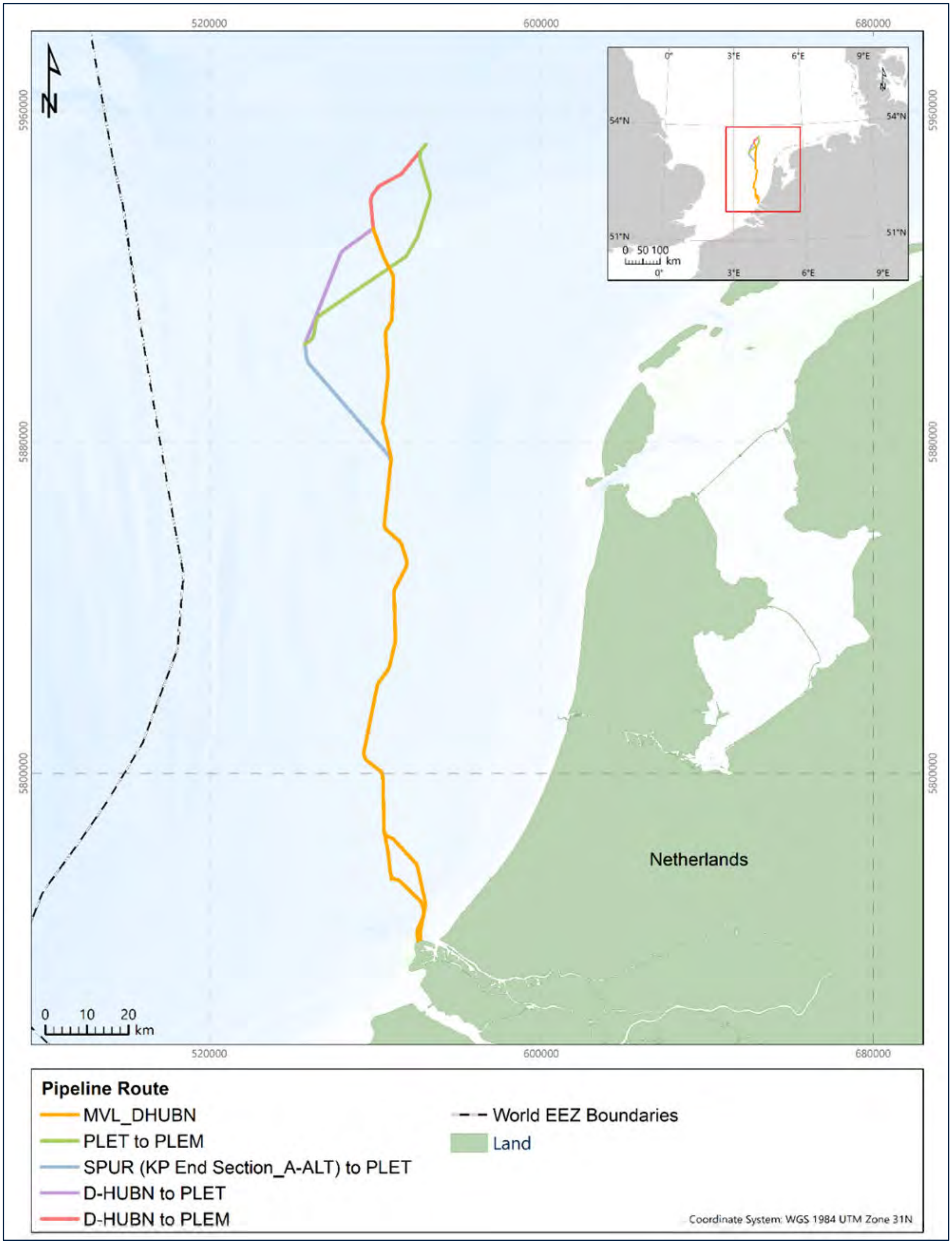


Figure 1.1: Overview of the proposed West-A and West Central routing options (source: Total Energies, 2022)

Water samples are proposed to be collected using a 5 L water sampler (Niskin® type) at near sea surface and near bottom and analysed for photosynthesis pigments, plankton content and chemistry parameters. Samples for environmental DNA (eDNA) are also proposed. Water profiles are also planned to be collected for depth, turbidity, temperature, dissolved oxygen, salinity, pH, and Redox potential using a multi-parameter probe.

Seabed video will be undertaken to collect contextual habitat information for each core / grab sampling station as well as information on larger, more mobile epibenthos (fish, crabs, shrimps) not normally sampled by corer or grab techniques, and to ground-truth any possible interest features identified from any prior acoustic survey.

1.2 DTS Study Aims

The aim of this DTS is to undertake a review of available documents and information including historic studies, mapping outputs, scientific literature, and on-line resources to characterise the environment within the study area, and more widely across the region to provide relevant context. The purpose of the DTS is to inform the forthcoming EBS design and to ensure that the sampling plan provides sufficient coverage of the habitat and seabed features likely to be encountered; and that ecologically sensitive areas, or features, are appropriately considered and mitigated accordingly.

1.3 Extents of the Study Area

The study area for this DTS encompasses the length of the proposed pipeline route between its offshore extents located within the central northern part of the Dutch Continental Shelf to its landfall site at Maasvlakte in South Holland (Zuid Holland) province at the entrance to the channel for the Port of Rotterdam. It also covers adjacent sea areas which may be affected by sediment disturbances during the installation of the pipeline as well as the wider region of the southern North Sea which supports a variety of marine mammals, fish, and bird species for which coastal and offshore sites on the Dutch Continental Shelf have been designated for nature protection under international statutes.

2. Conservation Designations

2.1 Legislative Context

The Netherlands supports a diverse range of marine and coastal habitats and species with many sites being recognised as ecologically important. It is a Contracting Party to a large number of global and regional treaties under which marine areas can be designated for the protection of natural assets within its maritime zone (Dotinga & Trouwborst., 2009) as follows;

Global treaties

- Convention on Biological Diversity (CBD),
- Ramsar Convention on Wetlands,
- World Heritage Convention,
- Bonn Convention on Migratory Species (CMS).

Regional treaties

- Convention on Migratory Species (CMS) Agreement on the Conservation of Seals in the Wadden Sea (WSSA),
- CMS Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS),
- CMS Agreement on the Conservation of African Eurasian Waterbirds (AEWA),
- Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention)
- Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention).

2.1.1 European Law

As a member of the European Union, the Netherlands is also obliged to implement the requirements of the EU Birds Directive and EU Habitats Directive and which include the establishment of a network of protected sites (collectively termed Natura 2000 sites). Natura 2000 sites comprise SPAs which are established under the Birds Directive for birds listed in Annex I and migratory birds and Special Areas of Conservation (SACs) which are established under the Habitats Directive for the achievement or maintenance of favourable conservation status of habitats and species listed in Annexes I and II respectively. Prior to formal designation by the member State, SACs are termed Sites of Community Importance (SCI) and recognise the site’s function in restoring or supporting favourable conservation status of a feature(s).

2.1.2 National Law

Protected areas in the Netherlands are designated under the Nature Conservation Act. Areas that can be protected under this Act are Natura 2000 areas divided in Habitats and Birds Directive areas, protected natural monuments and wetlands (van Bets, 2010). Currently, the North Sea coast, Voordelta and the 'Vlakte van de Raan' (Raan Flats), Klaverbank, Brown Bank Dogger Bank and Frisian Front (as well as all of the various sand dune sites of the Holland coast) are designated North Sea Natura 2000 sites by the Dutch government and as such are protected under the Nature Conservancy Act. Under the Act, the killing, disturbing and wounding of protected species is prohibited, unless an exemption has been obtained (or a general exemption applies). Further to these sites, several SPAs have been established for the extensive waterways at the Wadden Sea and Delta regions of the Netherlands.

Certain activities in protected (Natura 2000) areas may require permits from the relevant provincial or municipal administration (within 1 km of the coast) and central government (Netherlands Enterprise Agency) (Rijksdient voor Ondernermend) (RVO) beyond 1 km from the coast.

As well as the Natura 2000 network, the Dutch government has also implemented a National Ecological Network (NEN) comprising existing nature conservation areas, national parks, areas where new wildlife habitats are being created, agricultural land under nature-friendly management and certain areas of water: lakes, rivers as well as the North Sea coastal zone and the Wadden Sea. The entire Dutch part of the North Sea coast is part of the NEN.

2.1.3 International and Regional Commitments

As a Contracting Party to OSPAR, the Netherlands is required to designate sites (Marine Protected Areas) to the OSPAR Network of Marine Protected Areas (MPA) following established criteria. To date, four MPAs have been nominated including Klaver Bank, Dogger Bank, Voordelta and Noorzeekustzone.

The Netherlands is also a signatory to the Ramsar Convention on Wetlands of International Importance (1971) and is thus committed to agreeing to add suitable wetland areas to the list if international Wetlands based on enumerated criteria and manage these appropriately. Two main Ramsar wetland sites have been established in the Netherlands at Voordelta and Noorzeekustzone. These are broad ranging sites, encompassing a number of small wetland areas including Important Bird Areas (IBAs) and broadly aligning with the Natura 2000 boundaries for these locations. IBAs are areas which fulfil certain internationally agreed criteria as being globally important for birds.

2.1.4 Designated Sites

Table 2.1 summaries the nature conservation sites in the Dutch sector of the North Sea comprising the current Natura 2000, Ramsar and MPA networks in the vicinity of the forthcoming EBS. The locations of these North Sea sites in relation to the proposed pipeline routes is presented in Figure 2.1.

The proposed pipeline route and EBS do not impinge on any protected nature conservation site with the exception of the Voordelta Natura 2000 and Ramsar site at the southernmost extent at the landfall site. Interest features of this site includes habitats such as sandbanks that are covered by seawater all of the time, mudflats and saltmarsh and species such as anadromous fish, seals and seabirds. Advice from RVO should be sought as to any requirement for a permit for an exemption from the Nature Conservation Act for the intended EBS activities in this area.

The effects of the EBS on the seabed of the Natura 2000 site will be temporary and highly localised, limited to the bite area of the box core or grab sampler (i.e., 0.1m^2). Spatial effects will therefore be very small within the context of the total area of the designated site (835 km^2). The effects will also occur within an area already subject to considerable vessel traffic and seabed disturbances at the entrance to the Port of Rotterdam and at Maasvlakte 2 where active channel dredging and dredge spoil disposal is occurring. Against the backdrop of continual vessel movement and dredge activity at this location, the effects of temporary and highly localized EBS sampling is anticipated to be insignificant.

Marine mammals, fish and seabirds for which Natura 2000 sites are designated in the Netherlands are likely to range widely across the region beyond site boundaries as part of natural migration movements and for feeding and foraging. Recordings of the presence of seabirds and marine mammals made during the EBS will further the understanding of the temporal and spatial distribution of protected species in the Netherlands sector of the North Sea.

2.1.5 Nature Conservation Act 2017

The Nature Conservation Act (*Wet natuurbescherming, Wnb*) (2017) is the primary legislation for the protection of animals and habitats in the Netherlands and for the transcribing of the requirements of the EU Habitats and Birds Directives into national law. The Act came into force on 1 January 2017 and on so doing, replaced three pre-existing nature laws namely, the Nature Conservancy Act 1998, the Flora and Fauna Act and the Forestry Act. The provincial authorities in the Netherlands set rules and regulations on nature protection in their own provinces out to 1 km offshore including the issue of environmental permits and exemptions. Beyond this zone, the Netherlands Enterprise Agency (Rijksdient voor Ondernermend) (RVO) is responsible for decision making and permitting in marine protected areas. Central government remains responsible for the policy on major water bodies and international nature policy. The Ministry responsible for administering Nature Conservation legislation is the Ministry for Agriculture, Nature and Food Quality.

To rationalise existing environmental legislation and permitting, the Dutch government is introducing the Environment & Planning Act (Omgevingswet). The Act aims to simplify the regulations for spatial planning and to provide a single point of contact for permitting issues. Certain benefits relating to site data acquisition and longevity of data underpinning applications will be brought about through the introduction of the Act. The Act is due to come into force on 1 January 2023.

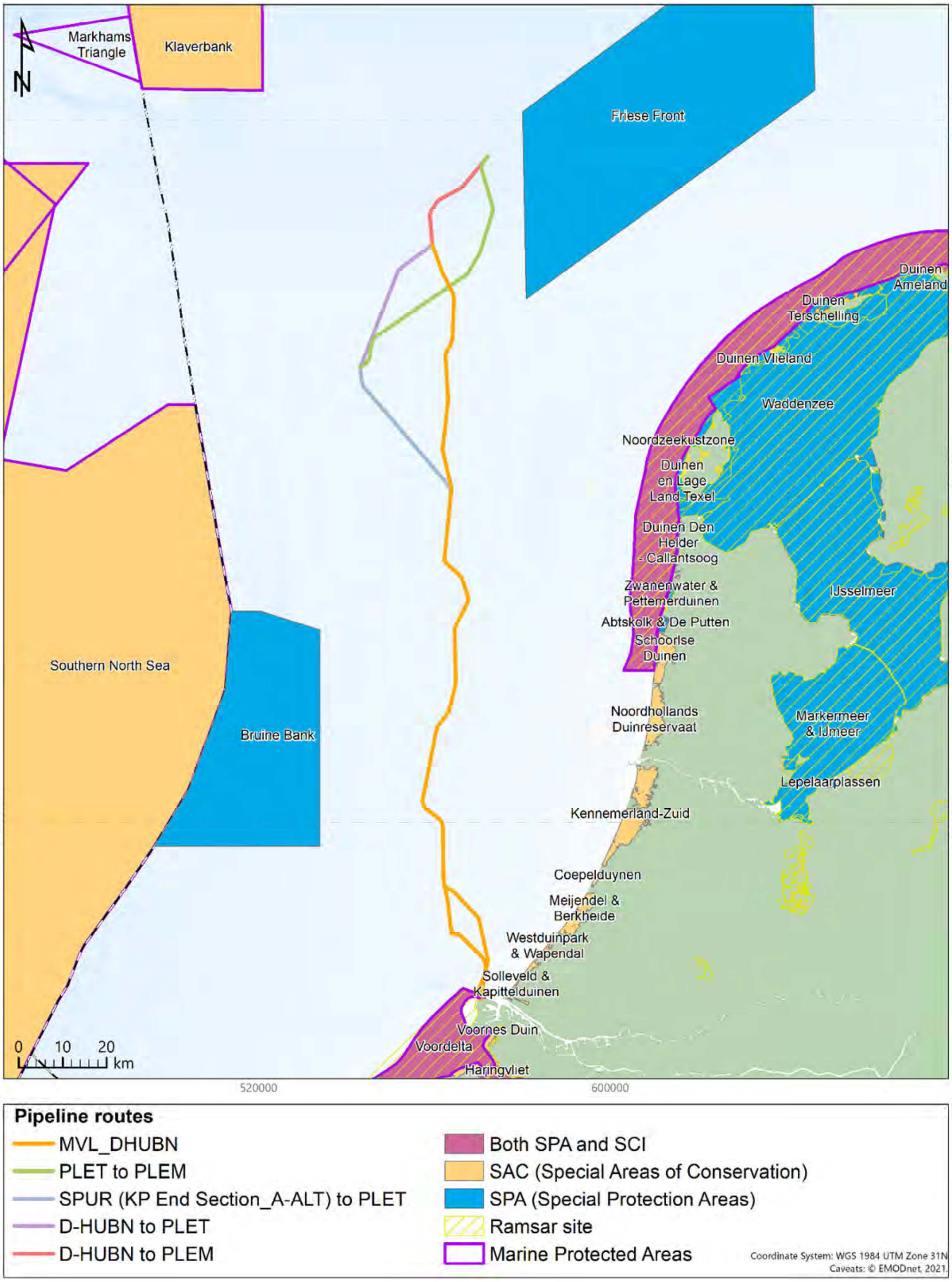


Figure 2.1: Location of nature conservation sites

Table 2.1: Conservation Areas in the vicinity of the area of interest

<table>
<tr><th>Site Name</th><th>Designation</th><th>Protected Species</th><th>Protected Habitats</th><th>Distance from proposed pipeline at closest point [km]†</th></tr>
<tr><td>Frisian Front
(Friese Front)</td><td>SPA (Birds Directive)</td><td>Seabirds
▪ Guillemot
▪ Great skua
▪ Great black-backed gull
▪ Lesser black-backed gull</td><td></td><td>7 from K14-L4A</td></tr>
<tr><td>Clover Bank
(Klaverbank)</td><td>SAC (Habitats Directive)
MPA (OSPAR)</td><td>Marine mammals
▪ Grey seal
▪ Harbor seal
▪ Harbour porpoise</td><td>▪ Reefs</td><td>46 from Section C</td></tr>
<tr><td>Voordelta</td><td>SAC (Habitats Directive)
SPA (Birds Directive)
RAMSAR (Ramsar Convention)
MPA (OSPAR)</td><td>Seabirds
▪ 30 species of wildfowl, waders and seabirds,
Fish
▪ allis shad
▪ twaite shad
▪ river lamprey
▪ sea lamprey
Marine mammals
▪ Grey seal
▪ Common seal</td><td rowspan="2">▪ Sandbanks which are slightly covered by sea water all the time
▪ Mudflats and sandflats not covered by seawater at low tide
▪ Salicornia and other annuals colonizing mud and sand
▪ Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
▪ Embryonic shifting dunes
▪ Humid dune slacks</td><td>Overlaps at southern-most extent of pipeline route</td></tr>
<tr><td>Noordzeekustzone</td><td>SAC (Habitats Directive)
SPA (Birds Directive)
RAMSAR (Ramsar Convention)
MPA (OSPAR)</td><td>Seabirds
▪ 20 species of wildfowl, waders and seabirds,
Fish
▪ allis shad,
▪ twaite shad
▪ river lamprey
▪ sea lamprey
Marine mammals
▪ Grey seal,
▪ Common seal
▪ Harbour porpoise</td><td>36 from A-Alt</td></tr>
</table>

Site Name	Designation	Protected Species	Protected Habitats	Distance from proposed pipeline at closest point [km]†
Multiple "sand dune" sites throughout the Holland coast including: Meijendel & Berkheide, Kennemerland-Zuid, Noordhollands Duinreservaat , Solleveld & Kapittelduinen, Westduinpark & Wapendal Coepelduynen, Kennemerland-Zuid and Schoorlse Duinen (coastal)	SAC (Habitats Directive)		Sand dune habitats including ▪ Embryonic shifting dunes ▪ Fixed coastal dunes ▪ Dunes with *Salix repens* ssp argentea (*Salicion arenariae*) ▪ Wooded dunes of the Atlantic, Continental and Boreal region ▪ Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* ▪ Humid dune slacks ▪ Water courses of plain to montane levels	Between 9 and 45
Brown Bank (Bruine Bank)	SPA (Birds Directive)	**Seabirds** ▪ Little gull ▪ Gannet ▪ Great skua ▪ Great black-backed gull ▪ Common guillemot ▪ Razorbill		23 from A-Alt
Vlakte van der Raan (not shown in Figure 2.1)	SAC Habitats Directive MPA (OSPAR)	**Fish** ▪ allis shad, ▪ twaite shad ▪ river lamprey ▪ sea lamprey **Marine mammals** ▪ Grey seal, ▪ Common seal ▪ Harbour porpoise	▪ Sandbanks which are slightly covered by sea water all the time.	70
Southern North Sea (UK)	SAC (Habitats Directive)	**Marine mammals** ▪ Harbour Porpoise		38 from Section F
Notes: SPA = Special Protection Area MPA = Marine Protected Area SAC = Special Area of Conservation				

3. Regional Environmental Context

The EBS will be conducted within the Dutch Continental Shelf of the southern North Sea which covers an area of around 57,000 km^2 and is bounded by the limits of its Exclusive Economic Zone (EEZ). The Dutch EEZ was established in 2000 and confers certain rights to the Netherlands including rights for the purposes of exploration, prospecting, exploitation, and conservation of the seabed's natural resources. In addition to the EEZ, the Netherlands exercises exclusive fishing rights within its territorial waters which extend 12 nautical miles from coastal baselines.

The total length of the Dutch coast is 390 km and comprises a dynamic and soft coastline with sandy beaches interspersed with dykes. The coast can be divided into three sections based on the different prevailing physical conditions. This includes a wave dominated central coast together with two tide influenced areas including a delta area to the south and the Wadden Sea to the north comprising a series of sandy islands bordering the intertidal Wadden Sea. Approximately 290 km of the coast consists of dunes and 60 km of that is protected by structures such as dykes and dams (Sistermans & Nieuwenhuis, undated). All three coastal sections support valuable coastal and shallow marine habitats and species, and which are protected under international statute (see Chapter 2: Conservation Designations).

Offshore, the seabed comprises shallow water clean, mobile sand sediments together with silty sand in deeper water areas. Large sandbanks (relicts of previous glacial events) including Dogger Bank (Doggersbank) and Brown Bank (Bruin Bank) are found and are important for nature conservation (see Chapter 5: Conservation Designations). Sand waves, mega-ripples and ripples occur frequently within coastal and nearshore and attest to the mobility of the seabed sediments here. Further offshore, tidal currents are reduced resulting in a more stable and more muddy seabed where finer grained sediments can settle and accumulate. Sand waves and ripples are generally absent on the seabed here.

The marine waters overlying the sediments of the Dutch Continental Shelf comprise two principal water masses. These include waters inflowing from the English Channel from the south and Atlantic water flowing around the UK and southwards through the North Sea. Water outflows from the North Sea via the Norwegian coast.

Where water masses meet, fronts may emerge. These fronts may often be associated with particularly high productivity due to the action of up-welling forces which can increase nutrient availability for plankton growth and/or concentrate plankton along the length of the front edge. Within the Dutch sector, the Frisian Front (Freise Front) emerges at around the 30 m contour and marks the location at which mixed English Chanel water and stratified Atlantic Ocean / central North Sea waters meet. In general, fronts in the North Sea are more distinct in summer compared to winter.

In summer, the waters offshore of the Dutch coast may become thermally stratified due to solar heating of the upper layers of the sea compared to the bottom layers, The development of a thermocline marks the division of upper warm water from bottom colder water and can reduce exchanges of oxygen and nutrients between upper and bottom water layers resulting in depleted conditions near the seabed. A thermocline develops at around 10 m depth to the north of the Frisian Front in summer. In winter, the waters are vertically mixed by the stronger wind conditions which break down stratified layers of seawater and the thermocline disappears.

Numerous rivers flow into the southern North Sea, including the Rhine, Scheldt, Meuse, Eems, Wesser, Elbe, Humber and Thames. These rivers carry quantities of silt as well as nutrients and other chemicals which subsequently disperse within the marine receiving waters influencing water and sediment quality within coastal waters and for distances of up to several kilometers offshore. Due to the presence of residual tidal currents in the North Sea, much of the dispersal of river discharges is alongshore. Figure 3.1 illustrates the extents of riverine influences in the southern North Sea and shows that the coastal waters within the Netherlands are influenced predominately by discharges from the Meuse / Rhine.

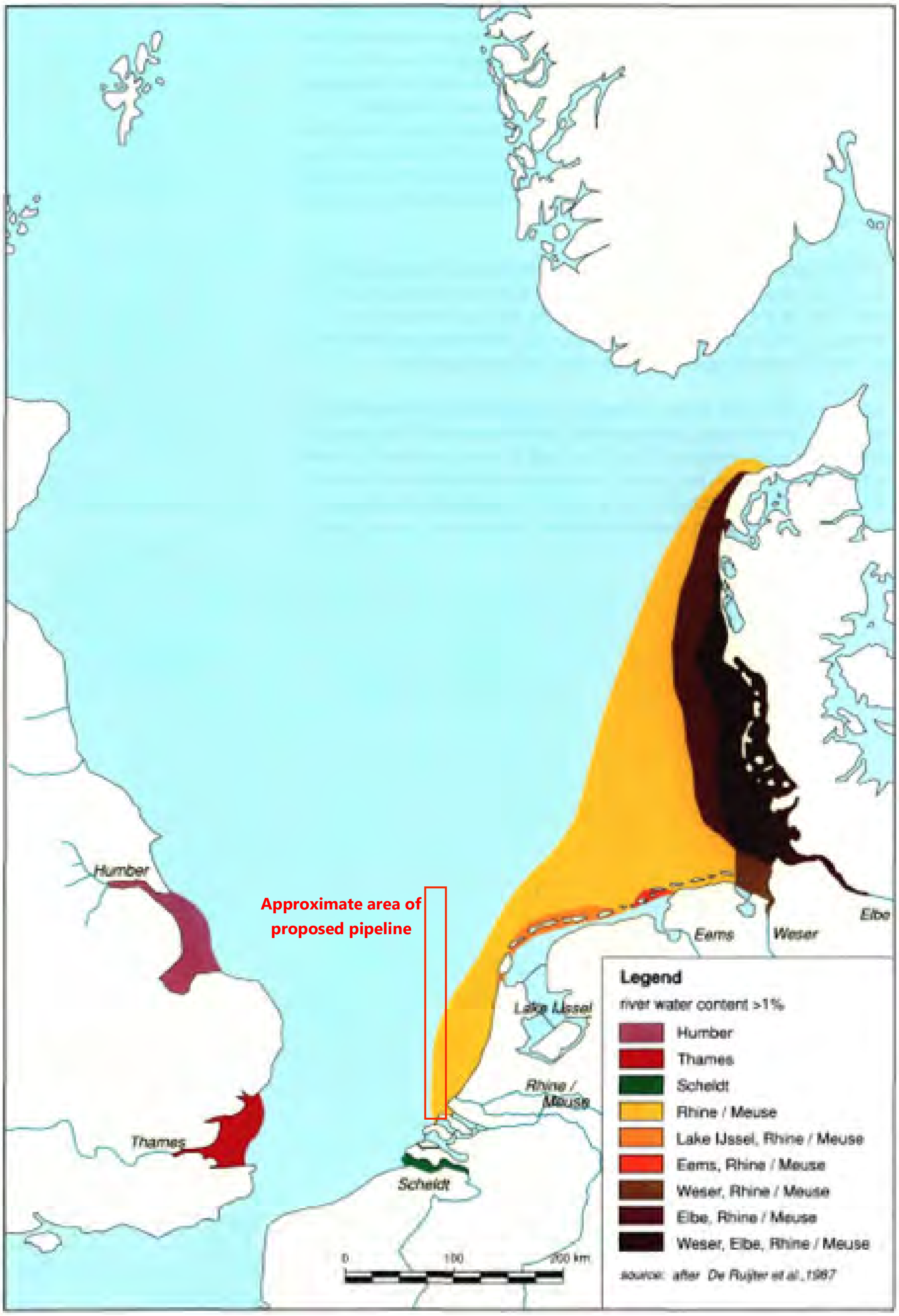


Figure 3.1: Extents of river water dispersal in the North Sea (source: ICONA, 1992)

The variable seabed depths, tidal conditions, river inputs and characteristics of the overlaying water masses have a strong influence on the physical and biological condition of the seabed. Five distinct sediment habitat zones on the Dutch Continental Shelf are recognised corresponding to different depth and hydrodynamic conditions as summarised in Figure 3.2 (see also Chapter 5: Biological Environment).

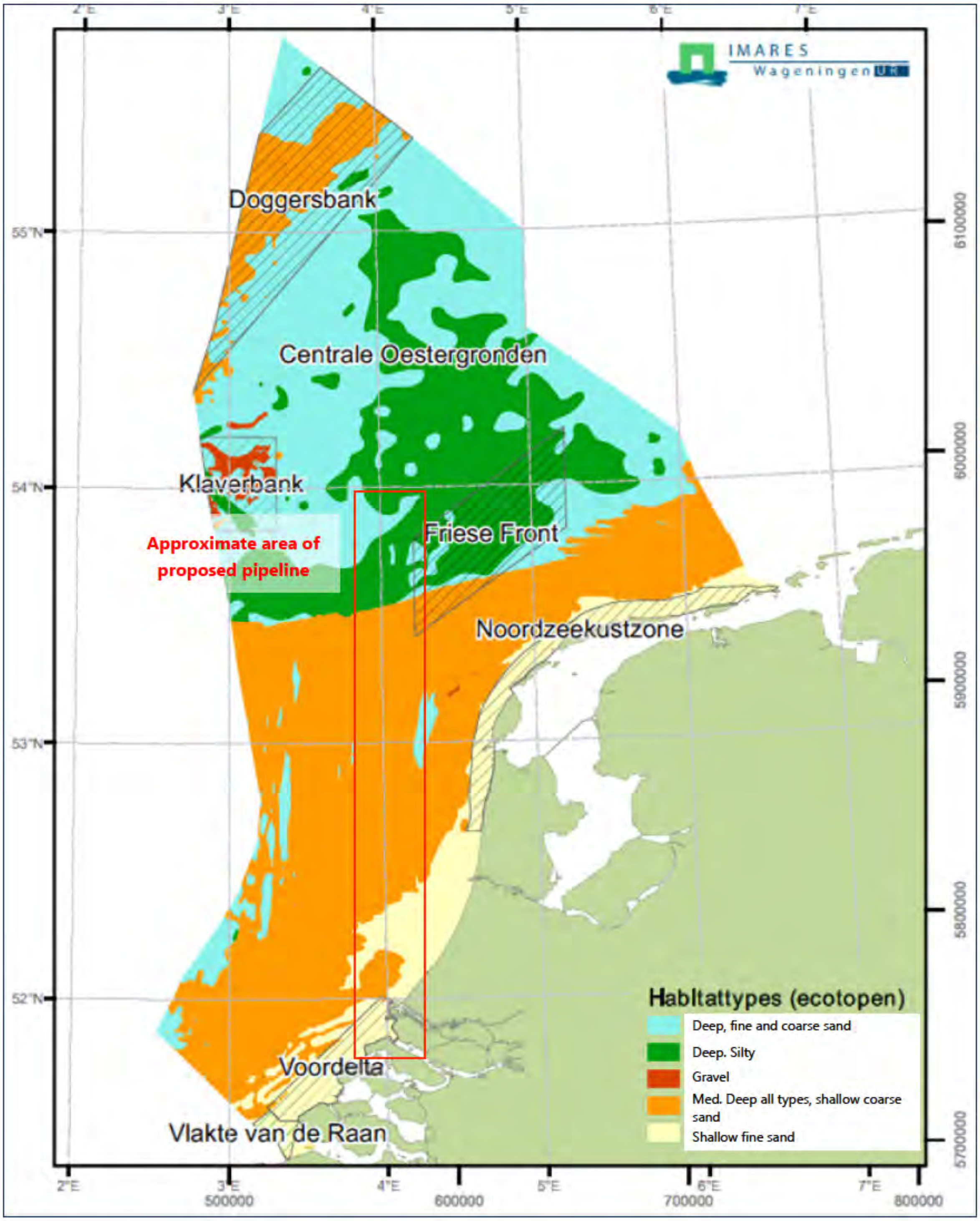


Figure 3.2 : Principal seabed habitat types (Lindeboom *et al.*, 2008)

Shallow mobile sediments under the influence of riverine inputs exist along the shore while coastal sands exist within the zone beyond that. Further offshore and in the region of the Oyster Ground (Centrale Oestergronden) the seabed is deeper and dominated by mud and silty sand substrates. Coarser substrates are rare on the Dutch Continental Shelf by may be found as gravel and boulders at the Clover Bank (Klaverbank).

The Dutch part of the North Sea is contiguous with the wider North Sea and is exposed to intense human activity and development such as fishing, ports and shipping. In addition, there seabed activities such as oil and gas exploration, marine sand extraction and offshore wind farm development. Port expansion has occurred at the Port of Rotterdam (Maasvlakte 2) involving considerable land reclamation. Maintenance dredging and dredge spoil disposal occurs within and adjacent to the channel of the Port of Rotterdam. In addition, the area forms part of a valuable marine ecosystem (Dotinga & Trouwborst, 2009). Knowledge of the morphology of the seafloor and the sediment and seawater properties is important, both to understand the ecosystem, as well as for developing infrastructural activities (Stolk & Laben, 2008) in a sustainable manner.

To assist in efforts for sustainable development, the Netherlands has completed a comprehensive review of the broadscale physico-chemical and biological characteristics across the south North Sea and which has culminated in the North Sea Atlas for Netherlands Policy and Management (ICONA, 1992). A later, digital version of the atlas was commissioned by the Interdepartmental North Sea Directors Consultation (IDOM) (IDOM, 2004). The Atlas forms part of a series of documents produced on behalf of the Interdepartmental Co-ordinating Committee for North Sea Affairs (ICONA) and IDOM for the purposes of exploring spatial policy in the North Sea. This work is followed up by the development of an ecological atlas of the North Sea (*Ecologische atlas Noordzee ten behoeve van gebiedsbescherming*) (Lindeboom *et al.*, 2008) and thematic maps of marine biodiversity (Leopold *et al.*, 2011) highlighting biodiversity hotspots in the Dutch North Sea. A Spatial Planning Policy document has now been produced with the aim to "*enhance the economic importance of the North Sea and maintain and develop the international ecological and landscape features by developing and harmonising sustainable spatial-economic activities in the North Sea, taking into account the ecological and landscape features of the North Sea*." This Plan is accompanied with an Integrated Management Plan for the North Sea (2015) and which sets out how the Spatial Planning Policy and other policies will be implemented. Further to this, the Netherlands have issued a strategy for achieving and/or maintaining good environmental status in their marine waters as required under the European Marine Strategy Framework Directive (MSFD). The Netherlands is implementing the requirements of the MSFD to '*protect and preserve the marine environment, promote the sustainable use of the marine environment and conserve marine ecosystems*'. Further commitments of the Netherlands in terms of marine nature conservation are summarised in Chapter 2 : Conservation Designations.

The National Water Programme and accompanying North Sea Programme 2022-2027 elaborates on the National Strategy for Spatial Planning and lays out the water policy and management of national waters and waterways with emphasis on river basin plans, flood risk management and climate adaptation as well as achieving good environmental status. In respect to anticipated CO_2 storage in the North Sea, the North Sea programme recognises that "*good spatial integration, taking into account all other uses in the North Sea and the ecological values, is essential*'.

Dotinga & Trouwborst (2009) note that notwithstanding the relatively uniform appearance of the North Sea, several areas stand out on account of their *ecological values* including higher biodiversity or other special ecological features. In the Dutch sector of the North Sea, ten such ecologically important areas are recognised as shown in Figure 3.3 and listed in Table 3.1 below.

Table 3.1: Marine areas with special ecological value (source: Dotinga & Trouwborst, 2009)

#	English name	Dutch name	Description
1	Coastal Sea	Kustzee;	Encompasses the entire Dutch coastline. An area of high primary (plankton) productivity and supporting rich communities of fish and shellfish. As well as populations of seabirds and marine mammals.
2	Dogger Bank ;	Doggersbank;	Shallow sandy bank within the central North Sea supporting rich and diverse benthic communities, fish foraging and nursery habitat.
3	Clover Bank ;	Klaverbank;	Distinct area of gravel and boulders supporting calcareous red algae and high diversity of benthic species,
4	Frisian Front ;	Friese Front;	A nutrient rich hydrodynamic front supporting rich fish communities important for feeding for seabirds. The seabed here supports the ocean quahog *Arctica islandica*.
5	Brown Bank ;	Bruine Bank	Supports elevated abundances of seabirds and marine mammals.
6	Central Oyster Grounds	Centrale Oestergronden;	A distinct area of comparatively deeper water and finer sediments located to the north of the Frissian Front and supporting benthic communities and seabirds.
7	Borkumse Stones	Borkumse Stenen;	Present at the border with Germany near the island of Schiermonnikoog and supporting seal haul out sites and special benthic communities.
8	Zeeuwse Banks	Zeeuwse Banken;	Shifting sandbanks located at the Dutch/Belgium border.
9	Gas Seeps ;	Gasfonteinen;	Area contains a concentration of gas seeps although the presence of any associated biogenic communities have not been confirmed.
10	*Arctica* Area	Noordkrompgebie	Between the Oyster Grounds and Dogger Bank, a relatively undisturbed area of seabed with a healthy population of ocean quahog.

Sites 1 to 5 have already been designated as protected areas, under the EU Habitats and Birds Directives by the Dutch government (the Coastal Sea site has been separated into different parts). In addition, sites 1 to 4 are also designated as Marine Protected Areas (MPA) under the OSPAR framework. It is envisaged that as more data becomes available, other sites noted as ecologically valuable can be further evaluated in terms of meeting Directive criteria and designated accordingly.

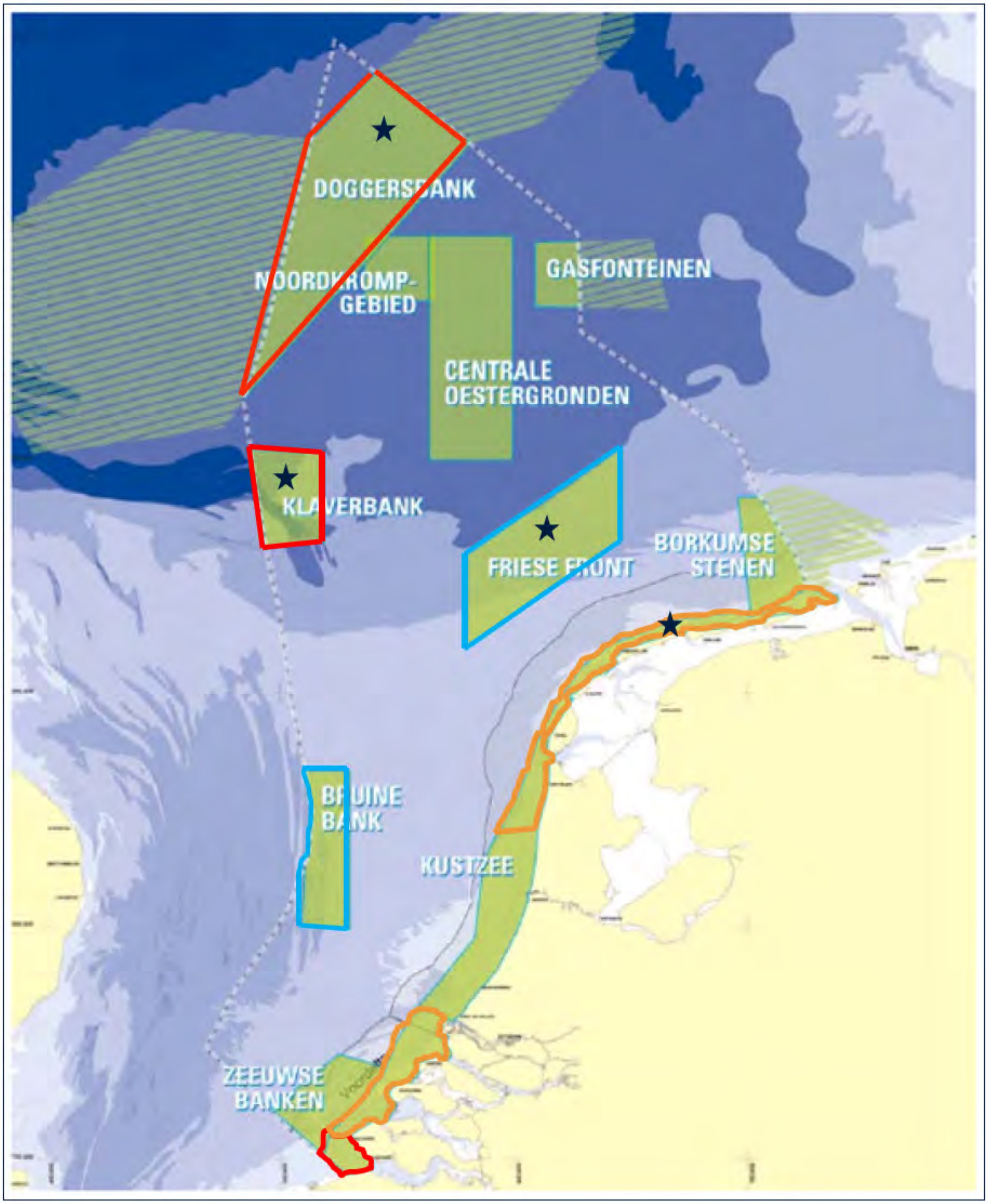


Figure 3.3: Areas with special ecological values (source: Dotinga & Trouwborst, 2009) and designations.

- (red box) = Special Area of Conservation (SAC) (EU Habitats Directive)
- (blue box) = Special Protection Area (SPA) (EU Birds Directive)
- (orange box) = Both SPA and SAC
- ★ = Marine Protected Area (MPA) (OSPAR)

4. Physical and Chemical Environment

4.1 Introduction

This Chapter describes the physico-chemical conditions within and around the proposed EBS including the nature and distribution of surface seabed sediments, waves, tides and currents and chemical composition of marine sediments and waters.

Information on sediment types and distributions presented here is drawn from seabed mapping studies summarised by Laban (2006) and broad-scale grab and geophysical survey campaigns aimed at characterizing the seabed of the Dutch sector in advance of planned offshore wind development (Stolk & Laban, 2002). Site specific geological information (surface sediments) has been acquired from a previous geological desk-top study relating to the Aramis project (Fugro, 2022a). Supplementary information is provided by the scientific literature and web sources as referenced in the text.

Data on metocean aspects have been acquired from Fugro's Metocean Planner tool, which provides instant access to metocean and weather window statistics at any given site, using historical data. Publicly available sources were also used for sediment and seawater quality including the International Council for the Exploration of the Sea (ICES) and information from the Government of the Netherlands website and CEFAS. A study from de Boer *et al.*, 2001 was also utilised to obtain minimum and maximum metal concentrations from stations sampled offshore Netherlands and these were compared against Southern North Sea (SNS) background and OSPAR levels.

4.2 Seabed Features

The Netherlands part of the North Sea is relatively shallow, up to 50 m deep with the deepest parts lying within central-northern areas of the Dutch Continental Shelf and in the vicinity of the central Oyster Grounds (Centrale Oestergronden). The general bathymetry of the Dutch Continental Shelf along the route of the proposed pipeline is show in Figure 4.1.

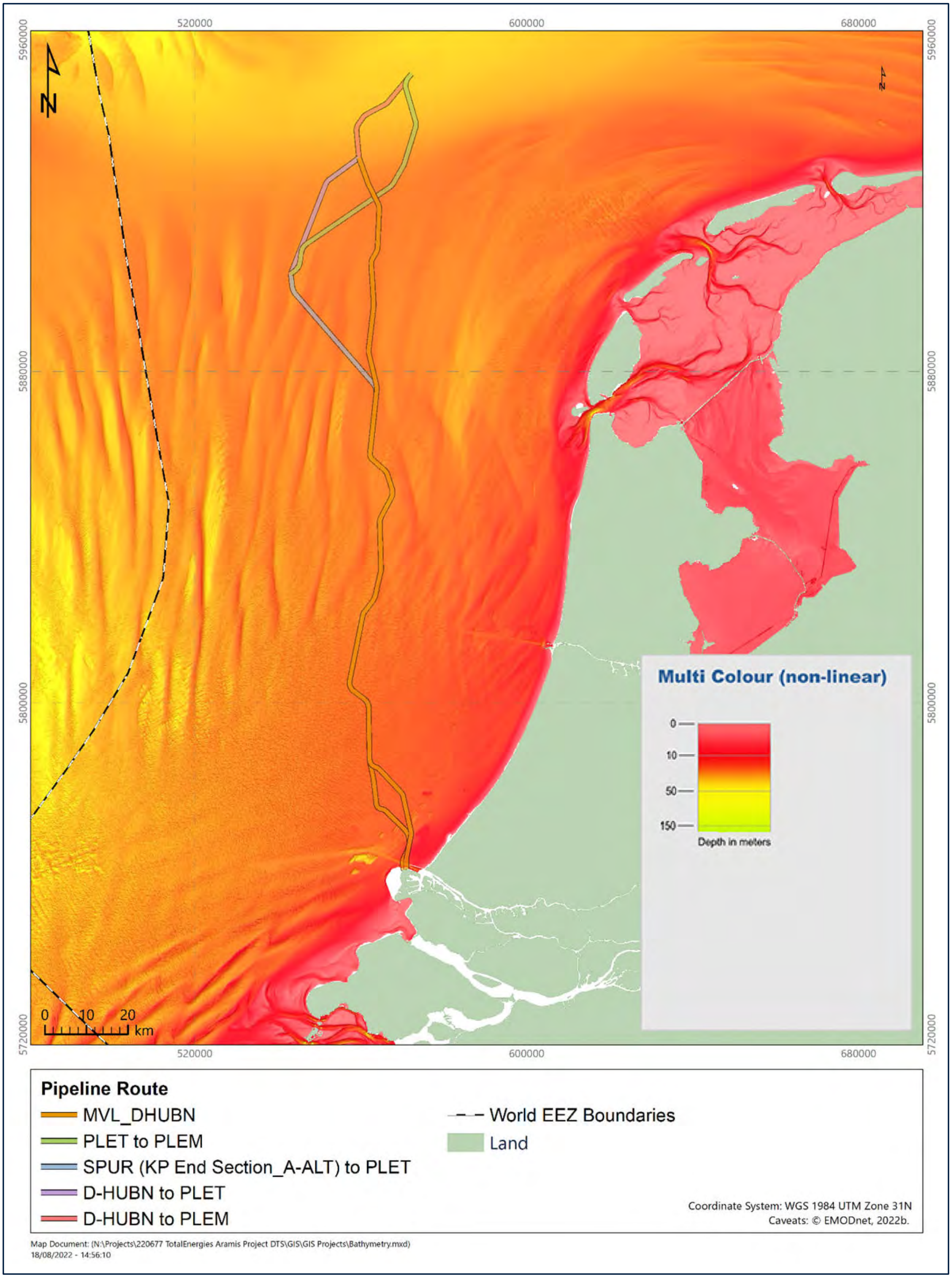


Figure 4.1: General bathymetry of the Dutch Continental Shelf (source: EMODnet, 2022)

The seafloor within the Dutch sector consists mainly of fine to medium grade sand with small areas of gravel in the northernmost parts (Stolk & Laben, 2002). Distinctive seabed features include a number of linear sand bank with crests aligned broadly north – south, such as the Zeeland Ridges and Brown Bank (Bruine Bank). Sandbanks are present as elongated ridges orientated parallel to the main current direction with ridges that are tens of kilometers in length and on average 10 m in height. The sand banks at Brown Bank are up to 20 m high.

Two types of sandbank are noted on the Dutch Continental Shelf including relict features, which have remained following the post glacial sea level rise, and newly formed features which have formed as a consequence of the current hydrodynamic conditions (Fugro, 2022a). Areas of deep troughs between 4 and 6 m in depth occur between the sand waves and which are oriented along comparable north-south axes.

Superimposed onto the sand banks are sand waves which are themselves covered with mega-ripples and ripples on their stoss sides. The height of the sand waves varies between 0.5 and 4.0 m. The morphology of the sand waves suggests a dominant movement of sand to the north and north-north-east.

Overall, Fugro (2022a) concluded that three distinct morphological zones can be discerned across the Dutch sector of the North Sea as follows;

- a coastal zone covered by a complex compound of rhythmic bedforms;
- shallow continental shelf with low-angle topography covered by a complex compound of rhythmic bedforms; and
- a relatively deep, low-energy zone (comparatively low water current speeds) with low-angle topography

Bedforms are absent within the deeper low-energy zone towards the northern most extents of the proposed pipeline. Bedforms are similarly absent at the southernmost extent of the proposed pipeline route with the exception of small areas of sand ripples as recently identified in geophysical data at dredging sites (Fugro, 2022a; 2022b).

Other seabed features of the Dutch Continental Shelf include deep (20 m) valleys, channels and pockmarks. Valleys are incised into the seafloor at offshore locations and are artefacts of glacial meltwater run-off. Additionally, there are relic river channels (paleochannel channels) similarly cut into the seabed and which extend from the land offshore. These features are not immediately expressed at the seabed and are infilled and overlaid with present-day substrates. Nevertheless, these features attest to the pre-glacial environmental conditions and are thus of paleao-archeological interest

Pockmarks have been discovered to the north of the Dutch Continental Shelf (Schroot & Shüttenhelm, 2003). These features are the result of gas escapes from a gas reservoir located approximately 600 m below seabed to the seabed surface (Römer *et al.*, 2017). Pockmarks are expressed at surface as circular depressions between 10 and 300 m together with cemented sandstone. Emissions of gas have recently been measured from these pockmarks. Elsewhere in the North Sea pockmarks constitute Annex I habitat "*submarine structures made by leaking gas*" and are protected through the designation of sites as Special Areas of Conservation (SAC), for example Braemar Pockmarks SAC and Scanner Pockmark SAC in the UK. The area of gas seeps (Gasfonteinin) to the north of the Dutch sector is regarded as an ecologically sensitive area (see Figure 3.3) but is not currently designated as a protected area.

4.3 Sediments

Sediment types along the pipeline route EBS are expected to be dominated by sand with mud and muddy sand in the deeper northern extents (Figure 4.2). In general, the grain size of the surficial sands decrease with increasing distance northwards. In the south, median sand with mean grain sizes between 250 – 500 µm dominate. Further north fine sand (125 – 250 µm) or even very fine sand (63 – 125 µm) occurs.

Sediments found in the shallow water along the coast and to around 15 – 20 m depth are predominantly fine mobile sand. The sediment is exposed to comparatively strong tidal flows up to 1.0 m/s resulting in a mobile substrate and turbid nearshore environment. The overlying water originates from the English Channel but receives freshwater inputs from rivers resulting in variable salinities (between 27 and 34 ‰). Between 20 – 30 m water depth, the substrate comprises mixed fine to coarse sand. Substrates here are continually mobilized by tidal currents and wave action.

In contrast, sediment within deeper central-northern portions of Dutch seafloor (up to 50 m water depth) are muddier. The overlaying water originates from the Atlantic following southwards. Here, tidal current speeds are comparatively reduced, and wave action is unlikely to significantly affect bottom sediments allowing settlement and accumulation of finer mud substrates.

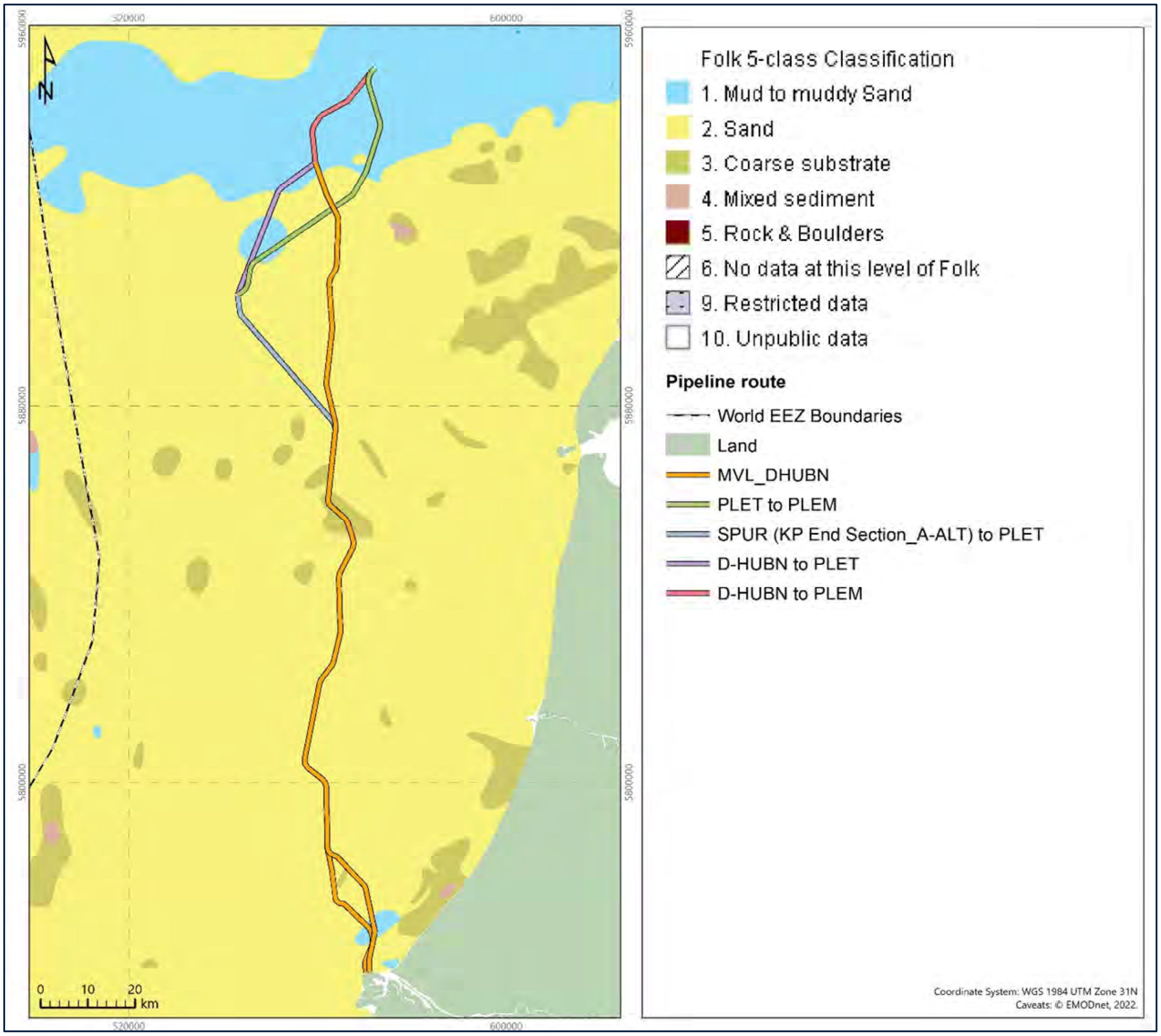


Figure 4.2: Distribution of expected seabed sediment types (source: EMODnet, 2022)

Based on experience, Fugro (2022a) predicted that clayey or silty sand and locally slightly gravelly sediments dominate the seafloor at the southernmost extents of the proposed EBS area outside of the Maamond Kanaal. Within the Kanaal, very soft to soft clay dominates (Fugro, 2022a).

Gravel deposits are relatively uncommon in the Dutch sector but where they do occur, they relate to glacial features such as moraines. The Klaverbank (Clover Bank) is the only location within Dutch boundaries where appreciable quantities of gravel occur although other gravel deposits are known at the Vlieland Rough located to the north-west of Texel Island. Hard substrata as biogenic *Sabellaria spinulosa* reef is also known at Brown Bank (Bruine Bank) (Garcia *et al*., 2019).

4.4 Water Currents

General water current movements within the southern North Sea in summer and winter are shown Figure 4.3.

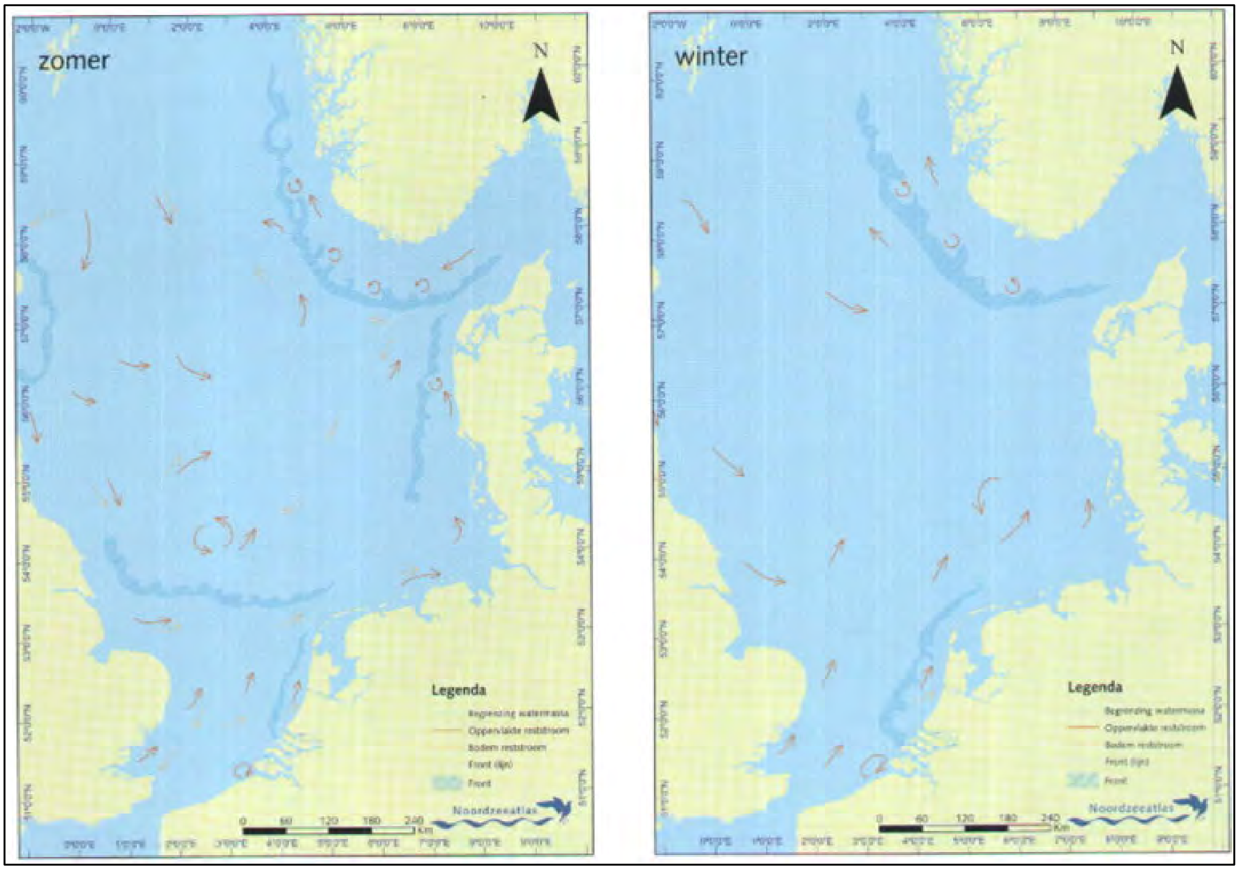


Figure 4.3: Summer and winter water current movements and positions of fronts (source: IDOM, 2004)

Atlantic water enters the North Sea from the south via the English Channel and from the north around the Scottish coast. Water moves generally to the east towards the Skagerrak. Outflowing water leaves the North Sea along the Norwegian coast (ICONA, 1992; IDOM, 2004).

The main pattern of water movement in the North Sea is counter-clockwise. In coastal areas the flow is mixed with fresher water from rivers and estuaries. On average, the annual residual current flow along the Netherlands coast is a few centimeters per second (ICONA, 1992; IDOM, 2004). The flow moves eastward towards the Skagerrak, where it meets brackish water from the Baltic and turns northward. The current then, follows the Norwegian coast westward and becomes the Norwegian Coastal Current (NCC).

4.5 Waves

Significant wave height data for indicative offshore and nearshore locations within the vicinity of the proposals are shown in Figure 4.4 and derive from Fugro's Metocean Planner tool. In general, wave heights offshore average between 0.5 and 1.0 meters and are generally <2.0 m in height for around 80 % of the time. Monthly mean significant wave heights (10 year average) at the offshore location range from 0.9 m to 1.9 m with the highest mean wave heights occurring in December and January and lowest wave heights in June and July.

Wave heights are comparatively reduced at the near shore location and are less than 2.0 m for over 96% of the time. Monthly mean wave heights (10 year average) range between 0.6 m during the period May to August and 1.1 m in December.

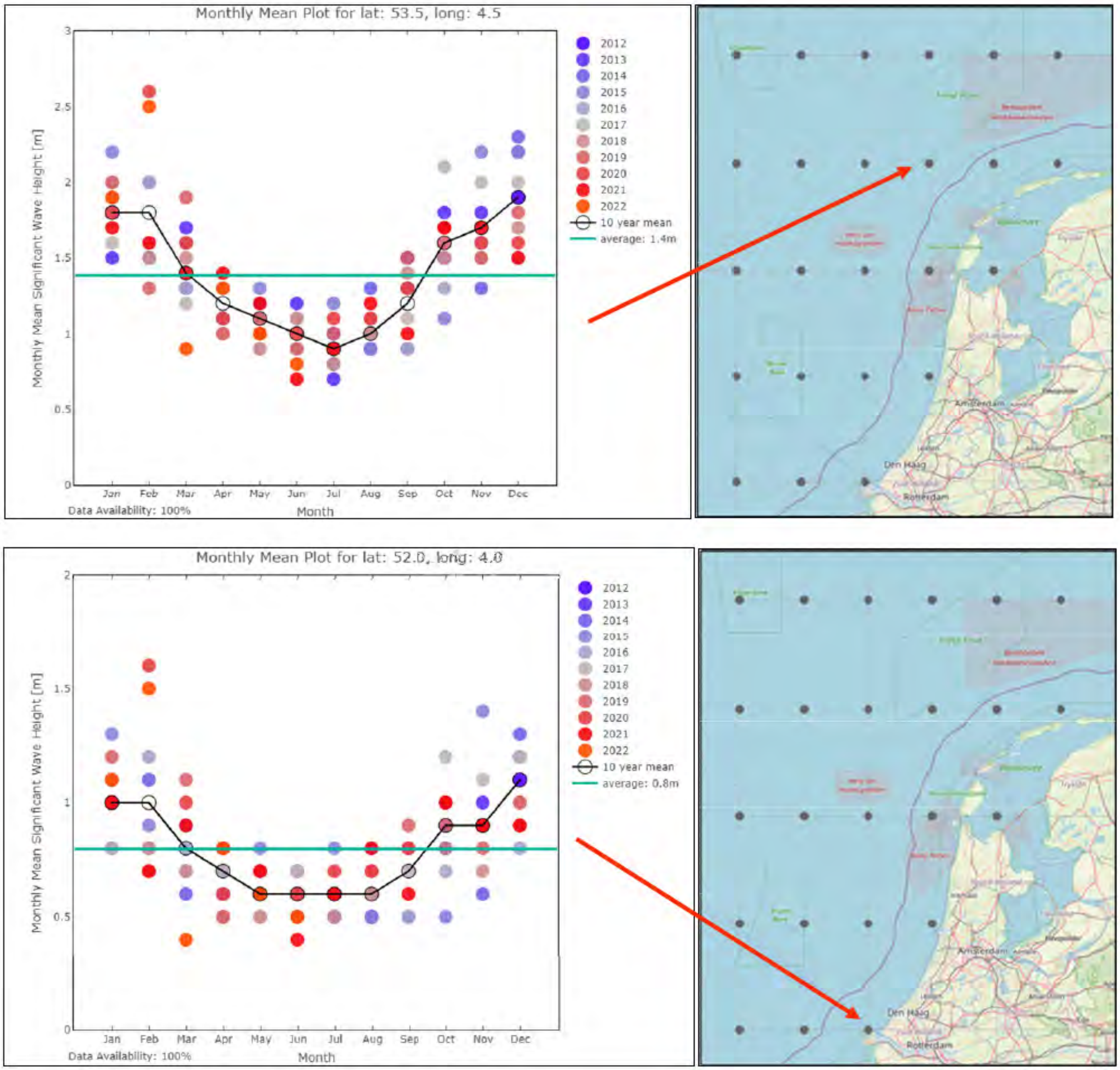


Figure 4.4. Significant wave heights for indicative onshore and offshore locations (source: Fugro, 2022)

4.6 Winds

Wind speed and directions (wind roses) for indicative onshore and offshore locations at 10 m height within the vicinity of the proposals are shown in Figure 4.5. Wind direction is dominated by south-westerly winds for both locations with speeds up to 16 to 18 m/s with monthly mean wind speeds ranging between 6.1 and 8.1 m/s. Highest speed are recorded in the period between December and February. These values are broadly in agreement with other surveys reporting mean wind speeds at 100 m of height ranging from 9.63 m/s to 9.73 m/s for the period 2008 to 2017 (DOWA, 2022).

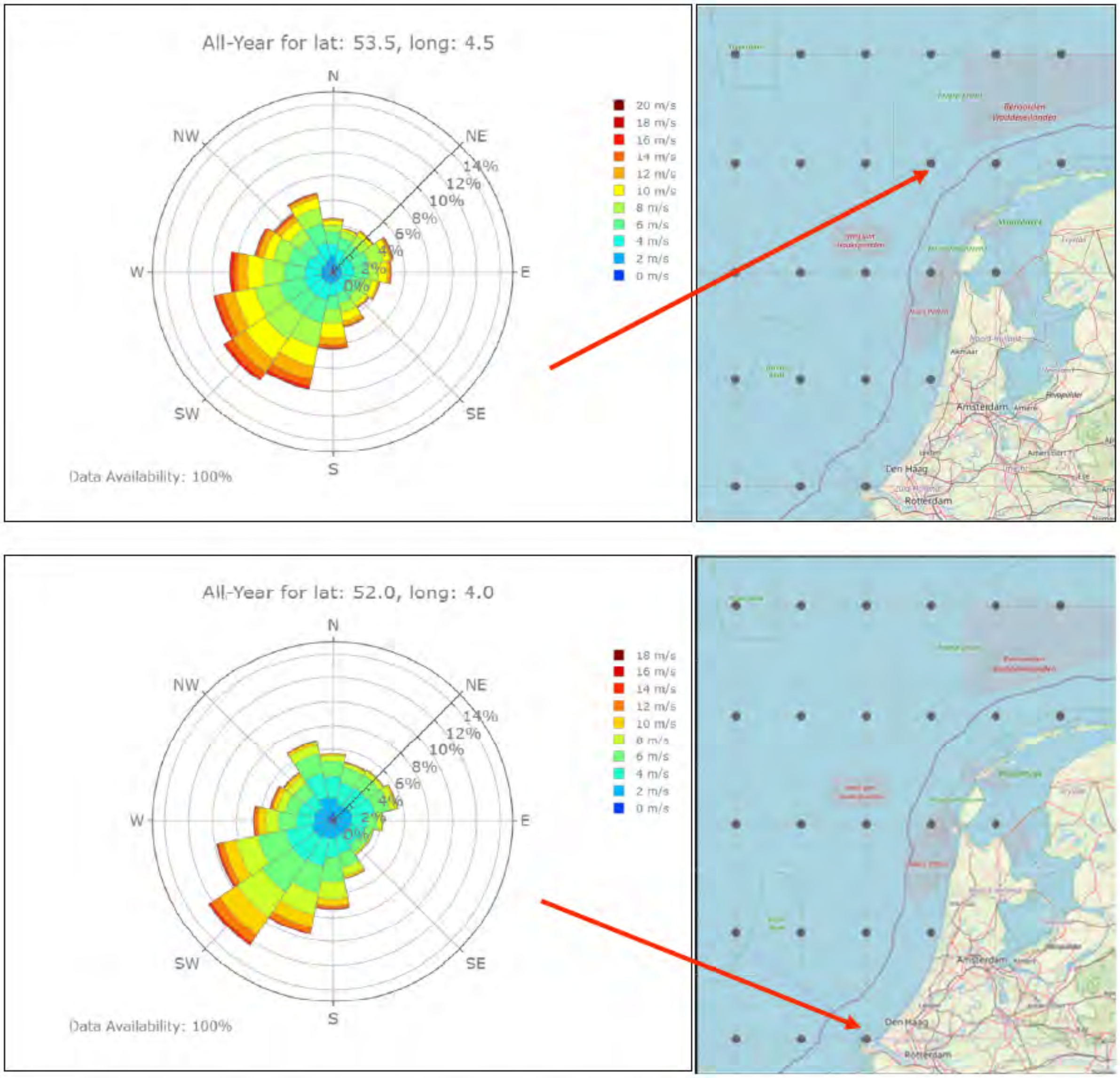


Figure 4.5: Wind speed and direction for indicative offshore and onshore locations (source: Fugro, 2022)

4.7 Sediment Quality

Levels of metals contaminants in seabed sediments derive from International Council for the Exploration of the Sea (ICES) and are shown in Table 4.1. Sampling locations are shown in Figure 4.6. Note only those data collected in 2015 and 2018 are presented as they are most relevant to the location of the current proposals. Other surveys within the ICES dataset were undertaken in estuarine and river waters and so were considered un-representative of the current study area.

Table 4.1: Sediment metal concentrations for the Dutch Continental Shelf and regional south North Sea (2015 data) (Source: ICES, 2022, de Boer et al, 2001; ERT, 2003; UKOOA, 2001)

	Stats	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
ICES Netherlands (2018 data)*	Minimum	0.200	30.4	10.3	23.8	0.064	69.4
	Maximum	2.46	80.4	37.3	158	1.17	447
ICES Netherlands (2015 data)†	Minimum	0.200	31.4	7.95	28.4	n/d	81.3
	Maximum	1.00	81.5	27	127	n/d	229
Dutch Nearshore (de Boer et al., 2001)‡	Minimum	0.81	92	21	57	0.30	162
	Maximum	2.34	142	77	272	2.43	587
Regional (Southern North Sea)#	Minimum	<0.01	2	<1	<5	<0.01	3
	Maximum	0.16	11	6	19	<0.01	30
Guideline Standards							
UKOOA Mean (southern North Sea)		0.16	10.7	3.83	8.39	0.02	15.88
UKOOA 95th Percentile		0.72	44.77	13.86	21.03	0.05	35.80
CEMP Assessment Criteria ERL		1.20	81.0	34.0	47.0	0.150	150

Notes:
Concentrations in ug/g
* = ICES data represents metals concentrations obtained from 39 stations sampled in 2018
† = ICES data represents metals concentrations obtained from 43 stations sampled in 2015
‡ = Nitric acid digestion used
# = Aqua-regia digestion used. Area 1, SEA2 survey

ICES data shows that minimum and maximum concentrations for all metals concentrations measured (cadmium, chromium, copper, lead, mercury and zinc) exceeded respective mean background concentration for the southern North Sea (UKOOA, 2001). In addition, the maximum concentrations of lead and zinc exceeded respective effects range low (ERL) values (OSPAR, 2014), which means that it is likely that detrimental impacts to the benthic communities would occur.

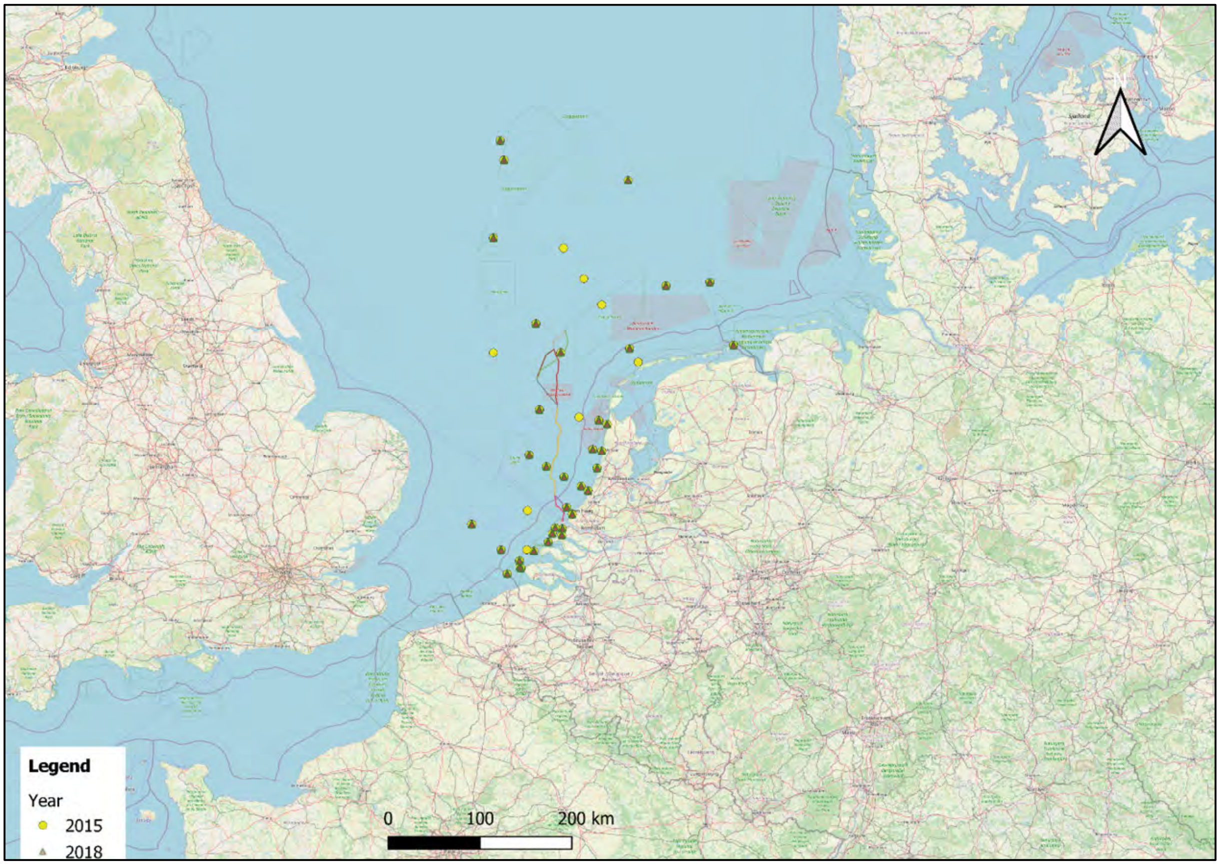


Figure 4.6: Sampling locations for sediment metal concentrations in 2015 and 2018 (source: ICES, 2022)

Table 4.1 also presents minimum and maximum sediment metals (cadmium, copper, lead, mercury and zinc) concentrations reported from five sampling stations located offshore of Amsterdam and Rotterdam (de Boer *et al.*, 2001; Figure 4.7). All the minimum and maximum values reported at this time, exceeded mean background concentrations for the southern North Sea, as well as 95th percentile values (UKOOA, 2001) and effects range low (ERL) values (OSPAR, 2014). Within Rotterdam and Amsterdam harbours, polychlorinated biphenyl, trace metals, triphenyltin and PAH concentrations were all found at values that exceeded the Dutch maximum permissible concentrations (de Boer *et al.*, 2001). The comparatively high levels recorded may be due to anthropogenic activities (e.g. maintenance vessel operations).

The current Coordinated Environmental Monitoring Programme (CEMP) environmental focus around heavy metals is on cadmium, mercury and lead (OSPAR, 2014). Cadmium and lead both occur naturally in the marine environment; however, they are toxic and liable to bio-accumulate so there is a concern for both the overall health of the environment and for the human consumption of seafood. Mercury is an extremely rare element in the earth's crust but does occur naturally in young geologically active areas (volcanic regions). It is extremely toxic to humans and biota and can be transformed once in the environment into more toxic organometallic compounds (OSPAR, 2009a).

Finally, Table 4.1 also shows metals levels for the wider south North Sea for regional context (ERT, 2003). In general, metals levels for Dutch waters exceed those for the wider region of the southern North Sea.

It should be noted that the values presented in Table 4.1 derive from different digestion techniques, hence these results are not directly comparable and are presented for illustrative purposes.

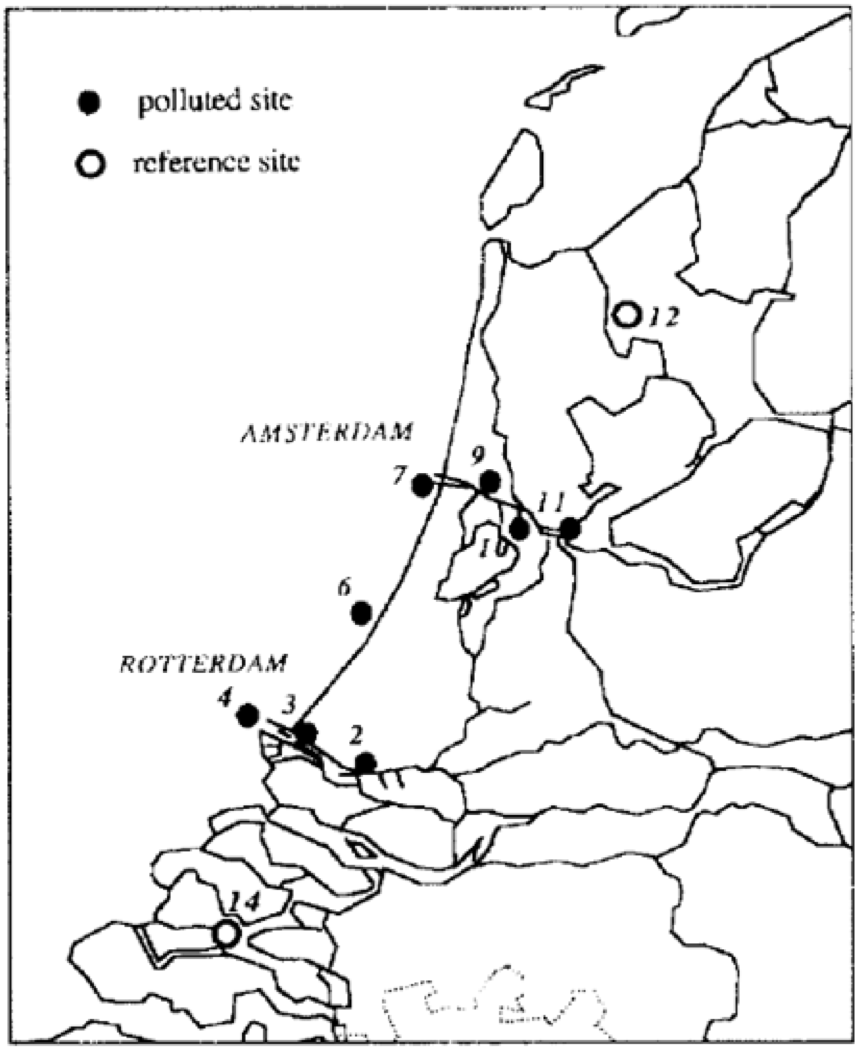
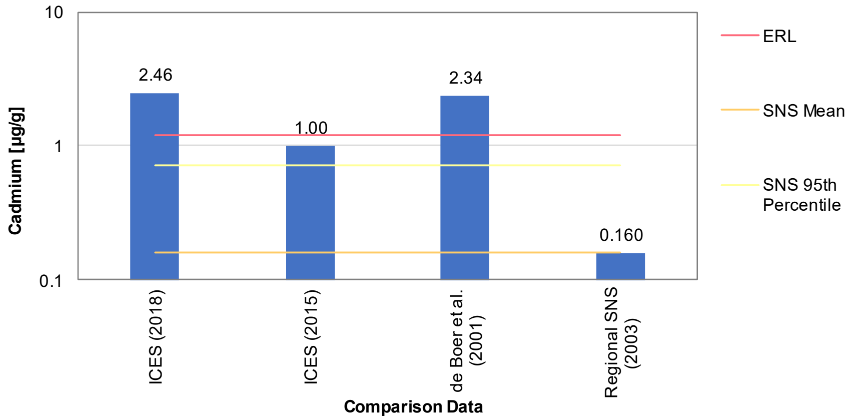
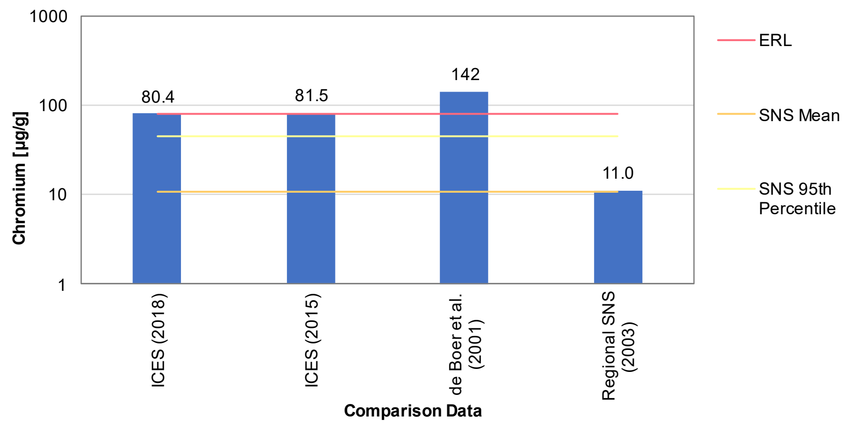
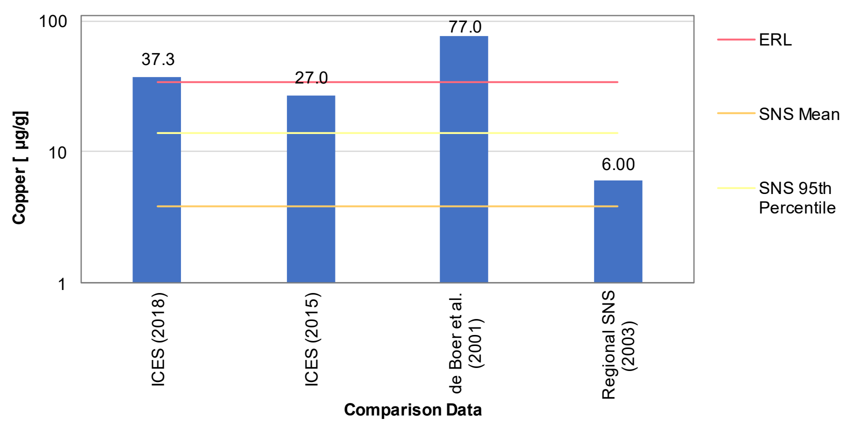


Figure 4.7: Sampling locations (source: de Boer *et al.*, 2001)

Figure 4.8 also presents graphically these results and compares the maximum reported concentration against background levels. Again, presenting maximum values with means should only be used for illustration purposes.


