RAPPORT

Aanvraag Mbb-vergunning pijpleiding en kabel op zee inclusief mededeling voornemen ten behoeve van mer-beoordeling

Shell - Verbindingsleiding van de zeeleiding naar platform K14-FA-2

Klant: Shell Gas & Power Development B.V.

Referentie: ARM-PFE-B10-ENV-EIA-2039

Status: Definitief/02

Datum: 19 september 2024

ARAMIS	**CCS-ARAMIS Project**	
	Environment Impact Assessment – Baseline report	
	Document No.	ARM-PFE-B10-ENV-EIA-2039
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Classificatie
Projectgerelateerd

Inhoud

Bijlagen

1 Inleiding

Een consortium onder de naam Aramis wil een CO_2-transportinfrastructuur ontwikkelen om koolstofdioxide (CO_2) geproduceerd op land op te slaan in lege offshore gasvelden. Een belangrijk onderdeel van deze infrastructuur is de hoofdtransportleiding (zeeleiding) waarmee de CO_2 vanaf de Maasvlakte richting de gasvelden wordt getransporteerd. Vanaf aftakkingen (inline Ts, hierna: ILT) en het eindpunt van deze zeeleiding, het zogenaamde distributieplatform, transporteren meerdere verbindingsleidingen CO_2 naar platforms, vanwaar de CO_2 in leeggeproduceerde gasvelden onder de zeebodem wordt geïnjecteerd en daar permanent wordt opgeslagen. Naar dit geheel van activiteiten zal worden verwezen als het Aramis initiatief, waarin verschillende partijen samenwerken.

De infrastructuur vanaf de aftakkingen en het distributieplatform wordt door individuele partijen ingevuld. In dit kader vraagt Shell aan het Ministerie van Klimaat en Groene Groei (hierna: KGG) toestemming voor de aanleg van een verbindingsleiding vanaf een T-stuk op de zeeleiding (onderzees aftakpunt of inline-T (ILT)) naar het K-14-FA-2-platform in de Noordzee. Voorliggend document betreft een tweeledige aanvraag: er wordt een vergunning in het kader van artikel 94 van het Mijnbouwbesluit (hierna: Mbb) voor het aanleggen van een pijpleiding (verbindingsleiding) in de exclusieve economische zone (EZ) aangevraagd, alsook een vergunning in het kader van artikel 106 van het Mbb voor het aanleggen van een onderzeese umbilical. Een umbilcal is een bundel van kabels en kleine leidingen in dit geval voor de bediening van een afsluiterstation en wordt hierna kabel genoemd. Deze kabel maakt het mogelijk de afsluiter op het afsluiterstation bij de ILT te bedienen.

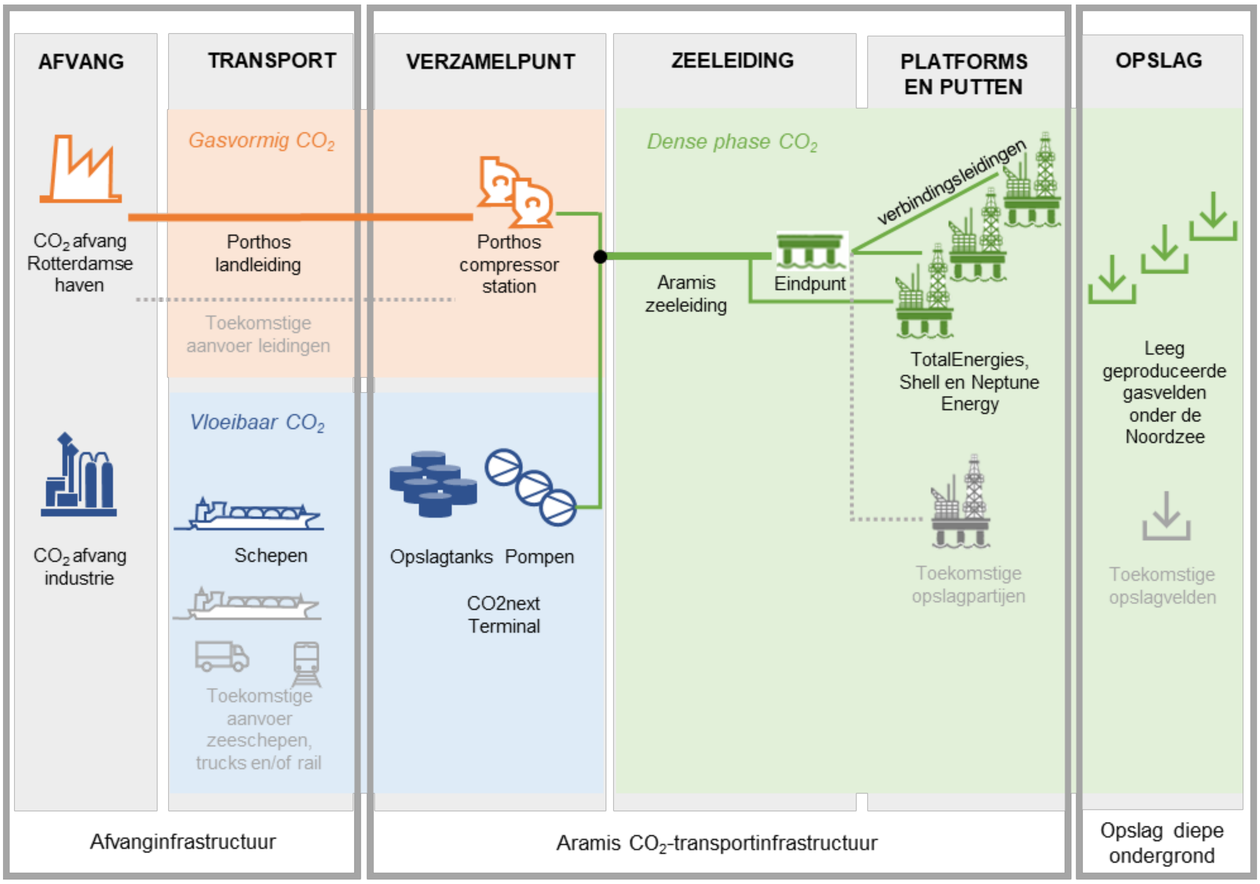
De aanleg en het in gebruik nemen van een dergelijke pijpleiding is mer-beoordelingsplichtig op grond van het Omgevingsbesluit (bijlage V, categorie J9). Het voorliggende document is naast de vergunningaanvraag in het kader van de Mbb ook de mededeling voornemen aan de hand waarvan bepaald kan worden of aanzienlijke milieueffecten kunnen optreden en of een milieueffectrapport (MER) opgesteld moet worden voor de CO_2-leiding[1]. De kabel is niet mer-(beoordelings)plichtig.

Doel

Het doel van het Aramis initiatief is ondergrondse opslag van door bedrijven afgevangen CO_2 in lege aardgasvelden op zee mogelijk maken. Het project draagt hiermee bij aan het reduceren van de emissies van broeikasgassen naar de atmosfeer en het project draagt daarmee bij aan het beperken van de opwarming van de aarde. Het afvangen en opslaan van CO_2 in de diepe ondergrond staat bekend als Carbon Capture and Storage (CCS). Met het Aramis initiatief wordt vanuit het Rotterdamse havengebied CCS-infrastructuur ontwikkeld. Deze bestaat onder andere uit een zeeleiding van ongeveer 230 km lengte, die een eerste (klein) deel over land loopt, dan onder de zeewering en Maasgeul doorgaat, en vervolgens over de zeebodem loopt. De zeeleiding transporteert CO_2 in vloeibare of superkritische staat (dense phase) naar een centraal distributieplatform op de Noordzee waarop operators kunnen aansluiten met een eigen verbindingsleiding. Op de Aramis zeeleiding worden ook T-stukken aangebracht zodat ook 'onderweg' aftakkingen naar afnemers worden gemaakt. Voor Shell geldt dat de verbindingsleiding CO_2 vanaf zo'n T-stuk naar het bestaande K-14-FA-2-platform van Shell transporteert. Vandaaruit wordt de CO_2 in het offshore gasveld K14-FA geïnjecteerd voor geologische opslag.

Figuur 1-1 geeft een overzicht van de nu geplande infrastructuur en de toekomstig mogelijke uitbreidingen.

[1] *De term mer staat voor milieueffectrapportage (procedure). Het MER is het milieueffectrapport.*



Figuur 1-1. Overzicht van de integrale CCS-keten met daarin de componenten die onderdeel zijn van de voorgenomen activiteit, namelijk: de Aramis CO_2 transport- en opslaginfrastructuur.

Vergunningen

Op grond van artikel 94 van het Mbb is het verboden zonder vergunning van de minister van KGG een pijpleiding aan te leggen in de territoriale zee, op het continentaal plat, of in een ander gebied waarvoor op grond van het Besluit milieueffectrapportage het maken van een MER nodig is.
Op grond van artikel 106 van het Mbb is het verboden zonder vergunning van de minister van KGG een kabel aan te leggen in de territoriale zee, op het continentaal plat, of in een ander gebied waarvoor op grond van het Besluit milieueffectrapportage het maken van een MER nodig is.
Dit document omvat de vergunningaanvraag voor de leiding en kabel op grond van het Mbb.

MER

Op grond van artikel 16.43 en bijlage V van het Omgevingsbesluit is de aanleg van een buisleiding mer-plichtig of mer-beoordelingsplichtig, dat hangt af van de afmetingen van de buisleiding In het onderhavige geval geldt dat de afmetingen van de verbindingsleiding (zie paragraaf 3.3) niet zodanig zijn dat sprake is van een mer-plicht, maar van een mer-beoordelingsplicht.

De initiatiefnemer van een mer-beoordelingsplichtig project deelt zo spoedig mogelijk mee aan het bevoegd gezag dat hij een dergelijk project wil ondernemen. Artikel 11.10 van het Omgevingsbesluit gaat nader in op de inhoud van de mededeling voornemen. De initiatiefnemer moet rekening houden met de relevante criteria van bijlage III bij de Europese mer-richtlijn en, voor zover relevant, met de beschikbare resultaten van andere relevante beoordelingen van de milieueffecten. Bij de mededeling voornemen kan een beschrijving worden verstrekt van de kenmerken van het voorgenomen project en van de voorgenomen maatregelen om mogelijk aanzienlijke milieueffecten te vermijden of te voorkomen.

Het voorliggende document betreft naast de vergunningaanvraag ook de mededeling voornemen in het kader van de mer-beoordelingsplicht voor deze verbindingsleiding. Het bevat de benodigde informatie voor het bevoegde gezag om te bepalen of het opstellen van een MER al dan niet nodig is. Voor de verbindingsleiding betreft het alleen de beoordeling van een project en niet van een plan.

Overigens is relevant te vermelden dat het Aramis initiatief als geheel inclusief transportleidingen op land en op zee mer-plichtig is. Hiervoor is een gecombineerd plan- en project-MER opgesteld, voor respectievelijk het projectbesluit en de vereiste vergunningen (anders dan die voor de verbindingsleidingen). In dit gecombineerde plan- en project-MER zijn de effecten van de verbindingsleidingen als onderdeel van het gehele project ook al beschouwd.

De voorliggende mededeling voornemen richt zich op het effect van de verbindingsleiding in het bijzonder. Het gecombineerde plan- en project-MER voor het gehele Aramis initiatief zal tevens bij deze vergunningaanvraag worden gevoegd. Hiermee kan de bredere context van de verbindingsleiding en milieueffecten worden meegewogen in het besluit of het noodzakelijk is om de effecten van de verbindingsleiding in een project-MER in meer detail te onderzoeken.

Initiatiefnemer
De vergunning in het kader van het Mbb wordt aangevraagd door Shell. Met de deze aanvraag vraagt Shell vergunning aan voor de aanleg van de genoemde verbindingsleiding en kabel.

Planning
De verwachting is dat vanaf 2027 met de leiding- en kabelaanleg op zee kan worden aangevangen. De totale doorloop van aanleg neemt ongeveer een jaar in beslag. Vanaf 2028 kan begonnen worden met testen en het opstarten van de CO_2-transport en -opslag. Mocht er vertraging of beroep worden aangetekend tegen het ontwerpbesluit, het ontwerpprojectbesluit, of het MER, dan dient rekening gehouden te worden met een vertraging van één tot twee jaar. In dat geval wordt de start van CO_2-transport en -opslag verwacht vanaf 2029/2030. De ontwerplevensduur van de verbindingsleiding en kabel is 30 jaar.

1.1 Scope van de aanvraag

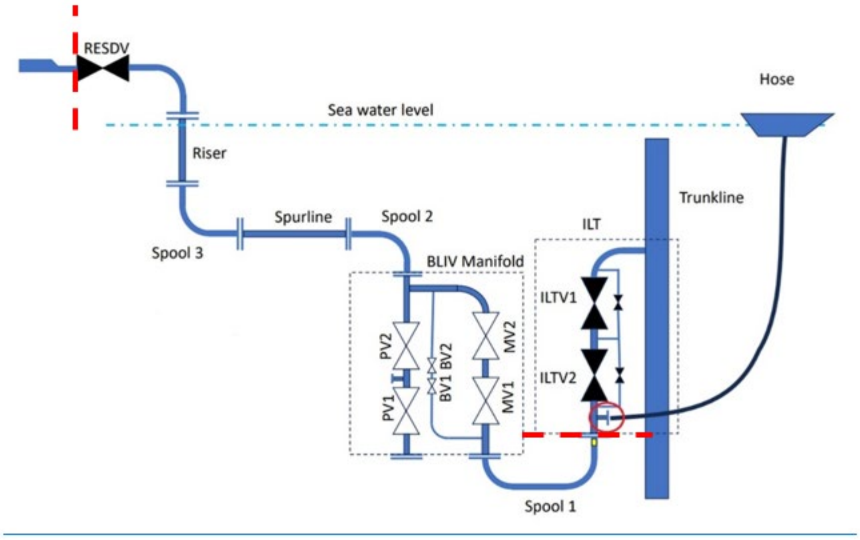
Deze aanvraag is opgesteld in het kader van de besluitvorming over de Mijnbouwvergunning voor de aanleg en ingebruikname van de verbindingsleiding voor het transport van CO_2 en de aanleg en ingebruikname van de kabel. De Mijnbouwvergunning wordt aangevraagd bij de Minister van KGG in het kader van artikel 94 van het Mijnbouwbesluit.

1.1.1 Scope verbindingsleiding

De omvang van de aanvraag voor de verbindingsleiding is als volgt.

Het beginpunt van de verbindingsleiding is de ILT op de Aramis zeeleiding.
- Het eindpunt van de verbindingsleiding is de automatische isolatieafsluiter op platform K-14-FA-2 van Shell op de Noordzee (locatie is op een kaart weergegeven in Figuur 3-1). De leiding wordt met een riser verbonden met het platform. De hose wordt besproken in paragraaf 3.4.

Het leidingtracé omvat de gehele onderzochte strook zoals weergegeven in bijlage 2.



Figuur 1-2. Scope van de aanvraag verbindingsleiding in het kader van artikel 94 Mbb, schematisch en in detail.

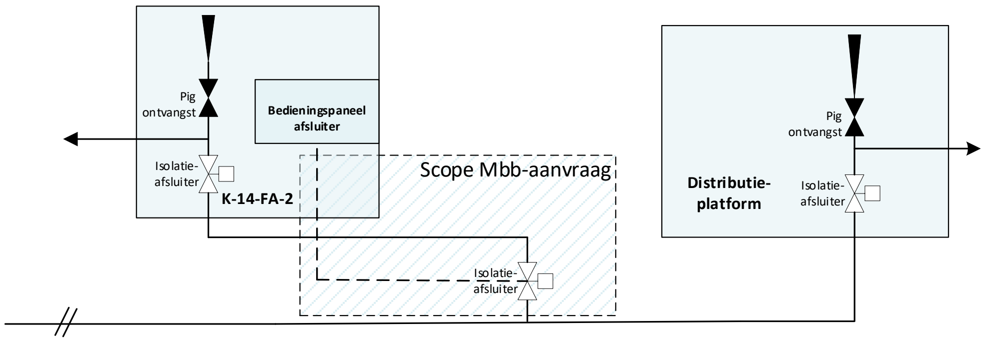
Gebied tussen de gestippelde rode lijnen geeft de omvang van de aanvraag weer.

Bij het ontwerp van verbindingsleiding wordt onderzocht of dit zodanig kan worden uitgevoerd dat de natuur hier voordeel van heeft. Hiermee wordt invulling gegeven aan de afspraken uit het Noordzeeakkoord (NZA) over natuurversterkend bouwen. Als duidelijk is waar natuurversterkend wordt gebouwd, wordt onderzocht of en in welk kader hiervoor toestemming van het bevoegd gezag vereist is. Het natuurversterkend bouwen valt buiten de omvang van deze artikel 94 Mbb-vergunningsaanvraag.

1.1.2 Scope kabel

De omvang van de aanvraag (zie Figuur 1-3) voor de kabel is als volgt:

- Het beginpunt van de kabel is afsluiterstation bij de ILT op de Aramis zeeleiding;
- Het eindpunt van de kabel is platform K-14-FA-2 van Shell op de Noordzee.



Figuur 1-3. Scope van de aanvraag kabel in het kader van artikel 94 Mbb. Het gearceerde gebied geeft de omvang van de aanvraag weer.

1.2 Leeswijzer

Hoofdstuk 1 geeft een inleiding op het project en hoofdstuk 2 geeft de algemene gegevens van de aanvrager, de pijpleiding, tijdvak, en locatie van de aanvraag. Hoofdstuk 3 gaat in op de details van de vergunningaanvraag, waaronder de aard en sterkte van de pijpleiding, het tracé, de wijze van aanleg, de getransporteerde stoffen, testen, en bedrijfsvoering. Hoofdstuk 4 omvat de relevante effecten op het milieu en de omgeving in het kader van de vergunningaanvraag en mer-beoordeling. Hoofdstuk 5 gaat in op mogelijke cumulatie met andere activiteiten. In hoofdstuk 6 is de conclusie van de mer-beoordeling aangegeven. Hoofdstuk 7 bevat ten slotte een kruisverwijzing tussen de indieningsvereisten van de mijnbouwwetgeving met deze aanvraag.

2 Algemene gegevens

2.1 Gegevens aanvrager

Tabel 1 bevat een overzicht van de relevante gegevens van de aanvrager.

Tabel 1: Gegevens aanvrager

Aanvrager	
Statutaire naam aanvrager	Shell Gas & Power Development (SGPD) B.V. (hierna Shell)
Ligging project	**Platform K14-FA-2:** Geografisch: Lat: 53° 16’ 17.658”N Lon: 003° 38’ 18.035”E ETRS89 [EPSG:4258] conform ED50 to WGS84 (18) [EPSG:1133] transformation Projectie: Northing: 5903555 - Easting: 409285 Coordinaten System: ED50 / TM 5 NE [EPSG:23095] **ILT 2 Coordinaten:** Geografisch: Lat: 53° 16’ 22.648”N Lon: 03° 38’ 58.740”E ETRS89 [EPSG:4258] conform ED50 to WGS84 (18) [EPSG:1133] transformation Projectie: Northing: 5903694.9 - Easting: E: 410041.9 Coordinaten Systeem ED50 / TM 5 NE [EPSG:23095]
Handelsnaam	Shell
Vestigingsadres bedrijf	Carel van Bylandtlaan 30 2596 HR Den Haag Nederland
Correspondentieadres	Zie vestigingsadres
Contactpersoon	[redacted]
Telefoonnummer contactpersoon	
E-mailadres	

2.2 Activiteit

Verbindingsleiding

Shell heeft het voornemen een verbindingsleiding aan te leggen van de ILT naar het K14-FA-2 platform van Shell op de Noordzee (zie ook Figuur 2-1). De verbindingsleiding begint bij de ILT op de zeeleiding en eindigt bij het CO_2-injectieplatform K14-FA-2. Van daaruit wordt de CO_2 in het uitgeproduceerde offshore gasveld K14-FA geïnjecteerd voor geologische opslag. Om de afsluiter op de manifold op afstand te kunnen bedienen, wordt ook een kabel aangelegd. De ILT zal door Aramis JT beheerd worden, Shell bouwt de pipeline end manifold waarop de afsluiter zit die op afstand bediend zal kunnen worden. Zie ook bovenstaande figuren.

De beoogde verbindingsleiding is ongeveer 850 m lang en heeft een buitendiameter van 16” (circa 40 cm). De verbindingsleiding ligt uitsluitend in de exclusieve economische zone (EEZ). De verbindingsleiding wordt aan de ene kant met een riser verbonden van het K-14-FA-2-platform en aan de andere kant aan de ILT. De verbindingsleiding wordt waar nodig ingegraven en afgedekt met matrassen. De kabel wordt over het grootste deel ingegraven. Over de manifold met afsluiters wordt een beschermingskooi geplaatst. Bij het K14-FA-2 platform wordt het uiteinde bedekt met matrassen.

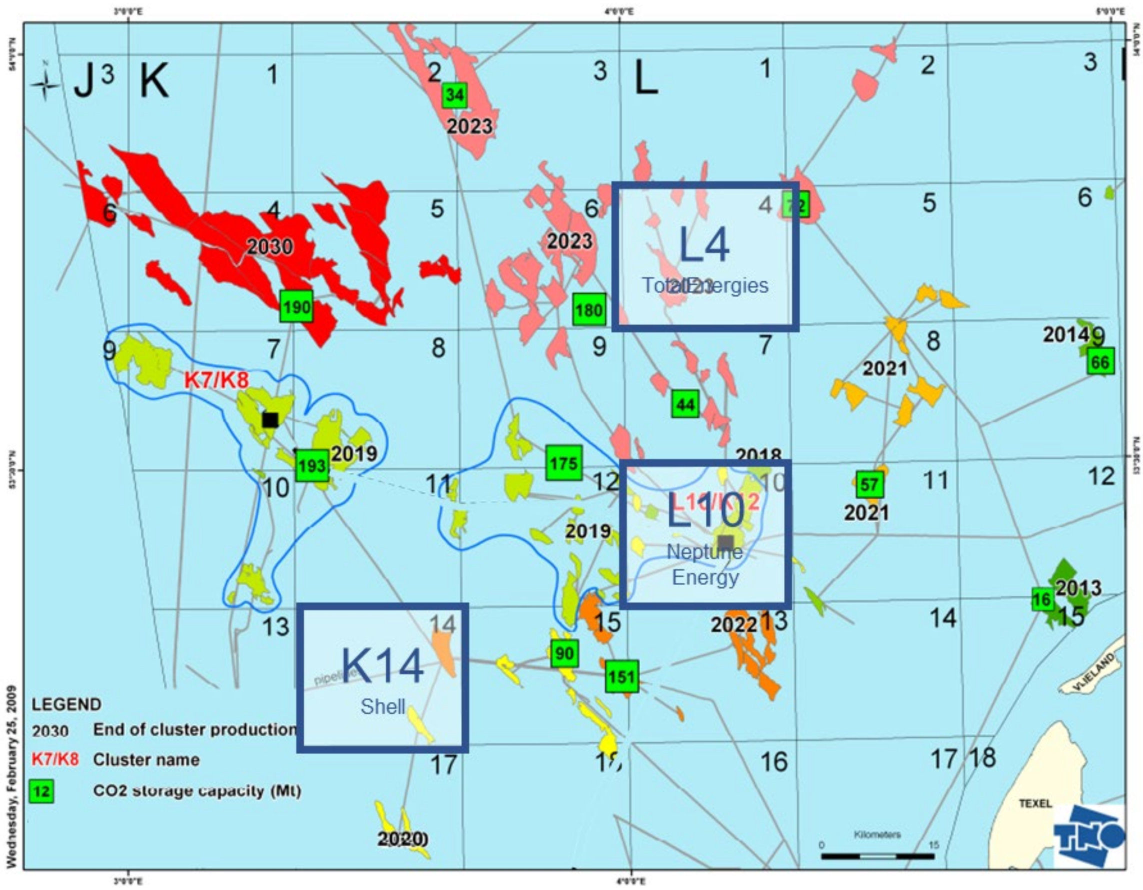
De kabel bevat een datakabel voor de bediening van het afsluiterstation bij het ILT en een hydroliekleiding voor de datawerkelijke sturing van de afsluiter, plus een reserve hydroliekleiding. De beoogde kabel is eveneens ongeveer 850 m lang en heeft een buitendiameter van circa 170 cm.

2.3 Tijdvak van de vergunning

Het tijdvak waarvoor een vergunning op grond van artikel 94 van het Mbb wordt aangevraagd loopt vanaf de start van de werkzaamheden, vooralsnog gepland in 2027. De vergunning voor zowel de verbindingsleiding als kabel wordt voor onbepaalde tijd aangevraagd. De pijpleiding en kabel worden ontworpen voor een periode van 30 jaar.

2.4 Gebied van de aanvraag

Deze aanvraag betreft de aanleg van een pijpleiding en kabel in de EEZ. De EEZ strekt zich uit voorbij de Nederlandse territoriale zee (vanaf 12 zeemijl[2] uit de kust) tot aan de EEZ van onze buurlanden en Nederland heeft hier soevereine economische rechten. De locatie van blok K14 is weergegeven op de kaart in Figuur 2-1.



Figuur 2-1. Locatie van het K14 blok op de Noordzee.

2 *1 zeemijl is 1852 meter*

2.5 Wettelijk kader en bevoegd gezag

Op grond van de definities in artikel 1 Mbw onder ag valt de aangevraagde pijpleiding onder de Mbw omdat dit een leiding betreft die twee of meer mijnbouwwerken met elkaar verbindt ten behoeve van het vervoer van stoffen. De kabel is vergunningsplichtig op grond van artikel 106 Mbb. Voor de kabel gelden overeenkomstig eisen als voor de leiding. De relevante wet- en regelgeving met betrekking tot mijnbouwpijpleidingen en -kabels is geregeld in het Mbb en de Mbr. § 6.2 van het Mbb regelt de vergunningplicht van pijpleidingen in de territoriale zee of op het continentaal plat, of in een ander gebied waarvoor op grond van het Omgevingsbesluit het maken van een milieueffectrapport verplicht is. §1.7.2 Mbr regelt de inhoud van de vergunningsaanvraag. Hoofdstuk 3 gaat in op de in artikel 1.7.1 Mbr gevraagde gegevens met betrekking tot de vergunningsaanvraag. De Minister van KGG is op grond van artikel 94 van het Mbb het bevoegd gezag. De aanvraag volgt de reguliere voorbereidingsprocedure.

Milieueffectrapportage

De voorgenomen activiteit van Shell is mer-beoordelingsplichtig op grond van categorie J9 in bijlage V van het Omgevingsbesluit:

> *De aanleg, wijziging, of uitbreiding van een buisleiding voor het transport van gas, olie, chemicaliën of voor het transport van kooldioxide (CO_2) stromen ten behoeve van geologische opslag*.

Er is geen sprake van een buisleiding met een diameter van meer dan 0,8 meter en een lengte van meer dan 40 km, zodat de beoogde activiteit niet mer-plichtig is. Wel is sprake van aanleg van een buisleiding voor het transport van kooldioxidestromen voor geologische opslag, zodat alleen sprake is van een mer-beoordelingsplicht. Uit hoofde van deze verplichting zijn de activiteiten van Shell beschreven, onderzocht en beoordeeld in dit document. Veel van de gegevens en studies zijn gebaseerd op c.q. uitgevoerd in het kader van het MER dat is opgesteld ten behoeve van het Aramis initiatief. De kabel is niet genoemd in bijlage V van het Omgevingsbesluit; hiervoor geldt geen mer(-beoordelings)plicht.

Het Aramis initiatief bestaat uit meerdere onderling samenhangende onderdelen. Voor de realisatie en gebruik hiervan zijn vergunningen nodig, waaronder vergunningen waarvoor een milieueffectrapportageprocedure (mer) nodig is. Zo zijn aanleg en gebruik van de Aramis zeeleiding mer-plichtig evenals de aanpassing en het gebruik van de platforms als onderdeel van de CO_2-opslaglocaties. Verder zijn de benodigde diepboringen (het boren van de CO_2-injectieputten) mer-beoordelingsplichtig. Om aan alle mer-verplichtingen te voldoen, is voor veel onderdelen van het Aramis initiatief één uitgebreide mer-procedure doorlopen.

2.6 Vooroverleg

Het tracé op zee is zo gekozen dat het zoveel mogelijk bestaande leidingen volgt en gevoelige gebieden en andere bestaande en toekomstige gebruiksfuncties zo min mogelijk te belemmert. Dit betreft zandwingebieden, huidige en toekomstige windparken, militaire gebieden, scheepswrakken, vaarroutes, visserijgebieden, en natuurgebieden. In het kader van de zeeleiding die door Aramis wordt gerealiseerd, is met verschillende instanties vooroverleg(gen) gevoerd, waarbij de aan te leggen verbindingsleidingen (van zowel Shell als andere operators) ook zijn besproken. Onderstaand een overzicht.

Ministerie van Economische Zaken en Klimaat: afstemming met betrekking tot het project als geheel inclusief tracé offshore pijpleiding en vergunningen;

Rijkswaterstaat: afstemming met betrekking tot boren onder de zeewering en pijpleidingtracé op zee;

Staatstoezicht op de Mijnen: afstemming met betrekking tot technische aspecten en vergunningen;

Gemeente Rotterdam: afstemming met Leidingenbureau voor het landdeel van de zeeleiding;

Ministerie van Defensie: ligging leiding ten opzichte van defensiegebieden;

Rijksdienst Cultureel Erfgoed: afstemming in het kader van mogelijke verstoring van archeologische waarden;

Leidingeigenaren op zee: afstemming tracés van leidingen en kabels;

Offshore olie- en gasoperators: afstemming leidingtracé inclusief kruisingen van leidingen en kabels;

Operators offshore windparken: afstemming leidingtracé met bestaande en geplande windparken;

Rijkswaterstaat Zee en Delta, Kustwacht en Loodswezen: afstemming over nautische veiligheid, ligging ten opzichte van tracé bij kruisingen en parallelloop met scheepvaartroutes;

Natuur- en milieuorganisaties: afstemming over effect infrastructuur op natuur en biodiversiteit & natuurversterkend bouwen;

Vissersbonden: gevolgen Aramis infrastructuur op visserij.

Voor het gehele Aramis initiatief wordt een uitgebreid participatieproces doorlopen. De in dit kader uitgevoerde participatie is beschreven in het participatieplan voor het Aramis initiatief. Een samenvatting hiervan is opgenomen in bijlage 7.

3 Details vergunningsaanvraag

Dit hoofdstuk bevat informatie van de voorgenomen activiteit ten behoeve van de aanvraag voor de leiding-vergunning op grond van artikel 94 Mbb en de kabel op grond van artikel 105 Mbb.

3.1 Naleven van wettelijke eisen en normen

De verbindingsleiding voldoet aan de relevante eisen gesteld in de NEN 3650-serie of gelijkwaardig[3]:

- NEN 3650-1:2020 Eisen voor buisleidingsystemen (generiek)
- NEN 3650-2:2020 Eisen voor stalen buisleidingsystemen
- NEN 3654:2023 Wederzijdse beïnvloeding van buisleidingen en hoogspanningssystemen
- NEN 3655:2020 Veiligheidsbeheersysteem (VBS) voor buisleidingsystemen voor het transport van gevaarlijke stoffen - Functionele eisen
- NEN 3656:2022 Eisen voor stalen zeeleidingsystemen.

3.1.1 Verbindingsleiding

Er wordt voldaan aan de eisen van artikel 93 Mbb:

1. **‘De pijpleiding bestaat uit pijpen die voldoende sterk zijn en op doelmatige wijze met elkaar zijn verbonden. De pijpleiding is tegen uitwendige corrosie en krachten beschermd’.**
   - De ontwerpdruk van de verbindingsleiding is gebaseerd op de maximale bedrijfsdruk. Overschrijding van de maximale bedrijfsdruk wordt voorkomen door instrumentele beveiliging indien nodig in combinatie met veiligheidskleppen. Alle leidinglassen worden volledig gecontroleerd, mogelijk met uitzondering van enkele ‘gouden lassen’ voor het koppelen van lange leidinglengtes. De gehele leiding wordt voor ingebruikname afgeperst of op een vergelijkbare wijze op drukvastheid beproefd. Zie voor een verdere toelichting paragraaf 3.5.2;
   - De verbindingsleiding wordt uitwendig gecoat en voorzien van een kathodische protectie tegen corrosie en waar nodig voorzien van een betonnen ballastcoating;
   - De verbindingsleiding wordt tegen uitwendig krachten beschermd door deze aan te leggen volgens NEN 3656.
2. **‘De ligging van de pijpleiding is zodanig dat geen schade wordt veroorzaakt of zoveel mogelijk voorkomen’.**
   - Het tracé is afgestemd met de Kustwacht, Rijkswaterstaat en SodM;
   - Kruisingen met bestaande in bedrijf zijnde pijpleidingen en kabels worden zodanig uitgevoerd met stortsteen en betonmatrassen dat de bestaande leiding niet wordt beschadigd. De kruising wordt vervolgens afgedekt met stenen zodat ze overvisbaar zijn. Bij het platform worden stenen en/of betonmatrassen op leidingen gelegd om te beschermen tegen ‘dropped objects’ en ter voorkoming van erosie (uitspoelingskuilen);

[3] De NEN 3650-serie of gelijkwaardig kan als BBT (Beste Beschikbare Technieken) worden beschouwd. De NEN 3650-serie is niet dwingend in de wetgeving voorgeschreven, dus er mag vanaf geweken worden. Er wordt aan de NEN 3650-serie voldaan of aan een vergelijkbaar kwaliteitsniveau zoals door gebruik van DNV-standards, waarmee wordt voldaan een artikel 93 van het Mijnbouwbesluit. Overal waar in deze aanvraag is vermeld dat aan de NEN 3650-serie wordt voldaan, kan dus ook een vergelijkbare wijze aan de voorschriften worden voldaan. Bij afwijken wordt in de ontwerpdocumentatie vastgelegd wat de afwijking betreft en hoe is zekergesteld dat alternatieve oplossing ten minste gelijkwaardig is. Waar nodig worden afwijkingen en de onderbouwing van de gelijkwaardigheid gemeld aan SodM.

- De beheerders van bestaande leidingen en kabels zijn waar mogelijk geïnformeerd en details met betrekking tot de ligging nabij bestaande Kabels en Leidingen (K&L) worden met hen afgestemd en eventueel in crossing agreements vastgelegd.

3 **De eigenschappen, de aanleg, de ligging en het onderhoud van de pijpleiding voldoen aan bij ministeriële regeling te stellen eisen.**

- De pijpleiding voldoet aan artikel 10.1 Mbr: de leidingen zijn ontworpen conform de relevante bepalingen van de NEN 3650-serie of gelijkwaardig.

3.1.2 Kabel

Er wordt voldaan aan de eisen van artikel 105 Mbb:

1 De kabel bezit zodanige eigenschappen en wordt zodanig aangelegd dat er geen schade wordt veroorzaakt. De ontwerpdruk van de vloeistofleidingen in de kabel is gebaseerd op de maximale bedrijfsdruk.

- De ligging van de kabel is zodanig dat er geen schade wordt veroorzaakt;

2 De beheerders van bestaande leidingen en kabels zijn waar mogelijk geïnformeerd en details met betrekking tot de ligging nabij bestaande Kabels en Leidingen (K&L) worden met hen afgestemd en eventueel in crossing agreements vastgelegd.

3 De eigenschappen, de aanleg, en de ligging van de kabel voldoen aan bij ministeriële regeling te stellen eisen.

3.2 Voorontwerp van de pijpleiding en kabel

Door Shell is een voorlopig ontwerp van de verbindingsleiding opgesteld. Daarnaast zijn ook de specificaties van de aan te leggen kabel opgesteld. Het voorontwerp van de pijpleiding en de kabel is bijgevoegd in bijlage 1a, 1b en 1c bij deze aanvraag. Specifiek voor de in artikel 1.7.1 Mbr onder e van de Mbr gevraagde punten staat hieronder aangegeven waar deze punten in deze aanvraag zijn beschreven:

1 De eigenschappen en diameter van de pijpleiding zijn beschreven in paragraaf 3.3 ;

2 De stoffen die erin worden vervoerd, zijn beschreven in paragraaf 3.6;

3 Een analyse van de veiligheids- en milieurisico's is gegeven in hoofdstuk 4 en de risico's zijn daarnaast ook beschreven in het MER dat gelijktijdig met deze aanvraag is ingediend;

4 De tijd gedurende welke de pijpleiding wordt gebruikt voor het vervoer van die stoffen zijn beschreven in paragraaf 3.6.

3.3 Karakteristieken van de pijpleiding

De karakteristieken van de pijpleiding zijn afkomstig uit de voorlopige ontwerpstudie. Het rapport van het voorontwerp van de pijpleiding zoals bedoeld in Artikel 1.7.1 lid 1 onder e van de Mbr is in de vorm van deze voorlopige ontwerpstudie van de verbindingsleiding (pre-FEED) opgenomen in bijlage 1a, b en c.

Lengte, diameter, wanddikte: De beoogde verbindingsleiding is ongeveer 850 meter lang. de diameter is 406.4 mm en de wanddikte is 16 mm. De spools hebben een wanddikte van 17.5 mm.

Materiaal: Het materiaal van de verbindingsleiding is roestvrij duplex staal (DSS),

De buitendiameter: 16" (40 cm). Verschillende diktes gelden voor verschillende veiligheidszones (volgens NEN 3656), maar het grootste deel van de verbindingsleiding wordt uitgevoerd met een wanddikte van ongeveer 16 mm (medium veiligheidszone). Het materiaal is laag- of ongelegeerd koolstofstaal voor lage temperaturen (fijnkorrel koolstofstaal/fine grain carbon steel).

Ontwerpdruk: 200 bar CO_2 in ‘dense phase’.

Ontwerptemperatuur: -46 tot 30°C[4];

Corrosietoeslag: 0 mm.
Corrosiebescherming: externe anti-corrosie coating in combinatie met kathodische corrosie-bescherming (met opofferingsanoden). Door de materiaalkeuze van roestvrij duplex staal is interne corrosiebescherming niet nodig. Ook door strikte eisen te handhaven aan de samenstelling van de CO_2 wordt corrosie voorkomen. Tijdens de EPCI-fase wordt nog nader ingegaan op de bewaking van het optreden van interne corrosie en gedocumenteerd. De toepassing van een kathodisch beschermingssysteem is stand der techniek in aanvulling op de uitwendige bekleding, die de eerste beschermingslaag vormt. De toepassing van een kathodisch beschermingssysteem is vereist op grond van NEN 3635 voor offshore stalen buisleidingen.

Ballastcoating: betonmantel waar nodig.

Ligging op of in de bodem
De verbindingsleiding wordt hoogstwaarschijnlijk ingegraven vanuit stabiliteitsredenenen. Zie verder paragraaf 3.4.

Thermische expansie
Er is een voorlopige thermische uitzettingsevaluatie uitgevoerd, rekening houdend met de (voorlopige) ontwerptemperatuur van 30°C. Aan beide zijden van de pijpleiding is een relatief lage uitzetting voorzien van ongeveer 40 cm, wat kan worden opgevangen door een standaard expansiepasstuk.

Monitoring
Om CO_2-lekkage vanuit de verbindingsleiding te voorkomen wordt corrosiebescherming en monitoring via drukmetingen en onderwaterinspecties toegepast, zoals bedoeld in artikel 10.1 Mbr. Er wordt een programma opgesteld voor monitoring van de integriteit van de leiding in de gebruiksfase. De verbindingsleiding wordt inwendig geïnspecteerd met behulp van pigging en uitwendige inspectie vindt plaats ten behoeve van een goede stabiele ligging zonder ontoelaatbare free-spans. De toelaatbare omvang van free-spans wordt tijdens het detailontwerp van de leiding bepaald en wordt conform NEN 3656 in de ontwerpdocumenten vastgelegd.

Flow assurance (hydraulisch ontwerp)
Conform NEN 3656 moet de keuze van de leidingdiameter en het -materiaal berusten op een zorgvuldige analyse en optimalisatie van alle relevante aspecten. Deze analyse moet onder meer ingaan op alle mogelijke optredende bedrijfssituaties van debieten en drukken gedurende ontwerplevensduur, rekening houdend met de gewenste einddrukken. In lijn hiermee is voor het ontwerp van de Aramis zeeleiding een flow assurance-onderzoek (hydraulisch onderzoek) uitgevoerd, waaruit volgt binnen welke randvoorwaarden en onder welke omstandigheden CO_2 veilig en technisch effectief kan worden getransporteerd en geïnjecteerd. Het rapport van het onderzoek is als bijlage 5 toegevoegd.

Het flow assurancerapport presenteert de thermo-hydraulische analyse tijdens normaal stationaire operatie en tijdens bijzondere omstandigheden. De analyse is uitgevoerd voor het transport en de injectie van de CO_2 in leeggeproduceerde aardgasvelden en gaat met name in op het transport via de Aramis zeeleiding. Een aandachtspunt bij de analyse is dat de te injecteren CO_2 een aantal onzuiverheden kan bevatten die een belangrijk effect kunnen hebben op de operabiliteit van het injectiesysteem, en meer specifiek via de hoofdleiding. Bij de thermo-hydraulische analyse is de invloed van deze onzuiverheden daarom met name onderzocht. Naast stationair bedrijf zijn ook bijzondere bedrijfsomstandigheden onderzocht zoals de initiële vulling van het systeem en het van druk aflaten van de leiding.

[4] *De optimale ontwerptemperatuur wordt nog verder onderzocht tijdens de FEED-fase en deze waarde kan hierdoor nog wijzigen.*

De doelstellingen van het flow assurance-onderzoek zijn als volgt:

- Bepalen van stationaire condities om de operabiliteit van het netwerk te bevestigen, waarbij ervoor gezorgd moet worden dat de CO_2 in de dense phase blijft.
- Input leveren voor de voorbereiding van de operationele filosofie en van relevante procedures en apparatuur voor tijdelijke bedrijfsomstandigheden zoals de eerste vulling, drukverlaging, enzovoort.

De conclusie van de uitgevoerde flow assurance analyse is dat geen grote struikelblokken zijn geïdentificeerd voor het halen van de voorgenomen CO2-transportcapaciteit door de verbindingsleiding met de voorgestelde pijpdiameter.

3.4 Karakteristieken van de kabel

De kabel zal gefabriceerd, getest en geleverd worden volgens API 17E 5th Edition.

De kabel zal bestaan uit een combinatie van thermoplastisch materiaal en gegalvaniseerd staaldraden:
- 3 hydraulische kabels (2 operationeel, 1 reserve) met een diameter van ½ inch;
- 9 elektrische kabels (6 operationeel, 3 reserves) met een doorsnede van 2.5 mm2.

De uitwendige kabeldiameter zal bepaald/ontworpen worden door de kabel leverancier.

De hydraulische kabels zullen gemaakt worden van thermoplastische hoses. De liners in de hoses zullen compatibel zijn met de hydraulische vloeistof. Het type hydraulische vloeistof moet nog bepaald worden.

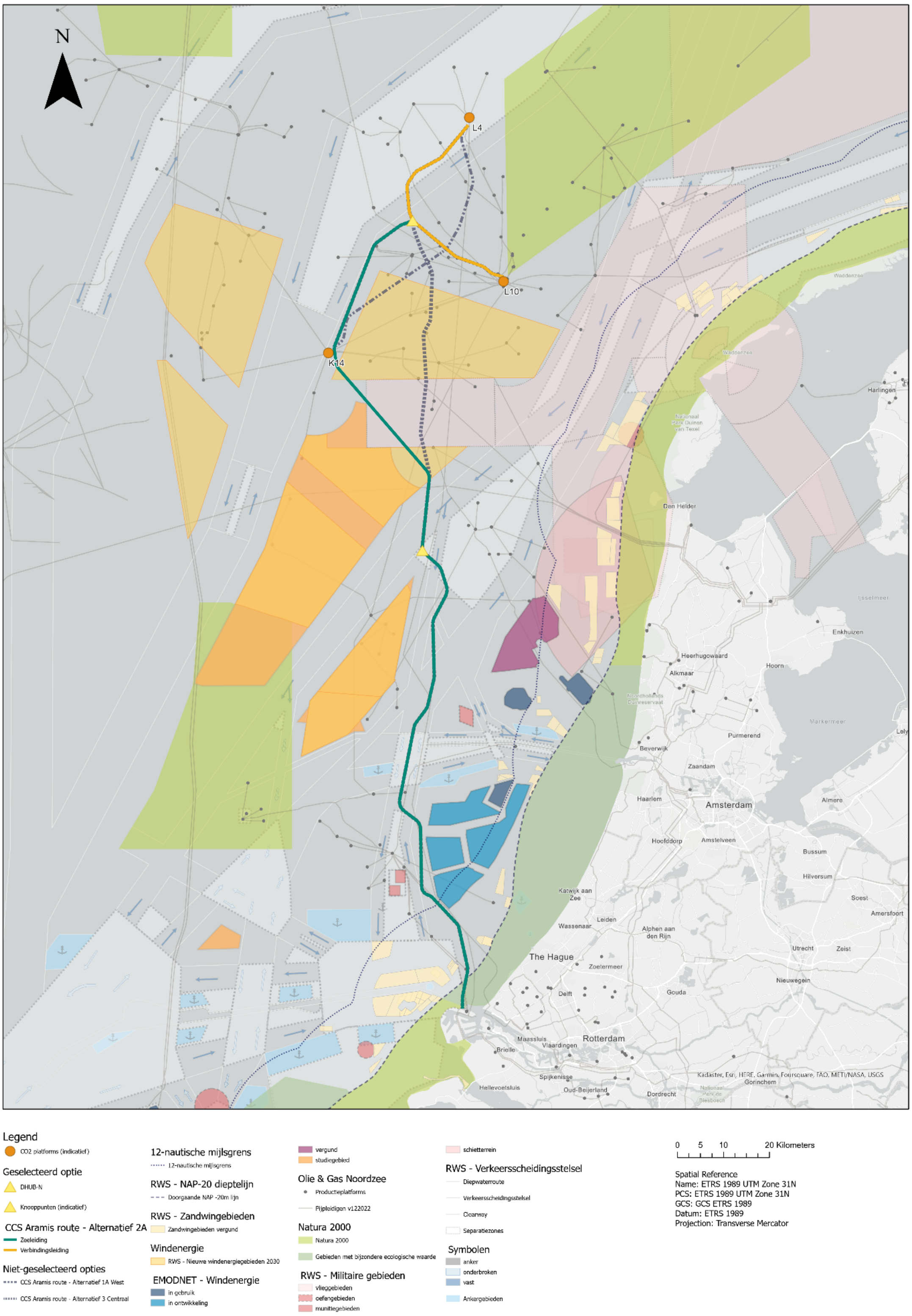
De elektrische kabels zullen gemaakt worden geisoleerd zeer goed geleidend koperdraad.

Zie ook bijlage 1c: ARS-200-BB4A-K14FA2-10-LA-7771-00006 Subsea Control Umbilical Specification and Datasheet

3.5 Beschrijving tracé en aanleg verbindingsleiding en kabel

3.5.1 Tracé

Het gehele tracé van de zeeleiding en verbindingsleidingen, waaronder de leiding (en kabel) van Shell, is getoond in Figuur 3-1a en b.



Figuur 3-1a: Gepland tracé van de zeeleiding en de hierop aansluitende verbindingsleidingen waaronder die van Shell (van het distributieplatform naar K-14-FA-2).

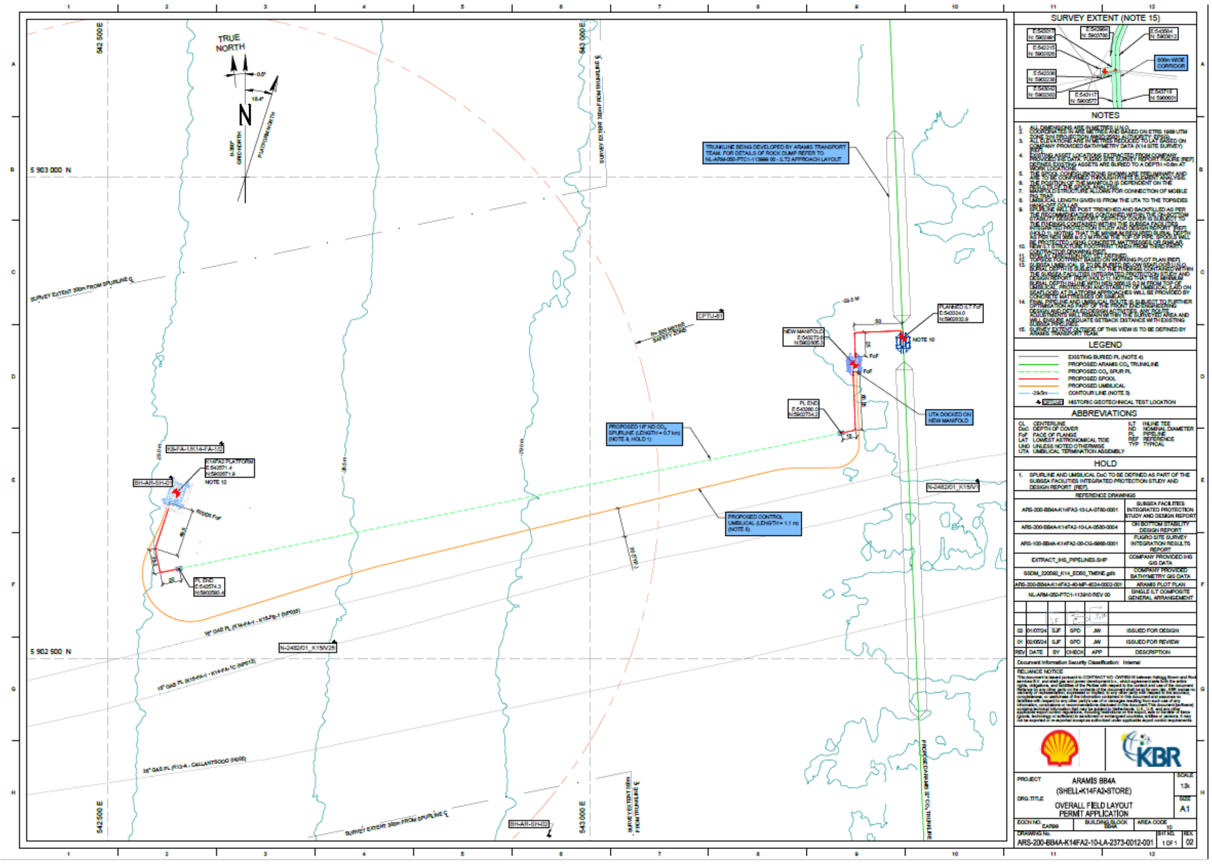


Figure 3-1b K14FA2 Overall Field Layout (spurline en kabel)

3.5.2 Aanleg verbindingsleiding

Op grond van paragraaf 6.4.2 van NEN 3656 hoeven leidingen van DN 400 of groter (≥ 400 mm of ca. 16") niet te worden ingegraven omdat dit soort grote leidingen 'overvisbaar' zijn wat wil zeggen dat trawlnetten van vissers er niet achter blijven haken. Het uitgangspunt is daarom dat de verbindingsleiding boven op de zeebodem wordt aangelegd, behalve waar dat uit operationele- regelingen of veiligheidsredenen niet is toegestaan. In gebieden met een verhoogd risico wordt de diepteligging van de zeeleiding bepaald op basis van een risicogestuurde methode volgens paragraaf 6.3.1 van NEN 3656, waarbij rekening wordt gehouden met onder meer omstandigheden van de scheepvaartroutes (ligging, scheepsintensiteit en dergelijke, toekomstige diepte) en het specifieke gedrag van schepen in dergelijke routes. De aan te houden minimale gronddekking bij het ingegraven wordt vastgesteld aan de hand van NEN 3656.

Route survey en schoonmaken

Voordat de verbindingsleiding wordt aangelegd, moet de leidingroute vrij zijn van obstakels, zoals buiten gebruik gestelde kabels, leidingen, schroot en van nature voorkomende stenen. Mogelijke obstakels zijn geïdentificeerd tijdens de route survey (zie paragraaf 3.5.3). Aan de hand van een analyse van de data van de route survey wordt beoordeeld of obstakels kunnen worden vermeden of vooraf verwijderd moeten worden.

Leggen van de leiding op de zeebodem

De verbindingsleiding wordt met een pijpenlegschip gelegd. De verbindingsleiding wordt opgebouwd uit leidingsegmenten met een lengte van ongeveer 12 meter. De leidingsegmenten zijn in de fabriek uitwendig al voorzien van een anticorrosiecoating van kunststof en betonnen mantel. Aan wal wordt in een geschikte haven een depot aangelegd voor de leidingsegmenten. De leidingsegmenten worden met bevoorradingsschepen vanuit dit depot naar het pijpenlegschip aangevoerd en op zee op het pijpenlegschip overgeladen. Op het pijpenlegschip wordt steeds een nieuw segment aan de opgebouwde leiding gelast. Alle lassen worden in- en uitwendig gecontroleerd. De leiding wordt voorzien van opofferingsanoden voor de kathodische bescherming. Vervolgens wordt de leiding gecontroleerd en worden de lassen behandeld tegen uitwendige corrosie. De leiding wordt hierna via de stinger op de achterzijde van de pijpenlegger het water ingeleid en op de zeebodem gelegd[5]. De leiding wordt leeg (niet gevuld met water) aangelegd om het gewicht van de leiding te beperken.

Het pijpenlegschip wordt bij het leggen met dynamic of static (ankeren) positioning in positie gehouden, zodat de leiding nauwkeurig op het vooraf vastgestelde tracé op de zeebodem kan worden gelegd. Op de plaatsen waar de leiding wordt ingegraven, wordt dit gedaan met een tweede schip met een ingraafmachine die over de zeebodem rijdt of wordt getrokken. Voor kruisingen van shipping lanes wordt mogelijk eerst een sleuf gebaggerd, als de benodigde ingraafdiepte te groot is voor een ingraafmachine. Waar nodig wordt de zeebodem na aanleg geëgaliseerd.

Bij het bereiken van het injectieplatform wordt op het uiteinde van de leiding een blindflens geplaatst. De leiding wordt daarna op de zeebodem achtergelaten totdat het K-14-FA-2 platform gereed is om de leiding te kunnen aansluiten. Op dat moment wordt alles ingemeten, en wordt de metrologie spool[6] gemaakt, die beiden uiteneinden (riser en spurline) aan elkaar verbindt.

Indien en waar de Kustwacht dat vereist, is tijdens het leggen van de leiding een wachtschip (guard vessel) bij het pijpenlegschip stand-by om andere scheepvaart op voldoende afstand te houden en voor het bieden van eerste hulp bijvoorbeeld bij man overboord.

Kruisingen met andere kabels en leidingen en expansiebochten

Het offshore tracé kruist geen bestaande leidingen en kabels. Wel kruist de kabel de verbindingsleiding naar K14-FA-2 (zie figuur 3-1b). Gezien de verwevenheid van het ontwerp en de aanleg van de kabel bij de verbindingsleiding wordt deze kruising bij het ontwerp nader uitgewerkt met het oog op het voorkomen van schade.

[5] *Er wordt nog onderzocht of het mogelijk is de leiding met behulp van reel lay te leggen.*

[6] *Een **metrologie spool** is een kort stuk stijve pijp dat speciaal is vervaardigd om metingen onder water mogelijk te maken, zodat het precies aansluit. Deze spool wordt gebruikt om subsea-structuren en pijpleidingen nauwkeurig met elkaar te verbinden.*

Testen en inspectie van de leiding

Afsluitend aan de constructie van de verbindingsleiding wordt deze geïnspecteerd en getest. De exacte wijze van de eindinspectie en het testen ligt nog niet vast maar voorlopig wordt ervan uitgegaan dat drukvastheid met een hydrotest wordt beproefd. Hierbij wordt de leiding gevuld met gefilterd zeewater waaraan bepaalde chemicaliën zijn toegevoegd om onder andere corrosie tijdens het testen te voorkomen. Vervolgens worden achter elkaar verschillende pigs door de leiding gepompt met gefilterd en geconditioneerd zeewater om de leiding te reinigen, te inspecteren op onvolkomenheden (deuken of knikken) en hydrostatisch te beproeven. Na het testen wordt de leiding geleegd door speciale afsluitende pigs dit keer met perslucht door de leiding heen te sturen. De verwachting is dat de tijdsduur dat de leiding gevuld is met testwater minder dan 90 dagen duurt. Na het testen wordt de leiding drooggeblazen met lucht en vervolgens gevuld met stikstof om hem intern tegen corrosie te beschermen. Tot slot wordt de leiding tot ingebruikname aan weerszijden afgesloten zodat er niet opnieuw vocht in de leiding kan komen. Als het testen goed is verlopen, is de leiding geschikt voor ingebruikname.

Bovenstaand testproces wordt uitgevoerd met tijdelijke lanceer- en ontvangstinstallaties voor het versturen van de pigs die aan de uiteinden van de leiding zijn bevestigd en op hun beurt weer zijn aangesloten op tijdelijke pompen en ontwaterings(lucht)compressoren die zowel op de platformen, op de zeebodem als op een speciaal schip geplaatst zullen worden.

Het hydrostatisch testen wordt uitgevoerd met gefilterd zeewater. Er wordt verwacht drie spoelgangen nodig zijn met elk een volume van ongeveer 100 m^3 zeewater om de pijpleiding voldoende te testen en te spoelen. Op basis van onderzoek door Aramis kan besloten worden of het mogelijk is om het testwater niet te conditioneren, maar als nadere studies aantonen dat conditionering vereist is, wordt uitgegaan dat voor het conditioneren de volgende typen stoffen in het water worden gedoseerd[7]:

- Oxygen scavenger (zuurstofvanger): oxygen scavenger wordt gebruikt om de in het testwater opgeloste zuurstof te binden zodat deze niet het staal van de leiding kan aantasten. De zuurstofvanger moet worden geselecteerd als wateroplosbaar, zwak bio-accumulerend, minder giftig, en snel reagerend met opgeloste zuurstof. Een zuurstofvanger zoals ammoniumbissulfiet heeft deze kenmerken, of een gelijkwaardig equivalent. De te doseren concentratie is afhankelijk van het zuurstofgehalte van het testwater.
- Biociden in lage concentraties, doorgaans 100 - 200 ppm bij een testduur van 90 tot 180 dagen, om biologische groei in het water te remmen. Biologische groei kan de leidingwand vervuilen of aantasten.
- Corrosie-inhibitor(en) om corrosie van de leidingwand te remmen, indicatieve concentratie 100 ppm. De toe te passen inhibitor zijn olie-oplosbaar en waterdispergeerbaar en moeten biologisch afbreekbaar zijn.

Momenteel zijn nog geen specifieke chemicaliën voor de testwaterconditionering geïdentificeerd, maar er kunnen alleen chemicaliën worden gebruikt die zijn geregistreerd onder REACH en HOCNF. Biocides zullen daarnaast zijn geregistreerd in de databank van het College voor de toelating van gewasbeschermingsmiddelen en biociden (Ctgb) of de Europese ECHA-database. Shell selecteert bij voorkeur chemicaliën met een lage impact maar wel aan de operationele vereisten voldoen. Deze beoordeling zal gebaseerd zijn op vastgestelde Hazard Quotients (HQ-)waarden (volgens het huidige CEFAS-register op het moment van gebruik) en leveranciersspecificaties. Voordat een in aanmerking komende stof offshore wordt gebruikt of geloosd, zal een gedetailleerde chemische risicobeoordeling worden uitgevoerd en zal vergunning worden aangevraagd bij SodM.

7 Het druktesten van de leiding en de daarbij te gebruiken chemicaliën wordt uitgevoerd op basis van de specificatie die Aramis hiervoor ontwikkeld heeft (Specification for Testing and Pre-commissioning Offshore Pipeline, ILT's, Riser and Pig Receiver distributionplatform (NL-ARM-010-PTC1-100505). Deze specificatie geeft de randvoorwaarden voor de contractor die de contractor in acht moet nemen bij het beproeven van de leiding. De toe te passen conditioneringsmiddelen voor het testwater zijn afhankelijk van de kwaliteit van het te gebruiken water en de tijd dat het water in de leiding aanwezig is. De in deze paragraaf genoemde specificaties geven een voorzichtig-realistische schatting. Maximale concentraties zijn gegeven in de genoemde specificatie.

Onderzocht wordt nog wat na gebruik met het hydrotestwater moet worden gedaan. Het testwater kan mogelijk aan land worden opgevangen, of het testwater kan mogelijk offshore worden geloosd op de D-Hub-locatie of elders. Verder wordt de mogelijkheid onderzocht een ontheffing voor de hydrostatische druktest van de leiding te verkrijgen. De leiding voldoet in principe al aan de testeisen vanwege de zeer strenge eisen die aan het fabricageproces worden gesteld (een hydrostatische test wordt in de fabriek al per pijpstuk uitgevoerd) en tijdens de constructiefase worden toegepast (alle lassen worden ultrasoon getest op eventuele lasfouten). Uitgangspunt voor het beproeven van de sterkte is dat aan de eisen van de NEN 3650-serie hierover wordt voldaan.

De te kiezen optie wordt op grond van nadere studie vastgesteld en gecommuniceerd met het bevoegd gezag. Hoe dan ook zal bij eventuele lozing het te lozen hydrotestwater voldoen aan de eisen van hoofdstuk 9 van de Mbr.

3.5.3 Tracéonderzoek

Geotechnisch onderzoek

§1.7 Mbr vraagt dat de aanvrager bij de aanvraag om een vergunning tot aanleg van een pijpleiding en kabel gegevens verstrekt ten aanzien van het geotechnisch onderzoek van het tracé en een strook ter weerszijden. Hiertoe heeft Fugro in opdracht van Aramis een geotechnisch onderzoek uitgevoerd naar het leidingtracé. Dit onderzoek dient om informatie te verzamelen over onder meer het zeebed, daar aanwezige objecten en de bodemopbouw van het zeebed.

Het geotechnisch onderzoek door Fugro is uitgevoerd voor het voorgenomen traject, waarvan de as van de strook samenvalt met het gekozen traject. In het rapport is beschreven:

1. Het profiel van de zeebodem;
2. De aanwezige obstakels;
3. De ligging van bestaande pijpleidingen en kabels;
4. De grondmechanische eigenschappen;
5. De stratigrafie van de zeebodem, en
6. De analyse en kwaliteit van de bodemmonsters en sonderingen.

Het rapport van het geotechnisch onderzoek is als bijlage 2 bij deze uitvraag opgenomen en dekt het hele voorgenomen traject van de leiding en kabel in een strook van circa 500 meter, waarvan de as van de strook samenvalt met het gekozen traject.

Cultuurhistorisch / archeologisch onderzoek

Er bestaat een kans dat in het tracé objecten met cultuurhistorische en/of archeologische waarde aanwezig zijn. Voor het bepalen of de aanleg van de verbindingsleiding kan leiden tot aantasting of vernietiging van mogelijk aanwezige archeologische resten is een archeologisch vooronderzoek (bureauonderzoek) uitgevoerd (zie bijlage 6). Na het bureauonderzoek wordt waar nodig inventariserend veldonderzoek uitgevoerd om de archeologische verwachting te toetsen.

Mogelijke wijziging definitief tracé

Indien het definitieve tracé wijzigt op grond van onvoorzien omstandigheden en deze tracéwijziging(en) niet binnen de onderzochte strook vallen, wordt hiervoor ter plaatse aanvullend onderzoek uitgevoerd. Conform artikel 98 Mbb zal Shell binnen vier weken na de aanleg van de pijpleiding de exacte ligging van de pijpleiding verstrekken.

3.5.4 Aanleg kabel

Een speciaal schip begraaft de kabel in de zeebodem.
De kabel wordt getest op functionaliteit en veiligheid voordat deze operationeel wordt.

3.6 Getransporteerde stoffen via de verbindingsleiding en kabel

In Tabel 3-1 staan de momenteel geldende grenswaarden voor de CO_2 die per schip of leiding wordt aangeleverd aan Aramis en uiteindelijk geïnjecteerd wordt in de gasvelden van Shell (en andere operators). De aangeleverde CO_2 van leveranciers moet aantoonbaar binnen deze randvoorwaarden blijven. Daarvoor komt er een meetprogramma bij elke leverancier.

Tabel 3-1. Specificaties aangeleverde CO_2 als geldend op dit moment.

Klasse	Component	Eenheid	Grenswaarde	Leiding
Koolstofdioxide	CO_2	mol%	Groter dan	95
Water	H_2O	ppm-mol	Minder dan	70(1)
Inerte stoffen	N_2	mol%	Minder dan	2,4
	O_2	ppm-mol	Minder dan	40
	H_2	ppm-mol	Minder dan	7500
	Ar	mol%	Minder dan	0,4
	CH_4	Mol%	Minder dan	1
	CO	ppm-mol	Minder dan	750
	$O_2+N_2+H_2+Ar+CH_4+CO$	ppm-mol	Som minder dan	40 000
Stikstof	NO_x	ppm-mol	Som minder dan	2,5(4)
Zwavelhoudende componenten	SO_x	ppm-mol	Som minder dan	-
	H_2S	ppm-mol	Minder dan	5
	Carbonylsulfide	ppm-mol	Minder dan	0,12)
	Dimethylsulfide	ppm-mol	Minder dan	1,1(2)
	H_2S + COS + SO_x +DMS	ppm-mol	Som minder dan	20
Vluchtige organische componenten	Amine	ppm-mol	Minder dan	1
	Formaldehyde	ppm-mol	Minder dan	-
	Acetaldehyde	ppm-mol	Minder dan	0,2(2)
	Aldehyden	ppm-mol	Som minder dan	10
	Carbolylzuren en amines	ppm-mol	Som minder dan	1
	Fosforhoudende verbindingen	ppm-mol	Som minder dan	1
	NH_3	ppm-mol	Minder dan	3
	Ethyleen (C_2H_4)	ppm-mol	Som minder dan	1(2)
	H-cyanide (HCN)	ppm-mol	Minder dan	2
	Totaal aan vluchtige organische stoffen (excl. MeOH, EtOH, aldehyden)	ppm-mol	Som minder dan	10
	Methanol	ppm-mol	Minder dan	620

Klasse	Component	Eenheid	Grenswaarde	Leiding
	Ethanol	ppm-mol	Minder dan	20
Zwaardere koolwaterstof verbindingen	Glycolen (TEG)		Som minder dan	Volgens dauw-puntspec
	C_{2+} (alifatische koolwaterstof-fen)	ppm-mol	Som minder dan	1200
	Aromatische koolwaterstoffen	ppm-mol	Som minder dan	0,1
Metalen	Hg	ppm-mol	Minder dan	-
	Cadmium + thalium	ppm-mol	Som minder dan	-
Dauwpunt	Dauwpunt (elke vloeibare fase)	°C (@ 20 bar)	Som minder dan	-10(3)
Vaste stoffen	Volledige verwijderingsdiame-ter	micron	Minder dan	1(4)

Opmerkingen bij de tabel:
Voor een aantal componenten is geen specifieke concentratielimiet opgenomen. Als deze componenten in de aangeleverde CO_2-stroom worden verwacht in gehalten boven 1 ppm-mol, voert Aramis een risicobeoordeling uit om inzicht te krijgen in de maximale hoeveelheid die kan worden getolereerd. Als er componenten in de aangeleverde CO_2-stromen worden verwacht die niet in de specificatie van Tabel 3-1 zijn opgenomen en wel nadelige gevolgen kunnen hebben, stelt Aramis een bovenste concentratiegrens vast.

1 Specificatie afgestemd met Porthos CO2-specificatie v 3.1 voor Porthos-infrastructuur; watergehalte maximaal 40 ppm-mol).

2 Specificatie volgens OCAP-specificatie en alleen van toepassing op toeleveranciers die ook via de OCAP-infrastructuur leveren.

3 Dit is de ingangsspecificatie voor vaste stoffen/stof voor de beoogde Aramis opslagen. Om dit te bereiken verzoekt Aramis de leveranciers stofverwijderingsinstallaties te installeren met een ondergrens van minimaal 10 micron. Voorts is Aramis van plan om op de beoogde compressor- en eindstations op optimale locaties filters met te plaatsen.

4 Strengere specificatie dan Porthos CO2-specificatie v 3.1.

Druk en temperatuur

CO_2 wordt tijdens normaal bedrijf in de dense phase getransporteerd door de verbindingsleiding. De verbindingsleiding is ontworpen op de meest maatgevende belasting ten gevolge van druk en temperatuur. De ontwerpdruk van de verbindingsleiding is 200 bar. Bij de maximale transportcapaciteit van 22 Mton per jaar neemt de druk over de lengte van de verbindingsleiding af tot circa 140 bar bij het platform K-14-FA-2.

De ontwerptemperatuur van de verbindingsleiding is -46 - 30˚C[8], maar de getransporteerde CO_2 is bij aankomst op het distributieplatform afgekoeld tot ongeveer zeewatertemperatuur. Dit is ook de aankomsttemperatuur op K-14-FA-2.

De druk en temperatuur van het geïnjecteerde CO_2-mengsel worden geregeld vanaf het compressorstation. De condities in de verbindingsleiding worden zodoende gereguleerd vanuit het compressorstation met als doel onder in de put de juiste omstandigheden te creëren. Tevens zijn gewenste condities voor de verbindingsleiding zelf vastgesteld. Bij het transport van CO_2 is het van belang dat druk en debiet binnen de vastgestelde bandbreedte blijven, zodat de injectie van CO_2 in de putten kan worden uitgevoerd. Onder in de put zijn de druk en temperatuur afhankelijk van het aangevoerde gasmengsel en van de druk en temperatuur in het reservoir. Deze eigenschappen hebben invloed op de injectiviteit van de CO_2 in het opslagreservoir.

8 *De ontwerptemperatuur wordt nog verder onderzocht.*

Stoffen kabel
De kabel bevat een kunststoffen, metalen (koper) en hydraulische vloeistof.

3.7 Bedrijfsvoering

K-14-FA-2 is een nieuw te bouwen platform voor CO2 injectie dat beschikt over alle relevante veiligheidssystemen op basis van de noodzakelijke veiligheidsstudies en gedocumenteerd in de VG documentatie zoals wordt ingediend bij SodM.. De inrichting is ontworpen in overeenstemming met de eisen van de Mijnbouwwet- en regelgeving en industriestandaards, en voldoet daarmee aan de eisen op het gebied van veiligheid, milieu en procesbeveiliging. Er zijn onderhouds- en inspectieplannen en calamiteiten- en reddingsplannen, waarin ook communicatie met de Centrale Controle kamer (CCK), bemande platforms in de omgeving, de Kustwacht, SodM en andere relevante partijen wordt geadresseerd, ook wat betreft de aangesloten verbindingsleiding.

De bedrijfsvoering van de leidingen wordt gebaseerd op een bedrijfsmanagementsysteem (BMS) inclusief een veiligheid en milieubeheerssysteem om een veilige en duurzame bedrijfsvoering voor mens en milieu gedurende de totale levensduur te waarborgen. De bedrijfsvoering kan worden uitgevoerd door Shell of door een aan te wijzen exploitant. Het nog op te stellen BMS wordt conform NEN 3656 gebaseerd op gedocumenteerde doelen op het gebied van risicomanagement en niet zozeer op middelen.

Een inspectieplan maakt deel uit van het BMS. De inspectie- en onderhoudsfrequentie wordt bepaald op basis van het BMS en de resultaten van eerdere inspecties en van een risico-inventarisatie en -evaluatie. Het BMS is gereed voordat de leiding in gebruik wordt genomen.

Procesregeling
Het platform is normaal onbemand. Dit betekent dat het proces voor normale operatie gecontroleerd wordt door industriële automatisering. Primair wordt er gestuurd op druk en temperatuur van de CO2. Apparatuur op het platform kan vanaf de centrale controlekamer door de operators bestuurd worden. De druk en temperatuur van de CO2 wordt op het platform gemeten. De regelkleppen van de putten worden bediend door de automatisering of vanuit de centrale controlekamer, en daarmee het debiet van de CO2 gereguleerd. In het compressorstation en de CO2-next-terminal is al veiliggesteld dat het watergehalte van de aangeleverde CO2 dusdanig laag is dat geen condensvorming kan optreden, waardoor vochtophoping en corrosie voorkomen worden. De specificaties van de aangeleverde CO2 zijn met voldoende marge vastgesteld en het watergehalte wordt bewaakt met analysers bij de CO2-leveranciers en de CO2Next-terminal.

Procesbeveiliging
Onafhankelijk van het regelsysteem is een beveiligingssysteem geïnstalleerd, dat de installatie naar een veilige situatie brengt in geval het regelsysteem uitvalt. Tijdens een Emergency Shut Down (ESD) worden de installaties ingesloten en onder druk gehouden.

De leiding tussen de platforms zijn aan weerszijde voorzien van automatische veiligheidskleppen waardoor de leidingen kunnen worden ingesloten.

Monitoring
In de gebruiksfase wordt zowel de staat van de riser en de aansluiting op de platforms als de onderwater Battery Limit Isolation Valve (BLIV) op het manifold regelmatig geïnspecteerd.

Daarnaast Spurline ligging ('right of way') wordt naar verwachting tweejaarlijks uitgevoerd. Dit betekent een akoestisch onderzoek om de begravings-/blootstellingsstatus van de spurline te bevestigen. Indien van toepassing kan het onderzoek ook een visuele inspectie omvatten met ROV- en anodepotentiaalmetingen.

Verzoek tot instemming ingebruikname

Conform het Mbb dient de operator van de verbindingsleiding uiterlijk twee weken voor de geplande ingebruikname van de pijpleiding een verzoek in bij het ministerie van KGG (gemandateerd aan de Inspecteur-Generaal der Mijnen (IGM)) voor instemming met de ingebruikname daarvan. Onderdeel van dit verzoek zijn:

1. Een verklaring van een onafhankelijke deskundige, waarin wordt beoordeeld of de eigenschappen en de aanleg van de pijpleiding voldoen aan de bij of krachtens artikel 93 gestelde eisen, en
2. Gegevens waaruit blijkt dat de ligging van de pijpleiding die is aangelegd in de territoriale zee of het continentaal plat voldoet aan de bij of krachtens artikel 93 gestelde eisen en, voor zover van toepassing, aan de desbetreffende vergunningvoorschriften.

3.8 Buitengebruikstelling en verwijderen van de verbindingsleiding en kabel

Na de buitengebruikstelling aan het einde van de levensduur wordt zowel de verbindingsleiding als de kabel conform de dan geldende regelgeving uit bedrijf genomen en veiliggesteld. Vervolgstappen met betrekking tot eventuele verwijdering van zowel leiding als kabel zullen worden genomen conform de dan geldende wet- en regelgeving.

4 De effecten op het milieu en de omgeving

4.1 Inleiding

In het kader van deze vergunningaanvraag dient ook te worden beoordeeld of de milieugevolgen van het project aanleiding geven om een mer te doorlopen. Met het oog daarop worden in onderstaande paragrafen de milieugevolgen van het project weergegeven. Daarbij wordt gebruik gemaakt van de onderzoeken van het MER dat voor het Aramis initiatief als geheel is opgesteld (Deelrapport Milieueffecten, MER CO_2-transportinfrastructuur Aramis, Royal HaskoningDHV, 9 februari, ARM-PFE-B10-ENV-EIA-2030).

4.2 Bodem en water

Bestaande situatie
Morfologie en dynamiek
De verbindingsleiding vanaf de aftakking op de Aramis zeeleiding naar K-14-FA-2 ligt in het diepere deel van de Nederlandse Noordzee met relatief weinig bodemdynamiek. Dit gebied ligt aan de noordrand van een systeem van zandgolven waardoor de bodem in dit gebied wel enig reliëf kent. De waterdiepte in dit gebied is ongeveer 25 meter. De zeebodem in dit gebied is overwegend vlak zonder duidelijke structuren. De bodem bestaat uit (licht grindig) zand.

Aanleg
Morfologie en dynamiek
In de aanlegfase vinden diverse werkzaamheden plaats die van invloed zijn op de zeebodem en de lokale waterkwaliteit. De werkzaamheden zijn in paragraaf 3.5.2 beschreven en worden hier kort aangehaald:

- Survey en schoonmaken van zeebodem ten behoeve van de verbindingsleiding;
- Egaliseren van de zeebodem daar waar nodig en mits noodzakelijk;
- Leiding leggen op of in zeebodem (de leiding wordt ingegraven waar dit op grond van een risicoanalyse nodig is).
- Storten van stenen en leggen van matrassen daar waar bestaande leidingen en/of kabels worden gekruist en nabij platformen.

Wanneer op grote schaal bodemberoering plaatsvindt tijdens de aanlegfase kan de integriteit van de zeebodem in het gedrang komen. De integriteit van de zeebodem dient zodanig te blijven dat de structuur en de functies van de ecosystemen gewaarborgd blijven en dat met name bentische ecosystemen niet onevenredig worden aangetast.

Zeewaterkwaliteit
De zeewaterkwaliteit kan beïnvloed worden door de lozing van testwater dat geringe hoeveelheden conditioneringschemicaliën kan bevatten (zie paragraaf 3.5.2). De chemicaliën die gebruikt worden, zijn toegelaten meldingsplichtige chemicaliën die mogen worden geloosd en bij de lozing voldoet het te lozen hydrotestwater aan de eisen van hoofdstuk 9 van de Mbr. Mede door de continue verversing en stroming van het zeewater wordt het effect van de lozing op de kwaliteit van het zeewater als nihil geschat.

Daarnaast komen bij de inzet van schepen kleine hoeveelheden antifouling vrij in zee en kan depositie van rookgassen van werkschepen invloed hebben op de waterkwaliteit. In het MER voor het Aramis initiatief is uiteengezet dat de concentraties koper die vanwege het gebruik van koperhoudende antifoulings in het zeewater terecht kunnen komen, dermate laag zijn dat enig effect op de kwaliteit van habitats uit te sluiten is. Ook de depositie van door werkmaterieel uitgestoten verbrandingsstoffen (stikstof- en zwaveloxiden) leidt niet tot enige effect op het mariene milieu. De maximale verhoging van de stikstof- en zwavelconcentraties in het water als gevolg van de verbranding en uitstoot van de verbrandingsstoffen is verwaarloosbaar, ten opzichte van de in de kustzee voorkomende achtergrondconcentraties van 51 mg N/l en 910 g S/l. Als gevolg van de netto noordwaarts gerichte getijdestroming vindt namelijk voortdurend verversing van het water rond de aanleglocatie plaats, waardoor de nutriënten zich over een veel grotere oppervlakte verspreiden.

Bovenstaande analyse is van toepassing op het Aramis initiatief als geheel, en geldt ook voor de verbindingsleiding naar K-14-FA-2.

Gebruiksfase

Zodra de leiding is aangelegd is geen sprake meer van bodemroering waardoor geen sprake meer is van een impact op de zeebodem. Tijdens de gebruiksfase van het Aramis initiatief vinden geen lozingen van antifoulings op het zeewater of uitstoot van emissies van verbrandingsstoffen plaats door werkmaterieel met uitzondering van de monitoring naar de ligging van de leiding.

In paragraaf 3.3 is de voorziene bescherming tegen externe corrosie van de verbindingsleiding beschreven. De opofferingsanoden bestaan uit blokken van een aluminiumlegering (AL – Zn), conform ISO 15589-2. Omdat de anoden uit een onedelere metaallegering bestaan dan het staal van de verbindingsleiding, corroderen de anodes bij eventuele beschadigingen van de coating eerder dan het staal van de leiding en voorkomen op deze wijze dat de stalen leiding corrodeert. De opofferingsanoden worden verspreid over de gehele leidinglengte aangebracht.

Tijdens de levensduur van de leiding lossen de opofferingsanoden langzaam op in het zeewater en resulteren daarbij in een emissie naar water. Deze emissie treedt op tijdens de hele levensduur van de leiding. De specificatie van het corrosiebeschermingssysteem is:

Ontwerplevensduur: ca. 30 jaar levensduur + 2 jaar reserve;

Anodesamenstelling (min / max gewichtsprocenten):

- aluminium ca. 94% (balans)
- zink 2,5 - 5,75%
- overig 0,016 - 0,040%
- Aantal anodes: 23 stuks
- Gewicht per anode: 67 kg

Als conservatief wordt uitgegaan van het volledig oplossen van alle anodes in 32 jaar, resulteert dit in een jaarlijkse emissie naar water van 3,8 kg Al, 0,2 kg ton Zn, en minimale hoeveelheden In, Fe, Si, Cu, en Cd. Deze emissie treedt op over de gehele lengte van de verbindingsleiding van circa 850 m. Gezien de langzame geleidelijke oplossing en het grote volume zeewater waarin de anoden oplossen, en de korte lengte van de verbindingsleiding, leidt deze emissie tot een niet of nauwelijks meetbare concentratieverhoging van de anodecomponenten in zeewater.

Overige situaties
Onder de overige situaties vallen de opstartfase, regulier onderhoud, en eventuele onvoorziene situaties. Uit het monitoringsprogramma kan blijken dat onderhoudswerkzaamheden nodig zijn; zo kunnen er delen van de verbindingsleiding komen bloot te liggen of vrije overspanningen ontstaan die moeten worden gestabiliseerd of herbegraven.

In geval van falen of beschadigen van de verbindingsleiding, als gevolg van aanvaring door of ongeval met de scheepvaart, zijn ingrijpendere werkzaamheden nodig om de verbindingsleiding te vervangen of repareren.

De onderhouds- en eventuele reparatiewerkzaamheden zijn in het uiterste geval vergelijkbaar met de aanlegactiviteiten, maar zullen zeer waarschijnlijk slechts zeer beperkt zijn.

Conclusie
Er zijn geen aanzienlijke gevolgen voor de zeebodem en het zeewater te verwachten als gevolg van de aanleg en het gebruik van de verbindingsleiding. Ook reguliere onderhouds- en eventuele reparatiewerkzaamheden zullen niet tot aanzienlijke gevolgen leiden voor de zeebodem en waterkwaliteit.

4.3 Verstoring door onderwatergeluid

Bestaande situatie
Op verschillende plaatsen op de Noordzee is sprake is van onderwatergeluid. Logischerwijs treedt dat voornamelijk op bij de bouw van windparken op zee en door de scheepvaart nabij scheepvaartroutes, havenactiviteiten en andere activiteiten die op de Noordzee plaatsvinden.

Aanleg
Tijdens de aanlegfase vinden diverse werkzaamheden plaats waardoor tijdelijk onderwatergeluid optreedt. Voor de verbindingsleiding betreft dit hoofdzakelijk werkzaamheden met een pijplegschip en eventuele andere werkschepen. In het MER voor Aramis is aangegeven wat hiervan de te verwachten geluidbelasting is.

Voor een representatief groot pijplegschip zijn het geluiddrukniveau (SPL) en het bijbehorende sound exposure level over 24 uren op 100 meter afstand bepaald.[9] Deze zijn afgezet tegen de PTS (permanent threshold schift) van verschillende vis- en zoogdiersoorten; oftewel het sound exposure level waarbij een permanente verhoging van de gehoordrempel optreedt (gehoorschade). Vervolgens zijn de veilige afstand en veilige verblijfstijd berekend voor vissen en zeezoogdieren samenhangend met het in werking zijnde pijplegschip. Tot slot is bepaald vanaf welke afstand diersoorten het onderwatergeluid zullen mijden (gedragsbeïnvloeding). De verkregen informatie is in onderstaande tabellen weergegeven. Ook duikende vogels kunnen last hebben van onderwatergeluid maar de impact daarvan is vergelijkbaar of kleiner dan die op zeezoogdieren.

[9] *Mogelijk wordt een kleiner pijplegschip gebruikt. De hiervan te verwachten hinder zal kleiner zijn. Voor de effect inschatting wordt vooralsnog van een groot schip uitgegaan zodat de worst case in beeld is gebracht.*

Tabel 4-1 Afstand en verblijftijd samenhangend met PTS vanwege een groot 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
Pijpenleggen	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 4-2 Afstand samenhangend met mijding vanwege een groot pijplegschip, representatieve situatie

Bron van onder-watergeluid	Mijding gerelateerd				
	Dier-soort	Drempel mijding SPL in dB re 1 μPa	Drempel mijding* SPL in dB re 1 μPa ver-hoogde achtergrond	Mijding op af-stand in m	Mijding op afstand in m mits ver-hoogde achtergrond
Pijpenleggen	Bruin-vis	120	130	16	2
	Grote vis	150	n.v.t.	89	n.v.t.
	Klein e vis	150	n.v.t.	89	n.v.t.
	Zee-hond	120	130	22909	2291

*NOAA stelt dat de drempel van 120 dB mag worden verhoogd bij achtergrondgeluidniveaus ≥ 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 4-2 is dit aangeduid als een zogenoemde verhoogde achtergrond.

De berekende veilige afstanden en verblijfstijden zijn in de tabellen 4-1 en 4-2 vermeld. De drempels PTS SEL in tabel 4-1 betreffen ongewogen waarden. Het verschil in de eigenschappen tussen de bruinvis en zeehond (uitgedrukt in de weegfactoren) is significant, als gevolg daarvan treedt bijvoorbeeld in tabel 4-2 bij een identieke drempel een groot verschil in mijdingsafstand op.

Werkzaamheden op de zeebodem die worden verricht voorafgaand en na het realiseren van leidingen en kabels, betreffen het plaatsen van zogenoemde matrassen en andere zeebodemstabilisatie, het graven van sleuven, het storten van stortsteen en het verwijderen van oneffenheden met een sleephopperzuiger (baggeren). Daarvan is uitsluitend het baggeren geluidrelevant en kan een impact hebben in de omgeving. De geluiduitstraling van een groot baggervaartuig is beperkt lager of gelijkwaardig aan het genoemde pijplegschip.

De onderwatergeluidbelasting kan impact hebben op het mariene milieu.

Gebruiksfase
In de gebruiksfase treedt geen onderwatergeluid op vanaf de verbindingsleiding.

Overige situaties
Tijdens onderhouds- en eventuele reparatiewerkzaamheden wordt materieel ingezet. Bij de periodieke monitoring van de goede ligging van de leiding wordt gebruik gemaakt van sonar, wat een bron van onderwatergeluid is. Dit zal aanzienlijk minder onderwatergeluid veroorzaken dan de aanlegactiviteiten.

Conclusie
Als gevolg van de aanlegwerkzaamheden, en in veel mindere mate ook de onderhouds- en eventuele reparatiewerkzaamheden zijn tijdelijk negatieve effecten van onderwatergeluid te verwachten maar gezien de bepekte omvang van het geluid, zal dit niet aanzienlijk zijn.

4.4 Emissies naar de lucht

Bestaande situatie
Luchtkwaliteit wordt bepaald nabij woongebieden zodat de gevolgen voor de volksgezondheid in acht kunnen worden genomen. Op zee is dit niet aan de orde. Daarnaast worden op zee behalve door schepen en platforms geen emissies naar de lucht uitgestoten, waardoor de luchtkwaliteit op zee doorgaans goed is.

Aanleg
Tijdens de aanleg van de verbindingsleiding worden diverse schepen en werktuigen met verbrandingsmotoren ingezet die emissies naar de lucht veroorzaken (stikstof- en zwaveloxiden en fijnstof). De uitgestoten stoffen kunnen een effect hebben op het mariene milieu en in theorie op de natuur op land.
In paragraaf 4.2 is al aangegeven dat geen effect van deze emissies en dientengevolge depositie op het mariene milieu verwacht hoeft te worden.

In het MER voor het Aramis initiatief is onderzocht wat het mogelijke effect van stikstofdepositie vanwege de aanleg van de hele CO_2-transportinfrastructuur op de natuur op land is. Daarbij is geconcludeerd dat er, mede vanwege het reduceren van de uitstoot door het inzetten van zo mogelijk elektrisch materieel onshore, geen relevant effect verwacht hoeft te worden. Daarbij moet bovendien begrepen worden dat de grootste emissiebronnen ingezet worden op de Maasvlakte, ten behoeve van de realisatie van de terminal en de kruising van de zeeleiding met de Maasgeul.

Voor de aanleg van de verbindingsleiding geldt dat deze aanleg veel verder dan 25 km van de onshore stikstofgevoelige Natura 2000-gebieden plaatsvindt. Door de vaste afstandsgrens in AERIUS-calculator van 25 km zullen stikstofemissies als gevolg van de leidingaanleg niet tot relevante stikstofdeposities leiden. De Natura 2000-gebieden op zee zijn ook niet stikstofgevoelig. Bovendien hoeven emissies van scheepvaart buitengaats volgens de instructiegegevens invoer voor Aerius 2023 van BIJ12 niet te worden gemodelleerd omdat zeescheepvaart wordt beschouwd als onderdeel van het heersende verkeersbeeld.

Het effect van de stikstofemissies die samenhangen met de aanleg van de verbindingsleiding is daarmee te verwaarlozen en is zeker geen aanzienlijk effect.

Gebruiksfase
Tijdens de gebruiksfase van de pijpleiding treden geen emissies op naar de lucht en zijn daarvan geen effecten te verwachten.

Overige situaties
Tijdens onderhouds- en eventuele reparatiewerkzaamheden wordt materieel ingezet dat emissies naar de lucht uitstoot. Dit zal in geen geval meer bedragen dan de emissies tijdens de aanlegfase.

Conclusie
Emissies naar de lucht treden alleen op door de inzet van materieel tijdens de aanlegfase, en in (veel) mindere mate tijdens operationele fase, onderhouds-, monitoring en eventuele reparatie-werkzaamheden.

De emissies zijn te laag om via depositie tot relevante effecten in het mariene milieu, de natuur - of leefomgeving op land te leiden. Er wordt niet getoetst aan de luchtkwaliteit ter plaatse van de werkzaamheden voor de verbindingsleiding omdat het Besluit kwaliteit leefomheving (Bkl) niet van toepassing is. Ten aanzien van de mer-beoordeling geldt dat emissies naar de lucht zeker geen aanzienlijk effect zullen veroorzaken.

4.5 Visuele aspecten

De verbindingsleiding van de Trunkleiding naar platform K-14-FA-2 ligt op zee waar scheepvaart en visserij plaatsvindt.

Aanleg
Tijdens de aanleg van de verbindingsleiding is werkmaterieel ter plaatse aanwezig. De locatie ligt te ver van de kust om zichtbaar te zijn vanaf land. Ook de lichtuitstraling van nachtelijke werkzaamheden is niet zichtbaar vanaf land.

Gebruiksfase
Tijdens de gebruiksfase ligt de verbindingsleiding onder het zeeoppervlak waardoor geen visuele hinder optreedt.

Overige situaties
In geval van onderhouds-, monitoring- of reparatiewerkzaamheden treden mogelijk gelijksoortige (tijdelijke) effecten op als in de aanlegfase.

Conclusie
Tijdens aanleg-, onderhouds- en eventuele reparatiewerkzaamheden treedt mogelijk tijdelijk enige hinder op door lichtverstoring maar deze is verwaarloosbaar tot niet zichtbaar gezien de grote afstand tot land.

4.6 Effecten op beschermde gebieden en soorten

Bestaande situatie
In de wijdere omgeving van de verbindingsleiding zijn meerdere beschermde Natura 2000-gebieden aangewezen, waarvan het Friese Front en de Bruine bank de dichtstbijzijnde zijn. Daarin en in de omringende Noordzee komen tevens diverse beschermde vissoorten, zeezoogdieren, vogels en vleermuizen voor.

Aanleg
In het MER voor het Aramis initiatief (en bijhorende passende beoordeling) zijn de effecten op deze (en andere) beschermde gebieden en soorten onderzocht. Relevante effecten worden hieronder genoemd.

Gebieden
De passende beoordeling bij het MER (milieustudie bijlage 5 bij het MER) is rond de verbindingsleiding niet van toepassing voor wat betreft de zandkokerworm en platte oester. Rond de verbindingsleiding komt de zandkokerworm en de platte oester niet of amper voor.

Verder treden indirecte effecten op voor bruinvissen door onderwatergeluid. Hierbij geldt dat er in de Natura 2000-gebieden (waaronder Natura 2000-gebied de Klaverbank, de Noordzeekustzone en de Voordelta) geen significante directe effecten optreden, maar wel mogelijk op de gehele Noordzee bruinvispopulatie buiten de aangewezen gebieden. Bij de verbindingsleiding wordt niet geheid waardoor geluidsbeperkende maatregelen voor heigeluid hier niet van toepassing zijn. Om continu onderwatergeluid door de in te zetten schepen te minimaliseren, moet zoveel mogelijk gebruik gemaakt worden van stille schepen.

Soorten
In het MER voor Aramis wordt aangegeven dat voor verschillende voorkomende beschermde soorten mitigerende maatregelen nodig zijn om negatieve effecten zoveel mogelijk te voorkomen of verzachten. Hiervoor wordt vergunning aangevraagd.

Gebruiksfase
In de gebruiksfase zijn geen effecten op beschermde gebieden en soorten te verwachten.

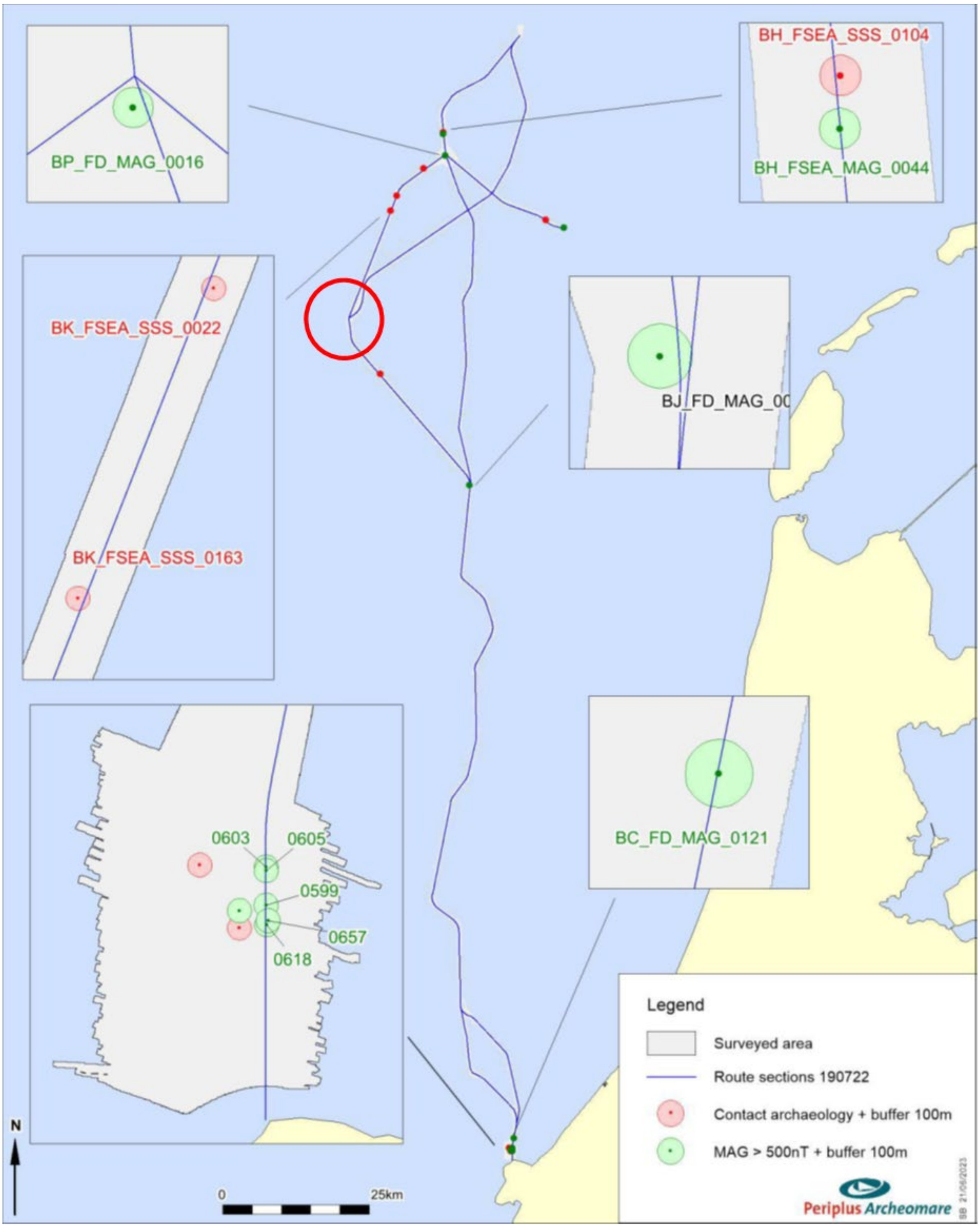
Overige situaties
Tijdens onderhouds- en eventuele reparatiewerkzaamheden wordt materieel ingezet. Dit zal doorgaans (aanzienlijk) minder onderwatergeluid veroorzaken dan de aanlegactiviteiten.

Conclusie
Negatieve effecten op beschermde gebieden en soorten als gevolg van de voorziene werkzaamheden zijn niet uit te sluiten maar deze effecten kunnen in voldoende mate worden beperkt worden door de aanwezige voorzieningen. In het MER voor het Aramis initiatief wordt aangegeven dat aanzienlijke effecten kunnen worden uitgesloten.

4.7 Archeologie

Bestaande situatie
Voor het MER voor het Aramis initiatief zijn diverse onderzoeken uitgevoerd naar archeologische resten op of in de zeebodem[10]. Hieruit blijkt dat zich verschillende objecten op de zeebodem bevinden waaraan een archeologische verwachting moet worden toegekend. In overeenstemming met de Nederlandse wet- en regelgeving mogen er geen bodemberoeringen worden uitgevoerd binnen 100 meter van dit soort locaties. Indien er werkzaamheden plaatsvinden binnen 100 meter van een potentiële archeologische vindplaats, wordt in overleg met Rijkswaterstaat en de Rijksdienst voor het Cultureel Erfgoed (RCE) per geval bekeken of de 100 meter afstand behouden blijft. Daarnaast zijn er magnetische anomalieën aangetroffen die van archeologische waarde kunnen zijn. Figuur 4.1 geeft deze locaties weer.

[10] *Het onderzoek betrof een bureaustudie en geofysisch onderzoeken binnen het studiegebied, waaronder:*
- *Aramis Pipeline Routing Desktop Study – Expected Site Conditions, Consultancy Report (R201644 (03) | 10 February 2022)*
- *Geophysical Results Report, Geophysical and Geotechnical Site Investigation F197217-REP-001 | 01 | 18 April 2023*
- *Document 22A030-01 Aramis pipeline – an archaeological assessment of geophysical survey data, by Periplus Archeomare, 31-08-2023 Final*
- *Route selection document including aspects as morphology, safety.*



Figuur 4-1 Kaart met 8 objecten (Archeologische verwachting, die zichtbaar zijn aan het bodemoppervlak) en 10 anomalieën (Archeologie, objecten alsook potentieel NGE, die niet zichtbaar zijn aan het bodemoppervlak). Rood omlijnd de verbindingsleiding naar K-14-FA-2. De rode cirkel in de afbeelding markeert het gebied waar K14 ligt..

Aanleg, gebruiksfase en overige situaties

Het uitgevoerde archeologische onderzoek (litertauuronderzoek en survey) en de daarbij gevonden cq potentieel archeologische objecten (anomalieen) zijn vergeleken met de route van de verbindings-leiding. Hieruit bleek dat de dichtbijzijnde potentiele archeologische objecten op meer dan 9 km afstand liggen. De bodem ter plaatse van de verbindingsleiding wordt tijdens de aanleg geroerd. Maar omdat er geen potentiele archeologische objecten mogen worden verwacht binnen de 100 meter worden in de aanleg-, gebruiksfase of bij onvoorziene situaties, geen verstoringen verwacht op eventuele archeologische objecten.

Conclusie

De verbindingsleiding komt niet dichter dan 100 m in de buurt van potentiele archeologische objecten. Daardoor is verder onderzoek of optimaliseren van het tracé voor de verbindingsleiding niet van toepassing.

4.8 Nautische veiligheid

Bestaande situatie

Voor de nautische veiligheid is relevant dat K14-FA-2, ILT en daardoor ook de verbindingsleiding zich aan de oostelijke rand van een vaarroute bevinden. De verbindingsleiding kruist de vaarroute niet. Daarnaast maakt de visserij gebruik van het gebied.

Aanleg

De verbindingsleiding wordt ingegraven op de locaties waar dat vereist is op basis van een risicoanalyse van het gebied volgens paragraaf 6.3.1 van NEN 3656. De kabel wordt altijd ingegraven. Het tracé in ieder geval ook in de oostelijke rand van de scheepvaartroute (VSS: Verkeers-Scheiding-Stelsels). Zie hiervoor figuur 4-2, waar de verbindingsleiding naar K-14-FA-2 rood omlijnd is.

Een verbindingsleiding wordt gelegd door een combinatie van een legschip en een ingraafmachine. De snelheid waarmee gevaren wordt is geschat op 3 km per dag. Gezien de korte afstand van de verbidingsleiding in en nabij de vaarroute én de werksnelheid, zal de hinder van werkmaterieel naar het overige scheepvaartverkeer naar verwachting gedurende een dag plaats vinden. Bovendien worden op basis van de Aanvraag 'North Sea Activity' (NSA) bij de Kustwacht voorzorgsmaatregelen overlegd en ingesteld, zodanig dat de kans op verstoring en eventueel een incident van doorgaande scheepvaart met werkmaterieel en los drijvend bouwmateriaal onwaarschijnlijk zal zijn. Aanwezigheid van een sleepboot voor werkmaterieel als begeleiding of de aanwezigheid van een Noordzeeloods op de pijpenlegger wordt in latere fase overwogen in overleg met aannemer.

Figuur 4-2 Overzicht K14-FA02 en verbindingsleiding ten opzichte van shipping lane. Donkergroene lijn is de Aramis Trunkline. Links van de smalle roze lijn de shipping lane.

Gebruiksfase
De risico's tijdens de gebruiksfase zijn het mogelijk falen of beschadigen van de verbindingsleiding of kabel als gevolg van aanvaring door of ongeval met de scheepvaart. De kans hierop wordt bepaald door corrosie of materiaaldefecten, en door de impact van bijvoorbeeld ankers of een aanvaring door of ongeval met de scheepvaart. De vier hoogste ongevalsfrequenties betreffen:

- Vissende vissersschepen die over de buisleiding of kabel varen;
- Anker haakt achter de buisleiding en/of kabel;
- Containers vallen overboord op de buisleiding of kabel;
- Schip zinkt op buisleiding of kabel (al dan niet als gevolg van een aanvaring).

De kans op een ongeval is echter beperkt en dit geldt te meer voor de verbindingsleiding en kabel naar K14-FA-2 gezien de korte lengte van de leiding en kabel en het ingraven

Overige situaties
Tijdens regulier onderhoud, inspectie en eventuele reparatiewerkzaamheden is ter plaatste werk-materieel aanwezig. Als gevolg daarvan zijn - tijdelijk vergelijkbare risico's te verwachten als in de aanlegfase.

Conclusie
Als gevolg van aanleg-, onderhouds- en eventuele reparatiewerkzaamheden zijn goed beheersbare nautische risico's te verwachten. Al deze geplande activiteiten worden gemeld bij de Kustwacht waarna overleg kan plaatsvinden hoe de nautische risico's te mitigeren.

4.9 Afvalproductie

Bestaande situatie
Vanzelfsprekend is er voorafgaand aan het project geen sprake van afval vanwege het project.

Aanleg
Tijdens de aanleg van de verbindingsleiding worden geen gevaarlijke stoffen gebruikt.
Ook komt er vrijwel geen restafval vrij bij de aanleg. Het restafval dat vanwege de aanlegoperatie vrijkomt wordt op een reguliere wijze verwerkt.

Gebruiksfase
Tijdens de gebruiksfase worden geen gevaarlijke stoffen gebruikt en komt geen restafval vrij.
Ook tijdens onderhouds- en eventuele reparatiewerkzaamheden worden geen gevaarlijke stoffen gebruikt en komen niet of nauwelijks reststoffen vrij.

Decommissioning
Tijdens de decommissioning wordt de leiding volgens de huidige regels weer verwijderd. Hergebruik voor een 30 jaar oude leiding wordt klein geacht, waardoor de leiding als afval moet worden beschouwd. Het staal van de leiding kan worden gerecycled, coating worden verbrand en beton gestort.

Conclusie
Er is geen sprake van het gebruik van gevaarlijke stoffen die tot gevaarlijk afval kunnen leiden, noch van grote hoeveelheden restafval.

4.10 Energieverbruik en CO_2-balans

Voor de aanleg van de verbindingsleiding en de overige onderdelen van de Aramis CO_2-infrastructuurketen wordt materiaal gebruikt (staal) en wordt werkmaterieel ingezet waarvoor aanzienlijke hoeveelheden energie nodig zijn. Het grootste energieverbruik vindt echter plaats in de gebruiksfase. De verbindingsleiding heeft in dit geheel een beperkt aandeel.

In het MER voor het Aramis initiatief is het totaal van de benodigde energie voor de aanleg en de gebruiksfase omgezet naar CO_2-emissies, en zijn deze afgezet tegen de CO_2-uitstoot die met het initiatief wordt vermeden. Daaruit volgt dat over de gehele levensduur van de keten gezien, de initiële extra hoeveelheid benodigde energie per saldo resulteert in een grote reductie van CO_2-emissies naar de atmosfeer.

Geconcludeerd kan worden dat voor het Aramis initiatief als geheel grote hoeveelheden energie benodigd zijn, en dat er tegelijkertijd per saldo een veel grotere reductie van CO_2-emissies bereikt wordt.

4.11 Overige aspecten

In voorgaande paragrafen zijn de relevante milieu-onderwerpen en -risico's besproken. Het MER voor het Aramis initiatief gaat daarnaast ook in op de gevolgen voor overige gebruiksfuncties op zee.

5 Cumulatie van effecten

De effecten van afzonderlijke projecten kunnen op zichzelf relatief beperkt zijn, maar kunnen in combinatie met andere projecten of handelingen, significant negatieve gevolgen hebben voor een (Natura 2000-)gebied. Dit wordt cumulatie genoemd. Het al dan niet optreden van cumulatie is afhankelijk van de milieueffecten, effectafstanden, de planning en de locatie van uitvoering van de activiteit. Het optreden van cumulatie kan uitgesloten worden als aan de volgende twee criteria wordt voldaan:

- De afstand tussen de locaties van twee activiteiten is groter dan de som van de maximale effectafstanden van gelijktijdig optredende effecten;
- De tussenpozen tussen de uitvoering van twee activiteiten is voldoende om samenloop van effecten te voorkomen.

Voor wat betreft de verbindingsleiding is er naast de overige onderdelen van de Aramis CO_2-infrastructuur nog een aantal andere ontwikkelingen op het Nederlandse deel van de Noordzee die tot cumulatie kunnen leiden. In de volgende paragrafen wordt mogelijke cumulatie van effecten met deze twee categorieën beschouwd.

5.1 Cumulatie met overige onderdelen van het Aramis initiatief

In het MER voor het Aramis initiatief zijn de effecten van het gehele initiatief in beeld gebracht. Deze merbeoordeling voor de verbindingsleiding naar K-14-FA-2 gaat in op de gecumuleerde effecten van stikstofdepositie van het gehele initiatief en op de gecumuleerde effecten van andere ketenonderdelen op zee op andere factoren dan stikstofdepositie (zoals verstoring door geluid, licht, oppervlakteverlies etc.). De effectafstanden van onderdelen op land op andere milieuthema's dan stikstof zijn te groot om tot cumulatie te leiden op het mariene milieu nabij de verbindingsleiding.

5.1.1 Stikstofdepositie

Voor stikstofemissies is een rekenmodel gebouwd waarmee cumulatieve verspreidingsberekeningen van alle Aramis onderdelen in de aanlegfase en in de gebruiksfase zijn uitgevoerd. Daarmee zijn de effecten van stikstofdepositie van Aramis op onshore Natura 2000-gebieden bepaald. Tijdens de aanlegfase zijn de emissies en depositie het hoogst waardoor deze situatie maatgevend is. Uit de berekeningen komt naar voren dat het noodzakelijk is de depositie zoveel mogelijk te beperken; daarvoor wordt nabij de onshore natura 2000 gebieden zoveel mogelijk elektrisch materieel ingezet en wordt de uitstoot van fossiele emissies zoveel mogelijk beperkt.

Uit de beoordeling van de effecten van de berekende tijdelijke extra stikstofdepositiebijdrage op de kwaliteit van deze habitattypen blijkt dat de beperkte eenmalige extra stikstofdepositie in de aanlegfase niet zal leiden tot veranderingen in de vegetatiesamenstelling, groeisnelheid of onderlinge concurrentieverhoudingen tussen plantensoorten van de betreffende habitats. Evenmin leidt deze eenmalige en kleine stikstofdepositie tot een verzwaring van de beheeropgave of tot een belemmering bij het uitvoeren van herstelmaatregelen.

Geconcludeerd wordt dat tijdelijke gecumuleerde depositiebijdrage tijdens de aanlegfase van de verbindingsleiding niet leidt tot een aantasting van de kwaliteit van de beoordeelde onshore Natura 2000-gebieden of tot belemmering van de mogelijkheden maatregelen te treffen die noodzakelijk zijn voor het behalen van de instandhoudingsdoelstellingen van deze Natura 2000-gebieden.

5.1.2 Onderwatergeluid

Onderwatergeluid heeft een negatief effect op de mariene ecologie, en in het bijzonder voor zeezoogdieren bruinvis, grijze zeehond en zeehond. Voor onderwatergeluid is bepaald in hoeverre de geluidscontouren overlappend zijn in ruimte en tijd. Vooral het heien van verankeringspalen en conductors van het distributieplatform en platforms op zee leidt tot verstoring van zeezoogdieren en kan overlap hebben met de verstoring vanwege de aanleg van de verbindingsleiding.

Om het effect van onderwatergeluid te minimaliseren worden onder andere de volgende maatregelen genomen in verschillende onderdelen van de CO_2 -infrastructuurketen:

- Een deel van het onderwatergeluid is gerelateerd aan scheepvaart. Zoveel als mogelijk worden de bestaande scheepvaartroutes gevolgd waar in de referentiesituatie al veel scheepsverkeer plaatsvindt.
- De meeste invloed van onderwatergeluid is afkomstig van het heien van de funderingspalen voor platforms en conductors bij het boren van putten. Om dit geluid te verminderen wordt allereerst een ADD (wat staat voor het Engelse Acoustic Deterrent Device) toegepast bij het heien van de conductor, het platform en de aanlegsteigers in combinatie met een soft start. Tevens wordt een HSD-systeem gebruikt (dat staat voor het Engelse Hydrosound Demper) en indien nodig een bellenscherm toegepast om het onderwatergeluid te beperken. Ook wordt waar nodig gebruik gemaakt van een Marine Mammal Observer (MMO) en Passive Acoustic Monitoring (PAM).

5.1.3 Overige storingsfactoren

Van overige storingsfactoren worden geen relevante gecumuleerde effecten verwacht.

5.2 Cumulatie met andere ontwikkelingen

In het MER voor het Aramis initiatief is cumulatie met andere ontwikkelingen onderzocht. Op zee betreft dit de volgende ontwikkelingen:

Tabel 5-1. Overzicht van projecten die worden meegenomen in de cumulatietoets en relevante effecten voor cumulatie, waarbij wordt opgemerkt dat pijpleiding aanleg plaats zal vinden tussen 1 January 2026 - 31 December 2030.

Project	Planning	Relevante effecten
Aramis CCS	2025 – 2030	Vertroebeling, onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Net op Zee IJmuiden Ver Alpha	2024 – 2029	Vertroebeling, onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Net op Zee IJmuiden Ver Beta en Gamma	2024 – 2029	Vertroebeling, onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Net op Zee Nederwiek 1 en 2	2025 – 2030	Vertroebeling, onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Wind op Zee Nederland	2024 – 2031	Onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Seismisch onderzoek Shell	2026	Onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie
Exploratieboring P11-B	2023 - 2024	Vertroebeling, onderwatergeluid, verstoring door licht en beweging/optiek, stikstofdepositie

Bij deze ontwikkelingen is sprake van effecten van onderwatergeluid op zeezoogdieren, vogelslachtoffers door aanvaringen en habitatverlies, verstoring van vogels en zeezoogdieren door licht, beweging en optiek en stikstofdepositie. Deze effecten kunnen cumuleren met de effecten van het Aramis initiatief.

Uit de passende beoordeling bij het MER voor Aramis blijkt dat rondom de Natura 2000-gebieden Voordelta en de Noordzeekustzone mitigerende maatregelen nodig zijn om cumulatie van negatieve effecten te voorkomen:

- In de Voordelta zal gedurende de winter een afstand van 1.500 meter aangehouden moeten worden van het deel van de zandplaat(platen) waarop zich grijze of gewone zeehonden bevinden.
- In de Noordzeekustzone moeten schepen minimaal 500 meter afstand houden van vogelconcentraties van topper, eidereend en zwarte zee-eend alsmede 1.500 meter van het deel van de zandplaat(platen) waarop zich grijze of gewone zeehonden bevinden.

In de passende beoordeling is ingeschat dat de cumulatie van deze effecten na mitigatie beperkt zal zijn. Dit geldt temeer voor de verbindingsleiding naar K-14-FA-2 omdat deze ver van de genoemde gebieden ligt.

5.3 Conclusie

Er treedt cumulatie op van effecten van de verbindingsleiding met effecten van andere onderdelen van het Aramis initiatief en in beperkte mate met effecten van andere ontwikkelingen op de Noordzee dan het Aramis initiatief. Door mitigerende maatregelen te treffen kunnen aanzienlijke cumulerende effecten worden voorkomen.

6 Conclusie mer-beoordeling

6.1 Inleiding

In dit hoofdstuk worden de verschillende kenmerken van de voorgenomen verbindingsleidingaanleg voor het transport van CO2 van de In-Line Tee (ILT) naar het nog te bouwen CO2-injectieplatform K14-FA-2 beoordeeld op basis van de formele mer-beoordelingscriteria uit bijlage III van de Europese richtlijn inzake milieueffectbeoordeling. Op grond van artikel 16.43 derde lid onder a van de Omgevingswet moet het bevoegd gezag bij het nemen van een mer-beoordelingsbesluit ook rekening houden met deze criteria.

6.2 Beoordeling voorgenomen activiteit

In bijlage III van de Europese richtlijn wordt onderscheidt gemaakt tussen drie aspecten van een voorgenomen activiteit of project:

1. De kenmerken van het project;
2. De locatie van het project;
3. De soort en kenmerken van het potentiële effect.

De voorgenomen boringen wordt hieronder beoordeeld aan de hand van de verschillende criteria die aan deze drie aspecten zijn verbonden.

De kenmerken van het project

In tabel 6-1 is de beoordeling van de meest relevante kenmerken van het project opgenomen.

Tabel 6-1: Beoordelingscriteria in relatie tot de kenmerken van het project.

Criterium	Beoordeling	Referentie
De omvang en het ontwerp van het project.	Het project (de verbindingsleiding) is onderdeel van een omvangrijk initiatief om CO_2 infrastructuur aan te leggen waarmee CO_2 in leeggeproduceerde gasvelden kan worden opgeslagen.	Hfst.1
De cumulatie met andere bestaande en/of goedgekeurde projecten.	Het project (de verbindingsleiding) is onderdeel van het Aramis initiatief, waartoe gelijktijdig met een Projectbesluit besloten wordt.	Hfst 5
Het gebruik van natuurlijke hulpbronnen, met name land, bodem, water en biodiversiteit.	De uitvoering van het project vereist het gebruik van een relatief beperkte hoeveelheid (natuurlijke) hulpbronnen: Staal voor de leidingen; Beperkt ruimtebeslag van de zeebodem voor het leggen van de leiding.	Hfst. 4 § 4.10 § 4.11
De productie van afvalstoffen.	De leidingen worden na de gebruiksduur weer opgegraven en gerecycled. Bij het testen van de leidingen tijdens de aanleg zal circa 300 m^3 water worden geloosd. De gevolgen van het vrijkomen van afval tijdens de aanleg, zijn verwaarloosbaar door de kleine hoeveelheid en de aard van de gebruikte stoffen. Daarnaast zal er bij de aanleg een beperkte hoeveelheid restafval vrijkomen dat op gecontroleerde wijze wordt verwerkt zodat de effecten daarvan ook minimaal zijn.	Hfst. 3 § 4.9
Verontreiniging en hinder.	De aanlegwerkzaamheden voor de pijpleidingen kunnen hinderlijk zijn voor de scheepvaart, vooral bij het kruisen van vaarroutes. Door een goede planning in overleg met de scheepvaartautoriteiten en het inzetten van loodsen kan de hinder beperkt blijven. Risico's op verontreiniging van het aquatisch milieu zijn verwaarloosbaar (zie hiervoor bovenstaande punt over afvalstoffen).	Hfst. 4

Criterium	Beoordeling	Referentie
Het risico van zware ongevallen en rampen die relevant zijn voor het project in kwestie, waaronder rampen die worden veroorzaakt door klimaatverandering, in overeenstemming met wetenschappelijke kennis.	Het risico van zware ongevallen is vanwege de zeer hoge offshore-veiligheidstandaard minimaal.	Hfst. 3 § 4.8
De risico's voor de menselijke gezondheid (bijvoorbeeld als gevolg van waterverontreiniging of luchtvervuiling).	Het project wordt uitgevoerd op de Noordzee vanaf circa 75 kilometer uit de kust. Risico's voor de menselijk gezondheid kunnen op basis van de afstand tot onshore leefomgeving en verwachte effecten uitgesloten worden.	Hfst. 4

De locatie van het project

In tabel 6-2 zijn de belangrijkste criteria opgenomen ten aanzien van de kwetsbaarheid van het milieu in de gebieden waarop het project van invloed kan zijn.

Tabel 6-2: Beoordelingscriteria in relatie tot de locatie van het project.

Criterium	Beoordeling	Referentie
Het bestaande en goedgekeurde grondgebruik.	Het deel van de Noordzee waar het project wordt uitgevoerd, wordt tevens gebruikt door de scheepvaart en visserij. Tijdens de uitvoering van het project gelden plaatselijk geringe beperkingen voor deze activiteiten.	§ 2.4 en 4.8
De relatieve rijkdom aan en beschikbaarheid, kwaliteit en regeneratievermogen van natuurlijke hulpbronnen (met inbegrip van bodem, land, water en biodiversiteit) in het gebied en de ondergrond ervan.	Het project heeft geen permanente gevolgen voor de relevante natuurlijke hulpbronnen van het gebied.	Hfst. 4
Het opnamevermogen van het natuurlijke milieu, met in het bijzonder aandacht voor de volgende typen gebieden: **I.** Wetlands, oeverformaties, riviermondingen; **II.** Kustgebieden en het mariene milieu; **III.** Berg- en bosgebieden; **IV.** Natuurreservaten en -parken; **V.** Gebieden die in de nationale wetgeving zijn aangeduid of door die wetgeving worden beschermd; Natura 2000-gebieden die door de lidstaten zijn aangewezen krachtens Richtlijn 92/43/EEG en Richtlijn 2009/147/EG; **VI.** Gebieden waar de milieukwaliteitsnormen, in de wetgeving van de Unie vastgesteld en relevant voor het project, al niet worden nagekomen of worden beschouwd als niet-nagekomen; **VII.** Gebieden met een hoge bevolkingsdichtheid; **VIII.** Landschappen en plaatsen van historisch, cultureel of archeologisch belang.	In de omgeving bevinden zich Natura 2000-gebieden. Het mariene milieu van de Noordzee ter plaatse van de verbindingsleiding hangt daarmee samen. Er zijn van de aanlegwerkzaamheden tijdelijke negatieve effecten te verwachten op beschermde natuurwaarden. In het MER voor het Aramis initiatief is beoordeeld dat significant negatieve effecten op de instandhoudingsdoelstellingen van deze Natura 2000-gebieden uitgesloten kan worden. Ter plaatse van het tracé voor de verbindingsleiding bevinden zich geen potetiele archeologische objecten op of in zeebodem.	Hfst. 4 Bijl. 2 Bijl. 3

De soort en kenmerken van het potentiële effect

Tabel 6-3 geeft een beoordeling van de meest waarschijnlijke aanzienlijke milieueffecten van het project in relatie tot de kenmerken en locatie van het project.

Tabel 6-3: Beoordelingscriteria in relatie tot de soort en kenmerken van het potentiële effect

Criterium	Beoordeling	Referentie
De orde van grootte en het ruimtelijk bereik van de effecten (bijvoorbeeld geografisch gebied en omvang van de bevolking die getroffen kan worden).	Het bereik van de potentiële effecten van het project is beperkt tot het plangebied en de omgeving daarvan. Wel kunnen de tijdelijke aanlegwerkzaamheden op grotere afstand tot hinder van onderwatergeluid leiden voor met name zeezoogdieren.	Hfst. 4 Bijl. 2
De aard van het effect.	De potentiële effecten van het project zijn over het algemeen beperkt en lokaal van aard. De meest relevante effecten hebben betrekking op natuur en nautische veiligheid. Hiervoor worden maatregelen genomen om de effecten in voldoende mate te mitigeren.	Hfst. 4 Bijl. 2
Het grensoverschrijdende karakter van het effect.	Het projectgebied ligt niet nabij een grens van een buurland.	Hfst. 2 Bijl. 2
De intensiteit en de complexiteit van het effect.	De intensiteit en complexiteit van de potentiële effecten van het project zijn beperkt, met name door de relatief korte tijdsduur waarbinnen effecten optreden (aanlegfase) in combinatie met de snelle verspreiding en/of verwijdering van de optredende emissies in het zeewater en de atmosfeer.	Hfst. 4 Bijl. 2
De waarschijnlijkheid van het effect.	Het optreden van de potentiële effecten van het project is goed voorspelbaar omdat de werkzaamheden vaker voorkomen.	Hfst. 4 Bijl. 3
De verwachte aanvang, duur, de frequentie en de omkeerbaarheid van het effect.	De potentiële effecten van het project zijn beperkt, en treden voor een groot deel slechts op over een periode van maximaal enkele weken tot maanden. Ook zijn de (belangrijkste) effecten omkeerbaar.	Hfst. 4 Bijl. 2
De cumulatie van effecten met de effecten van andere bestaande en/of goedgekeurde projecten.	Cumulatie met bestaande en/of goedgekeurde projecten is niet uit te sluiten maar zal naar verwachting niet tot significant grotere of andere effecten leiden.	Hfst. 5
De mogelijkheid om de effecten doeltreffend te verminderen.	De potentiële effecten van het project kunnen, indien nodig, met behulp van diverse maatregelen verminderd of voorkomen worden.	Hfst. 4 Bijl. 3

6.3 Conclusie mer-beoordeling

Voor de besluitvorming over de vergunning voor de verbindingsleiding en kabelmoet het bevoegde gezag afwegen of een mer nodig is. In de voorliggende aanvraag is de informatie beschreven op basis waarvan deze afweging kan worden uitgevoerd.

Uit de voorgaande hoofdstukken komt naar voren wat de kenmerken van het project zijn (verbindingsleiding), en wat de kenmerken van de omgeving en milieueffecten zijn. Over het geheel gezien kan worden geconcludeerd dat van de aanleg en het gebruik van de verbindingsleiding in relatie tot in de omgeving aanwezige gevoeligheden geen aanzienlijke effecten verwacht worden. Op grond daarvan kan geoordeeld worden dat geen mer nodig is.

De verbindingsleiding is onderdeel van het Aramis initiatief dat meer omvattend is dan de verbindingsleiding. Voor het Aramis initiatief als geheel wordt een mer-procedure doorlopen en is een MER opgesteld.

7 Indieningsvereisten

Tabel 7-1 bevat een kruisverwijzing tussen de indieningsvereisten conform artikel 1.7.1 Mbr en de vindplaats(en) hiervan in deze aanvraag.

Tabel 7-1: Kruisverwijzing indieningsvereisten Mbr

Kader	Indieningsvereiste	Paragraaf	Rapport / bijlage
Algemeen	Gegevens aanvrager	2.1	
	Ligging project	2.4	
	Statutaire naam aanvrager	2.1	
	Handelsnaam	2.1	
	Vestigingsadres bedrijf	2.1	
	Correspondentieadres	2.1	
	Telefoonnummer contactpersoon	2.1	
	E-mailadres	2.1	
Vereisten Mbr 1.7.1	1 Bij de aanvraag om een vergunning tot aanleg van een pijpleiding als bedoeld in artikel 94 van het besluit verstrekt de aanvrager gegevens omtrent:		
	a. het tijdvak waarvoor de vergunning wordt gevraagd;	2.3	
	b. het traject van de pijpleiding;	3.4	
	c. de wijze waarop de pijpleiding wordt aangelegd en de diepte waarop de pijpleiding in de bodem wordt gelegd;	3.4	
	d. de resultaten van het onderzoek van het voorgenomen traject in een strook van 600 meter, waarvan de as van de strook samenvalt met het gekozen traject, en waarin is beschreven:	3.4	Bijlage 2, 3, en 7
	1°. het profiel van de zeebodem;		
	2°. de aanwezige obstakels;		
	3°. de ligging van bestaande pijpleidingen en kabels;		
	4°. de grondmechanische eigenschappen;		
	5°. de stratigrafie van de zeebodem;		
	6°. de analyse en kwaliteit van de bodemmonsters en sonderingen.		
	e. een rapport van het voorontwerp van de pijpleiding waarin is beschreven:	3.2, 3.3, en 3.6	Bijlage 1
	1°. de eigenschappen en diameter van de pijpleiding;		
	2°. de stoffen die erin worden vervoerd;		
	3°. een analyse van de veiligheids- en milieurisico's, en		
	4°. de tijd gedurende welke de pijpleiding wordt gebruikt voor het vervoer van die stoffen.		

Bijlage 1: Voorontwerp van de verbindingsleiding

Bijlage 2: Geotechnisch tracéonderzoek

Bijlage 3: Onderbouwing tracékeuze en bodemgesteldheid

Bijlage 4: Kaarten met ligging tracé

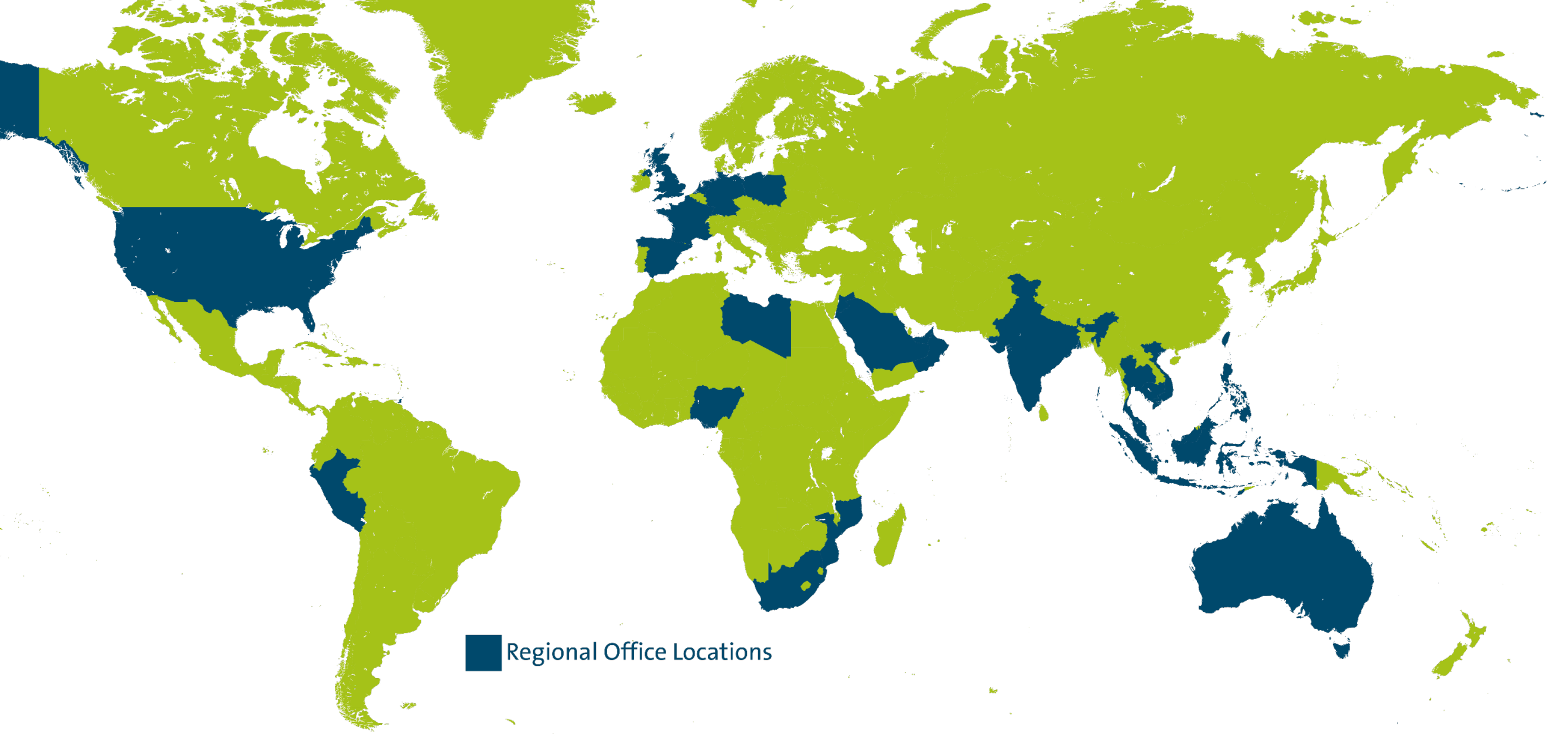
Bijlage 5: Aramis flow assurance study

Bijlage 6: Archeologisch onderzoek

Bijlage 7: Participatie

Bijlage 8: Natuurtoets

Bijlage 9: Nautische veiligheidsstudie



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.

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Aramis BB4A (Shell-K14FA2-Store)

Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis

Shell Document Number	ARS-200-BB4A-K14FA2-10-LA-7704-0002
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REVISION HISTORY

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CHANGE/HOLD HISTORY

Rev#	Reason for Hold / Change

SUMMARY/ABSTRACT

This document presents the basis of design for the Aramis Spurline and subsea facilities, including the risers, tie-in spools, manifold, umbilical and subsea controls, and OBS system.

Contents

ABBREVIATIONS:

BLIV	Battery limit isolation valve
CCS	Carbon Capture Storage
CO2	Carbon Dioxide
CC(U)S	Carbon Capture Utilization Storage
OBS	Ocean Bottom Seismometers
OPEX	Operating Expenditure
PACO	Process Automation Control & Optimization
TTE	Total Energies
CWC	Concrete Weight Coating
NAP	Normaal Amsterdamse Peil [Normal Amsterdam Gauge (onshore compression station/trunkline inlet train average elevation)]
LAT	Lowest Astronomical Tide
HAT	Highest Astronomical Tide
MSL	Mean Sea Level
MMV	Measurement Monitoring & Verification
TBC	To Be Confirmed
TBD	To Be Defined
DSS	Duplex Stainless Steel
CS	Carbon Steel

1. INTRODUCTION

1.1. Aramis Project Background

The Aramis carbon capture and storage (CCS) project is incorporating, from the onset, a cross-border approach, providing a decarbonisation solution for North-West Europe. Aramis is developing a technical concept of CCS to contribute to the decarbonisation of industrial areas of The Netherlands, Belgium, France and Germany. Aramis is also seeking synergies with Porthos, another ongoing CCS project in The Netherlands, to form a fully integrated CC(U)S model in The Netherlands for these industrial clusters. The scope of the Aramis CCS project, contains the following transport and storage elements:

- Shipping by barges or coasters for customers not connected to the terminal by pipeline.
- New shipping terminal at the Maasvlakte to be built and operated by CO2nnect, receiving liquid (cryogenic) CO2 from different industrial clusters located in the Northwest Europe region. The terminal will have temporary storage capacity.
- Compressor station for gas phase (vapour) CO2 volumes coming by Porthos onshore pipeline from Rotterdam and its hinterlands
- Trunkline to transport dense phse CO2 over ~200km to the offshore platforms / blocks, with over capacity and potential tie-in points to cater for future growth.
- Offshore Storage in K14 (Shell) and K6/L4 (Total Energies) and in future other fields is expected

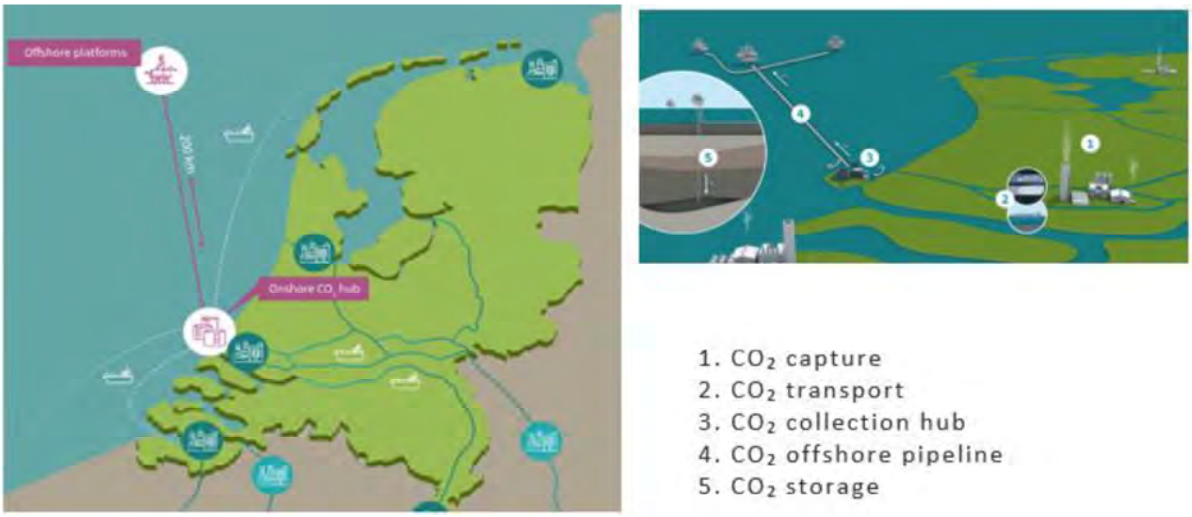


Figure 1-1 Aramis Overview

The key value drivers (and targets) for the Aramis project are:

- Meet SDE++ timeline – first CO2 in store latest end 2028
- System availability > 95% (from emitter to store)
- No early life failures –flawless start-up of the chain
- Lifecycle costs / OPEX: Make sure the running costs are as low as possible (note that lifecycle costs include 'Growth')
- Build reputation - public acceptance (incl. safety)
- Enable future growth and open access (volumes, stores)
- Successful and early transfer of liability after end of injection

K14 and L4 from Shell and Total respectively are the two stores of the Launch phase of the Aramis project. The transport system (compressor, terminal and trunkline) will be open access while stores will be in competition. The Aramis project consists of the several building blocks. Following the CO2 flow from the onshore terminal to the stores, Shell and TTE, it flows via the following building blocks:

- BB1 - Onshore terminal
- BB2 - Onshore compression
- BB3 - CO2 trunkline from Rotterdam Maasvlakte to the offshore K&L blocks ending in a Distribution Hub platform
- BB4a - Shell store (K14FA field) – The Facility scope of BB4a is subject of this document
- BB4b - TTE store (Total Energies)

1.2. Document Purpose

This document is prepared to present design data and requirements for the Front-End Engineering Design (FEED), relevant to spurline and subsea facilities Mechanical Design for the BB4a building block of the ARAMIS CCS project.

The document objectives are to define the required data for the design of the following.

- Spurline
- Riser and Tie-in Spools
- Umbilical and Subsea Controls
- Subsea Manifold

2. FACILITY LOCATION & DESCRIPTION

2.1. General

The Aramis Shell CCS facility, BB4a starts at its battery limit with BB3 where the Spool imports the fluid from the BB3 ILT. Following the flow of CO2 from the trunkline towards the reservoir the high-level elements of K14FA2 project are:

- Subsea manifold with automated battery limit isolation valve (BLIV), including the connection to the trunkline.
- Spurline and umbilical connecting manifold with the CO2 injection platform
- New normally unmanned wellhead platform; topsides and jacket
- Interface scope between wells and the facilities
- Installation of the OBS (ocean bottom seismometers) and connection to the PACO systems on the platform

A schematic overview of the system is shown below:

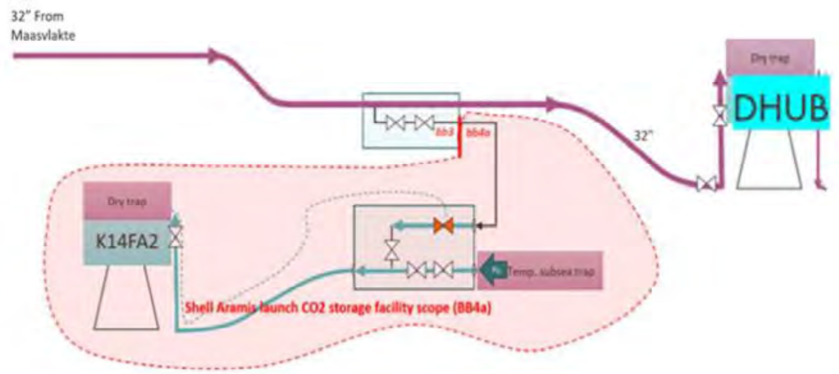
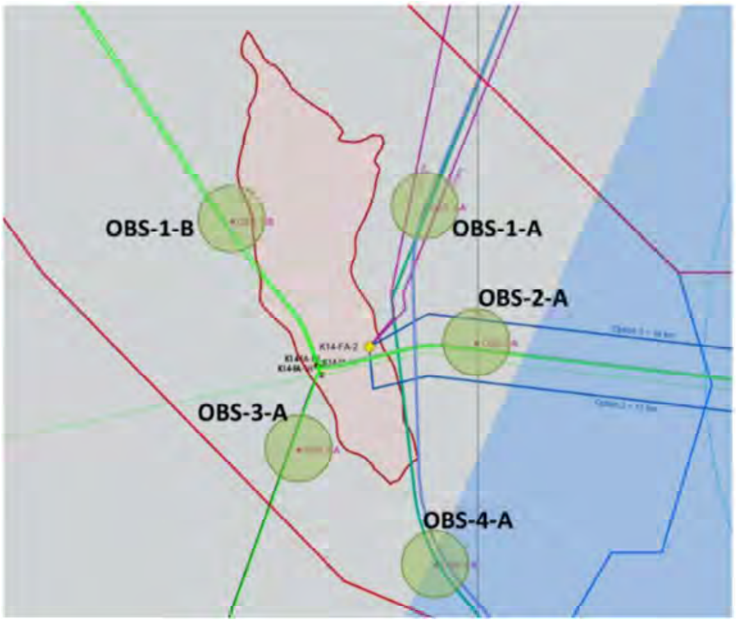


Table 2-1 Schematic overview of Aramis Launch Shell storage scope (inside dotted red line).

2.2. Platform, In-line Tee and OBS Nodes Coordinates

Figure 2-1 illustrates the suggested locations and coordinates of OBS stations Ref.7.



OBS	Easting (m)	Northing(m)
OBS 1-A	410257.38	5905838.94
OBS 1-B	407053.53	5905674.17
OBS 2-A	411072.42	5903576.61
OBS 3-A	408084.68	5901864.45
OBS 4-A	410329.46	5899911.46

CRS: ED50 / TM 5 NE (EPSG:23095)

Figure 2-1 OBS proposed nodes on the field layout

K14FA2 platform, BB3 ILT and OBS stations coordinates are presented in Table 2-2

Item	Easting(m)	Northing(m)
K14FA2 Platform	409 285.00 (1)	5 903 555.00 (1)
BB3 ILT	TBC	TBC
OBS 1-A	410257.38	5905838.94
OBS 1-B	407053.53	5905674.17
OBS 2-A	411072.42	5903576.61
OBS 3-A	408084.68	5901864.45
OBS 4-A	410329.46	5899911.46

Table 2-2 Coordinates of K14FA2 platform and BB3 ILT

Note 1: These coordinates may be subject to change [APPENDIX 1]

3. LEGISLATION, REGULATIONS, CODES & STANDARDS

3.1. General

The Aramis FEED scope will be designed to recognised International Standards and selected relevant COMPANY General Specifications. Any deviations will be informed to COMPANY for prior approval.

3.2. Legislation and Regulations

The subsea system design shall comply with all the relevant local, national, and international legislation and regulations.

3.3. National Design Codes and COMPANY General Specifications

The applicable COMPANY General Specification and Dutch Requirements will be used as guideline for the design of subsea pipeline and structures. The first three NEN Requirements, highlighted in bold, from number one to three are the leading documents.

1. **NEN 3650-1**, “Requirements for pipeline systems - Part 1: General requirements” (2020)
2. **NEN 3650-2**, “Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines” (2020)
3. **NEN 3656**, “Requirements for submarine steel pipeline systems” (2022)
4. DEP 31.40.00. 10Gen, “Design and Engineering Practice - Global technical standards index”
5. DEP 31.40.40.38-Gen, “Design and Engineering Practice - Hydrostatic pressure testing for new pipelines”
6. DEP 31.40.30.30-Gen, “Design and Engineering Practice - Concrete coating of linepipe (amendments/supplements to Ref.19)”
7. DEP 31.40.30.31-Gen, “Design and Engineering Practice - Technical specification for external polyethylene and polypropylene coating for line pipe”
8. DEP 30.48.00.31-Gen, “Design and Engineering Practice – Protecting coating for onshore facilities”.

3.4. Codes and Standards

The subsea system's design and installation must adhere to the Company's list of applicable codes, standards, and General Specifications (GSs) and Recommended Practices. These are listed as follows:

9. ISO 13623, “Petroleum and natural gas industries - Pipeline transportation systems”
10. ISO 27193: “Carbon dioxide capture, transportation and geological storage – Pipeline transportation system” (2016)
11. DNV_RP-F104, “Design and operation of carbon dioxide Pipelines” (2022)
12. DNV_ST_F101, Submarine Pipeline Systems (2021)
13. DNVGL-RP-F114, “Pipe-Soil Interaction for Submarine Pipelines” (2021)
14. DNV-RP-F105, “Free spanning pipelines” (2021)
15. DNV-RP-F109, “On-bottom stability design of submarine pipelines” (2021)
16. DNV-RP-F112, “Duplex stainless steel – design against hydrogen induced stress cracking” (2021)
17. ISO 13628, “Petroleum and natural gas industries – Design and operation of subsea production systems” – Part1 “General requirements and recommendations” (annex F5 datasheet) (2005)
18. ISO 13628, “Petroleum and natural gas industries – Design and operation of subsea production systems” - Part15 “Subsea structures and manifold” (2011)
19. ISO 21809, “Petroleum and natural gas industries – External coating for buried or submerged pipelines used in pipeline transportation systems” - Part5 “External concrete coating” (2010)

20. ISO 21809, "Petroleum and natural gas industries – External coating for buried or submerged pipelines used in pipeline transportation systems" – Part1 "Polyolefin coatings (3-layer PE and 3-layer PP)" (2011)
21. ISO 21809, "Petroleum and natural gas industries – External coating for buried or submerged pipelines used in pipeline transportation systems" – Part2 "Single layer fusion-bonded epoxy coatings" (2014)
22. NORSOK M-501, "Surface preparation and protective coating" - 6th Edition (2012)
23. IOGP S-715, "Supplementary Specification to Ref.22 Coating and Painting for Offshore, Marine Coastal and Subsea Environments" (2020)

3.5. COMPANY Documents

24. ARS-PFE-BB4a-GEO-REP-001, Offshore Metocean Design and Operational Criteria, Aramis (Block K14)
25. ARS-100-BB4A-K14FA2-00-CG-6968-0001_Rev01_Aramis K14 Store - Furgo Site Survey Integrations Results Report
26. ARS-100-BB4A-K14FA2-00-ZS-7180-0001 "Aramis Launch K14-FA – Ocean Bottom Seismometer (OBS)

3.6. Other Documents

27. ARS-200-BB4A-K14FA2-10-LA-7704-0001, Flow Assurance Basis of Design
28. ARS-200-BB4A-K14FA2-10-LA-7180-0001, Flow Assurance Study Report

3.7. REFERENCES

1. ARS-PFE-BB4a-ICS-BOD-002, "Aramis Store BfD"
2. DEP 31.40.40.38-Gen, "Design and Engineering Practice - Hydrostatic pressure testing for new pipelines"
3. DEP 31.40.30.30-Gen, "Design and Engineering Practice - Concrete coating of linepipe (amendments/supplements to Ref.13"
4. DEP 31.40.30.31-Gen, "Design and Engineering Practice - Technical specification for external polyethylene and polypropylene coating for line pipe
5. DEP 30.48.00.31-Gen, "Design and Engineering Practice – Protecting coating for onshore facilities".
6. ARS-PFE-BB4a-GEO-REP-001, Offshore Metocean Design and Operational Criteria, Aramis (Block K14)
7. ARS-200-BB4A-K14FA2-10-LA-7704-0001, Flow Assurance Basis of Design
8. ARS-200-BB4A-K14FA2-10-LA-7180-0001, Flow Assurance Study Report
9. ARS-200-BB4A-K14FA2-CS-8502-0006, Technical Query
10. ARS-100-BB4A-K14FA2-00-ZS-7180-0001 "Aramis Launch K14-FA – Ocean Bottom Seismometer (OBS)
11. ISO 13628, "Petroleum and natural gas industries – Design and operation of subsea production systems" – Part1 "General requirements and recommendations" (annex F5 datasheet) (2005)
12. ISO 13628, "Petroleum and natural gas industries – Design and operation of subsea production systems" - Part15 "Subsea structures and manifold" (2011)
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15. ISO 21809, “Petroleum and natural gas industries – External coating for buried or submerged pipelines used in pipeline transportation systems” – Part2 “Single layer fusion-bonded epoxy coatings” (2014)
16. NORSOK M-501, “Surface preparation and protective coating” - 6th Edition (2012)
17. IOGP S-715, “Supplementary Specification to Ref.16 Coating and Painting for Offshore, Marine Coastal and Subsea Environments” (2020)

4. GENERAL SYSTEM REQUIRMENTS

4.1. Design Life

The Design life of the facility shall be 30 years.

4.2. Units

International System (SI) units will be used throughout the design except for nominal pipe sizes and pressures which are expressed in inches and bar (a, g) respectively.

4.3. Battery Limits

The battery limit of the SURF scope of this Basis of Design (BoD) with Building Block 3 (BB3) Aramis CO2 trunkline is the flange interface of the branched tie-in connection on the ILT. This is the BB4a-BB3 battery limit.

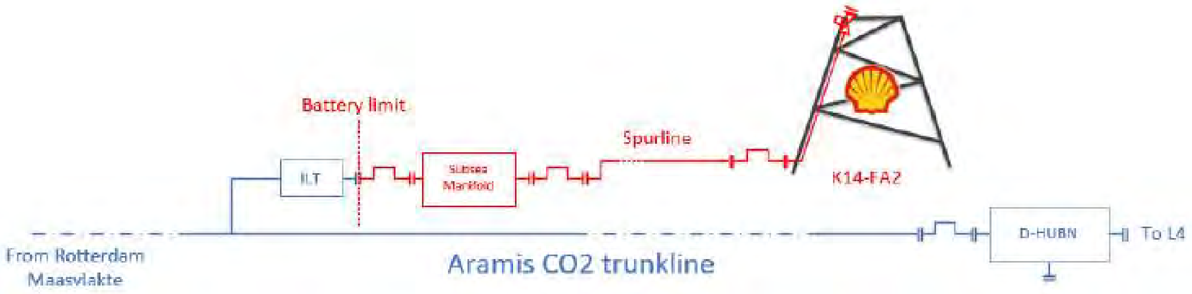


Table 4-1 Battery limit between CO2 import system and the BB3 Aramis CO2 trunkline

4.4. Pigging

The Spurline system to be designed piggable with minimum bend radius of 3 x pipe nominal outside diameter.

4.5. Protection

Subsea manifold, spools, pipeline and umbilical protection shall be assessed in compliance with Ref.11 and Ref.12 to ensure protection against damage from the following accidental loadings:

- Dropped objects.
- Fishing trawl gear impact loads.
- Fishing trawl gear pullover load.

Tie-in spool shall be adequately protected against dropped objects, fishing gear or other means of 3rd party damage. Spools shall be continuously supported in tie-in points and secured against snagging.