10
1
0.1
Cadmium [µg/g]
2.46
1.00
2.34
0.160
ICES (2018)
ICES (2015)
de Boer et al. (2001)
Regional SNS (2003)
Comparison Data
ERL
SNS Mean
SNS 95th Percentile


1000
100
10
1
Chromium [µg/g]
80.4
81.5
142
11.0
ICES (2018)
ICES (2015)
de Boer et al. (2001)
Regional SNS (2003)
Comparison Data
ERL
SNS Mean
SNS 95th Percentile


100
10
1
Copper [µg/g]
37.3
27.0
77.0
6.00
ICES (2018)
ICES (2015)
de Boer et al. (2001)
Regional SNS (2003)
Comparison Data
ERL
SNS Mean
SNS 95th Percentile

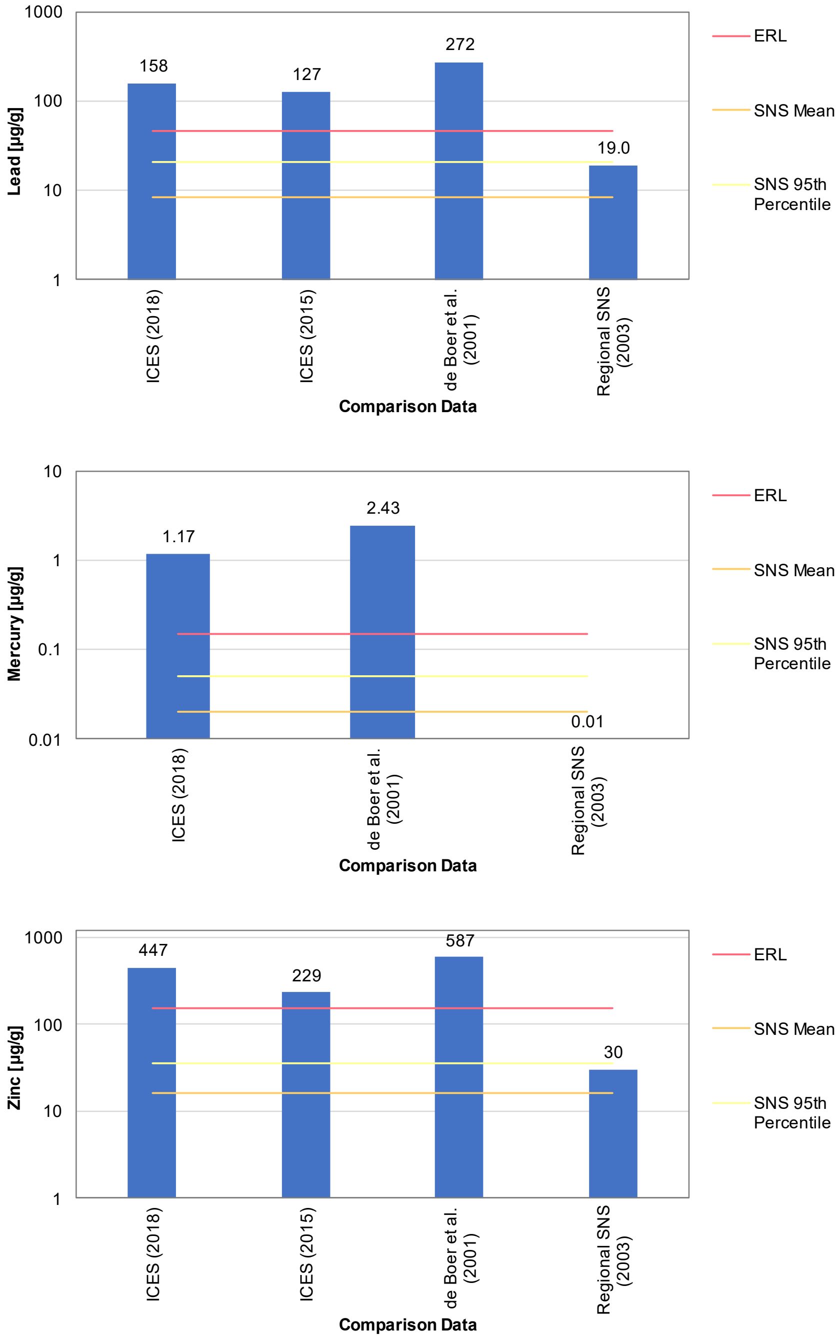


Figure 4.8: Reported metal concentrations from the existing literature

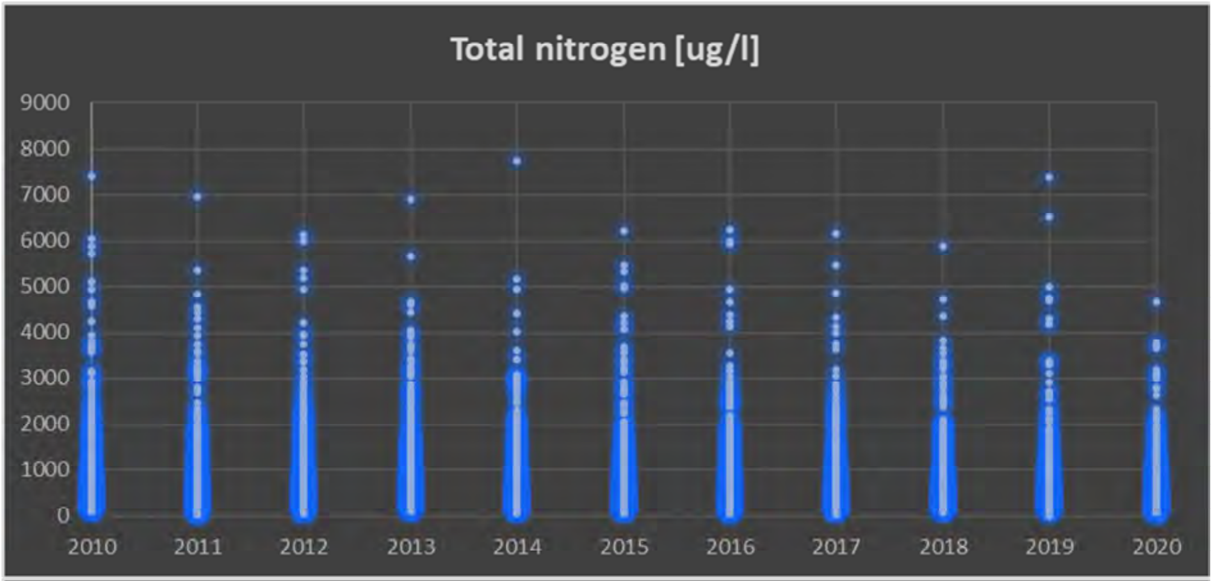
.

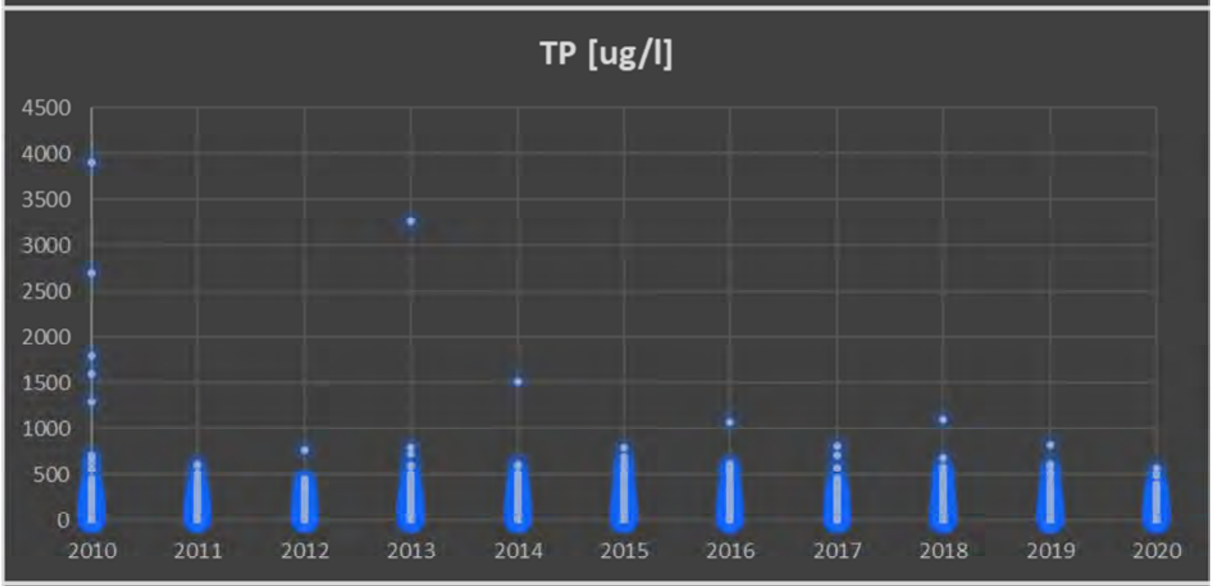
4.8 Seawater Quality

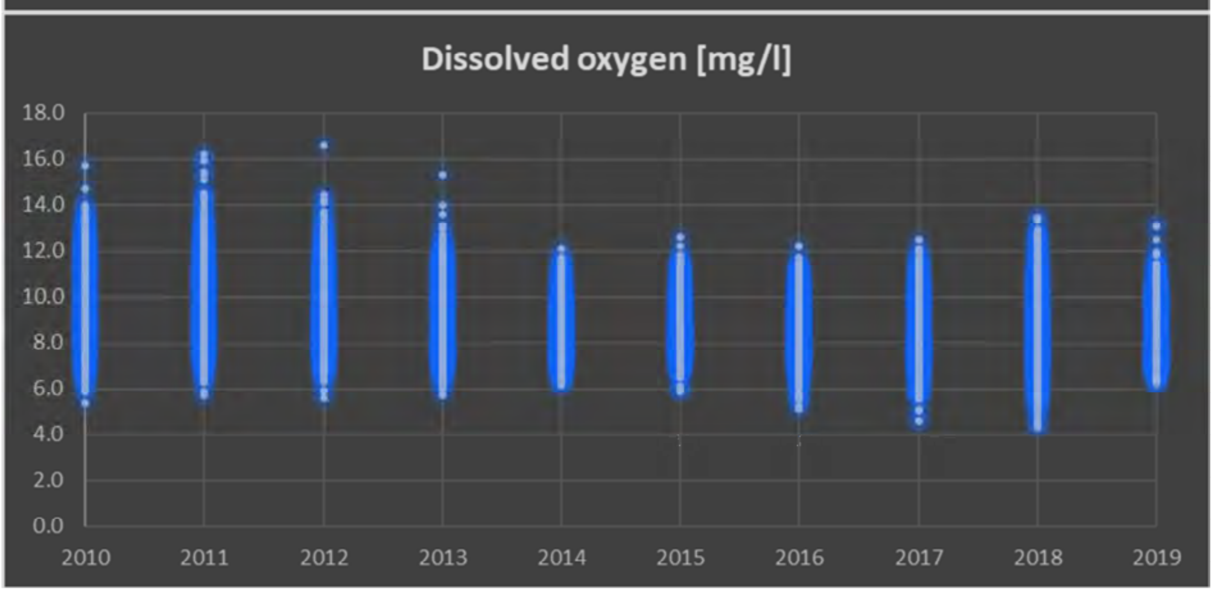
The southern half of the Netherlands part of the North Sea outside the coastal zone has a salinity in excess of 34 ‰ (Noordzeeloket, 2022c). The average seawater temperature in the region ranges from 6 (February) to 19°C (August) throughout the year and is heavily affected by weather conditions (Sea temperatures, 2022).

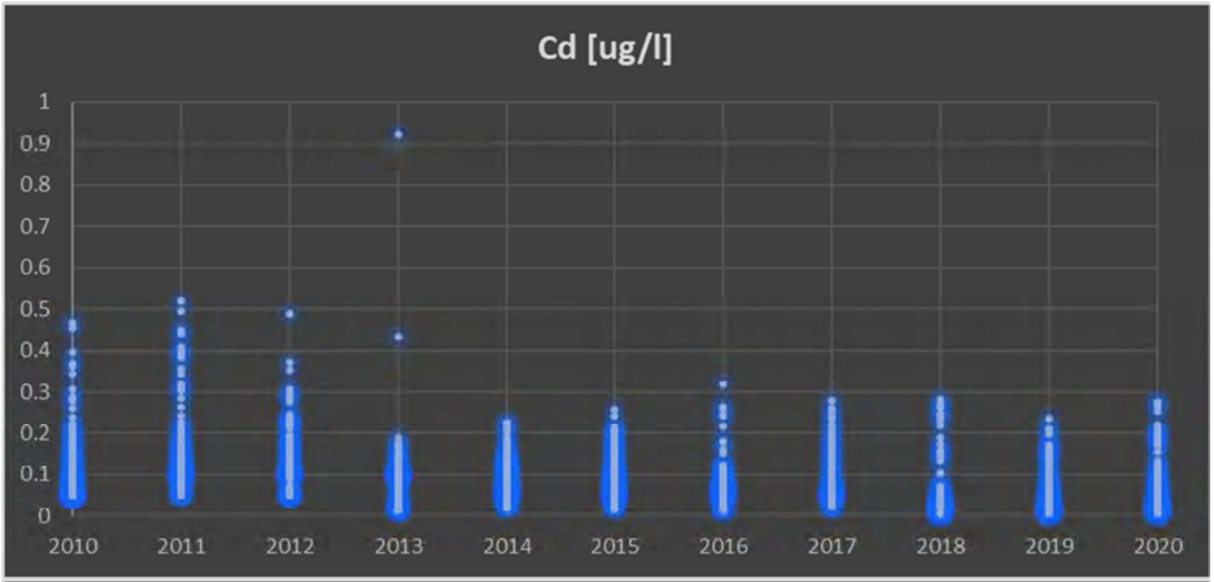
Contaminants levels for seawater between 2010 and 2020 are shown in Figure 4.9 and derive from International Council for the Exploration of the Sea (ICES) (ICES, 2022) data for the Netherlands. Routine sampling location from which seawater data are collected is shown in Figure 4.10. These data show an overall reduction in concentrations over this time for total nitrogen (TN), total phosphorous (TP), dissolved oxygen and metals including cadmium (Ca), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn).

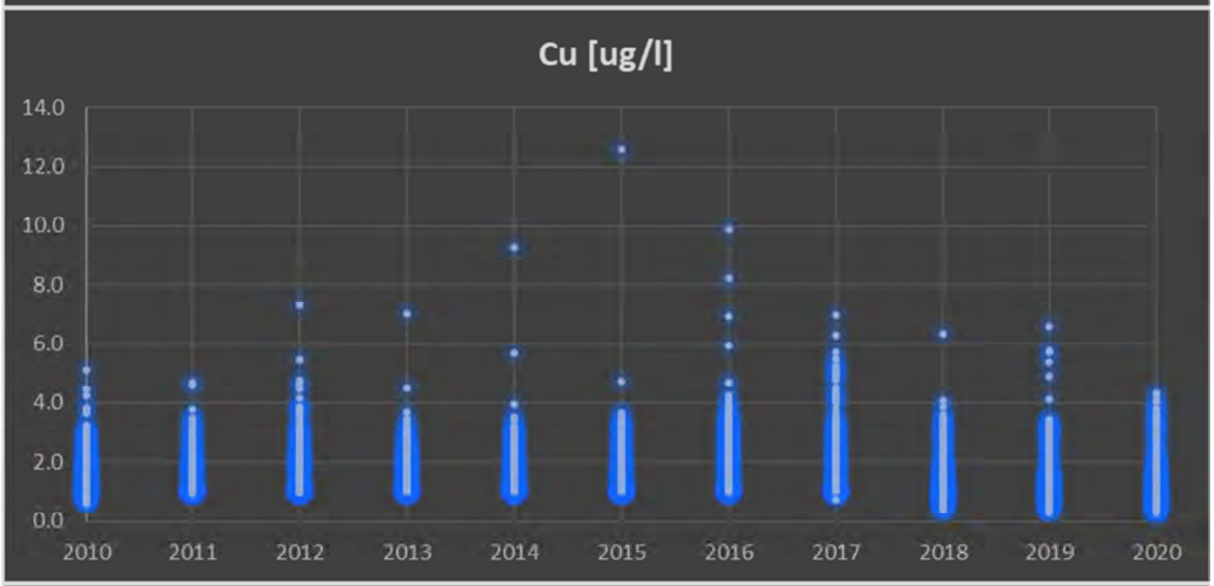
GON (2022) notes that chemical contaminants in seawater in the Netherlands are in general at levels that are below the maximum permissible limits for pollution. Overall, up to a 90 % reduction in heavy metal emissions from land-based sources has been reported between 1985 and 2000 in the Netherlands, with some areas (e.g., Western Scheldt estuary found south of the proposed route) demonstrating a total metal concentration in the water, sediments, and suspended particles to have decreased to levels similar to those being reported in the 1970's (Mubiana *et al.*, 2005). The exception to this is tributyltin (TBT) (GON, 2022) used as antifouling in ship hulls, which remains at levels above background levels. TBT is known to cause imposex to gastropods. Nitrogen concentrations are also reported to be above background levels in coastal waters and are attributed to land run-off.

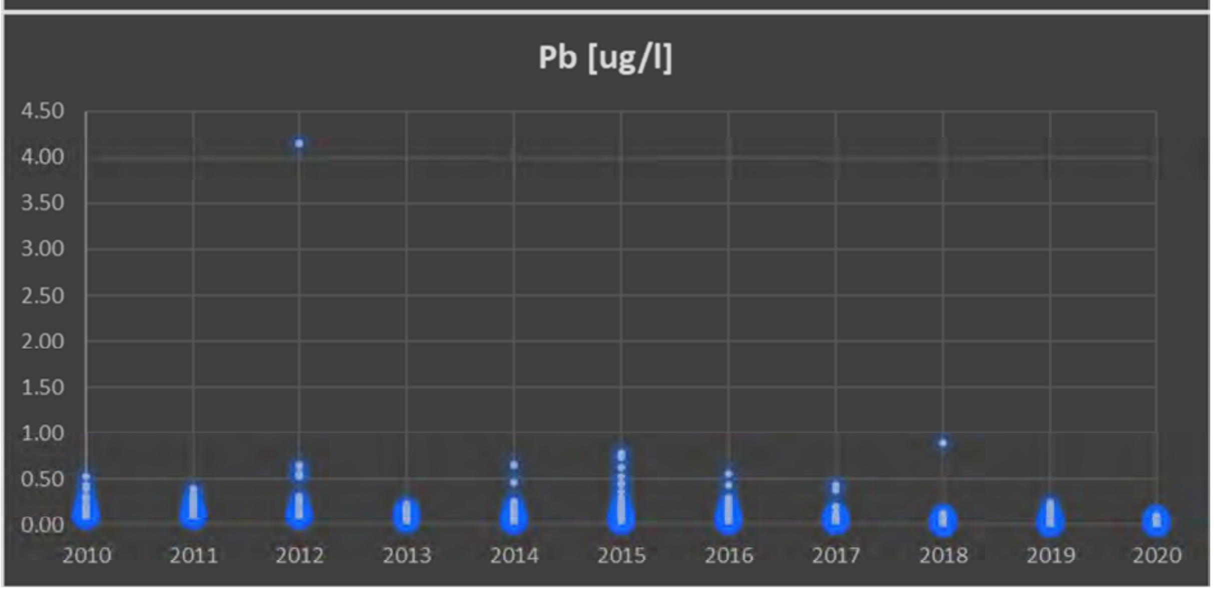

Total nitrogen [ug/l]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


TP [ug/l]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Dissolved oxygen [mg/l]
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019


Cd [ug/l]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Cu [ug/l]
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


Pb [ug/l]
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

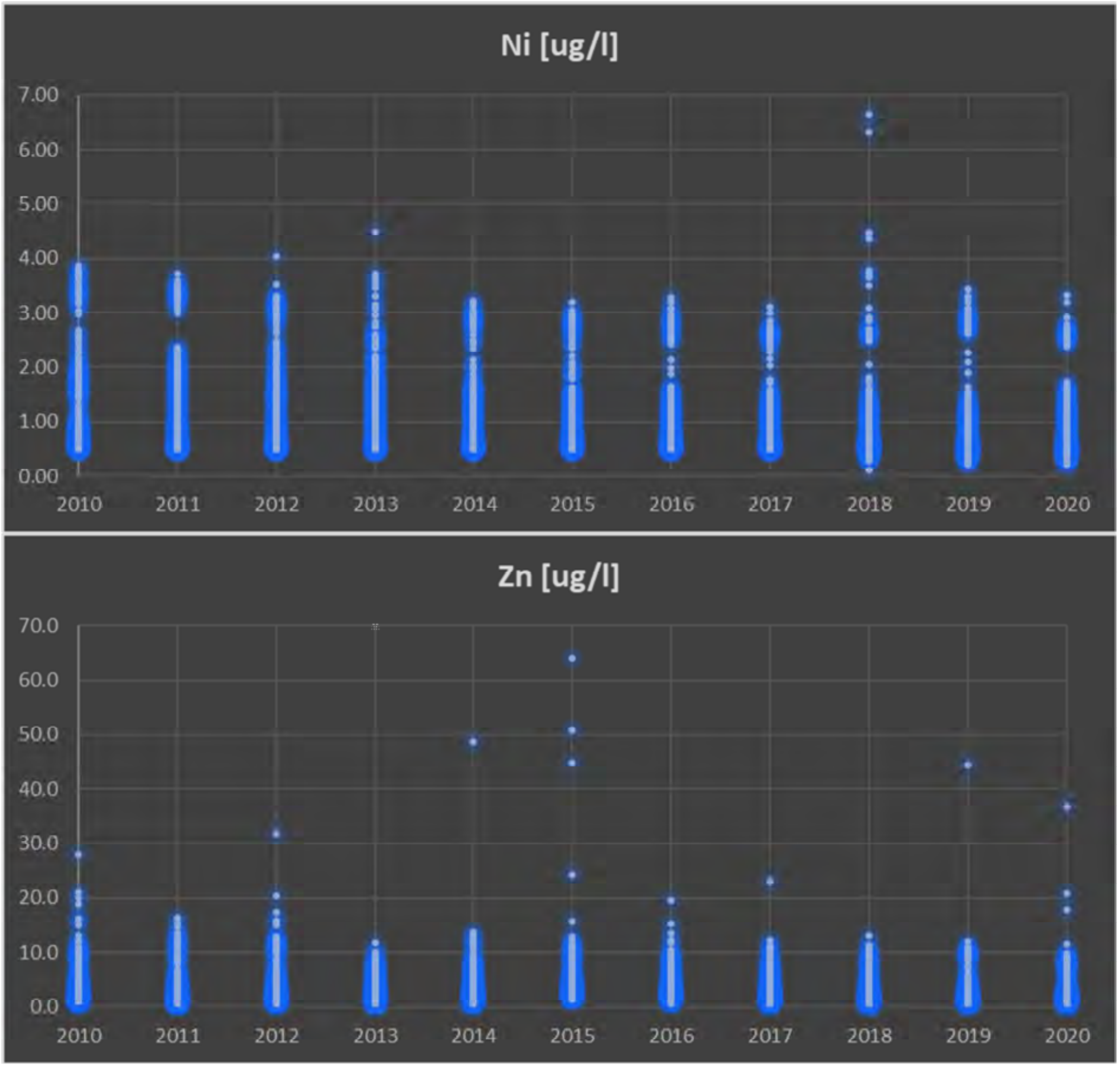


Figure 4.9: Concentrations of total nitrogen, total phosphorus, dissolved oxygen, cadmium, copper, nickel, lead, and zinc in seawater (ICES, 2022)

Figure 4.10: Seawater sampling locations (ICES, 2022)

A previous survey in the wider UK part of the SNS (CEFAS, 2001) has also demonstrated higher concentrations of total hydrocarbons (THCs) and polyaromatic hydrocarbons (PAHs) in coastal and estuarine samples, compared to offshore waters. Possible sources of THC or PAH inputs may relate to land or industrial run-off. PAH concentrations in offshore waters are usually low, or undetectable (CEFAS, 2001).

Additionally, turbidity levels have been reported to be elevated in Dutch waters in areas impacted by dredging waterways (GON, 2022), such as maintenance dredging operations within the Rotterdam harbour.

5. Biological Environment

5.1 Introduction

This Chapter describes the biological components of the marine environment within and around the proposed pipeline routes and EBS sampling areas, including seabed habitats and associated invertebrate communities, fish ecology, marine mammals and seabirds.

5.2 Seabed Habitats and Species

There has been a long history of study of seabed habitats and species within the North Sea (e.g., Peterson 1914; Duineveld *et al.*, 1991; Heip *et al.*, 1992; Kunitzer *et al.*, 1990; 1992; Eleftheriou & Basford, 1989; Rees *et al.*, 1999; Reiss *et al.*, 2010) and the broad-scale spatial and temporal distributions of seabed species communities and principal influencing factors are well-established.

Glémarc (1973) places the current study area within the "*étage infralittoral*" covering the southern North Sea area south of the northern flank of the Dogger Bank. It is characterized predominately by fine sand sediment habitats with traces of finer elements (silt and clay) supporting typical infaunal (sediment dwelling) brittlestars, bivalves and polychaete worm species. Within this étage, Glémarc also recognises distinct seabed communities off the Dutch coast including a community of bivalves, *Macoma balthica* and *Cardium edule* in nearshore variable salinity waters with bivalve *Abra prismatica* communities and the lancelet *Branchiostoma lanceolatum* in the coarser sediments present further offshore. Jennings *et al* (1999) similarly places the study area within a distinct "*southern North Sea grouping*" based on the prevailing seawater temperature variations and depth characteristics of the area and epifaunal (sediment surface dwelling) communities present including brittlestars *Ophiura*, seastars *Asterias rubens* and *Astropecten irregularis*, green urchin *Psammechinus miliaris*, hermit crab *Pagurus bernhardus,* hydroids *Hydractinia echinata, Hydralmania falcata* and *Sertularia argentea*, bryozoans *Electra Pilosa,* and soft coral *Alcyonium digitatum* present.

Following the methodology of De Jong (1999), Lindeboom *et al.* (2008) further develops Glémarc's initial habitat differentiation between near and offshore locations and divides the seabed of the Dutch sector of the North Sea into four 'ecotopes' relating to substrate types and depth conditions as follows (see also Figure 5.1):

- A nearshore shallow, fine sand habitat to around 15 – 20 m water depth corresponding to waters that originate from the English Channel but are influenced by silt and nutrients inputs from rivers and estuaries. The sandy composition and shallow nature of these sand deposits correspond to Habitats Directive 92/43/EEC definition for "*sandbanks that are slightly covered by the seawater all of the time*" and large sections of nearshore habitats along the Dutch coast are designated as a Natura 2000 site accordingly see Chapter 2: Conservation Designations).

- A predominately medium to coarse sand habitat in waters of around 20 – 30 m depth corresponding with waters flowing in from the English Channel. The seabed is naturally disturbed due to tidal and wave action and settlement and deposition of fine silty material does not occur; and
- deeper water sand and silty sand habitats, known as the Oyster Ground, in water depths of 40 – 50 m. Overlying water originate from the Atlantic and may be stratified, particularly during summer months. The seabed here is comparatively less affected by wave turbulence and tidal currents allowing greater settlement and accumulation of finer sediment material and thermoclines to be established in summer months.

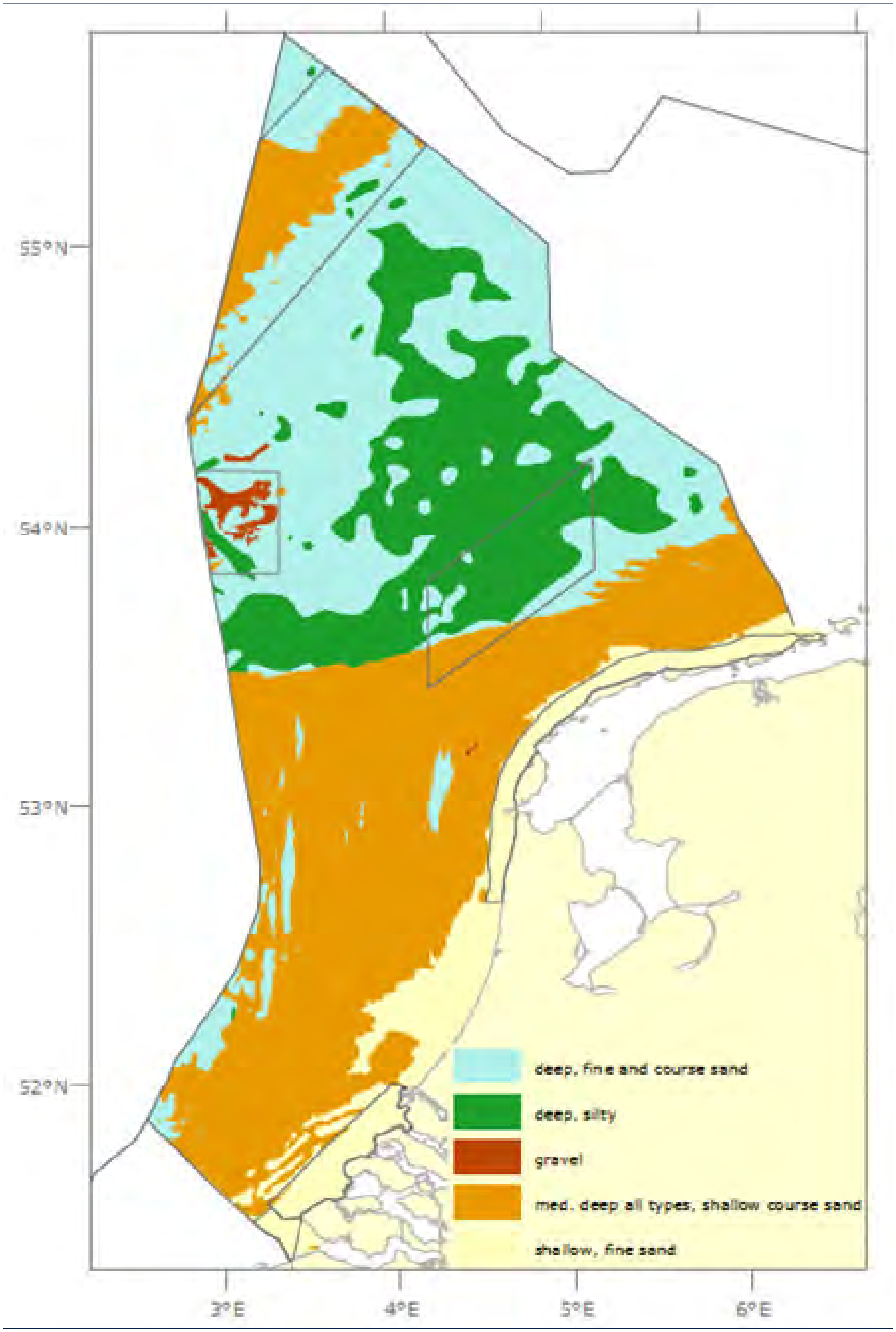


Figure 5.1 : Ecotope classifications (Lindeboom *et al.*, 2008)

A fifth habitat type comprising gravel and boulders is located at the west of the Dutch continental shelf at Clover Bank. The coarse material here is a relic of previous glaciation events and associated moraine deposits (Laban, 2006).

A hydrodynamic front (Friese Front) (Frisian Front) emerges at the point at which Atlantic water from the north meets the more mixed English Channel water from the south. The front coincides with a sharp seabed transition from sand to silt to silty sand due to the relatively silty, depositing environment within the Oyster Ground to the north and the more turbulent and mixed sandy environment further south.

Further detail on the species composition of these broad-scale habitat types derives from the national 'BIOMON' monitoring programme (Daan & Mulder, 2006; 2009). The programme similarly draws on the three distinct seabed regions ("coastal", "offshore" and "Oyster Ground") based on their water depth, sediment substrate and species characteristics. (A fourth region (Dogger Bank) is also noted within the BIOMON monitoring but is outside of the current study area and is not discussed further here).

Most recent BIOMON data (Daan & Mulder, 2006) recorded highest species variety occurring within the (Oyster Ground) and a general pattern of increasing species richness with increasing distance offshore. Conversely, greatest biomass was always found in the coastal areas and was related to the presence of bivalves *Spisula subtruncata* and *E. americanus*. Isolated pockets of high biomass across the Dutch sector was accounted for by the sampling of large-sized individuals such as large urchins *Echinocardium cordatum*.

In general, the area of the Oyster Ground was characterised by muddy sand species such the brittlestar *Amphiura filiformis*, mud shrimp *Callianassa subterranean*, bivalves Cor*bula gibba, Abra alba Mysella bidentata* and *Nucula nitido*sa, amphipods *Harpina antennaria*, horseshoe worm Phoronida and polychaetes*, Nephtys hombergii* and *Goniada maculata* and while shallower water and coastal habitats supported typical sand/slightly muddy sand and mobile sand fauna characterized by the polychaetes *Nepthys cirrosa, Spiophanes bombyx Magelona johnstoni and Scoloplos armiger,* the thumbnail crab *Thia scutellata,* amphipods *Bathyporeia elegans* and *Urothoe poseidonis* and bivalves *Ensis americanis* and *Tellina fabula*. Densities of species varied (sometimes considerably) between years while others exhibited slower (several years) trends of decline and subsequent recovery.

The results of site-specific ecological monitoring of the seabed using box cores and dredges at and around the sites of the Egmond aan Zee offshore wind farm and Near Shore Windfarm (Daan *et al.*, 2006; Jarvis *et al*, 2004) broadly agreed with those derived from the BIOMON programme for coastal and offshore areas. These wind farm sites were characterised by medium to coarse grade sand supporting polychaetes *N. cirrosa*, *S. bombyx* and *Lanice conchilega*, the amphipod *U. poseidonis,* the brittlestar *Ophiura,* the urchin *E. cordatum* and the bivalve *Spisula* *subtrancata*. Dredge sampling revealed several species of crabs, fish and shrimps not recorded within the box core samples.

Witbaard & Bergman (2013) have recorded comparatively dense populations of the ocean quahog *Arctica islandica* within the Oyster Ground although densities and sizes of individuals were reduced compared those in some areas in the northern North Sea. *A. islandica* is listed on the OSPAR list of threatened and/or declining species and habitats in response to measured declines of this species within the OSPAR region. Species on this list are recognised as needing protection. Recordings of *A. islandica* should be separated into juveniles and adult specimens and shell dimensions (length and width) measured for assessment of population structure. Also, the seabed video footage should be carefully examined for the presence of siphons of *A. islandica* on the seabed to further determine the distribution and abundance of this species within the EBS area.

Contemporary data on the distribution of current seabed habitats found across the proposed pipeline and landfall site include the European Marine Observation and Data Network (EMODnet) database portal (https://www.emodnet-seabedhabitats.eu/). The EMODnet database collates and standardises marine data from a wide variety of European agencies for public dissemination and is a valuable resource for broadscale habitat data. Seabed habitats in the database are classified according to the European Nature Information System (EUNIS) hierarchical classification nomenclature and are available at various levels of resolution including seabed sediment types and more detailed biotopes (Davies *et al.*, 2004). For the purposes of this review, habitats are referred to at the level of sediment types. Figure 5.2 presents the EMODnet distribution of EUNIS classified seabed sediment types across the pipeline routes.

The coastal part of the proposed pipeline routes comprises mostly of high energy circalittoral fine sand (A5.25) or circalittoral muddy sand (A5.26; EMODnet, 2020). Patches of deep circalittoral sand (A5.27), circalittoral sandy mud (A5.35) and deep circalittoral mud (A5.37) can also be present but in a lesser extent.

Further offshore, areas of moderate and high energy circalittoral fine sand (A5.25) or circalittoral muddy sand (A5.26; EMODnet, 2020), as well as patches of high energy deep circalittoral sand (A5.27) are present.

Hard seabed substrata are generally lacking and accounts for only around 1% of the seabed of the Netherlands (Lindenboom *et al.*, 2008). Clover Bank, located approximately 46 km north west and Bruine Bank, 23 km west of the proposed pipeline routes, represent the main locations where natural hard seabed substrata, including gravel and cobbles and biogenic (*Sabellaria spinulosa*) reef (Laban, 2006; Garcia *et al*, 2019). These hard rock habitats are considered representative of Annex I (EC Habitats Directive) geogenic and biogenic reef requiring protection through the designation of Natura 2000 sites. Both the Clover Bank and Bruine Bank are well outside the current proposed pipeline route and are not expected to be covered by the forthcoming EBS. Other hard rock habitats include artificial substrata including wrecks and submerged parts of oil and gas and renewables structures.

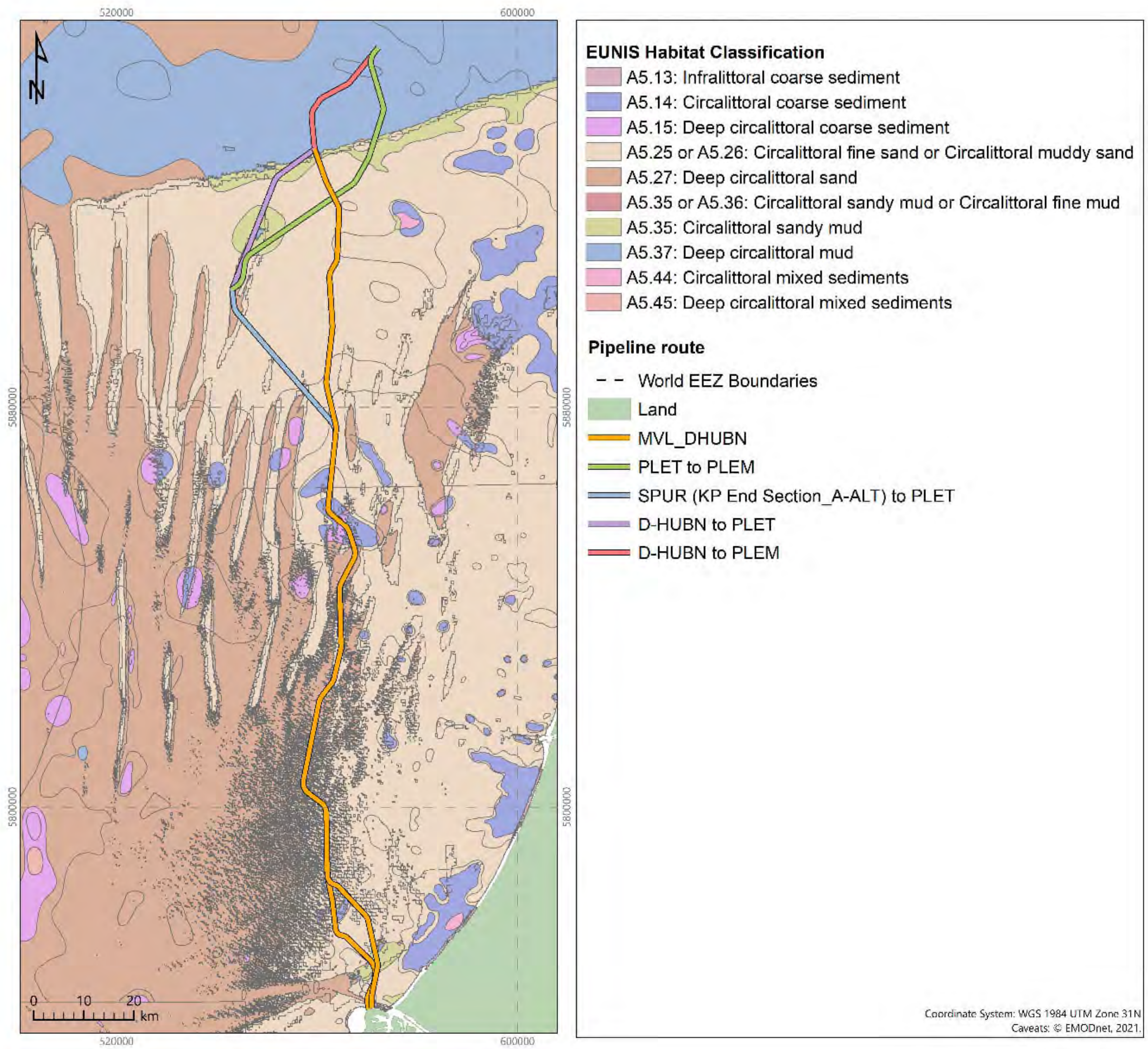


Figure 5.2: EMODnet distribution of EUNIS classified seabed sediment types across the pipeline routes

Geophysical surveying to characterise seabed sediments and features along the pipeline route is ongoing at the time of writing this environmental DTS. Nonetheless, a small section of pipeline route at the landfall site at the Port of Rotterdam Channel and to around the 15 m contour has been surveyed in July (Fugro, 2022b), results of which (side scan sonar) are presented in Figure 5.3.

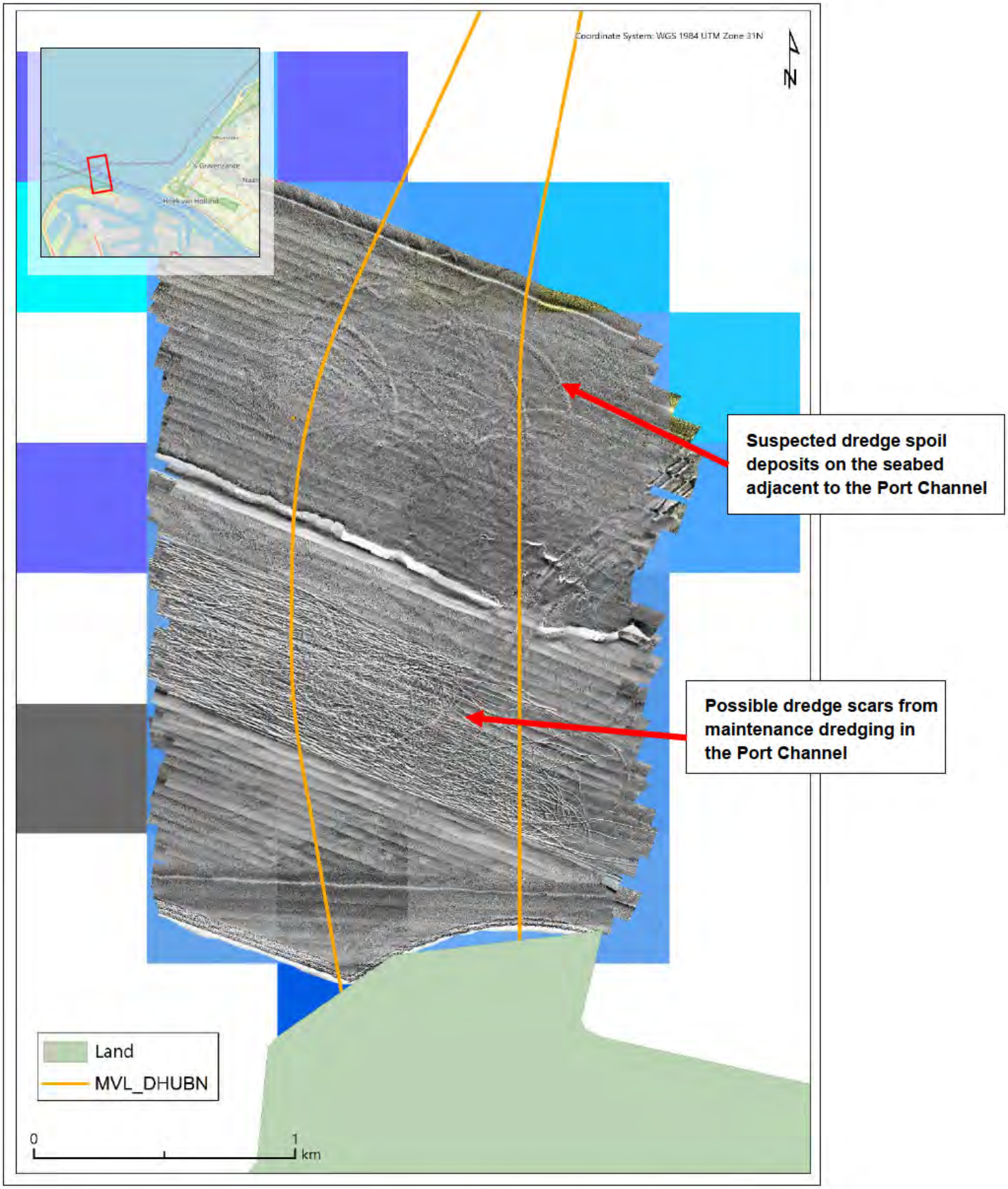


Figure 5.3: Side scan sonar data for the inshore section of the proposed pipeline route (Fugro, in prep.)

The geophysical data show multiple seabed features within the Port channel interpreted to be dredge scars and assumed to be the result of channel maintenance dredging. The majority of the channel area surveyed appears to be affected by dredge scars. To the north of the channel, the data indicates the presence of deposited material, assumed to be deposits of dredge spoil from the adjacent channel dredging. Again, the majority of seabed adjacent to the channel appears to be affected by spoil deposits. Multiple objects (boulders) of size 0.5 m or larger occur on the seabed possibly as a result of the seabed disturbances associated with dredge activity. Other objects, including possible discarded fishing gear have also been observed within the geophysical data. Small patches of rippled sand attest to the presence of transient sand deposits in this area. Two possible shipwrecks have also been recorded in the area within the new geophysical data.

Effects on sediment communities in dredge affected areas can be severe (Newell *et al.*, 1998; Hitchcock & Bell, 2004; Miró *et al.*, 2022) resulting in significantly reduced diversity, abundance and biomass of sediment fauna as well as the re-mobilisation of sediments and associated contaminants. Overall, the geophysical data points to a highly disturbed seabed environment subject to dredging and spoil disposal and it is expected that seabed communities at this location will be in a reduced state compared to natural conditions outside of the influences of dredging and disposal. Recovery of the fauna will likely occur on cessation of seabed disturbances.

5.3 Plankton

Plankton monitoring data for the Netherlands are routinely collected by Rijkswaterstaat Ministry of Infrastructure and Water Management and shared on the Marine Information and Data Centre (IHM) (https://www.informatiehuismarien.nl/uk/) as part of wider North Sea environmental reporting. These comprehensive datasets have been used by various researchers to describe plankton distribution and relationships with nutrient levels and riverine inputs in Dutch waters as referenced below. Further to this, plankton data for the Belgium sector of the North Sea and adjacent areas, including the Netherlands, are provided by the Belgium Plankton Database and are reviewed here (Nohe *et al.*, 2018). Finally, data on regional -scale plankton communities in the southern North Sea derives from results of the Continuous Plankton Recorder (CPR) as summarised in Johns and Reid (2001). The CPR comprises a long-term data series of plankton records sampled during tows of plankton recorders from suitable vessels traversing the North Sea (see https://www.cprsurvey.org/).

Plankton can be divided into phytoplankton and zooplankton as follows.

- Phytoplankton is made up of small, sometimes microscopic plants which drift, or use flagella to move, within the upper surfaces of water bodies where sufficient sunlight is available for photosynthesis. They may be divided broadly into two types including the diatoms (generally non-motile species) and dinoflagellates (generally species which are able to propel themselves through the water with the use of flagella). Phytoplankton are primary producers, forming the basis of most marine food webs through the fixing of the sun's energy by converting and storing it as sugars. They are thus vital to aquatic ecosystems and form the basis of most marine food webs representing plants and animals generally.

- Zooplankton comprise small animals, including crustaceans as well as the larvae of larger benthic and pelagic species. They have some mobility and may undergo vertical and horizontal migrations to maintain position in optimal conditions. Zooplankton play an important ecosystem role by consuming the phytoplankton and providing food for a wide variety of species including fish, mammals, and squid.

Johns & Reid (2001) explain that the pycnocline is a zone of marked density gradient between stratified upper layers and mixed lower waters. It generally forms over deeper water areas of the northern North Sea in summer months but is also known to form in the region of the Oyster Ground at the northern extents of the forthcoming EBS area. Plankton may be relatively dense at the pycnocline which may extend up to the surface forming a 'front'. The depth of the pycnocline can vary throughout the year (Johns & Reid, 2001).

Figure 5.4 shows the long-term changes in phytoplankton biomass in the North Sea, as indicated as change in colour, and suggests that the level of phytoplankton biomass has increased over the last four decades over the majority of the North Sea (Johns & Reid, 2001). Such broad-scale changes that appear to affect large areas of open sea are likely attributable to wide environmental changes such as increases in sea surface temperatures (Johns & Reid, 2001) with changes closer to the shore and within the influences of river and coastal inputs likely related to eutrophication effects and elevated nutrient levels.

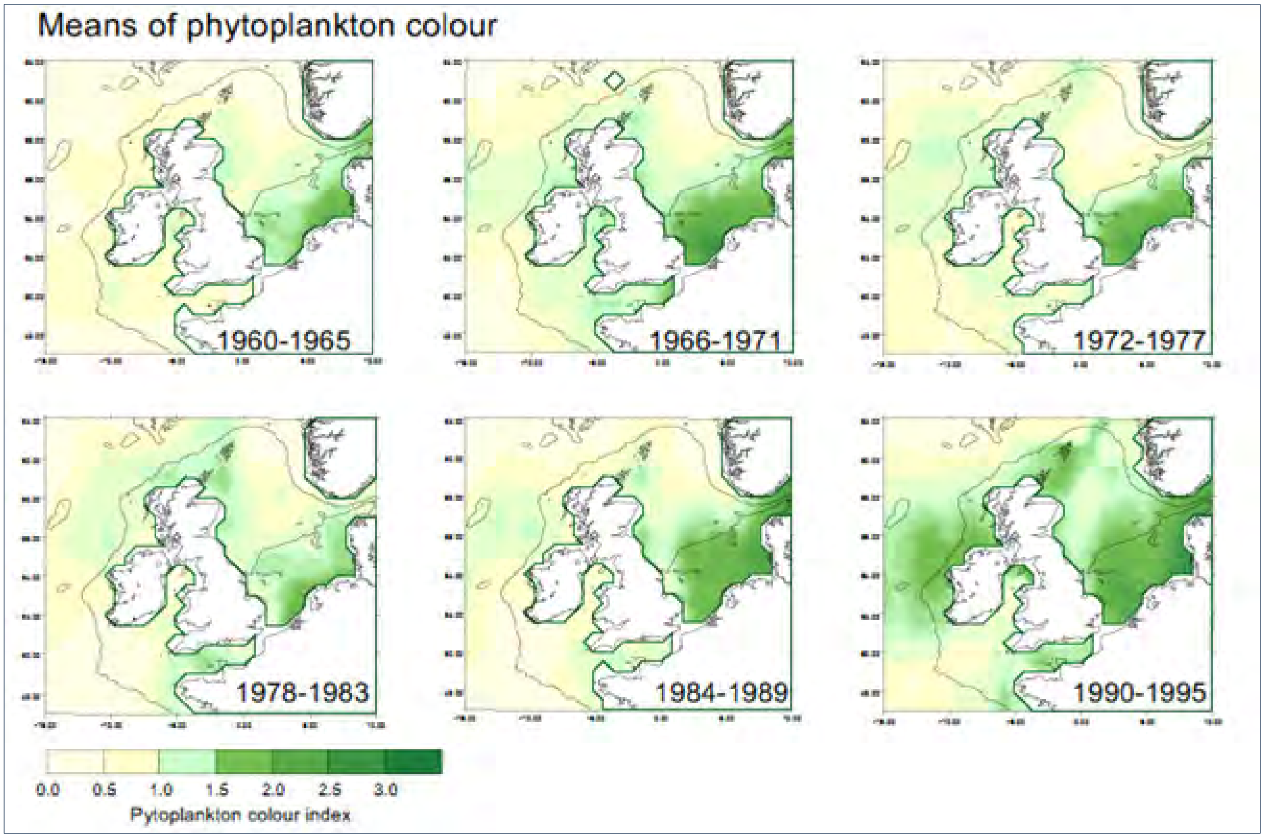


Figure 5.4: Estimates of mean phytoplankton biomass (expressed as colour) for six time periods 1960 -1995 (source Johns & Reid, 2001)

Joint & Pomroy (1993) mapped monthly surface chlorophyll concentrations in the southern North Sea between August 1988 and October 1989. The resulting seasonal changes showed comparatively low phytoplankton biomass in the western and central regions and higher phytoplankton biomass, which develops in the spring and early summer, in the Southern and German Bights, including areas within the vicinity of the forthcoming EBS. A large area of the Dutch coast exhibited consistently high chlorophyll concentrations (Joint & Pomroy, 1993) throughout the 15-month monitoring period. Primary production for the relevant North Sea ICES sub-division, encompassing the forthcoming EBS, was estimated as 199 g C m-2 yr. The authors noted that this region is influenced with by inflows of Channel water and that chlorophyll concentrations were mixed throughout the water column. Also, in winter and early spring, the euphotic depth in the region off the Belgian and Dutch coast is as great as the water column depth meaning that light for photosynthesis will reach the bottom sediments and which may be a factor in the early development of *Phaeocystis* blooms in these regions.

Phytoplankton abundance in the North Sea, increases in the spring (spring bloom) in response to raised temperatures, seawater stratification and increased light availability for photosynthesis. Prins *et al* (2002) suggests that nutrient inputs from rivers also fuels phytoplankton blooms in Dutch waters although influences of freshwater inputs are thought to be relatively limited to a narrow band of up to 20–50 km wide along the Dutch coast. Abundances of plankton then slowly decline over the spring and summer as nutrients in the seawater become depleted. A smaller increase in phytoplankton is also experienced in the autumn (autumn bloom) due to increased wind speeds and seabed disturbances which release seabed nutrients into the overlying water column for phytoplankton growth. Phytoplankton growth is inhibited during the winter months when light availability is limited. During this period, seawater nutrient levels increase in concentrations, as little or no primary production is taking place to utilise them (Johns & Reid, 2001).

Seasonal variability in phytoplankton populations within Dutch waters has been demonstrated by Aardema *et al.*, 2018 and Baretta Bekker *et al.*, 2009. Maximum phytoplankton concentrations occur in April with communities gradually breaking down over subsequent months. Monthly averages of chlorophyll a levels are presented in Table 5.1.

Table 5.1: Monthly average chlorophyll a levels (source: Aardema *et al.*, 2018)

	April	May	June	August
Chlorophyll a (µg/l)	18.32 ± 19.71	5.67 ± 10.39	4.08 ± 4.11	3.98 ± 3.91

The phytoplankton bloom period in Dutch waters occurs in April and is typified by high biomass and chlorophyll a concentrations. The bloom quickly collapses in May as shown by high variability in biomass concentrations. Low phytoplankton concentrations continue over the summer into August. A second bloom period is known to occur in some regions of the Dutch North Sea which may occur later than August.

In the southern North Sea the phytoplankton communities are dominated by *Ceratium* species and diatoms of the genus of *Chaetoceros* (*Hyalochaeta* and *Phaeoceros*). Zooplankton populations are generally characterised by copepods including *Para-Pseudocalanus, Acartia* spp. and *Temora longipes*. The ten most abundant phyto- and zooplankton species sampled by the continuous plankton recorder data in the southern North Sea as presented in Table 5.2.

Table 5.2: Top ten most abundance plankton species in the southern North Sea (source Johns & Reid, 2001)

Phytoplankton	Zooplankton
Ceratium fusus	Total copepods
Ceratium furca	*Echinoderm larvae*
Ceratium tripos	*Para-Pseudocalanus* spp.
Chaetoceros (Phaeoceros) spp.	*Acartia* spp.
Chaetoceros (Hyalochaeta) spp.	*Temora longipes*
Ceratium macroceros	*Evadne* spp.
Thalassiosira spp.	*Pseudocalanus* adult.
Protoperidinium spp.	*Oithona* spp.

Phytoplankton	Zooplankton
Ceratium hirridum	*Calanus traverse*
Ceratium longipes	*Podon* spp.

Synthesis of Dutch long-term plankton monitoring data (Baretta Bekker *et al.*, 2009; Prins *et al.*, 2012) have shown that *Phaeocystis* is the dominant near-shore species. Diatoms make up approximately 30–40% of the average phytoplankton biomass at offshore stations and 50% at the other locations. *Phaeocystis* contributes about 20–40% to the average biomass. Flagellates (mainly Chrysomonodales, Cryptophyceae and Euglenophyceae) ae also important contributors to the biomass. Dinoflagellates contribute to 10–15% of the average biomass, and there is a tendency toward relatively higher biomass of these plankton species at the offshore stations.

Sampling via vertical hauls of plankton nets in Dutch coastal waters in 2017 and 2018 as part of wider coastal fisheries studies (Couperus *et al*, 2020) revealed the dinoflagellate *Noctiluca scintillans* to be the dominant species in the net samples at all stations suggesting a bloom of this species at the times of sampling. The coastal zooplankton community was dominated by copepods such as *Temora longicornis, Acarcia clausi, Paracalanus parvus, Centropages hamatus, Pseudocalanus elongatus, Centropages typicus, Calanus helgolandicus* and the harpacticoid *Euterpina acutifrons*. Total abundances of copepods varied across the sampling stations between 1000-3000 individuals per m^3.

The Dutch plankton data also reveals significant increases in diatom biomass in the period 1990–2007 at several stations near the coast as well as significant but smaller increases offshore (Prins *et al.*, 2012). Dinoflagellates have also increased significantly at offshore and coastal locations over this time but there is no overall trend of decreasing biomass within increasing distance offshore (Baretta Bekker *et al.*, 2009; Prins *et al.*, 2012). In addition, there has been a marked increase in the magnitude and frequency of blooms of diatoms at several of coastal locations over this time. The pattern of increase in total diatom biomass and the increase in blooms of diatoms are considered to reflect the spatial pattern of river influence and relate to the increase in riverine silicon levels (Prins *et al.*, 2012).

Spatial differences are also apparent in plankton composition in Dutch waters. Barett Bekker *et al.* (2009) note that with increasing distance from the shore, coinciding with a decrease in nutrient availability and increasing water depth, total phytoplankton biomass as well as the biomass of diatoms, flagellates and *Phaeocystis* spp. decreases. This pattern was not true for the dinoflagellates, which occurred at more or less the same biomass throughout the region. Also, stations near river mouths and in the Wadden Sea outlets had much higher phytoplankton biomass than stations further away from freshwater discharges.

5.4 Fish Ecology

Broad-scale sampling of the North Sea region by small (2 m) beam trawl (Rees *et al.*, 1999) identified a typical southern North Sea sandy fish assemblage characterised by gobies Gobiidae, dab (*Limanda limanda*), solenette (*Buglossidium luteum*), sacldfish (*Arnoglossus laterna*) and dragonet (*Callionymus lyra*), as well as shellfish such as brown shrimps (*Crangon crangon* and *C. allmani*), hermit crabs (Paguridae) and flying crab (*Liocarcinus holsatus)*.

Typical fish within the Dutch sector largely reflect the assemblages found across the wider southern North Sea (Lindeboom *et al.*, 2008) and include solenette, horse mackerel (*Trachurus trachurus*), weaver fish (*Echiichthys vipera*), mackerel (*Scomber scombrus*), striped-red mullet (*Mullus surmuletus*), dab, plaice (*Pleuronectes platessa*), scaldfish, spratt (*Sprattus sprattus*) and common sole (*Solea vulgaris*). Brown shrimps are distributed within shallow nearshore waters along the coast of the Netherlands (Lindeboom *et al.*, 2008).

Along the coast and within the predominately sandy shallow sediment, the fish fauna caught in 3 m beam trawl samples (Couperus *et al.*, 2020) were dominated by herring (*Clupea harengus*) and sprat. Low numbers of sand eels were also captured in the trawls.

Environmental monitoring (Triple-D dredge) at Egmond aan Zee offshore wind farm (Figure 5.5) recorded a total of 15 fish species the most numerous of which included sand eels (*Ammodytes tobianus* and *Hyperoplus lanceolatus*), goby (*Pomatoschistos* sp.), solenette and dab (Daan *et al.*, 2006). Similar sampling at Princess Amalia offshore wind farm (van Hal, 2013) (Figure 5.5) recorded 17 species of fish. The dominant species found included sprat which comprised over 80% of the total catch. Herring were also commonly caught and comprised a further 17% of the catch. Other species recorded included whiting (*Merlanguis merlangus*), dab, plaice, and sand eels.

On the whole, the diversity of marine fish species in the Netherlands is greatest along coastal areas (Lindeboom *et al*, 2008) with lowest diversity occurring offshore (see Figure 5.6). This spatial pattern of biodiversity is thought to be a consequence of warmer water species entering the North Sea by way of the English Channel and subsequently spreading alongshore as well as the presence of species originating from the Wadden Sea area and also from diadromous species migrating from rivers to the sea.

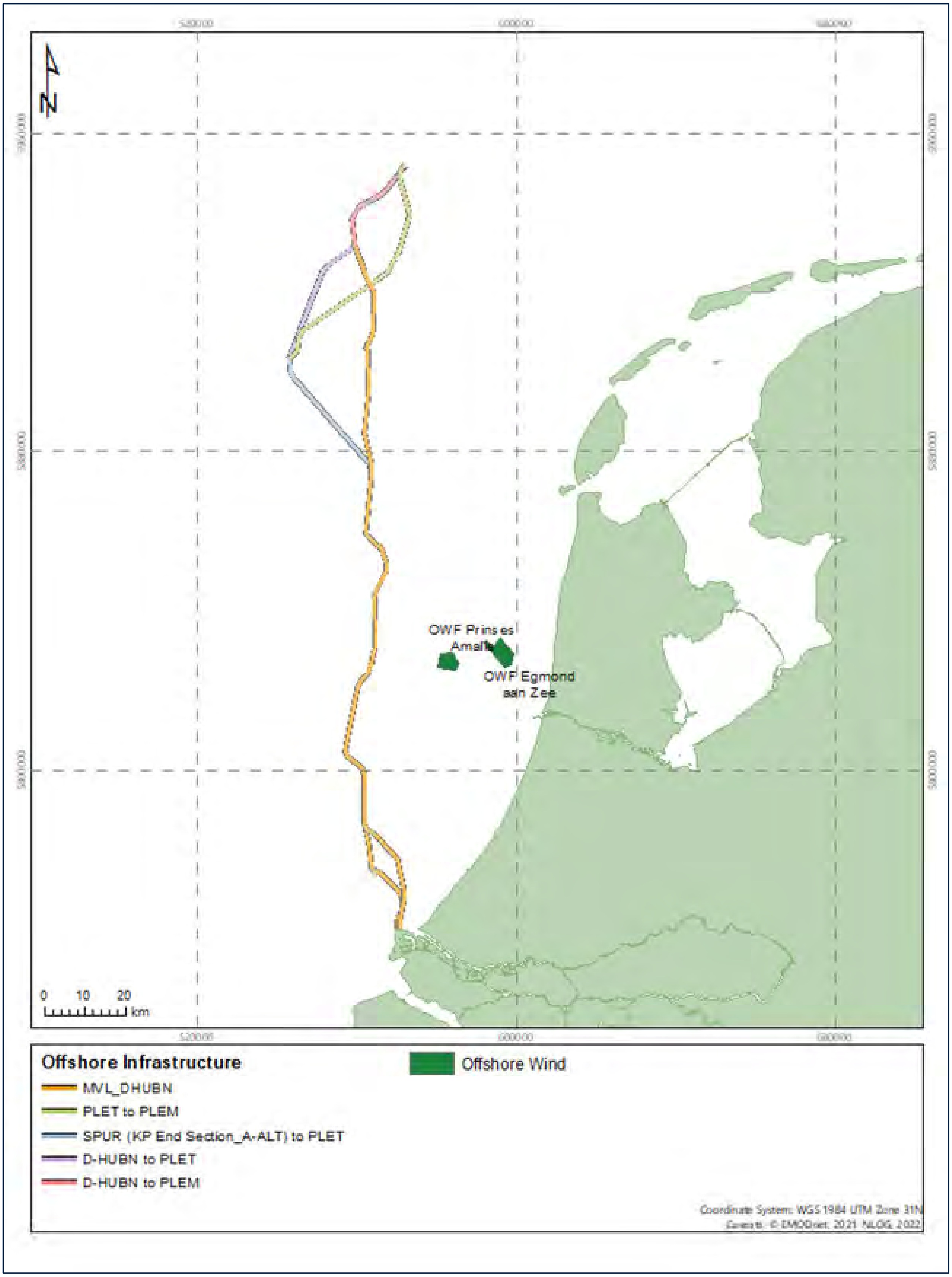


Figure 5.5. Location of Egmond aan Zee and Princess Amalia offshore wind farms.

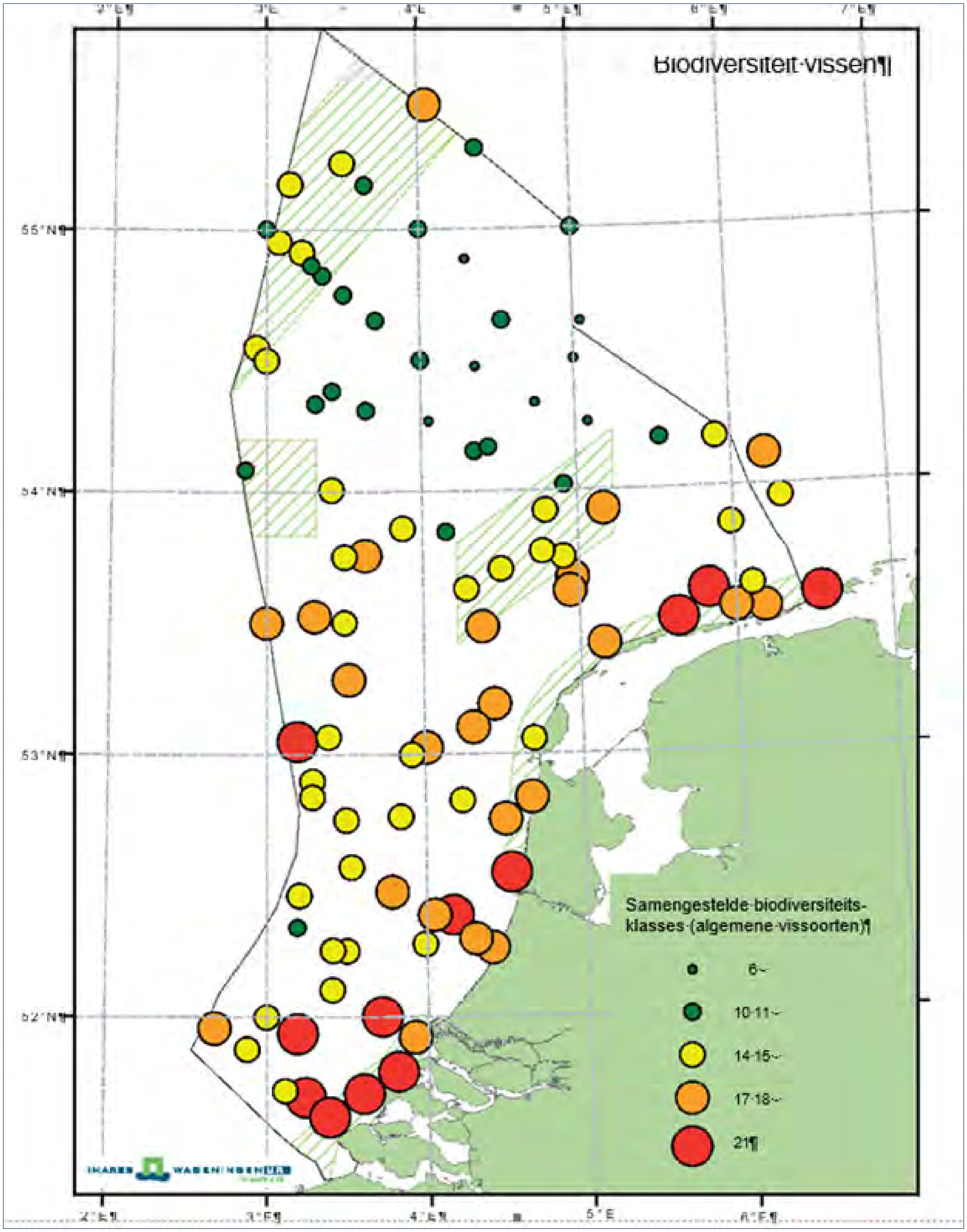


Figure 5.6: Distribution of diversity values for marine fish within the Dutch sector (source: Lindeboom *et al.*, 2008)

5.4.1 Important Fish Species

Protected fish species in Dutch waters include those for which Natura 2000 sites are designated including allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*), river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*). These species are anadromous, spawning in freshwater but spending part of their life cycle in estuarine or marine waters. Spawning migrations take place in May and June.

These species are protected within the Voordelta SAC, North Sea Coastal Zone SAC and Vlakte van de Raan SAC (see Chapter 2: Conservation Designations). It is Fugro's experience that anadromous fish are encountered very rarely during EBS and monitoring. Other techniques, such as eDNA analysis may be more useful in determining the presence of those fish species in the vicinity of the EBS area.

As well as protected status, important fish in Dutch waters may also include those that play a key ecosystem roles. For example, sand eels, together with pelagic fish such as herring, and sprat, are considered to be keystone species within local marine ecosystems as they are important in the diets of seabirds, marine mammals and larger fish.

Sandeels exhibit a strong preference for clean, medium to coarse sand habitat and may thus be particularly vulnerable to seabed disturbance as they are unable to easily relocate to other habitats elsewhere if disturbed. Couperus *et al.* (2020) considers that the sandy coast of the Netherlands to be an important area for sand eels including the species *Ammodytes tobianus* and *A. marinus*. The supports earlier mapping of sand eel habitat in the North Sea (Jensen *et al.*, 2010) which included several areas adjacent to the Dutch coast as important in this regard (see Figure 5.7).

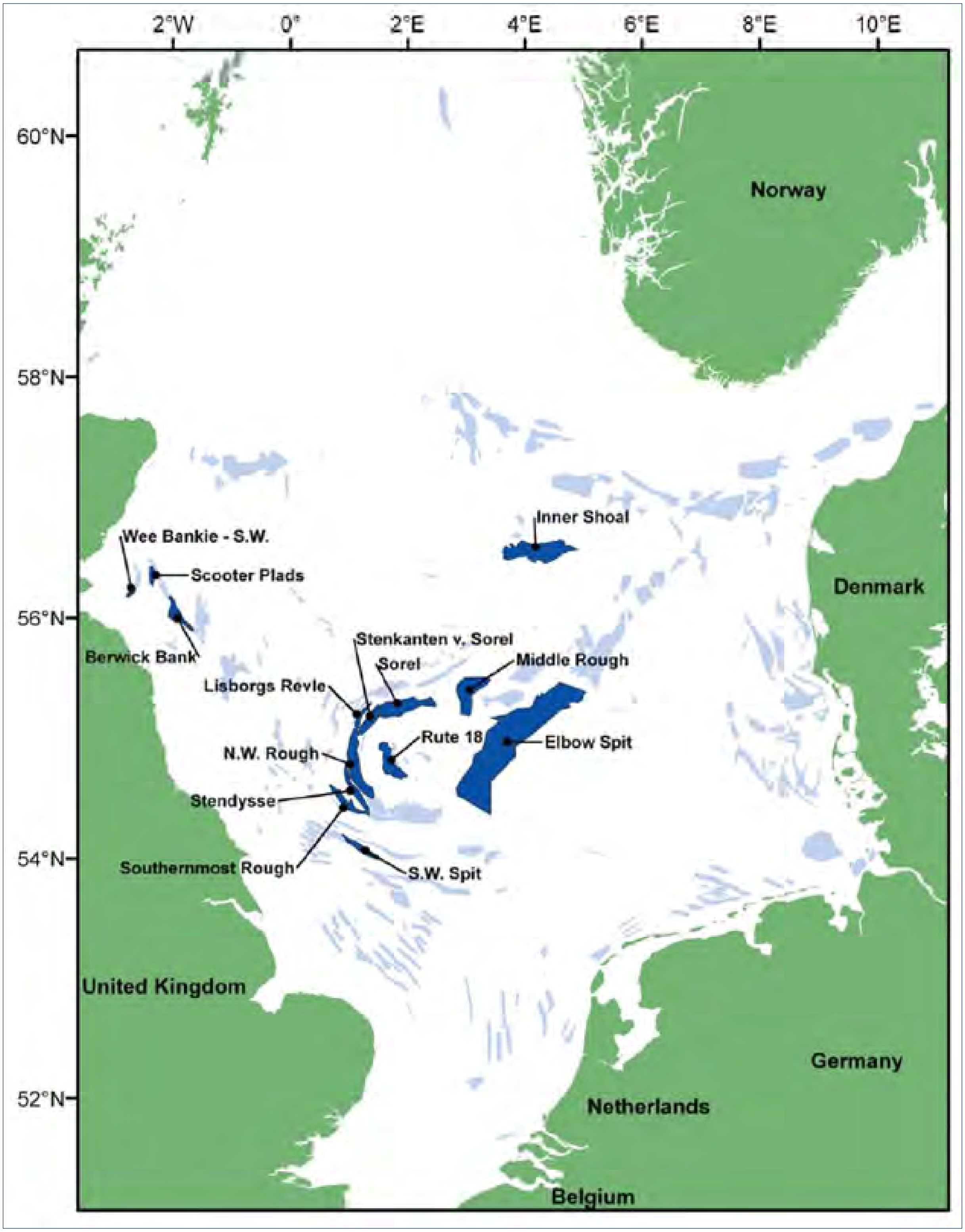


Figure 5.7: Distribution of predicted sandeel habitat (areas with potentially high density of non-buried sandeel) within the North Sea (with selected fishing grounds shown in dark blue) (source: Jensen *et al.*, 2010)

5.4.2 Important Fish Habitats

Areas of sea supporting spawning and/or nursery populations of fish can be regarded as sensitive areas (Coull *et al.*, 1998; Ellis *et al.*, 2012). The distribution of predicted fish nursery and spawning areas in the North Sea in relation to the proposed pipeline routes are shown in Figure 5.8. Table 5.3 summarises the spawning periods for fish species within the vicinity.

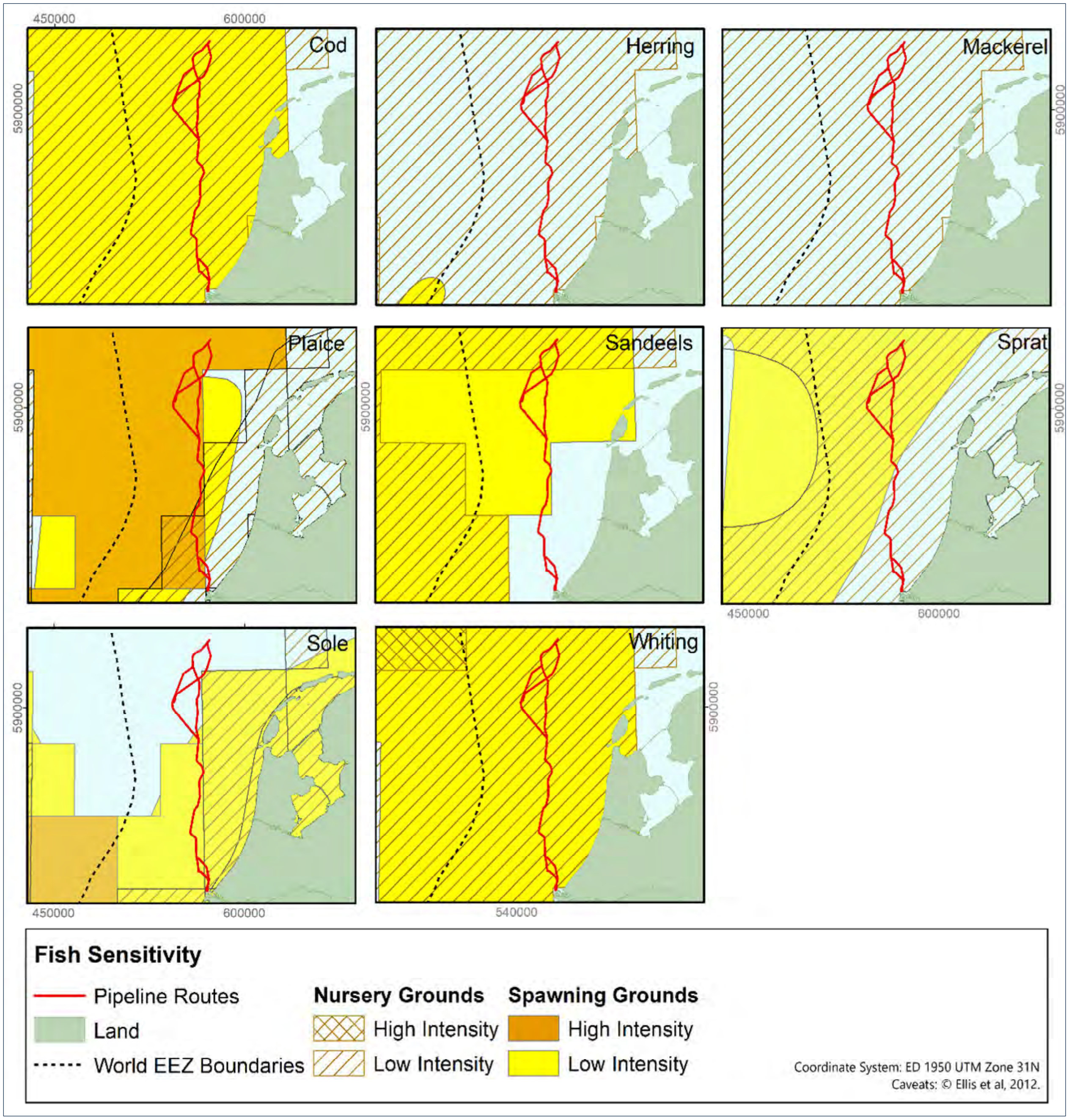


Figure 5.8: Distribution of fish spawning and nursery areas (source: Coull *et al.*, 1998; Ellis *et al.*, 2012)

Table 5.3: Spawning times of key fish species in the vicinity of the proposed Aramis pipeline

Species	Month												Nursery Ground
	J	F	M	A	M	J	J	A	S	O	N	D	
Herring (Downs) (*Clupea harengus*)													✓
Whiting (*Merlangius merlangus*)													✓
Cod (*Gadus morhua*)		*	*										✓
Mackerel (*Scomber scombrus*)					*	*	*						✓
Sandeel (Ammodytidae)													✓
Plaice (*Pleuronectes platessa*)	*	*											✓
Sole (*Solea* sp.)													✓
Sprat (*Sprattus sprattus*)													✓

Notes:
* = peak spawning

The proposals coincide with the spawning and/or nursery ground of eight fish species including cod *Gadus morhua*, herring, mackerel, plaice, sandeel, sprat, sole and whiting. In general, the EBS study area coincides with areas of low fish spawning and nursery intensity with the exception of plaice, suggesting use by relatively small number of individuals of respective populations.

5.5 Marine Invasive Species

Marine invasive species pose a threat to biodiversity in the Netherlands where they can establish and out-compete indigenous species. In the Dutch marine environment, for example, the bivalve *Spisula subtruncata* has been displaced by the invasive Atlantic jack-knife clam *Ensis leei* (formerly *E. directus* which has had adverse effects on bird (scoter) feeding. In addition, the native flat oyster *Ostrea edulis* has been displaced by the introduced Pacific oyster *Crassostrea gigas* and is now near extinct in the Netherlands. *C. gigas* has also introduced the pathogen *Bonamia* to which native oysters have succumbed and which may be preventing their re-establishment.

In response to commitments under the EU Marine Strategy Framework Directive, the Dutch Department of Nature & Biodiversity of the Ministry of Agriculture, Nature and Food Quality and the Office for Risk Assessment and Research of the Netherlands Food and Consumer Product

Safety listed a total of 178 species, of which 153 species have originated from outside of north-west Europe (Gittenberger *et al.*, 2017). It was assumed likely that 54 of these 153 species are settled in the Dutch part of the North Sea. Shellfish transports, ballast water transports and hull fouling are regarded as the most important pathways for the transmission of marine invasive species into the Netherlands together with natural spreading once established.

Policies introduced in the Netherlands to control the introduction and spread of marine invasive species include adoption of ballast water regulations based on International Maritime Organisation (IMO) protocols and imposing strict requirements on the issuance of Nature Conservation Act permits for shellfish transfers to limit or prevent the introduction of invasive non-indigenous species into Natura 2000 areas. Guidelines on ship biofouling management are also available (MEPC) (MPEC, 2011).

5.6 Marine Mammals

This section describes the spatial and temporal distribution of marine mammals including pinnipeds (seals) and cetaceans (whales, dolphins and porpoises) within the general area of the proposals.

Data on pinnipeds are drawn from population studies (Ecomare, 2022; SCOS, 2020; Jensen *et al.,* 2017; Aarts 2016; Brasseur *et al.,* 2015; van Neer *et al.,* 2015; Jones *et al.*, 2015; Leopold *et al.*, 2015; Bouveroux *et al.,* 2014; Scheidat *et al.,* 2011; Gilles *et al.,* 2008; Lockyer & Kinze, 2003; Reijnders *et al.*, 2010; 1997; and Van Utrecht 1978). Other distributional data for pinnipeds derives from the work on identifying Dutch marine biodiversity hotspots (Bos *et al.*, 2011).

Data on cetaceans are drawn from the North Sea SCANS-III survey data (Hammond *et al.*, 2021). The SCANS surveys cetacean counts collected by aerial surveillance (shelf waters) and ship observations (offshore waters) from across European Atlantic waters. Count data are presented for discrete survey regions (blocks) of sea. For the current EBS, SCANS Block N is the appropriate region, and which covers an area of 69,86 km^2 of the southern North Sea between the Dutch coast and central North Sea / Dogger Bank area.

Other distributional data for cetaceans derives from the work on identifying Dutch marine biodiversity hotspots (Bos *et al.*, 2011) which itself drew upon ship-based European Seabirds at Sea (ESAS) monitoring data and routine bi-monthly aerial monitoring data. Densities of harbour porpoises with Dutch waters have been monitored by aerial survey in 2008 and 2009 (Scheidat & Verdat, 2009) and up to 2017 (Geelhoed *et al.*, 2018).

5.6.1 Pinnipeds

Two species of pinnipeds are present within Dutch waters including harbour seals *Phoca vitulina* and grey seals *Halichoerus grypus*. Both species are listed as protected species under Annex II and Annex V of the European Community's Habitats Directive (EEA, 2019a; 2019b) and both are protected features of the Voordelta SAC, North Sea Coastal Zone SAC, Vlakte van de Raan SAC, Dogger Bank SAC and, Clover Bank SAC. Relative abundances of these two species within the Dutch sector of the North Sea are presented in Figure 5.9.

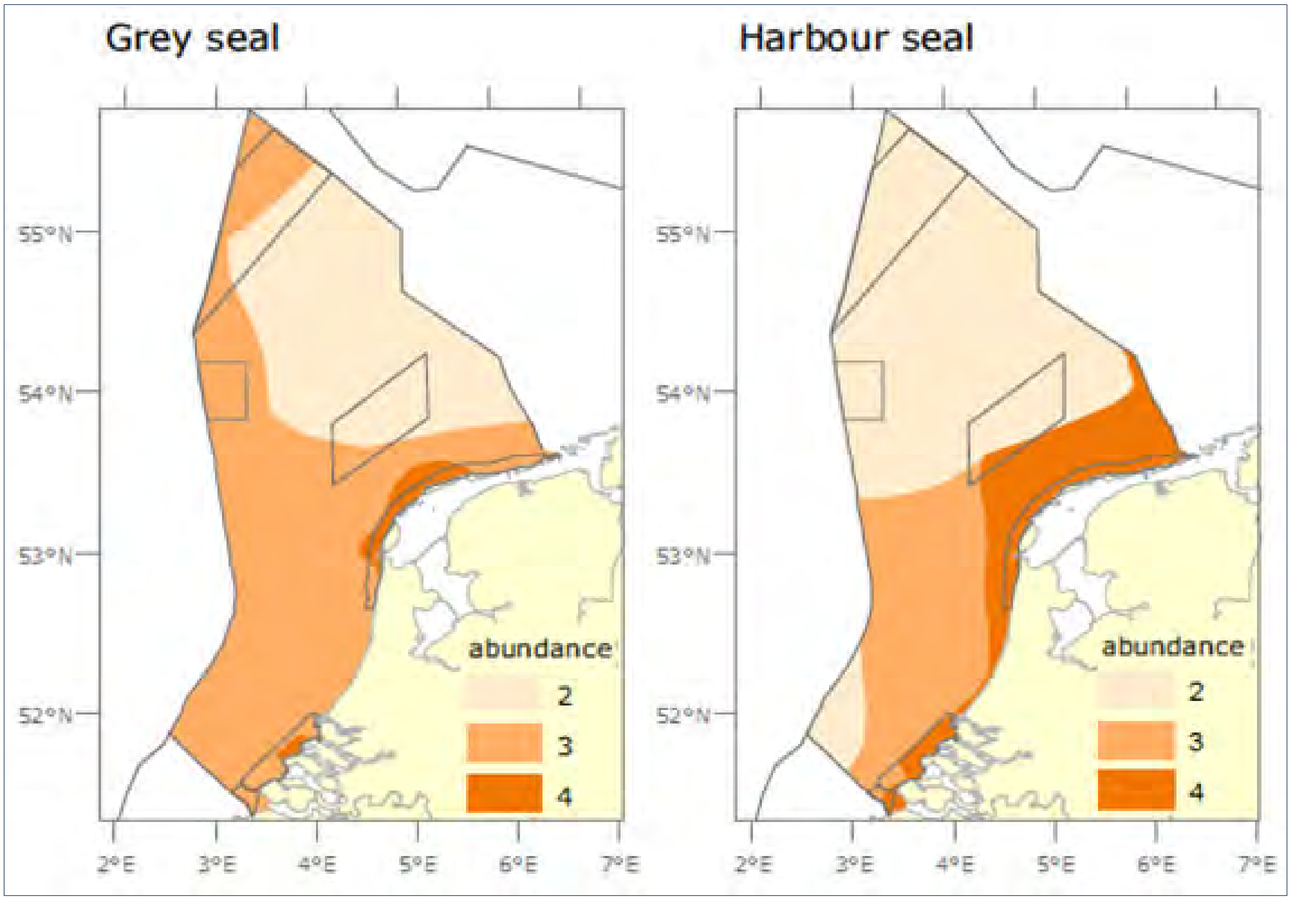


Figure 5.9: Distribution maps of grey seal and harbour seal showing roughly estimated abundances on a scale of 0 (absent) to 4 (abundant) (Bos *et al.*, 2011)

5.6.1.1 Harbour Seal (*Phoca Vitulina*)

The harbour seal is the most abundant seal species in the Wadden Sea, with an estimated population size at 38 126 animals in 2017 (Reijnders *et al.*, 1997). Dutch populations are part of the wider Eastern Atlantic population of harbour seals. Key locations for harbour seals include the Wadden Sea / North Sea Coastal Zone and delta areas in the south-west of the coast.

Breeding, pupping, and moulting are undertaken at haul out sites including sheltered estuaries and on sandbanks, but also on rocky areas (SCOS, 2020). The species breed between June and July, while the peak of the moult is in August (Jensen *et al.*, 2017).

Seal haul out sites identified from aerial surveys are shown in Figure 5.10 and highlight the concentrations of seals within the Wadden Sea and delta areas. In the Wadden Sea, harbour seal haul out sites tend to be to the east while grey seals tend to have haul out sites to the west of the Wadden Sea. Tracking of individuals prior to the construction of the Luchterduinen offshore wind farm (Kirkwood *et al.*, 2014) found considerable movement of seals throughout the North Sea coastal zone between the Wadden Sea and Voordelta areas.

Harbour seals have been reported from tagging studies to travel far away from their haul-outs and into the southern North Sea to forage but occasionally use channel areas in the Delta region (Brasseur *et al.*, 2010; Reijnders *et al.*, 2010; Aart, 2016). Their diet varies locally and also depends on seasons but broadly includes fish such as gadoids, flatfish and sand eels (Gilles *et al.*, 2008; de la Vega *et al.*, 2016). Figure 5.11 shows the locations of tagged harbour seal at sea.

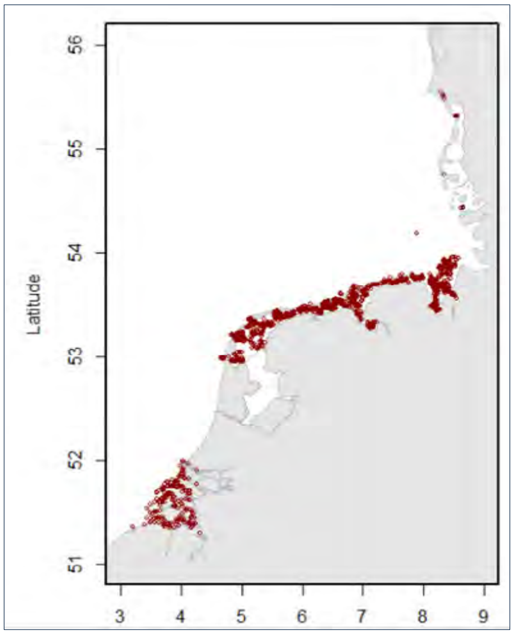


Figure 5.10 : Harbour seal haul out sites (source : Arts et al, 2016)

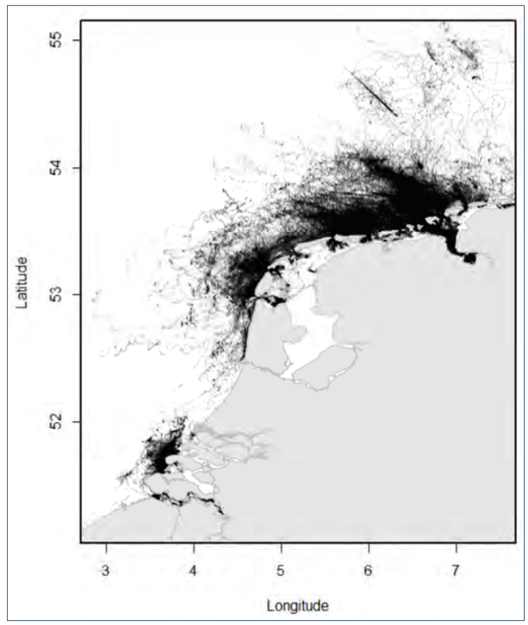


Figure 5.11: At-sea locations recorded for all harbour seals tracked for >10 d between 2007 and 2015 (source: Arts et al, 2016)

5.6.1.2 Grey Seal (*Halichoerus Grypus*)

In the past, grey seals were abundant in the Wadden Sea. However, by the 16th century, the species had completely disappeared from the area probably due to severe hunting. The species gradually returned in the mid-1900s with a small breeding colony being formed in the German part of the Wadden Sea and later in the Dutch part. Since their return, grey seal numbers have increased, with the first survey in 2006 estimating a total abundance of 2139 individuals and a 2017 survey estimating a total abundance of 5445. Furthermore, the increase of population size resulted in the expansion of their distribution in the Wadden Sea up to the Danish waters. Demographic modeling has shown that part of the increase is due to an influx of grey seals from the British Isles (Brasseur *et al.*, 2015). The Netherlands population is therefore part of the Eastern Atlantic grey seal population estimated to comprise 111 600 animals (SCOS, 2015).

The diet of grey seals has been reported to largely overlap with that of the harbour seals, feeding mainly on demersal fish species. Additionally, recent studies have reported incidents of grey seals preying on harbour seals (van Neer *et al.*, 2015) and harbour porpoises (Bouveroux *et al.*, 2014; Leopold *et al.*, 2015).

Grey seals use outlying islands and remote coastlines as moulting, pupping and general haul-out sites. They spend a high proportion of their time ashore during their pupping and moulting seasons (Hammond *et al.*, 2001). Grey seals pup from September to late November and then moult from December to April (SCOS, 2020). Satellite tracking has shown that grey seal foraging trips can extend several hundred kilometres offshore; however, most foraging tends to occur within 100 km of a haul out site (SCOS, 2020; Jones *et al.*, 2015). Locations of tracked grey seals is shown in

In comparison with harbour seals, grey seals are concentrated within the Wadden Sea and Voordelata area with individuals traversing the Dutch coast between the two sites. Overall, the range movements of grey seals are larger than those for harbour seals although use of channel areas of the Voordelta is more limited (Figure 5.12).

Figure 5.12: Locations of tracked grey seals adjacent to the coast and more broadly over the North Sea during 2013

5.6.2 Cetaceans

The study area falls within area N of the SCANS-III broad-scale cetacean survey (Hammond et al, 2021) and which covers an area of 69,386 km^2 the southern North Sea between the Dutch coastline and Dogger Bank area. Observations within this area have recorded only one species of cetacean, the harbour porpoise *Phocoena phocoena*.

Dutch reconnaissance data records the presence of minke whale *Balaenoptera acutorostrata* and white beaked dolphin *Lagenorhynchus albirostris* (Kirkwood *et al.*, 2014). Minke whales occur only rarely and tend to occur at Dogger Bank and Clover Bank only. White-beaked dolphin are similarly scarce in Dutch waters with sightings concentrated at the Brown Bank, Clover Bank and Dogger Bank. Sightings within 10 km of the coast are rare (Kirkwood *et al.*, 2014).

5.6.2.1 Harbour Porpoise (*Phocoena phocoena*)

The harbour porpoise is listed in Annex II and IV (Animal and Plant Species of Community Interest in Need of Strict Protection) of the European Commission's (EC) Habitats Directive (referred as European Protected Species). It is a protected feature of the North Sea Coastal Zone SAC, Vlakte van de Raan SAC, Dogger Bank SAC and, Clover Bank SAC. The Netherlands have produced a Harbour Porpoise plan for the conservation of the species (Camphuysen & Siemensma, 2011).

It is the most abundant cetacean in the North Sea and the only cetacean that inhabits the Wadden Sea (Jensen *et al.*, 2017). Most recent SCANS-III survey data for the wider southern North Sea (survey Block N) indicated that there are 58,066 individuals (CI 32,372 -91,372) equating to a density of 0.837 animals per km^2 (Hammond *et al.*, 2021). Density estimates within the Dutch sector up to 120 km from the coast ranged between 0.52 and 1.12 animals per km^2 (Scheidat & Verdaat, 2009). Total numbers of harbour porpoise on the Dutch Continental Shelf have been more recently estimated at 46,902 animals with highest densities occurring within offshore areas (Figure 5.13).

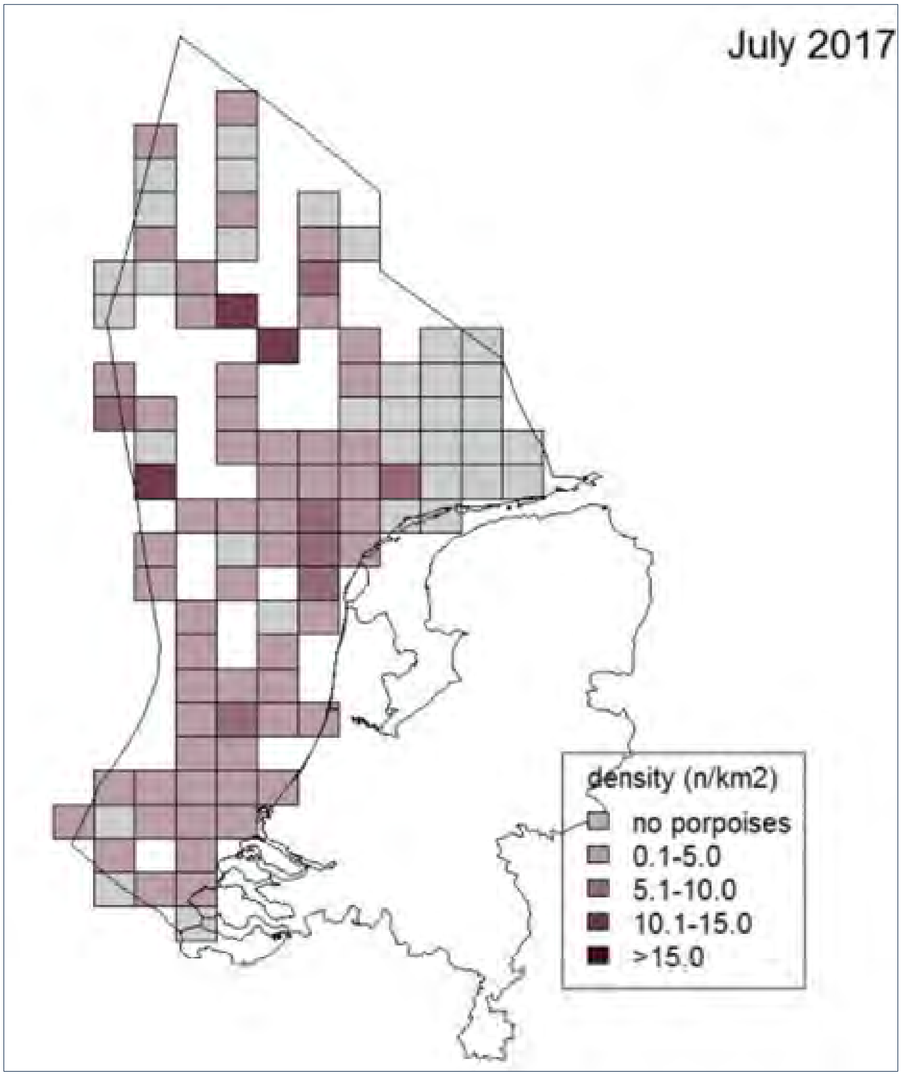


Figure 5.13: Distribution of the density of harbour porpoise from aerial survey July 2017 (source: Geelhoed et al, 2018)

The density of harbour porpoises within the region changes seasonally, increasing during late winter and early spring along the coast of the Netherlands and Lower Saxony, with high summer densities being observed in the eastern part of the German Bight along the coast of Denmark and Schleswig-Holstein (Scheidat *et al*., 2011; Thomsen *et al*., 2007; Hammond *et al*., 2002). The species distribution is mostly driven by the availability of prey species, including sand eels, gadoids, clupeids and gobids and squids (Gilles *et al*., 2009 & 2016; Leopold, 2015; Lockyer & Kinze 2003). Sexual maturity is reached at the age of 6 years in Dutch waters (Van Utrecht, 1978) and calves are born in June and July.

5.7 Seabirds

Spatial distribution maps of selected seabirds within the Dutch sector of the North Sea are taken from the North Sea Ecological Atlas (Lindeboom *et al*., 2008) and from historical data (Camphuysen & Leopold, 1994). The 2008 distribution maps are based on count data collected via aerial surveillance between 1991 and 2002 and which are supplemented by European Seabirds at Sea (ESAS) 'ship -count' data collected to help inform Marine Protected Areas (Lindeboom *et al.*, 2008). The seabirds selected for mapping were those that were important in determining site designation for protection under the EU Birds Directive and which met EU Birds Directive criteria (listed on Annex of the Birds Directive or were present at any time in numbers that equalled or exceeded 1% of their population in an area to be protected). Maximum numbers recorded during the winters of 1987 – 2003 were used for the mapping of black scoters. Aerial surveys of seabirds have also been undertaken in relation to planned offshore wind farms and from which density maps have been produced for 19 species or species groups of seabirds (Poot *et al.*, 2011).

Following on from the work of Lindeboom *et al.* (2008), important biodiversity 'hotspots' have been assessed by Bos *et al.* (2011) to inform assessment of the '*Biodiversity is maintained*' descriptor for Good Environmental Status (GES) under the EU Marine Strategy Framework Directive. This work included the development of thematic maps of bird conservation values and accounted for a wider range of species compared to Lindeboom *et al.* (2008). Assessment of the proportion of each biogeographical population of migrant seabird found within the Dutch sector was also undertaken (Bos *et al.*, 2011).

Contextual data on seabird distributions and important areas within the wider North Sea region is given by Skov *et al.*, 1995 and Stone *et al.*, 1995 based on seabird surveillance data. Site specific data on seabird abundances and are provided from monitoring surveys at offshore wind farm sites (Leopold *et al.*, 2011). Other data are sourced from public scientific literature as referenced below.

Seabirds are protected under the European Union (EU) Birds Directive, requiring the conservation of habitats in a way that allows birds to breed, moult, migrate and overwinter (EC, 2009). Species listed in Annex I of the EU Birds Directive and important habitats for migrating species are targeted for special protection measures. Furthermore, the conservation and sustainable use of migratory waterbird species is governed by the African-Eurasian Migratory Waterbird Agreement (AEMW), which is a legally binding international of which the EU is a Contracting Party. Seabird densities and species assemblies vary across the North Sea, both in space and between seasons (Camphuysen & Leopold, 1994; Skov *et al.,* 1995; Stone *et al.,* 1995; Arts & Berrevoets, 2006; Arts, 2009).

The Dutch Continental Shelf (DCS) of the North Sea is home to an ecologically diverse avian community that fluctuates in number and composition throughout the year (Fijn *et al.*, 2018; Camphuysen & Leopold 1994) and utilises the intertidal, coastal, and pelagic areas of the DCS to roost and forage (van Erp *et al.*, 2021). Barett *et al.* (2006) reported that seabird populations in the Northeast International Council for the Exploration of the Sea (ICES) region are broadly stable throughout the year, with a slight decline during spring season (February - April).

However, this statement should be treated with caution as the argument is based on few data collected in the 1970s and 1980s. Overall, publicly available information was not considered sufficient to provide advise in temporal seabird abundance/distribution in the DCS with confidence.

Numerous bird taxa have been assessed during both breeding and non-breeding seasons in the Dutch part of the North Sea. Table 5.4 presents the list of taxa potentially present within, or in the vicinity of, the proposed survey area, along with their respective IUCN status (IUCN, 2022) and EU Birds Directive criteria.

Table 5.4: Bird species potentially present within and around the area of interest

Species	Breeding	Non-breeding	Coastal		Offshore (diving/ surface foraging)	IUCN Red List Status	Annex I and/or 1% of pop.
			Diving foraging	Surface foraging			
Gavia stellata		X	X			LC	✓
Gavia arctica		X	X			LC	✓
Gavia immer		X		X		LC	✓
Gavia adamsii		X		X		VU	
Fulmarus glacialis					X	VU	1%
Morus bassanus		X			X	LC	
Phalacrocorax carbo	X		X			LC	
Gulosus aristotelis		X	X			LC	
Hydrocoloeus (Larus) minutus		X		X		LC	1%
Chroicocephalus ridibundus		X		X		LC	
Larus canus	X			X		LC	1%
Larus argentatus	X			X		LC	1%
Larus fuscus	X			X		LC	1%
Larus marinus	X			X		LC	
Rissa tridactyla		X			X	VU	
Sterna sandvicensis	X			X		LC	✓ 1%
Sterna hirundo	X			X		LC	✓
Sterna paradisaea	X			X		LC	✓ 1%
Sternula albifrons		X		X		LC	✓
Uria aalge		X			X	LC	✓ 1%
Alca torda		X			X	LC	
Podiceps grisegena		X	X			VU	
Podiceps nigricollis		X	X			VU	
Podiceps cristatus		X	X			LC	1%
Podiceps auritus		X	X			VU	✓
Aythya marila		X	X			LC	
Somateria mollissima	X		X			EN	
Clangula hyemalis		X	X			VU	
Melanitta fusca		X	X			VU	
Melanitta nigra		X	X			LC	
Bucephala clangula		X	X	X		LC	
Mergus serrator	X			X		LC	
Stercorarius pomarinus		X	X			LC	

Species	Breeding	Non-breeding	Coastal		Offshore (diving/ surface foraging)	IUCN Red List Status	Annex I and/or 1% of pop.
			Diving foraging	Surface foraging			
Stercorarius parasiticus		X	X			EN	1%
Stercorarius longicaudus		X	X			LC	
Stercorarius skua		X			X	LC	1%
Ichthyaetus melanocephalus		X		X		LC	
Chlidonias niger		X		X		LC	✓
Cepphus grylle		X	X			LC	
Alle alle		X	X			LC	
Fratercula arctica		X			X	VU	
Calidris alpina schinzii	X			X		NE	✓
Calidris pugnax	X	X				NT	
Calidris alba		X		X		LC	
Calidris canutus		X		X		LC	
Gallinago gallinago	X			X		LC	
Gelochelidon nilotica	X			X		LC	
Tadorna tadorna	X		X			LC	
Haematopus ostralegus	X			X		NT	
Recurvirostra avosetta	X			X		LC	✓
Tringa totanus	X			X		LC	
Tringa nebularia		X		X		LC	
Tringa erythropus		X		X		LC	
Limosa limosa	X			X		LC	
Limosa lapponica		X		X		LC	✓
Charadrius hiaticula	X			X		LC	
Charadrius alexandrinus	X			X		LC	✓
Vanellus vanellus	X			X		NT	
Egretta garzetta	X			X		LC	✓
Numenius phaeopus		X		X		LC	
Arenaria interpres	X			X		LC	

Notes
NE = Not evaluated
LC = Least concern
NT = Near threatened
VU = Vulnerable
EN = Endangered
IUCN = International Union for Conservation of Nature
Sources: iNaturalist (2022), IUCN (2022), Asjes *et al.*, (2021), Paruk, *et al.*, (2021), Butler *et al.*, (2020), Brown & Fredrickson, (2020), Enners *et al.*, (2019), Koffijberg *et al.*, (2017), Van Gils *et al.*, (2015), Leopold *et al.*, (2013), Crowe *et al.*, (2009), Poot *et al.*, (2009), Norton-Griffiths, (2008), Vandendriessche *et al.*, (2007), Scheiffarth, (2001), Atkinson, (1996), amas (1990) and Eriksson, (1976)

Many of the species listed above are temporary (seasonal) visitors including summer migrants which use parts of the Dutch coast for breeding and as well as winter migrants which use coastal wetlands and sediment flats and offshore marine areas for over-wintering. Table 5.5 presents migratory seabird species recorded within the Dutch sector of the North Sea together with the season in which they appear and their maximum recorded population sizes in the Netherlands.

This shows that the Dutch coast and marine environments support significant numbers of several species of migrants (supports 1% of the total biogeographical population) including winter populations of red throated divers, great crested grebe, northern gannet, greater scaup, common eider, herring gull, great black-backed gull, black-legged kittiwake, guillemot and razorbill and summer populations of great cormorant, little gull, sandwich tern and little tern. Great skua and common tern occur in significant numbers in autumn.

Table 5.5: Migratory seabirds and population sizes in the Dutch sector of the North Sea (source: Bos *et al.*, 2011)

Species	Scientific Name	Biogeographical Population Size (x1000)	Maximum Number in Dutch Sector	Max. %	Season
Red/throated Diver	*Gavia stellata*	183/420	9800	5.4 (19.6)	Win
Black/throated Diver	*Gavia arctica*	360/690	400	0.1	Win/Migr
Great Crested Grebe	*Podiceps cristatus*	370/580	21 100	4.4	Win
Red/necked Grebe	*Podiceps grisegena*	90/420	50	0.1	Win
Northern Fulmar	*Fulmarus glacialis*	10000	95 800	1	Aug/Sep
Northern Gannet	*Morus bassanus*	892	25 600	2.9	Aut
Great Cormorant	*Phalacrocorax carbo*	276/342	4000	1.3	Sum
Greater Scaup	*Aythya marila*	310	5000	1.6	Win
Common Eider	*Somateria mollissima*	850/1200	70 000	6.8	Win
Long/tailed Duck	*Clangula hyemalis*	4600	60	0	Win
Common Scoter	*Melanitta nigra*	1600	110 000	6.9	Win
Velvet Scoter	*Melanitta fusca*	1000	5000	0.5 (1.2)	Win
Common Goldeneye	*Bucephala clangula*	400	500	0.1	Win
Red/breasted Merganser	*Mergus serrator*	170	250	0.1	Win
Parasitic jaegar/Arctic Skua	*Stercorarius parasiticus*	55	300	0.5	Aut
Great Skua	*Stercorarius skua*	27	1500	5.5	Aug/Sep
Mediterranean Gull	*Larus melanocephalus*	570/1110	100	0	Sum
Little Gull	*Larus minutus*	66/102	14200	16.9	Spr/Sum
Black/headed Gull	*Larus ridibundus*	5600/7300	24900	0.4	Win
Common Gull	*Larus canus*	1300/2100	61500	3.6	Win
Lesser Black/backed gull	*Larus fusus*	525	82900	15.8	Spr/Sum
Herring Gull	*Larus argentatus*	1090	139 200	12.8	Win
Great black-backed Gull	*Larus marinu*	420/510	36000	7.7	Win
Black-legged Kittiwake	*Rissa tridactyla*	8400	155 700	1.9	Win
Sandwich Tern	*Sterna sandvicensis*	159/171	7000	4.1	Spr/Sum
Common Tern	*Sterna hirundo*	500/1000	10 600	1.4	Aug/Sep
Arctic Tern	*Sterna paradisaea*	1320/2280	1000	0.1	-
Comic tern	*S. hirundo/S. paradisaea*	1000	-	0	-
Little Tern	*Sterna albifrons*	31/32	500	1.6	Spr
Common Guillemot	*Uria aalge*	8000	133 185	1.7	Aut
Large alcid	*Uria aalge*	6600	157 400	2.4	Aut/Win
Razorbill	*Alca torda*	2400	24215	1	Win
Little Auk	*Alle alle*	1500	4300	0.3	Win

Species	Scientific Name	Biogeographical Population Size (x1000)	Maximum Number in Dutch Sector	Max. %	Season
Atlantic Puffin	*Fratercula arctica*	12000	820	0	Win

5.7.1 Important species

Important species are identified in this DTS with reference to the International Union for Conservation of Nature (IUCN) red list which recognises and classifies species considered to be of conservation concern. Important species also include those listed within Annex I of the EU Birds Directive and/or for which populations exceed 1 % of national and international populations (see Table 5.5 above).

Common eiders (*Somateria mollissima*) and parasitic jaegers (*Stercorarius parasiticus*) are assessed as 'endangered' according to the IUCN Red List of species (2022) meaning that there is a very high risk of these species becoming extinct in the wild. With reference to Table 5.5, common eiders are present in significant numbers in winter.

The eider duck (*Somateria mollissima*) has been reported to decrease in numbers during the last two decades in Dutch waters and their presence is considered to be related to the decline of mussels (*Mytilus edulis*) (Cervencl *et al.*, 2015) upon which they prey. The Netherlands makes up the southern border of their nesting area and 10 000 nesting pairs are estimated to inhabit Dutch waters (Noordzeeloket, 2022).

The parasitic jaeger *(Stercorarius parasiticus)*, also known as the Arctic skua, Arctic jaeger or parasitic skua, has an extremely large range, but as with many seabird populations it has declined substantially over the past decades (Frederiksen, 2010). The species relies on host species for their food provisioning (kleptoparasites), with their breeding success often linked with their hosts (Phillips *et al.*, 1996). Moreover, studies from Scotland demonstrated that their reproductive success is directly influenced by the declining availability of pelagic forage fish, in particular lesser sand eels *Ammodytes marinus*; (Phillips *et al.*, 1996, Miles *et al.*, 2015). The species is an autumn migrant to Dutch offshore waters.

Northern fulmars (*Fulmarus glacialis*), black-legged kittiwakes (*Rissa tridactyla*), yellow-billed loons (*Gavia adamsii*), red- and black-necked grebes (*Podiceps grisegena* and *Podiceps nigricollis*), horned grebes (*Podiceps auratus*), long-tailed ducks (*Clangula hyemalis*), velvet scoters (*Melanitta fusca*) and Atlantic puffins (*Fratercula arctica*) are classified as 'vulnerable' by the IUCN, meaning that they are considered to be at high risk of unnatural (human-caused) extinction without further human intervention.

Ruffs (*Calidris pugnax*), Eurasian oystercatchers (*Haematopus ostralegus*) and northern lapwings (*Vanellus vanellus*) are assessed as 'near threatened' whereas all of the remaining taxa (except for dunlins (*Calidris alpina schinzii* – 'not evaluated')) are of 'least concern'.

5.7.2 Seabird abundance and distribution

Figures 0.019 to 0.022 show distributions of selected seabirds at sea within the Dutch sector based on aerial surveillance and supplemented by European Seabirds at Sea (ESAS) 'ship -count' data as explained above (Lindeboom *et al.*, 2008).

The timing of the EBS is outside of the main breeding season and so effects on bird breeding are not expected due to proposed EBS activities. Many of the bird species listed in Table 5.5 appear in the greatest numbers during winter months. The EBS is planned for October and may therefore coincide with the commencement of the arrival of these wintering species.

From observations at offshore wind farms (Egmond aan Zee and Princess Amalia) (Leopold *et al.*, 2011), typical seabird species characterising nearshore areas between September and November included divers (mostly red-throated divers), grebes, common scoter (*Melanitta nigra*) and gulls whereas birds found away from the coast at this time of year included gannet (*Morus bassanus*), northern fulmar (*Fulmaris glacialis*), black-legged kittiwake (*Rissa tridactyla*), razorbill (*Alca torda*) and guillemot (*Uria aalge*).

Over the course of the observation period at Egmond aan Zee and Princess Amalia it was generally noted that large gulls were the most numerous species and were frequently seen following fishing vessels in pursuit of discards. Common gulls, lesser black-backed gulls, herring gulls were reported to occur throughout most of the year. Great black-backed gulls and kittiwakes visit the Dutch coastline outside of the breeding season and were recorded most frequently in winter and early spring. Similarly, guillemots (*Uria aalge*) and razorbills (*Alca torda*) are autumn/winter visitors to the Netherlands remaining relatively dispersed in offshore waters at this time. Little gulls may also occur far offshore during winter for resting or feeding (Leopold *et al.*, 2011).

Divers, grebes, and sea ducks are generally distributed close to the shore although larger numbers can be found offshore in some years possibly due to spring migration movements (Leopold *et al.*, 2011). Cormorants similarly tend to stay close to the coast throughout the year although the presence of offshore wind farms can provide resting stages and perches for fishing and appear to have allowed for their range expansion offshore.

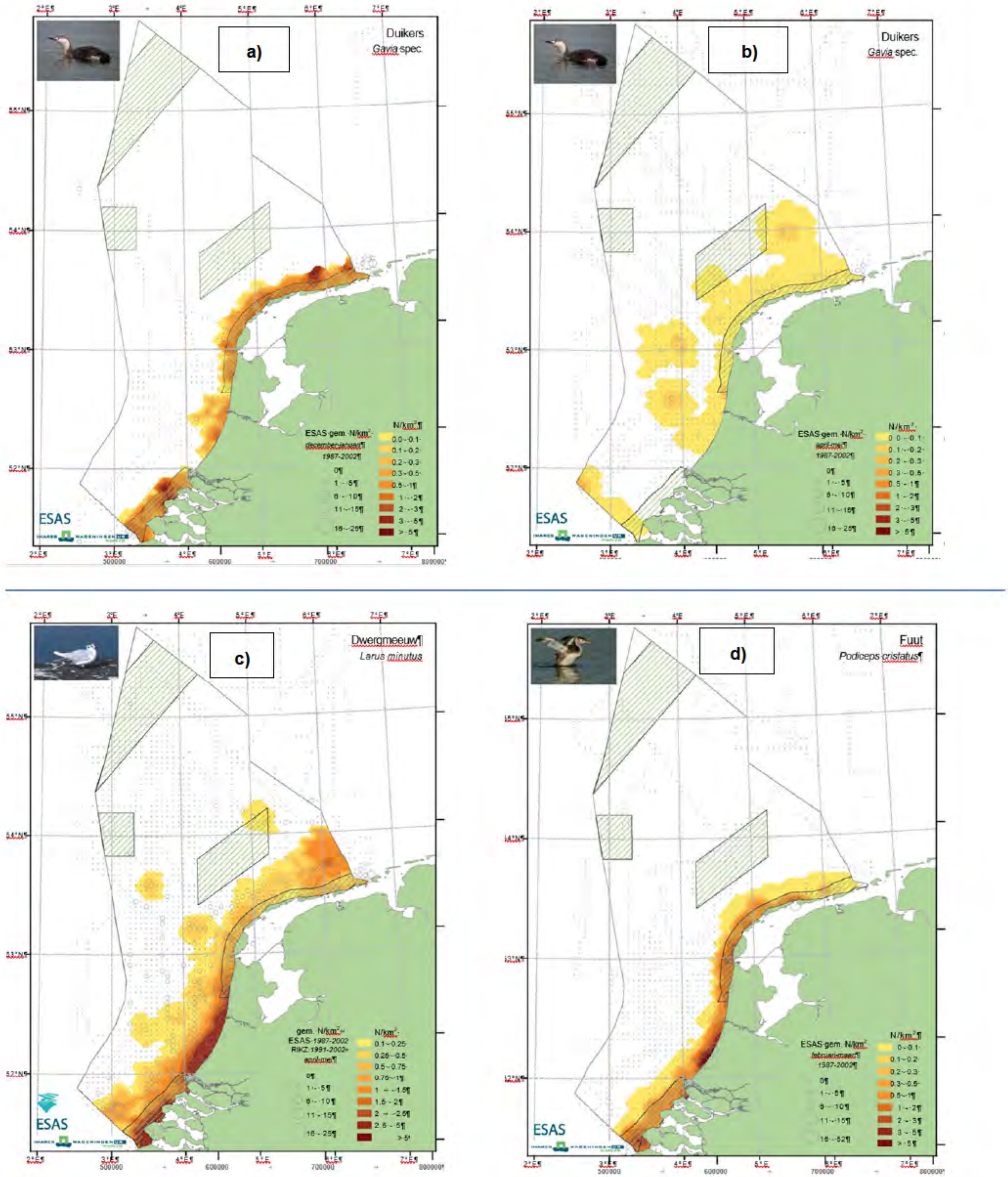


Figure 5.14: Distribution of a) all divers (winter), b) all divers (spring) c) Little gull and d) Great-crested grebe

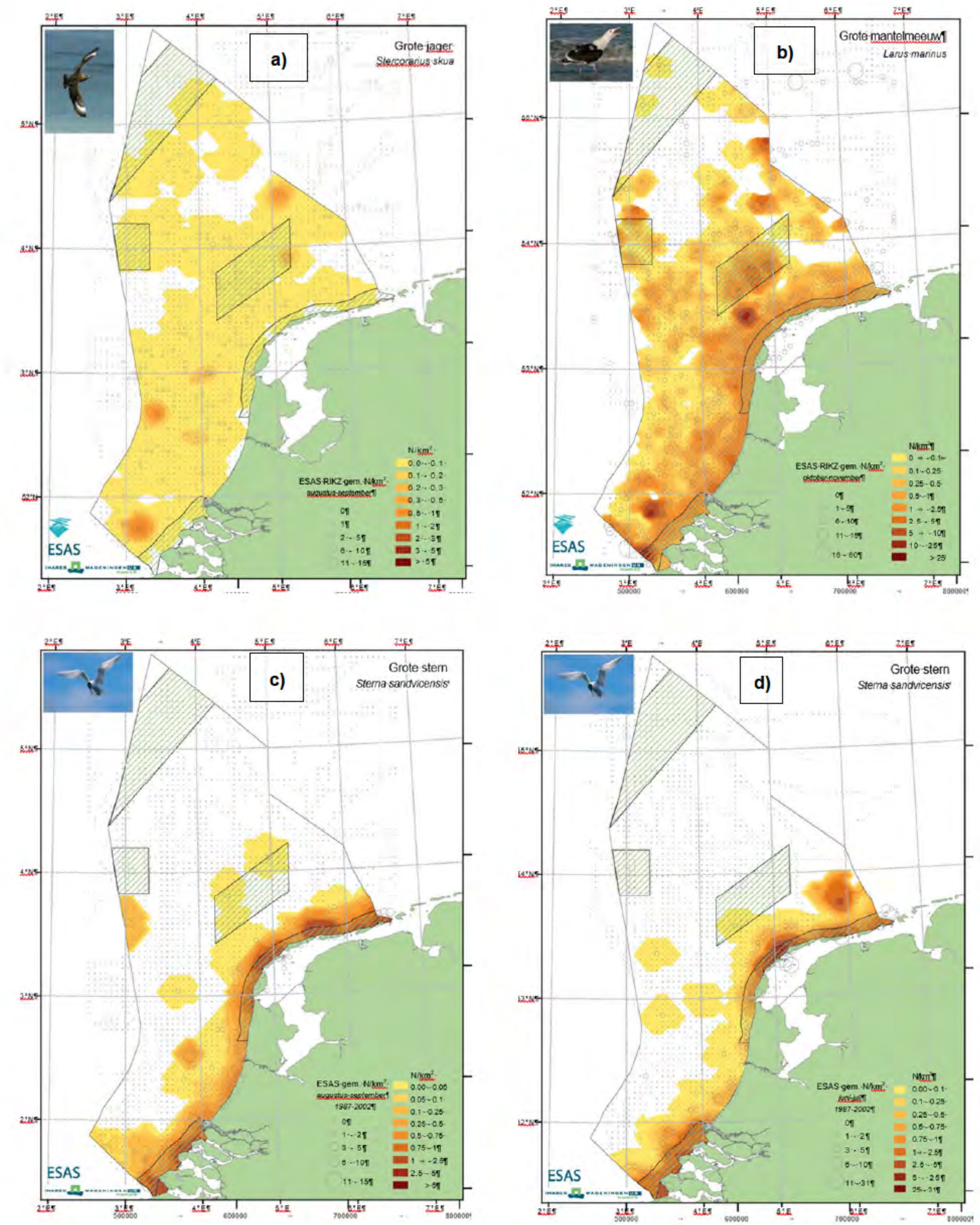


Figure 5.15: Distribution of a) Great skua, b) Great black-backed gull c) Sandwich tern (autumn) and d) Sandwich tern (summer)

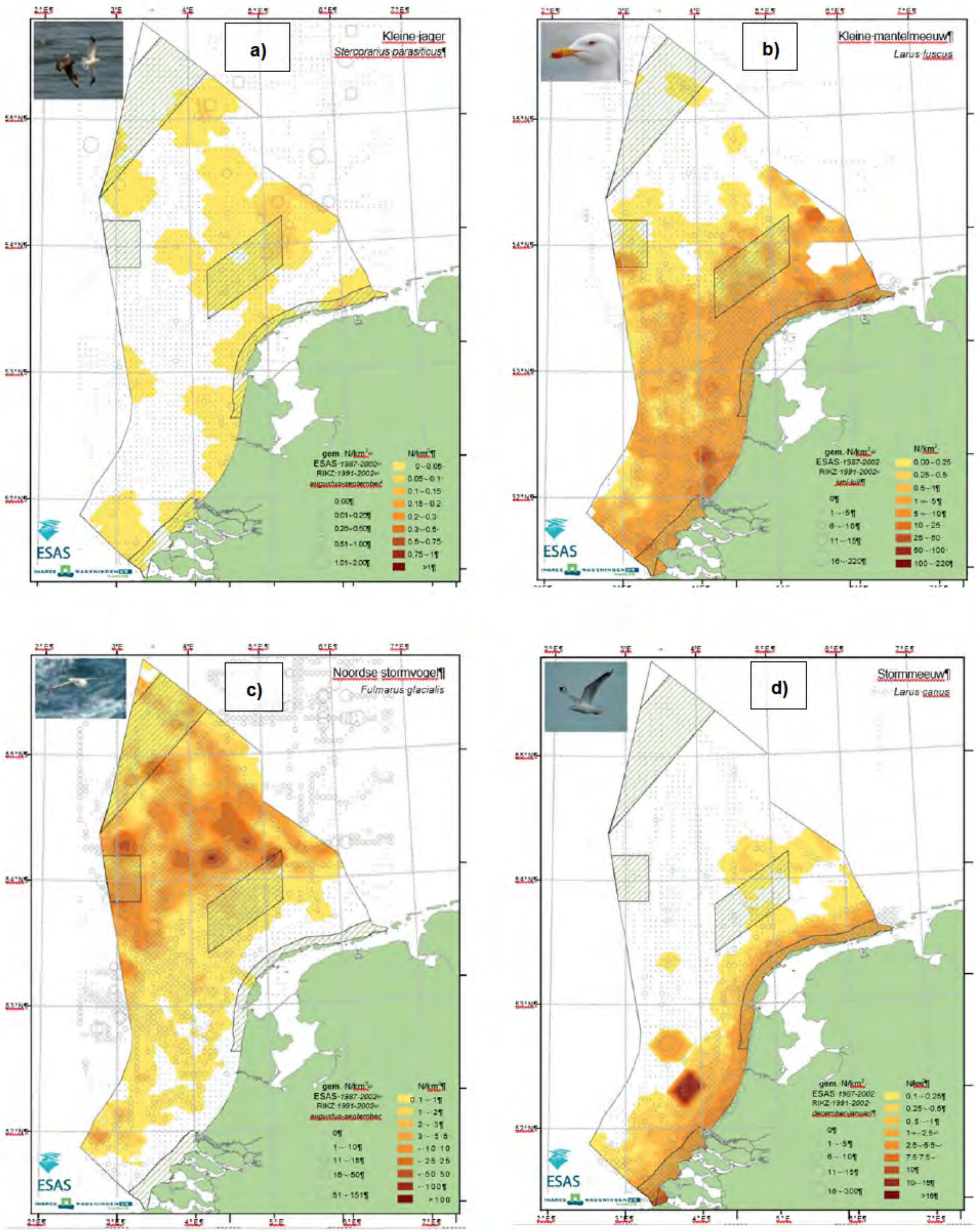


Figure 5.16: Distribution of a) Parasitic jaegar, b) Lesser black-backed gull, c) Northern fulmar and d) Common gull

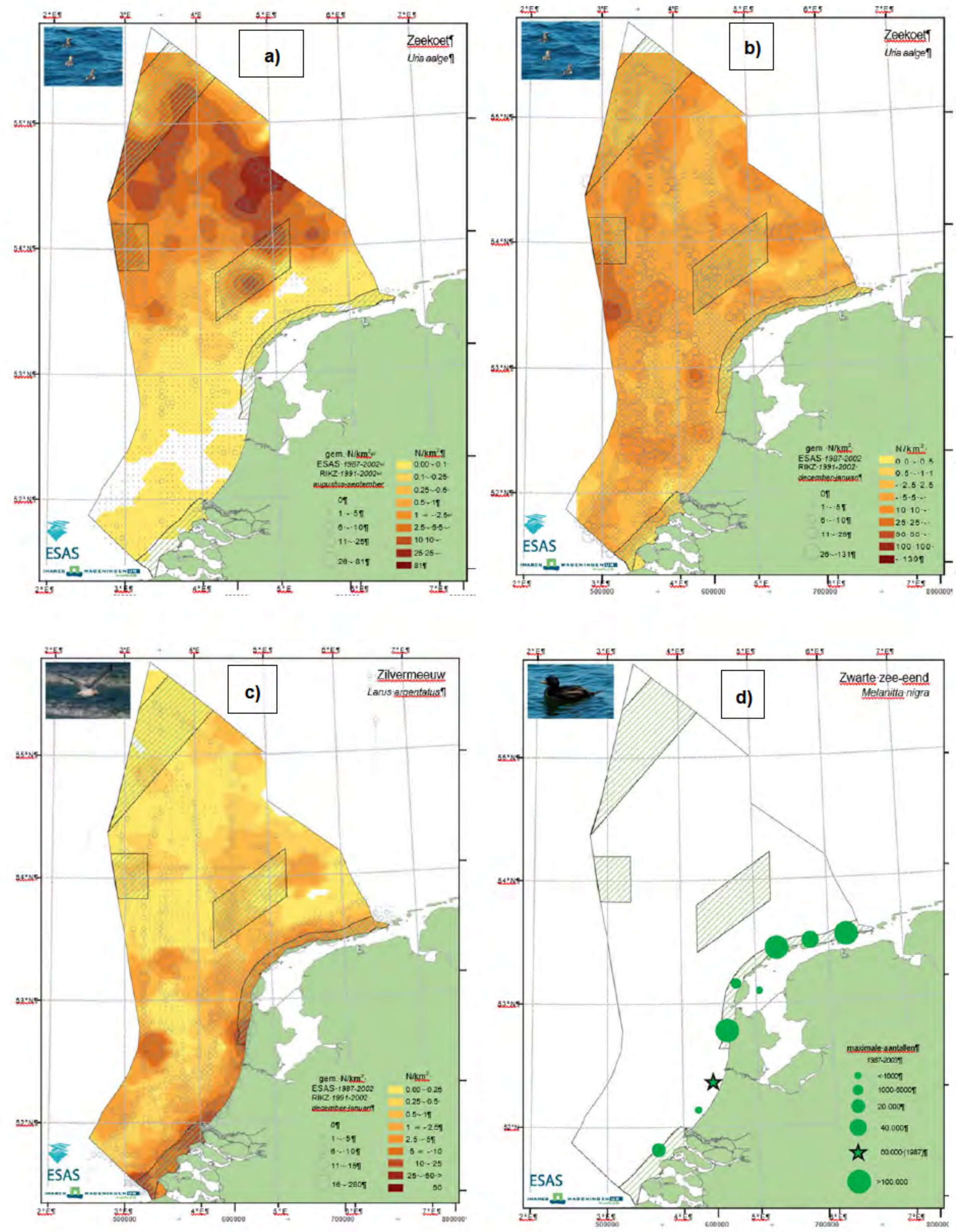


Figure 5.17: Distribution of a) Guillemot (autumn), b) Guillemot (winter), c) Herring gull and d) Black scoter

5.7.3 Important Bird Areas

Important bird areas include the Frisian Front, Brown Bank, Voordelta, and North Sea Coast Zone. The latter two sites provide high quality intertidal and wetland habitats for numerous over-wintering waders and wildfowl species, shingle beach habitat for summer breeding species, such as terns and shallow nearshore sediment areas supporting pelagic fish such as sprat, herring and also sand eels for bird feeding. The Frisian Front is a hydrodynamic front located offshore and represents a localised area of high productivity attracting high concentrations of fish and seabirds for feeding. The Brown Bank represents an expansive sandy area of seabed with sand banks that can be up to 20 m in height. The area attracts seabirds, fish, and marine mammals for feeding and is an important spawning area for fish such as cod, herring and mackerel area.

The availability of high quality habitat at these locations is recognised through the statutory designations of these sites as protected areas including Special Protection Areas (SPA) under the EU Birds Directive, Special Areas of Conservation (SAC) under the EU Habitats Directive, Ramsar sites under the Ramsar Convention and Marine Protected Area (MPA) under the OSPAR framework (see Chapter 2: Conservation Designations). Skov et al (1995) notes that red-and black throated divers, great crested grebe, common scoter, kittle gull, herring gull, lesser black-backed gull and Sandwich tern occur in internationally important numbers along the Dutch coast and adjacent costs between Gris Nez and Schierrmonnikoog highlighting the important of the Dutch coastal zone in general to seabirds (see also Table 5.5).

In addition to the designated sites for birds, a total of six marine areas within Dutch waters have been proposed as candidate important bird areas (IBA) (Vreeswilk *et al.*, 2019). Further analysis is required to determine whether they fulfil the relevant criteria for full designation. The Brown Bank (Bruine Bank) has also been recognised as important for seabirds (Skov et al, 1995; Garcia et al, 2019) including guillemots and razorbills.

Protected sites for birds and candidate IBAs identified to date are summarised in Table 5.6. Important birds' areas are presented in Figure 5.18.

Table 5.6: Protected areas for birds and candidate marine IBAs and qualifying / potential qualifying species

Site Name	Species name	Scientific name
Protected Sites for Birds		
Frisian Front (SPA)	Great skua Great black-backed gull Common guillemot Lesser black-backed gull	*Stercorarius skua* *Larus marinus* *Uria aalge* *Larus fuscus*
Voordelta (SPA, Ramsar, SAC, MPA)	Thirty seabird species including the following IUCN red list species; Horned grebe (VU)	*Podiceps auratus* *Somateria mollissima* *Melanitta nigra*

Site Name	Species name	Scientific name
	Common eider (EN) Black scoter (VU) Oystercatcher (NT)	*Haematopus ostralegus*
North Sea Coast Zone SPA, SAC, Ramsar, MPA	Twenty seabird species including the following IUCN red list species; Common eider (EN) Black scoter (VU) Oystercatcher (NT)	*Somateria mollissima* *Melanitta nigra* *Haematopus ostralegus*
Brown Bank SPA	Little gull Gannet Great skua Common guillemot Razorbill Great black backed gull	*Larus mainus* *Morus bassanus* *Stercorarius skua* *Uria aalge* *Alca torda* *Larus marinus*
Candidate IBAs		
Borkumse stenen	Sandwich Tern	*Thalasseus sandvicensis*
	Lesser black-backed gull	*Larus fuscus*
	Red-throated diver	*Gavia stellatus*
Centrale Oestergronden	Lesser black-backed gull	*Larus fuscus*
Doggersbank	Great cormorant	*Phalacrocorax carbo*
	Guillemot	*Uria aalge*
Klaverbank	To be identified	-
Vlakte van de Raan	Lesser black-backed gull	*Larus fuscus*
	Red throated diver	*Gavia stellatus*
Zeeuwse Banken	Little gull	*Hydrocoloeus minutus*
	Sandwich tern	*Thalasseus sandvicensis*
	Lesser black-backed gull	*Larus fuscus*
	Red-throated diver	*Gavia stellatus*

Notes:
NT = Near threatened
VU = Vulnerable
EN = Endangered
IUCN = International Union for Conservation of Nature
IBA = Important bird areas
SPA = Special Protection Areas
SAC = Special Areas of Conservation
MPA = Marine Protected Area

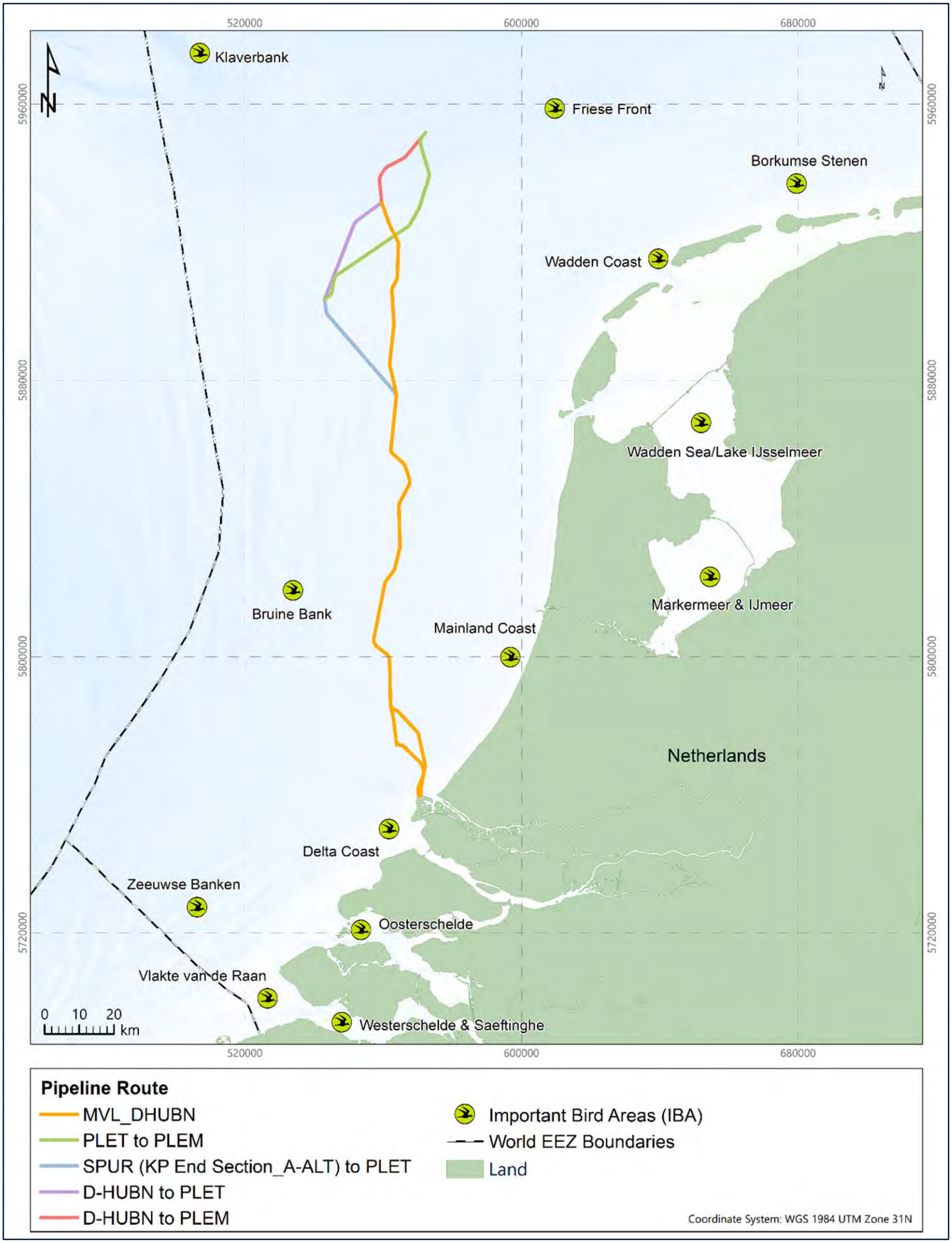


Figure 5.18: Location of important bird areas

6. Other Uses of the Sea

6.1 Commercial Fishing

Fisheries policy for the North Sea is made by the EU and commercial fisheries fall under the Common Fisheries Policy, which aims to prevent overfishing and ensure sustainable fish stocks. All North Sea fisheries must comply with the EU regulations. Dutch rules regulate fishing in coastal and inland waters, whereas the EU and the Dutch government promote the development of sustainable fishing methods by the fishing industry. There are 11 Producer Organisations in the Netherlands which implement the requirements of the Common Fisheries Policy and coordinate their members (https://oceans-and-fisheries.ec.europa.eu/system/files/2022-07/list-of-recognised-producer-organisations-and-associations-of-producer-organisations_0.pdf).

The Dutch commercial fleet comprises over 800 vessels and includes the coastal and North Sea fishery, industrial maritime fishery (pelagic freezer trawlers), shellfish fishery and trammel fishery. Important species targeted by the fleets include sole, plaice *Nephrops* (langoustine), herring, mackerel, brown shrimps (*Crangon* spp.) mussels and oysters. Fish sales in 2021 was €336M (https://www.eumofa.eu/documents/20178/61322/Netherlands.pdf). The distribution of average annual fishing intensities is shown in Figure 6.1.

A detailed review of commercial fishing is being undertaken elsewhere and is not considered further in this desk top study. With respect to the forthcoming EBS however, it will be necessary to issue a Notice to Mariners (NtM) to inform fishers (and other mariners) as to the planned EBS activities, including the timings of the survey, the locations of the survey, the vessel to be used and associated call sign and contact information and any spatial restrictions that need to apply.

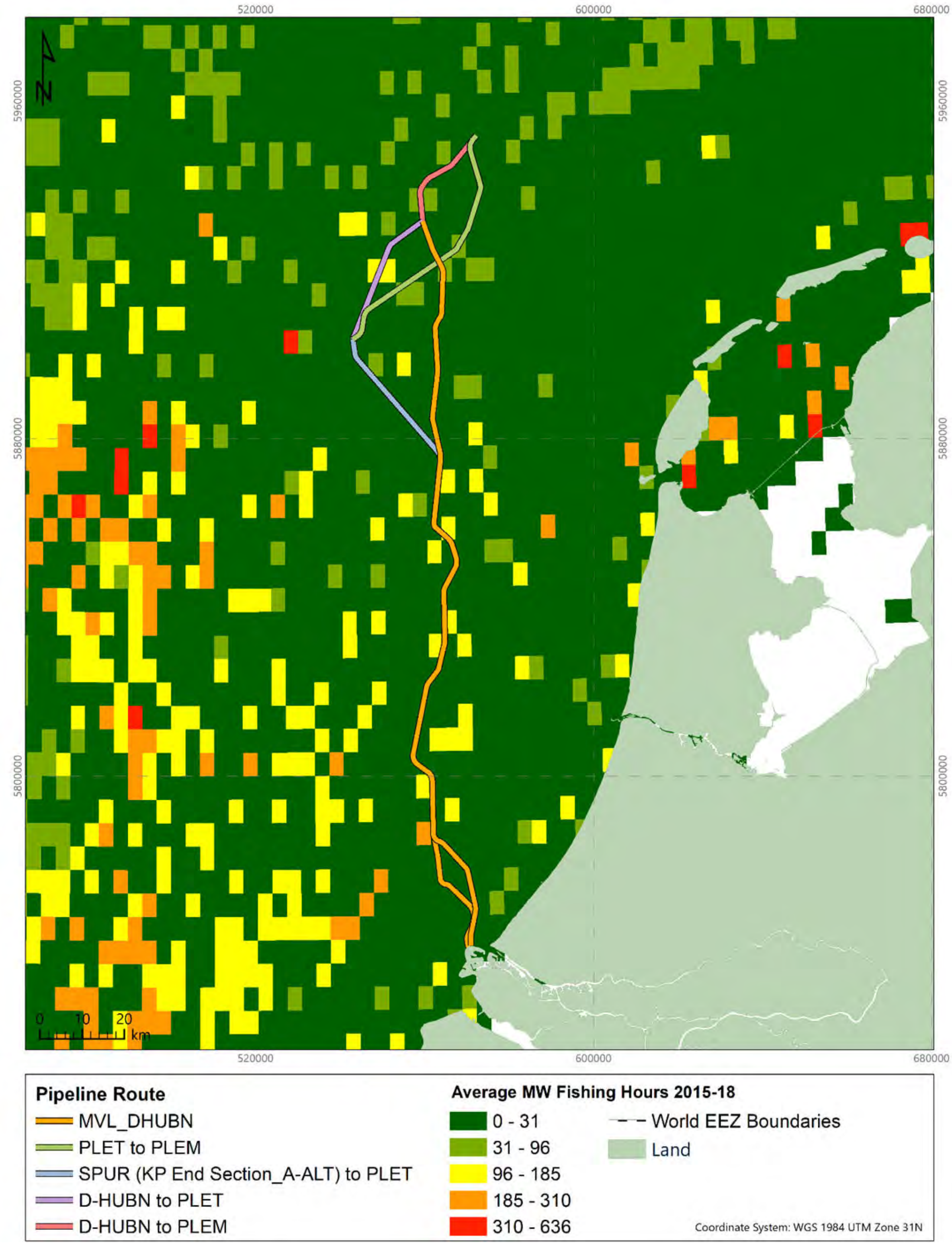


Figure 6.1: Spatial distribution of average annual fishing effort (2015-2018) (source: EMODnet, 2022)

6.2 Shipping

The distribution of annual (2020) average ship traffic densities is presented in Figure 6.2 and shows comparatively intense activity over the southern extents of the proposed route.

The Marine Strategy for the Netherlands recognises the North Sea as an important hub in the international transport network, with some 260,000 shipping movements in the Netherlands part of the North Sea as a whole. Important seaports along the Dutch coast include The Port of Rotterdam, the Port of Amsterdam, Port of Moerdijk, Zeeland seaports and Groningen Seaports.

New shipping routes through Dutch waters were modified in collaboration with the International Maritime Organisation (IMO), and other stakeholders in 2013 for the purposes of optimizing vessel safety and accessibility to the major seaports and avoiding new offshore wind farms and oil and gas structures.

The southern extent of the proposed pipelines and forthcoming EBS in close proximity to the port of Rotterdam and coincides with the outer Port channel area which is dredged. Overall, the port's throughput of commodities exceeded 468 million tonnes in 2021 including coal and oil and agricultural products in addition to ferry traffic and it remains one of the world's busiest sea ports.

The Dutch Hydrographic Service updates navigational charts and publications and informs mariners on matters of shipping routes, the seabed, and underwater hazards such as shipwrecks.

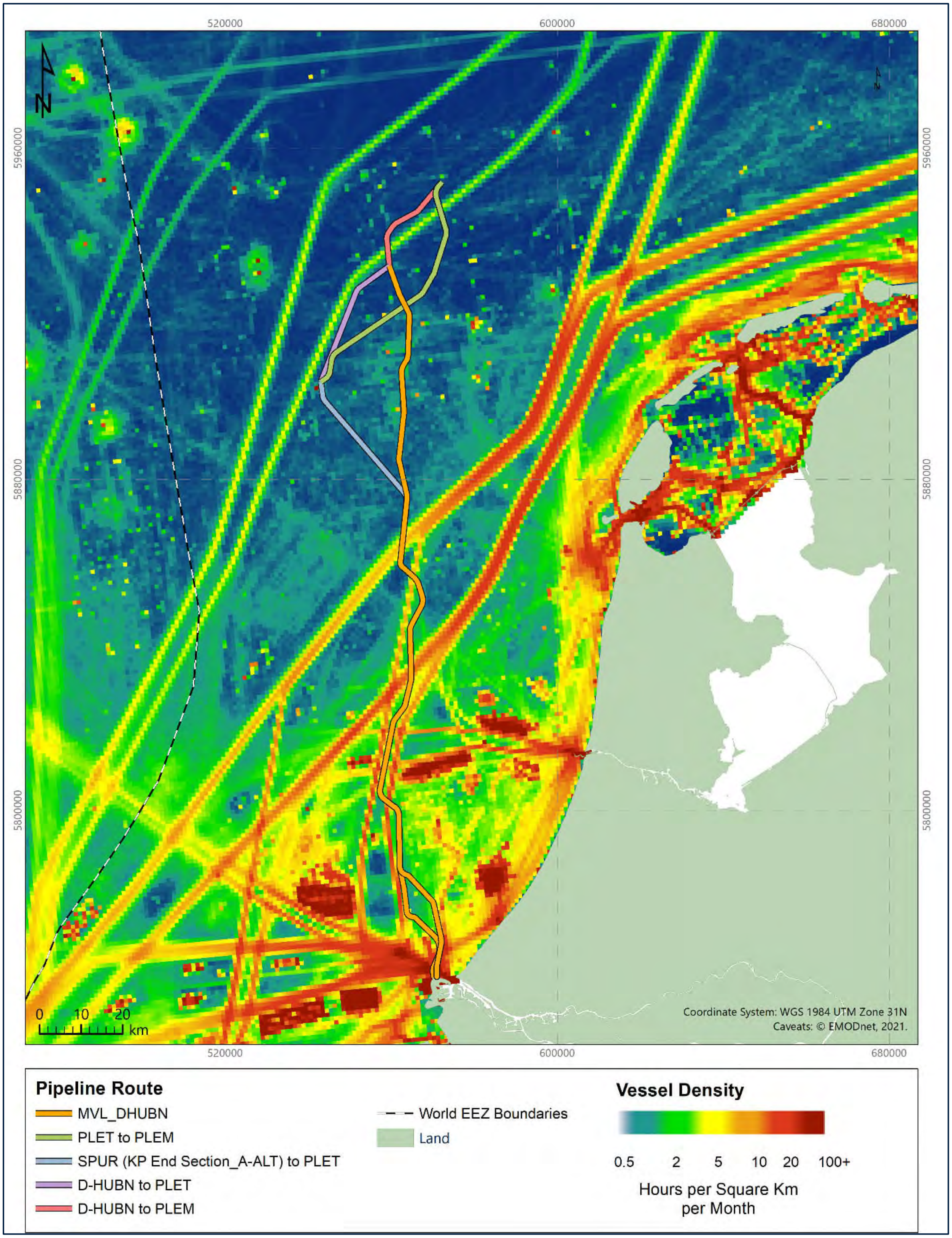


Figure 6.2: Average vessel density over a one-year period (2020)

6.3 Seabed Infrastructure

6.3.1 Oil and Gas Infrastructure

Numerous oil and gas infrastructure (e.g., pipelines or platforms) are present in the vicinity of the proposed pipeline routes. Figure 6.3 shows the locations of oil and gas fields and other infrastructure in relation to the proposed pipeline. Figure 6.4 shows the locations of existing pipelines within the vicinity of the proposed Aramis project.

The MVL_DHUBN section of the proposed pipeline route passes through several oil and gas fields. These include: Q16-FA, a gas field operated by Total Energies, Vermilion Energy, ONE-Dyas and EBN; Q16-Maas, a gas field operated by ONE-Dyas BV and TAQA Offshore BV; Q16-Maasmond, an oil field owned by ONE-Dyas; several P18 gas fields (P18-2, P18-7, P18-6) owned by TAQA Offshore BV; P12-C, a gas field operated by Wintershall, and the K12 and K15 gas fields operated by Gaz de France Suez and Nederlandse Aardolie Maatschappij respectively.

The PLET to PLEM section of the proposed pipeline route passes through L10-S3, a gas field operated by Placid International Oil Limited, Gaz de France Suez and Neptune Energy.

The SPUR to PLET section of the proposed pipeline route passes through K14-FA, a gas field operated by Nederlandse Aardolie Maatschappij.

The DHUBN to PLET section of the proposed pipeline route passes through K12-A and K09c-B, gas fields operated by Gaz de France and Neptune Energy respectively.

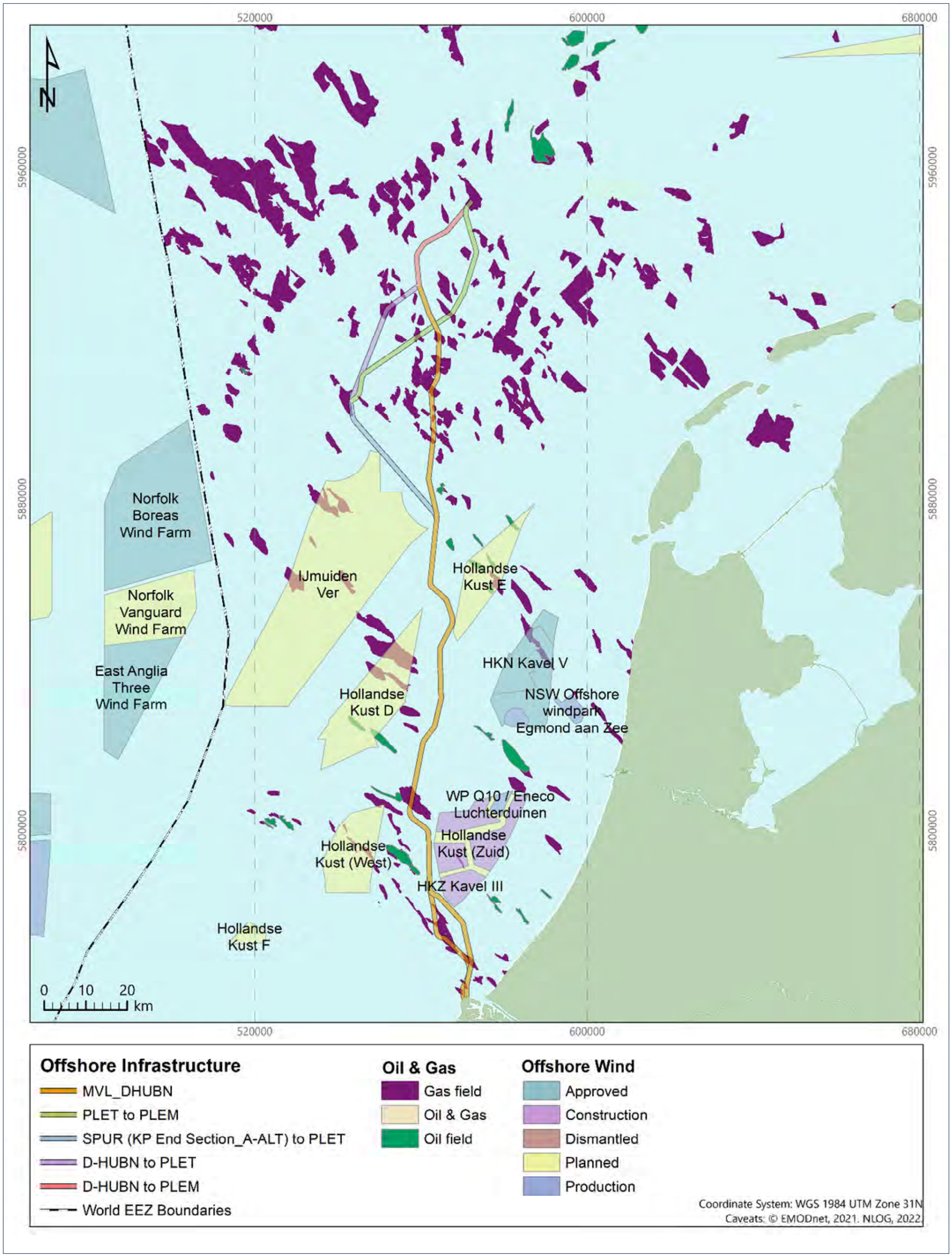


Figure 6.3: Existing infrastructure and areas used by others within/in the vicinity of the proposed pipeline routes

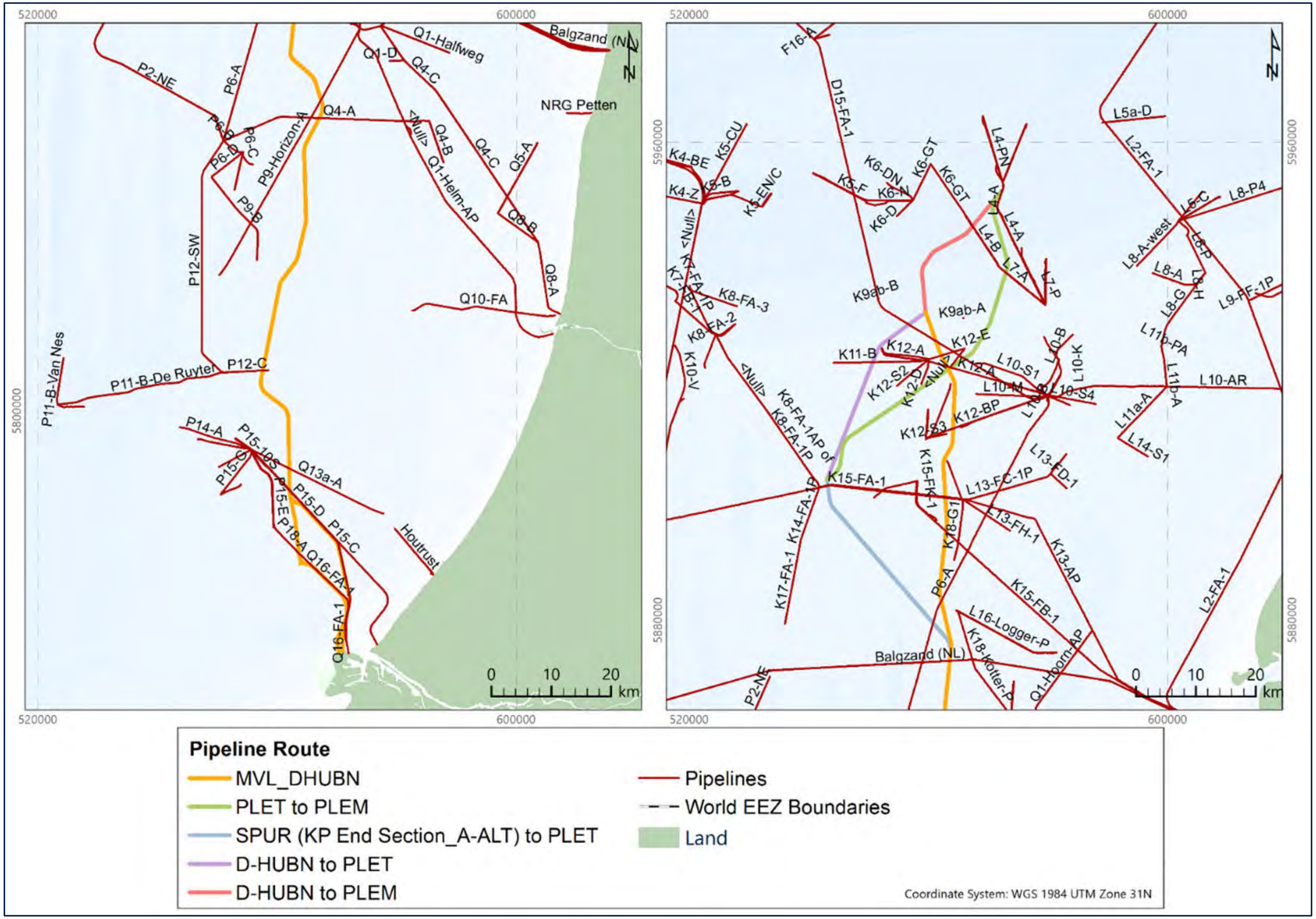


Figure 6.4: Locations of existing pipelines in relation to the Aramis project

6.3.2 Submarine Cables

Numerous telecommunication and power cables exist within and in the vicinity of the proposed pipeline routes (Table 6.1; Figure 6.5).

Typically, grab or core sampling would not be undertaken within 250 to 500 m of a cable (depth depending) although sampling may be undertaken at closer distances where the position of the cable on the seabed is known to a high degree of confidence or where prior survey, i.e., video or magnetometer, confirms that the seabed is clear of any obstructions.

Liaison with submarine cable operators before, during and after the completion of the proposed EBS work may be required to notify owners of intended survey operations.

Table 6.1: Submarine cables in the vicinity of the proposed pipeline routes

Cable	Type	Connecting countries	Owner(s)	Crossings
Concerto 1	Submarine telecommunications cable system	UK, Belgium, Netherlands	EXA Infrastructure	2
TAT14* (decommissioned)	Transatlantic telecommunications system	Europe, USA	Consortium owners comprising AT&T	1
Circe North	Submarine telecommunications cable system	UK, France, Germany, Belgium, Netherlands	Consortium owners comprising euNetworks and VTL Wavenet.	1
Atlantic Crossing-1 (AC-1)	Optical submarine telecommunications cable system	Europe, USA	Lumen	1
Ulysses	Submarine telecommunications cable system	UK, France, Germany, Belgium, Netherlands	Verizon	1
UK-Netherlands 14	Fiber optic submarine telecommunications cable system	UK, Netherlands	Consortium owners comprising BT, KPN and Vodafone	1
SeaMeWe-3	Optical submarine telecommunications cable	South-East Asia, the Middle East and Western Europe	Consortium owners comprising AT&T, BT, erizon and Vodafone	1
Notes: * = currently inactive				

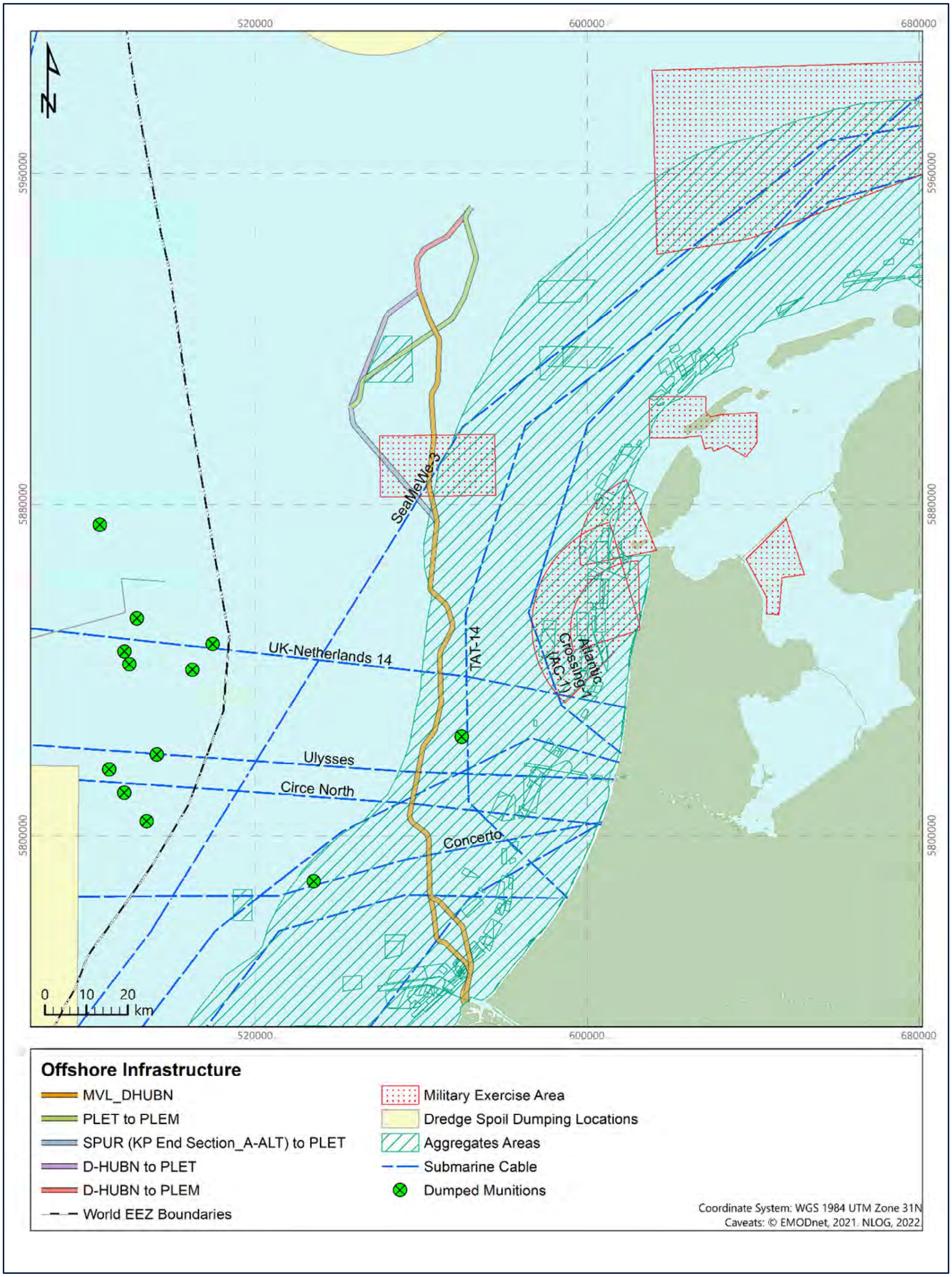


Figure 6.5: Offshore infrastructure (military exercise areas, dredge spoil grounds, aggregate extraction (source: EMODnet, 2022)

6.3.3 Offshore Wind Farms

The Netherlands has an ambitious plan for the construction of offshore wind farms as part of its energy transmission goals and to meet climate obligations made under the Paris Agreement. Figure 6.3 shows the locations of offshore wind farms (planned, in construction, operating) within the vicinity of the proposed cable routes. Minimum safety distances from operating wind farms and construction areas will need to be maintained during the EBS.

6.3.4 Aggregate Extraction

Aggregate extraction activities for coastal nourishments and construction are found in the vicinity of the proposed pipeline routes (Figure 6.5). Approximately 24 000 000 m^3 of sand is extracted and used annually. It is projection that than 40-85 000 000 m^3 will need to be extracted to counteract effects of future sea level rise expected (Deltacommissie, 2008).

6.3.5 Military Exercise Areas

Areas utilised by the Dutch military for surface exercises and firing are found within the vicinity of the proposed survey area (Figure 6.5). The figure shows that both the MVL to D-HUBN and SPUR (KP End Section_A-ALT) to PLET sections of the proposed pipeline routes, and forthcoming EBS, will traverse a military exercise area, known as North Sea, west of Haaksgronden. This area has been designated as an exercise area for anti-aircraft exercises for The Royal Netherlands Navy (Royal Netherlands Navy, 2022).

In general, any firing exercises are announced in Netherlands Notice to Mariners (NtM) or by signals and/or announcements from a Navy vessel in the vicinity.

6.3.6 Waste Disposal

There are no waste disposal areas identified within the proposed pipeline routes. Dredge spoil from is disposed to the north of the channel for the Port of Rotterdam (Figure 6.5).

7. Cultural Heritage

A comprehensive desk top study, including mapping, of the archaeological potential of the area was conducted as part of the earlier geological desk top study for the Aramis Project (Fugro 2022a). This found that there is a high expectation of the remains of ships and WWII plane wreck to occur within the area.

The report noted that currently there are 458 known shipwrecks recorded within the vicinity of the site and it was also considered that the local area could hold further shipwrecks and plane wrecks not yet recorded. An overview map of wrecks is provided at https://www.noordzeeloket.nl/en/policy/noordzee-2050/wrakken-noordzee/.

In addition, it was expected that locally prehistoric landscapes have been preserved intact including artefacts of Palaeolithic and Mesolithic communities.

In addition to the result of the archaeological desk study, the recent geophysical survey conducted by Fugro at the inshore extent of the proposed cable route (Fugro, 2022b) identified two targets interpreted to be wrecks. The location and dimensions of the wrecks are presented in Table 7.1. An example side scan sonar image of a possible wreck at the inshore section of the proposed pipeline route is shown in Figure 7.1.