Concrete weight coating specification shall follow Ref.13 and the requirements presented in Ref.3.

4.6. External Corrosion

External corrosion protection shall be achieved with a combination of the application of high integrity coatings and a Cathodic Protection (CP) system. The spurline and tie-in spools will be fitted with half shell bracelet sacrificial anodes, the manifold piping and structure will be protected using standard stand-off bar anodes and the risers and j-tubes will be protected by the jacket CP system.

Pipeline external coating specification shall follow Ref.14 and Ref.15, and the requirements presented in Ref.4.

Riser, J-tube, support structures, subsea manifold piping (including components and fittings) and structural steel painting and coating selection shall be in accordance with Ref.15 as supplemented/amended by Ref.16 and Ref.5.

A summary of external anti-corrosion coating is presented in Table 4-2

Item	External coating
ILT Spool and Spurline	2.8 mm 3LPE
Risers & J-tube	None

Table 4-2 External anti-corrosion coating

Cathodic protection shall be provided via a Sacrificial Anode Cathodic Protection (SACP) system. Design shall cater for Hydrogen Induced Stress Cracking (HISC) avoidance.

4.7. Level Reference

Pressures and Bathymetry are generally defined relative to NAP and LAT respectively, unless mentioned otherwise. Table 4-3 defines the different Reference and Tidal levels relative to LAT.

Reference / Tidal Level	Level (m)
HAT	2.30
MSL	1.16
NAP	1.16
LAT	0.00

Table 4-3 Reference and Tidal Levels Relative to LAT

5. SPURLINE AND SUBSEA FACILITIES

5.1. Spurline

The pipe dimension and material data are presented in Table 5-1

Items	Nominal size (inch)	Material	Corrosion allowance (mm)
Spurline	16	DSS	0

Table 5-1 Spurline Properties

Spurline material is Duplex Stainless Steel (DSS), grade LC65-2205 conform ASTM A790 with Pitting Resistance Equivalent Number (PREN) > 34.

At 0 Celsius, the DSS linepipe material shall have an average minimum and single minimum Charpy V-Notch (CVN) impact energy of 250 J and 188 J, respectively.

At -46 Celsius, the DSS linepipe material shall have an average minimum and single minimum Charpy V-Notch (CVN) impact energy of 60 J and 45 J, respectively. To avoid brittle fracture.

5.2. Riser and Tie-in Spools

The risers and Tie-in Spools material is identical to that of the Spurline mentioned in previous section. Import system made of uniform material, eliminates requirement for in-line inspection. Table 5-2 summaries the pipe dimension and material data for the Risers and the Tie-in Spools.

Items	Nominal size (inch)	Material	Corrosion allowance (mm)
Risers & Tie-in Spools	16	DSS	0

Table 5-2 Riser and Tie-in Spools Properties

Note: Export risers are made of Carbon Steel grade X65

5.3. Umbilical and Subsea Controls

Umbilical are connecting the SSIV on the manifold to the Subsea Control umbilical on the Platform. This will enable the remote decoupling of the Aramis store from the 32” Trunkline in emergency cases. Table 5-3 summaries the J-tube dimension and material data for the umbilical and OBS cables.

Items	Nominal size (inch)	Material
J-tubes	20	CS

Table 5-3 Umbilical and OBS cables J-tubes Properties

5.4. OBS System

Ocean/On Bottom Seismometer (OBS) comprises of several nodes(stations) spatially distributed over the area of interest. Power and data are transmitted via electrical wire and optical fibre respectively, combined in composite cables. As the exact location of the nodes will be determined during the EPC phase, a 500m radius exclusion zone shall apply to the field layout plus a 100m clearance from the subsea infrastructure.

6. PRODUCTION DATA

6.1. Design Data

The pipe dimension and material data are presented in Table 6-1

	Pipeline & Spools	Risers
Content	Carbon dioxide dense phase	Carbon dioxide dense phase
Content density (Kg/m^3)	757.1 to 973.4 (1)	757.1 to 973.4 (1)
Design Pressure (barg)	200 (2)	200 (2)
Operating Pressure (barg)	127 to 186 (2)	127 to 186 (2)
Min Operating Pressure (barg)	75 (2)	75 (2)
Design Temperature (C)	-46 to 30	-46(3) to 50

Table 6-1 Design Data

Note 1: A function of Pressure and Temperature (section 6.2)

Note 2: Pressures are referenced to +5m NAP [Ref.7]

Note 3: Future Export riser minimum design temperature is -25 Celsius

6.2. Pressure and Temperature Profiles

The pressure, temperature and density profiles for the import system are extracted from Flow Assurance Steady-State report [Ref.7] for different scenarios, summarised in Table 6-2, are presented in Figure 6-1, Figure 6-2 and Figure 6-3. There will be additional scenarios with impurities to simulate the actual operational conditions apart from the following pure Carbon Dioxide cases.

N	Steady State Scenario Condition	Ambient	Burial
1	Design Flow Rate (1) – High pressure (2)	Summer (18.0°C)	100% Exposed
2	Design Flow Rate – Low pressure	Summer (18.0°C)	100% Exposed
3	Average Flow Rate – Low Pressure	Summer (18.0°C)	100% Exposed
4	Peak Flow Rate – Low Pressure	Summer (18.0°C)	100% Exposed
5	Design Flow Rate – Late Life – Low Pressure	Summer (18.0°C)	100% Exposed
6	Average Flow Rate – Minimum Pressure	Summer (18.0°C)	100% Exposed
7	Design Flow Rate – Minimum Pressure	Summer (18.0°C)	100% Exposed
8	Design Flow Rate – High Pressure	Winter (3.6°C)	100% Exposed
9	Design Flow Rate – High Pressure	Summer (18.0°C)	50% Buried
10	Average Flow Rate – High Pressure	Winter (3.6°C)	50% Buried

Table 6-2 Flow Assurance Steady States Scenarios

Note 1: Average and Peak Flow Rates are defined by COMPANY. Design Flow Rate is defined by TOTAL which is significantly higher than the COMPANY Peak Rate.

Note 2: Pressures are measured at the Downstream of the Wellhead Choke Point

KP0 in the following profiles represents the battery limit defined in Section 4.3. Sharp slope change at the end of the profile represents the start of the riser. The very last part where the profile becomes almost vertical is related to the Wellhead and can be ignored.

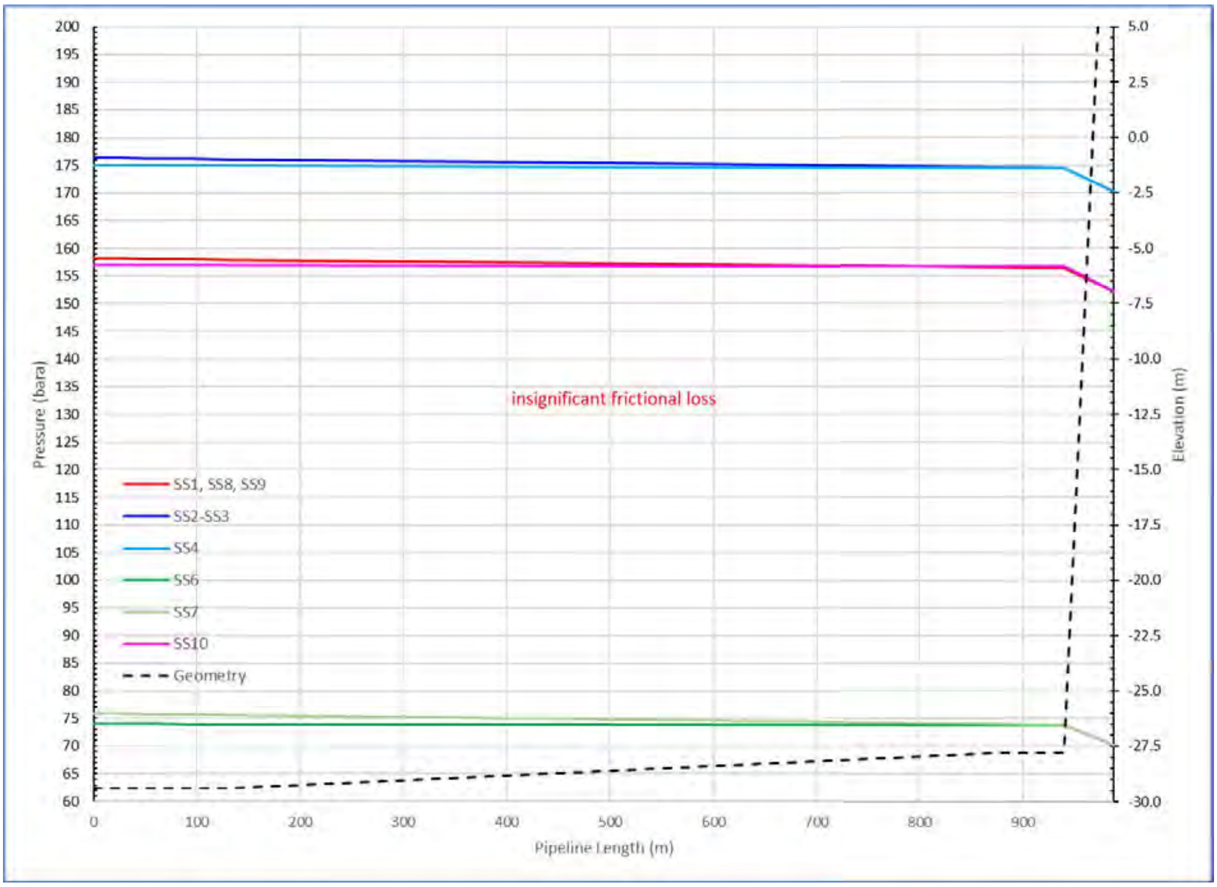


Figure 6-1 Spurline Steady State Pressure Profiles

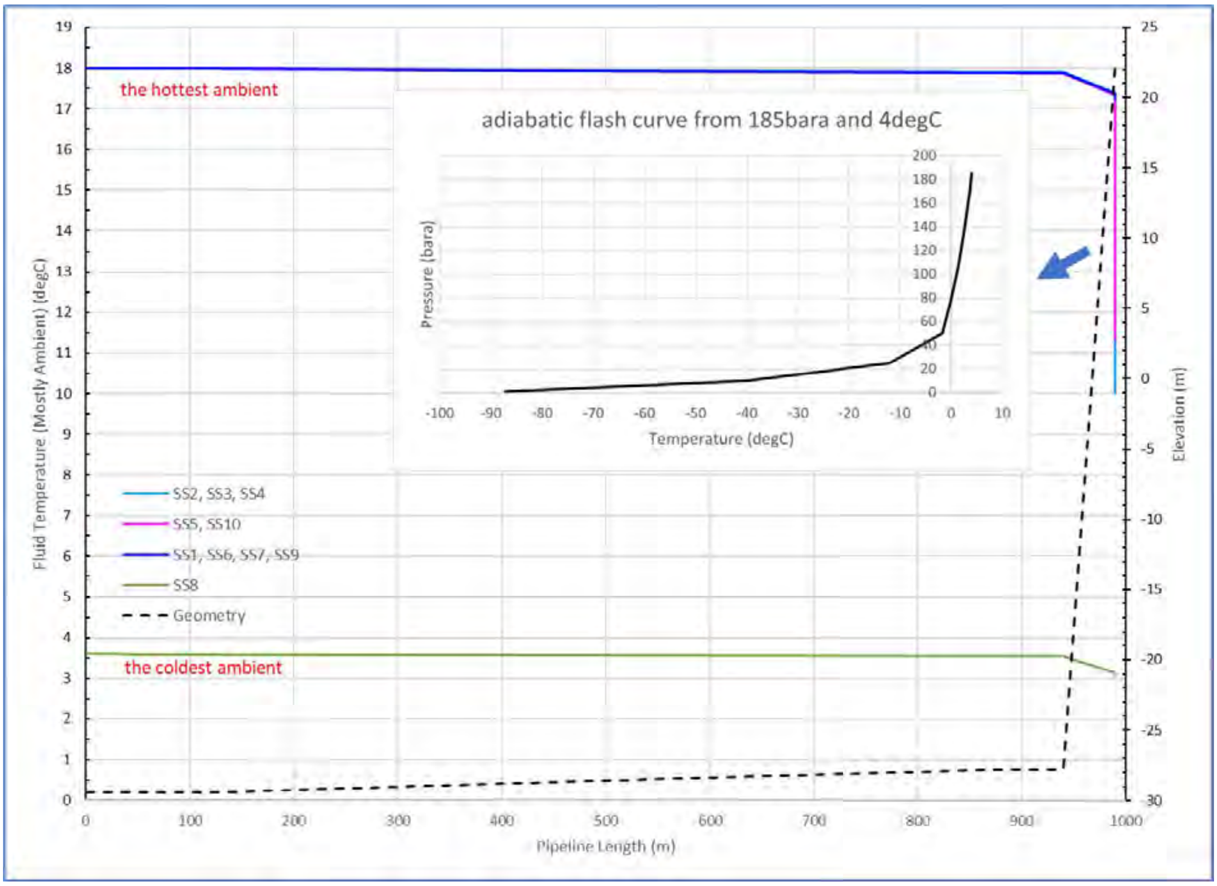


Figure 6-2 Spurline Steady State Temperature Profiles

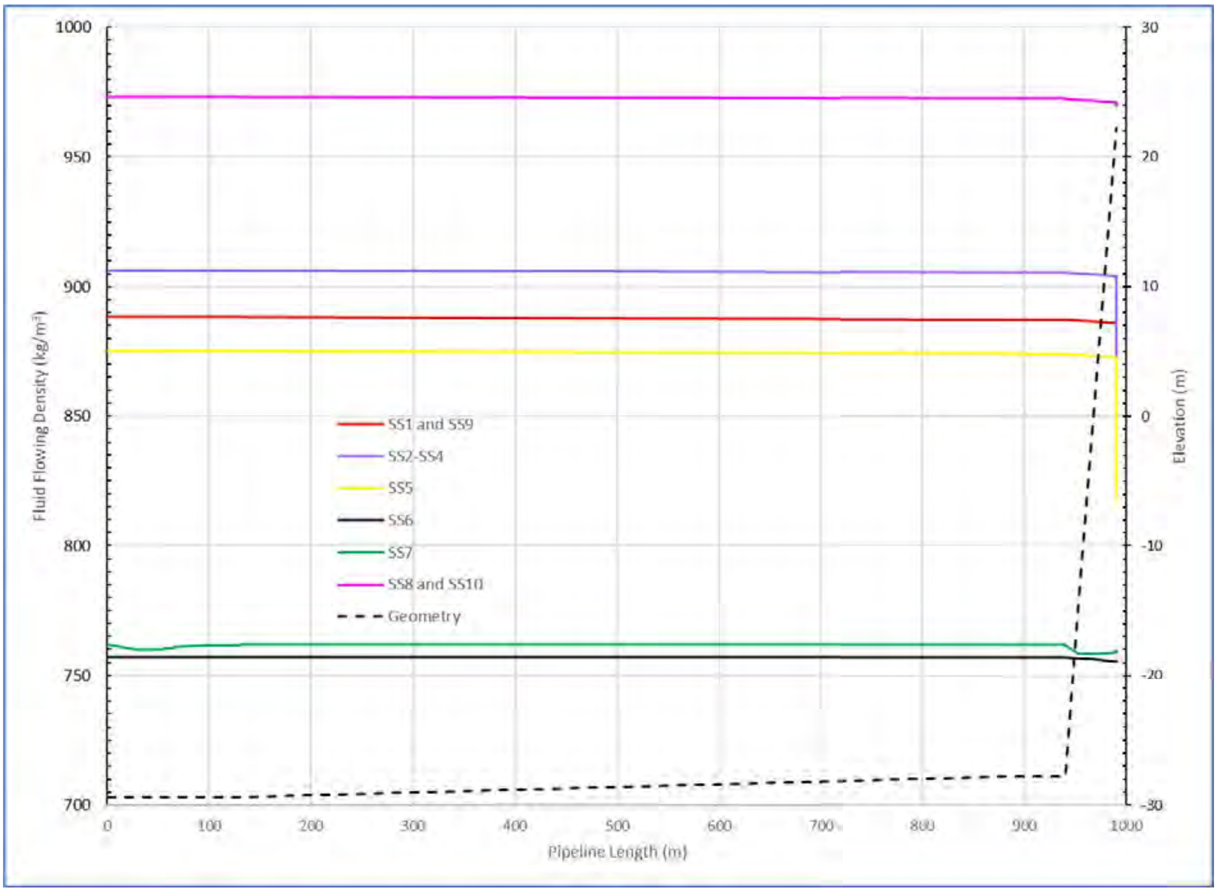


Figure 6-3 Spurline Steady State Fluid Density Profiles

6.3. Fluid Composition

The CO2 fluid shall be considered as non-corrosive under normal operating conditions. The CO2 fluid is not being considered as a very toxic as per the classification method outlined in part III of DEP 01.00.01.30-Gen. The impurities in the fluid do not meet the defined threshold limit for classification as very toxic. The injected CO2 fluid is a mixture of two sources which have different permitted impurity levels. Table 6-3 below, summarizes the main fluid compositions [Ref.7].

Component	CO_2	CH_4	N_2	Ar	H_2	CO	H_2O	O_2	NO_X
Amount	>95	<4	<2.4	<0.1	<7500	<750	<70	<40	<2.5
Unit	mol%				ppmmol				

Table 6-3 Fluid Composition

7. GEOPHYSICAL AND GEOTECHNICAL DATA

7.1. Bathymetry

A summary of the bathymetry data available is shown in Table 7-1

The water depth gently increases across the survey area from 25.1 m in the west to 29.5 m in the east (gradient typically < 1°).

Aramis CCS			
Reference	Route Length (m)	Max Depth (m)	Min Depth (m)
Spurline	800 (TBC)	29.5	25.1

Table 7-1 Aramis Flowlines Bathymetry Data

7.2. Seabed Soils

The seafloor sediments across the survey area are interpreted to comprise medium dense to dense sand. Areas of high reflectivity are observed surrounding the K14-FF-1 platform are interpreted to represent gravel.

Ripple-like features are observed over large areas of the site. Their orientation changes rapidly suggesting they are highly mobile, likely because of the strong currents and shallow water depth at the survey area. Scour survey data is available for the existing platform foundations.

The condition of soil up to 3.6m depth can be defined as very loose to medium dense slightly silty fine sand. Silty sand is considered as partially drained. Therefore, according to both Drained and Undrained conditions shall be considered during the design.

The following conditions of the soil have been determined, and summarised in Table 7-2, Table 7-3, Table 7-4 and Table 7-5

Selected submerged soil unit weight for soil-pipeline interaction			
Depth (m)	Submerged soil unit weight, γ' (kN/m^3)		
	LE	BE	HE
0 – 1.0	TBD	TBD	TBD

Table 7-2 Selected Submerged Soil Unit Weight for Soil-Pipeline Interaction Analysis

Drained shear strength profiles for pipe-soil interaction analyses			
Depth (m)	Drained Shear Strength Profile (KPa)		
	LE	BE	HE
0.00 - 0.10	TBD	TBD	TBD
0.10 - 0.15	TBD	TBD	TBD
0.15 - 0.30	TBD	TBD	TBD
0.30 - 0.40	TBD	TBD	TBD

Table 7-3 Drained Shear Strength Profiles for Pipe-Soil Interaction Analyses

Intact Undrained shear strength profiles for pipe-soil interaction analyses			
Depth (m)	Intact Undrained Shear Strength Profile (KPa)		
	LE	BE	HE
0.00 - 0.10	TBD	TBD	TBD
0.10 - 0.15	TBD	TBD	TBD
0.15 - 0.30	TBD	TBD	TBD
0.30 - 0.40	TBD	TBD	TBD

Table 7-4 Intact Undrained Shear Strength Profiles for Pipe-Soil Interaction Analyses

Remoulded Undrained shear strength profiles for pipe-soil interaction analyses			
Depth (m)	Remoulded Undrained Shear Strength Profile (KPa)		
	LE	BE	HE
0.00 - 0.10	TBD	TBD	TBD
0.10 - 0.15	TBD	TBD	TBD
0.15 - 0.30	TBD	TBD	TBD
0.30 - 0.40	TBD	TBD	TBD
Sensitivity*(-)			
Depth (m)	LE	BE	HE
0 – 1.0	TBD	TBD	TBD

Table 7-5 Remoulded Undrained Shear Strength Profiles for Pipe-Soil Interaction Analyses

8. METEOCEAN DATA

8.1. Wave & Current Data

The Significant Wave Height (HS), and Time Period (TP), Wind speed and Current profiles are defined in Figure 8-1 Ref. 6

All YEAR

	RETURN PERIOD (YEARS)				
	1	10	100	1K	10K
WIND SPEED 10 m asl [m/s]					
V (1-hr)	22.1	25.4	28.1	31.6	36.2
V (10-min)	24.1	27.7	30.8	34.9	40.2
V (1-min)	26.5	30.7	34.3	39.1	45.5
Gust (3-sec)	29.7	34.6	38.9	44.6	52.3
WAVE HEIGHT [m] & PERIOD [s]					
Hs (3-hr)	5.9	7.7	9.8	12.1	14.9
Tz (central)	8.1	9.0	9.7	10.4	11.0
Tp (central)	10.9	12.0	13.1	13.9	14.8
Hmax	11.2	14.2	17.2	19.7	21.9
Tass	9.8	10.8	11.7	12.5	13.3
Spectral Shape	γ: mid 2.0, range 1.0 - 5.0 σ_A: 0.07 σ_B: 0.09. φ = 0.91				
CURRENT PROFILE [m/s]					
1.00d	0.89	1.06	1.24	1.40	1.54
0.75d	0.89	1.06	1.24	1.40	1.54
0.50d	0.89	1.06	1.24	1.40	1.54
0.30d	0.82	0.98	1.15	1.30	1.43
0.10d	0.70	0.84	0.98	1.11	1.22
0.05d	0.64	0.76	0.89	1.00	1.11
1m asb	0.61	0.73	0.85	0.96	1.06

Figure 8-1 Wave and Current Data – Aramis CCS Field (see note)

Note: Profile: d = the water depth, therefore 1.0 d represents the sea surface, and 0.5 d represents mid-depth. 1 m asb (above seabed) represents near seabed conditions.

The Significant Wave Height (HS), and Time Period (TP), and Current profiles (@1m abs) including directionality are defined in Table 8-1 Ref. 6

Period	Type	Direction (From)								
		N	NE	E	SE	S	SW	W	NW	Omni
1 Year	Wave H_s	6.4	4.9	3.9	3.4	5.3	6.1	6.4	6.4	5.9
	Wave T_p	13.2	11.0	9.2	7.4	9.4	9.7	10.1	12.6	10.9
	Current	0.54	0.53	0.49	0.47	0.62	0.68	0.62	0.56	0.61
10 Year	Wave H_s	8.2	7.0	5.6	4.7	6.4	7.3	7.9	8.2	7.7
	Wave T_p	14.8	12.9	10.4	8.1	10.0	10.2	10.6	14.0	12.0
	Current	0.62	0.62	0.57	0.54	0.73	0.80	0.75	0.65	0.73
100 Year	Wave H_s	10.3	8.9	7.0	6.0	7.3	8.4	9.4	10.3	9.8
	Wave T_p	16.3	14.1	11.2	8.6	10.4	10.5	11.0	15.3	13.1
	Current	0.73	0.69	0.64	0.71	0.85	0.92	0.87	0.75	0.85

Table 8-1 Directional Wave Height (Hs (3h)), Time Period (Central Tp) and 1m-asb Current in SI unit

The Seasonal April to September Significant Wave Height (HS), and Time Period (TP), and Current profiles (@1m abs) including directionality are defined in Table 8-2 Ref. 6

Period	Type	Direction (From)								
		N	NE	E	SE	S	SW	W	NW	Omni
1 Year	Wave H_s	4.3	3.3	2.9	2.6	3.7	4.4	4.3	4.5	4.0
	Wave T_p	11.0	9.2	8.2	6.9	8.3	8.9	9.1	10.9	9.4
	Current	0.48	0.47	0.45	0.45	0.52	0.60	0.54	0.48	0.52
10 Year	Wave H_s	5.7	4.7	4.1	3.5	4.9	5.3	5.6	5.9	5.4
	Wave T_p	12.6	10.9	9.3	7.5	9.2	9.4	9.8	12.2	10.5
	Current	0.53	0.53	0.50	0.47	0.62	0.69	0.63	0.55	0.62
100 Year	Wave H_s	7.0	6.1	5.4	4.7	5.9	6.3	6.6	7.1	6.6
	Wave T_p	13.8	12.1	10.3	8.1	9.8	9.8	10.2	13.2	11.4
	Current	0.59	0.60	0.57	0.53	0.70	0.78	0.71	0.66	0.71

Table 8-2 April to September Directional Wave Height (Hs (3h)), Time Period (Central Tp) and 1m-asb Current in SI unit

Design total extreme water levels and their associated still water levels for different return periods are presented in Figure 8-2.

	Wave Crest Elevation (m) **Point**	Wave Crest Elevation (m) **Area**	Associated Still Water Level (m) (Rel LAT)	Total Extreme Water Level (**Area**) (m) (Rel LAT)
100-years	11.1	11.6	2.8	14.5
1,000-years	12.9	13.5	3.1	16.7
10,000-years	14.5	15.1	3.6	18.8

LAT reference derived from POLPRED CS3

***Area** calculations undertaken assuming deck dimensions of 25 m x 19 m.*

Sea-level rise to 2035 is accounted for in the Total Extreme Water Level (Area) calculations.

Figure 8-2 Design Total Extreme Water level by Return Period

Note: The one-year return associated still water level can be considered same as 100-year associated still water level [Ref.9] (TBC for the pipeline if one-year data is used. COMPANY made this statement for topside and platform design).

Positive and Negative Surges and their associated still water levels for different return periods are presented in Figure 8-3.

	Positive Still Water Levels (m, Rel LAT)	Negative Still Water Levels (m, Rel LAT)	Positive Surge (m)	Negative Surge (m)
1-year	3.27	-0.22	1.63	-0.79
10-years	3.69	-0.40	2.09	-0.98
50-years	3.97	-0.51	2.41	-1.11
100-years	4.08	-0.55	2.55	-1.17
1,000-years	4.45	-0.69	3.01	-1.35
10,000-years	4.80	-0.82	3.46	-1.53

Data Source: Surges and Still Water Levels from Existing NAM ERD (Existing Platforms) - Interpolation

LAT reference derived from POLPRED CS3

To take account of projected global sea level rise, add on 7.5 mm per year (based on IPCC AR5).

Figure 8-3 Positive and Negative Surges and Still Water Levels by Return Period

Note: Minimum low water values can be conservatively considered the same as negative still water levels [Ref.9] (TBC for the pipeline. COMPANY made this statement for topside and platform design).

8.2. Seawater Properties

Table 8-3 provides information on seawater properties (Ref. [HOLD])

Seawater characteristics		
Density	kg/m^3	1025
Viscosity	cP	1.2
Thermal conductivity	W/m/K	0.57
Heat capacity (1)	J/kg/K	3987

Table 8-3 Seawater Characteristics

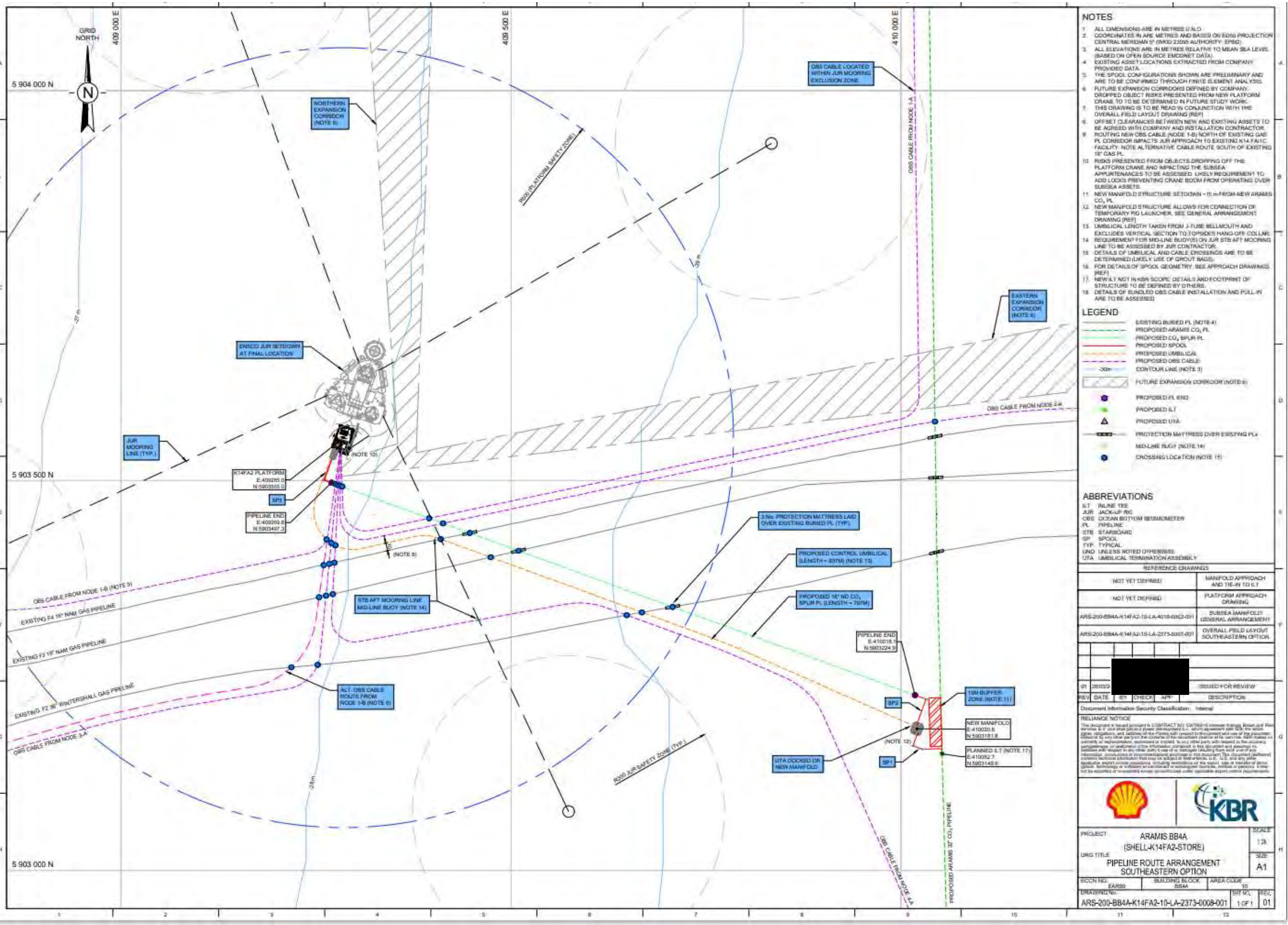
The mean, minimum and maximum seawater temperatures are shown below, in Table 8-4 Ref.6

Seawater temperatures			
Water depth (m)	Mean temperature (°C)	Minimum temperature (°C)	Maximum temperature (°C)
Sea level	9.5 (TBC)	-2	21
Seabed	8 (TBC)	-2 (1)	18

Table 8-4 Seawater Temperature

Note 1: Profile: This is a 100-year return extreme value at seabed location. At 1m asb (above seabed) which represents near seabed conditions, this value can be taken as 3.6

APPENDIX 1. ARAMIS FIELD LAYOUT



Aramis BB4A (Shell-K14FA2-Store)

Wall Thickness Selection Report including Stress Assessment

Shell Document Number	ARS-200-BB4A-K14FA2-10-LA-0580-0003
Building Block	BB4A
Block, Field & Platform\Area Code	K14FA2
PCAP ID	NA
Document Revision	01
Document Status	IFR - Issued for Review
Discipline **Document Type**	LA – Pipeline & Riser 0580 – Wall Thickness Selection
Originator / Author	[redacted]
Originating Company	KBR
Issue Date	11/04/2024
ECCN	EAR99
Security Classification	Internal
Disclosure	Refer to Reliance Notice below
Revision History Shown on next page	

Rev#	Issue Date	Document Status	Originator	Reviewer	Approver
01	11-04-2024	Issued For Review	[redacted]		

REVISION HISTORY

CHANGE/HOLD HISTORY

Rev#	Reason for Hold / Change

SUMMARY/ABSTRACT

This document presents the wall selection methodology and stress assessment for the Aramis Spurline, riser and tie-in spools.

Contents

ABBREVIATIONS:

BLIV	Battery limit isolation valve
CCS	Carbon Capture Storage
CO2	Carbon Dioxide
CC(U)S	Carbon Capture Utilization Storage
OBS	Ocean Bottom Seismometers
OPEX	Operating Expenditure
PACO	Process Automation Control & Optimization
TTE	Total Energies
CWC	Concrete Weight Coating
NAP	Normaal Amsterdamse Peil [Normal Amsterdam Gauge (onshore compression station/trunkline inlet train average elevation)]
LAT	Lowest Astronomical Tide
HAT	Highest Astronomical Tide
MSL	Mean Sea Level
MMV	Measurement Monitoring & Verification
TBC	To Be Confirmed
TBD	To Be Defined
DSS	Duplex Stainless Steel
CS	Carbon Steel
MOP	Maximum Operating Pressure
MAOP	Maximum Allowable Operating Pressure
MOPu	Maximum Operating Pressure upstream
MIPd	Maximum Incidental Pressure downstream
STPd	System Test Pressure downstream

1. INTRODUCTION

1.1. Aramis Project Background

The Aramis carbon capture and storage (CCS) project is incorporating, from the onset, a cross-border approach, providing a decarbonisation solution for North-West Europe. Aramis is developing a technical concept of CCS to contribute to the decarbonisation of industrial areas of The Netherlands, Belgium, France and Germany. Aramis is also seeking synergies with Porthos, another ongoing CCS project in The Netherlands, to form a fully integrated CC(U)S model in The Netherlands for these industrial clusters. The scope of the Aramis CCS project, contains the following transport and storage elements:

- Shipping by barges or coasters for customers not connected to the terminal by pipeline.
- New shipping terminal at the Maasvlakte to be built and operated by CO2nnect, receiving liquid (cryogenic) CO2 from different industrial clusters located in the Northwest Europe region. The terminal will have temporary storage capacity.
- Compressor station for gas phase (vapour) CO2 volumes coming by Porthos onshore pipeline from Rotterdam and its hinterlands
- Trunkline to transport dense phse CO2 over ~200km to the offshore platforms / blocks, with over capacity and potential tie-in points to cater for future growth.
- Offshore Storage in K14 (Shell) and K6/L4 (Total Energies) and in future other fields is expected

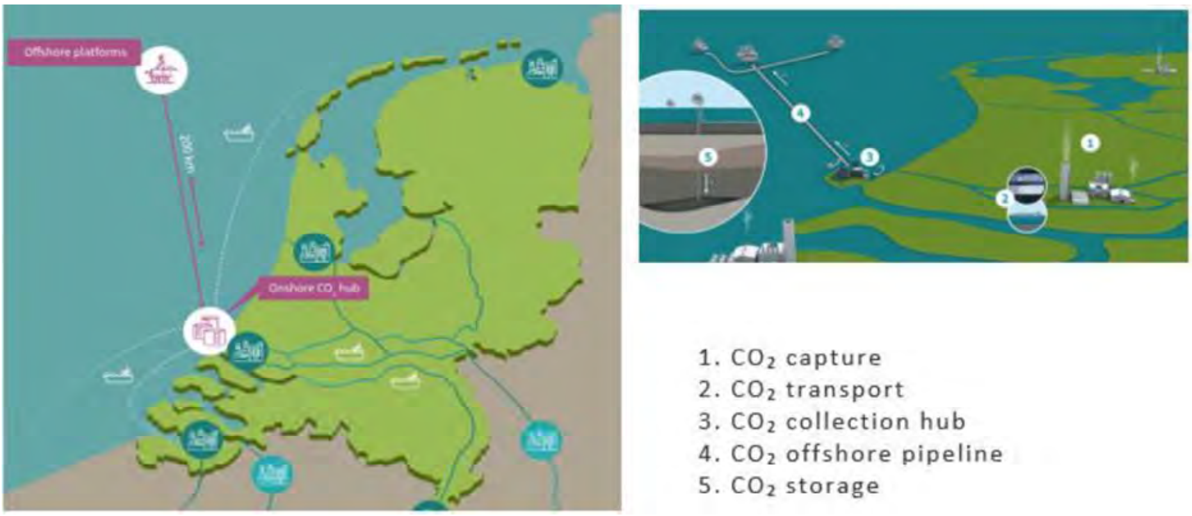


Figure 1-1 Aramis Overview

The key value drivers (and targets) for the Aramis project are:

- Meet SDE++ timeline – first CO2 in store latest end 2028
- System availability > 95% (from emitter to store)
- No early life failures –flawless start-up of the chain
- Lifecycle costs / OPEX: Make sure the running costs are as low as possible (note that lifecycle costs include 'Growth')
- Build reputation - public acceptance (incl. safety)
- Enable future growth and open access (volumes, stores)
- Successful and early transfer of liability after end of injection

K14 and L4 from Shell and Total respectively are the two stores of the Launch phase of the Aramis project. The transport system (compressor, terminal and trunkline) will be open access while stores will be in competition. The Aramis project consists of the several building blocks. Following the CO2 flow from the onshore terminal to the stores, Shell and TTE, it flows via the following building blocks:

- BB1 - Onshore terminal
- BB2 - Onshore compression
- BB3 - CO2 trunkline from Rotterdam Maasvlakte to the offshore K&L blocks ending in a Distribution Hub platform
- BB4a - Shell store (K14FA field) – The Facility scope of BB4a is subject of this document
- BB4b - TTE store (Total Energies)

1.2. Document Purpose

This document is prepared to define the wall thickness for the Front-End Engineering Design (FEED), for the BB4a building block of the ARAMIS CCS project.

The document objectives are to define the required Wall Thickness of the following.

- Spurline
- Riser and Tie-in Spools

2. FACILITY LOCATION & DESCRIPTION

2.1. General

The Aramis Shell CCS facility, BB4a starts at its battery limit with BB3 where the Spool imports the fluid from the BB3 ILT. Following the flow of CO2 from the trunkline towards the reservoir the high-level elements of K14FA2 project are:

- Subsea manifold with automated battery limit isolation valve (BLIV), including the connection to the trunkline.
- Spurline and umbilical connecting manifold with the CO2 injection platform
- New normally unmanned wellhead platform; topsides and jacket
- Interface scope between wells and the facilities
- Installation of the OBS (ocean bottom seismometers) and connection to the PACO systems on the platform

A schematic overview of the system is shown below:

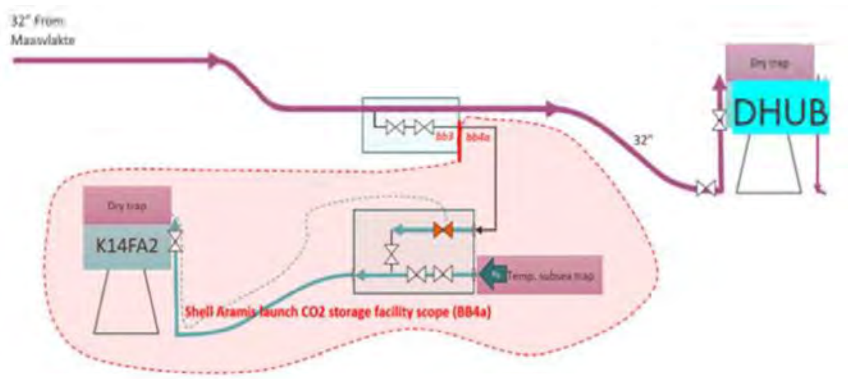
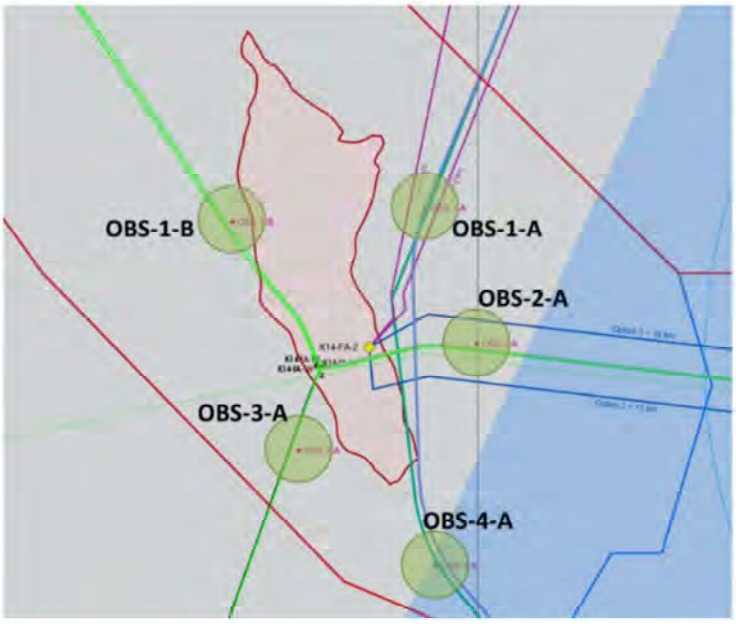


Table 2-1 Schematic overview of Aramis Launch Shell storage scope (inside dotted red line).

2.2. Platform, In-line Tee and OBS Nodes Coordinates

Figure 2-1 illustrates the suggested locations and coordinates of OBS stations



OBS	Easting (m)	Northing(m)
OBS 1-A	410257.38	5905838.94
OBS 1-B	407053.53	5905674.17
OBS 2-A	411072.42	5903576.61
OBS 3-A	408084.68	5901864.45
OBS 4-A	410329.46	5899911.46

CRS: ED50 / TM 5 NE (EPSG:23095)

Figure 2-1 OBS proposed nodes on the field layout

K14FA2 platform, BB3 ILT and OBS stations coordinates are presented in Table 2-2

Item	Easting(m)	Northing(m)
K14FA2 Platform	409 285.00 (1)	5 903 555.00 (1)
BB3 ILT	TBC	TBC
OBS 1-A	410257.38	5905838.94
OBS 1-B	407053.53	5905674.17
OBS 2-A	411072.42	5903576.61
OBS 3-A	408084.68	5901864.45
OBS 4-A	410329.46	5899911.46

Table 2-2 Coordinates of K14FA2 platform and BB3 ILT

Note 1: These coordinates may be subject to change

3. LEGISLATION, REGULATIONS, CODES & STANDARDS

3.1. General

The Aramis FEED scope will be designed to recognised International Standards and selected relevant COMPANY General Specifications. Any deviations will be informed to COMPANY for prior approval.

3.2. Legislation and Regulations

The subsea system design shall comply with all the relevant local, national, and international legislation and regulations.

3.3. National Design Codes and COMPANY General Specifications

The applicable COMPANY General Specification and Dutch Requirements will be used as guideline for the design of subsea pipeline and structures. The first three NEN Requirements, highlighted in bold, from number one to three are the leading documents.

1. **NEN 3650-1**, “Requirements for pipeline systems - Part 1: General requirements” (2020)
2. **NEN 3650-2**, “Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines” (2020)
3. **NEN 3656**, “Requirements for submarine steel pipeline systems” (2022)
4. DEP 31.40.00. 10Gen, “Design and Engineering Practice - Global technical standards index”
5. DEP 31.40.40.38-Gen, “Design and Engineering Practice - Hydrostatic pressure testing for new pipelines”
6. DEP 31.40.30.30-Gen, “Design and Engineering Practice - Concrete coating of linepipe (amendments/supplements to Ref.8)”
7. DEP 31.40.30.31-Gen, “Design and Engineering Practice - Technical specification for external polyethylene and polypropylene coating for line pipe”
8. DEP 30.48.00.31-Gen, “Design and Engineering Practice – Protecting coating for onshore facilities”.
9. DEP 31.40.00.10-Gen Feb 2021 “Pipeline Engineering (Amendments/Suplements to ISO 13623)

3.4. Codes and Standards

The pipeline wall thickness has been calculated based on NEN 3656 [Ref.3], NEN 3650-1 [Ref.1] and NEN 3650-2 [Ref.2]. A secondary and more conservative wall thickness for comparison purposes is calculated based on ISO 13623 [Ref.10] amended by DEP 31.40.00.10-Gen [Ref.5].

DNV-ST-F101 [Ref.6] has been used for the Collapse and Buckle Propagation assessment. For Running Ductile Fracture verification, ISO 27193 [Ref.6] has been utilized.

10. ISO 13623, “Petroleum and natural gas industries - Pipeline transportation systems”
11. ISO 27193: “Carbon dioxide capture, transportation and geological storage – Pipeline transportation system” (2016)
12. DNV_ST_F101, Submarine Pipeline Systems (2021)

3.5. COMPANY Documents

13. ARS-200-BB4A-K14FA2-00-LA-7704-0013, Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis

3.6. Other Documents

14. ARS-200-BB4A-K14FA2-10-LA-7704-0001, Flow Assurance Basis of Design
15. ARS-200-BB4A-K14FA2-10-LA-7180-0001, Flow Assurance Study Report

3.7. REFERENCES

1. **NEN 3650-1**, "Requirements for pipeline systems - Part 1: General requirements" (2020)
2. **NEN 3650-2**, "Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines" (2020)
3. **NEN 3656**, "Requirements for submarine steel pipeline systems" (2022)
4. ISO 13623, "Petroleum and natural gas industries - Pipeline transportation systems"
5. DEP 31.40.00.10-Gen Feb 2021 "Pipeline Engineering (Amendments/Supplements to ISO 13623)
6. DNV_ST_F101, Submarine Pipeline Systems (2021)
7. ISO 27193: "Carbon dioxide capture, transportation and geological storage – Pipeline transportation system" (2016)
8. ISO 13623:2017/FDAmd 1
9. ARS-200-BB4A-K14FA2-00-LA-7704-0013, Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis
10. ARS-PFE-BB4a-ICS-BOD-002, "Aramis Store BfD"

4. WALL THICKNESS DESIGN METHODOLOGY

4.1. General

The pipeline, riser and spool pieces wall thicknesses are checked for compliance with NEN 3656 [Ref.3], NEN 3650-1 [Ref.1] and NEN 3650-2 [Ref.2]. The result have been compared with the secondary wall thickness calculated based on ISO 13623 [Ref.4] and its amendment DEP 31.40.00.10-Gen [Ref.5].

Considering the shallow water condition, The Wall Thickness selection is merely based on one governing criterion for design condition:

- Pressure containment (burst) due to internal overpressure

However the selected wall thickness has been checked against the following criteria using DNV-ST-F101 [Ref.6] for the first two and ISO 27913 [Ref.11] for the last one:

- Hydrostatic collapse due to external overpressure
- Buckle propagation
- Running Ductile Fracture

Finally, it has been demonstrated that the Design condition guarantees the integrity of the pipeline during incidental and pressure test scenarios.

Temperature derating is applied to the SMYS as per DNV-ST-F101 [Ref.6].

4.2. Von Mises relative to Hoop Stress

Von Mises stress for plane stress condition is

$\sqrt{(\sigma_h^2 + \sigma_l^2 - \sigma_h * \sigma_l - 3*\tau^2)}$

For Burst (internal pressure only), shear stress is nil due to symmetry and $\sigma_l = \sigma_h/2$

$\sqrt{(\sigma_h^2 + \sigma_h^2/4 - \sigma_h^2/2)}$

Thus

$\sigma_v = 0.87 * \sigma_h$ (Eq.1)

For Burst criterion, longitudinal stress can be ignored, therefore

$\sigma_v = \sigma_h$ (Eq.2)

4.3. NEN Bend Effect on Hoop Stress

NEN considers the effect of bend wall thinning by applying a factor on the Hoop Stress for bends. Therefore, this effect is taken into account for the Tie-in Spools.

$\sigma_p(bi) = (2*R - D_e/2) / (2*R - D_e) * \sigma_h$ Corrected Hoop Stress at Bend Intrados

$\sigma_p(bu) = (2*R + D_e/2) / (2*R + D_e) * \sigma_h$ Corrected Hoop Stress at Bend Extrados

Where

R is the Bend radius, and D_e is the external diameter of the pipeline without coating.

Considering $R = 3 * D_e$ (Piggable 3D-Bend) and the above formulas

Max Bend Effect Factor on Hoop Stress = max (1.1,0.93) = 1.1

4.4. Design Factors & Safety Factors

NEN standards are implementing Design Factors for its limit state equation, while ISO+DEP are utilizing Safety Factors on its criterion formula. Comparison is made in Section 5.4.

4.5. Burst Limit States and Criteria

Burst is assessed differently in NEN and DEP+ISO, but comparable.

4.5.1. NEN

NEN does not assess for hoop stresses only, it assesses for combined stresses using the Von Mises criteria as a limit state for Burst condition (Load Case 2).

$\sigma_v \leq R_e(\theta)/\gamma_m$

where

σ_v is the Von Mises Stress

$R_e(\theta)$ is the Specified Minimum Yield Strength (SMYS) at temperature θ

By applying the load and Model Factors, the limit state for Burst will be

$\gamma_s * \sigma_v <= SMYS / (\gamma_M * \gamma_m)$ (Eq.3)

Where

γ_s , γ_M & γ_m are Load, Model and Material Factors, quantified in Section 5.3.1.

4.5.2. ISO

DEP+ISO implements Criteria for Burst condition for Hoop and Combined stress using Von Mises.

$\sigma_h <= f_h * SMYS$ (Eq.4)

$\sigma_v <= f_{eq} * SMYS$ (Eq.5)

Where

f_h and f_{eq} are safety factors, quantified in Section 5.3.2.

4.6. Running Ductile Fracture

Running Ductile fracture shall be checked for high pressure pipelines. Running Ductile Fracture is used to calculate the required material toughness for the selected wall thickness. The following formula from ISO 27913 [Ref.11] has been used. A factor of 1000 is removed from the original formula to match the SI unit in MathCAD.

$$C_V := A_c \cdot \sigma_f^{\,2} \cdot \frac{(R_p \cdot t_{ms})^{0.5}}{E} \cdot \frac{24}{\pi} \cdot \left(\ln\left(\sec\left(\frac{\pi}{2} \cdot \frac{C_{cf} \cdot 3.33 \cdot \sigma_a}{\sigma_f} \right) \right) \right)$$

Where

Cv is the Material toughness (J)

Ac is the are of the notched-bar impact specimen

Ccf is the correction factor of 1.25 recommended by COMPANY

σ_f is the flow stress equivalent to yield stress + 68.9MPa

R is the average pipe radius

t_{ms} is the pipe minimum selected standard wall thickness

P_s is the maximum saturation pressure of 7.937 MPa for impure Carbon Dioxide

σ_a is the arrest stress equal to P_s*OD/(2*t_{ms})

5. DESIGN DATA

5.1. Pressure Definition and Pressure Safety System

Test, incidental and maximum allowable operating pressures relation to design pressure are summarized in Table 5-1.

Pressure item	Pt	Pinc	MAOP
Relative to PD	1.30 * PD	1.15 * PD	PD

Table 5-1 Different Pressures relative to Design Pressure

MOPu which is the Upstream Maximum Operating Pressure of 200 bar. Downstream Maximum Incidental Pressure can be calculated as following.

MIPd = 1.15*P_D + Content Pressure Head > 230 bar. Therefore MOPu < MIPd. According to Table 5-2 [Ref.1], Pressure Safety system is not required.

Pressure Ratio	Pressure Regulation	Pressure Alarm	Pressure Safety
MOPu ≤ MIPd	Yes	Yes	0
MOPu > MIPd	Yes	Yes	1
MOPu – MOPd > 1.6 MPa & MOPu >STPd	Yes	Yes	2 (1)

Table 5-2 Components of Deterministically Designed Pressure Control System (2)

Note 1: Two pressure safety systems working independently.
Note 2: This table applies to high-pressure gas pipeline. For liquid pipeline in Group I, Design Pressure can be used instead of MOP. Considering Carbon Dense phase as liquid, this table is applicable to Aramis import system. If the condition in the second line of the table is satisfied, the condition in the third line of the table shall be checked as well.

5.2. Input Data

The design data such as design pressure and temperature, environmental data and other applicable input data are taken from the Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis [Ref.9]. unless otherwise specified in this report.

The design data is summarized in Table 5-3, [Ref.9].

Items	Spurline	Spool	Riser
Outside Diameter (mm)	406.4		
Corrosion Allowance	0		
Material Grade	LC65 2205		
Design Pressure (@+5 NAP)	200 bar		

Design Temperature (Max/Min)	-46 to 30 °C	-46 to 30 °C	-46 to 50 °C
Water Depth (Max/Min) (MSL)	-25.1 to -29.5 m	-25.1 to -29.5 m	0 to -29.5 m

Table 5-3 Design Data

5.3. Wall Thickness Design Factors

NEN, ISO and DNV implement different factors to address the safety requirements.

5.3.1. NEN

The design factors used in calculation as per NEN standards are listed in Table 5-4. NEN standard defines the pipeline within the 500m vicinity of the platform as "pipeline in station" and override the offshore design factors using onshore values. See note 2 below.

NEN Parameter	γ_s (Load Factor)	γ_m (Material Factor)	γ_M (Model Factor)
Burst (Internal Pressure Only)	1.5/1.1 (2)	1.1(1)	1.0(1)

Table 5-4 NEN Design Factors

Note 1: According to NEN 3656 Table 4 [Ref.3]

Note 2: According to NEN 3650-2 Section 8.5.2 [Ref.2]. Factor of 1.25 is overridden.

5.3.2. ISO+DEP

According to ISO 2017 Amendment [Ref.8] Carbon dioxide is considered sufficiently toxic to be classified as Fluid category E. The safety factors used per ISO+DEP standard is listed in Table 5-5.

ISO+DEP	f_h (Hoop Stress Safety Factor)	f_{eq} (Equivalent Stress Safety Factor)
Spurline & Spool	0.77 (1)	0.9 (1)
Riser	0.55(2)	0.9 (1)

Table 5-5 DEP+ISO Safety Factors

Note 1: According to ISO Table 4 [Ref.4]

Note 2: According to DEP Table 3 [Ref.5] amendment on ISO [Ref.4]

5.3.3. DNV

Partial safety factors according to DNV-FS-F101 [Ref.6] for Buckle Propagation and Collapse criteria are summarized in Table 5-6.

DNV	Collapse	Buckle Propagation
α_u (Material Strength factor)	0.96	0.96
α_{fab} (Fabrication Factor)	1 (1)	1.0
γ_{mD} (Material Resistance Factor)	1.15	1.15
γ_{SC} (Safety Class Resistance Factor)	1.14 (2) / 1.04 (3)	NA

Table 5-6 DNV Partial Safety Factors

Note 1: Assuming Seamless linepipe

Note 2: For Design and Operation cases.

Note 3: For Installation case

5.4. Comparison between NEN & DEP+ISO

Quantified Design and Safety factors are applied on NEN and DEP+ISO criteria respectively for the purpose of comparison.

5.4.1. NEN

By combining Eq.2 and Eq.3 and implementing the Design Factors

$(1.5/1.1) * \sigma_h <= SMYS / (1.0 * 1.1)$

For the spool, Bend effect on Hoop Stress shall be taken in to account according to Section 4.3 Therefore, the Burst limit state will be

$\sigma_h \leq 0.606 * SMYS$ for Spool (Eq.6)

$\sigma_h \leq 0.667 * SMYS$ for Spurline & Riser (Eq.7)

5.4.2. DEP+ISO

By implementing the Safety Factors on Eq.4 and the combination of Eq.2 and Eq.5

$\sigma_h \leq 0.77 * SMYS$ for Spool & Spurline

$\sigma_h \leq 0.55 * SMYS$ for Riser

$\sigma_h \leq 0.90 * SMYS$

The latter (Equivalent Stress criterion) is satisfied by the formers (Hoop Stress criterion), therefore the Burst Criteria will be

$\sigma_h \leq 0.77 * SMYS$ for Spool & Spurline (Eq.8)

$\sigma_h \leq 0.55 * SMYS$ for Riser (Eq.9)

5.4.3. Comparison

Table 5-7 summarizes the comparison between NEN and DEP+ISO.

Standard	Spurline	Spool	Riser
NEN	0.667	0.606	0.667
DEP+ISO	0.77	0.77	0.55
The more conservative	NEN	NEN	DEP+ISO
The governing	NEN	DEP+ISO (1)	
Selected Standard	NEN (2)		

Table 5-7 Final Combined Factor for Burst _ NEN versus DEP+ISO

Note 1: Riser and Spool shall have the same wall thickness.

Note 2: COMPANY grants DEP+ISO exemption.

6. WALL THICKNESS ANALYSIS RESULT

6.1. Design, Operation & Installation

The calculated wall thicknesses for Burst under Design condition are presented for Spurline, Spool and Riser separately according to NEN and DEP+ISO standards are summarized in Table 6-1. Then Collapse and Propagating Buckling are checked for the calculated Wall Thicknesses according to DNV.

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Case</th><th colspan="2">Burst (mm)</th><th rowspan="2">Collapse Check</th><th rowspan="2">Propagation Buckling Check</th><th colspan="2">Minimum Required Wall Thickness (mm)</th><th rowspan="2">Min Selected Wall Thickness (mm)</th><th rowspan="2">Required Material Toughness (J)</th></tr>
<tr><th>NEN</th><th>DEP + ISO</th><th>NEN</th><th>DEP + ISO</th></tr>
<tr><td rowspan="3">Spurline</td><td>Installation</td><td>-</td><td>-</td><td>Pass</td><td>Pass</td><td rowspan="3">15.9</td><td rowspan="3">14.3</td><td rowspan="3">15.9</td><td rowspan="3">66.6</td></tr>
<tr><td>Design</td><td>15.3</td><td>13.1</td><td>Pass</td><td>Pass</td></tr>
<tr><td>System Test</td><td colspan="4">Note 1</td></tr>
<tr><td rowspan="3">Spool</td><td>Installation</td><td>-</td><td>-</td><td>Pass</td><td>Pass</td><td rowspan="3">17.5</td><td rowspan="3">14.3</td><td rowspan="6">17.5 (2)(3)</td><td rowspan="6">48.5</td></tr>
<tr><td>Design</td><td>16.8</td><td>13.1</td><td>Pass</td><td>Pass</td></tr>
<tr><td>System Test</td><td colspan="4">Note 1</td></tr>
<tr><td rowspan="3">Riser</td><td>Installation</td><td>-</td><td>-</td><td>Pass</td><td>Pass</td><td rowspan="3">17.5</td><td rowspan="3">20.6 (3)</td></tr>
<tr><td>Design</td><td>16.3</td><td>19.3</td><td>Pass</td><td>Pass</td></tr>
<tr><td>System Test</td><td colspan="4">Note 1</td></tr>
</table>

Table 6-1 Selected Wall Thicknesses and Material Toughness Summary

Note 1: Pressure test is covered within the Wall Thickness calculation of Design Pressure. Further explanation is provided in Section 6.2.

Note 2: Riser and Spool shall have the same wall thickness.

Note 3: COMPANY grants exemption for DEP+ISO

6.2. Incidental and Pressure Test

NEN clearly states that the maximum incidental pressure does not have to be assessed separately for Burst criterion but shall be guaranteed by the pressure control system. However, in this section it is demonstrated using simple mathematical arguments, that both Incidental and Test Pressures are covered within the NEN wall thickness design.

According to Section 5.1, test and incidental pressures can be calculated relative to design pressure as following.

$P_t = 1.3 * P_D$
$P_{inc} = 1.15 * P_D$

NEN [Ref.1] defines the Hoop Stress as

$\sigma_h = P * D_g / 2 * d$

Where

P is the positive internal pressure
D_g is the average pipe diameter equal to D_e – d
D_e is the Outside diameter without coating
d is the minimum wall thickness taking into account fabrication tolerance, corrosion and abrasion

As per sections 5.3.1 and 5.4.1, wall thickness is calculated using load factor γ_s of 1.5/1.1=1.36 which is greater than 1.3 and 1.15 factors for test and incidental pressure, therefore both test and incidental pressure induced hoop stress are below the hoop stress induced by design pressure using 1.36 load factor. The effect of the external pressure is neglected compared with high internal pressure

APPENDIX 1. ATTACHMENTS

MathCAD NEN ISO DNV _ Spurline&Spoo

MathCAD NEN ISO DNV _ Riser.pdf

		REVISION	Model 0		Case 1		
		Date	4/4/24				
CLIENT	SHELL	BY	Baset Rastgar				
PROJECT	Aramis Project	CHECKED	Jonathan Franklin				
CALCULATION NUMBER		CASE NO.		JOB NO.			
CODE		YEAR			Rev.		

References

1. NEN 3656 2022
2. NEN 3650-1 2020
3. NEN 3650-2 2020
4. ISO 13623 2015 + Am 2017
5. DEP 31.40.20.34_Gen feb 2021
6. ISO 27913 2016
7. DNV ST F101 2021

All references are to [1] unless otherwise noted

Methodology

This calculation determines the required nominal wall thickness for a pipeline system in line with design process outlined within NEN and ISO. The effect of bend on the wall thickness has been taken in to account for the spools only. Therefore a separate wall thickness is defined for the spurline. Running Ductile Fracture has been checked to calculate the required material toughness for the selected wall thickness.

Assumptions

The value of 1.5/1.1 for γ_s is taken from On-shore code, instead of 1.25 for offshore pipeline, because the riser, big part of the Spurline and the riser spool are all within the 500m proximity of the platform. Because the content density is less than water, for burst we use the minimum depth to define the absolute internal and external pressures. For Collapse and Buckle Propagation, max depth is used to define the absolute external pressure, and internal pressure is assumed nil for vaccum.

Inputs

$OD := 406.4mm$	Outside Diameter of the Pipeline without coating
$\gamma_s := \frac{1.5}{1.1}$	NEN 3650-2 2020 Onshore Load factor for the entire calculation model (Sec 8.5.2)
$\gamma_m := 1.1$	Material factor for the entire calculation model
$\gamma_M := 1.0$	Model factor for the entire calculation model
$P_{atm} := 101325Pa$	Atmospheric pressure at MSL
$P_{dref} := 20MPa + P_{atm}$	Absolute Design Pressure at the reference point $P_{dref} = 20101325\,Pa$
$h_{ref} := 5m$	Refernce for the Design pressure relative to NAP (MSL)
$SMYS := 448MPa$	Specified Minimum Yield Strength
$Der := 13.34MPa$	SMYS Derating [Ref.7]
$Der_{inst} := 0$	SMYS Derating for installation
$BT := 3$	3 if 3D-Bend, n for nD-Bend
$f_h := 0.77$	Hoop stress design factor ISO [Ref.4] (Table 2&3)
$h_{ref} := 5m$	Refrence level
$h_{max} := 29.5m$	Maximum water depth
$h_{min} := 25.1m$	Minimum water depth
$\rho_w := 1025\frac{kg}{m^3}$	Seawater density
$\rho_{max} := 973.4\frac{kg}{m^3}$	Max content density
$\rho_{min} := 757.1\frac{kg}{m^3}$	Min content density
$t_{fab} := 10\%$	Negative fabrication tolerance percentage relative to the nominal wall thickness

Calculations

$P_d := P_{dref} \cdots + \rho_{max} \cdot g \cdot (h_{min} + h_{ref})$	Max absolute design pressure at min depth	$P_d = 20.389 \times 10^6\,Pa$
$P_e := \rho_w \cdot g \cdot h_{min} + P_{atm}$	Absolute external pressure at min depth	$P_e = 3.54 \times 10^5\,Pa$
$P_{e\_max} := \rho_w \cdot g \cdot h_{max} + P_{atm}$	Absolute external pressure at max depth	$P_{e\_max} = 3.98 \times 10^5\,Pa$

NEN

$R := BT \cdot OD$	Bend radius	$R = 1.219\,m$
$BE := \max\left(\dfrac{2 \cdot R - 0.5 \cdot OD}{2 \cdot R - OD}, \dfrac{2 \cdot R + 0.5 \cdot OD}{2 \cdot R + OD}\right)$	Bend effect on hoop stress	$BE = 1.1$
$t_{minN} := \dfrac{\gamma_s \cdot (P_d - P_e) \cdot OD}{\gamma_s \cdot (P_d - P_e) + 2 \cdot \dfrac{(SMYS - Der)}{\gamma_m \cdot \gamma_M}}$	NEN Min Wallthickness	$t_{minN} = 0.0136\,m$
$t_{minNf} := \dfrac{t_{minN}}{1 - t_{fab}}$	NEN Min wall thickness including fabrication tolerance	$t_{minNf} = 0.0151\,m$
$t_{minNb} := \dfrac{BE \cdot \gamma_s \cdot (P_d - P_e) \cdot OD}{BE \cdot \gamma_s \cdot (P_d - P_e) + \dfrac{2 \cdot (SMYS - Der)}{\gamma_m \cdot \gamma_M}}$	Min Wall thickness_Bend Eff	$t_{minNb} = 0.0149\,m$
$t_{minNbf} := \dfrac{t_{minNb}}{1 - t_{fab}}$	NEN Min wall thickness_Bend efect including fabrication tolerance	$t_{minNbf} = 0.0165\,m$

ISO

$t_{minI} := \dfrac{(P_d - P_e) \cdot OD}{P_d - P_e + 2.f_h \cdot (SMYS - Der)}$	ISO Min Wall thickness	$t_{minI} = 0.0118\,m$
$t_{minIf} := \dfrac{t_{minI}}{1 - t_{fab}}$	ISO Min wall thickness including fabrication tolerance	$t_{minIf} = 0.0131\,m$

Min and Standard required Wall thickness

$t_{min} := \max(t_{minNf}, t_{minIf})$	Min required wall thickness	$t_{min} = 0.0151\,m$
$t_{minb} := \max(t_{minNbf}, t_{minIf})$	Min required wall thickness with bend effect	$t_{minb} = 0.0165\,m$

$t_{ms} := 15.9mm$ Min Standard wall thickness

$t_{msb} := 17.5mm$ Min Standard wall thickness with bend effect

Inputs for Running Ductile Fracture Ref.6

$A_c := 80mm^2$	Full-sized speciment area of the Charpy-V-notch	
$P_s := 7.937MPa$	Max Saturation Pressure for impure Carbon Dioxide	
$E := 200GPa$	Young Modulus	
$C_{cf} := 1.25$	Correction factor [Ref.6]	

Calculations for Running Ductile Fracture Ref.6

$R_p := \frac{OD - t_{ms}}{2}$	Average pipe radius	$R_p = 0.195\,m$
$R_{pb} := \frac{OD - t_{msb}}{2}$	Average pipe radius with bend effect	$R_{pb} = 0.194\,m$
$\sigma_f := SMYS - Der + 68.9MPa$	Flow stress	$\sigma_f = 503.56 \times 10^6\,Pa$
$\sigma_a := \frac{P_s \cdot OD}{2 \cdot t_{ms}}$	Arrest stress	$\sigma_a = 101.43 \times 10^6\,Pa$
$\sigma_{ab} := \frac{P_s \cdot OD}{2 \cdot t_{msb}}$	Arrest stress with bend effect	$\sigma_{ab} = 92.16 \times 10^6\,Pa$
$AA := \sec\left(\frac{\pi}{2} \cdot \frac{C_{cf} \cdot 3.33 \cdot \sigma_a}{\sigma_f}\right)$	Intermediate calculation	$AA = 3.984$
$C_v := A_c \cdot \sigma_f^2 \cdot \frac{(R_p \cdot t_{ms})^{0.5}}{E} \cdot \frac{24}{\pi} \cdot (\ln(AA))$	Required Material toughness for t_{ms}	$C_v = 59.675\,J$
$AA_b := \sec\left(\frac{\pi}{2} \cdot \frac{C_{cf} \cdot 3.33 \cdot \sigma_{ab}}{\sigma_f}\right)$	Intermediate calculation	$AA_b = 2.736$
$C_{vb} := A_c \cdot \sigma_f^2 \cdot \frac{(R_{pb} \cdot t_{msb})^{0.5}}{E} \cdot \frac{24}{\pi} \cdot (\ln(AA_b))$	Required Material toughness for t_{msb}	$C_{vb} = 45.496\,J$

Inputs for Buckle propagation Ref.7

$P_{min} := 0$ — Min absolute internal pressures during installation or Operation for vaccum

$\gamma_{sc.LB.inst} := 1.04$

$\gamma_{sc.LB.op} := 1.14$

Installation & Operation Safety Class Resistance Factors Table 5-2 Ref.7

$t_{cor} := 0$ — Corrosion allowance

$\alpha_{fab} := 1$ — Max fabrication factor Table 5.4 Ref.7

$\alpha_u := 0.96$ — Material strength factor Table 5.3 Ref.7

$\gamma_{mD} := 1.15$ — Material resistance factor Table 5.1 Ref.7

Calculations

Buckle Propagation for Installation

$f_y := \alpha_u \cdot (SMYS - Der_{inst})$	Characteristic material strength factor for Installation	$f_y = 430.08 \times 10^6\,Pa$
$P_{pr} := 35 \cdot f_y \cdot \alpha_{fab} \cdot \left(\frac{t_{ms} - t_{cor}}{OD}\right)^{2.5}$	For installation	$P_{pr} = 4.557 \times 10^6\,Pa$
$P_{prb} := 35 \cdot f_y \cdot \alpha_{fab} \cdot \left(\frac{t_{msb} - t_{cor}}{OD}\right)^{2.5}$	For installation	$P_{prb} = 5.792 \times 10^6\,Pa$
$f_{yop} := \alpha_u \cdot (SMYS - Der)$	Characteristic material strength factor for Operation	$f_{yop} = 417.274 \times 10^6\,Pa$
$P_{prop} := 35 \cdot f_{yop} \cdot \alpha_{fab} \cdot \left(\frac{t_{ms} - t_{cor}}{OD}\right)^{2.5}$	For operation	$P_{pr} = 4.557 \times 10^6\,Pa$
$P_{propb} := 35 \cdot f_{yop} \cdot \alpha_{fab} \cdot \left(\frac{t_{msb} - t_{cor}}{OD}\right)^{2.5}$	For operation	$P_{prb} = 5.792 \times 10^6\,Pa$
$P_c := P_{e\_max} - P_{min} - \frac{P_{pr}}{\gamma_{mD} \cdot \gamma_{sc.LB.inst}}$	Installation propagation buckling criterion	$P_c = -3.413 \times 10^6\,Pa$
$P_{cb} := P_{e\_max} - P_{min} - \frac{P_{prb}}{\gamma_{mD} \cdot \gamma_{sc.LB.inst}}$	Installation propagation buckling criterion with bend effect	$P_{cb} = -4.445 \times 10^6\,Pa$

$P_{cop} := P_{e\_max} - P_{min} - \frac{P_{prop}}{\gamma_{mD} \cdot \gamma_{sc.LB.op}}$ Operation propagation buckling criterion $P_{cop} = -2.975 \times 10^6 \, Pa$

$P_{copb} := P_{e\_max} - P_{min} - \frac{P_{propb}}{\gamma_{mD} \cdot \gamma_{sc.LB.op}}$ Operation propagation buckling criterion with bend effect $P_{copb} = -3.889 \times 10^6 \, Pa$

$P_{Binst} := \text{if}\left[\left(P_c > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Binst} = \text{"No Buckle Propagation"}$

$P_{Bop} := \text{if}\left[\left(P_{cop} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Bop} = \text{"No Buckle Propagation"}$

$P_{Binstb} := \text{if}\left[\left(P_{cb} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Binstb} = \text{"No Buckle Propagation"}$

$P_{Bopb} := \text{if}\left[\left(P_{copb} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Bopb} = \text{"No Buckle Propagation"}$

Inputs for Collapse Ref.7

$\nu := 0.3$ Poisson ratio

$O_o := 1.5\%$ Ovality

Calculations

Collapse without Bend Effect for Installation

$t_{mswf} := t_{ms} \cdot (1 - t_{fab})$ $t_{mswf} = 0.014\,m$ Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{mswf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_y \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{mswf}}{OD}$$

$b := -P_{el}$ $c_1 := -\left(P_p^{\ 2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{mswf}}\right)$ $d := P_{el} \cdot P_p^{\ 2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\phi := \mathrm{acos}\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$$y := -2. \sqrt{-u} \cdot \cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$$

$$P_{col} := y - \frac{b}{3}$$

$$P_{cc\_inst} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.inst}\right)$$

$P_{Cinst} := \mathrm{if}\left[\left(P_{cc\_inst} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $P_{Cinst} = \text{"No Collapse"}$

Collapse without Bend Effect for Operation

$t_{mswf} := t_{ms} \cdot (1 - t_{fab})$ $t_{mswf} = 0.014\,m$ Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{mswf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_{yop} \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{mswf}}{OD}$$

$b := -P_{el}$ $\quad c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{mswf}}\right)$ $\quad d := P_{el} \cdot P_p^{\,2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $\quad v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\quad \phi := acos\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$y := -2.\sqrt{-u} \cdot cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$

$P_{col} := y - \frac{b}{3}$

$P_{cc\_op} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.op}\right)$

$P_{Cop} := if\left[\left(P_{cc\_op} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $\quad P_{Cop} = \text{"No Collapse"}$

Collapse with Bend Effect for Installation

$t_{msbwf} := t_{msb} \cdot \left(1 - t_{fab}\right)$ $\quad t_{msbwf} = 0.016\,m$

Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{msbwf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_y \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{msbwf}}{OD}$$

$b := -P_{el}$ $\quad c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{msbwf}}\right)$ $\quad d := P_{el} \cdot P_p^{\,2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $\quad v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\quad \phi := acos\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$y := -2.\sqrt{-u} \cdot cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$

$P_{colb} := y - \frac{b}{3}$

$P_{cc\_instb} := P_{colb} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.inst}\right)$

$P_{Cinstb} := if\left[\left(P_{cc\_instb} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $\quad P_{Cinstb} = \text{"No Collapse"}$

Collapse with Bend Effect for Operation

$t_{msbwf} := t_{msb} \cdot \left(1 - t_{fab}\right)$ $\quad t_{msbwf} = 0.016\,m$

Min Standard Wall Thickness Without Negative Fabrication

Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{msbwf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_{yop} \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{msbwf}}{OD}$$

$$b := -P_{el} \qquad c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{msbwf}}\right) \qquad d := P_{el} \cdot P_p^{\,2}$$

$$u := \frac{1}{3} \cdot \left(\frac{-1}{3}.b^2 + c_1\right) \qquad v := \frac{1}{2} \cdot \left(\frac{2}{27}.b^3 - \frac{b.c}{3} + d\right) \qquad \phi := \operatorname{acos}\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$$

$$y := -2.\sqrt{-u} \cdot \cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$$

$$P_{colb} := y - \frac{b}{3}$$

$$P_{cc\_opb} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.op}\right)$$

$$P_{Copb} := \text{if}\left[\left(P_{cc\_opb} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right] \qquad P_{Copb} = \text{"No Collapse"}$$

		REVISION	Model 1		Case 1		
		Date	4/4/24				
CLIENT	SHELL	BY	[redacted]				
PROJECT	Shell Aramis	CHECKED					
CALCULATION NUMBER		CASE NO.		JOB NO.			
CODE		YEAR			Rev.		

References

1. NEN 3656 2022
2. NEN 3650-1 2020
3. NEN 3650-2 2020
4. ISO 13623 2015 + Am 2017
5. DEP 31.40.20.34_Gen feb 2021
6. ISO 27913 2016
7. DNV ST F101 2021

All references are to [1] unless otherwise noted

Methodology

This calculation determines the required nominal wall thickness for a pipeline system in line with design process outlined within NEN and ISO. The effect of bend on the wall thickness has been taken in to account for the spools only. Therefore a separate wall thickness is defined for the spurline. Running Ductile Fracture has been checked to calculate the required material toughness for the selected wall thickness.

Assumptions

The value of 1.5/1.1 for γ_s is taken from On-shore code, instead of 1.25 for offshore pipeline, because the riser, big part of the Spurline and the riser spool are all within the 500m proximity of the platform. Because the content density is less than water, for burst we use the minimum depth to define the absolute internal and external pressures. For Collapse and Buckle Propagation, max depth is used to define the absolute external pressure, and internal pressure is assumed nil for vaccum.

Inputs

$OD := 406.4mm$	Outside Diameter of the Pipeline without coating
$\gamma_s := \frac{1.5}{1.1}$	NEN 3650-2 2020 Onshore Load factor for the entire calculation model (Sec 8.5.2)
$\gamma_m := 1.1$	Material factor for the entire calculation model
$\gamma_M := 1.0$	Model factor for the entire calculation model
$P_{atm} := 101325Pa$	Atmospheric pressure at MSL
$P_{dref} := 20MPa + P_{atm}$	Absolute Design Pressure at the reference point $P_{dref} = 20101325\,Pa$
$h_{ref} := 5m$	Refernce for the Design pressure relative to NAP (MSL)
$SMYS := 448MPa$	Specified Minimum Yield Strength
$Der := 40MPa$	SMYS Derating [Ref.7]
$Der_{inst} := 0$	SMYS Derating for installation
$BT := 3$	3 if 3D-Bend, n for nD-Bend
$f_h := 0.55$	Hoop stress design factor ISO [Ref.4] (Table 2&3)
$h_{ref} := 5m$	Refrence level
$h_{max} := 29.5m$	Maximum water depth
$h_{min} := 0m$	Minimum water depth
$\rho_w := 1025\frac{kg}{m^3}$	Seawater density
$\rho_{max} := 973.4\frac{kg}{m^3}$	Max content density
$\rho_{min} := 757.1\frac{kg}{m^3}$	Min content density
$t_{fab} := 10\%$	Negative fabrication tolerance percentage relative to the nominal wall thickness

Calculations

$P_d := P_{dref} \cdots + \rho_{max} \cdot g \cdot (h_{min} + h_{ref})$	Max absolute design pressure at min depth	$P_d = 20.149 \times 10^6\,Pa$
$P_e := \rho_w \cdot g \cdot h_{min} + P_{atm}$	Absolute external pressure at min depth	$P_e = 1.01 \times 10^5\,Pa$
$P_{e\_max} := \rho_w \cdot g \cdot h_{max} + P_{atm}$	Absolute external pressure at max depth	$P_{e\_max} = 3.98 \times 10^5\,Pa$

NEN

$R := BT \cdot OD$	Bend radius	$R = 1.219\,m$
$BE := \max\left(\frac{2 \cdot R - 0.5 \cdot OD}{2 \cdot R - OD}, \frac{2 \cdot R + 0.5 \cdot OD}{2 \cdot R + OD}\right)$	Bend effect on hoop stress	$BE = 1.1$
$t_{minN} := \frac{\gamma_s \cdot (P_d - P_e) \cdot OD}{\gamma_s \cdot (P_d - P_e) + 2 \cdot \frac{(SMYS - Der)}{\gamma_m \cdot \gamma_M}}$	NEN Min Wallthickness	$t_{minN} = 0.0144\,m$
$t_{minNf} := \frac{t_{minN}}{1 - t_{fab}}$	NEN Min wall thickness including fabrication tolerance	$t_{minNf} = 0.016\,m$
$t_{minNb} := \frac{BE \cdot \gamma_s \cdot (P_d - P_e) \cdot OD}{BE \cdot \gamma_s \cdot (P_d - P_e) + \frac{2 \cdot (SMYS - Der)}{\gamma_m \cdot \gamma_M}}$	Min Wall thickness_Bend Eff	$t_{minNb} = 0.0158\,m$
$t_{minNbf} := \frac{t_{minNb}}{1 - t_{fab}}$	NEN Min wall thickness_Bend efect including fabrication tolerance	$t_{minNbf} = 0.0176\,m$

ISO

$t_{minI} := \frac{(P_d - P_e) \cdot OD}{P_d - P_e + 2.f_h \cdot (SMYS - Der)}$	ISO Min Wall thickness	$t_{minI} = 0.0174\,m$
$t_{minIf} := \frac{t_{minI}}{1 - t_{fab}}$	ISO Min wall thickness including fabrication tolerance	$t_{minIf} = 0.0193\,m$

Min and Standard required Wall thickness

$t_{min} := \max(t_{minNf}, t_{minIf})$	Min required wall thickness	$t_{min} = 0.0193\,m$
$t_{minb} := \max(t_{minNbf}, t_{minIf})$	Min required wall thickness with bend effect	$t_{minb} = 0.0193\,m$

$t_{ms} := 17.5mm$	Min Standard wall thickness
$t_{msb} := 19.1mm$	Min Standard wall thickness with bend effect

Inputs for Running Ductile Fracture Ref.6

$A_c := 80mm^2$	Full-sized speciment area of the Charpy-V-notch
$P_s := 7.937MPa$	Max Saturation Pressure for impure Carbon Dioxide
$E := 200GPa$	Young Modulus
$C_{cf} := 1.25$	Correction factor [Ref.6]

Calculations for Running Ductile Fracture Ref.6

$R_p := \dfrac{OD - t_{ms}}{2}$	Average pipe radius	$R_p = 0.194\,m$
$R_{pb} := \dfrac{OD - t_{msb}}{2}$	Average pipe radius with bend effect	$R_{pb} = 0.194\,m$
$\sigma_f := SMYS - Der + 68.9MPa$	Flow stress	$\sigma_f = 476.9 \times 10^6\,Pa$
$\sigma_a := \dfrac{P_s \cdot OD}{2 \cdot t_{ms}}$	Arrest stress	$\sigma_a = 92.16 \times 10^6\,Pa$
$\sigma_{ab} := \dfrac{P_s \cdot OD}{2 \cdot t_{msb}}$	Arrest stress with bend effect	$\sigma_{ab} = 84.44 \times 10^6\,Pa$
$AA := \sec\left(\dfrac{\pi}{2} \cdot \dfrac{C_{cf} \cdot 3.33 \cdot \sigma_a}{\sigma_f}\right)$	Intermediate calculation	$AA = 3.306$
$C_v := A_c \cdot \sigma_f^{\,2} \cdot \dfrac{(R_p \cdot t_{ms})^{0.5}}{E} \cdot \dfrac{24}{\pi} \cdot (\ln(AA))$	Required Material toughness for t_{ms}	$C_v = 48.482\,J$
$AA_b := \sec\left(\dfrac{\pi}{2} \cdot \dfrac{C_{cf} \cdot 3.33 \cdot \sigma_{ab}}{\sigma_f}\right)$	Intermediate calculation	$AA_b = 2.491$
$C_{vb} := A_c \cdot \sigma_f^{\,2} \cdot \dfrac{(R_{pb} \cdot t_{msb})^{0.5}}{E} \cdot \dfrac{24}{\pi} \cdot (\ln(AA_b))$	Required Material toughness for t_{msb}	$C_{vb} = 38.576\,J$

Inputs for Buckle propagation Ref.7

$P_{min} := 0$ — Min absolute internal pressures during installation or Operation for vaccum

$\gamma_{sc.LB.inst} := 1.04$

$\gamma_{sc.LB.op} := 1.14$ — Installation & Operation Safety Class Resistance Factors Table 5-2 Ref.7

$t_{cor} := 0$ — Corrosion allowance

$\alpha_{fab} := 1$ — Max fabrication factor Table 5.4 Ref.7

$\alpha_u := 0.96$ — Material strength factor Table 5.3 Ref.7

$\gamma_{mD} := 1.15$ — Material resistance factor Table 5.1 Ref.7

Calculations

Buckle Propagation for Installation

$f_y := \alpha_u \cdot (SMYS - Der_{inst})$ — Characteristic material strength factor for Installation — $f_y = 430.08 \times 10^6\ Pa$

$P_{pr} := 35 \cdot f_y \cdot \alpha_{fab} \cdot \left(\frac{t_{ms} - t_{cor}}{OD}\right)^{2.5}$ — For installation — $P_{pr} = 5.792 \times 10^6\ Pa$

$P_{prb} := 35 \cdot f_y \cdot \alpha_{fab} \cdot \left(\frac{t_{msb} - t_{cor}}{OD}\right)^{2.5}$ — For installation — $P_{prb} = 7.208 \times 10^6\ Pa$

$f_{yop} := \alpha_u \cdot (SMYS - Der)$ — Characteristic material strength factor for Operation — $f_{yop} = 391.68 \times 10^6\ Pa$

$P_{prop} := 35 \cdot f_{yop} \cdot \alpha_{fab} \cdot \left(\frac{t_{ms} - t_{cor}}{OD}\right)^{2.5}$ — For operation — $P_{pr} = 5.792 \times 10^6\ Pa$

$P_{propb} := 35 \cdot f_{yop} \cdot \alpha_{fab} \cdot \left(\frac{t_{msb} - t_{cor}}{OD}\right)^{2.5}$ — For operation — $P_{prb} = 7.208 \times 10^6\ Pa$

$P_c := P_{e\_max} - P_{min} - \frac{P_{pr}}{\gamma_{mD} \cdot \gamma_{sc.LB.inst}}$ — Installation propagation buckling criterion — $P_c = -4.445 \times 10^6\ Pa$

$P_{cb} := P_{e\_max} - P_{min} - \frac{P_{prb}}{\gamma_{mD} \cdot \gamma_{sc.LB.inst}}$ — Installation propagation buckling criterion with bend effect — $P_{cb} = -5.629 \times 10^6\ Pa$

$$P_{cop} := P_{e\_max} - P_{min} - \frac{P_{prop}}{\gamma_{mD} \cdot \gamma_{sc.LB.op}}$$ Operation propagation buckling criterion $P_{cop} = -3.626 \times 10^6\,Pa$

$$P_{copb} := P_{e\_max} - P_{min} - \frac{P_{propb}}{\gamma_{mD} \cdot \gamma_{sc.LB.op}}$$ Operation propagation buckling criterion with bend effect $P_{copb} = -4.609 \times 10^6\,Pa$

$P_{Binst} := \text{if}\left[\left(P_c > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Binst} = \text{"No Buckle Propagation"}$

$P_{Bop} := \text{if}\left[\left(P_{cop} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Bop} = \text{"No Buckle Propagation"}$

$P_{Binstb} := \text{if}\left[\left(P_{cb} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Binstb} = \text{"No Buckle Propagation"}$

$P_{Bopb} := \text{if}\left[\left(P_{copb} > 0\right), \text{"Buckle Propagation"}, \text{"No Buckle Propagation"}\right]$ $P_{Bopb} = \text{"No Buckle Propagation"}$

Inputs for Collapse Ref.7

$\nu := 0.3$ Poisson ratio

$O_o := 1.5\%$ Ovality

Calculations

Collapse without Bend Effect for Installation

$t_{mswf} := t_{ms} \cdot (1 - t_{fab})$ $t_{mswf} = 0.016\,m$ Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{mswf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_y \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{mswf}}{OD}$$

$b := -P_{el}$ $c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{mswf}}\right)$ $d := P_{el} \cdot P_p^{\,2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\phi := \mathrm{acos}\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$$y := -2. \sqrt{-u} \cdot \cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$$

$$P_{col} := y - \frac{b}{3}$$

$$P_{cc\_inst} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.inst}\right)$$

$P_{Cinst} := \mathrm{if}\left[\left(P_{cc\_inst} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $P_{Cinst} = \text{"No Collapse"}$

Collapse without Bend Effect for Operation

$t_{mswf} := t_{ms} \cdot (1 - t_{fab})$ $t_{mswf} = 0.016\,m$ Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{mswf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_{yop} \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{mswf}}{OD}$$

$b := -P_{el}$ $\quad c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{mswf}}\right)$ $\quad d := P_{el} \cdot P_p^{\,2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $\quad v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\quad \phi := acos\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$y := -2 . \sqrt{-u} \cdot cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$

$P_{col} := y - \frac{b}{3}$

$P_{cc\_op} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.op}\right)$

$P_{Cop} := if\left[\left(P_{cc\_op} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $\quad P_{Cop} = \text{"No Collapse"}$

Collapse with Bend Effect for Installation

$t_{msbwf} := t_{msb} \cdot \left(1 - t_{fab}\right)$ $\quad t_{msbwf} = 0.017\,m$ $\quad$ Min Standard Wall Thickness Without Negative Fabrication Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{msbwf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_y \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{msbwf}}{OD}$$

$b := -P_{el}$ $\quad c_1 := -\left(P_p^{\,2} + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{msbwf}}\right)$ $\quad d := P_{el} \cdot P_p^{\,2}$

$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right)$ $\quad v := \frac{1}{2} \cdot \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right)$ $\quad \phi := acos\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$

$y := -2 . \sqrt{-u} \cdot cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$

$P_{colb} := y - \frac{b}{3}$

$P_{cc\_instb} := P_{colb} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.inst}\right)$

$P_{Cinstb} := if\left[\left(P_{cc\_instb} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right]$ $\quad P_{Cinstb} = \text{"No Collapse"}$

Collapse with Bend Effect for Operation

$t_{msbwf} := t_{msb} \cdot \left(1 - t_{fab}\right)$ $\quad t_{msbwf} = 0.017\,m$ $\quad$ Min Standard Wall Thickness Without Negative Fabrication

Tolerance

$$P_{el} := \frac{2 \cdot E \cdot \left(\frac{t_{msbwf}}{OD}\right)^3}{1 - \nu^2}$$

$$P_p := f_{yop} \cdot \alpha_{fab} \cdot \frac{2 \cdot t_{msbwf}}{OD}$$

$$b := -P_{el} \qquad c_1 := -\left(P_p{}^2 + P_p \cdot P_{el} \cdot O_o \cdot \frac{OD}{t_{msbwf}}\right) \qquad d := P_{el} \cdot P_p{}^2$$

$$u := \frac{1}{3} \cdot \left(\frac{-1}{3} . b^2 + c_1\right) \qquad v := \frac{1}{2} . \left(\frac{2}{27} . b^3 - \frac{b.c}{3} + d\right) \qquad \phi := \mathrm{acos}\left[\frac{-v}{\left(\sqrt{-u^3}\right)}\right]$$

$$y := -2 . \sqrt{-u} \cdot \cos\left(\frac{\phi}{3} + \frac{\pi}{3}\right)$$

$$P_{colb} := y - \frac{b}{3}$$

$$P_{cc\_opb} := P_{col} - \left(P_{e\_max} - P_{min}\right) \cdot \left(\gamma_{mD} \cdot \gamma_{sc.LB.op}\right)$$

$$P_{Copb} := \mathrm{if}\left[\left(P_{cc\_opb} > 0\right), \text{"No Collapse"}, \text{"Collapse"}\right] \qquad P_{Copb} = \text{"No Collapse"}$$

Aramis BB4A (Shell-K14FA2-Store)

Subsea Control Umbilical Specification and Datasheet

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01	31-05-2024	Issued For Review	[redacted]		

REVISION HISTORY

CHANGE/HOLD HISTORY

Rev#	Reason for Hold / Change
01	HOLD 1, Section 2.4 & 2.12: Length of umbilical pigtails at platform.
01	HOLD 2, Section 2.6 & Appendix 1: hydraulic control fluid type.
01	HOLD 3, Section 2.13: Internal diameter of J-tube.
01	HOLD 4, Section 2.16: Requirement and length of spare umbilical to be confirmed.
01	HOLD 5, Section 3.1 & 5: Stand-alone CP requirement for SUTA.
01	HOLD 6, Section 4: Method of fixing TUTA to platform.
01	HOLD 7, Section 4: Zone rating of TUTA location.
01	HOLD 8, Section 4: JB rating.
01	HOLD 9, Appendix 1: Storage temperature
01	HOLD 10: Hydraulic hose size, to be confirmed by CONTRACTOR hydraulic analysis.

SUMMARY/ABSTRACT

This document details the specification for the Aramis Subsea Control Umbilical and appurtenances, Subsea Umbilical Termination Assembly and Topsides Umbilical Termination Assembly.

Contents

ABBREVIATIONS:

API	American Petroleum Institute
BLIV	Battery Limit Isolation Valve
CCS	Carbon Capture and Storage
CC(U)S	Carbon Capture, Utilization and Storage
CO_2	Carbon Dioxide
CP	Cathodic Protection
CR	Conductor Resistance
DWP	Design Working Pressure
EFAT	Extended Factory Acceptance Test
FAT	Factory Acceptance Test
FEED	Front End Engineering Design
IR	Insulation Resistance
ISO	International Organization for Standards
JIC	Joint Industry Committee
LP	Low Pressure [hydraulics]
LVDT	Linear Variable Differential Transformer
MSV	Multipurpose Support Vessel
MTO	Material Take-Off
OBS	Ocean bottom seismometers
OD	Outer Diameter
OPEX	Operating Expenditure
P&ID	Piping and Instrumentation Diagram
PACO	Process Automation Control & Optimization
SUTA	Subsea Umbilical Termination Assembly
SUTAMB	Subsea Umbilical Termination Assembly Mounting Base
TDR	Time Domain Reflectometry
TTE	Total Energies
TUTA	Topsides Umbilical Termination Assembly

1. INTRODUCTION

1.1. Document Purpose

This specification defines the minimum technical and functional requirements for the manufacture, testing and supply of the Subsea Control Umbilical and associated equipment. The Subsea Control Umbilical shall meet all requirements of ISO 13628-5 and additional specifications herein.

All parameters and values are subject to CONTRACTOR's detail design. CONTRACTOR is encouraged to propose alternative designs where there are cost and/or technical benefits to COMPANY, however, this specification shall form the base case for tendering purposes.

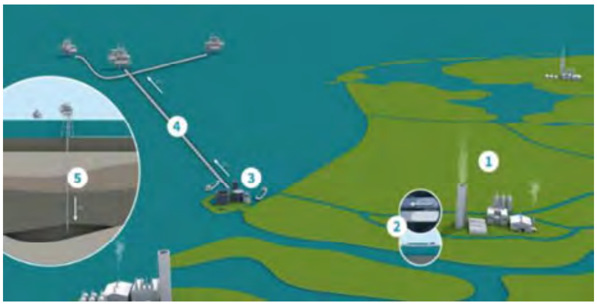
1.2. Scope

This document applies to the Aramis Project Offshore scope BB4A Subsea Control Umbilical, umbilical appurtenances, Topsides Umbilical Termination Assembly (TUTA) and Subsea Umbilical Termination Assembly (SUTA).

1.3. Aramis Project Background

The Aramis carbon capture and storage (CCS) project is incorporating, from the onset, a cross-border approach, providing a decarbonisation solution for North-West Europe. Aramis is developing a technical concept of CCS to contribute to the decarbonisation of industrial areas of The Netherlands, Belgium, France and Germany. Aramis is also seeking synergies with Porthos, another ongoing CCS project in The Netherlands, to form a fully integrated CC(U)S model in The Netherlands for these industrial clusters. The scope of the Aramis CCS project, contains the following transport and storage elements:

- Shipping by barges or coasters for customers not connected to the terminal by pipeline
- New shipping terminal at the Maasvlakte to be built and operated by CO2nnect, receiving liquid (cryogenic) CO_2 from different industrial clusters located in the Northwest Europe region. The terminal will have temporary storage capacity.
- Compressor station for gas phase (vapour) CO_2 volumes coming by Porthos onshore pipeline from Rotterdam and its hinterlands
- Trunkline to transport dense phase CO_2 over ~200km to the offshore platforms / blocks, with over capacity and potential tie-in points to cater for future growth.
- Offshore Storage in K14 (Shell) and K6/L4 (Total Energies) and in future other fields is expected.



1. CO_2 capture
2. CO_2 transport
3. CO_2 collection hub
4. CO_2 offshore pipeline
5. CO_2 storage

Figure 1.3.1: Aramis Overview

The key value drivers (and targets) for the Aramis project are:

- Meet SDE++ timeline – first CO_2 in store latest end 2028
- System availability > 95% (from emitter to store)
- No early life failures –flawless start-up of the chain
- Lifecycle costs / OPEX: Make sure the running costs are as low as possible (note that lifecycle costs include 'Growth')
- Build reputation - public acceptance (incl. safety)
- Enable future growth and open access (volumes, stores)
- Successful and early transfer of liability after end of injection

K14 and L4 from Shell and Total respectively are the two stores of the Launch phase of the Aramis project. The transport system (compressor, terminal and trunkline) will be open access while stores will be in competition. The Aramis project consists of the several building blocks. Following the CO_2 flow from the onshore terminal to the stores, Shell and TTE, it flows via the following building blocks:

- BB1 - Onshore terminal
- BB2 - Onshore compression
- BB3 - CO_2 trunkline from Rotterdam Maasvlakte to the offshore K&L blocks ending in a Distribution Hub platform
- BB4a - Shell store (K14FA field) – The Facility scope of BB4a is subject of this document
- BB4b - TTE store (Total Energies)

Following the flow of CO_2 from the trunkline towards the reservoir the high level elements of K14FA2 project are:

- Subsea manifold with automated battery limit isolation valve (BLIV), including the connection to the trunkline
- Spurline and umbilical connecting manifold with the CO_2 injection platform
- New normally unmanned wellhead platform; topsides and jacket
- Interface scope between wells and the facilities
- Installation of the OBS (ocean bottom seismometers) and connection to the PACO systems on the platform

A schematic overview of the system is shown below:

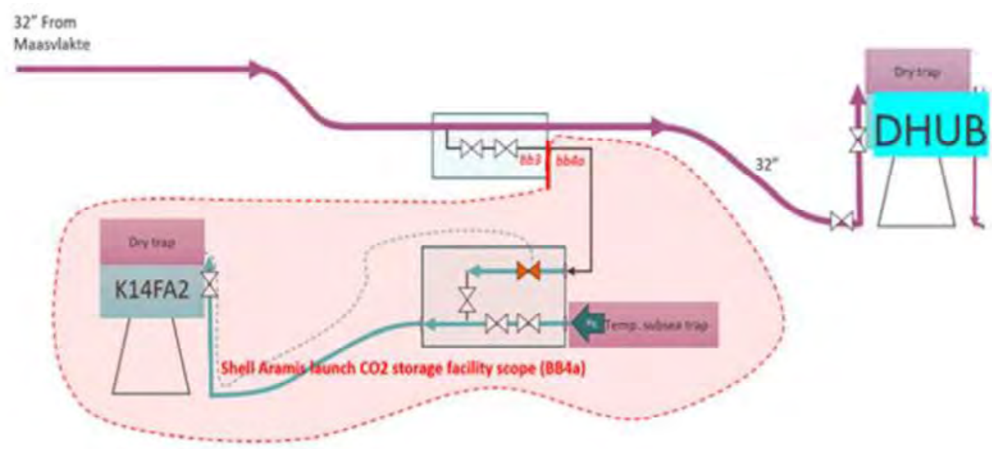


Figure 1.3.2: schematic overview Aramis Launch Shell storage scope (inside dotted red line)

2. UMBILICAL FUNCTIONAL REQUIREMENTS

2.1. Subsea Control Umbilical Overview

The Aramis Subsea Control Umbilical (hereinafter 'umbilical') shall provide the means to transmit hydraulic control fluid and communications to the subsea hydraulically actuated valves and instrumentation that are located at the spurline subsea manifold, located approximately 1,000m from the platform. A direct hydraulic system, utilising 4-20mA instrument loops, will be employed to achieve the control requirements.

The valves and instruments requiring control and monitoring may be summarised as:

- 16" manifold header valve;
- 3" header bypass valve;
- 16" header valve position indicator (LVDT type);
- 3" bypass valve position indicator (LVDT type);
- Process pressure transmitters, upstream and downstream of the header isolation valves;
- Process temperature transmitters, upstream and downstream of the header isolation valves.

Reference may be made to the Process Engineering Flow Scheme (ref. 1) and preliminary (FEED) General Arrangement drawing (ref. 5) for the Subsea Manifold for details of the application of the manifold valves and instruments.

The umbilical will be routed directly from the new wellhead platform to the subsea manifold. At the platform end it will be pulled through a dedicated J-tube where the umbilical function lines will be broken out and terminated at a TUTA. The SUTA and TUTA form part of the umbilical scope of supply and are the battery limits for the scope of this umbilical specification.

2.2. Installation Methodology

It is envisaged that the umbilical will be installed from an MSV.

The pull-in head will be deployed from the vessel and pulled into a J-tube mounted on the wellhead platform by means of a winch and pre-installed messenger wire. The umbilical hang-off flange will be installed, the pull head removed and test equipment connected to the umbilical cores. The umbilical will then be laid away from the platform towards the manifold.

A simultaneous lay and trench procedure may be adopted or the umbilical may be trenched as a separate operation. The cores of the umbilical will be continuously monitored throughout the laying and trenching operations. Any exposed lengths of umbilical shall be protected with concrete mattresses.

At the manifold, the second end of the umbilical, complete with the Subsea Umbilical Termination Assembly (SUTA), will be laid down in a target area close to the manifold structure. The section of umbilical close to manifold will be laid in an 'S', 'C' or similar configuration in order to take-up any excess umbilical length and to allow the SUTA to be pulled-in, by divers, to a pre-installed mounting base on the manifold.

2.3. General Requirements

The umbilical shall be manufactured, tested and delivered in accordance with ISO 13628-5 (Ref. 9).

The umbilical shall be manufactured, tested and delivered as one continuous length with no post lay-up splices.

The subsea control umbilical shall satisfy the following general requirements:-

- All subsea equipment shall be designed upon the principle of zero maintenance;

- The CONTRACTOR shall ensure that any subsea cathodic protection (CP) system is in alignment with the overall field CP system;
- All equipment shall be suitable for the environment in which it is to be used. The umbilical shall be suitable for installation in a trench as trawling activity is prevalent in the area. The umbilical shall also be suitable for use with concrete mattress protection;
- All equipment shall be designed to operate within the environmental conditions as specified in Section 5 and the Bases of Design (Ref. 2 and 3).

2.4. Length

The overall umbilical (and spare length) are detailed within the MTO (Ref. 4). The umbilical length is from the underside of the hang-off flange to the face of the subsea termination flange and is subject to confirmation by CONTRACTOR's detail design and installation analysis.

The lengths of the cable and hose pigtails at the platform end of the umbilical shall be a minimum of 5m [HOLD 1].

Umbilical lengths required for any specific qualification testing to be undertaken are not included in the MTO and are to be provided separately.

2.5. Cross Section Requirements

The cross section requirements (quantity, type and rating for each core) are detailed within Sections 2.6 and 2.7 and the Umbilical Data Sheet (APPENDIX 1). The umbilical data given within the data sheet are the minimum requirements for the development, including a minimum number of spares. Cross section requirements shall be finalised by CONTRACTOR in detailed design.

The umbilical cross section shall be designed with the minimum possible Outer Diameter (OD) without compromising protection or increasing bend stiffness.

2.6. Hydraulic Lines

The hydraulic lines shall be formed of thermoplastic hoses. The hose liners shall be fully compatible with the selected control system fluid.

The control umbilical shall include the following hydraulic lines:

Duty	Qty	Nominal Bore* (inch)	Working / Fill Fluid	DWP (PSI)
LP Hydraulic Fluid Supply	2	½ [Hold 10]	Oil based control fluid [HOLD 2]	5,000
Spare Hydraulic	1			

*Sized to be confirmed by hydraulic analysis, by CONTRACTOR, during detailed design.

Table 2-1: Umbilical Hydraulic Functions

The minimum bend radius for the hydraulic tubes shall not be exceeded during any stage of the manufacturing process.

Prior to shipment all lines shall be flushed and filled with the specified hydraulic control fluid (supplied by CONTRACTOR) and flushed clean to SAE AS4059 6B-F.

The proposed methods of flushing and measuring cleanliness are to be submitted to COMPANY for approval.

2.7. Electrical Cables

Each electrical conductor shall be fabricated from highly conductive copper wire and shall comply with the relevant conductivity and material requirements of IEC 60228, IEC 60502-1, and ISO 13628-5.

Electrical conductors, insulation and cable elements shall be manufactured as continuous lengths without any requirement for factory splices.

The control umbilical shall include the following electrical cables:

Duty	Type	Qty	Rating (kV)	Service
Signal Pair	2.5mm² Twisted Screened Pair	6	0.6 / 1 (1.2)	LVDT position sensors and process instruments. One pair per instrument.
Spare Signal Pair		3		

Table 2-2: Umbilical Electrical Functions

2.8. Umbilical Armour

The umbilical shall resist all crushing and tensile loads due to service and installation conditions. The thermoplastic hoses and electrical cores shall be isolated from significant tensile loads. Suitable protection and tensile capacity may be provided by armouring with two layers of contra-helically wound galvanised steel wire over an internal layer of extruded thermoplastic sheath. The CONTRACTOR shall confirm during the detailed design stage that the umbilical shall have sufficient tensile strength for a 15-tonne pull-in at the platform and manifold and state the actual maximum capacity.

2.9. Oversheath

The umbilical shall be over-sheathed with an extruded layer of thermoplastic material. The use of pp-yarn roving is not permitted to any material layer.

2.10. On Bottom Stability

The umbilical shall have sufficient submerged weight to ensure on bottom stability during installation and operation. The use of lead (Pb), in any form, is not acceptable to achieve on bottom stability. Calculations for on bottom stability are to be submitted to COMPANY for approval.

2.11. Subsea Termination with Bend Limiter

The umbilical shall terminate at the subsea end with a SUTA (see Section 3). The SUTA will be integrated with the umbilical at the CONTRACTOR's works.

The structural interface between umbilical and SUTA shall be a flange. The umbilical flange shall be provided with a suitable bend limiter and tensile loads shall pass directly from the umbilical armour into the flange. The flange shall have a tensile capacity of at least that of the umbilical.

2.12. Topsides Termination and Hang-off Flange

The umbilical shall terminate at the topside end with a hang-off collar connected to the umbilical armouring or tensile members. The hang-off collar shall be rated to a capacity equal to that of the umbilical and shall be provided with a profile which allows simultaneous connection of the pull-in head and hang-off flange. The electrical cable and hydraulic hoses shall extend as 'pigtails' from the hang-off flange. A pigtail length of 5 metres [HOLD 1] shall be assumed for hoses and cables.

Hose pigtails shall be terminated with female swivel connections of 316 stainless steel. The pigtails shall be capped to retain internal pressure and to prevent the ingress of seawater during umbilical installation. Means of safely bleeding down any trapped pressure within the umbilical cores prior to cap removal shall be provided.

Cable pigtails shall be water blocked to prevent the ingress of seawater during umbilical installation.

After pull-in of the umbilical, the hang-off flange will be fitted to secure the umbilical to the top flange of the J-tube. The hang-off flange may be of split flange design. It shall have a load rating equal to that the umbilical. The dimensions of the J-tube flange will be confirmed during CONTRACTOR's detail design. A bolting set for securing the hang-off flange to the J-tube shall be supplied by CONTRACTOR. The hang-off flange shall be provided with a plugged port to enable periodic dosing of the J-tube with corrosion inhibitors or biocide.

The hang-off collar, hang-off flange and securing fixings shall be manufactured from 316 stainless steel. A means of ensuring electrical continuity between hang-off collar, hang-off flange and J-tube shall be provided by CONTRACTOR.

2.13. Pull-in Head

A pull-in head shall be supplied to facilitate installation of the umbilical at the platform. The pull-in head assembly shall:

- Be compact and streamlined to minimise the risk of snagging during installation;
- Be provided with a swivel with a suitable connection point for the pull-in cable;
- Provide mechanical protection during umbilical pull-in for the electrical cable and hydraulic hoses extending from the hang-off flange;
- Be capable of pulling the umbilical through the platform 'J'-tube. An internal diameter of [HOLD 3] mm and minimum bend radius of 5m shall be assumed for the J tube, to be confirmed during CONTRACTOR's detail design;
- Be removable without the use of power tools;
- Be rated to a tensile capacity equal to that of the umbilical.

2.14. J-Tube Seal

A sealing device shall be provided to seal the annular space between the umbilical and the J-tube at its lower end. This shall prevent the passage of seawater into the annular space or the passage of fluids from the annular space to the sea.

It is preferred that the seal be self-locating when the umbilical is installed as it is pulled into the J-tube. If this is not possible and diver assistance is required, then this should be clearly stated.

2.15. Sheath Repair Kit

A kit suitable for performing repairs on localised outer sheath damage during installation shall be provided. The kit shall include several sections of material sufficient to repair 5-metres of damaged outer sheath. Zip-lock heat-shrink sleeves, or similar, are suitable materials. Self-amalgamating tape is not acceptable.

2.16. Umbilical Repair Kit

A control umbilical splice kit shall be provided to support an umbilical splice during the control umbilical installation in the event of an umbilical failure.

A kit shall be provided to effect a repair of all elements comprising the umbilical section (including cores, armouring and outer sheathing, but not including filler pieces) either during installation or post installation.

The repair kit shall comprise –

- Two cylindrical 'field splice' units capable of containing and protecting all spliced elements of the umbilical. If the umbilical suffers localised damage during installation it is intended that one field splice kit be utilised. If a repair of the umbilical is required after installation, two field splice kits will be utilised with a length of spare umbilical between the two kits.
- To facilitate post installation repairs, a 50-metre [HOLD 4] length of spare umbilical shall be provided. This shall be provided on a steel storage drum, tested, packed and with suitable for lifting offshore.

Any proposed field splices shall be as compact as practically possible and of a sufficiently short length to facilitate ease of handling during installation. Any method proposed to splice the cables and hoses shall be supported by documentation of previous use or qualification testing for the design water depth. The overall time to repair shall be kept as short as practically possible. To this extent no repair shall be allowed if it relies on moulding or curing of resins, unless these activities can take place in parallel with other stages of repair. All repair stages shall take place above water on the repair vessel. As such it is not acceptable to propose methods that include subsea mating of field splices or components.

At this stage the spare umbilical length is mandatory. Alternate methods may be suggested, but they shall not form the base case.

2.17. Umbilical Analyses

The umbilical shall be confirmed as fit for purpose through analyses meeting the Iso 13628-5 (Ref. 9) requirements.

The analyses shall include, but not be limited, to those analyses outlined in this section, and reference shall be made to ISO 13628-5, other industry standards, and best industry practice for all applicable analyses requirements.

2.17.1. Static and Stress Analyses

An analysis of the umbilical shall be performed to predict its behaviour with consideration to pull-in at platform, installation and pull-in at the design water depths using an installation vessel, environmental conditions, and in-service conditions.

2.17.2. Cross Sectional Analysis

A cross sectional analysis shall be completed and results reported in line with ISO 13628-5.

2.17.3. On Bottom Stability

On-Bottom Stability analysis shall be completed and results reported in line with DNV RP F109.

If any section is found un-stable, then all possible mitigating measures/solutions shall be identified for stabilising the umbilical and results reported. The CONTRACTOR shall suitably address the mitigation measure from the identified measures on Company approval.

2.17.4. Hydraulic Analysis

Hydraulic analysis shall be undertaken to determine the optimum umbilical hydraulic hose size. The analysis shall model the hydraulic system from end-to-end (i.e. hydraulic power unit (by others) to the valve actuators (by others)) for the base case hose diameter and two standard sizes (as defined within ISO 13628-5) above and below this size. The optimum diameter shall be determined in consultation with COMPANY with reference to the hydraulic analysis findings.

2.18. Testing Requirements

Each umbilical and umbilical ancillary equipment shall be fully tested in accordance with ISO 13628-5 requirements.

Formal test procedures shall be prepared with acceptance criteria for all qualification testing, verification testing, and acceptance testing (FAT and EFAT).

A full test schedule shall be prepared as part of the Quality Plan (QP) and Inspection Test Plan (ITP).

All component (piece/part) designs shall be qualified to the appropriate environmental requirements prior to manufacture. Formal test procedures shall be used, in accordance with accepted industry practices, for the validation of each component prior to final lay-up. All intermediate testing shall comply with ISO 13628-5. If qualification is required, it shall be treated as a separate programme and shall have its own Quality Plan and report.

2.18.1. Umbilical Qualification

Test records from previously performed qualification testing on each and every component shall be provided.

Additional qualification testing and/or validation shall be applied to any new component, prototype component, new design, new technology, or any umbilical and/or component that is of new technology or high risk.

Qualification verification shall be performed prior to the manufacture of any umbilical.

2.18.2. Umbilical Verification

Prior to umbilical lay-up, all individual cores (i.e., components within the completed umbilical) shall be tested in accordance ISO 13628-5 Annex B. Each core shall be fully tested prior to bundling within the complete umbilical.

Additionally, the completed umbilical length shall be verified with respect to any specified design requirement and/or predicted umbilical parameters.

2.18.3. Factory Acceptance Testing

A Factory Acceptance Test (FAT) shall be performed prior to integration with the SUTA. The FAT shall include the following tests:

- Visual Inspection;
- Electrical Conductor Testing;
  - Conductor resistance
  - Insulation resistance between conductors and conductors and shielding
  - Loop resistance
  - Inductance characteristics
  - Capacitance characteristics
  - Attenuation characteristics
  - Characteristic impedance
  - Cross talk
  - Time-domain reflectometry (TDR)
- Hydraulic Acceptance Testing;
  - Hydrostatic pressure test
  - Fluid cleanliness
  - Flow rate

Failure to pass any of the tests above shall be cause for rejection, rework or replacement at the discretion of COMPANY.

2.18.4. Extended Factory Acceptance Test

An Extended Factory Acceptance Test (EFAT) shall be performed on the completed umbilical system including the SUTA. The EFAT shall include:

- Conductor resistance;
- Insulation resistance between conductors and conductors and shielding;
- Loop resistance;
- Positive fluid continuity verification;
- Hydrostatic pressure testing to a minimum of 1.1 times the DWP.

2.18.5. Load Out Testing

Pre-load-out testing shall be conducted if the umbilical has been stored for a period greater than three months as per ISO 13628-5.

Hydraulic line testing shall be performed by monitoring the retained pressure of each line during the course of the load-out.

Electrical IR and CR tests shall be performed pre-load and post load out.

Tests shall be witnessed and signed-off by Umbilical CONTRACTOR and Installation CONTRACTOR.

3. SUTA AND SUTA MOUNTING BASE FUNCTIONAL REQUIREMENTS

3.1. General Requirements

The SUTA provides a subsea termination point for the control umbilical. It will be pulled-in and located on a dedicated mounting base on the subsea manifold. The SUTA shall be able to pulled-in and fastened in its final resting position in any orientation.

Connection points, in the form of electrical connectors and hydraulic couplings, shall be provided for all umbilical cores, as identified in Table 2-1 and Table 2-2 within Sections 2.6.

The SUTA shall be provided with sufficient lifting points and a pull-in eye to allow the SUTA and umbilical to be deployed to the seabed and pulled-in to its final location on the manifold. Suitable slings shall be provided to facilitate shop / test site and offshore handling.

The SUTA may be of a steel construction with a suitable coating to provide protection in a subsea marine environment.

Post pull-in to the manifold structure, the SUTA shall be tied-in to the manifold cathodic protection system by means of an earth strap (to be supplied with the SUTA). There may be a significant interval between deployment of the SUTA and umbilical and final pull-in to the manifold. The SUTA shall therefore be provided with a stand-alone cathodic protection system capable of protecting the unit for a minimum period of six (6) months [HOLD 5]. Additionally, all umbilical line connections shall be provided with suitable long-term protection covers and caps.

The SUTA and SUTA Mounting Base shall be designed and tested in accordance with API STD 17F: 2017 (4th Edition). Note also that the SUTA shall be subject to an EFAT once integrated with the umbilical, refer to Section 2.18.4 of this specification.

3.2. Hydraulic Connections

Each hydraulic core shall terminate in a self-sealing pressure retaining hydraulic coupling. The couplings shall be configured such that the seals are contained in the retrievable (jumper) half of the connection.

The hydraulic couplings shall be provided with long term sealing caps such that pressure testing of the umbilical cores may be performed throughout the deployment and installation process.

All couplings shall incorporate a visual means of identification suitable for recognition by diver.

If tubing is required within the SUTA it shall be by welded connections only.

3.3. Electrical Connections

Each incoming signal line shall be terminated in a 'Controlled Environment' conductive type electrical connector. The controlled environment half of connections (ie the half containing sockets) shall be mounted on the umbilical and utilised for the SUTA outlets.

Each output electrical connector shall be provided with a long-term cap. The contacts of the electrical caps shall be interconnected to allow loop resistance testing of the umbilical cores to be performed throughout the deployment and installation process.

All connections shall incorporate a visual means of identification suitable for recognition by diver.

3.4. Umbilical Interface

The umbilical will be provided with a termination flange and bend restrictor (supplied by CONTRACTOR), reference Section 2.11, to which the SUTA shall be permanently attached.

Hydraulic couplings and electrical connectors shall be configured to interface with each umbilical core.

The primary seal of the hydraulic hose connections to the SUTA piping/couplings will be by suitable means. Means, such as lock nuts shall be used to ensure that the swivel nut cannot become loose in operation due to torsional inputs, hydraulic cycling etc.

3.5. SUTA Mounting Base

The SUTA Mounting Base (SUTAMB) shall be permanently affixed to the manifold structure by means of threaded fixings. It shall provide a means of supporting the SUTA and provide a reaction point and guidance for pull-in of the umbilical. A pull-in load of 15 Tonnes shall be allowed for in the design.

The SUTAMB shall be provided with parking positions for each subsea flying lead that is to be permanently connected. This will be suitable for long-term storage of interfacing hydraulic and electrical flying leads. The parking positions shall be provided with protective caps to prohibit marine growth when they are unused.

The SUTAMB shall be electrically earthed to the manifold structure by means of an earth strap (provided by CONTRACTOR) such that it is tied-in to the cathodic protection system of the manifold. The SUTA shall be provided with an earth point and earth strap to connect the SUTA to the SUTAMB, and hence the cathodic protection system of the manifold structure, after final pull-in. The SUTA stand-alone cathodic protection system shall be compatible with that of the manifold structure.

4. TUTA FUNCTIONAL REQUIREMENTS

The TUTA provides the interface between the platform-supplied subsea services and the umbilical. The TUTA shall be fabricated in 316 stainless steel or carbon steel painted to a suitable offshore specification. Hydraulic components and junction boxes shall be manufactured from 316 stainless steel.

The TUTA will be mounted on the platform adjacent to the control umbilical hang-off point at the top of the J-tube. Mounting points shall be provided to allow the TUTA to be floor mounted by using threaded fasteners [HOLD 6].

The TUTA shall be suitable for installation in a Zone 1, Gas Group IIB, Temperature class T3 Hazardous Area as defined by IEC 60079 [HOLD 7].

The electrical junction boxes and hydraulic valves shall be lockable. Should a housing cabinet be used it shall be fitted with louvres or other means of complying with the required hazardous area rating.

The junction boxe(s) shall be protection type 'ib' [HOLD 8] and have IP56 ingress protection to IEC 60529 as a minimum and be provided with undrilled gland plates for side or bottom entry. Top entry is not permitted.

Junction boxes shall be provided with an IS earth bar and 100% spare terminals. Earthing shall be to be in accordance with in accordance with the Electrical Systems Design Philosophy (Ref. 7).

All umbilical hydraulic lines, including the spare line, shall be provided with double block and bleed valves. Each line shall have a return leg to enable the ability to vent each umbilical core back into the platform drains system. Each bleed is to be routed to a tundish for connection into the open drains system. Each function line shall incorporate a 63mm diameter (minimum) pressure gauge downstream of the double block and bleed arrangement.

The block valves on the spare line shall be fitted with a capped –8 JIC male connection. The caps shall have bleed holes in the nuts to indicate the presence of any contained pressure during initial slackening, or other means of verifying that no contained pressure exists prior to disengagement.

The block valves shall interface with the female cone and nut type umbilical hose terminations and be provided with the platform standard compression fittings for connection to the platform tubing/pipework.

The TUTA shall be designed and tested in accordance with API STD 17F: 2017 (4^{th} Edition).

5. SYSTEM PARAMETERS

The following system parameters shall apply for the design of the umbilical, umbilical appurtenances, SUTA and TUTA.

Parameter	Requirement
Design Life	30 years, including 6 months wet storage [HOLD 5]
Rated design and operating temperature	Refer to Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis [Ref. 2] for umbilical and SUTA. Refer to Topsides Basis of Design [Ref. 3] for TUTA.
Maximum water depth	30 m
Design water depth	35m
Storage temperature	Any and all temperature extremes (minimum to maximum temperature) from umbilical manufacture to final umbilical installation. To be confirmed by CONTRACTOR.
Accidental loads	Snag: None. Impact: TBC in detailed design. Crush: TBC by the installation contractor

Table 5-1: System Design Parameters

6. TEST AND INSTALLATION EQUIPMENT

CONTRACTOR shall make available all test equipment to enable completion of all onshore and offshore testing and installation activities for the umbilical (and SUTA). This shall include:

- Test hydraulic couplings;
- Test electrical connectors;
- Handling/ shipping equipment (e.g. slings, spreader bars, reel etc);
- Test hydraulic power unit, suitable for offshore use.

7. REFERENCES

7.1. Project Documents

Reference shall be made to the latest revision of the following project documents.

1	ARS-200-BB4A-K14FA2-10-PX-2365-0001-001	Process Engineering Flow Scheme, CO2 Pipeline Subsea Manifold,
2	ARS-200-BB4A-K14FA2-10-LA-7704-0002	Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis
3	ARS-200-BB4A-K14FA2-40-CS-7704-0002	Topsides Basis of Design
4	ARS-200-BB4A-K14FA2-10-LA-3309-0003	Subsea Control System MTO
5	ARS-200-BB4A-K14FA2-10-LA-4018-0002 - 001/005	Subsea Manifold General Arrangement Drawing, Sheets 1 to 5
6	ARS-200-BB4A-K14FA2-10-LA-7771-0004	Subsea Flying Lead Specification
7	ARS-200-BB4A-K14FA2-00-EA-5507-0001	Electrical Systems Design Philosophy

7.2. International Codes and Standards

8	ISO 13628-1: 2005	Design and operation of subsea production systems. Part 1: General requirements and recommendations
9	ISO 13628-5: 2009	Design and operation of subsea production systems. Part 5: Subsea umbilicals
10	API STD 17F-2017 (4th Edition)	Standard for Subsea Production Control Systems

APPENDIX 1. UMBILICAL DATA SHEET

ARAMIS UMBILICAL DATA SHEET	
GENERAL	
Umbilical Design Specifications	ISO 13628-1:2005 ISO 13628-5:2009
Umbilical Design Life	30 years service life including 6 months wet storage
Umbilical Design Depth	Refer to Subsea Basis of Design (Ref. 2)
Operating Temperature	Refer to Subsea Basis of Design (Ref. 2)
Storage Temperature	-20ºC to +40 ºC [HOLD 9]
Sea Surface Temperature	Refer to Subsea Basis of Design (Ref. 2)
Sea Bed Temperature	Refer to Subsea Basis of Design (Ref. 2)
Metocean Data	Refer to Subsea Basis of Design (Ref. 2)
Protection Requirements	Trenched and buried, concrete mattress where required.
Hydraulic Fluid	Oil based control fluid [HOLD 2]
Outer Sheathing Colour	TBC by Company during detailed design.
Terminations	Subsea Umbilical Termination Assembly at manifold end. Pull-in head (with pigtails) at platform end, fitted with hang-off collar.
Umbilical Lay Direction	To be advised by Installation Contractor during detailed design.
UMBILICAL LENGTHS	
From hang-off collar to umbilical termination interface.	1,050 m, to be confirmed by Installation Contractor during detailed design.

THERMOPLASTIC HOSES							
Description		**Qty**	**Size (inch)**	**DWP (psi)**	**Min (psi)**	**Fluids**	
						Service	**Test/Ship**
Hydraulic	Duty	2	½ (HOLD 10)	5,000	0	Hydraulic control fluid	Hydraulic control fluid
	Spare	1					
Cleanliness level at delivery			SAE AS 4059E class 6 B-F or better				

ELECTRICAL CABLES		
Description	**Qty**	**Conductor Type**
Duty Pair	6	$2.5mm^2$ Twisted Screened Pair 0.6/1 kV (1.2)
Spare Pair	3	$2.5mm^2$ Twisted Screened Pair 0.6/1 kV (1.2)

TESTING	
Umbilical	FAT per ISO13628-5, with SUTA assembled to umbilical.
Umbilical Type	Full Scale Test as per ISO 13628-5

ARAMIS UMBILICAL DATA SHEET	
Load Out and Installation Testing	Pre-load-out, post load-out and installation monitoring.
ANCILLARY EQUIPMENT	
Subsea Termination with Bend Limiter	Flanged subsea termination with bend limiter required at SUTA termination interface.
Installation Aids	To include items such as slings, spreader bars, reels, and any other temporary tools or fixtures to support the umbilical installation. Details to be determined in consultation with the installation contractor.
J-Tube Seal	Self-locating or diver-installed unit.

Aramis Pipeline Route
Integrated Geophysical Survey Results Report

Managementsamenvatting geofysisch onderzoek

Op instructie van TotalEnergies MV hebben Fugro Discovery, Fugro Seeker en Fugro Searcher een geofysisch onderzoek uitgevoerd langs het tracé van de Aramis-zeeleiding (trunk line). Het algemene routeprogramma is onderverdeeld in de volgende gebieden: geofysisch onderzoek, UXO, 2D-UHRS, EBS en geotechnisch onderzoek.

De gegevens werden verzameld tussen juli 2022 en januari 2023.

Dit rapport geeft informatie over de resultaten van de geofysische onderzoeken die zijn uitgevoerd boven de Aramis-route.

Sectie 2 van het rapport geeft informatie over mobilisatie, werkzaamheden, methodologie en interpretatie van gegevens. Secties 3 en 4 geven een overzicht van de omstandigheden op de zeebodem en onder de zeebodem. Gedetailleerde resultaten en beschrijvingen voor elk deel van de route vindt u in de secties 5 tot en met 14.

Locatieonderzoek Aramis-trunklijn		
Onderzoeksdata	Geofysisch	Juli 2022 tot januari 2023
Uitrusting	Geofysisch	Multibeam echolood (MBES), side scan sonar (SSS), enkelvoudige magnetometer (MAG), sub-bottom profiler (SBP), 2D-UHRS.
	UXO	Dicht bij de kust: Miniwing (2 x G882 MAG) Offshore: dubbele Katria Scanfish magnetometer array, (8 x G882 MAG)
Coördinatensysteem		ETRS89 / UTM zone 31N
Bathymetrie		
De algemene waterdiepte varieert tussen 0 m en 39,5 m langs het traject van de Aramis-trunklijn.		
Morfologie van de zeebodem		
De volgende morfologische kenmerken werden geïdentificeerd: bedvormen (rimpelingen, megarippels en zandgolven), onregelmatige zeebodem, gebied met talrijke keien, gebied met af en toe keien.		
Sedimenten van de zeebodem		
De interpretatie en classificatie van zeebodemsedimenten was gebaseerd op een combinatie van gegevens van MBES en SSS, waarbij gebruik werd gemaakt van akoestische kenmerken zoals algemeen patroon, ruwheid en reflectiviteit. De interpretatie is herzien aan de hand van de resultaten van geotechnische gegevens. De geïdentificeerde zeebodemsedimenten zijn: (1) kiezelhoudend ZAND, (2) licht kiezelhoudend ZAND, (3) modderig (ziltig) ZAND en (4) ZAND		
Doelen op de zeebodem en potentiële locatiespecifieke gevaren		
Wrakken	4 Wrakken zijn geïdentificeerd en geïnterpreteerd	
Pijpleidingen/kabels	Verschillende pijpleidingen kruisen de route. Sommige pijpleidingen liggen gedeeltelijk bloot en gedeeltelijk begraven, maar de meeste pijpleidingen liggen begraven.	
Puin / vermoedelijk puin	159 sonarcontacten zijn geclassificeerd als puin 517 sonarcontacten zijn geclassificeerd als vermoedelijk puin	
Matrassen	2 Matrassen zijn geclassificeerd in de nabijheid van het Platform L4A	
Keien	3110 keien zijn geïnterpreteerd	
Andere doelen	Er zijn schuurplekken van vistuig en sporen van sleepnetten gevonden	
Magnetische anomalieën.	2745 magnetische anomalieën zijn gevonden	
Gekruiste gecorreleerde contacten	11 SSS-contacten zijn gekruist gecorreleerd met MAG doelen	

Ondergrondse geologische kenmerken	
Begraven kanalen	Interne ondergrondse geulen en geulen aan de basis werden waargenomen in alle units, behalve Unit A. Ingegraven geulen in Unit B werden in kaart gebracht op basis van SBP-gegevens. Deze kanalen bevinden zich vaak aan de bovenkant van de eenheid, zijn NW-ZO georiënteerd en hebben een beperkte omvang. Ze hebben vaak een gelaagde vulling. De basis van Unit B, Unit C en Unit D is plaatselijk gekanaliseerd. De basis van Unit F vormt de diep ingesneden glaciale tunneldalen. Nabij de top van Unit F werden plaatselijk beddingvormige, kanaalachtige reflectoren waargenomen. Deze kenmerken lijken een late fase van de opvulling van deze tunnelvalleien te vertegenwoordigen, die mogelijk in een lacustriene omgeving plaatsvond.
Veen	Hoge negatieve amplitudeanomalieën werden waargenomen in de 2D-UHRS seismische gegevens. Deze gebeurtenissen met een negatieve amplitude vertegenwoordigen waarschijnlijk veen en/of organisch-rijke klei. Er werden veenlagen geïdentificeerd op drie stratigrafische niveaus: ***veenniveau 1*** - behorend bij Unit B, ***veenniveau 2*** - behorend bij Unit C, Unit D en Unit E en ***veenniveau 3*** - behorend bij Unit F en Unit G. Op de SBP-gegevens werden de reflectoren met hoge amplitude, die op veen en/of organische klei kunnen duiden, geassocieerd met eenheid B. Veen komt het meest voor in het noordelijke deel van de route, met uitzondering van 2D-UHR_peat level 3, dat langs de hele route aanwezig is, maar de verspreiding ervan is zeer beperkt.
Ondiep gas	Akoestische blanking kan de aanwezigheid van gas in de bodem aangeven. Het werd plaatselijk in het kustgebied waargenomen. De kleine akoestische blanking of signaalvervorming die onder enkele van de negatieve amplitudeanomalieën werd waargenomen, houdt vermoedelijk verband met de aanwezigheid van veen. De aanwezigheid van met gas/vloeistof gevulde sedimenten kan echter niet volledig worden uitgesloten.
Rotsblokken, keien en grind	In de SBP-gegevens werden een paar diffractiehyperbolen waargenomen. Deze worden geïnterpreteerd als mogelijke rotsblokken, keien en/of grof grind. Er moet opgemerkt worden dat de interpretatie van deze kenmerken speculatief is en dat hyperbolen van diffractie het resultaat kunnen zijn van andere factoren dan de aanwezigheid van rotsblokken, keien of grof grind. Gezien de geologische omgeving (d.w.z. de verwachte aanwezigheid van periglaciale en glaciale sedimenten) kunnen keien en keien worden verwacht langs de Aramis-route. Hun aanwezigheid kan dus niet worden uitgesloten.
Glaciale vervorming	Glaciale vervorming komt typisch tot uiting in seismische gegevens als chaotische interne reflecties, hellende afschuifvlakken, vervormde en geplooide lagen en verstoring van de oorspronkelijke interne structuur. Bewijzen van mogelijke vervorming werden waargenomen in Unit G, vooral in de buurt van glaciale tunneldalen (Unit F). Men denkt dat deze kenmerken verband houden met de Elsteriaanse ijstijd.
Fouten	Breuken werden niet eenduidig geïdentificeerd in de seismische reflectiegegevens. De aanwezigheid van breuken en/of scheuringen kan echter niet worden uitgesloten.
Geologie van de ondergrond	
Unit A	Unit A is over de hele route aanwezig. Het lijkt akoestisch transparant te zijn. Plaatselijk werden hoge amplitude interne puntreflecties of korte reflectoren waargenomen. In de grotere zandgolven werden lokaal zwakke progradatiestructuren waargenomen. De eenheid wordt geïnterpreteerd als afgezet in een open mariene omgeving, als reactie op de mariene transgressie tijdens het Laat-Holoceen, en behoort tot de zuidelijke Bocht Formatie. Bodemtype: Zeer los tot zeer dicht zwak ziltig tot zwak fijn en matig ZAND, plaatselijk zwak zandige KLEI.
Unit B	Unit B is aanwezig in de hele route, behalve in het Maasmondkanaal. De unit heeft een variabel intern seismisch karakter, variërend van semi-transparant tot chaotisch met talrijke discontinue en vaak onder een grote hoek liggende reflecties met middelhoge tot hoge amplitude. Interne kanalen en kanalen aan de basis met verschillende afmetingen werden waargenomen in de unit.

Geologie van de ondergrond	
	De vulling van de geulen is variabel, maar meestal goed gelaagd en met reflectoren met een hoge amplitude. Hoge negatieve amplitudeanomalieën komen vaak voor in deze eenheid, vooral in het noordelijke deel van de route, die mogelijk lagen veen en/of organisch-rijke klei voorstellen. De unit wordt geïnterpreteerd als kust- en getijdenafzettingen uit het vroege Holoceen en behoort mogelijk tot de Naaldwijk Formatie. Plaatselijk kan de eenheid sedimenten van de Formatie van Boxtel bevatten en vooral in het zuidelijke en zuid-centrale deel van de route kan een groot deel van deze eenheid tot de Kreftenheye Formatie behoren. Het onderscheid tussen deze formaties is moeilijk te maken vanwege de vergelijkbare bodemgesteldheid (voornamelijk zand). In het kustgebied liggen afzettingen van de Kreftenheye Formatie onder de basis van de geïnterpreteerde Naaldwijk Formatie. Bodemtype: Matig tot zeer dicht zwak ziltig fijn en matig ZAND, plaatselijk met bedden van zandige KLEI en VEEN.
Unit C	Unit C is aanwezig in het centrale en gedeeltelijk in het noordelijke deel van de route. De unit wordt voor het grootste deel van de route gekarakteriseerd door bedding van seismische facies, bestaande uit parallelle reflectoren. Plaatselijk, in het bovenste deel van de unit, werden structuurloze, semi-transparante intervallen waargenomen. In het noordoostelijke deel van de route wordt de unit gekenmerkt door algemene semi-transparante seismische facies met lokale negatieve reflectoren met hoge amplitude (2D-UHRS) van verschillende omvang. De reflectoren met hoge amplitude kunnen duiden op lagen met lagen veen en/of organische klei. De gelaagde aard van de unit zal naar verwachting correleren met afwisseling van zand en klei en plaatselijke veenbedden. De unit wordt geïnterpreteerd als afgezet in een reeks van kust- (estuariene), getijdenvlakte- of laguneomgevingen en komt overeen met het Brown Bank Lid. Bodemtype: Zeer los tot dicht zeer ziltig fijn en middelfijn ZAND, plaatselijk zandig KLAAR en zandig kleiig SILT.
Unit D	Unit D is over de hele route aanwezig, met uitzondering van een klein deel van de route (ongeveer 15 km) in het centrale deel, en in het meest zuidelijke deel. De unit heeft over het algemeen een structuurloos en semi-transparant akoestisch karakter. Plaatselijk gelaagde intervallen, interne erosieoppervlakken gemarkeerd door sterk hellende reflectoren of die brede kanaalachtige kenmerken vormen. Inwendige begraven kanalen zijn plaatselijk aanwezig. Unit D bestaat naar verwachting voornamelijk uit zand, met zeer plaatselijk klei- of veenafwisselingen, afgezet in omgevingen van open zee en getijden. Men denkt dat de eenheid tot de Eem Formatie behoort. Bodemtype: Los tot zeer dicht zwak ziltig fijn en matig ZAND, af en toe licht grindig.
Unit E	Unit E is alleen aanwezig in het noordelijke deel van de route. Wordt gekenmerkt door akoestisch transparante tot semi-transparante en structuurloze seismische fracties. Unit D zal naar verwachting voornamelijk uit zand bestaan, afgezet in omgevingen van open zee en getijden. Men denkt dat de eenheid behoort tot de Egmond Formatie. Bodemtype: Gemiddeld dicht tot zeer dicht ZAND plaatselijk met bedden van KLEI en ZOUT.

Unit F	Unit F is plaatselijk aanwezig in de noordelijke helft van de route. De unit vormt de opvulling van diep insnijdende U-vormige kanaalachtige kenmerken met steile flanken. Ze snijden in de onderliggende Unit G en bereiken plaatselijk diepten onder de penetratie van de 2D-UHRS gegevens. Dergelijke kenmerken in dit deel van de Noordzee worden beschouwd als glaciale tunneldalen. De unit zal naar verwachting voornamelijk bestaan uit klei met frequente (ziltige) zandbeddingen afgezet in glaciale, glaciofluviale en glaciolacustriene omgevingen. Deze afzettingen worden geïnterpreteerd als behorend tot de Peelo Formatie. Het interne karakter wordt over het algemeen gekenmerkt door semi-transparante tot chaotische seismische facies. Vaak, vooral in het bovenste deel, werden discontinue, onregelmatige en golvende (geplooide?) reflectoren van gemiddelde tot hoge amplitude waargenomen. Bodemtype: Verweven matig dicht tot zeer dicht (ziltig) ZAND en hoogvast tot zeer hoogvast (zandige) KLEI
Geologie van de ondergrond	
Unit G	Unit G is de diepste unit die is waargenomen in de seismische gegevens binnen de diepte van interesse en is aanwezig over het hele traject. De basis van deze unit ligt buiten de penetratiediepte van de 2D-UHRS. Het interne akoestische karakter van de unit is complex, van semi-transparant tot chaotisch, met plaatselijk discontinue reflectoren, interne erosieoppervlakken en verschillende interne kanalen. Deze complexiteit is het gevolg van de aard van de afzettingsomgeving van deze unit (fluviatiel tot deltaïsch) en post-depositionele processen zoals glaciale activiteit, inclusief erosie en mogelijk vervorming. De eenheid bestaat naar verwachting voornamelijk uit zand met af en toe klei- en sliblagen en plaatselijk dunne veenbedden. De eenheid wordt geïnterpreteerd als overeenkomend met de Yarmouth Roads Formatie. Bodemtype: Matig dicht tot zeer dicht ZAND, plaatselijk met lagen hoogvaste tot zeer hoogvaste KLEI of ZILT, plaatselijk gelamineerd

Geophysical Survey Results Report

Aramis Project – Geophysical and Geotechnical Site Investigation

Survey Period: July 2022 – January 2023

F197217-REP-001 | 03 | 8 December 2023

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Project Team

Initials	Name	Role
[redacted]		

Executive Summary

On the instruction of TotalEnergies MV Fugro Discovery, Fugro Seeker and Fugro Searcher performed a geophysical survey along the Aramis trunkline route. The overall route program has been divided into following scopes: geophysical survey, UXO, 2D-UHRS, EBS and geotechnical surveys.

Data acquisition was carried out between July 2022 and January 2023.

This report provides information on the results of the geophysical surveys conducted over the Aramis route.

Section 2 of the report provides information about mobilisation, operations, methodology and data interpretation. Sections 3 and 4 provide overview of the seafloor and sub-seafloor conditions. Detailed results and descriptions for each section of the route are provided in Sections 5 through 14.

Site Investigation Aramis trunkline		
Survey Dates	Geophysical	July 2022 to January 2023
Equipment	Geophysical	Multibeam echo sounder (MBES), side scan sonar (SSS), single magnetometer (MAG), sub-bottom profiler (SBP), 2D-UHRS.
	UXO	Nearshore: Miniwing (2 x G882 MAG) Offshore: dual Katria Scanfish magnetometer array, (8 x G882 MAG)
Coordinate System		ETRS89 / UTM zone 31N
Bathymetry		
The overall water depth varies between 0 m and 39.5 m along the Aramis trunkline route.		
Seafloor Morphology		
The following morphological characteristics were identified: bedforms (ripples, megaripples and sand waves), irregular seafloor, area with numerous boulders, area with occasional boulders.		
Seafloor Sediments		
Seafloor sediment interpretation and classification was based on a combination of data from MBES and SSS, using acoustic characteristics such as overall pattern, roughness and reflectivity. The interpretation has been revised using geotechnical data results. The seafloor sediments identified are: (1) gravelly SAND, (2) slightly gravelly SAND, (3) muddy (silty) SAND and (4) SAND		
Seafloor Targets and Potential Site-Specific Hazards		
Wrecks	4 Wreck have been identified and interpreted	
Pipeline/Cables	Several pipelines are crossing the route. Some pipelines are partially exposed and partially buried, however most of the pipelines are buried.	
Debris / Suspected debris	159 sonar contacts have been classified as debris 517 sonarcontacts have been classified as suspected debris	
Mattresses	2 Mattresses have been classified in proximity of the Platform L4A	
Boulders	3110 boulders have been interpreted	
Other targets	Fishing gears scours, trawl marks have been found	
Magnetic anomalies.	2745 magnetic anomalies have been picked	
Cross correlated contacts	11 SSS contacts have been cross correlated with MAG targets	

Sub-Seafloor Geological Features	
Buried channels	Internal buried channels and channels at the base were observed in all units except Unit A. Buried channels in Unit B were mapped based on SBP data. These channels are often located towards the top of the unit, have NW-SE orientation and limited extent. They often have a layered infill. The base of Unit B, Unit C and Unit D is locally channelised. The base of Unit F forms the deeply incised glacial tunnel valleys. Near the top of Unit F, locally bedded, forming channel-like shape reflectors were observed. These features appear to represent a late stage of the infill of these tunnel valleys that may took place in lacustrine environment.
Peat	High negative amplitude anomalies were observed in the 2D-UHRS seismic data. These negative amplitude events most likely represent peat and/or organic-rich clay. Peat layers were identified at three stratigraphic levels: *peat level 1* – associated with Unit B, *peat level 2* – associated with Unit C, Unit D and Unit E and *peat level 3* – associated with Unit F and Unit G On the SBP data, the high amplitude reflectors that may indicate peat and/or organic clay were associated with Unit B. Peat is most common in the northern part of the route, except 2D-UHR_peat level 3, which is present along the entire route, but its distribution is very limited.
Shallow gas	Acoustic blanking can indicate presence of gas in soil. It was observed locally in the nearshore area. The minor acoustic blanking or signal distortion that was observed below some of the negative amplitude anomalies is thought to be related to the presence of peat. However, the presence of gas/fluid-charged sediments cannot be excluded entirely.
Boulders, cobbles and gravel	A few diffraction hyperbolas were observed in the SBP data and are interpreted to represent possible boulders, cobbles and/or coarse gravel. It should be noted that interpretation of these features is speculative and diffraction hyperbolas may be the result of factors other than the presence of boulders, cobbles or coarse gravel. Given the geological setting (i.e. the expected presence of periglacial and glacial sediments), boulders and cobbles can be expected along the Aramis route. Hence, their presence cannot be ruled out.
Glacial deformation	Glacial deformation is typically expressed in seismic data as chaotic internal reflections, inclined shear planes, deformed and folded strata and disturbance of the original internal structure. Evidence of possible deformation was observed in Unit G, especially in proximity of glacial tunnel valleys (Unit F). These features are thought to be related to the Elsterian glaciation.
Faults	Faults were not unequivocally identified in the seismic reflection data. However, the presence of faults and/or fractures cannot be ruled out.
Sub-Seafloor Geology	
Unit A	Unit A is present across the entire route. It appears to be acoustically transparent. Locally, high amplitude internal point reflections or short reflectors were observed. In the larger sand waves, locally weak progradational structures were observed. The unit is interpreted to be deposited in an open marine environment in response to the marine transgression during the Late Holocene and belongs to the southern Bight Formation. Soil type: Very loose to very dense slightly silty to silty fine and medium SAND, locally slightly sandy CLAY.
Unit B	Unit B is present in the entire route, except in the Maasmond Kanaal. The unit has a variable internal seismic character, ranging from semi-transparent to chaotic with numerous discontinuous and often high-angle medium to high-amplitude reflections. Internal channels and channels at the base with different dimensions were observed in

Sub-Seafloor Geology	
	the unit. The infill of the channels is variable, but typically well-layered and with high-amplitude reflectors. High negative amplitude anomalies are common in this unit, especially in the northern part of the route, which potentially represent layers of peat and/or organic-rich clay. The unit is interpreted to represent early Holocene coastal and tidal deposits, and possibly belonging to the Naaldwijk Formation. Locally the unit may include sediments of Boxtel Formation and especially in the southern and south-central part of the route, a large part of this unit may belong to the Kreftenheye Formation. The differentiation between these formations is difficult due to similar soil conditions (predominantly sand). In the nearshore area, deposits of the Kreftenheye Formation are below the base of the interpreted Naaldwijk Formation. Soil type: Medium to very dense slightly silty fine and medium SAND, locally with beds of sandy CLAY and PEAT.
Unit C	Unit C is present in the central and partially in the northern part of the route. The unit for most of the route is characterised by bedded seismic facies, consisting of parallel reflectors. Locally, in the upper part of the unit, structureless, semi-transparent intervals were observed. In the north-eastern part of the route, the unit is characterised by overall semi-transparent seismic facies with local high amplitude negative (2D-UHRS) reflectors of various extent. The high amplitude reflectors may indicate layers of pockets of peat and/or organic clay. The layered nature of the unit is expected to correlate with sand and clay alternations, and local beds of peat. The unit is interpreted to be deposited in a range of coastal (estuarine), tidal flat or lagoonal environments and corresponds to the Brown Bank Member. Soil type: Very loose to dense very silty fine and medium SAND, locally sandy CLAY and sandy clayey SILT.
Unit D	Unit D is present across the entire route, except small part of the route (approximately 15 km) in the central part, and in the most southern part. The unit has in general a structureless and semi-transparent acoustic character. Locally, layered intervals, internal erosion surfaces marked by strong inclined reflectors or forming broad channel-like features. Internal buried channels are locally present. Unit D is expected to comprise predominantly sand, with very locally clay or peat alternations, deposited in open marine and tidal environments. The unit is thought to belong to the Eem Formation. Soil type: Loose to very dense slightly silty fine and medium SAND, occasionally slightly gravelly.
Unit E	Unit E is present only in the northern part of the route. Is characterised by acoustically transparent to semi-transparent and structureless seismic facies. Unit D is expected to comprise predominantly sand, deposited in open marine and tidal environments. The unit is thought to belong to the Egmond Ground Formation. Soil type: Medium dense to very dense SAND locally with beds of CLAY and SILT.
Unit F	Unit F is present locally in the northern half of the route. The unit forms the infill of deeply incisive U-shaped channel-like features with steep flanks. They cut into the underlying Unit G, reaching locally depths below the penetration of the 2D-UHRS data. Such features in this part of the North Sea are considered as glacial tunnel valleys. The unit is expected to consist of mainly clay with frequent (silty) sand interbeds deposited in glacial, glaciofluvial and glaciolacustrine environments. These deposits are interpreted to belong to the Peelo Formation. The internal character is characterised in general by semi-transparent to chaotic seismic facies. Often, especially in the upper part, discontinuous, irregular, and wavy (folded?) medium to high-amplitude reflectors were observed. Soil type: Interbedded medium dense to very dense (silty) SAND and high strength to very high strength (sandy) CLAY

Sub-Seafloor Geology	
Unit G	Unit G is the deepest unit observed in the seismic data within depth of interest and is present across the entire route. The base of this unit is beyond the penetration depth of the 2D-UHRS. The internal acoustic character of the unit is complex, from semi-transparent to chaotic, with locally discontinuous reflectors, internal erosion surfaces and various internal channels. This complexity results from the nature of the depositional setting of this unit (fluvial to deltaic) and post-depositional processes such as glacial activity, including erosion and possibly deformation. The unit is expected to consist of predominantly sand with occasional clay and silt interbeds, and local thin beds of peat. The unit is interpreted to correspond to the Yarmouth Roads Formation. Soil type: Medium dense to very dense SAND, locally with layers of high strength to very high strength CLAY or SILT, locally laminated

Document Arrangement

Document Title	Description	Client Document No.
F197217-REP-ENV-001	Environmental Desk Top Study	
F197217-REP-MOB-SK	Mobilisation Fugro Seeker	
F197217-REP-MOB-SR	Mobilisation Fugro Searcher	
F197217-REP-MOB-DIS	Mobilisation Fugro Discovery	
F197217-REP-OPS-SEA	Operations Report Fugro Searcher	
F197217-REP-OPS-FD 01	Operations Report Fugro Discovery	
F197217-R-1 01	Field Operations and Preliminary Results Report NMM & K.Orca	
F197217-REP-RES-001	Nearshore Geophysical Survey Report (preliminary results)	
F197217-REP-001	Geophysical Survey Results Report	
F197217-REP-002	Environmental Field Report	
F197217-REP-003	Diversity Observation Report	
F197217-REP-004	EBS (includes Habitat Report)	
F197217-REP-005	eDNA Report	
F197217-REP-006	Measured and Derived Geotechnical Parameters and Final Results Report	

Content

Figures in the Main Text

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Abbreviations

bsb	Below seabed
BS	British Standard
BSF	Below seafloor
CPT	Cone penetration test
CRP	Common reference point
CUBE	Combined Uncertainty and Bathymetric Estimator
DGPS	Differential global positioning system
DTM	Digital Terrain Model
EBS	Environmental baseline survey
EPSG	European Petroleum Survey Group
ETRF	European Terrestrial Reference Frame
ETRS	European Terrestrial Reference System
EVT	Equipment verification test
FF	Fugro Frontier
Fm	Geological formation
FNLM	Fugro Netherlands Marine
FV	Fugro Venturer
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GRS	Geodetic Reference System
GS	Grab sample
HVF	Hips vessel file
IHO	International Hydrographic Organization
ISO	International Hydrographic Organization
ITRF	International Terrestrial Reference Frame
IAC	Inter-array cable
KP	Kilometre post
LAT	Lowest Astronomical Tide
LGM	Last Glacial Maximum
MAG	Magnetometer
MASW	Multichannel analysis of surface waves
Mb	Geological member
MBES	Multibeam echosounder
MSL	Mean Sea Level
MV	Motor vessel
OCR	Offshore client representative
OPS	Operations

OWF	Offshore windfarm
PSD	Particle size distribution
QA	Quality Assurance
QC	Quality control
REP	Report
RPL	Route Position List
SBP	Sub-bottom profiler
SHP	Shapefile
SSS	Side scan sonar
SVP	Sound velocity profile
THU	Total horizontal uncertainty
TPU	Total propagated uncertainty
TVU	Total vertical uncertainty
TWTT	Two-way travel time
UHRS	Ultra high resolution seismic
UKHO	United Kingdom Hydrographic Office
USBL	Ultra-short Baseline
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
UXO	Unexploded ordinance
VC	Vibrocore
VORF	Vertical Offshore Reference Frame
WP	Work package
WTG	Wind turbine generator

1. Introduction

1.1 Project Description

The Carbon Capture and Storage (CCS) Aramis Project is developing CO_2 transport facilities to enable offshore gas storage. Once captured, the CO_2 is collected at the compressor station and shipping terminal at Maasvlakte, a hub in the port of Rotterdam. From this hub, CO_2 is transported to offshore gas fields to be injected into depleted offshore gas field at a depth of approximately 3 km to 4 km below the seafloor.