Table 7.1: Targets identified during geophysical survey at the inshore section of the proposed pipeline route (source: Fugro, 2022b)

Target	Easting [m]	Northing [m]	Length [m]	Width [m]	Height [m]
Wreck	570710.63	5761481.22	4.32	2.42	0.28
Wreck	570397.06	5761996.28	31.86	20.45	1.59

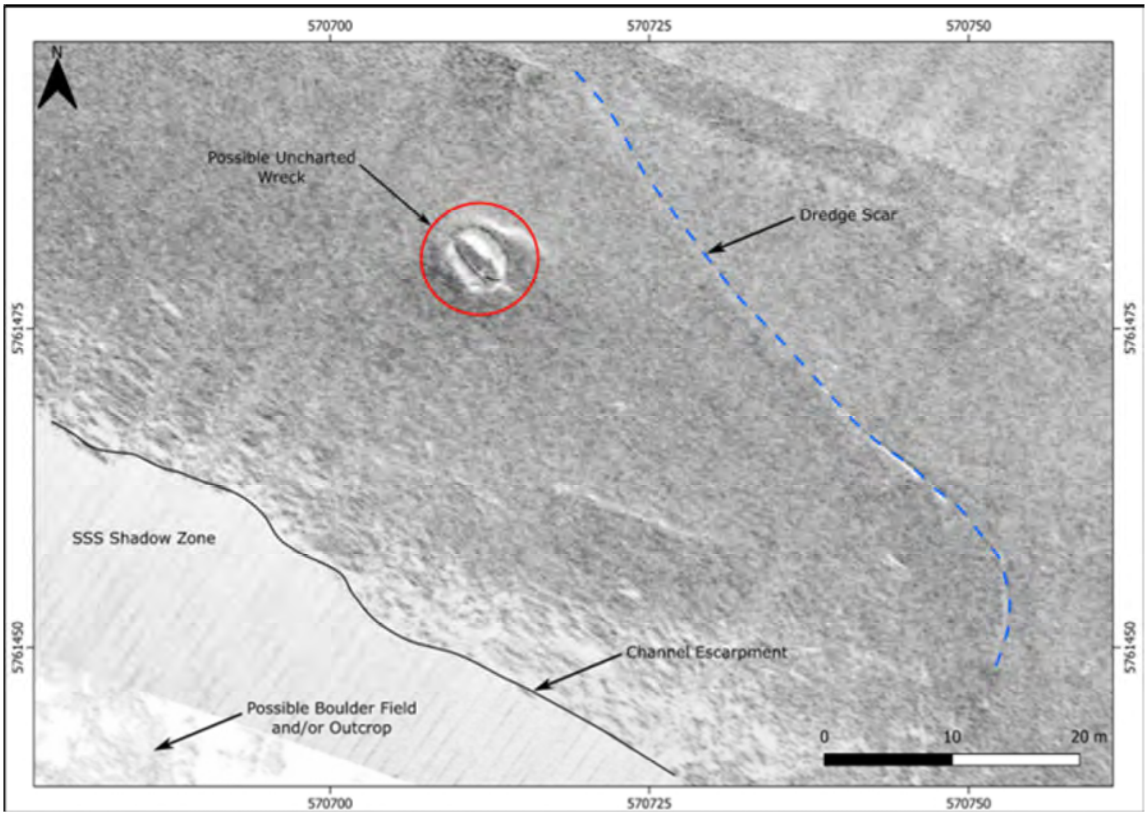


Figure 7.1: Example side scan sonar image of a possible wreck (source: Fugro, 2022b)

8. Project Stakeholders Identified

The IFC Stakeholder Engagement Good Practice Handbook (2007) defines stakeholders as "persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and / or the ability to influence its outcome, either positively or negatively".

Table 8.1 presents potential stakeholder groups that could be affected by the project or that are likely to be involved with any formal future consultation activities in support of further development activities of the Aramis project in respect of the marine environment.

Table 8.1: Prospective stakeholders identified

Stakeholder	Description
Government Bodies	
Ministry of the Interior and Kingdom Relations Binnenlandse Zaken en Koninkrijksrelaties (BZK)	Government department responsible for development and implementing domestic policy, regulations and legislation and deals with democracy and the rule of law and public administration amongst other duties.
Ministry of Infrastructure and the Environment (Rijkswaterstaat Ministerie van Verkeer en Waterstaat)	Government department responsible for to the design, construction and management of the main infrastructure facilities in the Netherlands. It is part of the Ministry of Infrastructure and the Environment.
Ministry of Infrastructure and Water management (Ministerie van Infrastructuur en Waterstaat)	Government department responsible for the transport, housing public works, spatial planning, land and water management. Incorporates the Directorate-General for Public Works and Water Management (Rijkswaterstaat) and Royal Netherlands Meteorological Institute (Koninklijk Nederlands Meteorologisch Instituut (KNMI))
Ministry of Economic Affairs and Climate (Rijksoverheid Ministerie van Economische Zaken en Klimaat) (EZK)	Government department responsible for international trade and commerce as well as environmental and climate and energy policy.
Netherlands Enterprise Agency (Rijksdienst voor Ondernemend (RVO))	Agency of the Ministry of Economic Affairs and Climate assisting business development including advice on regulation and compliance. It is responsible for the issuance of certain licences, such as fishing licences.
Office of Energy Projects (Bureau Energiprojecten)	As part of the Netherlands Enterprise Agency (above) the Office of Energy Projects coordinates and supports the permits and permitting activities of the provinces, municipalities, and government departments in cases of large or complex energy projects.
Ministry of Agriculture, Nature and Food Quality (Ministerie van Landbouw, Natuur en Voedselkwaliteit)	Government department responsible for the development and implementation of policies on nature, nature reserves and sustainability food production. Responsible for the issuance of permits under the Nature Conservation Act.

Stakeholder	Description
PBL Netherlands Environmental Assessment Agency	National institute for research and analyses underpinning strategic policy relating to environment, nature and spatial planning. The Institute comprises partner agencies including CPB Netherlands Bureau for Economic Policy Analysis and the Netherlands Institute for Social Research (SCP).
Energie Beheer Nederland (EBN)	Public energy company owned by the Dutch state involved in gas exploration and production and transportation. He company os now pivoting to sustainable energy provision including CO_2 storage as well as other initiatives. EBN is one of the initiators of the current Aramis project.
Cultural Heritage Agency) (Rijksdienst voor het Cultureel Erfgoed (RCE)).	Part of the Ministry of Education, Culture and Science, the Cultural Heritage Agency (RCE) should be notified of any change finds of potential archaeological interest.
Fishing Groups	
Federation of Fisheries Associations (Federatie van visserijverenigingen)	Association representing the interests of Dutch cutter fishers
Dutch Fishermen's Association (Nederlandse Visserbond	Organisation comprising offshore, coastal and inland professional fishermen, ship owners and crew on the Netherlands.
Netherlands Institute for Fisheries Research (RIVO)	Research institute conducting fishery research within the Netherlands and overseas. Now forms part of IMARES – Wageningen UR (see below).
Coöperatieve Visserij Organisatie (CVO)	Representative of around eight demersal fishing companies
Fishermen's Union (Nederlandse Visserbond)	Group for Dutch professional fishermen, owners and passengers in sea, coastal and inland fisheries and aimed at sustainable development of member organisations.
Pelagic Freezer-trawler Association (PFA)	Representative of around three pelagic fishing companies
Research and Campaign Organisations	
Nederlands Instituut voor Zeeonderzoek (NIOZ) (Royal Netherlands Institute for Sea Research)	Conducts research on oceanology, chemistry, marine geology and ecology to in open oceans and delta areas to further the understanding of ocean system functioning and interactions between ecosystem components. The Institute comprises four main departments including estuarine and delta systems, coastal systems, ocean systems and marine microbiology and biogeochemistry.
IMARES – Wageningen UR (Institute for Marine Resources and Ecosystem Studies)	Research institute providing scientific research to inform and support policy making on the marine environment, fishery activities, aquaculture and the marine sector in the Netherlands. Incorporates Alterra – Wageningen UR which conducts research on flora and fauna, water environment, remote sensing and spatial planning related to sustainable use of living resources and Netherlands Institute for Fisheries Research RIVO).
Wageningen UR (Wageningen University and Research Centre)	University and research centre based in Wageningen, Netherlands and consisting of the former agricultural research institutes (Dienst Landbouwkundig Onderzoek (DLO)) of the Dutch Ministry of Agriculture. The institute is involved in the training of scientists in life sciences and for conducting research on natural resources and agriculture. o

Stakeholder	Description
Bureau Waadenburg bv	Independent research facility providing advice on ecology, nature and the environment. Typically works for government and private companies providing nature consultation advice.
Bird Protection Netherlands (Vogelbescherming Nederland)	Part of BirdLife International, Vogelbeschermng is a bird conservation organisation conducting campaigns, lobbying and education programs for the conservation of birds and bord habitats.
Dutch Mammal Society (Bureau van de Zoogdiervereniging)_	Independent, non-governmental organisation. Conducts and coordinates groups involved in research on mammals for the purposes of conservation of species and habitat. Work includes monitoring of species, development of monitoring standards, outreach through education and literature and consultation advice.
SEAMARCO (Sea Mammal Research Company)	Conducts research on sea mammal behaviour, acoustics, anatomy and welfare in collaboration with research institutes, universities companies to inform management decision making in regard to marine ecosystems.
North Sea Foundation	Consortium of Dutch environmental organisations for the coordination and dissemination of knowledge regarding aspects of the marine environment and sustainable use in the North Sea.
Dutch Centre for Field Ornithology (Sovon Vogelonderzoek Nederland)	Organises and conducts monitoring and research on bird populations and distributions in the Netherlands. Data are primarily collated by volunteer bird watchers.
Netherlands Organisation for Applied Scientific Research (Nederlandse Organisatie voor toegepastnatuurwetenschappelijk Onderzoek (TNO))	Independent research and consultancy organisation supporting trade and industry in relation to technical innovation and knowledge transfer.
Bird Protection Netherlands (Vogelbescherming Nedereland)	Independent private organisation for the protection of birds and their habitats.
Netherlands Institute of Ecology (Nederlands Instituut voor Ecologie (NIOO))	Part of the Royal Netherlands Academy of Arts and Sciences the NIOO consists of research and students conducting ecological research at species, population and community / ecosystem levels.
Deltares	Private organisation conducting applied research on water, subsurface and infrastructure with a focus on deltas, coastal regions and river basins.
Other Users of the Sea	
Oil and Gas Licence Block Holders	There are 470 discovered gas field 250 of which are producing. In addition, there are 50 discovered oil fields 15 of which are producing. The EBS will be undertaken within the vicinity of a number of these fields and there may be a requirement to transit through some of these as part of the survey operations. Discussions with the relevant operators should take place to ensure the survey operations do not impinge on any proposed operations taking place at the same time. Similarly, when construction operations commence, appropriate communications should be held with any relevant licence block holders who may need to be made aware.
Marine Authorities	The proposed pipeline route supports shipping routes to/from the major seaports in the Netherlands and North Sea and therefore there is potential for vessel traffic to be disrupted. Details of the survey operations and radio communications should be issued to ensure Marine Authorities are aware of vessel movements and activities being undertaken

Stakeholder	Description
Other Mariners in the Area	As above, the proposed pipeline route supports shipping routes to/from the major ports and harbours within the North Sea therefore there is potential for vessel traffic to be disrupted. Radio communications should be issued throughout the course of the survey operations to ensure mariners are aware of vessel movements
Oil Spill Contingency Plan (OSCP) Contacts	An OSCP may be required and will need to be provided to relevant authorities and parties who may be involved in executing the plan in the event of an oil spill.

9. Recommendations for Design and Conduct of the EBS

9.1 Summary of Environmental Sensitivities Identified

Figure 9.1 presents a summary map of the sensitive and important ecological receptors as described in this DTS. The mapping follows the symbology from the IPIECA (2012) guidance for the mapping of the sensitivity of the environment to accidental oil spills but is considered also relevant to the current proposals.

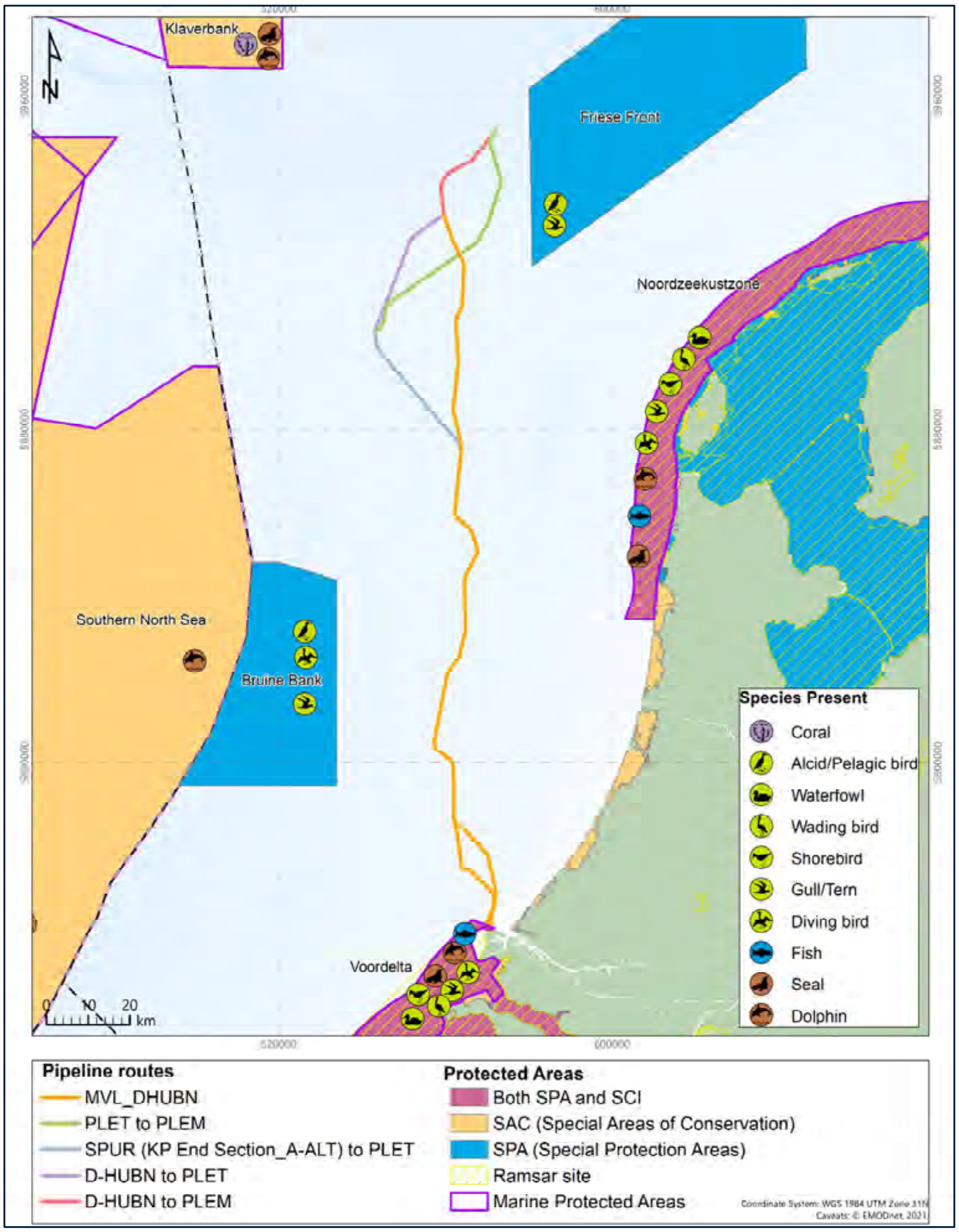


Figure 9.1: Summary environmental sensitivity map

No sensitive ecological receptors or protected areas have been identified within the immediate route of the proposed pipeline. Accordingly, no deviations or special requirements for the EBS design are required in respect of protected features. The exception to this is the Voordelta Natura 2000 site which coincides with the southern-most extents of the pipeline route. Features for which this site is designated include sandbank habitat, fish (allis shad, twaite shad, river lamprey and sea lamprey) and 30 species of seabirds. It is recommended to consult RVO as to any permit requirements for exemption of EBS activities from the Nature Conservation Act, 2017.

Fish, seabirds, and marine mammals, for which other Natura 2000 sites are designated, are transient across the wider region and may thus be encountered outside of Natura 2000 site boundaries.

9.2 General Considerations for the EBS Sampling Array Design

This section presents a synthesis of the findings of the DTS and highlights survey array aspects that are recommended to be considered for the forthcoming EBSs. A summary of the recommendations is given in Table 9.1.

The EBS will be designed to ensure that there is adequate coverage of the range of habitats, seawater conditions and features present. Where available, geophysical survey data (side scan sonar and multi-beam echo sounder (MBES)) will be used to identify sediment habitat boundaries for stratification of the seabed sample stations.

Although not expected along the route of the proposed pipeline, any potential sensitive features encountered will be initially assessed using the seabed video system prior to deployment of the box core or grab sampler to avoid damage caused by the seabed sampling.

Whilst also providing contextual data at each sampling site, the video should also be deployed to characterise transitions between habitat types apparent in the geophysical data so that habitat boundaries can be adequately mapped.

The video camera shall also be used to collect information on larger, more mobile epibenthic species such as fish and crabs, and which are not readily sampled by box cores or grab samplers. In particular, the video should also be used to collect information on the distribution of sand eels which is a key species within the ecosystem. Where possible, the extents and distributions of any sand eel habitat will be mapped.

At offshore locations, the video footage collected should also be carefully assessed for the presence of large burrowing mud shrimps (Callianassidae) and ocean quahog and which may be evidenced by the presence of mounds and borrows and exposed siphons on the seabed surface.

Before the deployment of the sampling equipment, drop-down video will be used to ensure that the seabed is clear from any obstructions and that no hazards are present for the vessel and crew.

Selected EBS locations will be used also for environmental DNA (eDNA), plankton and seawater quality sampling. Environmental DNA may be used to detect for the presence and use of the area by protected fish and marine mammals.

There are two principal water masses within the EBS study area including Atlantic water inflowing from the north and English Channel water flowing from the south. In addition, coastal water is influenced by river inputs affecting nutrient, turbidity and salinity levels. It will be important to ensure that the water samples are collected along the length of the proposed pipeline and at various depths (i.e., near surface, mid-water and near bottom depths) so that all representative seawater profiles are sampled.

9.2.1 General Good Practice Considerations

A range of best practices are recommended for the duration of the proposed EBS operations. These include:

- A sufficient amount of box core / grab sample stations and camera transects to be deployed to cover the habitats/features likely present along the proposed pipeline routes, as well as to set up a baseline of physico-chemical conditions in the area;
- Seabed sampling should be minimised as far as possible to avoid localised seabed disturbances within SAC boundaries;
- Observations of birds and marine mammals should be reported.
- Any material of potential archaeological interest should be preserved and reported (see Chapter 6: Cultural Heritage);
- Environmental sampling to avoid close proximity to existing infrastructure, and to stay outside of any exclusion zones or to obtain permission from relevant operators if required.
- A notice to mariners should be issued prior to operations to inform other maritime users of intended EBS activities. Notices to mariners issued by others should be observed.
- As a signatory to MARPOL 73/78, survey vessels in Dutch waters will apply the appropriate standards with regards to safeguarding the marine environment. This should include adequate controls of the release of oily substances and garbage from survey vessels.

9.2.2 Suggested analysis suites

Recommended analysis suites for sediment and seawater samples to inform the EIA for the proposed carbon capture and storage project are presented below. The final detailed suite will be agreed with Total Energies and may include some or all of the following items.

Recommended strategies for environmental monitoring of CCS projects are provided by STEM-CCS (2020). The authors note the unique nature of each CCS operation and the requirement for a bespoke programme of monitoring.

Recommended samples analysis suites

Sediment	Seawater	Depth profiles
▪ Macrofaunal content (species) ▪ Particle size distribution analysis ▪ Total organic carbon ▪ Total nitrogen ▪ Total hydrocarbons ▪ Total n-alkanes ▪ Total poly-aromatic hydrocarbons ▪ Heavy metals (to include, but not necessarily limited to, Ba, Cd, Cr, Cu, Pb, Hg, Zn)	▪ pH or pCO_2 (partial pressure of CO_2) ▪ Total organic carbon ▪ Dissolved inorganic carbon ▪ Bicarbonate ▪ Total alkalinity ▪ Nutrients ▪ Dissolved oxygen ▪ Dissolved calcium	▪ Salinity ▪ Temperature ▪ pH ▪ Conductivity ▪ Turbidity ▪ Dissolved oxygen

9.3 Sensitive or Important Benthic Habitats

Seabed surveillance using seabed cameras prior to sampling at each station will avoid potential damage to sensitive or important seabed features, e.g., pockmark or biogenic reef communities, if present. It will also ensure sample locations will avoid any manmade obstructions, such as seabed infrastructure, boulders including subsea cables, as well as any unknown dropped objects or wrecks. Where available, acoustic data should be reviewed to determine the presence of any such seabed features.

Should any sensitive habitats (or other seabed obstruction) be encountered, the station will be relocated according to approach to be agreed with Total Energies.

9.4 Approach to Sensitive or Important Habitats

Sensitive seabed habitats are not expected to be encountered during the EBS based in the findings of this DTS. Sandbanks within the Dutch sector of the North Sea are likely to be representative of EU Habitats Directive Annex I habitat but are not anticipated to be significantly adversely affected by the proposed EBS sampling. In the event of encountering a potentially sensitive or important feature, other than a sandbank, the following protocol will apply.

An initial seabed camera should start on a safe transect for a minimum of 100 m to identify the boundary of sensitive habitats and locate a suitable area to survey with the grab or box core. Should a suitable area for sampling not be found within a maximum range from the proposed sampling location, or if it is not safe to move sampling location within the transect, the station shall be abandoned with agreement of the Client Representative (CR) and resulting video data used to classify habitat and identify the location of the sensitive area. If a sampling location is to be relocated for full sampling requirement, including prior seabed video clearance, a variation order shall be agreed.

9.5 Benthos

9.5.1 Sampling design (offshore)

The data supports a general transition in seabed morphology and habitat types as characterised by a general fining of the sediment, a deepening of the seabed and a decrease in tidal and wave induced seabed mobility with increasing distance offshore. Furthermore, benthic diversity generally increases with increasing distance from the coast. There is a sharp transition between sandy and silty seabed types at around the 30 m depth contour. Camera tows in this area would be helpful to characterise this transition, and as guided by the available geophysical data.

The observed pattern of seabed transition provides a good opportunity to stratify the benthic sampling according to principal habitat type. The EMODnet data on surficial sediments and EUNIS classified habitats, together with the available geophysical data should be used to apportion sampling stations along the pipeline route according to the different habitats expected.

Seabed substrates are expected to include mostly sand with silty sand and mud occurring in deeper water areas to the north of the study area. A box core or Hamon grab sampler (or similar) is recommended for the quantitative sampling of these substrate types.

9.5.2 Sampling design (inshore)

Geophysical data collected for the inshore section of the proposed pipeline routes shows a disturbed seabed and potential seabed obstructions assumed to be related to channel dredging and dredge spoil disposal activities (see Figure 9.2). The presence of possible discarded fishing gears, possible wreck sites and multiple boulders on the seabed may limit effective and safe sampling here. Benthic communities are likely to be reduced in comparison to adjacent unaffected areas as a result of dredge and spoil disposal related disturbances in the area.

For EBS sampling in this area, it is recommended that the seabed camera is initially employed to check for obstructions, such as boulders and/or discarded fishing gears and shipwrecks prior to sampling. This should involve a series of drop-down deployments of the camera to the seabed rather than any seabed tows to minimise the risk of snagging. Sample station positions may need to be adjusted on site depending on the bottom conditions.

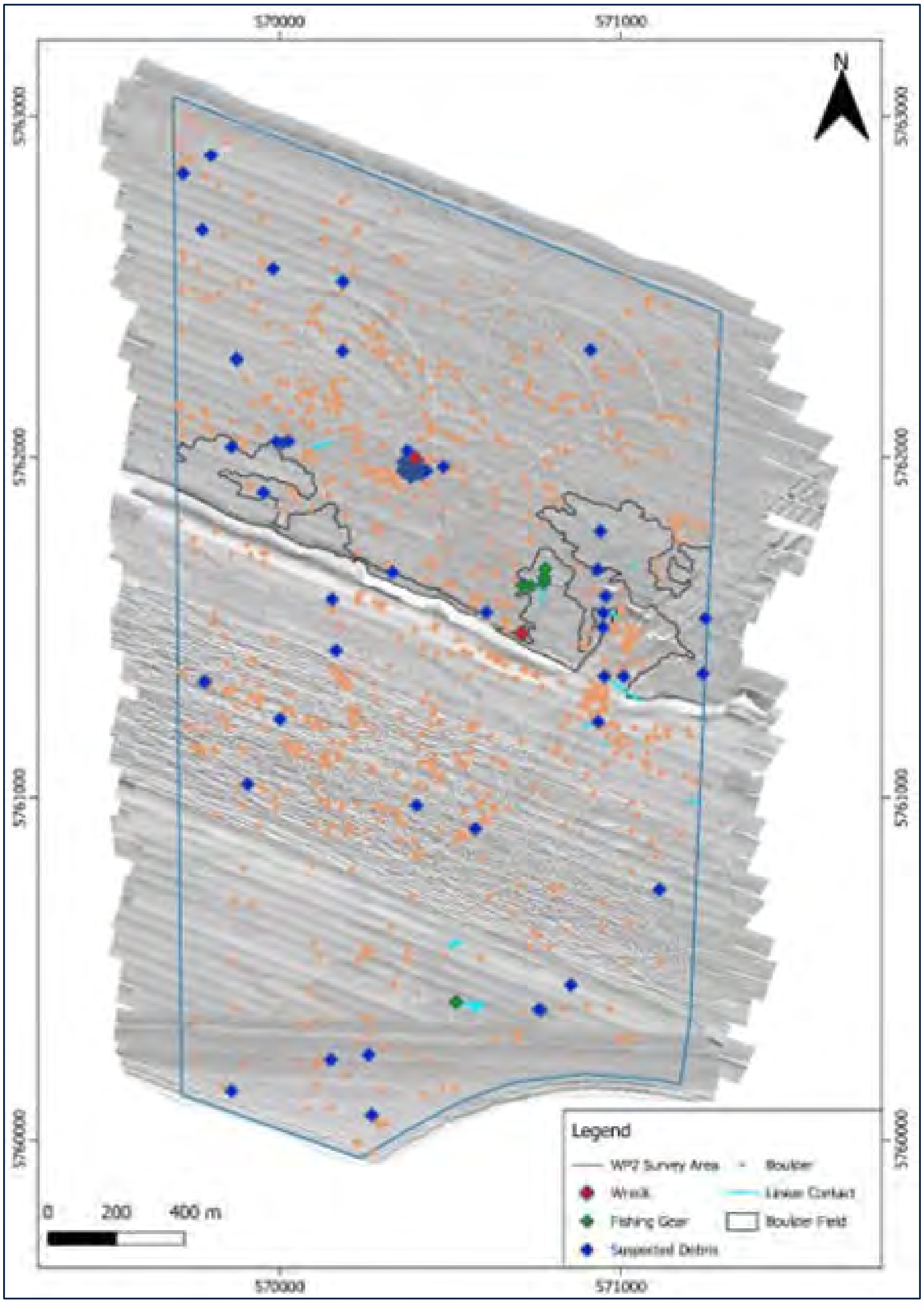


Figure 9.2: Location of potential seabed obstructions at the inshore sampling location (source: Fugro 2022b)

9.5.3 Ocean quahog (*Arctica islandica*)

The OSPAR threatened and/or declining species *A. islandica* is known to occur at relatively high densities at offshore locations in muddy sand substrates around the northern extents of the proposed pipeline. Actions and measures have been identified for the improvement of its conservation status in the North Sea (OSPAR, 2009). The Netherlands have historically contributed trend data for ocean quahog to OSPAR (OSPAR 2009) to help inform overall conservation status within the region. With respect to the forthcoming EBS, it is recommended that in addition to abundance and sampling location data, other information for any recovered ocean quahog should also be reported including weight, shell length and shell width. These data, together with the sampling location information will contribute to any Dutch reporting commitments to OSPAR regarding *A. islandica* status in the North Sea.

The use of the box core is recommended as it is able to penetrate the seabed sediments to sufficient depths to collect deep-burrowing *A. islandica* specimens (Witbaard & Bergman, 2003). Seabed video data should be analysed for the presence of siphons of *A. islandica* on the seabed

9.6 Marine Invasive Species

Common vectors for the transmission of marine invasive species into the Netherlands includes hull fouling and ballast water. Guidelines on ship biofouling management are provided by the Marine Environment Protection Committee (MEPC) (MPEC, 2011). Furthermore, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (the BWM Convention) sets out measures for the management of ballast waters for minimizing the risk of transferring marine invasive species.

It is recommended that where appropriate, the recommendations provide by the guidelines and BMW Convention are adhered to so that the risk of introducing and spreading invasive species within Dutch marine waters as a result of EBS activities is minimised as far as is practicable.

9.7 Fish Ecology

The EBS should avoid peak fish spawning events where possible.

Fish are likely to be able to avoid highly localised and temporary EBS activities if disturbed and significant adverse effects on key fish habitats are not expected. No special measures are considered necessary in respect of fish ecology.

Given the ecological value of sand eels, the EBS should attempt to delineate the boundaries of any potential sand eel habitat through assessment of sediment particle size distribution characteristics and seabed video evidence of sand eels. Any mapped sand eel habitat may inform final pipeline route design and impact assessment.

Environmental DNA analyses of water samples may be expanded for protected lamprey and shad species, as well as sand eels to assess their presence and use of the area.

9.8 Marine Mammals and Seabirds

Marine mammals and seabirds will use offshore and inshore areas for feeding and migration. Important feeding areas include the Frisian Front and Brown Bank and are remote from the forthcoming EBS.

Seabirds will be widely dispersed from coastal breeding sites at the time of the survey (winter). They are expected to be able to avoid highly localised and temporary EBS activities if they choose to do so and no significant adverse effects are expected in this regard.

Similarly, marine mammals are expected to be able to avoid the EBS activities. The sampling equipment proposed for use during the EBS does not produce any underwater noise over and above that of the vessel. Significant levels of underwater noise due to the proposed EBS activities that might otherwise disturb marine species over and above the physical presence of the survey vessel are thus not anticipated.

Water sampling and testing for eDNA would provide information on the presence and use of the area by marine mammals.

Observations of birds and marine mammals during the survey should be recorded together with time and positional information and reported as part of the EBS report. This information will contribute to the overall understanding of the temporal and spatial distributions of bird species in local waters. Observation data can be submitted to the Nationale Databank Flora en Fauna (NDFF) (https://www.ndff.nl/) and can contribute to the understanding of biodiversity in the Dutch sector of the North Sea. Parasitic jaeger (endangered) are autumn migrants to offshore areas within the Dutch sector and may be encountered within the offshore extents of the EBS area at this time.

The risk of collision with marine mammals increases with vessel speed (Schoeman *et al.*, 2020). Limiting the transit speed of all project vessels to 10 nm/hour (18.52 km/hour) during routine operations is estimated to reduce the risk of ship strike mortality for large cetaceans offshore by 80% to 90% (Conn & Silber, 2013).

9.9 Nature Conservation

The EBS is not envisaged to significantly encroach upon any site that has been designated for nature conservation and is not expected to significantly affect species for which marine sites have been designated. I

The exception to this is a small overlap with the Voordelta Natura 2000 site at the landward extents of the proposed pipeline route. Advice from Rijksdient voor Ondernermend (RVO) should be sought as to any requirement for permits for sampling in the Voordelta Natura 2000 site.

9.10 Cultural Heritage

The Heritage Act (Erfgoedwet) (2016) provides a description of cultural heritage and lays down responsibilities for movable heritage and how this is monitored as well as *inter alia* rules for conservation, registration, and protection in the Netherlands.

The Cultural Heritage Agency of the Ministry of Education, Culture and Science is responsible for the preservation and maintenance of cultural heritage and represents the center of expertise regarding conservation registration of museum collections.

Article 5.10 of the Heritage Act regulates accidental archaeological finds and requires finders to report the find to the Minister of Education, Culture and Science as soon as possible.

Given the high archaeological potential of the general area, it is recommended to develop a chance find protocol detailing the methods for recording, preserving and transference of any suspected material of archaeological importance found during the EBS. To facilitate this, relevant procedures from The Crown Estate *Protocol for Archaeological Discoveries: Offshore Renewables Projects* may be followed (TCE, 2014). Items observed on the seabed must be photographed in situ, and the position and depth logged. Items recovered to the vessel in box core samples shall be treated according to the following TCE procedures, as follows:

- All material must be handled with care;
- Any rust, sediment, concretion or marine growth shall not be removed and ‘groups’ of items or sediments must not be separated;
- The item shall be photographed in the condition in which it was recovered;
- The position at which the artefact/sediments was/were recovered must be recorded;
- The artefact must be labelled appropriately with a unique ID;
- The item must be stored in seawater, in a clean, covered container.

Any finds should be notified to the Cultural Heritage Agency (Rijksdienst voor het Cultureel Erfgoed (RCE)) as representatives of the Minister responsible in the first instance. In addition, finds may also be reported to Rijkswaterstaat Zee en Delta who maintain a complete list of known wrecks and objects on the Dutch Continental shelf and to who have expertise in archaeology including maritime heritage. Contact details as below.

Rijkswaterstaat Sea and Delta	Cultural Heritage Agency
(Rijkswaterstaat Zee en Delta) P.O. Box 2232 3500 GE Utrecht The Netherlands https://www.informatiehuismarien.nl/uk/contact/	(Rijksdienst voor het Cultureel Erfgoed (RCE)). (033) 421 7 456 info@cultureelerfgoed.nl

The discovery of any new obstructions on the seabed, and which may cause a hazard to vessel safety, should be reported to the Hydrographic Service (info@hydro.nl).

9.11 Stakeholders

The temporary and short-term duration and offshore location of the survey is not anticipated to significantly affect any of the stakeholders identified in this DTS.

A Notice to Mariners (NtMs) should be issued prior to the commencement of the EBS to inform other maritime users of intended activities.

It is recommended to inform cable owners of intended activities should any sampling be planned close to existing seabed cables and to check NtMs with respect to anticipated firing events within the west of Haaksgronden offshore firing range.

Table 9.1: Summary of EBS recommendations

Theme	Component	Environmental Issue	EBS Recommendation
Physical environment	Meteorology	No issues identified	None required
	Bathymetry	No issues identified	None required
	Seabed sediment	No issues identified	None required
	Water characteristics	No issues identified	• The EBS area comprises different water masses as well as river inputs. Sampling should be representative of these different waters and potential river influences.
Chemical environment	Water contaminants	No issues identified	None required. A suggested suite for CCS monitoring is provided.
	Sediment contaminants	No issues identified	None required. A suggested suite for CCS monitoring is provided.
Biological environment	Plankton	No issues identified	None required
	Benthos	No issues identified	▪ Careful use of geophysical data (where available) and seabed video to avoid sampling over boulders and/or other obstructions as well as subsequent mapping of habitats including potential sand eel habitat. ▪ Counts of *Arctica islandica* should be supplemented with weight and shell height and width data.
	Marine Invasive Species	No issues identified	▪ Relevant guidance in terms of hull fouling and ballast water management for the control of invasive species should be adhered to.
	Fish and shellfish	No issues identified	▪ Good practice and relevant guidance in terms of vessel operations, offshore discharges and waste disposal and ballast water management for the control of invasive species should be adhered to. ▪ Minimise vessel speed to a maximum of 10 nm/hour to minimise collision risk with, and injury to, marine mammals. ▪ Observations of seabirds and marine mammals should be recorded and reported in the EBS report. ▪ Allow sufficient distance separation from marine mammals to avoid disturbance. ▪ Consider eDNA analysis for protected fish species (shads and lampreys), sand eels and marine mammals.
	Marine mammals	Various marine mammal species occur and are protected	
	Birds	No issues identified	
Stakeholders	Conservation designations	Voordelta Natura 2000 site	▪ Advice on any permit requirements for EBS works within the boundaries of the Voordelta Natura 2000 site should be sought from RVO. ▪ Good practice and relevant guidance in terms of vessel operations, offshore discharges and waste disposal should be adhered to.
	Authorities	Notifications, shipping and fisheries.	▪ As required, notify and liaise with the appropriate authorities as to intended survey activities. ▪ Record any observations of fishing vessel and gear locations where possible.
	Marine Heritage	No issues identified	▪ Relevant procedures based on the *Protocol for Archaeological Discoveries: Offshore Renewables Projects* will be followed (e.g., TCE, 2014). ▪ Any chance finds should be reported to the Cultural Heritage Agency
	Submarine cables and pipelines	No issues identified	▪ Avoid areas of cables and pipelines and any associated exclusion zones. ▪ Adhere to NtMs with regards to firing in military exercise zones

10. References

Arts, F.A. (2009). Trends en verspreiding van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 1991-2008. Report RWS Waterdienst BM 09.08.

Arts, F.A. & Berrevoets, C.M. (2006). Monitoring van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 1991-2006. Report RIKZ/2006.018. Rijksinstituut voor Kust en Zee.

Atkinson P.W. (1996) The origins, moult, movements and changes in numbers of Bar-tailed Godwits *Limosa lapponica* on the Wash, England. *Bird Study, 43*(1), 60-72. DOI:10.1080/00063659609460996

Barrett, R.T., Chapdelaine, G., Anker-Nilssen, T., Mosbech, A., Montevecchi, W.A., Reid, J.B., Veit, R.R. (2006). Seabird numbers and prey consumption in the North Atlantic. *ICES Journal of Marine Science, 63(*6), 1145–1158, https://doi.org/10.1016/j.icesjms.2006.04.004

Baretta Bekker J.G. Baretta, J.W., Latuhihin, M.J. Desmit, X & Prins, T.C. (2009). Description of the long-term (1991–2005) temporal and spatial distribution of phytoplankton carbon biomass in the Dutch North Sea. *Journal of Sea Research 61*(1-2), pp 50-59.

BirdLife International. 2019. *Charadrius hiaticula* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2019: e.T22693759A155487854. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22693759A155487854.en. Accessed on 25 July 2022.

BirdLife International. 2021. *Larus melanocephalus*. The IUCN Red List of Threatened Species 2021: e.T22694443A166278154. https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T22694443A166278154.en. Accessed on 25 July 2022.

Boon, J., Brinkhuizen, D.C., Bunnik, F.P.M., Cohen, K., Cremer, H., Exaltus, R.P., Kappel, K., Kooistra, L.I., Koolmees, H., Kruyk, H., Kubiak-Martens, L., Moree, J.M., Niekus, M., Verbruggen, F., Vos, P., Zeiler, J., Peeters, J.H.M., Schiltmans, D.E.A. & Verbaas, A. (2015). Interdisciplinary Archaeological Research Programme Maasvlakte 2, Rotterdam - Part 1 - Twenty meters deep! The mesolithic period at the Yangtze Harbour site - Rotterdam Maasvlakte, the Netherlands.

Bos, O.G., Witbaard, R., Lavaleye, M., van Moorsel, G., Teal, L.R., van Hal, R., ven der Hammen, T., ter Hofstede, R., van Bemmelen, R., Witte, R.H., Geehoed, S. & Dijkman, E.M. (2011). Biodiversity hotspots on the Dutch Continental Shelf. A marine Strategy Framework Directive perspective. IMARES. Report number C071/11.

Bouveroux, T., Kiszka, J.J., Heithaus, M.R., Jauniaux, T. & Pezeril, S. (2014). Direct evidence for gray seal (*Halichoerus grypus*) predation and scavenging on harbour porpoises (*Phocoena phocoena*). *Marine Mammal Science, 30*,1542-1548. https://doi.org/10.1111/mms.12111

Brasseur, S., Aarts, G., Meesters, E., van Polanen-Petel, T., Dijkman, E., Cremer, J. & Reijnders, P. (2010). Habitat preferences of harbour seals in the Dutch coastal area: analyses and estimate of effects of offshore wind farms Report number: OWEZ R 252 T1 20100929 p. 55

Brasseur, S.M.J.M., van Polanen, P.T.D., Gerrodette, T., Meesters, E.H.W.G., Reijnders, P.J.H. & Aarts, G. (2015). Rapid recovery of Dutch gray seal colonies fueled by immigration. *Marine Mammal Science*, *31*, 405-426. https://doi.org/10.1111/mms.12160

Brown, P. W. & Fredrickson, L. H. (2020). White-winged Scoter (*Melanitta deglandi*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.whwsco2.01

Butler, R. G., Buckley, D. E., Nettleship, D. N., Boesman, P. F. D. & Garcia, E. F. J. (2020). Black Guillemot (*Cepphus grylle*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.blkgui.01

Camphuysen, C.J. & Leopold, M.F. (1994). Atlas of seabirds in the southern North Sea. IBN Research report 94/6, NIOZ Report 1994-8, Institute for Forestry and Nature Research, Netherlands Institute for Sea Research and Dutch Seabird Group, Texel.

Camphuysen C.J. & M.L. Siemensma (2011). Conservation plan for the Harbour Porpoise *Phocoena phocoena* in The Netherlands: towards a favourable conservation status. NIOZ Report 2011-07, Royal Netherlands Institute for Sea Research, Texel.

Chester, R. & Voutsinou, F. G. (1981). The initial assessment of trace metal pollution in coastal sediments. Marine Pollution Bulletin, 12, 84-91. https://doi.org/10.1016/0025 326X(81)90198 3

CEFAS, (2001). Contaminant status of the North Sea. Technical report produced for Strategic Environmental Assessment – SEA2. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/197352/TR_SEA2_Contamination.pdf

Cervencl, A., Troost, K., Dijkman, E., Jong, M., Smit, C., Leopold, M. & Ens, B. (2015). Distribution of wintering Common Eider *Somateria mollissima* in the Dutch Wadden Sea in relation to available food stocks. *Marine Biology, 162*. 153-168. 10.1007/s00227-014-2594-4.

Chester, R. & Voutsinou, F. G. (1981). The initial assessment of trace metal pollution in coastal sediments. *Marine Pollution Bulletin, 12,* 84-91. https://doi.org/10.1016/0025 326X(81)90198 3

Conn, P.B., and Silber, G.K., 2013. Vessel speed restrictions reduce risk of collision-related mortality for North Atlantic right whales. *Ecosphere*, *4*(4), 43. http://dx.doi.org/10.1890/ES13-00004.1

Couperus, B., Sakinan, S. & Burggraaf, D. (2020). Small pelagic fish and zooplankton in the Dutch coastal surf zone during the EGS-II survey in 2017-2018. Wageningen University & Research report C060/20.

Crowe, O., Wilson, J. & Aznar, I. (2009). A review of Ireland's waterbirds, with emphasis on wintering migrants and reference to H5N1 avian influenza. *Irish Veterinary Journal, 62*, 800. https://doi.org/10.1186/2046-0481-62-12-800

Daan, R. & Mulder, M. (2006). The macrobenthic fauna in the Dutch sector of the North Sea in 2005 and a comparison with previous data. Royal Netherlands Institute for Sea Research (NIOZ). NIOZ Rapport 2006-3.

Daan, R.; Mulder, M.; Bergman, M. (2006). *Impact of Windfarm OWEZ on the Local Macrobenthos Community* (Report No. OWEZ_R_261_T1_20090305). Report by IMARES - Wageningen UR.

Daan, R. & Mulder, M. (2009). Monitoring the invertebrate benthic fauna in the Dutch sector of the North Sea 1991 – 2005: an overview. Royal Netherlands Institute for Sea Research (NIOZ). NIOZ Rapport 2009-5.

Davies, C.E., Moss, D. & Hill, M.O. (2004). EUNIS Habitat Classification Revised 2004. Report to European Environment Agency European Topic Centre on Nature protection and Biodiversity. October 2004.

de Boer, J., van der Zande, T.E., Pieters, H., Ariese, F., Schipper, C.A., van Brummelen, T. & Vethaak, A.D (2001). Organic contaminants and trace metals in flounder liver and sediment from the Amsterdam and Rotterdam harbours and off the Dutch coast. *Journal of Environmental Monitoring, 4* (386-93). doi: 10.1039/b103814c. PMID: 11523438.

De Jong, D.J., 1999. Ecotopes in the Dutch Marine Tidal Waters. A proposal for a classification of ecotopes and a method to map them. RIKZ-Report 99.017 801 ISBN 90-369-3424-9.

de la Vega, C., Lebreton, B., Siebert, U., Guillou, G., Das, K., Asmus, R. & Asmus, H. (2016) Seasonal Variation of Harbour Seal's Diet from the Wadden Sea in Relation to Prey Availability. *PLoS ONE, 11*(5): e0155727.

Deltacommissie, (2008). Samen werken met water. *Hollandia Printing*. A living land building for its future.

Dotinga, H. and Trouwborst, A., 2009. The Netherlands and the designation of marine protected areas in the North Sea. Implementing international and European law. *Utrecht Law Review*, 5(1), pp.21–43. DOI: http://doi.org/10.18352/ulr.93

Duineveld, G. C. A., Künitzer, A., Niermann, U„ DeWilde, P. A. W. J., and Gray, J. S. 1991. The macrobenthos of the N orth Sea. Netherlands Journal of Sea Research, 28; 53-65.

Dutch Government (2017). Proposal for Fisheries Management Measures to protect the Common Guillemot (A199) in the Frisian Front Special Protection Area. https://fiskeristyrelsen.dk/fileadmin/user_upload/Fiskeristyrelsen/Beskyttede_omraader/Natura_2000/Natura_2000_og_fiskeriregulering_frem_mod_2020/holland_draft_background_document_frisian_front_birds_12_july_2017.pdf

Dutch Offshore Wind Atlas (2022). KNMI Data Platform. https://www.dutchoffshorewindatlas.nl/

ECOMARE, (2022). *Harbour seal*. https://www.ecomare.nl/en/in-depth/reading-material/animals/seals/harbour-seal/

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N., & Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. *Science Series Technical Report, 147*.

Enners, L., Chagas, A.L.J., Ismar-Rebitz, S.M.H., Schwemmer, P. & Garthe, S. (2019). Foraging patterns and diet composition of breeding Pied avocets (*Recurvirostra avosetta*) in the German Wadden Sea. *Estuarine, Coastal and Shelf Science, 229*. https://doi.org/10.1016/j.ecss.2019.106399.

Eriksson, M.O.G., (1976). Food and Feeding Habits of Downy Goldeneye *Bucephala clangula* (L.) Ducklings. *Ornis Scandinavica (Scandinavian Journal of Ornithology), 7*(2), 159–169. https://doi.org/10.2307/3676185

ERT (2003*). Sediment trace and heavy metals analyses of seabed sediments acquired in the DTI Strategic Environmental Assessment Area 2 (SEA2), Central and Southern North Sea, May/June 2001*. Technical report produced for Strategic Environmental Assessment – SEA2. Produced by ERT (Scotland) Ltd.

European Commission (EC). (2009). The Birds Directive. https://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm

European Environment Agency [EEA]. (2019a). Common seal - *Phoca vitulina*. https://eunis.eea.europa.eu/species/1507

European Environment Agency [EEA]. (2019b). *Grey seal - Halichoerus grypus.* https://eunis.eea.europa.eu/species/1421#legal_status

European Marine Observation Data Network [EMODnet]. (2020). *Seabed habitats project*. http://www.emodnet-seabedhabitats.eu.

European Marine Observation Data Network [EMODnet]. (2021). *Human activities data portal*. https://www.emodnet-humanactivities.eu/view-data.php. Accessed 09 August 2022.

European Marine Observation Data Network [EMODnet]. (2022a). *Geology map WMS.* https://www.emodnet-geology.eu/map-viewer/

European Marine Observation Data Network [EMODnet]. (2022b). *Bathymetry map WMS.* https://portal.emodnet-bathymetry.eu/

European Environment Agency (EEA) (2022). Human activities. https://eunis.eea.europa.eu/sites

Fijn, R.C., Arts, F.A., de Jong, J.W., Beuker, D., Bravo Rebolledo, E.L., Engels, B.W.R., Hoekstein, M.S.J., Jonkvorst, R.J., Lilipaly, S., Sluijter, M., van Straalen, K.D., Wolf, P.A. (2018). Verspreiding en abundantie van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 2017–2018. Bureau Waardenburg & Delta Project Management, Culemborg. https://puc.overheid.nl/rijkswaterstaat/doc/PUC_154358_31/. Accessed 02 Oct 2020

Frederiksen, M. (2010). Appendix 1: Seabirds in the North East Atlantic. A review of status, trends and anthropogenic impact. In: Action plan for seabirds in Western-Nordic areas. Report from a workshop in Malmö, Sweden, 4–5 May 2010. Nordic Council of Ministers.

Fugro, (2022a). Aramis Pipeline Routing Desktop Study - Expected Site Conditions (Fugro Report No. R201644 03). Fugro France SAS Report to Total Energies. 10 February 2022.

Fugro (2022b). Operations Report – Seeker (WP2). Total Energies Aramis Pipeline Survey. Report to Total Energies Report Number F197217-REP-OPS-SK Draft. August 2022.

García, S., Álvarez, H., Perry, A.L., Blanco, J., Maaholm, D.J. & Aguilar, R. (2019). Protecting the North Sea: Brown Bank. Oceana, Madrid.

Geelhoed SCV, Janinhoff N, Lagerveld S, Lehnert LS & Verdaat JP, 2018. Marine mammal surveys in Dutch North Sea waters in 2017. Wageningen Marine Research (University & Research centre), Wageningen Marine Research report C030/18.

Gilles, A., Andreasen, H., Müller, S. & Siebert, U. (2008). Nahrungsökologie von marinen Säugetieren und Seevögeln für das Management von NATURA 2000 Gebieten. Endbericht für das Bundesamt für Naturschutz.

Gilles, A., Scheidat, M. & Siebert, U. (2009) Seasonal distribution of harbour porpoises and possible interference of offshore wind farms in the German North Sea. *Marine Ecology Progress Series, 383*, 295-307.

Gilles, A., Viquerat, S., Becker, E.A., Forney, K.A., Geelhoed, S.C.V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., van Beest, F.M., van Bemmelen, R. & Aarts, G. (2016). Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment. *Ecosphere, 7*(6): e01367.

Glémarec, M. 1973. The benthic communities of the European North Atlantic continental shelf. Oceanography and Marine Biology Annual Review, 11:263-289.

Government of the Netherlands (GON). (2022, 16 August). *Water management, quality of water*. https://www.government.nl/topics/water-management/water-quality/quality-of-fresh-water-and-salt-water#:~:text=The%20quality%20of%20the%20water,that%20represent%20the%20ideal%20environment.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N. (2002). Abundance of the harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology, 39*, 361-376.

Hammond P.S., Lacey, C., Gilles, A., Viquerat, S., Börjesso, P., Herr, H., Macleod, K, Ridoux, V., Santos, M.B., Scheidat, M., Teilmann J., Vingada, J., Øien, N. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys.

Hammond P.S., Lacey, C., Gilles, A., Viquerat, S., Börjesso, P., Herr, H., Macleod, K, Ridoux, V., Santos, M.B., Scheidat, M., Teilmann J., Vingada, J., Øien, N. (2021). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. June 2021.

Heip, c, Basford, D., Craeymeersch, J. A., Dewarumez, J.-M., Dörjes, J., de Wilde, P., Duineveld, G., Eleftheriou, A., Herman, P. M. J., Niermann, V., Kingston, P., Künitzer, A., Rachor, E., Rumohr, H., Soetaert, K., and Soltwedel, K. 1992. Trends in biomass, density and diversity of North Sea macrofauna. - ICES J. mar. Sci., 49: 13-22.

Hitchcock, D.R. & Bell, S. (2004). Physical Impacts of Marine Aggregate Dredging on Seabed Resources in Coastal Deposits. Journal of Coastal Research (2004) 20 (1 (201)): 101–114. https://doi.org/10.2112/1551-5036(2004)20[101:PIOMAD]2.0.CO;2

Holland, G., Greenstreet, S., Gibb, I., Fraser, H., & Robertson, M. (2005). Identifying sand eel *Ammodytes marinus* sediment habitat preferences in the marine environment. Marine Ecology-progress Series - Mar Ecol Progr Ser. 303. 269-282. 10.3354/MEPS303269. International Finance Corporation (2007). *Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets*.

Interdepartmental North Sea Directors Consultation (IDOM) (2004). Noordzee-atlas Ministerie van Verkeer en Waterstaat/Rijkswaterstaat directie Noordzee. Available at https://www.noordzeeloket.nl/beheer/noordzeeatlas/.

iNaturalist (2022). https://www.inaturalist.org/taxa/3882-Tringa-erythropus

International Council for the Exploration of the Sea (ICES) (2022). Contaminants and biological effects of contaminants in biota. https://dome.ices.dk/views/ContaminantsBiota.aspx

International Union for Conservation of Nature's Red List of Threatened Species (IUCN), (2022). https://www.iucnredlist.org/

IPIECA (2012). *Sensitivity mapping for oil spill response. Good practice guidelines for incident management and emergency response personnel*. IOGP Report Number 477. Date of publication: July 2012.

Jarvis, S.; Allen, J.; Proctor, N.; Crossfield, A.; Dawes, O.; Leighton, A.; McNeill, L.; Musk, W. (2004). *North Sea Wind Farms NSW Lot 1 Benthic Fauna* (Report No. ZBB607.2-F-2004). Report by Institute of Estuarine and Coastal Studies (IECS).

Jennings, S., Lancaster, J, Woolmer, A & Cotter, J. (1999) Distribution, diversity and abundance of epibenthic fauna in the North Sea, J. Mar. Biol. Ass. 79, pp 385-399.

Jensen, L. F., Teilmann, J., Galatius, A., Pund, R., Czeck, R., Jess, A., Siebert, U., Körber, P. & Brasseur S. (2017). Marine mammals. In: Wadden Sea Quality Status Report 2017. Eds.: Kloepper S. *et al.*, Common Wadden Sea Secretariat, Wilhelmshaven, Germany. Available at: https://qsr.waddensea-worldheritage.org/reports/marine-mammals

Johns, D.G. & Reid, P.C. (2001). An overview of plankton ecology in the North Sea. Strategic Environmental Assessment - SEA2 Technical Report 005 – Plankton. Produced by SAHFOS, August 2001.

Joint, I & Pomroy, A. (1993). Phytoplankton biomass and production in the southern North Sea. Mar. Ecol. Prog. Ser. 99, pp 169-182.

Jones, E., McConnell, B., Smout, S., Hammond, P., Duck, C., Morris, C., Thompson, D., Russell, D., Vincent, C., Cronin, M., Sharples, R., & Matthiopoulos, J. (2015). Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. *Marine Ecology Progress Series*, *534*, 235–249. https://doi.org/10.3354/meps11370.

Kirlwood, R., Bos, O. & Brasseur, S. (2014). Seal monitoring and evaluation for the Luchterduinen offshore wind farm 1. T0 - 2013 report. Report number C067/14. IMARES Wageningen UR. April 2014.

Koffijberg, K., Frikke, J., Hälterlein, B., Laursen, K., Reichert, G. & Soldaat, L. (2017). Breeding birds. In: Wadden Sea Quality Status Report 2017. Eds.: Kloepper S. *et al.*, Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

Künitzer, A. (1990). The infauna and epifauna of the central North Sea. Meeresforschung, 33: 23-37.

Künitzer, A., Duineveld, G. C. A., Basford, D., Craeymeersch, J. A., Dewarumez, J.-M., Dörjes, J., Eleftheriou, A., Heip, c., Herman, P. M. J., Kingston, P., Niermann, V., Rumohr, H., and de Wilde, P. A. J. 1992. The Benthic Infauna of the North Sea: Species Distribution and Assemblages. ICES Journal of Marine Science.

Laban, C. (2006). Seabed Mapping in the Dutch Sector of the North Sea An Exploration of the Seabed for Sand and Gravel Resources. Sea Technology August 2006.

Leopold, M.F., Dijkman, E.M., Teal, L. et al (2011). Local birds in and around the offshore windfarm Egmond aan Zee (OWEZ) (T-) & T-1, 2002-2010). IMARES Report Number C187/11.

Leopold, M.F.; Bemmelen, R.S.A. & van; Zuur, A.F. (2013). Responses of Local Birds to the Offshore Wind Farms PAWP and OWEZ off the Dutch mainland coast. Den Burg: IMARES (Report / IMARES Wageningen UR C151/12) – 108.

Leopold, M.F., (2015). Eat and be eaten: porpoise diet studies. Diss. Wageningen University.

Leopold, M.F., Begeman, L., van Bleijswijk, J.D.L., IJsseldijk, L.L., Witte, H.J. & Gröne, A. (2015). Exposing the grey seal as a major predator of harbour porpoises. *Proceedings of the Royal Society B, Biological Sciences, 282:* 20142429. https://doi.org/10.1098/rspb.2014.2429

Lindeboom, H. J., Dijkman, E. M., Bos, O. G., Meesters, H. W. G., Cremer, J. S. M., de Raad, I., van Hal, R., & Bosma, A. (2008). *Ecologische atlas Noordzee ten behoeve van gebiedsbescherming, 2e dr*. Wageningen Imares. https://edepot.wur.nl/251730

Lockyer, C. & Kinze, C. (2003). Status, ecology and life history of harbour porpoise (*Phocoena phocoena*), in Danish waters. *NAMMCO Scientific Publications, 5,* 143-176.

Marine Environment Protection Committee (MEPC) (2011). 2011 Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species. MEPC 62/24/Add. 1. Annex 26. Resolution MEPC.207(62) Adopted 15 July 2011. Available on https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/RESOLUTION%20MEPC.207[62].pdf

Miró, J.M., Megina, C., Donázar-Aramendía, I. & García Gómez, J.C., (2022). Effects of maintenance dredging on the macrofauna of the water column in a turbid estuary Science of The Total Environment Volume 806, Part 3, 1 February 2022, 151304

Mubiana, V.K., Qadah, D., Meys, J. & Blust, R. (2005). Temporal and spatial trends in heavy metal concentrations in the marine mussel *Mytilus edulis* from the Western Scheldt estuary (The Netherlands). *Hydrobiologia 540*, 169–180. https://doi.org/10.1007/s10750-004-7134-7

NLOG. (2022). *Dutch Oil & Gas portal – files interactive map*. https://www.nlog.nl/en/files-interactive-map

Newell, R.C., Seiderer, L.J & Hitchcock, D.R. (1998). The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology: an Annual Review 1998,36,127-78.

Nohe, A., Knockaert, C., Goffin, A., Dewitte, E., De Cauwer, K., Desmit, X., Vyverman, W., Tyberghein, L., Lagring, R., & Sabbe K. (2018). Marine phytoplankton community composition data from the Belgian part of the North Sea, 1968-2010. Sci. Data 5:180126 doi: 10.1038/s.

Noordzeeloket (2022). Eider (*Somateria mollissima*) – A063. https://www.noordzeeloket.nl/en/policy/noordzee-natura-2000/gebieden/noordzeekustzone/north-sea-coastal/protected-species/birds/eider/

Noordzeeloket (2022a). Frisian Front. https://www.noordzeeloket.nl/en/policy/noordzee-natura-2000/gebieden/friese-front/

Noordzeeloket (2022b). Voordelta. https://www.noordzeeloket.nl/en/policy/noordzee-natura-2000/gebieden/voordelta/

Noordzeeloket (2022c). Marine Strategy for the Netherlands part of the North Sea 2012-2020, Part 1. https://www.noordzeeloket.nl/en/functions-and-use/natuur/@166937/marine-strategy-0/

Norton-Griffiths, M. (2008). Some ecological aspects of the feeding behaviour of the Oystercatcher *Haematopus ostralegus* on the Edible Mussel *Mytilus edulis*. *Ibis. 109,* 412 - 424. 10.1111/j.1474-919X.1967.tb04014.x.

OECD (2021). Fisheries and Aquaculture in Netherlands. https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/documents/report_cn_fish_nld.pdf

OSPAR (2009). Background Document for Ocean quahog *Arctica islandica*. Biodiversity Series 2009.

Oslo and Paris Commission (OSPAR), (2009a). Background document on CEMP assessment criteria for the QSR 2010. Monitoring and Assessment Series. Report No. 978-1-907390-08-1, pp. 25.

Oslo and Paris Commission [OSPAR]. (2014). Levels and trends in marine contaminants and their biological effects – CEMP assessment report 2013 (OSPAR Publication No. 631/2014). OSPAR Commission.

Paruk, J. D., Evers, D. C., McIntyre, J. W., Barr, J. F., Mager, J. & Piper, W. H. (2021). Common Loon (*Gavia immer*), version 2.0. In Birds of the World (P. G. Rodewald and B. K. Keeney, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.comloo.02

Periplus Archeomare BV, (2022). Archaeological desk study area of interest Aramis pipelines. Report 21A036-01.

Petersen, C. G. J. 1914. Valuation of the sea. II. The animal communities of the sea bottom and their importance for marine zoogeography. Rep. Dan. Biol. Stn. 21: 1-44.

Phillips, R. A., Caldow, R. W. G. & Furness, R. W. (1996). The influence of food availability on the breeding effort and reproductive success of Arctic Skuas *Stercorarius parasiticus*. https://doi.org/10.1111/j.1474-919X.1996.tb08059.x

Poot, M., Heunks, C., Verdaat, J.P., Prinsen, H., Wolf, P., Leopold, M.F. & Boudewijn, T.J. (2009). The shallow coastal zone in the SW-Netherlands as a concentration area for red-throated divers *Gavia stellata* - variation in occurrence in relation to wind and tide.

Poot, M.J.M., Fijn, R.C., Jonkvorst, R.J., Heunks, C., Collier, M.P., de Jong, J. & van Horrsson, P.W. (2011). Aerial surveys of seabirds in the Dutch North Sea May 2010 – April 2011 Seabird distribution in relation to future offshore wind farms. IMARES. Report No. 10-235.

Port of Rotterdam (2021). Port information guide. https://www.portofrotterdam.com/sites/default/files/2021-05/port-information-guide.pdf

Prop, J. & Van Eerden, M.R. (1981). The occurrence of migratory birds in the lauwerszee area the Netherlands from the embankment 1969 1978. *Limosa, 54*(1): 1-16. https://eurekamag.com/research/006/727/006727301.php Reijnders, P.G.H., Ries, E.H., Tougaard, S., Nørgaard, N., Heidemann, G., Schwarz, J., Vareschi, E. & Traut I.M (1997). Population development of harbour seals *Phoca vitulina* in the Wadden Sea after the 1988 virus epizootic, *Journal of Sea Research, 38*(1–2), 161-168. https://doi.org/10.1016/S1385-1101(97)00031-2.

Ramsar Sites Information Service (RSIS) (2014). Voordelta. https://rsis.ramsar.org/ris/1279

Reijnders, P.J.H., Brasseur, S.M.J.M., Tougaard, S., Siebert, U., Borchardt, T. & Stede, M. (2010). Population development and status of harbour seals (*Phoca vitulina*) in the Wadden Sea. *NAMMCO Scientific Publications, 8*, 95-106. DOI:10.7557/3.2677

Reiss, H., Degraer, S., Duineveld, G. C. A., Kro¨ncke, I., Aldridge, J., Craeymeersch, J., Eggleton, J. D., Hillewaert, H., Lavaleye, M. S. S., Moll, A., Pohlmann, T., Rachor, E., Robertson, M., vanden

Berghe, E., van Hoey, G., and Rees, H. L. (2010). Spatial patterns of infauna, epifauna, and demersal fish communities in the North Sea. – ICES Journal of Marine Science, 67: 278–293.

Rees, H. L., Pendle, M. A., Waldock, R., Limpenny, D. S., and Boyd, S. E. (1999). A comparison of benthic biodiversity in the North Sea, English Channel, and Celtic Seas. – ICES Journal of Marine Science, 56: 228–246

Rocha, A., Fonseca, D., Masero, J. & Ramos, J. (2016). Coastal saltpans are a good alternative breeding habitat for Kentish plover *Charadrius alexandrinus* when umbrella species are present. *Journal of Avian Biology. 47*. 10.1111/jav.00883.

Römer, M., S. Wenau, S. Mau,M. Veloso, J. Greinert, M. Schlüter, and G. Bohrmann (2017), Assessing marine gas emission activity and contribution to the atmospheric methane inventory: A multidisciplinary approach from the Dutch Dogger Bank seep area (North Sea), Geochem. Geophys. Geosyst.,18, 2617–2633,doi:10.1002/2017GC006995

Royal Netherlands Navy (2022). BaZ1 Notices to Mariners. Edition 2022.

Scheidat M. & Verdaat H. (2009) Distribution and density of harbour porpoises in the Dutch North Sea waters. Report C125/09, Wageningen IMARES. 30 November 2009.

Scheidat, M., Tougaard, J., Brasseur, S., Carstensen, J., Petel, T.V.P., Teilmann, J. & Reijnders, P. (2011). Harbour porpoises (*Phocoena phocoena*) and wind farms: a case study in the Dutch North Sea. *Environmental Research Letters, 6*: 025102.

Scheiffarth, G. (2001). The diet of Bar-tailed Godwits *Limosa lapponica* in the Wadden Sea: Combining visual observations and faeces analyses. *Ardea. 89,* 481-494.

Schoeman, R.P., Patterson-Abrolat, C. and Plön, S. (2020). A Global Review of Vessel Collisions with Marine Animals. *Frontiers in Marine Science*, *7*, 292. https://doi.org/10.3389/fmars.2020.00292

SCOS, (2015). Scientific advice on matters related to the management of seal populations: 2015 Reports of the UK Special Committee on Seals. http://smub.st-andrews.ac.uk.

SCOS (2020). *Advice on Matters Related to the Management of Seal Populations: 2020*. http://www.smru.st-andrews.ac.uk/files/2021/06/SCOS-2020.pdf

Sistermans, P. & Nieuwenhuis, O. (undated). Hollnad Coast (The Netherlands). Eurosion Case Study. Available at http://projects.eucc-d.de/files/000139_EUROSION_Holland_coast.pdf.

Skov, H., Durinck, J., Leopold, M.F. & Tasker ,M.L. (1995). Important bird areas in the North Sea, including the Channel and the Kattegat. *BirdLife International, Cambridge*.

Skov, H., Durinck, J., Leopold, M.F. & Tasker, M.L. (2007). A quantitative method for evaluating the importance of marine areas for conservation of birds. *Biological Conservation, 136*: 362-371.

Stolk, A & Laben C. (2002). The Dutch sector of the North Sea. A geological introduction. Ministry of Transport, Public Works and Water Management, North Sea Directorate and Netherlands Institute of Applied Geoscience-TNO

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J. & Pienkowski, M.W. (1995). An atlas of seabird distribution in north-west European waters. *Joint Nature Conservation Committee*.

Strategies for Environmental Monitoring of Marine Carbon Capture and Storage: Research Highlights (2020) by the STEMM-CCS project consortium, 36 pages. DOI 10.5281/zenodo.3627036.

Székely, T. (1990). Status and breeding biology of Kentish Plover *Charadrius alexandrinus* in Hungary- a progress report. *Wader Study Group Bulletin, 62*, 17-23.

The Crown Estate (TCE) (2014). Protocol for Archaeological Discoveries: Offshore Renewables Projects. https://www.wessexarch.co.uk/sites/default/files/field_file/2_Protocol%20For%20Archaeological%20Discoveries.pdf

Sea Temperatures, (2022). The Hague Sea Temperature. https://seatemperatures.net/europe/netherlands/the-hague/

Thomsen, F., Laczny, M. & Piper, W. (2007). The harbour porpoise (*Phocoena phocoena*) in the central German Bight: phenology, abundance and distribution in 2002-2004. *Helgoland Marine Research, 61*, 283-289.

United Kingdom Offshore Operators Association (UKOOA). (2001). An analysis of UK offshore oil and gas environmental gas surveys 1975-95. The United Kingdom Offshore Operators Association.

Vandendriessche, S., Stienen, E., Vincx, M. & Degraer, S. (2007). Seabirds Foraging at Floating Seaweeds in the Northeast Atlantic. Ardea -Wageningen-. 95. 289-298. 10.5253/078.095.0211.

van Erp, J.A., van Loon, E.E., Camphuysen, K.J. (2021). Temporal patterns in offshore bird abundance during the breeding season at the Dutch North Sea coast. *Marine Biology, 168*, 150. https://doi.org/10.1007/s00227-021-03954-4

Van Gils, J., Wiersma, P., Kirwan, G.M. and Sharpe, C.J. 2015. Common Snipe (*Gallinago gallinago*). In: del Hoyo, J., Elliott, A., Sargatal, J., Christie, D.A. and de Juana, E. (eds), Handbook of the Birds of the World Alive, Lynx Edicions, Barcelona.

van Hal, R. (2013). Roundfosh monitoring. Princess Amalia wind farm. IMARES Wageningen UR. Report number C117/13-A.

van Kooten, T., Deerenberg, C.M., Jak, R.G., van Hal, R., & Machiels, M.A.M. (2015). An exploration of potential effects on fisheries and exploited stocks of a network of marine protected areas in the North Sea. Report No. C093/14. IMARES, Wageningen, the Netherlands.

van Neer, A., Jensen, L.F. & Siebert, U. (2015). Grey seal (*Halichoerus grypus*) predation on harbour seals (*Phoca vitulina*) on the island of Helgoland, Germany. *Journal of Sea Research, 97*, 1-4. https://doi.org/10.1016/j.seares.2014.11.006

van Utrecht, W.L. (1978). Age and growth in *Phocoena* Linnaeus, 1758 (Cetacea, Odontoceti) from the North Sea. *Bijdragen tot de Dierkunde, 48*: 16–26.

van Vreeswijk, T., van Roomen, M., van Winden, E., Dotinga, H. & Korporaal N. (2019) Important Bird Areas in the Netherlands 2019. A revision of the national IBA inventory. Vogelbescherming Nederland, Zeist & Sovon Dutch Centre for Field Ornithology, Nijmegen.

Witbaard, R & Bergman, M.J.N. (2003). The distribution and population structure of the bivalve *Arctica islandica* L. in the North Sea: what possible factors are involved? Jour of Sea Res. 50, pp 11-25.

Witbaard, R., Bos, O.G., & Lindeboom, H.J. (2008). Basisinformatie over de Borkumer Stenen, Bruine Bank en Gasfonteinen, potentieel te beschermen gebieden op het NCP. Report No. C026/08. IMARES, Wageningen, the Netherlands.

Wojczulanis-Jakubas, K., Jakubas, D. & Stempniewicz, L. (2022). The Little Auk *Alle*: an ecological indicator of a changing Arctic and a model organism. *Polar Biology, 45*, 163–176. https://doi.org/10.1007/s00300-021-02981-7

Worsøe Clausen, L., Horsten, M.B., & Hoffmann, E. (2002). Gyde-og opvækstpladser for kommercielle fiskearter i Nordsøen, Skagerrak og Kattegat. Fiskeriundersøgelser, Danmarks. DFU-rapport No. 118-02. Charlottenlund, Danmarks Fiskeriundersøgelser.

Environmental Site Survey

Total Aramis Project

Dutch Sector
Field Report
Survey Period: 04 January 2023 to 23 January 2023

F197217-REP-002 01 | 8 February 2023
Draft
TotalEnergies E&P North Sea UK Limited

Document Control

Document Information

Document Title	Environmental Site Survey Total Aramis Project Dutch Sector Field Report
Fugro Project No.	220076
Fugro Document No.	F197217-REP-002
Issue Number	01
Issue Status	Complete
Fugro Legal Entity	Fugro GB Marine Limited
Issuing Office Address	1 – 9 The Curve, 32 Research Avenue North, Heriot-Watt Research Park, Edinburgh, EH14 4AP, United Kingdom

Client Information

Client	TotalEnergies E&P North Sea UK Limited
Client Address	Bordewijklaan 18, 2591 XR – The Hague – The Netherlands
Client Contact	[redacted]

Revision History

Issue	Date	Status	Comments on Content	Prepared By	Checked By	Approved By
01	8 February 2023	Complete	Issued to client	[redacted]	[redacted]	[redacted]

Project Team

Initials	Name	Role
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Executive Summary

Introduction

On the instruction of TotalEnergies E&P North Sea UK Limited, Fugro performed a site survey including geophysical, geotechnical, and environmental data acquisition at the Total Aramis project area. The site was located within the Dutch sector of the North Sea. Operations were conducted using the MV Fugro Searcher during the survey period 04 January 2023 to 23 January 2023.

Environmental Survey

Twenty-eight camera transects and grab sampling stations (ARS-01 to ARS-28) were predetermined by the client, with one additional transect (ARS-TE) to be run over the proposed tunnel exit. Each transect orientation and length (minimum 200 m) were to be decided on station location dependant on tides and currents. Photographic data were successfully acquired at 24 of the 28 proposed stations and transect ARS-TE. After failed attempts due to poor visibility, the freshwater lens camera frame (FWL) was used. Photographic data with the FWL were successfully acquired on first attempts at stations ARS-06, ARS-08, ARS-20, ARS-22, ARS-24, and ARS-26. Successful reruns were conducted at stations ARS-09a and ARS-21a. At station ARS-23, five additional transects were proposed by the client, however poor visibility was incurred at all transects resulting in unacceptable stills and video data. Stations ARS-25, ARS-27 and ARS-28 were aborted due to zero visibility using the FWL resulting in no photographic data acquisition.

A full suite of grab samples was successfully acquired from 26 of the 28 predefined stations. Stations ARS-24 and ARS-23 were completed using the Hamon grab and therefore no physico-chemical samples were acquired at these stations. A full suite of water samples was successfully acquired from all seven client predefined stations.

Seabed Habitats

Seabed sediments across the Aramis survey area generally comprised four sediment types; mud, sandy mud, muddy sand, and sand.

Benthic epifauna were sparse throughout the survey area, frequently observed fauna included brittlestars (Ophiuroidea), starfish (Asteroidea including *Asterias rubens*), and heart urchin (*Echinocardium flavescens*).

Potentially Sensitive Habitats

Burrows were observed within muddy sediments in the north of the survey area. The potential presence of the OSPAR (2008) habitat 'Sea pens and burrowing megafauna' will be further assessed in the environmental baseline survey report.

Sand eels were observed in video and photographic data and grab samples at stations ARS-25 and ARS-28. Further analysis will identify if these are the lesser sand eel, a Priority Species under the UK Biodiversity Framework (JNCC, 2012). No other potentially sensitive habitats or species were observed.

Biodiversity

There were 1005 hours and 11 minutes of visual monitoring and 658 hours and 31 minutes of passive acoustic monitoring (PAM) effort during the survey (totalling 1663 hours and 42 minutes of joint observation effort). Visual observations totalled 11334 sightings, including 4 species of mammals (7 sightings) and 63 species of avifauna (11327 sightings). There were no acoustic monitoring detections for the duration of the survey.

Contents

Appendices

Figures in the Main Text

Tables in the Main Text

Abbreviations

BSL	Below sea level
BTEX	Benzene, toluene, ethylbenzene and xylene
CCS	Carbon capture and storage
CM	Central meridian
CTD	Conductivity temperature depth
DVV	Dual van Veen grab
EOL	End of line
EU	European Union
FA/FB/FC	Faunal sample A, B or C
FWL	Freshwater lens camera frame
GNSS	Global Navigation Satellite System
HC	Hydrocarbon sample
HD	High Definition
HM	Heavy metal sample
JNCC	Joint Nature Conservation Committee
LED	Light emitting diode
MV	Motor vessel
NF	No fix
NS	No sample
ORP	Oxygen reduction potential
OSPAR	Oslo and Paris Commission
PAM	Passive acoustic monitoring
PC	Physico-chemical sample
PSD	Particle size distribution
SOL	Start of line
SSS	Side scan sonar
STR	Subsea Technology and Rentals
USBL	Ultra short baseline
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VHF	Very high frequency

1. Introduction

1.1 Background

On the instruction of TotalEnergies E&P North Sea UK Limited, Fugro performed a site survey including geophysical and environmental data acquisition at the Aramis project area. The site consists of a pipeline corridor running from Maasvlakte to offshore blocks L4/K6 and is located within the Dutch Sector of the North Sea. Operations were conducted using MV Fugro Searcher during the survey period 04 January 2023 to 23 January 2023.

The Carbon Capture and Storage (CCS) Aramis Project aims to reduce industrial CO_2 in the Netherlands by developing CO_2 transport facilities to allow for offshore storage of the gas. Once captured, the CO_2 is collected at a compressor station and shipping terminal at Maasvlakte, a hub in the port of Rotterdam. From this hub the CO_2 is transported to offshore gas fields to be injected into depleted reservoirs at a depth of about 3-4 km below the seabed.

The Aramis Project site survey was carried out to identify and map the seabed and sub-seabed conditions, including potential associated hazards (geohazards or man-made hazards), affecting the future installation of trunkline/flowline and riser access tower. The environmental survey was conducted to establish whether any sensitive habitats are present in the area, specifically habitats listed under Annex I of the EU Habitats Directive and habitats listed by the Oslo and Paris Commission (OSPAR) as threatened and/or declining habitats (OSPAR, 2008). In addition, grab samples were collected to establish physico-chemical and biological properties of the sediment at key locations.

This report details the environmental operations and presents a preliminary assessment of the data obtained in the field. The interpretation may change following further data analysis.

Appendix A outlines the guidelines for use of this report.

1.2 Coordinate Reference System

All coordinates detailed in this report are referenced to European Terrestrial Reference System 1989 (ETRS89) and Universal Transverse Mercator (UTM) projection Zone 31N central meridian 3° East (CM 3° E). Table 1.1 provides the detailed geodetic and projection parameters.

Table 1.1: Project geodetic and projection parameters

Name: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014],LAT (NL) [NLLAT2018]		
EPSG Code	EPSG:25831	
Global Navigation Satellite System (GNSS) Geodetic Parameters		
Datum	International Terrestrial Reference Frame 2014	EPSG:1165
Ellipsoid	GRS 1980	
Semi major axis	a = 6 378 137.00 m	
Inverse flattening	1/f = 298.257222101	
Local Geodetic Datum Parameters		
Datum	European Terrestrial Reference System 1989	EPSG:6258
Ellipsoid	GRS 1980	
Semi major axis	a = 6 378 137.00 m	
Inverse flattening	1/f = 298.257222101	
Datum Transformation Parameters from from ITRF2014 to ETRS89		
X-axis translation 0.05595 m	X-axis rotation -0.0027132″	Scale difference 0.00349455 ppm
Y-axis translation 0.05345 m	Y-axis rotation -0.016413″	Coordinate Frame rotation
Z-axis translation -0.09784 m	Z-axis rotation 0.0265287″	FUGRO:41366
Local Projection Parameters		
Map projection	Transverse Mercator	
Grid system	UTM zone 31N	EPSG:16031
Latitude origin	00° 00′ 00.000″ N	
Central meridian	003° 00′ 00.000″ E	
Scale factor on central meridian	0.9996	
False easting	500 000 m	
False northing	0 m	
Project Vertical Parameters		
Vertical coordinate reference system	LAT (NL)	FUGRO:41043
Datum	LAT Datum (NL)	FUGRO:40917
Transformation	ETRS89 to LAT (2018)	FUGRO:41475
Notes * The geodetic datum of Fugro's global GNSS correction data is ITRF2014, epoch 2022.496 (01/07/2022)		

2. Survey Strategy

Twenty-eight environmental sampling stations were predetermined by the client, positioned along the pipeline corridor. Sediment sampling was to be conducted at all stations, involving the collection of one physico-chemical, one eDNA and three macrofaunal grab samples. Water sampling was to be conducted at seven stations (ARW-01 to ARW-07) and zooplankton trawls were to be acquired at three stations (ARW-03, ARW-06 and ARW-07).

Prior to sampling, video and stills photography were to be acquired at each station. The transects were to be centred on the proposed grab stations and run for a minimum of 200 m in length. The orientation for each transect was to be decided when the vessel was on station location, to accommodate for wind and tide. One additional camera transect (ARS-TE) was predetermined by the client to cover the tunnel exit location (≥ 200 m).

Tables 2.1and Table 2.2 provide the coordinates, data to be acquired and rationale for each location. Acceptable sampling accuracy was agreed with the client representative as within 5 m of the target location. Figure 2.1 provides a spatial display of the proposed survey locations overlain on the SSS mosaic.