TotalEnergies contracted Fugro to perform an offshore geophysical, geotechnical and environmental site investigations of the proposed offshore pipeline corridor, running from landfall at the Maasvlakte to offshore Blocks L4/K6. A map of the site investigation location, including the proposed pipeline routes is shown in Figure 1.1.

1.2 Scope of Report

This report provides results of the geophysical survey and interpretation of the proposed 500 m wide pipeline corridors and a 2 km radius offshore distribution hub (Hub Area).

The report includes:

- Multibeam echosounder (MBES) data to provide accurate bathymetry in order to determine water depths, seafloor morphology and seafloor gradient;
- High-resolution side scan sonar (SSS) data to determine seafloor features, possible presence of boulders, seafloor sediments, objects / debris and items that may impact foundation and pipeline installation;
- Magnetometer (MAG) data across the site to determine any metallic objects / debris items;
- High-resolution sub-bottom profiler (SBP) and 2D-UHRS data to determine the sub-seafloor conditions that may influence foundation and pipeline installation such as shallow geology, geological features and geohazards;
- Cone Penetration Tests (CPT) and vibrocore samples (VC) along the pipeline route to ground truth the seismic reflection data and to allow for geotechnical soil characterisation of the interpreted units.

The CCS Aramis trunkline route has been divided into sections (Figure 1.1). Report Sections 3 and 4 provide a general overview of the results and interpretation, while Sections 5 to 14 provide a detailed description of each section of the CCS Aramis trunkline route.

This report is one in a series of reports that are prepared as part of this project and relate to offshore operations, processing, environmental and geotechnical surveys (refer to page 'Document Arrangement').

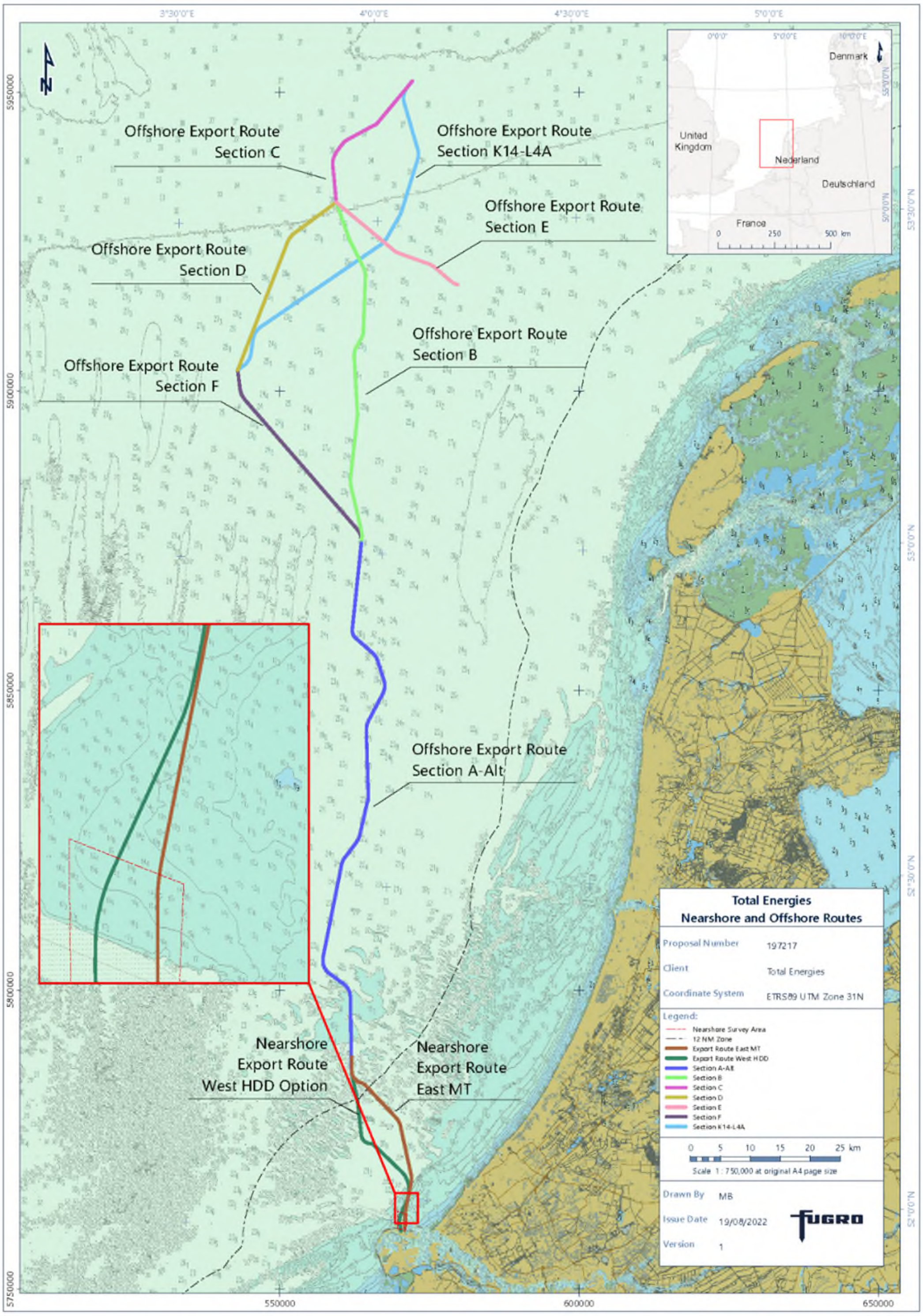


Figure 1.1: Overview of the Aramis trunkline route section divisions.

1.3 Geodesy

The project geodetic and projection parameters are summarised in Table 1.1.

Table 1: Project geodetic 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 = 6 378 137.000 m	
Inverse Flattening:	1/f = 298.257 222 101	
Local Geodetic Datum Parameters		
Datum:	ETRS89	EPSG: 6258
Ellipsoid:	GRS 1980	
Semi major axis:	a = 6 378 137.00 m	
Inverse Flattening:	1/f = 298.257 222 101	
Datum Transformation Parameters from ITRF2014 to ETRS89 (Note 2, Note 3)		
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
Project 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)		

Table 2: Validation calculation

ITRF2014	Test Point [Position]	Computed Point
Latitude	53° 32′ 37.50000″ N	53° 32′ 37.50000″ N
Longitude	004° 16′ 30.00000″ E	004° 16′ 30.00000″ E

ITRF2014	Test Point [Position]	Computed Point
Ellipsoidal height	0.000 m Ell	0.000 m Ell
ETRS89		
Latitude	53° 32′ 37.48043″ N	53° 32′ 37. 48043″ N
Longitude	004° 16′ 29.97086″ E	004° 16′ 29.97086″ E
Ellipsoidal height	-0.023 m Ell	-0.023 m Ell
UTM zone 31N		
Easting	584 484.290 m	584 484.290 m
Northing	5 933 516.515 m	5 933 516.515 m
Chart datum height	-40.248 m	-40.248 m

1.4 Vertical Datum

All vertical data for the survey were reduced to Lowest Astronomical Tide (LAT).

Vertical Datum	
Vertical coordinate reference system	ETRS89 to LAT height using NLLAT2018

2. Mobilisation, Operation and Processing

2.1 Mobilisations

The geophysical survey was carried from 3 July 2022 with the Fugro Seeker to 24 January 2023 when the Fugro Searcher left the project.

Table 3: Summary of events

Event	Dates
Mobilisation of Fugro Seeker	3-12 July 2022
Demobilisation of Fugro Seeker	14-15 October 2022
Mobilisation of Fugro Discovery	8-11 November 2022
Demobilisation of Fugro Discovery	17 December 2022
Mobilisation of Fugro Searcher	7 October 2022
Demobilisation of Fugro Searcher	24 January 2023

Please refer to the single vessel mobilisation reports for details regarding the equipment calibrations performed prior the project (*197217-REP-MOB-SK(04)_Mobilisation Fugro Seeker, F197217-REP-MOB-DIS_R01_Mobilisation Fugro Discovery , 24-197217_FugroSearcher_Mobilisation_Report_Issue_01*)

2.2 Operations, Acquisition and Processing

Refer to table Table 2.2 for an overview of the different scope of work for each vessel.

Table 4: Survey structure

Vessel	Scope of Work
Fugro Seeker	Geophysical Survey, Nearshore Including: MBES, SSS, SBP, MAG, 2D UHRS, seismic refraction and MASW, UXO Survey
Fugro Discovery	Geophysical Survey, Offshore Including: MBES, SSS, SBP, MAG
Fugro Searcher	Geophysical Survey, Offshore Including: MBES, SSS, SBP, MAG, 2D-UHRS, UXO survey and EBS
Kommandor Orca / Normand Mermaid	Geotechnical Survey Including: CPT testing and Vibrocore sampling

2.2.1 Operations – Fugro Seeker

The Seeker conducted a geophysical survey for the Nearshore area with multiple scopes as detailed in Table 2.3.

The objective of the survey was to identify and delineate any possible constraints and hazards from man-made, natural and geological features, which may affect the integrity of the investigation site/development area.

Table 5: Scope of work of Seeker

Area of Operation	No. Lines	Line km	Scope Requirements
Analogue Geophysical Scope	91	141.4	MBES, SSS, SBP and MAG collected on all survey lines.
UXO Scope	225	58.1	UXO - Miniwing
UHRS Scope	41	71.9	2D-UHRS seismic equipment
Refraction Seismic and MASW Scope	32	31.7	150 m refraction and MASW streamer & 90m MASW streamer

Initial Quality Assurance (QA) and processing of data acquired by all sensors was carried out onboard the vessel. Multibeam backscatter (MBBS), multibeam echosounder (MBES), side scan sonar (SSS) and sub-bottom profiler (SBP) data were sent to the Fugro office in Portchester, UK for full quality control (QC), final processing, and interpretation. UHRS data were sent to the Geo Surveys office for full QC, final processing, and interpretation. Refraction Seismic and MASW data were sent to the Fugro France officer for full QC, final processing, and interpretations.

2.2.2 Survey Requirements – Fugro Seeker

Table 6: Survey requirements overview

Equipment Method	Survey Requirements
Vessels	Seeker
Proposed Pipeline Survey Line Spacing	▪ Line spacing varied between blocks A & B: ▪ Block A line spacing was 20 m ▪ Block B line spacing was 40 m. ▪ Crosslines were set along the two potential cable routes with parallel wing lines offset 50 m either side of the main crosslines.
Survey Priority	Where sufficient overlap was not created infill lines were collected;
Target Vessel Speed	4.0 Kts
Surface Positioning	▪ Two independent positioning systems with full quality control amenities ▪ Positioning accuracy ± 2 m
USBL	▪ <10s gaps; ▪ Positioning accuracy ± 2 m;
Multibeam Echosounder	▪ As per Section 4.4 of the Scope of Work and tender deviations ▪ THU < 1.0 m (1.141σ), TVU < 30 cm (1σ) ▪ Acquisition of high-resolution swath bathymetry data within the planned survey area. ▪ Minimum hit count of 16 soundings per 1 m DTM cell size. 200 m^2 of continuous area with <16 soundings per 1 m bin require infill. ▪ 20 % overlap of MBES
Multibeam Backscatter	To be recorded and processed at 0.5 m resolution.

Equipment Method	Survey Requirements
Side Scan Sonar	■ As per Section 4.5 of the Scope of Work. ■ Dual operating frequency fish: minimum 300 kHz (low frequency) & minimum 600 kHz (high frequency). ■ 200 % coverage across the site, 100 % in the SSS nadir ■ Target resolution ≥ 0.5 m with high frequency (HF). ■ Mosaic resolution at 0.1 m
Innomar SBP	■ As per section 4.6 of the Scope of Work. ■ System resolution of up to 0.2 m penetration through unconsolidated sediments to a target depth of up to 10 m depending on water depth, geological and environmental conditions. ■ Output > 8 Kw ■ Beamwidth at 3 dBD ± 1º ■ Primary frequency 85 kHz to 115 kHz ■ Low frequency 2 kHz to 222 kHz ■ Soft start required
Magnetometer	■ As per section 4.7 in the Scope of Work ■ Single magnetometer with high sensitivity (0.01 nT) ■ Positioning known to within ± 2 m
SVP	■ Speed of sound in water measured in the survey area at the start of each day (as a minimum) and whenever deemed necessary (i.e. beginning to have MBES refraction artefact); ■ SVP sensor should have an accuracy of ± 0.05 m/s
2D-UHRS	As per section 4.9 in the Scope of Work.
Refraction Seismic and MASW	■ As per section 4.10 in the Scope of Work ■ 48 hydrophone streamer plus one spare; ■ Source (air gun) and trigger together with spare parts; ■ PC's in sufficient quantity to cover data acquisition and QC needs; ■ Software sufficient to cover data acquisition and QC/computing needs (refraction software); ■ Relevant Geodetic instrumentation for positioning/grid setting.

2.2.3 Processing – Fugro Seeker

2.2.3.1 Multibeam Echosounder

Table 7: Multibeam echosounder

Multibeam Echosounder	
Requirement	■ 0.25 m grid resolution ■ Minimum density 16 valid pings per 1 m^2 ■ Simultaneous recording of backscatter
Equipment	Two hull mounted Teledyne RESON 7125 multibeam echosounders with full rate dual head functionality.

Multibeam Echosounder	
Data Collection	▪ Multibeam data were collected in accordance with Fugro's standard work instructions, a component of Fugro's quality management system, which complies with the requirements of ISO 9001:2015, ensuring that data is collected in accordance with the scope of work and Fugro's work instructions WI351,352,356,362,110-402. ▪ On Seeker a dual-head Teledyne RESON 7125 multibeam echosounder system was pre-mobilised and consists of two transmit and receive arrays, one mounted on each hull. ▪ A Valeport Mini SVP was deployed by hand to measure the sound velocity of the water column, prior to the start of survey operations and at least once during each 6 to12 hour period. ▪ A RESON SVP-70 was mounted near the transmit array to determine the speed of sound at the transducer face and account for ray bending at the acoustic source. Continuous speed of sound measurements was provided by the SVS to the multibeam system. ▪ A real-time comparison was set up between the SVS and SVP readings as an indication of MBES refraction errors. If the comparison was greater than 2 m/s, the online surveyor assessed the raw data for refraction artefact. If an unresolvable refraction error existed, another SVP cast was taken and input to Starfix NG. ▪ Fugro used best industry practice to achieve the required 16 hits per 1 m bin requirement in the first instance by operating the multibeam echosounder at full rate dual head mode. During survey operations multibeam settings were constantly monitored to ensure optimal performance. Swath angle and vessel speed was monitored and reduced in deeper waters to focus the same number of receive beams over a smaller seabed area to ensure hit count was maintained. The effect of reducing swath width was reduced seabed coverage and therefore reduced line spacing. ▪ Prior to commencement of the survey a verification was undertaken for the following variables: i) latency, ii) pitch, iii) roll, iv) yaw. The verification data were processed before the start of the survey as described in Fugro's work instruction WI-207 and WI-229. At intervals throughout the survey this was repeated to ensure there has been no change to the calibration parameters. Calibrations were described in a mobilisation report. ▪ During vessel calibrations, a comparison of all SVP's was carried out with a simultaneous cast in a water depth similar to that expected during the survey. ▪ Survey data were collected to the required survey specification and monitored using Starfix.NG online sounding grid and Caris HIPS&SIPS offline sounding grid QC statistics.
Processing	▪ The data were processed according to Fugro's standard procedures. • CARIS HIPS files were corrected for any sound velocity refraction errors. • When required, data point cleaning was conducted in CARIS using the CUBE algorithm, which used site specific parameters to ensure no valid data were removed (noise was flagged only and remained within the raw data set). ▪ The CUBE algorithm search radius did not exceed the specified bin size. Data were finally quality controlled again to ensure compliance to the specification.
Data Outputs	▪ Gridded soundings at 0.25 m (.XYZ ASCII / .tif); ▪ Gridded hill shaded map (.tif) ▪ Gridded THU at 1 m (XYTHU ASCII) ▪ Gridded TVU at 1 m (XYTVU ASCII) ▪ Gridded Slope at 1 m (XYS ASCII) ▪ Vessel tracks (.shp)

Multibeam Echosounder	
Methods and Resolution Limitations	■ The multibeam bathymetry data collected were of good quality. Any noise present in the data were removed and the remaining data were corrected for residual tide and sound velocity errors. Density, THU and TVU of MBES footprints were monitored during acquisition. This ensured all data met the requirements as set out in the technical specifications. ■ The multibeam backscatter data collected were of good quality. Optimum power and gain settings were utilised during data acquisition to ensure high quality acquisition. During the survey multibeam range changes were minimised to maintain the quality of the MBES data. ■ There was some nadir noise present, primarily on the lines in the shallowest areas. To counter this, noise filters have been applied over these areas and manual cleaning has been performed to remove the remaining worst affected areas.

2.2.3.2 Backscatter

Table 8: Backscatter methodology

Item	Description
Equipment	As per the Multibeam
Data Collection	A dual-head Teledyne RESON SeaBat 7125 SV2 FP3 multibeam echo sounder system was pre-mobilised and mounted onto the hull of the vessel. To minimise intensity variations of the backscatter mosaic, power and gain changes were kept to a minimum during the survey. Any setting changes were done during line turns if possible. Survey data were collected to the required survey specification.
Processing and Interpretation	Following acquisition, data were returned to Fugro's Portchester office and copied to a dedicated project network with replication between the Portchester office and an on-site location. Backscatter data contained in the files were imported to the Fledermaus Geocoder toolbox (FMGT) in order to generate a georeferenced mosaic at suitable resolution. The software package was processed by taking the backscatter intensity of each survey line and applying corrections in an attempt to normalise the backscatter intensities. Corrections applied allowed for the differing intensity due to beam angle gain power, beam pattern and radiometric correction due to signal attenuation. Once the corrections were applied the final mosaicked intensity values represented the actual reflectivity of the seafloor. Manual normalisation was carried out where necessary, within FMGT to apply a brightness bias to individual survey lines to further improve the mosaic.
Data Outputs	Multibeam backscatter data grid at 0.5 m resolution (.XYA ASCII / .tif)

2.2.3.3 Subsea Positioning

Table 9: Subsea positioning.

Subsea Positioning	
Requirement	■ Provide positioning information to towed seabed sensors; ■ Update rate of 0.5 Hz or better (preferred is 1 Hz); ■ Consistent dropouts of duration > 5 seconds not accepted; ■ Following calibration of the USBL system, 95% (2 sigma) of beacon positions within ± 1 m.

Subsea Positioning	
Equipment	▪ Sonardyne Mini Ranger 2 USBL system ▪ Sonardyne WSM6+ transponders.
Data Collection	▪ Underwater positioning data were collected in accordance with Fugro's quality management system, which complies with the requirements of ISO 9001:2015 with specific reference to work instruction WI-212; ▪ The USBL transceiver was pole mounted. The USBL system received the following data corrected for the USBL transceiver location from the Fugro Starfix.NG navigation system: • Position (from Fugro StarPack GNSS); • Heading (from Applanix POSMV); • Motion (from Applanix POSMV). ▪ Additionally, SVP cast information was uploaded to the USBL system after each SVP was undertaken; ▪ The Fugro Starfix.NG navigation software was setup with a visual alert to highlight consistent and/or long-duration beacon dropouts to the online surveyor; ▪ Prior to the start of the survey the system was calibrated, and the calibration verified by "boxing in" a seabed transponder. During calibration a transponder beacon was deployed in an area where seabed depth was appropriate for the survey site and expected towing distance. An SVP cast was conducted and entered into the system, to ensure scale errors and errors due to refraction are minimised. A series of calibration lines were recorded while the USBL interrogated the transponder. After the calibration lines were recorded, the data were processed, and a calibration report generated. Data had to be filtered to ensure accurate calibration values. The calibration values were entered into Starfix and verified by confirmation lines recorded over the seabed transponder. Once the calibration was completed, the seabed transponder was recovered by use of an acoustic release system.
Methods and Resolution Limitations	The subsea positioning was generally good throughout the survey. At mobilisation, unprocessed SSS data were found to have an average target position deviating less than < 2.0 m from the position of the same target derived from MBES. Data required a very minimal amount of de-spiking, positioning was generally good throughout the survey.

2.2.3.4 Side Scan Sonar

Table 10: Side scan sonar

Side Scan Sonar	
Requirement	▪ Minimum 200% coverage (100% nadir coverage is required); ▪ Data resolution sufficient for detection of seabed objects/features ≥ 0.5 m (height, width or length); ▪ XY precision and accuracy of ≤ ±2.0 m; ▪ Survey speed of 4.0 knots ±10%, dependent on currents and acceptability of the data; ▪ Infill required where USBL gaps of more than 10 seconds along the survey line; ▪ Altitude of approximately 10% of operational range, dependant on water depth and operational safety considerations such as the height of the piggybacked MAG.
Equipment	▪ EdgeTech 4200 side scan sonar (300/600 kHz); ▪ USBL sub-sea positioning;

Side Scan Sonar	
	▪ EdgeTech Discover data acquisition software; ▪ Chesapeake SonarWiz data processing software.
Data Collection	▪ Side scan sonar data were collected in accordance with Fugro's Standard Procedures WI02_351, WI02_353 and WI02_354; ▪ The dual channel, dual frequency side scan sonar operated at a 50-75 m range to achieve the project requirements for coverage and resolution; ▪ Throughout the survey, both the high and low frequencies were recorded. Data were recorded as both XTF and JSF formats. Survey logs listing the data collection parameters were maintained throughout the survey; ▪ The SSS was positioned using USBL, with a beacon mounted on the aft handle of the instrument itself with no additional offset to the transceiver required. The system was set up, and data recorded in adherence to WI02_120 and WI02_220; ▪ Comprehensive survey logs listing the data collection parameters were maintained throughout the survey. Quality was continuously monitored by the online geophysicist using the online displays; further details regarding quality, possible re-runs and equipment performance were noted in the online log.
Processing	▪ Data QC, data processing and contact picking were completed by geophysicists at Fugro's Portchester office; ▪ The high frequency data were processed in SonarWiz from the JSF files (processing of low frequency data were not required, as stipulated in the scope of work); ▪ Data files were imported into SonarWiz processing software. The navigation was checked on import with corrections applied where required. The files were then bottom-tracked before the data files were gain adjusted. As a standard the Empirical Gain Normalisation (EGN) function was used to preserve changes in reflectivity from seabed sediment variations. Where required, additional Automatic Gain Control (AGC) was used to minimise the effects of motion on the data. ▪ The processor undertook QC of the positioning quality by using contacts or seabed features on lines run in opposite directions. The bathymetry data were also checked to ensure the data positioning was within expected tolerances; ▪ Contacts over 0.5 m in any dimension were picked and classified. Where required, contacts were rationalised to the MBES position or to their position within sonar files.
Methods and Resolution Limitations	SSS data quality was generally good across the site. Areas of data observed to experience excessive snatch were removed and subsequently infilled with acceptable data, whilst artefacts were always minor they were easily trimmed due to the high data density. Positioning of the SSS data was generally very good across the site and was continually checked throughout the survey to ensure that it remained within the project specification of ± 2.0 m. Features present at the survey site were used to check the SSS positioning against the MBES data. During acquisition four factors resulted in limitations within the SSS data. Limitations were mitigated through processing or data were recollected where required. The limitations were: ▪ Snatch in SSS data during marginal weather ▪ Interference from the MBES ▪ Sea defences in south of the survey area that bounces some of the acoustic signal back towards the vessel ▪ Steep escarpment resulting in shadowing On numerous SSS lines, snatch was observed in varying degrees of severity, from only minor intensity differences requiring additional automatic gain control (AGC) to

Side Scan Sonar	
	strong distortion of contacts and features resulting in infill or re-runs. This was attributed to a combination of marginal weather, marine and river currents, and passing ship waves and was therefore unpredictable and difficult to mitigate. The data were reviewed on a line-by-line basis with EGN applied to ensure quality was always sufficient to meet the interpretation requirements. After the data were deemed acceptable, high-resolution low-intensity AGC filters were applied to the final mosaic which greatly enhanced the interpretability of the data. On the majority of the SSS data acquired with 75 m range, noise in the outer ranges was observed in both channels. Due to sufficient data coverage and overlap it was determined that there was no significant impact on the interpretability of the data. All lines had their displayed ranges limited to 60 m in the final mosaic which removed this noise. The western half of the southern boundary of the survey area was characterised by an extensive sea defence related to the port of Rotterdam. This extends approximately 50 m from the boundary and consists of regularly shaped rock armour for 10-15 m from the boundary, becoming irregular rock dump for the final 35-40 m of the slope. Shadowing was observed in the centre of the site following a general trend of WNW-ESE. This represented an escarpment along the northern edge of the actively dredged channel. As lines were run near-parallel with this feature, many of the shadow zones were subsequently ensonified by adjacent lines, enabling identification of contacts. However, in regions where the gradient became very steep, the SSS was unable to ensonify these regions regardless of heading direction.

2.2.3.5 Sub-bottom Profiler

Table 11: Parametric sub-bottom profiler

Parametric Sub-bottom Profiler	
Requirement	▪ 10 m penetration; ▪ Vertical resolution: 0.2 metres; ▪ Total horizontal uncertainty 2 m or better.
Equipment	▪ System: Innomar SES-2000 Medium Parametric sub-bottom profiler; ▪ Acquisition system: SESWIN; ▪ Conversion Software: SES Convert; ▪ Processing Software: RadExPro.
Data Collection	▪ Sub-bottom profiler data were collected in accordance with Fugro's standard procedures, a component of Fugro's Quality Management System, which complies with the requirements of ISO 9001:2015, ensuring that data is collected in accordance with the scope of work and Fugro's procedures; ▪ A test was undertaken at the start of the survey to determine the optimum settings to achieve the best records with the system. As the survey progressed the system was adjusted to obtain the best records. Each change was entered into the survey logs; ▪ The data were acquired in a raw format and converted into SEGY. The data were frequency filtered online for the purposes of QA, although this filter was not applied to the recorded SES3 files. The optimum settings were determined as appropriate to the site; ▪ All data were recorded digitally in the SESWIN acquisition system along with positional data from the positioning system provided by Fugro Starfix. Any duplicates in source coordinates caused by shot interval and navigation point separation were corrected using an interpolation method;

Parametric Sub-bottom Profiler	
	■ Comprehensive survey logs listing the data collection parameters were maintained throughout the survey. Quality was continuously monitored by the online geophysicist using the online displays; further details regarding quality, possible re-runs and equipment performance were noted in the online log.
Processing	■ All data were quality checked and processed according to Fugro's standard procedures; ■ Initial data QC, data processing and deliverables were completed at Fugro's offices in Portchester: • Heave compensation. • Amplitude Correction: Time raised to the power: 2.0; • Bandpass filtering Low cut frequency 2,200 Hz and High cut frequency 14,000 Hz; • Burst Noise Removal: Window size: 7 traces, Rejection percentage of alpha trimmed average: 50%, Exclude amplitudes lower than 5% of average. ■ Data and navigation QC.
Methods and Resolution Limitations	SBP data quality was monitored throughout the survey and generally deemed to be high. The acquisition frequency was kept constant (6 kHz) throughout the project to maximise penetration. Across the site average depth penetration of the SBP data ranged between 5 – 10 m. Positioning of the SBP data was verified to ensure that it remained within the project specification of ± 2 m. Features present within the survey site were used to check the SBP positioning against the MBES data. During acquisition several factors resulted in limitations within the SBP data. Limitations were mitigated or data were recollected where possible. Limitations included: ■ Anthropogenic features impacting data penetration and quality. ■ Regions of seismic data transparency ■ Masking of data due to acoustic blanking ■ Unfit data quality due to aeration of water column ■ Weather effects

2.2.3.6 Single Magnetometer

Table 12: Magnetometer

Single Magnetometer	
Requirement	■ 10 m maximum flying altitude; ■ Magnetometer sampling frequency: 10 Hz; ■ Maximum noise level: ±1.5 nT; ■ Lateral blanking distance shall be 2.5 m and cell size of 0.5 m for grids; ■ Data rejected for any USBL gap or altitude out of spec for more than 10 seconds.
Equipment	■ 1x Geometrics G882 magnetometer fitted with a depth sensor and altimeter; ■ USBL subsea positioning; ■ Starfix data acquisition software; ■ Oasis Montaj data processing software.
Data Collection	■ Magnetometer data were collected and processed in accordance with Fugro's standard procedures, a component of Fugro's Quality Management System, which complies with the requirements of BS EN ISO 9001:2008.

Single Magnetometer	
	▪ The magnetometer was positioned using the USBL. Real-time positions for the sensor was then output to the acquisition software and recorded along with the magnetometer readings and altitude data. Magnetometers were towed at less than 10 m altitude, as close to the seafloor as possible. ▪ Magnetometer values in nT, depth and altimeter readings were collected at an update rate of 10 Hz. The data were logged in Starfix acquisition software together with navigation information and a time stamp. ▪ Additional required fields such as USBL sensor to vessel range were output from the navigation software and were logged as a separate text file. The data were sampled into the raw Oasis Montaj database on import. ▪ Magnetometer data were continuously QC'ed by personnel in Fugro's office in Portchester, UK. Re-runs and infills were acquired based on out of specification cases for magnetometer data.
Processing	▪ All data were processed and reported according to Fugro's standard procedures; ▪ All magnetometer data were QC'ed for data quality and processed at Fugro's offices in Portchester, UK. Processing was followed by gridding, picking and preparation of final deliverables; ▪ Magnetometer gaps / reruns and infill sections were finalized from onboard Seeker when required; ▪ Fugro's magnetometer processing and interpretation procedure can be broadly separated into the following stages: • Data import; • Navigation processing and QC of all data; • Export of all data for processing in Oasis Montaj; • Import into Oasis Montaj; • QC all data channels and double check for navigational errors; • De-spiking and QC of total field and altitude data; • Removal of data where the signal strength <100; • Removal of data set sections exhibiting greater than ±1.5 nT noise tolerance; • QC of total field data, signal strength and altitude; • Filtering and calculating residual. • Gridding of the total field data, magnetic residual, signal strength and altitude; ▪ Data were reviewed on a line-by-line basis and any sections exceeding system noise parameters (typically ±1.5 nT), altitude > 10 m and signal strength <100 were removed before gridding. Any data gaps resulting from such a process were infilled as required; ▪ Filtering and calculating the residual values involved the selection of suitable parameters to ensure that background variations in the magnetic field were removed, without affecting any potential anomalies. Data were subject to a beta-spline filter, followed by a series of non-linear filters with decreasing width and tolerance; ▪ The calculated background field was subtracted from the measured field to produce the magnetic residual; ▪ Data were interpreted as gridded datasets and profiles.
Methods and Resolution Limitations	The magnetometer data quality was monitored throughout the survey. Spatial accuracy within 2 m was achieved with a USBL positioning beacon placed on the towed side scan sonar fish. The overall data quality was good. The processors QCed the positioning and quality of the magnetometer data, all data met the specification requirements of the project.

Single Magnetometer	
	During acquisition, limitations to the data quality arose from challenges that were encountered as part of data collection. Limitations included: ▪ Magnetic signal spikes (due to defect equipment) ▪ Signal strength below 400 ▪ Navigation gaps longer than 10 seconds due to USBL failures When limitations in the data quality arose, the data were checked. Where possible small spikes were interpolated and short drops in signal strength were assessed to identify the impact on data quality. For the navigation gaps, and in regions where the reduction of signal strength impacted the data quality, data were infilled.

2.2.3.7 2D-UHRS

The seismic data acquisition was performed using an ultra-high-resolution seismic system including a single Geo-Source 400 tips LW sparker, two 2000XFO HV Geo-Spark power supplies, 24- channel streamer with a 1+2 m group interval, a 24-channel recording system, a single element reference hydrophone and GNSS positioning systems for the streamer's front buoy and tail buoy and source.

Figure 2.1 describes the 2D-UHRS equipment and the general acquisition parameters used in this project.

Sources	1x Geo-Source 400 tips LW
Source Towing Depth	0.3 m
SP Interval	1 m
Operating Power	Source @ 400J
Tuned delay	-
Power Supply	2 X Geo-Spark 2000XFO
CDP Bin Coverage	≈24 fold for 1 m CDP bin
Recorder	4x Multitrace24 – Geomarine Survey systems
Sample Rate	0.1 msec
Record Length	200 ms
Format	SEG-Y
Multichannel Streamer	Geo-Sense LW 24 channels
Streamer Depth	≈ 0.4 – 1.3 m
Group Interval	1+2m
Group Active Length	35 m
Reference hydrophone	Geo-Sense reference hydrophone – single element
Hydrophone Depth	5 m from the source
Group Interval	Single element
Group Active Length	Point receiver

Figure 2.1: Fugro Seeker 2D-UHRS system and parameters.

The seismic spread geometry used during the survey is presented in the Figure 2.2 with the respective measurements - offsets.

Refer to the *2D UHRS Survey Field Report*, part of the *F197217-REP-RES-002_Nearshore Geophysical Survey Report*, for a detailed description of the 2D-UHRS processing method.

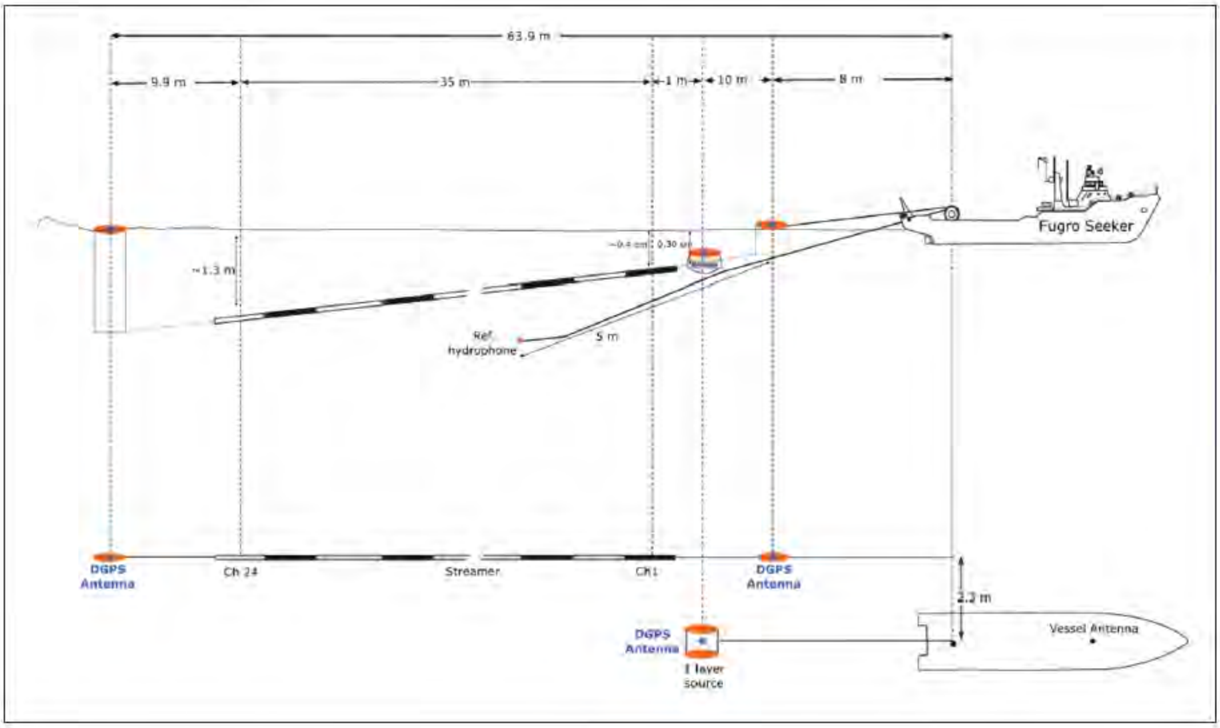


Figure 2.2: Vessel layout.

2.2.3.8 Refraction Seismic and MASW Scope

For the Refraction Seismic and GAMBAS scope, the line plan consisted of 39 lines in two parts. Within the shallow parts of the site, to the north and south of the channel, a 150m refraction and MASW stream was used. Within the deeper area of the channel, a 90m MASW streamer was used. The lines in the main channel, and some lines to the South, were parallel to the channel. The lines to the North of the channel were oriented North – South.

During acquisition, the Client requested Seeker concentrated on a set of priority lines due to the prospect of unworkable weather impacting progress. This reduced the number of remaining lines by half and involved acquiring every second line. Following the completion of priority lines, a further two non-priority lines were acquired whilst awaiting Client confirmation to cease acquisition. A total of 32 lines covering 31.7km were acquired.

Table 13: Refraction Seismic and MASW Scope

Single Magnetometer	
Requirement	■ Vessel speed <2.2knots ■ Sledge and streamer on the seabed
Equipment	■ Access channel: 48 hydrophones variable spacing, total length 90m, for MASW and Refraction acquisition ■ Shallowest water: Combination of 1 x 24 low frequency hydrophones (MASW+refrac) ■ 45m and 1x24 standard hydrophones (refrac only) 115m long. Total streamer length of approximately 150m allowing deeper penetration. ■ USBL subsea positioning for the sledge

Single Magnetometer	
Data Collection	■ Streamer and sledge were lowered down on the seabed 300m before the start of a line and brought back at the surface when a line was completed. ■ Acquisition started when the USBL showed that the sledge was at the beginning of the line and stopped when the sledge was after the end of the line to maximise coverage. ■ Buffer zones were decided onboard, for example when we had to deviate from the line because a buoy was there and equipment could get tangled in it. ■ The control panel on deck that fires the airgun gave the instruction to both the seismic recording system and the navigation system to log the data. ■ Recording parameters: length of 2sec and sampling rate of 0.250ms. ■ Air gun pressure between 95 and 110bars. ■ On-line QC was done for refraction and MASW data. It consisted of a check of individual hydrophone validity, validation of signal to noise ratio, checking that we could pick the first arrivals on the whole streamer for refraction and checking that we could see a dispersion curve for MASW. The position of the sledge was also checked in real time.
Processing	■ The processing involves 3 main steps: • Merge of positioning, bathymetric and seismic data; • Picking of regression curves for refraction; Picking of dispersion curves for MASW; • QC and exports of bar charts and maps. ■ The seismic refraction processing itself includes starts with the picking of the first arrival of the compressional wave recorded at each hydrophone. Picked times measured for each trace feed a Time-Distance curve for each shot point. Regression of Time-Distance curve allows to extract a series of compressional wave velocities (Vp) and corresponding thicknesses are identified. Each pair of values Vp - thickness is representative of a layer of constant average velocity. ■ The MASW processing starts with the picking and extraction of the dispersion curve of the fundamental mode for every shot. After inversion of every dispersion curve, data are merged and kriged to produce a 2D section of shear waves velocities (Vs).
Data Outputs	■ Refraction: Gridded bar charts which is the raw VP profile, meaning no smoothing, filtering or kriging has been applied. ■ MASW: Gridded 2D sections with kriging applied.

2.2.4 Operations – Fugro Discovery

The objective of the survey was to identify and delineate any possible constraints and hazards from man-made, natural and geological features which may affect the integrity of the exploration site/development area.

The geophysical survey line plan covers the pipeline RPL options with a centreline and contains a further eight wing lines, four per side. Line spacing is 60 m inside a 480-metre-wide corridor.

2.2.5 Survey Requirements – Fugro Discovery

Table 14: Work Element 3 survey requirements overview

Equipment Method	Survey Requirements
Vessel	Fugro Discovery
Line Spacing	Geophysical 60 m
Max. Vessel Speed	4 knots (±10%)
Surface Positioning	▪ THU < 1.0 m (1.414 – σ) ▪ TVU < 30 cm (1 - σ)
Subsea Positioning	Fugro will only be able to repeatedly achieve +/- 1 m accuracy for USBL calibration and +/-2 m accuracy for data acquired from towed sensors. i.e., a processed target accuracy of +/-2 m for SSS and magnetometer.
Multibeam Echosounder	▪ 100% coverage with 20% overlap between lines ▪ 0.25 m x 0.25 m bin size / 16 x pings per 1.0 m x 1.0 m
SVP	▪ The speed of sound in water shall be measured in the survey area. ▪ The Vertical Sound Velocity Profiles should be undertaken with an accuracy of ±0.05 m/s
Side Scan Sonar	▪ ≥0.5 m target size ▪ 200% coverage, 100% coverage in the SSS nadir ▪ Infill required where USBL gaps > 10 s
Magnetometer	▪ Single magnetometer ▪ 5 - 10 m altitude ▪ Magnetometer sampling frequency: 10 Hz ▪ Target size 5 nT ▪ Noise Level ± 1.5 nT (3 nT in total) ▪ Lateral blanking distance shall be 2.5 m ▪ Infill required where USBL gaps > 10 s, altitude out of spec for more than 5 m, or signal strength < 100
Sub-bottom profiler	10 m penetration with 0.2 m resolution

2.2.6 Processing – Fugro Discovery

2.2.6.1 Multibeam Echosounder

Bathymetry data collected from the hull mounted dual head Kongsberg EM2040 multibeam echosounder onboard the survey vessel, were processed with CARIS Hydrographic Information Processing System and Sonar Information Processing System (HIPS and SIPS) software (Version 11.4). The CARIS HIPS and SIPS general workflow is presented in Table 2.12. Neighbouring blocks were systematically merged towards completion of data processing.

Table 15: CARIS HIPS and SIPS bathymetry processing workflow

CARIS HIPS Work Step	Description
1. Raw MBES Data	MBES raw data as logged by Kongsberg SIS
2. HIPS Vessel File	Before data were converted into Caris HIPS, a so-called HIPS Vessel File (HVF) was defined. This HVF contains all relevant sensor definitions with information regarding offsets, correction values, and system configurations. The HVF defines amongst others: ▪ Offsets relative to the centre reference point (CRP);

CARIS HIPS Work Step	Description
	▪ Sound velocity information; ▪ Dynamic MBES motion (heading, roll, heave, pitch); ▪ Static corrections for gyro heading and error for roll, heave and yaw heading alignment of the multibeam system; ▪ Static TPU (total propagated uncertainty) settings including offsets and survey equipment standard deviations (based on technical specifications).
3. Data Conversion to HIPS	The multibeam raw data exported from the acquisition software was converted into HIPS format. Positioning information included in the raw data is based on geographical coordinates.
4. Quality Control (navigation, attitude data)	Navigation and attitude data were checked for spikes. This was done manually or by using self-defined filters. Spikes were marked and flagged as 'not to be used for further calculation.' Coverage was carefully checked for gaps and data density and infill lines were surveyed if necessary. Secondary (backup) systems for navigation and attitude data could be added to the HIPS and SIPS project if required.
5. Swath Filter	Depth information of one survey line was filtered for spurious values and data not to be used. Filter settings for flagging data as rejected can include the following settings: ▪ Min-max. accepted depth range; ▪ Distance off nadir; The filters are applied according to the encountered morphology, weather conditions etc. The applied values may vary from area to area. Nevertheless, each line was checked separately, and the filter parameters were adapted if necessary.
6. Tide Reduction	All depths were reduced to LAT using the NL2018LAT MSS model within Caris HIPS & SIPS. Navigation, motion and StarFix.G4+ GNSS elevation data were processed using Novatel´s Intertial Explorer software package. Ellipsoidal heights of the GNSS antennas were corrected for motions. The heights were reduced to the water line using draught and dimensional offset measurements. Waterline elevations are further reduced to the vertical datum (LAT) by means of NL2018LAT MSS model. A smooth tide curve was created to reduce MBES data to datum.
7. Sound Velocity Correction	Each track line was corrected for sound velocity.
8. Calculation of Final Position and Depth for each Beam (georeferenced bathymetry)	For each individual beam a position and a depth value were calculated with respect to vessel (gyro) heading, tide data (including dynamic draft) and sound velocity correction using time as correlation. In addition, the TVU and THU[1] for each sounding was calculated.
9. Create Work Surface	The pre-checked data were used to calculate a CUBE (Combined Uncertainty and Bathymetric Estimator) surface.
10. Surface Filter using "Swath Angle" grids	A HIPS "Swath Angle" surface allowing maximum sounding footprints was then used as a base for a surface filter, for which a data window of acceptance around this surface must be specified using certain parameters. The survey data is then checked against these conditions. Data outside the specified window of acceptance were rejected.
11. Create Quality Control Surfaces (CUBE)	The CUBE algorithm creates a hypothesis for the depth value of a grid cell from the first depth value that falls into a cell. Every following depth value is checked against this hypothesis and according to a variety of settings selected to contribute to the existing hypothesis, to create a new, second hypothesis or to be rejected. A most probable surface is resulting from these calculations. New base surfaces were calculated to check the result. Having undergone these procedures, the data is in a final state for delivery. Contour calculation was achieved by using Fugro Starfix Workbench and ESRI ArcGIS.

CARIS HIPS Work Step	Description
12. Quality Control	The data quality is mainly checked using the standard deviation, density (hit count), TVU/THU and visual bathymetry inspection. Local anomalies are removed manually or by a locally applied filter.
13. Data Export	As a deliverable from HIPS, a gridded and ungridded datasets were produced and exported as ASCII files. Fugro Starfix.Workbench and ArcGIS were used to create final deliverables.
Note 1: TVU and THU values were calculated using Caris HIPS&SIPS considering all contributing factors applicable for the vessels. TVU and THU are defined as follows by the IHO Standards for Hydrographic Surveys (S-44), 6th Edition: • Total horizontal uncertainty (THU): Component of total propagated uncertainty (TPU) calculated in the horizontal dimension. THU is a two-dimensional quantity with all contributing horizontal measurement uncertainties included. Total propagated uncertainty (TPU): Three-dimensional uncertainty with all contributing measurement uncertainties included. • Total vertical uncertainty (TVU): Component of total propagated uncertainty (TPU) calculated in the vertical dimension. TVU is a one-dimensional quantity with all contributing vertical measurement uncertainties included. • Uncertainty: Estimate characterising the range of values within which the true value of a measurement is expected to lie as defined within a particular confidence level. It is expressed as a positive value.	

2.2.6.2 Side Scan Sonar

Table 16: Side Scan Sonar

Side Scan Sonar	
Requirement	▪ Minimum 200% coverage (100% nadir coverage is required); ▪ Data resolution sufficient for detection of seabed objects/features ≥ 0.5 m (height, width or length); ▪ XY precision and accuracy of ≤ ±2.0 m; ▪ Survey speed of 4.0 knots ±10%, dependent on currents and acceptability of the data; ▪ Infill required where USBL gaps of more than 10 seconds along the survey line; ▪ Altitude of approximately 10% of operational range, dependant on water depth and operational safety considerations such as the height of the piggybacked MAG.
Equipment	▪ EdgeTech 4200 side scan sonar (300/600 kHz); ▪ USBL sub-sea positioning; ▪ EdgeTech Discover data acquisition software; ▪ Chesapeake SonarWiz data processing software.
Data Collection	▪ Raw SSS data were logged in XTF and JSF formats in the EdgeTech Discover acquisition software, with smoothed navigation integrated within them from the Qinsy online navigation software. ▪ The dual channel, dual frequency side scan sonar operated at a 50-75 m range to achieve the project requirements for coverage and resolution; ▪ Throughout the survey, both the high and low frequencies were recorded. Data were recorded as both XTF and JSF formats. Survey logs listing the data collection parameters were maintained throughout the survey
Processing	▪ The JSF formats files were then imported into SonarWiz on two separate projects, one for LF and HF. Navigation was smoothed with a 50-ping rolling mean on import. ▪ All data were bottom tracked to allow slant range corrections to be applied. Position and heading smoothing were applied to remove slight navigation jumps. Further navigation filters were applied in SonarWiz where required. Empirical gain normalization (EGN) was applied for every single line to level and average the sonar amplitudes by altitude and range to construct a homogenous

Side Scan Sonar	
	mosaic. Some manual adjustments to the gains were required to ensure a good match throughout. ■ To check the accuracy of the navigation data, SSS data from adjacent lines, run in opposite directions on a known MBES position, are compared and verified against each other and against the bathymetry. ■ Nadir transparency was set to 1.5 m and where necessary, the displayed sonar range was reduced to trim out any environmental artifact or fish ghosts. ■ Line order was adjusted to improve the overall appearance of the mosaic, sending marginal quality data to the back, and aiming to minimise the number of visible artifacts. ■ All contacts greater than 0.5 m in any dimension were identified and listed. Contacts were manually picked on a line-by-line basis from the waterfall display using the HF data. These were then measured (width, length, and height), classified, and moved to the MBES position, where possible. ■ The contact list was exported as csv and after curating, was converted to shapefile format in ArcGIS.
Methods and Resolution Limitations	■ SSS data quality was generally good across the site.

2.2.6.3 Parametric Sub-bottom Profiler

Table 17: Parametric sub-bottom profiler

Parametric Sub-bottom Profiler	
Requirement	■ 10 m penetration; ■ Vertical resolution: 0.2 metres; ■ Total horizontal uncertainty 2 m or better.
Equipment	■ System: Innomar SES-2000 Medium Parametric sub-bottom profiler; ■ Acquisition system: SESWIN;
Data Collection	■ Innomar SBP data were logged in SES3 format by the SESWIN acquisition software, with navigation integrated within them from the Qinsy online navigation software. The geometry correction of the transducers to the Centre of Gravity (COG) is applied during acquisition in Qinsy and SESWin. The SES3 files were converted to SEGY format with the Innomar SESConvert software and merged if the file had been split on different segments on acquisition. During conversion, deduplication and interpolation of the raw navigation was conducted to ensure each slot contained a unique coordinate. ■ The output SEGY files were processed in the GeoSuite Allworks processing software.
Processing	■ The signal processing flow comprised the following steps: ■ Shifting the data as per the record delay; ■ Amplitude correction Automatic Gain Control Window Length: 10 ms Percent: 25 %; ■ Butterworth bandpass filter with a low-cut of 2 kHz, and a high-cut of 15 kHz; ■ Burst noise removal (Window: 7, Rejection: 50 %); ■ Where occasional residual heave was observed, a swell filter was designed on a line-by-line basis over a 50 trace length smoothing filter

Parametric Sub-bottom Profiler	
	▪ After signal processing the tide correction was applied as a trace-by-trace tidal reduction applied to the COG using the tidal curve and further corrections of the SBP data for the vessel's heave and reduction of the data to LAT. ▪ Ultimately, the LAT corrected SEGY files were exported together with their headers and imported into the Kingdom software for QC against the MBES data to ensure that the tidal correction was successful and that there was a good correlation between the two datasets.

2.2.6.4 Single Magnetometer

Table 18: Magnetometer

Single Magnetometer	
Requirement	▪ 10 m maximum flying altitude; ▪ Magnetometer sampling frequency: 10 Hz; ▪ Maximum noise level: ±1.5 nT; ▪ Lateral blanking distance shall be 2.5 m and cell size of 0.5 m for grids; ▪ Data rejected for any USBL gap or altitude out of spec for more than 10 seconds.
Equipment	▪ 1x Geometrics G882 magnetometer fitted with a depth sensor and altimeter; ▪ USBL subsea positioning;
Data Collection	▪ The data was recorded in QPS qpd-format and exported in an ascii text file format, with raw navigation integrated. Exported ascii files were then imported into Oasis Montaj for processing.
Processing	▪ Once into Oasis Montaj the navigation data were cleaned; large spikes caused by any jumps in the USBL navigation were identified, removed manually and data interpolated. A 150-ping rolling mean filter was applied to remove any smaller erroneous values. ▪ The raw altitude, signal, and magnetic total field were checked and manually de-spiked, with altitudes above the 5 m specification being masked in most areas. ▪ Areas with signal strength below 400nT were carefully reviewed to ensure the data quality was still sufficient and consistent, being removed if not. Areas with signal strength below 100nT were deemed unreliable and were masked. ▪ The optimum ß-Spline filter settings for this project have been evaluated to be Smoothness 0.6 and Tension 0. These values were used to filter the raw magnetometer readings. ▪ A series of non-linear filters were applied to fit a smoothed curve to the data. The results of the non-linear filters were then subtracted from the results of the β-spline filter to calculate a residual magnetometer data channel. ▪ The filtered data were gridded using the minimum curvature gridding method. For gridding, a grid cell size of 0.5 m and a blanking distance of 2.5 m were used. ▪ Magnetic anomalies were picked manually on the total field profiles and reviewed against the residual field grid to remove duplicates and erroneous picks, and to manually pick any missed anomalies. The reviewed list of anomalies was then manually measured for peak-to-peak amplitude.

2.2.7 Operations – Fugro Searcher

The objective of the survey was to identify and delineate any possible constraints and hazards from man-made, natural and geological features which may affect the integrity of the exploration site/development area.

The Fugro Searcher was assigned four sections (Section C, Section F, Section D and Section K14-L4A) of the offshore main pipeline corridor and the offshore hub area. The scope was divided in four scopes as presented in Table 2.13.

Table 19: Scope of work of Fugro Searcher

Area of Operation	Scope Requirements
UHRS Scope	2D UHRS, MBES Acquired on pipeline route centreline & offshore hub area
UXO Scope	MBES, SSS, SBP and MAG Acquired at two lines in the areas assessed as moderate UXO risk
Analogue Geophysical Scope	MBES, SSS, SBP, MAG Acquired at pipeline route centreline with 8 wing lines, as well as offshore hub area.
Environmental Scope	Environmental Baseline Study

The UXO Scope dataset is not presented in this report and dataset.

The results of the Environmental Baseline Study will be incorporate in the upcoming integrated report.

2.2.8 Processing – Fugro Searcher

2.2.7.1 Multibeam Echosounder

Table 20: Multibeam Echosounder

Multibeam Echosounder	
Requirement	▪ 0.25 m grid resolution ▪ Minimum density 16 valid pings per 1 m^2 ▪ Simultaneous recording of backscatter
Equipment	▪ Hull mounted dual head Kongsberg EM2040
Data Collection	▪ Bathymetric data were logged within the Kongsberg SIS software for the EM2040 MBES, and within the Starfix. Logging application EA600 SBES system.
Processing	▪ Data were post-processed using the Caris HIPS&SIPS suite of applications. Both single beam and multibeam echosounder data were corrected for transducer draught, acoustic velocity through sea water and vessel heave, pitch and roll, and then positioned with reference to the echosounder transducer. ▪ Observed Mean Sea Surface (MSS) tides were recorded online. These tides were then reduced to Lowest Astronomical Tide (LAT) using the NL 2018 LAT model in the Dutch sector. ▪ The multibeam echosounder (MBES) data were processed using both Kongsberg's online software, SIS, and Caris HIPS&SIPS SIS computed the x,y,z coordinates of the multibeam data by transforming the travel time and angle of the beams, using the water's sound velocity and the vessel's motion data. The MBES data were then processed using Caris HIPS&SIPS to monitor quality and overlap using automated methods and then edited using manual methods for final cleaning of any erroneous data from the swathes. The files were then merged to form one large regular 0.25 m× 0.25 m grid and filtered. Points

Multibeam Echosounder	
	outside the accepted tolerances were removed automatically. The resultant output file was generated to form a regular XYZ file. ▪ All depths were reduced to Lowest Astronomical Tide (LAT).

2.2.7.2 Side Scan Sonar

Table 21: Side Scan Sonar

Side Scan Sonar	
Requirement	▪ Minimum 200% coverage (100% nadir coverage is required); ▪ Data resolution sufficient for detection of seabed objects/features ≥ 0.5 m (height, width or length); ▪ XY precision and accuracy of ≤ ±2.0 m; ▪ Survey speed of 4.0 knots ±10%, dependent on currents and acceptability of the data; ▪ Infill required where USBL gaps of more than 10 seconds along the survey line; ▪ Altitude of approximately 10% of operational range, dependant on water depth and operational safety considerations such as the height of the piggybacked MAG.
Equipment	▪ EdgeTech 4200 side scan sonar (300/600 kHz); ▪ USBL sub-sea positioning; ▪ EdgeTech Discover data acquisition software; ▪ Chesapeake SonarWiz data processing software.
Data Collection	▪ Raw SSS data were logged in XTF and JSF formats in the EdgeTech Discover acquisition software, with smoothed navigation integrated within them from the Starfix online navigation software. ▪ The dual channel, dual frequency side scan sonar operated at a 50-75 m range to achieve the project requirements for coverage and resolution; ▪ Throughout the survey, both the high and low frequencies were recorded. Data were recorded as both XTF and JSF formats. Survey logs listing the data collection parameters were maintained throughout the survey
Processing	▪ The JSF formats files were then imported into SonarWiz on two separate projects, one for LF and HF. Navigation was smoothed with a 50-ping rolling mean on import. ▪ All data were bottom tracked to allow slant range corrections to be applied. Position and heading smoothing were applied to remove slight navigation jumps. Further navigation filters were applied in SonarWiz where required. Empirical gain normalization (EGN) was applied for every single line to level and average the sonar amplitudes by altitude and range to construct a homogenous mosaic. Some manual adjustments to the gains were required to ensure a good match throughout. ▪ To check the accuracy of the navigation data, SSS data from adjacent lines, run in opposite directions on a known MBES position, are compared and verified against each other and against the bathymetry. ▪ Nadir transparency was set to 1.5 m and where necessary, the displayed sonar range was reduced to trim out any environmental artifact or fish ghosts. ▪ Line order was adjusted to improve the overall appearance of the mosaic, sending marginal quality data to the back, and aiming to minimise the number of visible artifacts. ▪ All contacts greater than 0.5 m in any dimension were identified and listed. Contacts were manually picked on a line-by-line basis from the waterfall display

Side Scan Sonar	
	using the HF data. These were then measured (width, length, and height), classified, and moved to the MBES position, where possible. ■ The contact list was exported as csv and after curating, was converted to shapefile format in ArcGIS.

2.2.7.3 Single Magnetometer

Table 22: Magnetometer

Single Magnetometer	
Requirement	■ 10 m maximum flying altitude; ■ Magnetometer sampling frequency: 10 Hz; ■ Maximum noise level: ±1.5 nT; ■ Lateral blanking distance shall be 2.5 m and cell size of 0.5 m for grids; ■ Data rejected for any USBL gap or altitude out of spec for more than 10 seconds.
Equipment	■ 1x Geometrics G882 magnetometer fitted with a depth sensor and altimeter; ■ USBL subsea positioning;
Data Collection	■ The MAG data were recorded in StarfixNG and produced in FBF file.
Processing	■ Once into Oasis Montaj the navigation data were cleaned; large spikes caused by any jumps in the USBL navigation were identified, removed manually and data interpolated. A 150-ping rolling mean filter was applied to remove any smaller erroneous values. ■ The raw altitude, signal, and magnetic total field were checked and manually de-spiked, with altitudes above the 5 m specification being masked in most areas. ■ Areas with signal strength below 400nT were carefully reviewed to ensure the data quality was still sufficient and consistent, being removed if not. Areas with signal strength below 100nT were deemed unreliable and were masked. ■ The optimum ß-Spline filter settings for this project have been evaluated to be Smoothness 0.6 and Tension 0. These values were used to filter the raw magnetometer readings. ■ A series of non-linear filters were applied to fit a smoothed curve to the data. The results of the non-linear filters were then subtracted from the results of the β-spline filter to calculate a residual magnetometer data channel. ■ The filtered data were gridded using the minimum curvature gridding method. For gridding, a grid cell size of 0.5 m and a blanking distance of 2.5 m were used. ■ Magnetic anomalies were picked manually on the total field profiles and reviewed against the residual field grid to remove duplicates and erroneous picks, and to manually pick any missed anomalies. The reviewed list of anomalies was then manually measured for peak-to-peak amplitude.

2.2.7.4 Parametric Sub-bottom Profiler

Table 23: Sub-bottom profiler

Parametric Sub-bottom Profiler	
Requirement	■ 10 m penetration; ■ Vertical resolution: 0.2 metres; ■ Total horizontal uncertainty 2 m or better.
Equipment	■ System: Innomar SES-2000 Medium Parametric sub-bottom profiler; ■ Acquisition system: SESWIN;

Parametric Sub-bottom Profiler	
Data Collection	■ Innomar SBP data were logged in SES3 format by the SESWIN acquisition software, with navigation integrated within them from the Starfixonline navigation software. The geometry correction of the transducers to the Centre of Gravity (COG) is applied during acquisition in Starfix and SESWin. The SES3 files were converted to SEGY format with the Innomar SESConvert software and merged if the file had been split on different segments on acquisition. During conversion, deduplication and interpolation of the raw navigation was conducted to ensure each slot contained a unique coordinate. ■ The output SEGY files were processed in the RadExPro.
Processing	■ The signal processing flow comprised the following steps: ■ Shifting the data as per the record delay; ■ Amplitude correction Automatic Gain Control Window Length: 10 ms Percent: 25 %; ■ Butterworth bandpass filter with a low-cut of 2 kHz, and a high-cut of 15 kHz; ■ Burst noise removal (Window: 7, Rejection: 50 %); ■ Where occasional residual heave was observed, a swell filter was designed on a line-by-line basis over a 50 trace length smoothing filter ■ After signal processing the tide correction was applied as a trace-by-trace tidal reduction applied to the COG using the tidal curve and further corrections of the SBP data for the vessel's heave and reduction of the data to LAT. ■ Ultimately, the LAT corrected SEGY files were exported together with their headers and imported into the Kingdom software for QC against the MBES data to ensure that the tidal correction was successful and that there was a good correlation between the two datasets.

2.2.7.5 2D-UHRS

The 2DUHR Sparker data was recorded in Geometric GeoEel Controller with output file format as SEGD. The SEGD files were loaded into SeisQC software for quality check on acquisition geometry, basic geometry (streamer and gun depth), active channel, noise level, and velocity picking. Brutestack of SEGY data were prepared for onboard deliverable. Further processing such as noise filtering, processing derived stacking velocities and output to fully migrated SEGY were carried out onshore.

Detailed description of the processing flow can be found in Appendix C (F197217-REP-2UHR-SR Seismic Processing Report).

3. Seafloor Overview

3.1 Bathymetry

The bathymetry along the Aramis trunkline route ranges between 0 m and 39.5 m. The nearshore area is relatively flat intersected by the dredged Maasmond Kanaal (navigation channel). The middle of the route is characterised by bedforms such as ripple, megaripple and sand waves.

The seafloor in the northern part of the route, till the Platform L4A, is mainly featureless without bedforms and water depth decreases gradually towards the north.

Bathymetry and its relative slope are given per route section (Section 5 to Section 14).

3.2 Seafloor Morphology

Seafloor morphology interpretation was based on the combination of data from MBES and SSS. The data analysis was carried out using acoustic characteristics such as overall pattern, roughness and reflectivity.

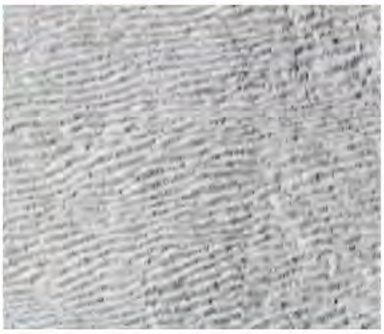
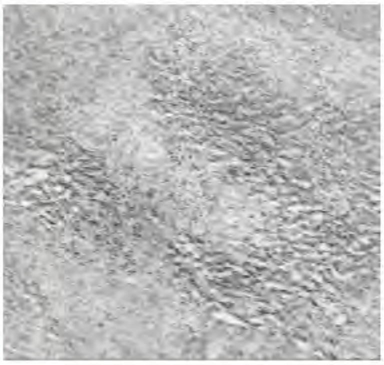
The following morphological characteristics / types were identified:

- Bedforms (ripples, megaripples and sand waves)
- Irregular seafloor
- Area with numerous boulders/debris
- Area with occasional boulders/debris

The acoustic characteristics of the identified morphological types are summarized in Table 3.1.

Table 24: Interpretation of seafloor morphology

SSS Image	Acoustic Description	Morphological Interpretation
	Low to medium reflectivity	Megaripples and sand waves

SSS Image	Acoustic Description	Morphological Interpretation
	Low to medium reflectivity	Ripples
 	Medium to high reflectivity	Irregular seafloor
	Medium to high reflectivity	Area with numerous boulders
	Medium reflectivity	Area with occasional boulders

The majority of the seafloor in the offshore area is featureless or characterised by presence of seafloor bedforms (i.e. ripples). Areas of boulders are observed through the entire route.

In the nearshore area, the seafloor is characterised by the presence of megaripples and sand waves, in addition, the seafloor is intersected by anthropogenic features.

3.2.1 Bedforms

Bedforms are produced by the action of bottom and tidal currents, which redistribute seabed sediments. Three types of bedforms were identified along the Aramis trunkline route:

- Sand waves
- Megaripples
- Ripples

Classification scheme by Ashley et al. 1990, was adopted in this report to distinguish and characterise bedforms and is detailed in Table 3.2.

Table 25: Classification scheme for bedforms (modified from Ashley et al. (1990)

First Order Description				
Size				
Spacing	0.6 to 5 m	5 to 10 m	10 to 100 m	>100 m
Height	0.075 to 0.4 m	0.4 to 0.75 m	0.75 to 5 m	>5 m
Term	*Small (ripples)*	*Medium (megaripples)*	*Large (sand waves)*	*Very large (sand dunes)*
Shape				
2D	Symmetric or asymmetric			
3D	Sinuous or hummocky			
Second Order Description				
Superposition				
Simple	No bedforms superimposed			
Compound	Smaller bedforms superimposed			

Along the Aramis trunkline route most of the bedforms fit in the range classified as ripples, although sometimes slight mismatch with the Ashley classification occurs.

Megaripples and sand waves can be found in topographical lows, where the sediment accumulates, and the currents rework the sediment creating these bedforms (Table 3.2 and Figure 3.1). In the nearshore area, the observed shape is symmetric, and the orientation is north-west to south-east. Their wavelength ranges from approximately 5.0 m to 8.0 m and the wave height varies between 0.3 m and 0.9 m. These bedforms are mostly associated with slightly gravelly SAND as interpreted from SSS and MBES data.

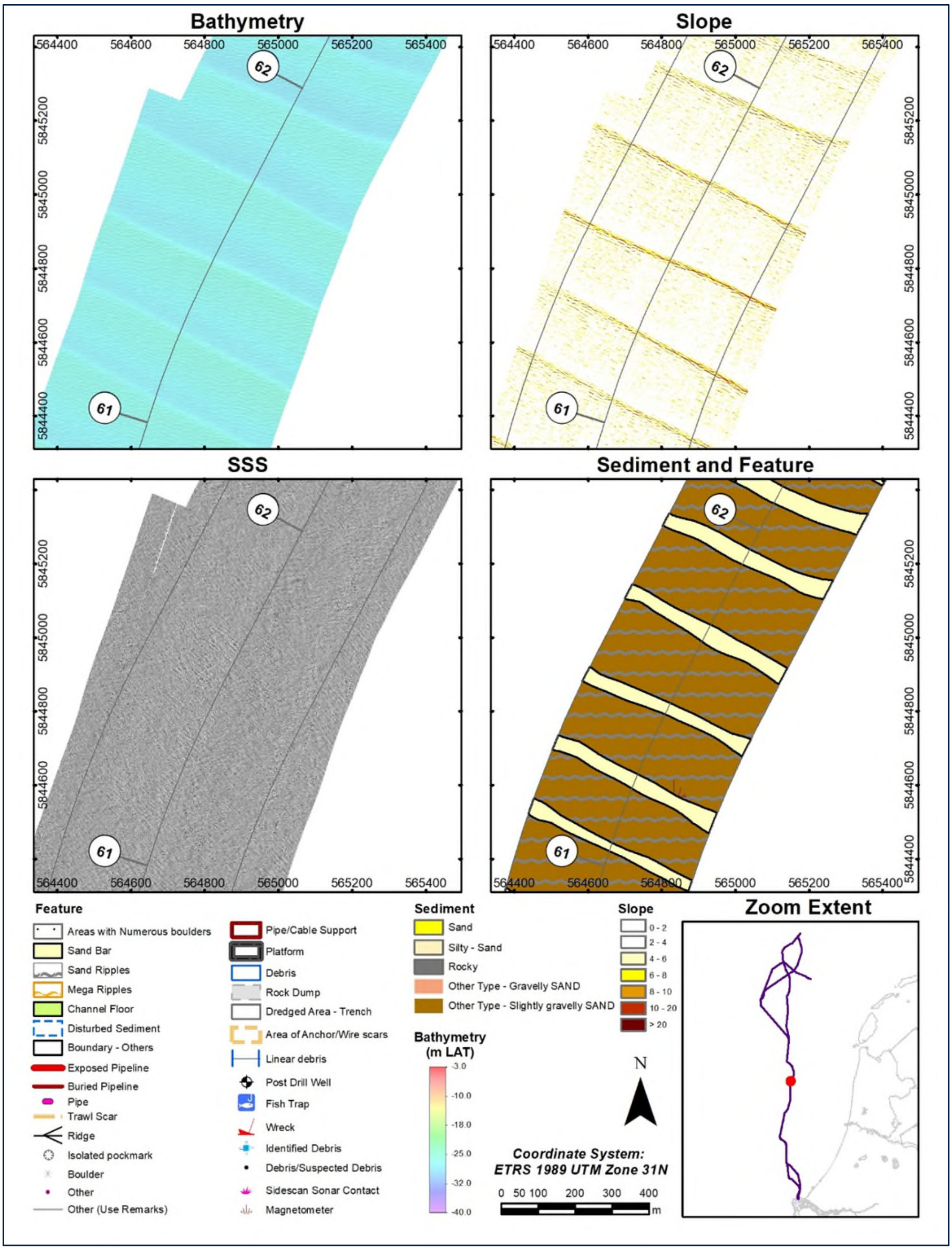


Figure 3.1: Example of megaripples ad sandwaves along the Aramis trunkline route.

In the offshore area, symmetrical (linear) ripples are the most common bedform type along the Aramis trunkline route. This type of ripples is typically found in shallow coastal waters and sandy substrate. They have generally north-west to south-east orientation. The wavelength ranges from approximately 3.0 m to 9.0 m and wave height varies between 0.1 m and 0.3 m (Figure 3.2). They are mostly associated with areas of slightly gravelly SAND as interpreted from the SSS and MBES data.

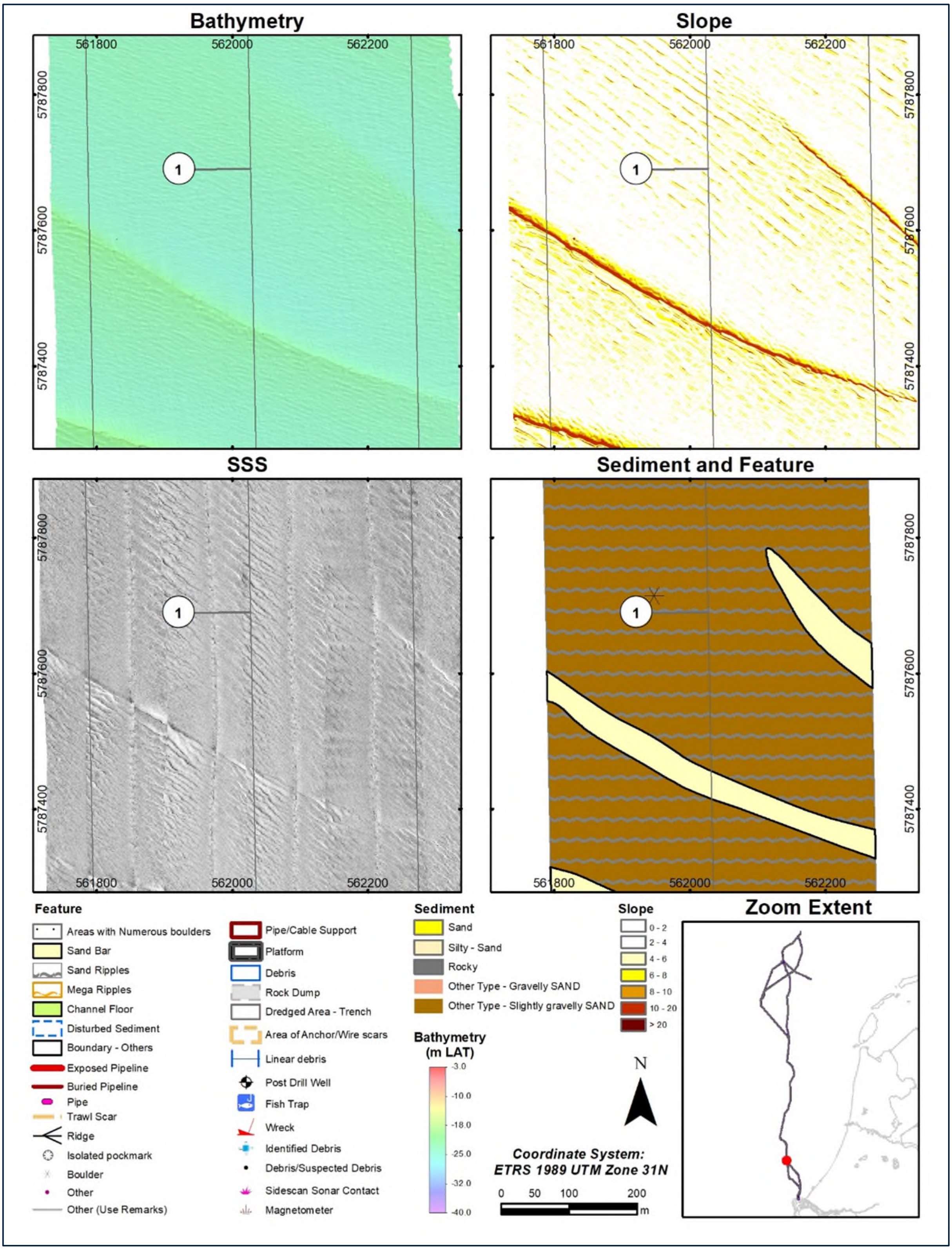


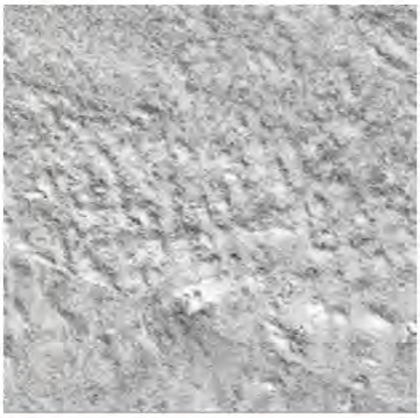
Figure 3.2: Typical area of symmetrical ripples along the Aramis trunkline route.

3.3 Seafloor Sediment Classification

Seafloor sediment interpretation and classification was based on a combination of data from MBES and SSS. The sediment classification was based on the British Standard code of practice (BSI, 2015). The data analysis was carried out using acoustic characteristics such as overall pattern, roughness and reflectivity.

The acoustic characteristics and the lithology (seafloor sediment types) identified are summarized in Table 3.3.

Table 26: Lithological classification

SSS Image	Acoustic Description	Lithological Classification
	High reflectivity	Gravelly SAND
	Medium to high reflectivity	Slightly gravelly SAND
	Patchy medium to high reflectivity areas	Muddy (silty) SAND

SSS Image	Acoustic Description	Lithological Classification
	Low reflectivity	SAND

The seafloor sediments identified by these sensors were as follows:

- Gravelly SAND
- Slightly gravelly SAND
- Muddy (silty) SAND
- SAND

3.4 Seafloor Features and Objects

Seafloor features and contacts were identified from one or more of the SSS, MBES and MAG sensors and cross-correlated, where possible. Only contacts greater than or equal to 0.5 m in any dimension were interpreted along the Aramis trunkline route.

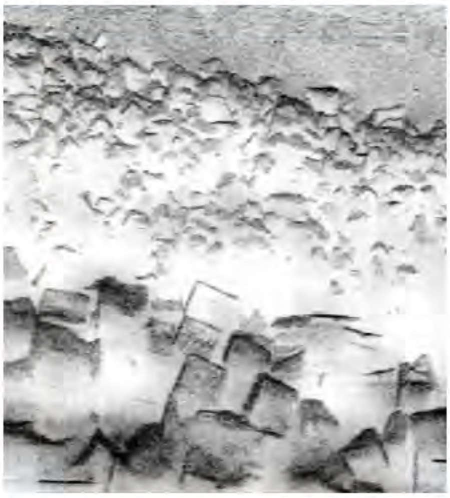
Table 3.4 summarises the identified seafloor features and Table 3.5 the quantities of contacts picked. Detailed description of distribution of the seafloor features is given in in Section 5 to Section 14).

The following seafloor features were identified:

- Scours/trawl marks
- Sediment dumping features
- Anthropogenic channel
- Wreck debris and possible wreck
- Possible fishing gear
- Cable trench (HKZ)
- Pipelines (buried or exposed)
- Cables
- Rock armour
- Unknown circular feature
- Unknown linear features

Table 27: Interpretation of seafloor features

SSS Image	Acoustic Description	Features Interpretation
	Low to medium reflectivity	Scours/Trawl marks
	Low to medium reflectivity	Sediment dumping features
	Low to high reflectivity	Anthropogenic channel
	Low to high reflectivity	Wreck debris and possible wreck

SSS Image	Acoustic Description	Features Interpretation
		
	Low to medium reflectivity	Possible fishing gear/fishing net
	Low to high reflectivity	Cable trench (HKZ)
	Low to high reflectivity	Rock armour

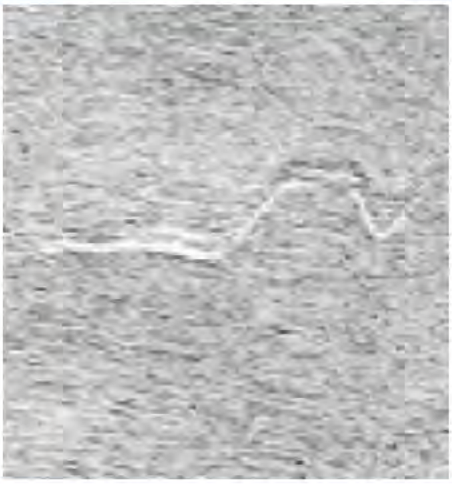
SSS Image	Acoustic Description	Features Interpretation
	Low to high reflectivity	Unknown circular features
	Low to high reflectivity	Unknown linear features
	Low to high reflectivity	Exposed pipeline

Table 28: Summary of seafloor contacts

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	3110
	Debris	159
	Depression pockmark	5
	Fishing gear	7
	Mattress	2
	Exposed pipe	4
	Seafloor mound	98
	Suspected debris	517
	Wreck	4
	Magnetic anomalies	2745
SSS/MBES/MAG	Debris	1

Sensor	Contact Classification	Quantity
Linear Features	Possible debris	1
	Fishing gear	4
	Possible fishing gear	42
	Large trawl scour	40
	Mound ridge	21
	Scour	7987
	Unknown linear feature	9
	Telecommunication cable	5
	Exposed pipeline	5
	Buried pipeline	41
	Magnetic linear feature	28

3.4.1 Cross Correlation of Contacts

A 2 m radius cross correlation between all SSS contacts and all MAG anomalies was performed. Only 11 point feature contacts cross correlate between the SSS and MAG sensors as reported in Table 3.6.

Table 29: Summary of cross corelating seafloor contacts

Section	SSS Target Name	MAG Target Name	Description
Section D	BK_FSEA_SSS_0084	BK_FSEA_MAG_0090	Debris
Section D	BK_FSEA_SSS_0086	BK_FSEA_MAG_0133	Debris
Section D	BK_FSEA_SSS_0163	BK_FSEA_MAG_0093	Debris
Nearshore area (Export Route East MT)	BB_FS_SSS_0593	BB_FS_MAG_0222	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0607	BB_FS_MAG_0247	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0642	BB_FS_MAG_0274	Suspected Debris
Nearshore area (Export Route East MT)	BB_FS_SSS_0884	BB_FS_MAG_0567	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0916	BB_FS_MAG_0605	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0929	BB_FS_MAG_0691	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0946	BB_FS_MAG_0710	Boulder
Nearshore area (Export Route East MT)	BB_FS_SSS_0678	BB_FS_MAG_0298	Wreck

4. Sub-seafloor Overview

4.1 Geological Setting

The investigation site is located in the southern North Sea.

The geological history of the southern North Sea started with the development of a complex system of basins and rifts in Northwest Europe during the Triassic (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).

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).

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.

During the Middle and Late Pleistocene, the depositional evolution of the North Sea basin was strongly influenced by climatic variations, glaciations and associated sea level fluctuations. Series of an alternating glacial and interglacial periods occurred (Figure 4.1) This resulted in a complex interplay of glacial, glaciolacustrine, glaciofluvial, fluvial, aeolian, deltaic and (shallow) marine environments and deposits (Laban, 1995; Peeters et al., 2015).

Detailed description of the different glacial and interglacial stages during the Pleistocene in the southern North Sea is provided below Figure 4.1.

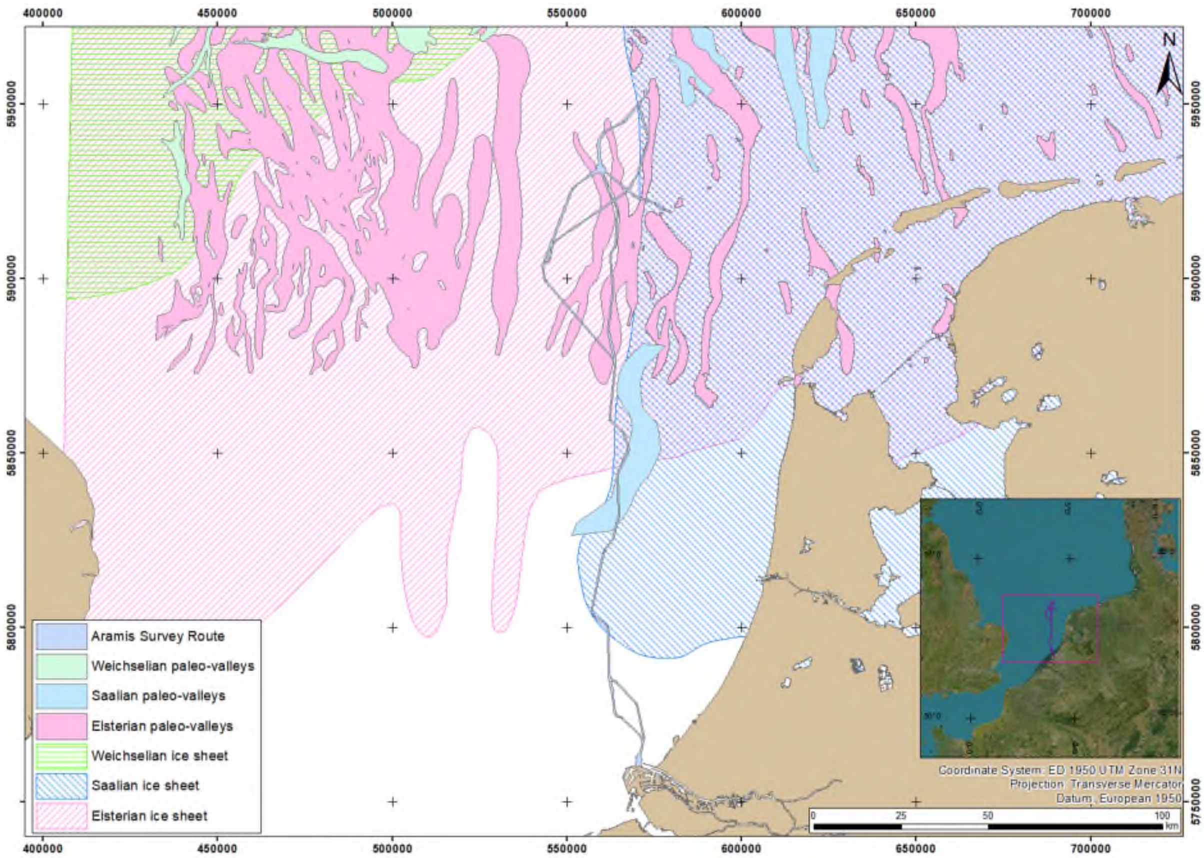


Figure 4.1: Maximum extent of the Quaternary glaciations in the southern North Sea.

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 Aramis route has been affected by the Elsterian ice sheet, while the southern half was influenced by the Rhine and Meuse River systems (Figure 4.2a). Deposition of predominantly low energy open marine deltaic sediments consisting of siliceous sands and clays resulted, which are thought to belong to the Yarmouth Roads Formation (Rijsdijk et al., 2005). Elsterian subglacial tunnel valleys were cut into the Yarmouth Roads Formation. They are present in the northern half of the route. The infill of these tunnel valleys comprises glaciofluvial (sand), glaciolacustrine (clay) and proglacial clays and sands of the former Swarte Bank Formation (now part of the Peelo Formation; Praeg, 1996; Graham et al., 2011; Moreau et al., 2012). The Elsterian valleys form a complex system of anastomosing, but mainly NNE–SSW trending, broad (approximately 1 km to 10 km wide) and deep (locally up to 400 m BSF) erosional features.

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. Fluvial and marine deposits were prevalent in this period. The fluvial deposits have been defined as the 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 comprise predominanlty marine sands, but locally can contain clay interbeds. The Egmond Ground Formation may locally incise into the underlying Yarmouth Roads Formation.

Saalian Glaciation (Middle to Late Pleistocene)

During the Saalian glaciation (370 ka to 130 ka BP), the Aramis route was near the Saalian Ice Margin (Figure 4.2.b). However, the exact limit of the ice sheet advance offshore remains uncertain.

Ice masses formed glacially scoured basins and several ice-pushed ridges (moraines). Numerous tunnel valleys were created during the Saalian in subglacial and proglacial settings. A major 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 Aramis route. 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). More tunnel valleys may be present near the north-eastern boundary of the Aramis route (Cameron et al., 1986; Joon et al., 1990).

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).

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.

Eemian Interglacial (Late Pleistocene)

A major marine transgression affected the southern North Sea during the Eemian interglacial (130 ka to 115 ka BP). The area became part of the delta plain of the river Rhine (Figure 4.2.c). 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.

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 northern part of the Aramis route (Figure 4.2.d; Cameron et al., 1986; GDN, 2018).

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 north-west of the Aramis site. 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 4.2.e).

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

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 of paleochannels. Locally, peat beds were deposited in shallow marsh settings (Nieuwkoop Formation). As transgression progressed, the site was overlain by sands of the Southern Bight Formation and muddy sands of the Urania Formation (only in the furthest north of the site).

The North Sea Basin has remained essentially sediment starved since the start of the Holocene, and deposits occur mainly in the form of sand banks and sand waves (Liu et al., 1993). Surficial sediments mainly consist of sand with shells and shell fragments typical of a high energy, open marine environment. These sands are partly derived from reworking of the sediments from the underlying fluvial deposits. Sands with a higher mud fraction are present in deeper parts and are indicative of a low energy open marine environment.

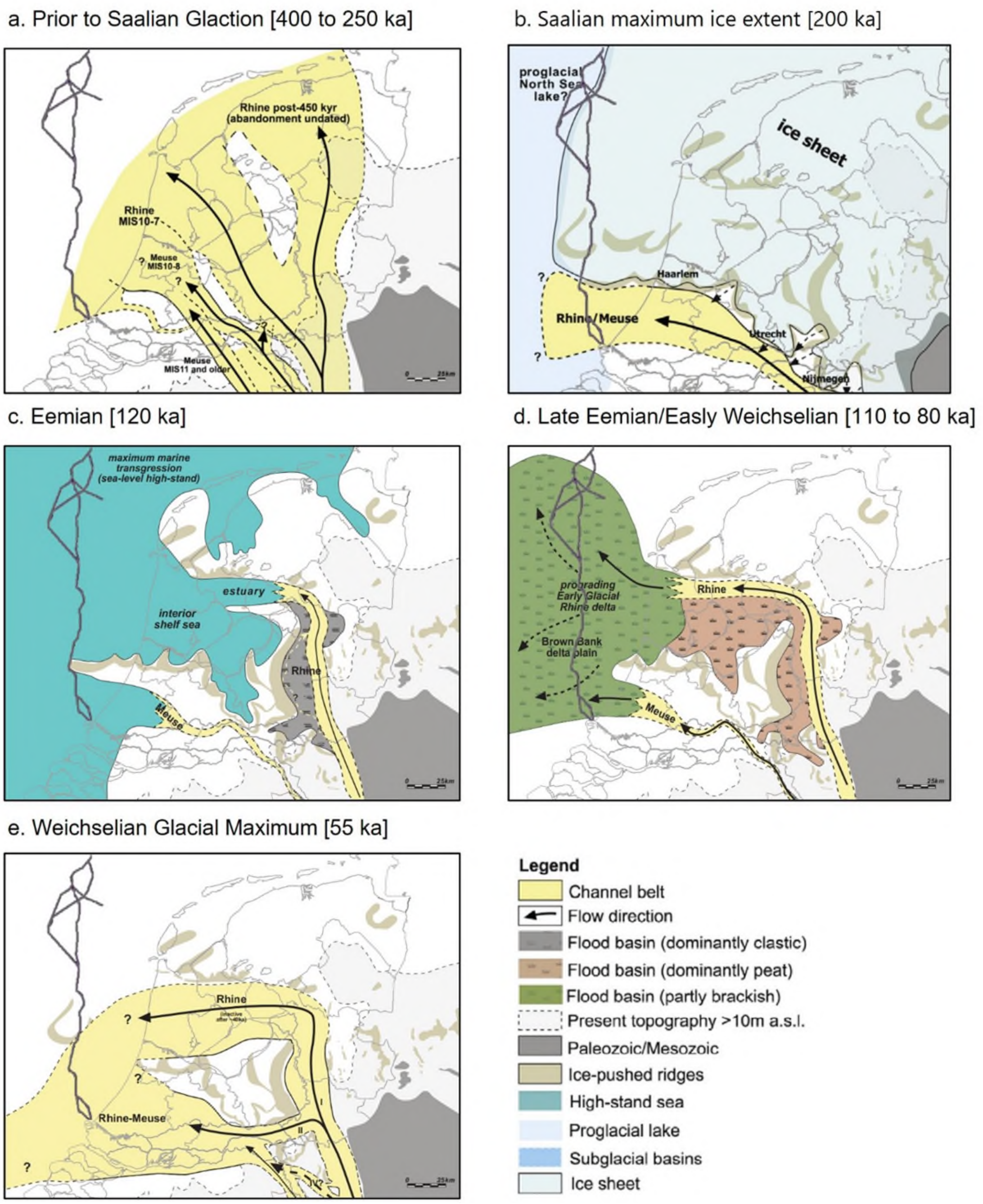


Figure 4.2: Palaeo-geographical reconstructions of the Netherlands during the Middle to Late Pleistocene. illustrated by five successive time frames. a) Rhine–Meuse drainage configuration prior to Saalian Glaciation. b) Maximum Saalian ice extent. c) Eemian interglacial maximum transgression during sea 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).

4.2 Seismostratigraphy

4.2.1 Overview

Table 4.1 provides an overview of the seismic horizons and corresponding seismostratigraphic units as interpreted in the SBP and 2D-UHRS data. The table and this section should be read in conjunction with the charts provided in Appendix A.

Nine horizons were interpreted, each representing a significant acoustic interface consistent across the site, which forms the base of a seismostratigraphic unit. In addition, the extent of geological features, such as intraformational buried channels, layers of potential peat and acoustic blanking, indicating possible gas in soil were interpreted.

The sub-seafloor information presented in this section considers two seismic reflection datasets. These include:

- Sub-bottom profiler (SBP) data with a typical penetration of the seismic signal below seafloor between approximately 8 m and 15 m BSF;
- 2D ultra-high-resolution multichannel seismic (2D-UHRS) data with a typical penetration of the seismic signal below seafloor of approximately 200 m BSF.

The SBP data were acquired within an approximately 500 m-wide corridor and the 2D-UHRS data, except of the nearshore area and the HUB area, were acquired along the centre line only. The 2D-UHRS data were interpreted down to a minimum depth of 100 m BSF.

Shallow seafloor CPT data were used to aid the interpretation of the SBP data. Details on geotechnical data (CPT and VC boreholes) with be integrated and provided in the next issue of this report.

The vertical scale in the seismic data examples presented in the following sections and on the geological profiles is in two-way travel time (TWTT) in seconds below LAT. Included is a vertical scale bar in metres that was estimated using a constant sub-seafloor velocity of 1600 m/s.

Refer to Section 3 for details on data processing, interpretation methodology and data resolution limitations.

Section 4 provides a general overview of the sub-seafloor geology, while a more detailed description is provided in Sections 5 through 14, where each section of the route is treated separately.

Table 30: Overview of interpreted seismostratigraphic units

Dataset	Unit	Horizon Top	Horizon Base	Seismic Signature and Character of the Base	Distribution	Lithology	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)	Very loose to very dense slightly silty fine and medium SAND	-	-
	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	Very loose to very dense slightly silty to silty fine and medium SAND with occasional shells and shell fragments Locally low to medium strength slightly sandy CLAY, with closely spaced thin laminae of silt Locally clayey fine 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	Medium to very dense slightly silty fine and medium SAND with occasional shells and shell fragments Locally with medium to thick beds of extremely low to high strength sandy CLAY Locally with very closely spaced thin laminae to medium beds 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	Very loose to dense very silty fine and medium SAND with occasional pockets of organic matter Locally low strength to high strength sandy CLAY with medium spaced very thin beds of sand Locally low to medium strength sandy clayey SILT	*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	Loose to very dense slightly silty fine and medium SAND, occasionally slightly gravelly	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	Medium dense to very dense SAND locally with beds of CLAY and SILT	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	Interbedded medium dense to very dense (silty) SAND and high strength to very high strength (sandy) CLAY	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	Medium dense to very dense SAND Locally with layers of high strength to very high strength CLAY or SILT, locally laminated	Yarmouth Roads	Fluvio-deltaic to marine

Notes:
DS = disturbed sediments
Hyphen = not applicable
BPD = below penetration depth of seismic reflection data

4.2.2 Unit DS

Disturbed sediments are present exclusively in the dredged Maasmond Kanaal. The base of these sediments is uncertain and taken at the base of high amplitude reflections or at the top of structured seismic facies, which were very locally observed. The unit has semi-transparent and chaotic seismic character.

4.2.3 Unit A

Unit A is the shallowest unit and is interpreted to be present across the entire route. The unit is interpreted to be absent in the Maasmond Kanaal in the nearshore part. Locally it is very thin and may be absent (seismic data cannot resolve the top approximately 30 cm). The thickness variation of the unit largely follows the seafloor morphology. The unit is thickest (approximately 3 m) near the crests of sand banks and sand waves and thins towards the troughs, where it may be locally absent (Figure 4.3).

The base is marked as Horizon H10, which is characterised by a near-flat surface It is typically a medium to high-amplitude reflector and/or the interface between seismically different characters.

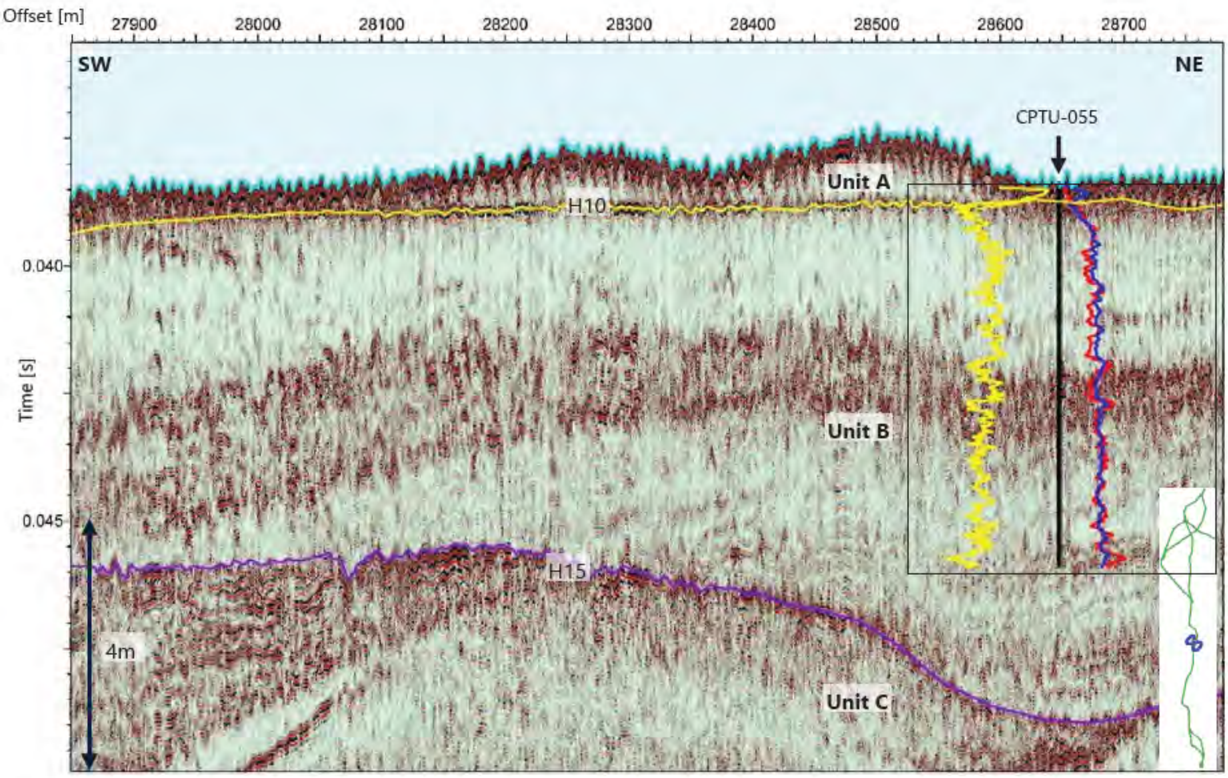


Figure 4.3: SBP data example of the internal seismic character of Unit A at sand waves. (Line SBP_TA3E2132P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 5 MPa, sleeve friction values (red curve) from 0 to 0.125 MPa and friction ratio (yellow curve) from 0 to 4 %.

Unit A generally appears to be acoustically transparent. Locally, high amplitude internal point reflections or short reflectors were observed. In the larger sand waves, locally weak progradational structures were observed.

The unit consists of loose to very dense sand. The unit is interpreted to be deposited in an open marine environment in response to the marine transgression during the Late Holocene and belongs to the southern Bight Formation. The unit represents mobile sediments, reworking material of underlying deposits.

4.2.4 Unit B

Unit B is interpreted to be present in the entire Aramis route, except in the Maasmond Kanaal. The thickness of this unit varies and is driven by the depth of the basal erosional surface, reaching locally a maximum depth of approximately 15 m BSF. Unit B is overlain by Unit A but may be locally exposed at seafloor, mostly in the troughs between the sand waves.

The base of Unit B is marked by Horizon H15, which forms a distinctive irregular erosional surface, locally cutting deeply into the underlying units (Figure 4.4).

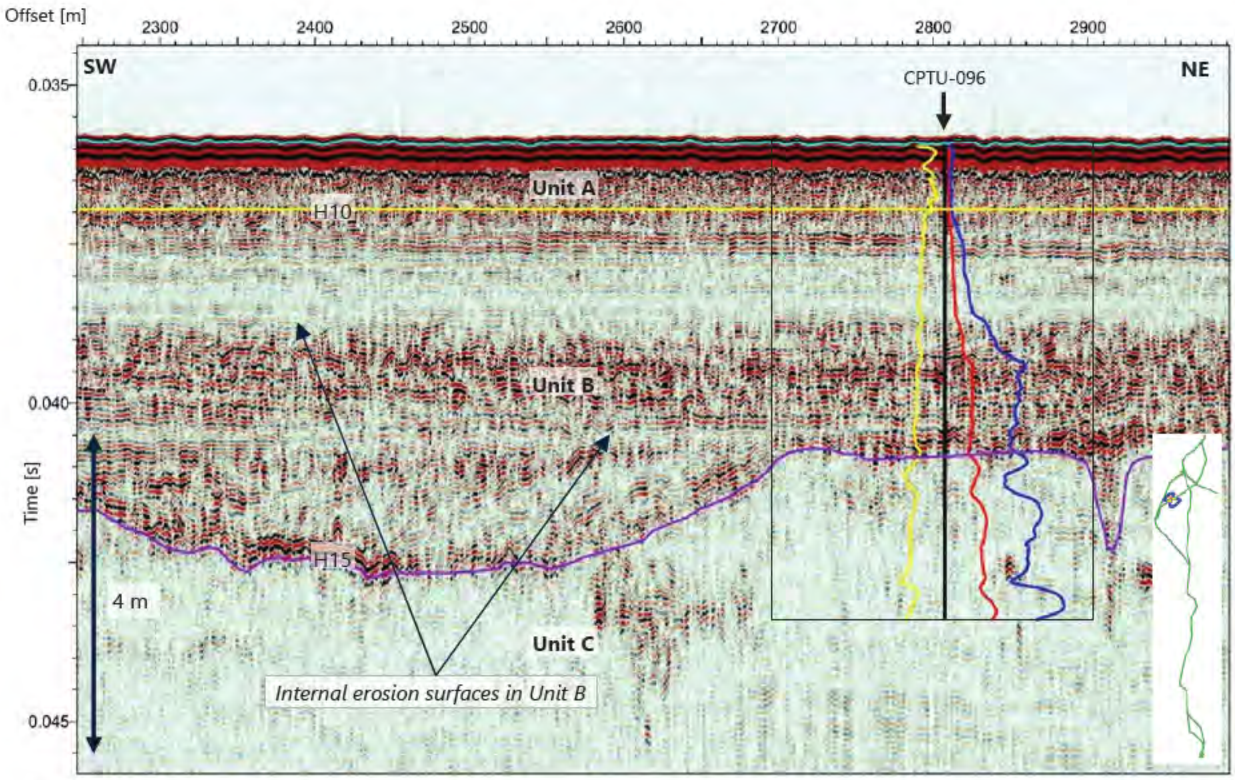


Figure 4.4: SBP data example of the internal seismic character of Unit B. (Line SBP_TA3M2320R1_2) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

In the SBP data, the basal reflector is typically a weak, low amplitude reflector in the southern part of the route and a medium to high amplitude reflector in the northern part of the route. In the south-central part of the route (Section A-Alt) the base of the unit is not visible or lies below penetration of the SBP data. This can be due the similar soil conditions (and thus low impedance contrast) between Unit B and the underlying Unit D in this part of the route.

In the 2D-UHRS data, the base of the unit is marked by a weak reflector of variable polarity, towards the north the base is marked increasingly by a medium to high amplitude negative reflector.

The unit has a variable internal seismic character, ranging from semi-transparent to chaotic with numerous discontinuous and often high-angle medium to high-amplitude reflections.

Internal channels and channels at the base with different dimensions were observed in the unit. The infill of the channels is variable, but typically well-layered and with high-amplitude reflectors.

High negative amplitude anomalies are common in this unit, especially in the northern part of the route, which potentially represent layers of peat and/or organic-rich clay.

The unit is variable in terms of soil conditions, comprising medium dense to very dense (silty) sand, with laminations and beds of clay, silt, and peat.

Based on its variable seismic character, stratigraphic position, and the presence of internal channels, this unit is interpreted to represent early Holocene coastal and tidal deposits, and possibly belonging to the Naaldwijk Formation. Locally the unit may include sediments of Boxtel Formation and especially in the southern and south-central part of the route, a large part of this unit may belong to the Kreftenheye Formation. The differentiation between these formations is difficult due to similar soil conditions (predominantly sand).

In the nearshore area, deposits of the Kreftenheye Formation are below the base of the interpreted Naaldwijk Formation.

4.2.5 Unit C

Unit C is present in the northern and central part of the route. The base of the unit is marked by Horizon H20, which typically forms a distinctive nearly flat erosional surface, locally, in the central part of the route it cuts into the underlying unit forming a wide depression(s). In this part of the route, the unit is thickest and several internal erosion surfaces were observed (Figure 4.5).

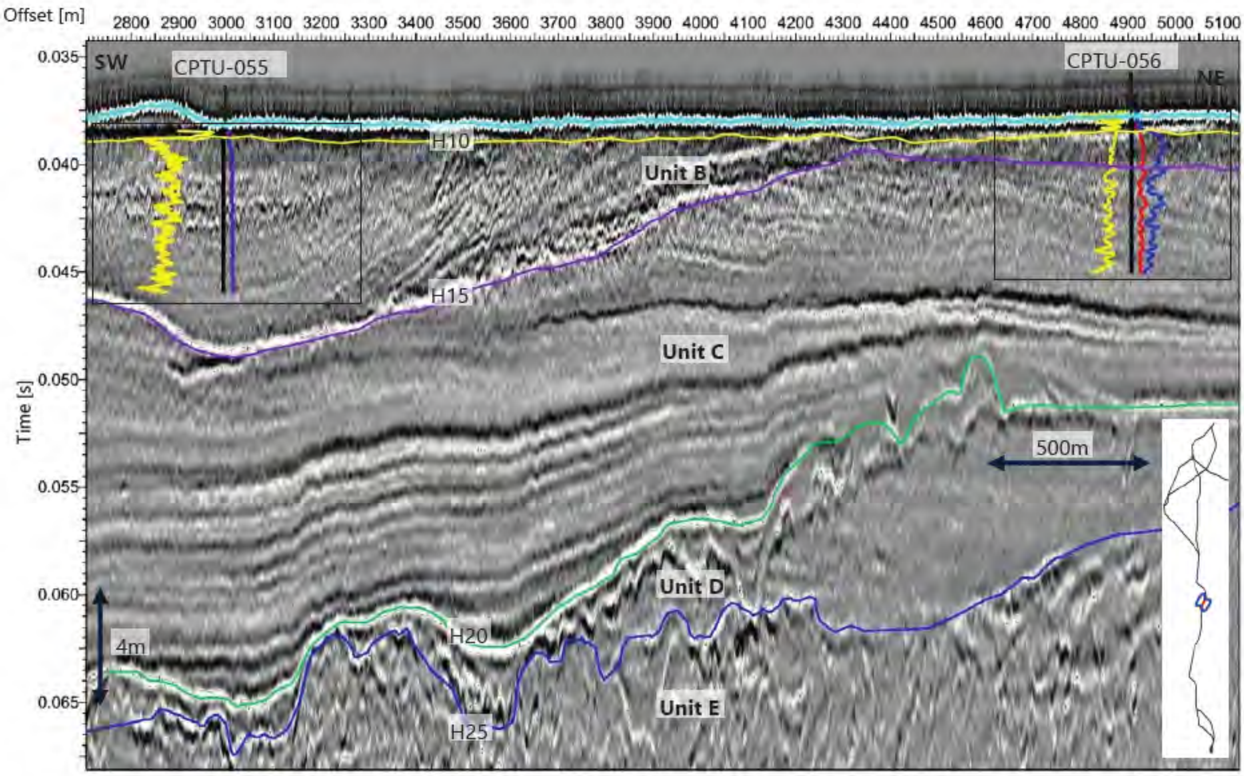


Figure 4.5: 2D-UHRS data example of the internal seismic character of Unit C. (Line 059-TA3A1542P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

The unit for most of the route is characterised by bedded seismic facies, consisting of parallel reflectors. Locally, in the upper part of the unit, structureless, semi-transparent intervals within the unit were observed. In the north-eastern part of the route, the unit is characterised by overall semi-transparent seismic facies with local high amplitude reflectors of various extent. The high amplitude negative (2D-UHRS data) reflectors may indicate layers of pockets of peat and/or organic clay.

The layered nature of the unit is expected to correlate with sand and clay alternations, and local beds of peat. The unit is interpreted to be deposited in a range of coastal (estuarine), tidal flat or lagoonal environments and corresponds to the Brown Bank Member.

4.2.6 Unit D

Unit D is present across the entire route, except small part of the route (approximately 15 km) in the central part, and in the most southern part, where it is interpreted to be absent. In the central part, the area where unit is absent, the base of the overlying Unit C is thickest and forms a wide depression.

The base of the unit is marked by Horizon H25 and generally forms a flat erosional surface, which is occasionally undulating and channelised (Figure 4.6). The base typically forms a medium to high-amplitude negative reflector, although this may vary due to the heterogeneity of the underlying sediments.

The unit has in general a structureless and semi-transparent acoustic character. Locally, layered intervals, internal erosion surfaces marked by strong inclined reflectors or forming broad channel-like features. Internal buried channels are locally present. The infill of these channels is various from chaotic to bedded with inclined parallel reflectors.

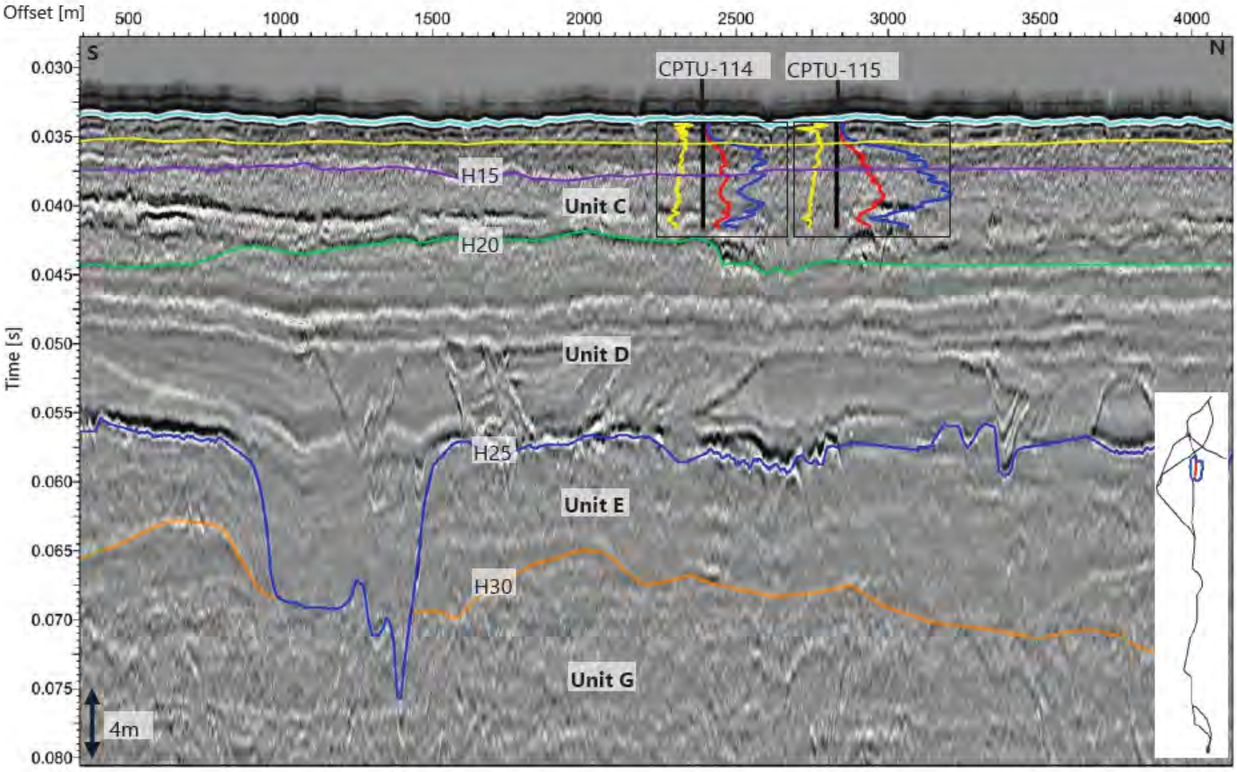


Figure 4.6: 2D-UHRS data example of the internal seismic character of Unit D. (Line 085-TA3A1562P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

Unit D is expected to comprise predominantly sand, with very locally clay or peat alternations, deposited in open marine and tidal environments. The unit is thought to belong to the Eem Formation.

4.2.7 Unit E

Unit E is present in the northern part of the route.

The base of the unit is marked by Horizon H30 and generally forms an undulating erosional surface. The base typically forms a weak low amplitude reflector.

The unit has in general a structureless and semi-transparent acoustic character, to locally chaotic with high amplitude negative point reflections (Figure 4.7). The acoustic facies of this unit are similar to the underlaying unit. As a result, it is very difficult to trace this interface in some parts of the route.

Unit D is expected to comprise predominantly sand, occasionally with thin layers or pockets of clay or peat, deposited in open marine and tidal environments. The unit is thought to belong to the Egmond Ground Formation.

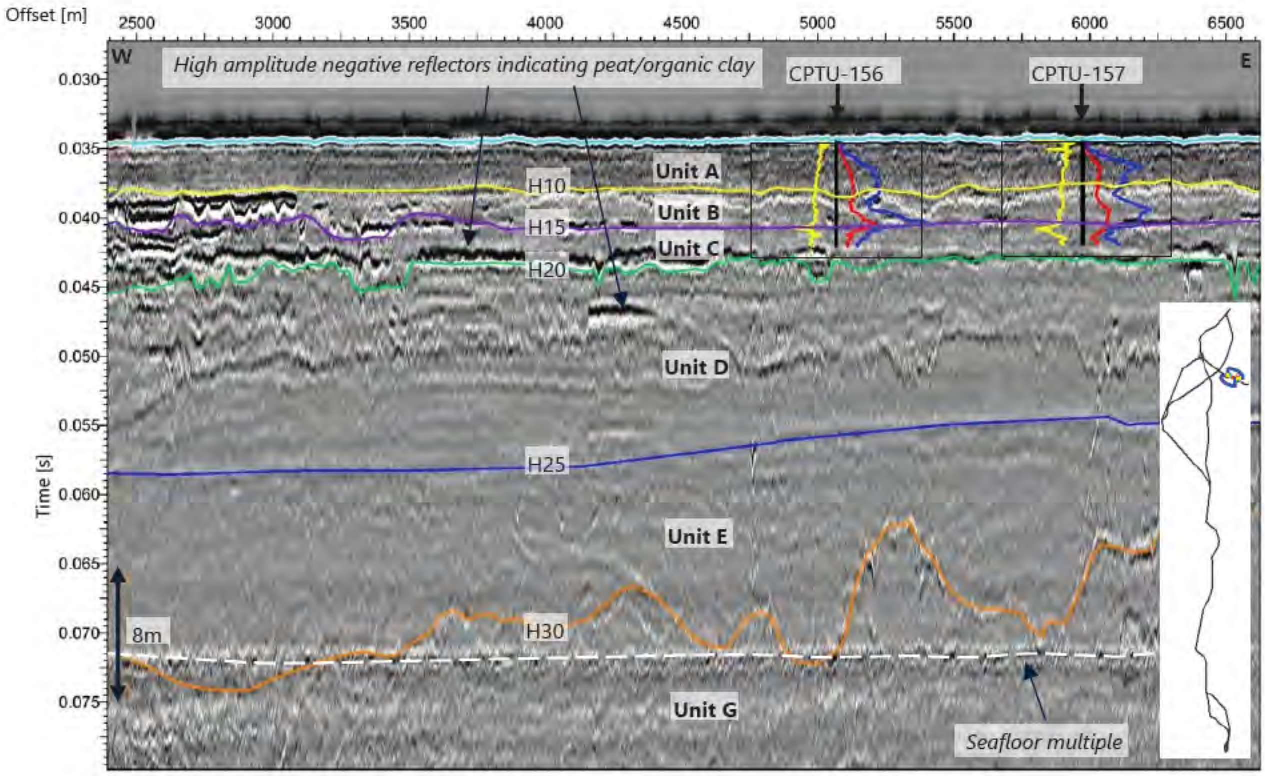


Figure 4.7: 2D-UHRS data example of the internal seismic character of Unit E. (Line 196-TA3A1608P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

4.2.8 Unit F

Unit F is present locally in the northern half of the route. The unit forms the infill of deeply incisive U-shaped channel-like features with steep flanks. They cut into the underlying Unit G, reaching locally depths below the penetration of the 2D-UHRS data. Such features in this part of the North Sea are considered as glacial tunnel valleys.

The base of the unit is marked by Horizon H35, which form a boundary between relatively more acoustically transparent infill (Unit F) and chaotic facies outside (Unit H). Flanks of these glacial valleys are not always clear on seismic data and given the data were acquired on a single line, they are difficult to trace locally. As a result, the extent of this unit is locally uncertain and may be larger than interpreted.

The internal character of Unit F is characterised in general by semi-transparent to chaotic seismic facies. Often, especially in the upper part, discontinuous, irregular, and wavy (folded?) medium to high-amplitude reflectors were observed (Figure 4.8). Occasional amplitude anomalies may be present within the unit.

Intra-formational channels with high-amplitude reflections are observed sometimes near the top of the unit.

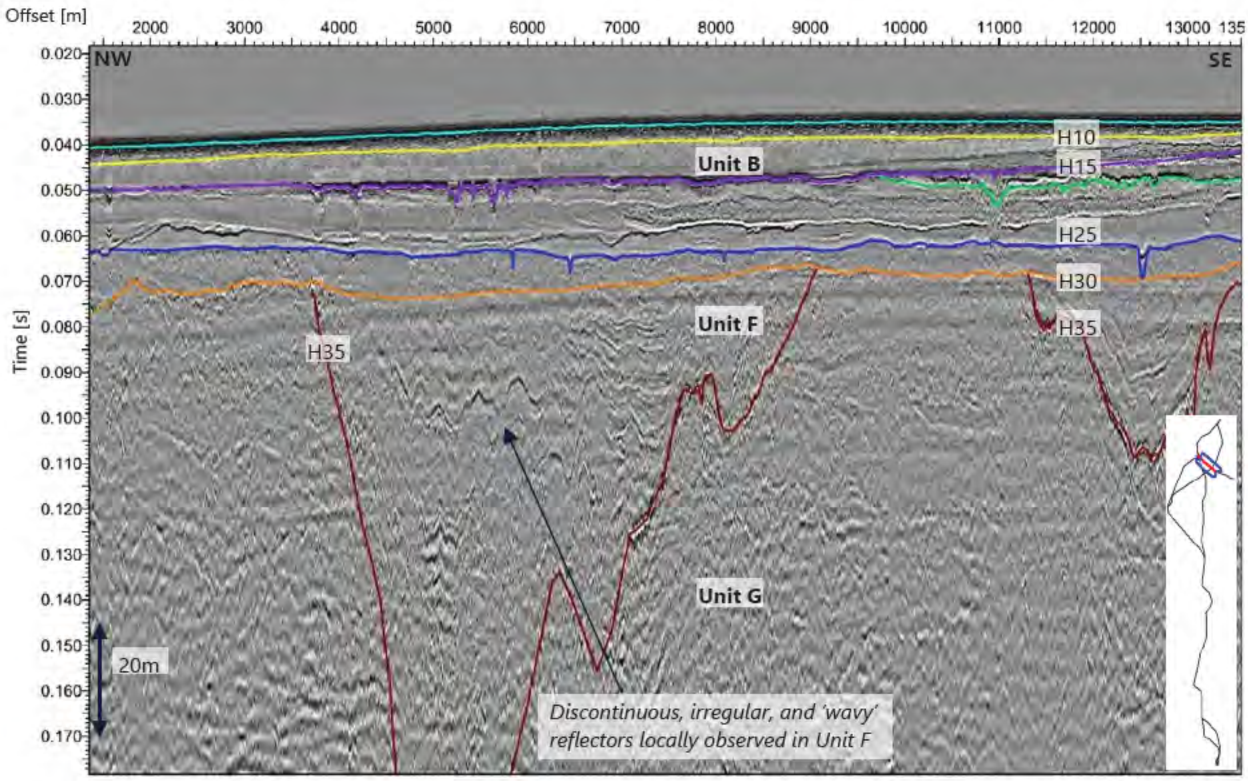


Figure 4.8: 2D-UHRS data example of the internal seismic character of Unit F. (Line 180-TA3A1606P1)

The dimensions and stratigraphic position of the glacial tunnel valleys correspond to the Elsterian age. Based on the public domain data and Fugro database, the unit is expected to consist of mainly clay with frequent (silty) sand interbeds deposited in glacial, glaciofluvial and glaciolacustrine environments. These deposits are interpreted to belong to the Peelo Formation.

4.2.9 Unit G

Unit G is the deepest unit observed in the seismic data within depth of interest and is present across the entire route. The base of this unit is beyond the penetration depth of the 2D-UHRS.

An internal reflector Horizon H40 was interpreted in the southern part of the route. Locally, this reflector shows high amplitude and negative polarity, indicating possible bed or laminae of peat and/or organic clay (Figure 4.9).

The internal acoustic character of the unit is complex, from semi-transparent to chaotic, with locally discontinuous reflectors, internal erosion surfaces and various internal channels. This complexity results from the nature of the depositional setting of this unit (fluvial to deltaic) and post-depositional processes such as glacial activity, including erosion and possibly deformation. Particularly, extensive glacial erosion affected the unit during Elsterian and Saalian glaciations.

The unit is expected to consist of predominantly sand with occasional clay and silt interbeds, and local beds of peat. Unit G is interpreted to be deposited in a fluvio-deltaic to marine environment and corresponds to the Yarmouth Roads Formation.

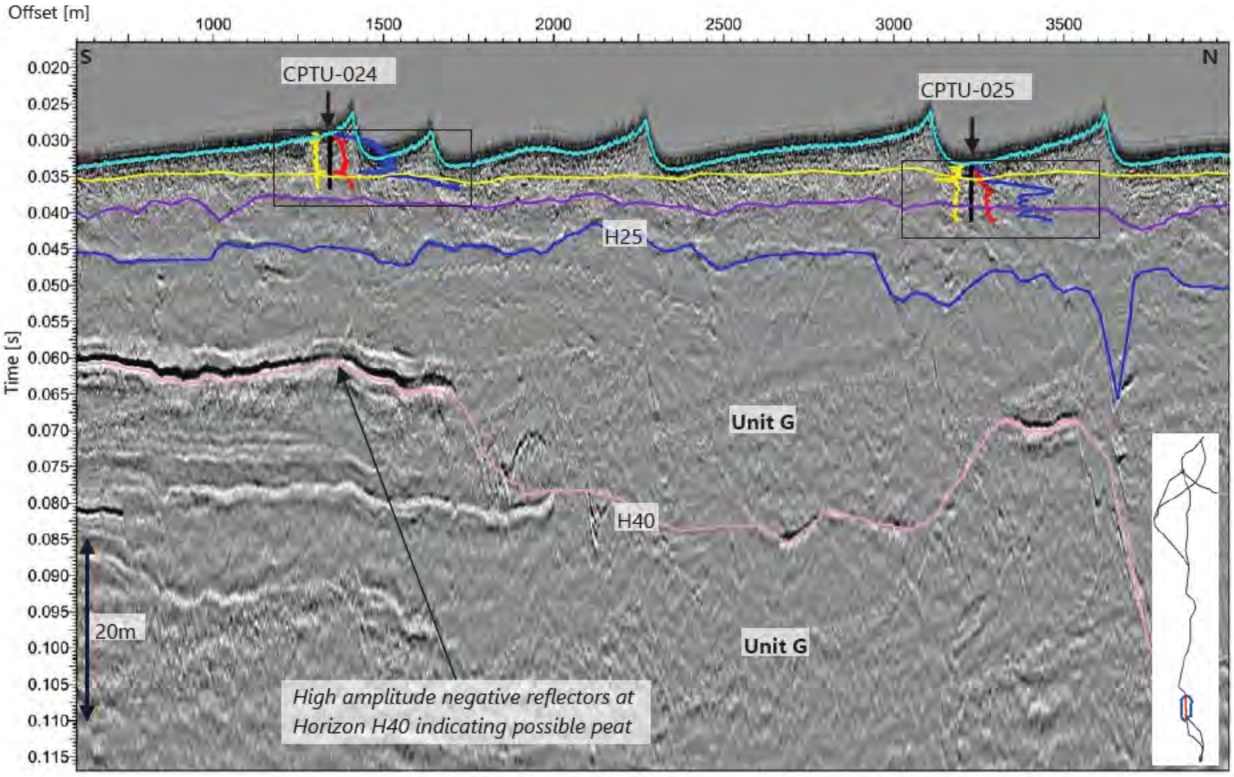


Figure 4.9: 2D-UHRS data example of the internal seismic character of Unit G. (Line 012-TA3A1525R1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 50 MPa, sleeve friction values (red curve) from 0 to 1.25 MPa and friction ratio (yellow curve) from 0 to 4 %.

4.3 Geological Features and Geohazards

4.3.1 Buried Channels

Repeated changes in depositional environment, multiple episodes of subaerial exposure, combined with marine transgression events and glacial and marine erosion during the Pleistocene have caused buried channel to be formed and filled over time.

Internal buried channels and channels at the base were observed in all units except Unit A.

Buried channels in Unit B were mapped based on SBP data. These channels are often located towards the top of the unit, have NW-SE orientation and limited extent (Figure 4.10). They often have a layered infill. The formation of these channels may be related to low-energy, coastal (tidal flat) depositional environments of the Early Holocene.

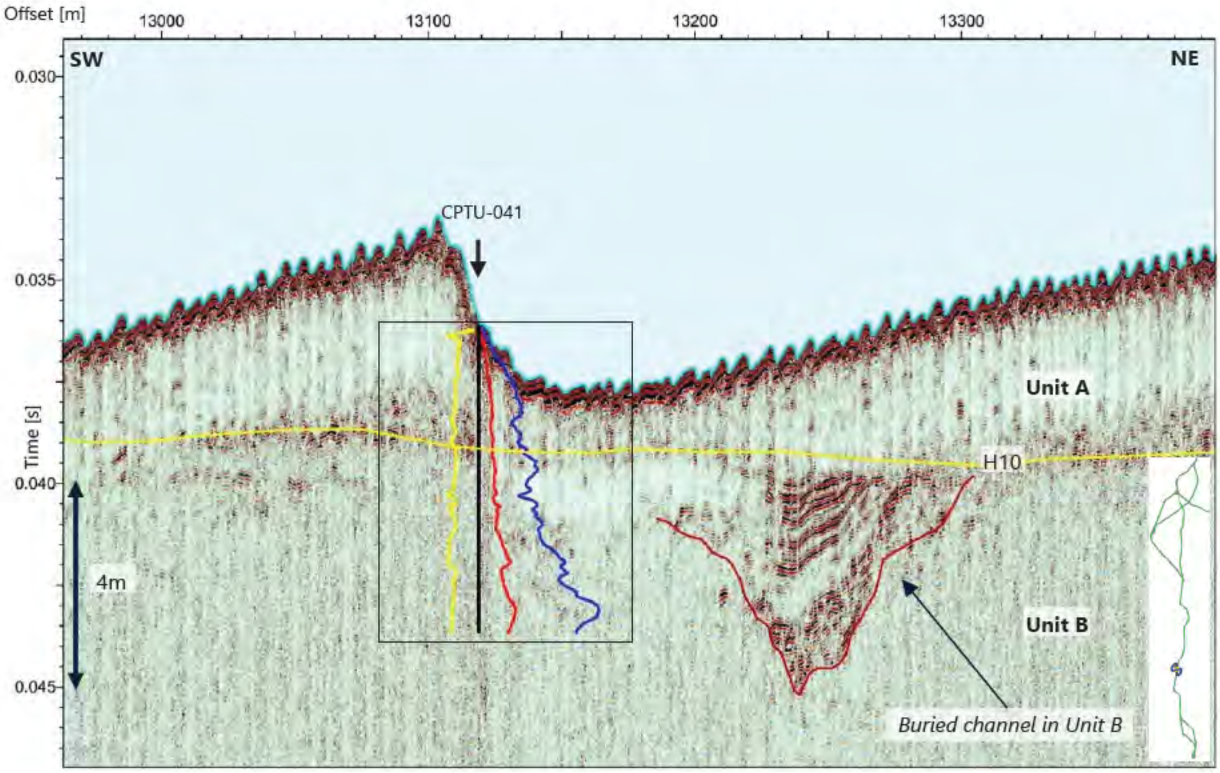


Figure 4.10: SBP data example of buried channels in Unit B. (Line SBP_TA3D2118P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

The base of Unit B, Unit C and Unit D is locally channelised (Figure 4.11). The base of Unit B is mainly channelised in the western part of the northern and central part of the route.

The base of Unit F forms the deeply incised glacial tunnel valleys.

Near the top of Unit F, locally bedded, high-amplitude reflectors forming channel-like shape were observed. These features are associated with the glacial tunnel valleys of Elsterian age and appear to represent a late stage of the infill of these tunnel valleys that may took place in lacustrine environment.

4.3.2 Peat

On the SBP data, the high amplitude reflectors that may indicate peat and/or organic clay were associated with Unit B (Figure 4.11).

High negative amplitude anomalies were observed in the 2D-UHRS seismic data. These negative amplitude events most likely represent peat and/or organic-rich clay. Peat layers were identified at a few stratigraphic levels: *2D-UHR_peat_level 1* – associated with Unit B; *2D-UHR_peat_level 2* – associated with Unit C, Unit D and Unit E; *2D-UHR_peat_level 3* – associated with Unit F and Unit G.

Peat is most common in the northern part of the route, except 2D-UHR_peat level 3, which is present along the entire route, but its distribution is very limited.

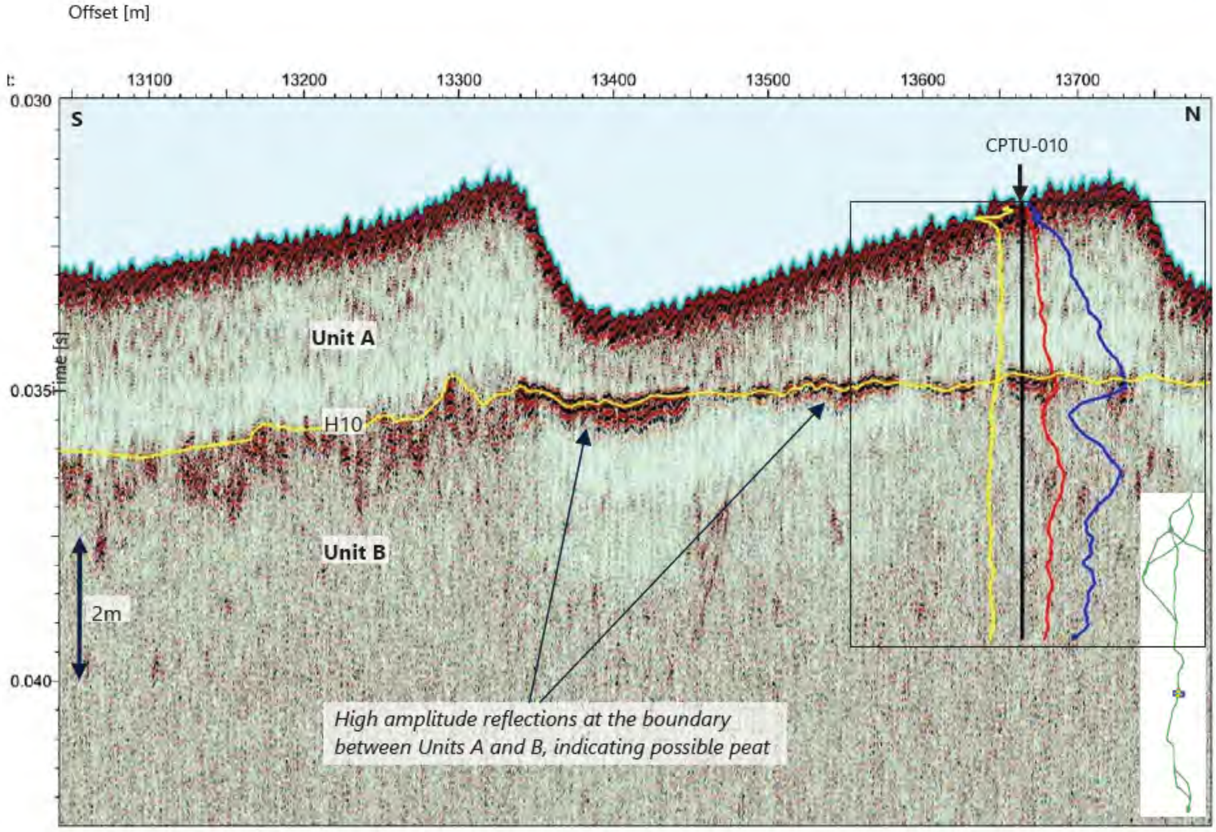


Figure 4.11: SBP data example of anomalies indicating possible peat in Unit B. (Line SBP_TA3E2134P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

4.3.3 Shallow Gas

Acoustic blanking can indicate presence of gas in soil. It was observed locally in the nearshore area. The minor acoustic blanking or signal distortion that was observed below some of the negative amplitude anomalies is thought to be related to the presence of peat (Figure 4.12). However, the presence of gas/fluid-charged sediments cannot be excluded entirely.

Acoustic blanking or signal distortion beneath some channels (mostly in Unit B) may be related to the high acoustic impedance contrast between the channel infill and surrounding sediments, in combination with the flanks of the channels being too steep to be imaged properly.

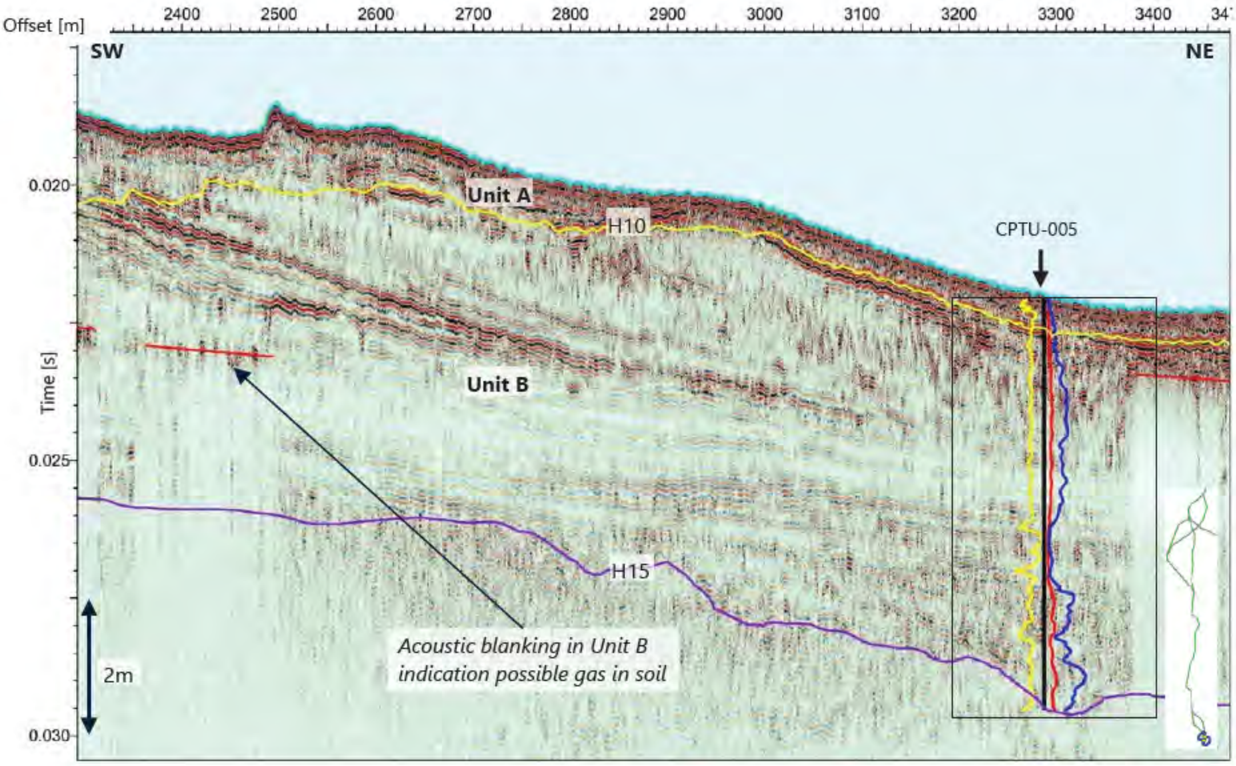


Figure 4.12: SBP data example of acoustic blanking in Unit B. (Line SBP_TA3C2020P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

4.3.4 Boulders, Cobbles and Gravel

A few diffraction hyperbolas were observed in the SBP data and are interpreted to represent possible boulders, cobbles and/or coarse gravel.

It should be noted that interpretation of these features is speculative and diffraction hyperbolas may be the result of factors other than the presence of boulders, cobbles or coarse gravel. Diffraction hyperbolas might be out of plane reflections which represent objects away from the SBP track line. Objects in between track lines may not be imaged in the SBP data and therefore not identified. Data quality influences the ability to image diffraction hyperbolas. Interpreting diffraction hyperbolas is subjective to some extent.

Given the geological setting (i.e. the expected presence of periglacial and glacial sediments), boulders and cobbles can be expected along the Aramis route. Hence, their presence cannot be ruled out.

4.3.5 Glacial Deformation

Glacial deformation is typically expressed in seismic data as chaotic internal reflections, inclined shear planes, deformed and folded strata and disturbance of the original internal structure.

The Aramis trunkline area has been affected by two glaciations, the Saalian and the Elsterian, which may have resulted in thrusting and folding of sediments due to glacial loading and ice sheet advances and retreats. The units that may have been affected are the pre-Saalian units (Unit F and Unit G).

Evidence of possible deformation was observed in Unit G, especially in proximity of glacial tunnel valleys (Unit F). These features are thought to be related to the Elsterian glaciation (Figure 4.13).

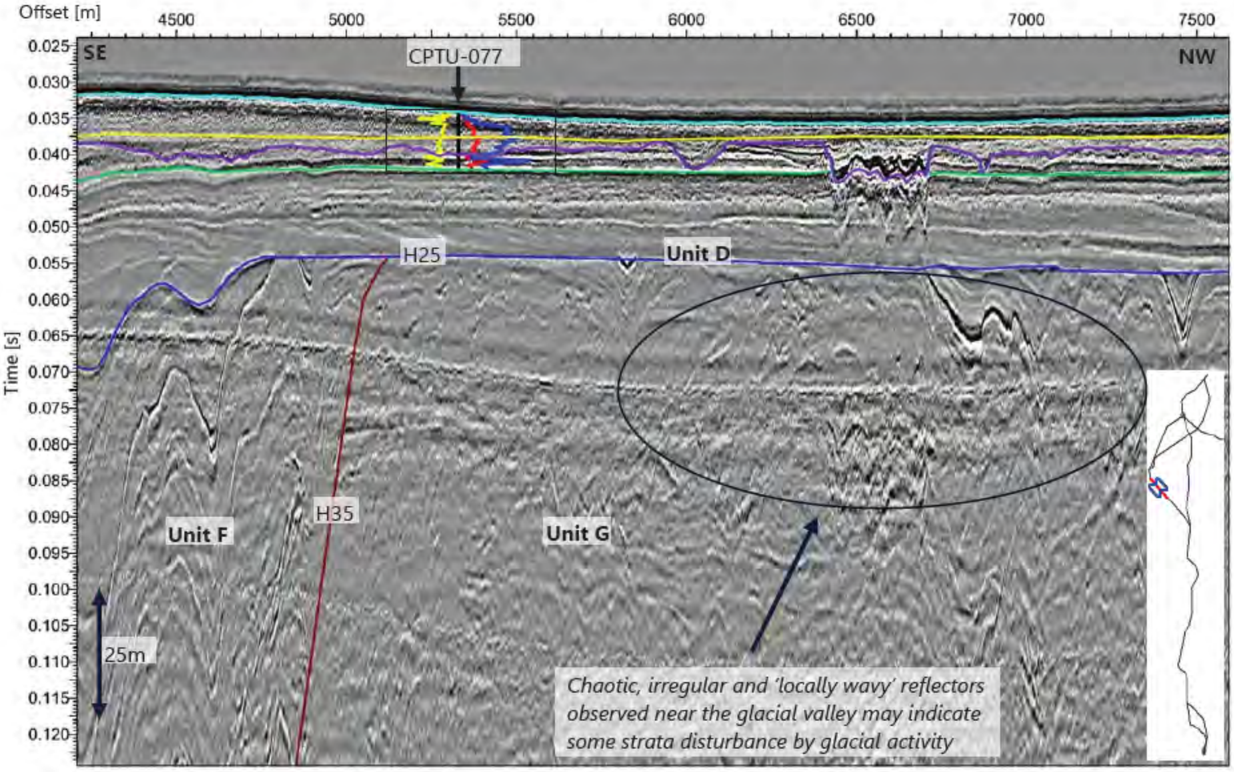


Figure 4.13: 2D-UHRS data example of possible glacial deformation in Unit G. (Line 212-TA3A1547P1) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

4.3.6 Faults

Due to the structureless seismic aspect that characterises a large part of the sub-seafloor vertically extensive / tectonic faults were not observed in the seismic reflection data. Small-scale faults associated with possible glaciotectonism or dewatering features may be present, as well as faults associated with the steep flanks of the tunnel valleys. The presence of more faults and/or fractures cannot be ruled out.

5. Export Route East MT

5.1 Export Route East MT Location

The location of the route section Export Route East MT is shown in Figure 5.1. This section of the route has a length of 30.5 km.

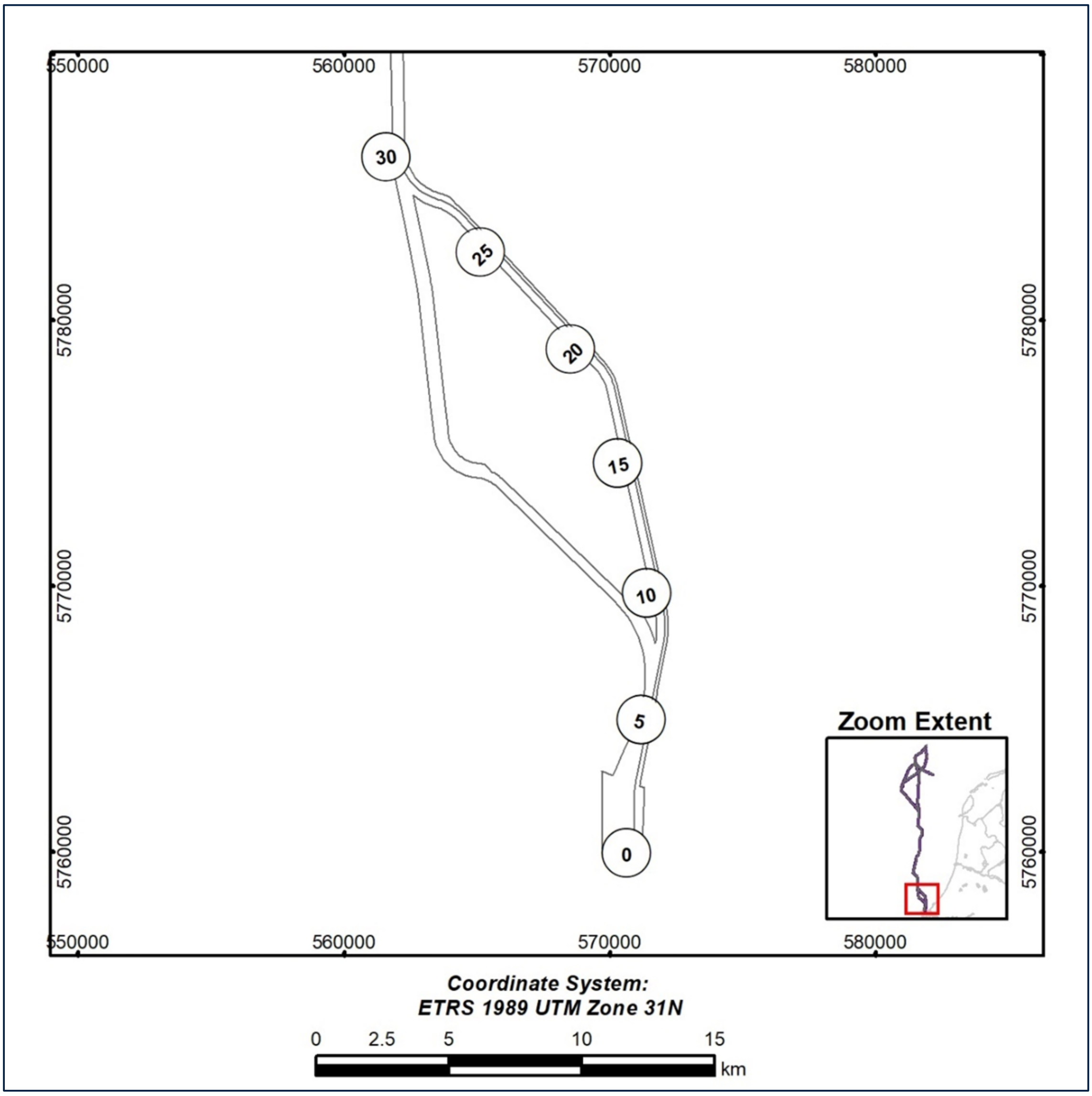


Figure 5.1: Location of the route section Export Route East MT.

5.2 Results

5.2.1 Bathymetry

The water depth within the Export Route East MT section ranges between 3.0 m and 24.0 m. An overview of the bathymetry is given in Figure 5.2.

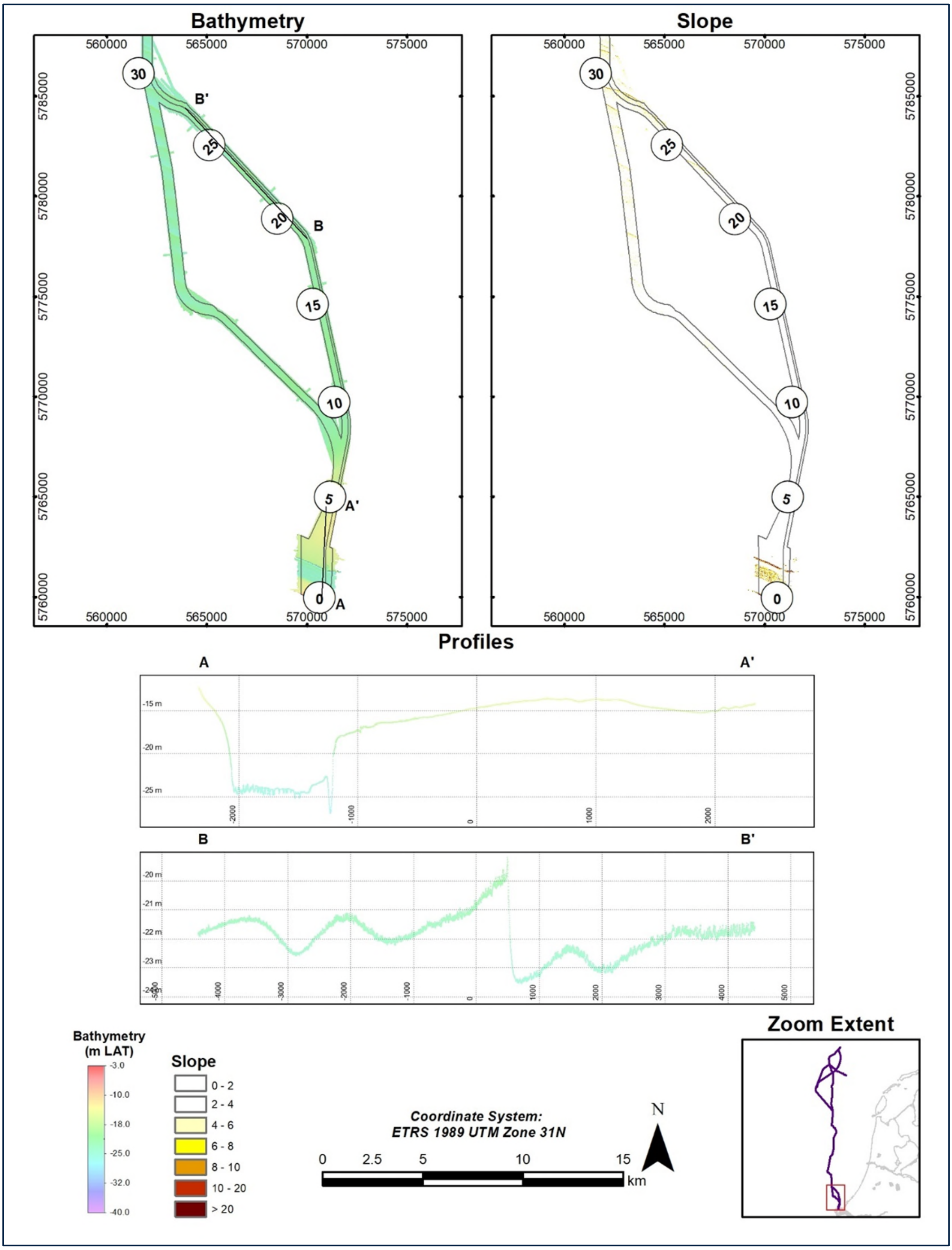


Figure 5.2: Bathymetry along Export Route East MT.

5.2.2 Seafloor Morphology

Overall, a strong correlation between seafloor sediment types and morphological types was observed along the Export Route East MT. An overview of the sediment and features encountered is given in Table 5.1.

Table 31: Sediment type with associated morphology in Export Route East MT

Sediment Type	Morphological Type
Gravelly SAND	Area with numerous boulders/debris Area with occasional boulders/debris Irregular seafloor or featureless
Slightly gravelly SAND	Ripples, megaripples and sand waves Irregular seafloor Cable trench (HKZ)
SAND	Featureless Irregular seafloor Navigation Channel / Maasmond Kanaal
Rock armour	Rock armour

Figure 5.3 to Figure 5.6 show the first 4 KPs of the Export Route East MT section. In the nearshore area, the main bathymetrical feature is the dredged Maasmond Kanaal (navigation channel) with its dredging scour marks.

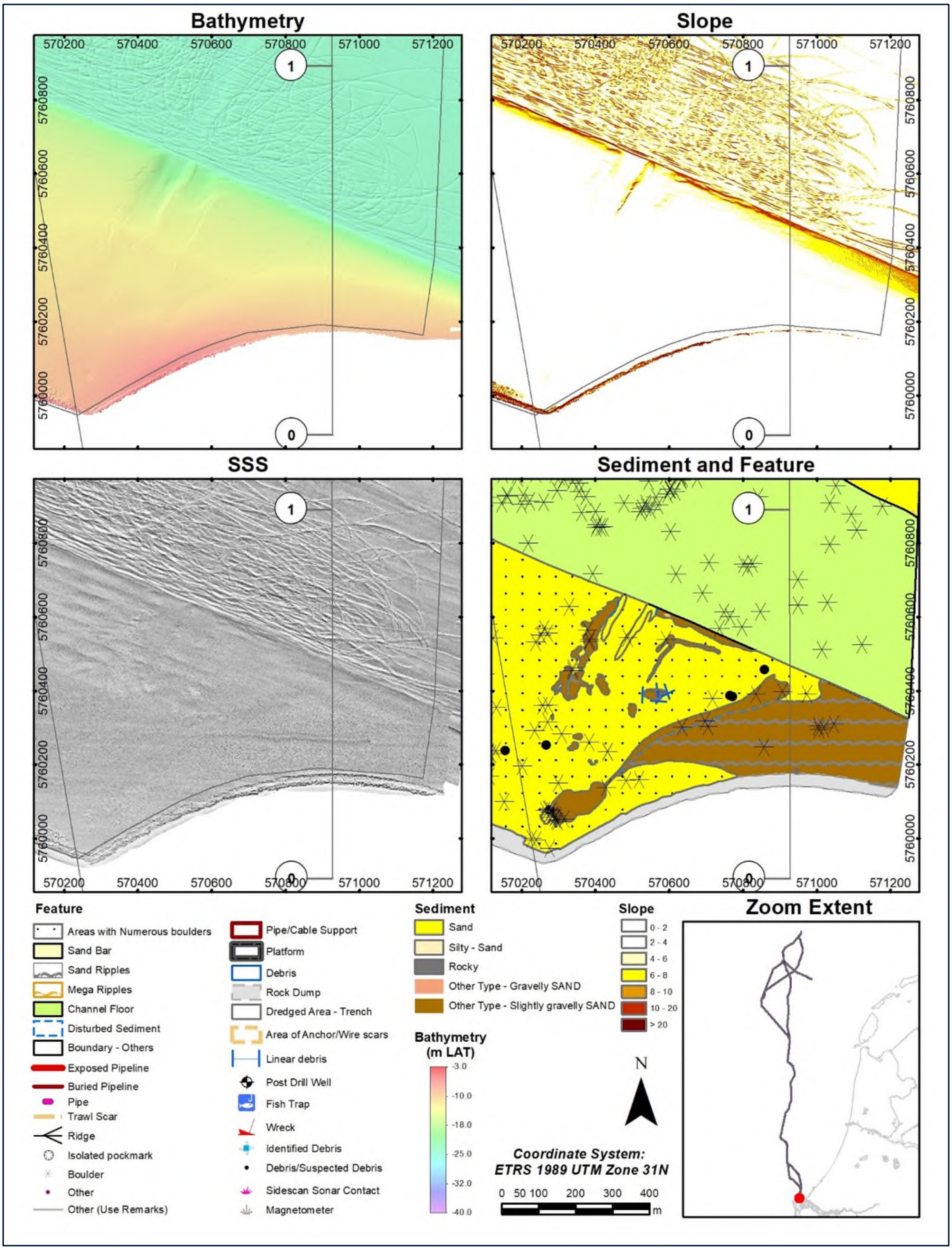


Figure 5.3: Overview of the sediments and morphology in Export Route East MT. : KP 0.0 to KP 1.0. Maasmond Kanaal with dredging scours visible.

Between KP 1.0 and KP 2.0 of the route section (Figure 5.4), trenches of the recently installed cables (Kabel van windgebied HK(Zuid) naar Maasvlakte) are visible.

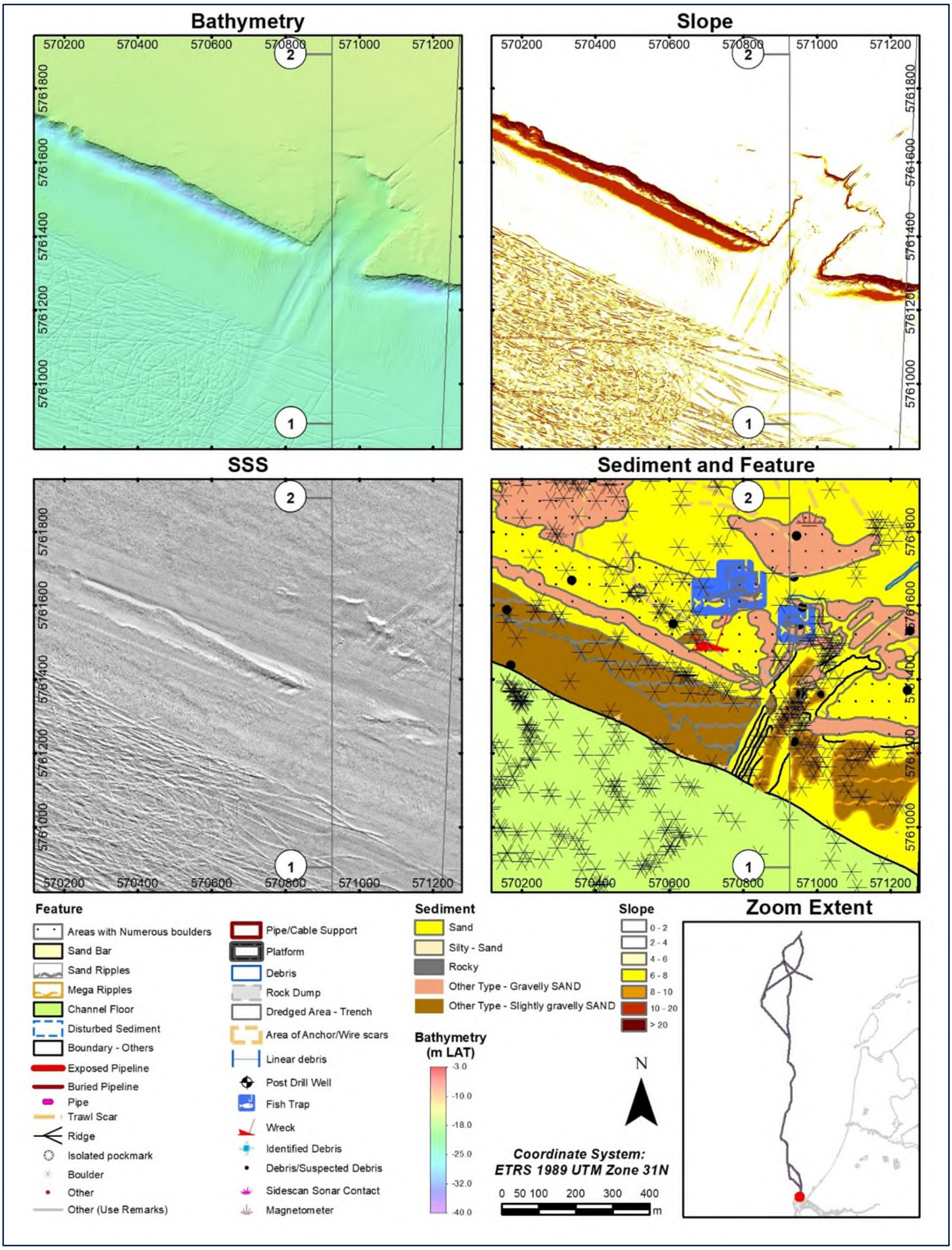


Figure 5.4: Overview of the sediments and morphology in Export Route East MT.: KP 1.0 to KP 2.0. Maasmond Kanaal with dredging scours and HKZ cable trenches visible.

Between KP 2.0 and KP 3.0 (Figure 5.5), an area with numerous boulders/debris and sediment dumping features is visible. At KP 2.5 there is a change in sediment type from SAND with sediment dumping features to slightly gravelly SAND with irregular seafloor.

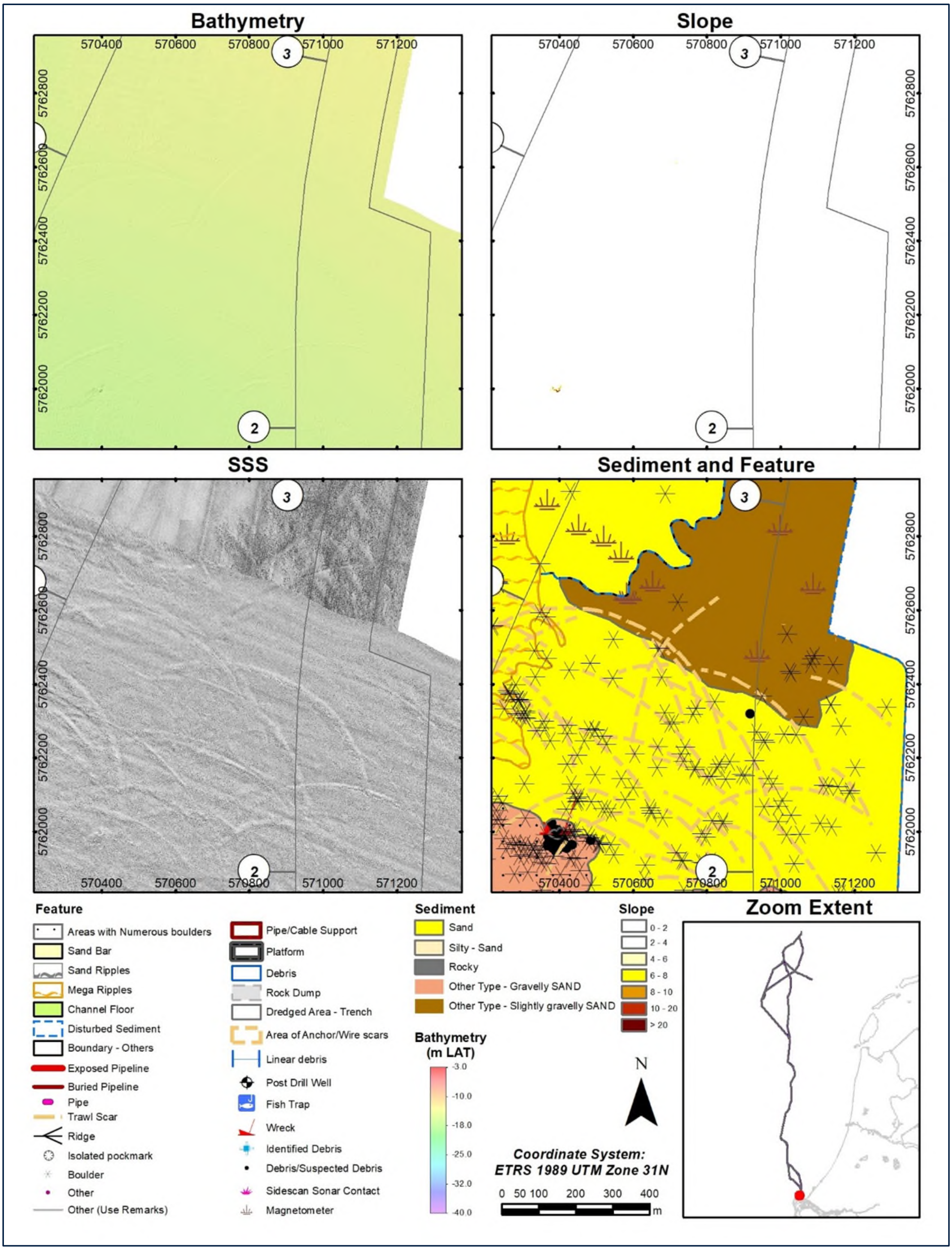


Figure 5.5: Overview of the sediments and morphology in Export Route East MT: KP 2.0 to KP 3.0.

Between KP 3.0 and KP 4.0 (Figure 5.6), an area with various MAG contacts is visible. This part of the section is relatively flat and characterised by various sediment types from featureless SAND to slightly gravelly SAND with irregular seafloor and patchy SSS reflectivity.

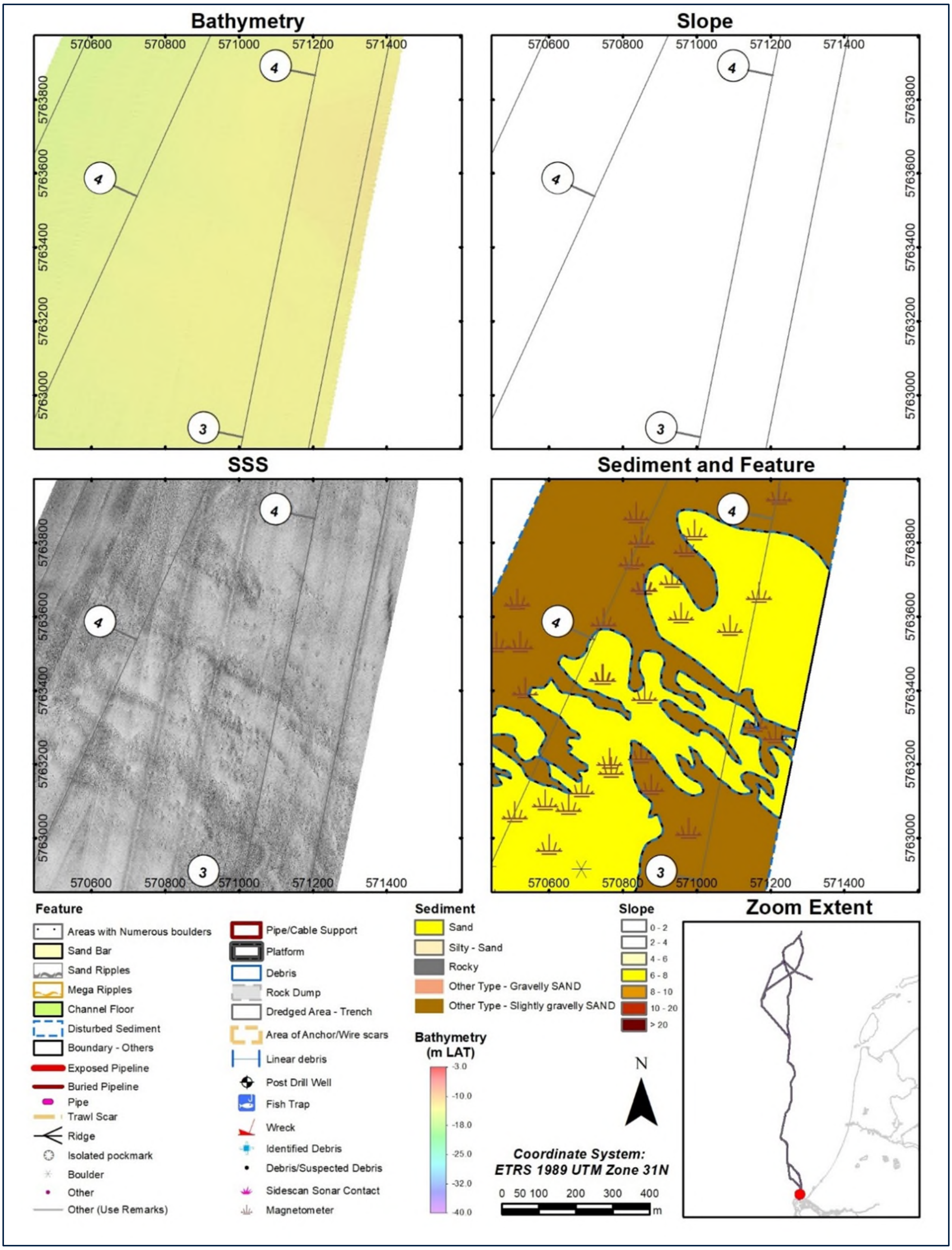


Figure 5.6: Overview of the sediments and morphology in Export Route East MT: KP 3.0 to KP 4.0.

Between KP 14.0 and the end of the section, the sediment type identified as slightly gravelly SAND is present, with the presence of ripples, megaripples and sand waves.

The sand waves are mostly symmetrical, with a northwest – southeast orientation, with an average length of 3.0 km, with the height between 1 m and 4 m.

5.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross correlated where possible.

Table 5.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the section boundary of each sensor and cross-correlated where multiple datasets were available. No targets cross correlate between sensors.

Table 32: Summary of seafloor contacts in Export Route East MT

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	576
	Debris	11
	Fishing gear	5
	Suspected debris	20
	Wreck	1
	Magnetic anomalies	1174
SSS/MBES/MAG Linear Features	Scour	1527
	Unknown linear feature	8
	Buried pipeline	6 segments (2 pipeline in total)
	Magnetic linear feature	7

An area of numerous boulders / debris has been identified between KP 23.5 and KP 26.0 (Figure 5.7).

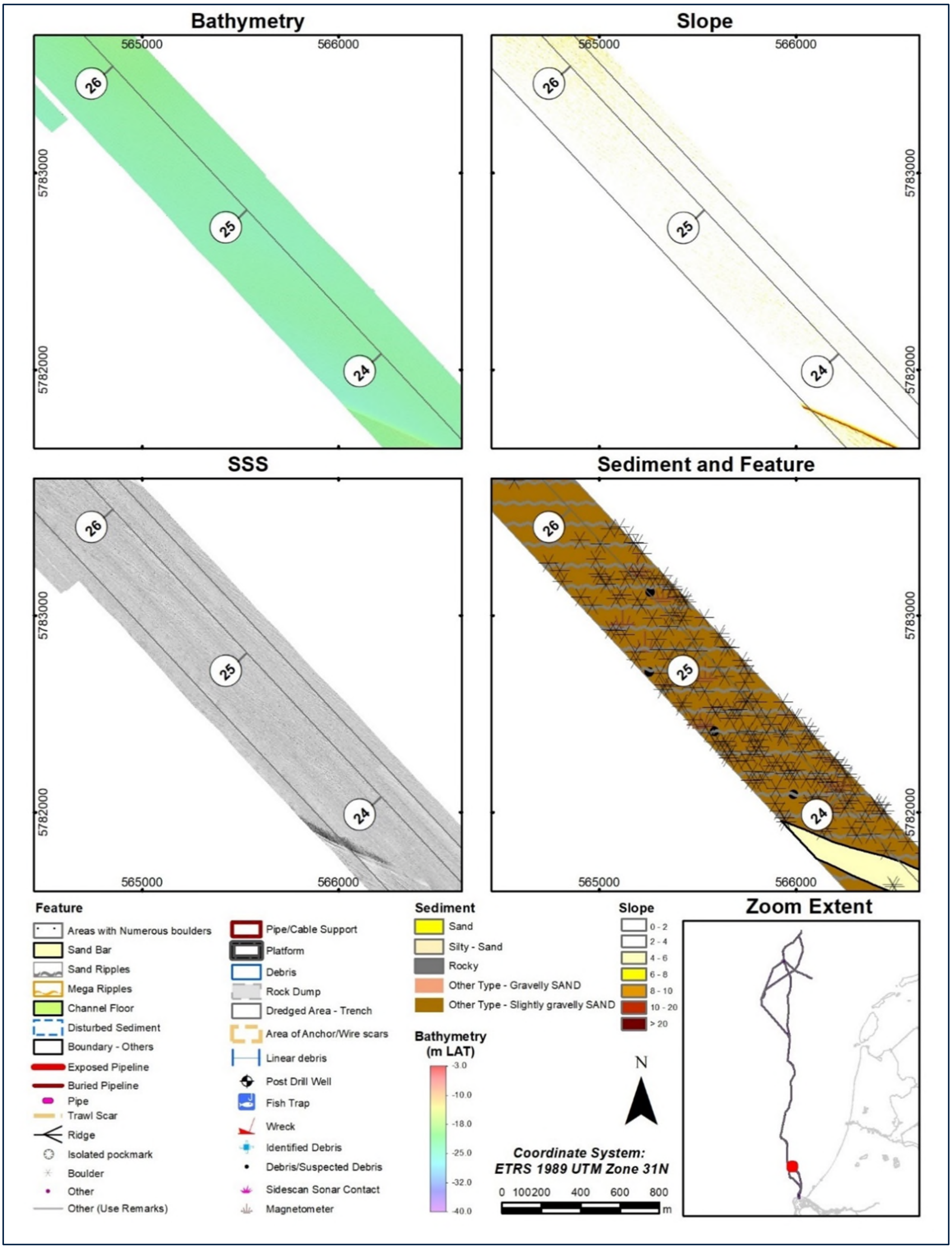


Figure 5.7: Overview of the sediments and morphology in Export Route East MT: KP 24.0 to KP 26.0.

Six (6) segments of two (2) buried pipelines are observed in route section Export Route East MT (Table 5.3 and Figure 5.8). The pipelines also cross the Export Route West HDD and the beginning of section A – Alt.

Table 33: Summary of pipelines in Export Route East MT

Contact ID	Pipeline Name	Comment
Pipeline (PL0039_PR)	P15-C to Hoek van Holland 10-inch oil trunkline	Buried (3 segments)
Pipeline (PL0099_PR)	P15-D to Maasmonding 26-inch gas pipeline	Buried (3 segments)

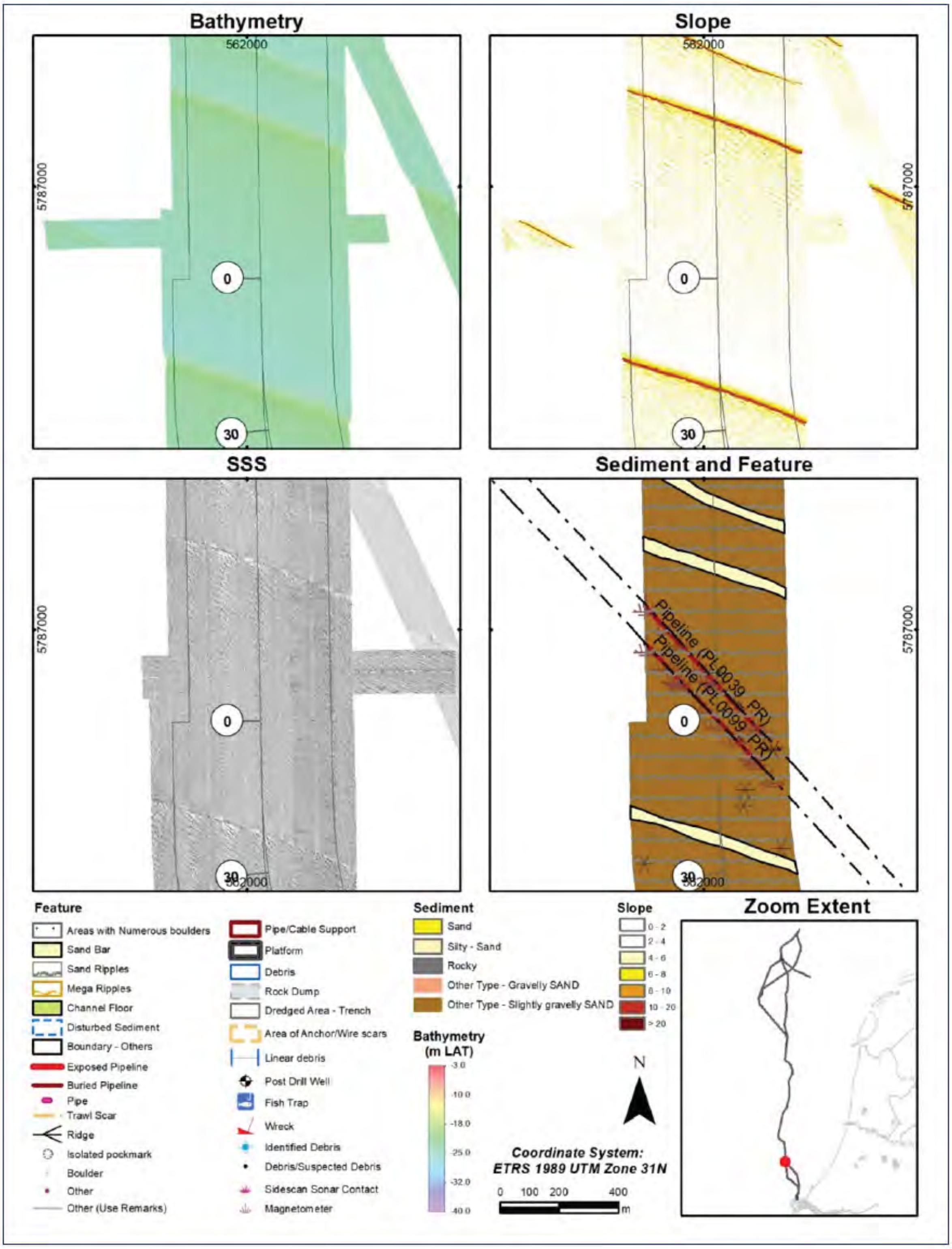


Figure 5.8: Pipelines encountered in Export Route East MT: KP 30.5.

5.2.4 Magnetometer Contacts

1174 magnetic contacts were found at the time the geophysical scope (single MAG survey) in Export Route East MT. The magnetometer anomalies range between 0.9 nT and 3867.1 nT. The highest magnetic amplitude is associated with the encountered pipelines. Most of the magnetic anomalies are located in the nearshore area, between KP 0.5 and KP 2.5, and are probably related to the very anthropogenically altered area close to the Port of Rotterdam.

5.2.5 Sub-seafloor Geology

Units DS, A, B, D and G are present in Export Route East MT (Figure 5.9).

Unit DS is present exclusively in the dredged Maasmond Kanaal. The base of these sediments is uncertain and taken at the base of high amplitude reflections or at the top of structured seismic facies, which were very locally observed. The unit has semi-transparent and chaotic seismic character.

Unit A is present basically in the entire section, except in the Maasmond Kanaal. The top unit in the Maasmond Kanaal consists of disturbed sediments (Unit DS) and deposits of Unit A were removed during dredging activities. Between KP 0.3 and KP 1.8 Unit A was not observed, however in this part of the section acoustic blanking is widespread, what greatly obscure the acoustic signal. Unit A is characterized by chaotic in the nearshore area to semi-transparent seismic facies, with locally point reflections further offshore. High amplitude reflectors of limited extent were observed locally between KP 2.0 and KP 10.0 in this unit. The maximum thickness of Unit A in this section is approximately 4.5 m.

Unit B is present across the entire section. Between KP 0.0 to KP 2.7 it is observed locally (as patches), what can be due to the acoustic blanking that hinder the interpretation. The unit exhibits transparent to semi-transparent seismic character. Between approximately KP 2.5 and KP 7.5 the unit exhibits often layered facies with flat to inclined parallel reflectors. Internal buried channels with layered infill were observed in this unit. The maximum thickness of Unit B in this section is approximately 5 m.

Unit B is underlain by Unit D (interpreted to be present from approximately KP 17.3) and Unit G. Unit D and G exhibit structureless acoustically transparent to semi-transparent seismic character in this section.

High amplitude anomalies in Unit G were interpreted between KP 18.3 to KP 30.0. These negative amplitude events most likely represent laminae or thin bed of peat and/or organic-rich clay (peat level 3).

Table 5.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 34: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
DS	0 to 4.5	Very loose to very dense slightly silty fine and medium SAND
A	0.2 to 4.0	Very loose to very dense slightly silty fine and medium SAND with frequent shells and shell fragments
B	2.0 to 10.5	Medium to very dense slightly silty fine and medium SAND with numerous shells and shell fragments
D	BPD	Dense to very dense slightly silty fine and medium SAND, occasionally slightly gravelly
Notes: BPD = below penetration depth of SBP data		

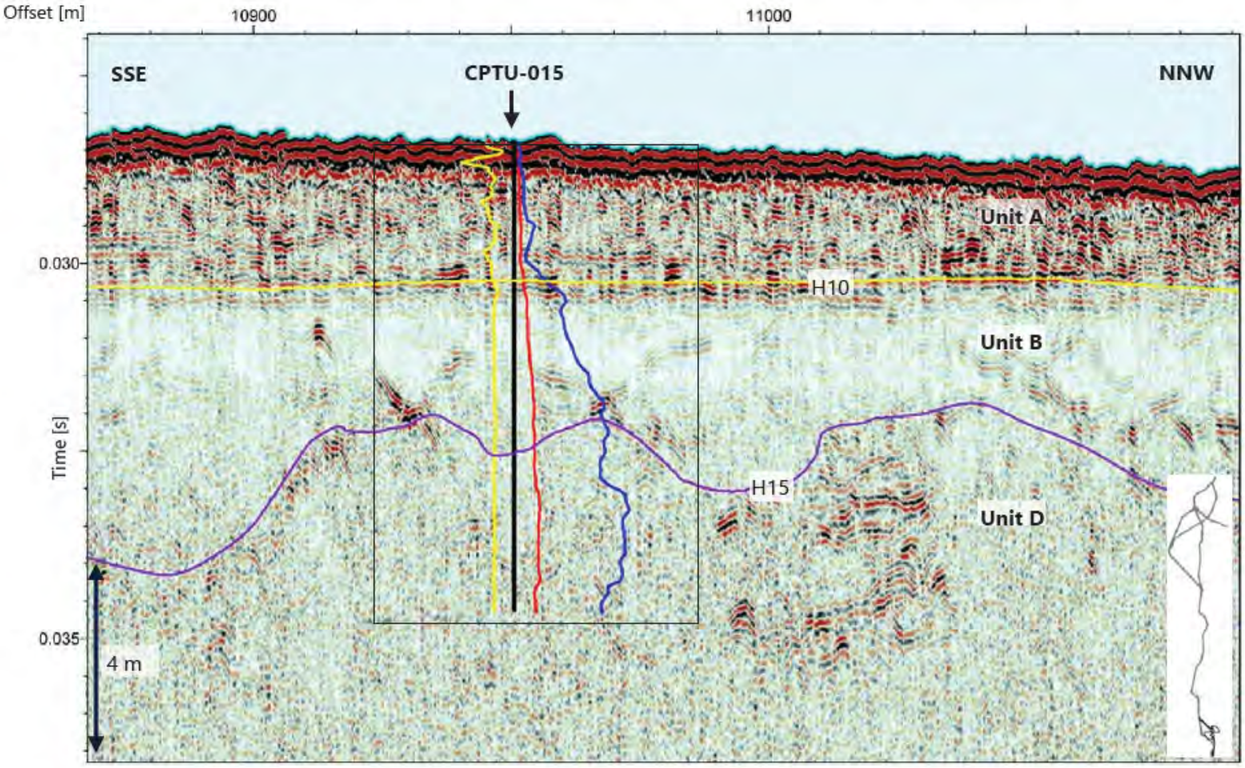


Figure 5.9: SBP data example of route section Export Route East MT. (Line SBP_TA3C2015P1) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

6. Export Route West HDD

6.1 Export Route West HDD Location

The location of the Export Route West HDD section is shown in Figure 6.1. This section of the route has a length of 31.0 km.

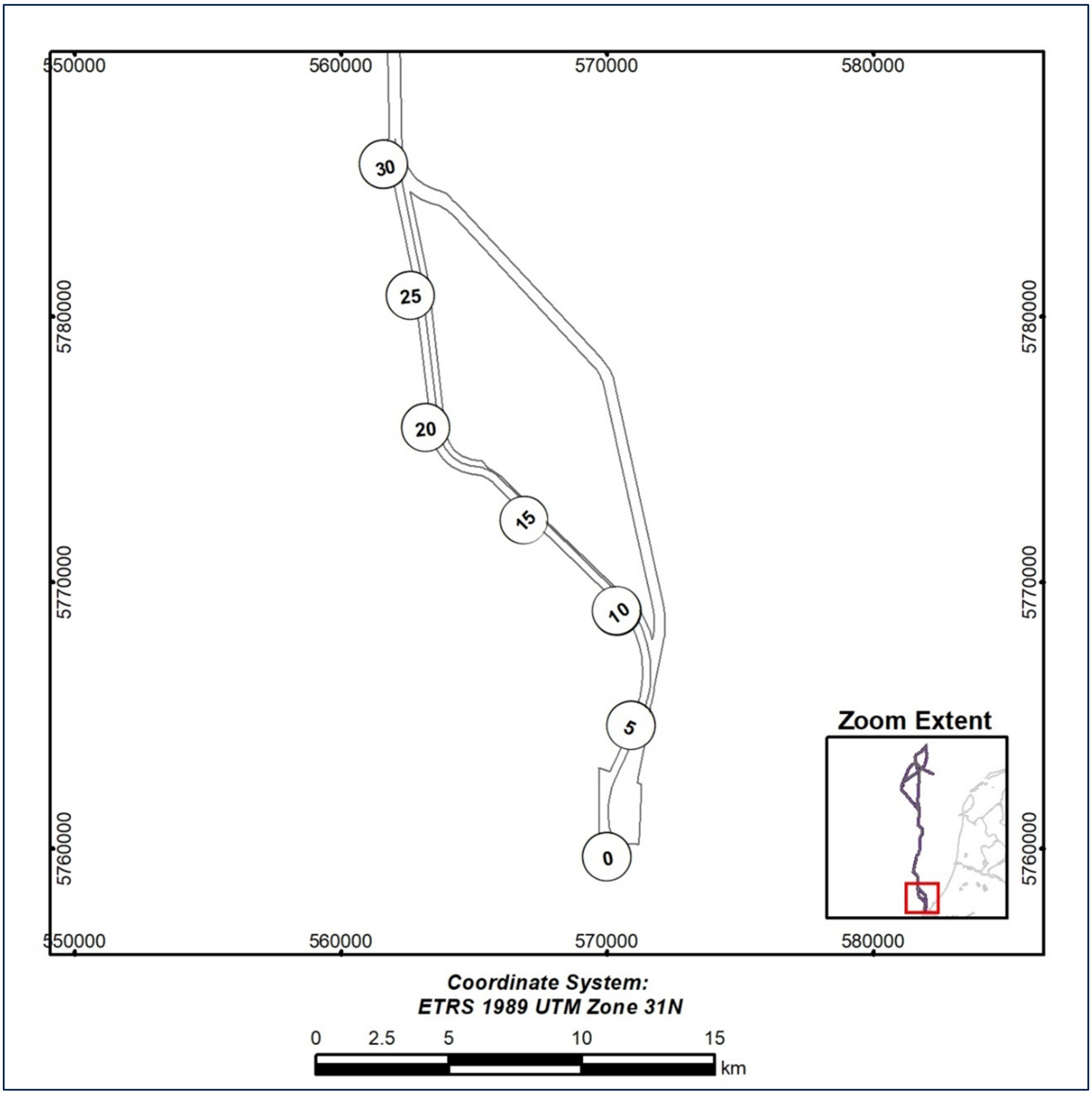


Figure 6.1: Location of the route section Export Route West HDD.

6.2 Results

6.2.1 Bathymetry

The water depth within Section Export Route West HDD ranges between 3.0 m and 24.0 m. An overview of the bathymetry is given in Figure 6.2.

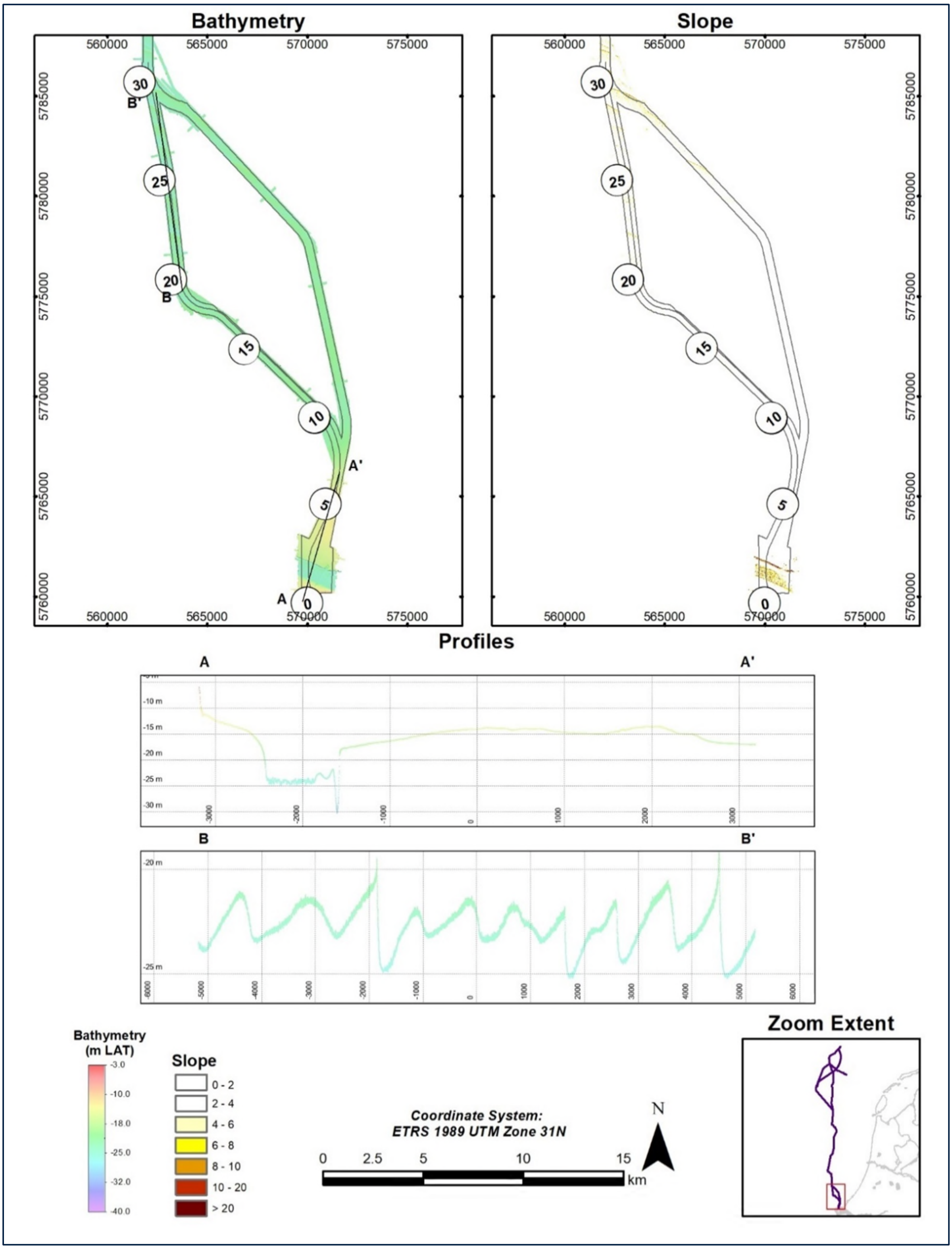


Figure 6.2: Bathymetry along Export Route West HDD.

6.2.2 Seafloor Morphology

A strong correlation between sediment types and morphological type was observed in the Export Route West HDD section, although some small variations are possible. An overview of encountered sediments and seafloor features is given in Table 6.1.

Table 35: Sediment type with associated morphology in Export Route West HDD

Sediment Type	Morphological Type
Gravelly SAND	Area with numerous boulders/debris Area with occasional boulders/debris Irregular seafloor or featureless
Slightly gravelly SAND	Ripples, megaripples and sand waves Irregular seafloor Cable trench (HKZ)
SAND	Featureless Irregular seafloor Navigation Channel / Maasmond Kanaal Wreck area
Rock armour	Rock armour

Figure 6.3 to Figure 6.5 show the first 3 KPs of the route section Export Route East MT.

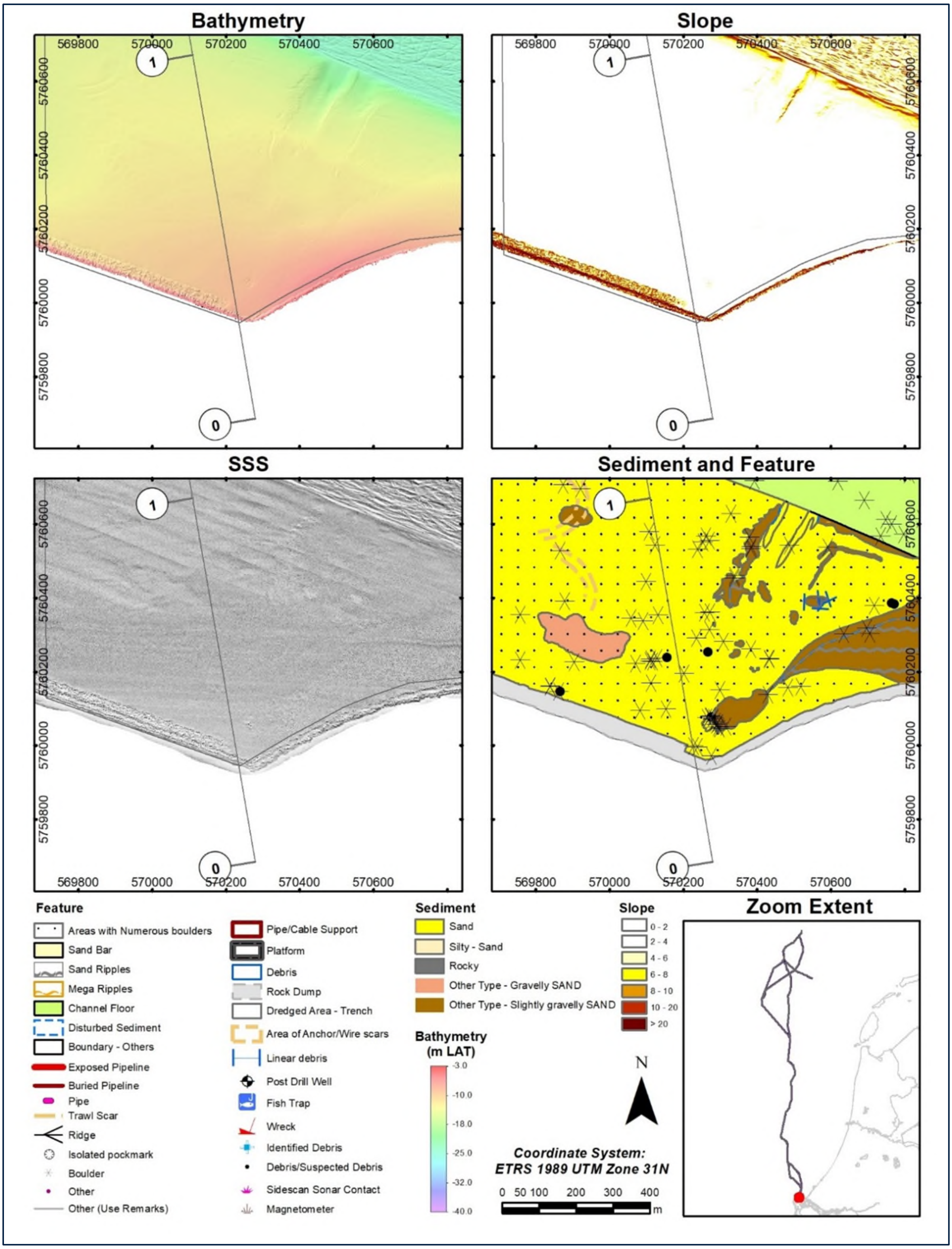


Figure 6.3: Overview of the sediments and morphology in Export Route West HDD: KP 0.0 to KP 1.0.

In the nearshore area, between KP 1.0 and KP 2.0, the main morphological feature is the dredged Maasmond Kanaal (navigation channel) with its dredging scour marks.

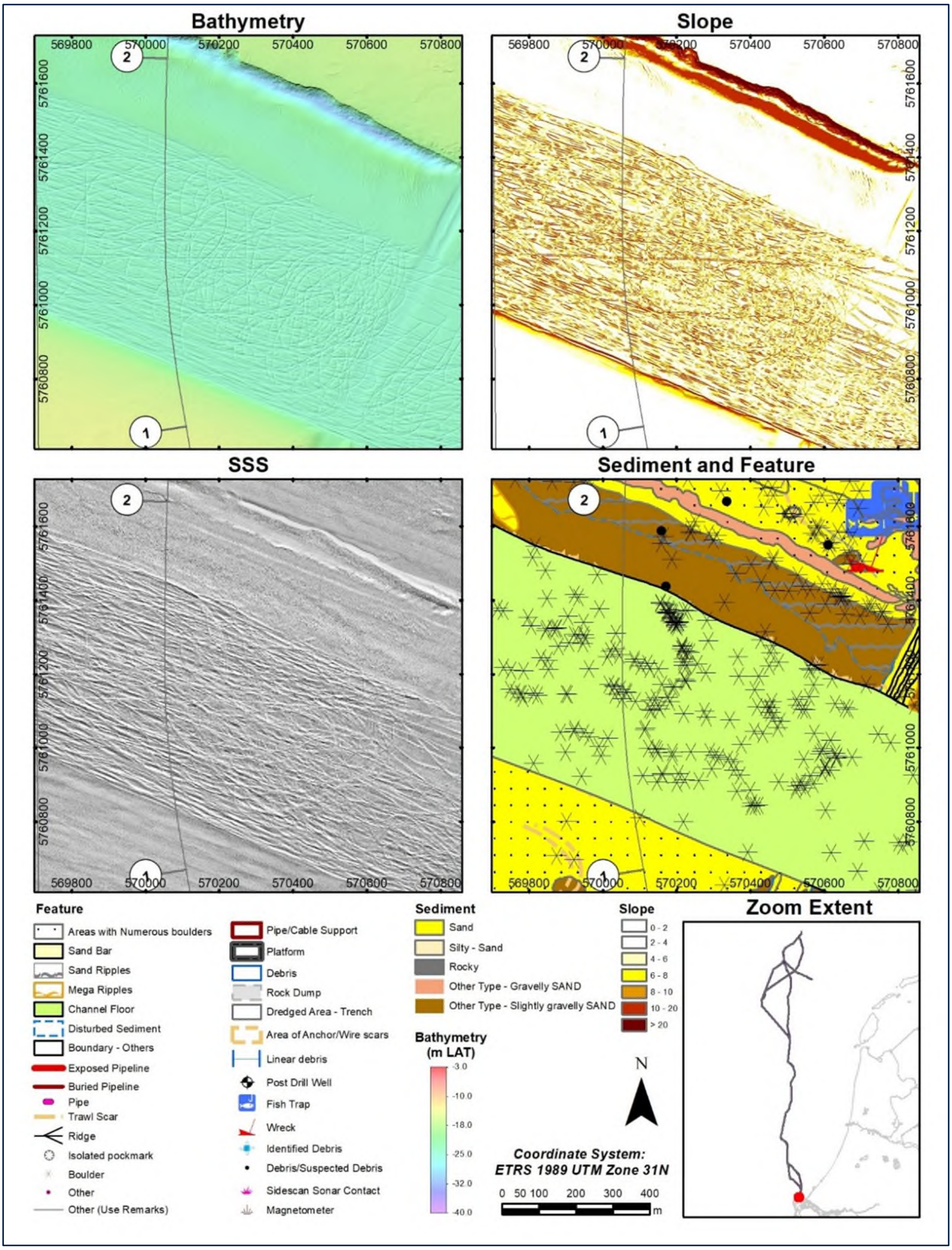


Figure 6.4: Overview of the sediments and morphology in Export Route West HDD: KP 1.0 to KP 2.0.

Between KP 2.0 and KP 3.0, an area with numerous boulders / debris and sediment dumping features is visible (Figure 6.5). At KP 2.4 of the section, and 0.4 km east from the centreline there is a debris wreck area identified.

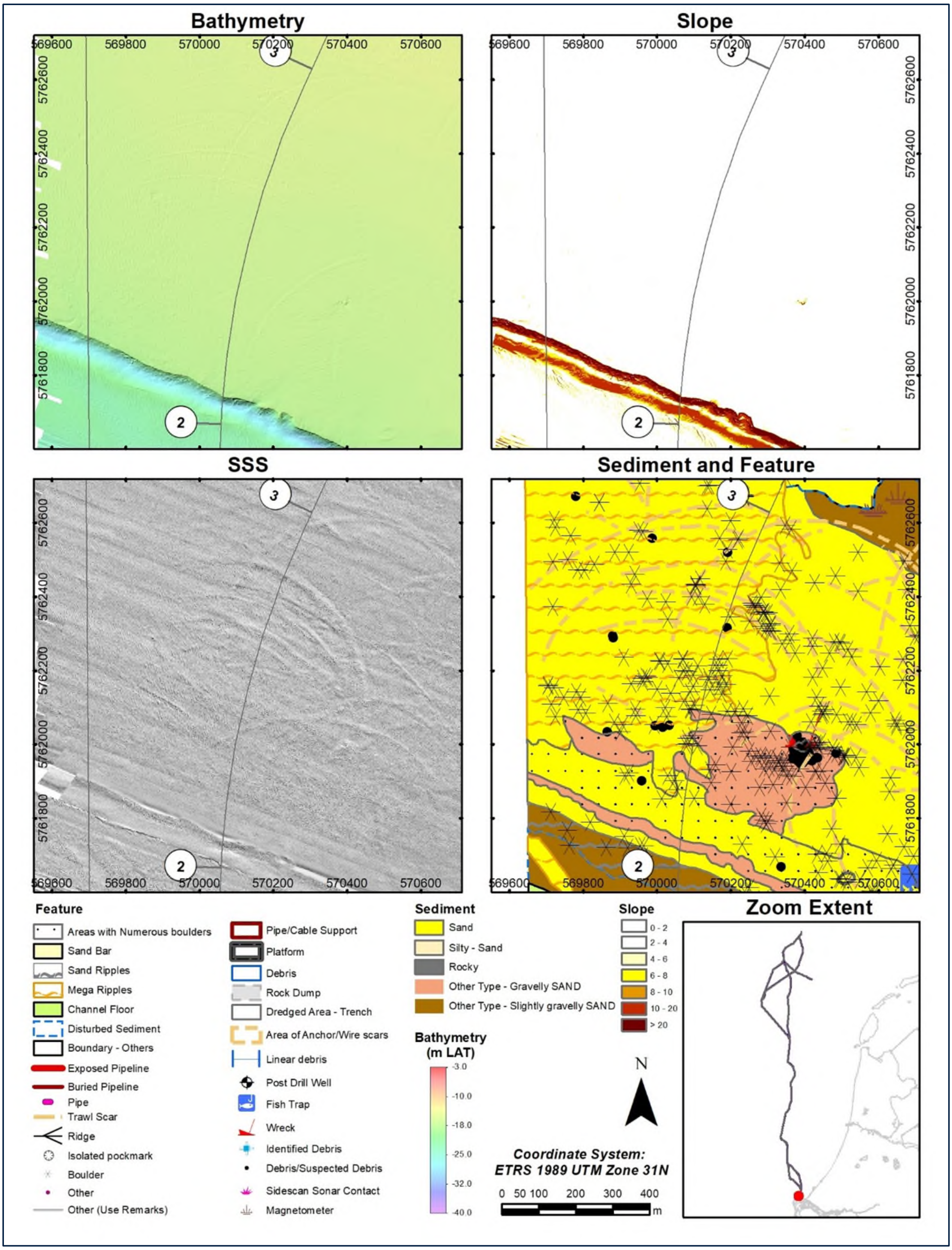


Figure 6.5: Overview of the sediments and morphology in Export Route West HDD: KP 2.0 to KP 3.0.

Between KP 12.0 and KP 13.0, a change of sediment type from a featureless SAND area to slightly gravelly SAND with ripples (Figure 6.6). From KP 12.5 till the end of this section the prevalent sediment is classified as slightly gravelly SAND with bedforms such as ripples, megaripples and sand waves.

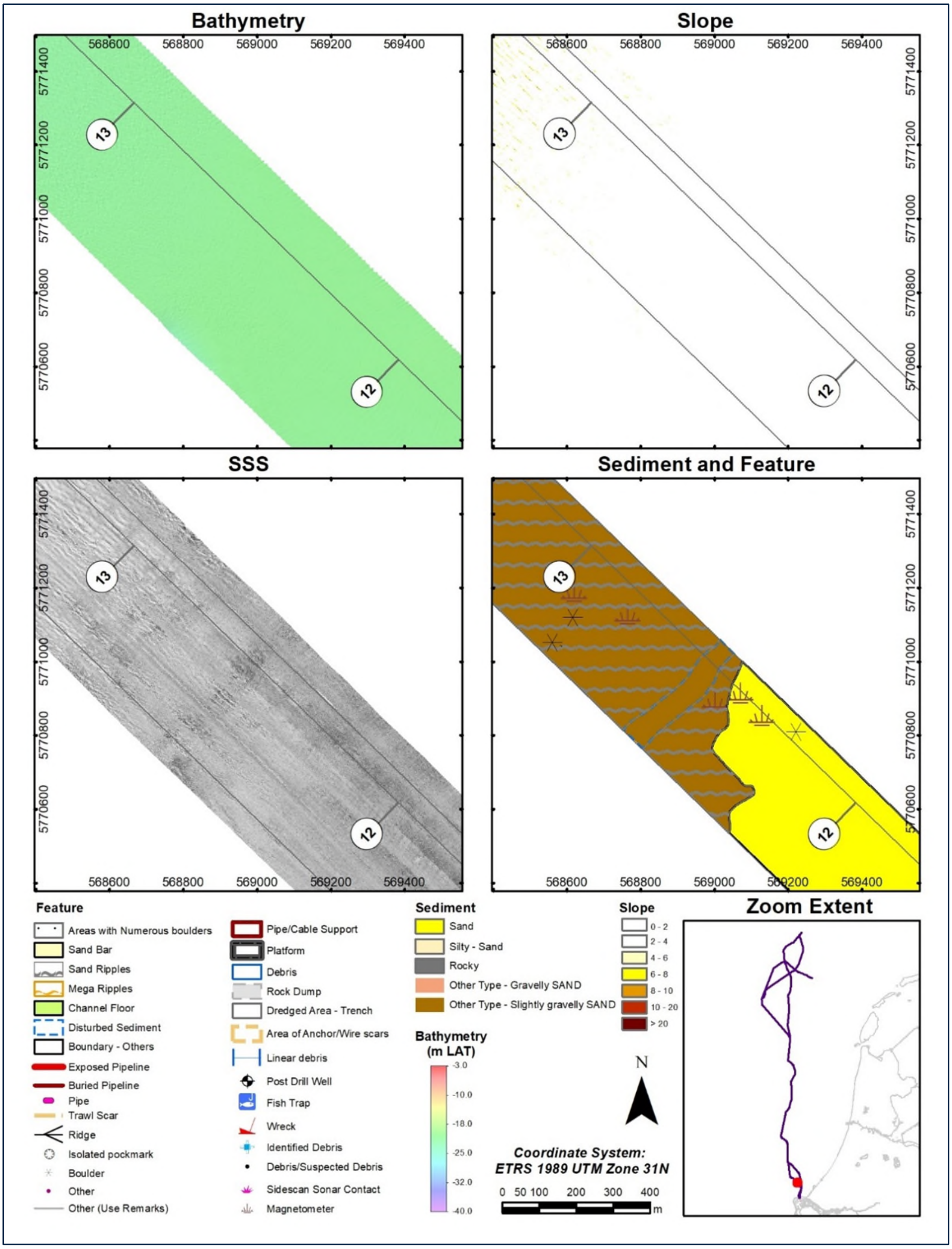


Figure 6.6: Overview of the sediments and morphology in Export Route West HDD: KP 12.0 to KP 13.0.

Between route sections Export Route East MT and Export Route West HDD, approximately 0.5 km from both sections, at KP 2.0, an unknown circular feature has been identified (Figure 6.7). This feature has a length of 47.7 m, a width of 24.8 m and a maximum depth of 0.54 m.

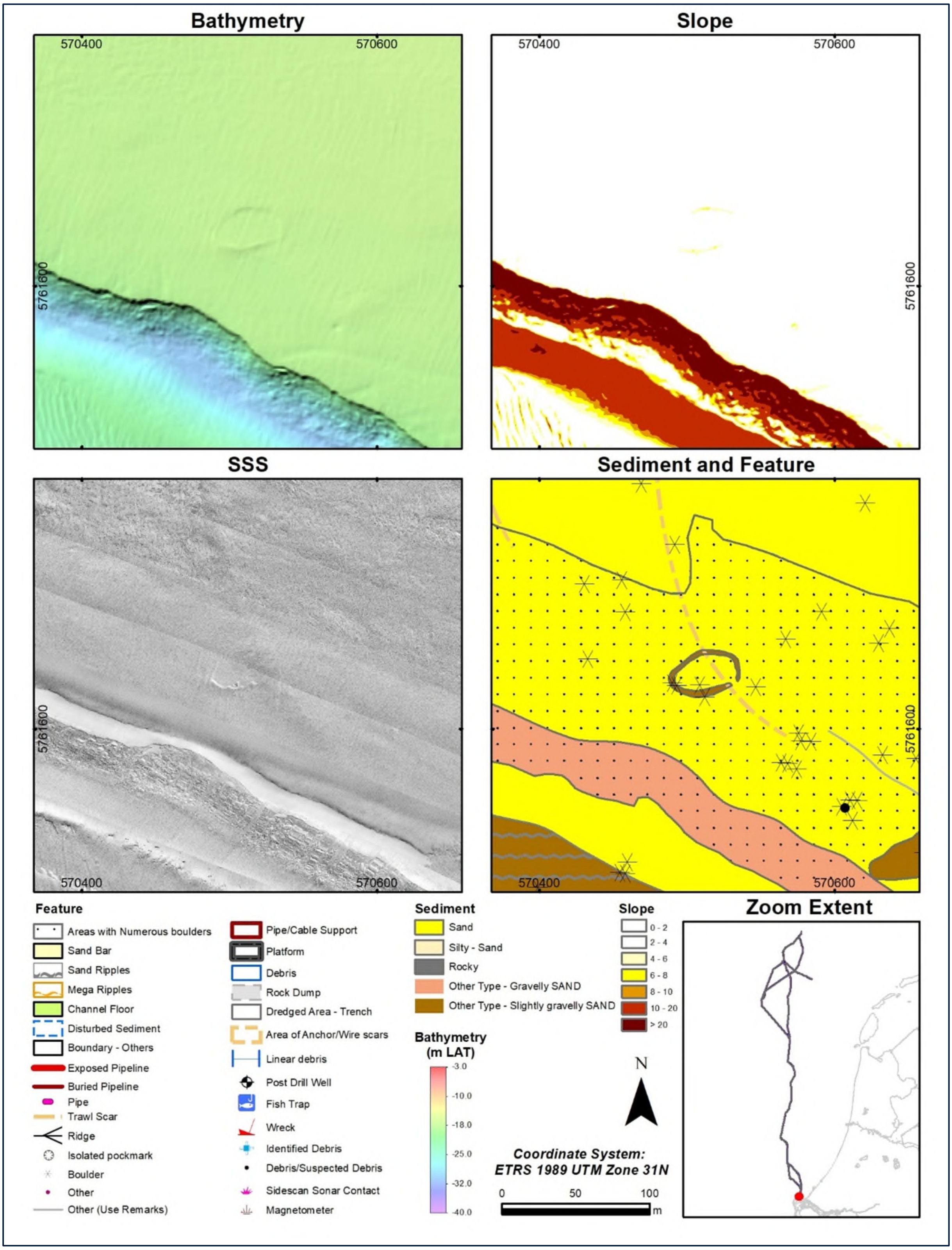


Figure 6.7: Overview of the sediments and morphology in Export Route West HDD: KP 2.0, unknown circular feature.

6.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated, where possible.

Table 6.2 summarizes the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available.

Table 36: Summary of seafloor contacts in Export Route West HDD

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	1885
	Debris	25
	Suspected debris	80
	Wreck	1
	Magnetic anomalies	651
SSS/MBES/MAG Linear Features	Possible fishing gear	3
	Mound ridge	2
	Scour	6460
	Telecommunication cable	1
	Buried pipeline	1
	Magnetic linear feature	4

8 targets cross correlate between sensors in section Export Route West HDD (Table 6.3).

Table 37: Summary of cross correlating seafloor contacts in Export Route West HDD

Section	SSS Target Name	MAG Target Name	Description
Near shore Area (Export Route West HDD)	BB_FS_SSS_0593	BB_FS_MAG_0222	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0607	BB_FS_MAG_0247	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0642	BB_FS_MAG_0274	Suspected debris
Near shore Area (Export Route West HDD)	BB_FS_SSS_0884	BB_FS_MAG_0567	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0916	BB_FS_MAG_0605	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0929	BB_FS_MAG_0691	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0946	BB_FS_MAG_0710	Boulder
Near shore Area (Export Route West HDD)	BB_FS_SSS_0678	BB_FS_MAG_0298	Wreck

An area of numerous boulders / debris was identified between KP 19.0 and KP 28.0 (Figure 6.8).

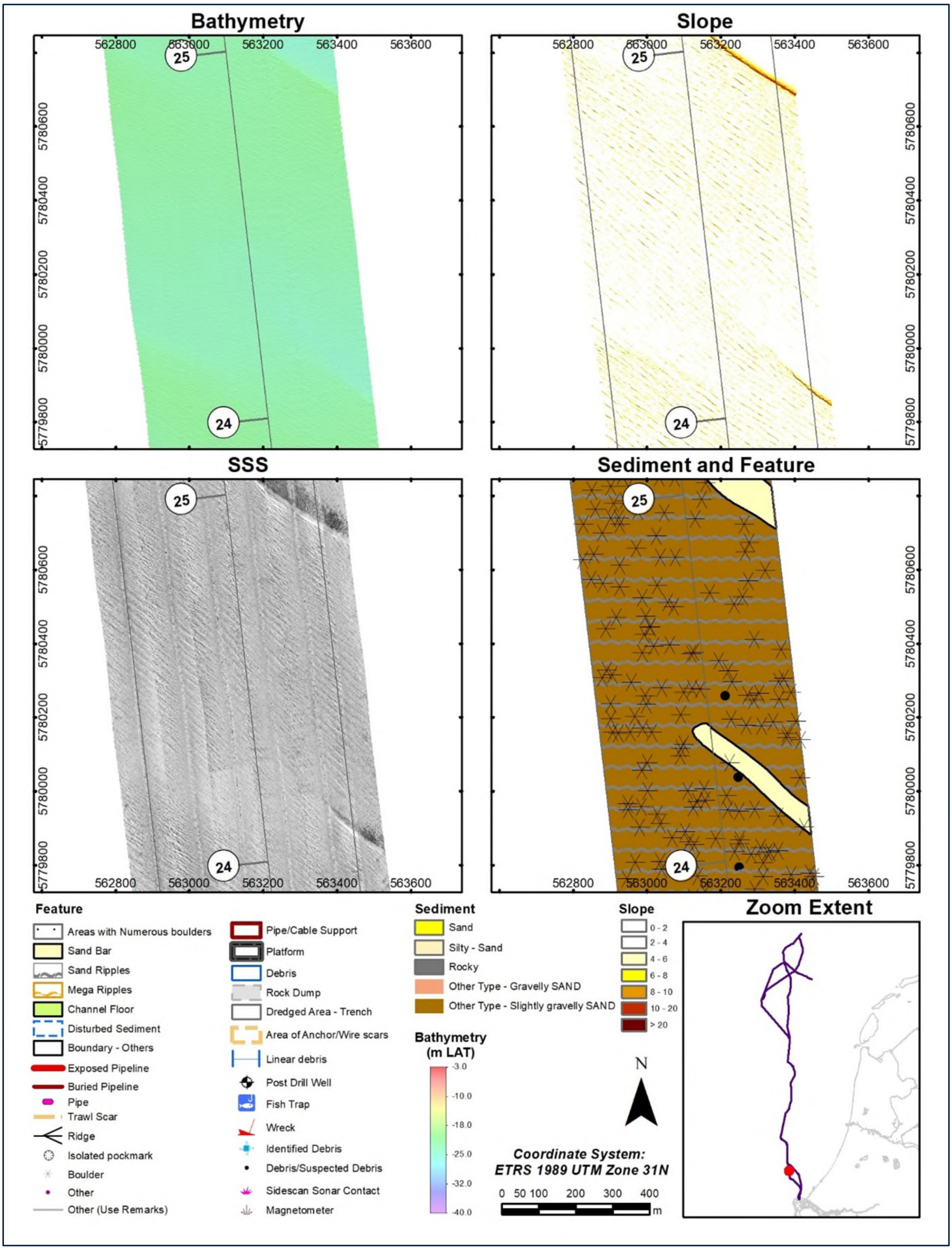


Figure 6.8: Example of area of boulders in Export Route West HDD.

Between KP 20 and KP 21 of the Export Route West HDD, a buried pipeline was identified (Table 5.3 and Figure 6.9).

Table 38: Summary of pipeline and cable in Export Route West HHD

Contact ID	Pipeline Name	Comment
Pipeline (PL0106_PR)	P18-A to P15-D 16-inch gas / 3-inch methanol pipeline bundle	Buried (1 segment)
Telecommunication cable (KB0002)	Concerto 1E	Buried (1 segment) (slightly visible in the magnetometer data)

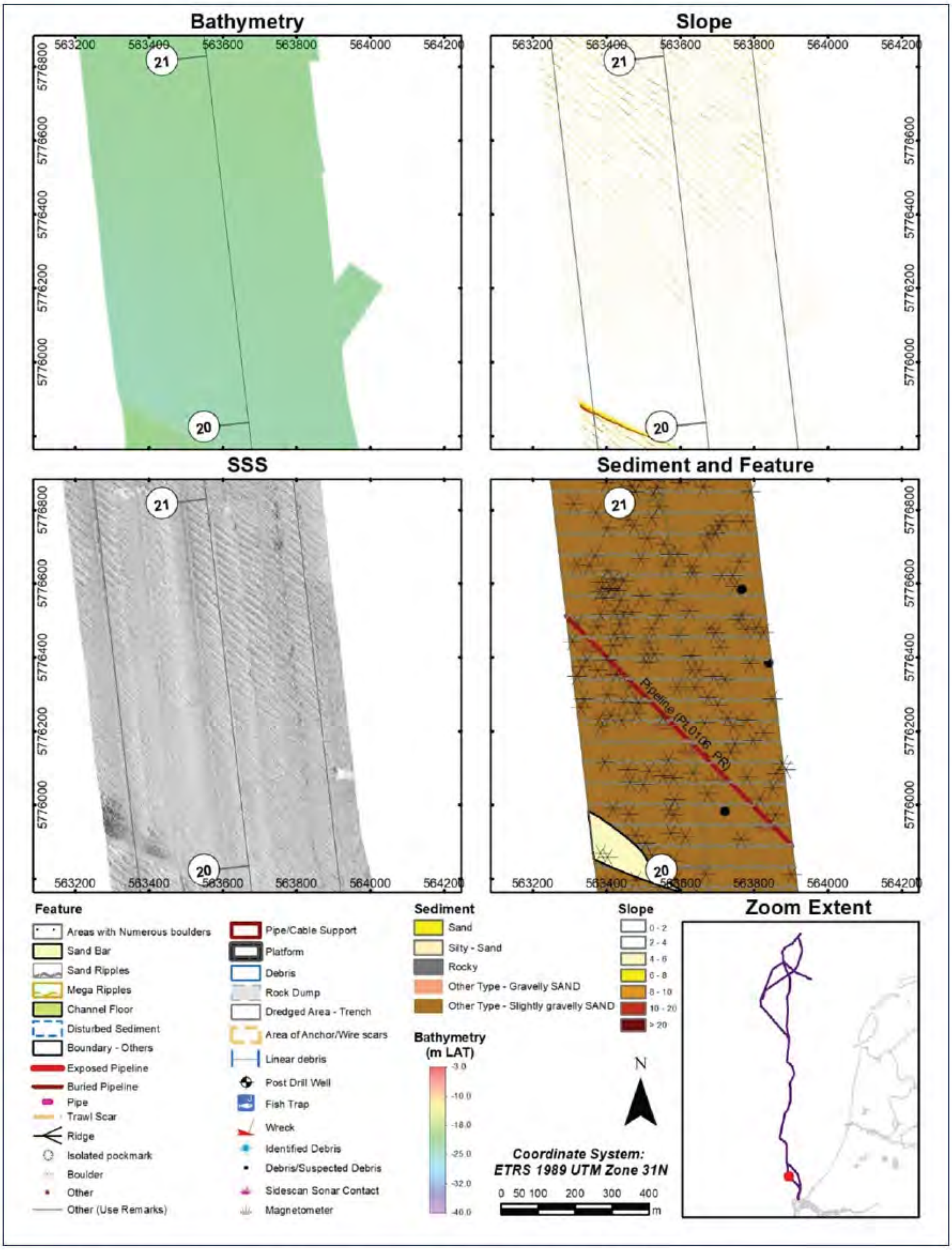


Figure 6.9: Example of area of boulders in Export Route West HDD: KP 20.0 to K9 21.0.

6.2.4 Magnetometer Contacts

651 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in Export Route West HDD. The magnetometer anomalies range between 1.1 nT and 1213.1 nT. The highest magnetic amplitude is associated with the encountered pipeline. Most of the magnetic anomalies are located in the nearshore area, between KP 0.5 and KP 3.0 and are probably related to the anthropogenically altered area close to the port of Rotterdam.

6.2.5 Sub-seafloor Geology

Units DS, A, B, D and G are present in Export Route West HD (Figure 6.10).

Unit A is present basically in the entire section, except in the Maasmond Kanaal, where the top unit consists of disturbed sediments (Unit DS) and Unit A was removed during dredging activities. Between KP 0.3 and KP 1.1 Unit A was not observed, due to the acoustic blanking that hinder the interpretation. Unit A is characterized by chaotic in the nearshore area to semi-transparent seismic facies, with locally point reflections further offshore. The maximum thickness of Unit A in this section is approximately 4 m.

Unit B is present across the entire section. Between KP 0.0 to KP 1.1 it is not observed due to the acoustic blanking that hinder the interpretation. The unit has in general transparent to semi-transparent seismic character. Between approximately KP 2.0 and KP 7.5 the unit exhibits mostly layered facies with flat to inclined parallel reflectors. Internal buried channels with layered infill were observed in this unit locally.

Unit B is underlain by Unit D (interpreted to be present from approximately KP 14.8) and Unit G. Unit D and G exhibit structureless acoustically transparent to semi-transparent seismic character in this section.

High amplitude anomalies in Unit G were interpreted between KP 20.5 and KP 21.0, at approximately KP 23, between KP 25.6 and KP 27.0 and between KP 30.1 and KP 30.8. These negative amplitude events most likely represent laminae or thin bed of peat and/or organic-rich clay (peat level 3).

Table 6.5 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 39: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
DS	0 to 4.5	Very loose to very dense slightly silty fine and medium SAND
A	0.3 to 4.2	Very loose to very dense slightly silty fine and medium SAND with frequent shells and shell fragments Locally low to medium strength slightly sandy CLAY, with closely spaced thin laminae of silt

Unit	Depth to Base [m BSF]	Lithology
B	2.2 to 9.2	Medium to very dense slightly silty fine and medium SAND with numerous shells and shell fragments, occasionally slightly gravelly Locally with medium to thick beds of extremely low to very low strength very dark grey sandy CLAY
Notes: BPD = below penetration depth of SBP data		

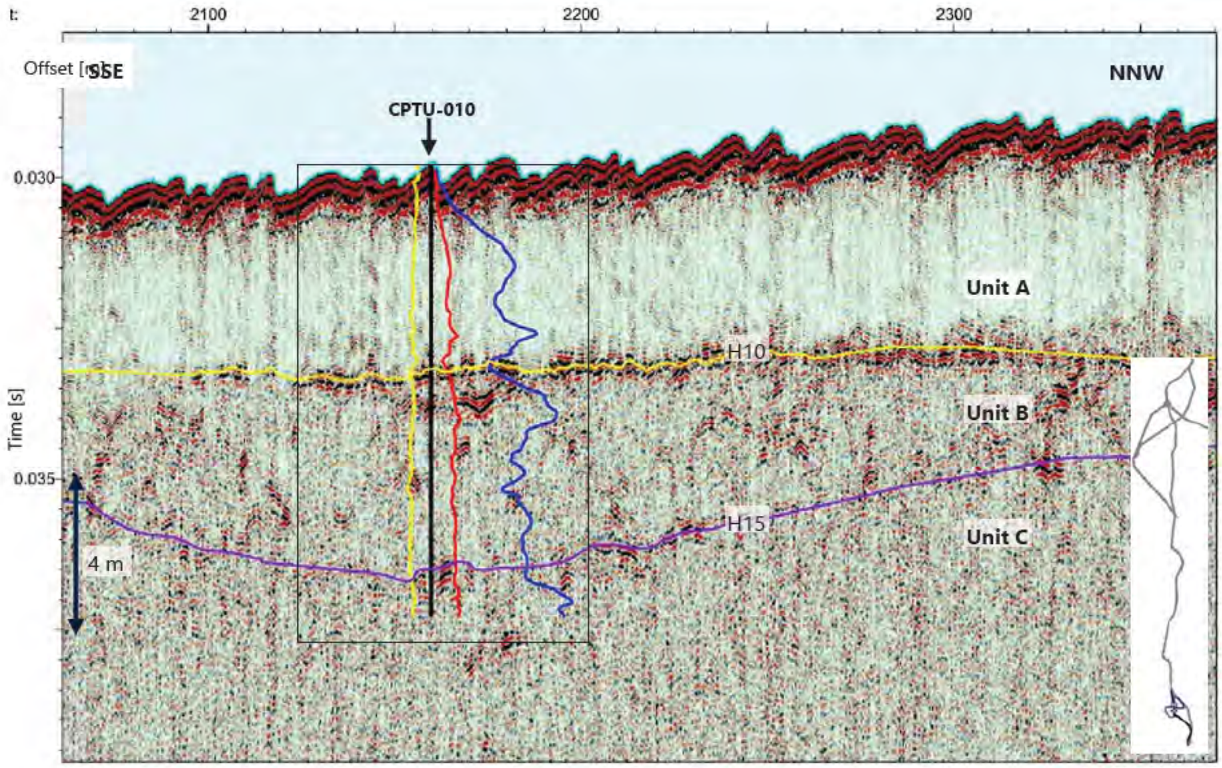


Figure 6.10: SBP data example of route section Export Route West HDD. (Line SBP_TA3D2079P2) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

7. Section A-Alt

7.1 Section A - Alt Location

The location of the route Section A - Alt is shown in Figure 7.1. This section of the route has a length of 94 km.

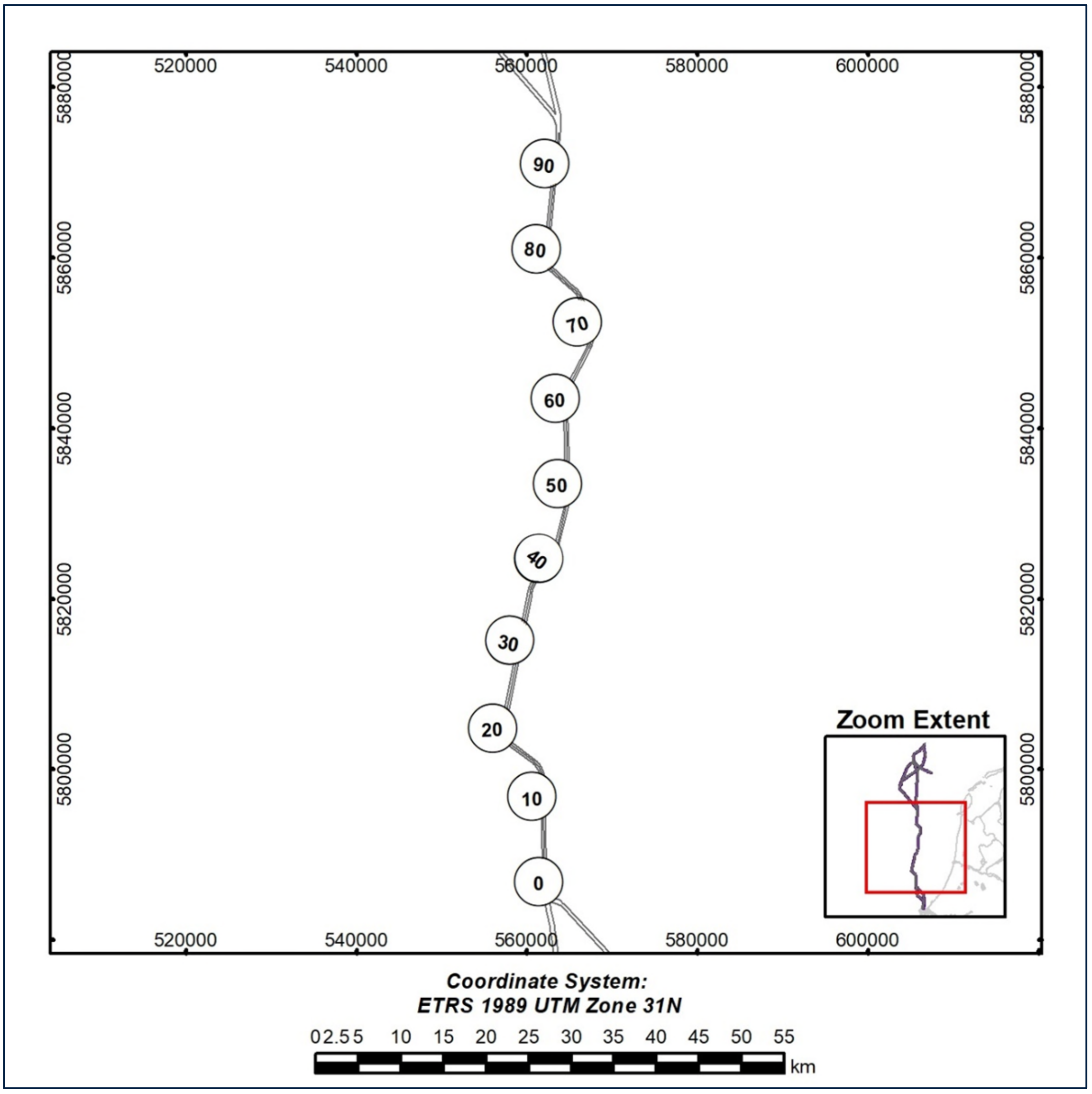


Figure 7.1: Location of the route section A – Alt.

7.2 Results

7.2.1 Bathymetry

The water depth in route Section A-Alt ranges between 24.0 m and 25.0 m. An overview of the bathymetry is given in Figure 7.2.

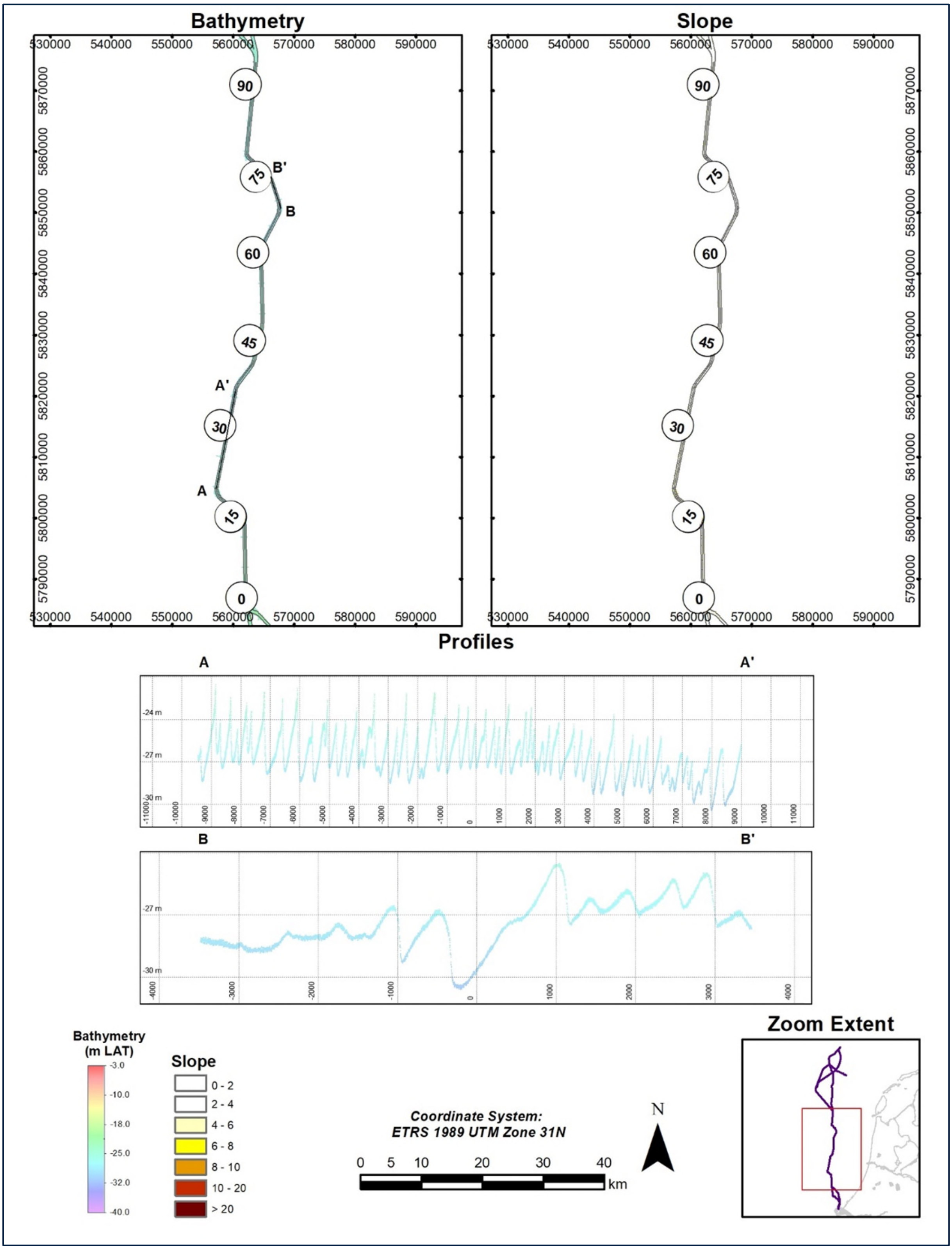


Figure 7.2: Bathymetry along the route Section A-Alt.

7.2.2 Seafloor Morphology

Overall, a strong correlation between sediment type and morphological type was observed, although some small variation is possible. An overview is given in Table 7.1 and Figure 7.3.

Table 40: Sediment type with associated morphology in route section A-Alt

Sediment Type	Morphological Type
Slightly gravelly SAND	Ripples or megaripples and sand waves

Figure 7.3 and Figure 7.4 show data examples of the route Section A – Alt. This area is characterised mostly by ripples, megaripples and sand waves.

The sand waves are symmetrical, with a northwest-southeast orientation, a wavelength ranging between 100 m and 600 m (on average 350 m), and an average height of 4.0 m.

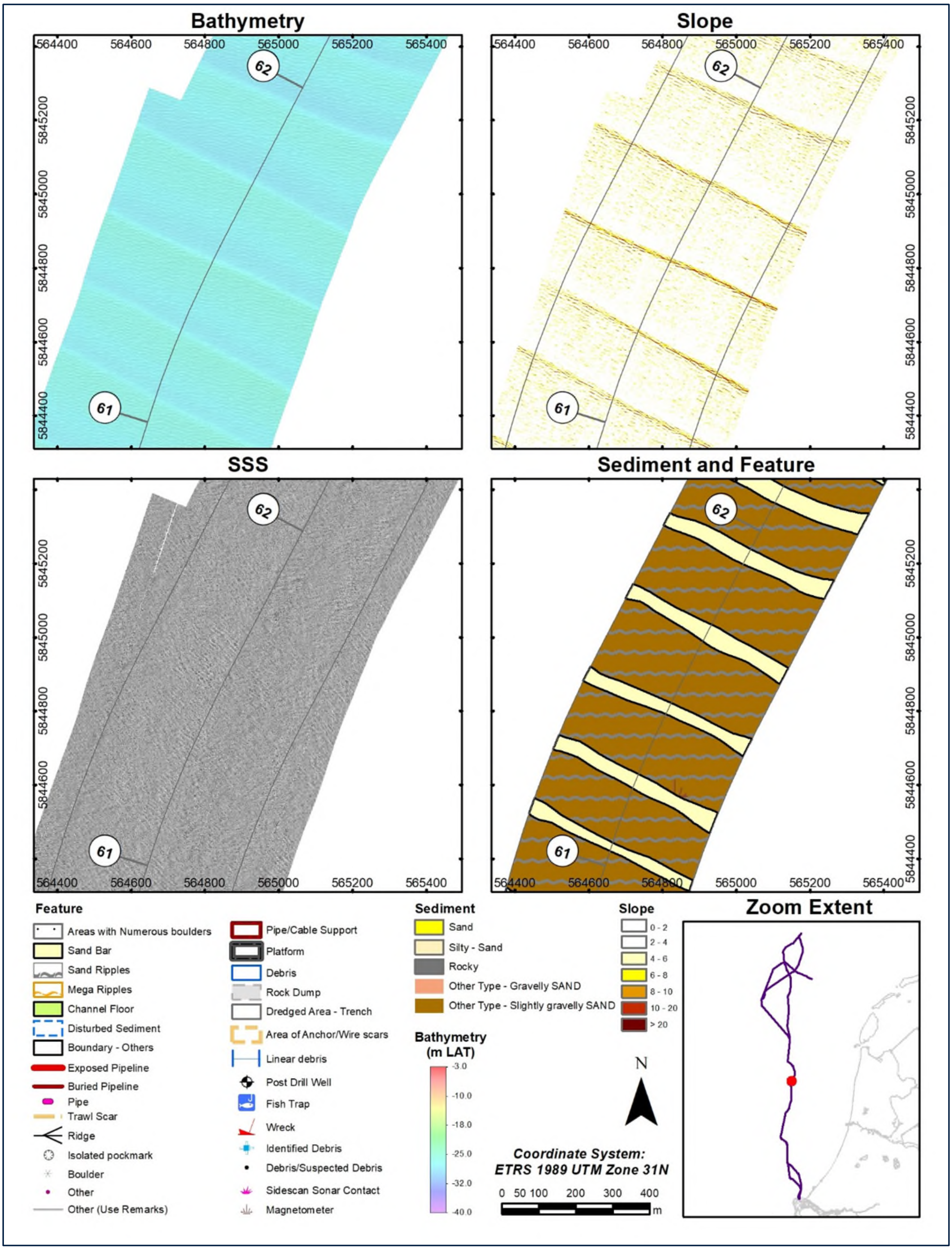


Figure 7.3: Overview of the sediments and morphology in route section A-Alt: KP 61.0 to KP 62.0.

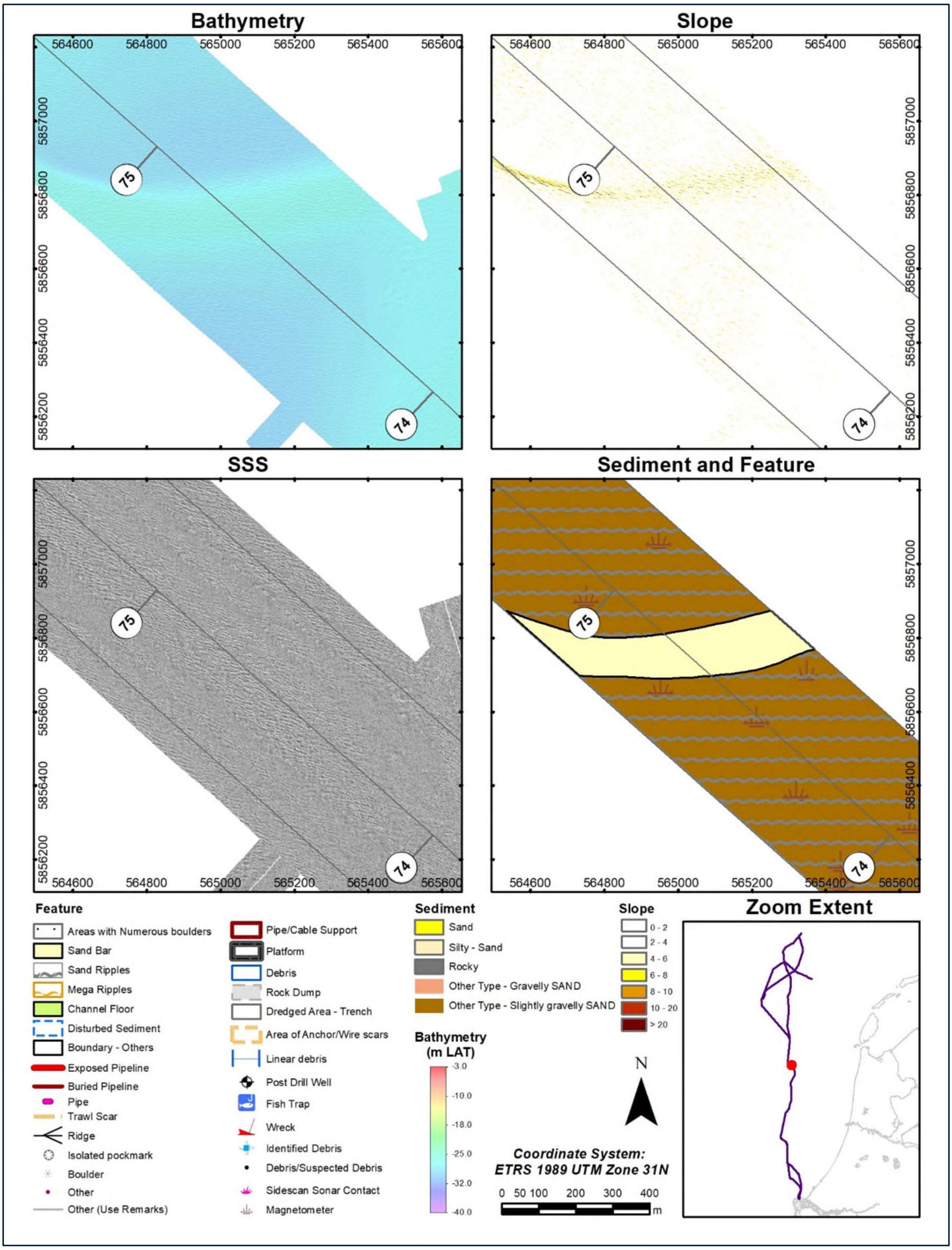


Figure 7.4: Overview of the sediments and morphology in route section A-Alt: KP 74.0 to KP 75.0.

7.2.3 Seafloor Feature and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 7.2 summarises the quantities of contacts picked in Section A - Alt. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 41: Summary of seafloor contacts in route section A-Alt

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	11
	Debris	13
	Suspected debris	37
	Magnetic anomalies	271
SSS/MBES/MAG Linear Features	Fishing gear	1
	Telecommunication cable	4
	Buried pipeline	5
	Magnetic linear feature	14

Five (5) buried pipelines and four (4) telecommunication cables were identified. Table 7.3 provides all the encountered and identified pipeline and cables.

Table 42: Summary of pipeline and telecommunication cables in route section A - Alt

Contact ID	Pipeline/Cable Name	Comment
Pipeline (PL0228_PR)	Q13a-A to P15-C 8-inch oil pipeline	Buried, KP 3.7
Mag Linear Feature	Q10 to P15-D pipeline	Buried, KP 18.0
Telecom Cable (KB0045)	Circe North	Buried, KP 19.6
Telecom Cable (KB0003)	Concerto 1 N	Buried, KP 20.5
Pipeline (PL0084_PR/HS)	P12-C to P12-SW 8-inch gas / 3-inch glycol pipeline bundle (abandoned)	Buried, KP 22.0
Telecom Cable (KB0015)	Rembrandt 1	Buried, KP 45.7
Telecom Cable (KB0067)	UK - Netherlands 14	Buried, KP 55.4
Pipeline (PL0148_PR)	Q4-A to P6-A 14-inch gas pipeline	Buried, KP 66.2
Pipeline (PL0109_PR)	Horizon to Helder-A 10-inch oil pipeline	Buried, KP 69.4
Pipeline (PL0176_PR)	Balgzand to Bacton	Buried, KP 92.5

Figure 7.5, Figure 7.6 and Figure 7.7 show data examples of encountered pipelines in in this section of the route.

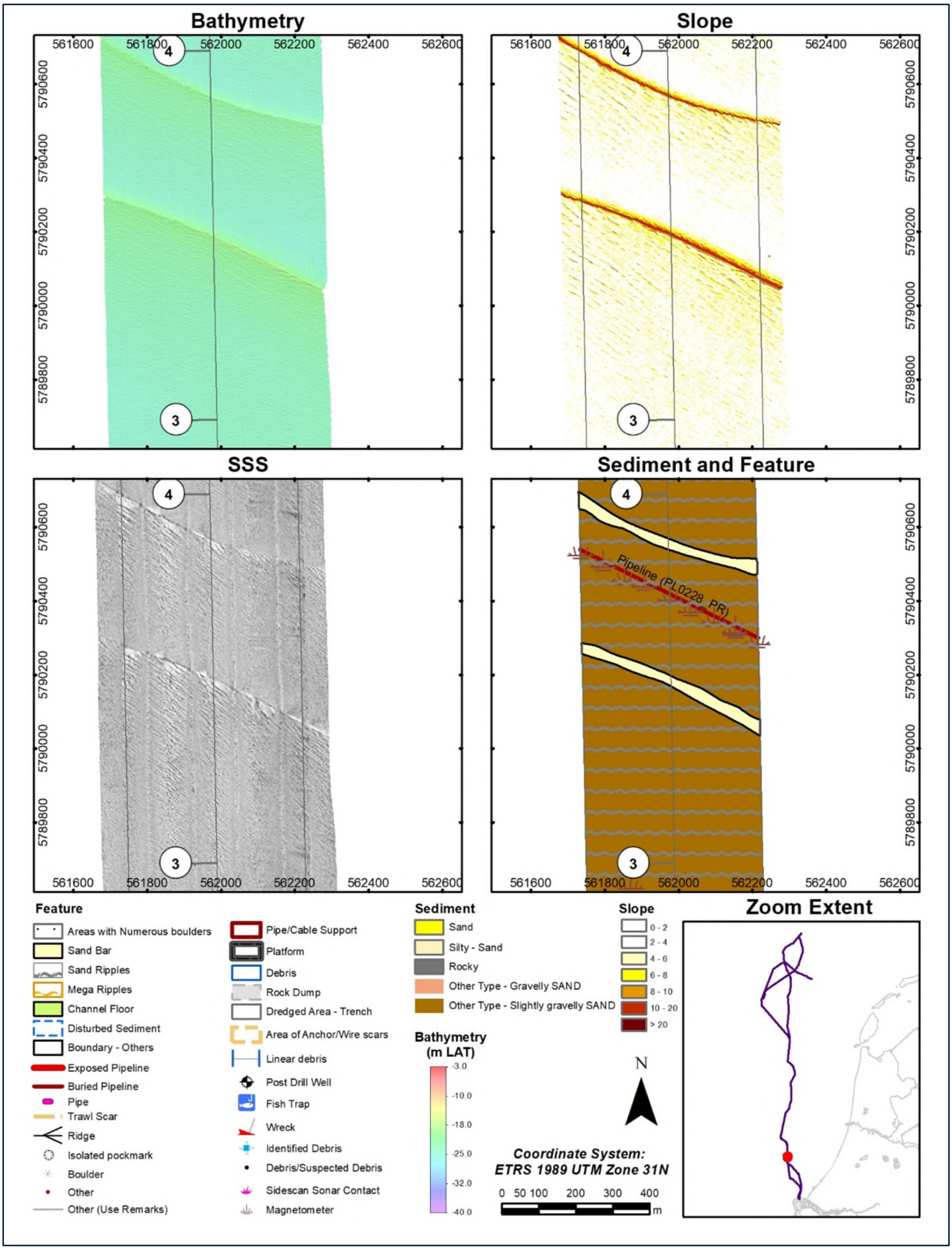


Figure 7.5: Overview of the sediments and morphology in route section A-Alt: KP 3.0 to KP 4.0, buried pipeline.

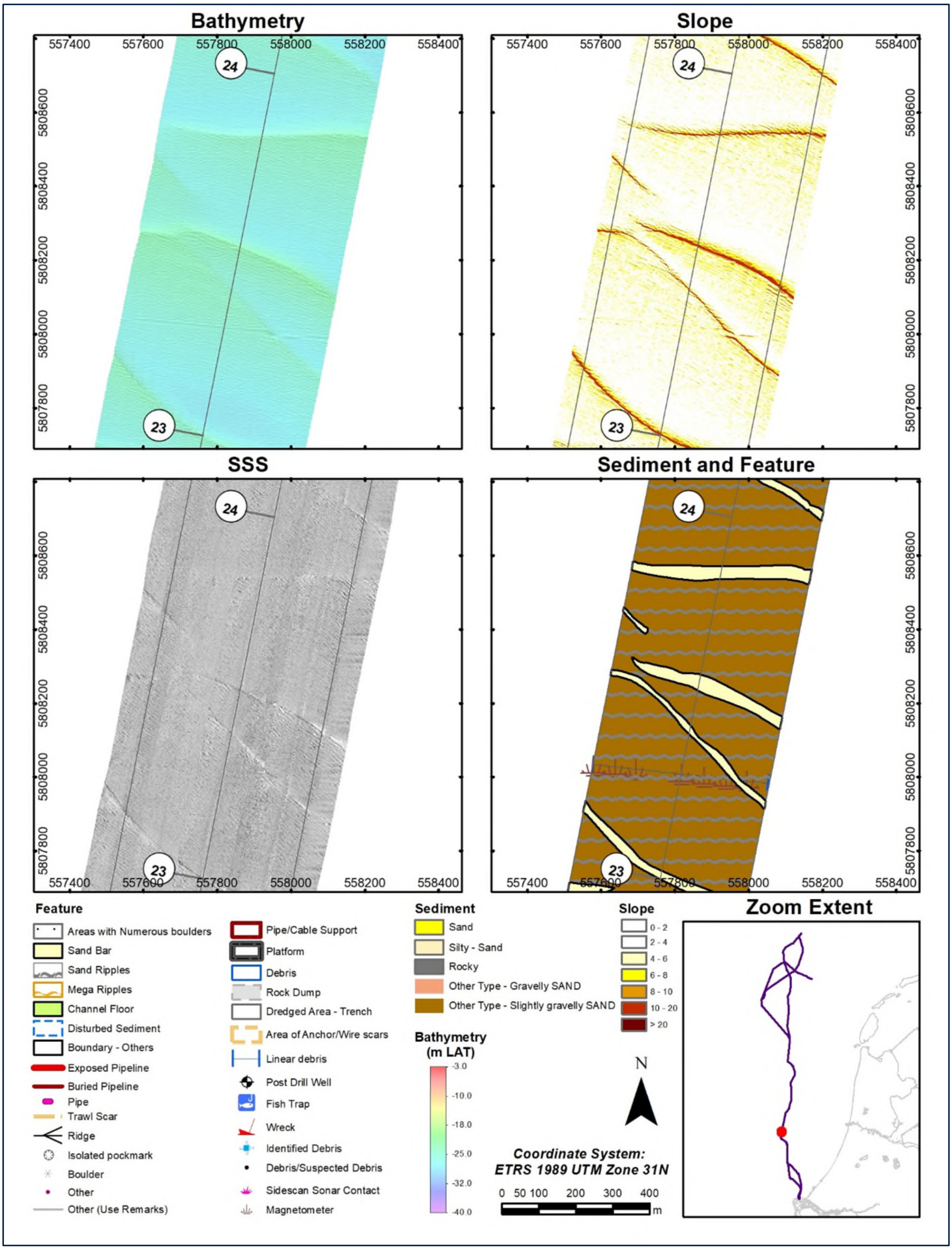


Figure 7.6: Overview of the sediments and morphology in route section A-Alt: KP 23.0 to KP 24.0, buried cable.

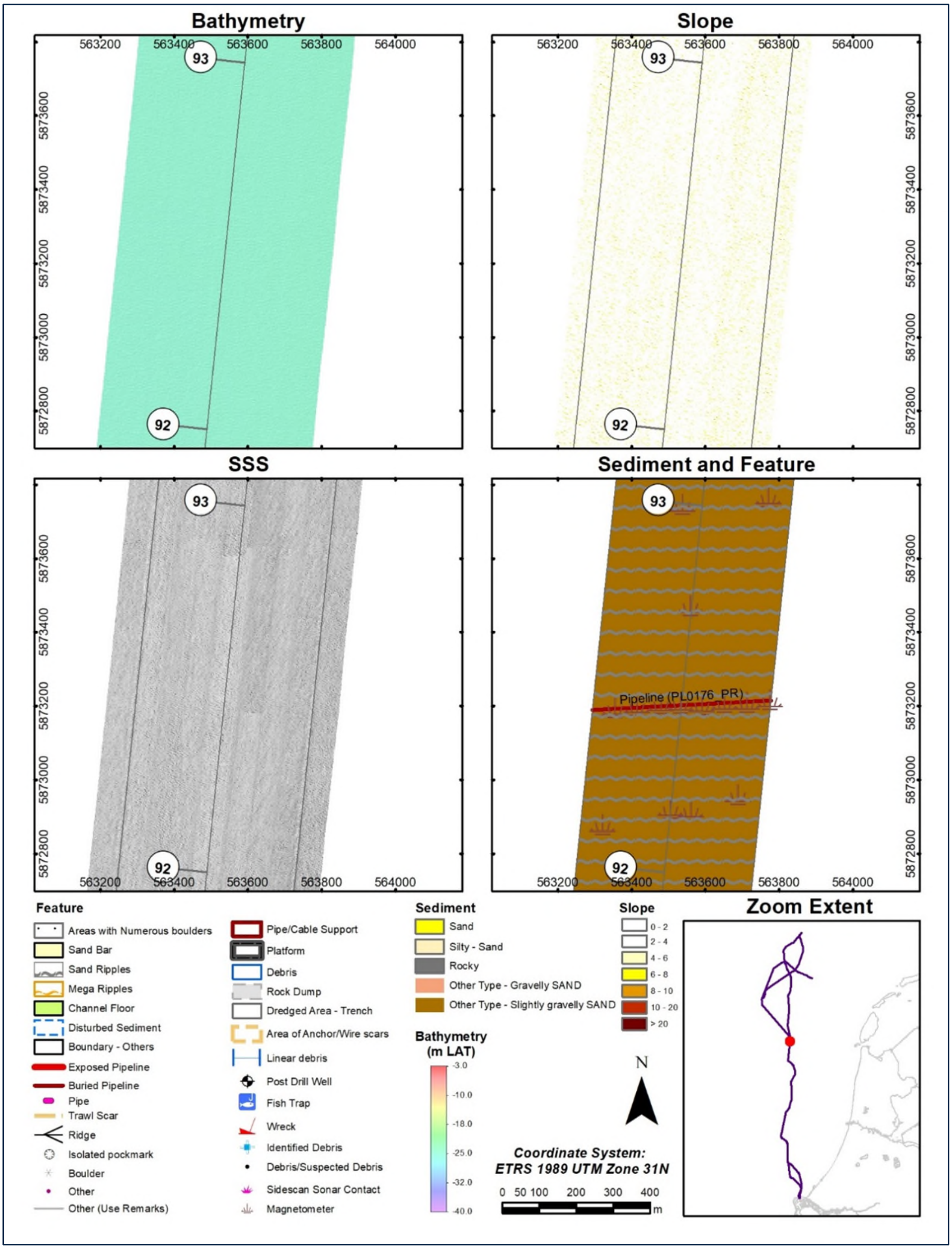


Figure 7.7: Overview of the sediments and morphology in route section A-Alt: KP 92.0 to KP 93.0, buried pipeline.

7.2.4 Magnetometer Contacts

271 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in route Section A – Alt. The magnetometer anomalies range between 5.0 nT and 2966.4 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

7.2.5 Sub-seafloor Geology

Units A, B, C, D, F and G are present in the route Section A-Alt (Figure 7.8).

Unit A is present in the entire section. It is characterized by acoustically transparent and semi-transparent seismic facies. Rarely, high amplitude reflectors of limited extent were observed in this unit. The maximum thickness of Unit A in this section is approximately 7 m.

Unit B is present across the entire section. On the SBP data, between KP 0.0 to KP 59.0 the base of the unit is observed locally and for the large part it is below the penetration depth of the data. The unit exhibits transparent to semi-transparent seismic character. Internal buried channels with layered infill were observed in this unit at approximately KP 23.5 to KP 59. High negative amplitude anomalies were also interpreted in this unit, most likely represent laminae or thin bed of peat and/or organic-rich clay (peat level 1). The maximum thickness of Unit A in this section is approximately 10 m.

Unit C is present between KP 42.0 to KP 94.0. This unit exhibits layered facies with low to high-amplitude parallel reflectors. High negative amplitude anomalies were also interpreted in this unit, most likely represent laminae or thin bed of peat and/or organic-rich clay (peat level 2). Maximum thickness of this unit is approximately 35 m.

Unit D is present across the entire section, but from KP 78.0 to KP 94.0 only in patches. It is acoustically transparent to semi-transparent and structureless. Maximum thickness of this unit in Section A-Alt is approximately 10 m.

Unit F is interpreted between KP 74.5 to KP 78.0. The basal reflector of this unit forms U-shaped channel with seismically transparent infill. Maximum thickness of this unit is approximately 90 m.

Unit G is present across the entire section. It exhibits transparent and semi-transparent seismic character. High negative amplitude anomalies were also interpreted in this unit (peat level 3).

Table 7.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 43: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.5 to 7.0	Very loose to very dense slightly silty fine and medium SAND with frequent shells and shell fragments
B	0.8 to 10.7	Medium to very dense slightly silty fine and medium SAND, occasionally with shells and shell fragments Locally low to high strength slightly sandy CLAY

Unit	Depth to Base [m BSF]	Lithology
C	BPD	Very loose to loose very silty fine and medium SAND with occasional pockets of organic matter Locally low strength to high strength very slightly sandy CLAY with medium spaced very thin beds of sand
Notes: BPD = below penetration depth of SBP data		

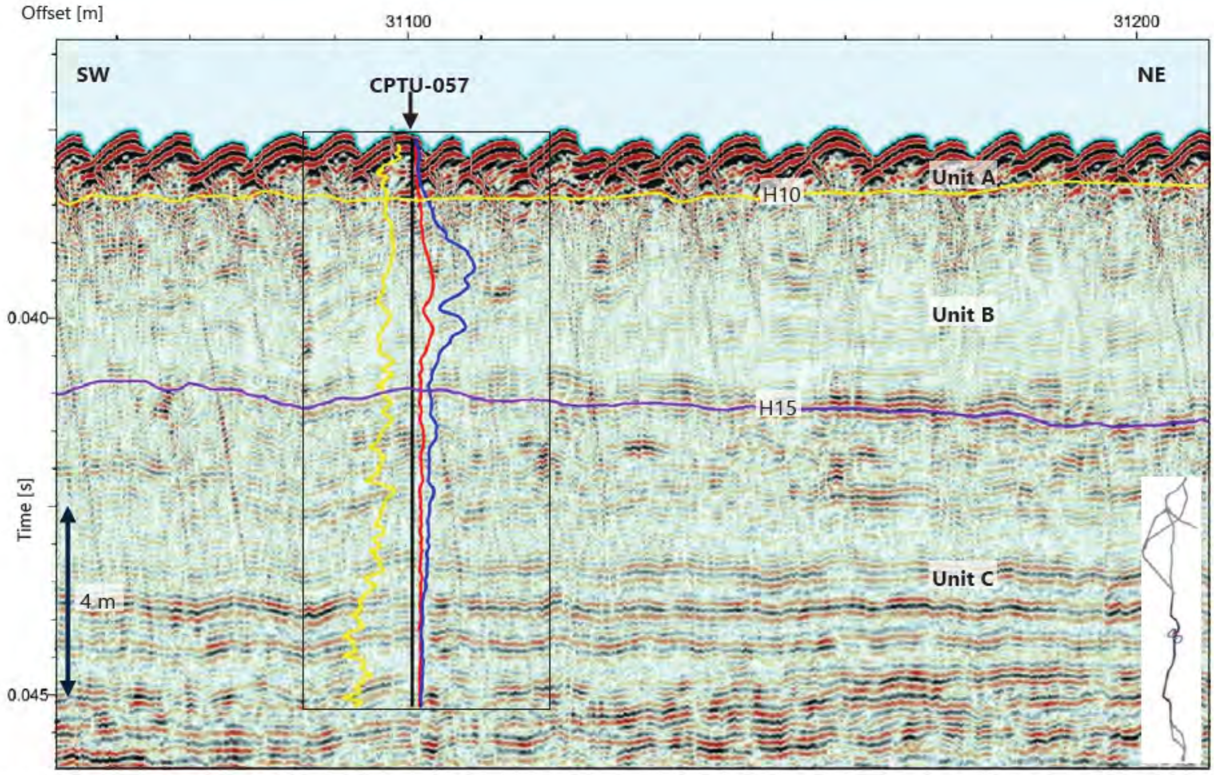


Figure 7.8: SBP data example of route section Alt-A. (Line SBP_TA3E2130P1) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

8. Section B

8.1 Section B Location

The location of the route Section B is showed in Figure 8.1. This section of the route has a length of 57.8 km.

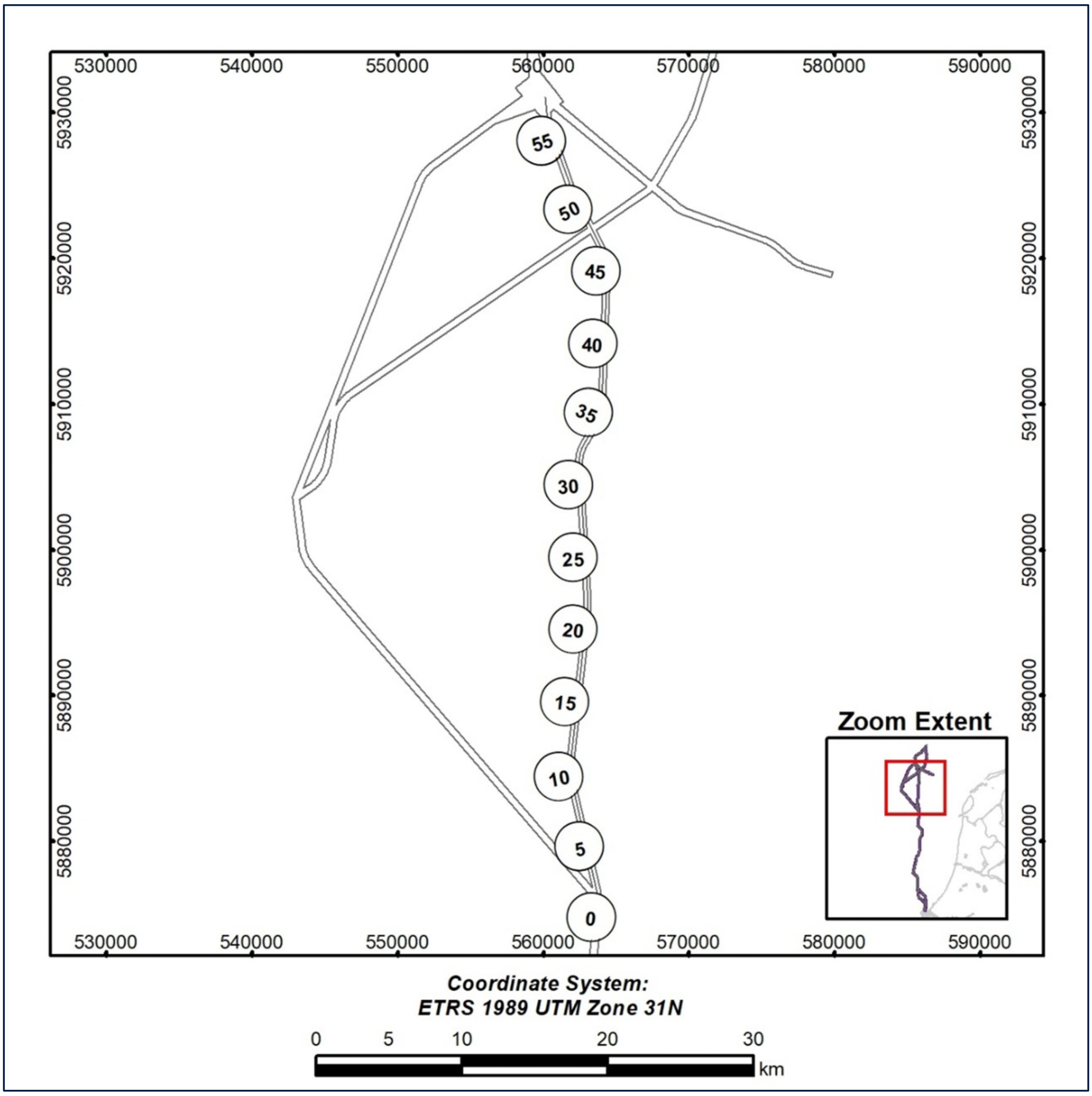


Figure 8.1: Location of the route section B.

8.2 Results

8.2.1 Bathymetry

The water depth in route Section B ranges between 25.0 m and 30.5 m. An overview of the bathymetry is given in Figure 8.2.

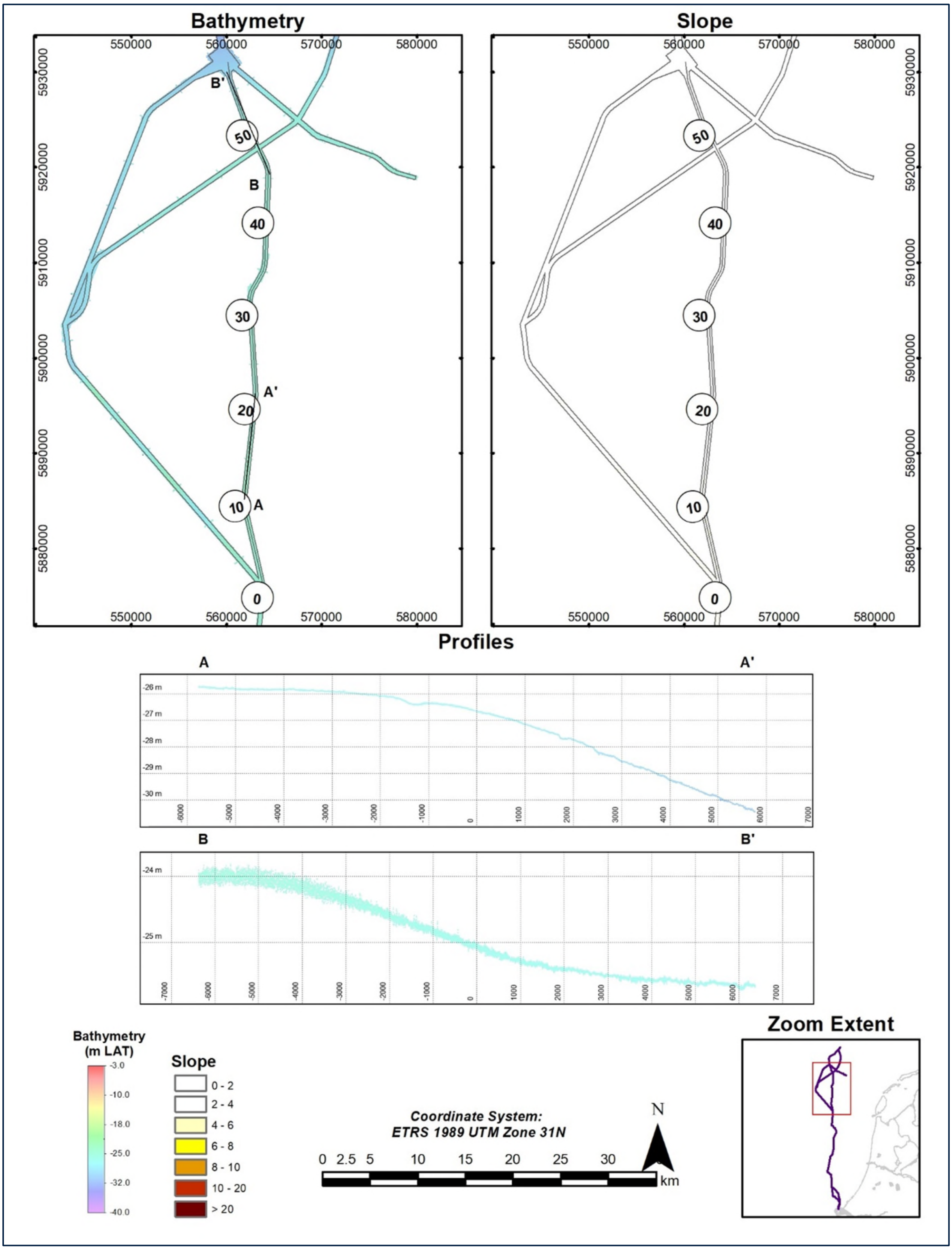


Figure 8.2: Bathymetry along the route section B.

8.2.2 Seafloor Morphology

A strong correlation between sediment type and morphological type was observed, although some small variation is possible. An overview is given in Table 8.1 and Figure 8.7 and Figure 8.8.

Table 44: Sediment type with associated morphology in route section B

Sediment Type	Morphological Type
Slightly gravelly SAND	Ripples, megaripples
SAND	Featureless

Between KP 0.0 and KP 17.5 and between KP 23.5 and KP 28.3, sediment was classified as slightly gravelly SAND with ripples and megaripples. The rest of Section B was classified as featureless SAND.

Figure 8.3 and Figure 8.4 show data examples of the sediment type and seafloor feature found in Section B.

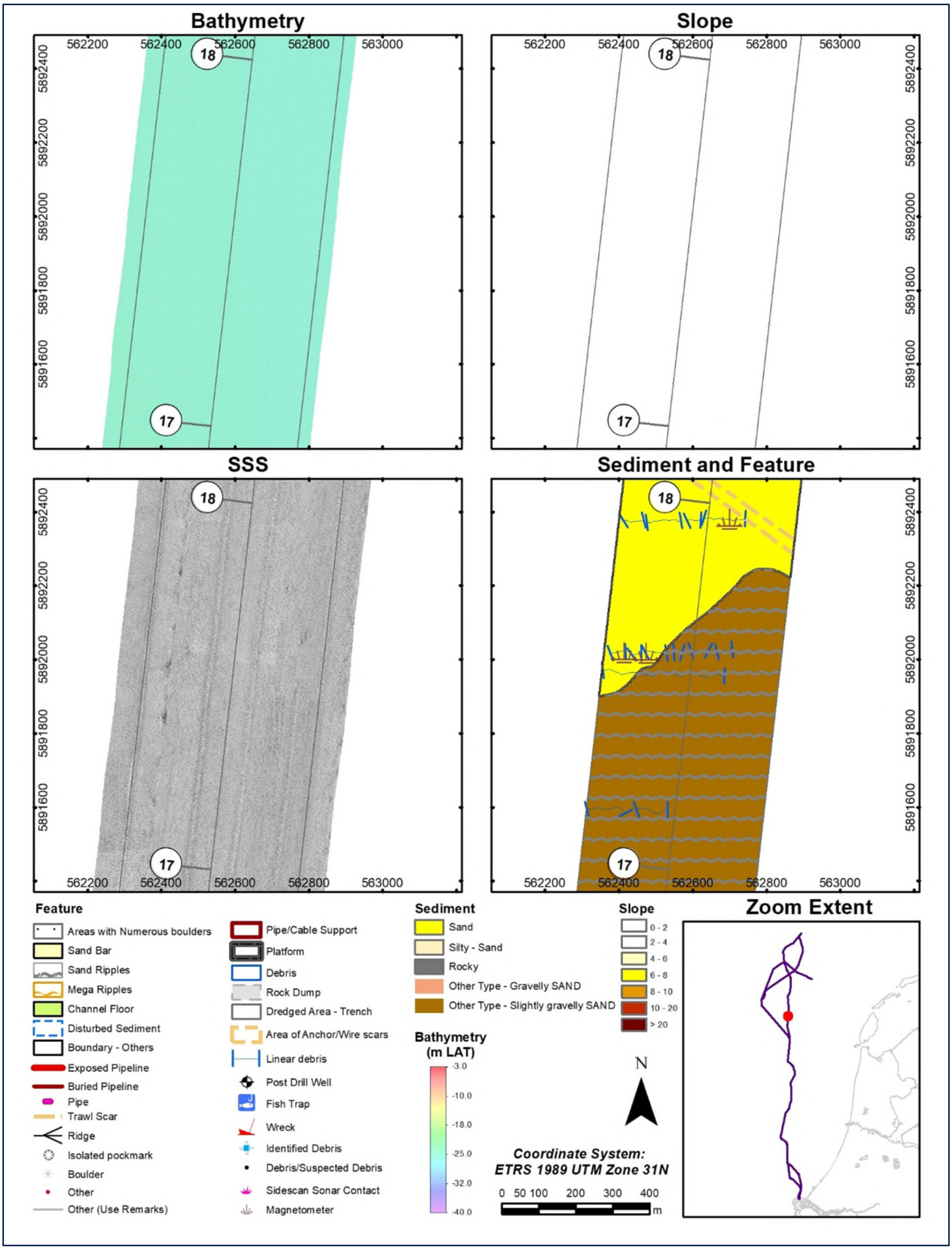


Figure 8.3: Overview of the sediments and morphology in route section B: KP 17.0 to KP 18.0.

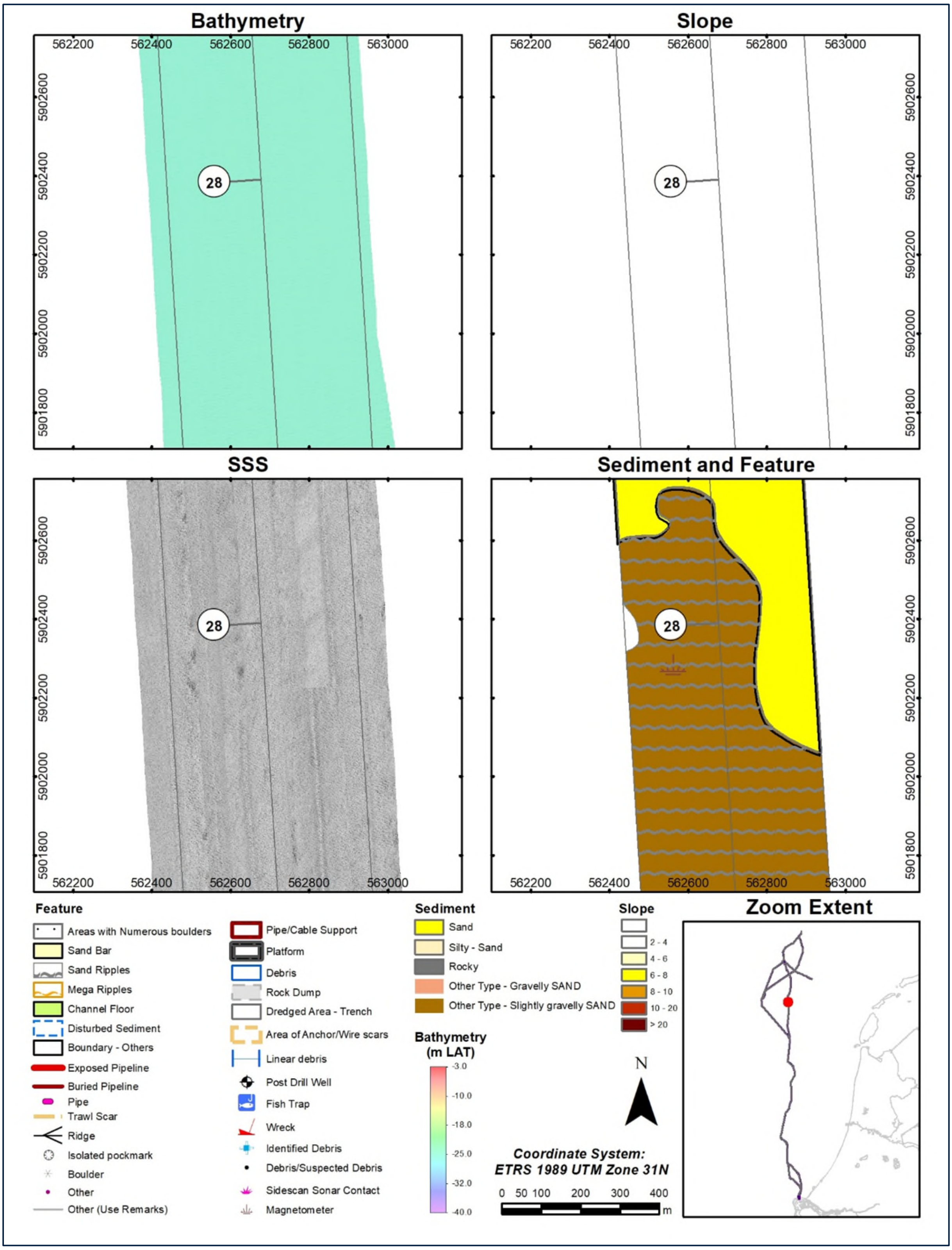


Figure 8.4: Overview of the sediments and morphology in route section B: KP 28.0.

8.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated, where possible.

Table 8.2 summarizes the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 45: Summary of seafloor contacts in route section B

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Debris	34
	Depression pockmark	1
	Fishing gear	2
	Exposed pipe	4
	Seabed mound	39
	Suspected debris	7
	Magnetic anomalies	133
SSS/MBES/MAG Linear Features	Fishing gear	2
	Possible fishing gear	39
	Large trawl scour	24
	Mound ridge	18
	Exposed pipeline	1 (3 segments exposed, 4 segments buried)
	Buried pipeline	7

Figure 8.5 shows two (2) seafloor contacts classified as possible fishing gears were identified at KP 25.0.

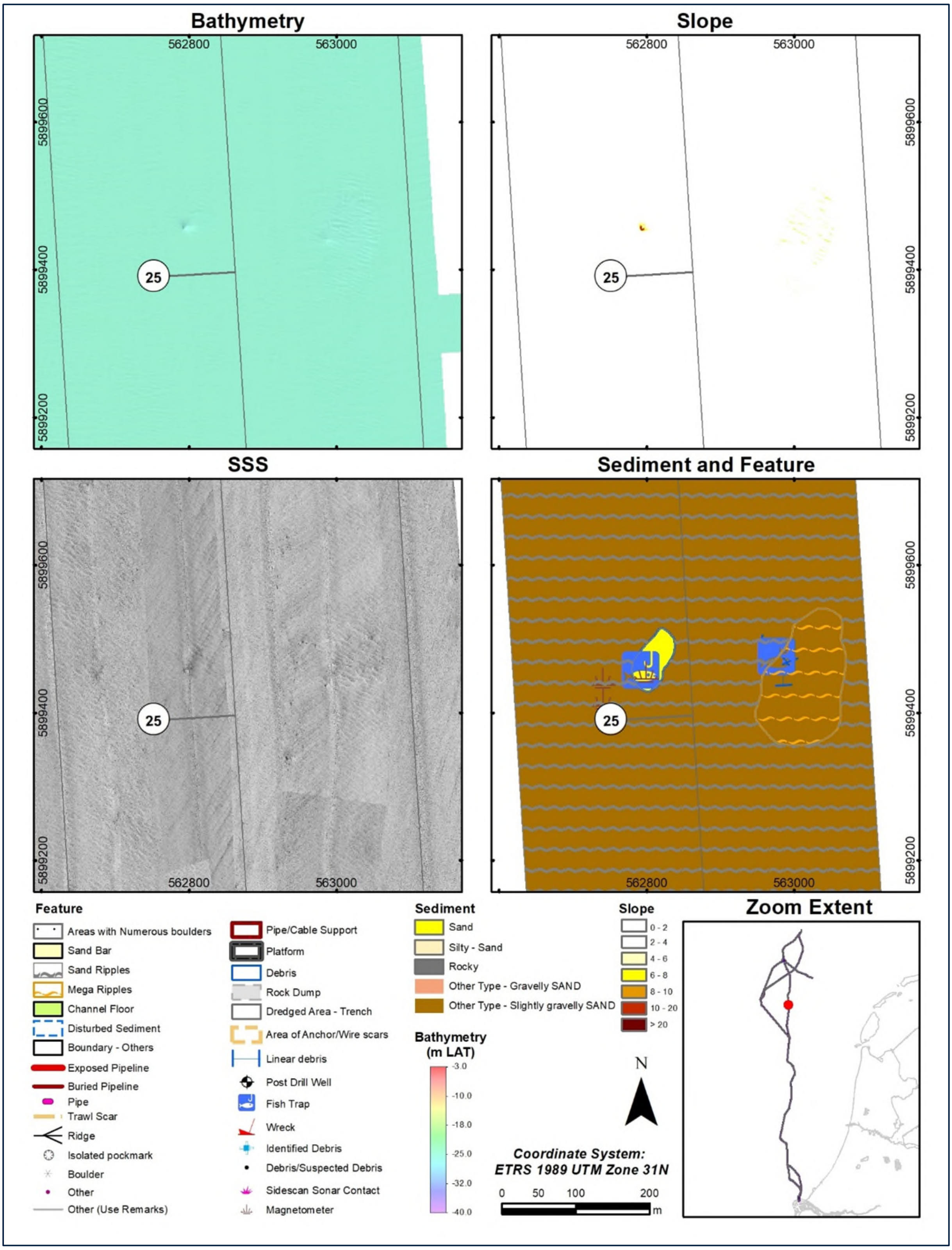


Figure 8.5: Overview of the sediments and morphology in route section B: KP 25.0, possible fishing gears.

Several buried pipelines were observed (Table 8.3 and Figure 8.6, Figure 8.7 and Figure 8.8).

Table 46: Summary of pipelines in route section B

Contact ID	Pipeline Name	Comment
Pipeline (PL0032_PR)	P6-A to L10-AR 20-inch gas pipeline	Buried, KP 8.7
Pipeline (PL0030_PR)	NAM_K15-FB-1 to Den Helder	Buried, KP 20.5
Pipeline (PL0004_PR)	K13-A to Den Helder 36-inch gas pipeline	Buried, KP 26.1
Pipeline (PL0062_PR)	K14-FA-1C TO K15-FA-1 18-inch pipeline	Buried, KP 26.2
Pipeline (PL0063_PR)	K12-BP to L10-AR 18-inch pipeline	Buried, KP 38.0
Pipeline (PL0029_HS)	K12-A to L10-AP 14/2-inch bundle	Buried, KP 48.7
Pipeline (PL0056_PR)	K12-E to K12-C 10-inch pipeline	Buried, KP 50.8
Pipeline (PL0142_PR)	D15-FA to L10-AC 36-inch pipeline	Partially buried and partially exposed, KP 53.4

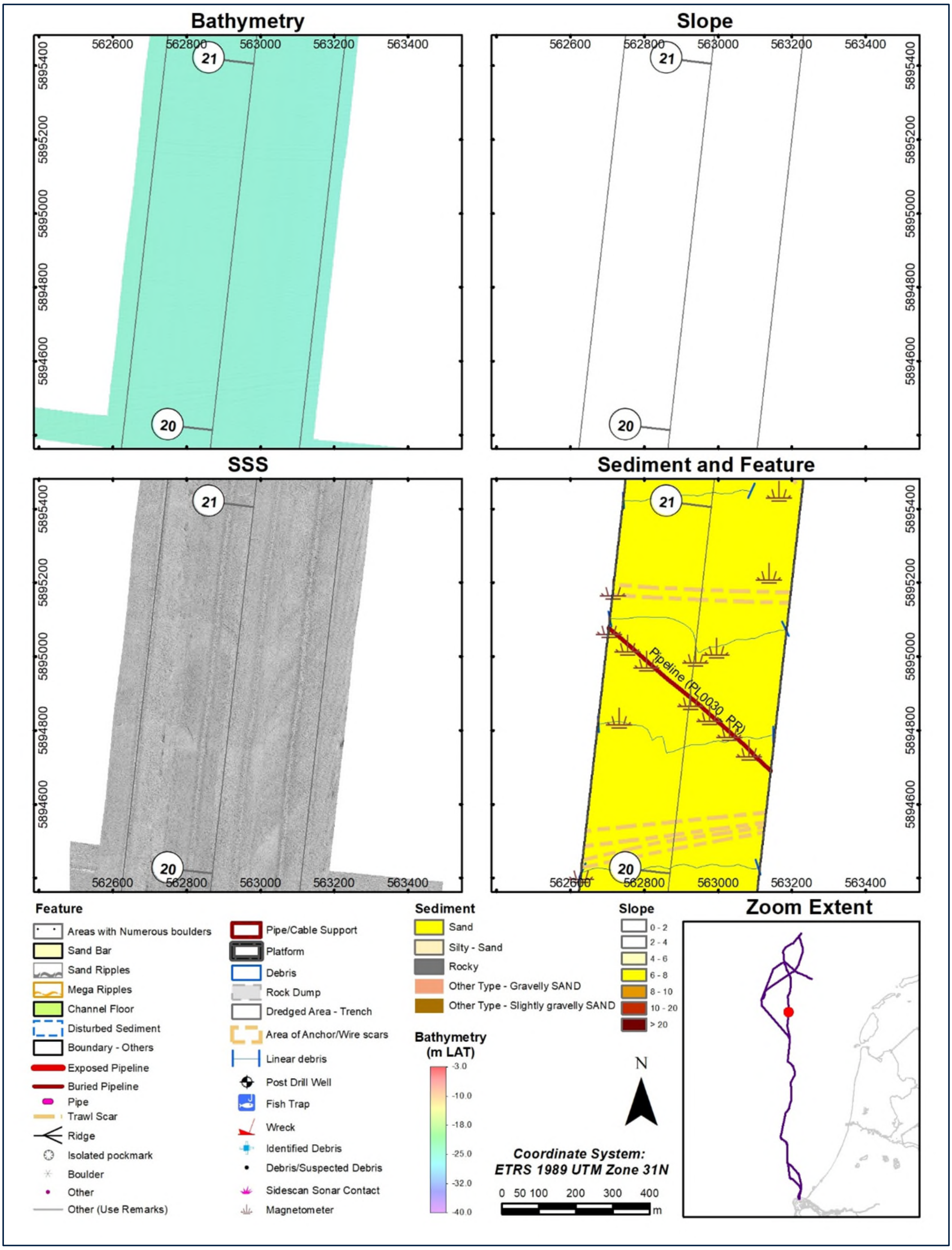


Figure 8.6: Overview of the sediments and morphology in route section B: KP 20.0 to KP 21.0, buried pipeline.

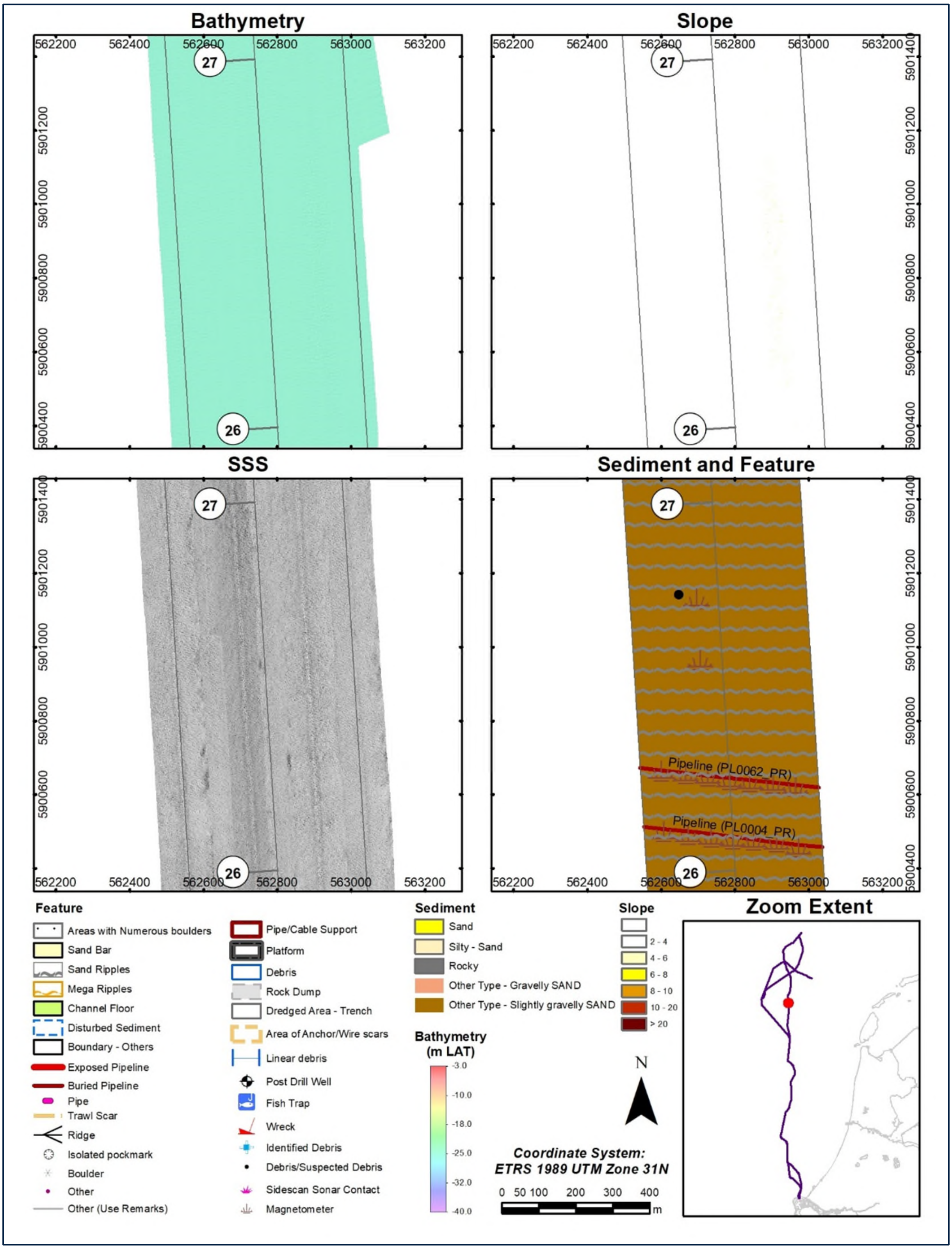


Figure 8.7: Overview of the sediments and morphology in route section B: KP 26.0 to KP 27.0, buried pipelines.

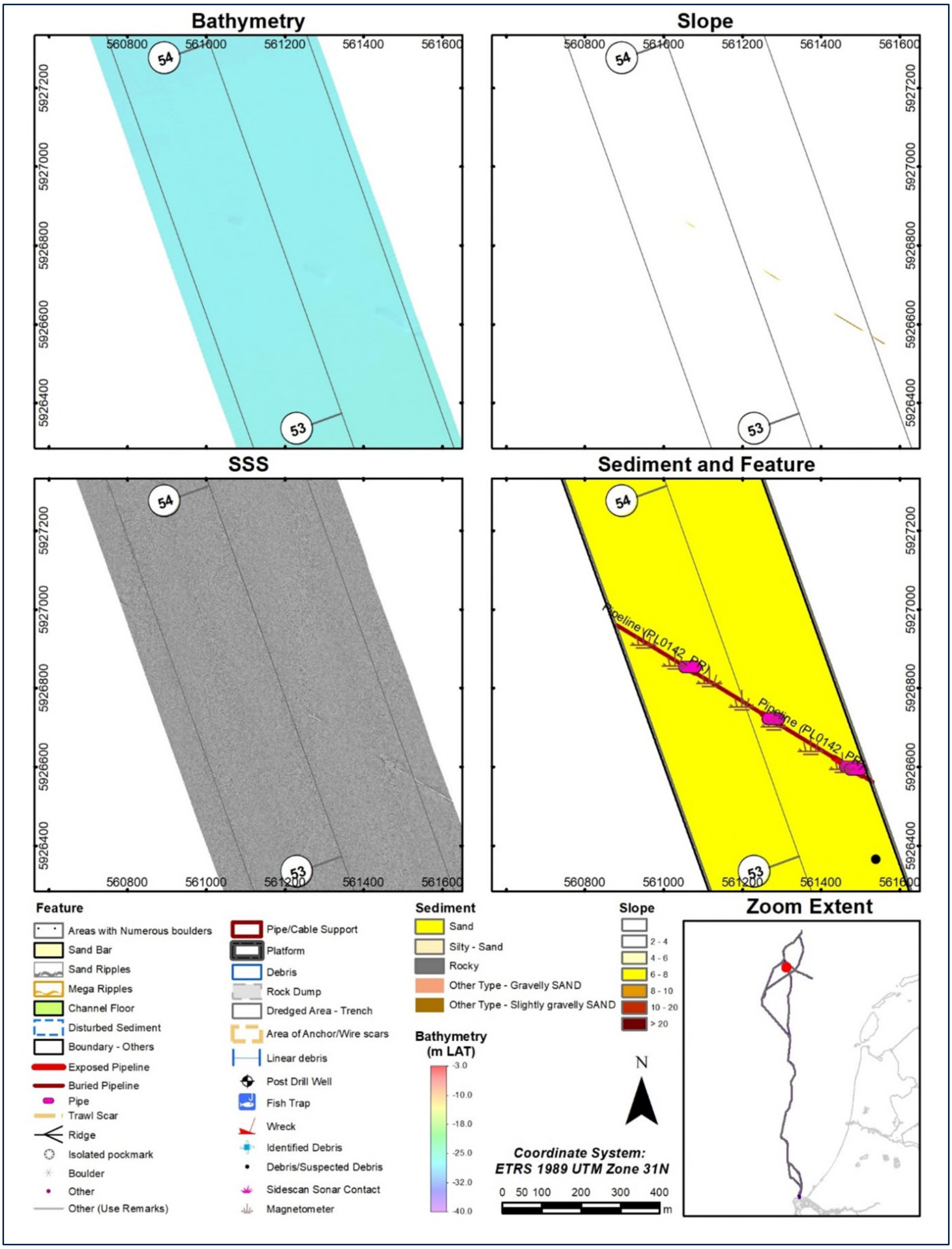


Figure 8.8: Overview of the sediments and morphology in route section B: KP 53.0 to KP 54.0, partially exposed pipeline.

8.2.4 Magnetometer Contacts

In Section B, 133 magnetic contacts were found at the time of the geophysical scope (single MAG survey). The magnetometer anomalies range between 5.2 nT and 7064.6 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

8.2.5 Sub-seafloor Geology

Units A, B, D, E, F and G are present in the route Section B (Figure 8.9).

Unit A is present in the entire section. Between KP 0.0 to KP 40.0 the unit is characterized by a chaotic and semi-transparent seismic character. Between KP 40.0 to KP 57.8 it is acoustically transparent. The maximum thickness of this unit in this section is approximately 3 m.

Unit B is present across the entire section. On the SBP data, the seismic character is semi-transparent and structureless, locally where the base is channelised the infill is structured, with medium-amplitude subparallel reflectors. On the 2D-UHRS, high amplitude negative anomalies were observed at the base of this unit, which represent laminae or thin bed of peat and/or organic-rich clay (peat level 1). The maximum thickness Unit B in this section is approximately 9 m.

Unit C is present across the entire section, except between KP 51.8 and the end of the section, where it is interpreted to be absent. The unit is characterized by locally transparent /structureless to layered facies, with medium to high amplitude parallel reflectors, which are locally irregular, discontinuous, and forming small channels. High negative amplitude reflectors are common in this unit, which most likely represent laminae or thin bed of peat and/or organic-rich clay (peat level 2). The thickness varies, on average it is approximately 5 m, the maximum reaches approximately 10 m.

Unit D is present in the entire section. Its seismic character is transparent to semi-transparent, with locally internal erosion surfaces. The maximum thickness of the Unit D in this section is approximately 15 m.

Unit E is present between KP 31.5 to KP 57.8. The unit is characterised by semi-transparent and structureless facies. The maximum thickness of this unit in this section is approximately 20 m.

Unit F (infill of glacial valley) is present between KP 41.9 to KP 51.7.