Table 2.1: Proposed sampling stations

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT ⟨NL⟩ [NLLAT2018]				
Station	Easting	Northing	Rationale	Data and Sample Acquisition
Sediment sampling stations				
ARS-01	571 894.4	5 951 473.2	Circalittoral, offshore mud	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-02	564 985.4	5 943 971.1	Circalittoral, offshore mud	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-03	572 748.1	5 941 648.9	Circalittoral, offshore mud	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-04	560 107.8	5 931 027.3	Circalittoral, offshore mud. Pipeline hub	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-05	570 710.0	5 931 115.0	Circalittoral, offshore mud / transition habitat	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-06	553 144.2	5 926 904.6	Circalittoral, offshore mud / transitional habitat	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-07	563 527.3	5 922 148.7	Circalittoral, offshore mud	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-08	578 591.9	5 919 165.5	Offshore circalittoral coarse sediment	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-09	547 602.9	5 915 256.7	Circalittoral mud	Video, stills, PC, FA/FB/FC, eDNA, micro

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT {NL} [NLLAT2018]				
Station	Easting	Northing	Rationale	Data and Sample Acquisition
ARS-10	547 193.2	5 895 223.4	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-11	562 965.1	5 897 735.1	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-12	563 692.3	5 876 163.8	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-13	564 630.9	5 857 180.7	Offshore circalittoral coarse sediment	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-14	564 546.8	5 839 661.3	Offshore circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-15	561 837.9	5 823 368.0	Offshore circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-16	558 200.0	5 809 927.6	Offshore circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-17	560 338.8	5 801 273.1	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-18	561 906.5	5 794 117.4	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-19	563 675.4	5 775 750.7	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-20	570 005.1	5 777 955.4	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-21	571 538.4	5 770 655.6	Infralittoral mud	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-22	571 471.2	5 765 755.8	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-23	570 088.4	5 761 867.1	Circalittoral sand / site of emergence of directional drill	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-24	570 921.07	5 762 071.8	Circalittoral sand / site of emergence of directional drill	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-25	570 054.4	5 761 675.9	Channel / spoil disposal area	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-26	570 873.6	5 762 018.8	Channel / spoil disposal area	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-27	570 122.5	5 760 530.0	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
ARS-28	570 927.9	5 760 339.9	Circalittoral sand	Video, stills, PC, FA/FB/FC, eDNA, micro
Water sampling				

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT {NL} [NLLAT2018]				
Station	Easting	Northing	Rationale	Data and Sample Acquisition
ARW-01	560 107.8	5 931 027.3	Offshore water at, or near, the Frissian Front pipeline hub	PC, eDNA, CHL, Phyto
ARW-02	565 390.0	5 922 968.9	Offshore water at, or near, the Frissian Front. Offset from pipeline in direction of main current flow	PC, eDNA, CHL, Phyto
ARW-03	566 182.1	5 858 841.5	English Channel influenced water. Offset from pipeline in direction of main current flow	PC, eDNA, CHL, Phyto, ZP
ARW-04	560 338.8	5 801 273.1	English Channel and riverine influenced water.	PC, eDNA, CHL, Phyto
ARW-05	571 538.4	5 770 655.6	English Channel and riverine influenced water.	PC, eDNA, CHL, Phyto
ARW-06	570 921.1	5 762 071.8	North of channel	PC, eDNA, CHL, Phyto, ZP
ARW-07	570 122.5	5 760 530.0	South of channel	PC, eDNA, CHL, Phyto, ZP

Notes
PC = Physico-chemical sample
FA/FB/FC = Faunal sample A, B or C
eDNA =Environmental deoxyribonucleic acid sample
Micro = Microbiology sample
Phyto = Phytoplankton
CHL = Chlorophyll
ZP = Zooplankton

Table 2.2: Proposed transects

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT {NL} [NLLAT2018]				
Station	Easting	Northing	Rationale	Data and Sample Acquisition
ARS-TE	570 907.2	5 762 045.2	Proposed tunnel exit location	Video, stills

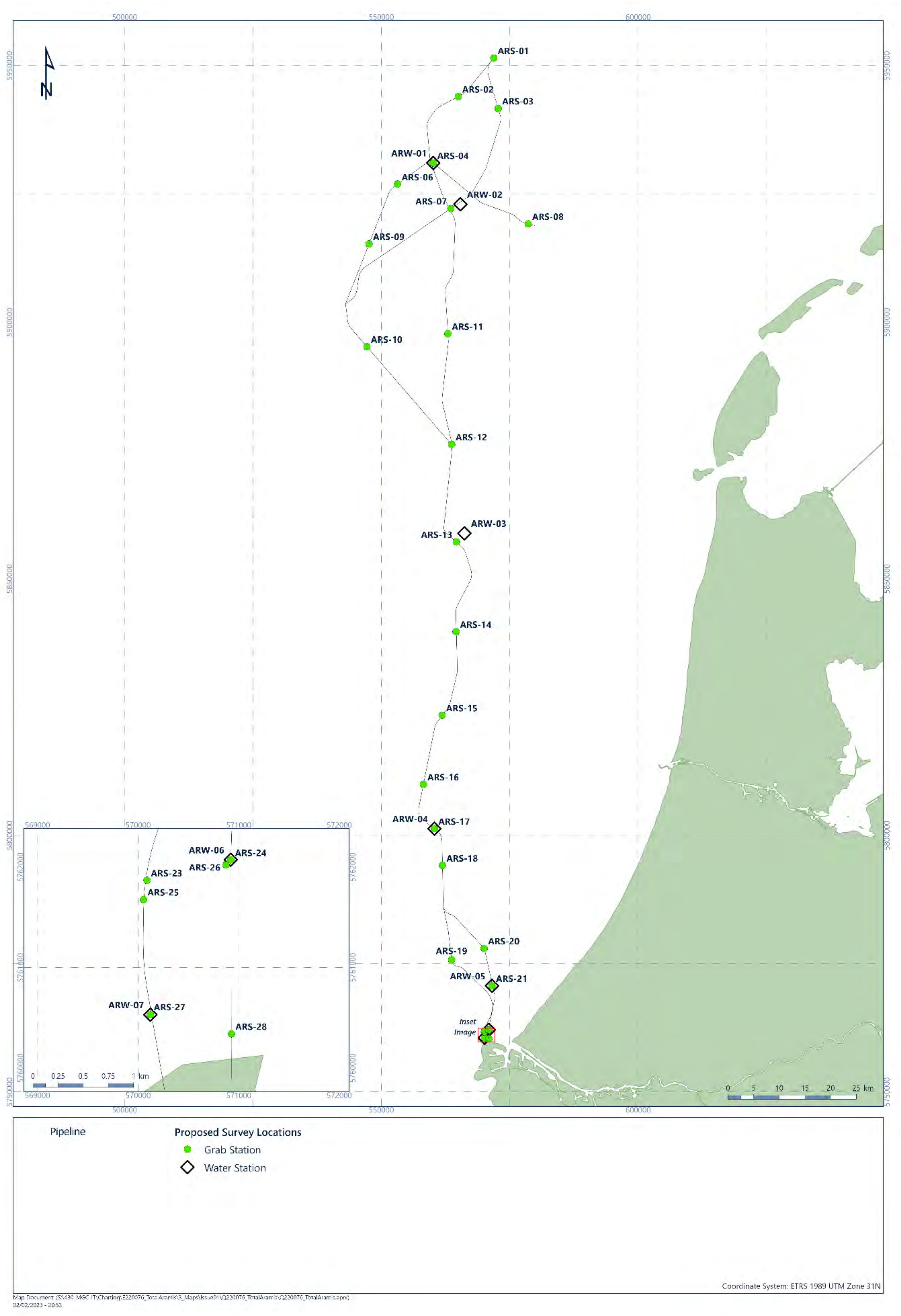


Figure 2.1: Proposed environmental survey locations, Total Aramis Project

3. Survey Methods

3.1 Seabed Photography

Seabed photography were captured using a Subsea Technology and Rentals (STR) Limited SeaSpyder deep-sea camera system, mounted within a purpose-built camera frame, complete with a high-definition video camera and high-resolution stills camera (24 megapixel). A separate high-power strobe and four high intensity LED lamps provided illumination and quad scaling lasers were set up 16.5 cm wide to provide a scale.

Where visibility was poor, seabed photography and video were acquired with an STR SeaSpyder Nano underwater camera system, mounted within a purpose-built freshwater lens camera frame (FWL). The camera system utilises a STR SeaSpectrum mini IP HD video camera and two STR SeaLight LED-1-DC lamps. The video camera was positioned within the freshwater housing and the lamps attached to the exterior of the frame. Lasers set at 10.3 cm distance provided a scale.

The camera systems were equipped with an ultra-short baseline (USBL) beacon for subsea positioning. Manual position fixes were recorded for every photograph captured and positional data were overlain on the recorded video, along with date, time, project and station information.

Seabed video footage was displayed on a computer monitor and recorded directly onto the server. A navigation string from the attached USBL beacon, including the time, date, depth and location (easting and northing) was overlain on the video. The survey location and station number were also displayed (manually updated). The stills camera imagery was visible on a second window of the computer. Footage was viewed in real time via a sonar cable, assisting in the control of the camera in the water.

Operational procedures for seabed photography were as follows:

- The camera was setup on deck prior to deployment and a test photograph taken;
- The camera was deployed into the water just below the sea surface, at which point the system was switched on;
- The camera was lowered to the seabed using the side scan sonar (SSS) winch and recording started when the seabed was visible;
- The vessel was moved along the line with the winch adjusted to keep the seabed visible on the live feed;
- Still photography were taken when the environmental scientist manually triggered the camera while the camera moved over the seabed. Whenever a photograph was taken the surveyor captured a positional fix;
- The camera system switched off just beneath the surface and then recovered to the deck;
- On completion, photographs were downloaded and backed up onto the ship's system and an external hard drive.

3.2 Sediment Grab Sampling

Seabed samples were acquired using a 0.1 m^2 dual van Veen grab, or a 0.1 m^2 mini Hamon grab in instances of coarse sediments.

Operational procedures for grab sampling were as follows:

- The grab was prepared for operations prior to arrival on station. A USBL beacon was attached to the grab frame. The Bridge communicated to the deck via a VHF radio when the vessel was steady and on location, and the grab was deployed from the starboard A-frame;
- When the engineer operating the winch observed that the grab had reached the seabed (evidenced through a distinct slackening of the wire rope and snatch block), the online surveyor was informed (via VHF radio) and a fix was taken;
- On recovery to the deck, the sample was inspected and judged acceptable or otherwise (see below for rejection criteria);
- Three accepted grab samples were retained for faunal analysis and one grab sample was retained and subsampled for physico-chemical analysis;
- Deck logs were completed for each sample acquired (including no samples) with: date, time, sample number, fix number, sediment type, depth and colour of strata in the sediment (if any) using Munsell colour codes, odour (i.e. H_2S), bioturbation or debris.

Samples were considered unacceptable in the following instances:

- Evidence of sediment washout caused through improperly closed grab jaws or inspection hatch;
- Sediment sample taken on an angle; where the grab jaws have not been parallel to the seabed when the grab fired;
- Disruption of the sample through striking the side of the vessel;
- Sample represented less than approximately 7 cm bite depth of the DVV grab (unless deemed acceptable by the client representative);
- Sample is more than 5 m from the target location (unless deemed acceptable by the client representative);
- Deemed unacceptable by the client representative for any other reason;

3.2.1 Physico-chemical Sample Processing

- Redox, temperature and pH readings were taken using a Hanna Redox probe;
- Hydrocarbon (HC) and benzene, toluene, ethylbenzene and xylene (BTEX) and microbiology samples were collected using a metal scoop to a nominal depth of 2 cm. Samples collected were HCA1, HCA2, BTEXA1, BTEXA2, MICROA1 and MICROA2. The HC and BTEX samples were preserved in glass jars at approximately −20 °C and 4 °C respectively, with the microbiology samples stored in polythene bags and frozen at approximately −20 °C;

- Heavy metal (HM) samples were collected using a plastic scoop to a nominal depth of 2 cm. Samples collected were HMA1 and HMA2. The samples were preserved in polythene bags at approximately −20 °C;
- Particle size distribution (PSD) samples were collected using a plastic scoop to a nominal depth of 5 cm. Samples collected were PSDA1 and PSDA2. The samples were preserved in polythene bags at approximately −20 °C.

3.2.2 Macrofauna Sample Processing

Macrofauna samples were processed as follows:

- Macrofauna samples were processed in their entirety, by opening the spades to drop the grab into a container. All supernatant water was processed along with the sediment;
- The sample was transferred to a 0.5 mm mesh sieve and transferred to the Wilson Autosiever and sediment washed out;
- Once sieved samples were transferred to containers labelled with the job number, station code and fauna code (e.g. FA) and fixed in 10 % buffered formal saline. The sample containers were then sealed, hazard labelled and stored securely on deck.

3.3 Water Sample Processing

Water samples were acquired using 12 L Niskin bottles.

Operational procedures were as follows:

- Prior to arrival on station, two 12 L Niskin bottles were linked together, attached to the lifting wire and armed for deployment. A USBL beacon was fitted above a clump weight, below all sampling apparatus, to allow subsea positioning;
- When the vessel was steady and on location, the Bridge communicated to the deck via a VHF radio, and the water sampling equipment was deployed from the stern A-frame;
- The equipment was lowered to the desired depth, where it was stopped. A messenger weight was attached to the lift wire and released to trigger the Niskin bottles;
- Once triggered (one minute to allow sufficient time for the messenger weight to reach the Niskin bottle mount and trigger the bottles), the online surveyor was informed (via VHF radio), a fix was captured and the equipment was recovered to deck.

eDNA samples were acquired using NatureMetrics aquatic testing kit and the following procedures:

- 5 litres of water were taken from the Niskin bottles for eDNA subsampling;
- The kit contains individually wrapped and pre-rolled nitrile gloves to avoid sample contamination;
- Each kit contained an enclosed filter disc, rubber tubing, a preservative syringe and disc caps, a double sealable sample storage bag with absorbent pad and a sample details card;

- The Vampire Peristaltic pump was used to draw the sample along the rubber tubing and through the filter disc;
- The filter disc was screwed into one end of the rubber tubing;
- The front of the Vampire sampler was lifted up and hinged open allowing the rubber tubing to be placed inside. It was checked that the pump would draw water towards the disc by triggering the sampler with the front open;
- The front of the sampler was closed and the open end of the rubber tubing inserted into the water to be sampled;
- The trigger was held on the sampler to process the sample. The sampler can run at maximum speed but pressure must be released approximately every 45 seconds by releasing the trigger for a second;
- Once all water had passed through the filter, the filter disc was unscrewed from the rubber tubing;
- The preservative syringe was uncapped and the filter disc screwed on to the syringe and the plunger slow pressed to inject the preservative into the disc;
- Once the preservative had started to drip from the disc, the provided red cap was screwed in to the bottom (exit) of the disc and the remaining preservative injected in to the disc;
- While still holding the plunger of the syringe down, the filter disc was unscrewed from the syringe. At this point some preservative would foam from the top of the filter disc;
- The provided white cap screwed on to the top (entry point) of the filter disc to seal it;
- The filter disc and filled in sample details form were placed into the sample storage bag and double sealed as per the instructions on the bag;
- The sample storage bag was stored in the freezer at approximately −20 ºC.

3.3.1 Water Sample Processing

Table 3.1 summarises the water subsample processing, including container and preservation method. All subsamples were labelled with the job number, station number and sample code.

Table 3.1: Summary of water sample processing

Subsample Type	Sample Name	Sampling Depth	Subsample Volume	Container	Storage
Spare 1	SPAREA1	TOP, MID, BOT	1 L	Plastic bottle	Frozen at -20 °C
HC	HCA1/HCA2	TOP, MID, BOT	1 L	Glass amber bottle	Frozen at -20 °C
TSS	TSSA1	TOP, MID, BOT	1 L	Plastic bottle	Frozen at -20 °C
TDS	TDSA1	TOP, MID, BOT	1 L	Plastic bottle	Frozen at -20 °C
HM	HMA1	TOP, MID, BOT	500 mL	Glass amber bottle	Frozen at -20 °C
Chlorophyll	CHLA1/CHLA2	TOP, MID, BOT	1 L	Plastic bottle. Processed onboard	Resultant filter paper foil wrapped and frozen at -20 °C

Subsample Type	Sample Name	Sampling Depth	Subsample Volume	Container	Storage
eDNA	eDNA	TOP, MID, BOT	5 L	Plastic filter in labelled bag	Frozen -20 °C

Notes
HCA1/HCA2 = Hydrocarbon (HC) subsamples 1 and 2
TSSA1/TSA2 = Total suspended solids (TSS) subsamples 1 and 2
TDSA1/TDSA2 = Total dissolved solids (TDS) subsamples 1 and 2
HMA1/HMAL = Heavy metals (HM), nutrients and TOC subsamples 1 and 2
CHLA1/CHLA2 = Chlorophyll subsamples 1 and 2
TOP = Near surface (approximately 5 m from surface)
MID = Maximum depth of fluorescence determined by EXO2 profile.
BOT = Near seabed (approximately 10 m from seabed)

3.4 Water profiling

3.4.1 Deployment and Recovery

Water profiling was conducted during the near seabed water sampling deployment at all sampling stations, simultaneously with water sampling (Section 3.3).

In situ vertical profiles of the water column were undertaken to determine depth, temperature, conductivity/salinity, pH, dissolved oxygen (DO), turbidity, and fluorescence maximum. Data were recorded both during downward and upward casts of the deployments. Water profiles were measured by means of a Valeport CTD+ sonde, with a YSI EXO2 used for profiling fluorescence maximum.

Operational procedures for water profiling were as follows:

- Prior to survey operations, both the pH and DO sensors of the CTD were calibrated and the data output checked to ensure readings were accurate and there was no drift in the data;
- Prior to arrival on station, the CTD was set up record conductivity, temperature, depth, turbidity, pH and DO in unattended mode and attached to the lifting wire above the clump weight;
- When the vessel was steady and on location, the Bridge communicated to the deck via a VHF radio, and the equipment array was deployed from the port side stern A-frame;
- The CTD was lowered into the water and the sensors allowed to acclimatise to the environmental conditions for approximately 3 minutes immediately below the surface;
- The equipment was then lowered through the water column at a rate of 0.5 m/s to 1.0 m/s to approximately 10 m above the seabed, when a positional fix was captured;
- The equipment was then recovered to deck at a rate of 0.5 m/s to 1.0 m/s.

3.4.2 Water Profile Processing

On recovery the water profiler was rinsed with clean water. The data from the CTD were downloaded and backed up onto the vessels computer system and onto an external hard drive.

All water profiles were labelled with the job number, station number and sample code.

Each water profile was translated to comma-separated values (.csv) file and checked for data quality on Datalog Pro and EXO2 software to ensure parameters were within the expected ranges for the area and that data were consistent between the down and upcasts of the instrument.

3.4.3 Zooplankton Sample Processing

Zooplankton samples were acquired vertically through the water column at stations ARW-03, ARW-06 and ARW-07.

Two mesh nets of 0.5 m in diameter and 1.6 m in length, with a 120 µm mesh size were prepared prior to arrival on station, using spreader bars. A clump weight and USBL beacon were added, and the nets launched from the A frame. The nets were lowered to as close as practical to the seabed without causing disturbance then recovered at approximately 1.0 m/s. Samples were carefully rinsed into the cod-end, decanted into bottles and preserved with formal saline.

3.5 Biodiversity Observations

Faunal observations were conducted from the bridge on board the Fugro Searcher (10.8 m eye height above sea level during daylight hours. During hours of darkness or poor visibility PAM was undertaken as a suitable alternative to marine mammal observation.

The primary observation technique used to spot marine mammals was to scan the sea ahead of and within the mitigation zone using the naked eye and with binoculars (7 × 50 magnification). Areas of interest on the water (e.g. waves going against the prevailing direction, white water during calm periods, dark shapes, splashes, bird activity, etc.) were used as visual cues. When fauna were observed the distance to the sighting was estimated using rangefinder stick. Species identification was based on observer experience and with reference to Shirihai and Jarrett (2006).

Avifauna observations were conducted in the same method as the marine mammal observations. The details of the avifaunal sightings were recorded on forms based on the European Seabirds at Sea (ESAS) recording forms with details such as species age (where identifiable), plumage, height above sea level and direction of travel from birds in flight and distance banding from vessel to birds on the water (designated by letter, increasing the further the bird is from the vessel path).

PAM operations were conducted from the instrument room, allowing instant communications with navigation surveyors if marine mammals were detected.

The system comprised a towed array of four hydrophones, deck cable, and electronics processing unit containing an audio output unit. The towed cable consisted of a 250 m umbilical with four built-in hydrophones and a depth transducer. A 100 m deck lead interfaces the array with the acquisition unit. The deck cable connected directly to the amp buffer box from which XLR cables fed the four channels from the four elements to a Fireface 800 soundcard (low and medium frequencies) to be digitised and used by PAMGuard. Additional filtering options for aural monitoring were possible using the Ultralink Pro mixer and Ultra-Curve Pro equalizer. Inside the bufferbox channels from hydrophones 0 and 3 fed into a National Instruments DAQ card USB-6251 to yield the high frequency signals.

4. Results

4.1 Field Operations

4.1.1 Seabed Photography

Photographic data were successfully acquired at 24 of the 28 predefined stations and one camera transect through the proposed tunnel exit area (Table 4.1). Due to high sediment load from riverine inputs in the south of the survey area, data could not be acquired from four stations, ARS-23, ARS-25, ARS-27, and ARS-28. At station ARS-23, five additional shorter transects were proposed by the client using the FWL (one rerun on the station, then four running perpendicular at 150 m, 450 m, 600 m, and 750 m north of the station). However, poor visibility was incurred at all five transects resulting in unacceptable still and video data at this station. Due to this no attempts to acquire further reruns were made at ARS-25, ARS-27, and ARS-28. Transects at stations ARS-06, ARS-08, ARS-20, ARS-22, ARS-24, and ARS-26 were completed using the FWL camera system, with successful reruns at stations ARS-09a and ARS-21a after failed attempts with the SeaSpyder camera.

Table 4.1: Completed transects

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT ⟨NL⟩ [NLLAT2018]						
Transect/Station		Easting	Northing	Depth [m BSL]	Length [m]	Data Acquisition
ARS-01	SOL	571 981.7	5 951 380.1	4.0	239.1	28 min 34 sec 29 stills
	EOL	571 818.9	5 951 555.2	39.7		
ARS-02	SOL	564 970.8	5 944 089.4	38.2	232.6	22 min 48 sec 20 stills
	EOL	565 001.8	5 943 858.9	38.1		
ARS-03	SOL	572 620.1	5 941 660.0	35.4	237.7	31 min 29 sec 31 stills
	EOL	572 856.8	5 941 638.4	35.5		
ARS-04	SOL	560 169.8	5 930 922.3	31.4	235.8	34 min 58 sec 45 stills
	EOL	560 050.0	5 931 125.5	31.4		
ARS-05	SOL	570 631.5	5 931 004.2	28.7	248.5	31 min 50 sec 27 stills
	EOL	570 774.8	5 931 207.2	28.6		
ARS-06	SOL	553 231.4	5 926 816.5	30.7	239.7	24 min 33 sec 24 stills
	EOL	553 063.0	5 926 987.1	30.1		
ARS-07	SOL	563 407.1	5 922 168.3	25.9	233.2	23 min 50 sec 36 stills
	EOL	563 637.2	5 922 130.0	26.2		
ARS-08	SOL	578 492.2	5 919 093.8	25.3	233.9	34 min 54 sec 47 stills
	EOL	579 680.4	5 919 232.7	25.1		
ARS-09	SOL	547 608.6	5 915 382.3	27.9	64.0	9 min 21 sec 10 stills
	EOL	547 605.4	5 915 318.4	29.6		

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]						
Transect/Station		Easting	Northing	Depth [m BSL]	Length [m]	Data Acquisition
ARS-09a	SOL	547 609.2	5 915 384.7	29.4	244.1	31 min 24 sec 30 stills
	EOL	547 600.9	5 915 140.7	29.8		
ARS-10	SOL	547 068.2	5 895 212.8	24.6	240.6	33 min 13 sec 23 stills
	EOL	547 307.8	5 895 235.1	25.8		
ARS-11	SOL	562 943.9	5 897 609.8	24.7	234.0	32 min 58 sec 57 stills
	EOL	562 980.1	5 897 841.0	25.5		
ARS-12	SOL	563 763.9	5 876 265.5	25.1	234.0	24 min 02 sec 43 stills
	EOL	563 632.2	5 876 072.1	25.8		
ARS-13	SOL	564 553.6	5 857 074.3	27.5	251.1	23 min 34 sec 18 stills
	EOL	564 711.1	5 857 269.9	27.1		
ARS-14	SOL	564 518.4	5 839 536.4	26.8	242.8	29 min 11 sec 19 stills
	EOL	564 571.9	5 839 773.2	27.2		
ARS-15	SOL	561 852.9	5 823 489.6	26.1	241.8	30 min 53 sec 22 stills
	EOL	561 825.1	5 823 249.4	27.0		
ARS-16	SOL	558 089.5	5 809 835.9	21.7	264.0	31 min 04 sec 23 stills
	EOL	558 291.1	5 810 006.4	27.5		
ARS-17	SOL	560 358.0	5 801 154.3	26.1	237.1	28 min 56 sec 38 stills
	EOL	560 320.2	5 801 388.3	24.3		
ARS-18	SOL	561 804.4	5 794 043.4	21.8	238.3	35 min 06 sec 46 stills
	EOL	561 996.4	5 794 184.5	24.4		
ARS-19	SOL	563 766.5	5 775 843.3	24.3	239.6	44 min 20 sec 46 stills
	EOL	563 598.0	5 775 673.0	22.2		
ARS-20	SOL	569 852.2	5 777 995.3	21.4	271.3	33 min 29 sec 28 stills
	EOL	570 114.5	5 777 925.6	21.5		
ARS-21	SOL	571 550.4	5 770 739.1	22.6	47.3	5 min 14 sec 23 stills
	EOL	571 544.2	5 770 692.2	22.6		
ARS-21a	SOL	571 614.2	5 770 759.3	23.3	246.6	28 min 50 sec 21 stills
	EOL	571 468.5	5770560.4	23.6		
ARS-22	SOL	571 392.4	5 765 850.2	17.4	244.5	30 min 25 sec 19 stills
	EOL	571 547.6	5 765 661.2	17.2		
ARS-23	SOL	570 004.1	5 761 993.2	18.3	82.6	6 min 31 sec 0 stills
	EOL	570 051.0	5 761 925.2	17.7		
ARS-23a	SOL	570 147.8	5 761 978.4	19.3	63.9	9 min 07 sec 0 stills
	EOL	570 119.9	5 761 920.9	19.3		
ARS-23b	SOL	570 162.6	5 762 141.3	19.3	26.3	4 min 19 sec

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]						
Transect/Station		Easting	Northing	Depth [m BSL]	Length [m]	Data Acquisition
	EOL	570 153.3	5 762 116.7	19.3		0 stills
ARS-23c	SOL	570 245.5	5 762 441.4	19.3	37.8	4 min 23 sec 0 stills
	EOL	570 227.3	5 762 408.3	19.3		
ARS-23d	SOL	570 279.0	5 762 567.0	19.3	39.3	3 min 59 sec 0 stills
	EOL	570 262.2	5 762 531.5	19.3		
ARS-23e	SOL	570 375.5	5 762 734.6	19.3	40.6	5 min 04 sec 0 stills
	EOL	570 359.5	5 762 697.3	19.3		
ARS-24	SOL	570 922.1	5 762 070.1	16.6	111.5	17 min 06 sec 12 stills
	EOL	570 951.8	5 761 962.5	16.7		
ARS-24_2	SOL	570 888.6	5 762 195.6	16.4	144.2	17 min 50 sec 8 stills
	EOL	570 922.4	5 762 055.4	16.5		
ARS-25	SOL	569 980.3	5 761 883.3	18.4	22.3	3 min 00 sec 0 stills
	EOL	569 988.1	5 761 862.4	18.0		
ARS-26	SOL	570 838.9	5 762 143.4	16.4	262.4	37 min 14 sec 59 stills
	EOL	570 909.4	5 761 890.6	16.8		
ARS-27	SOL	570 008.3	5 760 561.3	13.4	1.7	2 min 26 sec 0 stills
	EOL	570 007.9	5 760 559.6	17.7		
ARS-28	SOL	570 811.7	5 760 359.0	14.2	15.1	3 min 37 sec 0 stills
	EOL	570 826.6	5 760 356.2	13.9		
ARS-TE	SOL	570 895.3	5 762 124.4	17.5	145.1	28 min 31 sec 66 stills
	EOL	570 917.5	5 761 981.1	16.9		

Notes
BSL = Below sea level
SOL = Start of line
EOL = End of line
Transects with the suffix a-e were moved > 150 m from the previous transect
Transects with the suffix _2 were re runs due to poor visibility

4.1.2 Water Sampling

Water samples were successfully acquired at seven proposed stations. A complete suite of samples (two physico-chemical, two chlorophyll, two phytoplankton and three eDNA samples) were retained at seven stations (Table 4.2). Zooplankton samples were successfully acquired at all three stations (ARW-03, ARW-06 and ARW-07).

Table 4.2: Completed water sampling stations

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT ⟨NL⟩ [NLLAT2018]				
Station	Easting	Northing	Depth [m BSL]	Sample Acquisition
ARW-01 TOP	560 109.1	5 931 031.7	32.0	PC, eDNA, CHL, Phyto
ARW-01 BOT	560 107.9	5 931 030.3	32.0	PC, eDNA, CHL, Phyto
ARW-02 TOP	565 391.0	5 922 964.4	23.0	PC, eDNA, CHL, Phyto
ARW-02 BOT	565 389.8	5 922 967.4	23.0	PC, eDNA, CHL, Phyto
ARW-03 TOP	566 181.5	5 858 842.4	27.7	PC, eDNA, CHL, Phyto, ZP
ARW-03 BOT	566 182.4	5 858 841.8	28.5	PC, eDNA, CHL, Phyto
ARW-04 TOP	560 338.9	5 801 273.2	26.1	PC, eDNA, CHL, Phyto
ARW-04 BOT	560 336.9	5 801 272.0	26.1	PC, eDNA, CHL, Phyto
ARW-05 TOP	571 538.4	5 770 655.6	23.3	PC, eDNA, CHL, Phyto
ARW-05 BOT	571 538.2	5 770 661.4	23.2	PC, eDNA, CHL, Phyto
ARW-06 TOP	570 927.7	5 762 066.9	16.9	PC, eDNA, CHL, Phyto
ARW-06 BOT	570 921.9	5 762 073.3	17.1	PC, eDNA, CHL, Phyto, ZP
ARW-07 TOP	570 122.5	5 760 530.0	15.3	PC, eDNA, CHL, Phyto
ARW-07 BOT	570 122.0	5 760 526.5	15.5	PC, eDNA, CHL, Phyto, ZP

Notes
BSL = Below sea level
PC = Physico-chemical analysis
eDNA = Environmental deoxyribonucleic acid sample
CHL = Chlorophyll sample
Phyto = Phytoplankton sample
ZP = Zooplankton sample

4.1.3 Water Profile Data

Water column physico-chemical data were successfully acquired at seven proposed stations. A complete suite of parameters (temperature, depth, conductivity (salinity), dissolved oxygen (DO), pH, turbidity and oxygen reduction potential (ORP) were recorded at seven stations (Table 4.3).

Table 4.3: Completed water sampling stations

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]			
Station	Easting	Northing	Depth [m BSL]
ARW-01	560 110.1	5 931 027.5	32.0
ARW-02	565 394.7	5 922 964.4	25.8
ARW-03	566 182.2	5 858 842.7	27.5
ARW-04	560 337.5	5 801 273.5	26.1
ARW-05	571 540.3	5 770 653.8	23.3
ARW-06	570 917.3	5 762 077.0	17.2
ARW-07	570 120.7	5 760 530.0	15.9
Notes BSL = Below sea level			

4.1.4 Grab Sampling

A complete suite of samples (one physico-chemical and three macrofauna samples) were retained at 25 of the 28 stations using the dual van Veen grab. At station ARS-26, one PC sample was successfully acquired using the dual van Veen. Due to three further no samples due to shells lodged in the jaws, macrofaunal samples were attained using a Hamon grab. At stations ARS-23 and ARS-24, only macrofaunal samples were obtained due to coarse sediments requiring the use of the Hamon grab (Table 4.4).

Table 4.4: Completed sampling stations

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]				
Station	Easting*	Northing*	Depth [m BSL]	Sample Acquisition
ARS-01	571 894.7	5 951 471.1	40.3	PC, eDNA, FA, FB, FC
ARS-02	564 987.1	5 943 971.4	39.3	PC, eDNA, FA, FB, FC
ARS-03	572 749.0	5 941 649.7	36.9	PC, eDNA, FA, FB, FC
ARS-04	560 106.9	5 931 026.4	32.0	PC, eDNA, FA, FB, FC
ARS-05	570 709.9	5 931 113.2	29.2	PC, eDNA, FA, FB, FC
ARS-06	553 145.6	5 926 902.0	30.9	PC, eDNA, FA, FB, FC
ARS-07	563 529.6	5 922 147.2	27.5	PC, eDNA, FA, FB, FC
ARS-08	578 591.5	5 919 164.8	25.9	PC, eDNA, FA, FB, FC
ARS-09	547 604.1	5 915 259.9	30.6	PC, eDNA, FA, FB, FC
ARS-10	547 192.8	5 895 224.7	26.3	PC, eDNA, FA, FB, FC
ARS-11	562 964.0	5 897 735.1	26.0	PC, eDNA, FA, FB, FC
ARS-12	563 695.0	5 876 161.8	28.5	PC, eDNA, FA, FB, FC
ARS-13	564 629.8	5 857 181.0	28.6	PC, eDNA, FA, FB, FC
ARS-14	564 544.7	5 839 661.0	26.5	PC, eDNA, FA, FB, FC

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT ⟨NL⟩ [NLLAT2018]				
Station	Easting*	Northing*	Depth [m BSL]	Sample Acquisition
ARS-15	561 837.9	5 823 368.4	27.5	PC, eDNA, FA, FB, FC
ARS-16	558 199.5	5 809 931.0	27.8	PC, eDNA, FA, FB, FC
ARS-17	560 342.5	5 801 270.1	25.3	PC, eDNA, FA, FB, FC
ARS-18	561 906.2	5 794 113.6	19.9	PC, eDNA, FA, FB, FC
ARS-19	563 676.7	5 775 750.2	23.6	PC, eDNA, FA, FB, FC
ARS-20	570 004.5	5 777 955.4	23.1	PC, eDNA, FA, FB, FC
ARS-21	571 539.1	5 770 657.9	23.0	PC, eDNA, FA, FB, FC
ARS-22	571 471.1	5 765 755.6	18.0	PC, eDNA, FA, FB, FC
ARS-23	570 091.9	5 761 867.0	18.8	FA, FB, FC†
ARS-24	570 920.3	5 762 069.4	16.8	FA, FB, FC†
ARS-25	570 054.0	5 761 675.6	23.8	PC, eDNA, FA, FB, FC
ARS-26	570 870.3	5 762 019.1	16.8	PC, FA, FB, FC‡
ARS-27	570 122.2	5 760 529.4	14.5	PC, eDNA, FA, FB, FC
ARS-28	570 929.6	5 760 338.9	14.6	PC, eDNA, FA, FB, FC

Notes
* = Coordinates presented for the FA grab sample
† = Particle size sample taken from the FA grab sample due to the use of the Hamon grab
‡ = PC sample taken with dual van Veen and faunal samples were taken with Hamon grab
BSL = Below sea level
PC = Physico-chemical sample
FA/FB/FC = Faunal sample A, B or C
eDNA = Environmental deoxyribonucleic acid sample

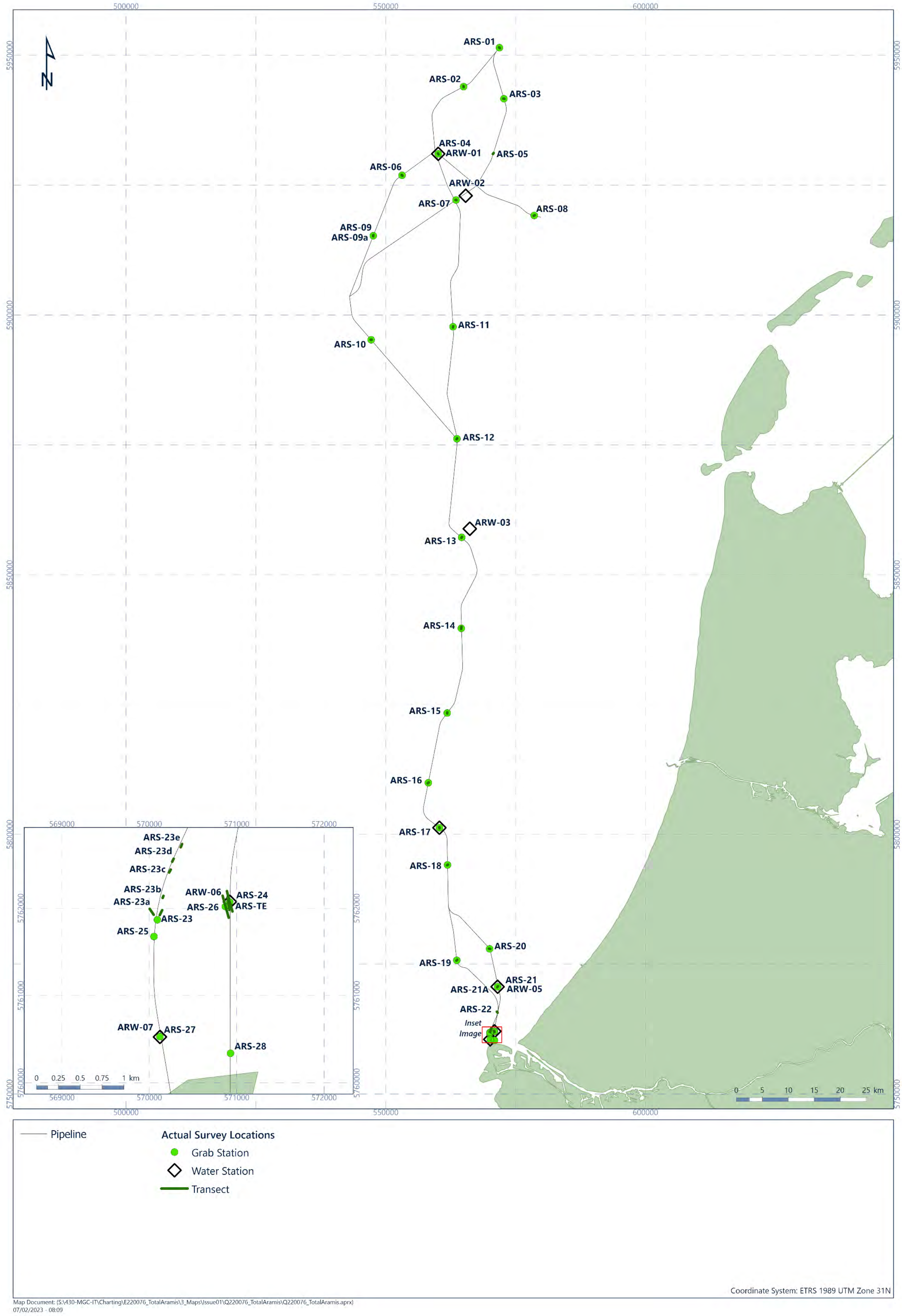


Figure 4.1: Completed environmental survey locations

4.2 Seabed Habitats and Fauna

4.2.1 Seabed Sediments

Seabed sediments across the Total Aramis survey area generally comprised four sediment types, these included mud, sandy mud, muddy sand, and sand. Varied proportions of shells were observed at stations comprised of sand sediments. Six stations (ARS-04, ARS-07, ARS-23, ARS-27, ARS-28, ARS-26) showed clear stratification with anoxic, fine black sediment with a strong smell present below the surface layer of sediment.

Figure 4.2 presents example seabed sediment photographs from the survey.

4.2.2 Benthic Fauna

Benthic epifauna were sparse across the survey area. Most commonly observed through grab sampling and associated with different sediment types across the survey area, were brittle stars (Ophiuroids) and heart urchins (*Echinocardium flavescens*). Fauna observed through video and photographic data were sparce with starfish (Asteroidea including *Asterias rubens*) and hermit crabs (Paguridae) observed.

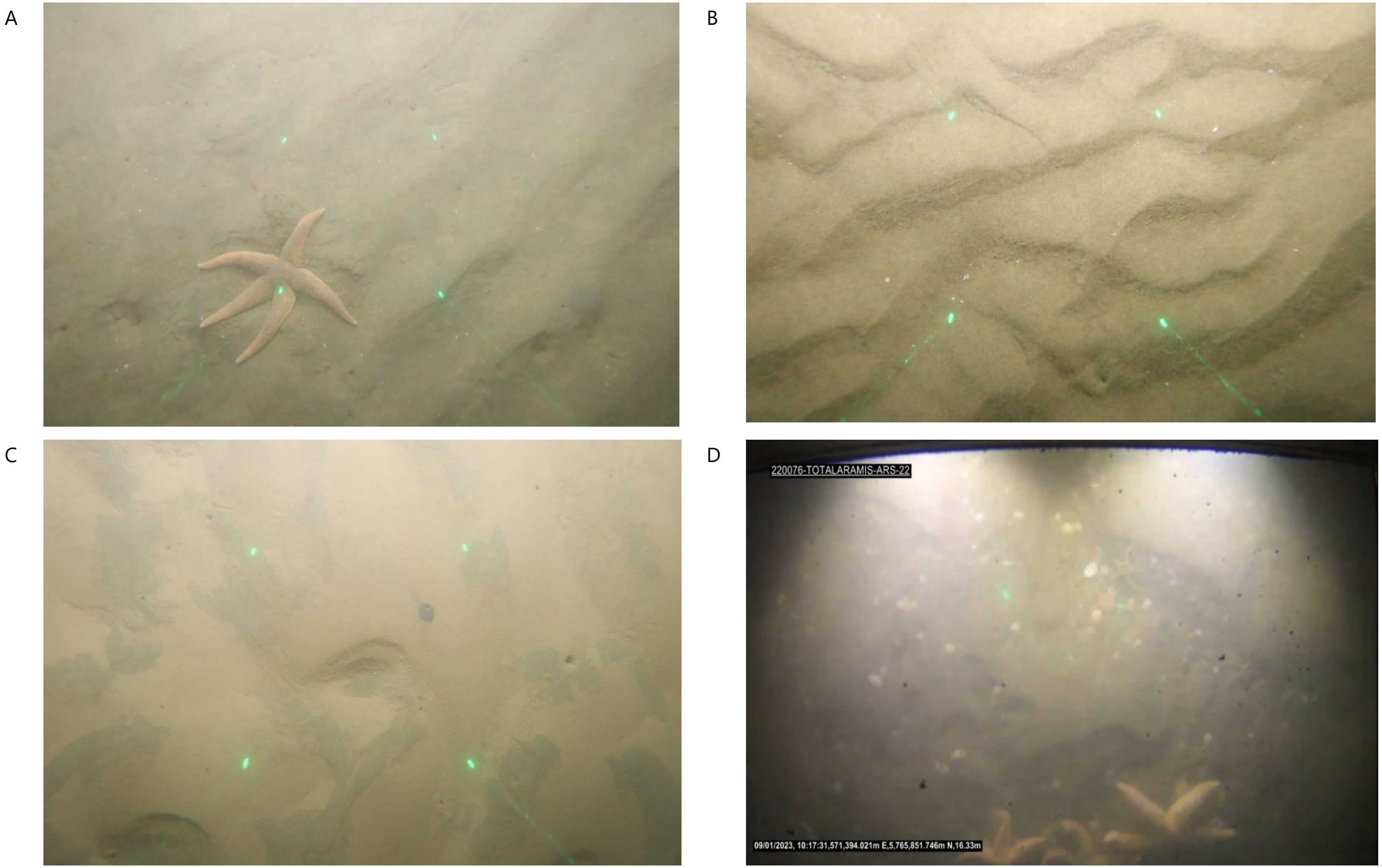
Figure 4.2 presents example photographs of observed fauna.

4.2.3 Potentially Sensitive Habitats or Species

Burrows were observed on transects associated with muddy sediments. The potential presence of the OSPAR (2008) habitat 'Sea pens and burrowing megafauna' will be further assessed in the habitat assessment report.

Sand eels were observed in video and photographic data and gab sampling at stations ARS-25 and ARS-28. Further analysis will identify if these are the lesser sand eel, a Priority Species under the UK Biodiversity Framework (JNCC, 2012).

No other potentially sensitive habitats or species were observed.



A: Photograph ARS-02_05

Mud

Common starfish (*Asterias rubens*)

Faunal burrows

B: Photograph ARS-12_02

Sand with shell fragments

Faunal burrow

No fauna observed

C: Photograph ARS-05_10

Sandy mud

Brittle star (Ophiuroidea)

Faunal burrow

D: Photograph ARS-22_06

Muddy sand with shell

Common starfish (*Asterias rubens*)

Brittlestar (Ophiuroidea)

Figure 4.2: Example seabed sediment photographs, Total Aramis Project

4.3 Biodiversity

There was a total of 7 marine mammal sightings and 11327 avifauna sightings.

Table 4.5 provides an overview of the sightings and detections from each faunal group.

Table 4.5: Summary of marine mammal and avifauna sightings

Species	No. of sightings	Number of Individuals*	IUCN Red List Status
Mammals			
Harbour porpoise (*Phocoena phocoena*)	3	3	Least Concern
Common seal (*Phoca vitulina*)	1	1	Least Concern
Unidentified seal (Pinnipeds)	1	1	-
Grey Seal (*Halichoerus grypus)*	2	2	Least Concern
Total Mammal Sightings	**7**	**7**	
Avifauna			
Auk (Alcidae)	205	498	-
Bewick's swan (*Cygnus columbianus*)	1	12	Least Concern
Black Headed gull (*Chroicocephalus ridibundus*)	62	142	Least Concern
Blackbird (*Turdus merula*)	4	4	Least Concern
Black-headed gull (*Chroicocephalus ridibundus*)	1	1	Least Concern
Black-legged kittiwake (*Rissa tridactyla*)	67	112	Vulnerable
Brambling (*Fringilla montifringilla*)	262	388	Least Concern
Brent goose (*Branta bernicla*)	2	7	Least Concern
Brown booby (*Sula leucogaster*)	1	2	Least Concern
Carion crow (*Corvus corone*)	1	1	Least Concern
Chaffinch (*Fringilla coelebs*)	1	1	Least Concern
Common eider (*Somateria mollissima*)	2	2	Least Concern
Common gull (*Larus canus*)	1	2	-
Common scoter (*Melanitta nigra*)	322	660	Least Concern
Common shelduck (*Tadorna tadorna*)	3	17	Least Concern
Cormorant (Phalacrocoracidae)	1	6	-
Diver sp. (Gaviidae)	59	410	-
Dove (Columbidae)	1	1	-
Duck (Anatidae)	14	57	-
Eurasian blackcap (*Sylvia atricapilla*)	1	13	Least Concern
Eurasian wigeon (*Mareca Penelope*)	1	34	Least Concern
Eurasian woodcock (*Scolopax rusticola*)	1	1	Least Concern
European shag (*Phalacrocorax aristotelis*)	1	4	Least Concern
European starling (*Sturnus vulgaris*)	1	1	Least Concern
Feral pigeon (*Columba livia domestica*)	1	1	Least Concern
Finch (Fringillidae)	1	1	-
Flycatcher (Muscicapidae)	1	1	-
Fulmar (Fulmarus)	4	6	-

Species	No. of sightings	Number of Individuals*	IUCN Red List Status
Gannet (Morus)	1	1	-
Goldcrest (*Regulus regulus*)	1	1	Least Concern
Goose (Anatidae)	11	69	-
Great black-backed gull (*Larus marinus*)	188	258	Least Concern
Great cormorant (*Phalacrocorax carbo*)	39	319	Least Concern
Great crested Grebe (*Podiceps cristatus*)	1	2	Least Concern
Great skua (*Stercorarius skua*)	1	1	Least Concern
Grebe (Podicipedidae)	7	28	-
Guillemot (*Uria aalge*)	249	560	Least Concern
Gull (Laridae)	1244	2627	-
Herring Gull (*Larus argentatus*)	309	495	Least Concern
Kittiwake (Rissa)	393	2934	-
Lesser black-backed gull (*Larus fuscus*)	67	162	Least Concern
Little auk (*Alle alle*)	19	40	Least Concern
Little gull (*Hydrocoloeus minutus*)	7	26	Least Concern
Northern gannet (*Morus bassanus*)	429	607	Least Concern
Passerine (Passeriformes)	66	362	-
Phalacrocorax (Phalacrocorax)	1	1	-
Pipit (Anthus)	2	3	-
Razorbill (*Alca torda*)	70	154	Least Concern
Reed bunting (*Emberiza schoeniclus*)	1	1	Least Concern
Robin (*Erithacus rubecula)*	1	1	Least Concern
Shearwater (Procellariidae)	7	9	-
Short-eared owl (*Asio flammeus*)	1	1	Least Concern
Skua (Stercorariidae)	4	4	-
Slender-billed gull (*Chroicocephalus genei*)	1	2	Least Concern
Starling (*Sturnus vulgaris*)	3	8	Least Concern
Tern (Sternidae)	3	6	-
Tundra swan (*Cygnus columbianus*)	1	5	Least Concern
Thrush (Turdidae)	1	1	-
Wader (Charadriiformes)	3	4	-
Warbler (Parulidae)	2	1	-
Wren (Troglodytidae)	2	2	-
Unidentified bird (Aves)	43	247	-
Total Avifauna Sightings	**11327**	**4200**	

Notes

* = Number of individuals is the best estimate from animals seen on the surface

5. References

Joint Nature Conservation Committee [JNCC]. (2012). *UK Post-2010 Biodiversity Framework*. JNCC and DEFRA. Available from: http://jncc.defra.gov.uk/page-6189

Oslo and Paris Commission [OSPAR]. (2008). *OSPAR list of threatened and/or declining species and habitats* (Reference Number 2008-06). OSPAR Commission.

Appendix A

Guidelines on Use of Report

Appendix B

Logs

B.1 Survey Log

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
05/01/2023	17:51:00	ARW-02	WP	Water Profile	3	565 390.0	5 922 968.9	565 394.7	5 922 964.4	25.8	6.5	
05/01/2023	19:02:48	ARW-02	WS	Top	4	565 390.0	5 922 968.9	565 391.4	5 922 965.6	1.0	3.6	No trigger
05/01/2023	19:06:54	ARW-02	WS	Top	5	565 390.0	5 922 968.9	565 391.0	5 922 964.4	1.0	4.6	
05/01/2023	20:36:12	ARW-02	WS	Bottom	6	565 390.0	5 922 968.9	565 387.6	5 922 967.0	23.0	3.1	No trigger
05/01/2023	20:47:37	ARW-02	WS	Bottom	7	565 390.0	5 922 968.9	565 389.8	5 922 967.4	23.0	1.5	
06/01/2023	21:40:23	ARW-01	WS	Top	15	560 107.8	5 931 027.3	560 109.1	5 931 031.7	32.0	4.6	
06/01/2023	22:09:42	ARW-01	WS	Bottom	16	560 107.8	5 931 027.3	560 107.9	5 931 030.3	32.0	3.0	
06/01/2023	23:24:07	ARW-01	WP	Water Profile	17	560 107.8	5 931 027.3	560 110.1	5 931 027.5	32.0	2.3	
08/01/2023	12:32:29	ARW-05	WP	Water Profile	18	571 538.4	5 770 655.6	571 540.3	5 770 653.8	23.3	2.6	
08/01/2023	17:25:11	ARW-05	WS	Top	19	571 538.4	5 770 655.6	571 543.2	5 770 659.2	23.3	6.0	
08/01/2023	17:53:55	ARW-05	WS	Bottom	20	571 538.4	5 770 655.6	571 538.2	5 770 661.4	23.2	5.8	
08/01/2023	19:14:25	ARS-21	Video	SOL	No fix	571 538.4	5 770 655.6	571 550.4	5 770 739.1	22.6	84.3	
08/01/2023	19:15:29	ARS-21	Still	ARS-21_01	21	571 538.4	5 770 655.6	571 555.2	5 770 766.2	22.6	111.8	
08/01/2023	19:15:55	ARS-21	Still	ARS-21_02	22	571 538.4	5 770 655.6	571 554.8	5 770 762.5	22.6	108.2	
08/01/2023	19:16:10	ARS-21	Still	ARS-21_03	23	571 538.4	5 770 655.6	571 555.8	5 770 762.3	22.7	108.1	
08/01/2023	19:16:40	ARS-21	Still	ARS-21_04	24	571 538.4	5 770 655.6	571 556.2	5 770 760.5	22.6	106.4	
08/01/2023	19:17:51	ARS-21	Still	ARS-21_05	25	571 538.4	5 770 655.6	571 552.3	5 770 747.6	22.6	93.0	
08/01/2023	19:18:41	ARS-21	Still	ARS-21_06	26	571 538.4	5 770 655.6	571 552.6	5 770 738.7	22.7	84.3	
08/01/2023	19:19:15	ARS-21	Still	ARS-21_07	27	571 538.4	5 770 655.6	571 551.9	5 770 735.4	22.7	80.9	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
08/01/2023	19:20:17	ARS-21	Still	ARS-21_08	28	571 538.4	5 770 655.6	571 549.3	5 770 729.3	22.6	74.5	
08/01/2023	19:20:31	ARS-21	Still	ARS-21_09	29	571 538.4	5 770 655.6	571 549.1	5 770 728.0	22.7	73.1	
08/01/2023	19:20:59	ARS-21	Still	ARS-21_10	30	571 538.4	5 770 655.6	571 548.4	5 770 725.5	22.7	70.6	
08/01/2023	19:21:27	ARS-21	Still	ARS-21_11	31	571 538.4	5 770 655.6	571 548.7	5 770 722.8	22.6	68.0	
08/01/2023	19:23:14	ARS-21	Still	ARS-21_12	32	571 538.4	5 770 655.6	571 547.1	5 770 719.1	22.6	64.1	
08/01/2023	19:20:58	ARS-21	Video	EOL	No fix	571 538.4	5 770 655.6	571 544.2	5 770 692.2	22.6	37.0	
09/01/2023	05:44:39	ARS-21A	Video	SOL	No fix	571 538.4	5 770 655.6	571 614.2	5 770 759.3	23.3	128.4	
09/01/2023	05:46:20	ARS-21A	Still	ARS-21A_01	34	571 538.4	5 770 655.6	571 608.1	5 770 747.9	23.4	115.7	
09/01/2023	05:48:01	ARS-21A	Still	ARS-21A_02	35	571 538.4	5 770 655.6	571 600.1	5 770 737.9	23.4	102.9	
09/01/2023	05:49:38	ARS-21A	Still	ARS-21A_03	36	571 538.4	5 770 655.6	571 593.5	5 770 726.9	23.4	90.1	
09/01/2023	05:51:34	ARS-21A	Still	ARS-21A_04	37	571 538.4	5 770 655.6	571 583.5	5 770 713.7	23.4	73.5	
09/01/2023	05:53:48	ARS-21A	Still	ARS-21A_05	38	571 538.4	5 770 655.6	571 573.3	5 770 698.1	23.4	55.0	
09/01/2023	05:55:58	ARS-21A	Still	ARS-21A_06	39	571 538.4	5 770 655.6	571 561.2	5 770 682.8	23.5	35.4	
09/01/2023	05:57:27	ARS-21A	Still	ARS-21A_07	40	571 538.4	5 770 655.6	571 551.6	5 770 670.0	23.5	19.5	
09/01/2023	05:58:31	ARS-21A	Still	ARS-21A_08	41	571 538.4	5 770 655.6	571 547.3	5 770 663.5	23.5	11.9	
09/01/2023	05:59:03	ARS-21A	Still	ARS-21A_09	42	571 538.4	5 770 655.6	571 545.5	5 770 660.6	23.6	8.7	
09/01/2023	05:59:50	ARS-21A	Still	ARS-21A_10	43	571 538.4	5 770 655.6	571 539.2	5 770 654.5	23.6	1.3	
09/01/2023	06:01:07	ARS-21A	Still	ARS-21A_11	44	571 538.4	5 770 655.6	571 533.4	5 770 647.2	23.5	9.8	
09/01/2023	06:02:05	ARS-21A	Still	ARS-21A_12	45	571 538.4	5 770 655.6	571 528.7	5 770 640.0	23.5	18.3	
09/01/2023	06:03:02	ARS-21A	Still	ARS-21A_13	46	571 538.4	5 770 655.6	571 523.3	5 770 632.7	23.6	27.4	
09/01/2023	06:03:54	ARS-21A	Still	ARS-21A_14	47	571 538.4	5 770 655.6	571 520.1	5 770 627.4	23.6	33.6	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
09/01/2023	06:05:18	ARS-21A	Still	ARS-21A_15	48	571 538.4	5 770 655.6	571 511.6	5 770 618.5	23.6	45.7	
09/01/2023	06:06:21	ARS-21A	Still	ARS-21A_16	49	571 538.4	5 770 655.6	571 508.8	5 770 613.1	23.6	51.8	
09/01/2023	06:07:54	ARS-21A	Still	ARS-21A_17	50	571 538.4	5 770 655.6	571 500.4	5 770 603.4	23.5	64.6	
09/01/2023	06:08:49	ARS-21A	Still	ARS-21A_18	51	571 538.4	5 770 655.6	571 493.7	5 770 595.7	23.5	74.7	
09/01/2023	06:09:45	ARS-21A	Still	ARS-21A_19	52	571 538.4	5 770 655.6	571 490.5	5 770 589.1	23.5	82.0	
09/01/2023	06:10:51	ARS-21A	Still	ARS-21A_20	53	571 538.4	5 770 655.6	571 484.9	5 770 581.9	23.7	91.0	
09/01/2023	06:12:05	ARS-21A	Still	ARS-21A_21	54	571 538.4	5 770 655.6	571 481.3	5 770 572.4	23.6	100.9	
09/01/2023	06:13:28	ARS-21A	Video	EOL	No fix	571 538.4	5 770 655.6	571 468.5	5 770 560.4	23.6	118.2	
09/01/2023	07:07:38	ARS-21	DVV	PC	57	571 538.4	5 770 655.6	571 535.1	5 770 653.3	23.0	4.0	
09/01/2023	07:34:23	ARS-21	DVV	FA, FB	59	571 538.4	5 770 655.6	571 539.1	5 770 657.9	23.0	2.4	
09/01/2023	07:49:53	ARS-21	DVV	FC, eDNA	60	571 538.4	5 770 655.6	571 538.0	5 770 657.2	23.0	1.6	
09/01/2023	10:17:04	ARS-22	Video	SOL	No fix	571 471.2	5 765 755.8	571 392.4	5 765 850.2	17.4	123.0	
09/01/2023	10:19:08	ARS-22	Still	ARS-22_01	61	571 471.2	5 765 755.8	571 398.5	5 765 842.8	17.4	113.4	
09/01/2023	10:20:09	ARS-22	Still	ARS-22_02	62	571 471.2	5 765 755.8	571 402.7	5 765 838.8	17.4	107.6	
09/01/2023	10:22:20	ARS-22	Still	ARS-22_03	63	571 471.2	5 765 755.8	571 410.1	5 765 827.6	17.4	94.3	
09/01/2023	10:23:21	ARS-22	Still	ARS-22_04	64	571 471.2	5 765 755.8	571 413.6	5 765 823.6	17.4	88.9	
09/01/2023	10:25:07	ARS-22	Still	ARS-22_05	65	571 471.2	5 765 755.8	571 419.6	5 765 816.3	17.5	79.5	
09/01/2023	10:27:00	ARS-22	Still	ARS-22_06	66	571 471.2	5 765 755.8	571 426.3	5 765 809.6	17.4	70.1	
09/01/2023	10:28:40	ARS-22	Still	ARS-22_07	67	571 471.2	5 765 755.8	571 435.4	5 765 797.8	17.4	55.2	
09/01/2023	10:31:53	ARS-22	Still	ARS-22_08	68	571 471.2	5 765 755.8	571 450.0	5 765 780.8	17.4	32.8	
09/01/2023	10:33:09	ARS-22	Still	ARS-22_09	69	571 471.2	5 765 755.8	571 457.5	5 765 771.9	17.4	21.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
09/01/2023	10:35:29	ARS-22	Still	ARS-22_10	70	571 471.2	5 765 755.8	571 472.1	5 765 755.1	17.4	1.1	
09/01/2023	10:35:58	ARS-22	Still	ARS-22_11	71	571 471.2	5 765 755.8	571 474.9	5 765 750.2	17.4	6.7	
09/01/2023	10:37:04	ARS-22	Still	ARS-22_12	72	571 471.2	5 765 755.8	571 482.2	5 765 740.9	17.4	18.5	
09/01/2023	10:38:24	ARS-22	Still	ARS-22_13	73	571 471.2	5 765 755.8	571 490.8	5 765 730.7	17.4	31.9	
09/01/2023	10:38:41	ARS-22	Still	ARS-22_14	74	571 471.2	5 765 755.8	571 493.2	5 765 727.8	17.4	35.6	
09/01/2023	10:40:49	ARS-22	Still	ARS-22_15	75	571 471.2	5 765 755.8	571 508.4	5 765 709.7	17.4	59.2	
09/01/2023	10:41:57	ARS-22	Still	ARS-22_16	76	571 471.2	5 765 755.8	571 515.2	5 765 700.0	17.3	71.1	
09/01/2023	10:43:57	ARS-22	Still	ARS-22_17	77	571 471.2	5 765 755.8	571 528.4	5 765 684.1	17.3	91.7	
09/01/2023	10:45:09	ARS-22	Still	No still	78	571 471.2	5 765 755.8	571 536.3	5 765 675.5	17.3	103.4	
09/01/2023	10:45:17	ARS-22	Still	ARS-22_18	79	571 471.2	5 765 755.8	571 536.7	5 765 674.9	17.3	104.1	
09/01/2023	10:46:28	ARS-22	Still	ARS-22_19	80	571 471.2	5 765 755.8	571 543.9	5 765 666.4	17.2	115.3	
09/01/2023	10:17:04	ARS-22	Video	EOL	No fix	571 471.2	5 765 755.8	571 547.6	5 765 661.2	17.2	121.6	
09/01/2023	11:57:46	ARS-22	DVV	PC, FA	81	571 471.2	5 765 755.8	571 471.1	5 765 755.6	18.0	0.3	
09/01/2023	12:23:33	ARS-22	DVV	FB, NS	82	571 471.2	5 765 755.8	571 471.5	5 765 756.7	18.0	0.9	
09/01/2023	12:34:04	ARS-22	DVV	FC, eDNA	83	571 471.2	5 765 755.8	571 471.3	5 765 755.4	18.0	0.5	
10/01/2023	09:40:07	ARS-24	Video	SOL	No fix	570 921.1	5 762 071.8	570 922.1	5 762 070.1	16.6	2.1	
10/01/2023	09:40:08	ARS-24	Still	ARS-24_01	85	570 921.1	5 762 071.8	570 922.1	5 762 070.1	16.6	2.1	
10/01/2023	09:40:44	ARS-24	Still	No still	86	570 921.1	5 762 071.8	570 922.0	5 762 070.3	16.5	1.8	
10/01/2023	09:41:05	ARS-24	Still	ARS-24_02	87	570 921.1	5 762 071.8	570 921.9	5 762 070.8	16.5	1.4	
10/01/2023	09:41:30	ARS-24	Still	ARS-24_03	88	570 921.1	5 762 071.8	570 921.5	5 762 070.2	16.5	1.7	
10/01/2023	09:41:47	ARS-24	Still	ARS-24_04	89	570 921.1	5 762 071.8	570 921.9	5 762 069.6	16.6	2.4	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	09:42:32	ARS-24	Still	ARS-24_05	90	570 921.1	5 762 071.8	570 921.3	5 762 069.3	16.5	2.5	
10/01/2023	09:43:27	ARS-24	Still	ARS-24_06	91	570 921.1	5 762 071.8	570 923.9	5 762 065.0	16.6	7.4	
10/01/2023	09:44:03	ARS-24	Still	ARS-24_07	92	570 921.1	5 762 071.8	570 924.3	5 762 061.6	16.6	10.7	
10/01/2023	09:46:21	ARS-24	Still	ARS-24_08	93	570 921.1	5 762 071.8	570 928.7	5 762 042.5	16.6	30.3	
10/01/2023	09:47:11	ARS-24	Still	ARS-24_09	94	570 921.1	5 762 071.8	570 929.3	5 762 036.3	16.6	36.5	
10/01/2023	09:48:14	ARS-24	Still	ARS-24_10	95	570 921.1	5 762 071.8	570 930.8	5 762 031.8	16.6	41.2	
10/01/2023	09:49:01	ARS-24	Still	ARS-24_11	96	570 921.1	5 762 071.8	570 932.2	5 762 028.1	16.6	45.1	
10/01/2023	09:53:14	ARS-24	Still	ARS-24_12	97	570 921.1	5 762 071.8	570 941.9	5 761 991.7	16.7	82.8	
10/01/2023	09:57:13	ARS-24	Video	EOL	No fix	570 921.1	5 762 071.8	570 951.8	5 761 962.5	16.7	113.6	
10/01/2023	10:12:24	ARS-24_2	Video	SOL	No fix	570 921.1	5 762 071.8	570 888.6	5 762 195.6	16.3	128.0	
10/01/2023	10:12:59	ARS-24_2	Still	ARS-24-2_01	99	570 921.1	5 762 071.8	570 888.7	5 762 195.5	16.3	127.8	
10/01/2023	10:14:48	ARS-24_2	Still	ARS-24-2_02	100	570 921.1	5 762 071.8	570 889.8	5 762 190.9	16.3	123.0	
10/01/2023	10:16:29	ARS-24_2	Still	ARS-24-2_03	101	570 921.1	5 762 071.8	570 892.5	5 762 175.2	16.3	107.2	
10/01/2023	10:16:59	ARS-24_2	Still	ARS-24-2_04	102	570 921.1	5 762 071.8	570 894.3	5 762 168.8	16.3	100.6	
10/01/2023	10:18:36	ARS-24_2	Still	ARS-24-2_05	103	570 921.1	5 762 071.8	570 898.4	5 762 150.4	16.4	81.8	
10/01/2023	10:19:21	ARS-24_2	Still	ARS-24-2_06	104	570 921.1	5 762 071.8	570 899.4	5 762 146.0	16.3	77.2	
10/01/2023	10:20:10	ARS-24_2	Still	ARS-24-2_07	105	570 921.1	5 762 071.8	570 899.3	5 762 139.2	16.3	70.8	
10/01/2023	10:25:18	ARS-24_2	Still	ARS-24-2_08	106	570 921.1	5 762 071.8	570 912.7	5 762 094.2	16.3	23.9	
10/01/2023	10:29:38	ARS-24_2	Video	EOL	No fix	570 921.1	5 762 071.8	570 922.4	5 762 055.4	16.5	16.5	
10/01/2023	11:45:43	ARS-26	Video	SOL	No fix	570 873.6	5 762 018.8	570 838.9	5 762 143.4	16.4	129.3	
10/01/2023	11:49:25	ARS-26	Still	ARS-26_01	108	570 873.6	5 762 018.8	570 843.6	5 762 128.3	16.4	113.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	11:50:14	ARS-26	Still	ARS-26_02	109	570 873.6	5 762 018.8	570 844.1	5 762 121.7	16.4	107.1	
10/01/2023	11:50:56	ARS-26	Still	ARS-26_03	110	570 873.6	5 762 018.8	570 847.1	5 762 119.1	16.4	103.7	
10/01/2023	11:51:39	ARS-26	Still	ARS-26_04	111	570 873.6	5 762 018.8	570 847.3	5 762 114.2	16.4	98.9	
10/01/2023	11:52:19	ARS-26	Still	ARS-26_05	112	570 873.6	5 762 018.8	570 848.7	5 762 110.9	16.5	95.3	
10/01/2023	11:52:50	ARS-26	Still	ARS-26_06	113	570 873.6	5 762 018.8	570 849.5	5 762 107.3	16.5	91.7	
10/01/2023	11:53:11	ARS-26	Still	ARS-26_07	114	570 873.6	5 762 018.8	570 849.8	5 762 104.7	16.5	89.1	
10/01/2023	11:53:58	ARS-26	Still	ARS-26_08	115	570 873.6	5 762 018.8	570 850.9	5 762 098.2	16.5	82.6	
10/01/2023	11:54:38	ARS-26	Still	ARS-26_09	116	570 873.6	5 762 018.8	570 853.0	5 762 095.2	16.5	79.1	
10/01/2023	11:55:11	ARS-26	Still	ARS-26_10	117	570 873.6	5 762 018.8	570 854.5	5 762 091.2	16.5	74.9	
10/01/2023	11:55:48	ARS-26	Still	ARS-26_11	118	570 873.6	5 762 018.8	570 854.2	5 762 085.7	16.5	69.7	
10/01/2023	11:56:21	ARS-26	Still	ARS-26_12	119	570 873.6	5 762 018.8	570 855.6	5 762 082.1	16.5	65.8	
10/01/2023	11:56:54	ARS-26	Still	ARS-26_13	120	570 873.6	5 762 018.8	570 856.8	5 762 078.4	16.6	61.9	
10/01/2023	11:57:16	ARS-26	Still	ARS-26_14	121	570 873.6	5 762 018.8	570 857.9	5 762 076.6	16.5	59.9	
10/01/2023	11:57:41	ARS-26	Still	ARS-26_15	122	570 873.6	5 762 018.8	570 859.1	5 762 072.9	16.6	56.0	
10/01/2023	11:58:22	ARS-26	Still	ARS-26_16	123	570 873.6	5 762 018.8	570 860.6	5 762 068.5	16.6	51.4	
10/01/2023	11:58:37	ARS-26	Still	ARS-26_17	124	570 873.6	5 762 018.8	570 860.3	5 762 067.2	16.6	50.2	
10/01/2023	11:58:51	ARS-26	Still	ARS-26_18	125	570 873.6	5 762 018.8	570 860.4	5 762 065.1	16.6	48.1	
10/01/2023	11:59:11	ARS-26	Still	ARS-26_19	126	570 873.6	5 762 018.8	570 860.3	5 762 061.5	16.6	44.7	
10/01/2023	12:00:07	ARS-26	Still	ARS-26_20	127	570 873.6	5 762 018.8	570 863.0	5 762 055.1	16.6	37.7	
10/01/2023	12:00:45	ARS-26	Still	ARS-26_21	128	570 873.6	5 762 018.8	570 865.9	5 762 052.5	16.6	34.6	
10/01/2023	12:01:24	ARS-26	Still	ARS-26_22	129	570 873.6	5 762 018.8	570 866.8	5 762 048.8	16.6	30.8	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	12:01:51	ARS-26	Still	ARS-26_23	130	570 873.6	5 762 018.8	570 865.7	5 762 044.2	16.6	26.5	
10/01/2023	12:02:27	ARS-26	Still	ARS-26_24	131	570 873.6	5 762 018.8	570 867.1	5 762 039.5	16.6	21.7	
10/01/2023	12:02:46	ARS-26	Still	ARS-26_25	132	570 873.6	5 762 018.8	570 869.3	5 762 037.4	16.6	19.1	
10/01/2023	12:03:35	ARS-26	Still	ARS-26_26	133	570 873.6	5 762 018.8	570 868.9	5 762 032.2	16.6	14.2	
10/01/2023	12:03:47	ARS-26	Still	ARS-26_27	134	570 873.6	5 762 018.8	570 868.8	5 762 029.5	16.6	11.8	
10/01/2023	12:04:08	ARS-26	Still	ARS-26_28	135	570 873.6	5 762 018.8	570 869.4	5 762 026.2	16.7	8.4	
10/01/2023	12:04:52	ARS-26	Still	ARS-26_29	136	570 873.6	5 762 018.8	570 871.8	5 762 020.6	16.7	2.6	
10/01/2023	12:05:11	ARS-26	Still	ARS-26_30	137	570 873.6	5 762 018.8	570 872.8	5 762 019.1	16.6	0.8	
10/01/2023	12:05:51	ARS-26	Still	ARS-26_31	138	570 873.6	5 762 018.8	570 873.4	5 762 014.1	16.7	4.7	
10/01/2023	12:06:25	ARS-26	Still	ARS-26_32	139	570 873.6	5 762 018.8	570 874.1	5 762 009.2	16.7	9.7	
10/01/2023	12:06:40	ARS-26	Still	ARS-26_33	140	570 873.6	5 762 018.8	570 874.7	5 762 007.0	16.7	11.9	
10/01/2023	12:06:54	ARS-26	Still	ARS-26_34	141	570 873.6	5 762 018.8	570 875.9	5 762 005.4	16.6	13.6	
10/01/2023	12:07:29	ARS-26	Still	ARS-26_35	142	570 873.6	5 762 018.8	570 877.1	5 762 001.4	16.7	17.8	
10/01/2023	12:08:13	ARS-26	Still	ARS-26_36	143	570 873.6	5 762 018.8	570 880.3	5 761 996.0	16.7	23.8	
10/01/2023	12:08:45	ARS-26	Still	ARS-26_37	144	570 873.6	5 762 018.8	570 881.6	5 761 991.0	16.7	29.0	
10/01/2023	12:09:37	ARS-26	Still	ARS-26_38	145	570 873.6	5 762 018.8	570 883.9	5 761 985.0	16.7	35.4	
10/01/2023	12:09:54	ARS-26	Still	ARS-26_39	146	570 873.6	5 762 018.8	570 884.7	5 761 983.5	16.7	37.0	
10/01/2023	12:11:01	ARS-26	Still	ARS-26_40	147	570 873.6	5 762 018.8	570 883.8	5 761 972.9	16.7	47.1	
10/01/2023	12:11:27	ARS-26	Still	ARS-26_41	148	570 873.6	5 762 018.8	570 883.6	5 761 968.9	16.7	50.9	
10/01/2023	12:12:47	ARS-26	Still	ARS-26_42	149	570 873.6	5 762 018.8	570 888.2	5 761 962.2	16.8	58.4	
10/01/2023	12:13:24	ARS-26	Still	ARS-26_43	150	570 873.6	5 762 018.8	570 890.2	5 761 957.7	16.8	63.3	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	12:13:45	ARS-26	Still	ARS-26_44	151	570 873.6	5 762 018.8	570 890.1	5 761 953.9	16.7	67.0	
10/01/2023	12:14:12	ARS-26	Still	ARS-26_45	152	570 873.6	5 762 018.8	570 890.1	5 761 950.7	16.8	70.1	
10/01/2023	12:14:28	ARS-26	Still	ARS-26_46	153	570 873.6	5 762 018.8	570 891.2	5 761 949.3	16.7	71.7	
10/01/2023		ARS-26	Still	ARS-26_47	No fix	570 873.6	5 762 018.8					
10/01/2023	12:15:35	ARS-26	Still	ARS-26_48	154	570 873.6	5 762 018.8	570 892.7	5 761 941.6	16.8	79.5	
10/01/2023	12:16:15	ARS-26	Still	ARS-26_49	155	570 873.6	5 762 018.8	570 891.5	5 761 934.0	16.8	86.7	
10/01/2023	12:16:59	ARS-26	Still	ARS-26_50	156	570 873.6	5 762 018.8	570 895.5	5 761 930.5	16.8	91.0	
10/01/2023	12:17:27	ARS-26	Still	ARS-26_51	157	570 873.6	5 762 018.8	570 895.2	5 761 928.4	16.8	93.0	
10/01/2023	12:18:12	ARS-26	Still	ARS-26_52	158	570 873.6	5 762 018.8	570 898.1	5 761 922.5	16.8	99.4	
10/01/2023	12:18:41	ARS-26	Still	ARS-26_53	159	570 873.6	5 762 018.8	570 899.3	5 761 919.5	16.8	102.6	
10/01/2023	12:19:03	ARS-26	Still	ARS-26_54	160	570 873.6	5 762 018.8	570 900.5	5 761 918.0	16.8	104.4	
10/01/2023	12:19:32	ARS-26	Still	ARS-26_55	161	570 873.6	5 762 018.8	570 900.9	5 761 915.1	16.8	107.3	
10/01/2023	12:20:07	ARS-26	Still	ARS-26_56	162	570 873.6	5 762 018.8	570 902.7	5 761 911.8	16.8	110.9	
10/01/2023	12:21:00	ARS-26	Still	ARS-26_57	163	570 873.6	5 762 018.8	570 901.1	5 761 903.4	16.8	118.7	
10/01/2023	12:22:16	ARS-26	Still	ARS-26_58	164	570 873.6	5 762 018.8	570 907.0	5 761 894.5	16.8	128.7	
10/01/2023	12:22:45	ARS-26	Still	ARS-26_59	165	570 873.6	5 762 018.8	570 909.1	5 761 891.7	16.8	132.0	
10/01/2023	12:22:56	ARS-26	Video	EOL	No fix	570 873.6	5 762 018.8	570 909.4	5 761 890.6	16.8	133.1	
10/01/2023	12:53:41	ARS-TE	Video	SOL	No fix	570 907.2	5 762 045.2	570 895.3	5 762 124.4	17.5	80.1	
10/01/2023	12:53:54	ARS-TE	Still	ARS-TE_01	166	570 907.2	5 762 045.2	570 895.1	5 762 124.2	16.4	79.9	
10/01/2023	12:54:43	ARS-TE	Still	ARS-TE_02	167	570 907.2	5 762 045.2	570 895.0	5 762 124.0	16.4	79.7	
10/01/2023	12:55:22	ARS-TE	Still	ARS-TE_03	168	570 907.2	5 762 045.2	570 897.5	5 762 120.8	16.4	76.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	12:55:49	ARS-TE	Still	ARS-TE_04	169	570 907.2	5 762 045.2	570 898.3	5 762 116.1	16.4	71.5	
10/01/2023	12:56:22	ARS-TE	Still	ARS-TE_05	170	570 907.2	5 762 045.2	570 897.7	5 762 111.3	16.5	66.8	
10/01/2023	12:56:28	ARS-TE	Still	ARS-TE_06	171	570 907.2	5 762 045.2	570 897.6	5 762 110.3	16.5	65.8	
10/01/2023	12:56:41	ARS-TE	Still	ARS-TE_07	172	570 907.2	5 762 045.2	570 897.5	5 762 108.7	16.5	64.2	
10/01/2023	12:56:59	ARS-TE	Still	ARS-TE_08	173	570 907.2	5 762 045.2	570 898.3	5 762 106.7	16.5	62.1	
10/01/2023	12:57:12	ARS-TE	Still	ARS-TE_09	174	570 907.2	5 762 045.2	570 898.5	5 762 105.1	16.5	60.6	
10/01/2023	12:57:24	ARS-TE	Still	ARS-TE_10	175	570 907.2	5 762 045.2	570 898.9	5 762 103.9	16.5	59.3	
10/01/2023	12:57:30	ARS-TE	Still	ARS-TE_11	176	570 907.2	5 762 045.2	570 899.2	5 762 103.0	16.5	58.4	
10/01/2023	12:57:49	ARS-TE	Still	ARS-TE_12	177	570 907.2	5 762 045.2	570 899.5	5 762 100.3	16.5	55.7	
10/01/2023	12:58:11	ARS-TE	Still	ARS-TE_13	178	570 907.2	5 762 045.2	570 899.6	5 762 096.7	16.5	52.1	
10/01/2023	12:58:17	ARS-TE	Still	ARS-TE_14	179	570 907.2	5 762 045.2	570 899.5	5 762 095.7	16.5	51.1	
10/01/2023	12:58:32	ARS-TE	Still	ARS-TE_15	180	570 907.2	5 762 045.2	570 899.3	5 762 094.1	16.5	49.5	
10/01/2023	12:59:29	ARS-TE	Still	ARS-TE_16	181	570 907.2	5 762 045.2	570 901.3	5 762 089.4	16.6	44.6	
10/01/2023	12:59:35	ARS-TE	Still	ARS-TE_17	182	570 907.2	5 762 045.2	570 901.5	5 762 088.8	16.6	44.0	
10/01/2023	13:00:11	ARS-TE	Still	ARS-TE_18	183	570 907.2	5 762 045.2	570 902.5	5 762 084.0	16.6	39.1	
10/01/2023	13:00:16	ARS-TE	Still	ARS-TE_19	184	570 907.2	5 762 045.2	570 902.2	5 762 083.1	16.6	38.3	
10/01/2023	13:00:25	ARS-TE	Still	ARS-TE_20	185	570 907.2	5 762 045.2	570 902.3	5 762 082.0	16.6	37.1	
10/01/2023	13:00:31	ARS-TE	Still	ARS-TE_21	186	570 907.2	5 762 045.2	570 902.1	5 762 081.6	16.6	36.7	
10/01/2023	13:00:52	ARS-TE	Still	ARS-TE_22	187	570 907.2	5 762 045.2	570 902.4	5 762 079.0	16.6	34.1	
10/01/2023	13:00:58	ARS-TE	Still	ARS-TE_23	188	570 907.2	5 762 045.2	570 902.3	5 762 078.5	16.6	33.6	
10/01/2023	13:01:13	ARS-TE	Still	ARS-TE_24	189	570 907.2	5 762 045.2	570 902.3	5 762 077.7	16.6	32.9	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	13:01:17	ARS-TE	Still	ARS-TE_25	190	570 907.2	5 762 045.2	570 902.3	5 762 077.1	16.6	32.2	
10/01/2023	13:01:45	ARS-TE	Still	ARS-TE_26	191	570 907.2	5 762 045.2	570 904.0	5 762 074.1	16.6	29.1	
10/01/2023	13:01:51	ARS-TE	Still	ARS-TE_27	192	570 907.2	5 762 045.2	570 904.2	5 762 073.7	16.6	28.7	
10/01/2023	13:01:56	ARS-TE	Still	ARS-TE_28	193	570 907.2	5 762 045.2	570 904.1	5 762 073.7	16.6	28.7	
10/01/2023	13:03:56	ARS-TE	Still	ARS-TE_29	194	570 907.2	5 762 045.2	570 905.4	5 762 070.0	16.6	24.9	
10/01/2023	13:04:06	ARS-TE	Still	ARS-TE_30	195	570 907.2	5 762 045.2	570 905.8	5 762 069.7	16.7	24.5	
10/01/2023	13:04:11	ARS-TE	Still	ARS-TE_31	196	570 907.2	5 762 045.2	570 905.4	5 762 069.9	16.7	24.8	
10/01/2023	13:04:46	ARS-TE	Still	ARS-TE_32	197	570 907.2	5 762 045.2	570 905.4	5 762 067.1	16.7	22.0	
10/01/2023	13:05:32	ARS-TE	Still	ARS-TE_33	198	570 907.2	5 762 045.2	570 907.2	5 762 063.0	16.7	17.8	
10/01/2023	13:05:54	ARS-TE	Still	ARS-TE_34	199	570 907.2	5 762 045.2	570 907.3	5 762 060.7	16.7	15.5	
10/01/2023	13:06:04	ARS-TE	Still	ARS-TE_35	200	570 907.2	5 762 045.2	570 907.6	5 762 059.9	16.7	14.7	
10/01/2023	13:06:41	ARS-TE	Still	ARS-TE_36	201	570 907.2	5 762 045.2	570 907.1	5 762 055.4	16.7	10.2	
10/01/2023	13:06:46	ARS-TE	Still	ARS-TE_37	202	570 907.2	5 762 045.2	570 906.9	5 762 055.5	16.7	10.3	
10/01/2023	13:07:28	ARS-TE	Still	ARS-TE_38	203	570 907.2	5 762 045.2	570 908.1	5 762 051.3	16.7	6.2	
10/01/2023	13:07:34	ARS-TE	Still	ARS-TE_39	204	570 907.2	5 762 045.2	570 908.2	5 762 050.6	16.7	5.5	
10/01/2023	13:07:56	ARS-TE	Still	ARS-TE_40	205	570 907.2	5 762 045.2	570 907.3	5 762 048.3	16.7	3.1	
10/01/2023	No fix	ARS-TE	Still	ARS-TE_41	No fix	570 907.2	5 762 045.2					
10/01/2023	13:09:02	ARS-TE	Still	ARS-TE_42	206	570 907.2	5 762 045.2	570 908.3	5 762 043.3	16.7	2.2	
10/01/2023	13:10:03	ARS-TE	Still	ARS-TE_43	207	570 907.2	5 762 045.2	570 909.9	5 762 039.2	16.7	6.6	
10/01/2023	13:10:10	ARS-TE	Still	ARS-TE_44	208	570 907.2	5 762 045.2	570 909.6	5 762 038.3	16.7	7.3	
10/01/2023	13:10:26	ARS-TE	Still	ARS-TE_45	209	570 907.2	5 762 045.2	570 909.5	5 762 036.4	16.7	9.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	13:10:44	ARS-TE	Still	ARS-TE_46	210	570 907.2	5 762 045.2	570 909.6	5 762 035.0	16.7	10.5	
10/01/2023	13:12:33	ARS-TE	Still	ARS-TE_47	211	570 907.2	5 762 045.2	570 911.7	5 762 026.1	16.7	19.6	
10/01/2023	13:12:45	ARS-TE	Still	ARS-TE_48	212	570 907.2	5 762 045.2	570 912.1	5 762 026.1	16.8	19.8	
10/01/2023	13:12:59	ARS-TE	Still	ARS-TE_49	213	570 907.2	5 762 045.2	570 912.8	5 762 025.8	16.8	19.9	
10/01/2023	13:13:06	ARS-TE	Still	ARS-TE_50	214	570 907.2	5 762 045.2	570 912.6	5 762 026.0	16.8	20.8	
10/01/2023	13:13:11	ARS-TE	Still	ARS-TE_51	215	570 907.2	5 762 045.2	570 912.5	5 762 025.1	16.8	23.1	
10/01/2023	13:14:03	ARS-TE	Still	ARS-TE_52	216	570 907.2	5 762 045.2	570 911.5	5 762 022.5	16.8	23.3	
10/01/2023	13:14:09	ARS-TE	Still	ARS-TE_53	217	570 907.2	5 762 045.2	570 911.4	5 762 022.3	16.8	24.3	
10/01/2023	13:14:15	ARS-TE	Still	ARS-TE_54	218	570 907.2	5 762 045.2	570 911.6	5 762 021.3	16.8	32.0	
10/01/2023	13:15:04	ARS-TE	Still	ARS-TE_55	219	570 907.2	5 762 045.2	570 911.3	5 762 013.4	16.8	33.0	
10/01/2023	13:15:12	ARS-TE	Still	ARS-TE_56	220	570 907.2	5 762 045.2	570 911.6	5 762 012.4	16.8	33.6	
10/01/2023	13:15:18	ARS-TE	Still	ARS-TE_57	221	570 907.2	5 762 045.2	570 911.6	5 762 011.9	16.8	36.1	
10/01/2023	13:15:39	ARS-TE	Still	ARS-TE_58	222	570 907.2	5 762 045.2	570 910.8	5 762 009.3	16.8	44.3	
10/01/2023	13:16:56	ARS-TE	Still	ARS-TE_59	223	570 907.2	5 762 045.2	570 913.1	5 762 001.3	16.8	45.9	
10/01/2023	13:17:06	ARS-TE	Still	ARS-TE_60	224	570 907.2	5 762 045.2	570 913.5	5 761 999.8	16.9	55.8	
10/01/2023	13:18:41	ARS-TE	Still	ARS-TE_61	225	570 907.2	5 762 045.2	570 917.3	5 761 990.3	16.9	56.2	
10/01/2023	13:18:46	ARS-TE	Still	ARS-TE_62	226	570 907.2	5 762 045.2	570 917.1	5 761 989.9	16.9	57.6	
10/01/2023	13:19:22	ARS-TE	Still	ARS-TE_63	227	570 907.2	5 762 045.2	570 917.1	5 761 988.5	16.9	57.4	
10/01/2023	13:19:27	ARS-TE	Still	ARS-TE_64	228	570 907.2	5 762 045.2	570 917.0	5 761 988.6	16.9	56.9	
10/01/2023	13:19:35	ARS-TE	Still	ARS-TE_65	229	570 907.2	5 762 045.2	570 916.8	5 761 989.1	16.9	55.2	
10/01/2023	13:20:55	ARS-TE	Still	ARS-TE_66	230	570 907.2	5 762 045.2	570 914.9	5 761 990.6	16.9	64.9	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
10/01/2023	13:22:11	ARS-TE	Video	EOL	No fix	570 907.2	5 762 045.2	570 917.5	5 761 981.1	16.9	64.9	
10/01/2023	12:53:28	ARS-24	DVV	NS	231	570 921.1	5 762 071.8	570 919.3	5 762 069.8	17.0	2.7	
10/01/2023	14:14:58	ARS-24	DVV	NS	232	570 921.1	5 762 071.8	570 924.3	5 762 071.0	17.0	3.4	
10/01/2023	14:28:56	ARS-24	DVV	NS	233	570 921.1	5 762 071.8	570 925.2	5 762 071.4	18.0	4.1	
11/01/2023	05:28:54	ARS-24	DVV	NS	234	570 921.1	5 762 071.8	570 921.1	5 762 071.8	18.0	0.0	
11/01/2023	05:37:19	ARS-24	DVV	NS	235	570 921.1	5 762 071.8	570 923.8	5 762 071.1	18.0	2.8	
11/01/2023	05:49:38	ARS-24	DVV	NS	236	570 921.1	5 762 071.8	570 919.8	5 762 077.5	18.0	5.8	
11/01/2023	06:22:13	ARS-26	DVV	NS	237	570 873.6	5 762 018.8	570 872.9	5 762 019.5	18.0	0.9	
11/01/2023	06:29:28	ARS-26	DVV	PC, NS	238	570 873.6	5 762 018.8	570 875.0	5 762 015.8	18.0	3.4	
11/01/2023	07:06:19	ARS-26	DVV	NS	239	570 873.6	5 762 018.8	570 872.2	5 762 017.3	18.0	2.0	
11/01/2023	07:44:44	ARW-06	WP	Water Profile	240	570 921.1	5 762 071.8	570 917.3	5 762 077.0	17.2	6.4	
11/01/2023	07:44:44	ARW-06	WS	NS	240	570 921.1	5 762 071.8	570 917.3	5 762 077.0	17.2	6.4	No trigger
11/01/2023	08:02:29	ARW-06	WS	Bottom	241	570 921.1	5 762 071.8	570 921.9	5 762 073.3	17.1	1.7	
11/01/2023	08:29:19	ARW-06	WS	Top	242	570 921.1	5 762 071.8	570 927.7	5 762 066.9	16.9	8.3	
16/01/2023	01:04:57	ARS-24	DVV	NS	244	570 921.1	5 762 071.8	570 917.1	5 762 070.1	16.9	4.4	
16/01/2023	01:12:35	ARS-24	DVV	NS	245	570 921.1	5 762 071.8	570 916.9	5 762 070.4	16.9	4.4	
16/01/2023	01:19:40	ARS-24	DVV	NS	246	570 921.1	5 762 071.8	570 918.3	5 762 070.4	16.9	3.2	
16/01/2023	02:32:42	ARS-24	HG	FA	247	570 921.1	5 762 071.8	570 920.3	5 762 069.4	16.8	2.5	
16/01/2023	02:41:50	ARS-24	HG	NS	248	570 921.1	5 762 071.8	570 919.3	5 762 068.6	16.8	3.7	
16/01/2023	02:47:46	ARS-24	HG	NS	249	570 921.1	5 762 071.8	570 920.5	5 762 069.3	16.8	2.6	
16/01/2023	02:51:59	ARS-24	HG	FB	250	570 921.1	5 762 071.8	570 921.5	5 762 071.3	16.8	0.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
16/01/2023	02:56:58	ARS-24	HG	FC	251	570 921.1	5 762 071.8	570 922.2	5 762 072.3	16.8	1.2	
16/01/2023	03:33:29	ARS-26	HG	FA	252	570 873.6	5 762 018.8	570 870.3	5 762 019.1	16.8	3.3	
16/01/2023	03:59:37	ARS-26	HG	FB	253	570 873.6	5 762 018.8	570 873.4	5 762 012.5	17.0	6.3	
16/01/2023	04:11:37	ARS-26	HG	FC	254	570 873.6	5 762 018.8	570 873.0	5 762 020.6	17.0	1.9	
16/01/2023	04:56:58	ARW-06	VZ	Zooplankton	256	570 921.1	5 762 071.8	570 921.1	5 762 071.8	16.9	0.0	
16/01/2023	07:33:00	ARS-23	Video	SOL	No fix	570 088.4	5 761 867.1	570 004.1	5 761 993.2	18.3	151.7	No visibility, line aborted
16/01/2023	07:39:31	ARS-23	Video	EOL	No fix	570 088.4	5 761 867.1	570 051.0	5 761 925.2	17.7	69.1	
16/01/2023	08:51:19	ARW-07	WP	Water Profile	259	570 122.5	5 760 530.0	570 120.7	5 760 530.0	15.9	1.8	
16/01/2023	09:19:37	ARW-07	WS	NS	260	570 122.5	5 760 530.0	570 119.9	5 760 530.5	15.8	2.7	No trigger
16/01/2023	09:46:18	ARW-07	WS	Bottom	262	570 122.5	5 760 530.0	570 122.0	5 760 526.5	15.5	3.5	
16/01/2023	10:16:44	ARW-07	WS	Top	263	570 122.5	5 760 530.0	570 122.0	5 760 527.6	15.3	2.4	
16/01/2023	12:17:57	ARS-27	Video	SOL	No fix	570 122.5	5 760 530.0	570 008.3	5 760 561.3	13.4	118	No visibility, line aborted
16/01/2023	12:20:22	ARS-27	Video	EOL	No fix	570 122.5	5 760 530.0	570 007.9	5 760 559.6	12.9	118	
16/01/2023	12:03:14	ARS-27	DVV	eDNA, PC	264	570 122.5	5 760 530.0	570 122.6	5 760 530.6	14.5	0.7	
16/01/2023	12:46:03	ARS-27	DVV	FA, FB	265	570 122.5	5 760 530.0	570 122.2	5 760 529.4	14.5	0.7	
16/01/2023	12:55:22	ARS-27	DVV	FC	266	570 122.5	5 760 530.0	570 122.2	5 760 528.8	14.5	1.2	
17/01/2023	10:49:59	ARS-25	Video	SOL	No fix	570 054.4	5 761 675.9	569 980.3	5 761 883.3	18.4	220	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
17/01/2023	10:52:53	ARS-25	Video	EOL	No fix	570 054.4	5 761 675.9	569 988.1	5 761 862.4	18.0	198	
17/01/2023	11:29:53	ARS-25	DVV	PC, eDNA	268	570 054.4	5 761 675.9	570 052.5	5 761 677.0	24.1	2.2	
17/01/2023	11:54:18	ARS-25	DVV	NS	269	570 054.4	5 761 675.9	570 054.1	5 761 675.8	23.9	0.3	No trigger
17/01/2023	11:58:19	ARS-25	DVV	FA, FB	270	570 054.4	5 761 675.9	570 054.0	5 761 675.6	23.8	0.5	
17/01/2023	12:06:06	ARS-25	DVV	FC	271	570 054.4	5 761 675.9	570 052.7	5 761 675.3	23.7	1.8	
17/01/2023	14:27:12	ARS-28	Video	SOL	No fix	570 927.9	5 760 339.9	570 811.7	5 760 359.0	14.2	117.7	
17/01/2023	14:30:41	ARS-28	Video	EOL	No fix	570 927.9	5 760 339.9	570 826.6	5 760 356.2	13.9	102.6	
17/01/2023	14:46:22	ARS-28	DVV	PC, eDNA	272	570 927.9	5 760 339.9	570 929.6	5 760 335.9	14.3	4.3	
17/01/2023	15:15:42	ARS-28	DVV	FC, NS	273	570 927.9	5 760 339.9	570 930.9	5 760 342.5	14.7	4.0	
17/01/2023	15:25:06	ARS-28	DVV	FA, NS	274	570 927.9	5 760 339.9	570 929.6	5 760 338.9	14.6	2.0	
17/01/2023	15:35:09	ARS-28	DVV	FB	275	570 927.9	5 760 339.9	570 929.6	5 760 339.7	14.7	1.7	
17/01/2023	16:34:59	ARW-07	VZ	Zooplankton	276	570 122.5	5 760 530.0	570 124.6	5 760 529.8	14.8	2.1	
17/01/2023	18:06:32	ARS-23	DVV	NS	277	570 088.4	5 761 867.1	570 087.4	5 761 870.7	18.2	3.7	
17/01/2023	18:15:25	ARS-23	DVV	NS	278	570 088.4	5 761 867.1	570 088.6	5 761 871.7	18.3	4.6	
17/01/2023	18:21:46	ARS-23	DVV	NS	279	570 088.4	5 761 867.1	570 089.3	5 761 868.4	18.4	1.6	
17/01/2023	18:28:58	ARS-23	DVV	NS	280	570 088.4	5 761 867.1	570 088.3	5 761 867.9	18.4	0.8	Triggered in water column
17/01/2023	18:33:09	ARS-23	DVV	NS	281	570 088.4	5 761 867.1	570 088.1	5 761 867.7	18.4	0.7	
17/01/2023	18:49:06	ARS-23	HG	PSD	282	570 088.4	5 761 867.1	570 090.0	5 761 865.7	18.5	2.1	
17/01/2023	19:03:16	ARS-23	HG	FA	283	570 088.4	5 761 867.1	570 091.9	5 761 867.0	18.8	3.5	
17/01/2023	19:19:09	ARS-23	HG	NS	284	570 088.4	5 761 867.1	570 091.9	5 761 868.2	18.8	3.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
17/01/2023	19:29:40	ARS-23	HG	NS	285	570 088.4	5 761 867.1	570 091.7	5 761 867.7	18.9	3.4	
17/01/2023	19:39:31	ARS-23	HG	FB	286	570 088.4	5 761 867.1	570 094.3	5 761 868.5	19.0	6.0	
17/01/2023	19:53:34	ARS-23	HG	FC	287	570 088.4	5 761 867.1	570 089.8	5 761 865.6	19.2	2.0	
17/01/2023	22:08:20	ARS-19	Video	SOL	No fix	563 675.4	5 775 750.7	563 766.5	5 775 843.3	24.3	129.9	
17/01/2023	22:09:16	ARS-19	Still	ARS-19_01	288	563 675.4	5 775 750.7	563 765.3	5 775 842.9	25.2	128.8	
17/01/2023	22:09:59	ARS-19	Still	ARS-19_02	289	563 675.4	5 775 750.7	563 763.5	5 775 842.4	25.2	127.2	
17/01/2023	22:10:29	ARS-19	Still	ARS-19_03	290	563 675.4	5 775 750.7	563 760.1	5 775 838.7	25.2	122.2	
17/01/2023	22:11:13	ARS-19	Still	ARS-19_04	291	563 675.4	5 775 750.7	563 755.1	5 775 833.2	25.4	114.7	
17/01/2023	22:11:51	ARS-19	Still	ARS-19_05	292	563 675.4	5 775 750.7	563 751.2	5 775 829.9	25.3	109.7	
17/01/2023	22:12:37	ARS-19	Still	ARS-19_06	293	563 675.4	5 775 750.7	563 747.4	5 775 827.2	25.2	105.1	
17/01/2023	22:13:28	ARS-19	Still	ARS-19_07	294	563 675.4	5 775 750.7	563 743.8	5 775 820.9	25.2	98.0	
17/01/2023	22:13:53	ARS-19	Still	ARS-19_08	295	563 675.4	5 775 750.7	563 741.9	5 775 820.4	25.3	96.3	
17/01/2023	22:14:19	ARS-19	Still	ARS-19_09	296	563 675.4	5 775 750.7	563 739.7	5 775 819.0	25.2	93.8	
17/01/2023	22:14:45	ARS-19	Still	ARS-19_10	297	563 675.4	5 775 750.7	563 739.0	5 775 818.4	25.2	92.9	
17/01/2023	22:15:19	ARS-19	Still	ARS-19_11	298	563 675.4	5 775 750.7	563 736.0	5 775 816.0	25.2	89.1	
17/01/2023	22:15:51	ARS-19	Still	ARS-19_12	299	563 675.4	5 775 750.7	563 734.3	5 775 814.1	25.2	86.5	
17/01/2023	22:16:21	ARS-19	Still	ARS-19_13	300	563 675.4	5 775 750.7	563 733.4	5 775 811.3	25.2	83.8	
17/01/2023		ARS-19	Still	ARS-19_14	No fix	563 675.4	5 775 750.7					
17/01/2023	22:17:55	ARS-19	Still	ARS-19_15	301	563 675.4	5 775 750.7	563 729.3	5 775 808.0	25.3	78.6	
17/01/2023	22:19:14	ARS-19	Still	ARS-19_16	302	563 675.4	5 775 750.7	563 720.6	5 775 800.4	25.2	67.2	
17/01/2023	22:19:42	ARS-19	Still	ARS-19_17	303	563 675.4	5 775 750.7	563 718.2	5 775 797.6	25.2	63.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
17/01/2023	22:21:23	ARS-19	Still	ARS-19_18	304	563 675.4	5 775 750.7	563 707.1	5 775 786.6	24.9	47.8	
17/01/2023	22:22:02	ARS-19	Still	ARS-19_19	305	563 675.4	5 775 750.7	563 703.8	5 775 782.6	24.9	42.7	
17/01/2023	22:23:20	ARS-19	Still	ARS-19_20	306	563 675.4	5 775 750.7	563 695.7	5 775 775.6	24.6	32.2	
17/01/2023	22:24:20	ARS-19	Still	ARS-19_21	307	563 675.4	5 775 750.7	563 688.0	5 775 769.5	24.4	22.6	
17/01/2023	22:25:15	ARS-19	Still	ARS-19_22	308	563 675.4	5 775 750.7	563 682.3	5 775 766.1	24.2	16.9	
17/01/2023	22:26:21	ARS-19	Still	ARS-19_23	309	563 675.4	5 775 750.7	563 681.8	5 775 765.5	24.2	16.1	
17/01/2023	22:27:32	ARS-19	Still	ARS-19_24	310	563 675.4	5 775 750.7	563 680.5	5 775 764.5	24.2	14.7	
17/01/2023	22:27:53	ARS-19	Still	ARS-19_25	311	563 675.4	5 775 750.7	563 678.7	5 775 761.1	24.2	10.9	
17/01/2023	22:29:53	ARS-19	Still	ARS-19_26	312	563 675.4	5 775 750.7	563 674.2	5 775 754.8	24.0	4.3	
17/01/2023	22:31:25	ARS-19	Still	ARS-19_27	313	563 675.4	5 775 750.7	563 676.9	5 775 753.1	23.9	2.8	
17/01/2023	22:33:20	ARS-19	Still	ARS-19_28	314	563 675.4	5 775 750.7	563 673.5	5 775 748.1	23.7	3.2	
17/01/2023	22:34:05	ARS-19	Still	ARS-19_29	315	563 675.4	5 775 750.7	563 668.9	5 775 746.2	23.6	7.9	
17/01/2023	22:34:46	ARS-19	Still	ARS-19_30	316	563 675.4	5 775 750.7	563 667.9	5 775 742.8	23.6	10.8	
17/01/2023	22:36:36	ARS-19	Still	ARS-19_31	317	563 675.4	5 775 750.7	563 665.6	5 775 740.8	23.6	14.0	
17/01/2023	22:36:48	ARS-19	Still	ARS-19_32	318	563 675.4	5 775 750.7	563 665.1	5 775 740.6	23.5	14.4	
17/01/2023	22:37:47	ARS-19	Still	ARS-19_33	319	563 675.4	5 775 750.7	563 660.5	5 775 735.0	23.4	21.7	
17/01/2023	22:38:50	ARS-19	Still	ARS-19_34	320	563 675.4	5 775 750.7	563 654.7	5 775 730.7	23.4	28.8	
17/01/2023	22:39:27	ARS-19	Still	ARS-19_35	321	563 675.4	5 775 750.7	563 651.2	5 775 728.5	23.3	32.9	
17/01/2023	22:40:24	ARS-19	Still	ARS-19_36	322	563 675.4	5 775 750.7	563 648.3	5 775 723.6	23.2	42.1	
17/01/2023	22:41:20	ARS-19	Still	ARS-19_37	323	563 675.4	5 775 750.7	563 645.4	5 775 721.2	23.2	53.7	
17/01/2023	22:43:17	ARS-19	Still	ARS-19_38	324	563 675.4	5 775 750.7	563 637.8	5 775 712.4	23.0	55.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
17/01/2023	22:44:20	ARS-19	Still	ARS-19_39	325	563 675.4	5 775 750.7	563 635.9	5 775 711.4	23.1	60.2	
17/01/2023	22:45:17	ARS-19	Still	ARS-19_40	326	563 675.4	5 775 750.7	563 632.2	5 775 708.9	23.2	71.6	
17/01/2023	22:46:39	ARS-19	Still	ARS-19_41	327	563 675.4	5 775 750.7	563 624.2	5 775 700.6	22.9	81.4	
17/01/2023	22:48:03	ARS-19	Still	ARS-19_42	328	563 675.4	5 775 750.7	563 617.7	5 775 693.4	23.0	85.8	
17/01/2023	22:48:40	ARS-19	Still	ARS-19_43	329	563 675.4	5 775 750.7	563 614.8	5 775 689.9	23.0	92.1	
17/01/2023	22:49:43	ARS-19	Still	ARS-19_44	330	563 675.4	5 775 750.7	563 610.2	5 775 685.7	23.1	99.4	
17/01/2023	22:50:56	ARS-19	Still	ARS-19_45	331	563 675.4	5 775 750.7	563 605.0	5 775 680.5	22.9	109.1	
17/01/2023	22:52:53	ARS-19	Still	ARS-19_46	332	563 675.4	5 775 750.7	563 598.1	5 775 673.8	23.0	109.0	
17/01/2023	22:52:56	ARS-19	Video	EOL	No fix	563 675.4	5 775 750.7	563 598.0	5 775 673.0	22.2	109.7	
18/01/2023	00:16:41	ARS-19	DVV	PC, eDNA	333	563 675.4	5 775 750.7	563 676.7	5 775 751.6	23.8	1.6	
18/01/2023	00:39:59	ARS-19	DVV	FA, FB	335	563 675.4	5 775 750.7	563 676.7	5 775 750.2	23.6	1.4	
18/01/2023	00:46:38	ARS-19	DVV	FC	336	563 675.4	5 775 750.7	563 676.5	5 775 750.8	23.5	1.1	
18/01/2023	02:48:54	ARS-20	Video	SOL	No fix	570 005.1	5 777 955.4	569 820.3	5 778 003.0	21.1	190.9	
18/01/2023	02:50:12	ARS-20	Video	EOL	No fix	570 005.1	5 777 955.4	569 832.2	5 778 003.4	22.5	179.4	
18/01/2023	03:22:55	ARS-20	Video	SOL	No fix	570 005.1	5 777 955.4	569 852.2	5 777 995.3	21.4	158.0	
18/01/2023	03:28:55	ARS-20	Still	ARS-20_01	337	570 005.1	5 777 955.4	569 890.6	5 777 982.2	22.8	117.6	
18/01/2023	03:29:36	ARS-20	Still	ARS-20_02	338	570 005.1	5 777 955.4	569 896.0	5 777 982.8	22.9	112.4	
18/01/2023	03:30:26	ARS-20	Still	ARS-20_03	339	570 005.1	5 777 955.4	569 901.3	5 777 983.2	22.9	107.4	
18/01/2023	03:31:20	ARS-20	Still	ARS-20_04	340	570 005.1	5 777 955.4	569 906.4	5 777 983.2	22.9	102.5	
18/01/2023	03:32:49	ARS-20	Still	ARS-20_05	341	570 005.1	5 777 955.4	569 917.7	5 777 977.2	23.0	90.1	
18/01/2023	03:34:39	ARS-20	Still	ARS-20_06	342	570 005.1	5 777 955.4	569 930.3	5 777 975.0	23.0	77.3	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
18/01/2023	03:35:30	ARS-20	Still	ARS-20_07	343	570 005.1	5 777 955.4	569 937.4	5 777 970.4	23.1	69.3	
18/01/2023	03:36:43	ARS-20	Still	ARS-20_08	344	570 005.1	5 777 955.4	569 946.3	5 777 967.7	23.1	60.1	
18/01/2023	03:37:20	ARS-20	Still	ARS-20_09	345	570 005.1	5 777 955.4	569 949.8	5 777 966.5	23.2	56.4	
18/01/2023	03:38:11	ARS-20	Still	ARS-20_10	346	570 005.1	5 777 955.4	569 955.8	5 777 966.8	23.1	50.6	
18/01/2023	03:39:05	ARS-20	Still	ARS-20_11	347	570 005.1	5 777 955.4	569 961.0	5 777 964.1	23.1	44.9	
18/01/2023	03:40:03	ARS-20	Still	ARS-20_12	348	570 005.1	5 777 955.4	569 968.7	5 777 963.4	23.1	37.3	
18/01/2023	03:40:48	ARS-20	Still	ARS-20_13	349	570 005.1	5 777 955.4	569 974.3	5 777 961.7	23.2	31.4	
18/01/2023	03:41:06	ARS-20	Still	ARS-20_14	350	570 005.1	5 777 955.4	569 977.8	5 777 961.6	23.2	28.0	
18/01/2023	03:41:29	ARS-20	Still	ARS-20_15	351	570 005.1	5 777 955.4	569 981.6	5 777 960.8	23.2	24.1	
18/01/2023	03:42:57	ARS-20	Still	ARS-20_16	352	570 005.1	5 777 955.4	569 989.9	5 777 957.7	23.2	15.4	
18/01/2023	03:44:26	ARS-20	Still	ARS-20_17	353	570 005.1	5 777 955.4	570 000.2	5 777 953.7	23.3	5.2	
18/01/2023	03:45:01	ARS-20	Still	ARS-20_18	354	570 005.1	5 777 955.4	570 004.9	5 777 954.0	23.2	1.4	
18/01/2023	03:45:49	ARS-20	Still	No still	355	570 005.1	5 777 955.4	570 009.9	5 777 954.9	23.3	4.9	
18/01/2023	03:46:22	ARS-20	Still	ARS-20_19	356	570 005.1	5 777 955.4	570 015.8	5 777 951.5	23.3	11.4	
18/01/2023	03:47:01	ARS-20	Still	ARS-20_20	357	570 005.1	5 777 955.4	570 022.7	5 777 949.1	23.4	18.7	
18/01/2023	03:47:56	ARS-20	Still	ARS-20_21	358	570 005.1	5 777 955.4	570 032.1	5 777 943.5	23.4	29.5	
18/01/2023	03:48:28	ARS-20	Still	ARS-20_22	359	570 005.1	5 777 955.4	570 036.6	5 777 942.7	23.4	34.0	
18/01/2023	03:49:06	ARS-20	Still	ARS-20_23	360	570 005.1	5 777 955.4	570 043.1	5 777 942.5	23.4	40.1	
18/01/2023	03:49:58	ARS-20	Still	ARS-20_24	361	570 005.1	5 777 955.4	570 053.0	5 777 939.2	23.4	50.6	
18/01/2023	03:51:53	ARS-20	Still	ARS-20_25	362	570 005.1	5 777 955.4	570 071.1	5 777 938.3	23.5	68.1	
18/01/2023	03:52:48	ARS-20	Still	ARS-20_26	363	570 005.1	5 777 955.4	570 080.1	5 777 934.5	23.5	77.9	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
18/01/2023	03:53:50	ARS-20	Still	ARS-20_27	364	570 005.1	5 777 955.4	570 090.9	5 777 931.8	23.7	89.0	
18/01/2023	03:54:43	ARS-20	Still	ARS-20_28	365	570 005.1	5 777 955.4	570 099.1	5 777 928.6	23.6	97.8	
18/01/2023	03:56:23	ARS-20	Video	EOL		570 005.1	5 777 955.4	570 114.5	5 777 925.6	21.5	113.4	
18/01/2023	04:24:47	ARS-20	DVV	PC, eDNA	367	570 005.1	5 777 955.4	570 004.5	5 777 953.7	23.2	1.8	
18/01/2023	04:43:30	ARS-20	DVV	FA, FB	368	570 005.1	5 777 955.4	570 004.5	5 777 955.4	23.1	0.6	
18/01/2023	04:55:19	ARS-20	DVV	FC	369	570 005.1	5 777 955.4	570 003.8	5 777 954.2	23.1	1.8	
19/01/2023	18:12:07	ARS-17	Video	SOL		560 338.8	5 801 273.1	560 358.0	5 801 154.3	26.1	120.4	
19/01/2023	18:12:41	ARS-17	Still	ARS-17_01	373	560 338.8	5 801 273.1	560 357.7	5 801 152.5	26.3	122.0	
19/01/2023	18:13:38	ARS-17	Still	ARS-17_02	374	560 338.8	5 801 273.1	560 356.8	5 801 159.1	26.1	115.4	
19/01/2023	18:14:20	ARS-17	Still	ARS-17_03	375	560 338.8	5 801 273.1	560 354.8	5 801 167.8	26.2	106.5	
19/01/2023	18:15:34	ARS-17	Still	ARS-17_04	376	560 338.8	5 801 273.1	560 350.0	5 801 178.8	26.2	95.0	
19/01/2023	18:16:10	ARS-17	Still	ARS-17_05	377	560 338.8	5 801 273.1	560 350.3	5 801 183.6	26.2	90.3	
19/01/2023	18:17:19	ARS-17	Still	ARS-17_06	378	560 338.8	5 801 273.1	560 351.1	5 801 190.1	26.1	83.9	
19/01/2023	18:18:22	ARS-17	Still	ARS-17_07	379	560 338.8	5 801 273.1	560 349.8	5 801 199.8	25.9	74.1	
19/01/2023	18:19:06	ARS-17	Still	ARS-17_08	380	560 338.8	5 801 273.1	560 349.9	5 801 203.6	26.2	70.3	
19/01/2023	18:20:30	ARS-17	Still	ARS-17_09	381	560 338.8	5 801 273.1	560 346.8	5 801 219.3	25.9	54.4	
19/01/2023	18:21:28	ARS-17	Still	ARS-17_10	382	560 338.8	5 801 273.1	560 345.9	5 801 225.7	25.9	47.9	
19/01/2023	18:22:16	ARS-17	Still	ARS-17_11	383	560 338.8	5 801 273.1	560 343.8	5 801 235.4	25.8	38.1	
19/01/2023	18:22:45	ARS-17	Still	ARS-17_12	384	560 338.8	5 801 273.1	560 344.3	5 801 236.7	25.9	36.8	
19/01/2023	18:23:27	ARS-17	Still	ARS-17_13	385	560 338.8	5 801 273.1	560 343.9	5 801 246.1	25.6	27.5	
19/01/2023	18:23:48	ARS-17	Still	ARS-17_14	386	560 338.8	5 801 273.1	560 343.4	5 801 251.4	25.7	22.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
19/01/2023	18:24:17	ARS-17	Still	ARS-17_15	387	560 338.8	5 801 273.1	560 343.9	5 801 253.4	25.7	20.3	
19/01/2023	18:24:40	ARS-17	Still	ARS-17_16	388	560 338.8	5 801 273.1	560 345.1	5 801 255.9	25.6	18.3	
19/01/2023	18:25:21	ARS-17	Still	ARS-17_17	389	560 338.8	5 801 273.1	560 344.6	5 801 259.8	25.6	14.5	
19/01/2023	18:25:48	ARS-17	Still	ARS-17_18	390	560 338.8	5 801 273.1	560 345.0	5 801 264.3	25.4	10.7	
19/01/2023	18:26:12	ARS-17	Still	ARS-17_19	391	560 338.8	5 801 273.1	560 344.1	5 801 268.4	25.6	7.1	
19/01/2023	18:28:19	ARS-17	Still	ARS-17_20	392	560 338.8	5 801 273.1	560 337.4	5 801 270.5	25.5	3.0	
19/01/2023	18:28:55	ARS-17	Still	ARS-17_21	393	560 338.8	5 801 273.1	560 337.1	5 801 268.7	25.4	4.7	
19/01/2023	18:29:59	ARS-17	Still	ARS-17_22	394	560 338.8	5 801 273.1	560 334.0	5 801 275.9	25.4	5.5	
19/01/2023	18:30:32	ARS-17	Still	ARS-17_23	395	560 338.8	5 801 273.1	560 333.8	5 801 279.9	25.6	8.5	
19/01/2023	18:31:08	ARS-17	Still	ARS-17_24	396	560 338.8	5 801 273.1	560 331.8	5 801 285.1	25.5	13.9	
19/01/2023	18:31:30	ARS-17	Still	ARS-17_25	397	560 338.8	5 801 273.1	560 330.2	5 801 287.9	25.2	17.1	
19/01/2023	18:31:59	ARS-17	Still	ARS-17_26	398	560 338.8	5 801 273.1	560 330.4	5 801 292.7	25.4	21.3	
19/01/2023	18:32:24	ARS-17	Still	ARS-17_27	399	560 338.8	5 801 273.1	560 330.9	5 801 297.5	25.5	25.7	
19/01/2023	18:32:49	ARS-17	Still	ARS-17_28	400	560 338.8	5 801 273.1	560 330.3	5 801 300.9	25.2	29.1	
19/01/2023	18:33:12	ARS-17	Still	ARS-17_29	401	560 338.8	5 801 273.1	560 328.8	5 801 303.8	25.4	32.3	
19/01/2023	18:34:07	ARS-17	Still	ARS-17_30	402	560 338.8	5 801 273.1	560 326.5	5 801 313.6	25.3	42.3	
19/01/2023	18:35:00	ARS-17	Still	ARS-17_31	403	560 338.8	5 801 273.1	560 326.7	5 801 324.1	25.3	52.5	
19/01/2023	18:35:48	ARS-17	Still	ARS-17_32	404	560 338.8	5 801 273.1	560 325.1	5 801 332.3	25.1	60.8	
19/01/2023	18:37:25	ARS-17	Still	ARS-17_33	405	560 338.8	5 801 273.1	560 322.9	5 801 350.1	24.8	78.7	
19/01/2023	18:39:07	ARS-17	Still	ARS-17_34	406	560 338.8	5 801 273.1	560 322.0	5 801 362.6	24.5	91.0	
19/01/2023	18:39:18	ARS-17	Still	ARS-17_35	407	560 338.8	5 801 273.1	560 321.8	5 801 364.7	24.7	93.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
19/01/2023	18:39:25	ARS-17	Still	No still	408	560 338.8	5 801 273.1	560 321.8	5 801 366.4	24.8	94.9	
19/01/2023	18:39:56	ARS-17	Still	ARS-17_36	409	560 338.8	5 801 273.1	560 320.9	5 801 374.4	24.6	102.9	
19/01/2023	18:40:33	ARS-17	Still	ARS-17_37	410	560 338.8	5 801 273.1	560 319.9	5 801 379.1	24.6	107.6	
19/01/2023	18:40:54	ARS-17	Still	ARS-17_38	411	560 338.8	5 801 273.1	560 319.6	5 801 383.4	24.4	112.0	
19/01/2023	18:41:13	ARS-17	Video	EOL	No fix	560 338.8	5 801 273.1	560 320.2	5 801 388.3	24.3	116.7	
19/01/2023	14:26:54	ARW-04	WP	Water Profile	370	560 338.8	5 801 273.1	560 337.5	5 801 273.5	26.1	1.4	
19/01/2023	15:06:06	ARW-04	WS	Top	371	560 338.8	5 801 273.1	560 338.9	5 801 273.2	26.1	0.2	
19/01/2023	15:38:01	ARW-04	WS	Bottom	372	560 338.8	5 801 273.1	560 336.9	5 801 272.0	26.1	2.2	
19/01/2023	19:06:29	ARS-17	DVV	NS	412	560 338.8	5 801 273.1	560 338.2	5 801 270.5	25.4	2.7	
19/01/2023	19:16:25	ARS-17	DVV	PC, FC	413	560 338.8	5 801 273.1	560 338.9	5 801 269.8	25.4	3.3	
19/01/2023	19:37:19	ARS-17	DVV	FA, FB	414	560 338.8	5 801 273.1	560 342.5	5 801 270.1	25.3	4.8	
19/01/2023	19:48:03	ARS-17	DVV	eDNA	415	560 338.8	5 801 273.1	560 338.3	5 801 269.2	25.3	3.9	
20/01/2023	01:04:47	ARS-23a	Video	SOL	No fix	570 088.4	5 761 867.1	570 147.8	5 761 978.4	19.3	126.2	Rerun in attempt to gain visibility
20/01/2023	01:13:53	ARS-23a	Video	EOL	No fix	570 088.4	5 761 867.1	570 119.9	5 761 920.9	19.3	62.3	
20/01/2023	01:31:40	ARS-23b	Video	SOL	No fix	570 088.4	5 761 867.1	570 162.6	5 762 141.3	19.3	284.1	Rerun in attempt to gain visibility
20/01/2023	01:35:58	ARS-23b	Video	EOL	No fix	570 088.4	5 761 867.1	570 153.3	5 762 116.7	19.3	257.9	
20/01/2023	02:03:22	ARS-23c	Video	SOL	No fix	570 088.4	5 761 867.1	570 245.5	5 762 441.4	19.3	595.4	Rerun in attempt to