Table 8.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 47: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.7 to 3.3	Very loose to very dense slightly silty to silty fine and medium SAND with frequent shells and shell fragments
B	2.4 to 11.1	Medium to very dense slightly silty fine and medium SAND with frequent shells and shell fragments Locally clayey fine and medium SAND

Unit	Depth to Base [m BSF]	Lithology
C	BPD	Thickly Interbedded Low to medium strength sandy clayey SILT and medium strength CLAY Occasionally medium dense to dense slightly silty fine and medium SAND with extremely closely to very closely spaced thin laminae to medium beds of peat and clay
D	BPD	Loose to medium dense slightly silty to silty fine and medium SAND
Notes: BPD = below penetration depth of SBP data		

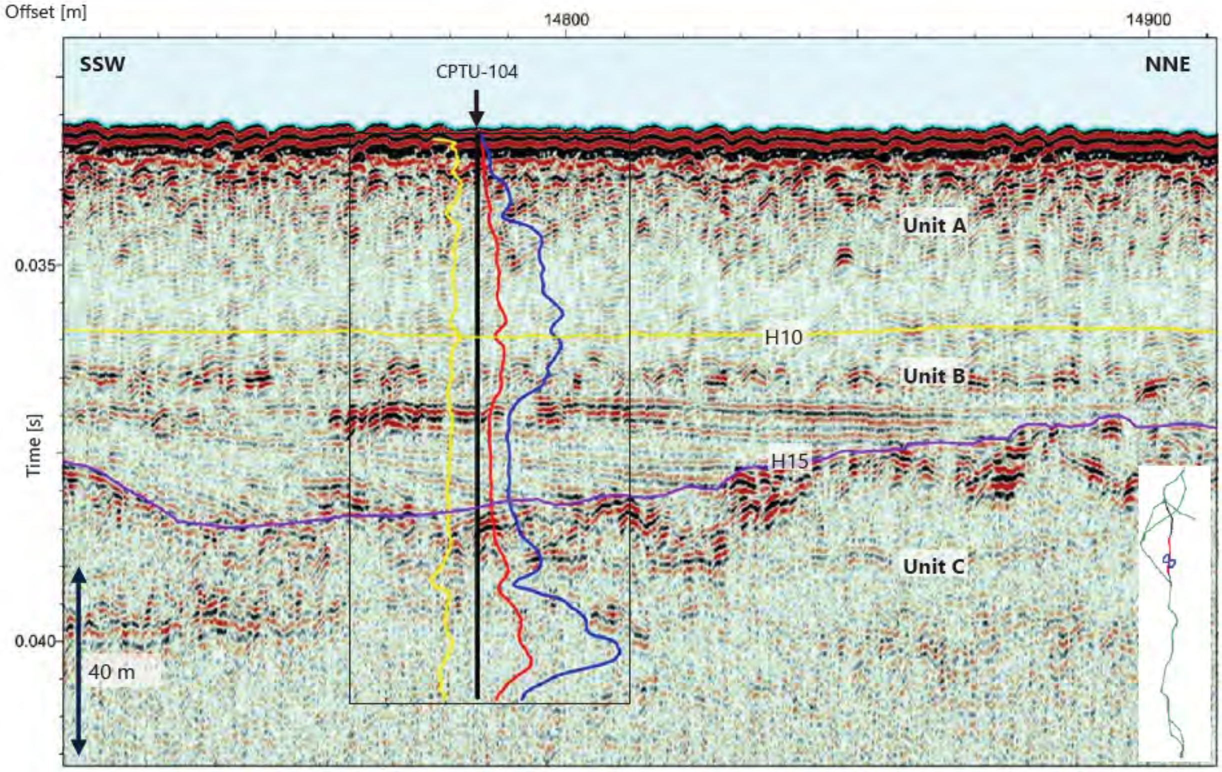


Figure 8.9: SBP data example of route section B. (Line SBP_ TA3F2184P2) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

9. Section C

9.1 Section C Location

The location of the Section C is showed in Figure 9.1. This section of the route has a length of 26.8 km and runs from the Hub Area to Platform LA4.

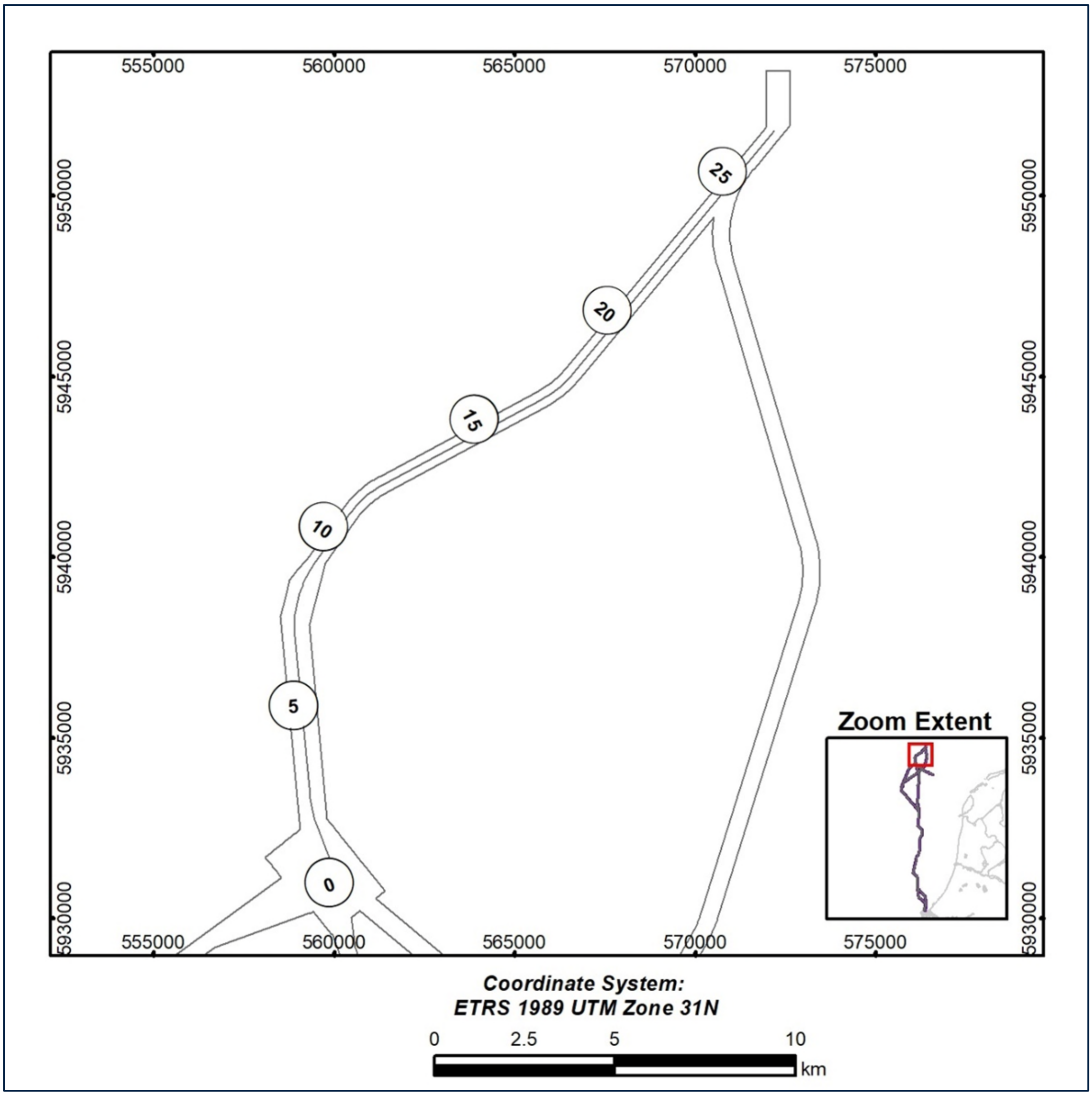


Figure 9.1: Location of the route section C.

9.2 Results

9.2.1 Bathymetry

The water depth in route Section C ranges between 31.0 m and 39.5 m. An overview of the bathymetry is given in Figure 9.2.

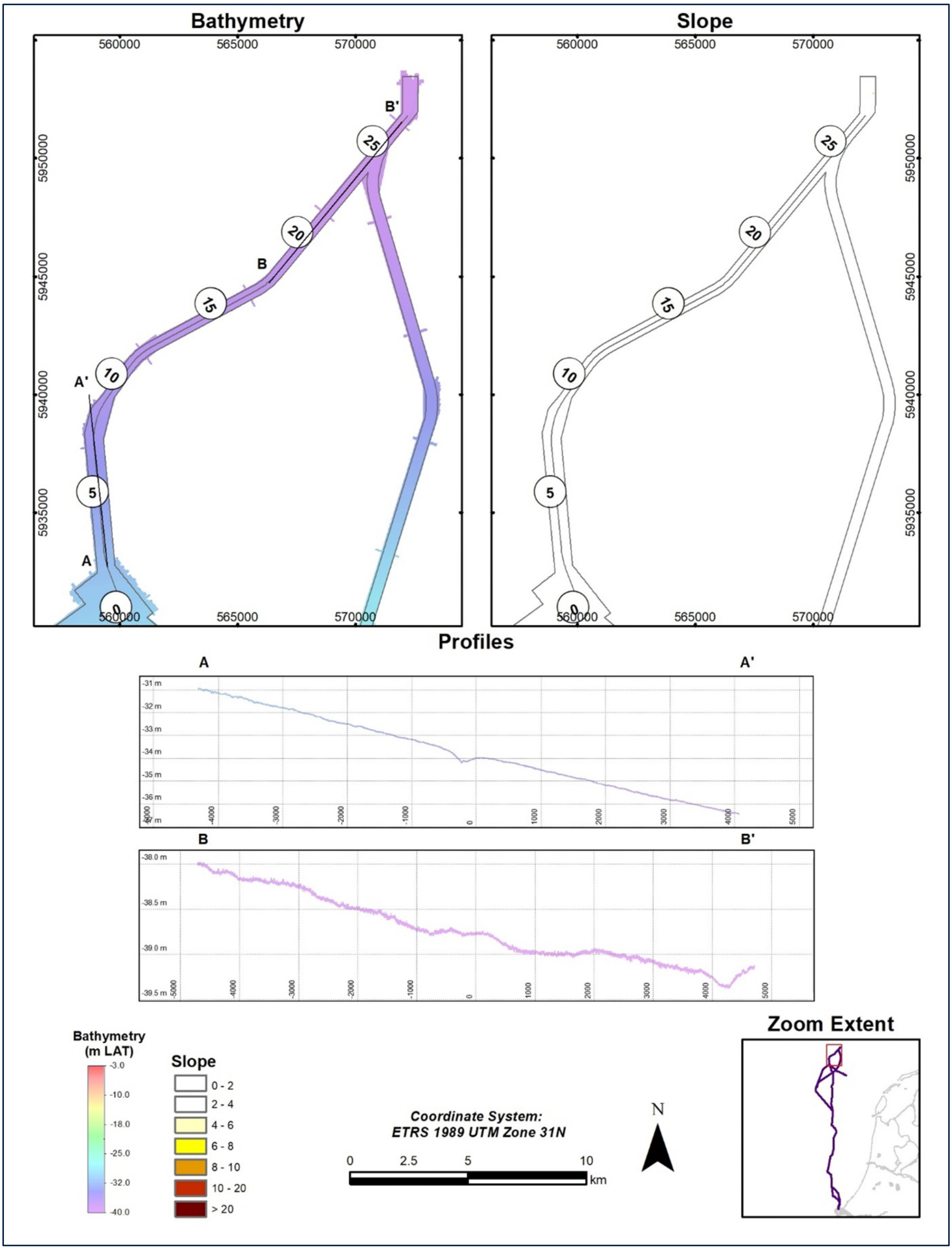


Figure 9.2: Bathymetry along the route section C.

9.2.2 Seafloor Morphology

Overall, a strong correlation between sediment type and morphological type was observed, although some small variation is possible. An overview is given in Table 9.1.

Table 48: Sediment type with associated morphology in route section C

Sediment Type	Morphological Type
Gravelly SAND	Patchy coarse sediments
Silty (muddy) SAND	Patchy fine sediments
SAND	Featureless, trawl marks area

The seafloor in Section C is mostly featureless with SAND as primary sediment. Between KP 2.5 and KP 5.5 two areas of gravelly SAND (patchy coarse sediments) have been identified. Isolated trawl marks have been found as well. From KP 20.0 to the Platform L4A there is a change in sediment type observed, which becomes silty (muddy) SAND (Figure 9.6).

9.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 9.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 49: Summary of seafloor contacts in route section C

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	148
	Depression pockmark	5
	Mattress	2
	Seabed mound	3
	Suspected debris	83
	Wreck	1
	Magnetic anomalies	118
SSS/MBES/MAG Linear Features	Exposed pipeline	3 (2 segments belonging to the same pipeline)
	Buried pipeline	8 (several segments belonging to the same pipelines)
	Magnetic linear feature	1

A wreck was identified at KP 4.5 of this route section (Figure 9.3).

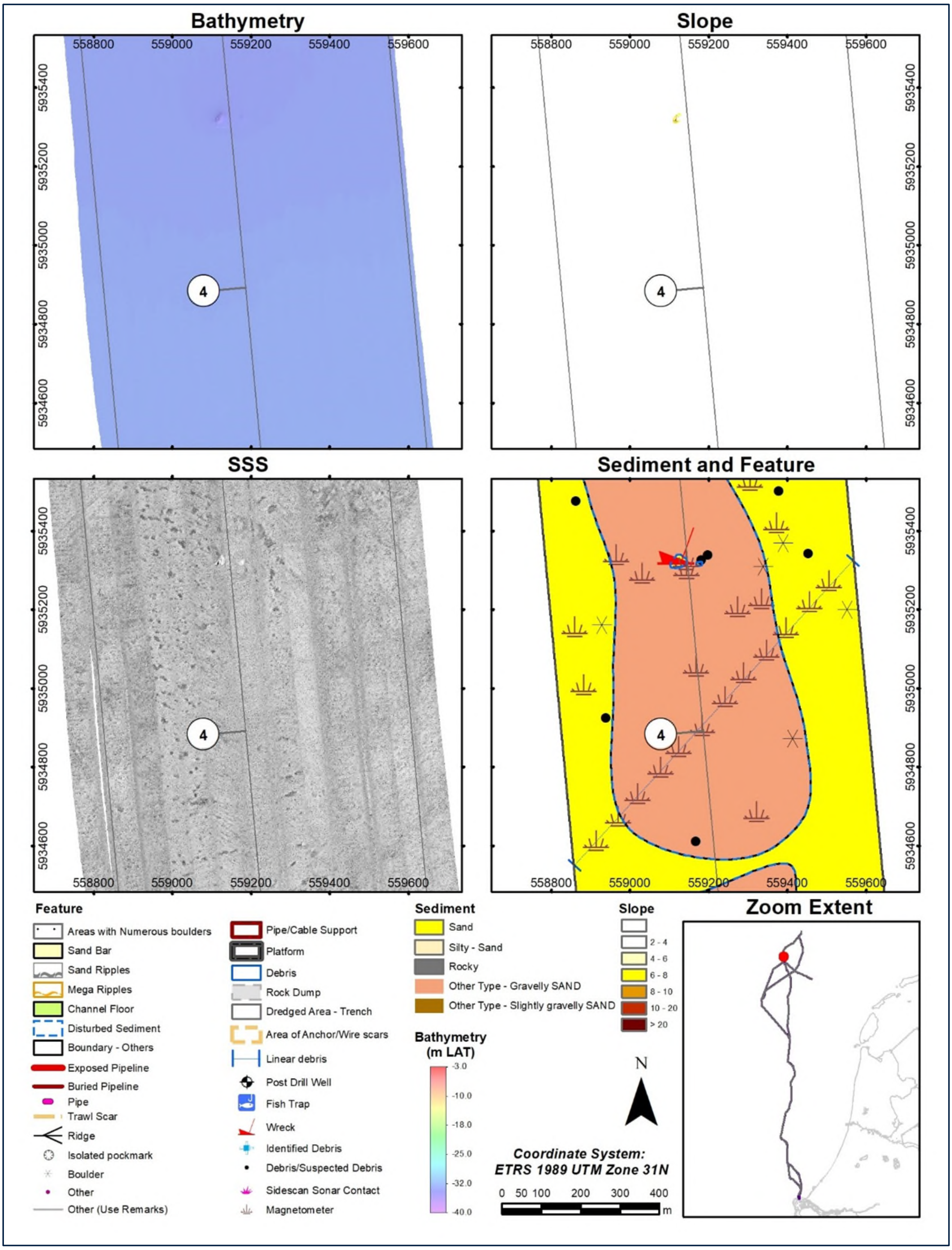


Figure 9.3: Overview of the sediments and morphology in route section C: KP 4.5.

Two (2) exposed segments of a pipeline and two (2) mattresses were identified near Platform L4A (Figure 9.4).

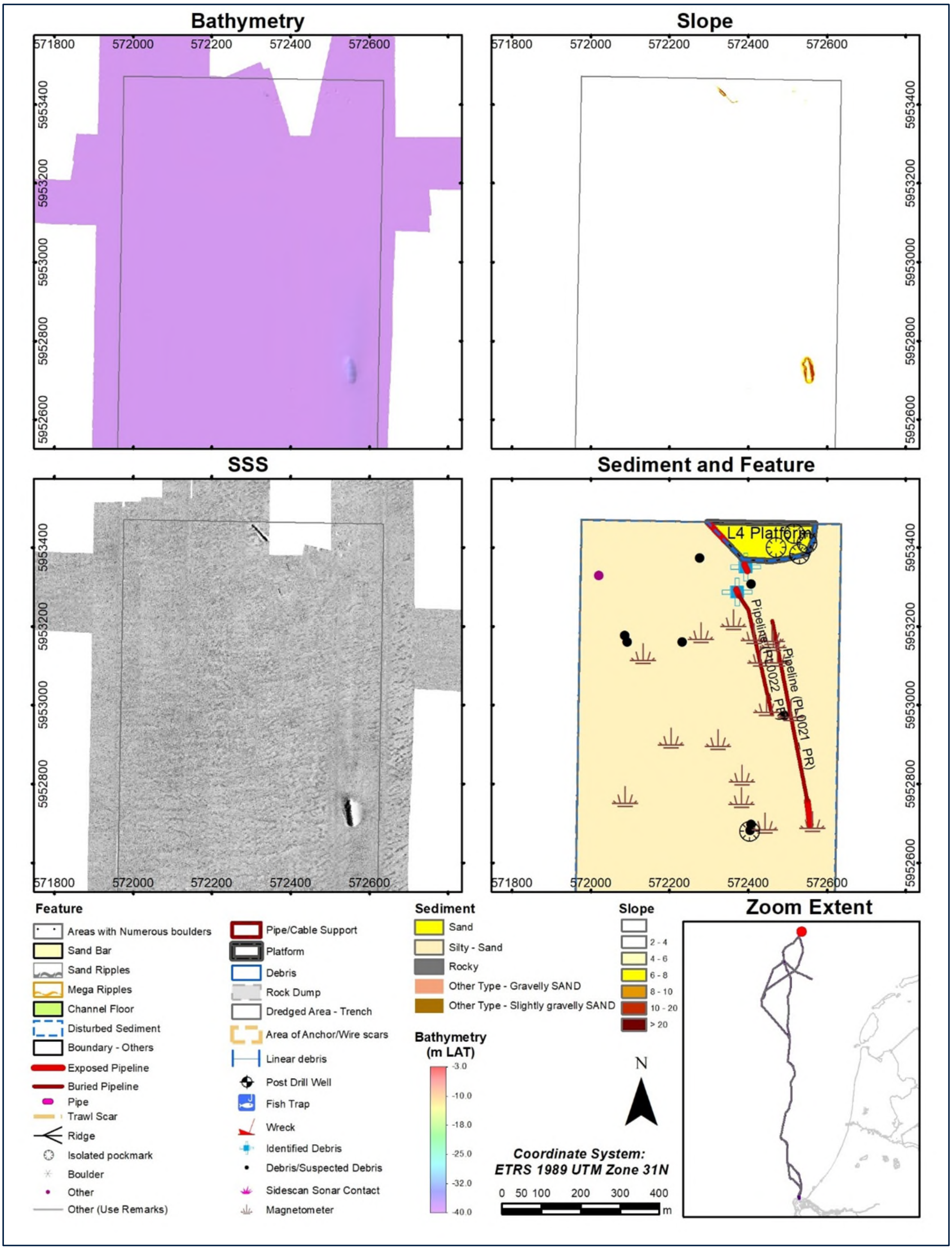


Figure 9.4: Overview of the sediments and morphology in route section C, near Platform L4A.

In Section C, five (5) pipelines and one (1) possible cable have been identified. One of the observed pipelines has two exposed segments in the proximity of the Platform L4A (Table 9.3, Figure 9.5, Figure 9.6 and Figure 9.7).

Table 50: Summary of pipelines in route section C

Contact ID	Pipeline Name	Comment
Pipeline (PL0064_PR)	K9c-A to L10-AR 16-inch pipeline	Buried, KP 9.7
Pipeline (PL0047_PR)	L4-B to L7-A 10.75-inch pipeline	Buried, KP 19.2
Pipeline (PL0048_PR)	L4-B to L7-A 3.5-inch pipeline	Buried, KP 19.3
Pipeline (PL0022_PR)	L4-A TO L7-P 3.5-inch pipeline (abandoned)	Buried (2 segments) (No KP information available)
Pipeline (PL0021_PR)	L4-A to L7-P 12.75-inch pipeline (abandoned)	2 Segments Exposed 1 Segment buried (No KP information available)
Magnetic linear feature (possible cable)	No available background information	Buried, KP 4

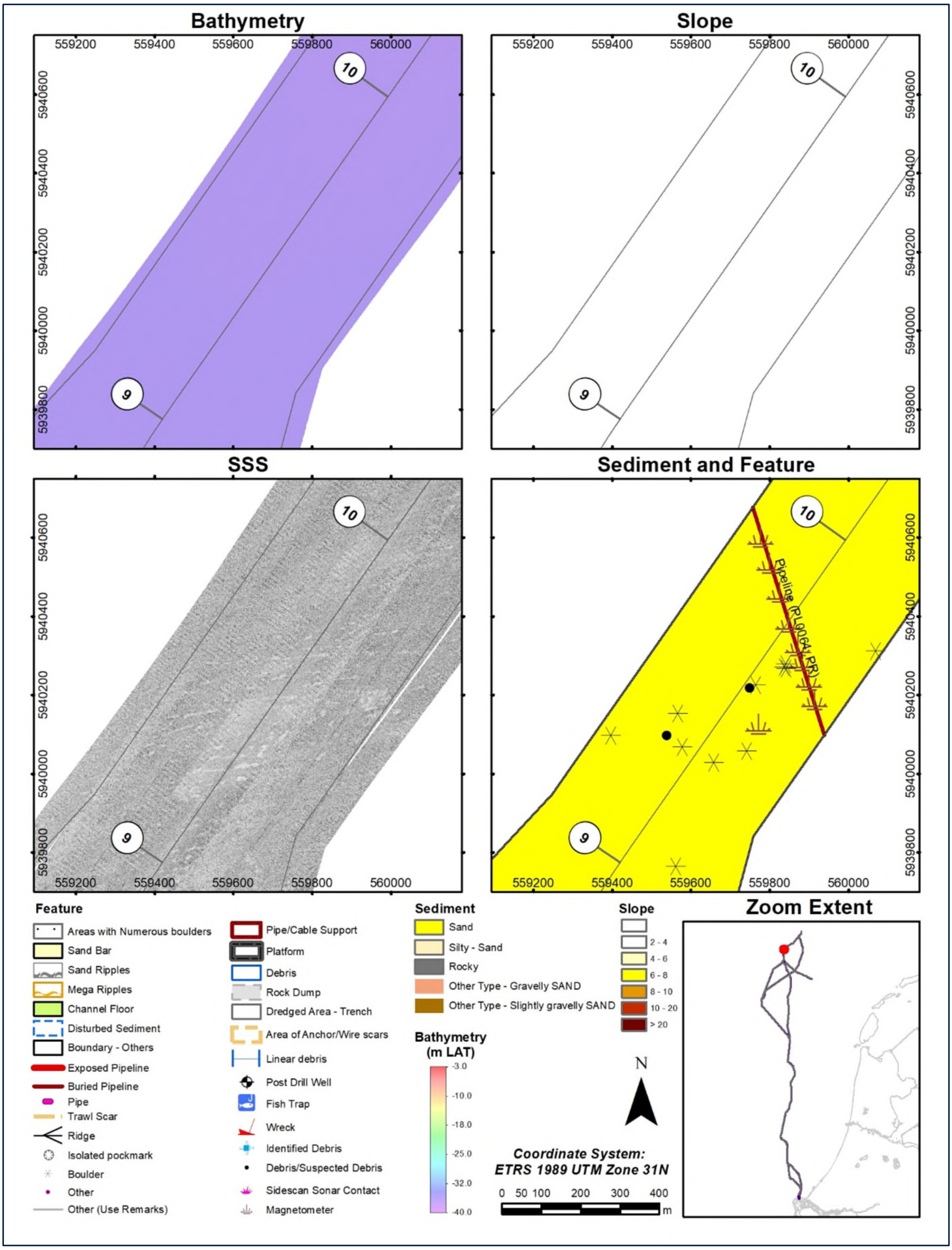


Figure 9.5: Overview of the sediments and morphology in route section C: KP 9.0 to KP 10.0; identified pipeline.

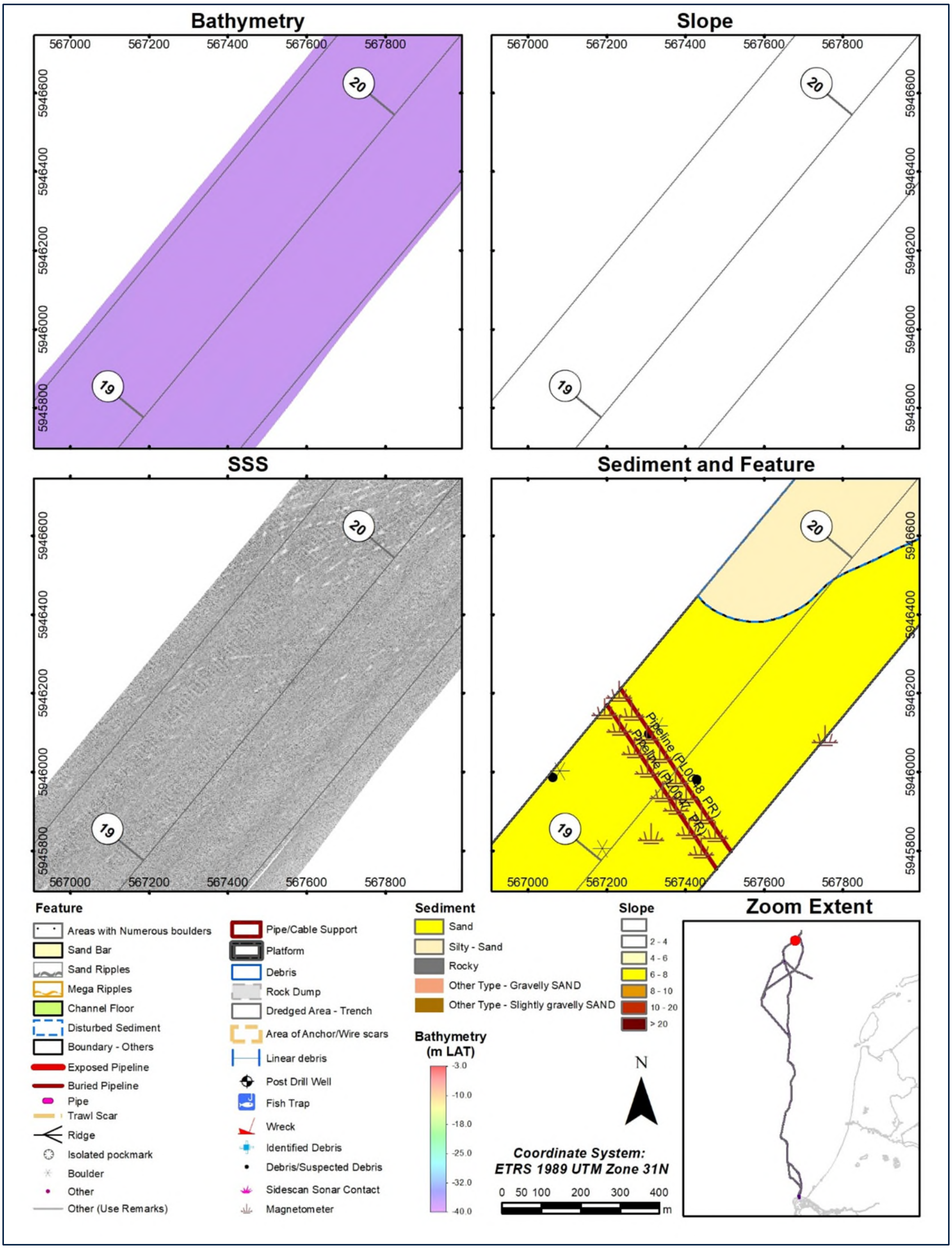


Figure 9.6: Overview of the sediments and morphology in section C: KP 19.0 to KP 20.0, identified pipelines.

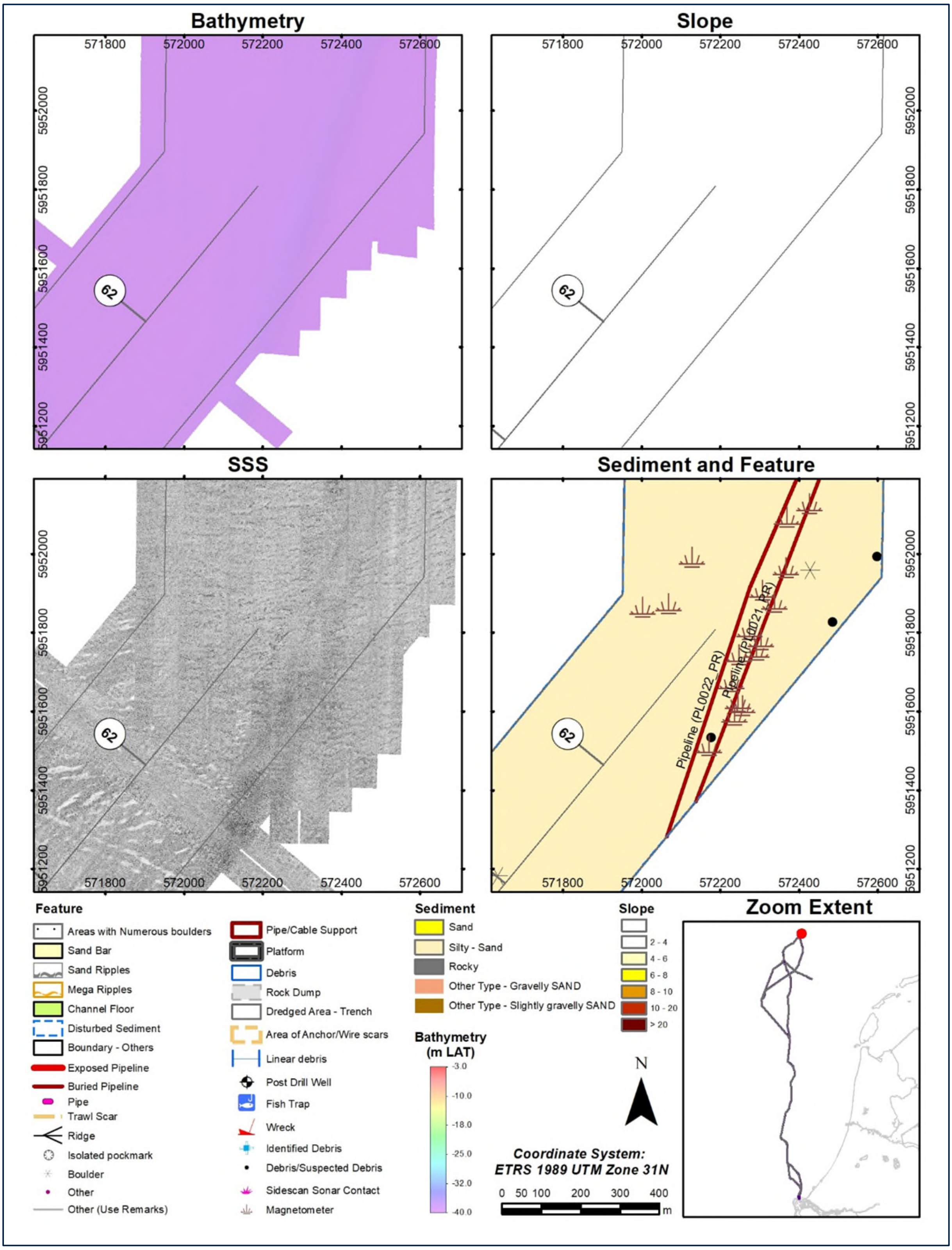


Figure 9.7: Overview of the sediments and morphology in section C: KP 62.0, buried pipelines.

9.2.4 Magnetometer Contacts

118 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in route Section C. The magnetometer anomalies range between 5.1 nT and 3529.9 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

9.2.5 Sub-seafloor Geology

Units A, B, D, E, F and G are present in the route Section C (Figure 9.8).

Unit A is present in the entire section. From KP 0.0 to KP 5.5 this unit is acoustically transparent. This changes between KP 5.5 to KP 26.8 with the upper half of the unit being acoustically semi-transparent with low to medium-amplitude parallel reflectors while the lower half of the unit remains acoustically transparent. The maximum thickness this unit in this section is approximately 3 m.

Unit B is present across the entire section. On the SBP data, the unit is characterized by layered facies, of medium to high amplitude parallel reflectors. In the initial part of this route section, the lower part of the unit is acoustically transparent. The transparent interval thins towards the north and from approximately KP 11.5 the entire unit has layered facies. Locally, the base is channelized. The infill of the channels at the base is structured or chaotic, with high amplitude reflectors. The maximum thickness Unit B in this section is approximately 7 m.

Unit D is present in the entire section. Its seismic character is transparent to semi-transparent, with parallel to sub parallel internal reflectors, marking erosion surfaces. Locally, channels and negative high amplitude anomalies were also interpreted in this unit (peat level 2). The maximum thickness of the Unit D in this section is approximately 15 m.

Unit E is present in the entire section. Acoustically it is semi-transparent and structureless. Locally high negative amplitude anomalies were also interpreted (peat level 3). The maximum thickness of this unit in this section is approximately 20 m.

Unit F (infill of glacial valley) is present between KP 24.6 to KP 26.5.

Table 9.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 51: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.8 to 3.2	Very loose slightly clayey fine SAND with frequent shells and shell fragments Locally silty fine SAND
B	1.2 to 7.5	Medium to very dense slightly silty fine and medium SAND Frequently a very thin to thick bed of very low to high strength slightly sandy CLAY
D	BDP	Medium to very dense slightly silty to silty fine and medium SAND
Notes: BPD = below penetration depth of SBP data		

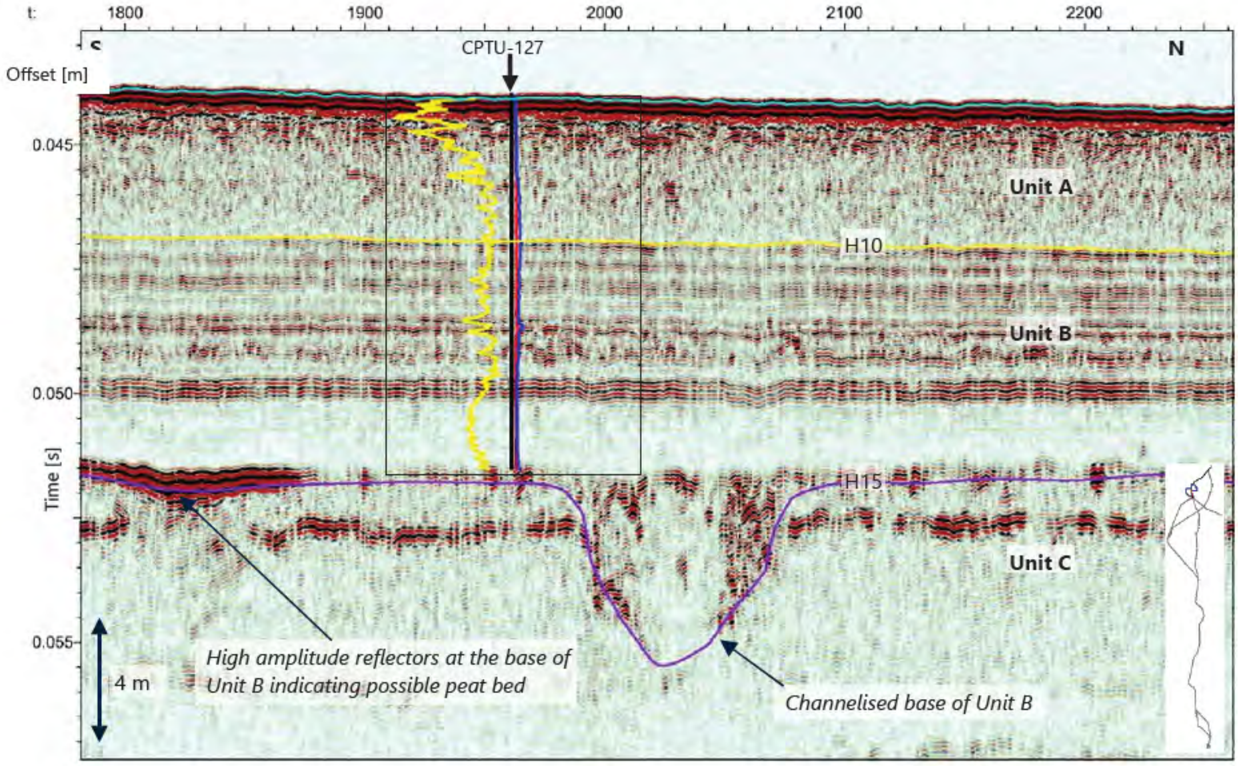


Figure 9.8: SBP data example of route section C. (Line SBP_TA3H23321P1_1) *Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.*

10. Section D

10.1 Section D Location

The location the route Section D is shown in Figure 10.1. This section of the route has a length of 33.8 km.

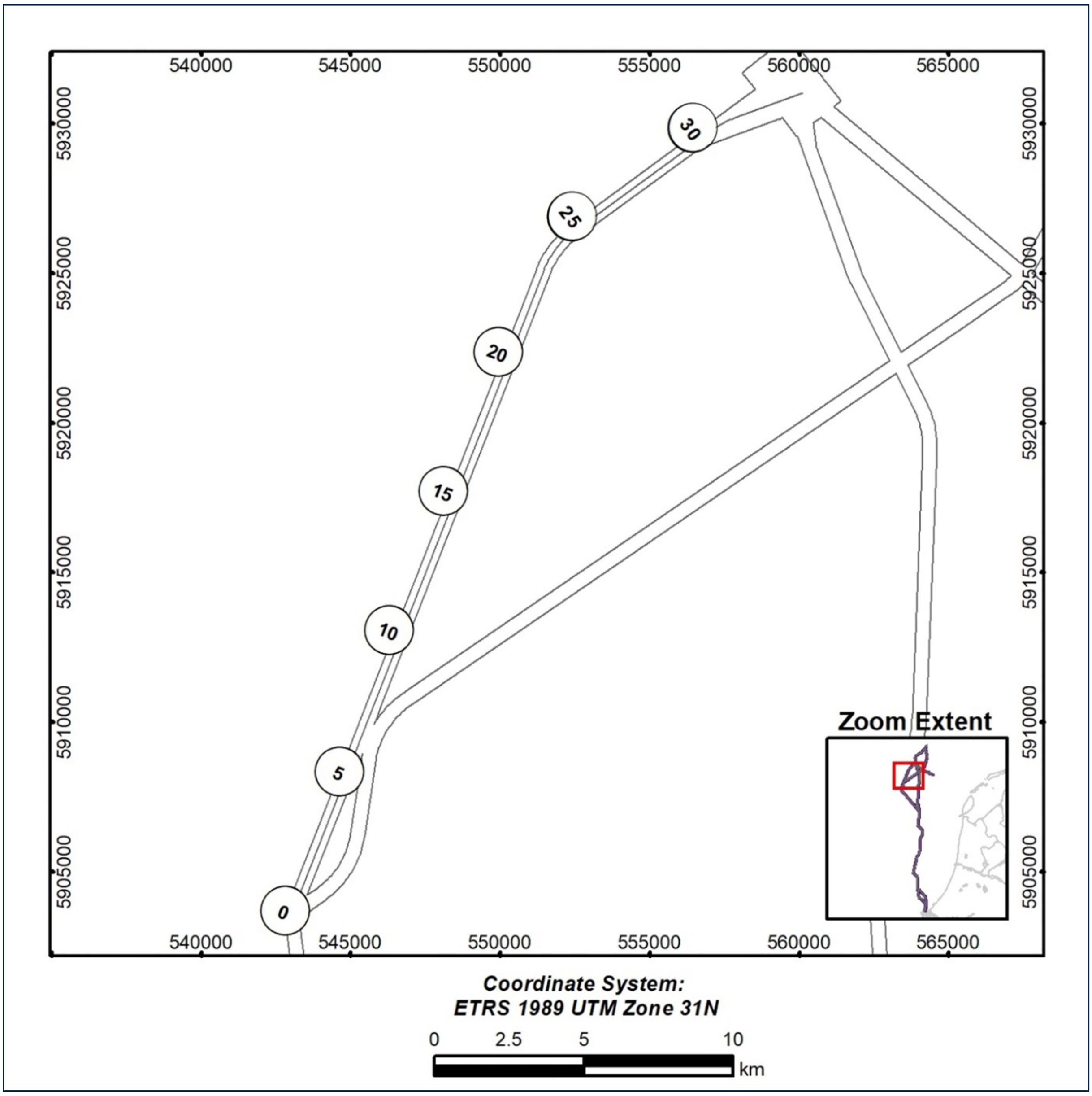


Figure 10.1: Location of the route section D.

10.2 Results

10.2.1 Bathymetry

The water depth in route Section D ranges between 29.5 m and 31.0 m. An overview of the bathymetry is given in Figure 10.2.

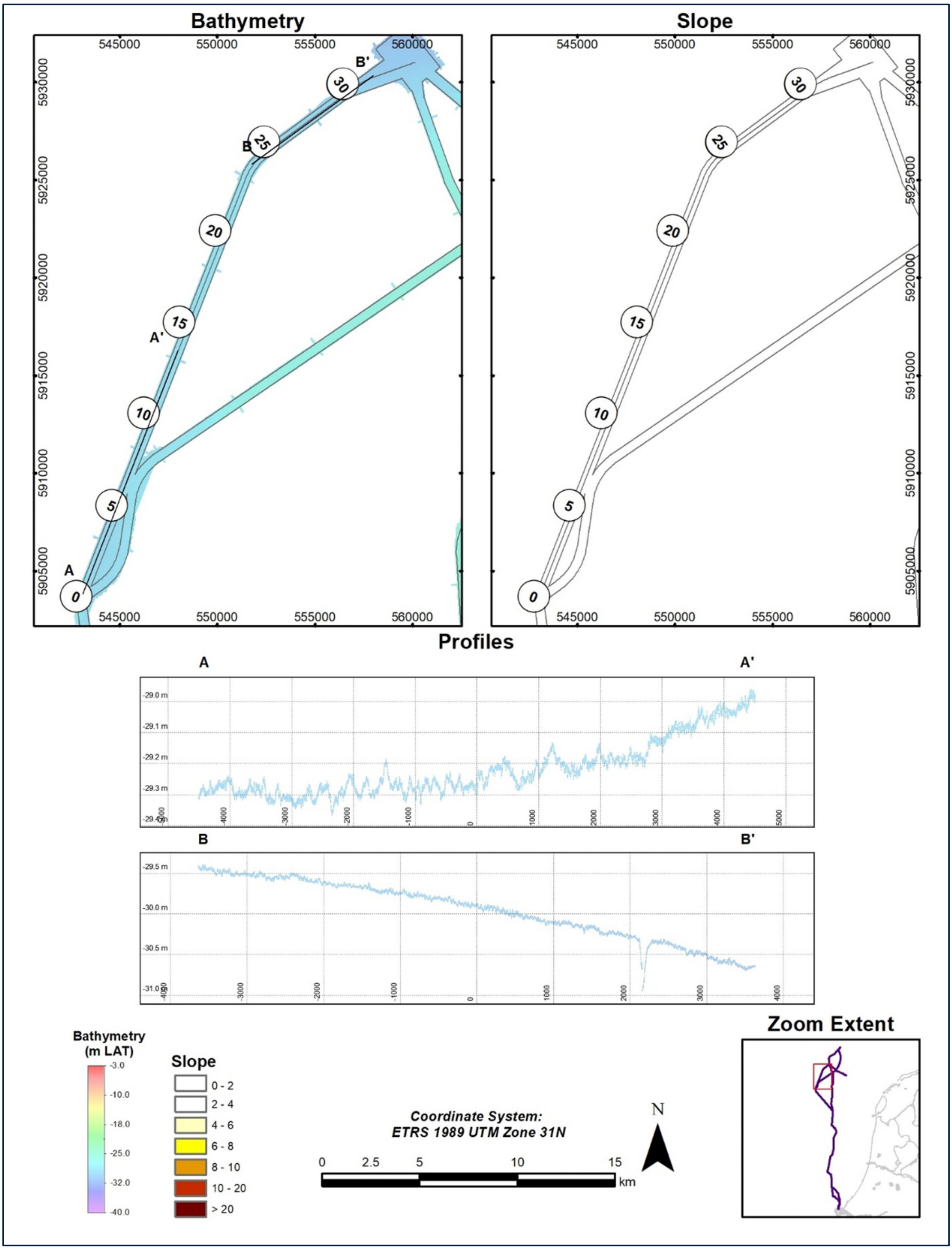


Figure 10.2: Bathymetry along the route section D.

10.2.2 Seafloor Morphology

A strong correlation between sediment types and morphological type was observed, although some small variation is possible. An overview is given in Table 10.1.

Table 52: Sediment type with associated morphology in route section D

Sediment Type	Morphological Type
Silty (muddy) SAND	Patchy fine sediments
SAND	Featureless, trawl marks area

Between KP 0.0 and KP 29, the dominant sediment is SAND, between KP 29.0 and KP 32.5 the sediment is classified as silty (muddy)SAND, between KP 32.5 and the end of the section (Hub Area) the sediment type is mostly SAND with isolated trawl marks.

10.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 10.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available. Three targets cross correlate between sensors.

Table 53: Summary of seafloor contacts in route section D

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	251
	Debris	9
	Magnetic anomalies	117
SSS/MBES/MAG Linear Features	Fishing gear	1
	Exposed pipeline	1 partially exposed (2 segments) and partially buried (1 segment)
	Buried pipeline	1

Table 10.3 shows the 3 targets that were cross correlated between sensors in Section D.

Table 54: Summary of cross correlating seafloor contacts in route section D

Section	SSS Target Name	MAG Target Name	Description
Section D	BK_FSEA_SSS_0084	BK_FSEA_MAG_0090	Debris
Section D	BK_FSEA_SSS_0086	BK_FSEA_MAG_0133	Debris
Section D	BK_FSEA_SSS_0163	BK_FSEA_MAG_0093	Debris

An example of a SSS/MBES target with a length of 2.5 m correlated with a MAG anomaly of 4576.5 nT, found at KP 19.8 of Section D, is shown in Figure 10.3. The distance between the target and the route is 63 m.

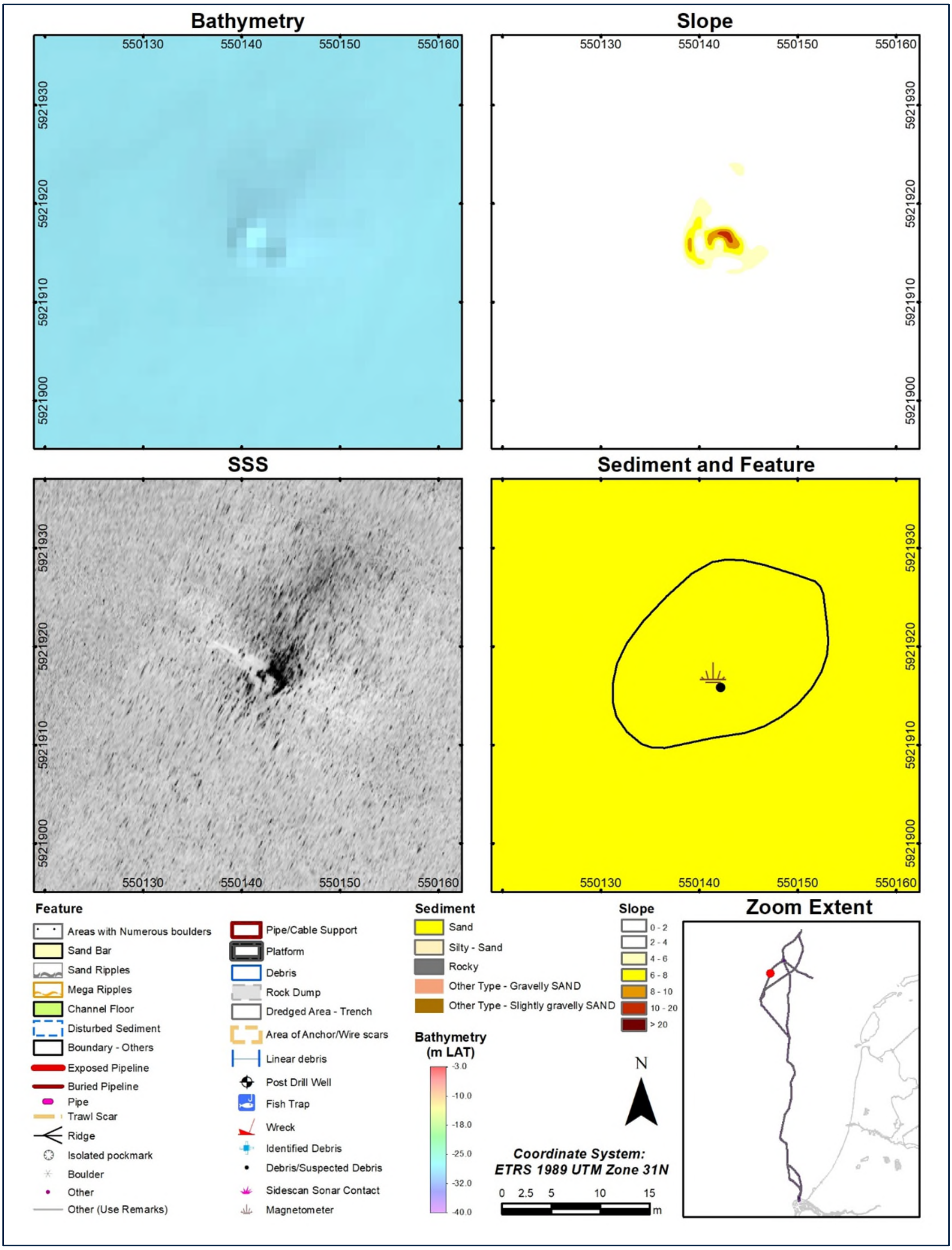


Figure 10.3: Example cross-correlated target found in route section D.

Two (2) pipelines were identified, one (1) buried and one (1) partially buried and partially exposed in this section of the route (Table 10.4 and Figure 10.4).

Table 55: Summary of pipelines in route section D

Contact ID	Pipeline Name	Comment
Pipeline (PL0119_PR)	K11-B to K12-C 14/2-inch pipeline bundle (abandoned 2005)	Buried, KP 21.1
Pipeline (PL0142_PR)	D15-FA to L10-AC 36-inch dry gas pipeline	Partially buried (1 segment), partially exposed (2 segments), KP 30.1

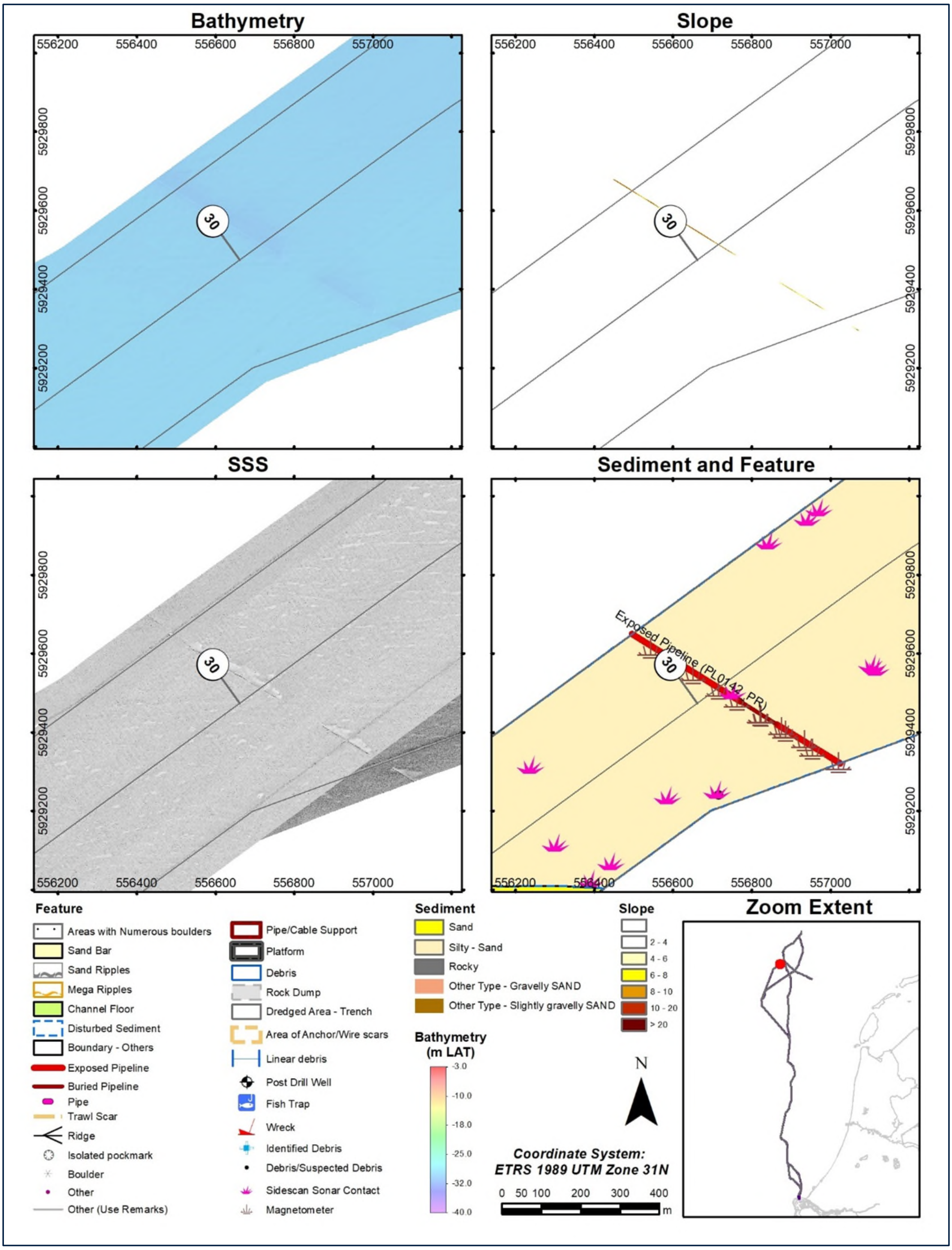


Figure 10.4: Example of partially buried and partially exposed pipeline in route section D.

10.2.4 Magnetometer Contacts

117 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in route Section D. The magnetometer anomalies range between 5.1 nT and 7221.3 nT. The highest magnetic amplitudes are associated with the encountered pipelines

10.2.5 Sub-seafloor Geology

Units A, B, C, D, E, F and G are present in the route Section D (Figure 10.5).

Unit A is present in the entire section. It characterized by acoustically transparent seismic character. The maximum thickness of this unit in this section is approximately 3 m.

Unit B is present across the entire section. On the SBP data, the seismic character is chaotic between KP 0.0 and KP 10.0, acoustically transparent between KP 10.0 and KP 21.0, and from KP 21.0 till the end of the route section layered seismic facies with low to medium-amplitude parallel reflectors. Where the base is channelised, the infill is chaotic or structured, with high amplitude reflectors. At the base of this unit high amplitude anomalies were observed, which may represent laminae or thin bed of peat and/or organic-rich clay (peat level 1). The maximum thickness of this unit in this section is approximately 5 m.

Unit C is present between KP 0.0 and KP 20.4. The unit exhibits mostly transparent/ structureless facies in this section, locally there are internal high amplitude semi-horizontal reflectors observed, especially towards the north. The thickness increases to the north and reaches maximum thickness of approximately 10 m.

Unit D is present between KP 4.0 and KP 28.9, between KP 31.5 and the end of the section. Its seismic character varies from acoustically transparent to bedded, with parallel reflectors. Locally, negative high amplitude anomalies were also interpreted (peat level 2). The maximum thickness of the Unit D in this section is approximately 15 m.

Unit E is present in the entire section. Acoustically it is transparent to semi-transparent and structureless. The maximum thickness of this unit in this section is approximately 20 m.

Unit F (infill of glacial valley) is present between KP 27.9 to KP 29.1.

Table 10.5 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 56: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.8 to 2.9	Very loose to medium dense silty fine and medium SAND, with occasional shells and shell fragments
B	1.3 to 9.0	Medium dense to dense slightly silty to silty fine and medium SAND with occasional shells and shell fragments Locally with thick beds of low to medium strength slightly sandy clayey SILT with closely spaced thin to thick laminae of sand, with closely spaced thin laminae of peat
C	BPD	Medium dense to dense silty to very silty fine and medium SAND
D	BPD	Low strength to high strength CLAY

Unit	Depth to Base [m BSF]	Lithology
Notes: BPD = below penetration depth of SBP data		

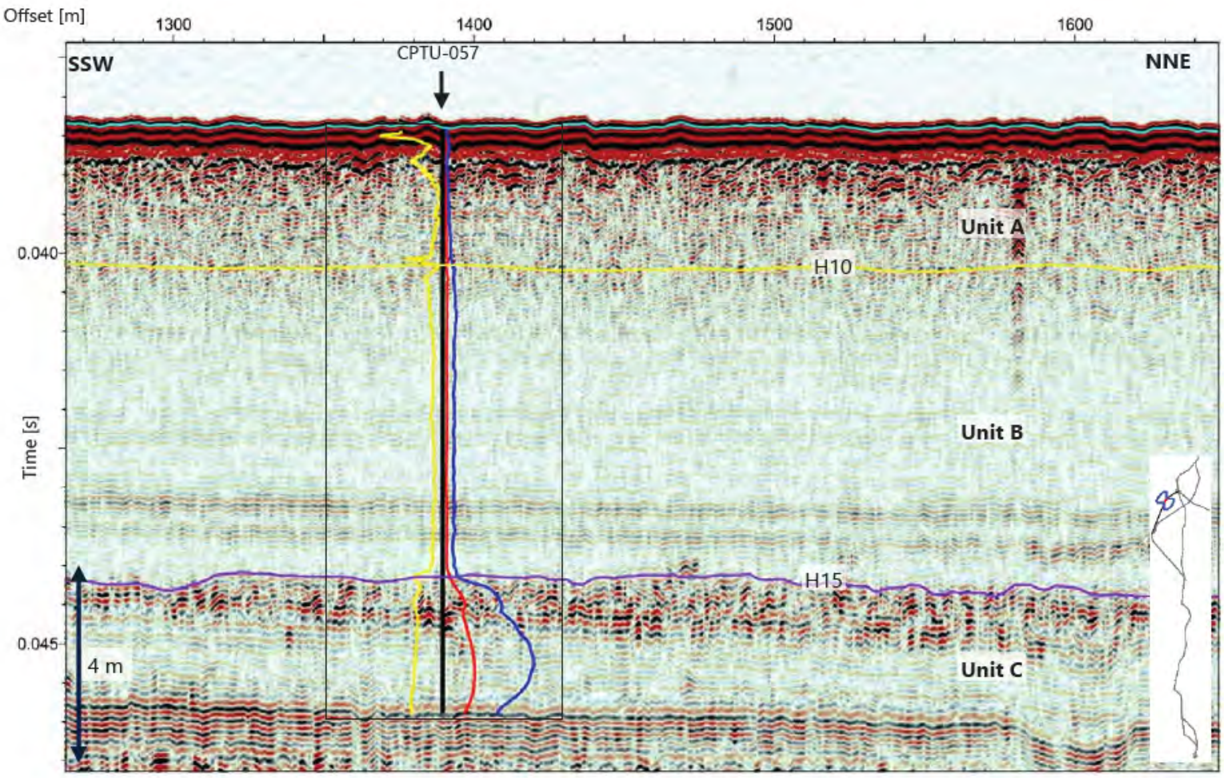


Figure 10.5: SBP data example of route section D. (Line SBP_TA3K2305P1_5) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

11. Section E Alternative

11.1 Section E Alternative Location

The location of the route Section E Alternative is shown in Figure 11.1. This section of the route has a length of 23.5 km.

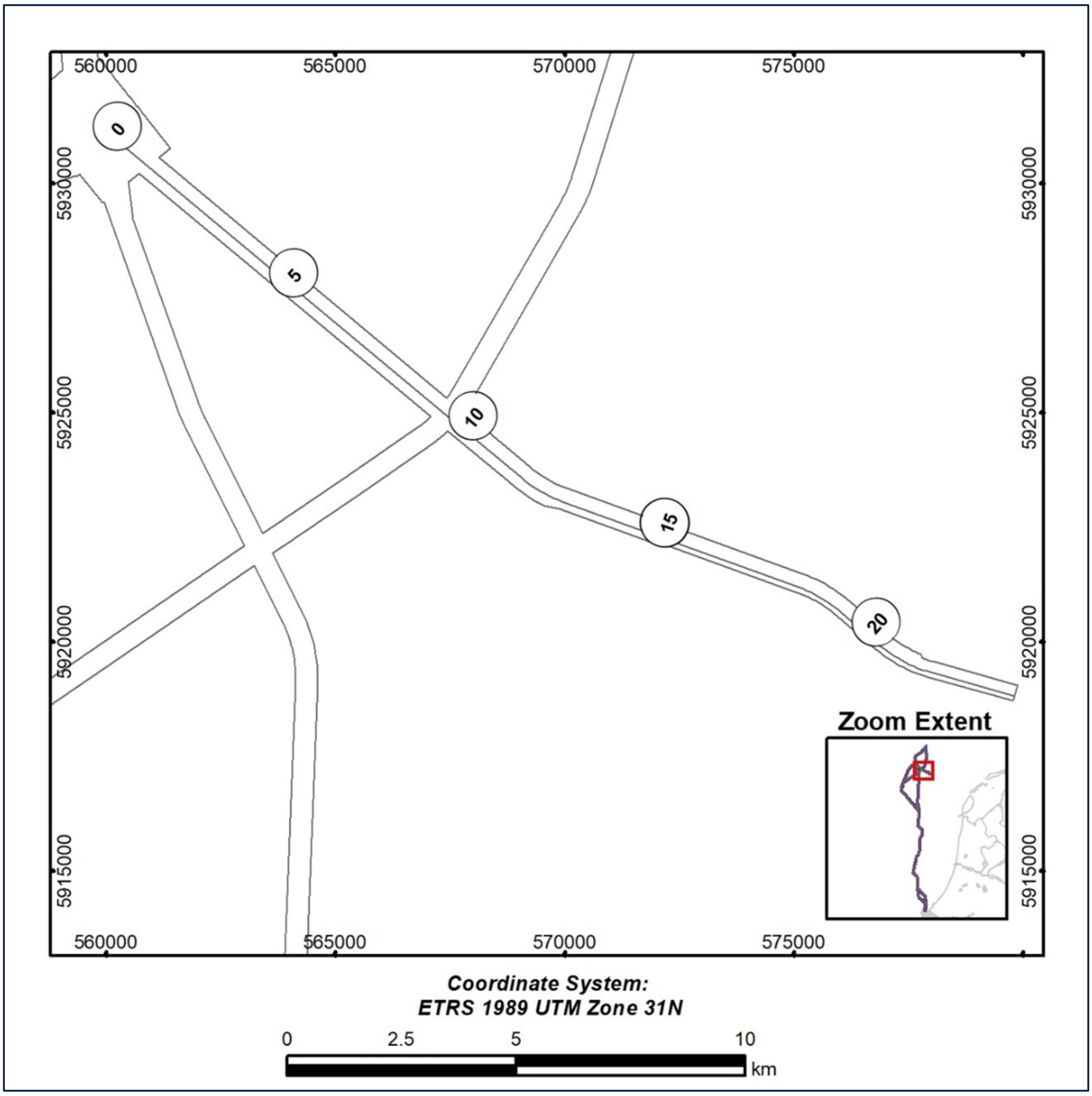


Figure 11.1: Location of the route section E Alternative.

11.2 Results

11.2.1 Bathymetry

The water depth in route Section E Alternative ranges between 26.0 m and 30.5 m. An overview of the bathymetry is given in Figure 11.2.

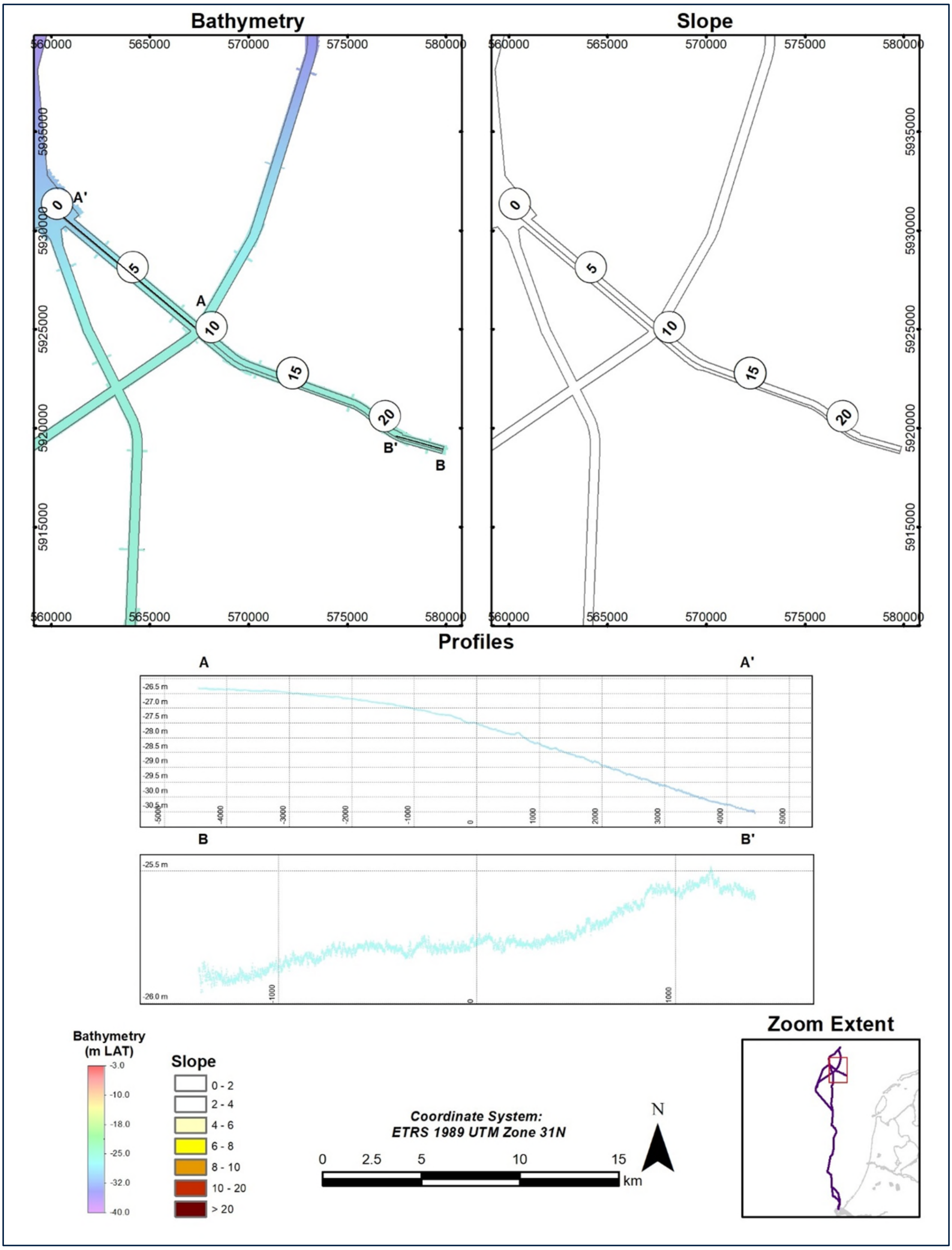


Figure 11.2: Bathymetry along the route section E Alternative.

11.2.2 Seafloor Morphology

A strong correlation between sediment types and morphological type was observed, although some small variation is possible. An overview is given in Table 11.1.

Table 57: Sediment type with associated morphology in route section E Alternative

Sediment Type	Morphological Type
Slightly gravelly SAND	Ripples
SAND	Featureless

From KP 0.0 to KP 22.0 the dominant sediment has been classified as SAND mostly featureless, from KP 22.0 till the end of Section E Alternative an area of sightly gravelly SAND with ripples has been identified.

11.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 11.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross correlated where multiple datasets were available. No targets cross-correlate in this section of the route.

Table 58: Summary of seafloor contacts in route section E Alternative

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Debris	34
	Suspected debris	2
	Wreck	1
	Magnetic anomalies	41
SSS/MBES/MAG Linear Features	Exposed pipeline	1 partially exposed and partially buried pipeline
	Buried pipeline	4
	Magnetic linear feature	1

A wreck was found at KP 20.0 of the route Section E Alternative (Figure 11.3). The wreck is located approximately 220 m from the route.

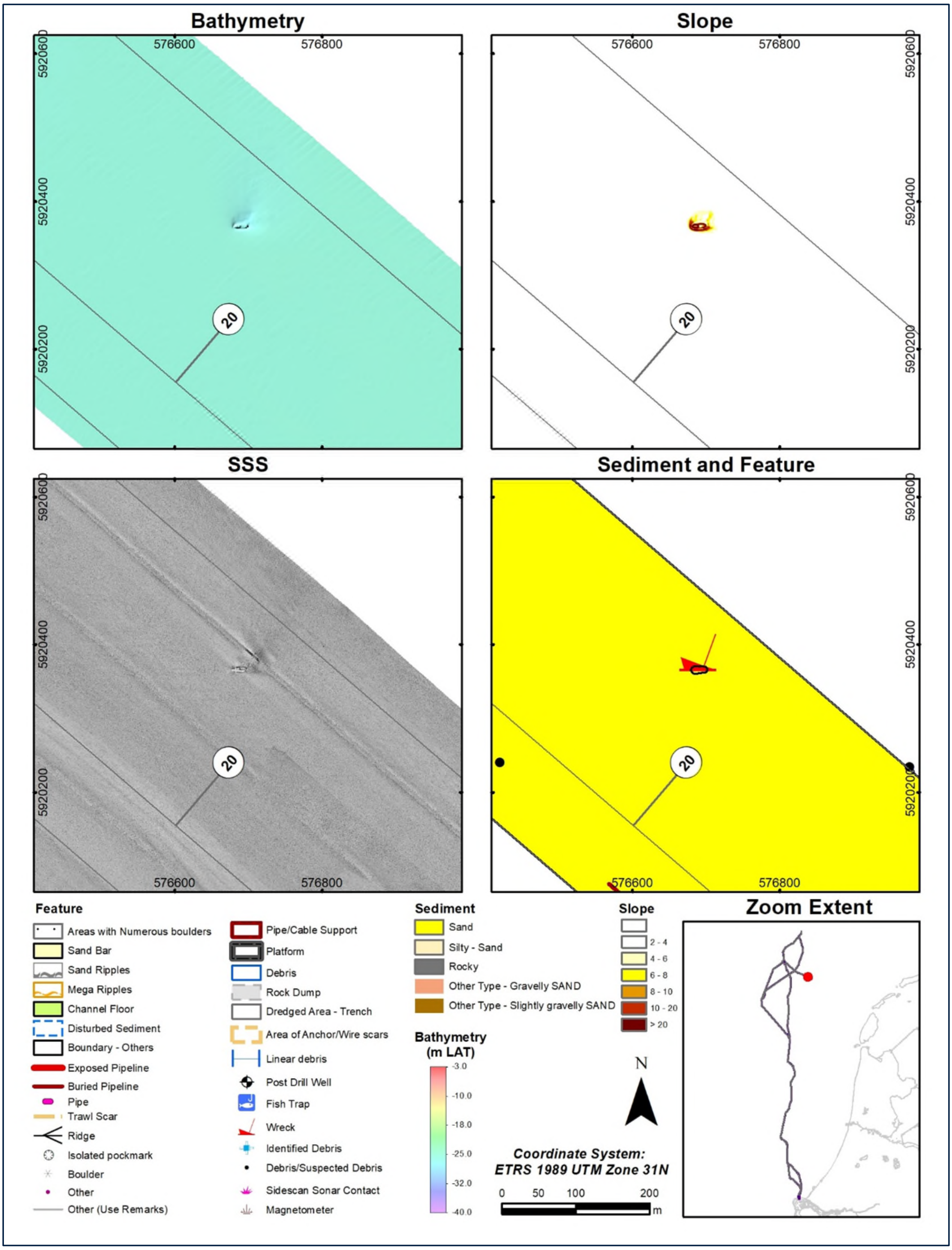


Figure 11.3: Example of wreck found in route section E Alternative.

Five (5) pipelines and one (1) possible cable were identified in route Section E Alternative (Table 11.3). One of the identified pipelines is partially exposed.

Table 59: Summary of pipeline in route section E Alternative

Contact ID	Pipeline Name	Comment
Pipeline (PL0064_PR)	K9c-A to L10-AR 16-inch dry gas pipeline	Buried, KP 18
Pipeline (PL0068_PR)	L10-S3 to L10-AP 6/2-inch pipeline bundle (abandoned 2005)	Buried KP 20, 21
Pipeline (PL0067_HS)	L10-L to L10-AP 10-inch gas / 2-inch methanol pipeline bundle	Partially buried (2 Segments) and partially exposed (1 segment), KP 22.5
Pipeline (PL0012_PR)	L7-P to L10-A 16-inch dry gas pipeline	Buried, KP 22.5
Pipeline (PL0002_HS)	L10-B to L10-AD 10-inch gas / 2-inch methanol pipeline bundle	Buried, KP 22.8
Mag Linear Feature (Possible cable)	Not present in the background database	Buried, KP 23.4

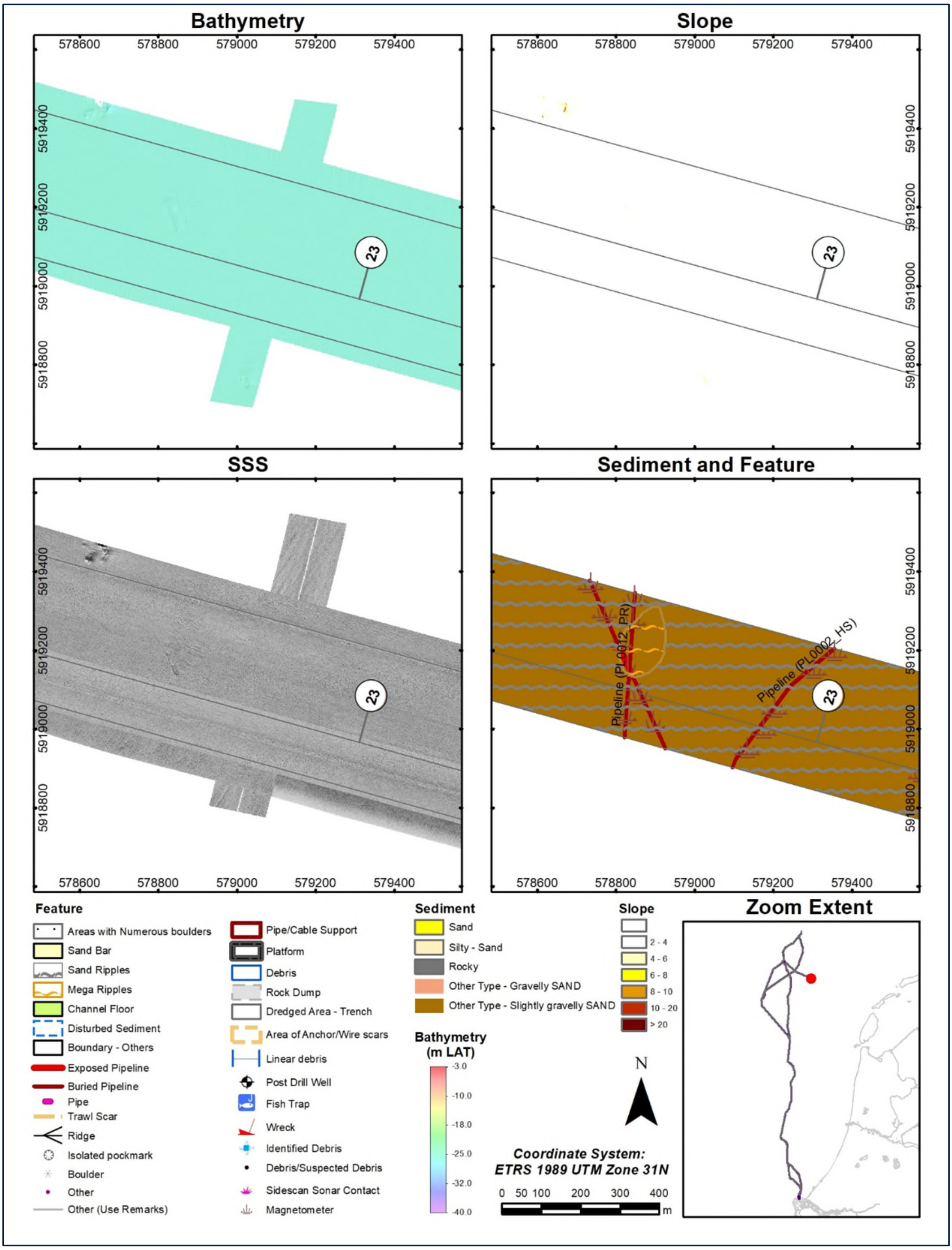


Figure 11.4: Example of pipelines found in route section E Alternative.

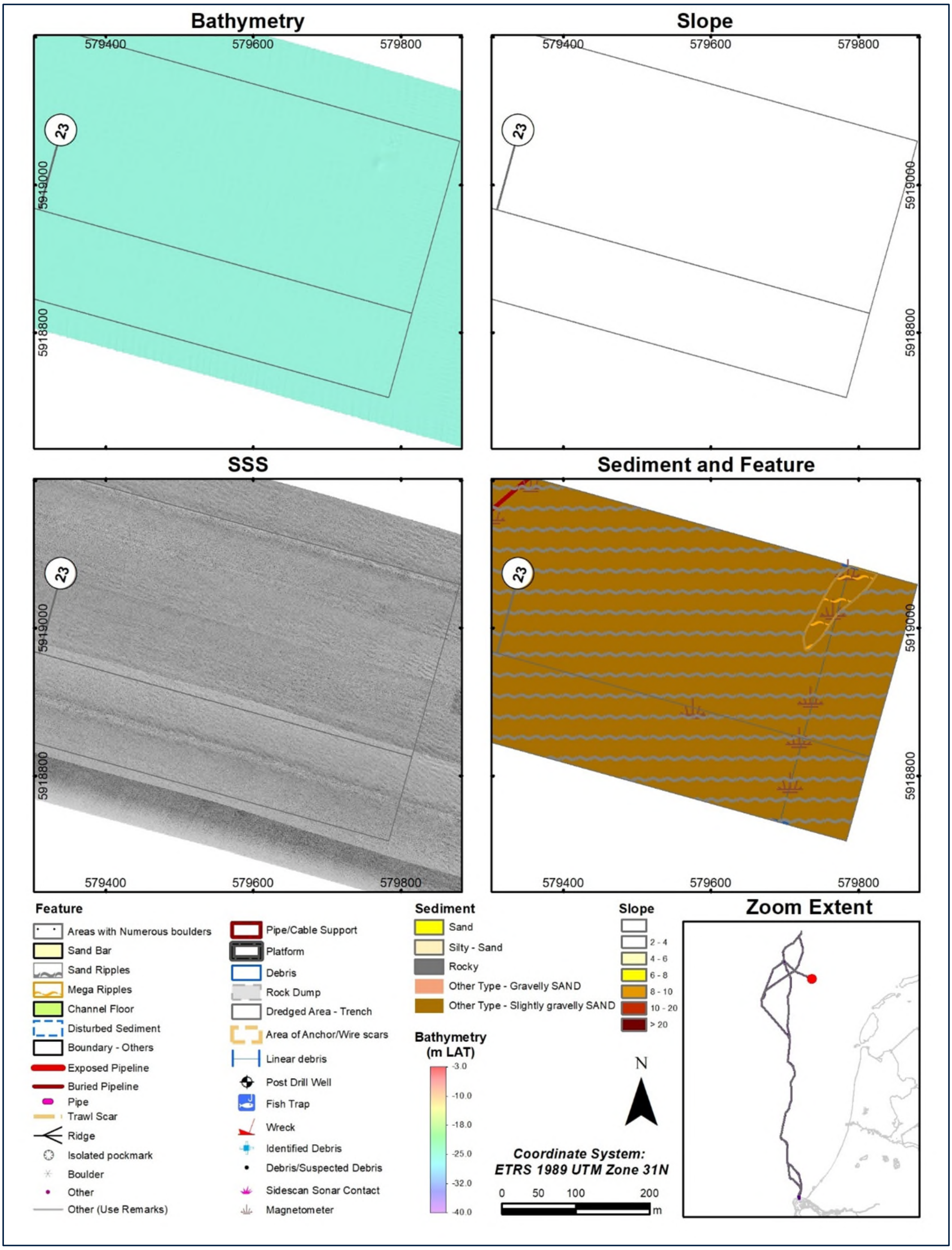


Figure 11.5: Example of possible cable found in route section E Alternative: KP 23.4.

11.2.4 Magnetometer Contacts

41 magnetic contacts were found at the time of the geophysical scope (single MAG survey). in route section E Alternative. The magnetometer anomalies range between 7.4 nT and 3424.2 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

11.2.5 Sub-seafloor Geology

Units A, B, C, D, E and F are present in route Section E Alternative (Figure 11.6).

Unit A is present in the entire section. It has transparent seismic character. From approximately KP 12.0 the unit shows locally chaotic intervals and undulating internal erosion surfaces marked by medium amplitude reflectors. The maximum thickness of this unit in this section is approximately 3 m.

Unit B is present across the entire section. The unit has predominantly acoustically transparent seismic character. Between KP 11.0 and KP 15.5, locally intervals with chaotic facies with high amplitude reflections are present. The base is locally channelised. Their infill is structured, with medium to high amplitude sub parallel reflectors. The maximum thickness of this unit in this section is approximately 6 m.

Unit C is present between KP 8.5 to KP 23.5. It exhibits semi-transparent seismic character, with locally internal high amplitude negative reflectors of various extent. These reflectors represent laminae or thin bed of peat and/or organic-rich clay. The maximum thickness of this unit in this section is approximately 4 m.

Unit D is present in the entire section. Its seismic character is semi-transparent with internal erosion surfaces marked by undulating medium to high amplitude reflectors. Locally, internal channels and negative high amplitude anomalies indicating peat were observed in this unit. The maximum thickness of the Unit D in this section is approximately 20 m.

Unit E is present in the entire section. Acoustically it is transparent to semi-transparent and structureless.

Unit F (glacial valley infill) is present locally between KP 2.5 and KP 22.7.

Table 11.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 60: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	2.3 to 2.8	Very loose to loose silty fine and medium SAND with occasional shells and shell fragments
B	3.9 to 10.9	Loose to dense slightly silty to very silty fine and medium SAND with occasional shells and shell fragments
C	BPD	Medium dense slightly silty to very silty fine and medium SAND Locally with a medium bed of sandy SILT Locally with a medium bed of medium strength CLAY

Notes:
BPD = below penetration depth of SBP data

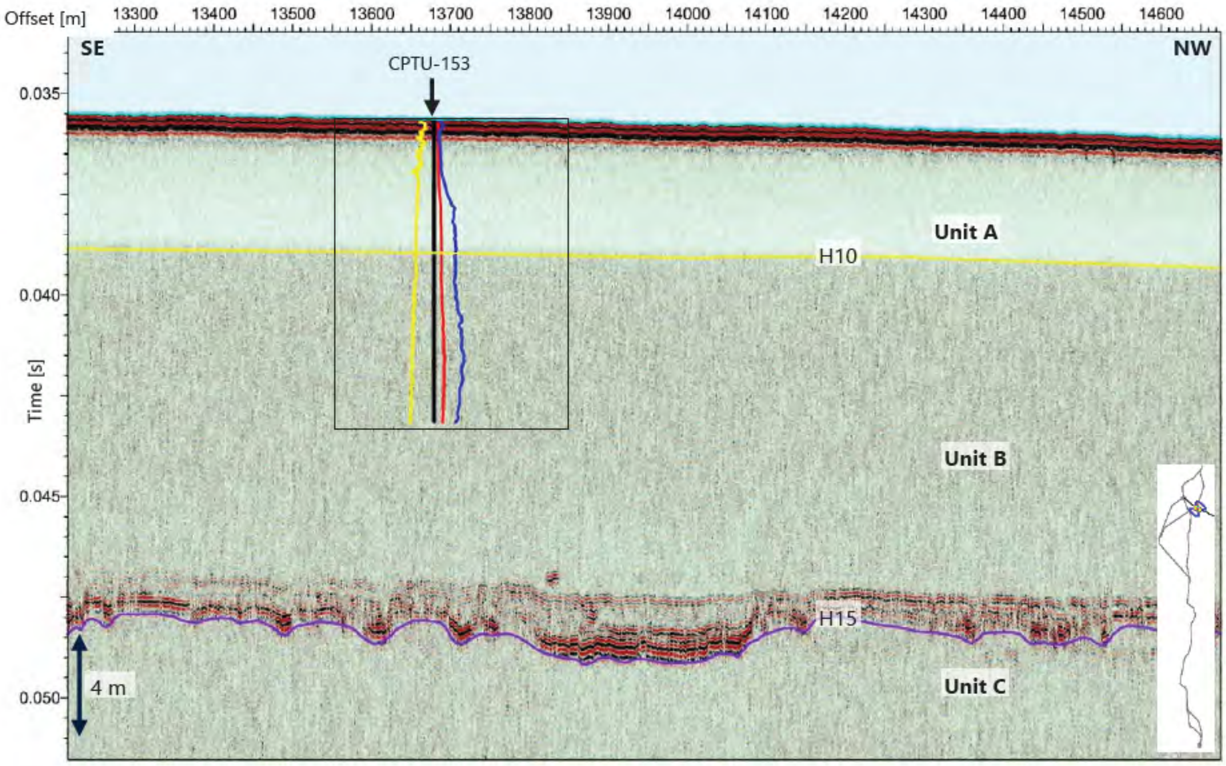


Figure 11.6: SBP data example of route section E Alternative. (Line SBP_TA3N2365P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

12. Section F

12.1 Section F Location

The location of in route Section F is shown in Figure 12.1. This section of the route has a length of 36.3 km.

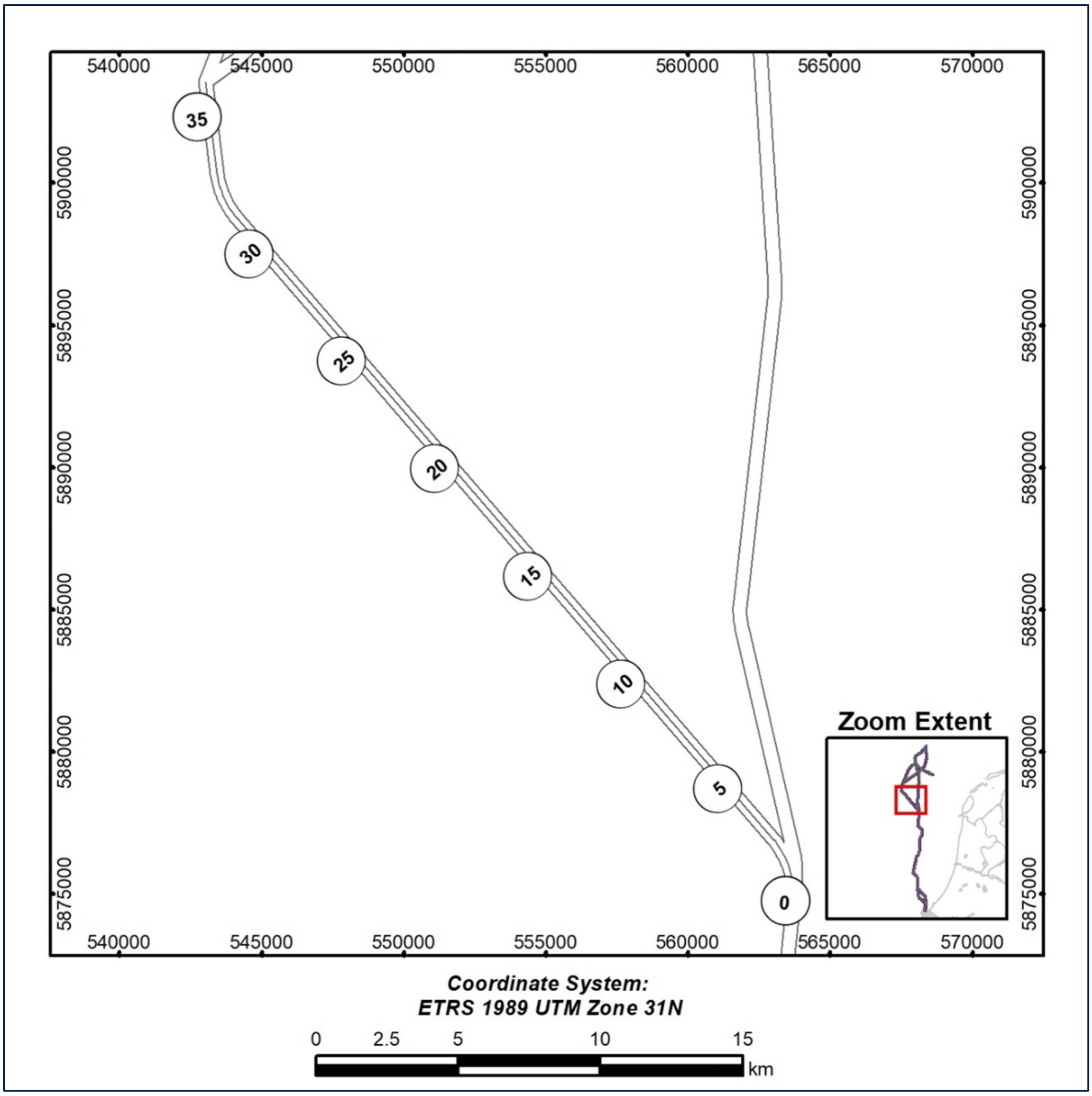


Figure 12.1: Location of the route section F.

12.2 Results

12.2.1 Bathymetry

The water depth in route Section F ranges between 24.0 m and 30.0 m. An overview of the bathymetry is given in Figure 12.2.

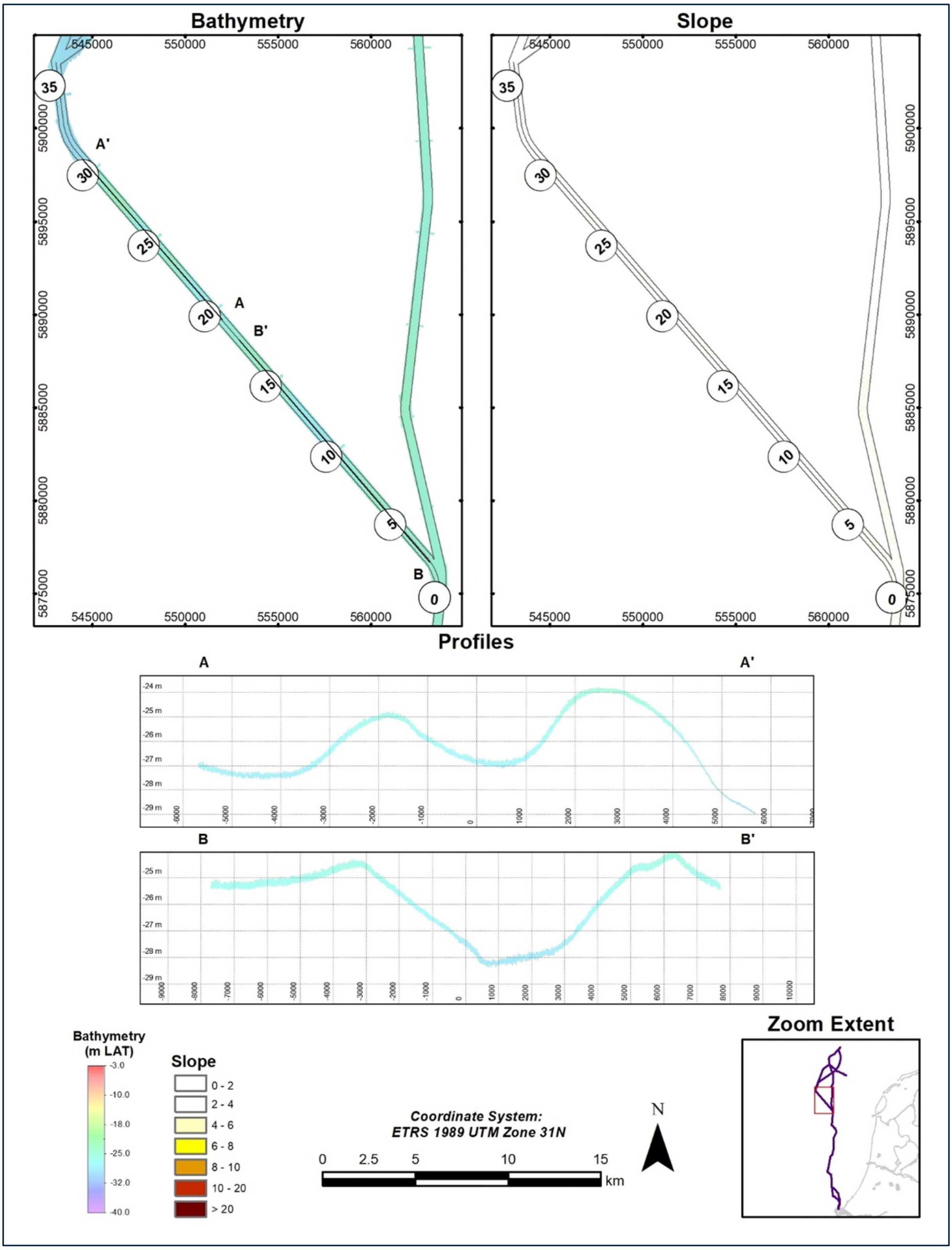


Figure 12.2: Bathymetry along the route section F.

12.2.2 Seafloor Morphology

A strong relation between sediment type and morphological type was observed, although some small variation is possible. An overview is given in Table 12.1.

Table 61: Sediment type with associated morphology in route section F

Sediment Type	Morphological Type
Slightly gravelly SAND	Ripples or megaripples and sand waves
SAND	Featureless

From KP 0.0 to KP 29.7 the dominant sediment was classified as slightly gravelly SAND with ripples, megaripples and sand waves. From KP 29.7 till the end of the section the sediments were classified as SAND mostly featureless. Figure 12.3 shows the sediment and morphology transition at KP 29.7.

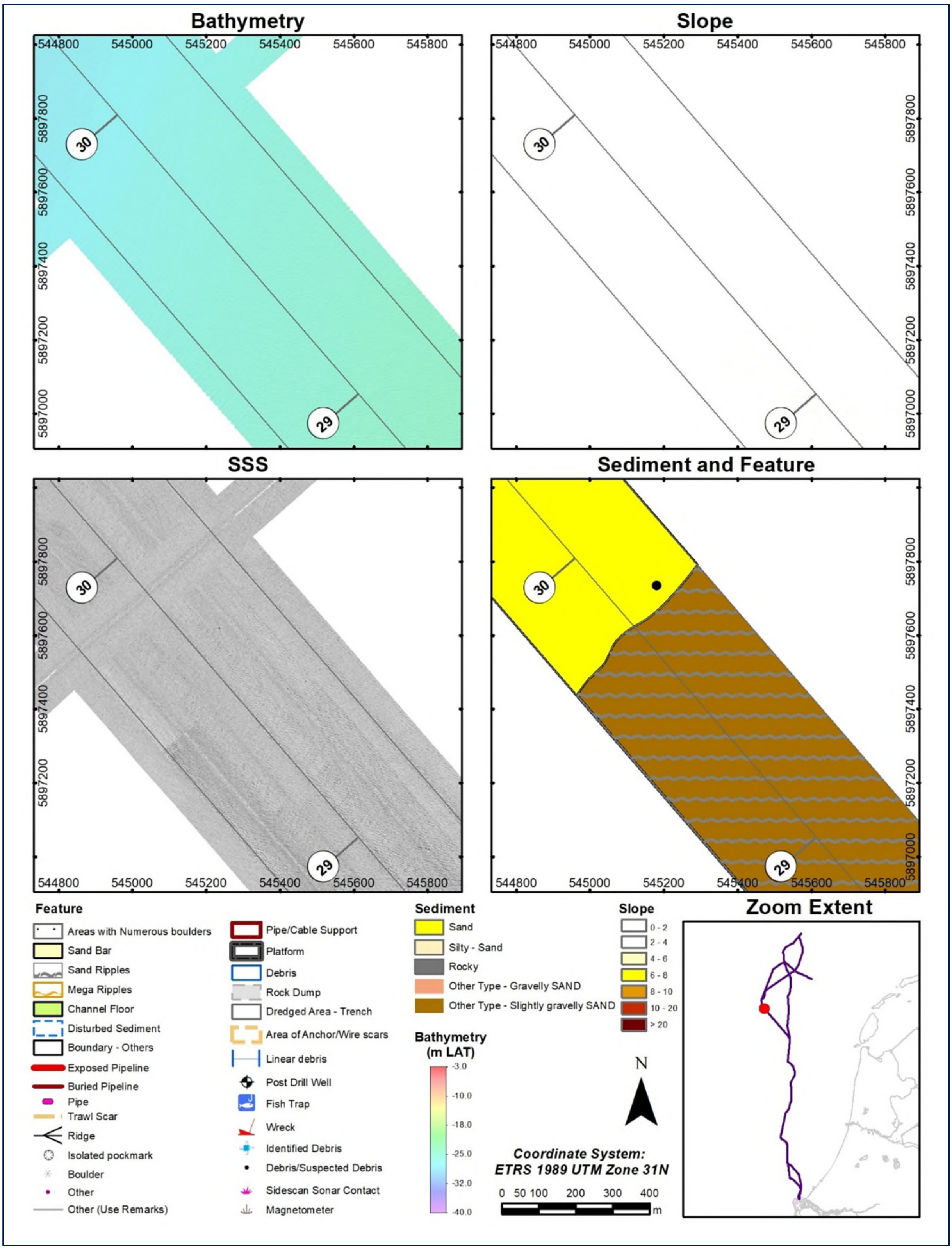


Figure 12.3: Overview of the sediments and morphology transition in rote section F: KP 29.0 to KP 30.0.

12.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross correlated where possible.

Table 12.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 62: Summary of seafloor contacts in route section F

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	10
	Debris	12
	Magnetic anomalies	70
SSS/MBES/MAG Linear Features	Debris	1
	Large trawl scour	16
	Buried pipeline	4

Four (4) buried pipelines were identified in route Section F (Table 12.3, Figure 12.4 and Figure 12.5).

Table 63: Summary of pipeline in route section F

Contact ID	Pipeline Name	Comment
Pipeline (PL0032_PR)	P6-A to L10-AR 20-inch gas pipeline	Buried, KP 5.8
Pipeline (PL0004_PR)	K13-A to Den Helder 36-inch gas pipeline	Buried, KP 36.2
Pipeline (PL0062_PR)	K14-FA-1C to K15-FA-1 18-inch pipeline	Buried, KP 36.3
Pipeline (PL0130_PR)	K14-FA-1 to K15-FB-1 pipeline	Buried, KP 36.35

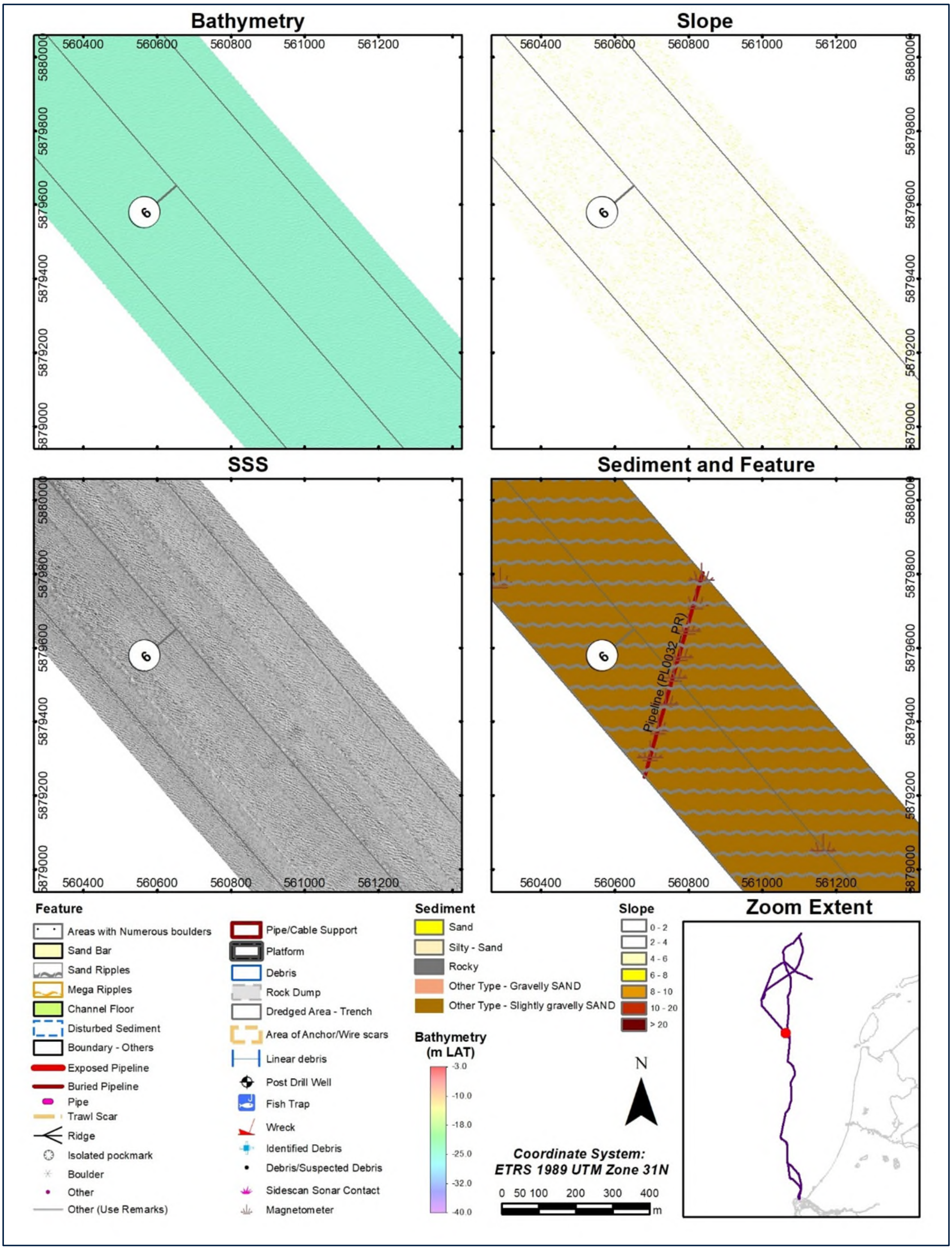


Figure 12.4: Example of pipeline crossing in route section F: KP 6.0.

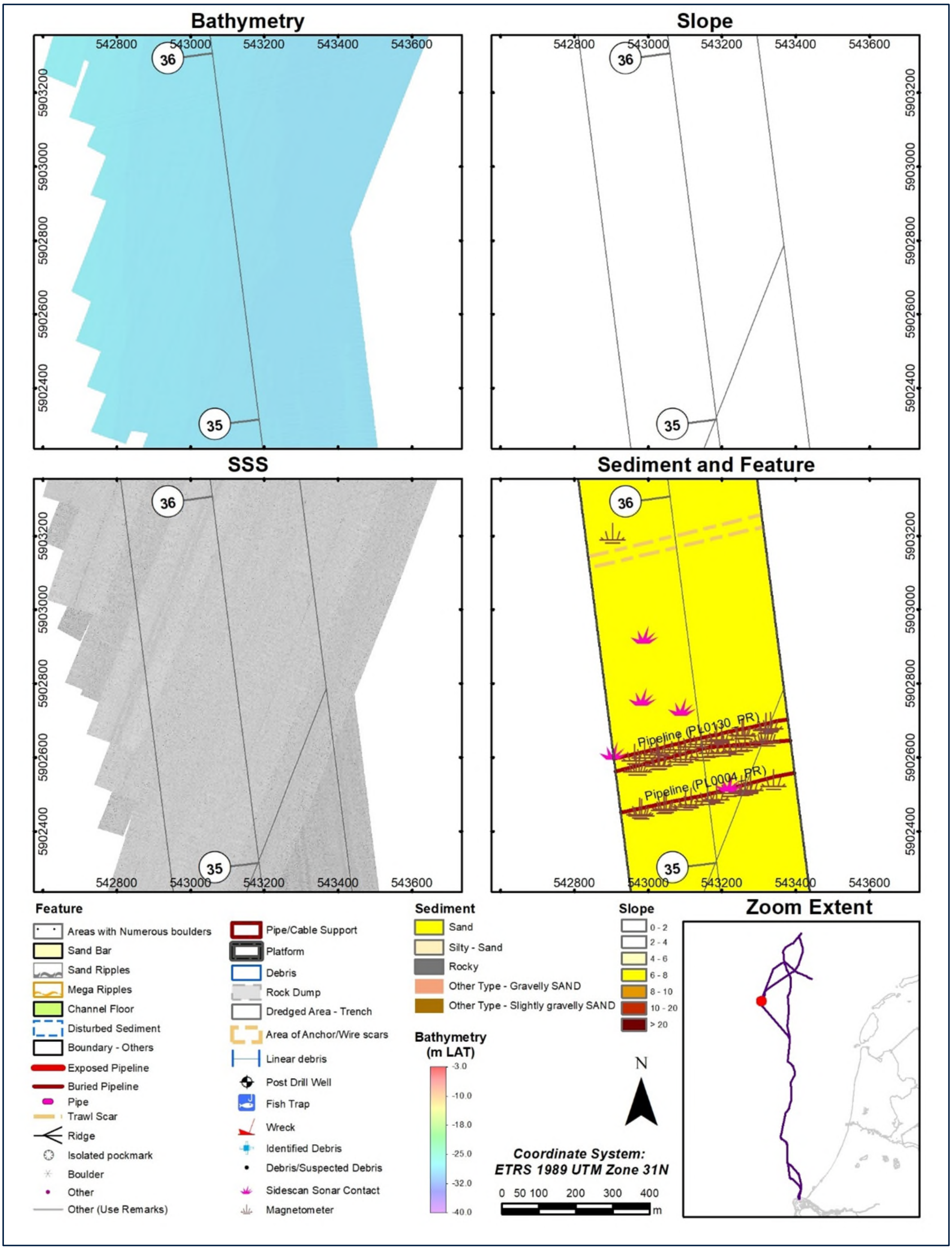


Figure 12.5: Example of pipelines crossing the route section F: KP 35.0 to KP 36.0.

12.2.4 Magnetometer Contacts

70 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in route section F. The magnetometer anomalies range between 13.7 nT and 3983.8 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

12.2.5 Sub-seafloor Geology

Units A, B, C, D, F and G are present in route Section F (Figure 12.6).

Unit A is present in the entire section. It has transparent seismic character. The maximum thickness of this unit in this section is approximately 5 m.

Unit B is present across the entire section. The unit is predominantly acoustically transparent. The base is locally channelised, with the infill characterised by layered character with high amplitude reflectors. At the base, locally high amplitude reflectors were observed, which represent laminae or thin bed of peat and/or organic-rich clay (peat level 1). The maximum thickness of this unit in this section is approximately 5 m.

Unit C is present in the entire section. It exhibits semi-transparent to chaotic seismic character, with local high amplitude negative reflectors, indicating laminae or thin bed of peat and/or organic-rich clay (peat level 2). The maximum thickness of this unit in this section is approximately 4 m.

Unit D is present in the entire section. Its seismic character changes along the route. Between KP 0.0 to KP 11.0 it is mainly acoustically transparent, between KP 11.0 and KP 27.0 it is bedded in the upper part and from approximately KP 27.0 the entire unit shows bedded facies with medium amplitude parallel reflectors. Locally, the base is channelised and high amplitude negative short reflectors were observed (peat level 2). The maximum thickness of the Unit D in this section is approximately 20 m.

Unit F (glacial valley infill) is present between KP 2.7 and KP 6.4, between KP 8.4 and KP 10.0, between KP 26.9 and KP 27.3 and between KP 28.4 and KP 31.7.

Table 12.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 64: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.7 to 4.7	Very loose to medium dense slightly silty fine and medium SAND
B	1.6 to 6.5	Medium to very dense slightly silty to very silty fine and medium SAND with occasional shells and shell fragments Locally with a medium to high strength slightly sandy clayey SILT
C	BPD	Very loose to very dense silty fine SAND with Locally with very closely to closely spaced thin laminae of peat Locally with a medium bed of medium to high strength CLAY
D	BPD	Low to high strength silty CLAY
Notes: BPD = below penetration depth of SBP data		

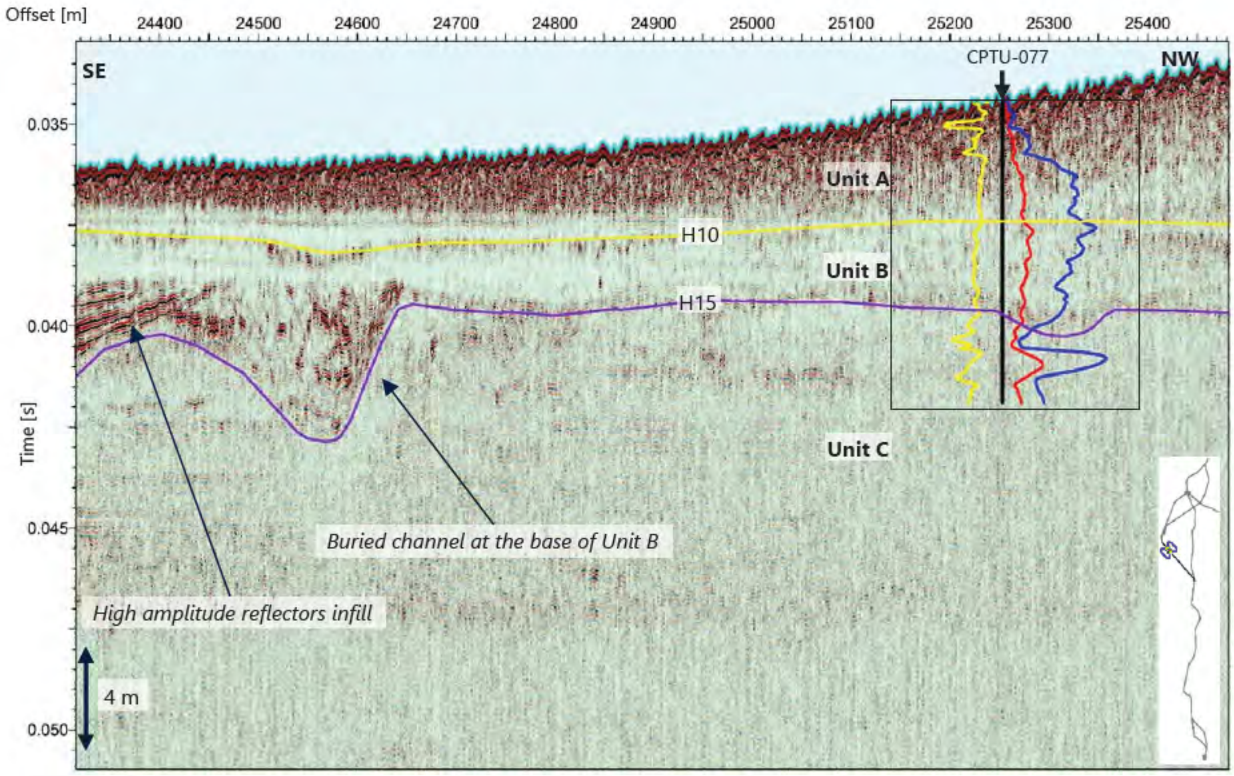


Figure 12.6: SBP data example of route section F. (Line SBP_TA3J2262P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 4 %.

13. Section K14-L4A

13.1 Section K14-L4A Locations

The location of in route Section K14-L4A is shown in Figure 13.1. This section of the route has a length of 62.4 km.

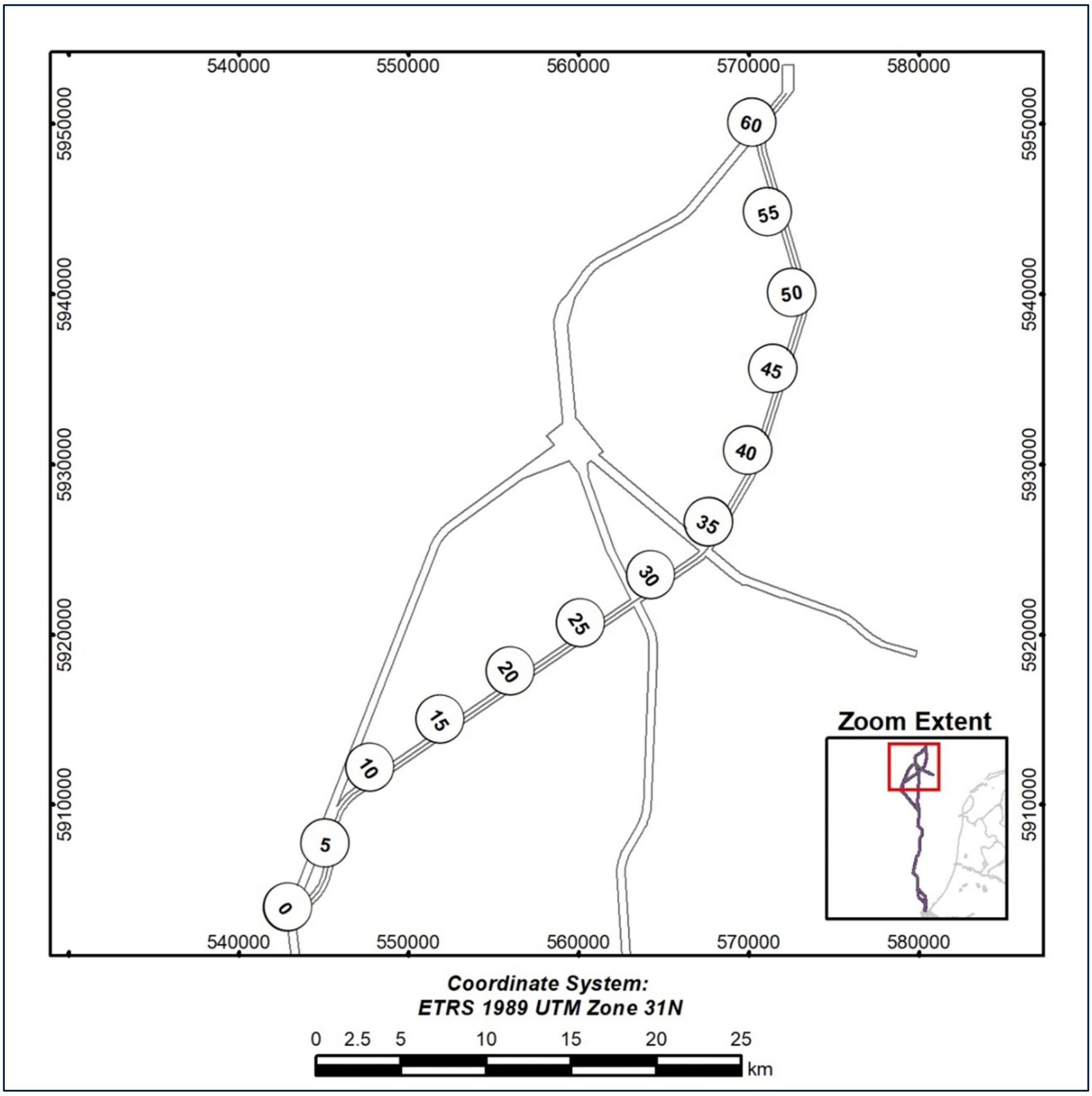


Figure 13.1: Location of the route section K14-L4A.

13.2 Results

13.2.1 Bathymetry

The water depth in route Section K14-L4A ranges between 26.0 m and 39.5 m. An overview of the bathymetry is given in Figure 13.2.

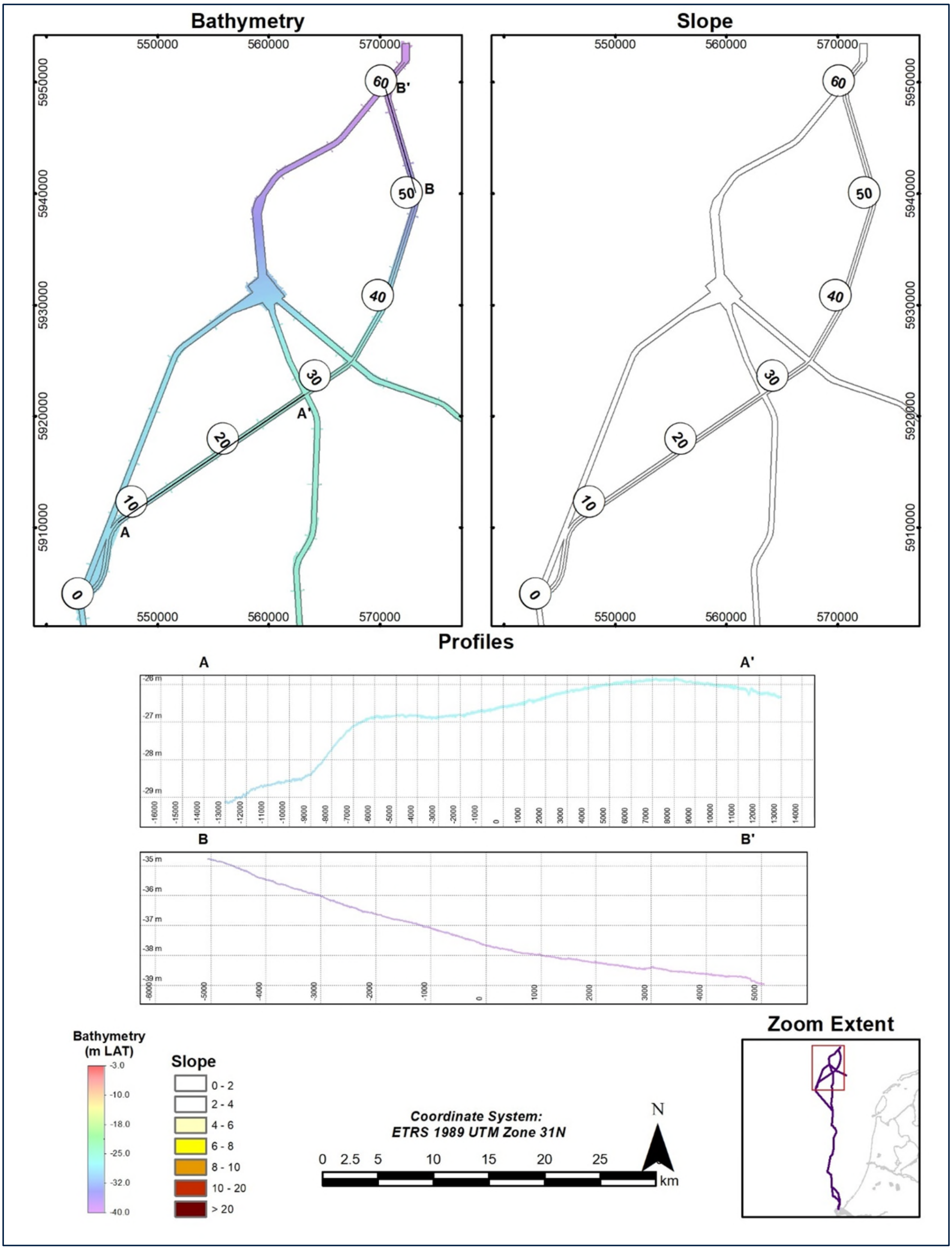


Figure 13.2: Bathymetry along the route section K14-L4A.

13.2.2 Seafloor Morphology

A strong correlation between seafloor sediment types and morphological type was observed, although some small variation is possible. An overview of the encountered sediment and features is given in Table 13.1.

Table 65: Sediment type with associated morphology in route section K14-L4A

Sediment Type	Morphological Type
Gravelly SAND	Patchy coarse sediments
Silty (muddy) SAND	Patchy fine sediments
SAND	Featureless, area with trawl marks

From KP 0.0 to KP 50.0 the route is characterised by sandy sediments with trawl marks. Between KP 50.0 and KP 58.0 there are sandy sediments with occasional patchy (fine and coarse) sediments. Figure 13.3 shows an example of sediments transition in this section of the route.

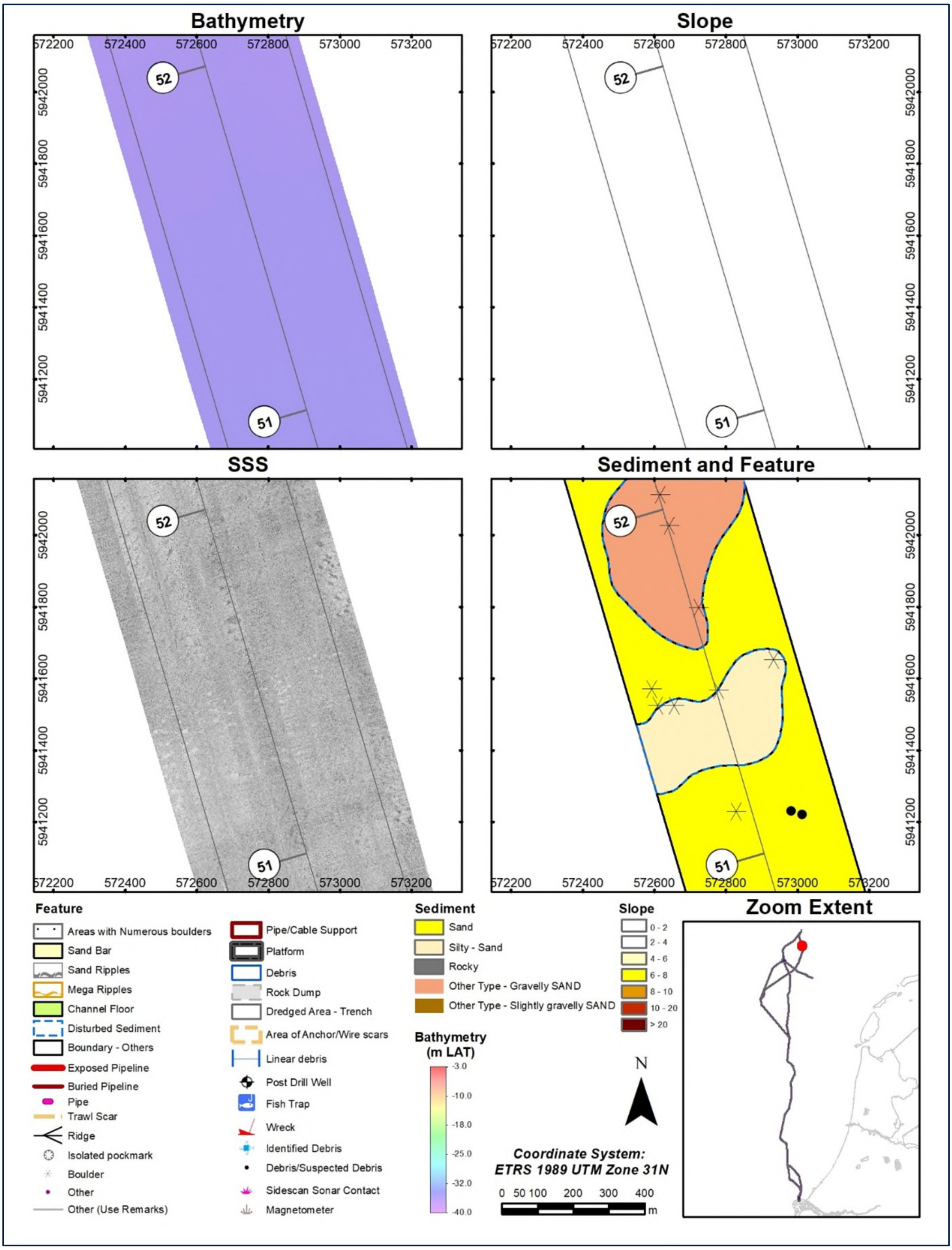


Figure 13.3: Overview of the sediments and morphology in route section K14-L4A: KP 51 to KP 52.

13.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 13.2 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 66: Summary of seafloor contacts in route section K14-L4A

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Boulder	129
	Debris	2
	Seabed mound	56
	Suspected debris	285
	Magnetic anomalies	132
SSS/MBES/MAG Linear Features	Possible debris	1
	Mound Ridge	1
	Unknown linear feature	1
	Buried pipeline	6
	Magnetic linear feature	1

Figure 13.4 shows the interpreted magnetic linear feature at KP 52.6.

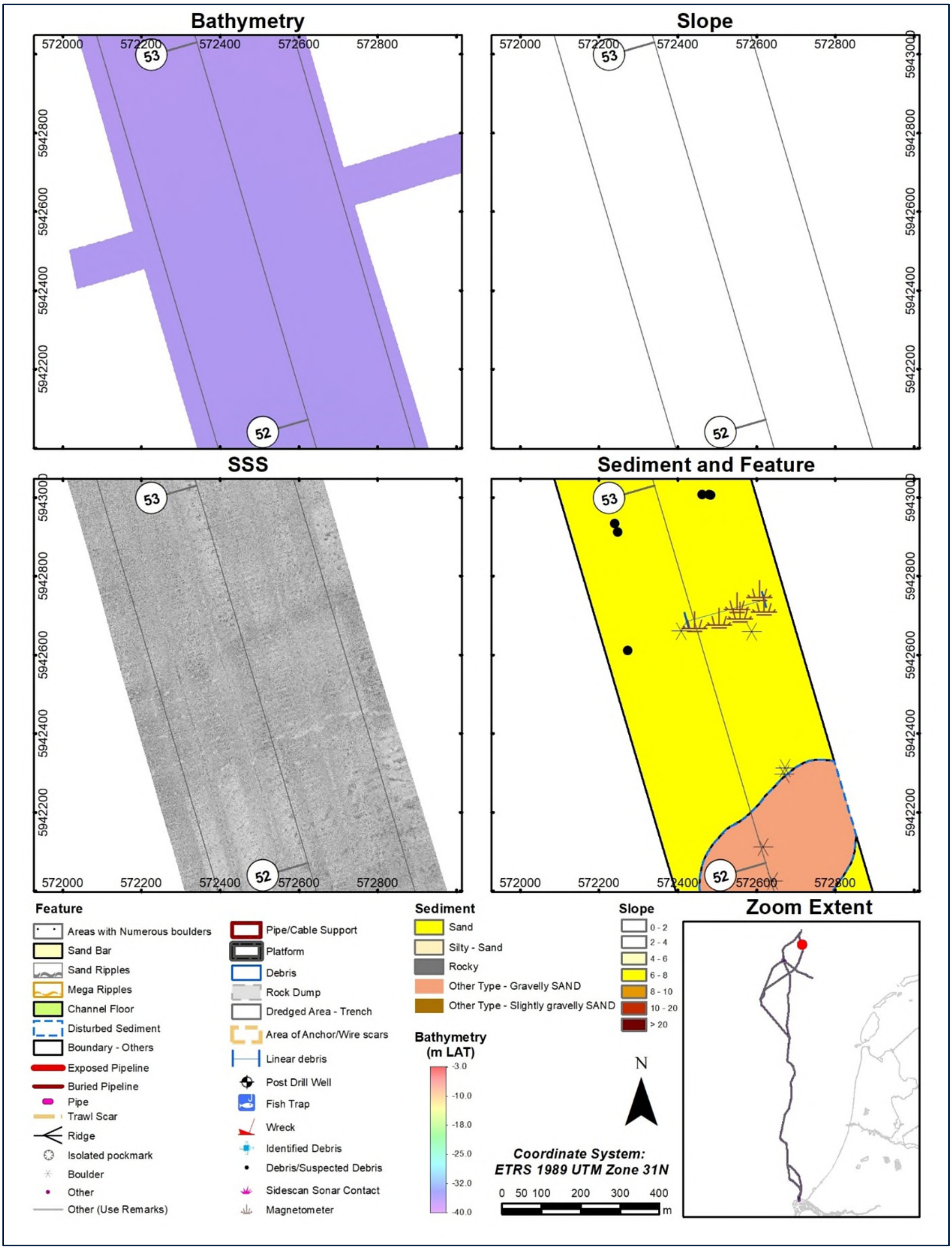


Figure 13.4: Overview of the magnetic linear feature interpreted in route section K14-L4A: KP 52.6.

Six (6) buried pipelines were identified in route Section K14-L4A (Table 13.3, Figure 13.5 and Figure 13.6).

Table 67: Summary of pipelines in route section K14-L4A

Contact ID	Pipeline name	Comment
Pipeline (PL0029_HS)	K12-A to L10-AP 14/2-inch bundle	Buried, KP 29.0
Pipeline (PL0055_HS)	SIDE-TAP KP 12.4 to K12-E 2-inch pipeline	Buried, KP 29.0
Pipeline (PL0142_PR)	D15-FA to L10-AC 36-inch pipeline	Buried, KP 31.7
Pipeline (PL0064_PR)	K9c-A to L10-AR 16-inch pipeline	Buried, KP 36.2
Pipeline (PL0049_PR)	L7-A to L7-P 10.75-inch pipeline	Buried, KP 48.0
Pipeline (PL0050_HS)	L7-A to L7-P 3.5-inch pipeline	Buried, KP 48.1

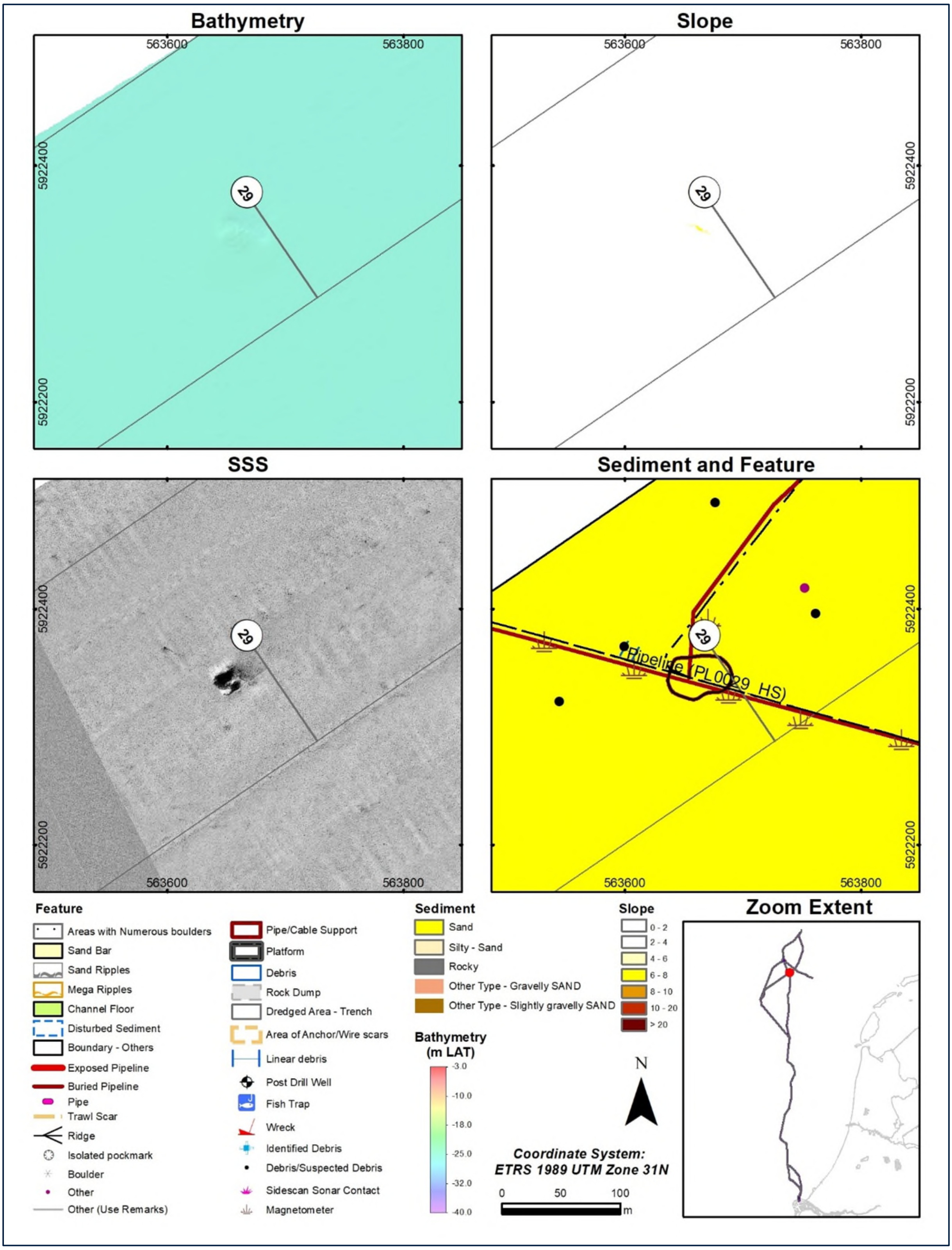


Figure 13.5: Pipelines conjunction encountered in route section K14-L4A: KP 29.0.

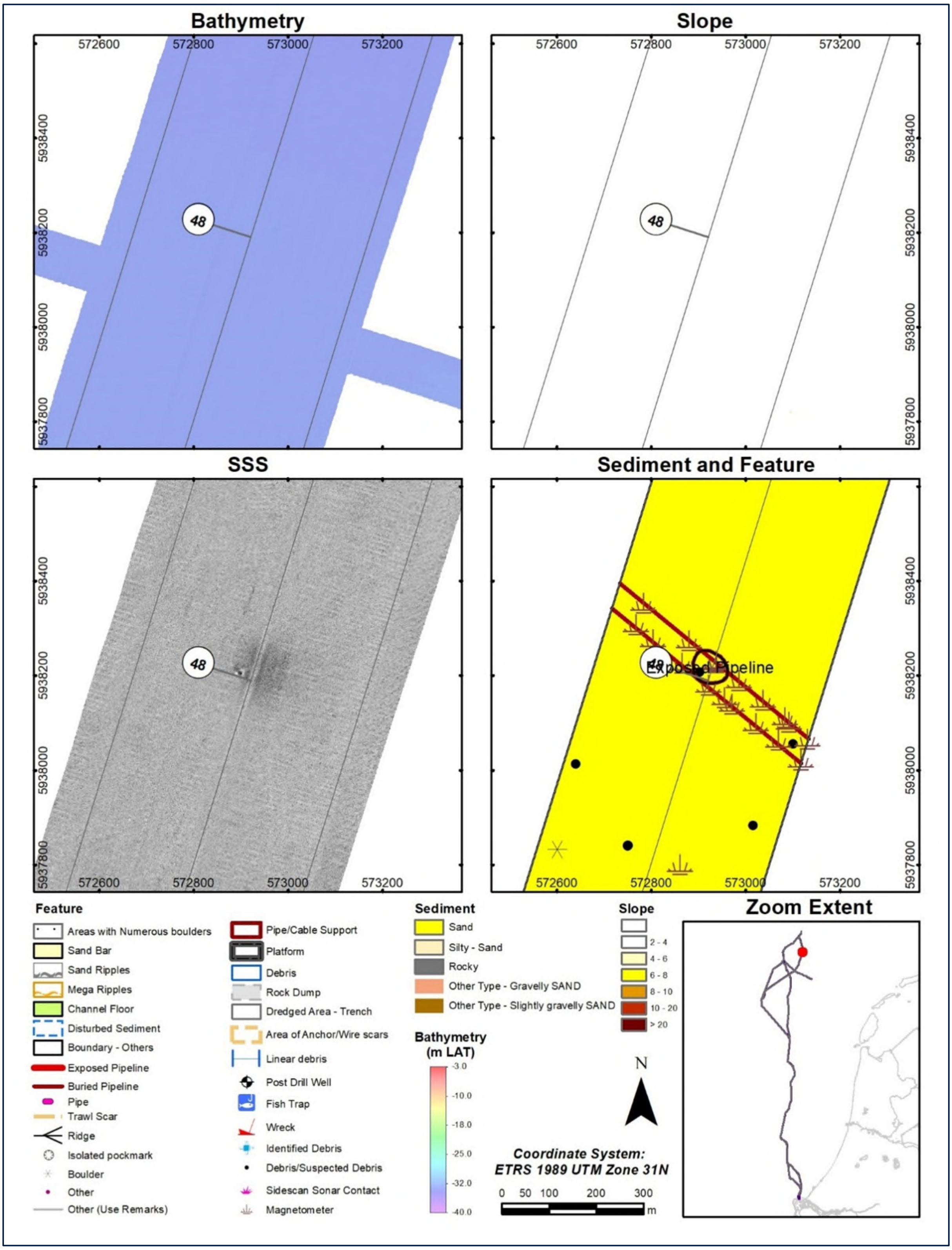


Figure 13.6: Pipelines encountered in route section K14-L4A: KP 48.0.

13.2.4 Magnetometer Contacts

132 magnetic contacts were found at the time of the geophysical scope (single MAG survey) in route Section K14-L4A. The magnetometer anomalies range between 5.1 nT and 2892.0 nT. The highest magnetic amplitudes are associated with the encountered pipelines.

13.2.5 Sub-seafloor Geology

Units A, B, C, D, E and G are present in the route Section K14-L4A (Figure 13.7).

Unit A is present in the entire section, characterized by homogenous acoustically semi-transparent seismic facies. The average thickness is 1.2 m between KP 0.0 and KP 21.0, between KP 21.0 and KP 52.0 it is approximately 2.5 m and further it gradually decreases towards the north.

Unit B is present across the entire section. On the SBP data, the unit is in general characterized by layered seismic facies, with low to high amplitude semi-horizontal to inclined reflectors. Between KP 0.0 and KP 9.0, the unit is relatively thin with chaotic seismic facies. From approximately KP 9.0, internal erosion surfaces are present. The upper part is in general more acoustically transparent with vague reflectors and the lower part with medium to high amplitude reflectors. Between KP 23.0 and KP 32.0, the lower part of the unit is structureless (chaotic) with point reflections. From KP 44.5 the unit exhibits entirely high amplitude parallel reflectors.

Unit C is present between approximately KP 0.0 and KP 38.5. The unit exhibits structureless and semi-transparent internal seismic facies in this section. Between KP 16.0 and KP 22.0, common local high amplitude negative reflectors are observed, pointing to possible pockets or beds of peat. The base is marked mostly by positive amplitude reflector.

Unit D is present in the entire route section and exhibits layered facies with low to high-amplitude parallel reflectors and locally transparent intervals. The base is locally channelised, also negative high amplitude short reflectors were observed at the base pointing to possible peat.

Unit E is absent between KP 0.0 and KP 3.1 and between KP 43.6 and KP 49.2. Unit G is present in the entire route section. Both units show similar chaotic seismic facies.

Unit F (glacial valley infill) is present between KP 28.3 and KP 31.4, between KP 33.9 and KP 35.5, between KP 36.9 and KP 37.8, between KP 43.3 and KP 46.1, between KP 60.4 and KP 62.1.

Table 13.4 provides lithology in the shallow sub-seafloor (within penetration depth of the SBP data), which is based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 68: Soil conditions in shallow sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	0.4 to 2.8	Very loose to loose slightly silty to silty fine and medium SAND with occasional shells and shell fragments Locally very loose clayey fine SAND

Unit	Depth to Base [m BSF]	Lithology
B	1.2 o 10.7	Medium to very dense slightly silty to very silty fine and medium SAND with occasional shells and shell fragments Locally with a thin bed of firm PEAT Locally with a thin to very thick bed of low strength sandy CLAY

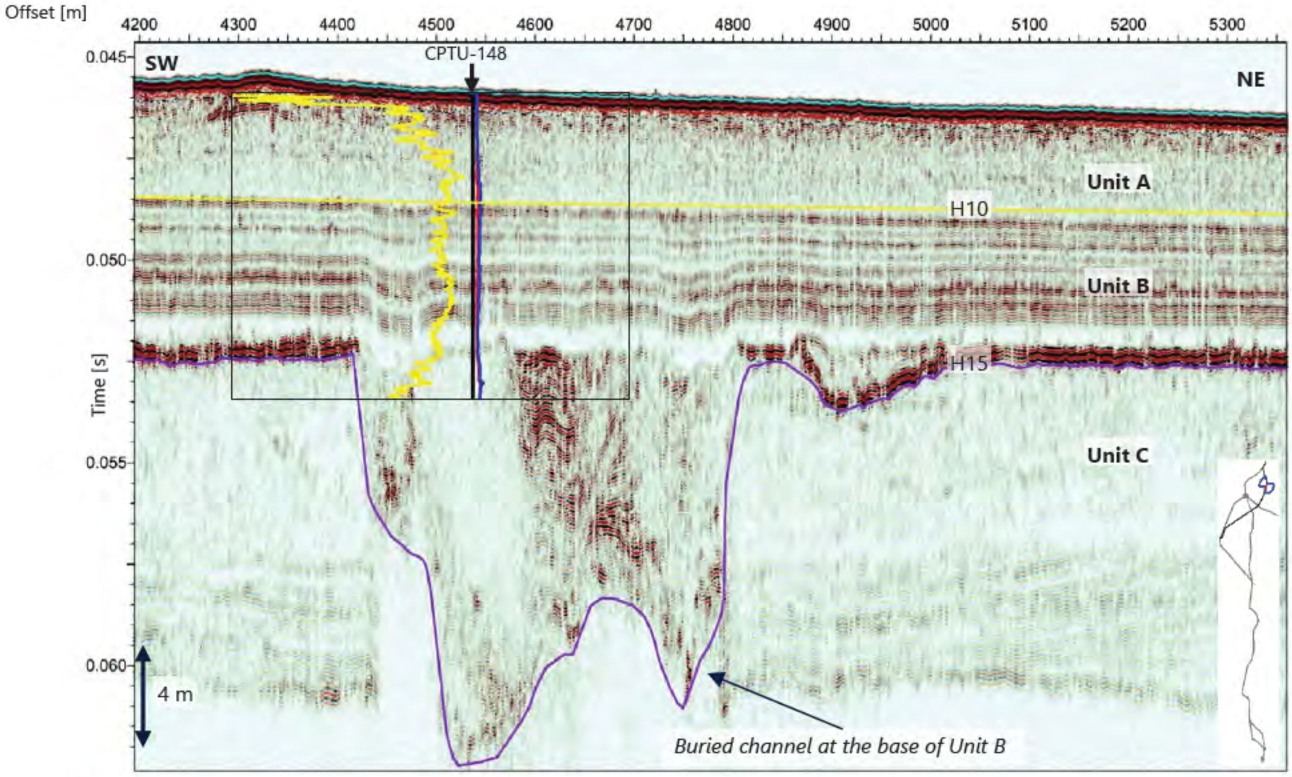


Figure 13.7: SBP data example of route section K14-L4A. (Line SBP_TA3M2320P1_3) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 8 %.

14. Hub Area

14.1 Hub Area Locations

The location of the Hub Area is shown in Figure 14.1.

The Hub Area is approximately 5.3 km^2 in size, situated in the crossing between route Section B, Section C, Section D and Section E Alternative.

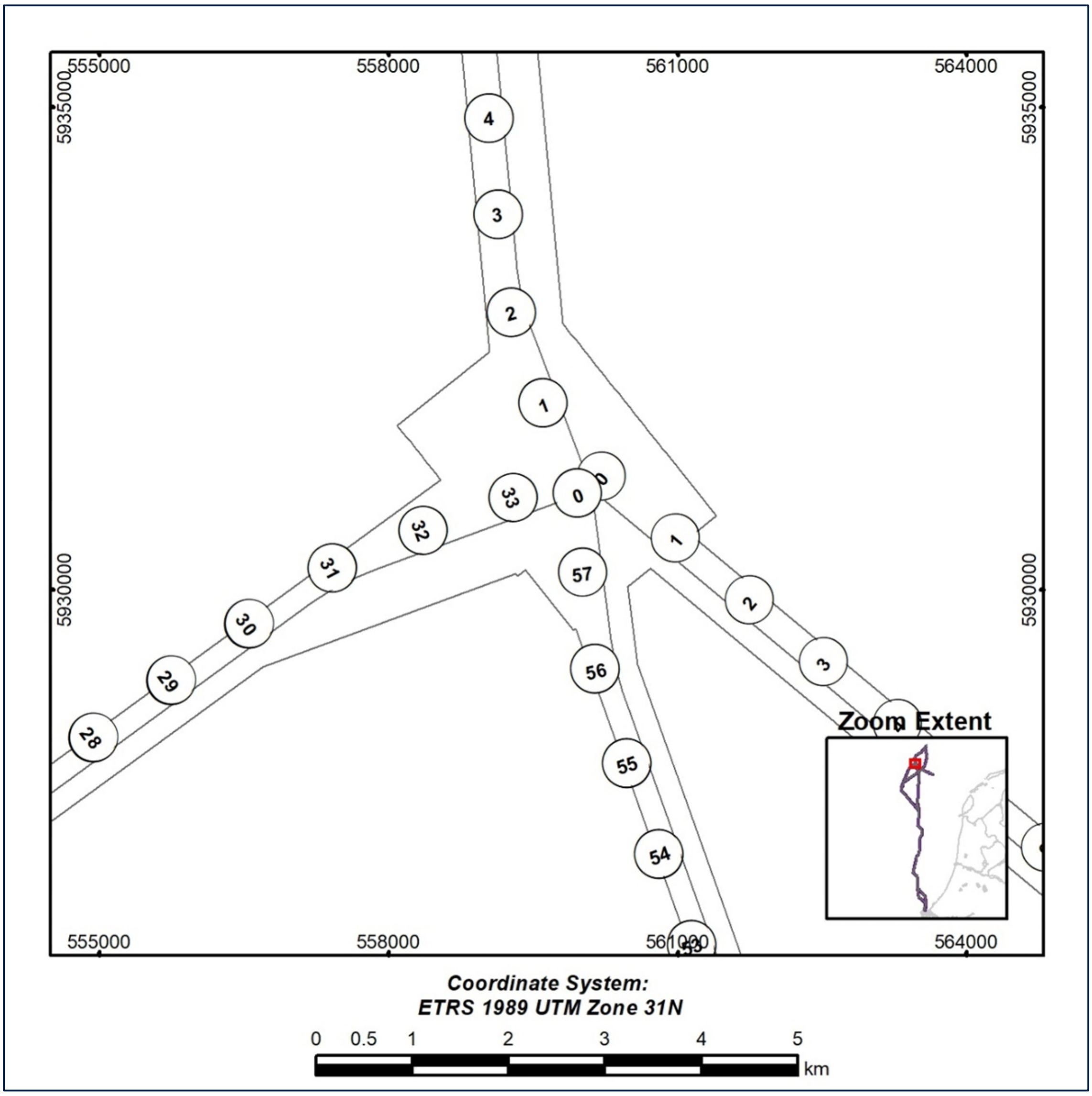


Figure 14.1: Location of the Hub Area.