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
												gain visibility
20/01/2023	02:07:44	ARS-23c	Video	EOL	No fix	570 088.4	5 761 867.1	570 227.3	5 762 408.3	19.3	558.7	
20/01/2023	02:22:07	ARS-23d	Video	SOL	No fix	570 088.4	5 761 867.1	570 279.0	5 762 567.0	19.3	725.4	Rerun in attempt to gain visibility
20/01/2023	02:26:05	ARS-23d	Video	EOL	No fix	570 088.4	5 761 867.1	570 262.2	5 762 531.5	19.3	686.8	
20/01/2023	02:54:27	ARS-23e	Video	SOL	No fix	570 088.4	5 761 867.1	570 375.7	5 762 734.6	19.3	913.8	Rerun in attempt to gain visibility
20/01/2023	02:59:30	ARS-23e	Video	EOL	No fix	570 088.4	5 761 867.1	570 359.5	5 762 697.3	19.3	873.3	
20/01/2023	20:59:56	ARS-18	Video	SOL	No fix	561 906.5	5 794 117.4	561 804.4	5 794 043.4	21.8	126.1	
20/01/2023	20:11:37	ARS-18	Still	ARS-18_01	417	561 906.5	5 794 117.4	561 803.6	5 794 043.4	22.7	126.7	
20/01/2023	20:12:23	ARS-18	Still	ARS-18_02	418	561 906.5	5 794 117.4	561 808.5	5 794 046.5	22.5	121.0	
20/01/2023	20:13:55	ARS-18	Still	ARS-18_03	419	561 906.5	5 794 117.4	561 818.6	5 794 052.8	22.4	109.1	
20/01/2023	20:14:22	ARS-18	Still	ARS-18_04	420	561 906.5	5 794 117.4	561 820.3	5 794 055.4	22.5	106.2	
20/01/2023	20:15:51	ARS-18	Still	ARS-18_05	421	561 906.5	5 794 117.4	561 823.6	5 794 060.7	22.4	100.5	
20/01/2023	20:16:43	ARS-18	Still	ARS-18_06	422	561 906.5	5 794 117.4	561 830.7	5 794 064.4	22.2	92.4	
20/01/2023	20:17:38	ARS-18	Still	ARS-18_07	423	561 906.5	5 794 117.4	561 835.1	5 794 066.7	22.3	87.5	
20/01/2023	20:18:31	ARS-18	Still	ARS-18_08	424	561 906.5	5 794 117.4	561 836.7	5 794 069.9	22.3	84.5	
20/01/2023	20:19:33	ARS-18	Still	ARS-18_09	425	561 906.5	5 794 117.4	561 843.1	5 794 071.4	22.2	78.3	
20/01/2023	20:20:59	ARS-18	Still	ARS-18_10	426	561 906.5	5 794 117.4	561 849.3	5 794 076.4	21.8	70.4	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
20/01/2023	20:22:31	ARS-18	Still	ARS-18_11	427	561 906.5	5 794 117.4	561 862.4	5 794 084.0	22.0	55.3	
20/01/2023	20:23:48	ARS-18	Still	ARS-18_12	428	561 906.5	5 794 117.4	561 869.2	5 794 089.0	21.8	46.8	
20/01/2023	20:24:58	ARS-18	Still	ARS-18_13	429	561 906.5	5 794 117.4	561 874.7	5 794 094.8	21.4	39.0	
20/01/2023	20:25:28	ARS-18	Still	ARS-18_14	430	561 906.5	5 794 117.4	561 878.4	5 794 097.7	21.3	34.4	
20/01/2023	20:26:23	ARS-18	Still	ARS-18_15	431	561 906.5	5 794 117.4	561 882.3	5 794 099.2	21.2	30.3	
20/01/2023	20:27:12	ARS-18	Still	ARS-18_16	432	561 906.5	5 794 117.4	561 887.6	5 794 103.9	20.9	23.2	
20/01/2023	20:28:45	ARS-18	Still	ARS-18_17	433	561 906.5	5 794 117.4	561 899.6	5 794 109.8	20.2	10.3	
20/01/2023	20:29:29	ARS-18	Still	ARS-18_18	434	561 906.5	5 794 117.4	561 904.2	5 794 113.2	20.0	4.8	
20/01/2023	20:30:16	ARS-18	Still	ARS-18_19	435	561 906.5	5 794 117.4	561 909.0	5 794 117.2	21.5	2.5	
20/01/2023	20:31:01	ARS-18	Still	ARS-18_20	436	561 906.5	5 794 117.4	561 911.0	5 794 119.6	22.0	5.0	
20/01/2023	20:32:07	ARS-18	Still	ARS-18_21	437	561 906.5	5 794 117.4	561 975.6	5 794 134.9	22.9	71.3	
20/01/2023	20:33:03	ARS-18	Still	ARS-18_22	438	561 906.5	5 794 117.4	561 918.9	5 794 127.5	23.4	16.0	
20/01/2023	20:33:58	ARS-18	Still	ARS-18_23	439	561 906.5	5 794 117.4	561 923.3	5 794 129.9	23.7	21.0	
20/01/2023	20:34:36	ARS-18	Still	ARS-18_24	440	561 906.5	5 794 117.4	561 926.5	5 794 131.1	24.1	24.2	
20/01/2023	20:35:04	ARS-18	Still	ARS-18_25	441	561 906.5	5 794 117.4	561 929.5	5 794 133.9	24.3	28.3	
20/01/2023	20:35:49	ARS-18	Still	ARS-18_26	442	561 906.5	5 794 117.4	561 931.4	5 794 137.1	24.5	31.8	
20/01/2023	20:36:48	ARS-18	Still	ARS-18_27	443	561 906.5	5 794 117.4	561 935.5	5 794 140.0	24.7	36.8	
20/01/2023	20:37:27	ARS-18	Still	ARS-18_28	444	561 906.5	5 794 117.4	561 939.7	5 794 141.0	24.9	40.7	
20/01/2023	20:37:52	ARS-18	Still	ARS-18_29	445	561 906.5	5 794 117.4	561 941.6	5 794 142.1	24.9	42.9	
20/01/2023	20:38:28	ARS-18	Still	ARS-18_30	446	561 906.5	5 794 117.4	561 946.0	5 794 145.2	25.0	48.3	
20/01/2023	20:39:19	ARS-18	Still	ARS-18_31	447	561 906.5	5 794 117.4	561 953.2	5 794 148.7	24.9	56.3	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
20/01/2023	20:40:15	ARS-18	Still	ARS-18_32	448	561 906.5	5 794 117.4	561 959.0	5 794 153.9	24.9	63.9	
20/01/2023	20:40:46	ARS-18	Still	ARS-18_33	449	561 906.5	5 794 117.4	561 963.7	5 794 158.0	25.1	70.2	
20/01/2023	20:41:28	ARS-18	Still	ARS-18_34	450	561 906.5	5 794 117.4	561 969.5	5 794 162.3	25.1	77.3	
20/01/2023	20:41:44	ARS-18	Still	ARS-18_35	451	561 906.5	5 794 117.4	561 970.3	5 794 162.7	25.0	78.3	
20/01/2023	20:41:51	ARS-18	Still	ARS-18_36	452	561 906.5	5 794 117.4	561 970.8	5 794 162.8	25.0	78.7	
20/01/2023	20:42:01	ARS-18	Still	ARS-18_37	453	561 906.5	5 794 117.4	561 971.5	5 794 163.0	25.0	79.4	
20/01/2023	20:42:08	ARS-18	Still	ARS-18_38	454	561 906.5	5 794 117.4	561 971.4	5 794 163.4	25.0	79.5	
20/01/2023	20:42:50	ARS-18	Still	ARS-18_39	455	561 906.5	5 794 117.4	561 970.8	5 794 164.9	24.9	79.9	
20/01/2023	20:42:54	ARS-18	Still	ARS-18_40	456	561 906.5	5 794 117.4	561 970.8	5 794 165.1	25.0	80.1	
20/01/2023	20:43:31	ARS-18	Still	ARS-18_41	457	561 906.5	5 794 117.4	561 971.9	5 794 168.2	25.0	82.8	
20/01/2023	20:44:08	ARS-18	Still	ARS-18_42	458	561 906.5	5 794 117.4	561 977.2	5 794 170.8	24.8	88.6	
20/01/2023	20:44:25	ARS-18	Still	ARS-18_43	459	561 906.5	5 794 117.4	561 980.2	5 794 172.4	25.0	92.0	
20/01/2023	20:44:56	ARS-18	Still	ARS-18_44	460	561 906.5	5 794 117.4	561 986.2	5 794 175.1	24.6	98.4	
20/01/2023	20:45:24	ARS-18	Still	ARS-18_45	461	561 906.5	5 794 117.4	561 991.2	5 794 178.8	24.8	104.6	
20/01/2023	20:45:50	ARS-18	Still	ARS-18_46	462	561 906.5	5 794 117.4	561 994.1	5 794 183.6	24.6	109.8	
20/01/2023	20:46:10	ARS-18	Video	EOL	No fix	561 906.5	5 794 117.4	561 996.4	5 794 184.5	24.4	112.2	
20/01/2023	21:03:31	ARS-18	DVV	FC, NS	463	561 906.5	5 794 117.4	561 904.7	5 794 114.2	20.0	3.6	Sample wash out
20/01/2023	21:13:19	ARS-18	DVV	PC, eDNA	464	561 906.5	5 794 117.4	561 906.7	5 794 113.8	19.9	3.6	
20/01/2023	21:32:49	ARS-18	DVV	FA, FB	465	561 906.5	5 794 117.4	561 906.2	5 794 113.6	19.9	3.8	
21/01/2023	00:05:46	ARS-16	Video	SOL	No fix	558 200.0	5 809 927.6	558 089.5	5 809 835.9	21.7	143.6	
21/01/2023	00:07:52	ARS-16	Still	ARS-16_01	466	558 200.0	5 809 927.6	558 099.6	5 809 844.9	28.5	130.0	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	00:09:07	ARS-16	Still	ARS-16_02	467	558 200.0	5 809 927.6	558 107.9	5 809 851.6	28.3	119.4	
21/01/2023	00:11:29	ARS-16	Still	ARS-16_03	468	558 200.0	5 809 927.6	558 121.8	5 809 862.9	28.4	101.5	
21/01/2023	00:13:27	ARS-16	Still	ARS-16_04	469	558 200.0	5 809 927.6	558 133.0	5 809 874.1	28.2	85.7	
21/01/2023	00:15:15	ARS-16	Still	ARS-16_05	470	558 200.0	5 809 927.6	558 144.1	5 809 883.5	28.3	71.2	
21/01/2023	00:16:45	ARS-16	Still	ARS-16_06	471	558 200.0	5 809 927.6	558 153.6	5 809 891.2	28.1	59.0	
21/01/2023	00:18:01	ARS-16	Still	ARS-16_07	472	558 200.0	5 809 927.6	558 161.0	5 809 896.5	28.0	49.9	
21/01/2023	00:19:35	ARS-16	Still	ARS-16_08	473	558 200.0	5 809 927.6	558 172.3	5 809 905.8	27.9	35.3	
21/01/2023	00:20:08	ARS-16	Still	ARS-16_09	474	558 200.0	5 809 927.6	558 176.0	5 809 909.3	27.7	30.2	
21/01/2023	00:20:29	ARS-16	Still	ARS-16_10	475	558 200.0	5 809 927.6	558 178.8	5 809 911.5	27.9	26.6	
21/01/2023	00:22:03	ARS-16	Still	ARS-16_11	476	558 200.0	5 809 927.6	558 190.9	5 809 920.7	27.9	11.5	
21/01/2023	00:23:00	ARS-16	Still	ARS-16_12	477	558 200.0	5 809 927.6	558 196.1	5 809 926.2	27.8	4.2	
21/01/2023	00:24:38	ARS-16	Still	ARS-16_13	478	558 200.0	5 809 927.6	558 204.2	5 809 932.8	27.7	6.7	
21/01/2023	00:26:00	ARS-16	Still	ARS-16_14	479	558 200.0	5 809 927.6	558 214.0	5 809 940.5	27.9	19.1	
21/01/2023	00:27:26	ARS-16	Still	ARS-16_15	480	558 200.0	5 809 927.6	558 224.7	5 809 950.1	28.0	33.4	
21/01/2023	00:28:49	ARS-16	Still	ARS-16_16	481	558 200.0	5 809 927.6	558 235.0	5 809 957.0	28.7	45.7	
21/01/2023	00:30:29	ARS-16	Still	ARS-16_17	482	558 200.0	5 809 927.6	558 244.6	5 809 967.0	28.9	59.5	
21/01/2023	00:31:14	ARS-16	Still	ARS-16_18	483	558 200.0	5 809 927.6	558 248.3	5 809 970.2	28.8	64.4	
21/01/2023	00:32:56	ARS-16	Still	ARS-16_19	484	558 200.0	5 809 927.6	558 262.2	5 809 981.6	28.7	82.4	
21/01/2023	00:33:30	ARS-16	Still	ARS-16_20	485	558 200.0	5 809 927.6	558 267.5	5 809 986.8	28.6	89.8	
21/01/2023	00:34:08	ARS-16	Still	ARS-16_21	486	558 200.0	5 809 927.6	558 272.8	5 809 990.9	28.5	96.4	
21/01/2023	00:35:26	ARS-16	Still	ARS-16_22	487	558 200.0	5 809 927.6	558 281.6	5 809 997.5	28.5	107.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	00:36:24	ARS-16	Still	ARS-16_23	488	558 200.0	5 809 927.6	558 288.1	5 810 003.6	28.5	116.3	
21/01/2023	00:37:01	ARS-16	Video	EOL	No fix	558 200.0	5 809 927.6	558 291.1	5 810 006.4	27.5	4.5	
21/01/2023	00:51:55	ARS-16	DVV	PC, eDNA	489	558 200.0	5 809 927.6	558 202.6	5 809 931.3	27.8	3.5	
21/01/2023	01:11:28	ARS-16	DVV	FA, FB	490	558 200.0	5 809 927.6	558 199.5	5 809 931.0	27.8	3.3	
21/01/2023	01:25:35	ARS-16	DVV	FC	491	558 200.0	5 809 927.6	558 201.0	5 809 930.8	27.8	3.3	
21/01/2023	03:23:18	ARS-15	Video	SOL	No fix	561 837.9	5 823 368.0	561 852.9	5 823 489.6	26.1	123	
21/01/2023	03:24:37	ARS-15	Still	ARS-15_01	492	561 837.9	5 823 368.0	561 852.1	5 823 478.0	28.4	111	
21/01/2023	03:26:14	ARS-15	Still	ARS-15_02	493	561 837.9	5 823 368.0	561 851.2	5 823 464.3	27.9	97.2	
21/01/2023	03:27:43	ARS-15	Still	ARS-15_03	494	561 837.9	5 823 368.0	561 849.7	5 823 453.5	27.8	86.3	
21/01/2023	03:29:17	ARS-15	Still	ARS-15_04	495	561 837.9	5 823 368.0	561 847.7	5 823 442.1	27.6	74.7	
21/01/2023	03:30:12	ARS-15	Still	ARS-15_05	496	561 837.9	5 823 368.0	561 846.6	5 823 433.9	27.5	66.5	
21/01/2023	03:31:57	ARS-15	Still	ARS-15_06	497	561 837.9	5 823 368.0	561 846.0	5 823 423.5	27.3	56.1	
21/01/2023	03:33:48	ARS-15	Still	ARS-15_07	498	561 837.9	5 823 368.0	561 844.9	5 823 409.8	27.3	42.3	
21/01/2023	03:35:46	ARS-15	Still	ARS-15_08	499	561 837.9	5 823 368.0	561 842.2	5 823 392.2	27.7	24.5	
21/01/2023	03:37:40	ARS-15	Still	ARS-15_09	500	561 837.9	5 823 368.0	561 841.2	5 823 380.2	27.7	12.6	
21/01/2023	03:39:17	ARS-15	Still	ARS-15_10	501	561 837.9	5 823 368.0	561 839.8	5 823 367.7	27.7	1.9	
21/01/2023	03:39:56	ARS-15	Still	ARS-15_11	502	561 837.9	5 823 368.0	561 838.3	5 823 363.1	27.8	4.9	
21/01/2023	03:42:03	ARS-15	Still	ARS-15_12	503	561 837.9	5 823 368.0	561 836.3	5 823 346.9	28.0	21.2	
21/01/2023	03:43:12	ARS-15	Still	ARS-15_13	504	561 837.9	5 823 368.0	561 836.1	5 823 339.0	28.0	29.0	
21/01/2023	03:44:10	ARS-15	Still	ARS-15_14	505	561 837.9	5 823 368.0	561 835.4	5 823 331.3	28.1	36.8	
21/01/2023	03:45:41	ARS-15	Still	ARS-15_15	506	561 837.9	5 823 368.0	561 833.3	5 823 320.4	28.2	47.8	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	03:46:05	ARS-15	Still	ARS-15_16	507	561 837.9	5 823 368.0	561 832.8	5 823 317.5	27.9	50.8	
21/01/2023	03:47:13	ARS-15	Still	ARS-15_17	508	561 837.9	5 823 368.0	561 831.7	5 823 309.7	28.1	58.7	
21/01/2023	03:47:29	ARS-15	Still	ARS-15_18	509	561 837.9	5 823 368.0	561 831.6	5 823 307.5	28.0	60.9	
21/01/2023	03:48:35	ARS-15	Still	ARS-15_19	510	561 837.9	5 823 368.0	561 831.1	5 823 299.2	28.1	69.1	
21/01/2023	03:49:30	ARS-15	Still	ARS-15_20	511	561 837.9	5 823 368.0	561 830.8	5 823 290.9	28.2	77.4	
21/01/2023	03:51:16	ARS-15	Still	ARS-15_21	512	561 837.9	5 823 368.0	561 828.2	5 823 275.9	28.4	92.6	
21/01/2023	03:52:57	ARS-15	Still	ARS-15_22	513	561 837.9	5 823 368.0	561 826.7	5 823 261.9	28.5	107	
21/01/2023	03:54:20	ARS-15	Video	EOL	No fix	561 837.9	5 823 368.0	561 825.1	5 823 249.4	27.0	119	
21/01/2023	04:09:45	ARS-15	DVV	PC, eDNA	514	561 837.9	5 823 368.0	561 837.2	5 823 369.1	27.5	1.3	
21/01/2023	04:27:54	ARS-15	DVV	FA, FB	515	561 837.9	5 823 368.0	561 837.9	5 823 368.4	27.5	0.4	
21/01/2023	04:34:02	ARS-15	DVV	FC	516	561 837.9	5 823 368.0	561 838.3	5 823 368.3	27.5	0.5	
21/01/2023	06:52:30	ARS-14	Video	SOL	No fix	564 546.8	5 839 661.3	564 518.4	5 839 536.4	26.8	128	
21/01/2023	06:53:59	ARS-14	Still	ARS-14_01	517	564 546.8	5 839 661.3	564 521.8	5 839 548.4	27.8	116	
21/01/2023	06:56:19	ARS-14	Still	ARS-14_02	518	564 546.8	5 839 661.3	564 523.7	5 839 560.9	27.5	103	
21/01/2023	07:00:04	ARS-14	Still	ARS-14_03	519	564 546.8	5 839 661.3	564 527.0	5 839 576.5	27.3	87.1	
21/01/2023	07:02:36	ARS-14	Still	ARS-14_04	520	564 546.8	5 839 661.3	564 532.3	5 839 600.0	27.2	63.0	
21/01/2023	07:02:59	ARS-14	Still	ARS-14_05	521	564 546.8	5 839 661.3	564 532.9	5 839 603.2	27.0	59.7	
21/01/2023	07:04:27	ARS-14	Still	ARS-14_06	522	564 546.8	5 839 661.3	564 536.8	5 839 619.5	27.1	43.0	
21/01/2023	07:05:28	ARS-14	Still	ARS-14_07	523	564 546.8	5 839 661.3	564 539.9	5 839 629.9	26.8	32.1	
21/01/2023	07:06:12	ARS-14	Still	ARS-14_08	524	564 546.8	5 839 661.3	564 542.0	5 839 637.2	26.6	24.6	
21/01/2023	07:06:52	ARS-14	Still	ARS-14_09	525	564 546.8	5 839 661.3	564 543.5	5 839 643.7	26.6	17.9	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	07:07:41	ARS-14	Still	ARS-14_10	526	564 546.8	5 839 661.3	564 545.2	5 839 651.1	26.7	10.3	
21/01/2023	07:09:34	ARS-14	Still	ARS-14_11	527	564 546.8	5 839 661.3	564 548.5	5 839 669.9	26.5	8.8	
21/01/2023	07:10:08	ARS-14	Still	ARS-14_12	528	564 546.8	5 839 661.3	564 549.4	5 839 674.1	26.5	13.1	
21/01/2023	07:10:43	ARS-14	Still	ARS-14_13	529	564 546.8	5 839 661.3	564 551.3	5 839 679.0	26.7	18.2	
21/01/2023	07:13:00	ARS-14	Still	ARS-14_14	530	564 546.8	5 839 661.3	564 553.7	5 839 696.0	27.4	35.3	
21/01/2023	07:13:21	ARS-14	Still	ARS-14_15	531	564 546.8	5 839 661.3	564 554.3	5 839 698.4	27.6	37.8	
21/01/2023	07:14:23	ARS-14	Still	ARS-14_16	532	564 546.8	5 839 661.3	564 556.8	5 839 706.0	28.0	45.8	
21/01/2023	07:15:00	ARS-14	Still	ARS-14_17	533	564 546.8	5 839 661.3	564 557.8	5 839 711.4	28.1	51.3	
21/01/2023	07:16:34	ARS-14	Still	ARS-14_18	534	564 546.8	5 839 661.3	564 561.0	5 839 723.2	28.1	63.5	
21/01/2023	07:19:44	ARS-14	Still	ARS-14_19	535	564 546.8	5 839 661.3	564 567.4	5 839 753.2	27.6	94.2	
21/01/2023	07:21:50	ARS-14	Video	EOL	No fix	564 546.8	5 839 661.3	564 572.9	5 839 977.5	27.2	317	
21/01/2023	07:42:35	ARS-14	DVV	PC, eDNA	536	564 546.8	5 839 661.3	564 545.2	5 839 658.3	26.7	3.4	
21/01/2023	08:03:37	ARS-14	DVV	FA, FB	537	564 546.8	5 839 661.3	564 544.7	5 839 661.0	26.5	2.1	
21/01/2023	08:10:56	ARS-14	DVV	FC	538	564 546.8	5 839 661.3	564 543.0	5 839 664.0	26.4	4.7	
21/01/2023	10:21:31	ARS-13	Video	SOL	No fix	564 630.9	5 857 180.7	564 553.6	5 857 074.3	27.5	132	
21/01/2023	10:23:09	ARS-13	Still	ARS-13_01	539	564 630.9	5 857 180.7	564 564.7	5 857 097.4	28.9	106	
21/01/2023	10:24:46	ARS-13	Still	ARS-13_02	540	564 630.9	5 857 180.7	564 574.2	5 857 109.4	28.8	91.1	
21/01/2023	10:25:27	ARS-13	Still	ARS-13_03	541	564 630.9	5 857 180.7	564 576.8	5 857 112.8	28.7	86.8	
21/01/2023	10:26:52	ARS-13	Still	ARS-13_04	542	564 630.9	5 857 180.7	564 585.2	5 857 122.4	28.9	74.0	
21/01/2023	10:27:46	ARS-13	Still	ARS-13_05	543	564 630.9	5 857 180.7	564 591.7	5 857 130.1	28.9	64.0	
21/01/2023	10:28:31	ARS-13	Still	ARS-13_06	544	564 630.9	5 857 180.7	564 596.5	5 857 136.3	28.8	56.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	10:29:34	ARS-13	Still	ARS-13_07	545	564 630.9	5 857 180.7	564 604.9	5 857 146.7	28.7	42.8	
21/01/2023	10:30:50	ARS-13	Still	ARS-13_08	546	564 630.9	5 857 180.7	564 614.2	5 857 158.5	28.8	27.8	
21/01/2023	10:32:07	ARS-13	Still	ARS-13_09	547	564 630.9	5 857 180.7	564 623.9	5 857 169.4	28.9	13.3	
21/01/2023	10:33:15	ARS-13	Still	ARS-13_10	548	564 630.9	5 857 180.7	564 629.1	5 857 176.3	28.8	4.7	
21/01/2023	10:34:49	ARS-13	Still	ARS-13_11	549	564 630.9	5 857 180.7	564 638.3	5 857 187.5	28.8	10.0	
21/01/2023	10:36:24	ARS-13	Still	ARS-13_12	550	564 630.9	5 857 180.7	564 649.3	5 857 198.9	28.7	25.8	
21/01/2023	10:37:07	ARS-13	Still	ARS-13_13	551	564 630.9	5 857 180.7	564 654.4	5 857 205.2	28.7	33.9	
21/01/2023	10:38:49	ARS-13	Still	ARS-13_14	552	564 630.9	5 857 180.7	564 665.4	5 857 219.3	28.8	51.8	
21/01/2023	10:40:10	ARS-13	Still	ARS-13_15	553	564 630.9	5 857 180.7	564 675.2	5 857 230.3	28.7	66.5	
21/01/2023	10:41:18	ARS-13	Still	ARS-13_16	554	564 630.9	5 857 180.7	564 683.0	5 857 239.1	28.6	78.2	
21/01/2023	10:42:03	ARS-13	Still	ARS-13_17	555	564 630.9	5 857 180.7	564 688.0	5 857 245.6	28.7	86.4	
21/01/2023	10:42:51	ARS-13	Still	ARS-13_18	556	564 630.9	5 857 180.7	564 693.4	5 857 252.3	28.6	95.1	
21/01/2023	10:45:11	ARS-13	Video	EOL	No fix	564 630.9	5 857 180.7	564 711.1	5 857 269.9	27.1	120	
21/01/2023	11:12:13	ARS-13	DVV	PC, eDNA	557	564 630.9	5 857 180.7	564 630.1	5 857 181.0	28.8	0.9	
21/01/2023	11:40:01	ARS-13	DVV	FA, FB	560	564 630.9	5 857 180.7	564 629.8	5 857 181.0	28.6	1.1	
21/01/2023	11:49:36	ARS-13	DVV	FC	561	564 630.9	5 857 180.7	564 630.1	5 857 181.5	28.6	1.1	
21/01/2023	12:42:20	ARW-03	WP	Water Profile	562	566 182.1	5 858 841.5	566 182.2	5 858 842.7	27.5	1.2	
21/01/2023	12:59:49	ARW-03	WS	Top	563	566 182.1	5 858 841.5	566 181.5	5 858 842.4	27.7	1.0	
21/01/2023	13:51:09	ARW-03	WS	Bottom	564	566 182.1	5 858 841.5	566 182.4	5 858 841.8	28.5	0.4	
21/01/2023	14:32:03	ARW-03	VZ	Zooplankton	565	566 182.1	5 858 841.5	566 191.3	5 858 862.9	28.8	23.3	
21/01/2023	17:19:49	ARS-12	Video	SOL	566	563 692.3	5 876 163.8	563 763.9	5 876 265.5	25.1	124	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	17:20:34	ARS-12	Still	ARS-12_01	567	563 692.3	5 876 163.8	563 760.1	5 876 259.3	25.3	117	
21/01/2023	17:21:02	ARS-12	Still	ARS-12_02	568	563 692.3	5 876 163.8	563 755.9	5 876 252.9	25.6	109	
21/01/2023	17:21:28	ARS-12	Still	ARS-12_03	569	563 692.3	5 876 163.8	563 753.3	5 876 249.4	26.0	105	
21/01/2023	17:22:08	ARS-12	Still	ARS-12_04	570	563 692.3	5 876 163.8	563 751.9	5 876 247.1	25.7	102	
21/01/2023	17:22:49	ARS-12	Still	ARS-12_05	571	563 692.3	5 876 163.8	563 748.1	5 876 242.1	25.9	96.2	
21/01/2023	17:23:14	ARS-12	Still	ARS-12_06	572	563 692.3	5 876 163.8	563 745.1	5 876 238.3	25.3	91.3	
21/01/2023	17:24:07	ARS-12	Still	ARS-12_07	573	563 692.3	5 876 163.8	563 740.2	5 876 229.2	25.1	81.0	
21/01/2023	17:24:24	ARS-12	Still	ARS-12_08	574	563 692.3	5 876 163.8	563 738.3	5 876 226.9	24.8	78.1	
21/01/2023	17:25:25	ARS-12	Still	No still	575	563 692.3	5 876 163.8	563 732.4	5 876 218.6	24.8	67.9	
21/01/2023	17:25:49	ARS-12	Still	ARS-12_09	576	563 692.3	5 876 163.8	563 730.1	5 876 215.4	25.5	63.9	
21/01/2023	17:26:31	ARS-12	Still	ARS-12_10	577	563 692.3	5 876 163.8	563 727.4	5 876 211.8	24.7	59.4	
21/01/2023	17:27:02	ARS-12	Still	ARS-12_11	578	563 692.3	5 876 163.8	563 723.9	5 876 207.4	25.7	53.8	
21/01/2023	17:27:35	ARS-12	Still	ARS-12_12	579	563 692.3	5 876 163.8	563 721.7	5 876 203.6	25.5	49.5	
21/01/2023	17:28:06	ARS-12	Still	ARS-12_13	580	563 692.3	5 876 163.8	563 718.2	5 876 198.2	25.8	43.0	
21/01/2023	17:28:25	ARS-12	Still	ARS-12_14	581	563 692.3	5 876 163.8	563 717.0	5 876 194.9	24.9	39.7	
21/01/2023	17:28:59	ARS-12	Still	ARS-12_15	582	563 692.3	5 876 163.8	563 713.7	5 876 189.6	25.3	33.5	
21/01/2023	17:29:23	ARS-12	Still	ARS-12_16	583	563 692.3	5 876 163.8	563 710.7	5 876 185.8	24.8	28.7	
21/01/2023	17:29:50	ARS-12	Still	ARS-12_17	584	563 692.3	5 876 163.8	563 707.2	5 876 181.6	25.4	23.2	
21/01/2023	17:30:11	ARS-12	Still	ARS-12_18	585	563 692.3	5 876 163.8	563 706.0	5 876 180.5	25.0	21.6	
21/01/2023	17:30:18	ARS-12	Still	ARS-12_19	586	563 692.3	5 876 163.8	563 705.7	5 876 180.4	24.9	21.3	
21/01/2023	17:30:26	ARS-12	Still	ARS-12_20	587	563 692.3	5 876 163.8	563 705.9	5 876 180.4	24.9	21.4	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	17:30:37	ARS-12	Still	ARS-12_21	588	563 692.3	5 876 163.8	563 705.5	5 876 180.4	25.4	21.2	
21/01/2023	17:31:07	ARS-12	Still	ARS-12_22	589	563 692.3	5 876 163.8	563 703.7	5 876 177.6	25.0	17.8	
21/01/2023	17:31:44	ARS-12	Still	ARS-12_23	590	563 692.3	5 876 163.8	563 698.2	5 876 168.8	25.6	7.6	
21/01/2023	17:32:01	ARS-12	Still	ARS-12_24	591	563 692.3	5 876 163.8	563 696.2	5 876 165.8	25.6	4.4	
21/01/2023	17:32:09	ARS-12	Still	ARS-12_25	592	563 692.3	5 876 163.8	563 696.0	5 876 165.3	25.1	4.0	
21/01/2023	17:32:45	ARS-12	Still	ARS-12_26	593	563 692.3	5 876 163.8	563 693.5	5 876 160.9	25.5	3.1	
21/01/2023	17:33:33	ARS-12	Still	ARS-12_27	594	563 692.3	5 876 163.8	563 689.2	5 876 156.0	25.4	8.5	
21/01/2023	17:33:39	ARS-12	Still	ARS-12_28	595	563 692.3	5 876 163.8	563 688.5	5 876 155.1	25.3	9.6	
21/01/2023	17:34:24	ARS-12	Still	ARS-12_29	596	563 692.3	5 876 163.8	563 683.4	5 876 147.8	25.2	18.3	
21/01/2023	17:35:08	ARS-12	Still	ARS-12_30	597	563 692.3	5 876 163.8	563 679.7	5 876 141.3	26.0	25.9	
21/01/2023	17:36:12	ARS-12	Still	ARS-12_31	598	563 692.3	5 876 163.8	563 673.1	5 876 132.5	25.6	36.8	
21/01/2023	17:37:00	ARS-12	Still	ARS-12_32	599	563 692.3	5 876 163.8	563 669.8	5 876 126.6	25.8	43.5	
21/01/2023	17:37:42	ARS-12	Still	ARS-12_33	600	563 692.3	5 876 163.8	563 666.7	5 876 121.4	25.2	49.6	
21/01/2023	17:38:13	ARS-12	Still	ARS-12_34	601	563 692.3	5 876 163.8	563 663.3	5 876 116.1	25.0	55.9	
21/01/2023	17:38:41	ARS-12	Still	ARS-12_35	602	563 692.3	5 876 163.8	563 660.1	5 876 112.0	25.6	61.0	
21/01/2023	17:39:12	ARS-12	Still	ARS-12_36	603	563 692.3	5 876 163.8	563 656.5	5 876 106.5	26.3	67.6	
21/01/2023	17:39:45	ARS-12	Still	ARS-12_37	604	563 692.3	5 876 163.8	563 653.5	5 876 102.2	25.5	72.9	
21/01/2023	17:40:39	ARS-12	Still	ARS-12_38	605	563 692.3	5 876 163.8	563 648.0	5 876 094.7	25.6	82.1	
21/01/2023	17:41:12	ARS-12	Still	ARS-12_39	606	563 692.3	5 876 163.8	563 645.5	5 876 091.0	25.3	86.6	
21/01/2023	17:41:40	ARS-12	Still	ARS-12_40	607	563 692.3	5 876 163.8	563 642.7	5 876 087.5	25.3	91.1	
21/01/2023	17:42:16	ARS-12	Still	ARS-12_41	608	563 692.3	5 876 163.8	563 638.9	5 876 081.5	25.8	98.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	17:42:45	ARS-12	Still	ARS-12_42	609	563 692.3	5 876 163.8	563 635.6	5 876 077.4	25.8	103.4	
21/01/2023	17:43:04	ARS-12	Still	ARS-12_43	610	563 692.3	5 876 163.8	563 633.7	5 876 074.6	25.7	106.8	
21/01/2023	17:43:19	ARS-12	Video	EOL	611	563 692.3	5 876 163.8	563 632.2	5 876 072.1	25.8	109.7	
21/01/2023	18:09:26	ARS-12	DVV	PC, eDNA	612	563 692.3	5 876 163.8	563 694.0	5 876 162.0	27.1	2.5	
21/01/2023	18:33:19	ARS-12	DVV	FA, FB	613	563 692.3	5 876 163.8	563 695.0	5 876 161.8	28.5	3.4	
21/01/2023	18:42:41	ARS-12	DVV	FC	614	563 692.3	5 876 163.8	563 694.7	5 876 161.9	27.2	3.1	
21/01/2023	21:16:50	ARS-11	Video	SOL	No fix	562 965.1	5 897 735.1	562 943.9	5 897 609.8	24.7	127.1	
21/01/2023	21:17:11	ARS-11	Still	ARS-11_01	615	562 965.1	5 897 735.1	562 943.8	5 897 610.1	26.4	126.8	
21/01/2023	21:17:53	ARS-11	Still	No still	616	562 965.1	5 897 735.1	562 944.7	5 897 612.8	26.4	124.0	
21/01/2023	21:18:43	ARS-11	Still	No still	617	562 965.1	5 897 735.1	562 945.4	5 897 621.3	26.3	115.5	
21/01/2023	21:19:10	ARS-11	Still	No still	618	562 965.1	5 897 735.1	562 945.9	5 897 623.4	26.3	113.3	
21/01/2023	21:19:35	ARS-11	Still	No still	619	562 965.1	5 897 735.1	562 946.7	5 897 629.6	26.3	107.1	
21/01/2023	21:20:21	ARS-11	Still	No still	620	562 965.1	5 897 735.1	562 948.7	5 897 638.8	26.3	97.7	
21/01/2023	21:21:00	ARS-11	Still	ARS-11_02	621	562 965.1	5 897 735.1	562 949.6	5 897 646.9	26.3	89.5	
21/01/2023	21:21:37	ARS-11	Still	ARS-11_03	622	562 965.1	5 897 735.1	562 950.8	5 897 652.3	26.3	84.1	
21/01/2023	21:22:25	ARS-11	Still	ARS-11_04	623	562 965.1	5 897 735.1	562 951.7	5 897 659.4	26.3	76.9	
21/01/2023	21:22:46	ARS-11	Still	ARS-11_05	624	562 965.1	5 897 735.1	562 952.0	5 897 662.0	26.3	74.3	
21/01/2023	21:23:07	ARS-11	Still	No still	625	562 965.1	5 897 735.1	562 952.1	5 897 663.7	26.3	72.6	
21/01/2023	21:23:24	ARS-11	Still	ARS-11_06	626	562 965.1	5 897 735.1	562 952.5	5 897 665.8	26.3	70.4	
21/01/2023	21:24:02	ARS-11	Still	No still	627	562 965.1	5 897 735.1	562 953.6	5 897 670.0	26.3	66.1	
21/01/2023	21:24:37	ARS-11	Still	No still	628	562 965.1	5 897 735.1	562 954.4	5 897 674.6	26.3	61.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	21:25:18	ARS-11	Still	ARS-11_07	629	562 965.1	5 897 735.1	562 954.7	5 897 678.5	26.3	57.5	
21/01/2023	21:25:49	ARS-11	Still	ARS-11_08	630	562 965.1	5 897 735.1	562 955.5	5 897 682.2	26.3	53.8	
21/01/2023	21:26:35	ARS-11	Still	ARS-11_09	631	562 965.1	5 897 735.1	562 955.9	5 897 686.9	26.3	49.1	
21/01/2023	21:27:04	ARS-11	Still	ARS-11_10	632	562 965.1	5 897 735.1	562 956.5	5 897 689.5	26.3	46.5	
21/01/2023	21:27:20	ARS-11	Still	ARS-11_11	633	562 965.1	5 897 735.1	562 956.7	5 897 690.7	26.3	45.2	
21/01/2023	21:27:58	ARS-11	Still	ARS-11_12	634	562 965.1	5 897 735.1	562 957.8	5 897 694.0	26.3	41.8	
21/01/2023	21:28:26	ARS-11	Still	ARS-11_13	635	562 965.1	5 897 735.1	562 958.1	5 897 696.9	26.3	38.8	
21/01/2023	21:28:52	ARS-11	Still	ARS-11_14	636	562 965.1	5 897 735.1	562 958.6	5 897 700.2	26.3	35.5	
21/01/2023	21:29:33	ARS-11	Still	ARS-11_15	637	562 965.1	5 897 735.1	562 958.9	5 897 704.8	26.3	30.9	
21/01/2023	21:30:07	ARS-11	Still	ARS-11_16	638	562 965.1	5 897 735.1	562 959.9	5 897 708.6	26.3	27.0	
21/01/2023	21:30:37	ARS-11	Still	ARS-11_17	639	562 965.1	5 897 735.1	562 960.3	5 897 711.6	26.3	24.0	
21/01/2023	21:31:11	ARS-11	Still	ARS-11_18	640	562 965.1	5 897 735.1	562 960.5	5 897 715.5	26.3	20.1	
21/01/2023	21:31:24	ARS-11	Still	ARS-11_19	641	562 965.1	5 897 735.1	562 960.7	5 897 717.6	26.3	18.1	
21/01/2023	21:32:05	ARS-11	Still	ARS-11_20	642	562 965.1	5 897 735.1	562 962.0	5 897 722.4	26.3	13.1	
21/01/2023	21:32:37	ARS-11	Still	ARS-11_21	643	562 965.1	5 897 735.1	562 962.3	5 897 725.6	26.3	9.9	
21/01/2023	21:33:05	ARS-11	Still	ARS-11_22	644	562 965.1	5 897 735.1	562 962.6	5 897 728.7	26.3	6.9	
21/01/2023	21:33:15	ARS-11	Still	ARS-11_23	645	562 965.1	5 897 735.1	562 962.7	5 897 729.4	26.3	6.2	
21/01/2023	21:33:30	ARS-11	Still	ARS-11_24	646	562 965.1	5 897 735.1	562 962.5	5 897 730.8	26.3	5.0	
21/01/2023	21:34:15	ARS-11	Still	ARS-11_25	647	562 965.1	5 897 735.1	562 963.4	5 897 735.4	26.3	1.7	
21/01/2023	21:34:37	ARS-11	Still	ARS-11_26	648	562 965.1	5 897 735.1	562 963.6	5 897 737.1	26.3	2.4	
21/01/2023	21:35:17	ARS-11	Still	ARS-11_27	649	562 965.1	5 897 735.1	562 964.5	5 897 740.4	26.3	5.4	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	21:35:32	ARS-11	Still	ARS-11_28	650	562 965.1	5 897 735.1	562 964.7	5 897 741.9	26.2	6.8	
21/01/2023	21:35:51	ARS-11	Still	ARS-11_29	651	562 965.1	5 897 735.1	562 965.3	5 897 744.1	26.3	9.0	
21/01/2023	21:36:28	ARS-11	Still	ARS-11_30	652	562 965.1	5 897 735.1	562 965.5	5 897 747.3	26.3	12.2	
21/01/2023	21:37:04	ARS-11	Still	ARS-11_31	653	562 965.1	5 897 735.1	562 966.2	5 897 751.8	26.2	16.8	
21/01/2023	21:37:26	ARS-11	Still	ARS-11_32	654	562 965.1	5 897 735.1	562 966.7	5 897 754.0	26.3	19.0	
21/01/2023	21:38:04	ARS-11	Still	ARS-11_33	655	562 965.1	5 897 735.1	562 967.6	5 897 759.2	26.3	24.2	
21/01/2023	21:38:45	ARS-11	Still	ARS-11_34	656	562 965.1	5 897 735.1	562 968.7	5 897 763.8	26.2	28.9	
21/01/2023	21:39:15	ARS-11	Still	ARS-11_35	657	562 965.1	5 897 735.1	562 969.2	5 897 768.2	26.2	33.4	
21/01/2023	21:39:33	ARS-11	Still	ARS-11_36	658	562 965.1	5 897 735.1	562 969.0	5 897 770.3	26.2	35.5	
21/01/2023	21:39:53	ARS-11	Still	ARS-11_37	659	562 965.1	5 897 735.1	562 969.9	5 897 773.8	26.2	39.0	
21/01/2023	21:40:24	ARS-11	Still	ARS-11_38	660	562 965.1	5 897 735.1	562 970.6	5 897 777.9	26.2	43.2	
21/01/2023	21:40:40	ARS-11	Still	ARS-11_39	661	562 965.1	5 897 735.1	562 970.6	5 897 779.5	26.3	44.8	
21/01/2023	21:40:56	ARS-11	Still	ARS-11_40	662	562 965.1	5 897 735.1	562 970.7	5 897 781.5	26.2	46.8	
21/01/2023	21:41:12	ARS-11	Still	ARS-11_41	663	562 965.1	5 897 735.1	562 971.1	5 897 783.4	26.2	48.6	
21/01/2023	21:41:23	ARS-11	Still	ARS-11_42	664	562 965.1	5 897 735.1	562 971.3	5 897 785.0	26.2	50.3	
21/01/2023	21:41:46	ARS-11	Still	ARS-11_43	665	562 965.1	5 897 735.1	562 971.7	5 897 788.3	26.2	53.6	
21/01/2023	21:42:23	ARS-11	Still	ARS-11_44	666	562 965.1	5 897 735.1	562 972.4	5 897 791.9	26.2	57.3	
21/01/2023	21:42:59	ARS-11	Still	ARS-11_45	667	562 965.1	5 897 735.1	562 973.1	5 897 795.6	26.2	61.0	
21/01/2023	21:43:47	ARS-11	Still	ARS-11_46	668	562 965.1	5 897 735.1	562 974.0	5 897 800.5	26.2	66.0	
21/01/2023	21:43:55	ARS-11	Still	ARS-11_47	669	562 965.1	5 897 735.1	562 974.0	5 897 801.6	26.2	67.0	
21/01/2023	21:44:15	ARS-11	Still	ARS-11_48	670	562 965.1	5 897 735.1	562 974.3	5 897 804.1	26.2	69.6	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
21/01/2023	21:44:33	ARS-11	Still	ARS-11_49	671	562 965.1	5 897 735.1	562 974.8	5 897 806.2	26.2	71.7	
21/01/2023	21:45:31	ARS-11	Still	ARS-11_50	672	562 965.1	5 897 735.1	562 975.5	5 897 811.2	26.2	76.8	
21/01/2023	21:46:13	ARS-11	Still	ARS-11_51	673	562 965.1	5 897 735.1	562 976.6	5 897 815.8	26.2	81.5	
21/01/2023	21:46:29	ARS-11	Still	ARS-11_52	674	562 965.1	5 897 735.1	562 976.7	5 897 816.8	26.2	82.5	
21/01/2023	21:47:11	ARS-11	Still	ARS-11_53	675	562 965.1	5 897 735.1	562 977.1	5 897 821.3	26.2	87.0	
21/01/2023	21:47:36	ARS-11	Still	ARS-11_54	676	562 965.1	5 897 735.1	562 977.5	5 897 824.6	26.2	90.3	
21/01/2023	21:48:11	ARS-11	Still	ARS-11_55	677	562 965.1	5 897 735.1	562 978.6	5 897 828.3	26.2	94.1	
21/01/2023	21:48:44	ARS-11	Still	ARS-11_56	678	562 965.1	5 897 735.1	562 979.4	5 897 832.1	26.1	98.0	
21/01/2023	21:48:55	ARS-11	Still	ARS-11_57	679	562 965.1	5 897 735.1	562 979.3	5 897 833.1	26.1	99.0	
21/01/2023	21:49:42	ARS-11	Still	No still	680	562 965.1	5 897 735.1	562 979.7	5 897 839.4	26.2	105.3	
21/01/2023	21:49:57	ARS-11	Video	EOL	No fix	562 965.1	5 897 735.1	562 980.1	5 897 841.0	25.5	107.0	
21/01/2023	21:13:40	ARS-11	DVV	FB, FC	681	562 965.1	5 897 735.1	562 963.8	5 897 734.8	26.0	1.3	
21/01/2023	22:22:11	ARS-11	DVV	NS	682	562 965.1	5 897 735.1	562 963.7	5 897 734.1	26.0	1.7	
21/01/2023	22:30:09	ARS-11	DVV	FA, NS	683	562 965.1	5 897 735.1	562 964.0	5 897 735.1	26.0	1.1	
21/01/2023	22:37:32	ARS-11	DVV	eDNA, NS	684	562 965.1	5 897 735.1	562 963.6	5 897 734.4	25.9	1.7	
21/01/2023	22:49:46	ARS-11	DVV	NS	685	562 965.1	5 897 735.1	562 963.7	5 897 734.7	25.9	1.4	
21/01/2023	22:57:06	ARS-11	DVV	PC	686	562 965.1	5 897 735.1	562 963.7	5 897 736.3	25.9	1.8	
22/01/2023	00:44:50	ARS-10	Video	SOL	No fix	547 193.2	5 895 223.4	547 068.2	5 895 212.8	24.6	125.4	
22/01/2023	00:46:45	ARS-10	Still	ARS-10-01	687	547 193.2	5 895 223.4	547 082.7	5 895 214.6	25.6	110.8	
22/01/2023	00:47:31	ARS-10	Still	ARS-10-02	688	547 193.2	5 895 223.4	547 088.6	5 895 215.0	25.7	104.9	
22/01/2023	00:48:12	ARS-10	Still	ARS-10-03	689	547 193.2	5 895 223.4	547 093.3	5 895 215.5	25.9	100.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	00:48:53	ARS-10	Still	ARS-10-04	690	547 193.2	5 895 223.4	547 098.3	5 895 215.9	25.8	95.2	
22/01/2023	00:49:24	ARS-10	Still	ARS-10-05	691	547 193.2	5 895 223.4	547 103.1	5 895 216.2	25.7	90.4	
22/01/2023	00:49:50	ARS-10	Still	ARS-10-06	692	547 193.2	5 895 223.4	547 106.0	5 895 216.3	25.8	87.5	
22/01/2023	00:50:41	ARS-10	Still	ARS-10-07	693	547 193.2	5 895 223.4	547 113.1	5 895 217.1	25.7	80.3	
22/01/2023	00:51:37	ARS-10	Still	ARS-10-08	694	547 193.2	5 895 223.4	547 118.2	5 895 217.9	25.7	75.2	
22/01/2023	00:52:00	ARS-10	Still	ARS-10-09	695	547 193.2	5 895 223.4	547 120.3	5 895 218.4	25.8	73.1	
22/01/2023	00:52:45	ARS-10	Still	ARS-10-10	696	547 193.2	5 895 223.4	547 124.7	5 895 218.7	25.8	68.6	
22/01/2023	00:53:38	ARS-10	Still	ARS-10-11	697	547 193.2	5 895 223.4	547 132.3	5 895 218.7	25.7	61.1	
22/01/2023	00:54:44	ARS-10	Still	ARS-10-12	698	547 193.2	5 895 223.4	547 140.8	5 895 218.8	25.9	52.6	
22/01/2023	00:55:26	ARS-10	Still	ARS-10-13	699	547 193.2	5 895 223.4	547 145.8	5 895 219.9	26.0	47.5	
22/01/2023	00:56:27	ARS-10	Still	ARS-10-14	700	547 193.2	5 895 223.4	547 153.2	5 895 221.0	25.8	40.1	
22/01/2023	00:57:55	ARS-10	Still	ARS-10-15	701	547 193.2	5 895 223.4	547 164.9	5 895 221.3	26.0	28.4	
22/01/2023	00:58:58	ARS-10	Still	ARS-10-16	702	547 193.2	5 895 223.4	547 174.1	5 895 222.2	26.1	19.1	
22/01/2023	00:59:52	ARS-10	Still	ARS-10-17	703	547 193.2	5 895 223.4	547 180.5	5 895 223.1	26.0	12.8	
22/01/2023	01:00:40	ARS-10	Still	ARS-10-18	704	547 193.2	5 895 223.4	547 186.8	5 895 223.3	26.2	6.4	
22/01/2023	01:01:02	ARS-10	Still	ARS-10-19	705	547 193.2	5 895 223.4	547 190.2	5 895 223.8	26.2	3.0	
22/01/2023	01:01:53	ARS-10	Still	ARS-10-20	706	547 193.2	5 895 223.4	547 198.0	5 895 224.6	26.1	5.0	
22/01/2023	01:02:42	ARS-10	Still	ARS-10-21	707	547 193.2	5 895 223.4	547 203.6	5 895 225.0	26.1	10.5	
22/01/2023	01:03:25	ARS-10	Still	ARS-10-22	708	547 193.2	5 895 223.4	547 208.7	5 895 225.3	26.2	15.6	
22/01/2023	01:04:25	ARS-10	Still	ARS-10-23	709	547 193.2	5 895 223.4	547 216.0	5 895 225.6	26.2	22.9	
22/01/2023	01:05:17	ARS-10	Still	ARS-10-24	710	547 193.2	5 895 223.4	547 222.5	5 895 226.6	26.1	29.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	01:06:11	ARS-10	Still	ARS-10-25	711	547 193.2	5 895 223.4	547 228.8	5 895 227.3	26.2	35.9	
22/01/2023	01:07:01	ARS-10	Still	ARS-10-26	712	547 193.2	5 895 223.4	547 234.5	5 895 227.1	26.1	41.4	
22/01/2023	01:07:54	ARS-10	Still	ARS-10-27	713	547 193.2	5 895 223.4	547 240.9	5 895 226.8	26.3	47.8	
22/01/2023	01:09:24	ARS-10	Still	ARS-10-28	714	547 193.2	5 895 223.4	547 251.5	5 895 229.2	26.1	58.6	
22/01/2023	01:10:27	ARS-10	Still	ARS-10-29	715	547 193.2	5 895 223.4	547 258.0	5 895 229.8	26.4	65.1	
22/01/2023	01:11:31	ARS-10	Still	ARS-10-30	716	547 193.2	5 895 223.4	547 265.2	5 895 230.7	26.2	72.4	
22/01/2023	01:12:26	ARS-10	Still	ARS-10-31	717	547 193.2	5 895 223.4	547 271.2	5 895 230.8	26.3	78.4	
22/01/2023	01:13:44	ARS-10	Still	ARS-10-32	718	547 193.2	5 895 223.4	547 279.8	5 895 232.2	26.3	87.0	
22/01/2023	01:14:55	ARS-10	Still	ARS-10-33	719	547 193.2	5 895 223.4	547 285.6	5 895 232.7	26.3	92.8	
22/01/2023	01:16:12	ARS-10	Still	ARS-10-34	720	547 193.2	5 895 223.4	547 292.8	5 895 234.1	26.3	100.1	
22/01/2023	01:17:07	ARS-10	Still	ARS-10-35	721	547 193.2	5 895 223.4	547 298.3	5 895 234.7	26.5	105.7	
22/01/2023	01:18:15	ARS-10	Video	EOL	No fix	547 193.2	5 895 223.4	547 307.8	5 895 235.1	25.8	115.2	
22/01/2023	01:37:15	ARS-10	DVV	PC, eDNA	722	547 193.2	5 895 223.4	547 193.2	5 895 224.7	26.2	1.3	
22/01/2023	01:52:58	ARS-10	DVV	NS	723	547 193.2	5 895 223.4	547 192.9	5 895 224.8	26.3	1.4	No trigger
22/01/2023	01:59:13	ARS-10	DVV	FA, FB	724	547 193.2	5 895 223.4	547 192.8	5 895 224.7	26.3	1.4	
22/01/2023	02:02:58	ARS-10	DVV	FC	725	547 193.2	5 895 223.4	547 194.2	5 895 224.2	26.4	1.3	
22/01/2023	04:02:27	ARS-09	Video	SOL	No fix	547 602.9	5 915 256.7	547 608.6	5 915 382.3	27.9	125.7	
22/01/2023	04:03:30	ARS-09	Still	No photo	726	547 602.9	5 915 256.7	547 608.0	5 915 374.0	30.3	117.4	
22/01/2023	04:03:59	ARS-09	Still	No photo	727	547 602.9	5 915 256.7	547 608.1	5 915 369.6	30.3	113.0	
22/01/2023		ARS-09	Still	ARS-09-01	No fix	547 602.9	5 915 256.7					
22/01/2023	04:06:21	ARS-09	Still	ARS-09-02	728	547 602.9	5 915 256.7	547 607.3	5 915 355.6	30.3	99.0	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	04:06:47	ARS-09	Still	ARS-09-03	729	547 602.9	5 915 256.7	547 606.7	5 915 351.1	30.3	94.5	
22/01/2023	04:07:13	ARS-09	Still	ARS-09-04	730	547 602.9	5 915 256.7	547 606.6	5 915 347.9	30.3	91.3	
22/01/2023	04:07:43	ARS-09	Still	ARS-09-05	731	547 602.9	5 915 256.7	547 606.4	5 915 345.3	30.3	88.6	
22/01/2023	04:08:08	ARS-09	Still	ARS-09-06	732	547 602.9	5 915 256.7	547 605.9	5 915 341.7	30.3	85.0	
22/01/2023	04:08:56	ARS-09	Still	ARS-09-07	733	547 602.9	5 915 256.7	547 605.7	5 915 337.0	30.3	80.3	
22/01/2023	04:09:26	ARS-09	Still	ARS-09-08	734	547 602.9	5 915 256.7	547 605.7	5 915 333.3	30.3	76.6	
22/01/2023	04:09:45	ARS-09	Still	ARS-09-09	735	547 602.9	5 915 256.7	547 605.8	5 915 331.5	30.3	74.8	
22/01/2023	04:11:16	ARS-09	Still	ARS-09-10	736	547 602.9	5 915 256.7	547 605.8	5 915 322.7	30.3	66.1	Aborted due to no visibility
22/01/2023	04:11:50	ARS-09	Video	EOL	No fix	547 602.9	5 915 256.7	547 605.4	5 915 318.4	29.6	61.8	
22/01/2023	04:38:19	ARS-09a	Video	SOL	No fix	547 602.9	5 915 256.7	547 609.2	5 915 384.7	29.4	128.2	FW lens
22/01/2023	04:40:08	ARS-09a	Still	ARS-09a_01	737	547 602.9	5 915 256.7	547 609.6	5 915 378.8	30.4	122.2	
22/01/2023	04:41:01	ARS-09a	Still	ARS-09a_02	738	547 602.9	5 915 256.7	547 609.6	5 915 373.1	30.4	116.6	
22/01/2023	04:41:42	ARS-09a	Still	ARS-09a_03	739	547 602.9	5 915 256.7	547 609.3	5 915 367.5	30.4	111.0	
22/01/2023	04:42:34	ARS-09a	Still	ARS-09a_04	740	547 602.9	5 915 256.7	547 608.9	5 915 361.8	30.5	105.3	
22/01/2023	04:43:55	ARS-09a	Still	ARS-09a_05	741	547 602.9	5 915 256.7	547 608.4	5 915 351.9	30.4	95.4	
22/01/2023	04:44:50	ARS-09a	Still	ARS-09a_06	742	547 602.9	5 915 256.7	547 608.2	5 915 345.1	30.5	88.5	
22/01/2023	04:45:42	ARS-09a	Still	ARS-09a_07	743	547 602.9	5 915 256.7	547 607.8	5 915 337.3	30.4	80.7	
22/01/2023	04:46:58	ARS-09a	Still	ARS-09a_08	744	547 602.9	5 915 256.7	547 607.3	5 915 325.8	30.5	69.2	
22/01/2023	04:47:46	ARS-09a	Still	ARS-09a_09	745	547 602.9	5 915 256.7	547 607.2	5 915 319.4	30.5	62.8	
22/01/2023	04:49:29	ARS-09a	Still	ARS-09a_10	746	547 602.9	5 915 256.7	547 606.4	5 915 307.2	30.5	50.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	04:50:10	ARS-09a	Still	ARS-09a_11	747	547 602.9	5 915 256.7	547 606.5	5 915 300.6	30.4	44.0	
22/01/2023	04:50:48	ARS-09a	Still	ARS-09a_12	748	547 602.9	5 915 256.7	547 606.3	5 915 294.7	30.5	38.2	
22/01/2023	04:51:04	ARS-09a	Still	ARS-09a_13	749	547 602.9	5 915 256.7	547 606.3	5 915 293.2	30.5	36.6	
22/01/2023	04:51:35	ARS-09a	Still	ARS-09a_14	750	547 602.9	5 915 256.7	547 606.4	5 915 289.4	30.5	32.8	
22/01/2023	04:52:04	ARS-09a	Still	ARS-09a_15	751	547 602.9	5 915 256.7	547 606.3	5 915 287.9	30.5	31.4	
22/01/2023	04:52:56	ARS-09a	Still	ARS-09a_16	752	547 602.9	5 915 256.7	547 605.7	5 915 283.2	30.5	26.7	
22/01/2023	04:54:12	ARS-09a	Still	ARS-09a_17	753	547 602.9	5 915 256.7	547 605.9	5 915 273.9	30.5	17.4	
22/01/2023	04:54:55	ARS-09a	Still	ARS-09a_18	754	547 602.9	5 915 256.7	547 605.7	5 915 269.0	30.5	12.6	
22/01/2023	04:55:59	ARS-09a	Still	ARS-09a_19	755	547 602.9	5 915 256.7	547 605.3	5 915 261.3	30.5	5.2	
22/01/2023	04:57:42	ARS-09a	Still	ARS-09a_20	756	547 602.9	5 915 256.7	547 604.7	5 915 246.8	30.5	10.0	
22/01/2023	04:58:41	ARS-09a	Still	ARS-09a_21	757	547 602.9	5 915 256.7	547 604.7	5 915 237.6	30.5	19.2	
22/01/2023	04:59:15	ARS-09a	Still	ARS-09a_22	758	547 602.9	5 915 256.7	547 604.6	5 915 232.7	30.6	24.1	
22/01/2023	04:59:53	ARS-09a	Still	ARS-09a_23	759	547 602.9	5 915 256.7	547 604.5	5 915 226.8	30.5	30.0	
22/01/2023	05:00:36	ARS-09a	Still	ARS-09a_24	760	547 602.9	5 915 256.7	547 604.1	5 915 221.1	30.5	35.6	
22/01/2023	05:01:57	ARS-09a	Still	ARS-09a_25	761	547 602.9	5 915 256.7	547 603.8	5 915 208.8	30.5	47.9	
22/01/2023	05:03:12	ARS-09a	Still	ARS-09a_26	762	547 602.9	5 915 256.7	547 603.1	5 915 199.2	30.5	57.5	
22/01/2023	05:04:05	ARS-09a	Still	ARS-09a_27	763	547 602.9	5 915 256.7	547 603.0	5 915 191.6	30.5	65.1	
22/01/2023	05:05:08	ARS-09a	Still	ARS-09a_28	764	547 602.9	5 915 256.7	547 602.6	5 915 183.1	30.5	73.6	
22/01/2023	05:06:06	ARS-09a	Still	ARS-09a_29	765	547 602.9	5 915 256.7	547 602.2	5 915 175.6	30.5	81.1	
22/01/2023	05:07:32	ARS-09a	Still	ARS-09a_30	766	547 602.9	5 915 256.7	547 601.5	5 915 162.5	30.5	94.2	
22/01/2023	05:09:42	ARS-09a	Video	EOL	No fix	547 602.9	5 915 256.7	547 600.9	5 915 140.7	29.8	116.0	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	05:29:00	ARS-09	DVV	FA/FB	767	547 602.9	5 915 256.7	547 604.1	5 915 259.9	30.6	3.4	
22/01/2023	05:37:15	ARS-09	DVV	PC/FC	768	547 602.9	5 915 256.7	547 604.6	5 915 259.4	30.6	3.1	
22/01/2023	05:57:23	ARS-09	DVV	eDNA	769	547 602.9	5 915 256.7	547 605.1	5 915 259.4	30.7	3.5	
22/01/2023	07:24:18	ARS-06	Video	SOL	No fix	553 144.2	5 926 904.6	553 231.4	5 926 816.5	30.7	124.0	
22/01/2023	07:25:17	ARS-06	Still	ARS-06_01	770	553 144.2	5 926 904.6	553 223.7	5 926 824.5	31.2	112.9	
22/01/2023	07:25:33	ARS-06	Still	ARS-06_02	771	553 144.2	5 926 904.6	553 222.8	5 926 825.3	31.2	111.7	
22/01/2023	07:26:13	ARS-06	Still	ARS-06_03	772	553 144.2	5 926 904.6	553 220.5	5 926 828.5	31.2	107.8	
22/01/2023	07:27:26	ARS-06	Still	ARS-06_04	773	553 144.2	5 926 904.6	553 211.3	5 926 837.6	31.2	94.8	
22/01/2023	07:28:12	ARS-06	Still	ARS-06_05	774	553 144.2	5 926 904.6	553 206.4	5 926 843.3	31.2	87.3	
22/01/2023	07:28:50	ARS-06	Still	ARS-06_06	775	553 144.2	5 926 904.6	553 203.1	5 926 846.4	31.2	82.8	
22/01/2023	07:29:46	ARS-06	Still	ARS-06_07	776	553 144.2	5 926 904.6	553 198.5	5 926 851.4	31.2	76.1	
22/01/2023	07:31:43	ARS-06	Still	ARS-06_08	777	553 144.2	5 926 904.6	553 187.2	5 926 862.5	31.2	60.1	
22/01/2023	07:32:34	ARS-06	Still	ARS-06_09	778	553 144.2	5 926 904.6	553 180.9	5 926 868.9	31.2	51.2	
22/01/2023	07:33:20	ARS-06	Still	ARS-06_10	779	553 144.2	5 926 904.6	553 175.3	5 926 874.5	31.2	43.3	
22/01/2023	07:34:32	ARS-06	Still	ARS-06_11	780	553 144.2	5 926 904.6	553 166.2	5 926 884.0	31.2	30.2	
22/01/2023	07:35:27	ARS-06	Still	ARS-06_12	781	553 144.2	5 926 904.6	553 159.2	5 926 890.2	31.2	20.8	
22/01/2023	07:36:16	ARS-06	Still	ARS-06_13	782	553 144.2	5 926 904.6	553 153.4	5 926 896.1	31.2	12.5	
22/01/2023	07:37:13	ARS-06	Still	ARS-06_14	783	553 144.2	5 926 904.6	553 146.5	5 926 903.9	31.2	2.4	
22/01/2023	07:37:41	ARS-06	Still	No photo	784	553 144.2	5 926 904.6	553 143.3	5 926 907.8	31.2	3.4	
22/01/2023	07:38:30	ARS-06	Still	No photo	785	553 144.2	5 926 904.6	553 136.9	5 926 913.7	31.2	11.7	
22/01/2023	07:39:18	ARS-06	Still	ARS-06_15	786	553 144.2	5 926 904.6	553 131.3	5 926 919.3	31.2	19.6	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	07:41:07	ARS-06	Still	ARS-06_16	787	553 144.2	5 926 904.6	553 119.0	5 926 931.8	31.2	37.1	
22/01/2023	07:42:14	ARS-06	Still	ARS-06_17	788	553 144.2	5 926 904.6	553 111.0	5 926 939.6	31.2	48.3	
22/01/2023	07:42:45	ARS-06	Still	ARS-06_18	789	553 144.2	5 926 904.6	553 107.5	5 926 943.2	31.3	53.3	
22/01/2023	07:43:35	ARS-06	Still	ARS-06_19	790	553 144.2	5 926 904.6	553 101.3	5 926 949.4	31.2	62.1	
22/01/2023	07:44:32	ARS-06	Still	ARS-06_20	791	553 144.2	5 926 904.6	553 093.7	5 926 957.7	31.3	73.3	
22/01/2023	07:45:00	ARS-06	Still	ARS-06_21	792	553 144.2	5 926 904.6	553 089.5	5 926 961.5	31.2	79.0	
22/01/2023	07:45:28	ARS-06	Still	ARS-06_22	793	553 144.2	5 926 904.6	553 086.1	5 926 965.3	31.2	84.0	
22/01/2023	07:46:19	ARS-06	Still	ARS-06_23	794	553 144.2	5 926 904.6	553 080.8	5 926 969.6	31.2	90.8	
22/01/2023	07:47:37	ARS-06	Still	ARS-06_24	795	553 144.2	5 926 904.6	553 073.6	5 926 976.5	31.2	100.8	
22/01/2023	07:48:50	ARS-06	Video	EOL	No fix	553 144.2	5 926 904.6	553 063.0	5 926 987.1	30.1	115.8	
22/01/2023	08:00:24	ARS-06	DVV	PC, eDNA	796	553 144.2	5 926 904.6	553 143.2	5 926 901.9	31.1	2.9	
22/01/2023	08:33:31	ARS-06	DVV	FA, FB	797	553 144.2	5 926 904.6	553 145.6	5 926 902.0	30.9	2.9	
22/01/2023	08:44:13	ARS-06	DVV	FC	798	553 144.2	5 926 904.6	553 143.6	5 926 904.7	30.8	0.7	
22/01/2023	12:07:59	ARS-08	Video	SOL	No fix	578 591.9	5 919 165.5	578 492.2	5 919 093.8	25.3	122.8	
22/01/2023	12:10:03	ARS-08	Still	ARS-08_01	799	578 591.9	5 919 165.5	578 500.9	5 919 101.3	26.1	111.4	
22/01/2023	12:10:52	ARS-08	Still	ARS-08_02	800	578 591.9	5 919 165.5	578 506.3	5 919 104.9	26.1	104.9	
22/01/2023	12:10:54	ARS-08	Still	ARS-08_03	801	578 591.9	5 919 165.5	578 506.4	5 919 104.9	26.1	104.8	
22/01/2023	12:11:31	ARS-08	Still	ARS-08_04	802	578 591.9	5 919 165.5	578 509.4	5 919 106.7	26.1	101.3	
22/01/2023	12:11:54	ARS-08	Still	ARS-08_05	803	578 591.9	5 919 165.5	578 511.3	5 919 107.5	26.1	99.3	
22/01/2023	12:13:03	ARS-08	Still	ARS-08_06	804	578 591.9	5 919 165.5	578 517.9	5 919 111.1	26.1	91.9	
22/01/2023	12:14:10	ARS-08	Still	ARS-08_07	805	578 591.9	5 919 165.5	578 522.9	5 919 115.7	26.0	85.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	12:15:06	ARS-08	Still	ARS-08_08	806	578 591.9	5 919 165.5	578 527.0	5 919 119.5	26.1	79.5	
22/01/2023	12:16:04	ARS-08	Still	ARS-08_09	807	578 591.9	5 919 165.5	578 533.9	5 919 123.8	26.0	71.5	
22/01/2023	12:17:49	ARS-08	Still	ARS-08_10	808	578 591.9	5 919 165.5	578 543.9	5 919 131.1	26.0	59.1	
22/01/2023	12:18:16	ARS-08	Still	ARS-08_11	809	578 591.9	5 919 165.5	578 546.3	5 919 132.6	26.1	56.2	
22/01/2023	12:19:04	ARS-08	Still	ARS-08_12	810	578 591.9	5 919 165.5	578 550.9	5 919 136.3	26.1	50.4	
22/01/2023	12:20:21	ARS-08	Still	ARS-08_13	811	578 591.9	5 919 165.5	578 557.7	5 919 141.8	26.0	41.6	
22/01/2023	12:20:41	ARS-08	Still	ARS-08_14	812	578 591.9	5 919 165.5	578 559.7	5 919 143.5	26.0	39.0	
22/01/2023	12:21:24	ARS-08	Still	ARS-08_15	813	578 591.9	5 919 165.5	578 562.9	5 919 146.7	26.0	34.5	
22/01/2023	12:22:36	ARS-08	Still	ARS-08_16	814	578 591.9	5 919 165.5	578 570.1	5 919 151.6	26.0	25.9	
22/01/2023	12:23:24	ARS-08	Still	ARS-08_17	815	578 591.9	5 919 165.5	578 574.9	5 919 155.1	26.0	19.9	
22/01/2023	12:23:38	ARS-08	Still	ARS-08_18	816	578 591.9	5 919 165.5	578 576.3	5 919 155.7	26.0	18.5	
22/01/2023	12:24:09	ARS-08	Still	ARS-08_19	817	578 591.9	5 919 165.5	578 578.8	5 919 156.9	26.0	15.7	
22/01/2023	12:25:50	ARS-08	Still	ARS-08_20	818	578 591.9	5 919 165.5	578 588.8	5 919 164.0	26.0	3.4	
22/01/2023	12:26:16	ARS-08	Still	ARS-08_21	819	578 591.9	5 919 165.5	578 591.3	5 919 165.7	26.0	0.6	
22/01/2023	12:27:00	ARS-08	Still	ARS-08_22	820	578 591.9	5 919 165.5	578 595.7	5 919 168.9	26.0	5.1	
22/01/2023	12:27:22	ARS-08	Still	ARS-08_23	821	578 591.9	5 919 165.5	578 598.6	5 919 170.9	26.0	8.6	
22/01/2023	12:27:50	ARS-08	Still	ARS-08_24	822	578 591.9	5 919 165.5	578 601.9	5 919 172.5	26.0	12.2	
22/01/2023	12:28:26	ARS-08	Still	ARS-08_25	823	578 591.9	5 919 165.5	578 606.1	5 919 176.1	26.0	17.7	
22/01/2023	12:28:47	ARS-08	Still	ARS-08_26	824	578 591.9	5 919 165.5	578 607.9	5 919 177.0	26.0	19.7	
22/01/2023	12:29:34	ARS-08	Still	ARS-08_27	825	578 591.9	5 919 165.5	578 613.4	5 919 180.1	26.0	26.0	
22/01/2023	12:30:33	ARS-08	Still	ARS-08_28	826	578 591.9	5 919 165.5	578 619.3	5 919 184.5	26.0	33.3	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	12:31:04	ARS-08	Still	ARS-08_29	827	578 591.9	5 919 165.5	578 622.2	5 919 187.1	26.0	37.2	
22/01/2023	12:31:46	ARS-08	Still	ARS-08_30	828	578 591.9	5 919 165.5	578 626.0	5 919 189.5	26.0	41.7	
22/01/2023	12:32:19	ARS-08	Still	ARS-08_31	829	578 591.9	5 919 165.5	578 629.2	5 919 192.1	26.0	45.8	
22/01/2023	12:32:53	ARS-08	Still	ARS-08_32	830	578 591.9	5 919 165.5	578 632.4	5 919 195.0	25.9	50.1	
22/01/2023	12:33:24	ARS-08	Still	ARS-08_33	831	578 591.9	5 919 165.5	578 635.8	5 919 197.6	26.0	54.4	
22/01/2023	12:33:53	ARS-08	Still	ARS-08_34	832	578 591.9	5 919 165.5	578 638.1	5 919 199.8	25.9	57.5	
22/01/2023	12:34:33	ARS-08	Still	ARS-08_35	833	578 591.9	5 919 165.5	578 640.3	5 919 202.1	26.0	60.7	
22/01/2023	12:34:38	ARS-08	Still	ARS-08_36	834	578 591.9	5 919 165.5	578 640.8	5 919 202.6	26.0	61.4	
22/01/2023	12:35:16	ARS-08	Still	ARS-08_37	835	578 591.9	5 919 165.5	578 643.6	5 919 205.1	25.9	65.1	
22/01/2023	12:35:51	ARS-08	Still	ARS-08_38	836	578 591.9	5 919 165.5	578 647.0	5 919 207.6	26.0	69.3	
22/01/2023	12:36:53	ARS-08	Still	ARS-08_39	837	578 591.9	5 919 165.5	578 654.5	5 919 212.2	26.0	78.1	
22/01/2023	12:37:43	ARS-08	Still	ARS-08_40	838	578 591.9	5 919 165.5	578 659.9	5 919 215.3	26.0	84.3	
22/01/2023	12:37:58	ARS-08	Still	ARS-08_41	839	578 591.9	5 919 165.5	578 661.3	5 919 216.2	26.0	86.0	
22/01/2023	12:38:46	ARS-08	Still	ARS-08_42	840	578 591.9	5 919 165.5	578 665.6	5 919 219.7	25.9	91.5	
22/01/2023	12:39:13	ARS-08	Still	ARS-08_43	841	578 591.9	5 919 165.5	578 667.9	5 919 221.3	26.0	94.3	
22/01/2023	12:40:06	ARS-08	Still	ARS-08_44	842	578 591.9	5 919 165.5	578 672.7	5 919 225.3	26.0	100.5	
22/01/2023	12:40:30	ARS-08	Still	ARS-08_45	843	578 591.9	5 919 165.5	578 675.5	5 919 227.3	25.9	104.0	
22/01/2023	12:40:57	ARS-08	Still	ARS-08_46	844	578 591.9	5 919 165.5	578 678.2	5 919 229.7	25.9	107.5	
22/01/2023	12:41:15	ARS-08	Still	ARS-08_47	845	578 591.9	5 919 165.5	578 679.3	5 919 230.8	26.0	109.1	
22/01/2023	12:41:42	ARS-08	Video	EOL	No fix	578 591.9	5 919 165.5	578 680.4	5 919 232.7	25.1	111.1	
22/01/2023	12:56:27	ARS-08	DVV	FB, FC	846	578 591.9	5 919 165.5	578 590.7	5 919 165.7	25.9	1.2	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	13:04:25	ARS-08	DVV	FA, NS	847	578 591.9	5 919 165.5	578 591.5	5 919 164.8	25.9	0.8	
22/01/2023	13:16:00	ARS-08	DVV	PC, eDNA	848	578 591.9	5 919 165.5	578 591.8	5 919 165.5	25.9	0.1	
22/01/2023	15:11:47	ARS-07	Video	SOL	No fix	563 527.3	5 922 148.7	563 407.1	5 922 168.3	25.9	121.8	
22/01/2023	15:13:09	ARS-07	Still	ARS-07_01	849	563 527.3	5 922 148.7	563 414.6	5 922 166.1	26.7	114.1	
22/01/2023	15:13:46	ARS-07	Still	ARS-07_02	850	563 527.3	5 922 148.7	563 423.4	5 922 165.9	26.7	105.3	
22/01/2023	15:13:59	ARS-07	Still	ARS-07_03	851	563 527.3	5 922 148.7	563 426.1	5 922 165.7	26.7	102.7	
22/01/2023	15:14:27	ARS-07	Still	ARS-07_04	852	563 527.3	5 922 148.7	563 429.5	5 922 165.0	26.7	99.1	
22/01/2023	15:14:59	ARS-07	Still	ARS-07_05	853	563 527.3	5 922 148.7	563 433.0	5 922 163.8	26.7	95.5	
22/01/2023	15:15:58	ARS-07	Still	ARS-07_06	854	563 527.3	5 922 148.7	563 442.4	5 922 161.7	26.7	85.9	
22/01/2023	15:16:56	ARS-07	Still	ARS-07_07	855	563 527.3	5 922 148.7	563 453.0	5 922 160.1	26.7	75.2	
22/01/2023	15:17:38	ARS-07	Still	ARS-07_08	856	563 527.3	5 922 148.7	563 459.2	5 922 159.1	26.8	68.9	
22/01/2023	15:17:48	ARS-07	Still	ARS-07_09	857	563 527.3	5 922 148.7	563 460.3	5 922 159.0	26.8	67.7	
22/01/2023	15:18:33	ARS-07	Still	ARS-07_10	858	563 527.3	5 922 148.7	563 466.4	5 922 157.8	26.7	61.6	
22/01/2023	15:19:05	ARS-07	Still	ARS-07_11	859	563 527.3	5 922 148.7	563 469.7	5 922 157.6	26.8	58.3	
22/01/2023	15:19:28	ARS-07	Still	ARS-07_12	860	563 527.3	5 922 148.7	563 473.1	5 922 157.0	26.8	54.8	
22/01/2023	15:20:13	ARS-07	Still	ARS-07_13	861	563 527.3	5 922 148.7	563 480.0	5 922 155.8	26.8	47.8	
22/01/2023	15:20:45	ARS-07	Still	ARS-07_14	862	563 527.3	5 922 148.7	563 484.9	5 922 155.0	26.8	42.8	
22/01/2023	15:21:24	ARS-07	Still	ARS-07_15	863	563 527.3	5 922 148.7	563 491.1	5 922 153.7	26.8	36.6	
22/01/2023	15:22:06	ARS-07	Still	ARS-07_16	864	563 527.3	5 922 148.7	563 497.2	5 922 153.3	26.8	30.5	
22/01/2023	15:22:23	ARS-07	Still	ARS-07_17	865	563 527.3	5 922 148.7	563 500.1	5 922 152.8	26.8	27.5	
22/01/2023	15:22:43	ARS-07	Still	ARS-07_18	866	563 527.3	5 922 148.7	563 503.3	5 922 152.4	26.8	24.3	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	15:22:59	ARS-07	Still	ARS-07_19	867	563 527.3	5 922 148.7	563 506.3	5 922 152.4	26.8	21.3	
22/01/2023	15:23:35	ARS-07	Still	ARS-07_20	868	563 527.3	5 922 148.7	563 512.5	5 922 150.9	26.8	15.0	
22/01/2023	15:24:09	ARS-07	Still	ARS-07_21	869	563 527.3	5 922 148.7	563 518.6	5 922 150.2	26.8	8.9	
22/01/2023	15:24:25	ARS-07	Still	ARS-07_22	870	563 527.3	5 922 148.7	563 521.4	5 922 149.1	26.8	5.9	
22/01/2023	15:26:03	ARS-07	Still	ARS-07_23	871	563 527.3	5 922 148.7	563 538.1	5 922 146.2	26.8	11.1	
22/01/2023	15:26:43	ARS-07	Still	ARS-07_24	872	563 527.3	5 922 148.7	563 543.5	5 922 146.7	26.8	16.4	
22/01/2023	15:27:33	ARS-07	Still	ARS-07_25	873	563 527.3	5 922 148.7	563 551.1	5 922 144.6	26.8	24.1	
22/01/2023	15:28:27	ARS-07	Still	No photo	874	563 527.3	5 922 148.7	563 559.5	5 922 143.3	26.8	32.6	
22/01/2023	15:29:18	ARS-07	Still	ARS-07_26	875	563 527.3	5 922 148.7	563 568.6	5 922 141.8	26.8	41.8	
22/01/2023		ARS-07	Still	ARS-07_27	No fix	563 527.3	5 922 148.7					
22/01/2023		ARS-07	Still	ARS-07_28	No fix	563 527.3	5 922 148.7					
22/01/2023	15:30:39	ARS-07	Still	ARS-07_29	876	563 527.3	5 922 148.7	563 583.1	5 922 139.7	26.9	56.5	
22/01/2023		ARS-07	Still	ARS-07_30	No fix	563 527.3	5 922 148.7					
22/01/2023	15:31:19	ARS-07	Still	ARS-07_31	877	563 527.3	5 922 148.7	563 588.7	5 922 138.8	26.9	62.2	
22/01/2023	15:32:27	ARS-07	Still	No photo	878	563 527.3	5 922 148.7	563 597.7	5 922 137.0	26.9	71.3	
22/01/2023	15:32:49	ARS-07	Still	No photo	879	563 527.3	5 922 148.7	563 602.4	5 922 136.4	26.9	76.1	
22/01/2023	15:33:22	ARS-07	Still	ARS-07_32	880	563 527.3	5 922 148.7	563 609.5	5 922 134.7	26.9	83.4	
22/01/2023	15:33:52	ARS-07	Still	ARS-07_33	881	563 527.3	5 922 148.7	563 615.3	5 922 134.0	26.9	89.2	
22/01/2023	15:34:21	ARS-07	Still	No photo	882	563 527.3	5 922 148.7	563 621.8	5 922 133.1	26.9	95.7	
22/01/2023	15:34:52	ARS-07	Still	ARS-07_34	883	563 527.3	5 922 148.7	563 626.6	5 922 131.4	26.9	100.8	
22/01/2023	15:35:17	ARS-07	Still	ARS-07_35	884	563 527.3	5 922 148.7	563 630.9	5 922 131.6	26.9	105.0	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	15:35:37	ARS-07	Still	ARS-07_36	885	563 527.3	5 922 148.7	563 635.7	5 922 130.7	27.0	109.9	
22/01/2023	15:35:45	ARS-07	Video	EOL	No fix	563 527.3	5 922 148.7	563 637.2	5 922 130.0	26.2	111.4	
22/01/2023	16:00:41	ARS-07	DVV	FC, NS	886	563 527.3	5 922 148.7	563 526.3	5 922 150.9	27.1	2.4	
22/01/2023	18:07:07	ARS-07	DVV	FA, NS	887	563 527.3	5 922 148.7	563 529.6	5 922 147.2	27.5	2.7	
22/01/2023	18:15:04	ARS-07	DVV	NS	888	563 527.3	5 922 148.7	563 528.8	5 922 147.3	27.5	2.1	
22/01/2023	18:21:41	ARS-07	DVV	NS	889	563 527.3	5 922 148.7	563 529.1	5 922 147.6	27.6	2.1	
22/01/2023	18:32:23	ARS-07	DVV	FB, NS	890	563 527.3	5 922 148.7	563 523.9	5 922 150.5	27.6	3.8	
22/01/2023	18:40:42	ARS-07	DVV	eDNA, NS	891	563 527.3	5 922 148.7	563 523.6	5 922 150.2	27.6	4.0	
22/01/2023	18:54:05	ARS-07	DVV	PC	892	563 527.3	5 922 148.7	563 523.4	5 922 150.1	27.7	4.1	
22/01/2023	20:12:04	ARS-04	Video	SOL	No fix	560 107.8	5 931 027.3	560 169.8	5 930 922.3	31.4	121.9	
22/01/2023	20:12:22	ARS-04	Still	No still	893	560 107.8	5 931 027.3	560 170.0	5 930 922.3	31.5	122.1	
22/01/2023	20:12:35	ARS-04	Still	ARS-04_01	894	560 107.8	5 931 027.3	560 170.1	5 930 922.3	31.5	122.1	
22/01/2023	20:13:19	ARS-04	Still	ARS-04_02	895	560 107.8	5 931 027.3	560 169.1	5 930 924.2	31.3	119.9	
22/01/2023	20:13:54	ARS-04	Still	ARS-04_03	896	560 107.8	5 931 027.3	560 166.8	5 930 928.8	31.4	114.8	
22/01/2023	20:14:06	ARS-04	Still	ARS-04_04	897	560 107.8	5 931 027.3	560 166.1	5 930 930.3	31.6	113.2	
22/01/2023	20:14:28	ARS-04	Still	ARS-04_05	898	560 107.8	5 931 027.3	560 163.6	5 930 934.2	31.6	108.6	
22/01/2023	20:14:32	ARS-04	Still	ARS-04_06	899	560 107.8	5 931 027.3	560 163.4	5 930 934.6	31.2	108.1	
22/01/2023	20:15:04	ARS-04	Still	ARS-04_07	900	560 107.8	5 931 027.3	560 159.4	5 930 942.4	31.3	99.4	
22/01/2023	20:15:48	ARS-04	Still	ARS-04_08	901	560 107.8	5 931 027.3	560 155.4	5 930 948.7	31.4	91.9	
22/01/2023	20:16:23	ARS-04	Still	ARS-04_09	902	560 107.8	5 931 027.3	560 153.1	5 930 951.6	31.4	88.2	
22/01/2023	20:17:54	ARS-04	Still	ARS-04_10	903	560 107.8	5 931 027.3	560 148.0	5 930 960.3	31.6	78.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	20:18:45	ARS-04	Still	ARS-04_11	904	560 107.8	5 931 027.3	560 144.2	5 930 966.7	31.4	70.8	
22/01/2023	20:19:29	ARS-04	Still	ARS-04_12	905	560 107.8	5 931 027.3	560 141.7	5 930 971.2	31.5	65.5	
22/01/2023	20:20:06	ARS-04	Still	ARS-04_13	906	560 107.8	5 931 027.3	560 139.3	5 930 974.5	31.4	61.5	
22/01/2023	20:20:17	ARS-04	Still	ARS-04_14	907	560 107.8	5 931 027.3	560 138.5	5 930 975.4	31.8	60.4	
22/01/2023	20:20:45	ARS-04	Still	ARS-04_15	908	560 107.8	5 931 027.3	560 137.4	5 930 977.4	31.5	58.0	
22/01/2023	20:21:39	ARS-04	Still	ARS-04_16	909	560 107.8	5 931 027.3	560 134.4	5 930 981.3	31.6	53.1	
22/01/2023	20:22:18	ARS-04	Still	ARS-04_17	910	560 107.8	5 931 027.3	560 133.2	5 930 983.9	31.2	50.3	
22/01/2023	20:23:06	ARS-04	Still	ARS-04_18	911	560 107.8	5 931 027.3	560 131.1	5 930 986.6	31.2	46.9	
22/01/2023	20:23:40	ARS-04	Still	ARS-04_19	912	560 107.8	5 931 027.3	560 130.5	5 930 988.2	31.4	45.2	
22/01/2023	20:26:46	ARS-04	Still	ARS-04_20	913	560 107.8	5 931 027.3	560 127.6	5 930 993.2	31.5	39.5	
22/01/2023	20:27:55	ARS-04	Still	ARS-04_21	914	560 107.8	5 931 027.3	560 123.5	5 931 001.2	31.2	30.5	
22/01/2023	20:28:50	ARS-04	Still	ARS-04_22	915	560 107.8	5 931 027.3	560 118.7	5 931 009.0	31.5	21.3	
22/01/2023	20:29:28	ARS-04	Still	ARS-04_23	916	560 107.8	5 931 027.3	560 116.2	5 931 013.4	31.6	16.3	
22/01/2023	20:30:20	ARS-04	Still	ARS-04_24	917	560 107.8	5 931 027.3	560 112.1	5 931 019.4	31.6	9.0	
22/01/2023	20:30:33	ARS-04	Still	ARS-04_25	918	560 107.8	5 931 027.3	560 111.5	5 931 020.2	31.2	8.0	
22/01/2023	20:31:25	ARS-04	Still	ARS-04_26	919	560 107.8	5 931 027.3	560 108.4	5 931 025.1	31.3	2.3	
22/01/2023	20:31:39	ARS-04	Still	ARS-04_27	920	560 107.8	5 931 027.3	560 107.7	5 931 026.4	31.8	0.9	
22/01/2023	20:32:53	ARS-04	Still	ARS-04_28	921	560 107.8	5 931 027.3	560 104.3	5 931 033.1	31.7	6.8	
22/01/2023	20:33:16	ARS-04	Still	ARS-04_29	922	560 107.8	5 931 027.3	560 103.1	5 931 035.2	31.6	9.2	
22/01/2023	20:33:53	ARS-04	Still	ARS-04_30	923	560 107.8	5 931 027.3	560 101.1	5 931 038.4	31.6	12.9	
22/01/2023	20:35:02	ARS-04	Still	ARS-04_31	924	560 107.8	5 931 027.3	560 098.0	5 931 044.4	31.4	19.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	20:35:18	ARS-04	Still	ARS-04_32	925	560 107.8	5 931 027.3	560 097.8	5 931 045.2	31.6	20.5	
22/01/2023	20:36:01	ARS-04	Still	ARS-04_33	926	560 107.8	5 931 027.3	560 095.2	5 931 049.5	31.8	25.5	
22/01/2023	20:37:24	ARS-04	Still	ARS-04_34	927	560 107.8	5 931 027.3	560 090.4	5 931 057.1	31.4	34.5	
22/01/2023	20:38:16	ARS-04	Still	ARS-04_35	928	560 107.8	5 931 027.3	560 087.5	5 931 061.3	31.1	39.5	
22/01/2023	20:39:20	ARS-04	Still	ARS-04_36	929	560 107.8	5 931 027.3	560 085.0	5 931 065.9	31.0	44.8	
22/01/2023	20:40:13	ARS-04	Still	ARS-04_37	930	560 107.8	5 931 027.3	560 082.7	5 931 070.8	31.4	50.2	
22/01/2023	20:40:58	ARS-04	Still	ARS-04_38	931	560 107.8	5 931 027.3	560 080.2	5 931 074.9	31.5	55.0	
22/01/2023	20:41:41	ARS-04	Still	ARS-04_39	932	560 107.8	5 931 027.3	560 076.7	5 931 080.4	31.6	61.5	
22/01/2023	20:42:40	ARS-04	Still	ARS-04_40	933	560 107.8	5 931 027.3	560 073.0	5 931 087.0	31.4	69.1	
22/01/2023	20:43:33	ARS-04	Still	ARS-04_41	934	560 107.8	5 931 027.3	560 068.8	5 931 093.8	31.4	77.1	
22/01/2023	20:44:26	ARS-04	Still	ARS-04_42	935	560 107.8	5 931 027.3	560 065.1	5 931 100.7	31.5	84.9	
22/01/2023	20:44:57	ARS-04	Still	ARS-04_43	936	560 107.8	5 931 027.3	560 062.9	5 931 104.1	31.2	88.9	
22/01/2023	20:45:52	ARS-04	Still	ARS-04_44	937	560 107.8	5 931 027.3	560 057.7	5 931 112.6	31.3	98.9	
22/01/2023	20:46:35	ARS-04	Still	ARS-04_45	938	560 107.8	5 931 027.3	560 054.3	5 931 119.0	31.3	106.1	
22/01/2023	20:47:17	ARS-04	Video	EOL	No fix	560 107.8	5 931 027.3	560 050.0	5 931 125.5	31.4	113.9	
22/01/2023	21:08:41	ARS-04	DVV	PC, eDNA	939	560 107.8	5 931 027.3	560 106.7	5 931 026.4	32.1	1.4	
22/01/2023	21:24:24	ARS-04	DVV	FA, FB	940	560 107.8	5 931 027.3	560 106.9	5 931 026.4	32.0	1.3	
22/01/2023	21:43:51	ARS-04	DVV	FC	941	560 107.8	5 931 027.3	560 107.6	5 931 027.2	31.9	0.2	
22/01/2023	23:44:57	ARS-05	Video	SOL	No fix	570 710.0	5 931 115.0	570 631.5	5 931 004.2	28.7	135.8	
22/01/2023	23:45:39	ARS-05	Still	ARS-05_01	942	570 710.0	5 931 115.0	570 633.1	5 931 006.9	29.4	132.6	
22/01/2023	23:47:52	ARS-05	Still	ARS-05_02	943	570 710.0	5 931 115.0	570 643.3	5 931 022.4	29.4	114.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
22/01/2023	23:49:42	ARS-05	Still	ARS-05_03	944	570 710.0	5 931 115.0	570 652.9	5 931 035.2	29.4	98.2	
22/01/2023	23:50:33	ARS-05	Still	ARS-05_04	945	570 710.0	5 931 115.0	570 656.9	5 931 040.4	29.4	91.6	
22/01/2023	23:51:53	ARS-05	Still	ARS-05_05	946	570 710.0	5 931 115.0	570 662.5	5 931 049.0	29.4	81.3	
22/01/2023	23:53:13	ARS-05	Still	ARS-05_06	947	570 710.0	5 931 115.0	570 668.5	5 931 057.6	29.4	70.8	
22/01/2023	23:53:30	ARS-05	Still	ARS-05_07	948	570 710.0	5 931 115.0	570 669.7	5 931 058.9	29.4	69.1	
22/01/2023	23:54:52	ARS-05	Still	ARS-05_08	949	570 710.0	5 931 115.0	570 676.1	5 931 068.0	29.4	57.9	
22/01/2023	23:56:06	ARS-05	Still	ARS-05_09	950	570 710.0	5 931 115.0	570 682.8	5 931 076.8	29.4	46.9	
22/01/2023	23:56:49	ARS-05	Still	ARS-05_10	951	570 710.0	5 931 115.0	570 685.4	5 931 081.1	29.4	41.9	
22/01/2023	23:57:17	ARS-05	Still	ARS-05_11	952	570 710.0	5 931 115.0	570 687.7	5 931 083.4	29.4	38.7	
22/01/2023	23:58:34	ARS-05	Still	ARS-05_12	953	570 710.0	5 931 115.0	570 691.7	5 931 091.0	29.4	30.2	
22/01/2023	23:59:23	ARS-05	Still	ARS-05_13	954	570 710.0	5 931 115.0	570 695.3	5 931 095.5	29.4	24.4	
23/01/2023	00:00:31	ARS-05	Still	ARS-05_14	955	570 710.0	5 931 115.0	570 701.1	5 931 103.4	29.4	14.6	
23/01/2023	00:01:37	ARS-05	Still	ARS-05_15	956	570 710.0	5 931 115.0	570 705.5	5 931 110.9	29.3	6.1	
23/01/2023	00:02:18	ARS-05	Still	ARS-05_16	957	570 710.0	5 931 115.0	570 709.1	5 931 115.7	29.3	1.1	
23/01/2023	00:02:55	ARS-05	Still	ARS-05_17	958	570 710.0	5 931 115.0	570 710.8	5 931 119.7	29.3	4.8	
23/01/2023	00:03:29	ARS-05	Still	ARS-05_18	959	570 710.0	5 931 115.0	570 713.6	5 931 123.8	29.4	9.5	
23/01/2023	00:04:17	ARS-05	Still	ARS-05_19	960	570 710.0	5 931 115.0	570 717.4	5 931 128.7	29.4	15.6	
23/01/2023	00:06:14	ARS-05	Still	ARS-05_20	961	570 710.0	5 931 115.0	570 724.4	5 931 138.9	29.4	27.9	
23/01/2023	00:06:54	ARS-05	Still	ARS-05_21	962	570 710.0	5 931 115.0	570 727.5	5 931 142.2	29.4	32.3	
23/01/2023	00:07:32	ARS-05	Still	ARS-05_22	963	570 710.0	5 931 115.0	570 730.2	5 931 146.1	29.3	37.1	
23/01/2023	00:08:25	ARS-05	Still	ARS-05_23	964	570 710.0	5 931 115.0	570 733.1	5 931 150.6	29.3	42.4	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	00:10:00	ARS-05	Still	ARS-05_24	965	570 710.0	5 931 115.0	570 739.4	5 931 158.5	29.3	52.5	
23/01/2023	00:10:45	ARS-05	Still	ARS-05_25	966	570 710.0	5 931 115.0	570 742.5	5 931 164.0	29.3	58.8	
23/01/2023	00:12:31	ARS-05	Still	ARS-05_26	967	570 710.0	5 931 115.0	570 752.0	5 931 175.8	29.4	73.9	
23/01/2023	00:14:26	ARS-05	Still	ARS-05_27	968	570 710.0	5 931 115.0	570 762.7	5 931 191.9	29.3	93.2	
23/01/2023	00:16:56	ARS-05	Video	EOL	No fix	570 710.0	5 931 115.0	570 774.8	5 931 207.2	28.6	112.7	
23/01/2023	03:50:29	ARS-05	DVV	PC, FA	969	570 710.0	5 931 115.0	570 709.9	5 931 113.2	29.2	1.8	
23/01/2023	04:13:53	ARS-05	DVV	FB, eDNA	970	570 710.0	5 931 115.0	570 709.6	5 931 115.1	29.1	0.4	
23/01/2023	04:21:37	ARS-05	DVV	FC	971	570 710.0	5 931 115.0	570 709.6	5 931 115.9	29.0	0.9	
23/01/2023	02:58:59	ARS-03	Video	SOL	No fix	572 748.1	5 941 648.9	572 620.1	5 941 660.0	35.4	128.5	
23/01/2023	03:00:19	ARS-03	Still	ARS_03_01	973	572 748.1	5 941 648.9	572 630.6	5 941 659.8	36.4	118.0	
23/01/2023	03:01:30	ARS-03	Still	ARS_03_02	974	572 748.1	5 941 648.9	572 640.4	5 941 660.3	36.4	108.3	
23/01/2023	03:02:35	ARS-03	Still	ARS_03_03	975	572 748.1	5 941 648.9	572 647.7	5 941 660.8	36.4	101.1	
23/01/2023	03:03:23	ARS-03	Still	ARS_03_04	976	572 748.1	5 941 648.9	572 653.3	5 941 660.0	36.4	95.4	
23/01/2023	03:05:38	ARS-03	Still	ARS_03_05	977	572 748.1	5 941 648.9	572 670.2	5 941 656.4	36.4	78.3	
23/01/2023	03:05:49	ARS-03	Still	ARS_03_06	978	572 748.1	5 941 648.9	572 671.3	5 941 655.7	36.4	77.1	
23/01/2023	03:06:45	ARS-03	Still	ARS_03_07	979	572 748.1	5 941 648.9	572 679.1	5 941 654.2	36.4	69.3	
23/01/2023	03:06:58	ARS-03	Still	ARS_03_08	980	572 748.1	5 941 648.9	572 680.9	5 941 654.0	36.4	67.4	
23/01/2023	03:07:24	ARS-03	Still	ARS_03_09	981	572 748.1	5 941 648.9	572 684.3	5 941 653.9	36.4	64.0	
23/01/2023	03:08:41	ARS-03	Still	ARS_03_10	982	572 748.1	5 941 648.9	572 693.8	5 941 653.0	36.4	54.4	
23/01/2023	03:08:55	ARS-03	Still	ARS_03_11	983	572 748.1	5 941 648.9	572 696.2	5 941 652.7	36.4	52.0	
23/01/2023	03:09:31	ARS-03	Still	ARS_03_12	984	572 748.1	5 941 648.9	572 701.5	5 941 652.3	36.4	46.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	03:11:26	ARS-03	Still	ARS_03_13	985	572 748.1	5 941 648.9	572 715.4	5 941 650.8	36.4	32.7	
23/01/2023	03:11:46	ARS-03	Still	ARS_03_14	986	572 748.1	5 941 648.9	572 717.6	5 941 650.7	36.5	30.6	
23/01/2023	03:13:08	ARS-03	Still	ARS_03_15	987	572 748.1	5 941 648.9	572 727.5	5 941 649.8	36.5	20.6	
23/01/2023	03:13:35	ARS-03	Still	ARS_03_16	988	572 748.1	5 941 648.9	572 730.7	5 941 649.5	36.4	17.4	
23/01/2023	03:14:05	ARS-03	Still	ARS_03_17	989	572 748.1	5 941 648.9	572 734.1	5 941 649.3	36.5	14.0	
23/01/2023	03:16:22	ARS-03	Still	ARS_03_18	990	572 748.1	5 941 648.9	572 750.4	5 941 648.1	36.5	2.5	
23/01/2023	03:17:45	ARS-03	Still	ARS_03_19	991	572 748.1	5 941 648.9	572 760.4	5 941 646.5	36.5	12.6	
23/01/2023	03:19:20	ARS-03	Still	ARS_03_20	992	572 748.1	5 941 648.9	572 772.6	5 941 645.6	36.5	24.7	
23/01/2023	03:20:24	ARS-03	Still	ARS_03_21	993	572 748.1	5 941 648.9	572 781.5	5 941 645.2	36.5	33.6	
23/01/2023	03:21:37	ARS-03	Still	ARS_03_22	994	572 748.1	5 941 648.9	572 790.9	5 941 644.1	36.5	43.1	
23/01/2023	03:22:33	ARS-03	Still	ARS_03_23	995	572 748.1	5 941 648.9	572 797.7	5 941 643.6	36.5	49.9	
23/01/2023	03:23:28	ARS-03	Still	ARS_03_24	996	572 748.1	5 941 648.9	572 804.6	5 941 642.9	36.5	56.8	
23/01/2023	03:25:01	ARS-03	Still	ARS_03_25	997	572 748.1	5 941 648.9	572 818.5	5 941 641.6	36.5	70.8	
23/01/2023	03:26:24	ARS-03	Still	ARS_03_26	998	572 748.1	5 941 648.9	572 827.9	5 941 640.7	36.5	80.2	
23/01/2023	03:27:43	ARS-03	Still	ARS_03_27	999	572 748.1	5 941 648.9	572 837.5	5 941 640.2	36.5	89.8	
23/01/2023	03:28:51	ARS-03	Still	ARS_03_28	1000	572 748.1	5 941 648.9	572 845.0	5 941 639.3	36.5	97.4	
23/01/2023	03:29:04	ARS-03	Still	ARS_03_29	1001	572 748.1	5 941 648.9	572 846.2	5 941 639.3	36.5	98.6	
23/01/2023	03:29:10	ARS-03	Still	ARS_03_30	1002	572 748.1	5 941 648.9	572 847.0	5 941 639.1	36.5	99.4	
23/01/2023	03:29:27	ARS-03	Still	ARS_03_31	1003	572 748.1	5 941 648.9	572 849.1	5 941 639.0	36.5	101.5	
23/01/2023	03:30:36	ARS-03	Video	EOL	No fix	572 748.1	5 941 648.9	572 856.8	5 941 638.4	35.5	109.2	
23/01/2023	03:50:29	ARS-03	DVV	PC, eDNA	1004	572 748.1	5 941 648.9	572 748.6	5 941 649.8	36.7	1.1	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	04:13:53	ARS-03	DVV	FA, FB	1005	572 748.1	5 941 648.9	572 749.0	5 941 649.7	36.9	1.2	
23/01/2023	04:21:37	ARS-03	DVV	FC	1006	572 748.1	5 941 648.9	572 749.7	5 941 649.4	36.9	1.6	
23/01/2023	05:33:58	ARS-02	Video	SOL	No fix	564 985.4	5 943 971.1	564 970.8	5 944 089.4	38.2	119.2	
23/01/2023	05:35:03	ARS-02	Still	ARS-02_01	1007	564 985.4	5 943 971.1	564 972.3	5 944 083.7	39.1	113.3	
23/01/2023	05:35:44	ARS-02	Still	ARS-02_02	1008	564 985.4	5 943 971.1	564 973.2	5 944 075.6	39.1	105.2	
23/01/2023	05:36:56	ARS-02	Still	No photo	1009	564 985.4	5 943 971.1	564 974.8	5 944 065.7	39.1	95.2	
23/01/2023	05:38:04	ARS-02	Still	ARS-02_03	1010	564 985.4	5 943 971.1	564 976.9	5 944 053.3	39.1	82.6	
23/01/2023	05:38:57	ARS-02	Still	No photo	1011	564 985.4	5 943 971.1	564 978.0	5 944 047.2	39.1	76.5	
23/01/2023	05:40:48	ARS-02	Still	ARS-02_04	1012	564 985.4	5 943 971.1	564 981.3	5 944 027.6	39.1	56.7	
23/01/2023	05:41:51	ARS-02	Still	ARS-02_05	1013	564 985.4	5 943 971.1	564 981.8	5 944 019.6	39.1	48.6	
23/01/2023	05:42:48	ARS-02	Still	ARS-02_06	1014	564 985.4	5 943 971.1	564 983.2	5 944 011.5	39.1	40.4	
23/01/2023	05:43:37	ARS-02	Still	ARS-02_07	1015	564 985.4	5 943 971.1	564 984.1	5 944 002.6	39.1	31.6	
23/01/2023	05:44:06	ARS-02	Still	No photo	1016	564 985.4	5 943 971.1	564 985.3	5 943 997.4	39.1	26.3	
23/01/2023	05:45:10	ARS-02	Still	ARS-02_08	1017	564 985.4	5 943 971.1	564 987.3	5 943 986.2	39.1	15.2	
23/01/2023	05:45:33	ARS-02	Still	ARS-02_09	1018	564 985.4	5 943 971.1	564 987.6	5 943 981.4	39.1	10.5	
23/01/2023	05:46:18	ARS-02	Still	ARS-02_10	1019	564 985.4	5 943 971.1	564 988.9	5 943 972.8	39.1	3.9	
23/01/2023	05:46:31	ARS-02	Still	No photo	1020	564 985.4	5 943 971.1	564 989.2	5 943 970.1	39.1	3.9	
23/01/2023	05:47:15	ARS-02	Still	ARS-02_11	1021	564 985.4	5 943 971.1	564 989.8	5 943 960.9	39.1	11.1	
23/01/2023	05:48:42	ARS-02	Still	ARS-02_12	1022	564 985.4	5 943 971.1	564 991.7	5 943 944.1	39.1	27.7	
23/01/2023	05:50:05	ARS-02	Still	ARS-02_13	1023	564 985.4	5 943 971.1	564 993.1	5 943 927.3	39.1	44.4	
23/01/2023	05:51:13	ARS-02	Still	ARS-02_14	1024	564 985.4	5 943 971.1	564 995.9	5 943 914.4	39.1	57.7	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	05:51:59	ARS-02	Still	ARS-02_15	1025	564 985.4	5 943 971.1	564 996.8	5 943 905.8	39.1	66.3	
23/01/2023	05:52:26	ARS-02	Still	ARS-02_16	1026	564 985.4	5 943 971.1	564 996.7	5 943 900.3	39.1	71.7	
23/01/2023	05:53:33	ARS-02	Still	ARS-02_17	1027	564 985.4	5 943 971.1	564 998.1	5 943 886.9	39.1	85.1	
23/01/2023	05:54:51	ARS-02	Still	ARS-02_18	1028	564 985.4	5 943 971.1	564 999.2	5 943 877.8	39.1	94.3	
23/01/2023	05:55:23	ARS-02	Still	ARS-02_19	1029	564 985.4	5 943 971.1	564 999.7	5 943 873.4	39.1	98.8	
23/01/2023	05:56:21	ARS-02	Still	ARS-02_20	1030	564 985.4	5 943 971.1	565 001.0	5 943 864.1	39.1	108.1	
23/01/2023	05:56:52	ARS-02	Video	EOL	No fix	564 985.4	5 943 971.1	565 001.8	5 943 858.9	38.1	113.4	
23/01/2023	06:26:07	ARS-02	DVV	PC, eDNA	1031	564 985.4	5 943 971.1	564 986.0	5 943 972.1	39.2	1.2	
23/01/2023	07:02:35	ARS-02	DVV	FA, FB	1032	564 985.4	5 943 971.1	564 987.1	5 943 971.4	39.3	1.7	
23/01/2023	07:25:18	ARS-02	DVV	NS	1033	564 985.4	5 943 971.1	564 987.0	5 943 971.3	39.4	1.6	No trigger
23/01/2023	07:29:41	ARS-02	DVV	FC	1034	564 985.4	5 943 971.1	564 986.5	5 943 971.6	39.4	1.2	
23/01/2023	08:43:00	ARS-01	Video	SOL	No fix	571 894.4	5 951 473.2	571 981.7	5 951 380.1	40.0	127.6	
23/01/2023	08:44:58	ARS-01	Still	No photo	1035	571 894.4	5 951 473.2	571 975.6	5 951 388.8	40.7	117.2	
23/01/2023	08:45:23	ARS-01	Still	ARS-01_01	1036	571 894.4	5 951 473.2	571 972.3	5 951 392.5	40.6	112.2	
23/01/2023	08:46:10	ARS-01	Still	ARS-01_02	1037	571 894.4	5 951 473.2	571 967.9	5 951 397.9	40.6	105.2	
23/01/2023	08:47:28	ARS-01	Still	ARS-01_03	1038	571 894.4	5 951 473.2	571 960.0	5 951 406.0	40.7	93.9	
23/01/2023	08:48:25	ARS-01	Still	ARS-01_04	1039	571 894.4	5 951 473.2	571 954.9	5 951 411.6	40.6	86.3	
23/01/2023	08:48:40	ARS-01	Still	ARS-01_05	1040	571 894.4	5 951 473.2	571 953.5	5 951 413.0	40.7	84.4	
23/01/2023	08:49:51	ARS-01	Still	ARS-01_06	1041	571 894.4	5 951 473.2	571 946.2	5 951 421.3	40.6	73.3	
23/01/2023	08:50:45	ARS-01	Still	ARS-01_07	1042	571 894.4	5 951 473.2	571 939.3	5 951 428.8	40.6	63.1	
23/01/2023	08:51:07	ARS-01	Still	ARS-01_08	1043	571 894.4	5 951 473.2	571 936.2	5 951 432.2	40.6	58.5	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	08:51:30	ARS-01	Still	ARS-01_09	1044	571 894.4	5 951 473.2	571 933.9	5 951 434.9	40.6	55.0	
23/01/2023	08:52:24	ARS-01	Still	ARS-01_10	1045	571 894.4	5 951 473.2	571 930.0	5 951 438.9	40.6	49.4	
23/01/2023	08:53:49	ARS-01	Still	ARS-01_11	1046	571 894.4	5 951 473.2	571 920.3	5 951 448.8	40.6	35.5	
23/01/2023	08:54:06	ARS-01	Still	ARS-01_12	1047	571 894.4	5 951 473.2	571 919.2	5 951 450.1	40.6	33.9	
23/01/2023	08:55:36	ARS-01	Still	ARS-01_13	1048	571 894.4	5 951 473.2	571 909.5	5 951 459.3	40.6	20.5	
23/01/2023	08:56:13	ARS-01	Still	ARS-01_14	1049	571 894.4	5 951 473.2	571 906.3	5 951 463.1	40.6	15.6	
23/01/2023	08:56:42	ARS-01	Still	ARS-01_15	1050	571 894.4	5 951 473.2	571 903.4	5 951 465.6	40.6	11.8	
23/01/2023	08:57:19	ARS-01	Still	ARS-01_16	1051	571 894.4	5 951 473.2	571 899.7	5 951 469.1	40.6	6.7	
23/01/2023	08:57:50	ARS-01	Still	ARS-01_17	1052	571 894.4	5 951 473.2	571 896.9	5 951 471.6	40.6	2.9	
23/01/2023	08:58:41	ARS-01	Still	ARS-01_18	1053	571 894.4	5 951 473.2	571 893.7	5 951 475.0	40.6	1.9	
23/01/2023	08:59:28	ARS-01	Still	ARS-01_19	1054	571 894.4	5 951 473.2	571 888.1	5 951 480.6	40.6	9.7	
23/01/2023	09:00:30	ARS-01	Still	ARS-01_20	1055	571 894.4	5 951 473.2	571 880.1	5 951 489.5	40.6	21.6	
23/01/2023	09:02:27	ARS-01	Still	ARS-01_21	1056	571 894.4	5 951 473.2	571 870.4	5 951 499.9	40.6	35.9	
23/01/2023	09:03:03	ARS-01	Still	ARS-01_22	1057	571 894.4	5 951 473.2	571 867.2	5 951 503.8	40.6	41.0	
23/01/2023	09:03:44	ARS-01	Still	ARS-01_23	1058	571 894.4	5 951 473.2	571 862.5	5 951 509.1	40.6	48.0	
23/01/2023	09:04:38	ARS-01	Still	ARS-01_24	1059	571 894.4	5 951 473.2	571 856.0	5 951 516.5	40.6	57.9	
23/01/2023	09:05:24	ARS-01	Still	ARS-01_25	1060	571 894.4	5 951 473.2	571 853.0	5 951 519.7	40.6	62.3	
23/01/2023	09:07:04	ARS-01	Still	ARS-01_26	1061	571 894.4	5 951 473.2	571 846.8	5 951 526.1	40.5	71.1	
23/01/2023	09:08:08	ARS-01	Still	ARS-01_27	1062	571 894.4	5 951 473.2	571 838.5	5 951 534.0	40.5	82.6	
23/01/2023	09:09:25	ARS-01	Still	ARS-01_28	1063	571 894.4	5 951 473.2	571 833.5	5 951 540.2	40.5	90.5	
23/01/2023	09:10:28	ARS-01	Still	ARS-01_29	1064	571 894.4	5 951 473.2	571 827.5	5 951 546.2	40.5	99.0	