14.2 Results

14.2.1 Bathymetry

The water depth within Hub Area ranges between 30.0 m and 31.5 m. An overview of the bathymetry is given in Figure 14.2

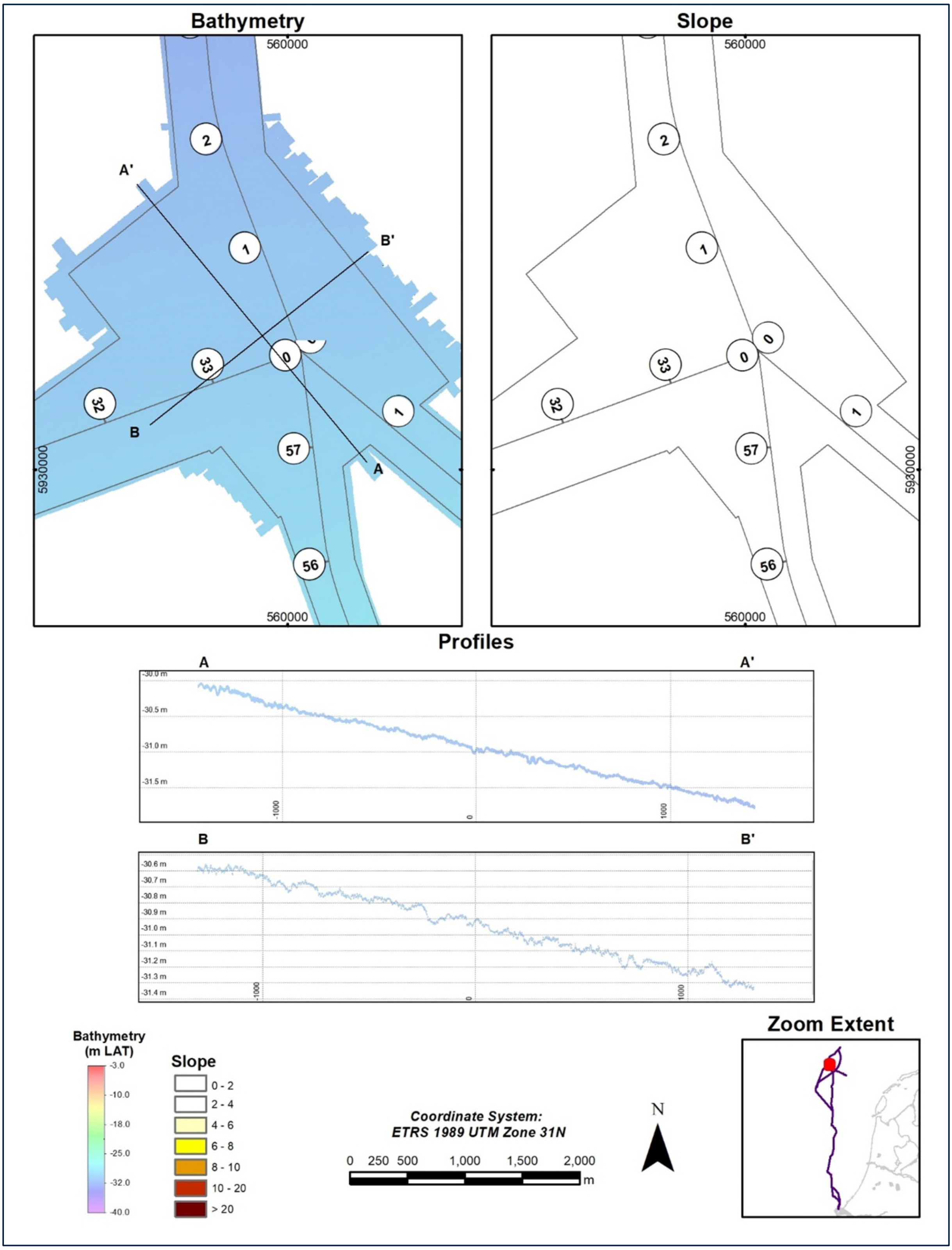


Figure 14.2: Bathymetry in the Hub Area.

14.2.2 Seafloor Morphology

No morphological features were identified in the Hub Area. The main sediment type has been classified as SAND with trawl marks. An overview of the sediment and the morphology in the Hub Area is given in Figure 14.3.

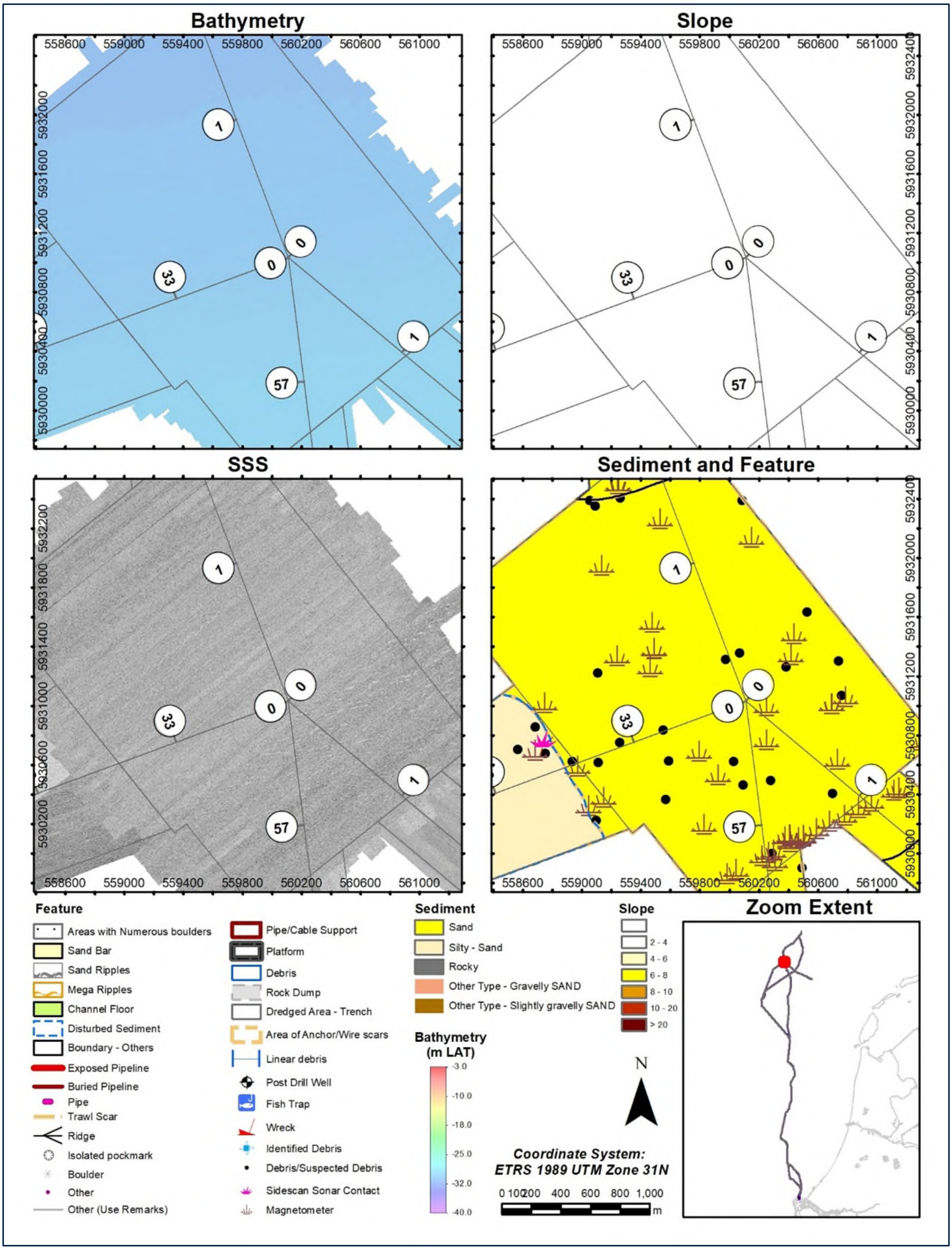


Figure 14.3: Overview of the sediments and morphology in the Hub Area.

14.2.3 Seafloor Features and Contacts

Seafloor features and contacts were identified from one or more of the SSS, MBES, MAG and SBP sensors and cross-correlated where possible.

Table 14.1 summarises the quantities of contacts picked. The survey extent for each sensor varied and contacts were picked within the survey boundary of each sensor and cross-correlated where multiple datasets were available. No targets cross correlate between sensors in this section of the route.

Table 69: Summary of seafloor contacts in the Hub Area

Sensor	Contact Classification	Quantity
SSS/MBES/MAG Point Features	Debris	19
	Suspected debris	3
	Magnetic anomalies	38

No linear features and no pipelines are crossing the Hub Area.

14.2.4 Magnetometer Contacts

In the Hub Area, 38 magnetic contacts were found at the time of the geophysical scope (single MAG survey). The magnetometer anomalies range between 6.0 nT and 591.0 nT. The highest magnetic amplitudes are associated with buried suspected debris (Figure 14.4)

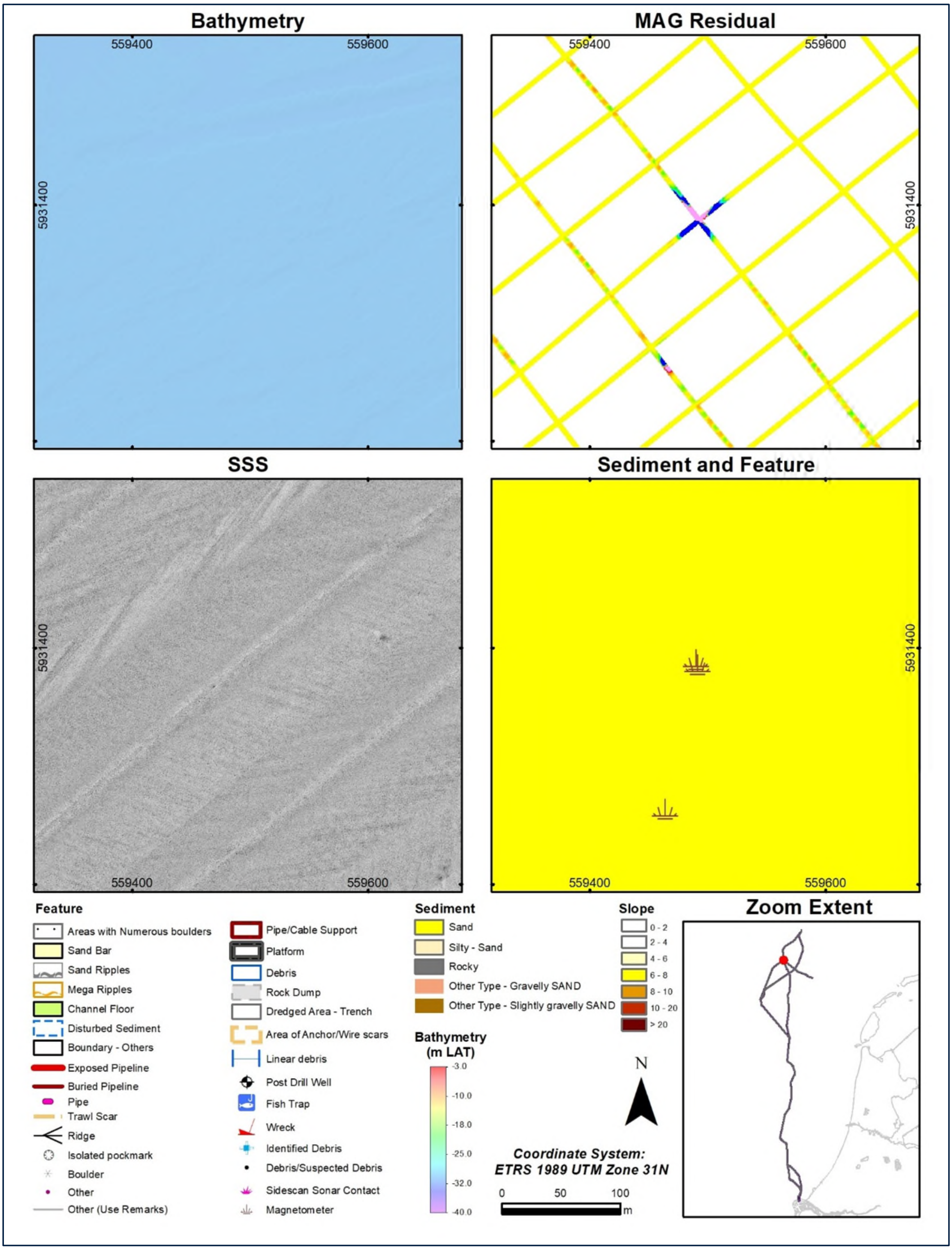


Figure 14.4: Position of the largest MAG contact in the Hub Area (MAG residual scale +/- 5 nT).

14.2.5 Sub-seafloor Stratigraphy

Units A, B, D, E and G are present in the Hub Area (Figure 14.5).

Unit A is present in the entire section. It has transparent seismic character. The average thickness of this unit in this route section is approximately 2.5 m.

Unit B is present across the entire section. This unit has a semi-transparent seismic character with low to medium-amplitude parallel to sub parallel reflectors. The base of this unit is locally channelised. Their infill is structured, with medium to high amplitude reflectors. Locally at the base, high amplitude short reflectors were observed, which represent laminae or thin bed of peat and/or organic-rich clay (peat level 1). The maximum thickness of this unit in this section is approximately 5 m.

Unit D is present in the entire section. Its seismic character is transparent to semi-transparent, with internal erosion surfaces, marked by inclined reflectors. Locally, channels and high negative amplitude anomalies were also interpreted (peat level 2). The maximum thickness of the Unit D in this section is approximately 20 m.

Unit E and G is present in the entire section. Both units show similar chaotic seismic facies.

Table 14.2 provides Lithology for the HUB Area based on the seafloor CPT and VC geotechnical data acquired as part of this geophysical survey. Details of the geotechnical data can be found in report F197217-REP-006.

Table 70: Soil conditions in sub-seafloor

Unit	Depth to Base [m BSF]	Lithology
A	1.5 to 3.3	Very loose clayey fine and medium SAND with occasional shells and shell fragments
B	5.8 to 9.6	Very loose clayey fine and medium SAND with occasional shells and shell fragments Locally with medium bed of very low to low strength sandy CLAY
D	17.3 to 19.0	Dense to very dense SAND
E	27.5 to 31.6	Dense to very dense SAND Locally with medium spaced thin to medium beds of CLAY

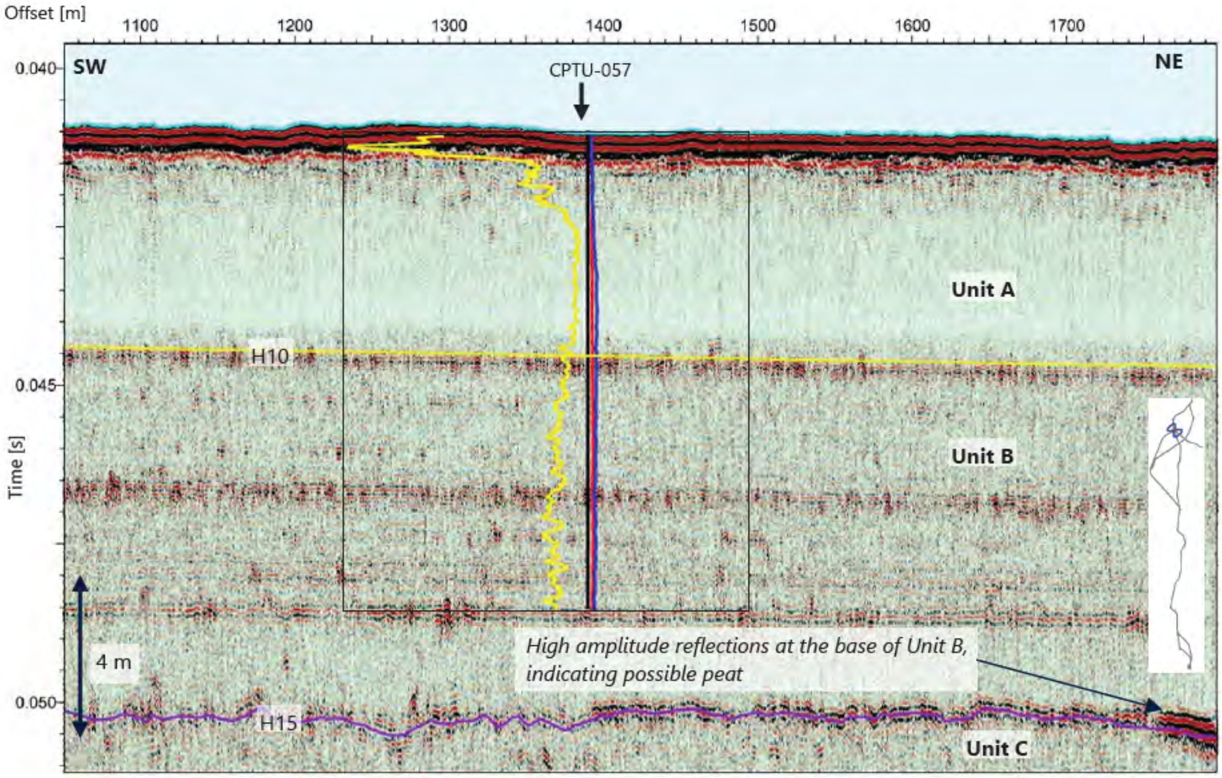


Figure 14.5: SBP data example of the Hub Area. (Line SBP_TA3P2428P1) Width of the CPT boxes show cone resistance values (blue curve) within range of 0 to 25 MPa, sleeve friction values (red curve) from 0 to 0.625 MPa and friction ratio (yellow curve) from 0 to 8 %.

15. References

Ashley, G.M, Boothroyd, J.C., Bridge, J.S., Clifton, H.E., Dalrymple, R.W., Elliott, T., Flemming, B.W., Harms, J.C., Harris, P.T., Hunter, R.E., Kreisa, R.D., Lancaster, N., Middleton, G.V., Paola, C., Rubin, D.M., Smith, J.D., Southard, J.B., Terwindt, J.H.I. & Twitchell, D.C. (1990). Classification of largescale subaqueous bedforms: a new look at an old problem. *Journal of Sedimentary Petrology, 60*, 160–172.

BSI (2015). Code *of practice for ground investigations* (BS 5930:2015). https://shop.bsigroup.com/ProductDetail?pid=000000000030268 443

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

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.

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.

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

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.

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.

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.

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.

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

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

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 the Use of the Report

This report (the "Report") was prepared as part of the services (the "Services") provided by Fugro for its client (the "Client") and in accordance with the terms of the relevant contract between the two parties (the Contract") and to the extent to which Fugro relied on Client or third-party information as was set out in the Contract.

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Appendix B

Alignment charts

B.1 Export Route

B.2 Section A-Alt

B.3 Section B

B.4 Section C

B.5 Section D

B.6 Section E Alternative

B.7 Section F

B.8 Section K14-L4A

B.9 Hub Area

Appendix C

2DUHR processing report

Appendix D

Operation Reports

D.1 Field Operations and Preliminary Results report from the Kommandor Orca and the Normand Mermaid

D.2 Field Operations from the Fugro Discovery

D.3 Field Operations from the Fugro Searcher

D.4 Field Operations from the Fugro Seeker

Appendix E

Nearshore Geophysical Survey Report (preliminary results)

Appendix F

Environmental Reports and Tests Results

F.1 Environmental Field Report

F.2 Biodiversity Observation Report

F.3 EBS Report

F.4 eDNA Report

Appendix G

Measured and Derived Geotechnical Parameters and Final Results Report

Appendix H

ISB Interpretation

Aramis BB4A (Shell-K14FA2-Store)

On Bottom Stability Design Report

Shell Document Number	ARS-200-BB4A-K14FA2-10-LA-0580-0004
Building Block	BB4A
Block, Field & Platform\Area Code	K14FA2
PCAP ID	NA
Document Revision	02
Document Status	IFR - Issued for Review
Discipline **Document Type**	LA – Pipeline & Riser 0580 – On Bottom Stability Design Report
Originator / Author	[redacted]
Originating Company	KBR
Issue Date	14/06/2024
ECCN	EAR99
Security Classification	Internal
Disclosure	Refer to Reliance Notice below
Revision History Shown on next page	

Rev#	Issue Date	Document Status	Originator	Reviewer	Approver
01	07-06-2024	Issued For Review	[redacted]		
02	14-06-2024	Issued For Review			

REVISION HISTORY

CHANGE/HOLD HISTORY

Rev#	Reason for Hold / Change

SUMMARY/ABSTRACT

This document presents the On Bottom Stability Design for the Aramis Spurline.

80mm/35mm are the CONTRACTOR's recommended CWC to achieve stability during empty/flooded installation for April to September period respectively. Mechanical burial to the required depth prior to operation shall be done as well during April to September. This option is designed to withstand 10-year return period storm. CONTRACTOR recommends 130mm if COMPANY considers the highly unlikely case of self-unburial during operation (sensitivity analyses below).

130mm/35mm are also able to achieve stability during installation for All-year/April to September period respectively. Mechanical burial to the required depth prior to operation shall be done during the same period as installation. This option is designed to withstand 1-year return period storm.

Sensitivity analyses on the highly unlikely case of self-unburial of the pipeline during operation or blowdown after mechanical burial proves that none of the above cases can withstand a 10-year return period storm. However, 100 and 130mm CWC are enough to withstand the 1-year return period storm during operation and blowdown respectively. Routing surveys is required and in the event of self-unburial, mechanical reburial is recommended to be carried out as soon as possible.

Contents

ABBREVIATIONS:

ASC	Associated Current
ASW	Associated Wave
AY	All Year
BD	Blow Down
BLIV	Battery limit isolation valve
CCS	Carbon Capture Storage
CC(U)S	Carbon Capture Utilization Storage
CO2	Carbon Dioxide
CWC	Concrete Weight Coating
E	Empty
F	Fine
Fl	Flooded
H	High
HAT	Highest Astronomical Tide
Ins	Installation
L	Low
LAT	Lowest Astronomical Tide
M	Medium
MSL	Mean Sea Level
NAP	Normaal Amsterdamse Peil [Normal Amsterdam Gauge (onshore compression station/trunkline inlet train average elevation)]
NV	Not Valid
OBS	Ocean Bottom Seismometers
Op	Operation
OPEX	Operating Expenditure
PACO	Process Automation Control & Optimization
TTE	Total Energies

1. INTRODUCTION

1.1. Aramis Project Background

The Aramis carbon capture and storage (CCS) project is incorporating, from the onset, a cross-border approach, providing a decarbonisation solution for North-West Europe. Aramis is developing a technical concept of CCS to contribute to the decarbonisation of industrial areas of The Netherlands, Belgium, France and Germany. Aramis is also seeking synergies with Porthos, another ongoing CCS project in The Netherlands, to form a fully integrated CC(U)S model in The Netherlands for these industrial clusters. The scope of the Aramis CCS project, contains the following transport and storage elements:

- Shipping by barges or coasters for customers not connected to the terminal by pipeline.
- New shipping terminal at the Maasvlakte to be built and operated by CO2nnect, receiving liquid (cryogenic) CO2 from different industrial clusters located in the Northwest Europe region. The terminal will have temporary storage capacity.
- Compressor station for gas phase (vapour) CO2 volumes coming by Porthos onshore pipeline from Rotterdam and its hinterlands
- Trunkline to transport dense phse CO2 over ~200km to the offshore platforms / blocks, with over capacity and potential tie-in points to cater for future growth.
- Offshore Storage in K14 (Shell) and K6/L4 (Total Energies) and in future other fields is expected

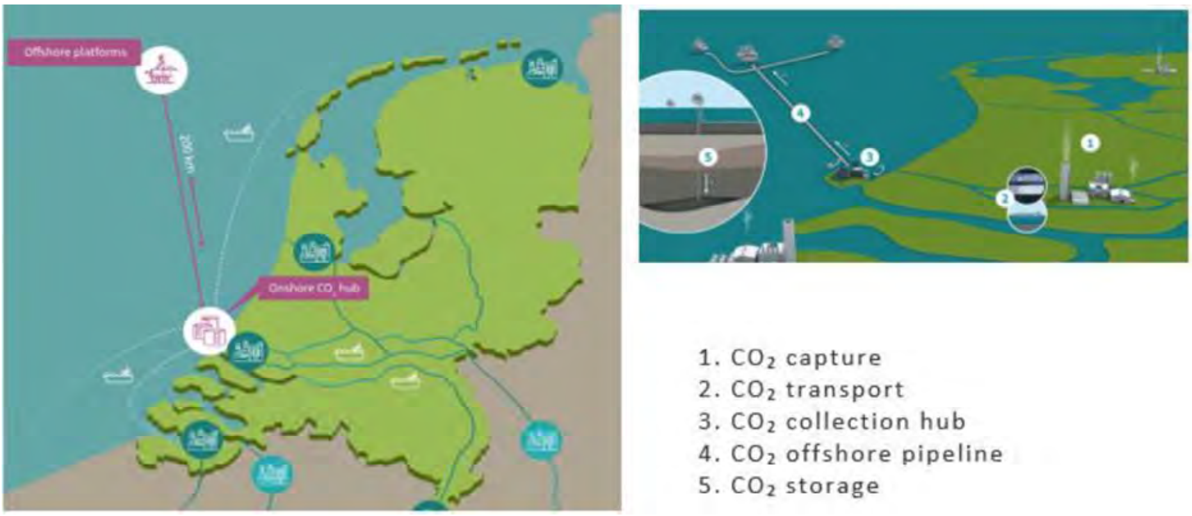


Figure 1-1 Aramis Overview

The key value drivers (and targets) for the Aramis project are:

- Meet SDE++ timeline – first CO2 in store latest end 2028
- System availability > 95% (from emitter to store)
- No early life failures –flawless start-up of the chain
- Lifecycle costs / OPEX: Make sure the running costs are as low as possible (note that lifecycle costs include 'Growth')
- Build reputation - public acceptance (incl. safety)
- Enable future growth and open access (volumes, stores)
- Successful and early transfer of liability after end of injection

K14 and L4 from Shell and Total respectively are the two stores of the Launch phase of the Aramis project. The transport system (compressor, terminal and trunkline) will be open access while stores will be in competition. The Aramis project consists of the several building blocks. Following the CO_2 flow from the onshore terminal to the stores, Shell and TTE, it flows via the following building blocks:

- BB1 - Onshore terminal
- BB2 - Onshore compression
- BB3 - CO_2 trunkline from Rotterdam Maasvlakte to the offshore K&L blocks ending in a Distribution Hub platform
- BB4a - Shell store (K14FA field) – The Facility scope of BB4a is subject of this document
- BB4b - TTE store (Total Energies)

1.2. Document Purpose

The purpose of this report is to demonstrate the vertical and lateral stability of the Spurline for the Front-End Engineering Design (FEED), for the BB4a building block of the ARAMIS CCS project.

2. FACILITY LOCATION & DESCRIPTION

2.1. General

The Aramis Shell CCS facility, BB4a starts at its battery limit with BB3 where the Spool imports the fluid from the BB3 ILT. Following the flow of CO2 from the trunkline towards the reservoir the high-level elements of K14FA2 project are:

- Subsea manifold with automated battery limit isolation valve (BLIV), including the connection to the trunkline.
- Spurline and umbilical connecting manifold with the CO2 injection platform
- New normally unmanned wellhead platform; topsides and jacket
- Interface scope between wells and the facilities
- Installation of the OBS (ocean bottom seismometers) and connection to the PACO systems on the platform

A schematic overview of the system is shown below:

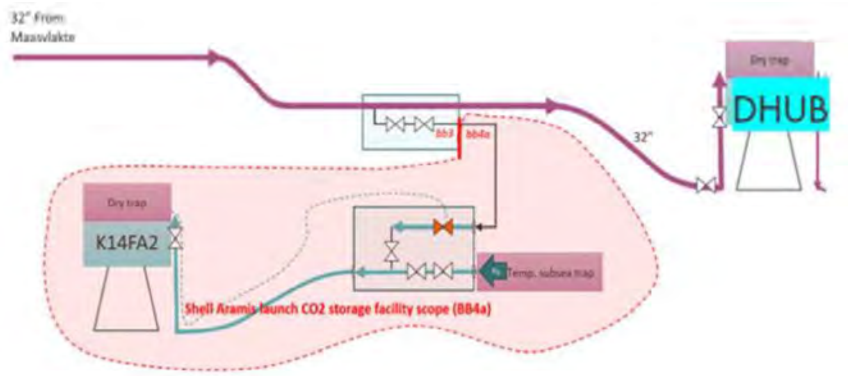


Table 2-1 Schematic overview of Aramis Launch Shell storage scope (inside dotted red line).

3. LEGISLATION, REGULATIONS, CODES & STANDARDS

The Standards, Specifications and Documents used in this report are as following.

3.1. General

The Aramis FEED scope will be designed to selected relevant COMPANY General Specifications and recognised International Standards. Any deviations will be informed to COMPANY for prior approval.

3.2. Legislation and Regulations

The subsea system design shall comply with all the relevant local, national, and international legislation and regulations.

3.3. National Design Codes and COMPANY General Specifications

The applicable COMPANY General Specification will be used as guideline for the design of subsea pipeline and structures. These three NEN Requirements, are the leading documents.

1. NEN 3650-1, “Requirements for pipeline systems - Part 1: General requirements” (2020)
2. NEN 3650-2, “Requirements for pipeline systems - Part 2: Additional specifications for steel pipelines” (2020)
3. NEN 3656, “Requirements for submarine steel pipeline systems” (2022)

3.4. Codes and Standards

The pipeline stability design has been carried out according to DNV-RP-F109 [Ref.4] as NEN series does not prescribe a calculation process according to Aramis Store BfD [Ref.8].

4. DNV-RP-F109 May 2021, “On-bottom stability design of submarine, pipelines, cables and umbilicals”
5. DNV-ST-F101, Dec. 2017, “Submarine Pipeline Systems”
6. DNV-RP-F114 May 2017, “Pipe-soil interaction for submarine pipelines”

3.5. COMPANY Documents

7. ARS-PFE-BB4a-ICS-BOD-002, “Aramis Store BfD
8. A-PFE-BB4a-GEO-REP-001, “Offshore Metocean Design and Operational Criteria, ARAMIS (Block K14)”

3.6. Other Documents

9. ARS-200-BB4A-K14FA2-00-LA-7704-0013_Rev02, “Spurline, Subsea Manifold, Tie-in Spools, Umbilical and Riser Design Basis”
10. ARS-200-BB4A-K14FA2-10-LA-7704-0001_Rev02 “Flow Assurance Basis of Design”
11. ARS-200-BB4A-K14FA2-10-LA-7180-0001, “Flow Assurance Study Report”
12. ARS-200-BB4A-K14FA2-40-CG-8372-0001, “Geotechnical Design Basis/Design Premise”

4. DESIGN METHODOLOGY

4.1. General

The on-bottom stability was checked in compliance with DNV-RP-F109 [Ref.4], as per BfD [Ref.7] during Installation (temporary), Operation (permanent) and Blowdown (temporary) cases and full compliance was not assured. However, as NEN 3656 [Ref.3] considers the pipeline stable if buried to the required depth, further analysis is not required for operation. An integrated protection study will be carried out by CONTRACTOR to calculate the mobile sand layer to be taken into account in the required burial depth. The Spurline stability was evaluated for the following:

4.1.1. Vertical Stability in Water

This is the buoyancy check to ensure that the pipe will not float for the selected CWC.

4.1.2. Vertical Stability on Sand

According to DNV-RP-F109 [Ref.4], if the pipe submerged weight for the selected CWC is more than the soil (fine sand) submerged weight, the exposed pipe is prone to sinking. Using Specific gravity instead of submerged weight, Table 4-1 shows that pipeline is prone to sinking and will not float even during post-laying trenching activities.

Item	35mm CWC Pipe	130mm CWC Pipe	Seabed Sand	Fluidized Seabed Sand
Specific Gravity	1.78	2.48	1.72	1.65 (1)

Table 4-1 Specific Gravity of Pipeline, Seabed Sand and Fluidized Seabed Sand

Note 1: This value is provided verbally by COMPANY

4.1.3. Absolute Stability

This criterion ensures that the pipe will not undergo any displacement in lateral and vertical directions. Hydrodynamic load combinations of 100-year wave/Associated current 10-year wave/Associated current and 10-year wave/Associated current 1-year wave/Associated current return periods are used for permanent and temporary conditions respectively.

4.1.4. Virtual Stability

This criterion ensures that the pipe will not be displaced laterally by a specific amount. DNV-RP-F109 [Ref.4] explains that less than about half a diameter displacement ensures that the pipeline does not move out of its cavity, i.e. the pipeline is virtually stable and will not achieve breakouts. Therefore 0.5D virtual stability criterion is chosen to have no accumulated displacement, and maximum displacement stays independent of time. Hydrodynamic load combinations of 100-year wave/Associated current 10-year wave/Associated current and 10-year wave/Associated current 1-year wave/Associated current return periods are used for permanent and temporary conditions respectively.

4.2. Safety Factors

Different safety factors are implemented as follows:

4.2.1. Vertical Stability in Water

Vertical stability criterion is defined using a safety factor of 1.1.

4.2.2. Absolute Stability

For temporary cases of installation and blowdown, low and medium safety class factors are selected for pre- and post-commissioning respectively. For permanent cases a high safety class is selected, as per Section 4.5.3 DNV-RP-F109 [Ref.4]. Table 4-1 displays a summary of the safety factors used in Absolute stability design.

Case	Installation	Operation	Blowdown
Safety Factor	Low	High (1)	Medium (2)

Table 4-2 Absolute Stability Safety Factors

Note 1: Low safety factors used for few operational load cases to assess the effect. Medium safety factor is used in the highly unlikely case of temporary self-unburial.
Note 2: DNV-ST-F101 prevails due to later edition.

4.2.3. Virtual Stability

Unlike Absolute stability, Virtual Stability requires no safety factor, because this criterion is based on engineering judgment and utilizes design curves obtained from several dynamic analyses that are considered as upper bound values.

4.3. Case Matrixes

Table 4-3 summarises the case matrix used for on-bottom stability assessments, using an in-house Mathcad sheet.

DSS has zero corrosion allowance, thus it is not mentioned even for operation.

Initial embedment is only relevant for the absolute stability where self-weight is the driving factor, and the dynamic effect is not taken into account. However virtual stability is based on design curves extracted from a large number of dynamic analyses which takes advantage of the build-up of passive resistance due to small displacements that the pipeline will experience in storm condition. This is an advantage of using Virtual stability regarding the right embedment compared with absolute stability.

5mm marine growth has been taken into account for the analyses.

Pre-lay trenching was studied for several cases to achieve stability considering the achievable trench angle limited by sand repose angle of 30° [Ref.12]. However, the trench geometry is prone to be filled by highly mobile sand prior to laying which requires a study if pre-lay trenching cases are adopted.

The results and Mathcad sheet presented in this document are on a limited selected set of cases, rather than every case studied.

Case	Condition	Safety Class	Wave (Y)	Current (Y)	Content Density (Kg/m^3)	Metocean Duration	Installation Condition	Effective Trench Depth (m)	Trench Angle(deg.)	Initial Embedment ratio to total OD (%)	Lateral Passive Resistance (KN/m)	Sand Type
1	Ins	L	1	ASC	0	AY	E	-	-	6.1	1.46	F
2	Ins	L	10	ASC	0	AY	E	-	-	6.6	5.86	F
3	Ins	L	10	ASC	0	AY	E	0.5	30	6.1	1.48	F

Case	Condition	Safety Class	Wave (Y)	Current (Y)	Content Density (Kg/m³)	Metocean Duration	Installation Condition	Effective Trench Depth (m)	Trench Angle(deg.)	Initial Embedment ratio to total OD (%)	Lateral Passive Resistance (KN/m)	Sand Type
4	Ins	L	10	ASC	0	AY	E	1.0	30	6.1	1.41	F
5	Ins	L	10	ASC	0	AY	Fl	-	-	6.6	5.50	F
6	Ins	L	10	ASC	0	AY	Fl	1.0	30	6.2	1.49	F
7	Ins	L	1	ASC	0	AS	E	-	-	5.7	0.79	F
8	Ins	L	10	ASC	0	AS	E	-	-	6.6	5.04	F
8F	Ins	L	10	ASC	0	AS	Fl	-	-	5.9	0.59	F
9	Ins	L	10	ASC	0	AS	E	0.932	30	4.7	0.31	F
10	Ins	L	1	ASC	0	AY	E	-	-	5.8	0.85	F
11	Ins	L	ASW	1	0	AY	E	-	-	6.0	0.68	F
12	Ins	L	1	ASC	0	AS	E	-	-	4.0	0.19	F
13	Ins	L	1	1	0	AY	E	-	-	6.1	1.41	F
14	Ins	L	1	1	0	AY	E	1.0	30	2.7	0.08	F
15	Op	H	10	ASC	757.1	AY	-	-	-	4.7	0.31	F
16	Op	H	100	ASC	757.1	AY	-	-	-	6.1	1.39	F
17	Op	L	100	ASC	757.1	AY	-	-	-	4.5	0.26	F
18	Op	L	100	ASC	757.1	AY	-	0.5	30	6.7	21.18	F
19	Op	L	100	ASC	757.1	AY	-	1.0	30	NV	NV	F
20	BD	M	1	ASC	0	AY	-	-	-	6.7	21.86	F
21	BD	M	10	ASC	0	AY	-	-	-	6.7	6.83	F
22	BD	M	10	ASC	0	AY	-	1.0	30	6.6	3.35	F
23	BD	M	10	ASC	0	AY	-	1.655	30	6.5	4.15	F
24	BD	M	10	ASC	0	AY	-	2.0	45	6.7	20.14	M

Table 4-3 Case Matrix for On-Bottom Stability Assessment

5. DESIGN DATA

5.1. General

The design data stated in this section was extracted from the Basis of Design [Ref.0], unless stated otherwise.

5.2. Pipeline data

The high-density concrete coating was allowed by COMPANY to improve the stability result.

Pipe	Outside Diameter (mm)	Wall Thickness (mm)	Content Density in Operation	3LPE Corrosion Coating		Concrete Density (Kg/m3)
				Thickness (mm)	Density (Kg/m3)	
Spurline	406.4	17.5	757.1	2.9	930	3300

Table 5-1 Spurline Data for Stability Analyses

5.3. Route Data

The seabed is considered smooth with a gentle constant slope. Heading was considered conservatively as 90° instead of 100 as routing was not still determined. Route data is summarized below.

Route Direction	Route Length (m)	Max Depth (m)	Min Depth (m)	Heading (degree)
East to West	800	29.5	25.1	100.0 (1)

Table 5-2 Spurline Data

Note 1: Heading was considered 90° in the analyses.

5.4. Metocean Data

The Significant Wave Height (HS), Time Period (TP) and Current profiles (@1m abs) including directionality are defined below [Ref.8]. The wave associated current profile @1m abs is calculated by applying a profile factor of 0.73 [Ref.8] to the associated current profile @mean depth. The directionality of the wave has been taken into account to decrease the severity of the result.

Period	Type	Direction (From)								
		N	NE	E	SE	S	SW	W	NW	Omni
1 Year	Wave Hs (m)	6.4	4.9	3.9	3.4	5.3	6.1	6.4	6.4	5.9
	Wave Tp (s)	13.2	11.0	9.2	7.4	9.4	9.7	10.1	12.6	10.9
	Current (m)	0.54	0.53	0.49	0.47	0.62	0.68	0.62	0.56	0.61
	ASW Hs (m)	2.3	3.0	3.1	1.3	1.8	3.7	4.1	2.7	2.7
	ASW Tp (s)	8.2	8.9	8.4	5.4	6.2	8.4	8.9	8.6	7.9
	ASC (m)	0.12	0.18	0.12	0.12	0.42	0.33	0.23	0.12	0.22
10 Year	Wave Hs (m)	8.2	7.0	5.6	4.7	6.4	7.3	7.9	8.2	7.7
	Wave Tp (s)	14.8	12.9	10.4	8.1	10.0	10.2	10.6	14.0	12.0
	Current (m)	0.62	0.62	0.57	0.54	0.73	0.80	0.75	0.65	0.73
	ASC (m)	0.18	0.30	0.20	0.18	0.54	0.41	0.31	0.14	0.30
100 Year	Wave Hs (m)	10.3	8.9	7.0	6.0	7.3	8.4	9.4	10.3	9.8
	Wave Tp (s)	16.3	14.1	11.2	8.6	10.4	10.5	11.0	15.3	13.1
	Current (m)	0.73	0.69	0.64	0.71	0.85	0.92	0.87	0.75	0.85

	ASC (m)	0.23	0.40	0.28	0.23	0.64	0.49	0.37	0.16	0.39

Table 5-3 All Year Directional Wave Height (Hs (3h)), Time Period (Central Tp) and 1m-asb Current in SI unit

The Seasonal April to September Significant Wave Height (HS), and Time Period (TP), and Current profiles (@1m abs) including directionality are defined below [Ref.8].

Period	Type	Direction (From)								
		N	NE	E	SE	S	SW	W	NW	Omni
1 Year	Wave Hs (m)	4.3	3.3	2.9	2.6	3.7	4.4	4.3	4.5	4.0
	Wave Tp (s)	11.0	9.2	8.2	6.9	8.3	8.9	9.1	10.9	9.4
	Current (m)	0.48	0.47	0.45	0.45	0.52	0.60	0.54	0.48	0.52
	ASC (m)	0.07	0.09	0.07	0.08	0.26	0.21	0.14	0.09	0.15
10 Year	Wave Hs (m)	5.7	4.7	4.1	3.5	4.9	5.3	5.6	5.9	5.4
	Wave Tp (s)	12.6	10.9	9.3	7.5	9.2	9.4	9.8	12.2	10.5
	Current (m)	0.53	0.53	0.50	0.47	0.62	0.69	0.63	0.55	0.62
	ASC (m)	0.10	0.18	0.13	0.12	0.38	0.28	0.20	0.11	0.20
100 Year	Wave Hs (m)	7.0	6.1	5.4	4.7	5.9	6.3	6.6	7.1	6.6
	Wave Tp (s)	13.8	12.1	10.3	8.1	9.8	9.8	10.2	13.2	11.4
	Current (m)	0.59	0.60	0.57	0.53	0.70	0.78	0.71	0.66	0.71
	ASC (m)	0.14	0.25	0.20	0.18	0.50	0.35	0.24	0.12	0.25

Table 5-4 April to September Directional Wave Height (Hs (3h)), Time Period (Central Tp) and 1m-asb Current in SI unit

5.5. Soil Data

The Aramis seabed mainly consists of fine sand [Ref.12]. COMPANY geotechnical team has approved the Drained only condition for all pipeline design analyses. Only LE sand unit weight is used for stability analyses to be conservative.

Parameter	LE	BE	HE
Unit Weight (kN/m3)	17.3	17.65	18.5

Table 5-5 Shell Aramis Seabed Dry Soil Unit Weight [Ref.12]

5.5.1. Trench Geometry Limitations

Trench geometry is limited by the sand angle of repose and the requirement in DNVRef.4.

Soil Type	Max Achievable Angle (degree)	Max Effective Depth (m)		
		CWC 63mm	CWC 83mm	CWC 272mm
Fine Sand	30 (1)	0.932 (2)	1.001 (2)	1.655 (2)

Table 5-6 Trench maximum achievable angle and effective depth in sand

Note 1: Fine sand angle of repose is around 30°. This is the angle that deposits stand in a ploughed trench.
Note 2: Using 30° maximum angle of repose at maximum 3D distance as per section 6.4.1.4 of Ref.4

6. ON BOTTOM STABILITY ANALYSIS RESULT

Because of the short length of the spurline, 10D lateral stability may create high induced loading at the pipeline extremities where tie-in spools are located. Therefore only 0.5 D Virtual, selected according to section 4.1.4, and Absolute stability results are presented.

6.1. Hydrodynamic Load

Table 6-1 summarizes the 1,10 and 100-Y return period peak wave and current induced particle velocity from the South direction perpendicular to pipeline at the maximum water depth.

Water Particle Velocity (m/s)	1-Year Wave 10-Year Current	10-Year Wave 1-Year Current	100-Year Wave 10-Year Current	10-Year Wave 100-Year Current	1-Year Wave 1-Year Current
Wave Induced	1.237	1.710	2.261	1.710	1.237
Current Induced	0.73	0.62	0.73	0.85	0.62
Total	1.967	2.330	2.991	2.560	1.857

Table 6-1 Water particle velocity at the pipe level for the maximum water depth

6.2. Vertical Stability on Sands

As the Pipe submerged weight without CWC and with min content density is around 8.56 KN/m3 and more than the maximum sand submerged weight of 8.45 KN/m3, thus the pipeline is susceptible to sinking.

6.3. Lateral and Vertical Stability

Table 6-2 summarises the cases used for on-bottom stability assessments, using an approved KBR Mathcad sheet and the required concrete coating thickness to meet 0.5D Virtual stability plus Absolute stability along with its buoyancy, horizontal and vertical ratios.

Case	Condition	Safety Class	Wave (Y)	Current (Y)	Cont. Den. (Kg/m^3)	Met. Duration	Installation Condition	Eff. Trench Depth (m)	Trench Angle(deg.)	Initial Embedment ratio to total OD (%)	Lateral Passive Resistance (KN/m)	Sand Type	Required Conc. Th.(mm)		Absolute Stability Ratio		
													Virtual 0.5D	Absolute	Buoyancy	Horizontal	Vertical
1	Ins	L	1	ASC	0	AY	E	-	-	6.1	1.41	F	155	358	2.71	1.00	2.91
2	Ins	L	10	ASC	0	AY	E	-	-	6.6	5.50	F	207(1)	865	2.89	1.00	2.78
3	Ins	L	10	ASC	0	AY	E	0.5	30	6.2	1.49	F	207(1)	372	2.72	1.00	3.38
4	Ins	L	10	ASC	0	AY	E	1.0	30	5.7	0.79	F	207(1)	233	2.55	1.00	4.00
5	Ins	L	10	ASC	0	AY	Fl	-	-	6.6	5.04	F	171(1)	814	2.91	1.00	2.86
6	Ins	L	10	ASC	0	AY	Fl	1.0	30	5.9	0.59	F	171(1)	165	2.62	1.00	4.28
7	Ins	L	1	ASC	0	AS	E	-	-	4.7	0.31	F	45	103	2.15	1.00	2.86
8	Ins	L	10	ASC	0	AS	E	-	-	5.8	0.85	F	76	246	2.58	1.00	2.95

Case	Condition	Safety Class	Wave (Y)	Current (Y)	Cont. Den. (Kg/m³)	Met. Duration	Installation Condition	Eff. Trench Depth (m)	Trench Angle(deg.)	Initial Embedment ratio to total OD (%)	Lateral Passive Resistance (KN/m)	Sand Type	Required Conc. Th.(mm)		Absolute Stability Ratio		
													Virtual 0.5D	Absolute	Buoyancy	Horizontal	Vertical
8F	Ins	L	10	ASC	0	AS	Fl	-	-	6.0	0.68	F	31	190	2.66	1.00	2.99
9	Ins	L	10	ASC	0	AS	E	0.932	30	4.0	0.19	F	76(3)	64(3)	1.90	1.01	4.73
10	Ins	L	1	ASC	0	AY	E	-	-	6.1	1.41	F	127	358	2.71	1.00	2.92
11	Ins	L	ASW	1	0	AY	E	-	-	2.7	0.08	F	16	20	1.45	1.00	3.33
12	Ins	L	1	ASC	0	AS	E	-	-	4.7	0.31	F	33	103	2.15	1.00	2.90
13	Ins	L	1	1	0	AY	E	-	-	6.1	1.39	F	177(1)	355	2.71	1.00	2.91
14	Ins	L	1	1	0	AY	E	1.0	30	4.5	0.26	F	177(1)	87	2.06	1.00	4.80
15	Op	H	10	ASC	757.1	AY	-	-	-	6.7	21.18	F	249(1)	1865	2.96	1.00	2.57
16	Op	H	100	ASC	757.1	AY	-	-	-	NV	NV	F	NV(2)	NV(2)	NV(2)	NV(2)	NV(2)
17	Op	L	100	ASC	757.1	AY	-	-	-	6.7	21.86	F	NV(2)	1898	2.96	1.00	2.72
18	Op	L	100	ASC	757.1	AY	-	0.5	30	6.7	6.83	F	NV(2)	976	2.93	1.00	3.11
19	Op	L	100	ASC	757.1	AY	-	1.0	30	6.6	3.35	F	NV(2)	628	2.88	1.00	3.49
20	BD	M	1	ASC	0	AY	-	-	-	6.5	4.15	F	152	725	2.87	1.00	2.64
21	BD	M	10	ASC	0	AY	-	-	-	6.7	20.14	F	203(1)	1816	2.95	1.00	2.63
22	BD	M	10	ASC	0	AY	-	1.0	30	6.4	2.62	F	203(1)	542	2.82	1.00	3.46
23	BD	M	10	ASC	0	AY	-	1.656	30	5.9	0.96	F	203(1)	269	2.61	1.00	4.73
24	BD	M	10	ASC	0	AY	-	1.653	45	5.9	0.97	M	201(1)	271	2.62	1.00	4.71

Table 6-2 On Bottom Stability Analyses Results

Note 1: Value at pipeline mid-point, as the result at KP end is outside the validity of DNV-RP-F109 formulas.
Note 2: Outside the validity of DNV-RP-F109 formulas.
Note 3: According to DNV-RP-F109, trench load reduction factor only applies to Absolute stability.
Note 4: Case 10 to 14 are based on NEN standard [Ref.3] to override DNV-RP-F109 [Ref.4] requirement and use 1Y-wave 1-Year Current data.

6.4. Sensitivity Analyses

Table 6-3 evaluates the stability during blowdown and operation if the pipeline become exposed again after mechanical or self-burial.

As COMPANY is supposed to bury the pipeline again within a short period, therefore operation is considered as a temporary case similar to blowdown and consequently 100-year Wave return period and high safety class do not apply.

Although very unlikely but self-unburial can occur anytime during the year. Thus, April to September seasonal data cannot be used for these sensitivity analyses.

Case S1 and Case 21 prove that stability cannot be achieved within the acceptable CWC range. Self-unburied Pipeline cannot withstand the 10-year storm during operation and blowdown.

Case S2 and S4 demonstrate that the stability during operation and blowdown of the self-unburied pipeline can be guaranteed with 100 and 130mm CWC respectively.

Case	Condition	Safety Class	Wave (Y)	Current (Y)	Cont. Den. (Kg/m^3)	Met. Duration	Installation Condition	Eff. Trench Depth (m)	Trench Angle(deg.)	Initial Embedment ratio to total OD (%)	Lateral Passive Resistance (KN/m)	Sand Type	Required Conc. Th.(mm)		Absolute Stability Ratio		
													Virtual 0.5D	Absolute	Buoyancy	Horizontal	Vertical
S1	Op	M	10	ASC	757.1	AY	-	-	-	6.7	19.95	F	178(1)	1804	2.95	1.00	2.63
S2	Op	M	1	ASC	757.1	AY	-	-	-	6.6	3.86	F	94	688	2.89	1.00	2.71
21	BD	M	10	ASC	0	AY	-	-	-	6.7	20.14	F	203(1)	1816	2.95	1.00	2.63
S4	BD	M	1	ASC	0	AY	-	-	-	6.5	4.03	F	125	712	2.87	1.00	2.70

Table 6-3 On-Bottom Stability Sensitivity Analyses Results

Note 1: Value at pipeline mid-point, as the result at KP end is outside the validity of DNV-RP-F109 formulas.

7. CONCLUSION AND RECOMMENDATION

None of the examined cases are stable during operation according to DNV-RP-F109 [Ref.4]. Therefore, mechanical protection is required. As stability is achievable for some of the cases during installation, and NEN 3656 [Ref.3] considers a buried pipeline as stable as long as it's buried to the required depth, therefore, mechanical burial is adopted to guarantee the stability during operation and blowdown.

If self-unburial is envisaged, all the recommended CWCs shall be overridden by 130mm according to sensitivity analyses case S4 in section 6.4. In this case routine survey is required and mechanical reburial shall be performed as soon as possible because re-exposed pipeline can withstand only the 1-year return period storm and not the 10-year one.

The analyses results provide two main hybrid solutions with two options for each as follows:

7.1. DNV + NEN 1-Year Return Period

This hybrid solution ensures the stability is achieved during installation according to DNV-RP-F109 [Ref.4] but using the refined NEN 1-Year Wave and associated current instead of DNV 10-year wave Associated Current requirement. NEN guarantees the stability during operation and blowdown via mechanical burial. COMPANY shall consider the risk of having a 10-year return period storm prior to burial as CWC is designed only to withstand 1-year return period storm.

7.1.1. All Year (case 10)

130mm is the selected CWC. Installation and mechanical burial shall be done during the year.

7.1.2. April to September (case 12)

35mm is the selected CWC. Installation and mechanical burial shall be done during April to September.

7.2. DNV

This hybrid solution, which is the CONTRACTOR's recommendation, ensures the stability is achieved during installation according to DNV-RP-F109 [Ref.4] using DNV 10-year wave 1-year current requirement (April to September). NEN guarantees the stability during operation and blowdown via mechanical burial. This recommended solution shall be overridden by 130mm CWC if the highly unlikely self-unburial of the pipeline is envisaged.

7.2.1. Installation Empty (case 8)

80mm is the selected CWC. Installation and mechanical burial shall be done during April to September.

7.2.2. Installation Flooded (case 8F)

35mm is the selected CWC. Installation and mechanical burial shall be done during April to September.

8. RECOMMENDED FOLLOW-UP WORK

Self-burial is considered as an option for the next stage. Analyses have been done according to DNV-RP-F109 [Ref.4], which proves that the pipeline is not stable during operation and blowdown using the selected CWC.

COMPANY survey data shows that several Pipelines at Aramis location are self-buried from 1 to 3 meters, protected from the waves and current and considered stable. The NEN 3656 [Ref.3] risk-based criteria which permits self-burial over a 1-year period has been analysed, utilizing 1-year wave (required for mechanical burial) and associated current (case 10) has been used instead of 3-year wave (required for self-burial) and associated current. It shows that the required CWC will be more than 130mm for virtual stability during installation. NEN requires that a survey be conducted within a year of construction to ensure adequate self-burial has occurred, and the in the event that this is not satisfied, mechanical burial or additional soil cover be provided. This option is designed to withstand 1-year return period storm.

APPENDIX 1. ATTACHMENTS

Mathcad - Case 8_Exp_Empt_Inst_10Y W_1Y C_Ap to Sep_DNV 2021.pdf

Mathcad - Case 8F_Exp_Flood_Inst_10Y W_1Y C_Ap to Sep_DNV 2021.pdf

KBR		REVISION	0 Model	1 Model	2 Model	3 Model	
		Date	10/06/2016	10/10/2016	07/06/2017	15/06/2021	
CLIENT	Shell	BY	MCB	MCB	MCB	VN	
PROJECT	Shell Aramis FEED	CHECKED	DMcN	JGF	JGF	JGF	
CALCULATION	On-Bottom Stability Assessment	CASE NO.	8	JOB NO.			
CODE	DNV RP F109	YEAR	2021		Rev.		

References

1. DNV-RP-F109 On-Bottom Stability Design of Submarine Pipelines, May 2021
2. DNVGL-ST-F101 Submarine Pipelines, December 2017
3. DNVGL-RP-C205 Environmental Conditions and Environmental Loads, August 2017
4. DVVGL-RP-F114 Pipe-Soil Interaction for Submarine Pipelines, May 2017

All references are to [1] unless otherwise noted

Assumptions

1. JONSWAP spectrum is valid for waves.
2. If pipeline installed flooded then assumed no heave occurs prior to operation (e.g. embedment remains at level from installation condition).
3. Piping of soil around pipe has not been considered.
4. Wave and current loading is applied perpendicular to pipe axis, either omni directional waves or local perpendicular waves.
5. Linear wave theory is applied and limited to non-breaking waves.
6. No account for change in wave height due to shoaling is include in MathCad this is assumed included in Excel data input.

Methodology

This calculation presents the assessment of the stability of a pipeline resting on the seabed. Required coating thicknesses are determined for Absolute and Generalised stability using DNV-RP-F109.

Input Data

Bathymetry and wave/current data is imported from excel spreadsheet. | bathydata := 109_Spurline_Input Data_Design Wave Associated Current_DNV 2021_April to Sept.x

Number of seabed nodes | $n := \text{rows}(\text{bathydata})$ | $n = 3$

KP points given in data | $x := \text{bathydata}^{\langle 0 \rangle} \cdot km$

$KP_{start} := \min(x)$ | $KP_{start} = 0 \cdot km$

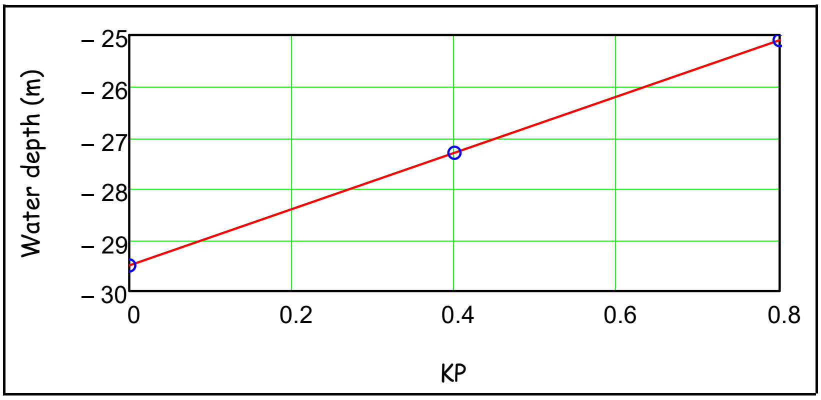
$KP_{end} := \max(x)$ | $KP_{end} = 0.8 \cdot km$

Water depth profile | $y := \text{bathydata}^{\langle 1 \rangle} \cdot m$ | $\max(y) = -25.1\,m$

Pipe heading | $\theta_{pipe} := \text{bathydata}^{\langle 2 \rangle} \cdot deg$

Analysis nodes | $J := 0 .. n - 1$

Water Depth (at each analysis node) | $depth_J := -y_J$



Node for minimum depth | $MinWD := \text{match}(-\max(y), depth)_0$ | $MinWD = 2$

"Operation" or "Installation" | Case ≡ "Installation"

"Yes" or "No" | Trench ≡ "No"

Is pipeline flooded during installation (used for calculating embedment): "Yes" or "No" | Flood_inst ≡ "No"

1, 10 or 100 year return period | Wave ≡ 10

1, 10 or 100 year return period | Current ≡ 1

Wave direction = 1 or 2 where:
1 Omni directional wave conditions are applied perpendicular to pipeline
2 Wave conditions perpendicular to pipeline applied (rounded to nearest 45deg segment) | Wave_Dir ≡ 2

Is corrosion allowance to be removed from wall thickness? "100%", "50%" or "0%" — Corr_removed ≡ "0%"

Is the a CRA cladding or lining inside pipe "Yes" or "No" — CRA ≡ "No"

Number of wave oscillations — $\tau \equiv 1000$

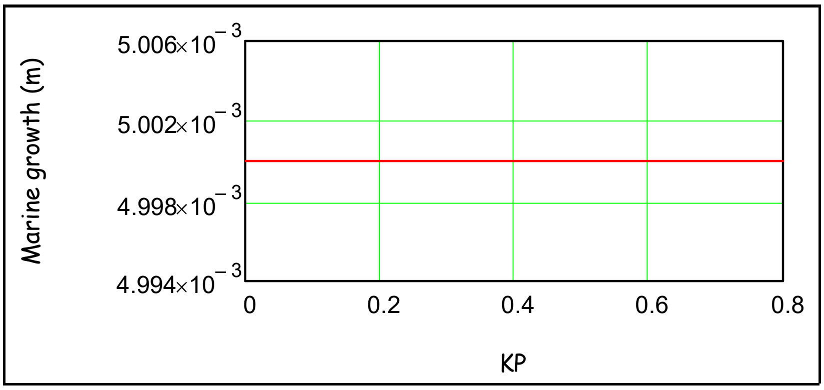
Pipe outer diameter — $D := 16 \cdot in$

CRA thickness — $t_{cra} := 0 \cdot mm$

Nominal wall thickness — $t_{nom} := 17.5 \cdot mm$

Corrosion allowance — $t_{ca} := 0 \cdot mm$

Marine growth — $t_{mar_J} := \begin{cases} 5 \cdot mm & \text{if } \; y_J > -100 \cdot m \\ 5 \cdot mm & \text{otherwise} \end{cases}$



Anti-corrosion coating thickness — $t_{cr} := 2.9mm$

Insulation coating thickness — $t_{in} := 0 \cdot mm$

Concrete thickness range factor — $jc := 0 .. 2000$

Concrete thickness — $t_{cn_{jc}} := jc \cdot mm$

If concrete coating thickness is known enter thickness in mm for cross check — $t_{conc\_input} := 243$

Product Density (operational cases) — $\rho_{prod} := 0.0 \cdot \frac{kg}{m^3}$

Pipe Density — $\rho_p := 7850 \, kg \cdot m^{-3}$

Corrosion coating — $\rho_{cr_{jc}} := \begin{cases} 930 \cdot \frac{kg}{m^3} & \text{if } \; t_{cn_{jc}} > 0 \cdot mm \\ 930 \cdot \frac{kg}{m^3} & \text{otherwise} \end{cases}$

Insulation density	$\rho_{in} := 0 \cdot \frac{kg}{m^3}$		
Concrete coating density	$\rho_{conc} := 3300 \frac{kg}{m^3}$		
Water absorption of coating	$abs := \begin{cases} 5\cdot\% & \text{if } Case = \text{"Operation"} \\ 3\cdot\% & \text{otherwise} \end{cases}$		$abs = 3\cdot\%$
Set soil types by KP region	$Soil_J :=$ "Fine sand"		

Types permitted:
"Silt and clay"
"Fine sand"
"Medium sand"
"Coarse sand"
"Gravel"
"Pebble"
"Cobble"
"Boulder"

Reference measurement height of seabed	$z_r := 1 \cdot m$		
Marine growth density	$\rho_{mar} := 1325 \cdot \frac{kg}{m^3}$		
Seawater density	$\rho_w := 1025 \cdot \frac{kg}{m^3}$		
Sand dry unit weight	$\gamma s_J := 17.3 \cdot \frac{kN}{m^3}$		
Sand submerged unit weight	$\gamma w s_J := \gamma s_J - \rho_w \cdot g$		$\gamma w s_0 = 7.248 \cdot \frac{kN}{m^3}$
Clay dry unit weight	$\gamma c s_J := 0 \cdot \frac{kN}{m^3}$		
Clay undrained shear strength	$s_{u_J} := 0 \cdot kPa$		
Safety Class	$SC \equiv$ "Low"	"Low", "Normal" or "High"	
Location	Location := "NS"	"North Sea" "Winter storms dominating: "GOM WS" or "SO WS" Cyclonic conditions dominating: "GOM Cyc" or "NW Shelf Cyc"	
Site specific spreading parameter	$sp := 8$	For North Sea range between 6 to 8 generally taken. If no site specific data available use most conservative of range 2 to 8 [Section 3.3]	
Trench Angle	$\theta_{trench_J} := 0deg$	Reduction factor valid between 5 and 45 degree trench depth [Equation 6.12 and 6.13]	
Trench Depth	$z_{t_J} := 0.0m$		

Safety factor on weight [3.2] $\gamma_w := 1.1$

Flag for input of result type:
"Absolute"
"Virtual"
"10D"

$$Result\_choice_J := \begin{cases} \text{"Absolute"} & \text{if } x_J \le 1000m \\ \text{"10D"} & \text{if } x_J \le 1000m \\ \text{"Virtual"} & \text{if } x_J \le 1000m \\ \text{"Absolute"} & \text{otherwise} \end{cases}$$

If pipe soil interaction is defined elsewhere, embedment and friction coefficients

$PSI := \text{"Calc"}$ If pipe soil interaction is predefined set to "Input" else set to "Calc"

Passive soil resistance $P\_input_{jc,J} := 0.700 \frac{kN}{m}$

Where total resistance is comprised of Coulomb friction (μW) + passive resistance.

Passive resistance for stability can be taken as lateral residual resistance less μW. This will be a function of location, soil and concrete coating.

Penetration Ratio $zD\_input_{jc,J} := 0.030$

This will be function of soil, location and concrete coating.

If JONSWOP peak enhancement factor is defined elsewhere:

Peak enhacement factor

$Peak := \text{"DNV"}$ If peak enhancement factor defined set to "Input" else "DNV"

User input peak enhancement factor, note axes (Hs, Tp) must be in ascending order.

$i := 0, 1 .. 7$ Bins for Hs

$j := 0, 1 .. 11$ Bins for Tp

$Range := 0.5$ If bins are centred on 0.5 value then enter 0.5 else enter 0

$$\gamma Input := \begin{pmatrix} 0 & 2.5 & 3.5 & 4.5 & 5.5 & 6.5 & 7.5 & 8.5 & 9.5 & 10.5 & 11.5 & 12.5 \\ 0.5 & 2.40 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 0.00 & 0.00 & 0.00 \\ 1.5 & 1.70 & 1.90 & 1.80 & 1.80 & 1.80 & 1.80 & 1.70 & 1.60 & 1.60 & 0.00 & 0.00 \\ 2.5 & 0.00 & 0.00 & 2.10 & 2.00 & 1.80 & 1.70 & 1.70 & 1.60 & 1.60 & 0.00 & 0.00 \\ 3.5 & 0.00 & 0.00 & 0.00 & 2.20 & 2.10 & 1.80 & 1.70 & 1.70 & 1.70 & 1.50 & 0.00 \\ 4.5 & 0.00 & 0.00 & 0.00 & 0.00 & 2.30 & 2.10 & 1.90 & 1.70 & 1.60 & 1.70 & 0.00 \\ 5.5 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 2.40 & 2.20 & 1.90 & 1.70 & 1.60 & 1.80 \\ 6.5 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 2.40 & 2.20 & 1.90 & 1.70 & 1.70 \end{pmatrix}$$

If Hs or Tp is not included in table then set γ to: $\gamma_{inputelse} := 2.0$

LOOKUP TABLES FOR INPUT DATA FROM EXCEL AND [1]

Group soil types down to Clay, Rock or Sand for friction coefficients

$$Soil\_group_J := \begin{cases} \text{"Sand"} & \text{if } Soil_J = \text{"Fine sand"} \lor Soil_J = \text{"Medium sand"} \lor Soil_J = \text{"Coarse sand"} \\ \text{"Rock"} & \text{if } Soil_J = \text{"Gravel"} \lor Soil_J = \text{"Pebble"} \lor Soil_J = \text{"Cobble"} \lor Soil_J = \text{"Boulder"} \\ \text{"Clay"} & \text{if } Soil_J = \text{"Silt and clay"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

Find which column of data in excel linked sheet the wave and current properties are found in.

Wave column

$$WC_J := \begin{cases} \text{if } Wave\_Dir = 1 \\ \quad \begin{cases} 67 & \text{if } Wave = 100 \\ 39 & \text{if } Wave = 10 \\ 11 & \text{if } Wave = 1 \\ \text{"Error"} & \text{otherwise} \end{cases} \\ \text{if } Wave\_Dir = 2 \\ \quad \begin{cases} \text{if } Wave = 1 \\ \quad \begin{cases} 12 & \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \lor (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 13 & \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \lor (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 14 & \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \lor (\theta_{pipe_J} \le 22.5deg) \lor (\theta_{pipe_J} > 337.5deg) \\ 15 & \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \lor (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{cases} \\ \text{if } Wave = 10 \\ \quad \begin{cases} 40 & \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \lor (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 41 & \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \lor (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 42 & \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \lor (\theta_{pipe_J} \le 22.5deg) \lor (\theta_{pipe_J} > 337.5deg) \\ 43 & \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \lor (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{cases} \\ \text{if } Wave = 100 \\ \quad \begin{cases} 68 & \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \lor (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 69 & \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \lor (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 70 & \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \lor (\theta_{pipe_J} \le 22.5deg) \lor (\theta_{pipe_J} > 337.5deg) \\ 71 & \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \lor (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{cases} \\ \text{"Error"} & \text{otherwise} \end{cases} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

$$WC_0 = 40$$

Wave period column $PC_J := WC_J + 13$ $PC_0 = 53$

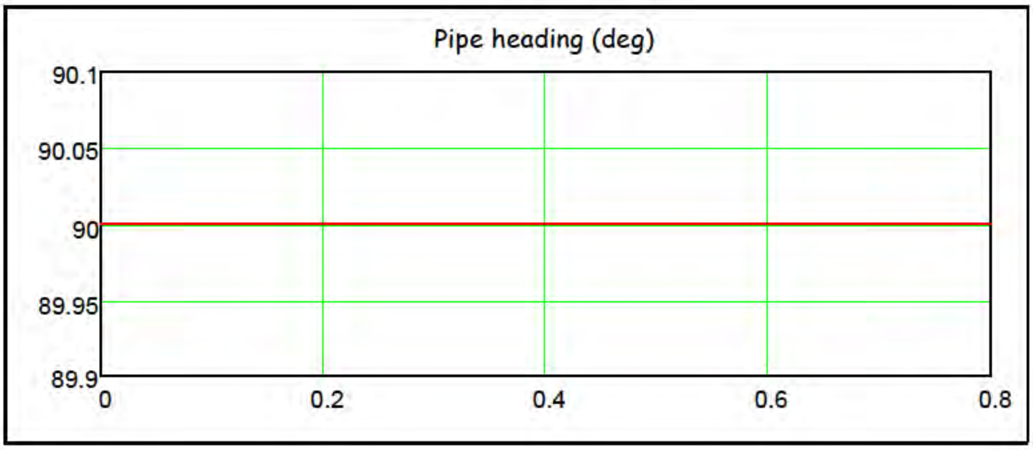
Current Column $CC := \begin{cases} 85 & \text{if } \text{Current} = 100 \\ 57 & \text{if } \text{Current} = 10 \\ 29 & \text{otherwise} \end{cases}$ $CC = 29$

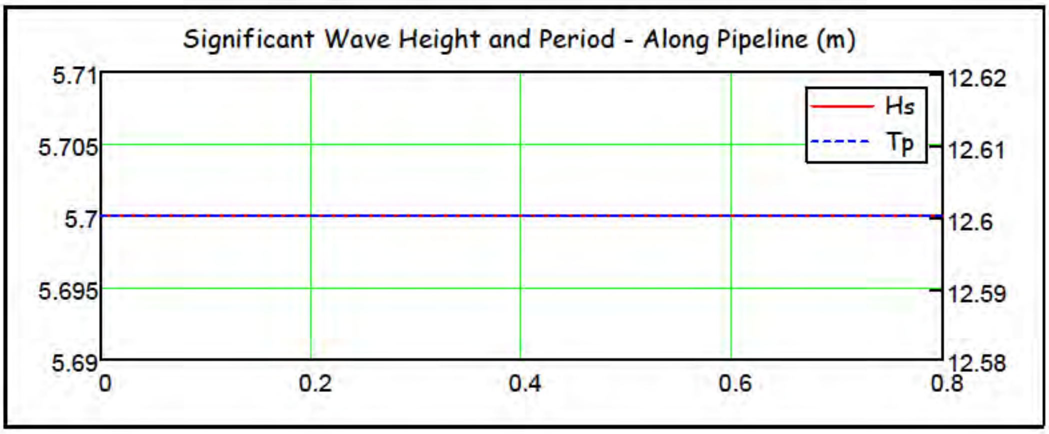
Current $V_c := \text{bathydata}^{\langle CC \rangle} \cdot \frac{m}{s}$

Wave Height $H_{s_J} := \left(\text{bathydata}^{\langle WC_J \rangle}\right)_J \cdot m$

Peak Period $T_{p_J} := \left(\text{bathydata}^{\langle PC_J \rangle}\right)_J \cdot s$

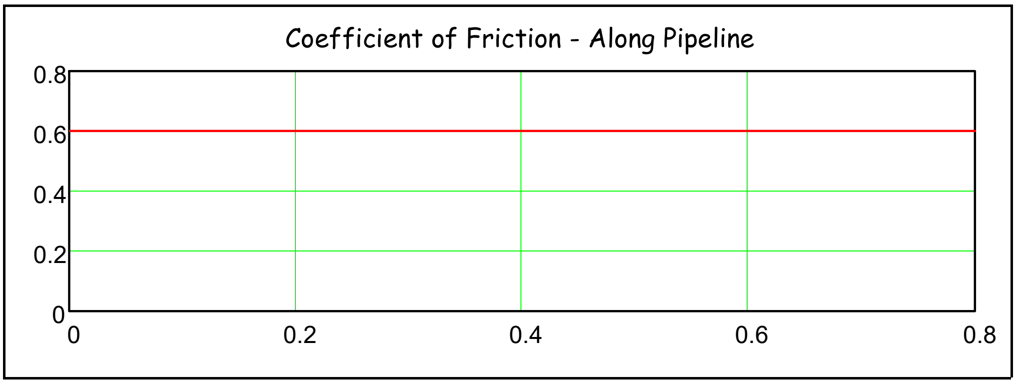
Current to Pipe Direction (assumes current is applied perpendicularly to pipe axis) $\theta_{relc_J} := 90\text{deg}$





Coefficient of friction between pipe and soil [7.6]

$$\mu_J := \begin{cases} 0.6 & \text{if } Soil\_group_J = \text{"Sand"} \\ 0.6 & \text{if } Soil\_group_J = \text{"Rock"} \\ 0.2 & \text{if } Soil\_group_J = \text{"Clay"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$



Seabed Roughness [Table 3-1]

$$z_{0_J} := \begin{cases} 5\cdot10^{-6}\cdot m & \text{if } Soil_J = \text{"Silt and clay"} \\ 1\cdot10^{-5}\cdot m & \text{if } Soil_J = \text{"Fine sand"} \\ 4\cdot10^{-5}\cdot m & \text{if } Soil_J = \text{"Medium sand"} \\ 1\cdot10^{-4}\cdot m & \text{if } Soil_J = \text{"Coarse sand"} \\ 3\cdot10^{-4}\cdot m & \text{if } Soil_J = \text{"Gravel"} \\ 2\cdot10^{-3}\cdot m & \text{if } Soil_J = \text{"Pebble"} \\ 1\cdot10^{-2}\cdot m & \text{if } Soil_J = \text{"Cobble"} \\ 4\cdot10^{-2}\cdot m & \text{if } Soil_J = \text{"Boulder"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

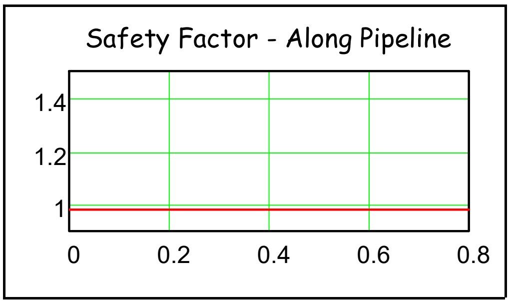
$z_{0_0} = 1 \times 10^{-5}\,m$

Grain Size [Table 3-1]

$$d_{50_J} := \begin{cases} 0.0625mm & \text{if } Soil_J = \text{"Silt and clay"} \\ 0.25mm & \text{if } Soil_J = \text{"Fine sand"} \\ 0.5mm & \text{if } Soil_J = \text{"Medium sand"} \\ 1mm & \text{if } Soil_J = \text{"Coarse sand"} \\ 4mm & \text{if } Soil_J = \text{"Gravel"} \\ 25mm & \text{if } Soil_J = \text{"Pebble"} \\ 125mm & \text{if } Soil_J = \text{"Cobble"} \\ 500mm & \text{if } Soil_J = \text{"Boulder"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

$d_{50_0} = 0.25\cdot mm$

Safety Factors
[Tables 4-1 to 4-4]



$\gamma_{sc_J} :=$

```
if  Location = "NS"
    if  SC = "Low"
        0.98  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.0  if  Soil_group_J = "Clay"
    if  SC = "Normal"
        1.32  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.4  if  Soil_group_J = "Clay"
    if  SC = "High"
        1.32  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.4  if  Soil_group_J = "Clay"
if  Location = "GOM WS" ∨ Location = "SO WS"
    if  SC = "Low"
        0.95  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        0.97  if  Soil_group_J = "Clay"
    if  SC = "Normal"
        1.41  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.5  if  Soil_group_J = "Clay"
    if  SC = "High"
        1.41  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.5  if  Soil_group_J = "Clay"
if  Location = "NW Shelf Cyc"
    0.95  if  SC = "Low"
    if  SC = "Normal"
        1.5  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.56  if  Soil_group_J = "Clay"
    if  SC = "High"
        1.5  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.56  if  Soil_group_J = "Clay"
if  Location = "GOM Cyc"
    if  SC = "Low"
        0.95  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        0.93  if  Soil_group_J = "Clay"
    1.64  if  SC = "Normal"
    if  SC = "High"
        1.64  if  Soil_group_J = "Sand" ∨ Soil_group_J = "Rock"
        1.64  if  Soil_group_J = "Clay"
```

$\gamma_{sc_0} = 0.98$

"Error" otherwise

LOOKUP TABLES FOR INPUT DATA FROM EXCEL AND [1]

Calculations

Outside diameter $OD_{jc,J} := D + 2\cdot\left(t_{cr} + t_{in} + t_{cn_{jc}}\right)$ $OD_{0,0} = 412.2\cdot mm$

Wall thickness for weight calculations $t := $ $t = 17.5\cdot mm$

if CRA = "No"

- t_{nom} if Corr_removed = "0%"
- $t_{nom} - 0.5t_{ca}$ if Corr_removed = "50%"
- $t_{nom} - t_{ca}$ if Corr_removed = "100%"
- "Error" otherwise

$t_{nom} + t_{cra}$ if CRA = "Yes"

"Error" otherwise

SUBMERGED WEIGHTS

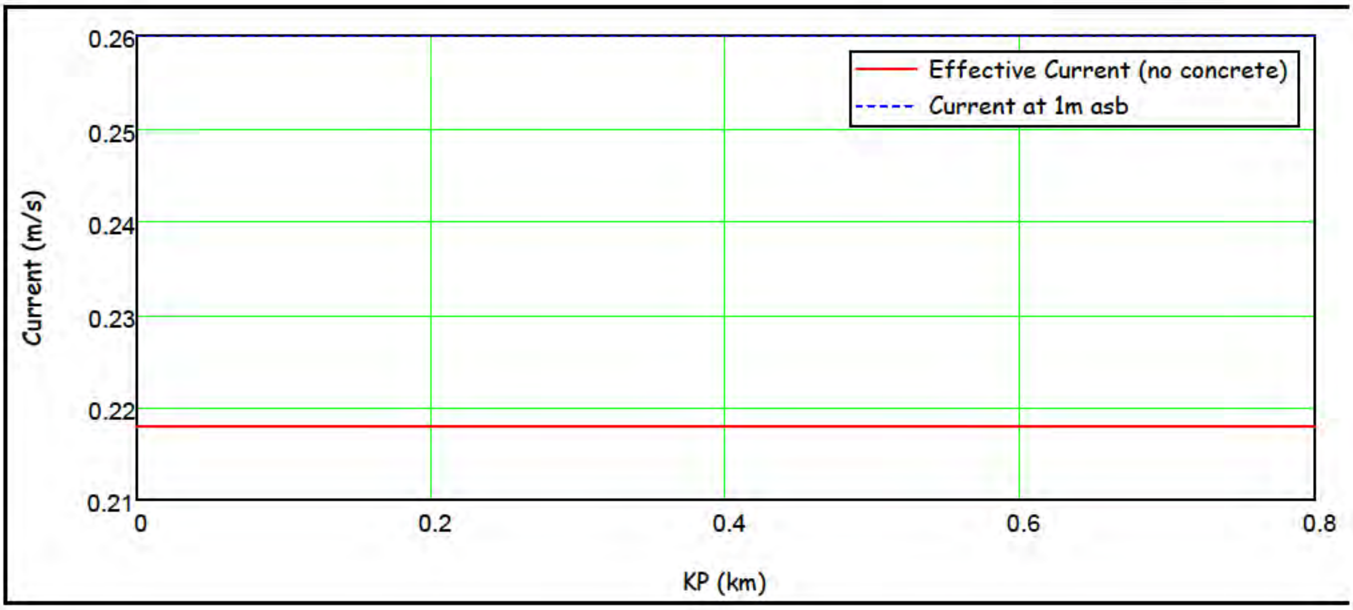
Submerged weight of pipe $W_{tot_{100,0}} = 3.977\cdot\frac{kN}{m}$ $W_{tot_{100,n-1}} = 3.977\cdot\frac{kN}{m}$

WAVE AND CURRENT VELOCITIES - SECTION 3

Effective Current Velocity

$$V_{effc_{jc,J}} := V_{c_J}\cdot\left|\sin\left(\theta_{relc_J}\right)\right|\cdot\frac{\left(1 + \frac{z_{0_J}}{OD_{jc,J} + 2\cdot t_{mar_J}}\right)\cdot\ln\left(\frac{OD_{jc,J} + 2\cdot t_{mar_J}}{z_{0_J}} + 1\right) - 1}{\ln\left(\frac{z_r}{z_{0_J}} + 1\right)}$$ [Equation 3.1]

$$V_{eff}\left(V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0\right) := V_c\cdot\left|\sin\left(\theta_{relc}\right)\right|\cdot\frac{\left(1 + \frac{z_0}{D + 2\cdot t_{cr} + 2\cdot t_{in} + 2\cdot t_{cn} + 2\cdot t_{mar}}\right)\cdot\ln\left(\frac{D + 2\cdot t_{cr} + 2\cdot t_{in} + 2\cdot t_{cn} + 2\cdot t_{mar}}{z_0} + 1\right) - 1}{\ln\left(\frac{z_r}{z_0} + 1\right)}$$



Wave

Wave frequency $\omega_{p_J} := 2\cdot\frac{\pi}{T_{p_J}}$ $\omega_{p_0} = 0.499\,s^{-1}$

$$\varphi_J := \frac{T_{p_J}\cdot s^{-1}}{\sqrt{H_{s_J}\cdot m^{-1}}}$$ [Equation 3.6] $\varphi_0 = 5.278$

Peak enhancement factor

$$\gamma In(H_s, T_p) := \gamma Input_{match\left(round(H_s+Range,0)-Range,\gamma Input^{\langle 0\rangle}\right)_0,\,match\left[round(T_p+Range,0)-Range,\left(\gamma Input^T\right)^{\langle 0\rangle}\right]_0}$$

Lookup using input table

$$\gamma_J := \begin{cases} \text{if Peak = "DNV"} & \begin{cases} 5.0 & \text{if } \varphi_J \le 3.6 \\ 1.0 & \text{if } \varphi_J \ge 5 \\ e^{5.75-1.15\cdot\varphi_J} & \text{otherwise} \end{cases} \\ \gamma_{inputelse} \text{ on error } \gamma In\left(\frac{H_{s_J}}{m}, \frac{T_{p_J}}{s}\right) & \text{otherwise} \end{cases}$$ [Equation 3.6] $\gamma_0 = 1$

Generalised Phillip's constant $\alpha_{p_J} := \frac{5}{16}\cdot\frac{\left(H_{s_J}\right)^2\cdot\left(\omega_{p_J}\right)^4}{g^2}\cdot\left(1 - 0.287\cdot\ln\left(\gamma_J\right)\right)$ [Equation 3.4] $\alpha_{p_0} = 6.528\times 10^{-3}$

Spectral width parameter

$$\sigma_{\omega}(\omega, \omega_p) := \begin{cases} 0.07 & \text{if } \omega < \omega_p \\ 0.09 & \text{otherwise} \end{cases}$$ [Equation 3.5]

JONSWAP Spectral density function

$$S_{\eta\eta}(\omega, \omega_p, \alpha_p, \gamma) := \alpha_p \cdot g^2 \cdot \omega^{-5} \cdot e^{\frac{-5}{4} \cdot \left(\frac{\omega}{\omega_p}\right)^{-4}} \cdot \gamma^{e^{-0.5 \cdot \left(\frac{\omega - \omega_p}{\sigma_{\omega}(\omega, \omega_p) \cdot \omega_p}\right)^2}}$$ [Equation 3.3]

Solve in terms of k

$$\omega k(k, depth) := \sqrt{g \cdot k \cdot \tanh(k \cdot depth)}$$ [Equation 3.9]

Transfer function

$$G(k, depth) := \frac{\omega k(k, depth)}{\sinh(k \cdot depth)}$$ [Equation 3.8]

Reference Period

$$T_{n_J} := \sqrt{\frac{depth_J}{g}}$$ [Equation 3.13]

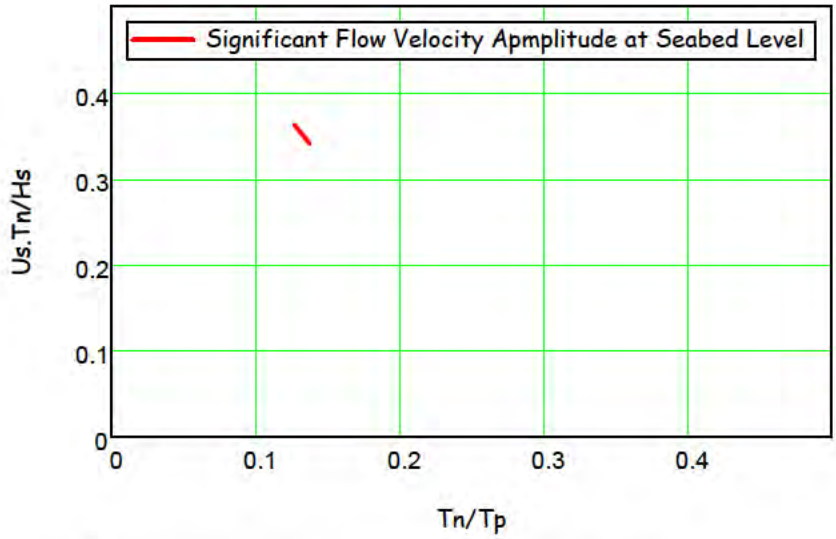
Significant Flow Velocity

$$TP_J := \begin{cases} \dfrac{T_{n_J}}{T_{p_J}} & \text{if } \dfrac{T_{n_J}}{T_{p_J}} < 0.5 \\ 0.5 & \text{otherwise} \end{cases}$$

[Figure 3-1]

$$U_{s_J} := \frac{H_{s_J}}{T_{n_J}} \cdot \left[465.359477141988 \cdot (TP_J)^6 - 723.680241354973 \cdot (TP_J)^5 + 373.8511181515026 \cdot (TP_J)^4 \ldots \atop + -56.981694780232 \cdot (TP_J)^3 - 5.463081493712 \cdot (TP_J)^2 - 0.06830042457 \cdot (TP_J) + 0.500368161167 \right]$$

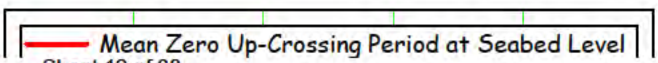
$$U_{s_J} := \begin{cases} U_{s_J} & \text{if } U_{s_J} > 0 \cdot \dfrac{m}{s} \\ 0.001 \cdot \dfrac{m}{s} & \text{otherwise} \end{cases}$$

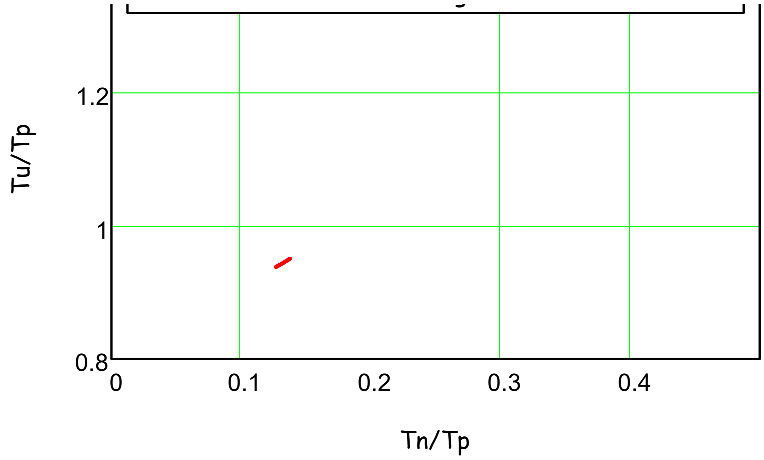


Mean Zero Up-crossing Period

[Figure 3-2]

$$T_{u_J} := T_{p_J} \cdot \left[-14.293625594 \cdot (TP_J)^4 + 15.8625305346 \cdot (TP_J)^3 \ldots \atop + \left[-5.7441116969 \cdot (TP_J)^2 + 1.9813546308 \cdot (TP_J) + 0.7498776919 \right] \right]$$





Appendix C:

$M_{s_J} := \dfrac{V_{c_J}}{U_{S_J}}$ $\quad K_{s_J} := \dfrac{U_{S_J} \cdot T_{u_J}}{D}$ $\quad A_{W_J} := \dfrac{K_{s_J} \cdot D}{2\pi}$ $\quad K_{b_J} := 2.5 \cdot d_{50_J}$ $\quad z_r = 1\,\mathrm{m}$

$$K_{a.250} := \begin{pmatrix} 15 & 70 & 200 & 320 & 320 \\ 13 & 45 & 90 & 110 & 110 \\ 9.5 & 22 & 28 & 24 & 24 \\ 8.2 & 17 & 18 & 13.3 & 13.3 \\ 6.9 & 11.7 & 11.1 & 7.7 & 7.7 \\ 5.7 & 7.8 & 5.4 & 3.2 & 3.2 \\ 4.5 & 5.3 & 3.3 & 1.8 & 1.8 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.500} := \begin{pmatrix} 16 & 75 & 240 & 440 & 440 \\ 14 & 50 & 110 & 140 & 140 \\ 10.2 & 25 & 36 & 33 & 33 \\ 9 & 19.5 & 23 & 19.2 & 19.2 \\ 7.6 & 13.8 & 14.5 & 10.2 & 10.2 \\ 5.9 & 8.6 & 7 & 4.2 & 4.2 \\ 5.1 & 6.5 & 4.2 & 2.3 & 2.3 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.1000} := \begin{pmatrix} 15 & 76 & 280 & 520 & 520 \\ 13 & 53 & 133 & 180 & 180 \\ 10 & 28 & 43 & 43 & 43 \\ 8.8 & 21 & 28 & 24 & 24 \\ 7.7 & 15.2 & 16.6 & 13 & 13 \\ 5.9 & 9.9 & 8.4 & 5.2 & 5.2 \\ 5.1 & 6.8 & 5 & 2.8 & 2.8 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.2000} := \begin{pmatrix} 16.3 & 80 & 310 & 610 & 610 \\ 14 & 57 & 150 & 210 & 210 \\ 11.2 & 32 & 52 & 54 & 54 \\ 10 & 24 & 34 & 31 & 31 \\ 8.1 & 15.3 & 16 & 11.4 & 11.4 \\ 7.2 & 11.9 & 10.7 & 7.1 & 7.1 \\ 6.2 & 8.8 & 6.7 & 3.9 & 3.9 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.5000} := \begin{pmatrix} 16.5 & 86 & 360 & 760 & 760 \\ 14.5 & 64 & 190 & 300 & 300 \\ 12 & 37 & 68 & 76 & 76 \\ 11 & 29 & 44 & 43 & 43 \\ 8.7 & 18.3 & 21 & 16 & 16 \\ 7.8 & 14.4 & 14.4 & 10 & 10 \\ 6.7 & 10.5 & 9 & 5.5 & 5.5 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.10000} := \begin{pmatrix} 16 & 87 & 390 & 950 & 950 \\ 14 & 65 & 210 & 360 & 360 \\ 11.5 & 39 & 79 & 94 & 94 \\ 10.4 & 31 & 53 & 56 & 56 \\ 8.4 & 19.5 & 24 & 20 & 20 \\ 7.6 & 15.7 & 17 & 12.6 & 12.6 \\ 6.6 & 11.4 & 10.6 & 6.9 & 6.9 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.30000} := \begin{pmatrix} 16 & 90 & 430 & 1100 & 1100 \\ 14 & 67 & 240 & 460 & 460 \\ 12.5 & 45 & 105 & 140 & 140 \\ 10.9 & 33 & 65 & 73 & 73 \\ 10 & 24 & 35 & 32 & 32 \\ 9 & 20 & 24 & 20 & 20 \\ 7.2 & 13.1 & 13.5 & 9.3 & 9.3 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$k_{a_J} := \left| \begin{array}{l} v_x \leftarrow (250 \;\; 500 \;\; 1000 \;\; 2000 \;\; 5000 \;\; 10000 \;\; 30000)^T \\ V_M \leftarrow (0.1 \;\; 0.2 \;\; 0.4 \;\; 0.5 \;\; 0.6 \;\; 0.8 \;\; 1 \;\; 1000)^T \\ V_{ZrKb} \leftarrow (10 \;\; 100 \;\; 1000 \;\; 5000 \;\; 100000)^T \\ \left(\begin{array}{l} \left| \begin{array}{l} \text{for } col \in 0..4 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.250}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.500}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.1000}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.2000}^{\langle col \rangle}, M_{s_J}\right) \end{array} \right. \end{array} \right. \end{array} \right.$$

$z_{0.a_J} := k_{a_J} \cdot z_{0_J}$

$M_{s_0} = 0.232$

$K_{s_0} = 32.956$

$A_{W_0} = 2.132 \times 10^3$

$K_{b_0} = 0.625 \cdot mm$

$\dfrac{A_{W_0}}{K_{b_0}} = 3.411 \times 10^{}$

$\dfrac{z_r}{K_{b_0}} = 1.6 \times 10^3$

$k_{a_0} = 89.675$

$z_{0_0} = 0.01 \cdot mm$

$z_{0.a_0} = 0.897 \cdot mm$

$$v_{y_J} \leftarrow$$

$$\text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right)$$

$$\begin{aligned} &\text{for } col \in 0..3 \\ &\quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.5000}{}^{\langle col \rangle}, M_{s_J}\right) \\ &\text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{aligned}$$

$$\begin{aligned} &\text{for } col \in 0..3 \\ &\quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.10000}{}^{\langle col \rangle}, M_{s_J}\right) \\ &\text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{aligned}$$

$$\begin{aligned} &\text{for } col \in 0..3 \\ &\quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.30000}{}^{\langle col \rangle}, M_{s_J}\right) \\ &\text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{aligned}$$

$$\text{return } \operatorname{linterp}\left(v_x, v_{y_J}, \frac{z_r}{K_{b_J}}\right)$$

$$V_{effc_{jc,J}} := V_{c_J} \cdot \left|\sin\left(\theta_{relc_J}\right)\right| \cdot \frac{\left(1 + \frac{z_{0.a_J}}{OD_{jc,J} + 2 \cdot t_{mar_J}}\right) \cdot \ln\left(\frac{OD_{jc,J} + 2 \cdot t_{mar_J}}{z_{0.a_J}} + 1\right) - 1}{\ln\left(\frac{z_r}{z_{0.a_J}} + 1\right)}$$ [Equation 3.1]

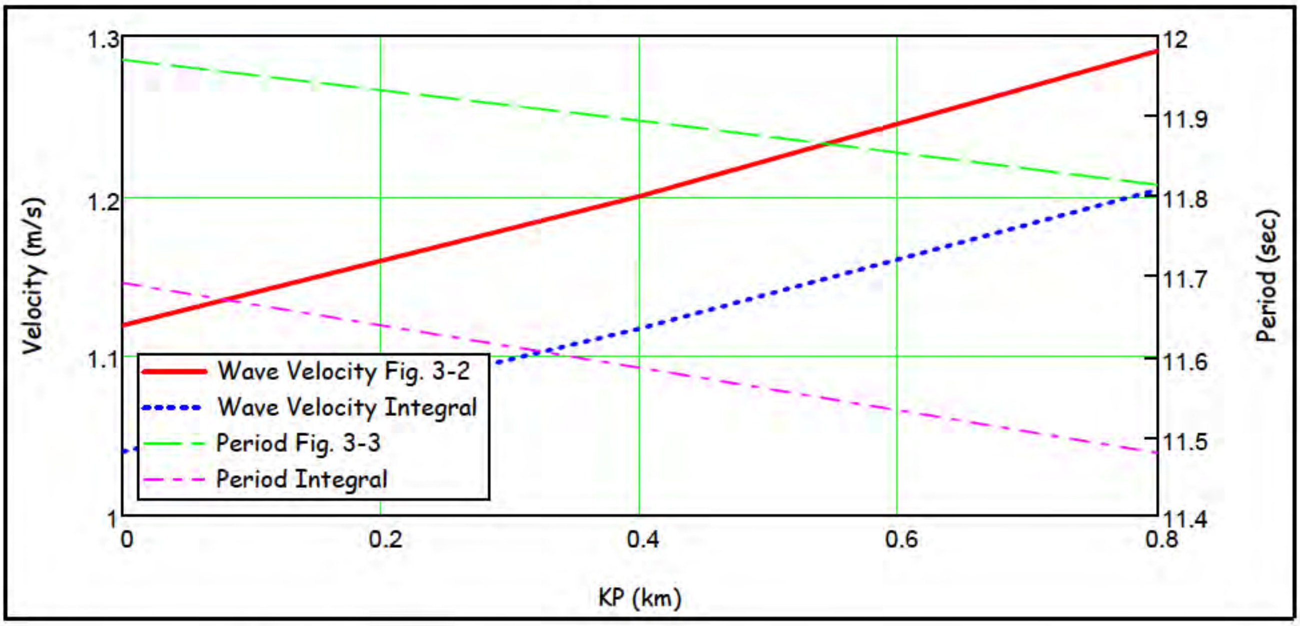
Spectral moments [Equation 3.10 and 3.7 substituting for ω]

$$M_{o_J} := \int_{\frac{0}{m}}^{\frac{0.1}{m}} G(k, depth_J)^2 \cdot S_{\eta\eta}\left(\omega k(k, depth_J), \omega_{p_J}, \alpha_{p_J}, \gamma_J\right) \cdot \frac{g\cdot\tanh(k\cdot depth_J) + g\cdot k\cdot\left(1-\tanh(k\cdot depth_J)^2\right)\cdot depth_J}{2\cdot\left(g\cdot k\cdot\tanh(k\cdot depth_J)\right)^{\frac{1}{2}}}$$

$$u_{S_J} := 2\cdot\sqrt{M_{o_J}}$$ [Equation 3.12]

$$M_{2_J} := \int_{\frac{0}{m}}^{\frac{0.1}{m}} \omega k(k, depth_J)^2 \cdot G(k, depth_J)^2 \cdot S_{\eta\eta}\left(\omega k(k, depth_J), \omega_{p_J}, \alpha_{p_J}, \gamma_J\right) \cdot \frac{g\cdot\tanh(k\cdot depth_J) + g\cdot k\cdot\left(1-\tanh(k\cdot de\right.}{2\cdot\left(g\cdot k\cdot\tanh(k\cdot depth_J)\right)^{\frac{1}{2}}}$$

$$t_{u_J} := 2\cdot\pi\cdot\sqrt{\frac{M_{o_J}}{M_{2_J}}}$$ [Equation 3.12]

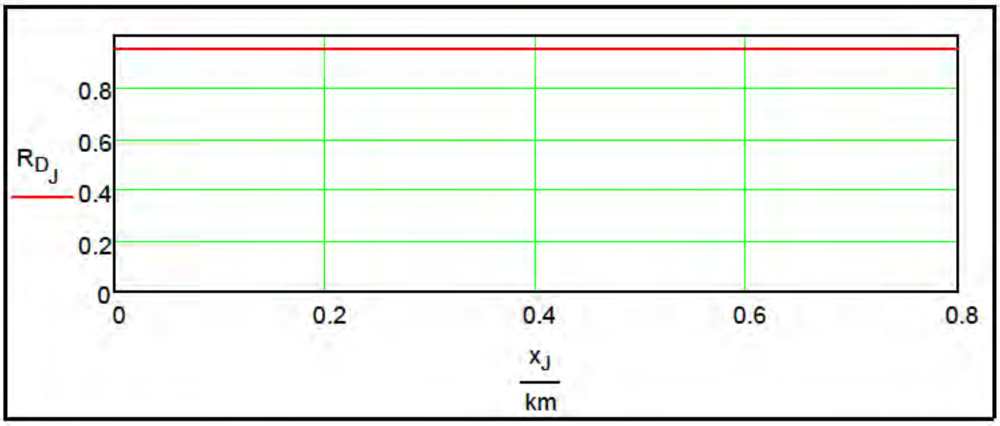


$$D_w(\theta) := \begin{cases} \frac{1}{\sqrt{\pi}}\cdot\frac{\Gamma\left(1+\frac{sp}{2}\right)}{\Gamma\left(\frac{1}{2}+\frac{sp}{2}\right)}\cdot\left(\cos(\theta)^{sp}\right)\cdot[\sin[(90deg)-\theta]]^2 & \text{if } |\theta| \le 90deg \\ 0 & \text{otherwise} \end{cases}$$ [3.3]

Reduction Factor

$$R_{D_J} := \sqrt{\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} D_w(\theta)\, d\theta}$$

$$R_{D_0} = 0.949$$



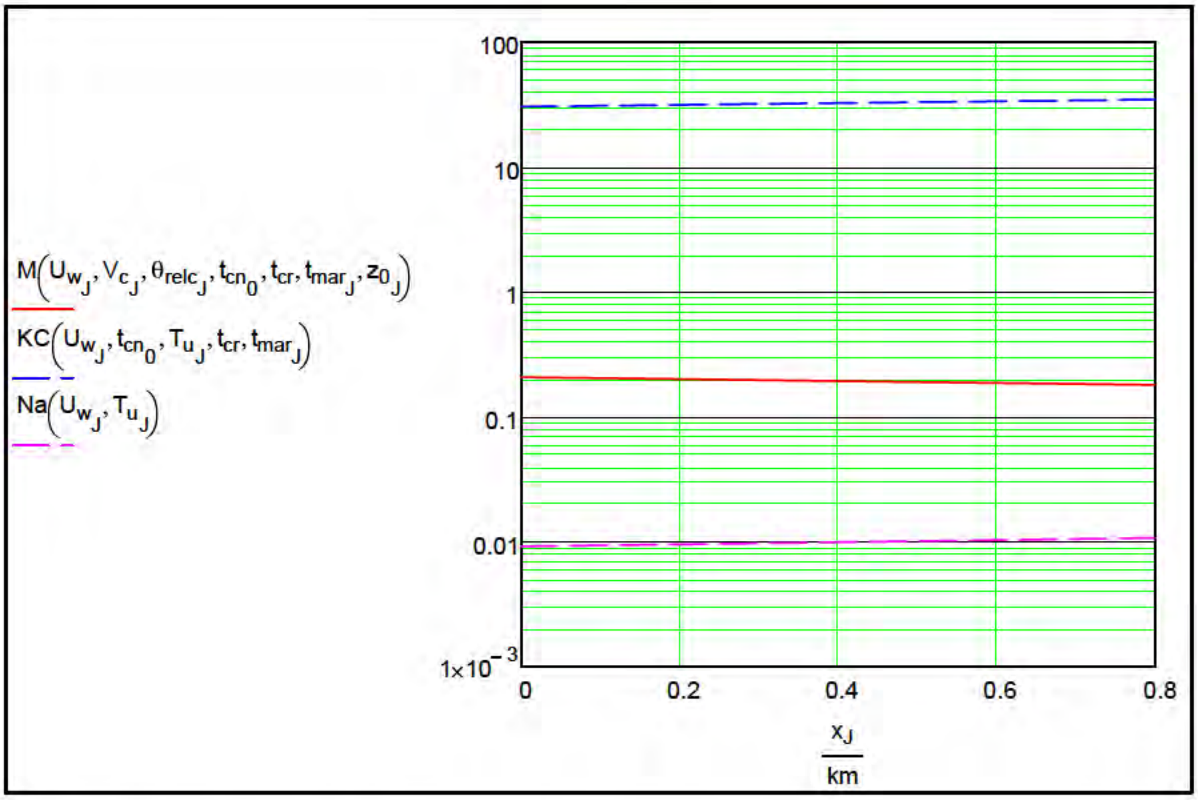
Significant water velocity (DNV) $U_{w_J} := R_{D_J} \cdot U_{S_J}$ [3.3]

$$u(U_w) := U_w$$

Current/Wave Velocity Ratio $M(U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0) := \dfrac{V_{eff}(V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0)}{U_w}$

Keulegan Carpenter Number $KC(U_w, t_{cn}, T_u, t_{cr}, t_{mar}) := \dfrac{U_w \cdot T_u}{D + 2 \cdot t_{cr} + 2 \cdot t_{in} + 2 \cdot t_{cn} + 2 \cdot t_{mar}}$

Spectral Acceleration $Na(U_w, T_u) := \dfrac{U_w}{g \cdot T_u}$



Ratio of single oscillation velocity and spectral velocity $k_U(\tau) := \frac{1}{2}\cdot\left(\sqrt{2\cdot\ln(\tau)} + \frac{0.5772}{\sqrt{2\cdot\ln(\tau)}}\right)$ [Equation 3.15] $k_U(\tau) = 1.936$

Ratio of single oscillation period and average zero up-crossing period

$$k_{t_J} := \begin{cases} 1.25 & \text{if } \gamma_J \le 1 \\ 1.2623 - 0.0015\cdot(\gamma_J)^2 - 0.0108\cdot\gamma_J & \text{if } 1 < \gamma_J \le 5 \\ 1.17 & \text{otherwise} \end{cases}$$

[Equation 3.16] $k_{t_0} = 1.25$

$$k_{T_J} := \begin{cases} k_{t_J} - 5\cdot\left(k_{t_J} - 1\right)\cdot\frac{T_{n_J}}{T_{u_J}} & \text{if } \frac{T_{n_J}}{T_{u_J}} \le 0.2 \\ 1 & \text{otherwise} \end{cases}$$

[Equation 3.16] $k_{T_0} = 1.069$

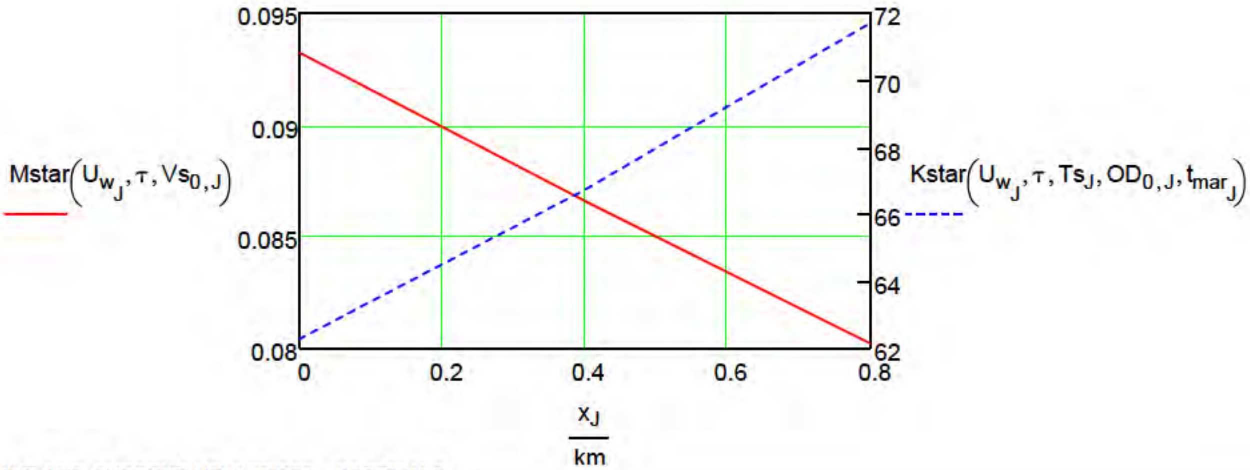
Single oscillation wave period $Ts_J := k_{T_J}\cdot T_{u_J}$ [Equation 3.16] $Ts_0 = 12.795\,s$

Single oscillation velocity $Us\_star(U_w, \tau) := k_U(\tau)\cdot U_w$ [Equation 3.15]

Single oscillation current $Vs_{jc,J} := V_{effc_{jc,J}}$

Significant Keulegan Carpenter number for single oscillation $Kstar(U_w, \tau, Ts, OD, t_{mar}) := \frac{Us\_star(U_w, \tau)\cdot Ts}{OD + 2\cdot t_{mar}}$

Single design oscillation current to wave velocity ratio $Mstar(U_w, \tau, Vs) := \frac{Vs}{Us\_star(U_w, \tau)}$



WAVE AND CURRENT VELOCITIES - SECTION 3

SOIL STRENGTHS AND SOIL RESISTANCE - SECTION 7 & REF [4]

Calculation of passive resistance: Sand

Ignoring influence of lift and including weight of water during installation if applicable Ref. [4] $\kappa_{sf_{jc,J}} := \frac{\gamma w_{s_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)^2}{W_{tot\_emb_{jc,J}}}$ Ref. [4] - A.4 $\kappa_{sf_{100,0}} = 0.706$

Initial penetration

$$zDsand_{jc,J} := \begin{cases} 0 & \text{if } \kappa_{sf_{jc,J}} < 0 \\ 0.037 \cdot \left(\kappa_{sf_{jc,J}}\right)^{-0.67} & \text{otherwise} \end{cases}$$

Ref. [4] - A.1

$zDsand_{0,0} = 0.015$

$zDsand_{100,0} = 0.047$

$zDsand_{243,1} = 0.058$

$$\kappa_{s_{jc,J}} := \frac{\gamma w_{s_J} \cdot \left(OD_{jc,J} + 2 \cdot t_{mar_J}\right)^2}{W_{tot_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{s_{100,0}} = 0.706$

Passive soil resistance, calculatec using the embedment from installa conditions but other terms with submerged weight due to conditio asessed.

$$Psand_{jc,J} := W_{tot_{jc,J}} \cdot \begin{cases} \left[5.0 \cdot \kappa_{s_{jc,J}} - 0.15 \cdot \left(\kappa_{s_{jc,J}}\right)^2\right] \cdot \left(zDsand_{jc,J}\right)^{1.25} & \text{if } \kappa_{s_{jc,J}} \le 26.7 \\ \kappa_{s_{jc,J}} \cdot \left(zDsand_{jc,J}\right)^{1.25} & \text{otherwise} \end{cases}$$

Ref. [4] - A.3 $Psand_{100,0} = 0.298 \cdot \frac{kN}{m}$

$Psand_{243,1} = 0.835 \cdot \frac{kN}{m}$

Calculation of passive resistance: Clay

Ignoring influence of lift and including weight of water during installation if applicable Ref. [4]

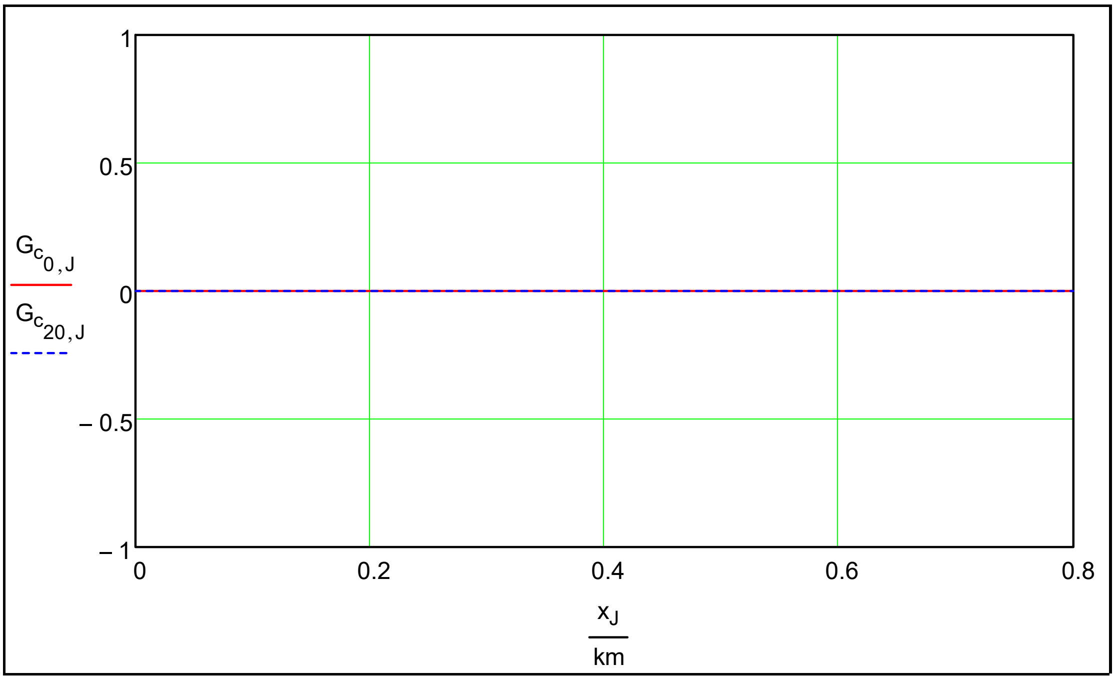
$$\kappa_{cf_{jc,J}} := \frac{s_{u_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)}{W_{tot\_emb_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{cf_{100,0}} = 0$

Clay Strength Factor

$$G_{c_{jc,J}} := \frac{s_{u_J}}{\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)\cdot\gamma c_{s_J}}$$

Ref. [4] - A.4 $G_{c_{100,0}} = 0$



Initial penetration

$$zDclay_{jc,J} := \begin{cases} 0 & \text{if } \kappa_{cf_{jc,J}} < 0 \\ 0.0071\cdot\left[\frac{\left(G_{c_{jc,J}}\right)^{0.3}}{\kappa_{cf_{jc,J}}}\right]^{3.2} + 0.062\cdot\left[\frac{\left(G_{c_{jc,J}}\right)^{0.3}}{\kappa_{cf_{jc,J}}}\right]^{0.7} & \text{otherwise} \end{cases}$$

[Ref. [4] - A.2

$zDclay_{0,0} = 0$

$zDclay_{100,0} = 0$

$$\kappa_{c_{jc,J}} := \frac{s_{u_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)}{W_{tot_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{c_{0,0}} = 0$

$\kappa_{c_{100,0}} = 0$

Passive soil resistance, calculated using the embedment from installation conditions but other terms with submerged weight due to condition asessed.

$$Pclay_{jc,J} := \frac{4.1\cdot\kappa_{c_{jc,J}}}{\left(G_{c_{jc,J}}\right)^{0.39}}\cdot\left(zDclay_{jc,J}\right)^{1.31}\cdot W_{tot_{jc,J}}$$

Ref. [4] - A.4

$Pclay_{0,0} = 0\cdot\frac{kN}{m}$

$Pclay_{100,0} = 0\cdot\frac{kN}{m}$

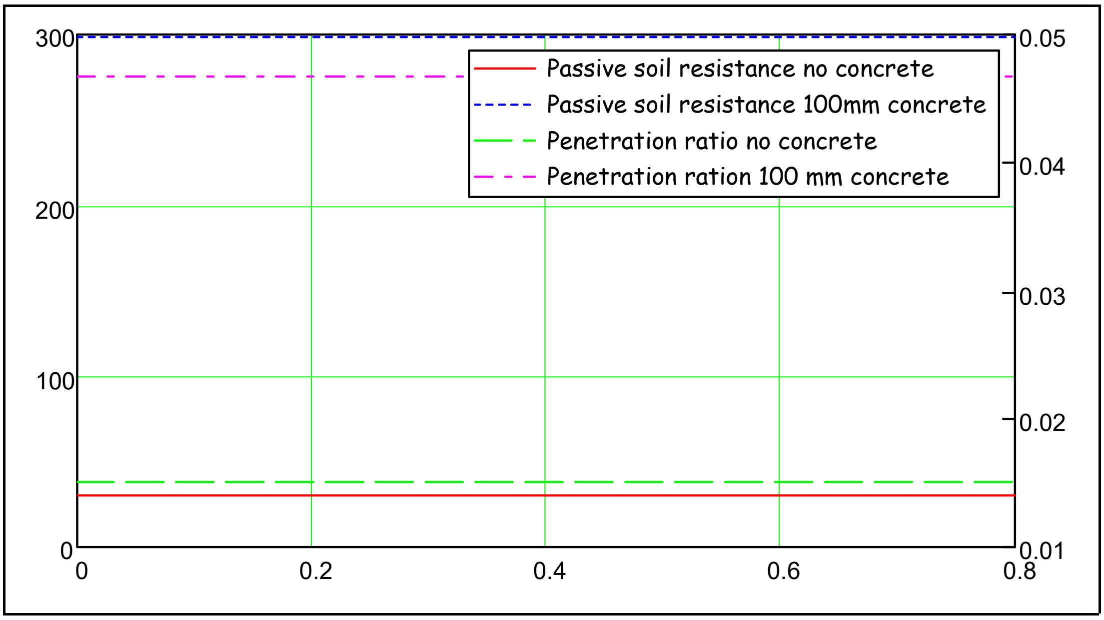
Passive soil resistance along pipeline

Passive Soil Resistance

$$P_{jc,J} := \begin{cases} \text{if } PSI = \text{"Calc"} \\ \quad \begin{cases} Psand_{jc,J} & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ Pclay_{jc,J} & \text{if } Soil\_group_J = \text{"Clay"} \end{cases} \\ P\_input_{jc,J} \quad \text{if } PSI = \text{"Input"} \\ \text{"Error"} \quad \text{otherwise} \end{cases}$$

Penetration Ratio

$$zD_{jc,J} := \begin{cases} \text{if } PSI = \text{"Calc"} \\ \quad \begin{cases} zDsand_{jc,J} & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ zDclay_{jc,J} & \text{if } Soil\_group_J = \text{"Clay"} \end{cases} \\ zD\_input_{jc,J} \quad \text{if } PSI = \text{"Input"} \\ \text{"Error"} \quad \text{otherwise} \end{cases}$$



SOIL STRENGTHS AND SOIL RESISTANCE - SECTION 7 & REF [4]

LOAD REDUCTION DUE TO SOIL PENETRATION - 6.4

Load reduction factor due to permeable seabed

$$r_{perm\_z_J} := \begin{cases} 0.7 & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ 1.0 & \text{if } Soil\_group_J = \text{"Clay"} \end{cases}$$

[6.4.1.2] $r_{perm\_z_0} = 0.7$

Load reduction factors due to penetration

Horizontal

$$r_{pen\_y_{jc,J}} := \begin{cases} 1 - 1.4 \cdot zD_{jc,J} & \text{if } zD_{jc,J} < 0.5 \\ 0.3 & \text{otherwise} \end{cases}$$

$r_{pen\_y_{100,0}} = 0.935$

[Equation 6.10]

Vertical

$$r_{pen\_z_{jc,J}} := \begin{cases} 1 & \text{if } zD_{jc,J} \le 0.1 \\ 1 - 1.3 \cdot (zD_{jc,J} - 0.1) & \text{if } 0.1 < zD_{jc,J} < \frac{1.13}{1.3} \\ 0 & \text{otherwise} \end{cases}$$

$r_{pen\_z_{100,0}} = 1$

[Equation 6.11]

Load reduction factors due to trenching

Horizontal

$$r_{tr\_y_{jc,J}} := \begin{cases} 1.0 - 0.18 \cdot \left[\frac{(\theta_{trench_J} - 5deg)}{deg}\right]^{0.25} \cdot \left(\frac{z_{t_J}}{OD_{jc,J} + 2 \cdot t_{mar_J}}\right)^{0.42} & \text{if } (5deg \le \theta_{trench_J} \le 45deg) \wedge Trench = \text{"Yes} \\ 1 & \text{otherwise} \end{cases}$$

[Equation 6.12] $r_{tr\_y_{100,0}} = 1$

Vertical

$$r_{tr\_z_{jc,J}} := \begin{cases} 1.0 - 0.14 \cdot \left[\frac{(\theta_{trench_J} - 5deg)}{deg}\right]^{0.43} \cdot \left(\frac{z_{t_J}}{OD_{jc,J} + 2 \cdot t_{mar_J}}\right)^{0.46} & \text{if } (5deg \le \theta_{trench_J} \le 45deg) \wedge Trench = \text{"Yes} \\ 1 & \text{otherwise} \end{cases}$$

[Equation 6.13] $r_{tr\_z_{100,0}} = 1$

Combined load reduction factor along pipeline

Horizontal load reduction factor $r_{tot\_y_{jc,J}} := r_{pen\_y_{jc,J}} \cdot r_{tr\_y_{jc,J}}$ [Equation 3.17] $r_{tot\_y_{100,0}} = 0.935$

Vertical load reduction factor $r_{tot\_z_{jc,J}} := r_{perm\_z_J} \cdot r_{pen\_z_{jc,J}} \cdot r_{tr\_z_{jc,J}}$ [Equation 3.17] $r_{tot\_z_{100,0}} = 0.7$

LOAD REDUCTION DUE TO SOIL PENETRATION - 6.4

Buoyancy Check

BUOYANCY CHECK

Absolute Lateral Stability

(For both Clay and Sand)

ABSOLUTE LATERAL STABILITY - 4.5

Peak horizontal load coefficients [Table 6-1]

$$Cy := \begin{pmatrix} 13 & 6.8 & 4.55 & 3.33 & 2.72 & 2.4 & 2.15 & 1.95 & 1.8 & 1.52 & 1.3 \\ 10.7 & 5.76 & 3.72 & 2.72 & 2.2 & 1.9 & 1.71 & 1.58 & 1.49 & 1.33 & 1.22 \\ 9.02 & 5 & 3.15 & 2.3 & 1.85 & 1.58 & 1.42 & 1.33 & 1.27 & 1.18 & 1.14 \\ 7.64 & 4.32 & 2.79 & 2.01 & 1.63 & 1.44 & 1.33 & 1.26 & 1.21 & 1.14 & 1.09 \\ 6.63 & 3.8 & 2.51 & 1.78 & 1.46 & 1.32 & 1.25 & 1.19 & 1.16 & 1.1 & 1.05 \\ 5.07 & 3.3 & 2.27 & 1.71 & 1.43 & 1.34 & 1.29 & 1.24 & 1.18 & 1.08 & 1 \\ 4.01 & 2.7 & 2.01 & 1.57 & 1.44 & 1.37 & 1.31 & 1.24 & 1.17 & 1.05 & 1 \\ 3.25 & 2.3 & 1.75 & 1.49 & 1.4 & 1.34 & 1.27 & 1.2 & 1.13 & 1.01 & 1 \\ 1.52 & 1.5 & 1.45 & 1.39 & 1.34 & 1.2 & 1.08 & 1.03 & 1 & 1 & 1 \\ 1.11 & 1.1 & 1.07 & 1.06 & 1.04 & 1.01 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$Ms := \begin{pmatrix} 0 \\ 0.1 \\ 0.2 \\ 0.3 \\ 0.4 \\ 0.6 \\ 0.8 \\ 1 \\ 2 \\ 5 \\ 10 \end{pmatrix} \qquad Ks := \begin{pmatrix} 2.5 \\ 5 \\ 10 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \\ 100 \\ 140 \end{pmatrix}$$

$Ms\_test := 2$

$Ks\_test := 15$

Interpolate down rows in matrices above to give a vectors for give M value

$$Cy_K(M_c) := \left[\begin{array}{l} \left| \begin{array}{ll} (Cy^{\langle 0\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 0\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 0\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 1\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 1\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 1\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 2\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 2\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 2\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 3\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 3\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 3\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 4\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 4\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 4\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 5\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 5\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 5\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 6\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 6\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 6\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 7\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 7\rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cy^{\langle 7\rangle}, M_c) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} (Cy^{\langle 8\rangle})_0 & \text{if } M_c \le 0 \\ (Cy^{\langle 8\rangle})_{10} & \text{if } M_c \ge 10 \end{array}\right. \end{array}\right.$$

$$Cy_K(Ms\_test) = \begin{pmatrix} 1.52 \\ 1.5 \\ 1.45 \\ 1.39 \\ 1.34 \\ 1.2 \\ 1.08 \\ 1.03 \\ 1 \\ 1 \\ 1 \end{pmatrix}$$

$$\left|\begin{array}{l} \left|\begin{array}{l} \text{linterp}\left(Ms, Cy^{\langle 8\rangle}, M_c\right) \quad \text{otherwise} \end{array}\right. \\ \left|\begin{array}{l} \left(Cy^{\langle 9\rangle}\right)_0 \quad \text{if} \quad M_c \le 0 \\ \left(Cy^{\langle 9\rangle}\right)_{10} \quad \text{if} \quad M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 9\rangle}, M_c\right) \quad \text{otherwise} \end{array}\right. \\ \left|\begin{array}{l} \left(Cy^{\langle 10\rangle}\right)_0 \quad \text{if} \quad M_c \le 0 \\ \left(Cy^{\langle 10\rangle}\right)_{10} \quad \text{if} \quad M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 10\rangle}, M_c\right) \quad \text{otherwise} \end{array}\right. \end{array}\right]$$

Interpolate within vectors by K.s to give value.

$$C_{y\_star}(M_s, K_s) := \left|\begin{array}{l} \text{if} \quad K_s < 2.5 \\ \quad \left|\begin{array}{l} Cy_K(M_s)_0 \cdot \dfrac{2.5}{K_s} \quad \text{if} \quad M_s < 2 \\ Cy_K(M_s)_0 \quad \text{otherwise} \end{array}\right. \\ Cy_K(M_s)_0 \quad \text{if} \quad K_s = 2.5 \\ Cy_K(M_s)_{10} \quad \text{if} \quad K_s \ge 140 \\ \text{linterp}\left(Ks, Cy_K(M_s), K_s\right) \quad \text{otherwise} \end{array}\right.$$

$C_{y\_star}(Ms\_test, Ks\_test) = 1.42$

For Ms>2 the trend in Figure 6-6 has been taken to prevent excessive Cy* returns for small waves.

Peak vertical load coefficients

[Table 6-2]

$$Cz := \begin{pmatrix} 5 & 5 & 4.85 & 3.21 & 2.55 & 2.26 & 2.01 & 1.81 & 1.63 & 1.26 & 1.05 \\ 3.87 & 4.08 & 4.23 & 2.87 & 2.15 & 1.77 & 1.55 & 1.41 & 1.31 & 1.11 & 0.97 \\ 3.16 & 3.45 & 3.74 & 2.6 & 1.86 & 1.45 & 1.26 & 1.16 & 1.09 & 1 & 0.9 \\ 3.01 & 3.25 & 3.53 & 2.14 & 1.52 & 1.26 & 1.1 & 1.01 & 0.99 & 0.95 & 0.9 \\ 2.87 & 3.08 & 3.35 & 1.82 & 1.29 & 1.11 & 0.98 & 0.9 & 0.9 & 0.9 & 0.9 \\ 2.21 & 2.36 & 2.59 & 1.59 & 1.2 & 1.03 & 0.92 & 0.9 & 0.9 & 0.9 & 0.9 \\ 1.53 & 1.61 & 1.8 & 1.18 & 1.05 & 0.97 & 0.92 & 0.9 & 0.9 & 0.9 & 0.9 \\ 1.05 & 1.13 & 1.28 & 1.12 & 0.99 & 0.91 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.96 & 1.03 & 1.05 & 1 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.91 & 0.92 & 0.93 & 0.91 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \end{pmatrix}$$

Interpolate down rows in matrices above to give a vectors for give M value

$$Cz_K(M_c) := \left[\begin{array}{l}
\left|\begin{array}{ll} \left(Cz^{\langle 0\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 0\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 0\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 1\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 1\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 1\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 2\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 2\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 2\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 3\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 3\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 3\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 4\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 4\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 4\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 5\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 5\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 5\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 6\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 6\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 6\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 7\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 7\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cz^{\langle 7\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\
\left|\begin{array}{ll} \left(Cz^{\langle 8\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cz^{\langle 8\rangle}\right)_{10} & \text{if } M_c \ge 10 \end{array}\right.
\end{array}\right]$$

$$Cz_K(Ms\_test) = \begin{pmatrix} 0.96 \\ 1.03 \\ 1.05 \\ 1 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \end{pmatrix}$$

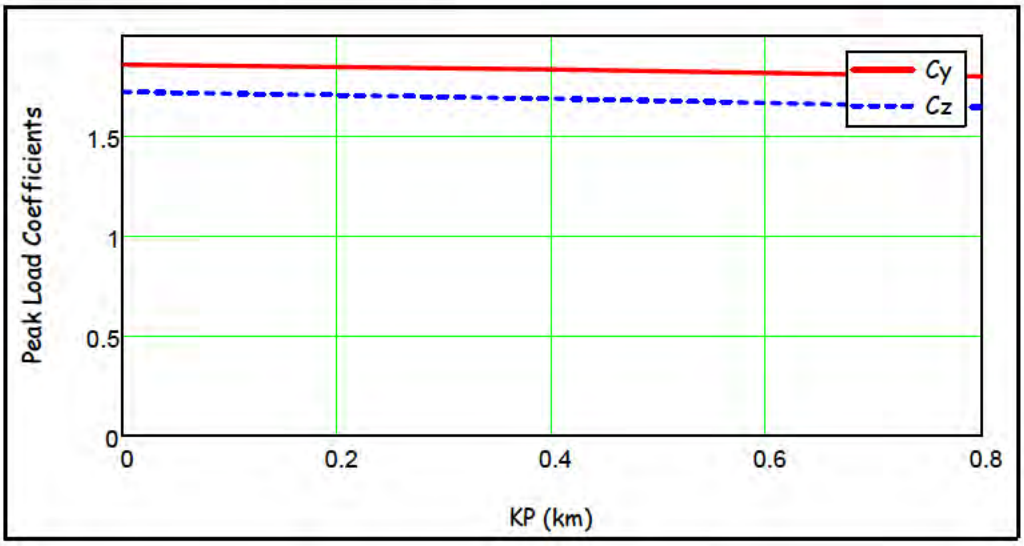
$$\left|\begin{array}{l} \mathrm{linterp}\left(Ms, Cz^{\langle 8\rangle}, M_c\right) \text{ otherwise} \\ \left(Cz^{\langle 9\rangle}\right)_0 \text{ if } M_c \le 0 \\ \left(Cz^{\langle 9\rangle}\right)_{10} \text{ if } M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cz^{\langle 9\rangle}, M_c\right) \text{ otherwise} \\ \left(Cz^{\langle 10\rangle}\right)_0 \text{ if } M_c \le 0 \\ \left(Cz^{\langle 10\rangle}\right)_{10} \text{ if } M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cz^{\langle 10\rangle}, M_c\right) \text{ otherwise} \end{array}\right.$$

Interpolate within vectors by K.s to give value.

$$C_{z\_star}(M_s, K_s) := \left|\begin{array}{l} Cz_K(M_s)_0 \text{ if } K_s \le 2.5 \\ Cz_K(M_s)_{10} \text{ if } K_s \ge 140 \\ \mathrm{linterp}\left(Ks, Cz_K(M_s), K_s\right) \text{ otherwise} \end{array}\right.$$

$$C_{z\_star}(Ms\_test, Ks\_test) = 1.025$$

Example graph for pipe with 100mm concrete coating



Peak Horizontal Load [Equation 6.16]

$$F_y(r_{tot\_y}, U_w, Vs, Ts, OD, t_{mar}) := r_{tot\_y} \cdot \frac{1}{2} \cdot \rho_w \cdot C_{y\_star}\left(Mstar(U_w, \tau, Vs), Kstar(U_w, \tau, Ts, OD, t_{mar})\right) \cdot (OD + t_{mar}) \cdot (Us\_$$

$$F_y\left(r_{tot\_y_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}\right) = 2.806 \times 10^3 \cdot \frac{N}{m}$$

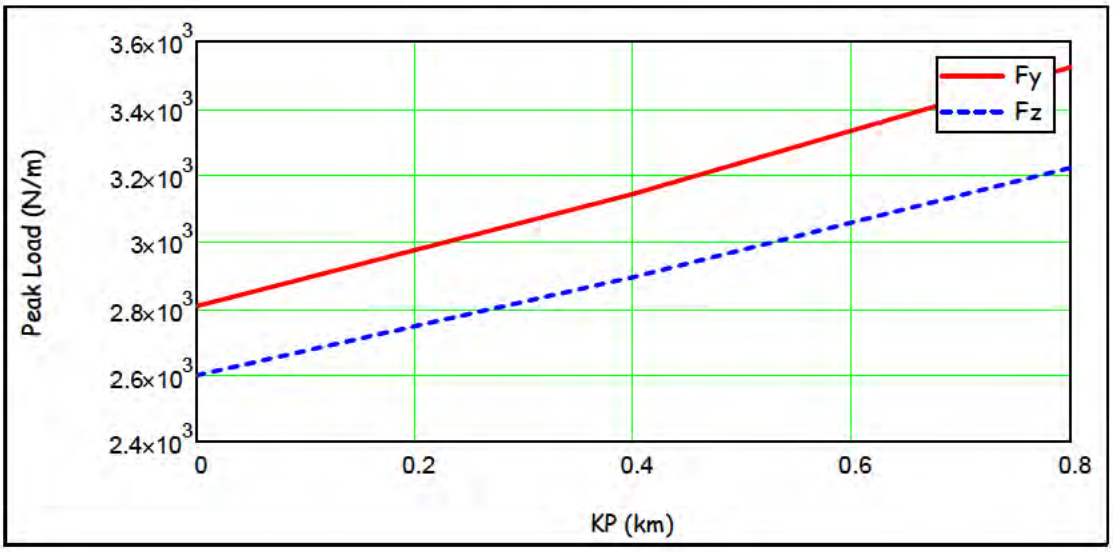
$$F_y\left(r_{tot\_y_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}\right) = 3.523 \times 10^3 \cdot \frac{N}{m}$$

Peak Vertical Load [Equation 6.17]

$$F_z(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}) := r_{tot\_z} \cdot \frac{1}{2} \cdot \rho_w \cdot C_{z\_star}(Mstar(U_w, \tau, Vs), Kstar(U_w, \tau, Ts, OD, t_{mar})) \cdot (OD + t_{mar}) \cdot (Us\_$$

$$F_z\left(r_{tot\_y_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}\right) = 2.599 \times 10^3 \cdot \frac{N}{m}$$

$$F_z\left(r_{tot\_y_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}\right) = 3.221 \times 10^3 \cdot \frac{N}{m}$$



Horizontal stability check

Unstable whilst ratio is less than 1 [Inverse of Equation 4.2]

$$RatioH(r_{tot\_y}, r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}, \gamma_{sc}, P, W_{tot}, \mu) := \frac{\mu \cdot W_{tot} + P}{(F_y(r_{tot\_y}, U_w, Vs, Ts, OD, t_{mar}) + \mu \cdot F_z(r_{tot\_z}, U_w, Vs, Ts,}$$

$$RatioH\left(r_{tot\_y_{100,0}}, r_{tot\_z_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}, \gamma_{sc_0}, P_{100,0}, W_{tot_{100,0}}, \mu_0\right) = 0.689$$

$$RatioH\left(r_{tot\_y_{100,n-1}}, r_{tot\_z_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}, \gamma_{sc_{n-1}}, P_{100,n-1}, W_{tot_{100,n-1}}, \mu_{n-1}\right.$$

Required concrete weight coating

$$f_H(J) := 2000 \text{ on error } \left| \begin{array}{l} j \leftarrow 0 \\ \text{while } RatioH\left[r_{tot\_y_{j,J}}, r_{tot\_z_{j,J}}, U_{w_J}, Vs_{j,J}, Ts_J, OD_{j,J} \cdot (1 - zD_{j,J}), t_{mar_J}, \gamma_{sc_J}, P_{j,J}, W_{tot_{j,J}} \right. \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$$t_{conabsH_J} := f_H(J) \cdot mm$$

Vertical stability check

Unstable whilst ratio is less than 1 [Inverse of Equation 4.3]

$$RatioV(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}, \gamma_{sc}, W_{tot}) := \frac{W_{tot}}{F_z(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}) \cdot \gamma_{sc}}$$

$$\mathrm{RatioV}\left(r_{tot\_z_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}, \gamma_{sc_0}, W_{tot_{100,0}}\right) = 2.085$$

$$\mathrm{RatioV}\left(r_{tot\_z_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}, \gamma_{sc_{n-1}}, W_{tot_{100,n-1}}\right) = 1.682$$

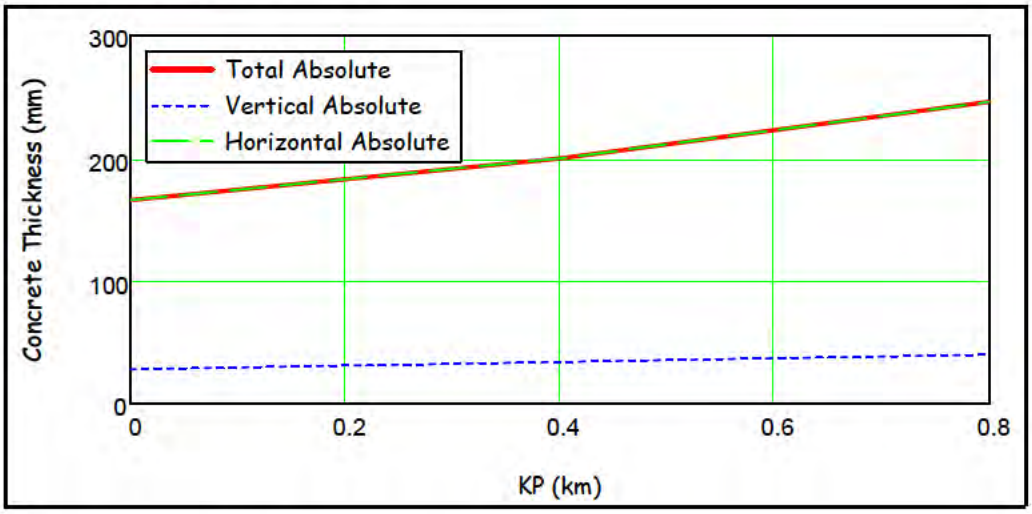
Required concrete weight coating

$$f_V(J) := 2000 \quad \text{on error} \quad \left| \begin{array}{l} j \leftarrow 0 \\ \text{while} \quad \mathrm{RatioV}\left[r_{tot\_z_{j,J}}, U_{w_J}, Vs_{j,J}, Ts_J, OD_{j,J}\cdot\left(1 - zD_{j,J}\right), t_{mar_J}, \gamma_{sc_J}, W_{tot_{j,J}}\right] \le 1 \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$$t_{conabsV_J} := f_V(J)\cdot mm$$

$$t_{conabs_J} := \max\left(t_{conabsH_J}, t_{conabsV_J}\right)$$

ABSOLUTE LATERAL STABILITY - 4.5



Generalised Lateral Stability

10D Lateral Displacement (1000 waves) for SAND

10D LATERAL DISPLACEMENT SAND - 4.6

Minimum Weight Ratio for Virtual Stability (Y < 0.5D) for SAND

VIRTUAL STABILITY SAND - 4.6

$$L_{stabTable2} := \begin{pmatrix} 1.5 & 1.42 & 1.35 & 1.25 & 1.22 & 1.22 \\ 1.82 & 1.7 & 1.61 & 1.53 & 1.5 & 1.5 \\ 2.19 & 1.97 & 1.83 & 1.69 & 1.61 & 1.61 \\ 2.65 & 2.35 & 2.18 & 1.99 & 1.85 & 1.72 \\ 3.05 & 2.55 & 2.32 & 2.13 & 2.01 & 1.9 \\ 3.05 & 2.55 & 2.4 & 2.2 & 2.06 & 1.95 \\ 2.65 & 2.45 & 2.36 & 2.24 & 2.11 & 2.09 \\ 2.5 & 2.4 & 2.35 & 2.27 & 2.22 & 2.19 \\ 2.45 & 2.4 & 2.39 & 2.37 & 2.37 & 2.37 \\ 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 \end{pmatrix}$$

For $K \geq 10$

[Table 4-5]

$$Mstab := \begin{pmatrix} 0.2 \\ 0.4 \\ 0.5 \\ 0.6 \\ 0.8 \\ 1 \\ 1.5 \\ 2 \\ 4 \\ 10 \end{pmatrix} \qquad Kstab := \begin{pmatrix} 10 \\ 15 \\ 20 \\ 30 \\ 40 \\ 60 \end{pmatrix}$$

$Ms\_test := 2$

$Ks\_test := 15$

Interpolate down rows in matrices above to give a vectors for give M value

$$L_{stabTable2K}(M_c) := \left[\begin{array}{l} \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 0\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 0\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 0\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 1\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 1\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 1\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 2\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 2\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 2\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 3\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 3\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 3\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 4\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 4\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 4\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}{}^{\langle 5\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}{}^{\langle 5\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}{}^{\langle 5\rangle}, M_c\right) & \text{otherwise} \end{array}\right. \end{array}\right]$$

$$L_{stabTable2K}(Ms\_test) = \begin{pmatrix} 2.5 \\ 2.4 \\ 2.35 \\ 2.27 \\ 2.22 \\ 2.19 \end{pmatrix}$$

Interpolate within vectors by K.s to give value.

$$L_{stabTable2\_}(M_s, K_s) := \left| \begin{array}{ll} L_{stabTable2K}(M_s)_0 & \text{if } K_s \le 10 \\ L_{stabTable2K}(M_s)_9 & \text{if } K_s \ge 60 \\ \text{linterp}\left(Kstab, L_{stabTable2K}(M_s), K_s\right) & \text{otherwise} \end{array}\right.$$

$$L_{stabTable2\_}(Ms\_test, Ks\_test) = 2.4$$

$$L_{stabTable3} := \begin{pmatrix} 1.55 & 1.45 & 1.34 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 2 & 1.65 & 1.34 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 3.3 & 2.6 & 1.91 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 3.75 & 3.07 & 2.38 & 1.7 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 4 & 3.45 & 2.9 & 2.36 & 1.81 & 1.81 & 1.81 & 1.81 & 1.81 & 1.81 \\ 3.9 & 3.5 & 3.1 & 2.71 & 2.31 & 2.31 & 2.31 & 2.31 & 2.31 & 2.31 \\ 3.25 & 3.13 & 3 & 2.88 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 \\ 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 \\ 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 \\ 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 \end{pmatrix}$$

For $K \le 5$

[Table 4-6]

$$Nstab := \begin{pmatrix} 0.003 \\ 0.006 \\ 0.012 \\ 0.024 \\ 0.048 \\ 0.04801 \\ 0.04802 \\ 0.04803 \\ 0.04804 \\ 0.04805 \end{pmatrix} \qquad Ns\_test := 0.003$$

Interpolate down rows in matrices above to give a vectors for give M value

$$L_{stabTable3N}(M_c) := \begin{bmatrix} \left| \begin{array}{ll} \left(L_{stabTable3}{}^{\langle 0\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable3}{}^{\langle 0\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}{}^{\langle 0\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable3}{}^{\langle 1\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable3}{}^{\langle 1\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}{}^{\langle 1\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable3}{}^{\langle 2\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable3}{}^{\langle 2\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}{}^{\langle 2\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable3}{}^{\langle 3\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable3}{}^{\langle 3\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}{}^{\langle 3\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable3}{}^{\langle 4\rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable3}{}^{\langle 4\rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}{}^{\langle 4\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \end{bmatrix}$$

$$L_{stabTable3N}(Ms\_test) = \begin{pmatrix} 2.75 \\ 2.75 \\ 2.75 \\ 2.75 \\ 2.75 \end{pmatrix}$$

Interpolate within vectors by N.s to give value.

$$L_{stabTable3\_}(M_s, N_s) := \left| \begin{array}{ll} L_{stabTable3N}(M_s)_0 & \text{if } N_s \le 0.003 \\ L_{stabTable3N}(M_s)_9 & \text{if } N_s \ge 0.048 \\ \text{linterp}\left(Nstab, L_{stabTable3N}(M_s), N_s\right) & \text{otherwise} \end{array} \right.$$

$$L_{stabTable3\_}(Ms\_test, Ns\_test) = 2.75$$

$$L_{stab\_}(M_{stab}, K_{stab}, N_{stab}) := \left| \begin{array}{ll} L_{stabTable2\_}(M_{stab}, K_{stab}) & \text{if } 5 \le K_{stab} \\ L_{stabTable3\_}(M_{stab}, N_{stab}) & \text{if } K_{stab} < 5 \\ \text{"Error"} & \text{otherwise} \end{array} \right.$$

$$L_{stab\_}(Ms\_test, Ks\_test, Ns\_test) = 2.4$$

Unstable whilst ratio is less than 1

Combine definition of L with output from lookup table $\dfrac{L_{stab}}{(2+M)^2} = L_{stab\_}$

$$\mathrm{Ratiostab}\left(W_{tot}, OD, U_S, U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0, T_u\right) := \frac{}{0.5\cdot\rho_w\cdot\left(OD + t_{mar}\right)\cdot\left(U_S\right)^2\cdot\left(2 + M\left(U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_r\right.\right.}$$

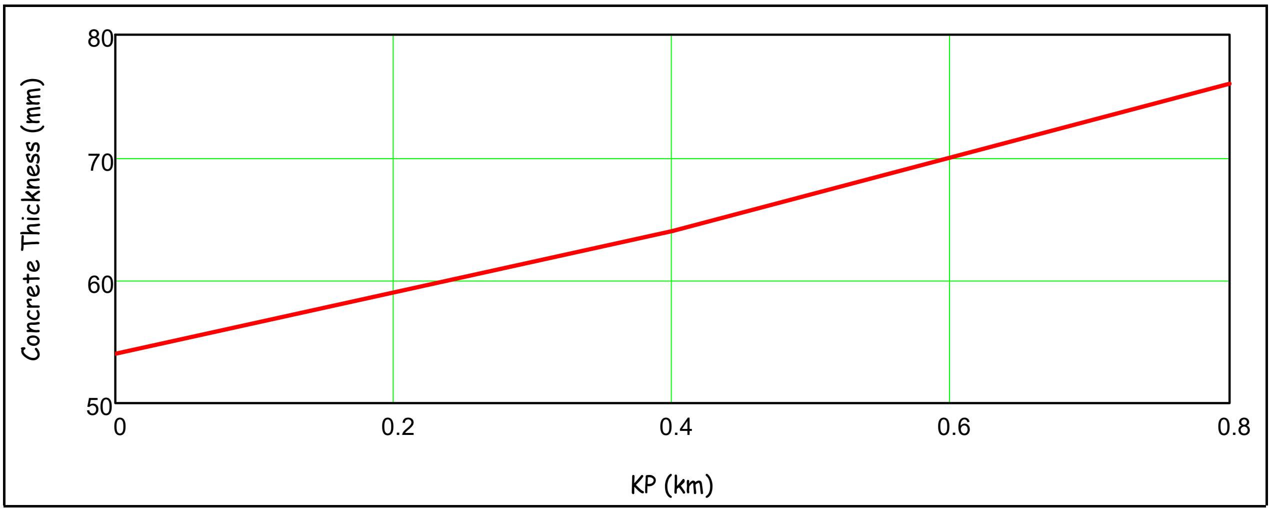
$$\mathrm{Ratiostab}\left(W_{tot_{100,0}}, OD_{100,0}, U_{S_0}, U_{w_0}, V_{c_0}, \theta_{relc_0}, t_{cn_{100}}, t_{cr}, t_{mar_0}, z_{0.a_0}, T_{u_0}\right) = 1.551$$

$$\mathrm{Ratiostab}\left(W_{tot_{100,n-1}}, OD_{100,n-1}, U_{S_{n-1}}, U_{w_{n-1}}, V_{c_{n-1}}, \theta_{relc_{n-1}}, t_{cn_{100}}, t_{cr}, t_{mar_{n-1}}, z_{0.a_{n-1}}, T_{u_{n-1}}\right) = 1.22$$

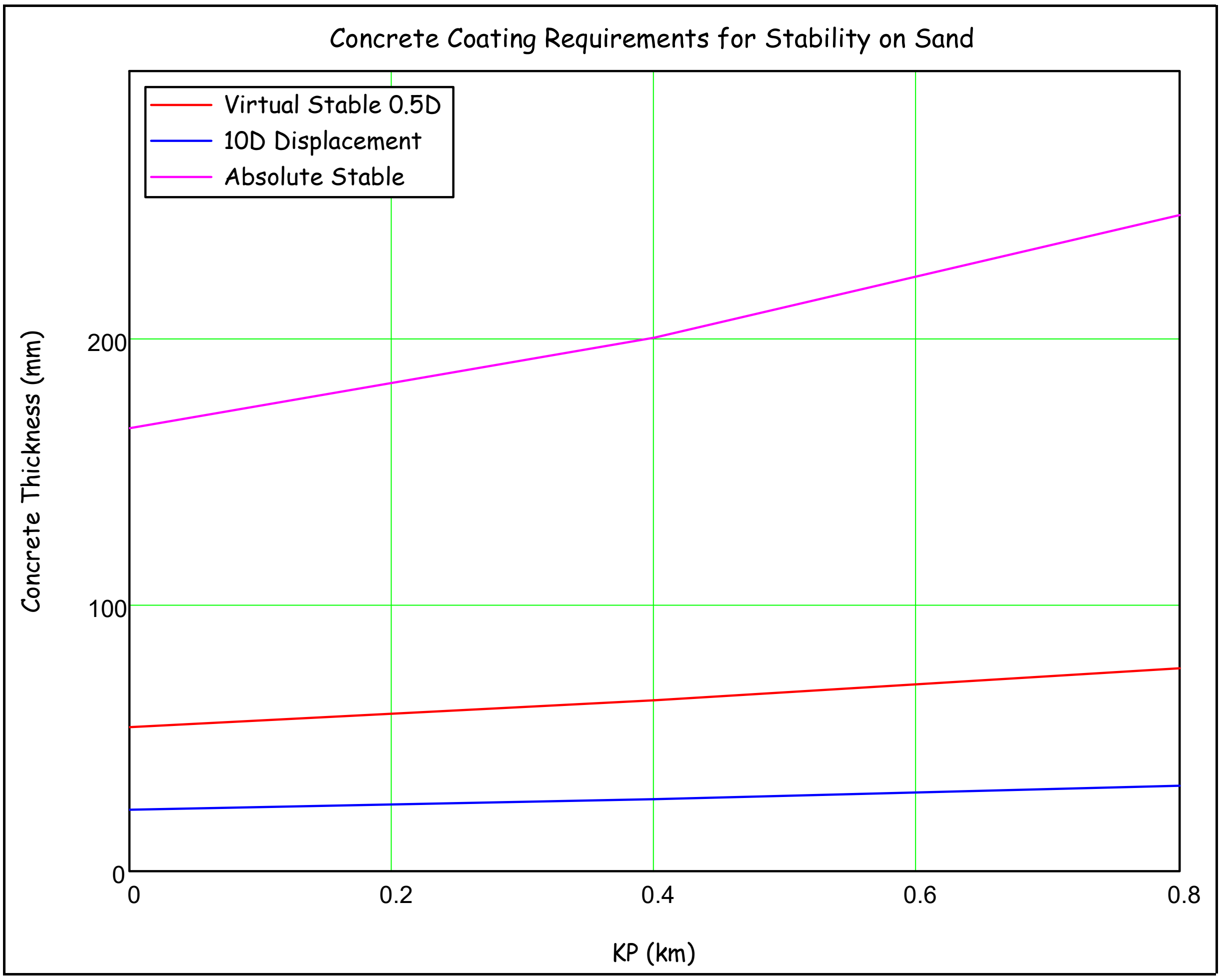
Required concrete weight coating

$$f_{stab}(J) := 2000 \quad \text{on error} \quad \begin{array}{|l} j \leftarrow 0 \\ \text{while } \mathrm{Ratiostab}\left(W_{tot_{j,J}}, OD_{j,J}, U_{S_J}, U_{w_J}, V_{c_J}, \theta_{relc_J}, t_{cn_j}, t_{cr}, t_{mar_J}, z_{0.a_J}, T_{u_J}\right) \le 1 \\ \quad j \leftarrow j + 1 \\ j \end{array}$$

$$t_{constab_J} := f_{stab}(J)\cdot mm$$



VIRTUAL STABILITY SAND - 4.6


Concrete Coating Requirements for Stability on Sand
Virtual Stable 0.5D
10D Displacement
Absolute Stable
Concrete Thickness (mm)
200
100
0
0
0.2
0.4
0.6
0.8
KP (km)

Minimum Weight Ratio for Virtual Stability (Y < 0.5D) for CLAY

VIRTUAL STABILITY CLAY - APP A

Minimum Weight Ratio for 10D Lateral Displacement for CLAY

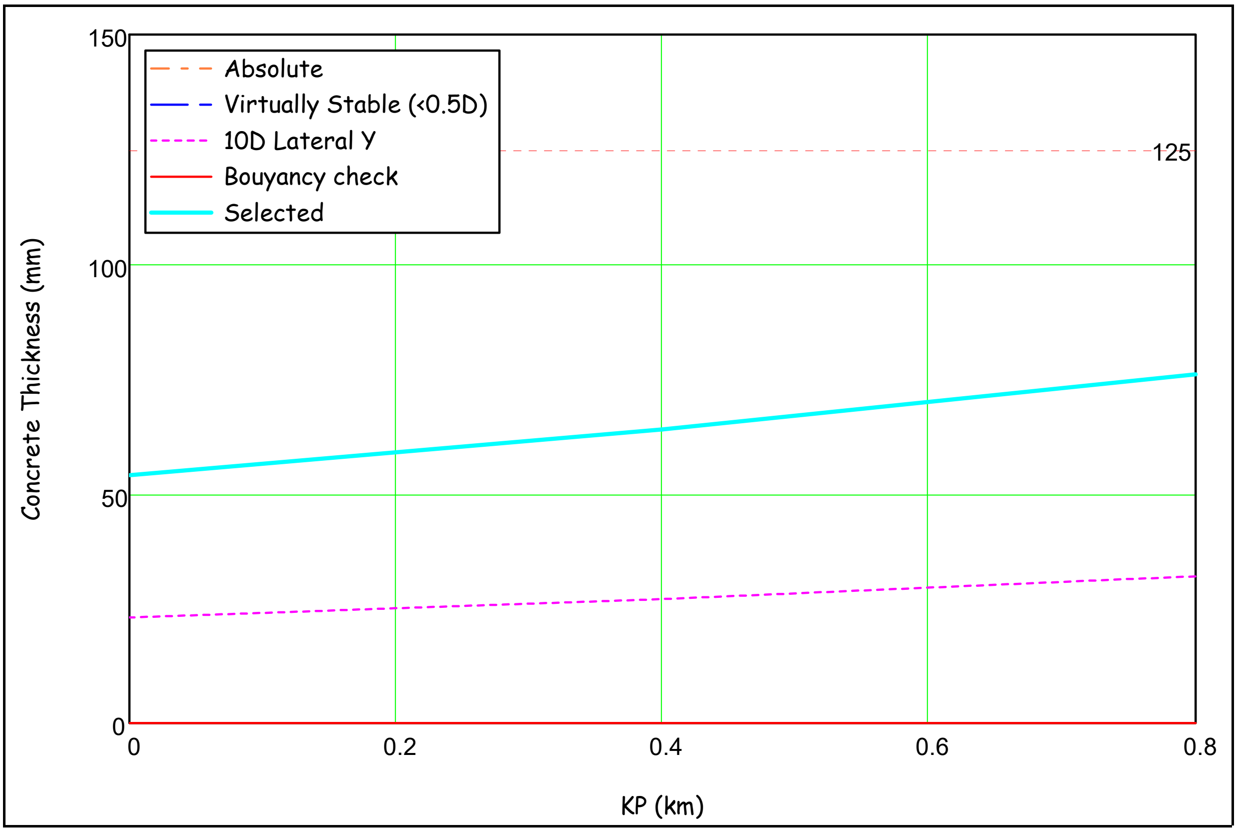
10D STABILITY CLAY - APP A

SORT BY SOIL TYPE AND VALIDITY

RESULTS

Result =

	KP (km) 0	Soil group 1	Water depth (m) 2	Bouyancy CWC thk (mm) 3	ABS CWC thk (mm) 4	0.5D CWC thk (mm) 5	0.5D Method Validity 6	10D CW thk (mm 7
0	0	"Sand"	29.5	0	166	54	"Valid"	
1	0.4	"Sand"	27.3	0	200	64	"Valid"	
2	0.8	"Sand"	25.1	0	246	76	"Valid"	
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								



Warning = "Coating density sufficient"

Maximum requried concrete coating thickness:

Not bouyant $\max(t_{conB}) = 0 \cdot mm$

Absolutely stable $\max(t_{conabs}) = 246 \cdot mm$

Virtually stable $\max(t_{cn5D}) = 76 \cdot mm$

10 Diameter displacement stability $\max(t_{cn10D}) = 32 \cdot mm$

Note maximum requriement for virtual / 10D displacement result may not be valid if falls outside table look-up regions, check above.