Geodetic Parameters: ETRS89 / UTM zone 31N [ETRF2000-ITRF2014], LAT (NL) [NLLAT2018]												
Date	Time [UTC]	Transect / Station	Type	Sample Rep / Still No.	Fix No.	Proposed Location		Actual Location		Water Depth [m BSL]	Offset [m]	Notes
						Easting	Northing	Easting	Northing			
23/01/2023	09:11:43	ARS-01	Video	EOL	No fix	571 894.4	5 951 473.2	571 818.9	5 951 555.2	39.7	111.5	
23/01/2023	09:30:51	ARS-01	DVV	PC, eDNA	1065	571 894.4	5 951 473.2	571 895.1	5 951 472.3	40.4	1.1	
23/01/2023	09:53:33	ARS-01	DVV	FA, FB	1066	571 894.4	5 951 473.2	571 894.7	5 951 471.1	40.3	2.1	
23/01/2023	10:15:20	ARS-01	DVV	FC	1067	571 894.4	5 951 473.2	571 895.4	5 951 471.3	40.2	2.1	

Notes
UTC = Coordinated Universal Time
BSL = Below sea level
SOL = Start of line
EOL = End of line
DVV = Dual van Veen grab
FA/FB/FC = Faunal sample A, B or C
PC = Physico-chemical sample
NS = No sample
NF = No fix

B.2 Grab Log

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
09/01/2023	ARS_21	PC	PC	57	10 cm	7.8	197.0	7.3		S	Sand	7.5 YR, 3/2	Shells. eDNA: A- 00395, B-00387, C- 00403
09/01/2023	ARS_21	FA, FB	FA	59	9 cm					S	Sand	7.5 YR, 3/2	Shells
09/01/2023	ARS_21	FB, FB	FB	59	10 cm					S	Sand	7.5 YR, 3/2	Shells, *E. flavescens*
09/01/2023	ARS_21	FC	FC	60	15 cm					mS	Muddy sand	7.5 YR, 3/2	Shells, *E. flavescens*
09/01/2023	ARS_22	PC, FA	FA	82	8 cm					mS	Muddy sand	2.5Y, 3/3	*A. rubens*, Ophiuroids, *B. lyrifera*, *E. flavescens*
09/01/2023	ARS_22	PC, FA	PC	82	9 cm	8.0	150	7.47		mS	Muddy sand	2.5Y, 3/3	*A. rubens*, Ophiuroids, *B. lyrifera*, *E. flavescens* eDNA: A-00431, B- 00390, C- 00459
09/01/2023	ARS_22	FB, FC	FB	83	7 cm					mS	Muddy sand	2.5Y, 3/3	*A. rubens*, Ophiuroids, *B. lyrifera*, *E. flavescens*
09/01/2023	ARS_22	FB, FC	NS	83	0 cm								Wash out
09/01/2023	ARS_22	FC, eDNA	FC	84	10 cm					mS	Muddy sand	2.5Y, 3/3	*A. rubens*, Ophiuroids, *B. lyrifera*, *E. flavescens*
09/01/2023	ARS_22	FC, eDNA	eDNA	84	10 cm	8.0	150	7.47		mS	Muddy sand	2.5Y, 3/3	*A. rubens*, Ophiuroids, *B. lyrifera*, *E. flavescens*
10/01/2023	ARS-24	PC, FA	NS	231	2 cm					mS	Muddy sand		
10/01/2023	ARS-24	PC, FA	NS	232	2 cm					mS	Muddy sand		Shells lodged in the jaws
10/01/2023	ARS-24	PC, FA	NS	233	2 cm					mS	Muddy sand		Shells lodged in the jaws
10/01/2023	ARS-24	PC, FA	NS	234	5 cm					mS	Muddy sand		Shells lodged in the jaws
11/01/2023	ARS-24	PC, FA	NS	234	> 4 cm					mS	Muddy sand		Shells lodged in the jaws

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
11/01/2023	ARS-24	PC, FA	NS	235	> 4 cm					mS	Muddy sand		Shells lodged in the jaws
11/01/2023	ARS-24	PC, FA	NS	236	> 4 cm					mS	Muddy sand		Shells lodged in the jaws
11/01/2023	ARS-26	PC, FA	NS	237	6 cm					mS	Muddy sand		Shells lodged in the jaws
11/01/2023	ARS-26	PC, FA	PC	238	8 cm					mS	Muddy sand		Ophiuroid, acquired HC, BTEX and HM
11/01/2023	ARS-26	FA, FB	NS	238	4 cm					mS	Muddy sand		Shells lodged in the jaws
11/01/2023	ARS-26	FA, FB	NS	239	4 cm					mS	Muddy sand		Shells lodged in the jaws
16/01/2023	ARS-24	FA, FB	NS	244	3 cm					mS	Muddy sand		Shells lodged in the jaws
16/01/2023	ARS-24	FA, FB	NS	245	3 cm					mS	Muddy sand		Shells lodged in the jaws
16/01/2023	ARS-24	FA, FB	NS	246	3 cm					mS	Muddy sand		Shells lodged in the jaws, *A. rubens*
16/01/2023	ARS-24	FA, FB	FA	247	5 L					mS	Muddy sand	2.5Y 3/3	Shells, Ophiuroids
16/01/2023	ARS-24	FB	NS	248	3 L					mS	Muddy sand		Shells
16/01/2023	ARS-24	FB, FC	NS	249	2 L					mS	Muddy sand		Shells
16/01/2023	ARS-24	FB, FC	FB	250	5 L					mS	Muddy sand	2.5Y 3/3	Shells
16/01/2023	ARS-24	FC	FC	251	6 L					mS	Muddy sand	2.5Y 3/3	Shells
16/01/2023	ARS-26	FA	FA	252	5 L				0-5	Sm	Sandy mud	2.5Y 4/3	Shells
									5-10	M	Mud	Gley 5GY	Thick dark mud
16/01/2023	ARS-26	FB	FB	253	5 L					Sm	Sandy mud	2.5Y 4/3	Shells
16/01/2023	ARS-26	FC	FC	254	5 L					Sm	Sandy mud	2.5Y 4/3	Shells
16/01/2023	ARS-27	PC	PC	264	15 cm				0-6	M	Mud	5Y 4/2	Soft mud. Numerous *B. lyrifera* in the top layer. eDNA: A- 00396, B-, C- 00410

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
									6-15	M	Mud	5Y 2.5/1	Thick black anoxic layer smelling of sewage. eDNA: A- 00396, B-, C- 00410
16/01/2023	ARS-27	eDNA	eDNA	264	15 cm	8.0	113	7.35	0-6	M	Mud	5Y 4/2	Soft mud. Numerous *B. lyrifera* in the top layer
									6-15	M	Mud	5Y 2.5/1	Thick black anoxic layer smelling of sewage
16/01/2023	ARS-27	FA, FB	FA	265	15 cm				0-6	M	Mud	5Y 4/2	Soft mud. Numerous *B. lyrifera* in the top layer
									6-15	M	Mud	5Y 2.5/1	Black anoxic layer smelling of sewage
16/01/2023	ARS-27	FA, FB	FB	265	15 cm				0-6	M	Mud	5Y 4/2	Numerous *B. lyrifera* in the top layer
									6-15	M	Mud	5Y 2.5/1	Black anoxic layer smelling of sewage
16/01/2023	ARS-27	FC	FC	266	15 cm				0-6	M	Mud	5Y 4/2	Soft mud. Numerous *B. lyrifera* in the top layer
									6-15	M	Mud	5Y 2.5/1	Black anoxic layer smelling of sewage
17/01/2023	ARS-25	PC, eDNA	PC	268	10 cm	11.0	195	8.25		S	Sand	2.5Y 5/3	eDNA: A- 00375, B- 00340, C- 00370
17/01/2023	ARS-25	PC, eDNA	eDNA	268	11 cm					S	Sand	2.5Y 5/3	
17/01/2023	ARS-25	NS	NS	269									No trigger
17/01/2023	ARS-25	NS	NS	269									No trigger
17/01/2023	ARS-25	FA, FB	FA	270	15 cm					S	Sand	2.5Y 5/3	

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
17/01/2023	ARS-25	FA, FB	FB	270	14 cm					S	Sand	2.5Y 5/3	
17/01/2023	ARS-25	FC	FC	271	10 cm					S	Sand	2.5Y 5/3	Sand eel
17/01/2023	ARS-28	PC, eDNA	PC	272	11 cm	6.4	205	8.61		mS	Muddy sand	2.5Y 5/3	eDNA: A- 00380, B- 00374, C-00373
17/01/2023	ARS-28	PC, eDNA	eDNA	272	11 cm					mS	Muddy sand	2.5Y 5/3	Sand eel
17/01/2023	ARS-28	FC, NS	FC	273	7 cm					mS	Muddy sand	2.5Y 5/3	
17/01/2023	ARS-28	NS	NS	273	3 cm								Wash out
17/01/2023	ARS-28	FA	FA	274	9 cm				0-5	mS	Muddy sand	2.5Y 5/3	
									5-8	M	Mud	GLEY1 3.5/N	Thick, black sticky mud. Anoxic layer, smells of sewage, clay-like. Potential oil contamination.
17/01/2023	ARS-28	FB	FB	275	8 cm				0-4	mS	Muddy sand	2.5Y 5/3	
									4-8	M	Mud	GLEY1 3.5/N	Thick, black sticky mud. Anoxic layer, smells of sewage, clay-like. Potential oil contamination.
17/01/2023	ARS-23	NS	NS	277	2 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	277	4 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	278	2 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
17/01/2023	ARS-23	NS	NS	278	2 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	279	3 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	279	3 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	280	0 cm								Triggered in water column
17/01/2023	ARS-23	NS	NS	280	0 cm								Triggered in water column
17/01/2023	ARS-23	NS	NS	281	2 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	281	1 cm								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	PSD	PSD	282	5 L					(g)sM	Slightly gravelly muddy sand	5 Y 3/2	Black, oily clay deposits
17/01/2023	ARS-23	FA	FA	283	5 L					(g)sM	Slightly gravelly muddy sand	5 Y 3/2	Clay patches. Sewage smell
17/01/2023	ARS-23	NS	NS	277	3 L								Washed out due to numerous bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	NS	NS	277	2 L								Washed out due to numerous

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
													bivalves (possible *S. subtruncata*) in the sediment
17/01/2023	ARS-23	FB	FB	286	6 L				0-4	mS	Muddy sand	2.5Y 5/3	
									4-8	M	Mud	GLEY1 3.5/N	Thick black mud. Anoxic layer, smells of sewage, clay-like. Potential oil contamination.
17/01/2023	ARS-23	FC	FC	287	5 L				0-4	mS	Muddy sand	2.5Y 5/3	
									4-8	M	Mud	GLEY1 3.5/N	Thick black mud. Anoxic layer, smells of sewage, clay-like. Potential oil contamination.
18/01/2023	ARS-19	PC	PC	333	8 cm	7.8	232	8.52		S	Sand	7.5 YR 4/3	*E. flavescens*
18/01/2023	ARS-19	eDNA	eDNA	333	8 cm					S	Sand	7.5 YR 4/3	eDNA: A- 00431, B- 00390, C- 00459
18/01/2023	ARS-19	FA	FA	335	8 cm					S	Sand	7.5 YR 4/3	
18/01/2023	ARS-19	FB	FB	335	12 cm					S	Sand	7.5 YR 4/3	
18/01/2023	ARS-19	FC	FC	336	10 cm					S	Sand	7.5 YR 4/3	
18/01/2023	ARS-20	PC	PC	367	11 cm	8.1	259	7.53		S	Sand	7.5 YR 4/3	Ophiuroids
18/01/2023	ARS-20	eDNA	eDNA	367	7 cm					S	Sand	7.5 YR 4/3	Ophiuroids. eDNA: A- 00397, B- 00392, C- 00399
18/01/2023	ARS-20	FA	FA	368	10 cm					S	Sand	7.5 YR 4/3	*E. flavescens*
18/01/2023	ARS-20	FB	FB	368	9 cm					S	Sand	7.5 YR 4/3	Mud shrimp
18/01/2023	ARS-20	FC	FC	369	10 cm					S	Sand	7.5 YR 4/3	
19/01/2023	ARS-17	NS	NS	412	-					S	Sand		Bungee snapped; lid open
19/01/2023	ARS-17	NS	NS	412	-					S	Sand		Wash out

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
19/01/2023	ARS-17	PC, FC	PC	413	8 cm	7.1	183	7.85		S	Sand	2.5Y 4/3	
19/01/2023	ARS-17	PC, FC	FC	413	8 cm					S	Sand	2.5Y 4/3	*E. flavescens*, Ophiuroid
19/01/2023	ARS-17	FA, FB	FA	414	8 cm					S	Sand	2.5Y 4/3	*E. flavescens*, Ophiuroid
19/01/2023	ARS-17	FA, FB	FB	414	8 cm					S	Sand	2.5Y 4/3	
19/01/2023	ARS-17	FC	FC	463	8 cm					S	Sand	2.5Y 4/3	*Ammodytes* sp. eDNA A: SGC-01-00402, B SGC-01-00391, C SGC-01-00405
20/01/2023	ARS-18	FC, NS	NS	463	4 cm					S	Sand		Wash out
20/01/2023	ARS-18	PC, eDNA	PC	464	7 cm	7.7	215	7.67		S	Sand	2.5Y 4/3	
20/01/2023	ARS-18	PC, eDNA	eDNA	464	7 cm					S	Sand	2.5Y 4/3	
20/01/2023	ARS-18	FA, FB	FA	465	9 cm					S	Sand	2.5Y 4/3	
20/01/2023	ARS-18	FA, FB	FB	465	11 cm					S	Sand	2.5Y 4/3	
21/01/2023	ARS-16	PC, eDNA	PC	489	10 cm	7.1	250	7.88		S	Sand	7.5 YR 4/3	eDNA A: SGC-01-00425, B: SGC-01-00371, C: SGC-01-00378
21/01/2023	ARS-16	PC, eDNA	eDNA	489	9 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-16	FA, FB	FA	490	10 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-16	FA, FB	FB	490	11 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-16	FC	FC	491	10 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-15	PC, eDNA	PC	514	7 cm	7.6	233	7.72		S	Sand	7.5 YR 4/3	eDNA A: SGC-01-00400, B: SGC-01-00375, C: SGC-01-00384
21/01/2023	ARS-15	PC, eDNA	eDNA	514	8 cm					S	Sand	7.5 YR 4/3	

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
21/01/2023	ARS-15	FA, FB	FA	515	10 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-15	FA, FB	FB	515	10 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-15	FC	FC	516	11 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-14	PC, eDNA	PC	536	8 cm	7.4	206	7.90		S	Sand	7.5 YR 4/3	eDNA: A: SGC-01-00417, B: SGC-01-000386, C: SGC-01-00376
21/01/2023	ARS-14	PC, eDNA	eDNA	536	8 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-14	FA, FB	FA	537	11 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-14	FA, FB	FB	537	11 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-14	FC	FC	538	10 cm					S	Sand	7.5 YR 4/3	Masked crab
21/01/2023	ARS-13	PC, eDNA	PC	557	14 cm					S	Sand	2.5Y 5/3	Shell fragments. eDNA A: SGC-01-00394, B: SGC-01-00372, SGC-01-00365
21/01/2023	ARS-13	PC, eDNA	eDNA	557	11 cm	9.8	259	7.70		S	Sand	2.5Y 5/4	Shell fragments
21/01/2023	ARS-13	FA, FB	FA	560	13 cm					S	Sand	2.5Y 5/5	Shell fragments
21/01/2023	ARS-13	FA, FB	FB	560	11 cm					S	Sand	2.5Y 5/6	Shell fragments
21/01/2023	ARS-13	FC	FC	561	11 cm					S	Sand	2.5Y 5/7	Shell fragments
21/01/2023	ARS-12	PC, eDNA	PC	612	8 cm					S	Sand	2.5Y 5/3	Shell fragments, eDNA A: SGC-01-00457, B: SGC-01-00382, C: SGC-01-00456
21/01/2023	ARS-12	PC, eDNA	eDNA	612	10 cm	8.4	248	7.26		S	Sand	2.5Y 5/3	Shell fragments
21/01/2023	ARS-12	FA, FB	FA	613	12 cm					S	Sand	2.5Y 5/3	Shell fragments
21/01/2023	ARS-12	FA, FB	FB	613	9 cm					S	Sand	2.5Y 5/3	Shell fragments