Selected $\max(t_{conc}) \cdot mm = 76 \cdot mm$

If Concrete coating is pre-selected and the following results are greater than 1 then pipeline is stable for selected criteria at minimum water depth location.

Only valid if wave/current data is constant along route.

Bouyancy

Not bouyant

$$\frac{1}{RatioB\left(OD_{t_{conc\_input}, MinWD}, t_{mar_{MinWD}}, W_{tot_{t_{conc\_input}, MinWD}}\right)} = 2.572$$

Absolute Stability

$$RatioH\_concinput := RatioH\left[r_{tot\_y_{t_{conc\_input}, MinWD}}, r_{tot\_z_{t_{conc\_input}, MinWD}}, U_{w_{MinWD}}, Vs_{t_{conc\_input}, MinWD}, Ts_{MinWD}, OD\right.$$

$$RatioH\_concinput = 0.995$$

$$RatioV\_concinput := RatioV\left[r_{tot\_z_{t_{conc\_input}, MinWD}}, U_{w_{MinWD}}, Vs_{t_{conc\_input}, MinWD}, Ts_{MinWD}, OD_{t_{conc\_input}, MinWD} \cdot (1 \cdot\right.$$

$$RatioV\_concinput = 2.93$$

KBR		REVISION	0 Model	1 Model	2 Model	3 Model	
		Date	10/06/2016	10/10/2016	07/06/2017	15/06/2021	
CLIENT	Shell	BY	MCB	MCB	MCB	VN	
PROJECT	Shell Aramis FEED	CHECKED	DMcN	JGF	JGF	JGF	
CALCULATION	On-Bottom Stability Assessment	CASE NO.	8 Flooded	JOB NO.			
CODE	DNV RP F109	YEAR	2021		Rev.		

References

1. DNV-RP-F109 On-Bottom Stability Design of Submarine Pipelines, May 2021
2. DNVGL-ST-F101 Submarine Pipelines, December 2017
3. DNVGL-RP-C205 Environmental Conditions and Environmental Loads, August 2017
4. DVVGL-RP-F114 Pipe-Soil Interaction for Submarine Pipelines, May 2017

All references are to [1] unless otherwise noted

Assumptions

1. JONSWAP spectrum is valid for waves.
2. If pipeline installed flooded then assumed no heave occurs prior to operation (e.g. embedment remains at level from installation condition).
3. Piping of soil around pipe has not been considered.
4. Wave and current loading is applied perpendicular to pipe axis, either omni directional waves or local perpendicular waves.
5. Linear wave theory is applied and limited to non-breaking waves.
6. No account for change in wave height due to shoaling is include in MathCad this is assumed included in Excel data input.

Methodology

This calculation presents the assessment of the stability of a pipeline resting on the seabed. Required coating thicknesses are determined for Absolute and Generalised stability using DNV-RP-F109.

Input Data

Bathymetry and wave/current data is imported from excel spreadsheet. bathydata := 109_Spurline_Input Data_Design Wave Associated Current_DNV 2021_April to Sept.x

Number of seabed nodes $n := \mathrm{rows}(bathydata)$ $n = 3$

KP points given in data $x := bathydata^{\langle 0 \rangle} \cdot km$

$KP_{start} := \min(x)$ $KP_{start} = 0 \cdot km$

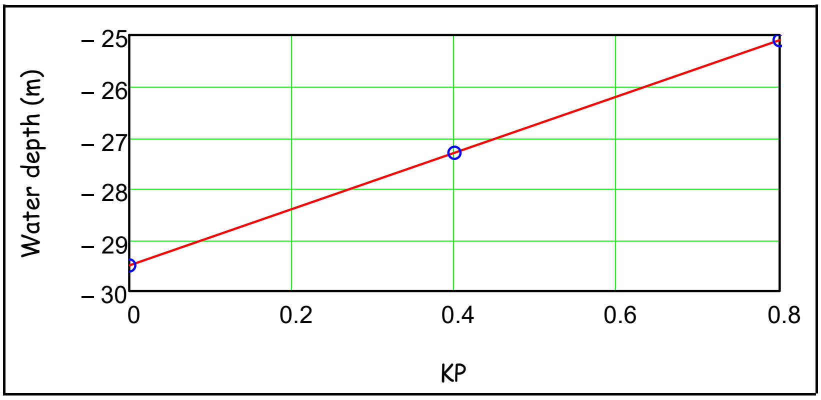
$KP_{end} := \max(x)$ $KP_{end} = 0.8 \cdot km$

Water depth profile $y := bathydata^{\langle 1 \rangle} \cdot m$ $\max(y) = -25.1\,m$

Pipe heading $\theta_{pipe} := bathydata^{\langle 2 \rangle} \cdot deg$

Analysis nodes $J := 0 .. n - 1$

Water Depth (at each analysis node) $depth_J := -y_J$



Node for minimum depth $MinWD := \mathrm{match}(-\max(y), depth)_0$ $MinWD = 2$

"Operation" or "Installation" Case ≡ "Installation"

"Yes" or "No" Trench ≡ "No"

Is pipeline flooded during installation (used for calculating embedment): "Yes" or "No" Flood_inst ≡ "Yes"

1, 10 or 100 year return period Wave ≡ 10

1, 10 or 100 year return period Current ≡ 1

Wave direction = 1 or 2 where:
1 Omni directional wave conditions are applied perpendicular to pipeline
2 Wave conditions perpendicular to pipeline applied (rounded to nearest 45deg segment)

Wave_Dir ≡ 2

Is corrosion allowance to be removed from wall thickness? "100%", "50%" or "0%" — Corr_removed ≡ "0%"

Is the a CRA cladding or lining inside pipe "Yes" or "No" — CRA ≡ "No"

Number of wave oscillations — $\tau \equiv 1000$

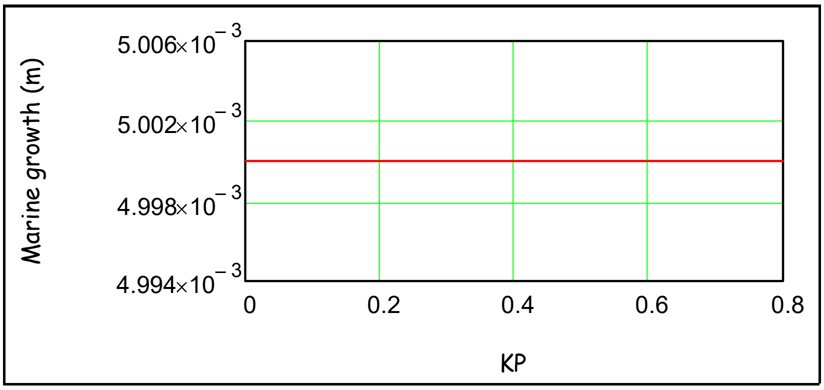
Pipe outer diameter — $D := 16 \cdot in$

CRA thickness — $t_{cra} := 0 \cdot mm$

Nominal wall thickness — $t_{nom} := 17.5 \cdot mm$

Corrosion allowance — $t_{ca} := 0 \cdot mm$

Marine growth — $t_{mar_J} := \begin{cases} 5 \cdot mm & \text{if } y_J > -100 \cdot m \\ 5 \cdot mm & \text{otherwise} \end{cases}$



Anti-corrosion coating thickness — $t_{cr} := 2.9mm$

Insulation coating thickness — $t_{in} := 0 \cdot mm$

Concrete thickness range factor — $jc := 0 .. 2000$

Concrete thickness — $t_{cn_{jc}} := jc \cdot mm$

If concrete coating thickness is known enter thickness in mm for cross check — $t_{conc\_input} := 183$

Product Density (operational cases) — $\rho_{prod} := 0.0 \cdot \frac{kg}{m^3}$

Pipe Density — $\rho_p := 7850 \, kg \cdot m^{-3}$

Corrosion coating — $\rho_{cr_{jc}} := \begin{cases} 930 \cdot \frac{kg}{m^3} & \text{if } t_{cn_{jc}} > 0 \cdot mm \\ 930 \cdot \frac{kg}{m^3} & \text{otherwise} \end{cases}$

Insulation density	$\rho_{in} := 0 \cdot \frac{kg}{m^3}$	
Concrete coating density	$\rho_{conc} := 3300 \frac{kg}{m^3}$	
Water absorption of coating	$abs := \begin{cases} 5\cdot\% & \text{if Case = "Operation"} \\ 3\cdot\% & \text{otherwise} \end{cases}$	$abs = 3\cdot\%$
Set soil types by KP region	$Soil_J :=$ "Fine sand"	

Types permitted:
"Silt and clay"
"Fine sand"
"Medium sand"
"Coarse sand"
"Gravel"
"Pebble"
"Cobble"
"Boulder"

Reference measurement height of seabed	$z_r := 1 \cdot m$	
Marine growth density	$\rho_{mar} := 1325 \cdot \frac{kg}{m^3}$	
Seawater density	$\rho_w := 1025 \cdot \frac{kg}{m^3}$	
Sand dry unit weight	$\gamma_{s_J} := 17.3 \cdot \frac{kN}{m^3}$	
Sand submerged unit weight	$\gamma w_{s_J} := \gamma_{s_J} - \rho_w \cdot g$	$\gamma w_{s_0} = 7.248 \cdot \frac{kN}{m^3}$
Clay dry unit weight	$\gamma c_{s_J} := 0 \cdot \frac{kN}{m^3}$	
Clay undrained shear strength	$s_{u_J} := 0 \cdot kPa$	
Safety Class	$SC \equiv$ "Low"	"Low", "Normal" or "High"
Location	Location := "NS"	"North Sea" "Winter storms dominating: "GOM WS" or "SO WS" Cyclonic conditions dominating: "GOM Cyc" or "NW Shelf Cyc"
Site specific spreading parameter	$sp := 8$	For North Sea range between 6 to 8 generally taken. If no site specific data available use most conservative of range 2 to 8 [Section 3.3]
Trench Angle	$\theta_{trench_J} := 0deg$	Reduction factor valid between 5 and 45 degree trench depth [Equation 6.12 and 6.13]
Trench Depth	$z_{t_J} := 0.0m$	

Safety factor on weight [3.2] $\gamma_w := 1.1$

Flag for input of result type:
"Absolute"
"Virtual"
"10D"

$$Result\_choice_J := \begin{cases} \text{"Absolute"} & \text{if } x_J \le 1000m \\ \text{"10D"} & \text{if } x_J \le 1000m \\ \text{"Virtual"} & \text{if } x_J \le 1000m \\ \text{"Absolute"} & \text{otherwise} \end{cases}$$

If pipe soil interaction is defined elsewhere, embedment and friction coefficients

$PSI := \text{"Calc"}$ If pipe soil interaction is predefined set to "Input" else set to "Calc"

Passive soil resistance $P\_input_{jc,J} := 0.700 \dfrac{kN}{m}$

Where total resistance is comprised of Coulomb friction (μW) + passive resistance.

Passive resistance for stability can be taken as lateral residual resistance less μW. This will be a function of location, soil and concrete coating.

Penetration Ratio $zD\_input_{jc,J} := 0.030$

This will be function of soil, location and concrete coating.

If JONSWOP peak enhancement factor is defined elsewhere:

Peak enhacement factor

$Peak := \text{"DNV"}$ If peak enhancement factor defined set to "Input" else "DNV"

User input peak enhancement factor, note axes (Hs, Tp) must be in ascending order.

$i := 0, 1 .. 7$ Bins for Hs

$j := 0, 1 .. 11$ Bins for Tp

$Range := 0.5$ If bins are centred on 0.5 value then enter 0.5 else enter 0

$$\gamma Input := \begin{pmatrix} 0 & 2.5 & 3.5 & 4.5 & 5.5 & 6.5 & 7.5 & 8.5 & 9.5 & 10.5 & 11.5 & 12.5 \\ 0.5 & 2.40 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 2.20 & 0.00 & 0.00 & 0.00 \\ 1.5 & 1.70 & 1.90 & 1.80 & 1.80 & 1.80 & 1.80 & 1.70 & 1.60 & 1.60 & 0.00 & 0.00 \\ 2.5 & 0.00 & 0.00 & 2.10 & 2.00 & 1.80 & 1.70 & 1.70 & 1.60 & 1.60 & 0.00 & 0.00 \\ 3.5 & 0.00 & 0.00 & 0.00 & 2.20 & 2.10 & 1.80 & 1.70 & 1.70 & 1.70 & 1.50 & 0.00 \\ 4.5 & 0.00 & 0.00 & 0.00 & 0.00 & 2.30 & 2.10 & 1.90 & 1.70 & 1.60 & 1.70 & 0.00 \\ 5.5 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 2.40 & 2.20 & 1.90 & 1.70 & 1.60 & 1.80 \\ 6.5 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 2.40 & 2.20 & 1.90 & 1.70 & 1.70 \end{pmatrix}$$

If Hs or Tp is not included in table then set γ to: $\gamma_{inputelse} := 2.0$

LOOKUP TABLES FOR INPUT DATA FROM EXCEL AND [1]

Group soil types down to Clay, Rock or Sand for friction coefficients

$$Soil\_group_J := \begin{cases} \text{"Sand"} & \text{if } Soil_J = \text{"Fine sand"} \vee Soil_J = \text{"Medium sand"} \vee Soil_J = \text{"Coarse sand"} \\ \text{"Rock"} & \text{if } Soil_J = \text{"Gravel"} \vee Soil_J = \text{"Pebble"} \vee Soil_J = \text{"Cobble"} \vee Soil_J = \text{"Boulder"} \\ \text{"Clay"} & \text{if } Soil_J = \text{"Silt and clay"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

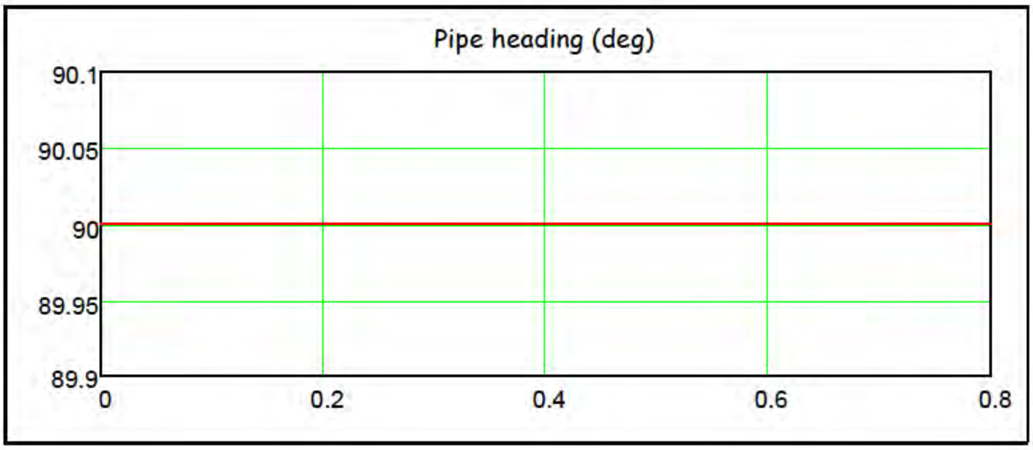
Find which column of data in excel linked sheet the wave and current properties are found in.

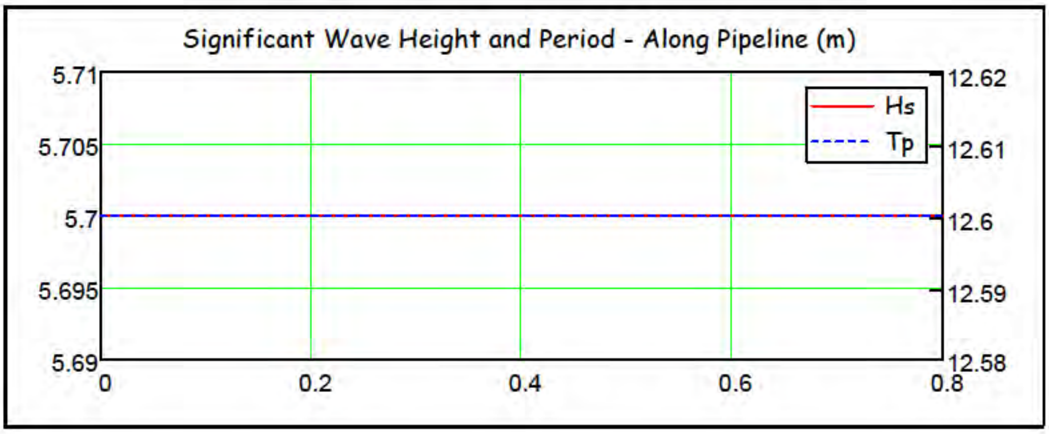
Wave column

$$WC_J := \begin{array}{|l} \text{if } Wave\_Dir = 1 \\ \quad \begin{array}{|l} 67 \ \text{if } Wave = 100 \\ 39 \ \text{if } Wave = 10 \\ 11 \ \text{if } Wave = 1 \\ \text{"Error" otherwise} \end{array} \\ \text{if } Wave\_Dir = 2 \\ \quad \begin{array}{|l} \text{if } Wave = 1 \\ \quad \begin{array}{|l} 12 \ \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \vee (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 13 \ \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \vee (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 14 \ \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \vee (\theta_{pipe_J} \le 22.5deg) \vee (\theta_{pipe_J} > 337.5deg) \\ 15 \ \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \vee (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{array} \\ \text{if } Wave = 10 \\ \quad \begin{array}{|l} 40 \ \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \vee (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 41 \ \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \vee (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 42 \ \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \vee (\theta_{pipe_J} \le 22.5deg) \vee (\theta_{pipe_J} > 337.5deg) \\ 43 \ \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \vee (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{array} \\ \text{if } Wave = 100 \\ \quad \begin{array}{|l} 68 \ \text{if } (67.5deg < \theta_{pipe_J} \le 112.5deg) \vee (247.5deg < \theta_{pipe_J} \le 292.5deg) \\ 69 \ \text{if } (112.5deg < \theta_{pipe_J} \le 157.5deg) \vee (292.5deg < \theta_{pipe_J} \le 337.5deg) \\ 70 \ \text{if } (157.5deg < \theta_{pipe_J} \le 202.5deg) \vee (\theta_{pipe_J} \le 22.5deg) \vee (\theta_{pipe_J} > 337.5deg) \\ 71 \ \text{if } (202.5deg < \theta_{pipe_J} \le 247.5deg) \vee (22.5deg < \theta_{pipe_J} \le 67.5deg) \end{array} \\ \text{"Error" otherwise} \end{array} \\ \text{"Error" otherwise} \end{array}$$

$WC_0 = 40$

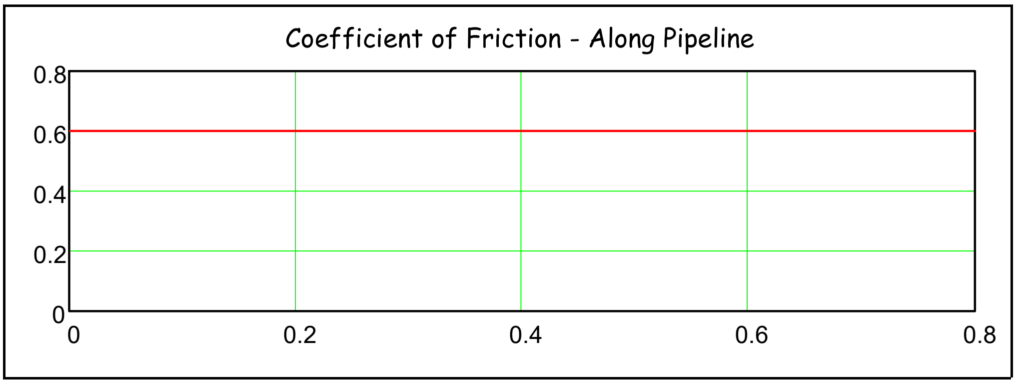
Wave period column	$PC_J := WC_J + 13$	$PC_0 = 53$
Current Column	$CC := \begin{cases} 85 & \text{if } \text{Current} = 100 \\ 57 & \text{if } \text{Current} = 10 \\ 29 & \text{otherwise} \end{cases}$	$CC = 29$
Current	$V_c := \text{bathydata}^{\langle CC \rangle} \cdot \frac{m}{s}$	
Wave Height	$H_{s_J} := \left(\text{bathydata}^{\langle WC_J \rangle}\right)_J \cdot m$	
Peak Period	$T_{p_J} := \left(\text{bathydata}^{\langle PC_J \rangle}\right)_J \cdot s$	
Current to Pipe Direction (assumes current is applied perpendicularly to pipe axis)	$\theta_{relc_J} := 90deg$	





Coefficient of friction between pipe and soil [7.6]

$$\mu_J := \begin{cases} 0.6 & \text{if } \ Soil\_group_J = \text{"Sand"} \\ 0.6 & \text{if } \ Soil\_group_J = \text{"Rock"} \\ 0.2 & \text{if } \ Soil\_group_J = \text{"Clay"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$



Seabed Roughness
[Table 3-1]

$$z_{0_J} := \begin{cases} 5\cdot 10^{-6}\cdot m & \text{if } \ Soil_J = \text{"Silt and clay"} \\ 1\cdot 10^{-5}\cdot m & \text{if } \ Soil_J = \text{"Fine sand"} \\ 4\cdot 10^{-5}\cdot m & \text{if } \ Soil_J = \text{"Medium sand"} \\ 1\cdot 10^{-4}\cdot m & \text{if } \ Soil_J = \text{"Coarse sand"} \\ 3\cdot 10^{-4}\cdot m & \text{if } \ Soil_J = \text{"Gravel"} \\ 2\cdot 10^{-3}\cdot m & \text{if } \ Soil_J = \text{"Pebble"} \\ 1\cdot 10^{-2}\cdot m & \text{if } \ Soil_J = \text{"Cobble"} \\ 4\cdot 10^{-2}\cdot m & \text{if } \ Soil_J = \text{"Boulder"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

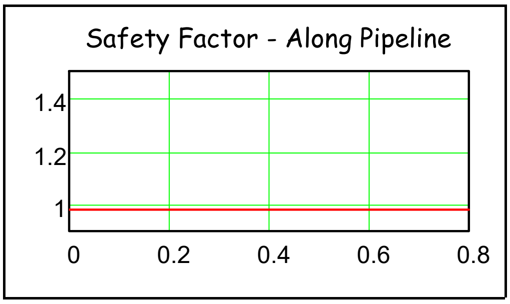
$$z_{0_0} = 1 \times 10^{-5}\, m$$

Grain Size
[Table 3-1]

$$d_{50_J} := \begin{cases} 0.0625mm & \text{if } \ Soil_J = \text{"Silt and clay"} \\ 0.25mm & \text{if } \ Soil_J = \text{"Fine sand"} \\ 0.5mm & \text{if } \ Soil_J = \text{"Medium sand"} \\ 1mm & \text{if } \ Soil_J = \text{"Coarse sand"} \\ 4mm & \text{if } \ Soil_J = \text{"Gravel"} \\ 25mm & \text{if } \ Soil_J = \text{"Pebble"} \\ 125mm & \text{if } \ Soil_J = \text{"Cobble"} \\ 500mm & \text{if } \ Soil_J = \text{"Boulder"} \\ \text{"Error"} & \text{otherwise} \end{cases}$$

$$d_{50_0} = 0.25\cdot mm$$

Safety Factors
[Tables 4-1 to 4-4]



$\gamma_{sc_J} :=$

if Location = "NS"

if SC = "Low"

0.98 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.0 if $Soil\_group_J$ = "Clay"

if SC = "Normal"

1.32 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.4 if $Soil\_group_J$ = "Clay"

if SC = "High"

1.32 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.4 if $Soil\_group_J$ = "Clay"

if Location = "GOM WS" $\vee$ Location = "SO WS"

if SC = "Low"

0.95 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

0.97 if $Soil\_group_J$ = "Clay"

if SC = "Normal"

1.41 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.5 if $Soil\_group_J$ = "Clay"

if SC = "High"

1.41 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.5 if $Soil\_group_J$ = "Clay"

if Location = "NW Shelf Cyc"

0.95 if SC = "Low"

if SC = "Normal"

1.5 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.56 if $Soil\_group_J$ = "Clay"

if SC = "High"

1.5 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.56 if $Soil\_group_J$ = "Clay"

if Location = "GOM Cyc"

if SC = "Low"

0.95 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

0.93 if $Soil\_group_J$ = "Clay"

1.64 if SC = "Normal"

if SC = "High"

1.64 if $Soil\_group_J$ = "Sand" $\vee$ $Soil\_group_J$ = "Rock"

1.64 if $Soil\_group_J$ = "Clay"

$\gamma_{sc_0} = 0.98$

"Error" otherwise

LOOKUP TABLES FOR INPUT DATA FROM EXCEL AND [1]

Calculations

Outside diameter $OD_{jc,J} := D + 2\cdot\left(t_{cr} + t_{in} + t_{cn_{jc}}\right)$ $OD_{0,0} = 412.2\cdot mm$

Wall thickness for weight calculations

$$t := \begin{cases} \text{if } CRA = \text{"No"} \\ \quad \begin{cases} t_{nom} & \text{if } Corr\_removed = \text{"0\%"} \\ t_{nom} - 0.5t_{ca} & \text{if } Corr\_removed = \text{"50\%"} \\ t_{nom} - t_{ca} & \text{if } Corr\_removed = \text{"100\%"} \\ \text{"Error"} & \text{otherwise} \end{cases} \\ t_{nom} + t_{cra} \quad \text{if } CRA = \text{"Yes"} \\ \text{"Error"} \quad \text{otherwise} \end{cases}$$

$t = 17.5\cdot mm$

SUBMERGED WEIGHTS

Submerged weight of pipe $W_{tot_{100,0}} = 5.066\cdot\frac{kN}{m}$ $W_{tot_{100,n-1}} = 5.066\cdot\frac{kN}{m}$

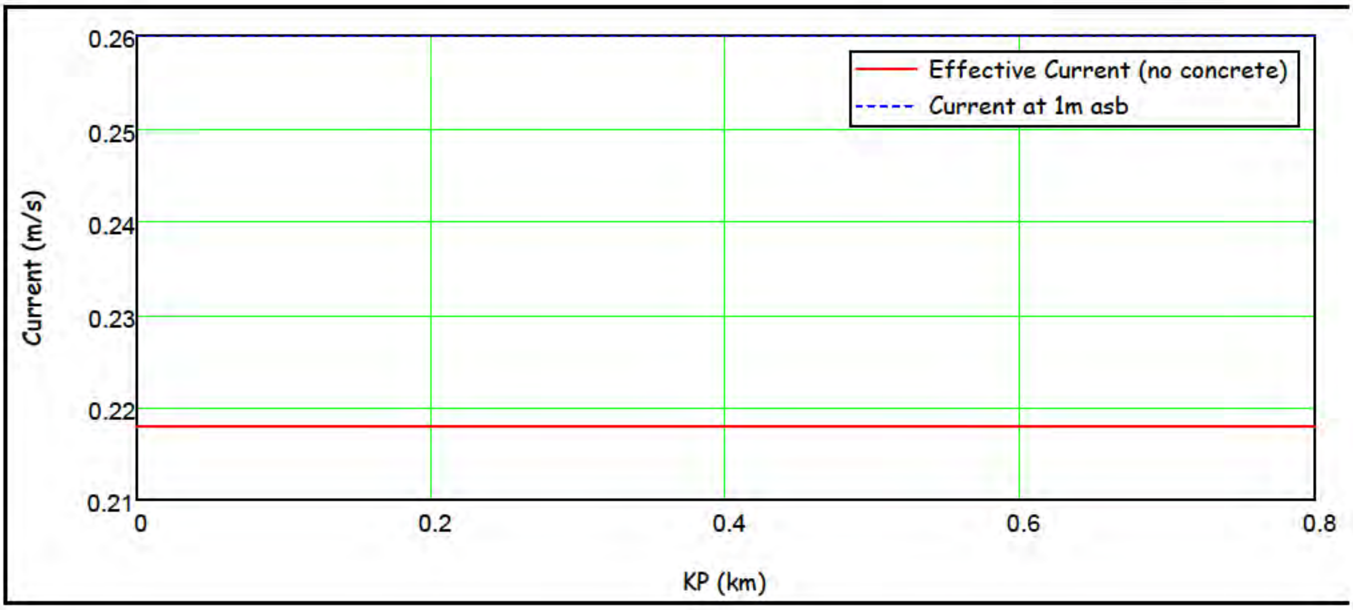
WAVE AND CURRENT VELOCITIES - SECTION 3

Effective Current Velocity

$$V_{effc_{jc,J}} := V_{c_J}\cdot\left|\sin\left(\theta_{relc_J}\right)\right|\cdot\frac{\left(1 + \frac{z_{0_J}}{OD_{jc,J} + 2\cdot t_{mar_J}}\right)\cdot\ln\left(\frac{OD_{jc,J} + 2\cdot t_{mar_J}}{z_{0_J}} + 1\right) - 1}{\ln\left(\frac{z_r}{z_{0_J}} + 1\right)}$$

[Equation 3.1]

$$V_{eff}\left(V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0\right) := V_c\cdot\left|\sin\left(\theta_{relc}\right)\right|\cdot\frac{\left(1 + \frac{z_0}{D + 2\cdot t_{cr} + 2\cdot t_{in} \ldots + 2\cdot t_{cn} + 2\cdot t_{mar}}\right)\cdot\ln\left(\frac{D + 2\cdot t_{cr} + 2\cdot t_{in} \ldots + 2\cdot t_{cn} + 2\cdot t_{mar}}{z_0} + 1\right) - 1}{\ln\left(\frac{z_r}{z_0} + 1\right)}$$



Wave

Wave frequency $\omega_{p_J} := 2 \cdot \frac{\pi}{T_{p_J}}$ $\qquad \omega_{p_0} = 0.499\,s^{-1}$

$$\varphi_J := \frac{T_{p_J} \cdot s^{-1}}{\sqrt{H_{s_J} \cdot m^{-1}}}$$ [Equation 3.6] $\qquad \varphi_0 = 5.278$

Peak enhancement factor

$$\gamma\mathrm{ln}(H_s, T_p) := \gamma\mathrm{Input}_{\mathrm{match}\left(\mathrm{round}(H_s+\mathrm{Range},0)-\mathrm{Range},\,\gamma\mathrm{Input}^{\langle 0\rangle}\right)_0,\ \mathrm{match}\left[\mathrm{round}(T_p+\mathrm{Range},0)-\mathrm{Range},\,\left(\gamma\mathrm{Input}^T\right)^{\langle 0\rangle}\right]_0}$$

Lookup using input table

$$\gamma_J := \begin{array}{|l} \text{if Peak} = \text{"DNV"} \\ \quad \begin{array}{|l} 5.0 \ \text{ if } \ \varphi_J \le 3.6 \\ 1.0 \ \text{ if } \ \varphi_J \ge 5 \\ e^{5.75-1.15\cdot\varphi_J} \ \text{ otherwise} \end{array} \\ \gamma_{\mathrm{inputelse}} \ \text{ on error } \ \gamma\mathrm{ln}\left(\frac{H_{s_J}}{m}, \frac{T_{p_J}}{s}\right) \ \text{ otherwise} \end{array}$$ [Equation 3.6] $\qquad \gamma_0 = 1$

Generalised Phillip's constant $\alpha_{p_J} := \frac{5}{16} \cdot \frac{\left(H_{s_J}\right)^2 \cdot \left(\omega_{p_J}\right)^4}{g^2} \cdot \left(1 - 0.287 \cdot \ln(\gamma_J)\right)$ [Equation 3.4] $\qquad \alpha_{p_0} = 6.528 \times 10^{-3}$

Spectral width parameter

$$\sigma_\omega(\omega, \omega_p) := \begin{cases} 0.07 & \text{if } \omega < \omega_p \\ 0.09 & \text{otherwise} \end{cases}$$

[Equation 3.5]

JONSWAP Spectral density function

$$S_{\eta\eta}(\omega, \omega_p, \alpha_p, \gamma) := \alpha_p \cdot g^2 \cdot \omega^{-5} \cdot e^{\frac{-5}{4} \cdot \left(\frac{\omega}{\omega_p}\right)^{-4}} \cdot \gamma^{e^{-0.5 \cdot \left(\frac{\omega - \omega_p}{\sigma_\omega(\omega, \omega_p) \cdot \omega_p}\right)^2}}$$

[Equation 3.3]

Solve in terms of k

$$\omega k(k, depth) := \sqrt{g \cdot k \cdot \tanh(k \cdot depth)}$$

[Equation 3.9]

Transfer function

$$G(k, depth) := \frac{\omega k(k, depth)}{\sinh(k \cdot depth)}$$

[Equation 3.8]

Reference Period

$$T_{n_J} := \sqrt{\frac{depth_J}{g}}$$

[Equation 3.13]

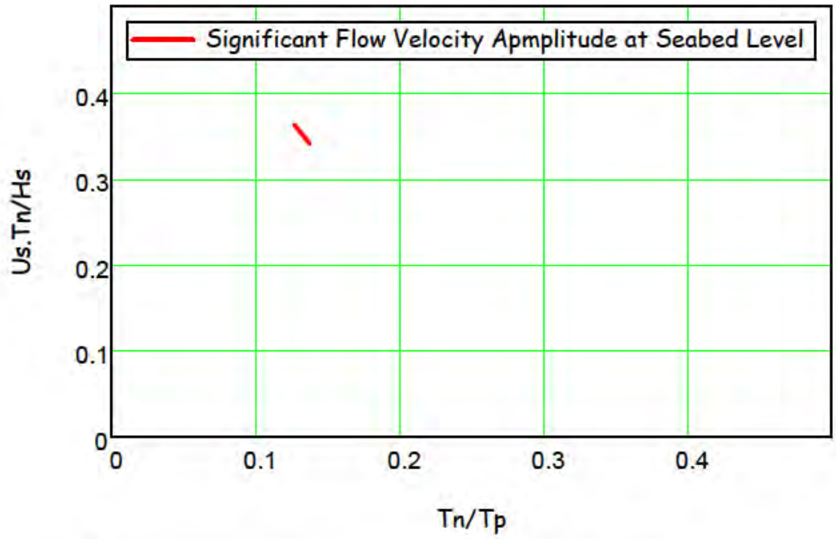
Significant Flow Velocity

$$TP_J := \begin{cases} \frac{T_{n_J}}{T_{p_J}} & \text{if } \frac{T_{n_J}}{T_{p_J}} < 0.5 \\ 0.5 & \text{otherwise} \end{cases}$$

[Figure 3-1]

$$U_{S_J} := \frac{H_{S_J}}{T_{n_J}} \cdot \left[465.359477141988 \cdot (TP_J)^6 - 723.680241354973 \cdot (TP_J)^5 + 373.8511181515026 \cdot (TP_J)^4 \ldots + -56.981694780232 \cdot (TP_J)^3 - 5.463081493712 \cdot (TP_J)^2 - 0.06830042457 \cdot (TP_J) + 0.500368161167\right]$$

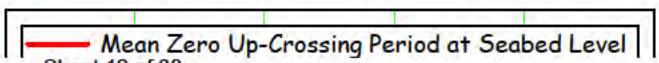
$$U_{S_J} := \begin{cases} U_{S_J} & \text{if } U_{S_J} > 0 \cdot \frac{m}{s} \\ 0.001 \cdot \frac{m}{s} & \text{otherwise} \end{cases}$$

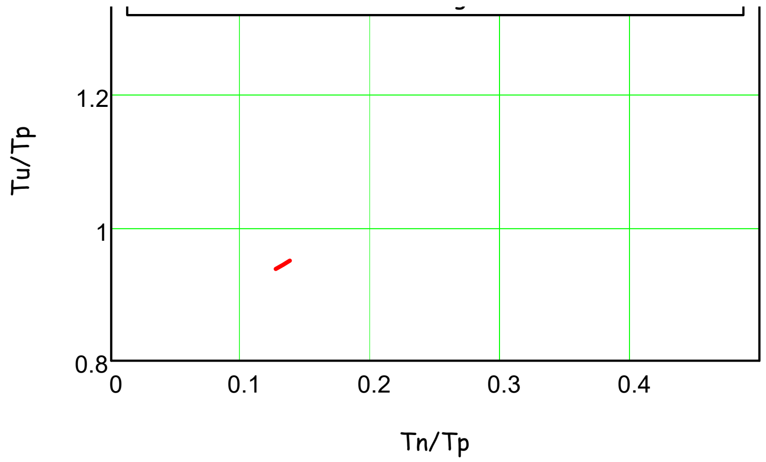


Mean Zero Up-crossing Period

[Figure 3-2]

$$T_{u_J} := T_{p_J} \cdot \left[-14.293625594 \cdot (TP_J)^4 + 15.8625305346 \cdot (TP_J)^3 \ldots + \left[-5.7441116969 \cdot (TP_J)^2 + 1.9813546308 \cdot (TP_J) + 0.7498776919\right]\right]$$





Appendix C:

$$M_{s_J} := \frac{V_{c_J}}{U_{S_J}} \qquad K_{s_J} := \frac{U_{S_J} \cdot T_{u_J}}{D} \qquad A_{W_J} := \frac{K_{s_J} \cdot D}{2\pi} \qquad K_{b_J} := 2.5 \cdot d_{50_J} \qquad z_r = 1\,\mathrm{m}$$

$$K_{a.250} := \begin{pmatrix} 15 & 70 & 200 & 320 & 320 \\ 13 & 45 & 90 & 110 & 110 \\ 9.5 & 22 & 28 & 24 & 24 \\ 8.2 & 17 & 18 & 13.3 & 13.3 \\ 6.9 & 11.7 & 11.1 & 7.7 & 7.7 \\ 5.7 & 7.8 & 5.4 & 3.2 & 3.2 \\ 4.5 & 5.3 & 3.3 & 1.8 & 1.8 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.500} := \begin{pmatrix} 16 & 75 & 240 & 440 & 440 \\ 14 & 50 & 110 & 140 & 140 \\ 10.2 & 25 & 36 & 33 & 33 \\ 9 & 19.5 & 23 & 19.2 & 19.2 \\ 7.6 & 13.8 & 14.5 & 10.2 & 10.2 \\ 5.9 & 8.6 & 7 & 4.2 & 4.2 \\ 5.1 & 6.5 & 4.2 & 2.3 & 2.3 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.1000} := \begin{pmatrix} 15 & 76 & 280 & 520 & 520 \\ 13 & 53 & 133 & 180 & 180 \\ 10 & 28 & 43 & 43 & 43 \\ 8.8 & 21 & 28 & 24 & 24 \\ 7.7 & 15.2 & 16.6 & 13 & 13 \\ 5.9 & 9.9 & 8.4 & 5.2 & 5.2 \\ 5.1 & 6.8 & 5 & 2.8 & 2.8 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.2000} := \begin{pmatrix} 16.3 & 80 & 310 & 610 & 610 \\ 14 & 57 & 150 & 210 & 210 \\ 11.2 & 32 & 52 & 54 & 54 \\ 10 & 24 & 34 & 31 & 31 \\ 8.1 & 15.3 & 16 & 11.4 & 11.4 \\ 7.2 & 11.9 & 10.7 & 7.1 & 7.1 \\ 6.2 & 8.8 & 6.7 & 3.9 & 3.9 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.5000} := \begin{pmatrix} 16.5 & 86 & 360 & 760 & 760 \\ 14.5 & 64 & 190 & 300 & 300 \\ 12 & 37 & 68 & 76 & 76 \\ 11 & 29 & 44 & 43 & 43 \\ 8.7 & 18.3 & 21 & 16 & 16 \\ 7.8 & 14.4 & 14.4 & 10 & 10 \\ 6.7 & 10.5 & 9 & 5.5 & 5.5 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix} \qquad K_{a.10000} := \begin{pmatrix} 16 & 87 & 390 & 950 & 950 \\ 14 & 65 & 210 & 360 & 360 \\ 11.5 & 39 & 79 & 94 & 94 \\ 10.4 & 31 & 53 & 56 & 56 \\ 8.4 & 19.5 & 24 & 20 & 20 \\ 7.6 & 15.7 & 17 & 12.6 & 12.6 \\ 6.6 & 11.4 & 10.6 & 6.9 & 6.9 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$K_{a.30000} := \begin{pmatrix} 16 & 90 & 430 & 1100 & 1100 \\ 14 & 67 & 240 & 460 & 460 \\ 12.5 & 45 & 105 & 140 & 140 \\ 10.9 & 33 & 65 & 73 & 73 \\ 10 & 24 & 35 & 32 & 32 \\ 9 & 20 & 24 & 20 & 20 \\ 7.2 & 13.1 & 13.5 & 9.3 & 9.3 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$k_{a_J} := \left| \begin{array}{l} v_x \leftarrow (250 \;\; 500 \;\; 1000 \;\; 2000 \;\; 5000 \;\; 10000 \;\; 30000)^T \\ V_M \leftarrow (0.1 \;\; 0.2 \;\; 0.4 \;\; 0.5 \;\; 0.6 \;\; 0.8 \;\; 1 \;\; 1000)^T \\ V_{ZrKb} \leftarrow (10 \;\; 100 \;\; 1000 \;\; 5000 \;\; 100000)^T \\ \left(\begin{array}{l} \left| \begin{array}{l} \text{for } col \in 0..4 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.250}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.500}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.1000}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return linterp}\left(V_{ZrKb}, M, \dfrac{A_{W_J}}{K_{b_J}}\right) \end{array} \right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \text{linterp}\left(V_M, K_{a.2000}^{\langle col \rangle}, M_{s_J}\right) \end{array} \right. \end{array} \right. \end{array} \right.$$

$z_{0.a_J} := k_{a_J} \cdot z_{0_J}$

$M_{s_0} = 0.232$

$K_{s_0} = 32.956$

$A_{W_0} = 2.132 \times 10^3$

$K_{b_0} = 0.625 \cdot mm$

$\dfrac{A_{W_0}}{K_{b_0}} = 3.411 \times 10^{3}$

$\dfrac{z_r}{K_{b_0}} = 1.6 \times 10^3$

$k_{a_0} = 89.675$

$z_{0_0} = 0.01 \cdot mm$

$z_{0.a_0} = 0.897 \cdot mm$

$$v_{y_J} \leftarrow \left| \begin{array}{l} \quad \text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.5000}{}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{array}\right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.10000}{}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{array}\right. \\ \left| \begin{array}{l} \text{for } col \in 0..3 \\ \quad M_{col} \leftarrow \operatorname{linterp}\left(V_M, K_{a.30000}{}^{\langle col \rangle}, M_{s_J}\right) \\ \text{return } \operatorname{linterp}\left(V_{ZrKb}, M, \frac{A_{W_J}}{K_{b_J}}\right) \end{array}\right. \end{array} \right)$$

$$\text{return } \operatorname{linterp}\left(v_x, v_{y_J}, \frac{z_r}{K_{b_J}}\right)$$

$$V_{effc_{jc,J}} := V_{c_J} \cdot \left|\sin\left(\theta_{relc_J}\right)\right| \cdot \frac{\left(1 + \frac{z_{0.a_J}}{OD_{jc,J} + 2 \cdot t_{mar_J}}\right) \cdot \ln\left(\frac{OD_{jc,J} + 2 \cdot t_{mar_J}}{z_{0.a_J}} + 1\right) - 1}{\ln\left(\frac{z_r}{z_{0.a_J}} + 1\right)}$$ [Equation 3.1]

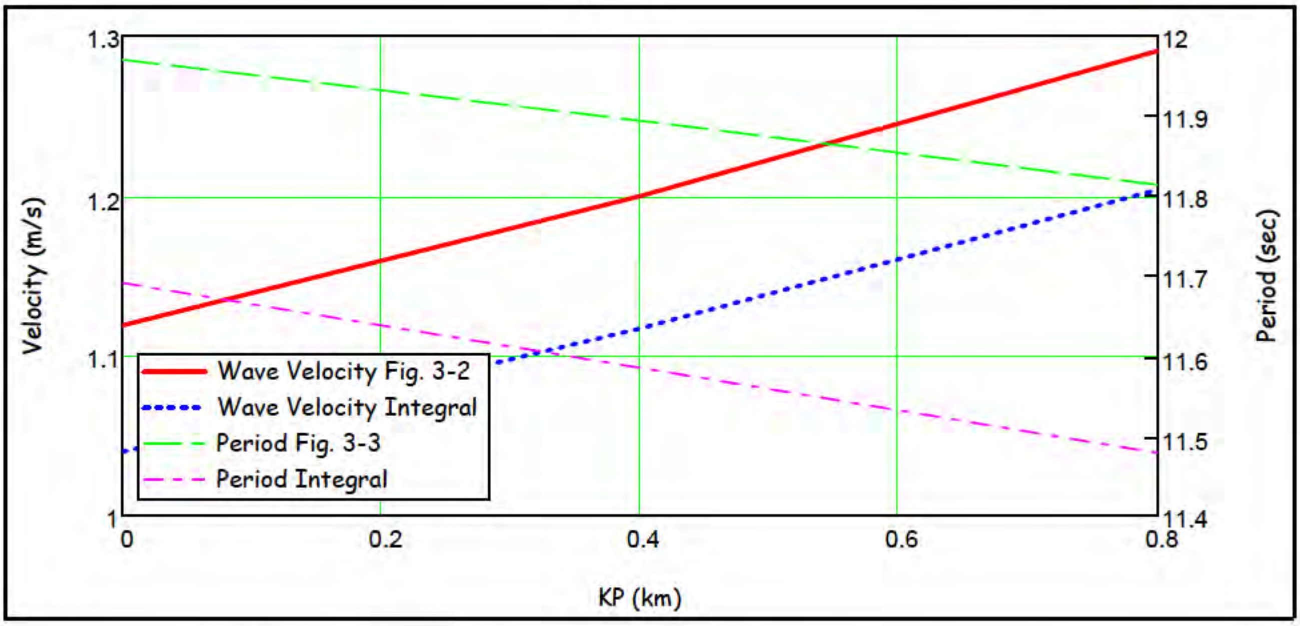
Spectral moments [Equation 3.10 and 3.7 substituting for ω]

$$M_{o_J} := \int_{\frac{0}{m}}^{\frac{0.1}{m}} G(k, depth_J)^2 \cdot S_{\eta\eta}\left(\omega k(k, depth_J), \omega_{p_J}, \alpha_{p_J}, \gamma_J\right) \cdot \frac{g \cdot \tanh(k \cdot depth_J) + g \cdot k \cdot \left(1 - \tanh(k \cdot depth_J)^2\right) \cdot depth_J}{2 \cdot (g \cdot k \cdot \tanh(k \cdot depth_J))^{\frac{1}{2}}}$$

$$u_{s_J} := 2 \cdot \sqrt{M_{o_J}}$$ [Equation 3.12]

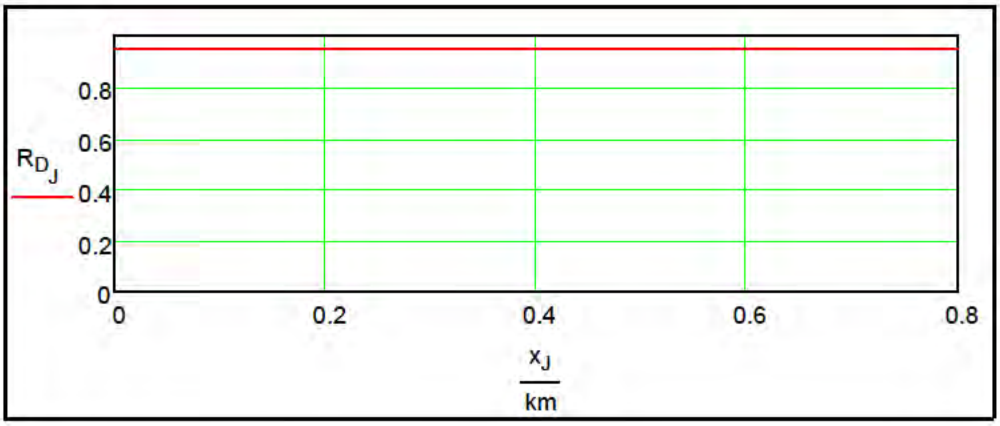
$$M_{2_J} := \int_{\frac{0}{m}}^{\frac{0.1}{m}} \omega k(k, depth_J)^2 \cdot G(k, depth_J)^2 \cdot S_{\eta\eta}\left(\omega k(k, depth_J), \omega_{p_J}, \alpha_{p_J}, \gamma_J\right) \cdot \frac{g \cdot \tanh(k \cdot depth_J) + g \cdot k \cdot \left(1 - \tanh(k \cdot de\right.}{2 \cdot (g \cdot k \cdot \tanh(k \cdot depth_J))^{\frac{1}{2}}}$$

$$t_{u_J} := 2 \cdot \pi \cdot \sqrt{\frac{M_{o_J}}{M_{2_J}}}$$ [Equation 3.12]



$$D_w(\theta) := \begin{cases} \frac{1}{\sqrt{\pi}} \cdot \frac{\Gamma\left(1 + \frac{sp}{2}\right)}{\Gamma\left(\frac{1}{2} + \frac{sp}{2}\right)} \cdot \left(\cos(\theta)^{sp}\right) \cdot [\sin[(90deg) - \theta]]^2 & \text{if } |\theta| \le 90deg \\ 0 & \text{otherwise} \end{cases}$$ [3.3]

Reduction Factor $$R_{D_J} := \sqrt{\int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} D_w(\theta)\, d\theta}$$ $R_{D_0} = 0.949$



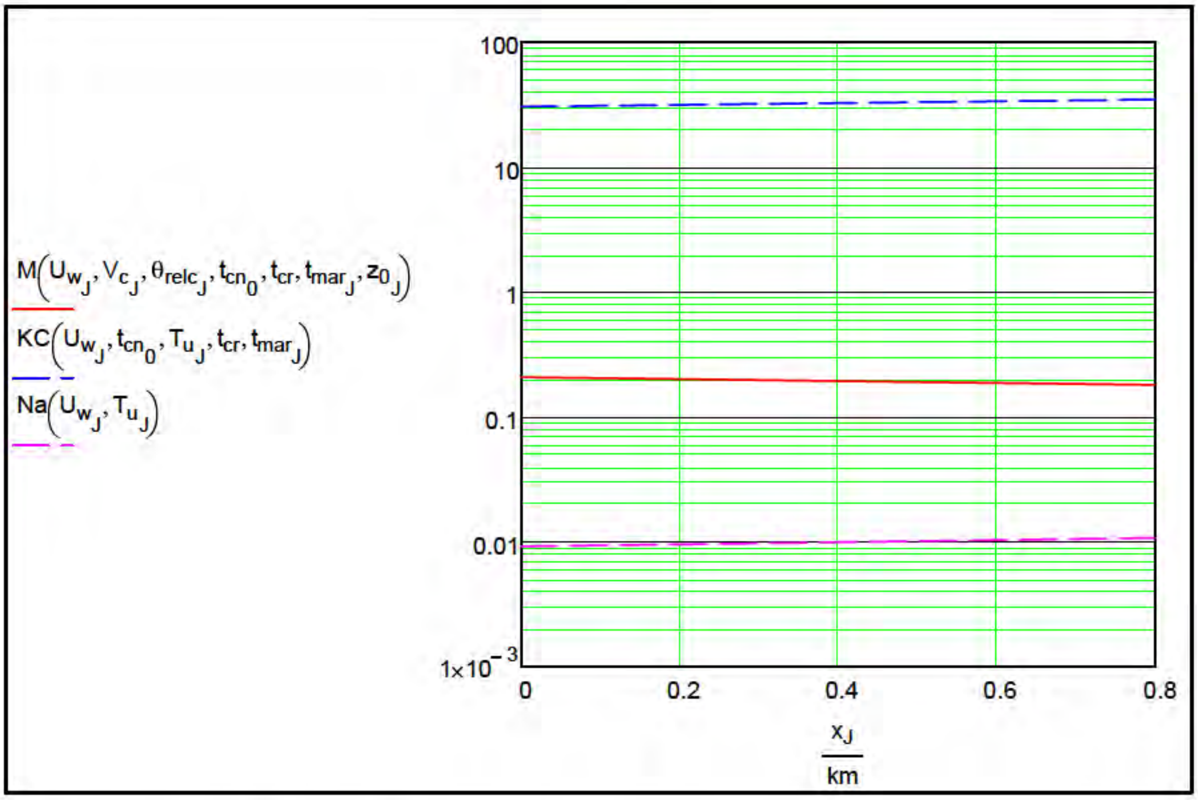
Significant water velocity (DNV) $U_{w_J} := R_{D_J} \cdot U_{S_J}$ [3.3]

$$u(U_w) := U_w$$

Current/Wave Velocity Ratio $M(U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0) := \dfrac{V_{eff}(V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0)}{U_w}$

Keulegan Carpenter Number $KC(U_w, t_{cn}, T_u, t_{cr}, t_{mar}) := \dfrac{U_w \cdot T_u}{D + 2 \cdot t_{cr} + 2 \cdot t_{in} + 2 \cdot t_{cn} + 2 \cdot t_{mar}}$

Spectral Acceleration $Na(U_w, T_u) := \dfrac{U_w}{g \cdot T_u}$



Ratio of single oscillation velocity and spectral velocity $k_U(\tau) := \frac{1}{2}\cdot\left(\sqrt{2\cdot\ln(\tau)} + \frac{0.5772}{\sqrt{2\cdot\ln(\tau)}}\right)$ [Equation 3.15] $k_U(\tau) = 1.936$

Ratio of single oscillation period and average zero up-crossing period

$$k_{t_J} := \begin{cases} 1.25 & \text{if } \gamma_J \le 1 \\ 1.2623 - 0.0015\cdot(\gamma_J)^2 - 0.0108\cdot\gamma_J & \text{if } 1 < \gamma_J \le 5 \\ 1.17 & \text{otherwise} \end{cases}$$

[Equation 3.16] $k_{t_0} = 1.25$

$$k_{T_J} := \begin{cases} k_{t_J} - 5\cdot\left(k_{t_J} - 1\right)\cdot\frac{T_{n_J}}{T_{u_J}} & \text{if } \frac{T_{n_J}}{T_{u_J}} \le 0.2 \\ 1 & \text{otherwise} \end{cases}$$

[Equation 3.16] $k_{T_0} = 1.069$

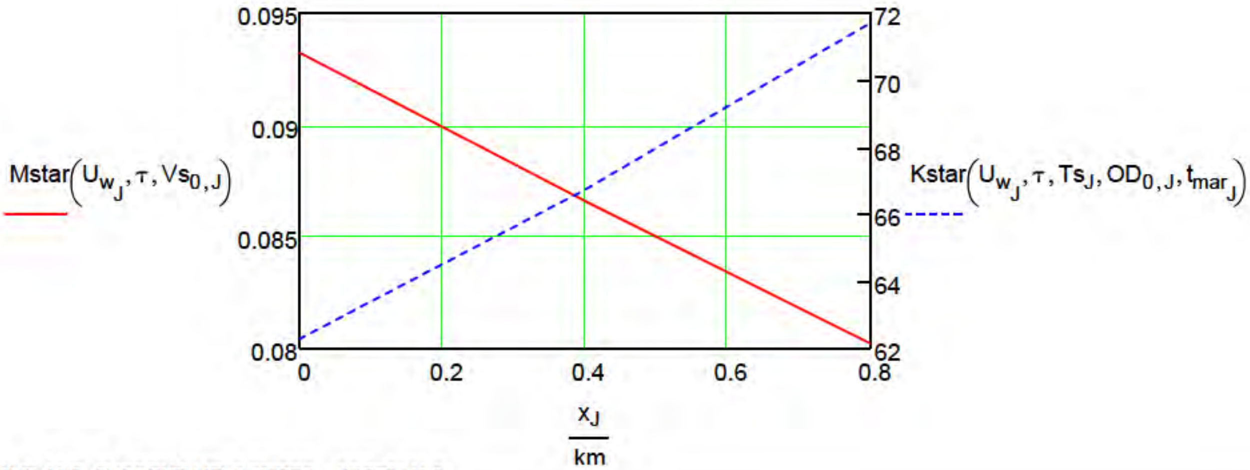
Single oscillation wave period $Ts_J := k_{T_J}\cdot T_{u_J}$ [Equation 3.16] $Ts_0 = 12.795\,s$

Single oscillation velocity $Us\_star(U_w,\tau) := k_U(\tau)\cdot U_w$ [Equation 3.15]

Single oscillation current $Vs_{jc,J} := V_{effc_{jc,J}}$

Significant Keulegan Carpenter number for single oscillation $Kstar(U_w,\tau,Ts,OD,t_{mar}) := \frac{Us\_star(U_w,\tau)\cdot Ts}{OD + 2\cdot t_{mar}}$

Single design oscillation current to wave velocity ratio $Mstar(U_w,\tau,Vs) := \frac{Vs}{Us\_star(U_w,\tau)}$



WAVE AND CURRENT VELOCITIES - SECTION 3

SOIL STRENGTHS AND SOIL RESISTANCE - SECTION 7 & REF [4]

Calculation of passive resistance: Sand

Ignoring influence of lift and including weight of water during installation if applicable Ref. [4] $\kappa_{sf_{jc,J}} := \frac{\gamma w_{s_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)^2}{W_{tot\_emb_{jc,J}}}$ Ref. [4] - A.4 $\kappa_{sf_{100,0}} = 0.554$

Initial penetration

$$zDsand_{jc,J} := \begin{cases} 0 & \text{if } \kappa_{sf_{jc,J}} < 0 \\ 0.037 \cdot \left(\kappa_{sf_{jc,J}}\right)^{-0.67} & \text{otherwise} \end{cases}$$

Ref. [4] - A.1

$zDsand_{0,0} = 0.04$

$zDsand_{100,0} = 0.055$

$zDsand_{183,1} = 0.06$

$$\kappa_{s_{jc,J}} := \frac{\gamma w_{s_J} \cdot \left(OD_{jc,J} + 2 \cdot t_{mar_J}\right)^2}{W_{tot_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{s_{100,0}} = 0.554$

Passive soil resistance, calculated using the embedment from installation conditions but other terms with submerged weight due to conditions asessed.

$$Psand_{jc,J} := W_{tot_{jc,J}} \cdot \begin{cases} \left[5.0 \cdot \kappa_{s_{jc,J}} - 0.15 \cdot \left(\kappa_{s_{jc,J}}\right)^2\right] \cdot \left(zDsand_{jc,J}\right)^{1.25} & \text{if } \kappa_{s_{jc,J}} \le 26.7 \\ \kappa_{s_{jc,J}} \cdot \left(zDsand_{jc,J}\right)^{1.25} & \text{otherwise} \end{cases}$$

Ref. [4] - A.3 $Psand_{100,0} = 0.367 \cdot \frac{kN}{m}$

$Psand_{183,1} = 0.653 \cdot \frac{kN}{m}$

Calculation of passive resistance: Clay

Ignoring influence of lift and including weight of water during installation if applicable Ref. [4]

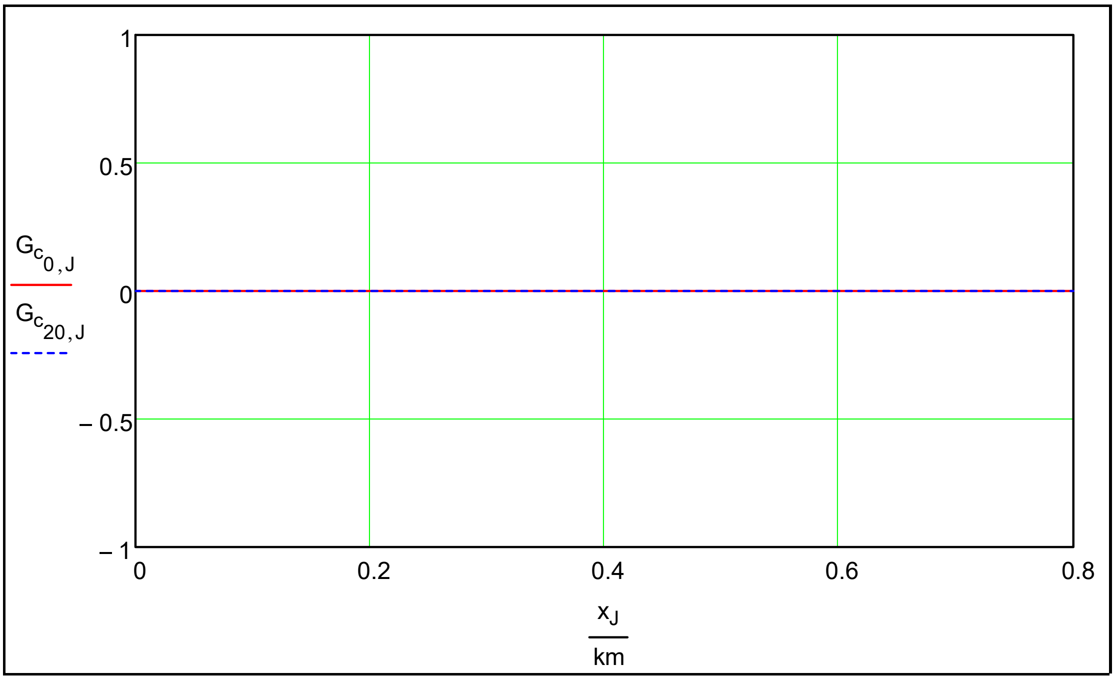
$$\kappa_{cf_{jc,J}} := \frac{s_{u_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)}{W_{tot\_emb_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{cf_{100,0}} = 0$

Clay Strength Factor

$$G_{c_{jc,J}} := \frac{s_{u_J}}{\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)\cdot \gamma c_{s_J}}$$

Ref. [4] - A.4 $G_{c_{100,0}} = 0$



Initial penetration

$$zDclay_{jc,J} := \begin{cases} 0 & \text{if } \kappa_{cf_{jc,J}} < 0 \\ 0.0071\cdot\left[\frac{\left(G_{c_{jc,J}}\right)^{0.3}}{\kappa_{cf_{jc,J}}}\right]^{3.2} + 0.062\cdot\left[\frac{\left(G_{c_{jc,J}}\right)^{0.3}}{\kappa_{cf_{jc,J}}}\right]^{0.7} & \text{otherwise} \end{cases}$$

[Ref. [4] - A.2

$zDclay_{0,0} = 0$

$zDclay_{100,0} = 0$

$$\kappa_{c_{jc,J}} := \frac{s_{u_J}\cdot\left(OD_{jc,J} + 2\cdot t_{mar_J}\right)}{W_{tot_{jc,J}}}$$

Ref. [4] - A.4 $\kappa_{c_{0,0}} = 0$

$\kappa_{c_{100,0}} = 0$

Passive soil resistance, calculated using the embedment from installation conditions but other terms with submerged weight due to condition asessed.

$$Pclay_{jc,J} := \frac{4.1\cdot\kappa_{c_{jc,J}}}{\left(G_{c_{jc,J}}\right)^{0.39}}\cdot\left(zDclay_{jc,J}\right)^{1.31}\cdot W_{tot_{jc,J}}$$

Ref. [4] - A.4

$Pclay_{0,0} = 0\cdot\frac{kN}{m}$

$Pclay_{100,0} = 0\cdot\frac{\kappa N}{m}$

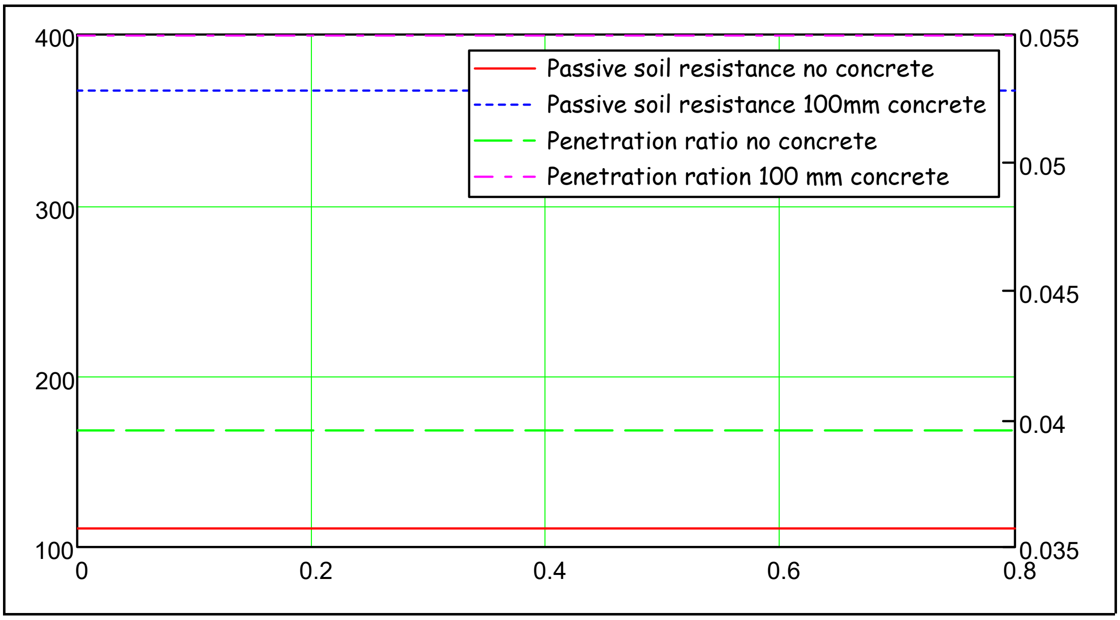
Passive soil resistance along pipeline

Passive Soil Resistance

$$P_{jc,J} := \begin{cases} \text{if } PSI = \text{"Calc"} \\ \quad \begin{cases} Psand_{jc,J} & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ Pclay_{jc,J} & \text{if } Soil\_group_J = \text{"Clay"} \end{cases} \\ P\_input_{jc,J} \quad \text{if } PSI = \text{"Input"} \\ \text{"Error"} \quad \text{otherwise} \end{cases}$$

Penetration Ratio

$$zD_{jc,J} := \begin{cases} \text{if } PSI = \text{"Calc"} \\ \quad \begin{cases} zDsand_{jc,J} & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ zDclay_{jc,J} & \text{if } Soil\_group_J = \text{"Clay"} \end{cases} \\ zD\_input_{jc,J} \quad \text{if } PSI = \text{"Input"} \\ \text{"Error"} \quad \text{otherwise} \end{cases}$$



SOIL STRENGTHS AND SOIL RESISTANCE - SECTION 7 & REF [4]

LOAD REDUCTION DUE TO SOIL PENETRATION - 6.4

Load reduction factor due to permeable seabed

$$r_{perm\_z_J} := \begin{cases} 0.7 & \text{if } Soil\_group_J = \text{"Sand"} \vee Soil\_group_J = \text{"Rock"} \\ 1.0 & \text{if } Soil\_group_J = \text{"Clay"} \end{cases}$$

[6.4.1.2] $r_{perm\_z_0} = 0.7$

Load reduction factors due to penetration

Horizontal

$$r_{pen\_y_{jc,J}} := \begin{cases} 1 - 1.4 \cdot zD_{jc,J} & \text{if } zD_{jc,J} < 0.5 \\ 0.3 & \text{otherwise} \end{cases}$$

$r_{pen\_y_{100,0}} = 0.923$

[Equation 6.10]

Vertical

$$r_{pen\_z_{jc,J}} := \begin{cases} 1 & \text{if } zD_{jc,J} \le 0.1 \\ 1 - 1.3\cdot\left(zD_{jc,J} - 0.1\right) & \text{if } 0.1 < zD_{jc,J} < \dfrac{1.13}{1.3} \\ 0 & \text{otherwise} \end{cases}$$

$r_{pen\_z_{100,0}} = 1$

[Equation 6.11]

Load reduction factors due to trenching

Horizontal

$$r_{tr\_y_{jc,J}} := \begin{cases} 1.0 - 0.18\cdot\left[\dfrac{\left(\theta_{trench_J} - 5deg\right)}{deg}\right]^{0.25}\cdot\left(\dfrac{z_{t_J}}{OD_{jc,J} + 2\cdot t_{mar_J}}\right)^{0.42} & \text{if } \left(5deg \le \theta_{trench_J} \le 45deg\right) \wedge Trench = \text{"Yes} \\ 1 & \text{otherwise} \end{cases}$$

[Equation 6.12] $r_{tr\_y_{100,0}} = 1$

Vertical

$$r_{tr\_z_{jc,J}} := \begin{cases} 1.0 - 0.14\cdot\left[\dfrac{\left(\theta_{trench_J} - 5deg\right)}{deg}\right]^{0.43}\cdot\left(\dfrac{z_{t_J}}{OD_{jc,J} + 2\cdot t_{mar_J}}\right)^{0.46} & \text{if } \left(5deg \le \theta_{trench_J} \le 45deg\right) \wedge Trench = \text{"Yes} \\ 1 & \text{otherwise} \end{cases}$$

[Equation 6.13] $r_{tr\_z_{100,0}} = 1$

Combined load reduction factor along pipeline

Horizontal load reduction factor $r_{tot\_y_{jc,J}} := r_{pen\_y_{jc,J}}\cdot r_{tr\_y_{jc,J}}$ [Equation 3.17] $r_{tot\_y_{100,0}} = 0.923$

Vertical load reduction factor $r_{tot\_z_{jc,J}} := r_{perm\_z_J}\cdot r_{pen\_z_{jc,J}}\cdot r_{tr\_z_{jc,J}}$ [Equation 3.17] $r_{tot\_z_{100,0}} = 0.7$

LOAD REDUCTION DUE TO SOIL PENETRATION - 6.4

Buoyancy Check

BUOYANCY CHECK

Absolute Lateral Stability

(For both Clay and Sand)

ABSOLUTE LATERAL STABILITY - 4.5

Peak horizontal load coefficients [Table 6-1]

$$Cy := \begin{pmatrix} 13 & 6.8 & 4.55 & 3.33 & 2.72 & 2.4 & 2.15 & 1.95 & 1.8 & 1.52 & 1.3 \\ 10.7 & 5.76 & 3.72 & 2.72 & 2.2 & 1.9 & 1.71 & 1.58 & 1.49 & 1.33 & 1.22 \\ 9.02 & 5 & 3.15 & 2.3 & 1.85 & 1.58 & 1.42 & 1.33 & 1.27 & 1.18 & 1.14 \\ 7.64 & 4.32 & 2.79 & 2.01 & 1.63 & 1.44 & 1.33 & 1.26 & 1.21 & 1.14 & 1.09 \\ 6.63 & 3.8 & 2.51 & 1.78 & 1.46 & 1.32 & 1.25 & 1.19 & 1.16 & 1.1 & 1.05 \\ 5.07 & 3.3 & 2.27 & 1.71 & 1.43 & 1.34 & 1.29 & 1.24 & 1.18 & 1.08 & 1 \\ 4.01 & 2.7 & 2.01 & 1.57 & 1.44 & 1.37 & 1.31 & 1.24 & 1.17 & 1.05 & 1 \\ 3.25 & 2.3 & 1.75 & 1.49 & 1.4 & 1.34 & 1.27 & 1.2 & 1.13 & 1.01 & 1 \\ 1.52 & 1.5 & 1.45 & 1.39 & 1.34 & 1.2 & 1.08 & 1.03 & 1 & 1 & 1 \\ 1.11 & 1.1 & 1.07 & 1.06 & 1.04 & 1.01 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

$$Ms := \begin{pmatrix} 0 \\ 0.1 \\ 0.2 \\ 0.3 \\ 0.4 \\ 0.6 \\ 0.8 \\ 1 \\ 2 \\ 5 \\ 10 \end{pmatrix} \qquad Ks := \begin{pmatrix} 2.5 \\ 5 \\ 10 \\ 20 \\ 30 \\ 40 \\ 50 \\ 60 \\ 70 \\ 100 \\ 140 \end{pmatrix}$$

$Ms\_test := 2$

$Ks\_test := 15$

Interpolate down rows in matrices above to give a vectors for give M value

$$
Cy_K(M_c) := \begin{bmatrix}
\begin{cases} \left(Cy^{\langle 0\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 0\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 0\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 1\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 1\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 1\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 2\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 2\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 2\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 3\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 3\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 3\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 4\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 4\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 4\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 5\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 5\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 5\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 6\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 6\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 6\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 7\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 7\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \text{linterp}\left(Ms, Cy^{\langle 7\rangle}, M_c\right) & \text{otherwise} \end{cases} \\
\begin{cases} \left(Cy^{\langle 8\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 8\rangle}\right)_{10} & \text{if } M_c \ge 10 \end{cases}
\end{bmatrix}
$$

$$
Cy_K(Ms\_test) = \begin{pmatrix} 1.52 \\ 1.5 \\ 1.45 \\ 1.39 \\ 1.34 \\ 1.2 \\ 1.08 \\ 1.03 \\ 1 \\ 1 \\ 1 \end{pmatrix}
$$

$$\left|\begin{array}{l} \left| \mathrm{linterp}\left(Ms, Cy^{\langle 8\rangle}, M_c\right) \quad \text{otherwise} \right. \\ \left| \begin{array}{ll} \left(Cy^{\langle 9\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 9\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cy^{\langle 9\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(Cy^{\langle 10\rangle}\right)_0 & \text{if } M_c \le 0 \\ \left(Cy^{\langle 10\rangle}\right)_{10} & \text{if } M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cy^{\langle 10\rangle}, M_c\right) & \text{otherwise} \end{array} \right. \end{array}\right|$$

Interpolate within vectors by K.s to give value.

$$C_{y\_star}(M_s, K_s) := \left| \begin{array}{l} \text{if } K_s < 2.5 \\ \quad \left| \begin{array}{ll} Cy_K(M_s)_0 \cdot \dfrac{2.5}{K_s} & \text{if } M_s < 2 \\ Cy_K(M_s)_0 & \text{otherwise} \end{array} \right. \\ Cy_K(M_s)_0 \quad \text{if } K_s = 2.5 \\ Cy_K(M_s)_{10} \quad \text{if } K_s \ge 140 \\ \mathrm{linterp}\left(Ks, Cy_K(M_s), K_s\right) \quad \text{otherwise} \end{array} \right.$$

$C_{y\_star}(Ms\_test, Ks\_test) = 1.42$

For Ms>2 the trend in Figure 6-6 has been taken to prevent excessive Cy* returns for small waves.

Peak vertical load coefficients

[Table 6-2]

$$Cz := \begin{pmatrix} 5 & 5 & 4.85 & 3.21 & 2.55 & 2.26 & 2.01 & 1.81 & 1.63 & 1.26 & 1.05 \\ 3.87 & 4.08 & 4.23 & 2.87 & 2.15 & 1.77 & 1.55 & 1.41 & 1.31 & 1.11 & 0.97 \\ 3.16 & 3.45 & 3.74 & 2.6 & 1.86 & 1.45 & 1.26 & 1.16 & 1.09 & 1 & 0.9 \\ 3.01 & 3.25 & 3.53 & 2.14 & 1.52 & 1.26 & 1.1 & 1.01 & 0.99 & 0.95 & 0.9 \\ 2.87 & 3.08 & 3.35 & 1.82 & 1.29 & 1.11 & 0.98 & 0.9 & 0.9 & 0.9 & 0.9 \\ 2.21 & 2.36 & 2.59 & 1.59 & 1.2 & 1.03 & 0.92 & 0.9 & 0.9 & 0.9 & 0.9 \\ 1.53 & 1.61 & 1.8 & 1.18 & 1.05 & 0.97 & 0.92 & 0.9 & 0.9 & 0.9 & 0.9 \\ 1.05 & 1.13 & 1.28 & 1.12 & 0.99 & 0.91 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.96 & 1.03 & 1.05 & 1 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.91 & 0.92 & 0.93 & 0.91 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \\ 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 & 0.9 \end{pmatrix}$$

Interpolate down rows in matrices above to give a vectors for give M value

$$Cz_K(M_c) := \left[\begin{array}{l} \left| \begin{array}{ll} (Cz^{\langle 0 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 0 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 0 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 1 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 1 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 1 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 2 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 2 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 2 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 3 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 3 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 3 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 4 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 4 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 4 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 5 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 5 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 5 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 6 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 6 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 6 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 7 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 7 \rangle})_{10} & \text{if } M_c \ge 10 \\ \text{linterp}(Ms, Cz^{\langle 7 \rangle}, M_c) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} (Cz^{\langle 8 \rangle})_0 & \text{if } M_c \le 0 \\ (Cz^{\langle 8 \rangle})_{10} & \text{if } M_c \ge 10 \end{array} \right. \end{array}\right.$$

$$Cz_K(Ms\_test) = \begin{pmatrix} 0.96 \\ 1.03 \\ 1.05 \\ 1 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \\ 0.9 \end{pmatrix}$$

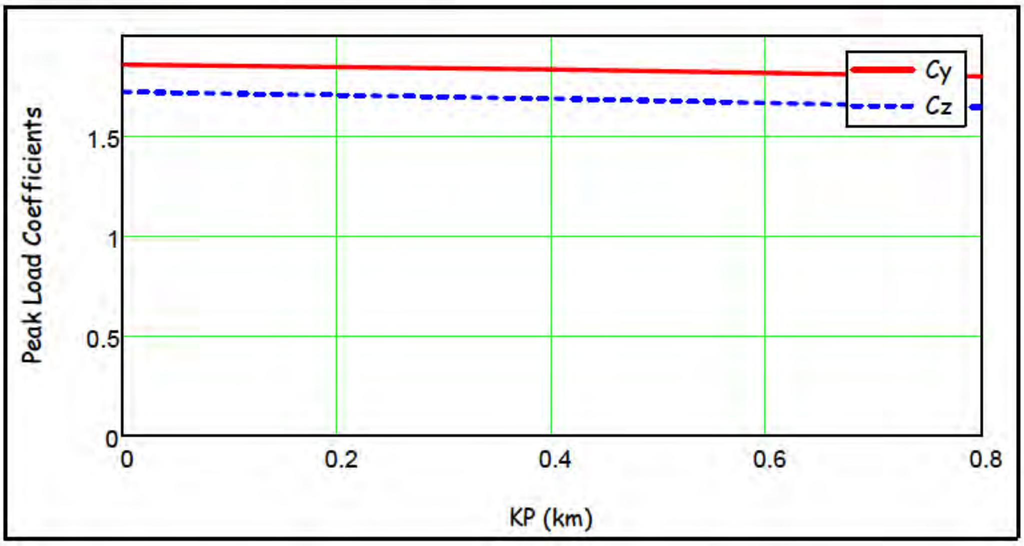
$$\left| \begin{array}{l} \mathrm{linterp}\left(Ms, Cz^{\langle 8 \rangle}, M_c\right) \quad \text{otherwise} \\ \left| \begin{array}{ll} \left(Cz^{\langle 9 \rangle}\right)_0 & \text{if} \quad M_c \le 0 \\ \left(Cz^{\langle 9 \rangle}\right)_{10} & \text{if} \quad M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cz^{\langle 9 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(Cz^{\langle 10 \rangle}\right)_0 & \text{if} \quad M_c \le 0 \\ \left(Cz^{\langle 10 \rangle}\right)_{10} & \text{if} \quad M_c \ge 10 \\ \mathrm{linterp}\left(Ms, Cz^{\langle 10 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \end{array} \right]$$

Interpolate within vectors by K.s to give value.

$$C_{z\_star}(M_s, K_s) := \left| \begin{array}{ll} Cz_K(M_s)_0 & \text{if} \quad K_s \le 2.5 \\ Cz_K(M_s)_{10} & \text{if} \quad K_s \ge 140 \\ \mathrm{linterp}(Ks, Cz_K(M_s), K_s) & \text{otherwise} \end{array} \right.$$

$$C_{z\_star}(Ms\_test, Ks\_test) = 1.025$$

Example graph for pipe with 100mm concrete coating



Peak Horizontal Load [Equation 6.16]

$$F_y(r_{tot\_y}, U_w, Vs, Ts, OD, t_{mar}) := r_{tot\_y} \cdot \frac{1}{2} \cdot \rho_w \cdot C_{y\_star}(Mstar(U_w, \tau, Vs), Kstar(U_w, \tau, Ts, OD, t_{mar})) \cdot (OD + t_{mar}) \cdot (Us\_$$

$$F_y\left(r_{tot\_y_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}\right) = 2.771 \times 10^3 \cdot \frac{N}{m}$$

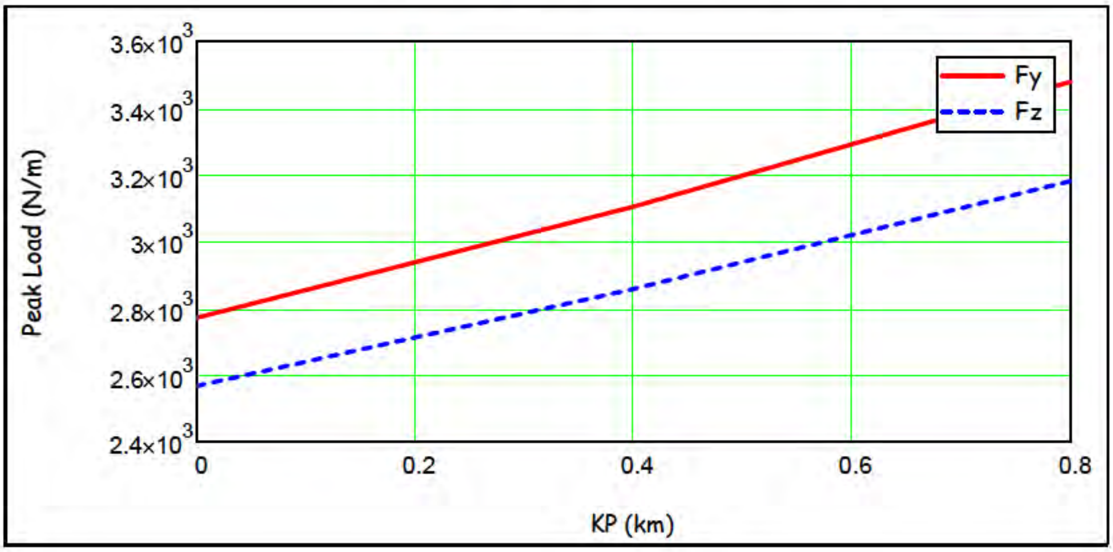
$$F_y\left(r_{tot\_y_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}\right) = 3.479 \times 10^3 \cdot \frac{N}{m}$$

Peak Vertical Load [Equation 6.17]

$$F_z(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}) := r_{tot\_z} \cdot \frac{1}{2} \cdot \rho_w \cdot C_{z\_star}(Mstar(U_w, \tau, Vs), Kstar(U_w, \tau, Ts, OD, t_{mar})) \cdot (OD + t_{mar}) \cdot (Us\_$$

$$F_z\left(r_{tot\_y_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}\right) = 2.567 \times 10^3 \cdot \frac{N}{m}$$

$$F_z\left(r_{tot\_y_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}\right) = 3.182 \times 10^3 \cdot \frac{N}{m}$$



Horizontal stability check

Unstable whilst ratio is less than 1 [Inverse of Equation 4.2]

$$RatioH(r_{tot\_y}, r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}, \gamma_{sc}, P, W_{tot}, \mu) := \frac{\mu \cdot W_{tot} + P}{(F_y(r_{tot\_y}, U_w, Vs, Ts, OD, t_{mar}) + \mu \cdot F_z(r_{tot\_z}, U_w, Vs, Ts,}$$

$$RatioH\left(r_{tot\_y_{100,0}}, r_{tot\_z_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}, \gamma_{sc_0}, P_{100,0}, W_{tot_{100,0}}, \mu_0\right) = 0.883$$

$$RatioH\left(r_{tot\_y_{100,n-1}}, r_{tot\_z_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}, \gamma_{sc_{n-1}}, P_{100,n-1}, W_{tot_{100,n-1}}, \mu_{n-1}\right.$$

Required concrete weight coating

$$f_H(J) := 2000 \text{ on error } \left| \begin{array}{l} j \leftarrow 0 \\ \text{while } RatioH\left[r_{tot\_y_{j,J}}, r_{tot\_z_{j,J}}, U_{w_J}, Vs_{j,J}, Ts_J, OD_{j,J} \cdot (1 - zD_{j,J}), t_{mar_J}, \gamma_{sc_J}, P_{j,J}, W_{tot_{j,J}} \right. \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$$t_{conabsH_J} := f_H(J) \cdot mm$$

Vertical stability check

Unstable whilst ratio is less than 1 [Inverse of Equation 4.3]

$$RatioV(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}, \gamma_{sc}, W_{tot}) := \frac{W_{tot}}{F_z(r_{tot\_z}, U_w, Vs, Ts, OD, t_{mar}) \cdot \gamma_{sc}}$$

$$\text{RatioV}\left(r_{tot\_z_{100,0}}, U_{w_0}, Vs_{100,0}, Ts_0, OD_{100,0}, t_{mar_0}, \gamma_{sc_0}, W_{tot_{100,0}}\right) = 2.656$$

$$\text{RatioV}\left(r_{tot\_z_{100,n-1}}, U_{w_{n-1}}, Vs_{100,n-1}, Ts_{n-1}, OD_{100,n-1}, t_{mar_{n-1}}, \gamma_{sc_{n-1}}, W_{tot_{100,n-1}}\right) = 2.143$$

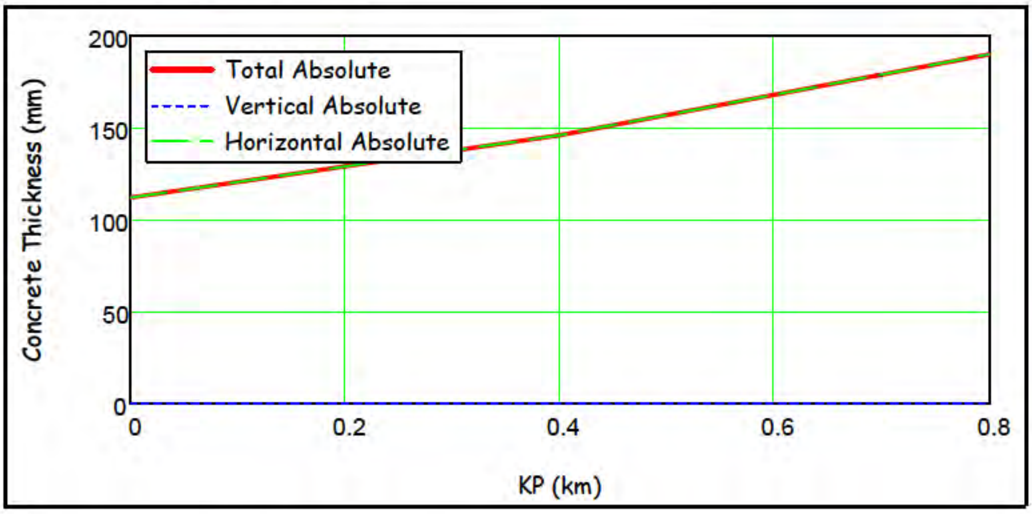
Required concrete weight coating

$$f_V(J) := 2000 \quad \text{on error} \quad \left| \begin{array}{l} j \leftarrow 0 \\ \text{while} \quad \text{RatioV}\left[r_{tot\_z_{j,J}}, U_{w_J}, Vs_{j,J}, Ts_J, OD_{j,J}\cdot\left(1 - zD_{j,J}\right), t_{mar_J}, \gamma_{sc_J}, W_{tot_{j,J}}\right] \le 1 \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$$t_{conabsV_J} := f_V(J)\cdot mm$$

$$t_{conabs_J} := \max\left(t_{conabsH_J}, t_{conabsV_J}\right)$$

ABSOLUTE LATERAL STABILITY - 4.5



Generalised Lateral Stability

10D Lateral Displacement (1000 waves) for SAND

10D LATERAL DISPLACEMENT SAND - 4.6

Minimum Weight Ratio for Virtual Stability (Y < 0.5D) for SAND

VIRTUAL STABILITY SAND - 4.6

$$L_{stabTable2} := \begin{pmatrix} 1.5 & 1.42 & 1.35 & 1.25 & 1.22 & 1.22 \\ 1.82 & 1.7 & 1.61 & 1.53 & 1.5 & 1.5 \\ 2.19 & 1.97 & 1.83 & 1.69 & 1.61 & 1.61 \\ 2.65 & 2.35 & 2.18 & 1.99 & 1.85 & 1.72 \\ 3.05 & 2.55 & 2.32 & 2.13 & 2.01 & 1.9 \\ 3.05 & 2.55 & 2.4 & 2.2 & 2.06 & 1.95 \\ 2.65 & 2.45 & 2.36 & 2.24 & 2.11 & 2.09 \\ 2.5 & 2.4 & 2.35 & 2.27 & 2.22 & 2.19 \\ 2.45 & 2.4 & 2.39 & 2.37 & 2.37 & 2.37 \\ 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 \end{pmatrix}$$

For $K \geq 10$

[Table 4-5]

$$Mstab := \begin{pmatrix} 0.2 \\ 0.4 \\ 0.5 \\ 0.6 \\ 0.8 \\ 1 \\ 1.5 \\ 2 \\ 4 \\ 10 \end{pmatrix} \qquad Kstab := \begin{pmatrix} 10 \\ 15 \\ 20 \\ 30 \\ 40 \\ 60 \end{pmatrix}$$

$Ms\_test := 2$

$Ks\_test := 15$

Interpolate down rows in matrices above to give a vectors for give M value

$$L_{stabTable2K}(M_c) := \begin{bmatrix} \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 0 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 0 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 0 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 1 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 1 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 1 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 2 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 2 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 2 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 3 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 3 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 3 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 4 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 4 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 4 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \\ \left| \begin{array}{ll} \left(L_{stabTable2}^{\langle 5 \rangle}\right)_0 & \text{if } M_c \le 0.2 \\ \left(L_{stabTable2}^{\langle 5 \rangle}\right)_9 & \text{if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable2}^{\langle 5 \rangle}, M_c\right) & \text{otherwise} \end{array} \right. \end{bmatrix}$$

$$L_{stabTable2K}(Ms\_test) = \begin{pmatrix} 2.5 \\ 2.4 \\ 2.35 \\ 2.27 \\ 2.22 \\ 2.19 \end{pmatrix}$$

Interpolate within vectors by K.s to give value.

$$L_{stabTable2\_}(M_s, K_s) := \left| \begin{array}{ll} L_{stabTable2K}(M_s)_0 & \text{if } K_s \le 10 \\ L_{stabTable2K}(M_s)_9 & \text{if } K_s \ge 60 \\ \text{linterp}\left(Kstab, L_{stabTable2K}(M_s), K_s\right) & \text{otherwise} \end{array} \right.$$

$$L_{stabTable2\_}(Ms\_test, Ks\_test) = 2.4$$

$$L_{stabTable3} := \begin{pmatrix} 1.55 & 1.45 & 1.34 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 2 & 1.65 & 1.34 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 3.3 & 2.6 & 1.91 & 1.24 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 3.75 & 3.07 & 2.38 & 1.7 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 & 1.13 \\ 4 & 3.45 & 2.9 & 2.36 & 1.81 & 1.81 & 1.81 & 1.81 & 1.81 & 1.81 \\ 3.9 & 3.5 & 3.1 & 2.71 & 2.31 & 2.31 & 2.31 & 2.31 & 2.31 & 2.31 \\ 3.25 & 3.13 & 3 & 2.88 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 \\ 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 & 2.75 \\ 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 & 2.6 \\ 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 & 2.5 \end{pmatrix}$$

For $K \leq 5$

[Table 4-6]

$$Nstab := \begin{pmatrix} 0.003 \\ 0.006 \\ 0.012 \\ 0.024 \\ 0.048 \\ 0.04801 \\ 0.04802 \\ 0.04803 \\ 0.04804 \\ 0.04805 \end{pmatrix} \qquad Ns\_test := 0.003$$

Interpolate down rows in matrices above to give a vectors for give M value

$$L_{stabTable3N}(M_c) := \begin{bmatrix} \left(L_{stabTable3}^{\langle 0 \rangle}\right)_0 \text{ if } M_c \le 0.2 \\ \left(L_{stabTable3}^{\langle 0 \rangle}\right)_9 \text{ if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}^{\langle 0 \rangle}, M_c\right) \text{ otherwise} \\ \left(L_{stabTable3}^{\langle 1 \rangle}\right)_0 \text{ if } M_c \le 0.2 \\ \left(L_{stabTable3}^{\langle 1 \rangle}\right)_9 \text{ if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}^{\langle 1 \rangle}, M_c\right) \text{ otherwise} \\ \left(L_{stabTable3}^{\langle 2 \rangle}\right)_0 \text{ if } M_c \le 0.2 \\ \left(L_{stabTable3}^{\langle 2 \rangle}\right)_9 \text{ if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}^{\langle 2 \rangle}, M_c\right) \text{ otherwise} \\ \left(L_{stabTable3}^{\langle 3 \rangle}\right)_0 \text{ if } M_c \le 0.2 \\ \left(L_{stabTable3}^{\langle 3 \rangle}\right)_9 \text{ if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}^{\langle 3 \rangle}, M_c\right) \text{ otherwise} \\ \left(L_{stabTable3}^{\langle 4 \rangle}\right)_0 \text{ if } M_c \le 0.2 \\ \left(L_{stabTable3}^{\langle 4 \rangle}\right)_9 \text{ if } M_c \ge 10 \\ \text{linterp}\left(Mstab, L_{stabTable3}^{\langle 4 \rangle}, M_c\right) \text{ otherwise} \end{bmatrix}$$

$$L_{stabTable3N}(Ms\_test) = \begin{pmatrix} 2.75 \\ 2.75 \\ 2.75 \\ 2.75 \\ 2.75 \end{pmatrix}$$

Interpolate within vectors by N.s to give value.

$$L_{stabTable3\_}(M_s, N_s) := \begin{cases} L_{stabTable3N}(M_s)_0 & \text{if } N_s \le 0.003 \\ L_{stabTable3N}(M_s)_9 & \text{if } N_s \ge 0.048 \\ \text{linterp}\left(Nstab, L_{stabTable3N}(M_s), N_s\right) & \text{otherwise} \end{cases}$$

$$L_{stabTable3\_}(Ms\_test, Ns\_test) = 2.75$$

$$L_{stab\_}(M_{stab}, K_{stab}, N_{stab}) := \begin{cases} L_{stabTable2\_}(M_{stab}, K_{stab}) & \text{if } 5 \le K_{stab} \\ L_{stabTable3\_}(M_{stab}, N_{stab}) & \text{if } K_{stab} < 5 \\ \text{"Error"} & \text{otherwise} \end{cases}$$

$$L_{stab\_}(Ms\_test, Ks\_test, Ns\_test) = 2.4$$

Unstable whilst ratio is less than 1

Combine definition of L with output from lookup table $\frac{L_{stab}}{(2 + M)^2} = L_{stab\_}$

$$\text{Ratiostab}\left(W_{tot}, OD, U_S, U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_{mar}, z_0, T_u\right) := \frac{}{0.5\cdot\rho_w\cdot\left(OD + t_{mar}\right)\cdot\left(U_S\right)^2\cdot\left(2 + M\left(U_w, V_c, \theta_{relc}, t_{cn}, t_{cr}, t_r\right.\right.}$$

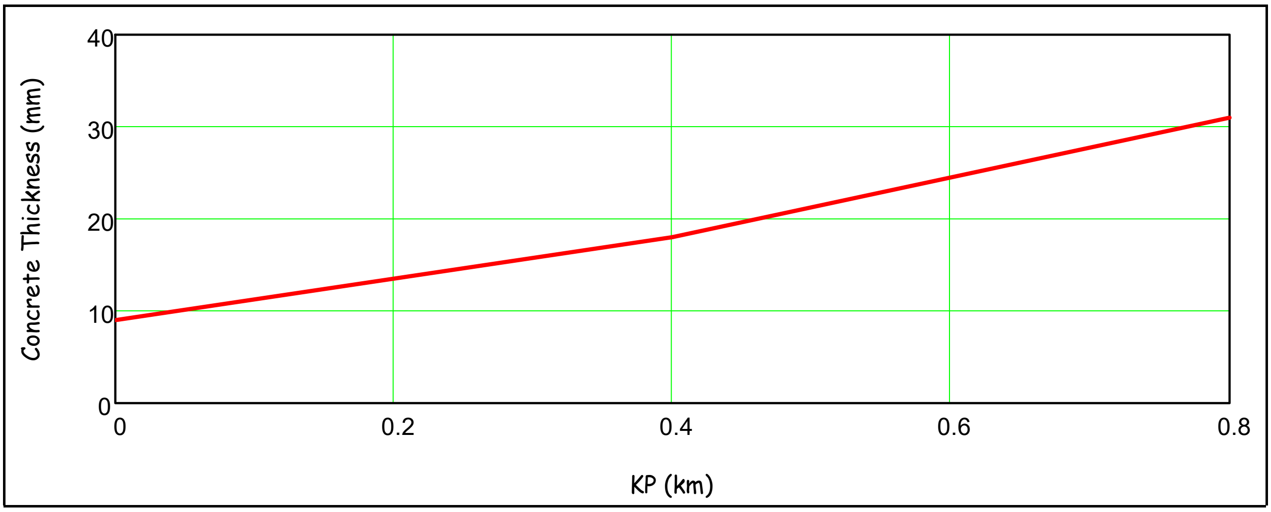
$$\text{Ratiostab}\left(W_{tot_{100,0}}, OD_{100,0}, U_{S_0}, U_{w_0}, V_{c_0}, \theta_{relc_0}, t_{cn_{100}}, t_{cr}, t_{mar_0}, z_{0.a_0}, T_{u_0}\right) = 1.975$$

$$\text{Ratiostab}\left(W_{tot_{100,n-1}}, OD_{100,n-1}, U_{S_{n-1}}, U_{w_{n-1}}, V_{c_{n-1}}, \theta_{relc_{n-1}}, t_{cn_{100}}, t_{cr}, t_{mar_{n-1}}, z_{0.a_{n-1}}, T_{u_{n-1}}\right) = 1.554$$

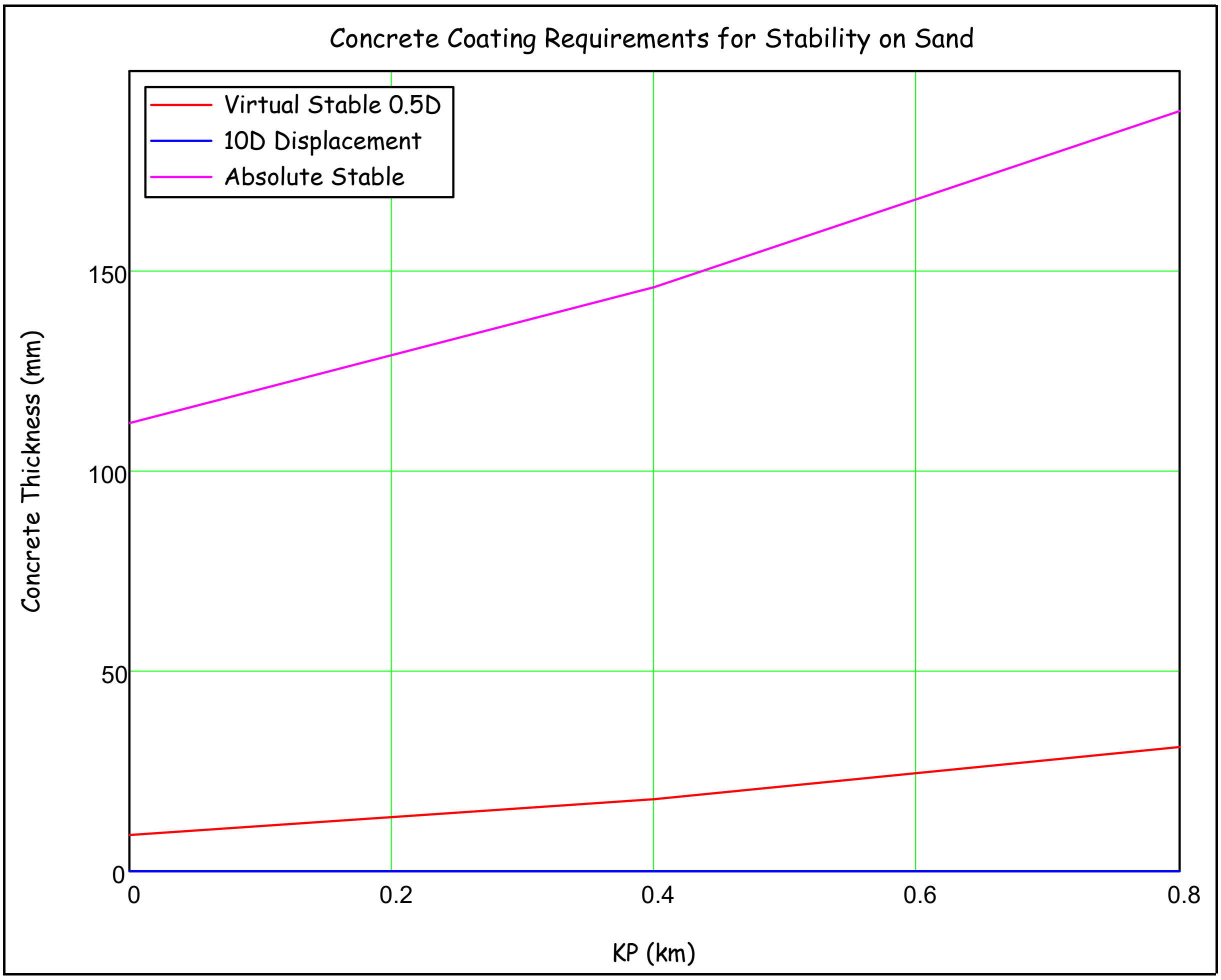
Required concrete weight coating

$$f_{stab}(J) := 2000 \quad \text{on error} \quad \left| \begin{array}{l} j \leftarrow 0 \\ \text{while} \quad \text{Ratiostab}\left(W_{tot_{j,J}}, OD_{j,J}, U_{S_J}, U_{w_J}, V_{c_J}, \theta_{relc_J}, t_{cn_j}, t_{cr}, t_{mar_J}, z_{0.a_J}, T_{u_J}\right) \le 1 \\ \quad j \leftarrow j + 1 \\ j \end{array} \right.$$

$$t_{constab_J} := f_{stab}(J)\cdot mm$$



VIRTUAL STABILITY SAND - 4.6


Concrete Coating Requirements for Stability on Sand
Virtual Stable 0.5D
10D Displacement
Absolute Stable
Concrete Thickness (mm)
KP (km)
0
50
100
150
0
0.2
0.4
0.6
0.8

Minimum Weight Ratio for Virtual Stability (Y < 0.5D) for CLAY

VIRTUAL STABILITY CLAY - APP A

Minimum Weight Ratio for 10D Lateral Displacement for CLAY

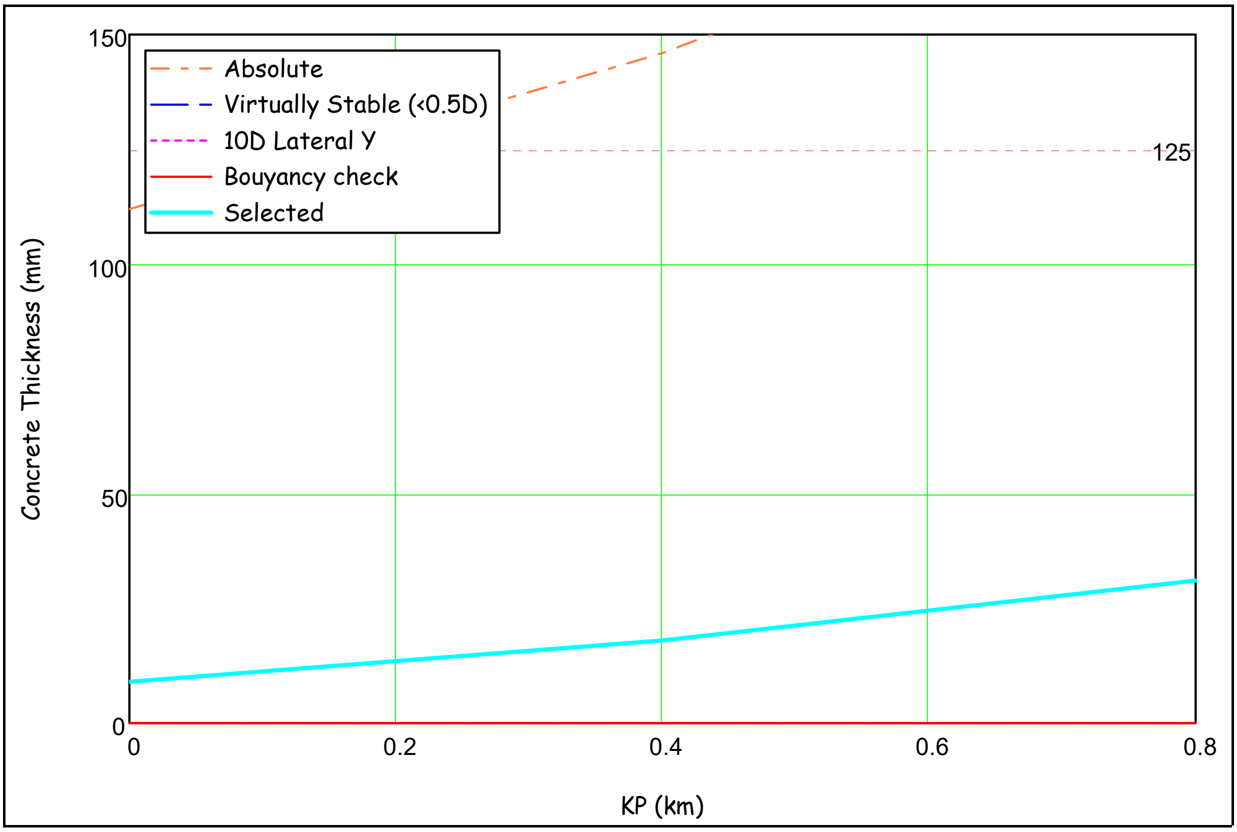
10D STABILITY CLAY - APP A

SORT BY SOIL TYPE AND VALIDITY

RESULTS

Result =

	KP (km) 0	Soil group 1	Water depth (m) 2	Bouyancy CWC thk (mm) 3	ABS CWC thk (mm) 4	0.5D CWC thk (mm) 5	0.5D Method Validity 6	10D CW thk (mm 7
0	0	"Sand"	29.5	0	112	9	"Valid"	
1	0.4	"Sand"	27.3	0	146	18	"Valid"	
2	0.8	"Sand"	25.1	0	190	31	"Valid"	
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								



Warning = "Coating density sufficient"

Maximum requried concrete coating thickness:

Not bouyant $\max(t_{conB}) = 0\cdot mm$

Absolutely stable $\max(t_{conabs}) = 190\cdot mm$

Virtually stable $\max(t_{cn5D}) = 31\cdot mm$

10 Diameter displacement stability $\max(t_{cn10D}) = 0\cdot mm$

Note maximum requriement for virtual / 10D displacement result may not be valid if falls outside table look-up regions, check above.

Selected $\max(t_{conc})\cdot mm = 31\cdot mm$

If Concrete coating is pre-selected and the following results are greater than 1 then pipeline is stable for selected criteria at minimum water depth location.

Only valid if wave/current data is constant along route.

Bouyancy

Not bouyant

$$\frac{1}{RatioB\left(OD_{t_{conc\_input}, MinWD}, t_{mar_{MinWD}}, W_{tot_{t_{conc\_input}, MinWD}}\right)} = 2.652$$

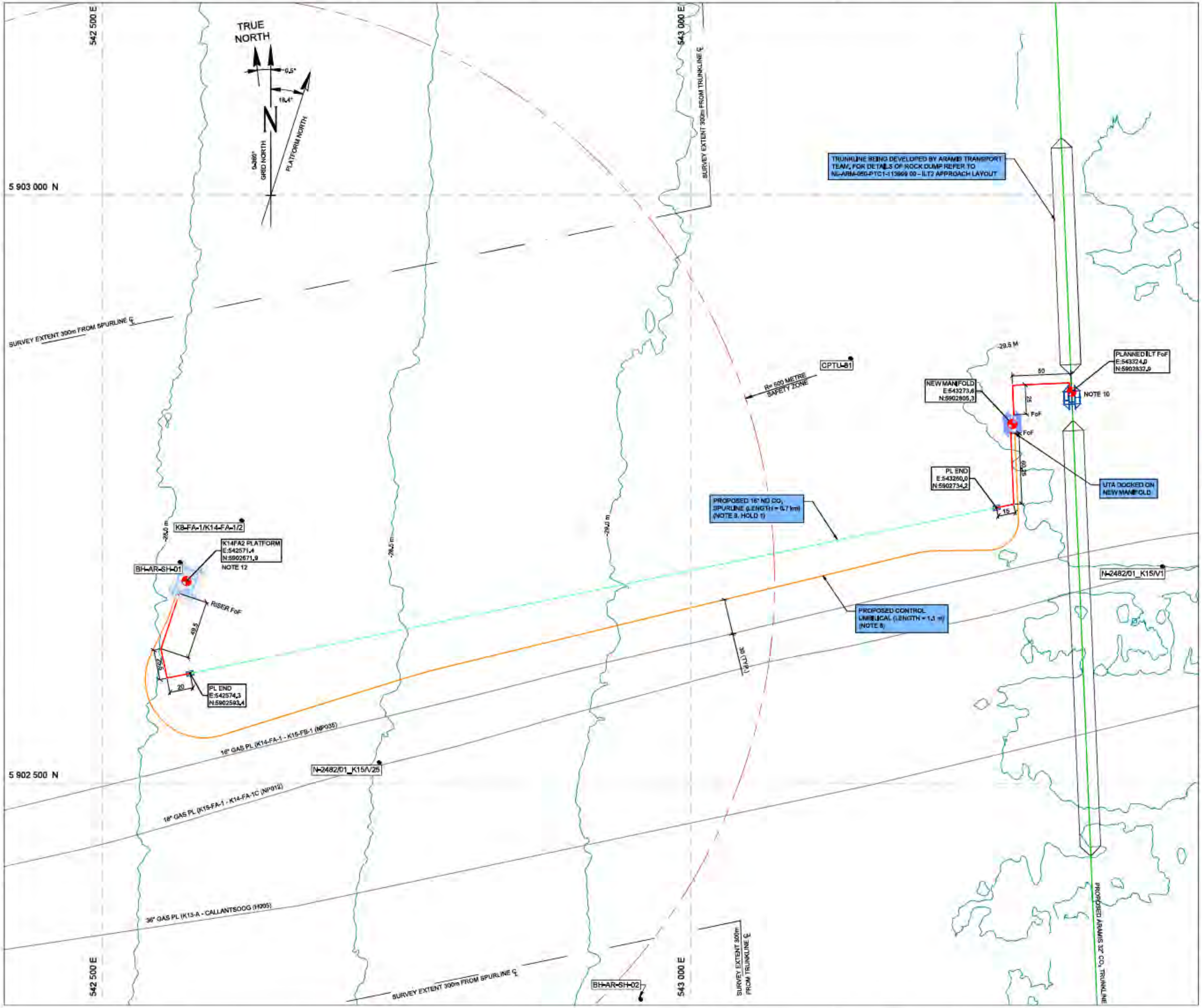
Absolute Stability

$$RatioH\_concinput := RatioH\left[r_{tot\_y_{t_{conc\_input}, MinWD}}, r_{tot\_z_{t_{conc\_input}, MinWD}}, U_{w_{MinWD}}, Vs_{t_{conc\_input}, MinWD}, Ts_{MinWD}, OD\right.$$

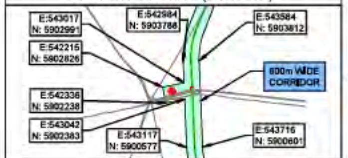
$$RatioH\_concinput = 0.984$$

$$RatioV\_concinput := RatioV\left[r_{tot\_z_{t_{conc\_input}, MinWD}}, U_{w_{MinWD}}, Vs_{t_{conc\_input}, MinWD}, Ts_{MinWD}, OD_{t_{conc\_input}, MinWD}\cdot(1\cdot\right.$$

$$RatioV\_concinput = 2.942$$



SURVEY EXTENT (NOTE 15)



NOTES

1. ALL DIMENSIONS ARE IN METRES U.N.O.
2. COORDINATES IN ARE METRES AND BASED ON ETRS 1989 UTM ZONE 31N PROJECTION (WKID:25831 AUTHORITY: EPSG).
3. ALL ELEVATIONS ARE IN METRES REDUCED TO LAT BASED ON COMPANY PROVIDED BATHYMETRY DATA (K14 SITE SURVEY) [REF].
4. EXISTING ASSET LOCATIONS EXTRACTED FROM COMPANY PROVIDED IHS DATA. FUGRO SITE SURVEY REPORT FIGURE [REF] DEFINES EXISTING ASSETS ARE BURIED TO A DEPTH >0,6m AT WORK LOCATIONS.
5. THE SPOOL CONFIGURATIONS SHOWN ARE PRELIMINARY AND ARE TO BE CONFIRMED THROUGH FINITE ELEMENT ANALYSIS.
6. THE POSITION OF THE MANIFOLD IS DEPENDENT ON THE RESULTS OF THE SPOOL ANALYSIS.
7. MANIFOLD STRUCTURE ALLOWS FOR CONNECTION OF MOBILE PIG TRAP.
8. UMBILICAL LENGTH GIVEN IS FROM THE UTA TO THE TOPSIDES HANG-OFF COLLAR.
9. SPURLINE WILL BE POST TRENCHED AND BACKFILLED AS PER THE RECOMMENDATIONS CONTAINED WITHIN THE ON-BOTTOM STABILITY DESIGN REPORT. DEPTH OF COVER IS SUBJECT TO THE FINDINGS CONTAINED WITHIN THE SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT [REF] (HOLD 1), NOTING THAT THE MINIMUM REQUIRED BURIAL DEPTH AS PER NEN 3656 is 0,2 M FROM THE TOP OF PIPE. SPOOLS WILL BE PROTECTED USING CONCRETE MATTRESSES OR SIMILAR.
10. NEW ILT STRUCTURE FOOTPRINT TAKEN FROM THIRD PARTY CONTRACTOR DRAWING [REF].
11. PIPELAY DIRECTION NOT YET DEFINED.
12. TOPSIDE FOOTPRINT BASED ON WORKING PLOT PLAN [REF].
13. SUBSEA UMBILICAL IS TO BE BURIED BELOW SEAFLOOR U.N.O. BURIAL DEPTH IS SUBJECT TO THE FINDINGS CONTAINED WITHIN THE SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT [REF] (HOLD 1), NOTING THAT THE MINIMUM BURIAL DEPTH IN-LINE WITH NEN 3656 IS 0,2 M FROM TOP OF UMBILICAL. PROTECTION AND STABILITY OF UMBILICAL (LAID ON SEAFLOOR) AT PLATFORM APPROACHES WILL BE PROVIDED BY CONCRETE MATTRESSES OR SIMILAR.
14. FINAL PIPELINE AND UMBILICAL ROUTE IS SUBJECT TO FURTHER OPTIMISATION AS PART OF THE FRONT END ENGINEERING DESIGN AND DETAILED DESIGN ACTIVITIES. ANY ROUTE ADJUSTMENTS WILL REMAIN WITHIN THE SURVEYED AREA AND WILL ENSURE ADEQUATE SETBACK DISTANCE WITH EXISTING SUBSEA PIPELINES.
15. SURVEY EXTENT OUTSIDE OF THIS VIEW IS TO BE DEFINED BY ARAMIS TRANSPORT TEAM.

LEGEND

- EXISTING BURIED PL (NOTE 4)
- PROPOSED ARAMIS CO_2 TRUNKLINE
- PROPOSED CO_2 SPUR PL
- PROPOSED SPOOL
- PROPOSED UMBILICAL
- -29,5m CONTOUR LINE (NOTE 3)
- CPTU-81 HISTORIC GEOTECHNICAL TEST LOCATION

ABBREVIATIONS

CL	CENTERLINE	ILT	INLINE TEE
DoC	DEPTH OF COVER	ND	NOMINAL DIAMETER
FoF	FACE OF FLANGE	PL	PIPELINE
LAT	LOWEST ASTRONOMICAL TIDE	REF	REFERENCE
UNO	UNLESS NOTED OTHERWISE	TYP	TYPICAL
UTA	UMBILICAL TERMINATION ASSEMBLY		

HOLD

1. SPURLINE AND UMBILICAL DoC TO BE DEFINED AS PART OF THE SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT [REF].

REFERENCE DRAWINGS	
ARS-200-BB4A-K14FA2-10-LA-0780-0001	SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT
ARS-200-BB4A-K14FA2-10-LA-0580-0004	ON BOTTOM STABILITY DESIGN REPORT
ARS-100-BB4A-K14FA2-00-CG-6958-0001	FUGRO SITE SURVEY INTEGRATION RESULTS REPORT
EXTRACT_IHS_PIPELINES.SHP	COMPANY PROVIDED IHS GIS DATA
SSDM_220592_K14_ED50_TM5NE.gdb	COMPANY PROVIDED BATHYMETRY GIS DATA
ARS-200-BB4A-K14FA2-40-MP-4024-0002-001	ARAMIS PLOT PLAN
NL-ARM-050-PTC1-113810 REV 00	SINGLE ILT COMPOSITE GENERAL ARRANGEMENT

REV	DATE	BY	CHECK	APP	DESCRIPTION
02	01/07/24	[redacted]			ISSUED FOR DESIGN
01	02/05/24				ISSUED FOR REVIEW

Document Information Security Classification: Internal

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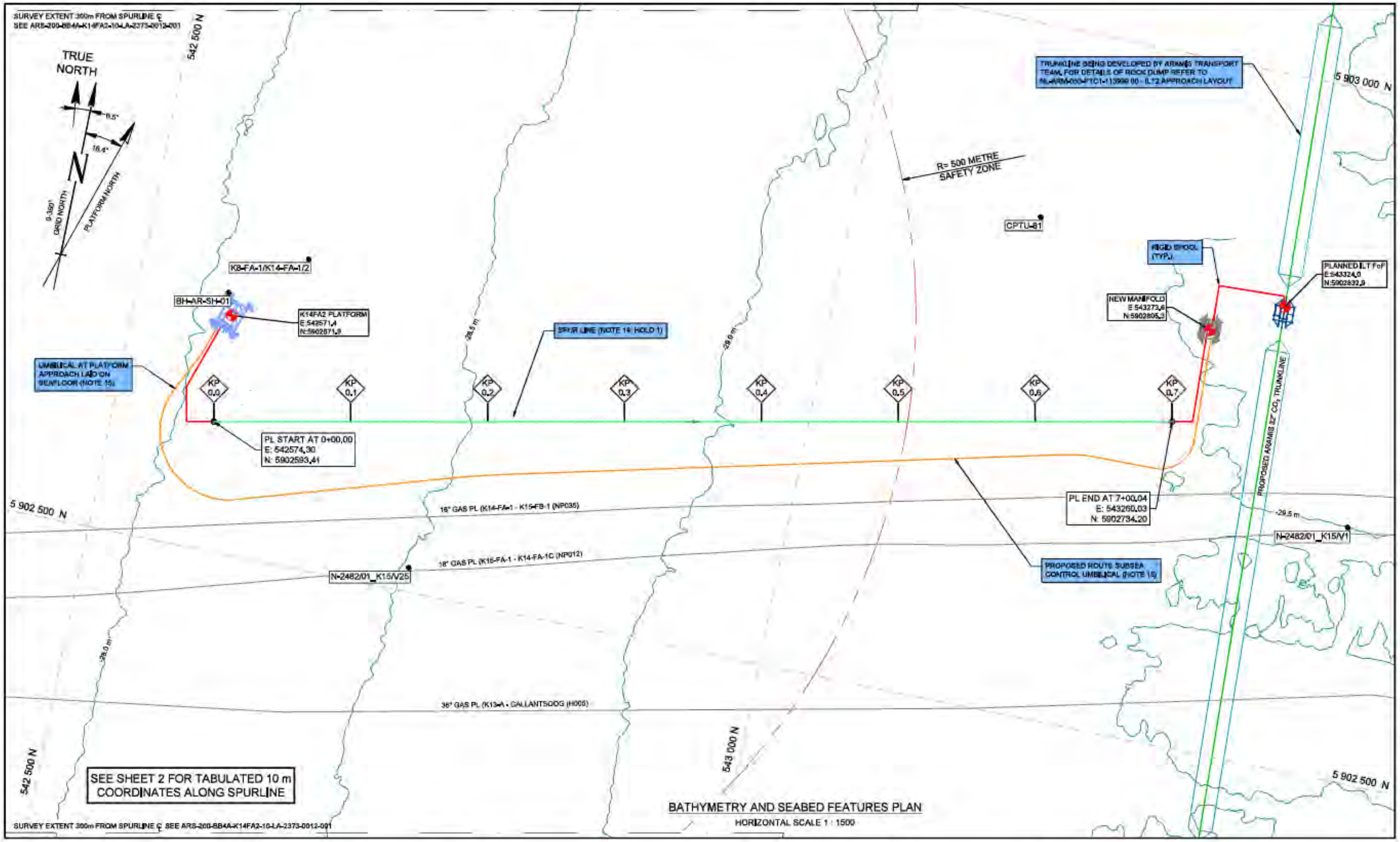
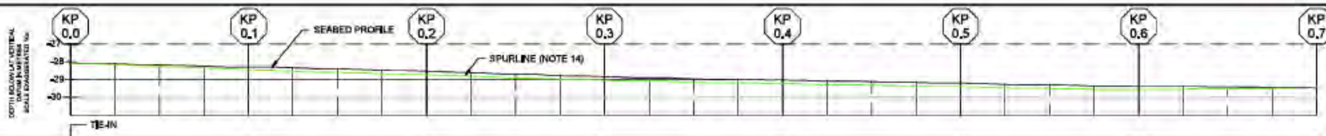
PROJECT	ARAMIS BB4A (SHELL-K14FA2-STORE)	SCALE 1:2k
DRG. TITLE	OVERALL FIELD LAYOUT PERMIT APPLICATION	SIZE A1
ECCN NO. EAR99	BUILDING BLOCK BB4A	AREA CODE 10
DRAWING No. ARS-200-BB4A-K14FA2-10-LA-2373-0012-001	SHT NO. 1 OF 1	REV. 02



BATHYMETRY AND SEABED FEATURES PLAN

HORIZONTAL SCALE 1 : 1500



KILOMETRE POINT ALONG PIPELINE ℄	KP 0,0 – KP 0,1 – KP 0,2 – KP 0,3 – KP 0,4 – KP 0,5 – KP 0,6 – KP 0,7
HORIZONTAL GEOMETRY	L = 700 m
PIPE - SIZE / WALL THICKNESS / GRADE	16" (406,4 mm OD) / 17,5 mm WT / API 5LC GRADE LC65-2205 DUPLEX STAINLESS STEEL LONGITUDINALLY WELDED
PIPE - EXTERNAL CORROSION COATING / THICKNESS / AVERAGE DENSITY	3-LAYER POLYETHYLENE (3LPE) / 2,9 mm THK. (MIN.) / DENSITY 930 kg/m3
PIPE - EXTERNAL CONCRETE WEIGHT COATING / THICKNESS / DENSITY	110 mm THK. (MIN.) / DENSITY 3300 kg/m3
FIELD JOINT COATING (FJC)	PE HEAT SHRINK SLEEVE - DENSITY 930 kg/m3 WITH PU INFILL - DENSITY 800 kg/m3
PIPE WEIGHT - DRY / SUBMERGED (EMPTY)/ SUBMERGED (FLOODED)	766,8 kg/m (IN AIR) / 445,1 kg/m (SUBMERGED EMPTY) / 556,1 kg/m (SUBMERGED FLOODED)
ANODE TYPE / NET MASS PER ANODE/SPACING	CP PROTECTION OF SPURLINE SHALL BE PROVIDED BY ANODES ON THE JACKET AND MANIFOLD STRUCTURE
LATERAL LAY TOLERANCE	± 5 m NORMAL PIPELAY
MAXIMUM ALLOWABLE UNSUPPORTED SPANS	INSTALLATION / OPERATION / HYDROTEST / FLOODED NOT YET DEFINED
SEABED RECTIFICATION / PROTECTION	NONE
CROSSING DETAILS	NONE
SOIL PROPERTIES / STRATIGRAPHY	VERY LOOSE TO MEDIUM DENSE SLIGHTLY SILTY SLIGHTLY CALCAREOUS FINE SAND WITH OCCASIONAL SHELL FRAGMENTS (NOTE 12)
BURIAL DEPTH	DEPTH OF COVER ON SPURLINE (HOLD 1) NOTE 14

LONGITUDINAL SEABED PROFILE

HORIZONTAL SCALE 1 : 1500 / VERTICAL SCALE 1 : 150

NOTES

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3. ALL ELEVATIONS ARE IN METRES REDUCED TO LAT BASED ON COMPANY PROVIDED BATHYMETRY DATA (K14 SITE SURVEY) [REF].
4. ROUTE LENGTHS ARE HORIZONTAL PROJECTION PLAN DISTANCES ONLY AND DO NOT TAKE INTO ACCOUNT ANY CHANGES TO VERTICAL ELEVATION AND BOTTOM ROUGHNESS EFFECTS.
5. PROPOSED ROUTE TO BE VERIFIED DURING PRE-INSTALLATION SURVEY.
6. EXISTING ASSET LOCATIONS EXTRACTED FROM COMPANY PROVIDED IHS DATA. FUGRO SITE SURVEY REPORT FIGURE [REF] DEFINES EXISTING ASSETS ARE BURIED TO A DEPTH >0,6m AT WORK LOCATIONS.
7. THE SPOOL CONFIGURATIONS SHOWN ARE PRELIMINARY AND ARE TO BE CONFIRMED THROUGH FINITE ELEMENT ANALYSIS.
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9. NEW ILT STRUCTURE FOOTPRINT TAKEN FROM THIRD PARTY CONTRACTOR DRAWING [REF].
10. PIPELAY DIRECTION NOT YET DEFINED.
11. TOPSIDE FOOTPRINT BASED ON WORKING PLOT PLAN [REF].
12. SOIL UNIT 1 EXTENDS FROM 0,0 TO 5,6 m BELOW SEAFLOOR, BASED ON GEOTECHNICAL DESIGN BASIS [REF].
13. FOR UMBILICAL ALIGNMENT SHEET, SEE [REF].
14. SPURLINE WILL BE POST TRENCHED AND BACKFILLED AS PER THE RECOMMENDATIONS CONTAINED WITHIN THE ON-BOTTOM STABILITY DESIGN REPORT. DEPTH OF COVER IS SUBJECT TO THE FINDINGS CONTAINED WITHIN THE SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT [REF] (HOLD 1), NOTING THAT THE MINIMUM REQUIRED BURIAL DEPTH AS PER NEN 3656 is 0,2 M FROM THE TOP OF PIPE. SPOOLS WILL BE PROTECTED USING CONCRETE MATTRESSES OR SIMILAR.
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LEGEND

- EXISTING BURIED PL (NOTE 6)
- PROPOSED ARAMIS CO_2 TRUNKLINE
- PROPOSED CO_2 SPUR PL
- PROPOSED SPOOL
- PROPOSED UMBILICAL
- -29,5m CONTOUR LINE (NOTE 3)
- CPTU-81 HISTORIC GEOTECHNICAL TEST LOCATION

ABBREVIATIONS

FoF	FACE OF FLANGE	CL	CENTERLINE
ILT	INLINE TEE	DoC	DEPTH OF COVER
LAT	LOWEST ASTRONOMICAL TIDE	KP	KILOMETER POINT
ND	NOMINAL DIAMETER	THK	THICK
PL	PIPELINE	PE	POLYETHYLENE
REF	REFERENCE	PU	POLYURETHANE
TYP	TYPICAL	OD	OUTER DIAMETER
UNO	UNLESS NOTED OTHERWISE	WT	WALL THICKNESS
UTA	UMBILICAL TERMINATION ASSEMBLY		

HOLD

1. SPURLINE AND UMBILICAL DoC TO BE DEFINED AS PART OF THE SUBSEA FACILITIES INTEGRATED PROTECTION STUDY AND DESIGN REPORT [REF]

REFERENCE DRAWINGS	
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ARS-200-BB4A-K14FA2-10-LA-0580-0004	ON BOTTOM STABILITY DESIGN REPORT
SEE SHEET 3 OF THIS FOLIO	UMBILICAL ALIGNMENT SHEET
ARS-200-BB4A-K14FA2-40-CG-8372-0001	GEOTECHNICAL DESIGN BASIS
ARS-100-BB4A-K14FA2-00-CG-8988-0001	FUGRO SITE SURVEY INTEGRATION RESULTS REPORT
EXTRACT_IHS_PIPELINES.SHP	COMPANY PROVIDED IHS GIS DATA
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NL-ARM-050-PTC1-113910 REV 00	SINGLE ILT COMPOSITE GENERAL ARRANGEMENT

REV	DATE	BY	CHECK	APP	DESCRIPTION
02	01/07/24	[redacted]			ISSUED FOR DESIGN
01	02/05/24				ISSUED FOR REVIEW

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PROJECT	ARAMIS BB4A (SHELL-K14FA2-STORE)
DRG. TITLE	SPURLINE AND UMBILICAL ALIGNMENT SHEET PERMIT APPLICATION
SCALE	1:1500
SIZE	A1
ECCN NO.	EAR99
BUILDING BLOCK	BB4A
AREA CODE	10
DRAWING No.	ARS-200-BB4A-K14FA2-10-LA-2373-0011-001
SHT NO.	1 OF 4
REV.	02

ARAMIS DEVELOPMENT

BB03 FLOW ASSURANCE STUDY REPORT

ARM-PFE-BB3-PRO-REP-0242 / Rev. 3

October 2023

Identification page

Title: Aramis development – Flow Assurance study

Entity: [redacted] Location – Date: [redacted] 12/10/2023

Issued by	Verified by	Approved by
[redacted]		

Keywords (10 max.- other than title): Netherlands, Aramis, Offshore, CO_2 injection, CO_2 with impurities, complex network

Geographical references: Netherlands, Rotterdam, Dutch Continental Shelf, Aramis

Abstract:

The Aramis project is a cooperation between Shell, TotalEnergies, EBN and GasUnie. It aims to develop a CO_2 transportation infrastructure that can bring captured CO_2 from emitters to offshore storage sites on the Dutch Continental Shelf.
The first phase of the project is estimated to bring just over 5 MTPA transport capacity with a full growth case estimated at some 22 MTPA. The design life of the transport infrastructure will be 30 years for end-of-life activities.
A number of impurities are included in the CO_2 specification which could be of a great challenge when defining operating philosophies.

This document presents the steady state and transient thermo-hydraulic analysis performed for the injection of CO_2 with impurities through Aramis injection system and more specifically its trunkline.

The objectives of this report are:

- Determine steady state conditions to confirm the operability of the network while ensuring that the CO_2 remains in the dense phase.
- Support the preparation of an operating philosophy and relevant procedures and equipment for transient operations (first filling, depressurization, Etc.).

Table of Content

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1 GENERAL

1.1 Project presentation

The Aramis project is a cooperation between Shell, TotalEnergies, EBN and GasUnie. Aramis aims to develop a CO_2 transportation infrastructure (together with CO2next and Porthos) that can bring captured CO_2 from emitter to offshore storage sites on the Dutch Continental Shelf.

Where efficient and applicable, the infrastructure will be developed in a phased manner to match the supply of CO_2 (scalable approach). The first phase is estimated to bring just over 5 MTPA transport capacity with a full growth case estimated at some 22 MTPA. The design life of the transport infrastructure will be 30 years for end-of-life activities.

Once the Aramis system is established, it would unlock the majority of offshore storage capacities in the Dutch sector of the North Sea, allowing incremental emitter by emitter decarbonization through incremental storage development.

Aramis Transport Launching phase is targeting to inject a minimum of 5 MTPA average of CO_2 with an aspirational RFSU in Q1 2028 (first pick up of CO_2 at emitters) and first injection in reservoir in Q1 2027. Of the 5 MTPA about 2 MTPA will be transported by barges to the CO2next Terminal. Another 3 MTPA will tie into the yet to be constructed Porthos onshore pipeline (vapor phase) and the existing OCAP pipeline. These volumes will arrive at the Porthos compressor station and will be compressed into the offshore trunkline transporting the CO_2 to the storage sites. The compressors are assumed to be located at the premises of the Porthos compressor station. The injection split for the Launch phase is assumed to be 50/50% between the Shell and TotalEnergies storage fields.

Aramis, a cooperation between TotalEnergies, Shell, EBN and Gasunie, is incorporating, from the onset, a cross-border approach, providing a decarbonization solution for North-West Europe. Aramis will deliver through studies and through establishing agreements with other operators in the transport infrastructure such as Co2next and Porthos an end-to-end transport solution for CO_2 molecules from emitter to store.

The Aramis Transport CCS network, contains the following:

- **Shipping solution - studied by Aramis** - that will collect liquified CO_2 from new export terminals located in the North Sea Port area on both sides of the Westerschelde estuary.
- **A new receiving shipping terminal at Maasvlakte - studied by CO2next** (to be built and operated by CO2next)**:** Liquid CO_2 will be transported by coasters/barges from different industrial clusters located in the Northwest Europe region to a new receiving terminal and temporary storage in an onshore hub located at the Maasvlakte near Rotterdam.
- **Adding compressor capacity to the Porthos compressors station – studied jointly between Aramis and Porthos.** Compressed (gas phase) CO_2 volumes coming by onshore pipeline from Rotterdam and its hinterlands will be further compressed in a compressor station and combined with liquid CO_2 for transport through a new high-pressure, ambient-temperature offshore trunkline to the receiving offshore platforms.
- **A trunkline – studied by Aramis:** Aramis envisages a ~200 km oversized trunkline (dense phase) to the offshore platforms / blocks with tie-in points to cater for future growth and enable third-party access.

The scope for the ARAMIS common infrastructure is divided into Building Blocks (BB). Aramis partners have agreed to develop Building Blocks jointly or individually, see figure below (Ref. [1]).

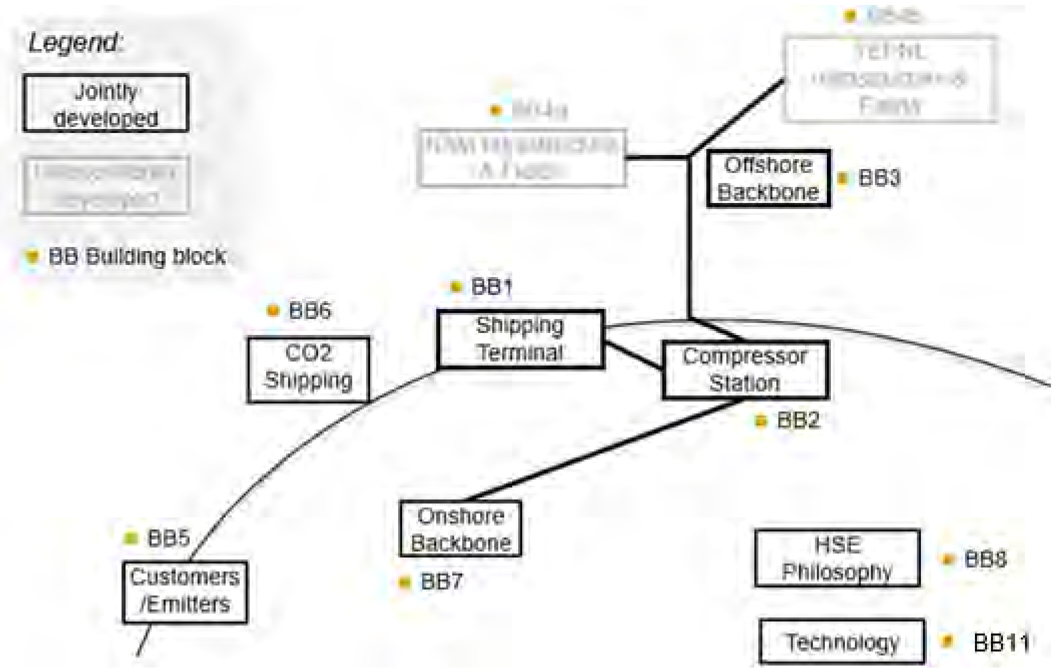

Figure 1-1: Aramis Transport Scope of Work

For the next phase (technical work until start of FEED) the technical work will be led by integrated ARAMIS teams with one company leading each block, as per below table:

	Description	Key focal point/Lead
BB01	Terminal	TotalEnergies
BB02	Compressor	Shell
BB03	Backbone	TotalEnergies
BB06	Shipping	Shell
BB08 A	Operations	Shell
BB08 B	HSSE	Shell / TotalEnergies combined
BB11	ICCS/Telecom	Shell / TotalEnergies combined

Table 1-1: Key focal point for each building block

1.2 Purpose of the document

This document presents the steady state and transient thermo-hydraulic analysis performed for the injection of CO_2 through Aramis trunkline.

The objectives of this report are:

- Determine steady state conditions to confirm the operability of the network while ensuring that the CO_2 remains in the dense phase
- Support the preliminary definition of an operating philosophy and procedures based on transient scenario analyses of key operations expected on field.

1.3 Reference documents

1.3.1 Company documents

The following COMPANY documents are referenced in this document

Ref. [X]	Title	Issuer
Ref. [1]	Aramis Transport: Project premises Document	[redacted]
Ref. [2]	Aramis Project – Aramis BB03 Process Report	

Table 1-2: COMPANY documents

2 EXECUTIVE SUMMARY

2.1 Introduction

Aramis project aims to develop a CO_2 transportation infrastructure that can bring captured CO_2 from emitters to offshore storage sites on the Dutch Continental Shelf. The infrastructure will be developed in a phased manner to match the supply of CO_2. The first phase is estimated to bring just over 5 MTPA transport capacity with a full growth case estimated at some 22 MTPA. The design life of the transport infrastructure will be 30 years for end-of-life activities.
A number of impurities are included in the CO_2 specification. The impurity level of several components, including H_2O, are directly linked to maintaining design integrity.

The injection system starts onshore at the Rotterdam port, goes through a 32'' OD trunkline subsea all the way to the K14 ILT/PLET where the take-off for SHELL wells occurs, before getting to the central platform D-HUBN (Also referred to as DHUB) at about 196 km from the inlet and 33 km from K14 ILT/PLET.

At the DHUB, a second take-off for Neptune wells (Platform L10) occurs. The remaining volume is injected in TotalEnergies area at about 26 km from the DHUB through a 24'' OD spurline. The TotalEnergies area, starts at the level of the PLEM and reaches first L4A platform. Only the trunkline and this part of the injected system are covered in this report.

This document presents the steady state and transient thermo-hydraulic analysis performed for the injection of CO_2 with impurities through Aramis injection system and more specifically its trunkline.

The objectives of this report are:

- Determine steady state conditions to confirm the operability of the integrated network while ensuring that the CO_2 remains in the dense phase. The number of steady state simulations has been optimized by selecting critical sizing years along the injection profiles and the inlet conditions. Only the base cases are presented in this section:

- **Base Case 1**: Max Flowrate of 22 MTPA – discharge pressure 180 barg – Inlet temperature 50°C, and considering subsequent reservoir pressure build-up,
- **Base Case 2**: Startup flowrate of 5 MTPA – discharge pressure 150 barg – Inlet temperature 50°C, with no pressure build-up at reservoir level.

- Support the preliminary definition of an operating philosophy and procedures based on transient scenario analyses of key operations expected on field. The injection case selected to perform transient analysis is 22 MTPA. The conducted transient simulations are listed here below:

- **Shutdown – Packing case 1:** Spurious closure of wells while the pumps are still in operation – 22 MTPA steady state as base case (Base Case 1)
- **Shutdown – Packing case 2**: Spurious closure of the Riser Isolation Valve (RIV) at the DHUB while the pumps are still in operation – 22 MTPA all the way to DHUB steady state as base case (Sensitivity Case 1).
- **Shutdown – Depacking**: Spurious shutdown of pumps while the wells are still open – 22 MTPA steady state as base case (Base Case 1).
- **Planned depressurization:** Shutdown of pumps while the wells are still open, then blowdown through the wells until the pressure in the transport line reaches 10 – 20 bar above highest WHSIP or 10 bar above pressure triggering two-phase flow, the wells are then closed, and

depressurization continues through the Restricted orifices (RO) topside – 22 MTPA steady state as base case (Base Case 1).

- **Depressurization after unplanned abnormal shutdown – wells available:** Spurious closure of wells while the pumps are still in operation which would pack the line at highest pressure, then blowdown through one well, the furthest and having the lowest WHSIP (controlled depressurization) until the pressure in the transport line reaches 10 – 20 bar above this lowest WHSIP or 10 bar above pressure triggering two-phase flow – 22 MTPA steady state as base case (Base Case 1).
- **Depressurization after unplanned abnormal shutdown – wells not available:** Spurious closure of wells while the pumps are still in operation which would pack the line at highest pressure, then blowdown through the RO topsides – 22 MTPA steady state as base case (Base Case 1).

2.2 Results & Recommendations

The main outcomes of the present Flow Assurance study for BB03 are summarized here after:

2.2.1 Steady state results

- **22 MTPA peak rate**

Here after are presented the arrival conditions at each platform along with the flowrates for the 22 MTPA peak rate:

Platform	K14	DHUB	L10	TTE PLEM (3)
Arrival flowrate (MTPA)	8	14	6	8
Arrival flowrate (kg/s)	253.68	443.94	190.26	253.68
Arrival pressure (bara) (1)	137.96	135.18	133.79	136.43
Arrival pressure + topside pressure drop margin (2)	132.96	135.18	128.79	136.43
Temperature (°C)	19.2	17.06	16	16.33

Note:

1. The indicated arrival pressure includes a 10% margin on the pressure drop. Reference height +24 m / MSL except for TTE PLEM which is at -39 m / MSL,

2. The indicated arrival pressure includes both 10% margin on pressure drop and a 5 bar margin representative of topside pressure drop related to piping and chokes. Reference height +24 m / MSL except for TTE PLEM which is at -39 m / MSL,

3. For the peak rate only indicative results of the subsea manifold at 1.9 km from L4A platform and -39 m of water depth are presented

Table 2-1: Arrival conditions at key points of the injection system for 22 MTPA base case

From the present Flow Assurance study, it appears that the injection of 22 MTPA might be highly challenging at the end of life, therefore highlighting the strong effect of the pressure build-up observed in the reservoir during field life.