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
21/01/2023	ARS-12	FC	FC	614	10 cm					S	Sand	2.5Y 5/3	Shell fragments
21/01/2023	ARS-11	FB, FC	FB	681	7 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-11	FB, FC	FC	681	7 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-11	FA	NS	682									Wash out
21/01/2023	ARS-11	FA	NS	682	-								Wash out
21/01/2023	ARS-11	FA, NS	FA	683	8 cm					S	Sand	7.5 YR 4/3	
21/01/2023	ARS-11	FA, NS	NS	683	6 cm								Wash out
21/01/2023	ARS-11	eDNA, NS	eDNA	684	7 cm	8.0	135	7.93		S	Sand	7.5 YR 4/3	
21/01/2023	ARS-11	eDNA, NS	NS	684	2 cm								Wash out
21/01/2023	ARS-11	NS	NS	682	5 cm								Wash out
21/01/2023	ARS-11	NS	NS	682	5 cm								Wash out
21/01/2023	ARS-11	PC	PC	686	8 cm					S	Sand	7.5 YR 4/3	
22/01/2023	ARS-10	PC, eDNA	PC	722	12 cm	8.8	184	7.84		S	Sand	7.5 YR 4/3	eDNA B: SGC-01-00420, C: SGC-01-00367
22/01/2023	ARS-10	PC, eDNA	eDNA	722	11 cm					S	Sand	7.5 YR 4/3	
22/01/2023	ARS-10	NS	NS	723	-								No trigger
22/01/2023	ARS-10	FA, FB	FA	724	8 cm					S	Sand	7.5 YR 4/3	
22/01/2023	ARS-10	FA, FB	FB	724	10 cm					S	Sand	7.5 YR 4/3	
22/01/2023	ARS-10	FC	FC	725	10 cm					S	Sand	7.5 YR 4/3	
22/01/2023	ARS-09	FA, FB	FA	767	11 cm					M	Mud	2.5 YR 3/2	
22/01/2023	ARS-09	FA, FB	FB	767	11 cm					M	Mud	2.5 YR 3/2	
22/01/2023	ARS-09	PC, FC	PC	768	10 cm	7.7	243	7.84		M	Mud	2.5 YR 3/2	eDNA A: SGC-01-00454, B:

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
													SGC-01-00455, C: SGC-01-00406
22/01/2023	ARS-09	PC, FC	FC	768	7 cm					M	Mud	2.5 YR 3/2	
22/01/2023	ARS-09	eDNA	eDNA	769	10 cm					M	Mud	2.5 YR 3/2	
22/01/2023	ARS-06	PC, eDNA	PC	796	10 cm	6	227	7.89		M	Mud	2.5 YR 3/2	eDNA: A: SGC-01-00379, B: SGC-01-00463, SGC-01-00427
22/01/2023	ARS-06	PC, eDNA	eDNA	796	10 cm					M	Mud	2.5 YR 3/2	
22/01/2023	ARS-06	FA, FB	FA	797	11 cm					M	Mud	2.5 YR 3/2	Brittle stars, *E. flavescens*, polychaete, masked crab
22/01/2023	ARS-06	FA, FB	FB	797	11 cm					M	Mud	2.5 YR 3/2	Brittle stars, *E. flavescens*, polychaete, masked crab
22/01/2023	ARS-06	FC	FC	798	11 cm					M	Mud	2.5 YR 3/2	Brittle stars, *E. flavescens*, polychaete, masked crab
22/01/2023	ARS-08	FB, FC	FB	846	7 cm				0-3	sM	Sandy mud	2.5Y 5/3	Top 1-3cm sandy mud
									3-7	M	Mud		Black anoxic layer
22/01/2023	ARS-08	FB, FC	FC	846	7 cm				0-3	sM	Sandy mud	2.5Y 5/3	Top 1-3cm sandy mud
									3-7	M	Mud		Black anoxic layer
22/01/2023	ARS-08	FA, NS	FA	847	8 cm				0-3	sM	Sandy mud	2.5Y 5/3	Top 1-3cm sandy mud
									3-8	M	Mud		Black anoxic layer
22/01/2023	ARS-08	FA, NS	NS	847	-					sM		2.5Y 5/3	Washed out
22/01/2023	ARS-08	PC, eDNA	PC	848	7 cm	8.0	225	7.85	0-3	sM	Sandy mud	2.5Y 5/3	Top 1-3cm sandy mud
									3-7	M	Mud		Black anoxic layer
22/01/2023	ARS-08	PC, eDNA	eDNA	848	7 cm				0-3	sM	Sandy mud	2.5Y 5/3	Top 1-3cm sandy mud

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
									3-7	M	Mud		Black anoxic layer
22/01/2023	ARS-07	FC, NS	FC	886	7 cm				0-3	sM	Sandy mud	5Y 4/2	Top 1-3cm sandy mud
									3-7	M	Mud		Black anoxic layer
22/01/2023	ARS-07	FC, NS	NS	886	1 cm					sM	Washed out	5Y 4/2	
22/01/2023	ARS-07	FA, NS	FA	887	10 cm				0-3	sM	Sandy mud	5Y 4/2	Top 1-3cm sandy mud
									3-10	M	Mud		Black anoxic layer
22/01/2023	ARS-07	FA, NS	NS	887	2 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	NS	NS	888	2 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	NS	NS	888	7 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	NS	NS	889	4 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	NS	NS	889	3 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	FB, NS	FB	890	8 cm					sM	Sandy mud	5Y 4/2	Black anoxic layer
22/01/2023	ARS-07	FB, NS	NS	890	7 cm					sM	Sandy mud	5Y 4/2	Wash out
22/01/2023	ARS-07	eDNA, NS	eDNA	891	7 cm					sM	Sandy mud	5Y 4/2	Black anoxic layer
22/01/2023	ARS-07	eDNA, NS	NS	891	7 cm					sM	Washed out	5Y 4/2	
22/01/2023	ARS-07	PC	PC	892	9 cm	6.0	156	7.85	0-3	sM	Sandy mud	5Y 4/2	Top 1-3cm sandy mud
									3-9	M	Mud		Black anoxic layer
22/01/2023	ARS-04	PC, eDNA	PC	939	15 cm	6.9	223	7.82	0-5	M	Mud	7.5 YR 3/4	
									5-15	M	Mud	7.5 YR 3/1	Soft, dark grey mud. Oily smell, clay-like texture
22/01/2023	ARS-04	PC, eDNA	eDNA	939	15 cm				0-5	M	Mud	7.5 YR 3/4	
									5-15	M	Mud	7.5 YR 3/1	Soft, dark grey mud. Oily

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
													smell, clay-like texture
22/01/2023	ARS-04	FA, FB	FA	940	15 cm				0-5	M	Mud	7.5 YR 3/4	*E. flavescens*
									5-15	M	Mud	7.5 YR 3/1	Oily smell, clay-like texture
22/01/2023	ARS-04	FA, FB	FB	940	15 cm				0-5	M	Mud	7.5 YR 3/4	*E. flavescens, B. lyrifera, Acanthocardia aculeata*
									5-15	M	Mud	7.5 YR 3/1	Oily smell, clay-like texture
22/01/2023	ARS-04	FC	FC	941	15 cm				0-5	M	Mud	7.5 YR 3/4	*E. flavescens, B. lyrifera*
									5-15	M	Mud	7.5 YR 3/1	Soft, dark grey mud. Oily smell, clay-like texture
23/01/2023	ARS-05	PC, FA	PC	969	9 cm	8.2	225	7.78		sM	Sandy mud	5Y 4/2	eDNA: A:SGC-01-00441, B: SGC-01-00447, C: SGC-01-00446
23/01/2023	ARS-05	PC, FA	FA	969	11 cm					sM	Sandy mud	5Y 4/2	
23/01/2023	ARS-05	FB, eDNA	FB	970	10 cm					sM	Sandy mud	5Y 4/2	
23/01/2023	ARS-05	FB, eDNA	eDNA	970	10 cm					sM	Sandy mud	5Y 4/2	
23/01/2023	ARS-05	FC	FC	971	11 cm					sM	Sandy mud	5Y, 4/2	
23/01/2023	ARS-03	PC, eDNA	PC	1004	11 cm	7.4	283	7.75		M	Mud	7.5 YR 3/4	eDNA: A: SGC-01-00423, B: SGC-01-00422, C: SGC-01-00411
23/01/2023	ARS-03	PC, eDNA	eDNA	1004	11 cm					M	Mud	7.5 YR 3/4	
23/01/2023	ARS-03	FA, FB	FA	1005	11 cm					M	Mud	7.5 YR 3/4	Crab, polychaetes, *E. flavescens*
23/01/2023	ARS-03	FA, FB	FB	1005	11 cm					M	Mud	7.5 YR 3/4	Crab, polychaetes, *E. flavescens*

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
23/01/2023	ARS-03	FC	FC	1006	11 cm					M	Mud	7.5 YR 3/4	Crab, polychaetes, *E. flavescens*, mud shrimp
23/01/2023	ARS-02	PC, eDNA	PC	1031	10 cm	7.7	238	7.79		M	Mud	7.5 YR 3/4	eDNA: A: SGC-01-00435, B: SGC-01-00419, SGC-01-00424
23/01/2023	ARS-02	PC, eDNA	eDNA	1031	10 cm					M	Mud	7.5 YR 3/4	
23/01/2023	ARS-02	FA, FB	FA	1032	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
23/01/2023	ARS-02	FA, FB	FB	1032	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
23/01/2023	ARS-02	FC	FC	1034	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
23/01/2023	ARS-01	PC, eDNA	PC	1065	10 cm	7.0	237	7.58		M	Mud	7.5 YR 3/4	eDNA: A: SGC-01-00443, B: SGC-01-00432, C: SGC-01-000415
23/01/2023	ARS-01	PC, eDNA	eDNA	1065	11 cm					M	Mud	7.5 YR 3/4	
23/01/2023	ARS-01	FA, FB	FA	1066	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
23/01/2023	ARS-01	FA, FB	FB	1066	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
23/01/2023	ARS-01	FC	FC	1067	11 cm					M	Mud	7.5 YR 3/4	Mud shrimps
09/01/2023	ARS_21	PC	PC	57	10 cm	7.8	197.0	7.3		S	Sand	7.5 YR 3/2	Shells. eDNA: A- 00395, B-00387, C- 00403
09/01/2023	ARS_21	FA, FB	FA	59	9 cm					S	Sand	7.5 YR 3/2	Shells
09/01/2023	ARS_21	FB, FB	FB	59	10 cm					S	Sand	7.5 YR 3/2	Shells, *E. flavescens*

Notes
SOL = Start of line
EOL = End of line
DVV = Dual van Veen grab
FA/FB/FC = Faunal sample A, B or C
PC = Physico-chemical sample

Date	Station	Event	Sample	Fix No.	Sample Depth [DVV cm, Hamon L]	Temp [°C]	Redox [mV]	pH	Sediment Description (including stratigraphy)				Comments (fauna, smell, bioturbation, debris)
									Depth [cm]	Sediment Type	Sediment Description	Munsell Colour	
NS = No sample													

Appendix C

Daily Progress Reports

Click on icons to open daily progress reports

EBS Progress 20230110.pdf

EBS Progress 20230111.pdf

EBS Progress 20230117.pdf

EBS Progress 20230122.pdf

Aramis Pipeline Route Geophysical, Geotechnical and Environmental Survey

Aramis Project Area

Dutch Sector

Biodiversity Observations Report

Survey Period: 11 July 2022 to 24 January 2023

F197217-REP-003 01 | 7 March 2023

Complete

TotalEnergies E&P North Sea UK Limited

Document Control

Document Information

Document Title	Aramis Pipeline Route Geophysical, Geotechnical and Environmental Survey Aramis Project Area Dutch Sector Biodiversity Observations Report
Fugro Project No.	F197217
Fugro Document No.	F197217-REP-003
Issue Number	01
Issue Status	Complete
Fugro Legal Entity	Fugro GB Marine Limited
Issuing Office Address	1-9 The Curve, 32 Research Avenue North, Heriot-Watt Research Park, Edinburgh, EH14 4AP, United Kingdom

Client Information

Client	TotalEnergies E&P North Sea UK Limited
Client Address	Bordewijklaan 18, 2591 XR, The Hague, The Netherlands
Client Contact	[redacted]

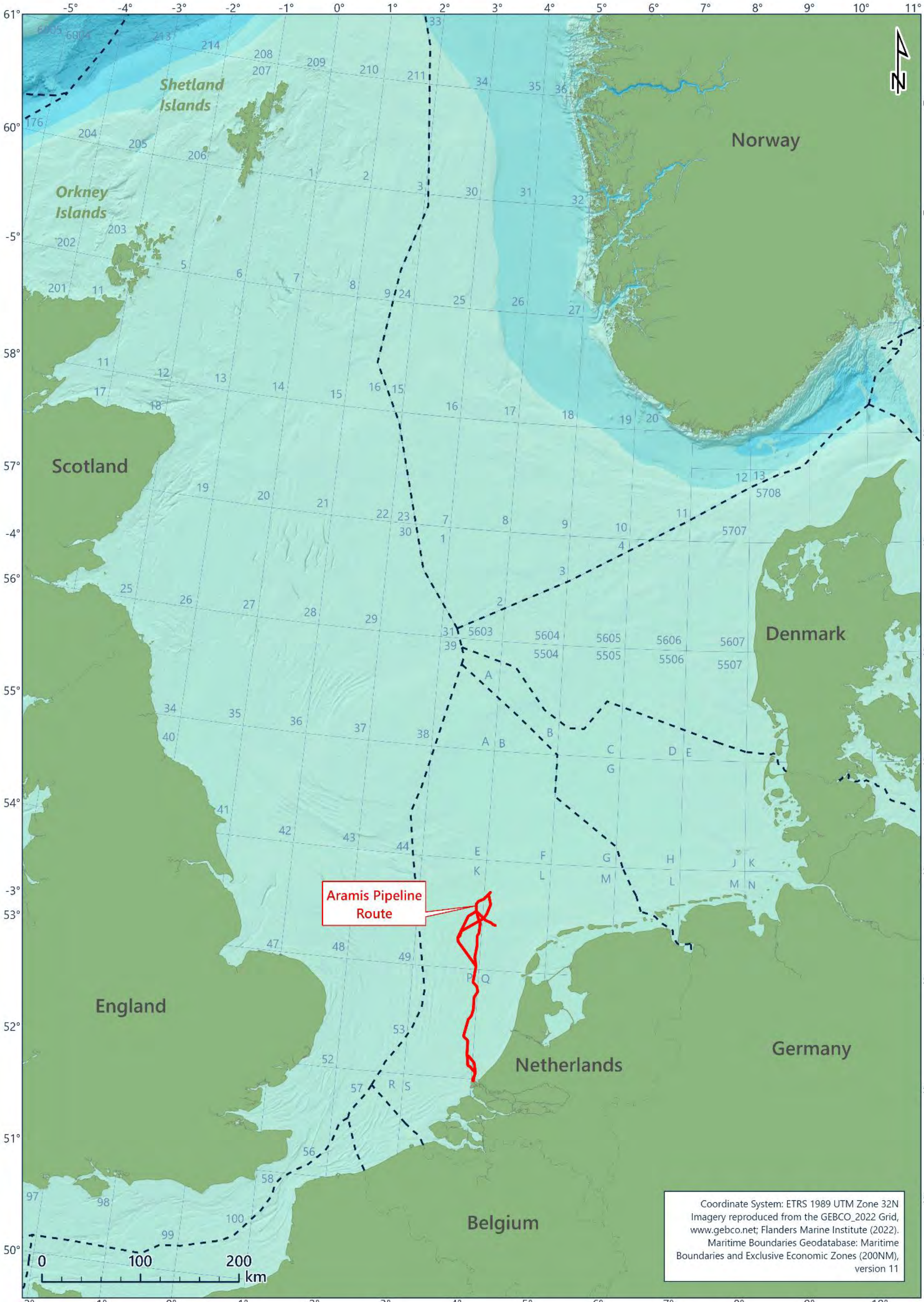
Revision History

Issue	Date	Status	Comments on Content	Prepared By	Checked By	Approved By
01	7 March 2023	Draft report	Issued to client	[redacted]	[redacted]	[redacted]

Project Team

Initials	Name	Role
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Frontispiece



Executive Summary

Introduction

Marine mammal mitigation and biodiversity operations were carried out onboard the MV Fugro Discovery, MV Fugro Searcher, MV Fugro Seeker, with biodiversity operations only carried out on the MV Kommandor Orca and MV Normand Mermaid, during the survey period 11 July 2022 to 24 January 2023 at the Aramis Project Area, located in the Dutch Continental Shelf (DCS) from Maasvlakte to offshore Blocks L4/K6 in the Dutch North Sea. The geophysical survey comprised two-dimensional high resolution (2DHR) seismic and sub-bottom profiler geophysical operations. The aims of the survey were to identify and map the seabed and sub-seabed conditions, including potential associated hazards (geohazards or man-made hazards), affecting the future installation of the trunkline/flowline and riser access tower. An unexploded ordinance (UXO) survey was also carried out on the MV Fugro Searcher and MV Fugro Seeker. The environmental survey comprised sampling to establish physio-chemical properties and camera transects to establish whether any sensitive habitats are present in the area, specifically habitats listed under Annex I of the EU Habitats Directive and habitats listed by the Oslo and Paris Commission (OSPAR) as threatened and/or declining habitats (OSPAR, 2008).

The onboard marine mammal observers (MMO) and passive acoustic monitoring (PAM) operators carried out dedicated and non-dedicated monitoring for marine mammals and avifauna within 500 m of the vessel prior to the commencement of geophysical operations. In addition, the MMOs kept a record of all marine mammals and avifauna for the duration of the survey to assess the biodiversity of the survey area.

Geophysical Survey

Geophysical data were acquired using 2DHR using seismic airguns, multibeam echosounders, sub-bottom profiler, magnetometer, and side scan sonar to identify the sub-seabed conditions, UXO's and accurately determine potential installation hazards prior to operations.

Due to the use of seismic airguns and other acoustic sources, the survey was undertaken in line with the Joint Nature Conservation Committee (JNCC) guidelines for minimising the risk of injury to marine mammals from geophysical surveys.

In addition to this, the Dutch Government required the use of an Acoustic Deterrent Device (ADD) under the Nature Conservation Act Exemption to run for at least 5 minutes before survey equipment was operational. This applied to the surveys onboard the MV Fugro Searcher and MV Fugro Discovery.

Marine Mammal Mitigation

During the survey, a total of 145 soft starts were undertaken, with the majority meeting the 20 minute minimum mitigation criterium.

Overall, the MMOs undertook 606 hours and 5 minutes of monitoring, and the PAM effort was 634 hours and 5 minutes. There were no positive PAM detections; however, one marine mammal sighting resulted in mitigation procedures being implicated.

Compliance

There were two occasions when pre-shooting searches were less than 30 minutes stated in the guidelines. The ADD was run for at least five minutes in all instances where it was required.

There were 12 soft starts that were under the guideline of 20 minutes. Eight of the short soft starts were onboard the Fugro Seeker during the GAMBAS/Refraction Seismic procedures, as this equipment had no capacity to 'ramp up' power.

There were 15 instances when the line turn was longer than 40 minutes and acoustic source was active, due to change in next line location or for safety of equipment, such as to avoid buoys.

There were 15 instances when time between start of soft start and start of line was not immediate due to technical issues with equipment.

Biodiversity

Across all operations and vessels, there were 1005 hours and 11 minutes of visual monitoring and 658 hours and 31 minutes of PAM effort during the survey (totalling 1663 hours and 42 minutes of joint observation effort). Visual observations totalled 11 334 sightings, including 4 species of mammals (7 sightings) and 63 species of avifauna (11 327 sightings). There were no acoustic monitoring detections for the duration of the survey.

Only one bird species (Black-legged kittiwake (*Rissa tridactyla*)) was listed as 'vulnerable' on the International Union for Conservation of Nature (IUCN) red list. All other species of birds and marine mammals were listed as 'Least Concern'. While the survey area is in proximity to a number of protected areas, the marine mammal and bird observations were as expected for the survey period.

Contents

Appendices

Figures in the Main Text

Tables in the Main Text

Abbreviations

2DHR	Two-dimensional high resolution
2DUHR	Two-dimensional ultra-high resolution
ADD	Acoustic deterrent device
BOEM	Bureau of Ocean Energy Management
BSL	Below sea level
CCS	Carbon Capture and Storage
DAQ	Data acquisition
EC	European Commission
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
ESAS	European Seabirds at Sea
MBES	Multibeam echosounder
MFO	Marine Fauna Observer
MMO	Marine mammal observer
MPA	Marine protected area
MV	Motor vessel
OSPAR	Oslo and Paris Commission
PAM	Passive acoustic monitoring
PSO	Protected species observer
RAMSAR	Ramsar Convention on Wetlands
SAC	Special areas of conservation

SBP	Sub-bottom profiler
SCI	Site of community importance
SPA	Special protection areas
SSS	Side-scan sonar
UHR	Ultra-high resolution
USB	Universal serial bus
UXO	Unexploded ordinance
XLR	External line return

1. Introduction

On the instruction of TotalEnergies E&P North Sea UK Limited, Fugro performed a geophysical and geotechnical site investigation as part of the Aramis carbon capture and storage (CCS) project in the Dutch Sector of the southern North Sea, between Maasvlakte and offshore Blocks L4/K6. Water depths ranged from 4 m below sea level (BSL) to 41 m BSL. Operations were conducted onboard the following vessels:

- MV Fugro Seeker during the survey period 11 July to 22 September 2022;
- MV Fugro Discovery during the survey period 11 November to 12 December 2022;
- MV Normand Mermaid during the survey period 11 November 2022 to 24 January 2023;
- MV Fugro Searcher during the survey period 9 October 2022 to 23 January 2023; and,
- MV Kommandor Orca during the survey period 2 to 12 December 2022.

The objectives of the geophysical survey, unexploded ordinance (UXO) survey, and geotechnical site investigation were to evaluate the seabed and sub-seabed conditions, including potential associated hazards (geohazards or man-made hazards), affecting the future installation of the trunkline/flowline and riser access tower of the Aramis CCS project.

The pipeline route area has been sub-divided into the landfall and nearshore areas, main pipeline corridor, and offshore hub area. Each vessel was assigned different sub-divisions of the pipeline area and used different geophysical, UXO, and geotechnical survey methods.

The objectives of the biodiversity survey were to record the presence of marine mammals and birds within the survey area and to highlight any sensitive species in relation to the International Union for Conservation of Nature (IUCN) categories. Information from the desk top study (Fugro, 2022) has been used to provide background information on the species observed and their vulnerability.

Appendix A outlines the guidelines for use of this report.

1.1 Mitigation

The geophysical phase of the survey, which required mitigation methods, was carried out on the Fugro Searcher, Fugro Seeker, and Fugro Discovery vessels. Procedures were applied to the acoustic sources in accordance with the Joint Nature Conservation Committee (JNCC) recommendations for minimising the risk of injury and disturbance to marine mammals from geophysical surveys (JNCC, 2017). In addition to the JNCC guidelines, the Dutch Government required the use of an Acoustic Deterrent Device (ADD) under the Nature Conservation Act Exemption to run for at least 5 minutes before survey equipment was operational. The ADD was required on the MV Fugro Searcher and MV Fugro Discovery before start of operations and operations were to be shut down if a marine mammal entered the mitigation zone.

An internal document detailing the adapted JNCC MMO guidelines, with the addition of the ADD, was in use onboard the MV Fugro Searcher and MV Fugro Discovery to ensure synchronised operating procedures.

Marine mammal observers (MMOs), passive acoustic monitoring (PAM) equipment, and PAM operators were provided by Fugro for the duration of the survey.

1.2 Biodiversity

In addition to marine mammal mitigation methods, records were made of all marine mammals and avifauna present throughout the geophysical, geotechnical, and environmental baseline phases of the survey on all vessels. Observation records help to contribute to the understanding of the spatial and temporal biodiversity throughout the survey area. A number of marine mammals and avifauna are protected in Dutch Marine waters through a number of legislative directives, further detailed in the environmental desktop study (Fugro, 2022).

Table 1.1 summaries the nature conservation sites in the Dutch sector of the North Sea comprising the current Natura 2000, Ramsar, and OSPAR Marine Protected Area (MPA) networks in the vicinity of the survey area. They are presented spatially in Figure 1.2.

1.2.1 IUCN Red List Threatened Species

Special note was made of many species that are listed by the International Union for Conservation of Nature (IUCN) as "Near threatened" or within its three threatened categories. Figure 1.1 shows the spectrum of destinations that the IUCN assigns to species that have been assessed based on that species' extinction risk.

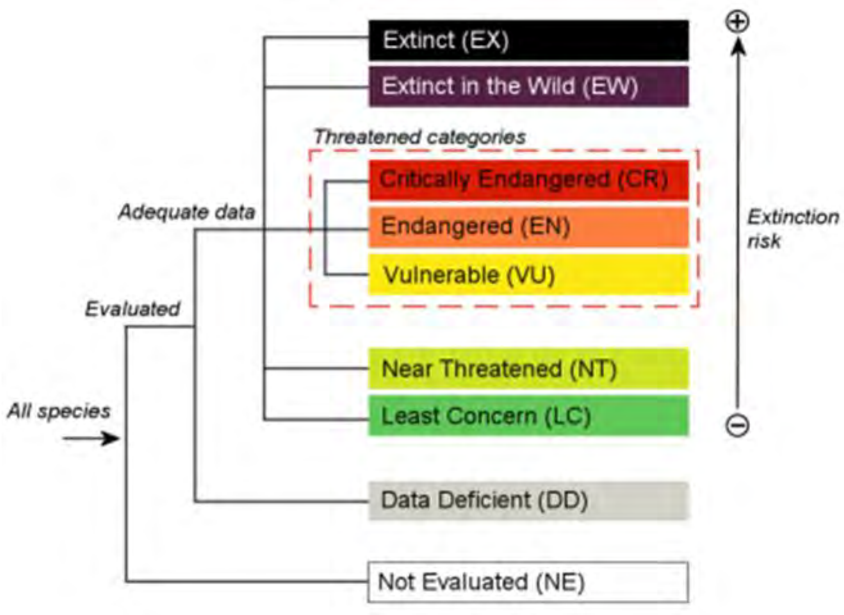


Figure 1.1: IUCN Red List designations (From IUCN, 2022)

The IUCN Red List is designed to catalogue and highlight species that are facing higher risks of extinction with the aim that preventative measures can be taken to decrease the risk to the continuation of that species. The classifications are based on a number of factors and each species that has been classified as 'Near Threatened' or worse has a justification provided for that designation. This justification is based on criteria that lead to the species Red List designation.

The criteria are split into;

- A reduction in population size based on a number of certain factors;
- Geographic range of either the extent of occurrence (B1) or the area of occupancy (B2);
- Population size estimated to number fewer than 10 000 mature individuals in combination with other factors;
- Population very small or restricted in the form of either populations size of less than 1000 mature individuals (D1) or very restricted area of occupancy (typically less than 20 km^2) (D2);
- Quantitative analysis showing the probability of extinction in the wild is at least 10 % within 100 years.

Table 1.1: Conservation Areas in the vicinity of the survey area

Site Name	Designation	Protected Species	Protected Habitats	Distance from proposed pipeline at closest point [km]†
Frisian Front (Friese Front)	SPA (Birds Directive) special protected areas	**Seabirds** ▪ Guillemot ▪ Great skua ▪ Great black-backed gull ▪ Lesser black-backed gull		7 from K14-L4A
Clover Bank (Klaverbank)	SAC (Habitats Directive) MPA (OSPAR)	**Marine mammals** ▪ Grey seal ▪ Harbor seal ▪ Harbour porpoise	▪ Reefs	46 from Section C
Voordelta	SAC (Habitats Directive) SPA (Birds Directive) RAMSAR (Ramsar Convention) MPA (OSPAR)	**Seabirds** ▪ 30 species of wildfowl, waders and seabirds, **Fish** ▪ Allis shad ▪ Twaite shad ▪ River lamprey ▪ Sea lamprey **Marine mammals** ▪ Grey seal ▪ Common seal	▪ Sandbanks which are slightly covered by sea water all the time ▪ Mudflats and sandflats not covered by seawater at low tide ▪ *Salicornia* and other annuals colonizing mud and sand ▪ Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) ▪ Embryonic shifting dunes ▪ Humid dune slacks	Overlaps at southern-most extent of pipeline route
Noordzeekustzone	SAC (Habitats Directive) SPA (Birds Directive) RAMSAR (Ramsar Convention) MPA (OSPAR)	**Seabirds** ▪ 20 species of wildfowl, waders and seabirds, **Fish** ▪ Allis shad, ▪ Twaite shad ▪ River lamprey ▪ Sea lamprey **Marine mammals** ▪ Grey seal,		36 from A-Alt

Site Name	Designation	Protected Species	Protected Habitats	Distance from proposed pipeline at closest point [km]†
		▪ Common seal ▪ Harbour porpoise		
Multiple "sand dune" sites throughout the Holland coast including: Meijendel & Berkheide, Kennemerland-Zuid, Noordhollands Duinreservaat , Solleveld & Kapittelduinen, Westduinpark & Wapendal Coepelduynen, Kennemerland-Zuid and Schoorlse Duinen (coastal)	SAC (Habitats Directive)		Sand dune habitats including ▪ Embryonic shifting dunes ▪ Fixed coastal dunes ▪ Dunes with *Salix repens* sp. argentea (*Salicion arenariae*) ▪ Wooded dunes of the Atlantic, Continental and Boreal region ▪ Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* ▪ Humid dune slacks ▪ Water courses of plain to montane levels	Between 9 and 45
Brown Bank (Bruine Bank)	SPA (Birds Directive)	**Seabirds** ▪ Little gull ▪ Gannet ▪ Great skua ▪ Great black-backed gull ▪ Common guillemot ▪ Razorbill		23 from A-Alt
Vlakte van der Raan (not shown in Figure 1.2)	SAC Habitats Directive MPA (OSPAR)	**Fish** ▪ Allis shad, ▪ Twaite shad ▪ River lamprey ▪ Sea lamprey **Marine mammals** ▪ Grey seal, ▪ Common seal ▪ Harbour porpoise	▪ Sandbanks which are slightly covered by sea water all the time.	70
Southern North Sea (UK)	SAC (Habitats Directive)	**Marine mammals** ▪ Harbour porpoise		38 from Section F

Site Name	Designation	Protected Species	Protected Habitats	Distance from proposed pipeline at closest point [km]†
Notes: SPA = Special Protection Area MPA = Marine Protected Area SAC = Special Area of Conservation				

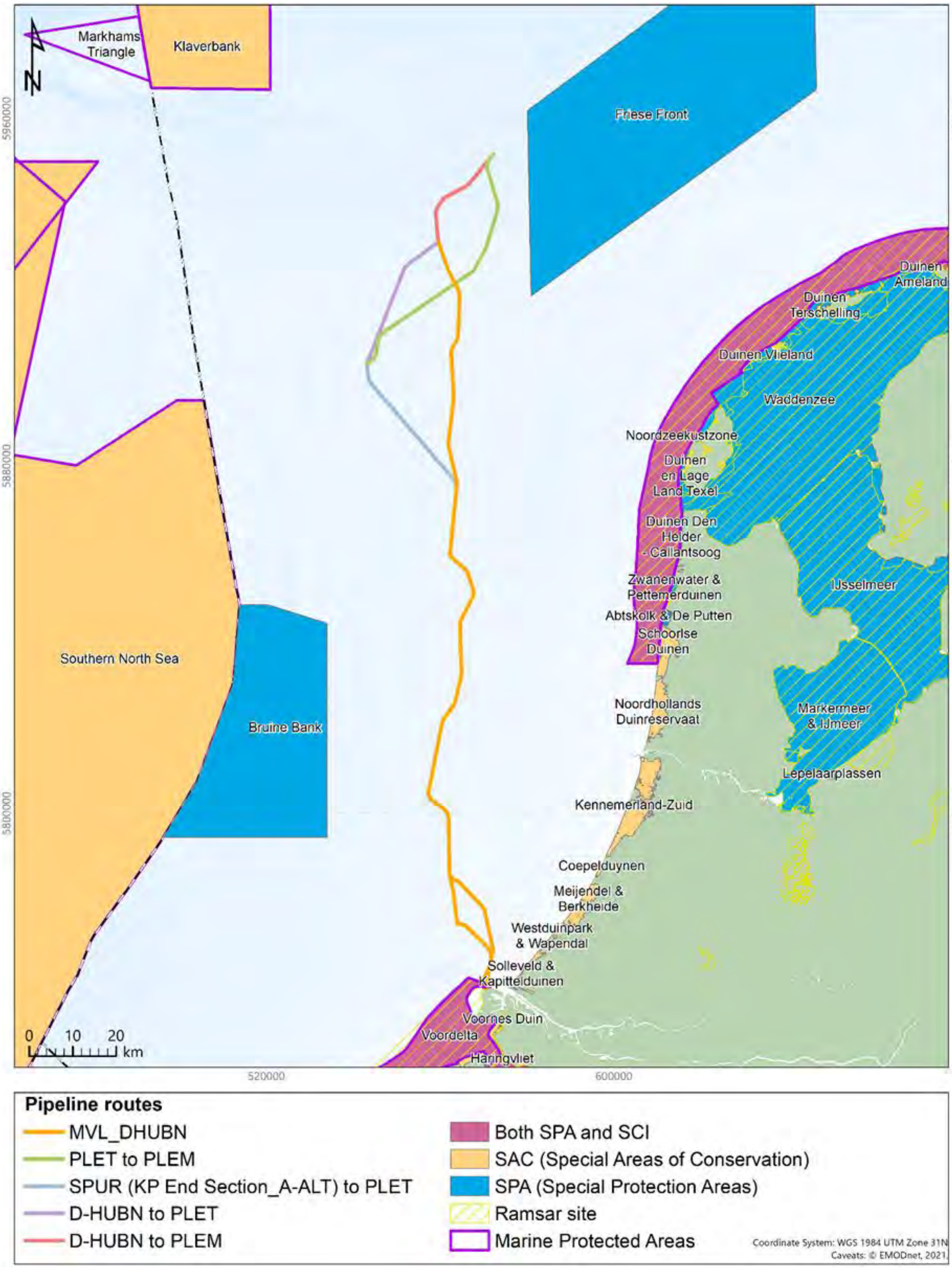


Figure 1.2: Location of relevant nature conservation sites

2. Survey Strategy

2.1 Fugro Discovery

2.1.1 Two-dimensional Ultra High-Resolution Equipment

The two-dimensional ultra-high resolution (2DUHR) seismic survey encompassed 2661.39 km and comprised 459 mainlines and 63 crosslines. Data was collected on each line by multibeam echosounders (MBES), side-scan sonar (SSS), sub-bottom profilers (SBP), and magnetometers.

Table 2.1: Ultra high-resolution seismic equipment

Source	
Type	Innomar SBP
Frequency	85 - 115 kHz
Energy output (Max Energy output)	>8 Kw
Source	
Type	Kongsberg EM2040 MBES
Source	
Type	EdgeTech 4205 side scan sonar
Frequency	230/540 kHz

2.2 Fugro Seeker

2.2.1 Two-dimensional Ultra High-Resolution Equipment

The 2DUHR seismic survey encompassed 32 lines comprising 31.7 km. The 2DUHR source was deployed from the MV Fugro Seeker and comprised a GAMBAS gun array, Innomar SBP, RESON MBES, and EdgeTech SSS. Table 2.2 provides equipment details.

Table 2.2: 2DUHR seismic equipment

Source	
Type	GAMBAS/ Refraction array
Tow depth	300 m
Shot point interval	0.250 ms
Pressure	95 to 110 bars
Source	
Type	Innomar SBP
Frequency	85 - 115 kHz
Energy output (Max Energy output)	> 8 Kw
Source	

Source	
Type	RESON 7125 multibeam echosounder system
Source	
Type	EdgeTech 4200 side scan sonar
Frequency	300/600 kHz

2.3 Fugro Searcher

2.3.1 Two-dimensional Ultra High-Resolution Equipment

The 2DUHR survey comprised 41 main lines and 21 cross lines. The 2DUHR sources were deployed from the MV Fugro Searcher and comprised a 3-deck sparker, an Innomar SBP. Table 2.3 provides equipment details.

Table 2.3: 2DUHR equipment

Source	
Type	Sparker
Energy output (Max Energy output)	900 joules
Shot point interval	1 m
Tow depth	Top deck = 0.72 m Mid deck = 0.87 m Bottom deck = 1.12 m
Source	
Type	Innomar SBP
Frequency	85 - 115 kHz
Energy output (Max Energy output)	>8 Kw
Source	
Type	EdgeTech 4200 side scan sonar
Frequency	300/600 kHz
Source	
Type	Hull mounted Kongsberg dual-head EM 2040
Frequency	0.4° at 400 kHz)

3. Methods

3.1 Pre-shooting Searches

Under the guidelines, operators must check for the presence of marine mammals within 500 m of the sound source for at least 30 minutes (60 minutes in waters greater than 200 m depth) prior to starting geophysical operations. Surveying should be delayed by at least 20 minutes if marine mammals are present within 500 m of the sound source to allow animals time to move out of the area. Water depths in the survey area were less than 200 m therefore pre-shooting searches were undertaken for at least 30 minutes.

3.2 Acoustic Deterrent Device

The use of the ADD was required on the MV Fugro Searcher and MV Fugro Discovery after the first 20 mins of pre-watch was completed for a total of 10 minutes prior to the commencement of a soft start. The ADD was required for the start of the project and any time in which the source had been inactive for more than 90 minutes.

The device was required by the client to be activated for a minimum of five minutes. For this project the ADD was run for 10 minutes before the start of a soft start to allow for discrepancies in timings caused by factors such as strong currents.

3.3 Survey Soft Start

The JNCC guidelines require a soft start procedure be undertaken prior to use of the airguns at full power. Power should be built up slowly from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding others) over 20 minutes to give adequate time for marine mammals to leave the area. This build-up of power should occur in uniform stages to provide a constant increase in output. Once the soft start has been performed and the airguns are at full power, the survey line should start immediately. Operators should avoid unnecessary firing at full power.

The soft start procedure onboard the MV Fugro Searcher was programmed to start with one deck of the Sparker being fired for 10 minutes, the second deck being added for a further 10 minutes, with the final deck being added in at 20 minutes. The Innomar chirp required a soft start with 5 minutes firing at 20 % full power, 5 minutes firing at 40 % full power, 5 minutes firing at a 75 % full power, 5 minutes firing between 75 % to 100 % full power, then firing at 100 % full power at the start of line.

The soft start procedure onboard the MV Fugro Seeker for the 2DUHR was 20 minutes with an increasing shot point interval. The soft start for the SBP was 20 minutes with a gradual increase in power. No soft start procedure was possible for the GAMBAS/Refraction Seismic equipment as it did not have the capacity to allow a ‘ramp up’ in power.

The soft start procedure onboard the MV Fugro Discovery for the SBP was 20 minutes with a gradual increase in power.

As the MV Normand Mermaid and MV Kommandor Orca were geotechnical operations only, soft starts were not applicable.

3.4 Survey Line Turns

Surveys utilising acoustic sources are treated as arrays less than 180 cubic inches in terms of mitigation guidelines. Therefore, the JNCC guidelines state that if the line change time is expected to be greater than 40 minutes, source firing should be terminated at the end of the line and a full soft start undertaken before the next line. To comply with these guidelines during the current survey, the source was stopped at the end of each line unless the line change was expected to take less than 40 minutes. During line changes expected to take less than 40 minutes, the power was decreased to the lowest setting then ramped up to full power before the start of the next line. If line turns were expected to be greater than 40 minutes, the noise source was shut down and a soft start was conducted before the next line.

3.5 Marine Mammal and Avifauna Observations

During daylight hours, faunal observations were conducted from the bridge on board the MV Fugro Searcher, MV Kommandor Orca, MV Normand Mermaid, and MV Fugro Discovery, ranging from 10.8 m to 21.3 m eye height above sea level. Observations were conducted from the back deck and wheelhouse onboard the MV Fugro Seeker. Non-dedicated MMO was undertaken on the MV Fugro Seeker. Consequently, sightings may have been missed. Dedicated MMO were undertaken onboard all other vessels. During hours of darkness or poor visibility, PAM was undertaken as a suitable alternative to marine mammal observation. Table 3.1 presents details of the MMOs and PAM operators for each vessel.

Table 3.1: Marine mammal/passive acoustic monitoring operator experience for each vessel

Name	Training	Level of Experience
Discovery		
[redacted]	JNCC approved MMO training course for UK waters Seiche PAM course	10 MMO surveys 10 PAM surveys
[redacted]	BOEM PSO training course JNCC PAM course BIOSONAR PAM refresher course	2 MMO surveys 3 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters BOEM PSO training course Seiche PAM course	21 MMO surveys 2 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters BOEM PSO training course NMFS approved PSO training course Seiche PAM course	18 MMO surveys 17 PAM surveys
Seeker		
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
Searcher		
[redacted]	JNCC approved MMO training course for UK waters PSO Training Seiche PAM course MSeis PAM Course	45 MMO surveys 29 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters PSO Training Seiche PAM course	43 MMO surveys 41 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters Seiche PAM course	18 MMO surveys 14 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters Seiche PAM course	3 MMO surveys 1 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	1 MMO survey
[redacted]	JNCC approved MMO training course for UK waters	13 MMO surveys 7 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters Seiche PAM course	16 MMO surveys 4 PAM surveys

Name	Training	Level of Experience
[redacted]	JNCC approved MMO training course for UK waters Seiche PAM course	6 MMO surveys 4 PAM surveys
Kommandor Orca		
[redacted]	JNCC approved MMO training course for UK waters Marine Team PAM course	16 MMO surveys 10 PAM surveys
Norman Mermaid		
[redacted]	JNCC approved MMO training course for UK waters Marine Team PAM course	16 MMO surveys 10 PAM surveys
[redacted]	JNCC approved MMO training course for UK waters PSO training Australian legal MFO course MMO and PAM certificate Seiche PAM course	52 MMO surveys 11 PAM surveys
Notes BOEM = Bureau of Ocean Energy Management JNCC = Joint Nature Conservation Committee MFO = Marine Fauna Observer MMO = Marine mammal observers PAM = Passive acoustic monitoring PSO = Protected species observer		

The primary observation technique used to spot marine mammals was to scan the sea ahead of, and within, the mitigation zone. The sea was scanned using the naked eye and with binoculars (8 × 42 onboard the MV Kommandor Orca and MV Normand Mermaid phase 1; 7 × 50 onboard MV Normand Mermaid phase 2, MV Fugro Searcher, MV Fugro Seeker, and MV Fugro Discovery). Areas of interest on the water (e.g. waves going against the prevailing direction, white water during calm periods, dark shapes, splashes, bird activity, etc.) were used as visual cues. When fauna were observed, the distance to the sighting was estimated using a rangefinder stick. Appendix B presents the completed JNCC recording forms.

Species identification was based on observer experience and with reference to Shirihai and Jarrett (2006). Whenever possible, photographs of sightings were captured to aid identification (Appendix C).

Avifauna observations were conducted in the same method as the marine mammal observations. The details of the avifaunal sightings were recorded on forms based on the European Seabirds at Sea (ESAS) recording forms with details such as species age (where identifiable), plumage, height above sea level and direction of travel from birds in flight, and distance banding from vessel to birds on the water (designated by letter, increasing the further the bird is from the vessel path).

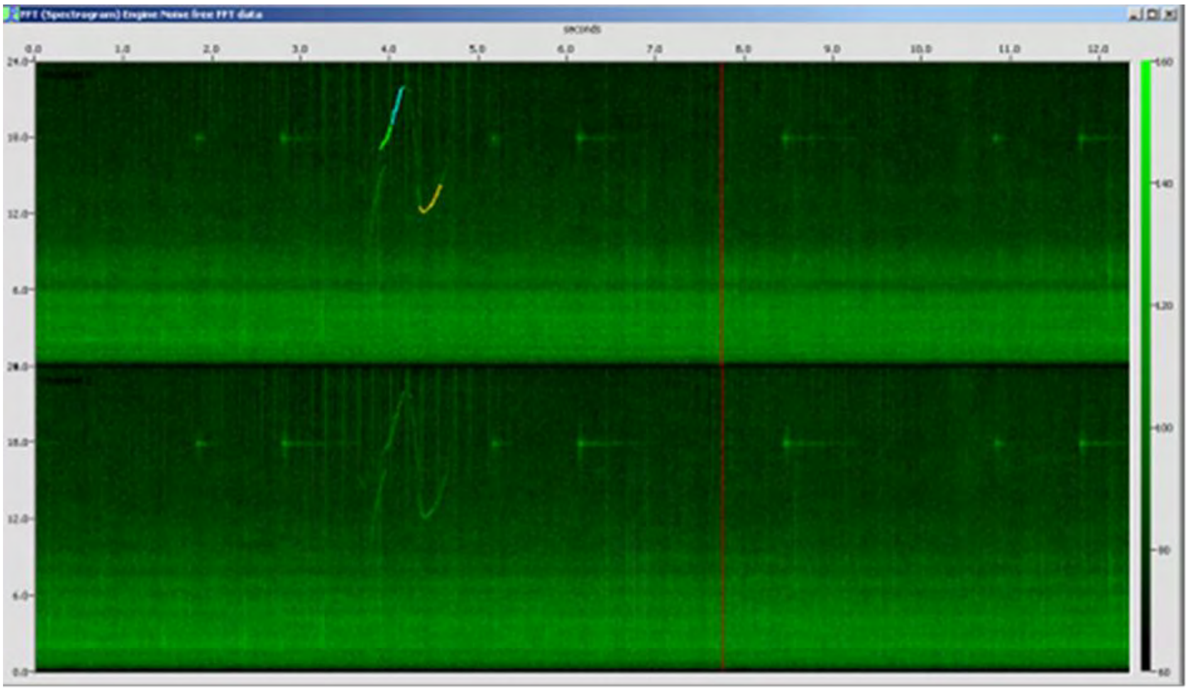
3.6 Passive Acoustic Monitoring Operations

PAM operations were conducted from the instrument room on the MV Fugro Searcher and MV Fugro Discovery, allowing instant communications with navigation surveyors if marine mammals were detected.

The system comprised a towed array of four hydrophones, deck cable, and electronics processing unit containing an audio output unit. The towed cable consisted of a 250 m umbilical with four built-in hydrophones and a depth transducer. A 100 m deck lead interfaces the array with the acquisition unit. The deck cable connected directly to the amp buffer box from which XLR cables fed the four channels from the four elements to a Fireface 800 soundcard (low and medium frequencies) to be digitised and used by PAMGuard. Additional filtering options for aural monitoring were possible using the Ultralink Pro mixer and Ultra-Curve Pro equalizer. Inside the bufferbox, channels from hydrophones 0 and 3 fed into a National Instruments DAQ card USB-6251 to yield the high frequency signals.

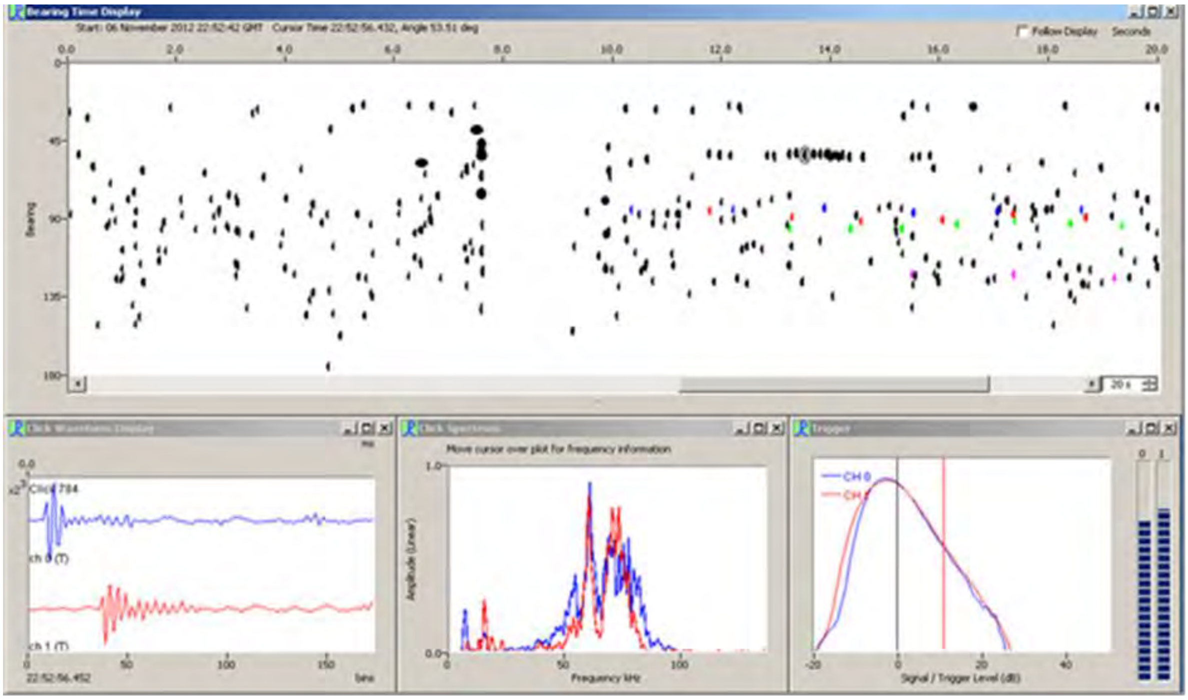
PAMGuard is open-source PAM software that consolidates existing PAM software functionality within a single application. PAMGuard version 2.02.03b was utilised as the primary user interface software during the current project with two output monitors. One screen was configured to display medium frequency (Figure 3.1) with the second screen configured to display high frequency signals using a click detector module and sound recorder (Figure 3.2).

The PAM operators listened to the audio signal while simultaneously interpreting the output of PAMGuard. Click and whistle detections would be plotted on a map display showing the relative positions of the vessel, the sound source, and the 500 m mitigation zone. Sound recordings and screen grabs of the display would be made during acoustic contacts. Judgement on whether a vocalising marine mammal had entered the 500 m mitigation zone would be done using a combination of the map display; a radar display, which allowed localisation and bearing calculation of the click and whistle detector functions, either by tracing signal amplitude relative to vessel or by tracking click trains or localised whistles; and the PAM operator’s aural interpretation of the amplitude of the received signals. All of which could be calibrated using distance estimates of coincident sightings if any occurred.



Two hydrophone channels are displayed on a rolling spectrogram; time(s) is displayed along the top, frequency (kHz) along the left-hand side and amplitude (dB) on the right-hand scale bar. A single whistle and several clicks can be seen between 3 and 5 seconds. The horizontal lines displayed at 18 kHz are produced by the vessel's echo sounder

Figure 3.1: Example medium frequency spectrogram display



The upper box displays each click as a circle or ellipse on the scrolling display as it is detected. Time is displayed along the top and bearing from the hydrophones on the left-hand side. The lower left-hand and centre boxes display the waveform and frequency spectrum of a click as it is detected or when a click is manually selected. In the example above, a click train can be identified between 12 and 15 seconds at a bearing of approximately 53°, a click within this train has been manually selected (circled)

Figure 3.2: Example high frequency click detector display

4. Results

4.1 Observer Effort and Conditions

The onboard observers carried out watches for marine mammals and birds within and adjacent to the 500 m mitigation zone prior to the commencement of, and during, geophysical operations. PAM operations took place during hours of darkness and low visibility. Table 4.1 presents the survey statistics that took place as mitigation procedures during the geophysical phase of the survey, and biodiversity effort that took place over the whole survey period.

As mitigation methods, the MMOs undertook 606 hours and 5 minutes of visual monitoring, and the PAM operators undertook 634 hours and 5 minutes of acoustic monitoring.

As biodiversity observations, the MMOs undertook 1005 hours 11 minutes of visual monitoring, and the PAM operators undertook 658 hours 31 minutes of acoustic monitoring.

Table 4.1: Geophysical survey statistics

Survey timings	
Total number of lines (including partial and rerun lines)	748
Total number of soft starts	145
Average length of completed soft start	19 minutes 21 seconds
Number of gun tests	3
Number of line turns (source active)	267
Average length of line turn (source active)	22 minutes 56 seconds
Mitigation	
Total MMO effort	606 hours and 5 minutes
Total PAM effort	634 hours and 5 minutes
Total number of mammal sightings	3
Total number of mammal detections	0
Number of delays to soft starts	1
Total standby time for marine mammals	30 mins
Incidences of non-compliance	0
Biodiversity Observation	
Total MMO effort	1005 hours 11 minutes
Total PAM effort	658 hours 31 minutes
Total number of mammal and avifauna sightings	11334
Total number of mammal detections	0

Prevailing sea conditions affect the ability of an observer to detect cetaceans (Stone, 2000), with sighting rates increasing as sea state and swell decreases and as visibility increases (Stone, 2003). Weather conditions varied slightly during the survey. During the survey, swell was low (less than 2 m), sea state was choppy (many white caps), and wind force ranged from Beaufort force 1 to 9. Figure 4.1 presents the environmental conditions recorded during marine mammal monitoring on the survey. During daylight hours, visibility was predominantly good (greater than 5 km).

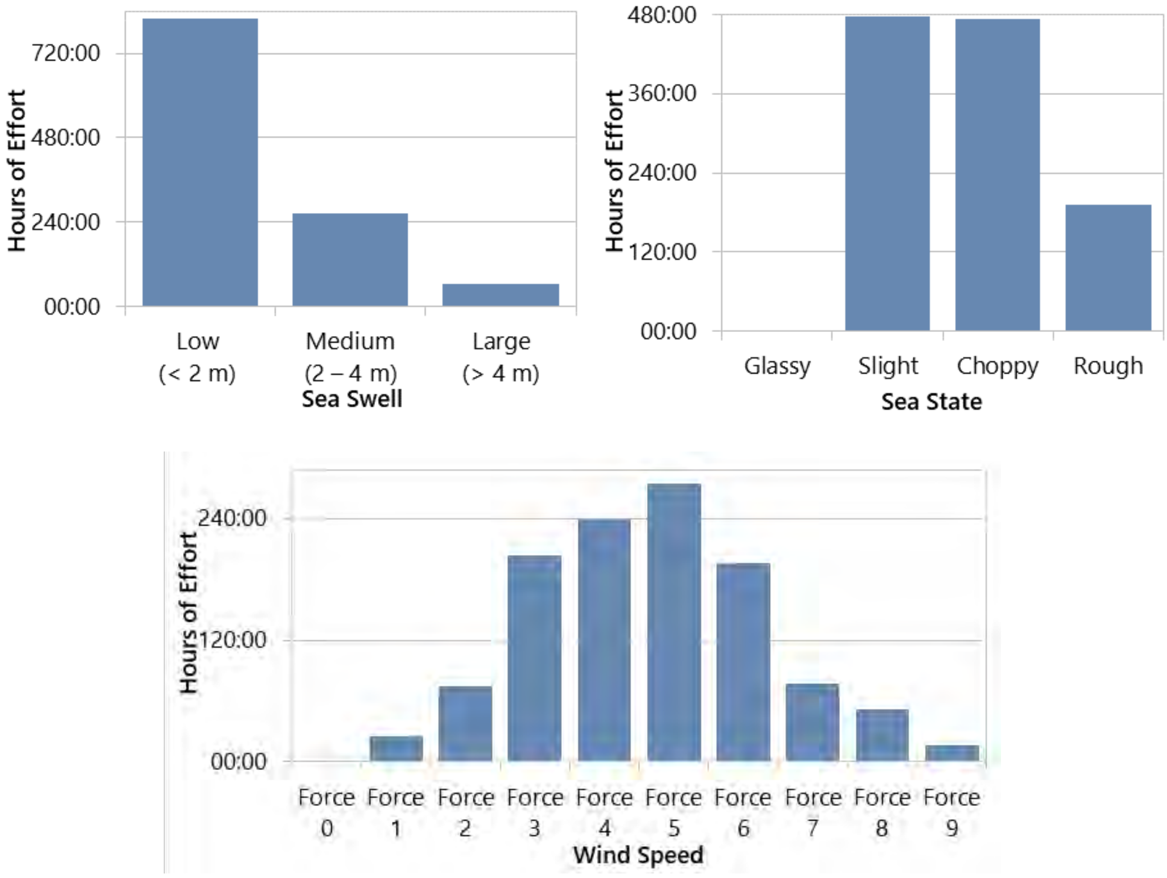


Figure 4.1: Environmental conditions

4.2 Compliance with the Guidelines

All pre-shooting searches were carried out for 30 minutes. There were two occasions when these pre-shooting searches were less than 30 minutes; both instances where onboard the MV Fugro Searcher. During the first occasion, there was a one minute break in the pre-watch period, meaning a full 30 minute pre-watch period was not completed. During the second instance, pre-watch was only carried out for 18 minutes due to a miscalculation of equipment timings.

All but 12 soft starts were conducted in accordance with the guidelines and complied with the consent. Detail of the 12 short soft starts are listed below:

- Eight were onboard the MV Fugro Seeker during the GAMBAS/Refraction Seismic procedures, where no soft start procedure was possible as the equipment does not have a 'ramp up' facility;
- One took place on the MV Fugro Seeker during the UHR seismic survey lasting 17 minutes;
- Two were onboard the MV Fugro Discovery, where the first lasted 15 minutes and the second lasted 12 minutes, due to line plan changes;
- One took place on the MV Fugro Searcher lasting 19 minutes, due to weather disruption.

There were 267 instances when line turns were implemented. There were 15 instances when the line turn was longer than 40 minutes while the source was still active, which all took place onboard the MV Fugro Searcher. Long turns lasted between 42 minutes and 2 hours 23 minutes. Reasons for long line turns include change in next line location and for safety of equipment such as to avoid buoys.

There were 15 instances when time between end of soft start and start of line was not immediate. These occurred on the MV Fugro Seeker and MV Fugro Searcher and ranged from 9 minutes to 48 minutes. Reasons for the delayed start of line included technical issues with equipment.

4.3 Marine Mammal Sightings and Detections

During the geophysical survey, there was a total of one marine mammal sighting made, onboard the MV Fugro Seeker, during visual observations and no passive acoustic detections. Table 4.2 provides a summary of the sighting.

Table 4.2: Summary of marine mammal sightings and acoustic detections

Date	Species	No. of Individuals	Activity/ Behaviour	Distance to Source [m]	Source Activity	Mitigation Required
11/10/2022	Unidentified seal (Pinnipedia)	1	Raised head then submerged	50	Inactive	Delay start of firing

4.4 Application of Mitigation Procedures

It was necessary to delay a soft start on one occasion due to the presence of marine mammals. This accounted for a total of 30 minutes of standby time.

4.5 Biodiversity Overview

Throughout the total duration of the survey period, the MMOs undertook 1005 hours and 11 minutes of visual observation. There was a total of seven marine mammal sightings and 11 327 avifauna sightings. Appendix C displays example photographs of marine fauna sightings.

Table 4.3 provides an overview of the sightings and detections from each faunal group.

Table 4.3: Summary of marine mammal and avifauna sightings

Species	No. of sightings	Number of Individuals*	IUCN Red List Status
Mammals			
Harbour porpoise (*Phocoena phocoena*)	3	3	Least Concern
Common seal (*Phoca vitulina*)	1	1	Least Concern
Unidentified seal (Pinnipeds)	1	1	-
Grey Seal (*Halichoerus grypus*)	2	2	Least Concern
Total Mammal Sightings	7	7	
Avifauna			
Auk (Alcidae)	205	498	-
Bewick's swan (*Cygnus columbianus*)	1	12	Least Concern
Black Headed gull (*Chroicocephalus ridibundus*)	62	142	Least Concern
Blackbird (*Turdus merula*)	4	4	Least Concern
Black-headed gull (*Chroicocephalus ridibundus*)	67	112	Least Concern
Black-legged kittiwake (*Rissa tridactyla*)	262	388	Vulnerable
Brambling (*Fringilla montifringilla*)	2	7	Least Concern
Brent goose (*Branta bernicla*)	1	2	Least Concern
Brown booby (*Sula leucogaster*)	1	1	Least Concern
Carrion crow (*Corvus corone*)	1	1	Least Concern
Chaffinch (*Fringilla coelebs*)	1	1	Least Concern
Common eider (*Somateria mollissima*)	2	2	Least Concern
Common gull (*Larus canus*)	1	2	-
Common scoter (*Melanitta nigra*)	322	660	Least Concern
Common shelduck (*Tadorna tadorna*)	3	17	Least Concern
Cormorant (Phalacrocoracidae)	1	6	-
Diver (Gaviidae)	59	410	-
Dove (Columbidae)	1	1	-
Duck (Anatidae)	14	57	-
Eurasian blackcap (*Sylvia atricapilla*)	1	13	Least Concern

Species	No. of sightings	Number of Individuals*	IUCN Red List Status
Eurasian wigeon (*Mareca Penelope*)	1	34	Least Concern
Eurasian woodcock (*Scolopax rusticola*)	1	1	Least Concern
European shag (*Phalacrocorax aristotelis*)	1	4	Least Concern
European starling (*Sturnus vulgaris*)	1	1	Least Concern
Feral pigeon (*Columba livia domestica*)	1	1	Least Concern
Finch (Fringillidae)	1	1	-
Flycatcher (Muscicapidae)	1	1	-
Fulmar (*Fulmarus*)	4	6	-
Gannet (*Morus*)	1	1	-
Goldcrest (*Regulus regulus*)	1	1	Least Concern
Goose (Anatidae)	11	69	-
Great black-backed gull (*Larus marinus*)	188	258	Least Concern
Great cormorant (*Phalacrocorax carbo*)	39	319	Least Concern
Great crested Grebe (*Podiceps cristatus*)	1	2	Least Concern
Great skua (*Stercorarius skua*)	1	1	Least Concern
Grebe (Podicipedidae)	7	28	-
Guillemot (*Uria aalge*)	249	560	Least Concern
Gull (Laridae)	1244	2627	-
Herring Gull (*Larus argentatus*)	309	495	Least Concern
Kittiwake (*Rissa*)	393	2934	-
Lesser black-backed gull (*Larus fuscus*)	67	162	Least Concern
Little auk (*Alle alle*)	19	40	Least Concern
Little gull (*Hydrocoloeus minutus*)	7	26	Least Concern
Northern gannet (*Morus bassanus*)	429	607	Least Concern
Passerine (Passeriformes)	66	362	-
Phalacrocorax (Phalacrocorax)	1	1	-
Pipit (*Anthus*)	2	3	-
Razorbill (*Alca torda*)	70	154	Least Concern
Reed bunting (*Emberiza schoeniclus*)	1	1	Least Concern
Robin (*Erithacus rubecula)*	1	1	Least Concern
Shearwater (Procellariidae)	7	9	-
Short-eared owl (*Asio flammeus*)	1	1	Least Concern
Skua (Stercorariidae)	4	4	-
Slender-billed gull (*Chroicocephalus genei*)	1	2	Least Concern
Starling (*Sturnus vulgaris*)	3	8	Least Concern
Tern (Sternidae)	3	6	-
Tundra swan (*Cygnus columbianus*)	1	5	Least Concern
Thrush (Turdidae)	1	1	-
Wader (Charadriiformes)	3	4	-
Warbler (Parulidae)	2	1	-

Species	No. of sightings	Number of Individuals*	IUCN Red List Status
Wren (Troglodytidae)	2	2	-
Unidentified bird (Aves)	43	247	-
Total Avifauna Sightings	**11327**	**4200**	

Notes
IUCN = International Union for Conservation of Nature
* = Number of individuals is the best estimate from animals seen on the surface

The limited duration of the survey works means that data collected should only be considered a seasonal 'snapshot' of the fauna communities that use these survey areas.

4.5.1 Marine Mammals

The most common marine mammal species observed throughout the survey period was the Harbour porpoise (*Phocoena phocoena*), with three individuals sighted. Other species observed included two grey seals (*Halichoerus grypus*), and one common seal (*Phoca vitulina*).

Although the harbour porpoise is listed in Annex II of the European Commission's (EC) Habitats Directive and is a protected species in the North Sea Coastal Zone SAC, Vlakte van de Raan SAC, Dogger Bank SAC, anD Clover Bank SAC, it is the most abundant cetacean in the North Sea and listed as 'Least Concern' on the IUCN red list.

Grey seals spend much of their time ashore in the pupping and moulting seasons from September through to April (Hammond et al., 2001), which can explain the limited sightings during the current survey. Grey seals are also classified as 'Least Concern' on the IUCN red list.

Common seals (or harbour seals) are the most abundant seal species in the Wadden Sea, with key locations for haul out sites located on the North Sea Coastal Zone and delta areas in the south-west of the coast. They are also classified as 'Least Concern' on the IUCN red list.

Grey Seals and common seals are also listed Annex II of the EC Habitats Directive and are protected species in the North Sea Coastal Zone SAC, Vlakte van de Raan SAC, Dogger Bank SAC, and Clover Bank SAC.

All mammal sightings were within 5 km of the coastline (Figure 4.2).

4.5.2 Birds

Seabirds are protected under the EU Birds Directive, requiring the conservation of habitats in a way that allows birds to breed, moult, migrate, and overwinter. The Dutch Continental Shelf of the North Sea is home to an ecologically diverse avian community that fluctuates in number and composition throughout the year (Fijn et al., 2018; Camphuysen & Leopold 1994) and utilises the intertidal, coastal, and pelagic areas to roost and forage (van Erp et al., 2021).

The most commonly observed avifauna were kittiwakes (Rissa) with 2934 individuals sighted, followed by unidentified gulls (Laridae), with 2627 individuals sighted, and common scoters (*Melanitta nigra*), with 660 individuals sighted.

This is in agreement with the desk top study that observed that large gulls such as herring gulls and common gulls were the most common species sighted throughout the year. Kittiwakes were frequently reported during the winter season.

Black-legged kittiwakes (*Rissa tridactyla*) were observed on multiple vessels during the survey. The black-legged kittiwake is listed as 'vulnerable', meaning that they are considered to be at high risk of unnatural (human-caused) extinction without further human intervention. The over-exploitation of fisheries (BirdLife International, 2019) has been targeted with increasing the risk to the populations. Black-legged kittiwake distribution during the current survey is shown in Figure 4.3.

Although the common scoter is listed as a species of 'Least Concern' on the IUCN red list, Skov et al. (1995) noted that they, along with several other species, occur in internationally important numbers along the Dutch coast, highlighting the importance of the Dutch coastal zone in general to seabirds.

Birds were recorded over the entire survey area. Figure 4.3 shows the distribution of avifauna sightings.

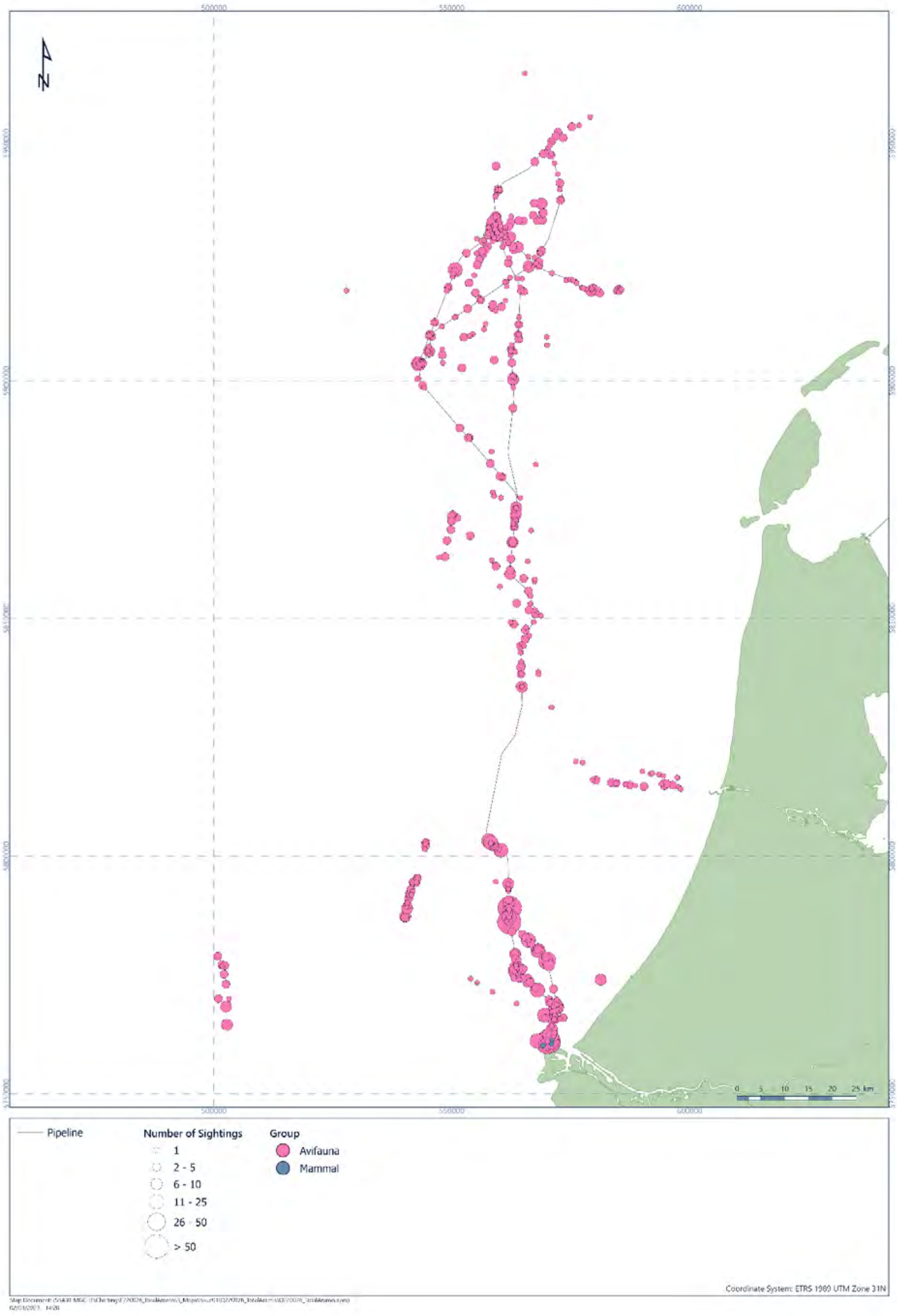


Figure 4.2: Distribution of mammal and avifauna sightings

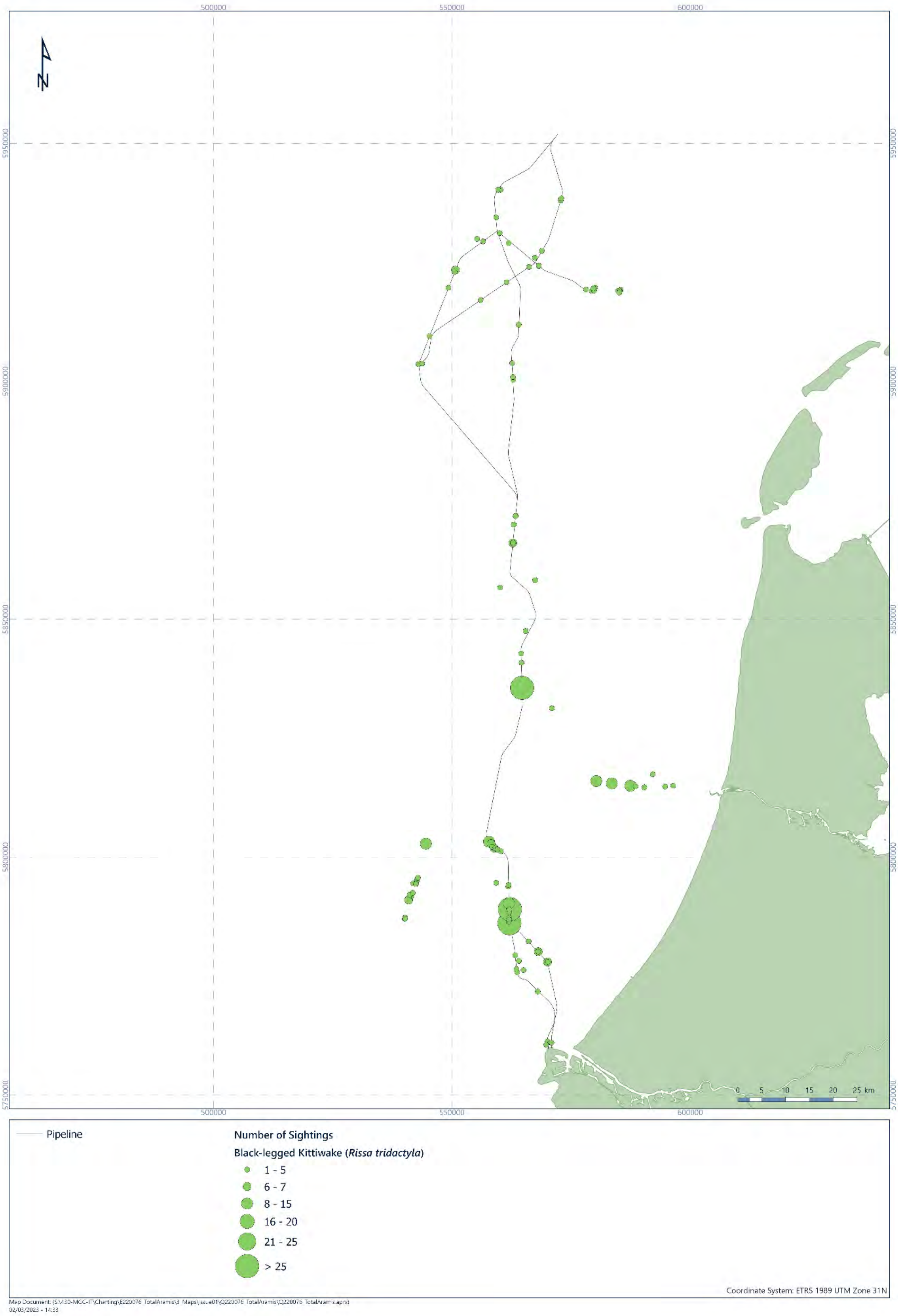


Figure 4.3: Distribution of Black-legged Kittiwake (*Rissa tridactyla*)

5. References

BirdLife International. 2019. Rissa tridactyla (amended version of 2018 assessment). The IUCN Red List of Threatened Species 2019: e.T22694497A155617539. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22694497A155617539.en

Camphuysen, C.J. & Leopold, M.F. (1994). *Atlas of seabirds in the southern North Sea. IBN Research report 94/6* (NIOZ Report 1994-8). Institute for Forestry and Nature Research, Netherlands Institute for Sea Research and Dutch Seabird Group, Texel.

Fijn, R.C., Arts, F.A., de Jong, J.W., Beuker, D., Bravo Rebolledo, E.L., Engels, B.W.R., Hoekstein, M.S.J., Jonkvorst, R.J., Lilipaly, S., Sluijter, M., van Straalen, K.D., Wolf, P.A. (2018). *Verspreiding en abundantie van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat 2017–2018*. Bureau Waardenburg & Delta Project Management, Culemborg. https://puc.overheid.nl/rijkswaterstaat/doc/PUC_154358_31/

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N. (2001). Abundance of the harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology, 39*(2), 361-376. https://doi.org/10.1046/j.1365-2664.2002.00713.x

IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org

Joint Nature Conservation Committee [JNCC]. (2017). *JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys*. JNCC.

Fugro, (2022). Environmental Desk Top Study (Fugro Report No F197217-REP-ENV-001 01). January 2023

Oslo and Paris Commission [OSPAR]. (2008). OSPAR list of threatened and/or declining species and habitats (Reference Number 2008-06). OSPAR Commission.

Shirihai, H. & Jarret, B. (2006). *Whales, dolphins and seals: A field guide to the marine mammals of the World*. A&C Black Publishers.

Skov, H., Durinck, J., Leopold, M.F. & Tasker ,M.L. (1995). *Important bird areas in the North Sea, including the Channel and the Kattegat*. BirdLife International, Cambridge.

Stone, C.J. (2000). *Cetacean observations during seismic surveys in 1998* (JNCC Report No. 301). JNCC.

Stone, C.J. (2003). *The effects of seismic activity on marine mammals in UK waters, 1998-2000* (JNCC Report No. 323). JNCC.

van Erp, J.A., van Loon, E.E., Camphuysen, K.J. (2021). Temporal patterns in offshore bird abundance during the breeding season at the Dutch North Sea coast. *Marine Biology, 168*, 150. https://doi.org/10.1007/s00227-021-03954-4

Appendix A

Guidelines on Use of Report

Appendix B

Logs

Click icon to open the completed bird sighting logs.

220076_Fugro Searcher

220076 Kommandor Orca

220076 Normand Mermaid

220076 Normand Mermaid_phase 2

220076 Fugro Seeker

Appendix C

Sample Sightings Photographs

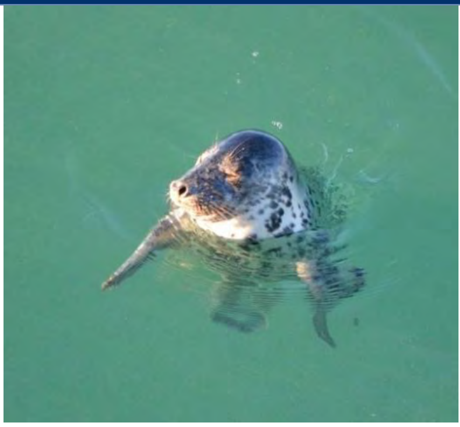
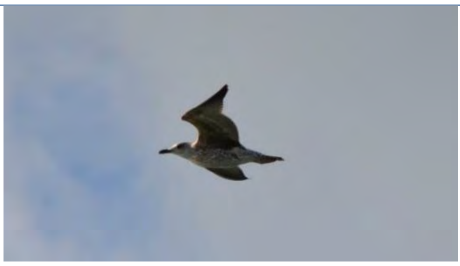
Image	Common Name/Species	Comments
Searcher		
Mammals		
	Grey seal (*Halichoerus grypus*)	Surfaced near to vessel, swam over to vessel, and investigated the hull before diving and swimming away
Avifauna		
	Great black back gull (*Larus marinus*)	
	Guillemot (Alcidae)	
	Gull (Laridae)	

Image	Common Name/Species	Comments
	Northern Gannet (*Morus bassanus*)	
	Auk (Alcidae)	
	Lesser black backed gull (*Larus fuscus*)	
	Herring gull (*Larus argentatus*)	
	Grebe (Podicipedidae)	

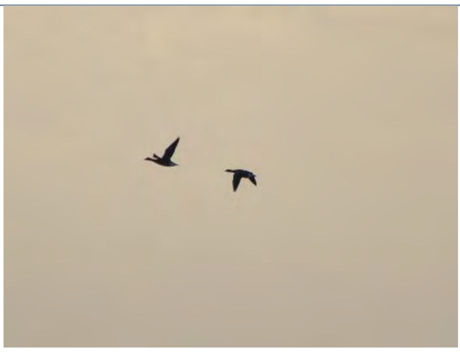
Image	Common Name/Species	Comments
	Great cormorant (*Phalacrocorax carbo*)	
	Brent goose (*Branta bernicla*)	
	Tern (Sternidae)	
	Skua (Stercorariidae)	
	Razorbill (*Alca torda*)	

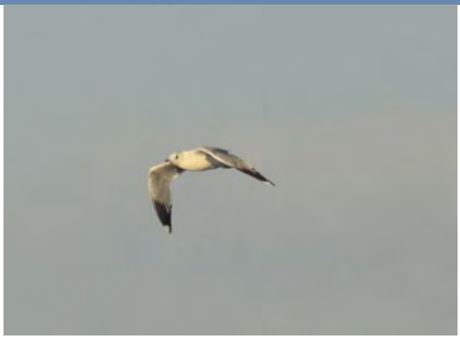
Image	Common Name/Species	Comments
	Kittiwake (*Rissa*)	
	Pipit (*Anthus*)	
	Passerine (Passeriformes)	
	Brambling (*Fringilla montifringilla*)	

Image	Common Name/Species	Comments
	Starling (Sturnidae)	
	Goose (Anatidae)	
	European shag (*Phalacrocorax aristotelis*)	
	Brown booby (*Sula leucogaster*)	
	Little Auk (*Alle alle*)	

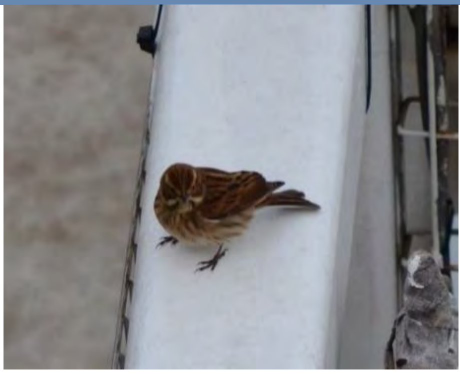
Image	Common Name/Species	Comments
	Reed bunting (*Emberiza schoeniclus*)	
	Unidentified warbler (Parulidae)	
	Chaffinch (*Fringilla coelebs*)	
	Robin (*Erithacus rubecula*)	

Image	Common Name/Species	Comments
	Blackcap (*Sylvia atricapilla*)	
	Short-eared owl (*Asio flammeus*)	
	Common scooter (*Melanitta nigra*)	
	Slender-billed gull (*Chroicocephalus genei*)	
	Flycatcher (Muscicapidae)	

Image	Common Name/Species	Comments
	Unidentified duck (Anatidae)	
	Eurasian woodcock (*Scolopax rusticola*)	
	Tundra swan (*Cygnus columbianus*)	
	Fulmar (*Fulmarus*)	
	Eurasian wigeon (*Mareca penelope*)	

Image	Common Name/Species	Comments
	Common eider (*Somateria mollissima*)	
	Great crested grebe (*Podiceps cristatus*)	
Seeker		
No sightings		
Discovery		
Mammals		
No sightings		
Avifauna		
	Starlings (*Sturnus vulgaris*)	
	Ducks (Anatidae)	

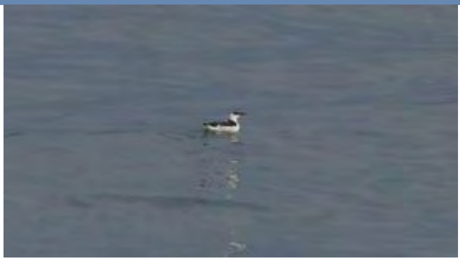
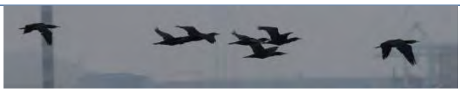
Image	Common Name/Species	Comments
	Guillemot (Alcidae)	
	Gull (Lari)	
	Northern gannet (*Morus bassanus*)	
	Pipit (*Anthus*)	
Kommandor Orca		
Cetaceans		
No sightings		
Pinnipeds		
No sightings		
Avifauna		

Image	Common Name/Species	Comments
	Blackbird (*Turdus merula*)	
	Woodcock (Scolopacidae)	
	Little Auk (*Alle alle*)	
Normand Mermaid		
Cetaceans		
No sightings		
Pinnipeds		
No sightings		
Avifauna		
	Paserine (Passeriformes)	

Image	Common Name/Species	Comments
	Northern Gannet (*Morus bassanus*)	
	Cormorant (Phalacrocoracidae)	
	Black-headed gull (*Chroicocephalus ridibundus*)	