This is a major uncertainty that is difficult to unlock at this stage.

- **5 MTPA start-up rate**

Here after are presented the arrival conditions at each platform along with the flowrates for the 5 MTPA start-up rate:

Platform	K14	DHUB	L4A
Arrival flowrate (MTPA)	2.5	2.5	2.5
Arrival flowrate (kg/s)	79.27	79.27	79.27
Arrival pressure (bara) (1)	146.49	146.47	146.26
Arrival pressure + topside pressure drop margin (2)	141.49	146.47	141.26
Temperature (°C)	16.96	16.62	15.5

Note:

1. The indicated arrival pressure includes a 10% margin on the pressure drop. Reference height +24 m / MSL,

2. The indicated arrival pressure includes both 10% margin on pressure drop and a 5 bar margin representative of topside pressure drop related to piping and chokes. Reference height +24 m / MSL.

Table 2-2: Arrival conditions at platforms for 5 MTPA base case

2.2.2 Transient simulations results

- **Shutdown – Packing Case 1**

This scenario consists in spurious closure of injection sites (Christmas Tree closure) while onshore pumps are still running.

Pressure build-up anticipated in transport pipeline for this shutdown scenario is presented here after. It is worth mentioning that a Pressure Protection System for the trunkline is supposed to be triggered at 200 barg.

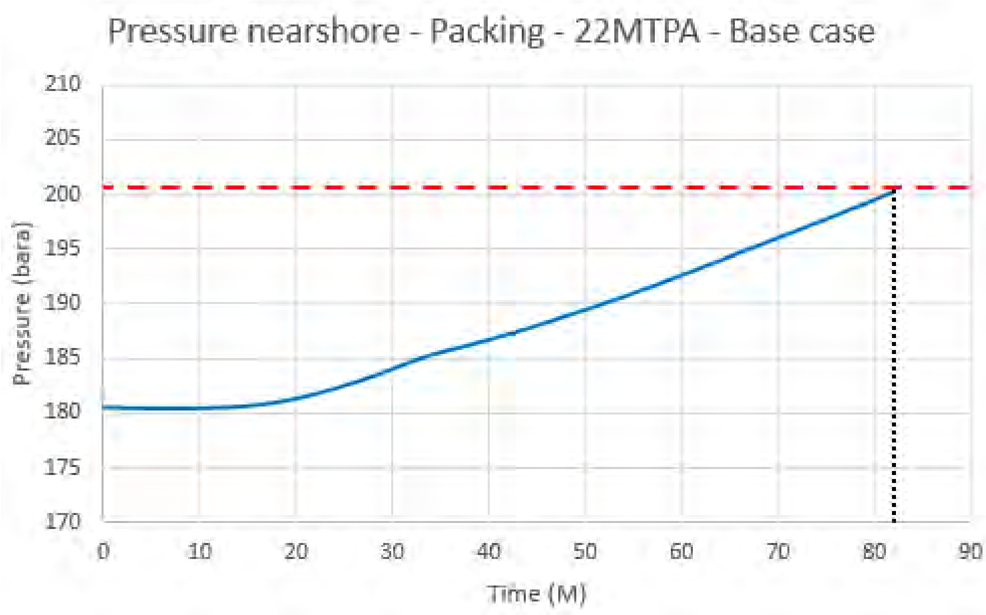

Figure 2-1: Pressure build-up in pipeline with shutdown at injection sites and no shutdown onshore – Base Case

The pressure build-up in the transport pipeline is relatively rapid because of the high initial steady state operating pressure. The higher is the pressure build-up in the reservoir due to CO_2 injection, then the faster is the packing of the transport pipeline. This means that at late life, packing of the trunkline will be faster than at early life conditions.

For the worst scenario (late life, 22 MTPA injection with reservoir pressure build-up), the Pressure Protection System alarm is triggered after 82 min of the unplanned shutdown, leaving enough time for the operators, the pipeline control or pipeline safety system to respond and to avoid a high pipeline shut-in pressure.

- **Shutdown – Packing Case 2**

This scenario consists in spurious closure of Riser Head valve at the central platform DHUB while onshore pumps are still running. This scenario is looked at as faster pressurization is anticipated due to the smaller volume of the pipeline.

Pressure build-up anticipated in transport pipeline for this shutdown scenario is presented here after.

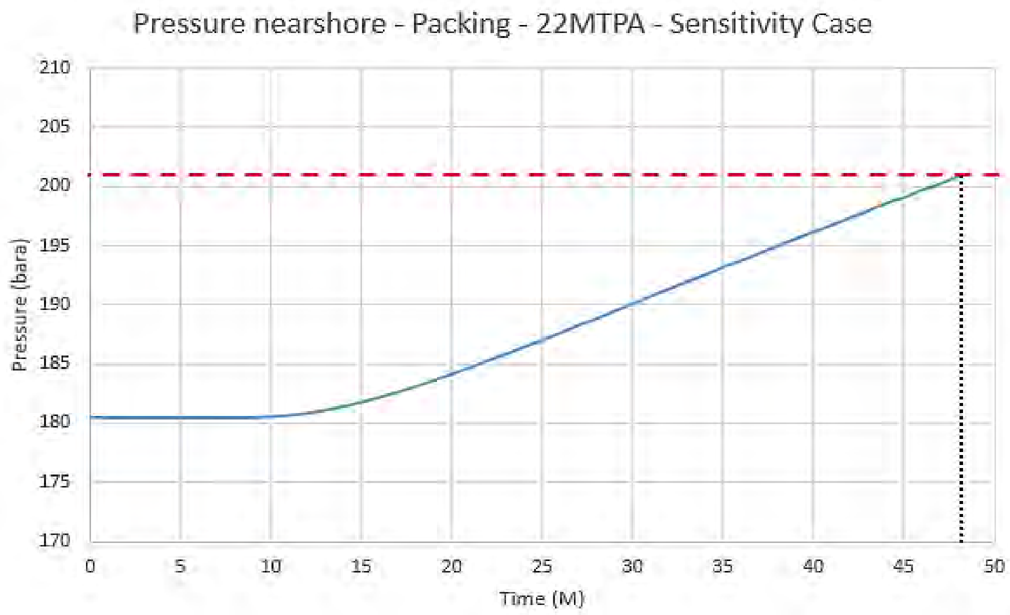

Figure 2-2: Pressure build-up in pipeline with RIV shutdown and no shutdown onshore – Sensitivity Case

As for packing case 1, worst conditions have been considered to define the shortest pressurization time for this sensitivity study, namely, late life conditions with pressurized reservoir and injection at 22 MTPA. For this scenario, the Pressure Protection System alarm is triggered after 48 min of the unplanned shutdown. Even though this case is most likely not to occur, the operators, the pipeline control or pipeline safety system should still have enough time to respond and to avoid a high pipeline shut-in pressure.

- **Shutdown – Depacking**

Transport pipeline blowdown into wells for such shutdown scenario is presented here after:

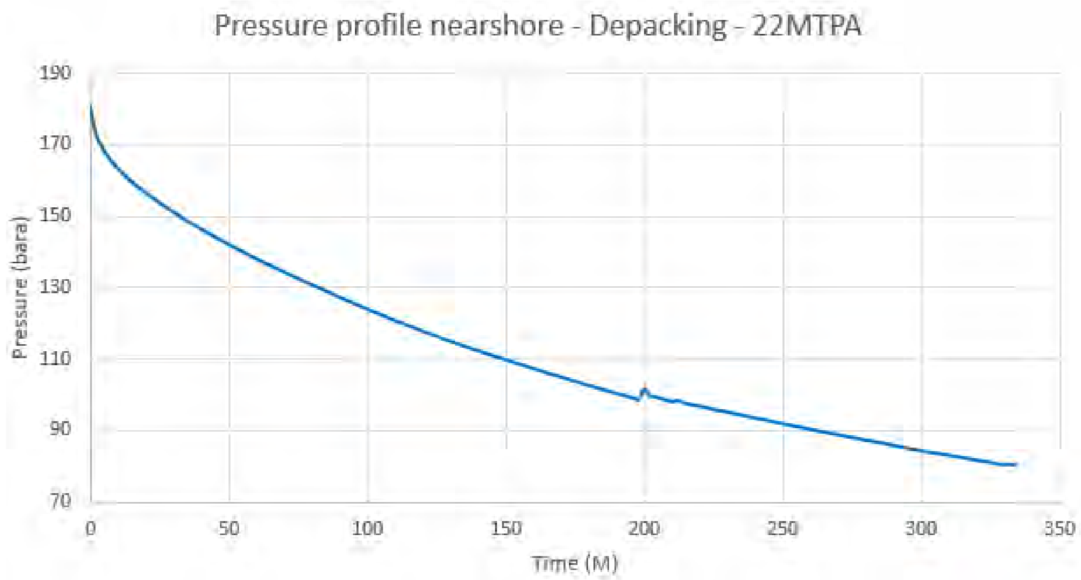

Figure 2-3: Transport pipeline blowdown into wells with shutdown onshore and no shutdown at injection sites

As presented on figure above, the pressure in the transport pipeline decreases by approximately 0.3 bar / min. The present study also highlights that gas flashing is experienced after about 5 hours (300 min) following unplanned shutdown in the beginning of the transport pipeline between the Onshore and the Micro-Tunnel sections.

Those two-phases conditions in the transport pipeline are observed as soon as the Pressure @ Maasvlakte goes below 82 barg. Even with such conditions, operators and control system should have enough time to respond and avoid the appearance of gas pockets within transport pipeline. A pressure set point of 90 barg including a 10 bar margin over the critical point for Low Pressure Alarm should be respected at Maasvlakte terminal, after which the risks of two-phase flow become unavoidable.

Another outcome of the present study is that no crossflow phenomena between the different injection wells will be observed, at least, in the first 5 hours following unplanned shutdown event. The potential risk of cross flow between the different wells has not been further assessed as the injection network should already be in two-phase flow conditions, what should be avoided and can be considered as driving parameter in case of blowdown events.

- **Depressurization**

There is no specific operational requirement for depressurization of the subsea network in normal situation / shutdown. The potential scenarios that may impose a depressurization of the subsea system could be:

- Damage of the transport pipeline requiring repair and then blow-down of subsea system prior any intervention,
- Formation of a plug requiring blow-down to attempt remediating,
- Pipeline decommissioning,
- Operational issues at onshore plant requiring blow-down of the subsea system to control CO_2 release if any.

In the frame of this study, 3 main scenarios have been considered. They are summarized here below. All cases have been covered and deeply assessed. Nevertheless, in order to ease the reading of this report, it has been decided not to present all the cases as all the results are almost similar and proposed design complies with all requirements.

➢ Normal / Planned shutdown:

- Shutdown of the export pumps while the wells are still open in order to empty the pipeline as much as possible,
- When the pressure reaches 90 barg at Maasvlakte terminal and before triggering the two-phase flow, the blowdown through the wells is stopped,
- 1 hour waiting time for the preparation of venting operations,
- Vent through restricted orifice(s),

➢ Abnormal / Unplanned shutdown:

- Spurious closure of wells while the export pumps are still in operation,
- Packing of the transport pipeline at the highest pressure,

- Blowdown operation into the furthest well having the lowest WHSIP (for better control of the depressurization activity, nevertheless number and location of wells still to be defined by Field Operations team – Single well or multi wells operation, acceptance of two-phase flow in well during blowdown, Etc.) until reaching the pressure set point of 90 barg at Maasvlakte terminal, or 10 bar above the lowest WHSIP
- After settle-out pressure in network is about 90 barg or 10 bar above the lowest WHSIP, well is shutdown, and vent through restricted orifice(s) initiated,

Because this case is similar to the planned shutdown with minor differences, only relative results will be presented.

➢ Abnormal / Unplanned shutdown with line packed and wells are not available,

- Representative scenario in case of hydrates plug before reaching the platforms,
- The export pumps are still in operation and the line is packed,
- 1 hour waiting time for the preparation of venting operations,
- Vent through restricted orifice(s).

This case has a very low probability of occurrence as wells should always be available, at least one, which means that blowdown and pressure reduction into transport pipeline should always be possible through the wells at first. Because this case is similar to the planned shutdown with minor differences, only relative results will be presented.

It is worth mentioning that when depressurizing the CO_2 to atmospheric conditions, extremely low temperatures are anticipated whatever the scenarios considered. Therefore, it is important to control the pressure in the transport pipeline during depressurization operations in order to comply with design temperatures of the transport pipeline. The control of the pressure during blow-down has been achieved by considering staggered depressurization sequence and by adjusting the diameter of the Restriction Orifices over depressurization sequence.

Since there is a high risk of ice formation around the pipe at very low temperatures and in order to take into account enough margin to cover the uncertainties related to *OLGA* software, the minimum considered temperature is 0°C. It is also worth mentioning that the depressurization simulations are very slow, and the temperature does not fall rapidly which means that the margin over the temperature could be relaxed as these calculations are not considered as fast transient.

The back pressure downstream Restriction Orifice should be also defined to avoid ice formation in the depressurization system. In the present study, and considering the phase diagram of CO_2, the pressure has been fixed at 7 bara (above triple point) to avoid ice formation and risk of plugging of depressurization lines. The transition from 7 bara to atmospheric conditions at vent and associated equipment should be developed by Process in accordance with Flow Assurance outcomes / recommendations presented in this report and to mitigate the risks of plugging of the depressurization network.

After completion of the different analyses, proposed design of depressurization system consists in implementing 4 Restriction Orifices. This arrangement has been identified as the best compromise in order to avoid too low temperatures in transport pipeline with regard to design temperature and water icing risks, but also to shorten the duration of the depressurization sequence.

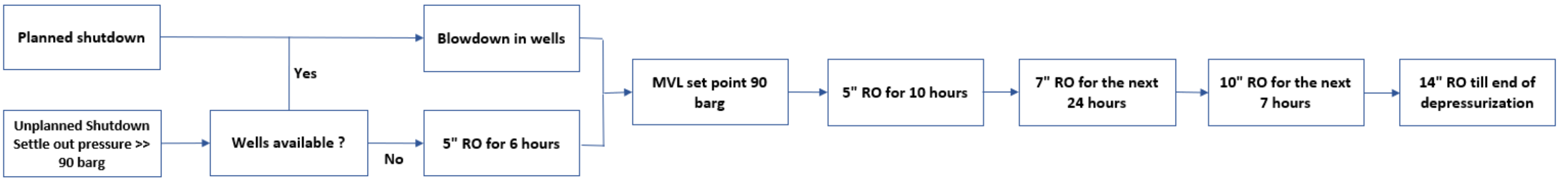

Figure 2-4: Depressurization sequence – Staggered Restriction Orifices

Proposed diameters of the Restriction Orifice are 5, 7, 10 and 14 inches for the depressurization of the BB03 trunkline. Those Restriction Orifices are used in sequence (the one after the other). The switch between the first and second Restriction Orifices occurs 10 hours after depressurization of first RO. 24 hours later, occurs the second switch. The third switch occurs 7 hours after depressurization of third RO. The minimum achieved bulk temperature is 1°C (for a few minutes) to which a 5°C margin should be applied to define the minimum design temperature of the pipeline.

The duration of the depressurization starting from a pressure set point of 90 barg at MVL lasts approximately 2 days and a half (58 hours).

Concerning the unplanned shutdown with wells available post packing of the line, the blowdown through the furthest well with the lowest WHSIP lasts a little more than 10 days until reaching the pressure set point of 90 barg. In the present study, the WHSIP of the considered well for blowdown operations being lower than 90 barg, the two-phase flow condition is driving the switch to Restriction Orifice to complete the depressurization of the injection network. Once the pressure set point is reached at MVL terminal, the proposed operating philosophy detailed above can be applied.

On the other hand, for the unplanned shutdown with line packing and wells not available, the procedure of the depressurization can start directly with a 5” RO (approximately 6 hours until reaching 90 barg at MVL then continue with 10 hours before switching to a bigger RO) and the steps detailed above can still be valid and applicable as the temperature can still be controlled and does not drop to very low values, respecting the 0°C threshold. The only possible difference with the planned shutdown sequence is that the first step of 5” RO can be longer than expected. Nevertheless, there is no risk of dropping to very low temperatures and ice formation around the pipe can be avoided.

Because of the isenthalpic phenomena during the liquid blow-down, the minimum expected temperature downstream the different Restriction Orifices is about -56°C. Those low temperatures should be experienced as long as liquid CO_2 will be observed downstream Restriction Orifice. A 20°C margin is then added to the minimum temperature leading to a design temperature of the topside piping of - 76°C.

3 BASIS OF DESIGN

3.1 Software and margins

3.1.1 Thermodynamic software

Because of the relatively new topics in the industry dealing with pure CO_2 injection, it is admitted that the accuracy of the different available thermodynamic packages might be questionable. This is mainly due to the presence of the various impurities that affect the phase envelope of the CO_2.

For compatibility reasons between the thermodynamic and multiphase flow software, *Multiflash – commercial version - 7.1* was used to generate the fluids. The following models and adjustments were used:

- Thermodynamic model: SRK Advanced (RKSA in *Multiflash*) with CO_2 volume shift (VSRK=6.2x10^{-6}m^3/mol)
- Viscosity: Super TRAPP
- Thermal conductivity: Super TRAPP

3.1.2 Multiphase flow software

OLGA 2021.2.0 has been used as a reference for all thermo-hydraulic analyses (steady state and transient).

Due to the nature of the fluid and the presence of the impurities, a compositional tracking approach has been considered as base case for all Flow Assurance studies.

3.2 Environmental data

The ambient conditions are presented in the following table (Ref. [1]):

Ambient temperature (°C)		
Depth (m)	**Cold case (winter)**	**Warm case (summer)**
Air	-4.7	21.7
0	-0.5	21.1
1	4.0	16.0
30	4.0	16.0
50	4.0	16.0

Table 3-1: Ambient conditions

In a conservative approach, the warm case set of data is considered for thermo-hydraulic calculations since it maximizes the pressure losses.

No current has been accounted for on the external surface of the production pipe in the frame of this study (faster cooling effect during transient operations, almost no impact on trenched / buried sections in the steady state, slightly under conservative for exposed sections in the steady state but impact negligible on the final results).

3.3 Injection system description

The injection system starts onshore at the Rotterdam port, goes through a 32'' OD trunkline subsea all the way to the K14 ILT/PLET where the take-off for SHELL wells occurs, before getting to the central platform D-HUBN (Also referred to as DHUB) at about 196 km from the inlet and 33 km from K14 ILT/PLET. At the DHUB, a second take-off for Neptune wells (Platform L10) occurs. The remaining volume is injected in TotalEnergies area at about 26 km from the DHUB through a 24'' OD spurline. The TotalEnergies area starts at the level of the PLEM. The L4A platform is located at 1.9 km from the PLEM. The trunkline is also referred to as BB03.

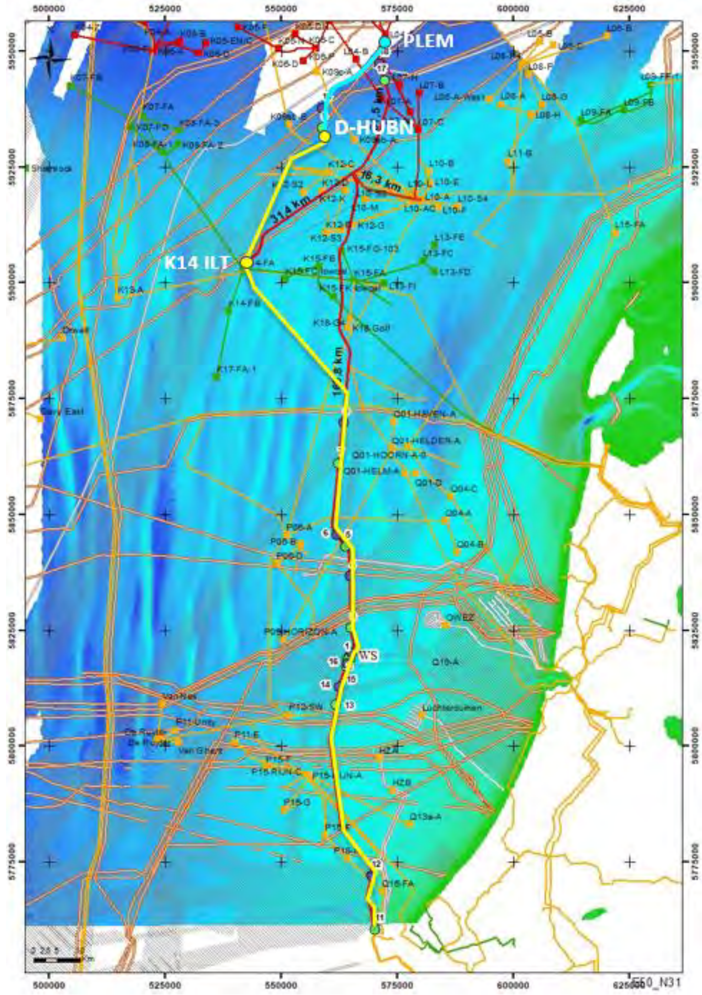

Figure 3-1: Aramis injection system

3.3.1 Injection system description

The following tables detail the characteristics of Aramis injection system (Ref. [1])

Flowline	Length (km)	Outer diameter (in)	Internal diameter (mm)	Roughness (mm) (1)
Onshore to Maasvlakte terminal	1.92	32	755.6	0.045
Maasvlakte terminal to K14 ILT	160.95	32	755.6	0.045
K14 ILT to DHUB	33.5	32	755.6	0.045
DHUB to PLEM	26.2	24	565.1	0.045
K14 ILT to K14 platform	2	24	565.1	0.045
DHUB to L10 platform	20	24	565.1	0.045
PLEM to L04-A	1.88	24	565.1	0.045
Note: **1.** The considered roughness is conservative and representative of the roughness after a few years in operation of the transport pipeline				

Table 3-2: Injection system characteristics

3.3.2 Bathymetries

The figures here below present the elevation profile of each section of the main trunkline and the spurlines provided by the geospatial team.

The status of the transport pipeline at seabed (exposed, trenched, Etc.) has been added to the different figures. When there is no available information, the pipe is considered exposed. Should the transport pipeline be fully or partially buried on short sections, then no impact is anticipated on the results of the Flow Assurance study summarized in the present report.

3.3.2.1 Main trunkline

The coating of the transport pipeline at seabed is very different from a section to another due to several external constraints (shipping lanes, platform zone, micro-tunnel nearshore...). The length and position of each section are shared by pipeline specialists (Onshore and nearshore flowlines) and geospatial team (Shipping lanes). The platform zone is an extended area 500 m from platforms as defined in pipeline design code / standards.

At shore approach, the transport pipeline connection to onshore facilities is achieved through a drilled micro-tunnel.

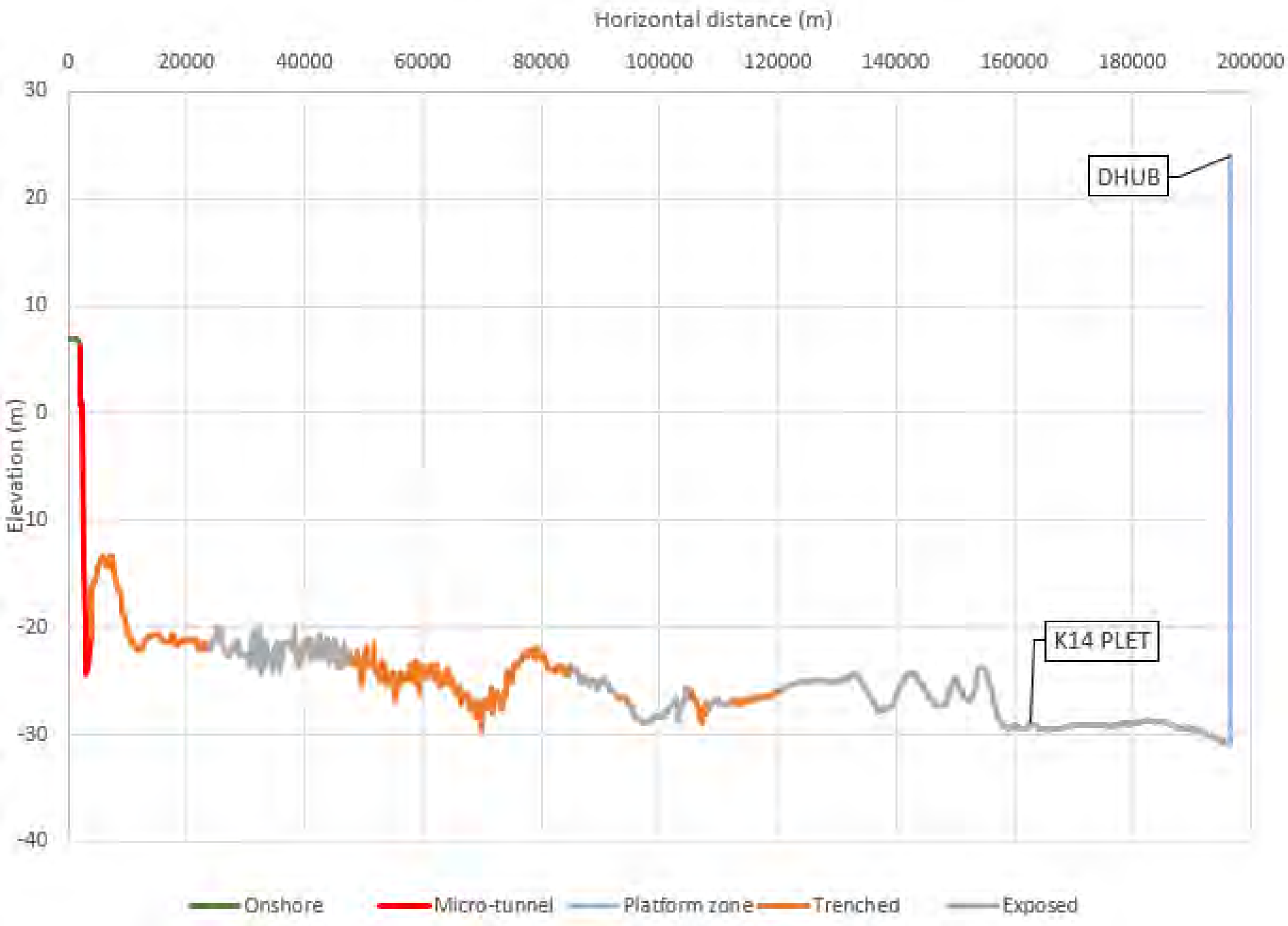

Figure 3-2: Trunkline - Onshore to DHUB pipeline bathymetries

The total measured length of the trunkline is about 198.3 km.

3.3.2.2 Main Spurlines

The main spurlines are part of the injection system. The pipe diameter is the main difference with the trunkline. The spurlines are listed here after:

- DHUB to L4A PLEM: Total measured length is about 26.2 km.
- L4A PLEM to L4A platform: Total measured length is about 1.9 km.
- K14 PLET to K14 platform: Total measured length is about 2 km.
- DHUB to L10 platform: Total measured length is about 20 km.

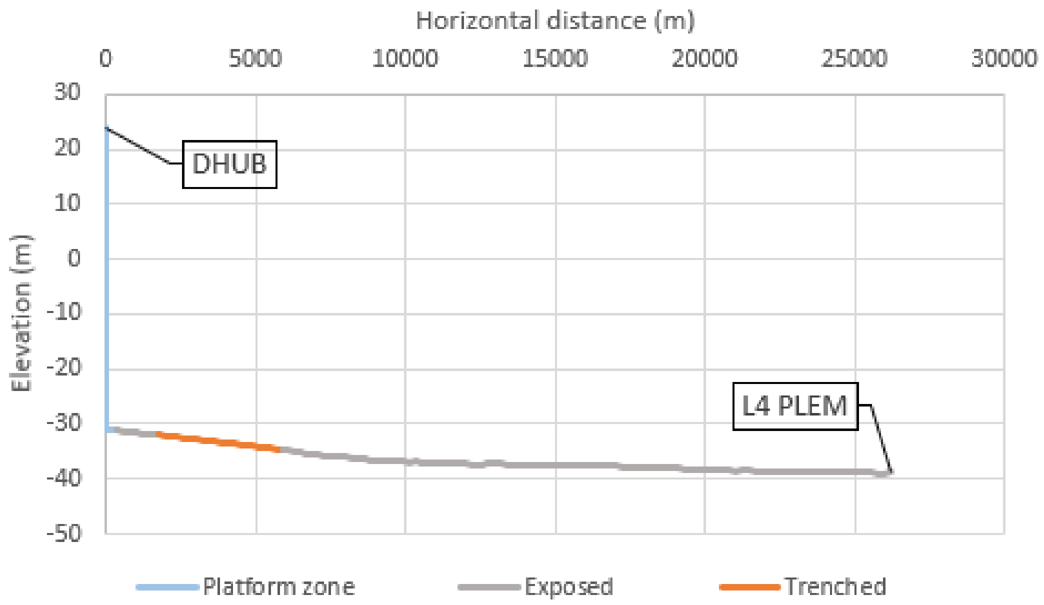

Figure 3-3: Section C (DHUB to L4A PLEM) pipeline bathymetries

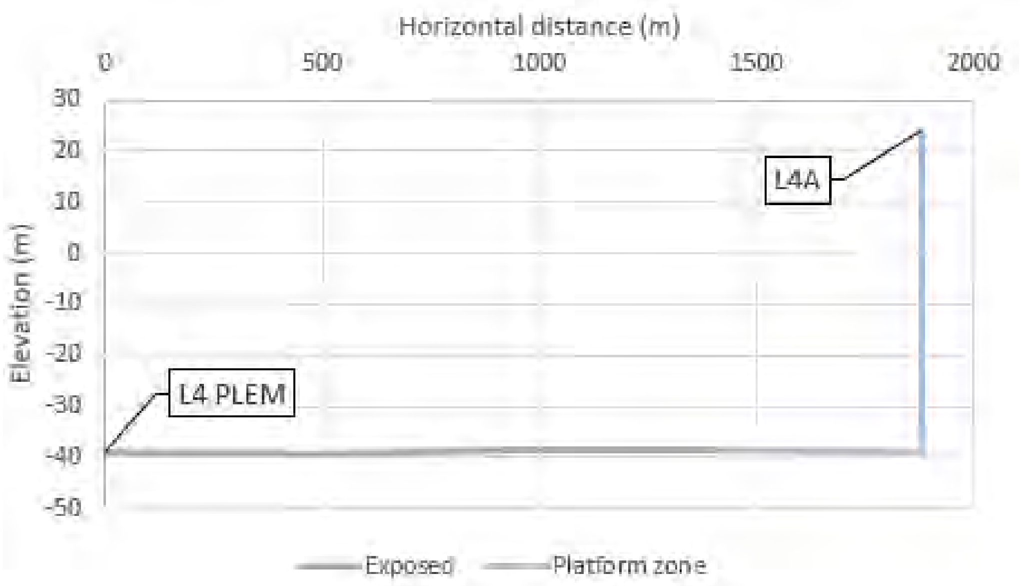

Figure 3-4: L4 PLEM to L4A platform pipeline bathymetries

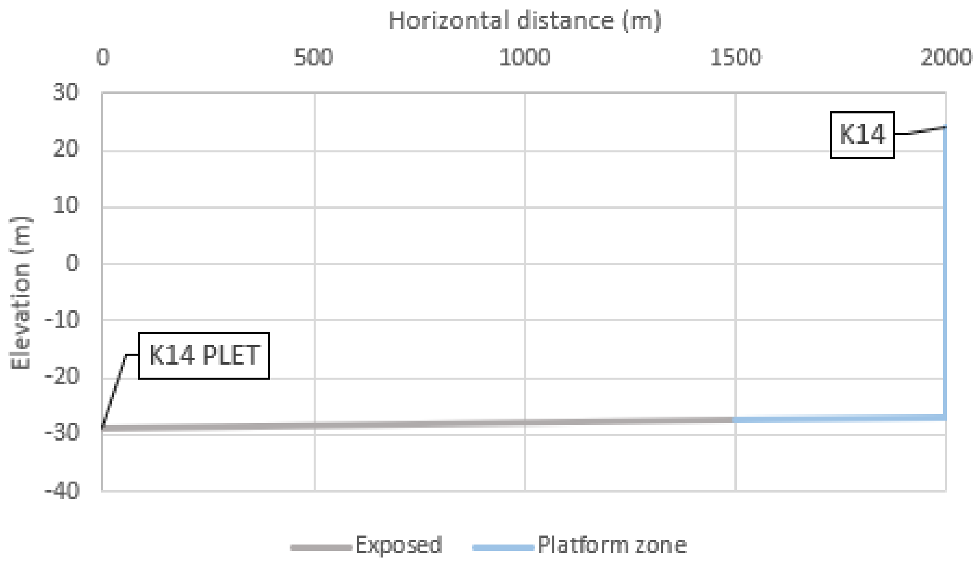

Figure 3-5: K14 PLET to K14 platform pipeline bathymetries

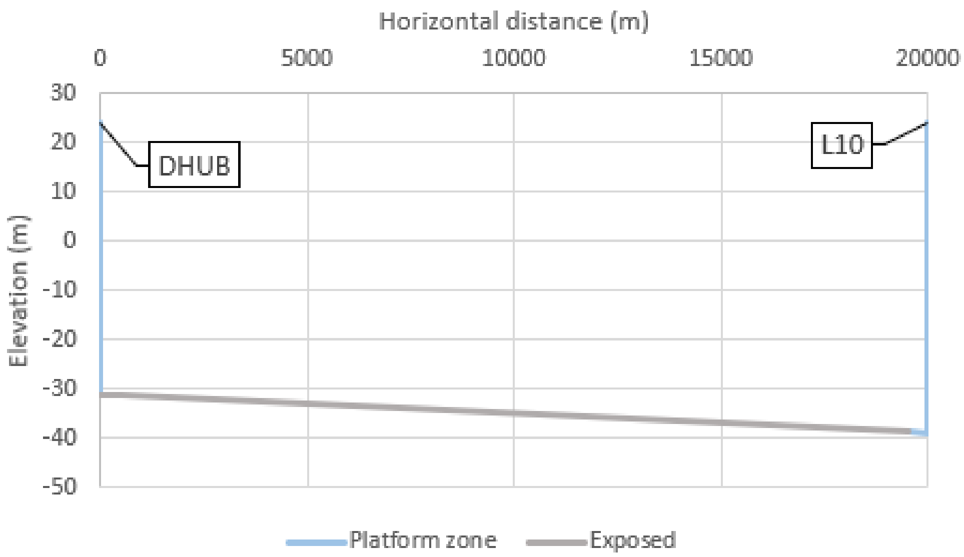

Figure 3-6: DHUB to L10 platform pipeline bathymetries

3.3.3 Cross sections of the flowlines

3.3.3.1 Main trunkline

The following table gives the cross section of the pipeline and risers considered for the study and the thermal properties of the different materials used in the analysis and as modelled in *OLGA*. These thermal properties are based on conservative values. Typically, the thermal conductivity is based on wet, aged values, while the density and heat capacity are based on initial conditions.

Different cross-sections for the transport pipeline will be observed along the pipe route due to the nature of soil, the presence of the micro-tunnel and several shipping lanes. In order to capture any potential impact of those different cross-sections during transient operations of the pipeline on the flowing temperature, a detailed modeling of the transport pipeline has been therefore developed in the *OLGA* model by implementing all the different cross sections.

Most of pipeline characteristics have been shared by the pipeline specialists. Should any information be missing, an assumption in then taken and discussed with the pipeline specialist.

It is worth mentioning that all burial depths have been recalculated by an internal tool (methodology almost similar to recommendation implemented in *OLGA User Manual*) that has been developed to estimate an equivalent thickness taking into account upper and lower layers of soil around the pipe. Because of the thickness of the equivalent layer, the density and heat capacity of the soil have been slightly modified to adjust the thermal inertia of the soil according to burial depth as per TotalEnergies internal practises in order not to over-estimate the Cool-Down time performance of the buried section. This should be revisited at next phase depending on the modelling approach considered for buried section modelling.

All pressure requirement calculations in the present Flow Assurance study are considering a transport pipeline roughness of 45 μm, which is conservative and representative of the roughness after few years in operations of the transport pipeline.

All the cross-sections included in the model are summarized in the different tables here below.

Buried – Onshore – 32'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m^3)**	**(J/kg.C)**
Carbon steel	755.64	28.6	812.8	45	7850	470
3LPP	812.8	3.0	818.8	0.22	900	1750
Concrete	818.8	150	1118.8	3	2500	960
Buried Sand	1118.8	2510.0 (1)	6138.72	1.8	1780	907.2

Note:
1. The pipe has a burial depth of 1 m. The presented value is an equivalent thickness taking into account lower layer as well.

Table 3-3: Cross sections & thermal properties of the Onshore section

Micro-tunnel – 32'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m^3)**	**(J/kg.C)**
Carbon steel	755.64	36.7	829.04	45	7850	470
3LPP	829.04	10	849.04	0.22	900	1750
Sea Water	849.04	3.7 (2)	856.36	0.6	1000	4180
Onshore rock	856.36	31174.5 (1)	63205.3	2.25	2300	850

Note:
1. The pipe has a burial depth of 15 m. The presented value is an equivalent thickness taking into account lower layer as well.
2. The thickness of the water layer has been calculated based on the volume of the drilled section

Table 3-4: Cross sections & thermal properties of the micro-tunnel

Shipping channels - trenched – 32'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m³)**	**(J/kg.C)**
Carbon steel	755.64	28.6	812.8	45	7850	470
3LPP	812.8	3.0	818.8	0.22	900	1750
Concrete	818.8	130	1078.8	3	2500	960
Buried Sand	1078.8	1679.5 (1)	4437.85	1.8	1780	907.2

Note:
1. The pipe has a burial depth of 0.6 m. The presented value is an equivalent thickness taking into account lower layer as well.

Table 3-5: Cross sections & thermal properties of the shipping channels (trenched) – trunkline

Platform zones – 32'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m³)**	**(J/kg.C)**
Carbon steel	755.64	30.2	816	45	7850	470
3LPP	816	3.0	822	0.22	900	1750
Concrete	822	150	1122	3	2500	960

Table 3-6: Cross sections & thermal properties of the platform zones – trunkline

Exposed pipes – 32'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m³)**	**(J/kg.C)**
Carbon steel	755.64	28.6	812.8	45	7850	470
3LPP	812.8	3.0	818.8	0.22	900	1750
Concrete	818.8	150	1118.8	3	2500	960

Table 3-7: Cross sections & thermal properties of the exposed pipes – trunkline

3.3.3.1 Main Spurlines

Shipping channels - trenched – 24'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m³)**	**(J/kg.C)**
Carbon steel	565.14	22.2	609.6	45	7850	470
3LPP	609.6	3.0	615.6	0.22	900	1750
Concrete	615.6	110	835.6	3	2500	960
Buried Sand	835.6	1147.6	3130.7	1.8	1780	907.2

Note:
1. The pipe has a burial depth of 0.6 m. The presented value is an equivalent thickness taking into account lower layer as well.

Table 3-8: Cross sections & thermal properties of the shipping channels (trenched) – Main spurlines

Platform zones – 24'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m^3)**	**(J/kg.C)**
Carbon steel	565.14	23.8	612.8	45	7850	470
3LPP	612.8	3.0	618.8	0.22	900	1750
Concrete	618.8	100	818.8	3	2500	960

Table 3-9: Cross sections & thermal properties of the platform zones – Main spurlines

Exposed pipes – 24'' OD						
Layer / Material	**ID**	**Thickness**	**OD**	**Conductivity**	**Density**	**Specific heat**
	mm	**mm**	**mm**	**(W/m.K)**	**(kg/m^3)**	**(J/kg.C)**
Carbon steel	565.14	22.2	609.6	45	7850	470
3LPP	609.6	3.0	615.6	0.22	900	1750
Concrete	615.6	110	835.6	3	2500	960

Table 3-10: Cross sections & thermal properties of the exposed pipes – Main spurlines

3.4 CO_2 specifications – key assumptions

Two entry specifications are considered, one for CO_2 arriving by ship (liquid CO_2) and one for CO_2 arriving by vapor phase pipeline (gaseous CO_2). This section outlines entry specifications and design compositions for the respective building blocks.

The following limits on impurities are carried (Ref. [1]):

Class	Component	Constraint	unit	value
	CO_2	larger than	mol%	balance
	H_2O	less than	ppmmol	30
inerts	N_2	less than	mol%	-
	O_2	less than	ppmmol	10
	H_2	less than	ppmmol	500
	Ar	less than	mol%	-
	CH_4	less than	mol%	-
	CO	less than	ppmmol	1200
	$O_2+N_2+H_2+Ar+CH_4+CO$	sum less than	ppmmol	2000
	NO_x	sum less than	ppmmol	10
sulphur	SO_x	sum less than	ppmmol	10
	H_2S	less than	ppmmol	5
	CarbonylSulphide	less than	ppmmol	-
	DimethylSulphide	less than	ppmmol	-
	H_2S + COS + SO_x + DMS	sum less than	ppmmol	-
Volatile organic components	Amine	less than	ppmmol	10
	Formaldehyde	less than	ppmmol	20
	Acetaldehyde	less than	ppmmol	20
	Aldehydes	sum less than	ppmmol	-
	carbolylic acids & amides	sum less than	ppmmol	-
	phosphorus-containing compounds	sum less than	ppmmol	-
	NH_3	less than	ppmmol	10
	Ethylene (C_2H_4)	sum less than	ppmmol	-
	H-Cyanide (HCN)	less than	ppmmol	-
	Total volatile organic compounds (excl. MeOH, EtOH, aldehydes)	sum less than	ppmmol	10
	Methanol	less than	ppmmol	40
	Ethanol	less than	ppmmol	20
Heavies	glycols (TEG)	sum less than		-
	C_{2+} (aliphatic hydrocarbons)	sum less than	ppmmol	-
	Aromatic Hydrocarbons	sum less than	ppmmol	-
Metals	Hg	less than	ppbmol	30
	Cadmium + Thalium	sum less than	ppbmol	30

Table 3-11: Aramis Liquid CO_2 - Specifications for CO_2 loaded in the CO_2 ships/barges

Class	Component	Constraint	unit	value
	CO_2	larger than	mol%	95
	H_2O	less than	ppmmol	70(1)
inerts	N_2	less than	mol%	2.4
	O_2	less than	ppmmol	40
	H_2	less than	ppmmol	7500
	Ar	less than	mol%	0.4
	CH_4	less than	mol%	1
	CO	less than	ppmmol	750
	$O_2+N_2+H_2+Ar+CH_4+CO$	sum less than	ppmmol	40000
	NO_x	sum less than	ppmmol	5
sulphur	SO_x	sum less than	ppmmol	-
	H_2S	less than	ppmmol	5
	CarbonylSulphide	less than	ppmmol	0.1(2)
	DimethylSulphide	less than	ppmmol	1.1(2)
	H_2S + COS + SO_x + DMS	sum less than	ppmmol	20
Volatile organic components	Amine	less than	ppmmol	1
	Formaldehyde	less than	ppmmol	-
	Acetaldehyde	less than	ppmmol	0.2 (2)
	Aldehydes	sum less than	ppmmol	10
	carbolylic acids & amides	sum less than	ppmmol	1
	phosphorus-containing compounds	sum less than	ppmmol	1
	NH_3	less than	ppmmol	3
	Ethylene (C_2H_4)	sum less than	ppmmol	1(2)
	H-Cyanide (HCN)	less than	ppmmol	2
	Total volatile organic compounds (excl. MeOH, EtOH, aldehydes)	sum less than	ppmmol	10
	Methanol	less than	ppmmol	620
	Ethanol	less than	ppmmol	20
Heavies	glycols (TEG)	sum less than		Follow dew-point specs
	C_{2+} (aliphatic hydrocarbons)	sum less than	ppmmol	1200
	Aromatic Hydrocarbons	sum less than	ppmmol	0.1
Metals	Hg	less than	ppbmol	-
	Cadmium + Thalium	sum less than	ppbmol	-
Dew-point	Dew point (any liquid phase)	sum less than	°C (@ 20 bar)	-10 (3)

Table 3-12: Aramis Gaseous CO_2 - Specification for CO_2 loaded in the CO_2 pipeline

Notes

1. Specification maintained at 40 ppmmol as per OCAP spec. CO2 spec v 3.1 for Porthos infrastructure is 70 ppm.

2. Specification as per OCAP specification (OCAP-ME-20180307-JLi) and only applicable for emitters that will also flow via OCAP infrastructure.

3. Measured or predicted using CPA equation of state.

A number of impurities are included in the overview without a specific limit to their content. Emitters agree to inform Aramis in case these components are expected in the CO_2 product at levels above 1 ppmmol. Aramis will then conduct a risk assessment study to understand the maximum amount that can be tolerated (Ref. [1]).

The Aramis design does not contain facilities to remove impurities above agreed values. The impurity level of several components, including H_2O, are directly linked to maintaining design integrity.

The design composition for phase behavior and thermophysical properties is derived as follows:

- Volatile organic components are modelled as Methanol
- C2+ is modelled as Ethane
- Components <= 1 ppmmol are ignored
- For pipeline, the nitrogen content is adjusted to meet the total inert spec. All other inert components are at their maximum allowable individual level.
- Sulphur oxides are modelled as SO_2.

Component	Amount (mol)
CO_2	95
H_2O	0.004
N_2	2.4
O2	0.004
H_2	0.75
AR	0.4
CH_4	1
CO	0.075
NO	0.003
NO_2	0.002
SO_2	0
H_2S	0.00511
NH_3	0.0003
HCN	0.0002
METHANOL	0.064
ETHANOL	0.002
ETHANE	0.12

Table 3-13: Final CO_2 specification

Due to the introduction of the impurities, the phase envelope is subject to be modified compared to initial specifications. The higher will be the impurities content in the specifications, the larger will be the phase envelope, therefore potentially triggering the risks to observe two-phases flow conditions in the transport system in case of low pressure. The effect of impurities may also impact the accuracy of the Flow Assurance outcomes in two phase operational area if any.

The figures here below summarize the phase envelope associated to the different specifications along with the Water Dew curve:

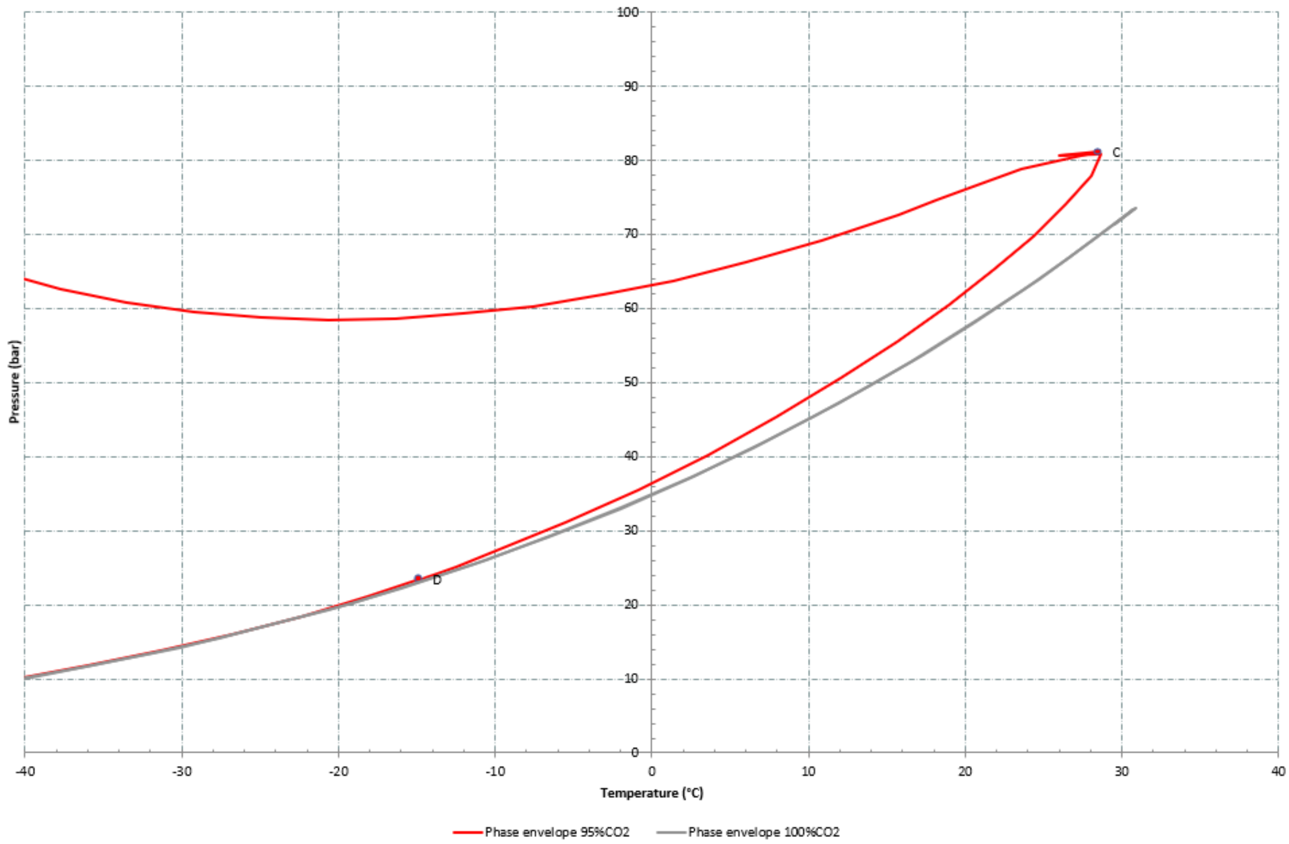

Figure 3-7: Comparisons of phase envelope between pure CO_2 & 95% CO_2 composition

As observed on the phase envelopes of pure CO_2 in comparison with CO_2 with impurities, the critical point of CO_2 fluid with impurities is higher than the one of pure CO_2 fluid (81.2 bar vs. 73.6 bar), making the fluid containing the impurities more conservative.

It is also worth mentioning that the introduction of impurities in the CO_2 specification affects the water solubility and therefore the water dew curve as those impurities will interact with water. This might increase the risks of appearance of free water and therefore the risks of corrosion.

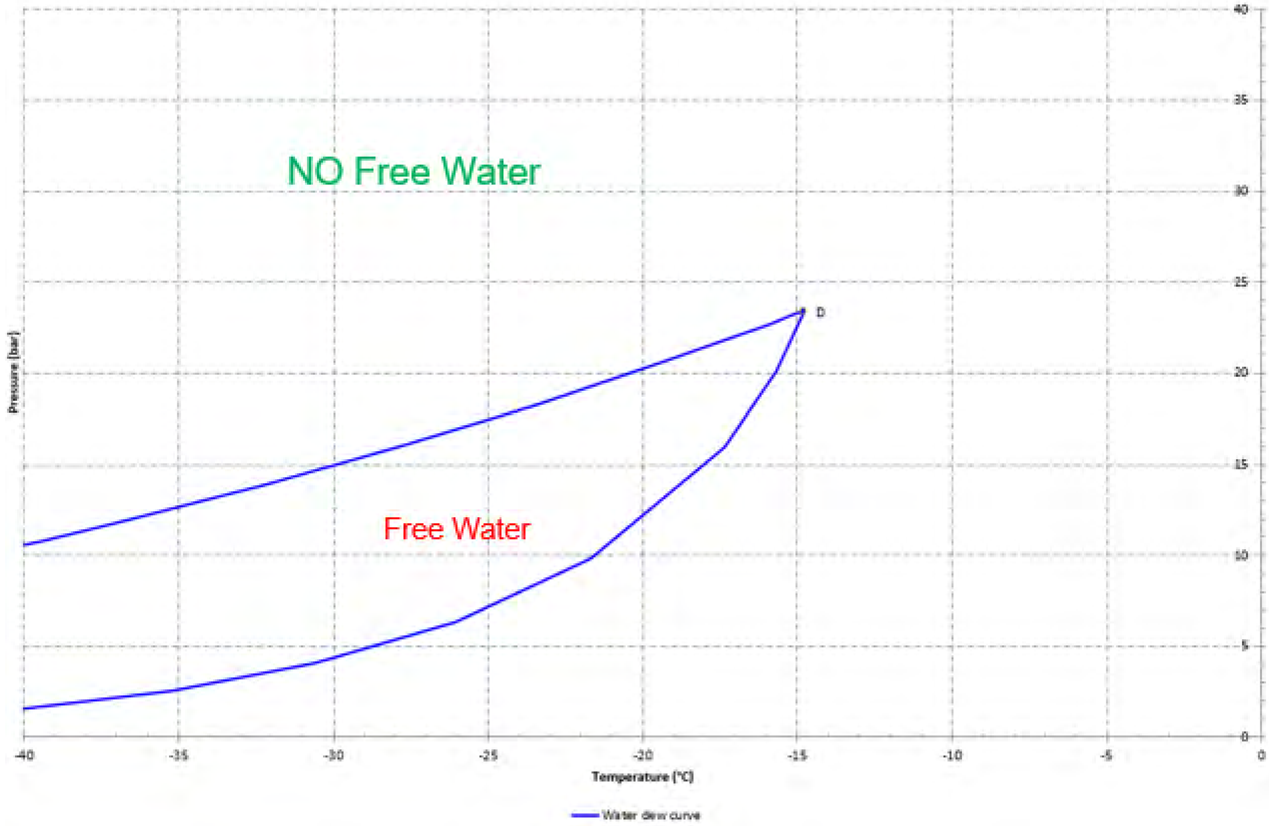

Figure 3-8: Water dew curve considering 95% CO_2 composition

According to liquid CO_2 specification and anticipated operating conditions in the injection system, there is no risk to observe free water, therefore mitigating the hydrates risks and the risks of corrosion in the system. Should the liquid CO_2 specification be revisited, then the risks to observe free water in the system should be updated accordingly.

Specific attention should be nevertheless paid during first filling operations of the trunkline with CO_2 as low pressure and low temperature might be observed during this specific operation, making operating conditions not so far from water dew curve with the latest proposed sequence by EBN (Appendix **Erreur ! Source du renvoi introuvable.**). This should be further evaluated at next phase of the project.

Due to CO_2 injection in an aquifer, hydrates risks could be triggered in the injection wells after "long" shutdown as the CO_2 stream should be saturated with higher water content than what is mentioned in the liquid CO_2 specification. The time for the CO_2 contained in the tubing to be saturated with water during shutdown is difficult to evaluate but risks cannot be neglected at this stage.

Such negative outcome imposes the implementation of specific operating procedure prior restarting wells as for instance bullheading of MEG within injection tubing before the opening of the Injection Choke valve in order to "dry" the fluid located at top part of the tubing.

In steady state operations, no hydrates risks are anticipated in the transport pipeline because of the low water content. Extremely low temperatures and low pressures have to be observed in the system before triggering any hydrates crystals formation, and those conditions are far from expected operating conditions of the transport system.

3.5 Injection profile and inlet conditions

3.5.1 Injection profile

For this phase of the project, a peak injection rate of 22 MTPA is defined. Two take-offs of 8 MTPA at K14 PLET and 6 MTPA at the DHUB towards L10 platform should be taken into account. The rest is injected into TotalEnrgies area.

In addition to the 22 MTPA peak rate, a 5 MTPA flowrate is simulated as it gives more insights on early life injection with lower reservoir pressure. The following table indicates the flowrates associated to each platform:

		Rate	
Inlet	MTPA	**5**	**22**
	Kg/s	158.55	697.62
K14	MTPA	**2.5**	**8**
	Kg/s	79.27	253.68
DHUB	MTPA	**2.5**	**14**
	Kg/s	79.27	443.94
L10	MTPA		**6**
	Kg/s		190.26
TTE PLEM	MTPA	**2.5**	**8**
	Kg/s	79.27	253.68
L4A	MTPA	**2.5**	**-**
	Kg/s	79.27	-
Note: For the peak rate, the flowrate for L4A platform is not mentioned. In this case, indicative results of the subsea manifold at 1.9 km from L4A platform and -39 m of water depth will be presented			

Table 3-14: Injection profile for the sizing years

3.5.2 Inlet conditions

The different discharge pressure requirements for both sizing years along with the discharge temperature are presented in the following table:

	5 MTPA case	22 MTPA case
Pressure (barg)	150	180
Temperature (°C)	50	50

Table 3-15: Trunkline inlet conditions

It is worth to mention that these values are input data from CCS development team working on Aramis project and are representative of future operations on Aramis. It has also been decided to consider the warmest inlet temperature as a conservative approach for thermo-hydraulic calculations since it maximizes the pressure losses. Several sensitivities are conducted regarding the inlet conditions mostly for the design temperature determination explicated in the next sections.

4 METHODOLOGY

4.1 Steady state

Steady state simulations have been performed for both peak rate and startup / early life flowrates with several inlet conditions using *OLGA 2021* for the base cases and an internal CO_2 spreadsheet developed by the Flow Assurance team in TotalEnergies and based on analytical model for pressure drop calculation for the sensitivity cases. This was possible thanks to the monophasic behavior of CO_2 transport in the network.

Concerning the *OLGA* simulations, it is worth mentioning that throughout the simulations, several parameters are assessed:

- Pressure and temperature at key points of the injection system including platforms and other focal arrival points,
- Flowrates throughout the injection system and target rates for each well,
- Injection wells chokes openings,
- The erosion velocity ratio as well as fluid velocities and flow regime inside the pipelines and riser.

For the calculations performed for this study using *OLGA*, and in order to capture the dynamic of the whole system, the entire injection system is modeled including the injection wells of TotalEnergies area. Only BB03 related information and results are presented in this report.

The number of thermo-hydraulic simulations has been optimized, mainly covering the following cases:

- <u>Base Case 1</u>: Max Flowrate of 22 MTPA – discharge pressure 180 barg – Inlet temperature 50°C
- <u>Base Case 2</u>: Startup / early life flowrate of 5 MTPA – discharge pressure 150 barg – Inlet temperature 50°C
- <u>Sensitivity Case 1</u>: Max Flowrate of 22 MTPA all the way to DHUB without any take-off at K14 PLET – discharge pressure 180 barg – Inlet temperature 50°C – Most likely not to occur but it was studied to evaluate the packing time.
- <u>Sensitivity Case 2</u>: Max Flowrate of 22 MTPA – discharge pressure 180 barg – Inlet temperature 65°C – Most likely not to occur but it was studied to define the design temperature of the trunkline.
- <u>Sensitivity Case 3</u>: Max Flowrate of 22 MTPA – discharge pressure 180 barg – Inlet temperature 56°C – This case was studied to further refine the design temperature of the trunkline, being less stringent.
- <u>Sensitivity Case 4</u>: Max Flowrate of 11 MTPA coming from Porthos – discharge pressure 180 barg vs 120 barg – Inlet temperature 65°C – This case was studied to further refine the design temperature of the trunkline being less stringent.

4.2 Transient calculations

The injection case selected to perform transient analysis is 22 MTPA, which is the injection case with maximum flowrate, maximum operating pressure, maximum settle-out pressure, high reservoir pressurization, Etc. This injection scenario is used to determine the operating philosophies and key equipment for all transient operations while ensuring pipeline integrity with regards to design conditions, risks of ice formation, hydrates risks, Etc.

The following table lists the transient simulation cases and provides further details on each case:

Transient operation	Sequence of operation	Verifications	Steady state initial case
Shutdown – Packing 1	1. Spurious closure of wells 2. Pumps still in operation	- Definition of the safe shutdown operation to avoid two-phases - Evaluation of the time for operators to react - Estimation of the hydrate and ice risk - Pressure, temperature & density profile evolution over time	22 MTPA base case
Shutdown – Packing 2	1. Closure of Riser Isolation Valve (RIV) upstream DHUB 2. Pumps still in operation		22 MTPA to DHUB with no take-off at K14 (sensitivity case 1)
Shutdown - Depacking	1. Spurious shutdown of pumps 2. Wells still open	- Determination of the minimum pressure and time required after shutdown to reach the vapor phase threshold pressure or crossflow between the injection wells	22 MTPA base case
Planned depressurization	1. Shutdown of pumps 2. Wells kept open 3. Blowdown through wells till reaching pressure in transport line 10 - 20 bar above highest WHSIP or 10 bar above pressure that triggers two phase flow. 4. Wells closed 5. Depressurization continued through RO topsides	- Procedure for planned depressurization offshore - Sequence in case of unplanned or emergency depressurization due to pipe blockage, collapse, Etc. - Restriction Orifice (RO) sizing - Depressurization flowrates to vent - Assess position of the depressurization system (onshore or offshore) - Accurate dynamic heat flow transfer modelling of the flowlines - Depressurization duration - Pressure and temperature profile vs time - Evaluation of hydrates and ice risks, high pressure drop / line blockage, free water & two-phase zone - Minimum temperature over the line	22 MTPA base case
Depressurization after unplanned abnormal shutdown - Wells available	1. Spurious closure of wells 2. Pumps still in operation 3. Packing of the transport pipeline at the highest pressure 4. Blowdown through furthest well presenting lowest WHSIP till reaching pressure in transport pipeline 10 - 20 bar above WHSIP or 10 bar above pressure that triggers two phase flow		22 MTPA base case
Depressurization after unplanned abnormal shutdown - Wells not available (Plug, Etc.)	1. Spurious closure of wells 2. Pumps still in operation 3. Packing of the transport pipeline at the highest pressure 4. Blowdown through RO topsides		22 MTPA base case

Table 4-1: Conducted transient simulations

5 STEADY STATE RESULTS

In this section are presented the main results of the steady state simulations for the base case of Aramis project along with a number of sensitivity studies changing the inlet conditions in order to analyze the impact over the temperature and pressure profiles over the trunkline.

5.1 Base case

Pressure results considered for the validation of the production profile are based on simulations for warm conditions maximizing pressure drop along the pipeline.

Two different flowrates have been studied:

- Peak flowrate: 22 MTPA with 180 barg as inlet pressure
- Early life flowrate: 5 MTPA with 150 barg as inlet pressure

5.1.1 22MTPA scenario

5.1.1.1 Operating conditions against phase envelope

The pressure and temperature profiles along the transport pipeline route have been compared to phase envelope in order to identify any risk of two-phases flow conditions anywhere in the injection system.

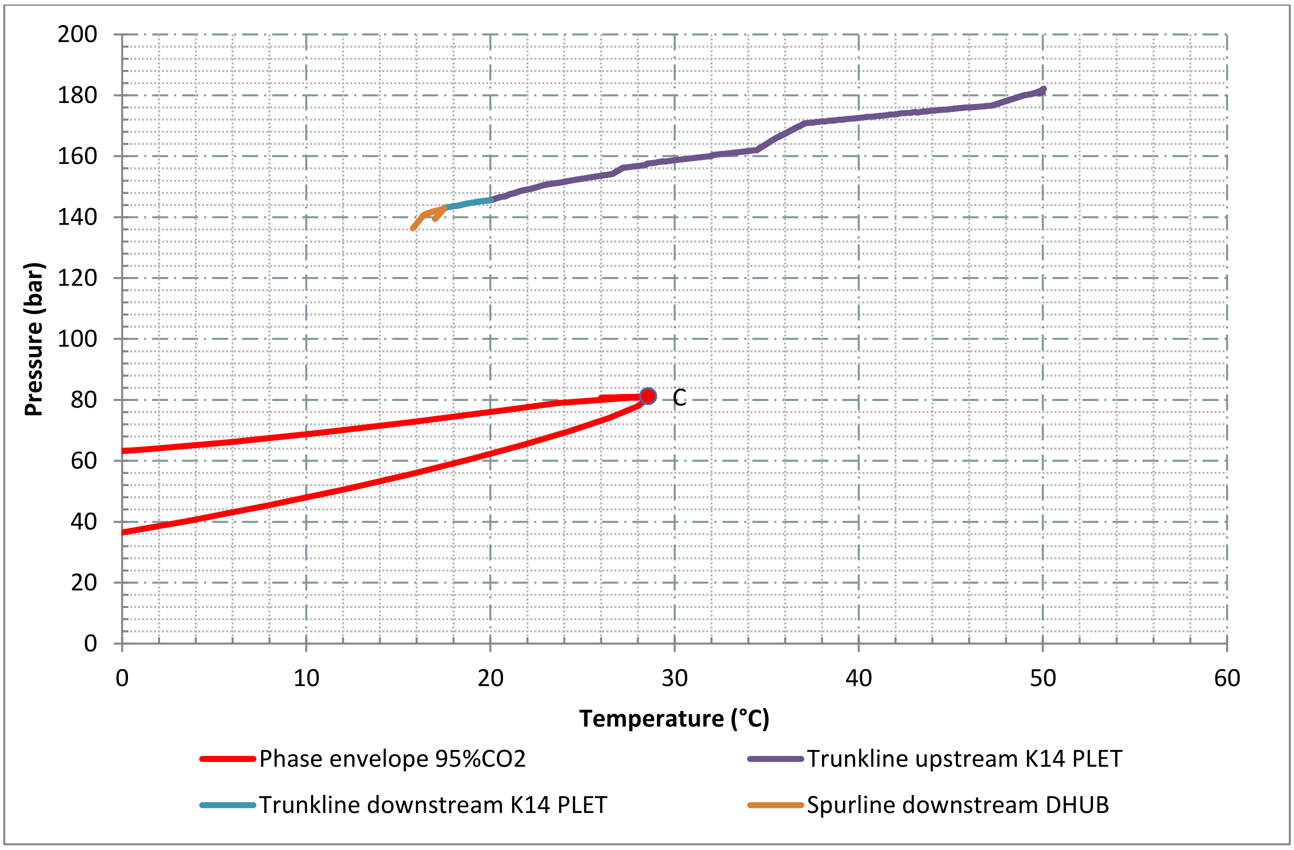

Figure 5-1: Operating conditions of transport pipeline at 22 MTPA against phase envelope

As observed on previous figure, there is no risk to operate the transport pipeline in two-phase flow conditions at 22 MTPA. The operating conditions are always far from the phase envelope with more than 60 bar from the critical point including a 10 bar margin when applied.

5.1.1.2 Pressure Profile

Here after is presented the pressure profile (more details are presented in the appendix 9.1.1.1) along the trunkline of 32 in OD for 22 MTPA with a take-off of 8 MTPA at K14 PLET and the spurline of 24 in OD after take-off of 6 MTPA at DHUB for L10 platform. The results include a 10% margin on total pressure drop.

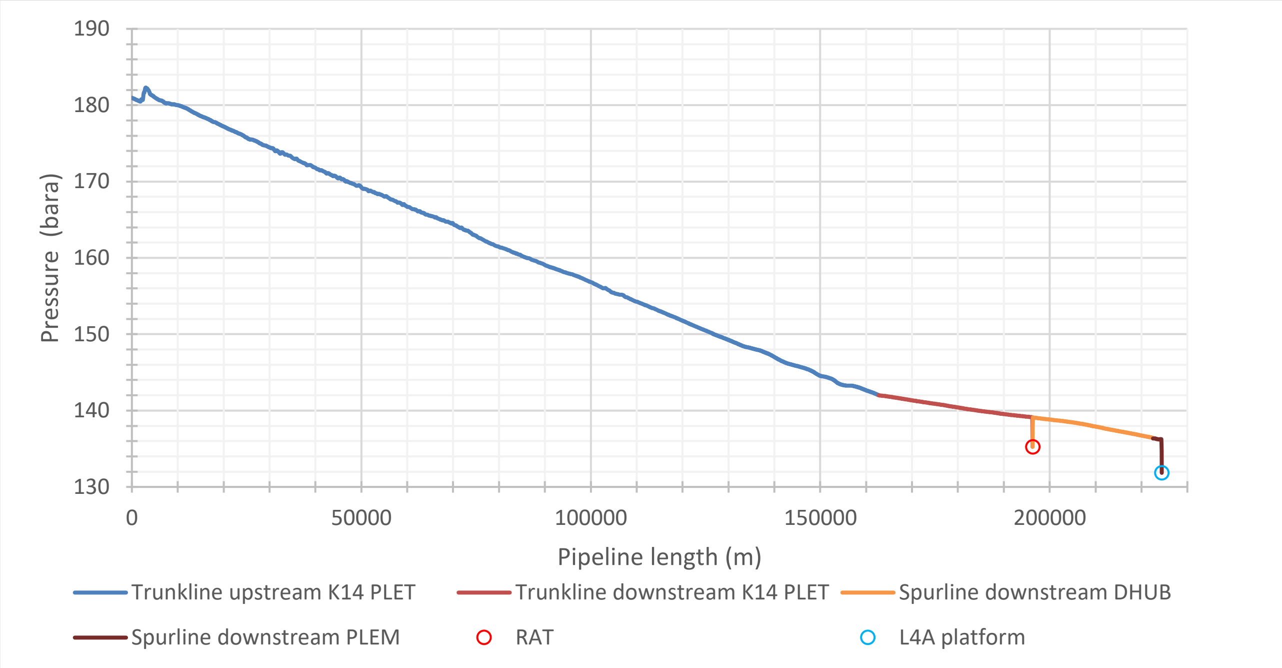

Figure 5-2: Pressure profile for the 22 MTPA case

As the figure indicates, with a 180 barg discharge pressure, the arrival pressure at K14 PLET is approximatively 141 barg and at top of DHUB 134.2 barg including the 10% margin on pressure drop. The arrival pressure at L4A platform is about 131 barg. Further indications on arrival pressures at platforms are presented in the following sections.

5.1.1.3 Temperature Profile

Here after is presented the temperature profile (more details are presented in the appendix 9.1.1.2) along the trunkline of 32 in OD for 22 MTPA with a take-off of 8 MTPA at K14 PLET and the spurline of 24 in OD after take-off of 6 MTPA at DHUB for L10 platform. The given results are for the warm case (summer conditions for ambient temperature and warmest temperature at inlet for a 22 MTPA flowrate).

As observed on the temperature profile, the arrival temperature at DHUB is about 17°C while the arrival temperature at top of L4A platform is about 15.8°C. It is worth mentioning that the fluid takes longer time than expected to be in thermal equilibrium with the seabed ambient temperature and that is due to the large flowrate, minimizing heat exchange with the ambient environment and the huge thermal inertia of the CO_2.

From this temperature profile, it appears that the range of temperature expected at the different injection sites should follow the sea water seasonal temperatures, meaning that the arrival temperature should range between 4°C and 16°C, whatever the injection temperature at onshore terminal.

It is worth mentioning that with reduced flowrate, the thermal equilibrium with surrounding sea water will be reached sooner in the trunkline, not modifying the conclusion above with regards to arrival temperature at different offshore platforms.

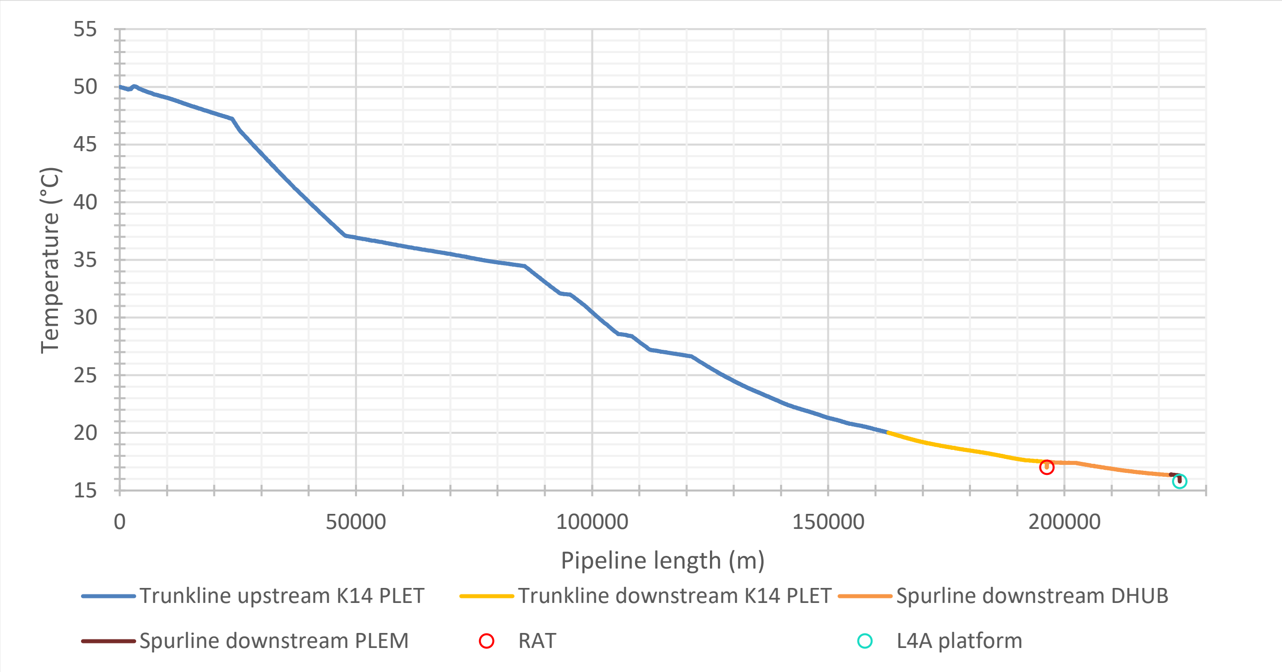

Figure 5-3: Temperature profile for the 22 MTPA warm case

5.1.1.4 Arrival conditions at platforms

Here after are presented the arrival conditions at each platform along with the reached flowrate.

From the present Flow Assurance study, it appears that the injection of 22 MTPA might be highly challenging at the end of life, therefore highlighting the strong effect of the pressure build-up observed in the reservoir during field life.

This is a major uncertainty that is difficult to unlock at this stage.

Platform	K14	DHUB	L10	TTE PLEM [3]
Arrival flowrate (MTPA)	8	14	6	8
Arrival flowrate (kg/s)	253.68	443.94	190.26	253.68
Arrival pressure (bara) [1]	137.96	135.18	133.79	136.43
Arrival pressure + topside pressure drop margin [2]	132.96	135.18	128.79	136.43
Temperature (°C)	19.2	17.06	16	16.33

Note:

1. The indicated arrival pressure includes a 10% margin on the pressure drop. Reference height +24 m / MSL except for TTE PLEM which is at -39 m / MSL,

2. The indicated arrival pressure includes both 10% margin on pressure drop and a 5 bar margin representative of topside pressure drop related to piping and chokes. Reference height +24 m / MSL except for TTE PLEM which is at -39 m / MSL,

3. For the peak rate only indicative results of the subsea manifold at 1.9 km from L4A platform and -39 m of water depth are presented

Table 5-1: Arrival conditions at platforms for 22 MTPA base case

5.1.1.5 Fluid velocity and Erosional Velocity Ratio

The fluid velocity and the Erosional velocity ratio (EVR) over transport pipeline route at peak injection rate (22 MTPA) ranges:

- Trunkline upstream DHUB:
  - Minimum Fluid velocity ranges from 1.15 to 2.34 m/s,
  - Maximum EVR ranges from 0.28 to 0.49.

- Spurlines downstream DHUB & from K14 PLET to K14 platform:
  - Minimum Fluid velocity ranges from 0.77 to 1.21 m/s,
  - Maximum EVR ranges from 0.18 to 0.29.

No erosion neither deposition (if any precipitates, particles, solids, Etc.) issues are anticipated in the mentioned flowlines as both EVR and fluid velocities are within an acceptable limit.

5.1.2 5 MTPA scenario

5.1.2.1 Operating conditions against phase envelope

The pressure and temperature profiles along transport pipeline route and within injection wells have been compared to phase envelope in order to identify any risk of two-phases flow conditions anywhere in injection system.

As observed on the following figure, there is no risk to operate the transport pipeline in two-phase flow conditions at 5 MTPA. The operating conditions are always far from phase envelope with more than 60 bar from the critical point including a 10 bar margin when applied.

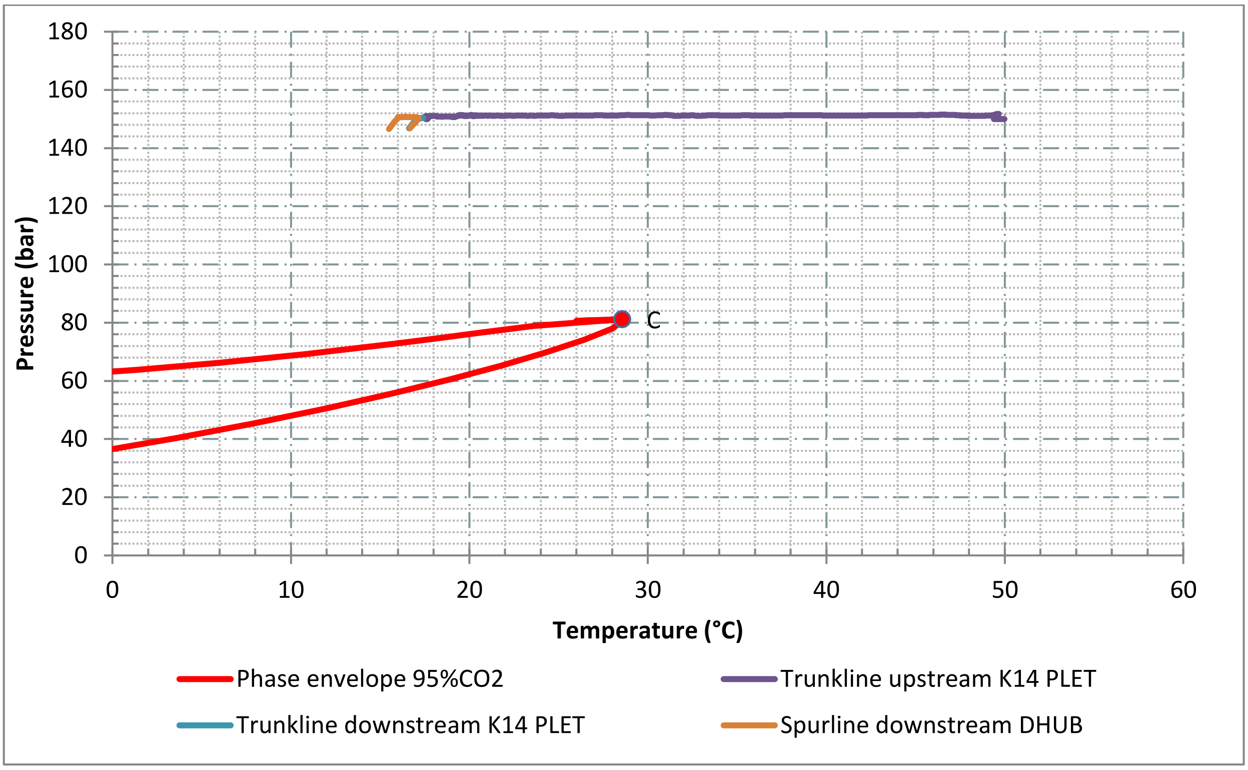

Figure 5-4: Operating conditions of transport pipeline at 5 MTPA against phase envelope

5.1.2.2 Pressure Profile

Here after is presented the pressure profile (More details are presented in the appendix 9.1.2.1) along the trunkline of 32 in OD for 5 MTPA with a take-off of 2.5 MTPA at K14 PLET and the spurline of 24 in OD downstream DHUB. The results include a 10% margin on total pressure drop.

As presented in the following figure, with a 150 barg discharge pressure, the arrival pressure at K14 PLET is approximatively 149.2 barg and at top of DHUB 145.4 barg including a 10% margin on pressure drop. The arrival pressure at L4A platform is about 145.1 barg. Further indications on arrival pressures at platforms are presented in the following sections.

Because of the low injection rate, there is almost no pressure drop into the injection system allowing reaching at injection platforms high delivery pressures. Those results are consistent.

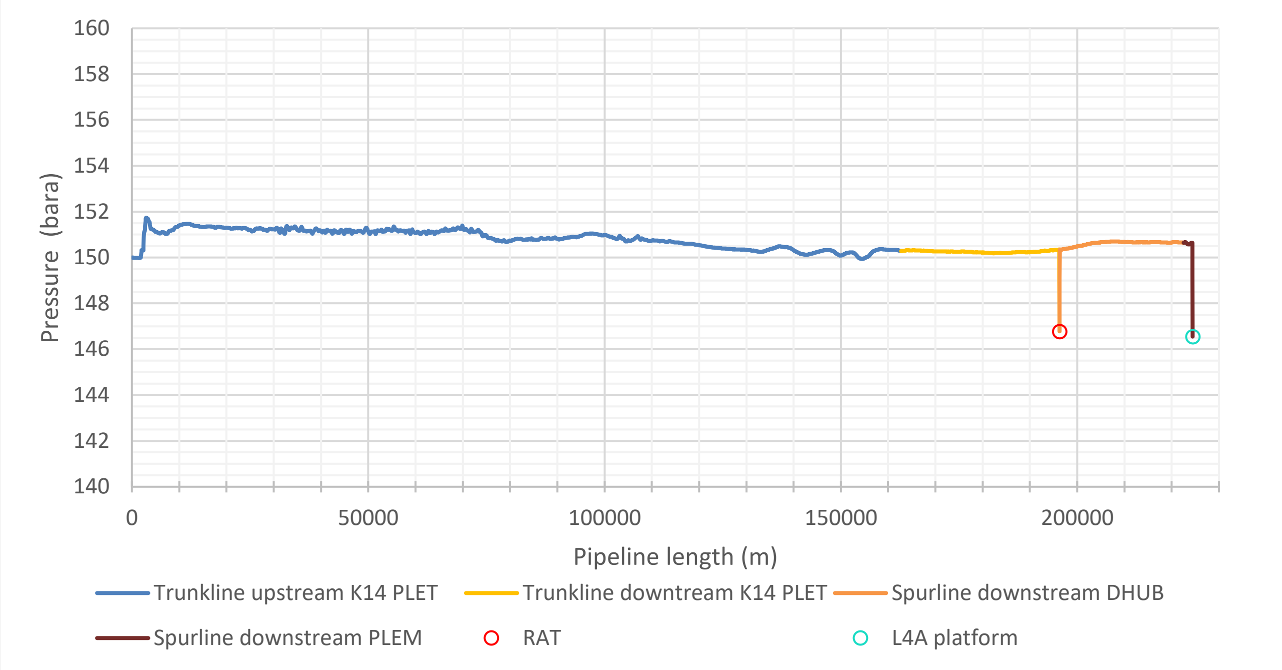

Figure 5-5: Pressure profile for the 5 MTPA case

5.1.2.3 Temperature Profile

Here after is presented the temperature profile (More details are presented in the appendix 9.1.2.2) along the trunkline of 32 in OD for 5 MTPA with a take-off of 2.5 MTPA at K14 PLET and the spurline of 24 in OD downstream DHUB. The given results are for the warm case (summer conditions for ambient temperature).

As observed on the temperature profile below, the arrival temperature at DHUB is about 16.7°C while the arrival temperature at top of L4A platform is about 15.5°C. Further indications on arrival temperatures at platforms are presented in the following sections.

As observed on the following figure, a fast thermal equilibrium with surrounding sea water is reached as soon as the CO_2 is reaching the first “exposed” section.

From this temperature profile, it appears that the range of temperature expected at the different injection platforms is unchanged compared to scenario of 22 MTPA and will follow the sea water seasonal temperatures, meaning that the arrival temperature should range between 4°C and 16°C, whatever the injection temperature at onshore terminal.

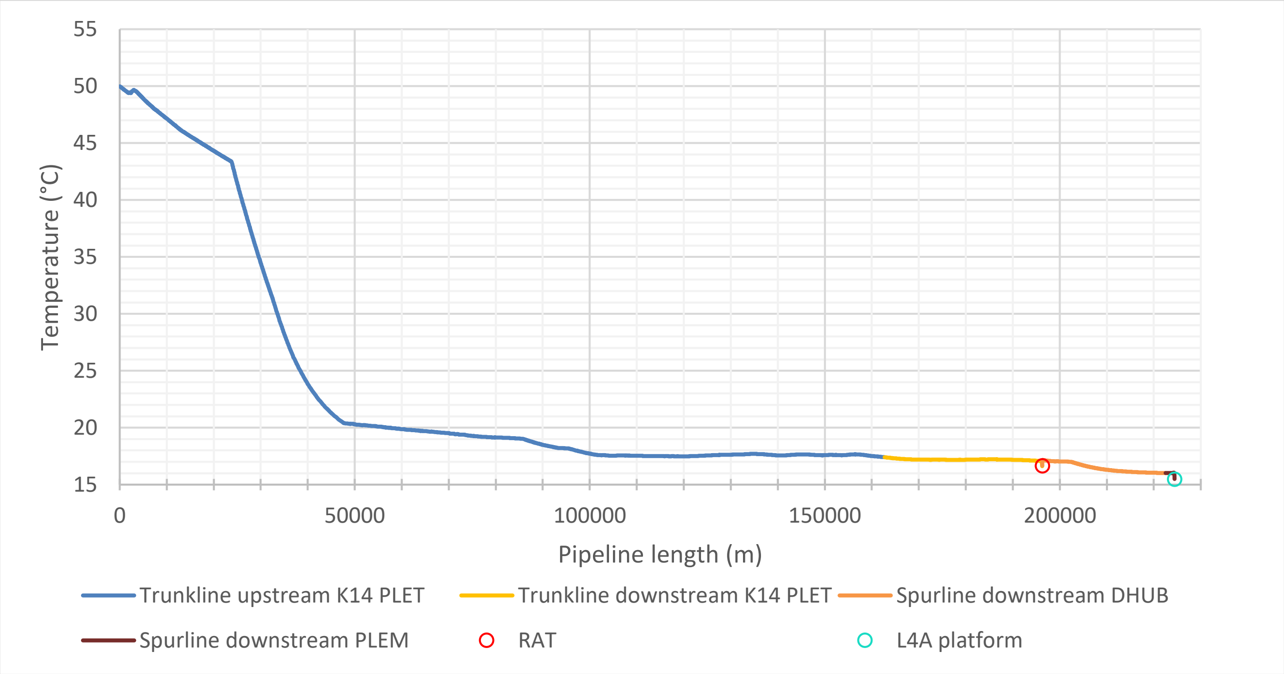

Figure 5-6: Temperature profile for the 5 MTPA warm case

5.1.2.4 Arrival pressures at platforms

Here after are presented the arrival conditions at each platform along with the reached flowrate:

Platform	K14	DHUB	L4A
Arrival flowrate (MTPA)	2.5	2.5	2.5
Arrival flowrate (kg/s)	79.27	79.27	79.27
Arrival pressure (bara) (1)	146.49	146.47	146.26
Arrival pressure + topside pressure drop margin (2)	141.49	146.47	141.26
Temperature (°C)	16.96	16.62	15.5
1. The indicated arrival pressure includes a 10% margin on the pressure drop. Reference height +24 m / MSL, **2**. The indicated arrival pressure includes both 10% margin on pressure drop and a 5 bar margin representative of topside pressure drop related to piping and chokes. Reference height +24 m / MSL.			

Table 5-2: Arrival conditions at platforms for 5 MTPA base case

5.1.2.5 Fluid velocity and Erosional Velocity Ratio

The fluid velocity and the Erosional Velocity Ratio (EVR) over transport pipeline route at 5 MTPA ranges:

- Trunkline upstream DHUB:
  - Minimum Fluid velocity ranges from 0.22 to 0.62 m/s,
  - Maximum EVR ranges from 0.05 to 0.12.

- Spurlines downstream DHUB & from K14 PLET to K14 platform:
  - Minimum Fluid velocity ranges from 0.37 to 0.39 m/s,
  - Maximum EVR ranges around 0.09.

For the 5 MTPA case, all fluid velocities are expected to be low. This could induce deposition of particles, solids, etc. if any and enhanced Corrosion Under Deposits Phenomena. For early life conditions, it is recommended to further investigate those issues in the upcoming phases of the project, more specifically the presence of any particles, solids that may settle / accumulate into the injection lines because of the low velocities.

On the other hand, the EVR limit is respected in all the mentioned injection flowlines.

5.2 Sensitivity studies

Several steady state sensitivities studying the impact of the initial conditions were conducted using the CO_2 spreadsheet or *OLGA* model. The main reasons are:

- The evaluation of the required packing time of the trunkline with comparison to the base case (Sensitivity study 1)
- The definition and refining of the trunkline's design temperature (Sensitivity study 2, 3 and 4)

The list and the description of the sensitivity studies is as follows:

Case	Flowrate (MTPA)	Discharge pressure (barg)	Inlet temperature (°C)	Details
Sensitivity study 1 *OLGA model*	22 MTPA all the way to DHUB without any take-off at K14 PLET	180	50	22 MTPA all the way to DHUB without any take-off at K14 PLET
Sensitivity study 2 *CO_2 spreadsheet*	22	180	65 (1)	Most likely not to occur but it was studied to evaluate the design temperature of the trunkline
Sensitivity study 3 *CO_2 spreadsheet*	22	180	56 (2)	This case was studied in order to further refine the design temperature of the trunkline.
Sensitivity study 4 *CO_2 spreadsheet*	11 (3)	180 vs. 120	65	This case was studied in order to further refine the design temperature of the trunkline.

Note:

1. 65°C is the maximum temperature outlet of Porthos, also considered as the Maximum Operating Temperature (MOT) for Porthos flowrate (Ref. [2]).

2. 56°C is the maximum temperature of the mix of all fluids corresponding to a flowrate of 22 MTPA at the inlet of the trunkline (Ref. [2]).

3. 11 MTPA is the maximum flowrate coming from Porthos (Ref. [2]).

Table 5-3: List of conducted steady state sensitivity cases

5.2.1 Sensitivity study 1

5.2.1.1 Pressure Profile

Here after is presented the pressure profile (More details are presented in the appendix 9.1.3.1) along the trunkline of 32 in OD for 22 MTPA with no take-off at K14 PLET. The results include a 10% margin on total pressure drop.

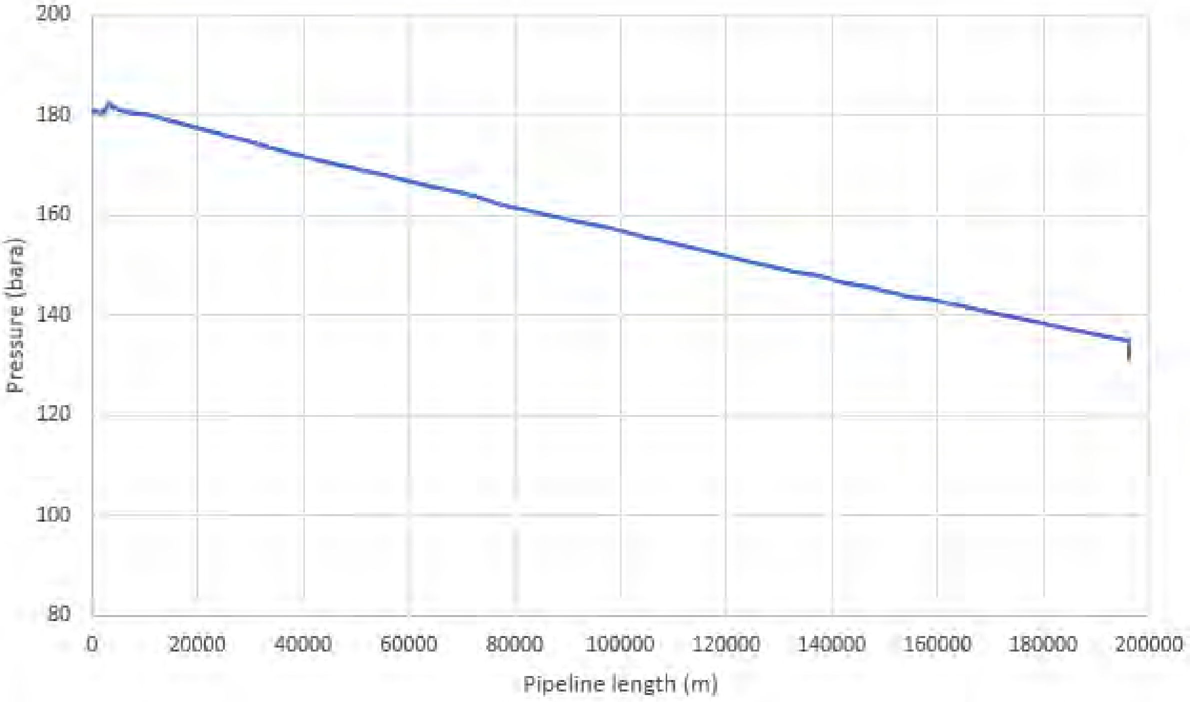

Figure 5-7: Pressure profile for the sensitivity study 1

As the figure indicates, with a 180 barg discharge pressure, the arrival pressure at top of DHUB is approximatively 130.1 barg including the 10% margin on pressure drop.

5.2.1.2 Temperature Profile

Here after is presented the temperature profile (More details are presented in the appendix 9.1.3.2) along the trunkline of 32 in OD for 22 MTPA with no take-off at K14 PLET.

As observed on the temperature profile, the arrival temperature at DHUB is about 17.3°C. It is worth reminding that the fluid takes longer time than expected to be in thermal equilibrium with the seabed ambient temperature and that is potentially due to the large flowrate minimizing the exchanges with the ambient environment and the huge thermal inertia of the CO_2.

From this sensitivity study, the expected range of arrival temperature at injection platforms remains unchanged compared to previous conclusions of the present report profile, namely this range will follow the sea water seasonal temperatures, meaning that the arrival temperature should oscillate between 4°C and 16°C, whatever the injection temperature at onshore terminal.

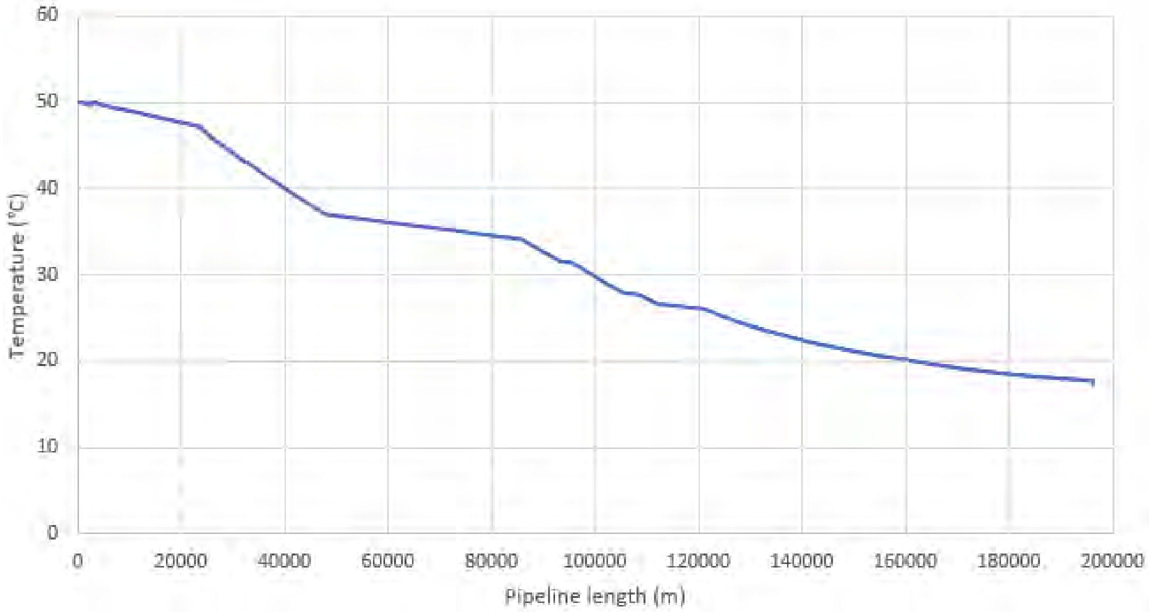

Figure 5-8: Temperature profile for the sensitivity study 1

5.2.2 Sensitivity study 2

5.2.2.1 Pressure Profile

Here after is presented the pressure profile (More details are presented in the appendix 9.1.4.1) along the trunkline of 32 in OD for 22 MTPA with a take-off of 8 MTPA at K14 PLET. The results include a 10% margin on total pressure drop.

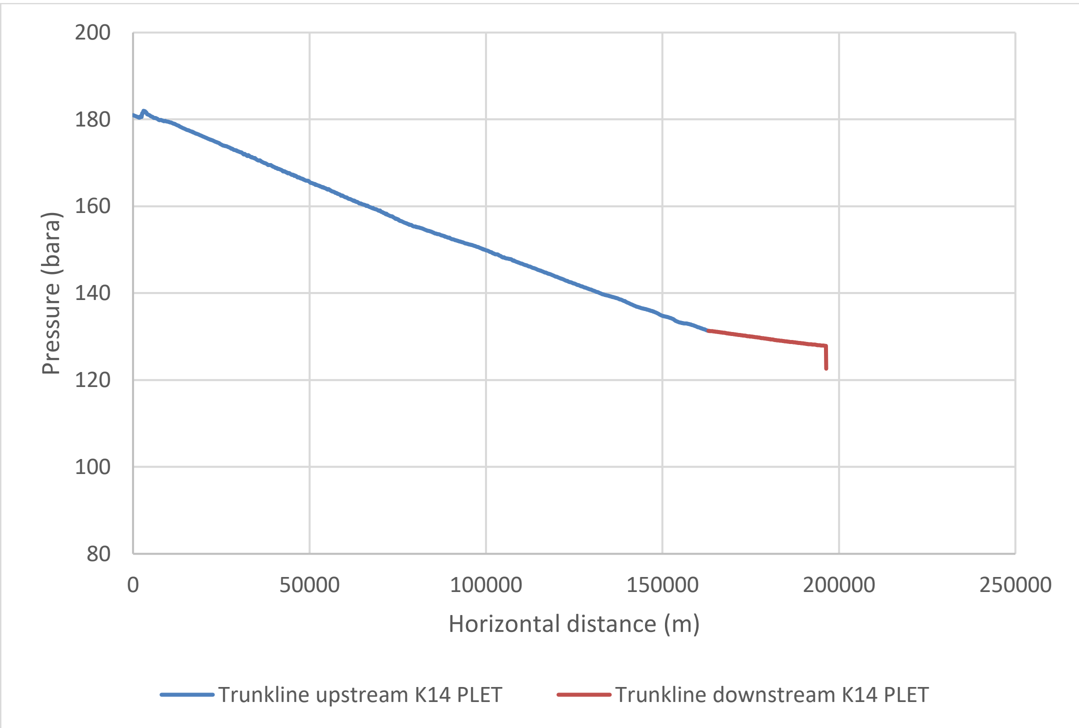

Figure 5-9: Pressure profile for the sensitivity study 2

As the figure indicates, with a 180 barg discharge pressure, the arrival pressure at K14 PLET is approximatively 130.2 barg and at top of DHUB 121.6 barg including the 10% margin on pressure drop.

5.2.2.1 Temperature Profile

Here after is presented the temperature profile (More details are presented in the appendix 9.1.4.2) along the trunkline of 32 in OD for 22 MTPA with a take-off of 8 MTPA at K14 PLET. The given results are for the warm case (summer conditions for ambient temperature and 65°C at inlet for a 22 MTPA flowrate).

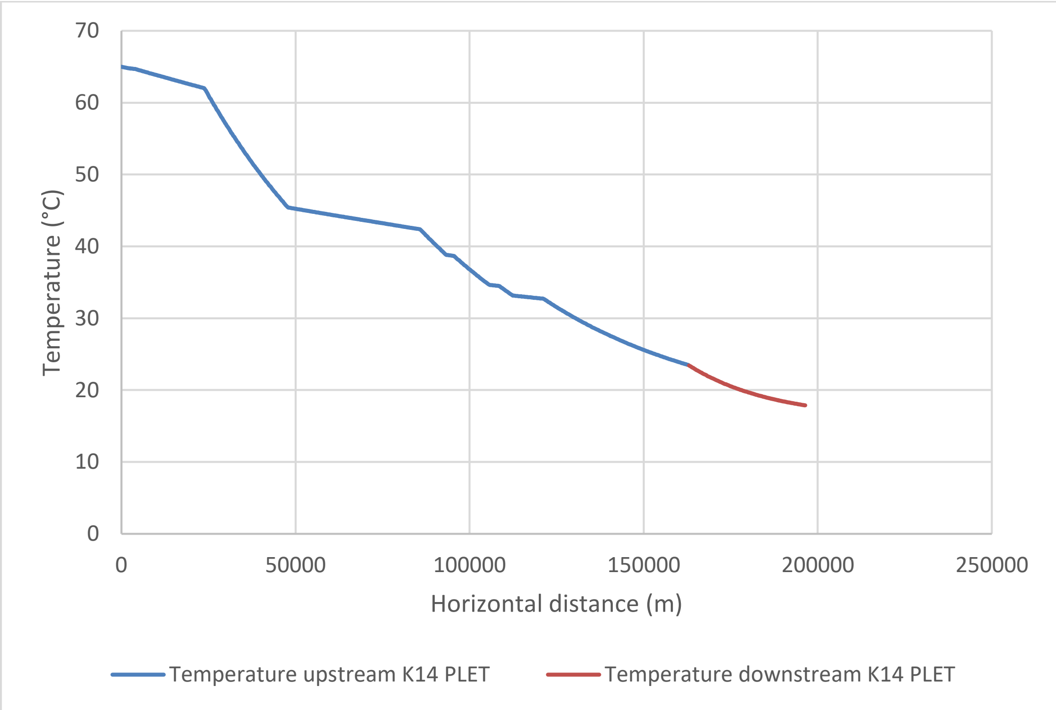

Figure 5-10: Temperature profile for the sensitivity study 2

As observed on the temperature profile, the arrival temperature at DHUB is about 17.9°C. It is worth reminding that the fluid takes longer time than expected to be in thermal equilibrium with the seabed ambient temperature and that is potentially due to the large flowrate minimizing the exchanges with the ambient environment and the huge thermal inertia of the CO_2.

5.2.3 Sensitivity study 3

This study has been conducted for the evaluation of the design temperature of the trunkline. All details are in the next section.

5.2.4 Sensitivity study 4

This study has been conducted for the evaluation of the design temperature of the trunkline. All details are in the next section.

5.3 Trunkline design temperature

Since CO2next Liquid CO_2 (LCO_2) Terminal (BB01) and Porthos Compression Station (BB02) have different conditions in terms of flowrate, temperature and pressure, in this section several sensitivities regarding the inlet conditions of the trunkline are lead.

Other sensitivities related to the length of the sections presenting different pipe characteristics (burial, coating…) are also conducted in order to cover all uncertainties related to the installation, any change of pipeline configuration following seabed surveys, Etc. and to account for marine growth or any small layers of soils that could have been transported by the sea current and laid over the pipe, affecting therefore the thermal exchange with surrounding sea water temperature.

The aim being to minimize the heat transfer conditions in order to determine the maximum design temperature of the trunkline and define a spec break location after which the design temperature could be decreased.

The base cases covering the maximum flowrates in accordance with the maximum operating temperatures (MOT) were provided by process team (Ref. [2]) and are as follow:

- **Case 1**: 11 MTPA as maximum flowrate with a MOT of 65°C
- **Case 2**: 22 MTPA as maximum flowrate with a MOT of 56°C

5.3.1 Case 1

The sensitivities conducted over this case are listed below:

- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / No additional lengths over buried sections.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / +540 m over Onshore section.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / +600 m over Micro-Tunnel section.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / + 580 m over trenched section at the exit of the Micro-Tunnel.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / + 980 m over trenched section at the exit of the Micro-Tunnel.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 180 barg / + 1580 m over trenched section at the exit of the Micro-Tunnel covering three additional lengths over the previously mentioned three buried sections.

Considering the most stringent temperature profiles, a sensitivity over the discharge pressure at the inlet has also been conducted. Giving that the lowest pressure switch (PSLL) is at 95 barg, and that any pressure lower that 120 barg at the inlet could trigger two-phase flow in the injection system, a pressure of 120 barg has been considered for this sensitivity.

- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 120 barg / + 1580 m over trenched section at the exit of the Micro-Tunnel.
- Flowrate: 11 MTPA / MOT: 65°C / Discharge pressure 120 barg / + 980 m over trenched section at the exit of the Micro-Tunnel.

5.3.2 Case 2

Considering the most stringent temperature profiles over case 1, the following sensitivities have been conducted over case 2:

- Flowrate: 22 MTPA / MOT: 56°C / Discharge pressure 180 barg / No additional lengths over buried sections.
- Flowrate: 22 MTPA / MOT: 56°C / Discharge pressure 180 barg / + 1580 m over trenched section at the exit of the Micro-Tunnel.
- Flowrate: 22 MTPA / MOT: 56°C / Discharge pressure 180 barg / + 980 m over trenched section at the exit of the Micro-Tunnel.

5.3.3 Trunkline design temperature study results

The following graph presents a comparison over all previously listed cases and sensitivities, including a 5°C margin:

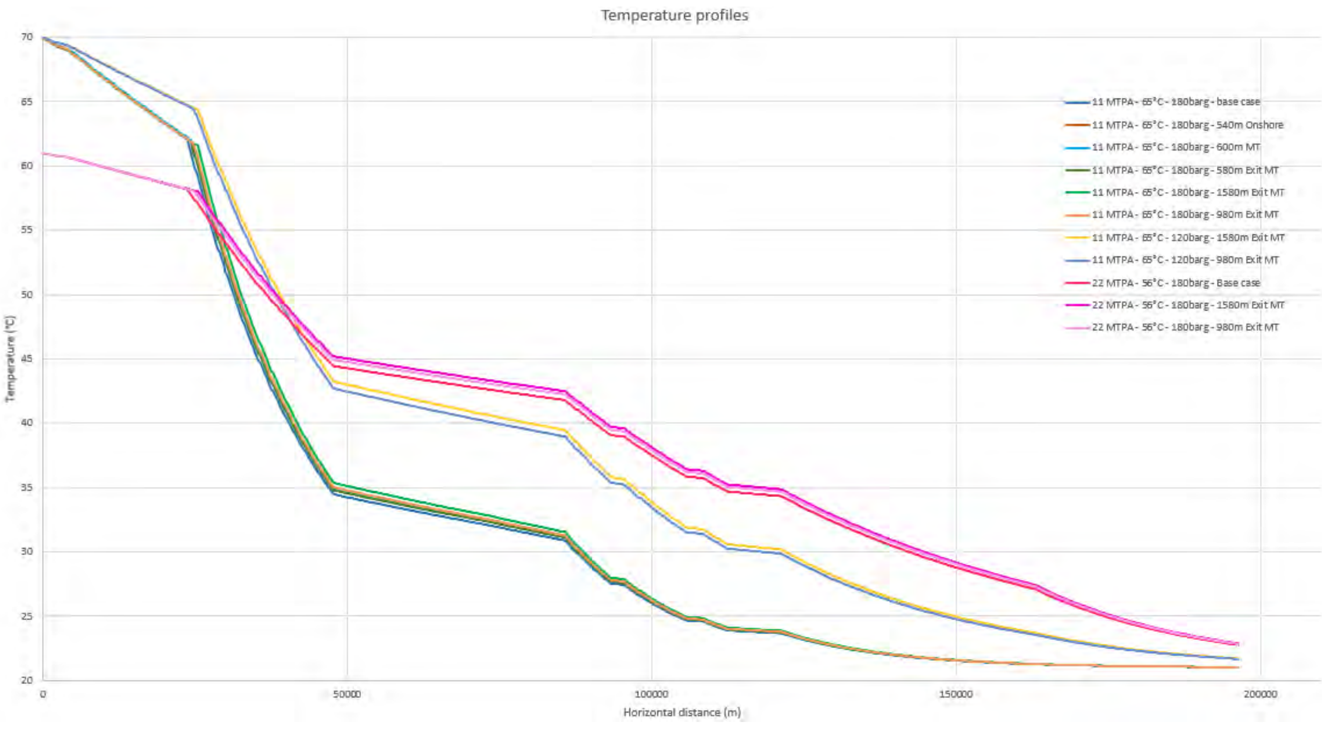

Figure 5-11: Temperature profiles for trunkline design temperature determination

As observed on the graph, the case where an 11 MTPA flowrate, a MOT of 65°C and a discharge pressure of 120 barg with a 1580 m of additional length over the buried sections all together presents the most stringent temperature profile for the first approximately 45 kilometers. The difference in the temperature profile over these first kilometers in both cases where a 980 m and 1580 m length of buried sections are added is very negligeable, meaning that any local adjustments of the pipeline configuration on the seabed will not affect the definition of the design temperature and the proposed spec break here after.

Over the rest of the trunkline, the case where a 22 MTPA flowrate, a MOT of 56°C and a discharge pressure of 180 barg with a 1580 m or 980 m of additional length over the buried sections all together presents the most stringent temperature profile.

As a conservative approach, and considering a 5°C margin, it is recommended to set a design temperature of

- 70°C over the first 50 kilometers and
- 50°C for the rest of the trunkline up to the distribution hub (DHUB).

6 TRANSIENT CALCULATION RESULTS

In this section are presented the main results of the transient calculations performed for Aramis phase 1 project.

6.1 Unplanned Shutdown – Packing & depacking phenomena

Shutdown simulations were performed for warm ambient conditions and for peak flowrate to assess the pressure and temperature profiles during the shutdown in order to define a safe shutdown operation to avoid 2-phases flow or crossflow between the injection wells and to evaluate the time needed by the operators to react following an unplanned shutdown.

6.1.1 Shutdown of injection wells & no shutdown onshore

Simulations have been performed to assess the pressure build-up in the trunkline in case of spurious shutdown of injection wells while the feed source from onshore facilities are still in operation. The packing of the transport pipeline has been assessed considering peak rate (22 MTPA) as it is considered as the most stringent. Should the injection rate be at plateau, then no major difference savings are anticipated compared to what is summarized here after.

Initial transport pipeline pressure for these considered scenarios are based on steady state operations at 22 MTPA. Both cases are listed here after:

- **Base case**: Steady state of 22 MTPA including a take-off of 8 MTPA at K14 PLET and remaining 14 MTPA flowrate to DHUB, followed by a well shutdown occurrence. The injection rate at shore is maintained constant, what is conservative considering anticipated export pump technology.
- **Sensitivity case – RIV closure**: Steady state of 22 MTPA all the way to the DHUB, followed by the RIV closure sequence. The injection rate at shore is maintained constant as well.

6.1.1.1 Base case

Pressure build-up anticipated in transport pipeline for this shutdown scenario is presented here after. It is worth mentioning that a Pressure Protection System for the trunkline is supposed to be triggered at 200 barg.

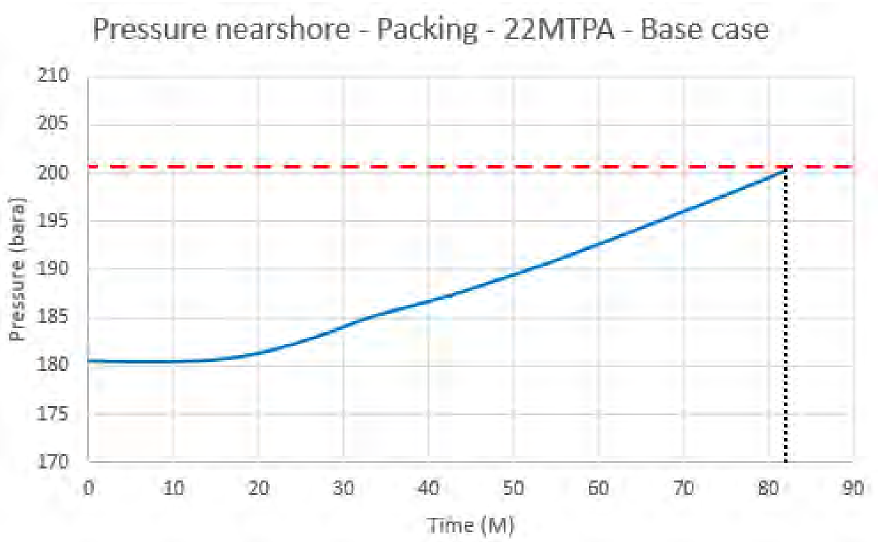

Figure 6-1: Pressure build-up in pipeline with shutdown of injection wells and no shutdown onshore – Base Case

As presented on figure above, the pressure build-up in the transport pipeline is relatively rapid because of the high initial steady state operating pressure. The higher is the pressure build-up in the reservoir due to CO_2 injection, then the faster is the packing of the transport pipeline.

During the first 12 min of the unplanned shutdown, due to the “small” compressibility of the CO_2, the pressure in the subsea system is almost constant and then increases by approximately 0.3 bar / min. The Pressure Protection System alarm is triggered after 82 min of the unplanned shutdown.

Even though the pressure build-up in the system could be relatively fast, consequence of the high initial steady state pressure in the system, the large volume of the trunkline and the low compressibility of the CO_2 (behaving as a liquid filled system), the operators, the pipeline control or pipeline safety system should have time to respond and to avoid a high pipeline shut-in pressure.

6.1.1.2 Sensitivity Case - RIV closure

Pressure build-up anticipated in transport pipeline for this shutdown scenario is presented here after. It is worth mentioning that a Pressure Protection System of the trunkline is supposed to be triggered at 200 barg.

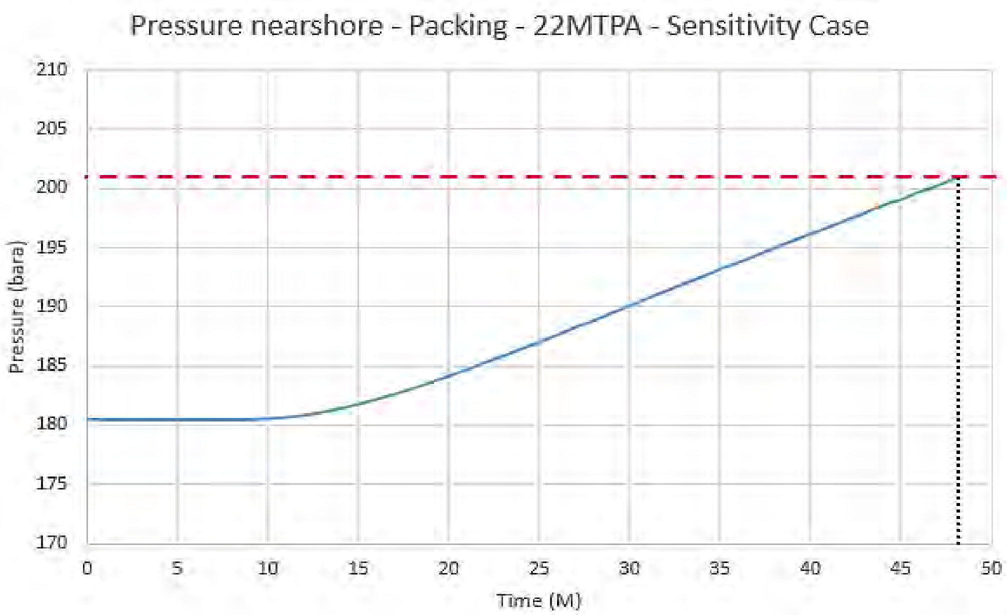

Figure 6-2: Pressure build-up in pipeline with RIV shutdown and no shutdown onshore – Sensitivity Case

During the first 10 min of the unplanned shutdown, the pressure in the subsea system is almost constant and then increases by approximately 0.6 bar / min. The Pressure Protection System alarm is triggered after 48 min of the unplanned shutdown.

Even though this case is most likely not to occur, the operators, the pipeline control or pipeline safety system should still have enough time to respond and to avoid a high pipeline shut-in pressure.

6.1.2 Shutdown onshore & no shutdown of the injection wells

A sudden shutdown onshore without shutdown of the injection wells may potentially result in low pipeline pressure and two-phases conditions in the transport pipeline. Transient shutdown simulations have been therefore performed in order to evaluate the time required before observing the minimum acceptable settle-out pressure in the transport pipeline before triggering the two-phases flow region envelope or any crossflow between the injection wells and therefore to evaluate the time for the operators to respond in case of such unplanned shutdown.

Initial transport pipeline pressure for this considered scenario is based on steady state operations at 22 MTPA. After onshore plant shutdown event, then the opening of the Injection Choke Valves is kept constant, what is relevant considering control philosophy of wells. No closure of Downhole safety valve is also considered in present study to evaluate the time between the shutdown event and the occurrence of back-flow from reservoir and crossflow between wells, if any.

Transport pipeline blowdown into wells for such shutdown scenario is presented here after.

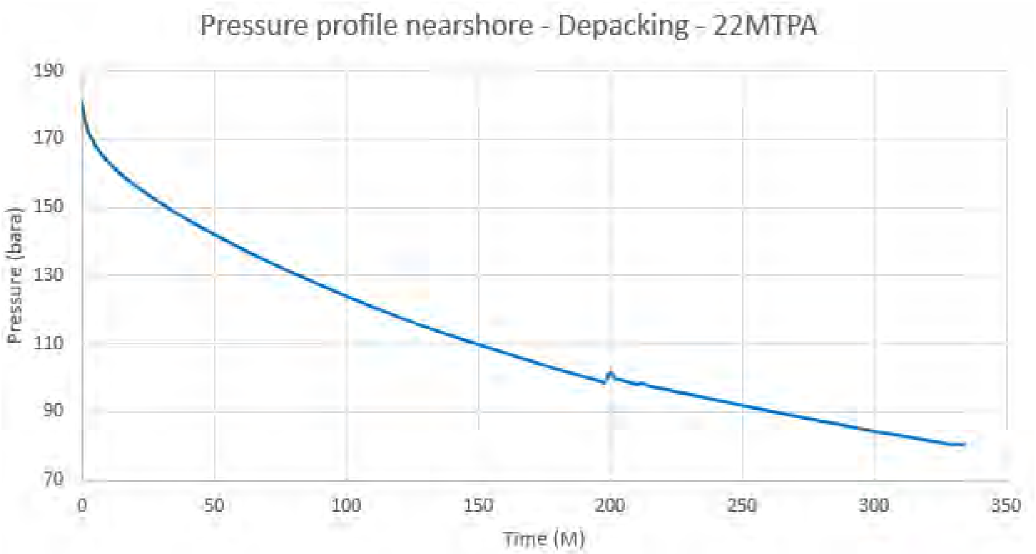

Figure 6-3: Transport pipeline blowdown into wells with shutdown onshore and no shutdown of injection wells

As presented on figure above, the pressure in the transport pipeline decreases by approximately 0.3 bar / min. The present study also highlights that gas flashing is experienced after about 5 hours following unplanned shutdown in the beginning of the transport pipeline between the Onshore and the Micro-Tunnel sections. The figure below illustrates the gas flashing through the liquid hold-up measurements near the Maasvlakte terminal just before entering the Micro-Tunnel.

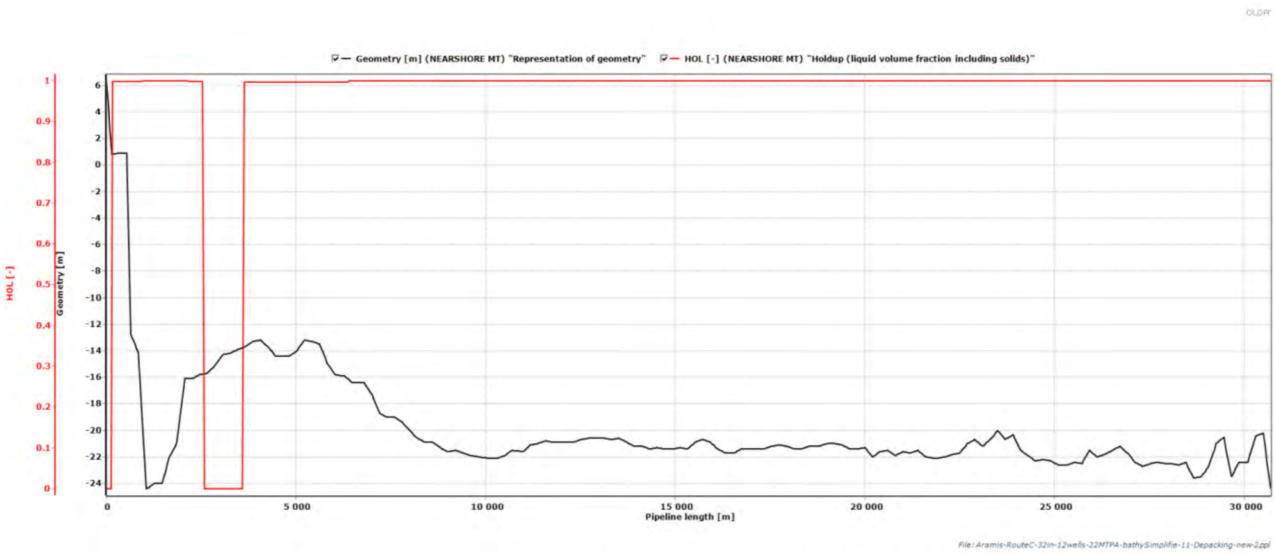

Figure 6-4: Liquid hold-up – Two-phase flow conditions in the Micro-Tunnel following unplanned shutdown of onshore facilities

Those two-phase conditions in the transport pipeline are observed as soon as the Pressure @ Maasvlakte goes below 82 barg considering the most stringent sea water ambient conditions and the CO_2 specification with impurities. It is worth mentioning that, with reservoir pressure build-up, the gas flashing should be delayed.

Even with such conditions, operators and control system should have enough time to respond and avoid the appearance of gas pockets within transport pipeline. A pressure set point of 90 barg including a 10 bar margin over the critical point should be respected at Maasvlakte terminal, after which the risks of two-phase flow become unavoidable. Should this situation occur, the Injection Choke Valves (or any other valves – Master Etc.) should be closed, and refilling operations of the transport pipeline should be carefully carried out from shore to go back in liquid filled conditions. The operating philosophy associated to those refilling operations should be developed in the upcoming phases of the project.

Another outcome of the present study is that no crossflow phenomena between the different injection wells will be observed, at least, in the first 5 hours following unplanned shutdown event as the appearance of two-phase flow conditions seems to be the driving parameter.

From the previous figure and blowdown analysis, it can be also extrapolated and estimated that at early life conditions, when injecting 5 MTPA, the time for the trunkline to blowdown into the injection wells if this scenario will be encountered will be also large enough for the operators to react before triggering the two-phase flow conditions. Indeed, a minimum 3.5 hours should be required before observing gas flashing into subsea network.

6.2 Trunkline depressurization

There is no specific operational requirement for depressurization of the subsea network in normal situation / shutdown. The potential scenarios that may impose a depressurization of the subsea system could be:

- Damage of the transport pipeline requiring repair and then blow-down of subsea system prior any intervention,
- Formation of a plug requiring blow-down to attempt remediating,
- Pipeline decommissioning,
- Operational issues at onshore plant requiring blow-down of the subsea system to control CO_2 release if any.

Depressurization of the transport pipeline should be avoided as much as possible because this operation will take time (more than 3 days) and refilling operations might be complex and will present non-negligible risks (gas pocket collapse, slack flow, low temperature, heater requirements, Etc.).

Nevertheless, even if infrequent operations, relevant facilities (Restriction Orifices, boot, Etc.) have to be integrated in the network.

When depressurizing the CO_2 to atmospheric conditions, extremely low temperatures are anticipated whatever the considered scenario. As the design temperature of the transport pipeline is supposed to be -25°C as per previous phase of the project (concept select), it is important to control the pressure in the transport pipeline during depressurization operations in order to comply with design temperatures of the transport pipeline. The control of the pressure during blow-down has been achieved by considering staggered depressurization sequence and by adjusting the diameter of the Restriction Orifices over depressurization sequence.

Since there is a high risk of ice formation around the pipe and in its layers at very low temperatures and in order to take into account enough margin to cover the uncertainties related to *OLGA* software, the minimum considered temperature is 0°C. It is also worth mentioning that the depressurization simulations are very slow, and the temperature does not fall rapidly with proposed sequence which means that the margin over the temperature could be relaxed as these calculations are not considered as fast transient.

Special attention should be also paid to the partially and totally buried sections of the transport pipeline that will not take benefits of the potential heating brought by the surrounding sea water.

The back pressure downstream Restriction Orifice should be also defined to avoid ice formation in the depressurization system. In the present study, and considering the phase diagram of CO_2, the pressure has been fixed at 7 bara (above triple point) to avoid ice formation and risk of plugging of depressurization lines. The transition from 7 bara to atmospheric conditions at vent and associated equipment should be developed by Process team in accordance with Flow Assurance outcomes / recommendations presented in this report and to mitigate the risks of plugging of the depressurization network.

In the frame of this study, 3 main scenarios have been considered. They are summarized here below. All cases have been covered and deeply assessed. Nevertheless, in order to ease the reading of this report, it has been decided not to present all the cases as all the results are almost similar and proposed design complies with all requirements.

➢ Normal / Planned shutdown:

- Shutdown of the export pumps while the wells are still open in order to empty the pipeline as much as possible,
- When the pressure reaches 90 barg at Maasvlakte terminal and before triggering the two-phase flow, the blowdown through the wells is stopped,
- 1 hour waiting time for the preparation of venting operations,
- Vent through restricted orifice(s),

➢ Abnormal / Unplanned shutdown:

- Spurious closure of wells while the export pumps are still in operation,
- Packing of the transport pipeline at the highest pressure,
- Blowdown operation into the furthest well having the lowest WHSIP (for better control of the depressurization activity, nevertheless number and location of wells still to be defined by Field Operations team– Single well or multi wells operation, acceptance of two-phase flow in well during blowdown, Etc.) until reaching the pressure set point of 90 barg at Maasvlakte terminal, or 10 bar above the lowest WHSIP
- After settle-out pressure in network is about 90 barg or 10 bar above the lowest WHSIP, well is shutdown, and vent through restricted orifice(s),

Because this case is similar to the planned shutdown with minor differences, only relative results will be presented.

- Abnormal / Unplanned shutdown with line packed and wells are not available,

- Representative scenario in case of hydrates plug before reaching the platforms,
- The export pumps are still in operation and the line is packed,
- 1 hour waiting time for the preparation of venting operations,
- Vent through restricted orifice(s).

This case has a very low probability of occurrence as wells should always be available, at least one, which means that blowdown and pressure reduction into transport pipeline should always be possible through the wells at first. Because this case is similar to the planned shutdown with minor differences, only relative results will be presented.

After completion of the different analyses, proposed design of depressurization system consists in implementing 4 Restriction Orifices. This arrangement has been identified as the best compromise in order to avoid too low temperatures in transport pipeline with regard to design temperature and water icing risks, but also to shorten the duration of the depressurization sequence.

Proposed diameters of the Restriction Orifice are 5, 7, 10 and 14 inches for the depressurization of the BB03 trunkline. Those Restriction Orifices are used in sequence (the one after the other). The switch between the first and second Restriction Orifices occurs 10 hours after depressurization of first RO. 24 hours later, occurs the second switch. The third switch occurs 7 hours after depressurization of third RO. The minimum achieved bulk temperature is 1°C (for a few minutes).

It is worth mentioning that the Restriction Orifice is modeled as a Leak in *OLGA*, which means it has a fixed diameter.

The following operating philosophy, which has been developed based on the different analyses carried out during the depressurization study, is proposed.

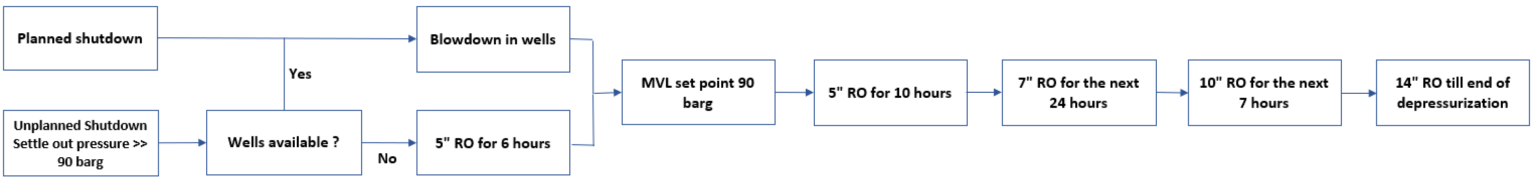

Figure 6-5: Operating philosophy of the depressurization post planned and unplanned shutdowns

The figures here below present the evolution of the pressure during depressurization at key positions of the trunkline in the case of a planned shutdown and unplanned shutdown with previous operating guidelines.

As illustrated on the sequence above, the duration of the depressurization starting from a pressure set point of 90 barg at MVL lasts approximately 2 days and a half (58 hours).

As illustrated on next figure, there is some delay / extended pressure gradient over the trunkline length. Indeed, the pressure decrease close to the DHUB appears to be faster than at onshore terminal as illustrated above. This gradient of pressure over the distance can be explained by the large volume of the trunkline and the pressure drop induced into the system due to fluid displacement.

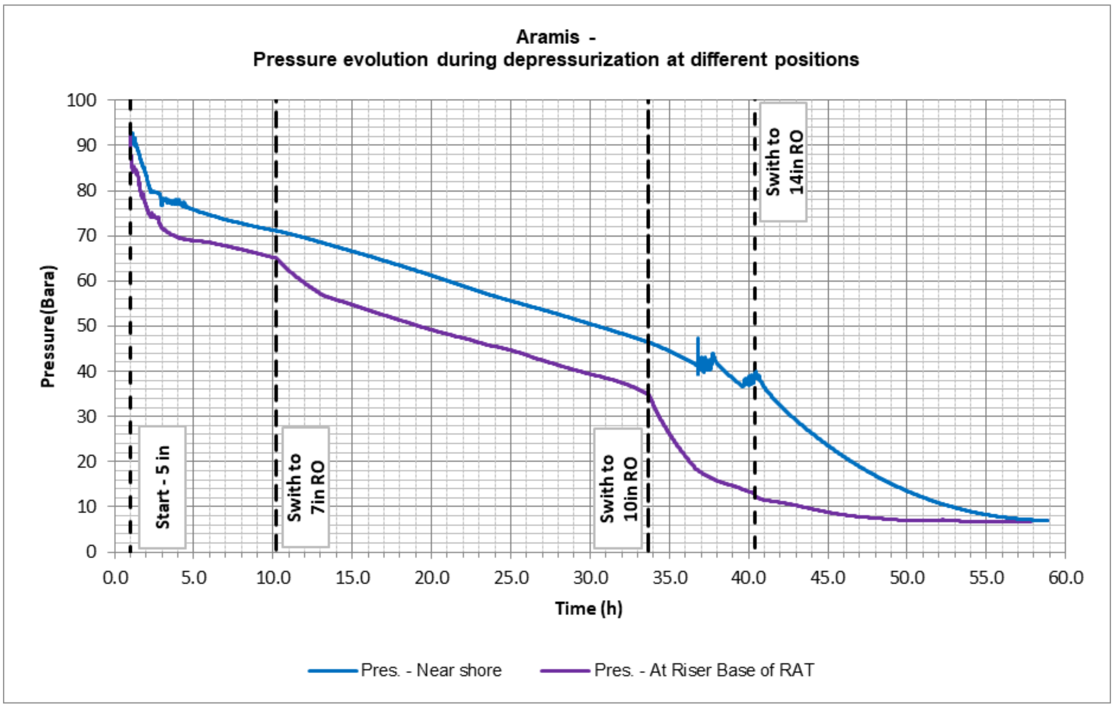

Figure 6-6: Pressure evolution in pipeline during depressurization after 90 barg set point is reached at MVL

It is worth reminding that for planned depressurization, the blowdown in wells before reaching the pressure set point at MVL terminal lasts about 5 hours after the shutdown.

Concerning the unplanned shutdown with wells available post packing of the line, the blowdown through the well with the lowest WHSIP lasts a little more than 10 days as illustrated in the figure below presenting the pressure at MVL terminal from shutdown until reaching the pressure set point of 90 barg. In the present study, the WHSIP of the considered well for blowdown operations being lower than 90 barg, the two-phase flow condition is driving the switch to Restriction Orifice to complete the depressurization of the injection network. Once the pressure set point is reached at MVL terminal, the proposed operating philosophy detailed above can be applied.

Applying the previous sequence of staggered Restriction Orifices as presented just before following the blowdown into the wells, then the results / behavior obtained will be almost similar to the case presenting here after in the report and referring to planned shutdown. This conclusion can be extrapolated from the different figures and behavior observed during the planned shutdown and by advanced analysis of the results.

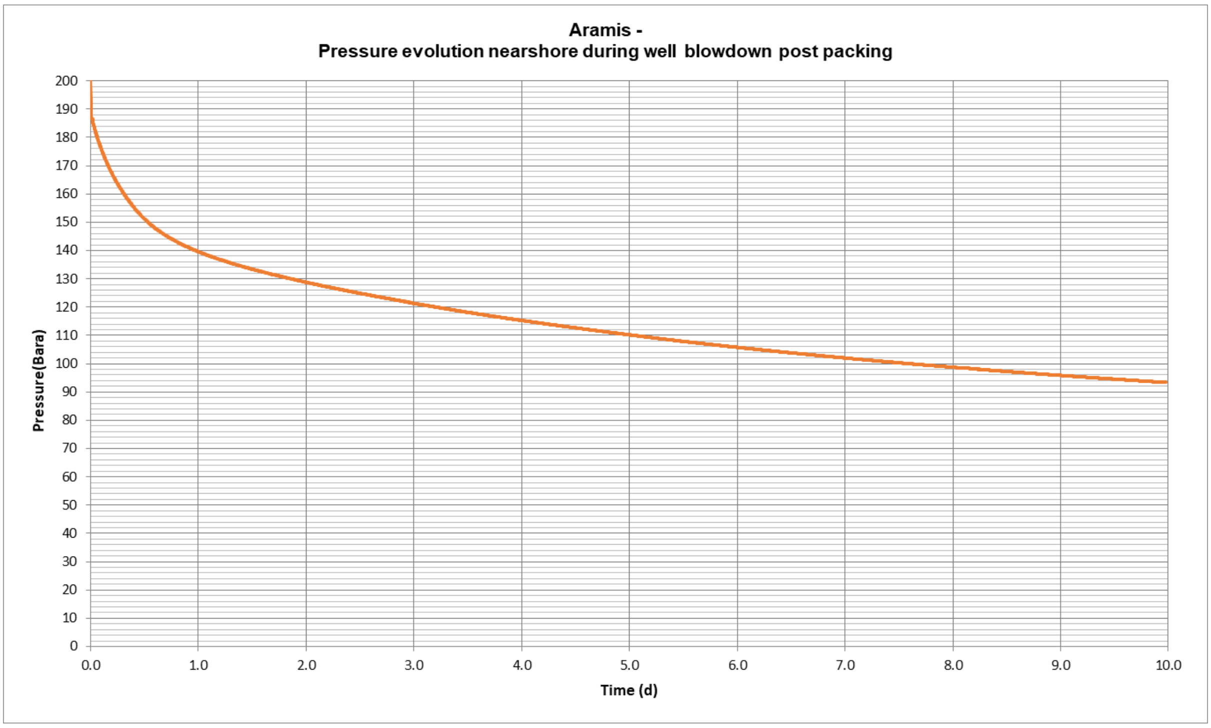

Figure 6-7: Pressure evolution in pipeline during well blowdown post unplanned shutdown - packing and prior reaching 90 barg set point at MVL

Once the pressure set point is reached at MVL terminal, the proposed operating philosophy detailed above can be applied.

On the other hand, for the unplanned shutdown with line packing and wells not available, the procedure of the depressurization can start directly with a 5” RO and the steps detailed above can still be valid and applicable as the temperature can still be controlled and does not drop to very low values, respecting the 0°C threshold. The temperature at Riser Base (coldest spot) is presented in the following figure.

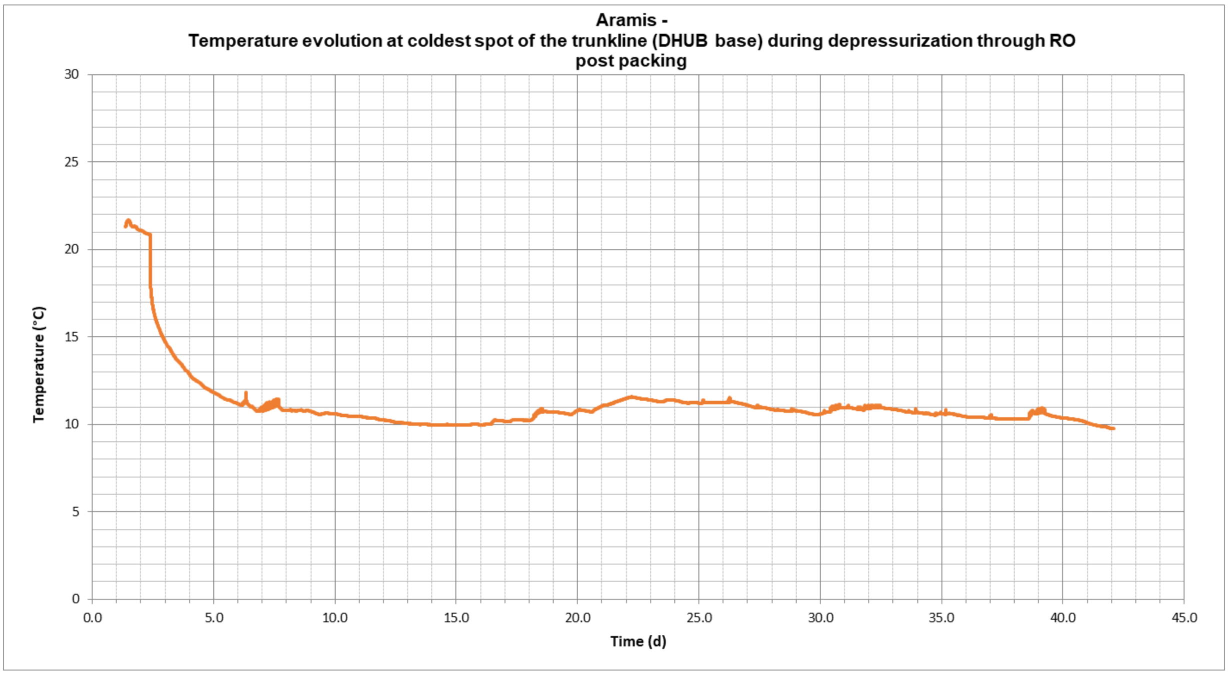

Figure 6-8: Temperature evolution at coldest spot of the trunkline (DHUB base) during depressurization through RO following unplanned shutdown - post packing

It is worth mentioning that the set point of 90 barg at MVL is reached after about 6 hours (357.9 min) of depressurization through the 5” RO in addition to the previously mentioned 10 hours. The rest of the proposed sequence for the depressurization remains unchanged with no risk of dropping to very low temperatures and ice formation around the pipe can be avoided.

As for the other unplanned shutdown, applying the previous sequence of staggered Restriction Orifices to this scenario after the blowdown through the 5” RO has been completed, then the results / behavior obtained will be almost similar to the case presenting here after in the report and referring to planned shutdown. This conclusion can be extrapolated from the different figures and behavior observed during the planned shutdown and by advanced analysis of the results.

Because of the isenthalpic phenomena during the liquid blow-down, the minimum expected temperature downstream the different Restriction Orifices is about -56°C whatever the shutdown scenario considered. Those low temperatures should be experienced as long as liquid CO_2 will be observed downstream Restriction Orifice. To cover the uncertainties related to modeling with *OLGA*, and because of the fast transient phenomena observed across Restriction Orifice, then a 20°C margin is added to the minimum temperature leading to a design temperature of the topside piping of - 76°C.

The figure below presents the evolution of the temperature downstream Restriction Orifice during the depressurization sequence. The liquid and gas mass rates are also presented downstream Restriction Orifice.

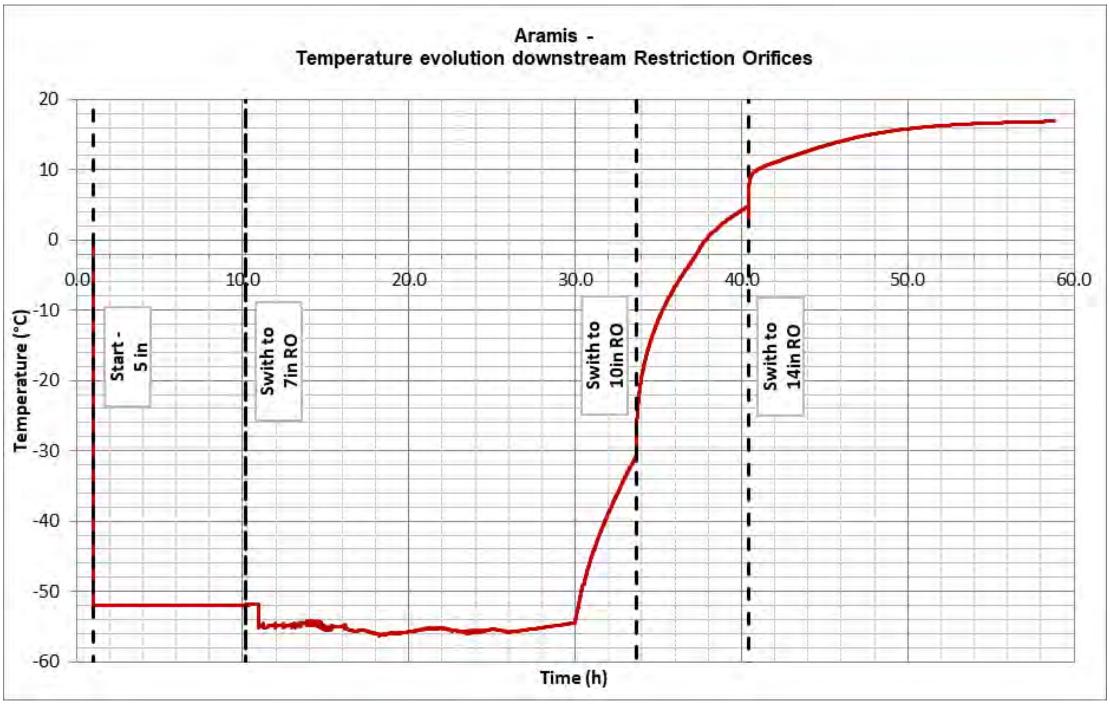

Figure 6-9: Temperature evolution downstream Restriction Orifices during depressurization

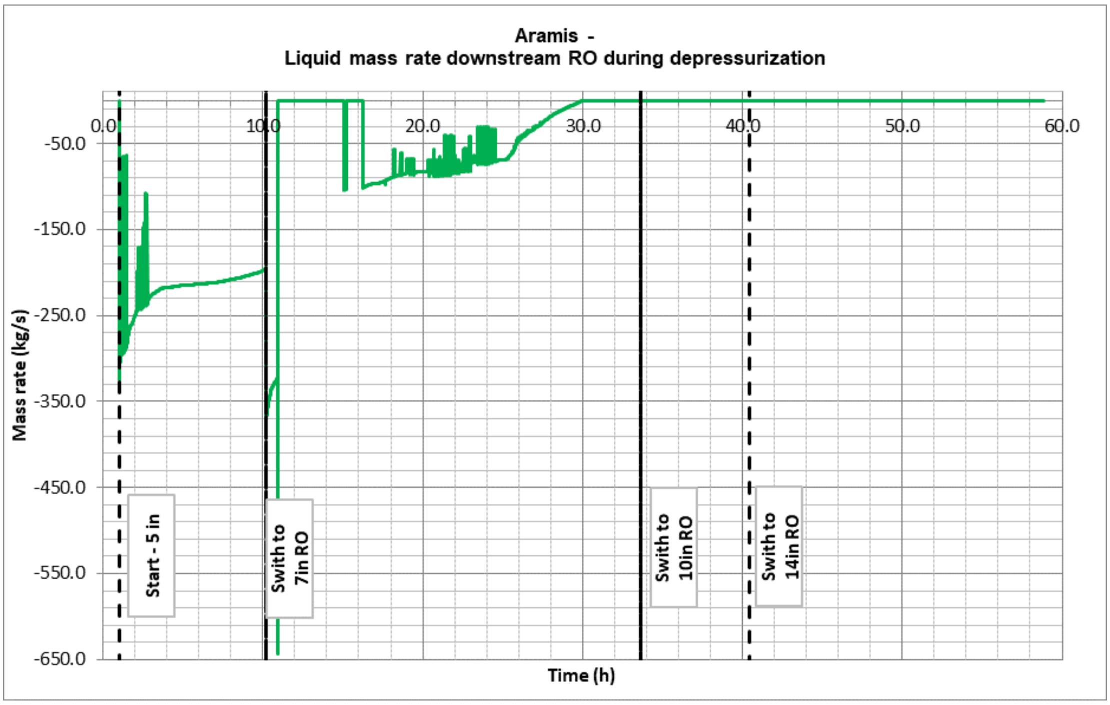

Figure 6-10: Liquid mass rates downstream Restriction Orifices during depressurization

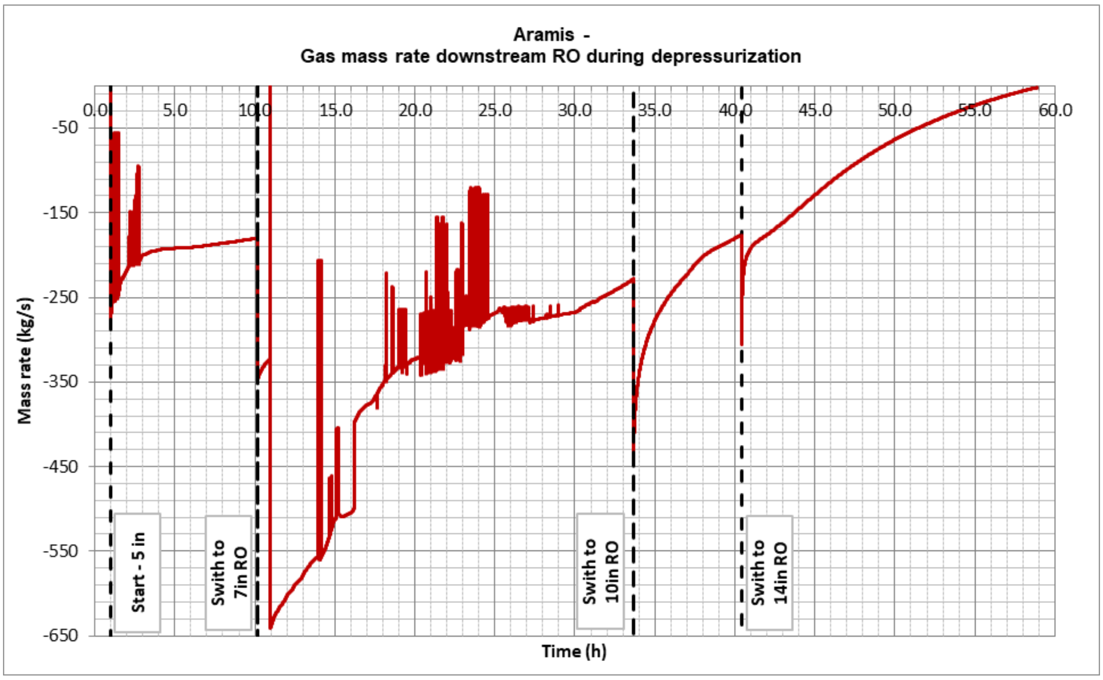

Figure 6-11: Gas mass rates downstream Restriction Orifices during depressurization

From the figures above, it is worth to mention that as soon as no more liquid CO_2 is expected downstream Restriction Orifice, then an increase of the temperature is also observed. Based on the different simulations performed, it appears that the increase of the temperature associated to the stop of liquid CO_2 flowing downstream could be used as the decision to switch to the third Restriction Orifice (10” RO) during the depressurization sequence.

Implementing TT sensors downstream Restriction Orifice is therefore recommended in order to support depressurization operations and the decision to activate the third Restriction Orifice. The last Restriction Orifice is used in order to vent faster the CO_2, once the risk of very low temperatures is over.

The following figure presents the minimum temperatures expected in the transport pipeline during the depressurization sequence for planned and unplanned shutdowns.

For all the scenarios considered in the present study, the critical location always corresponds to the section of the transport pipeline in front of the Restriction Orifice at least during the first 32 hours of the depressurization. After which, the coldest temperature can be seen close to the K14 PLET for a few hours until switching to a 10” RO, where the coldest temperatures are experienced in front of the RO again. After switching to a 14” RO all temperatures start converging to the same value.

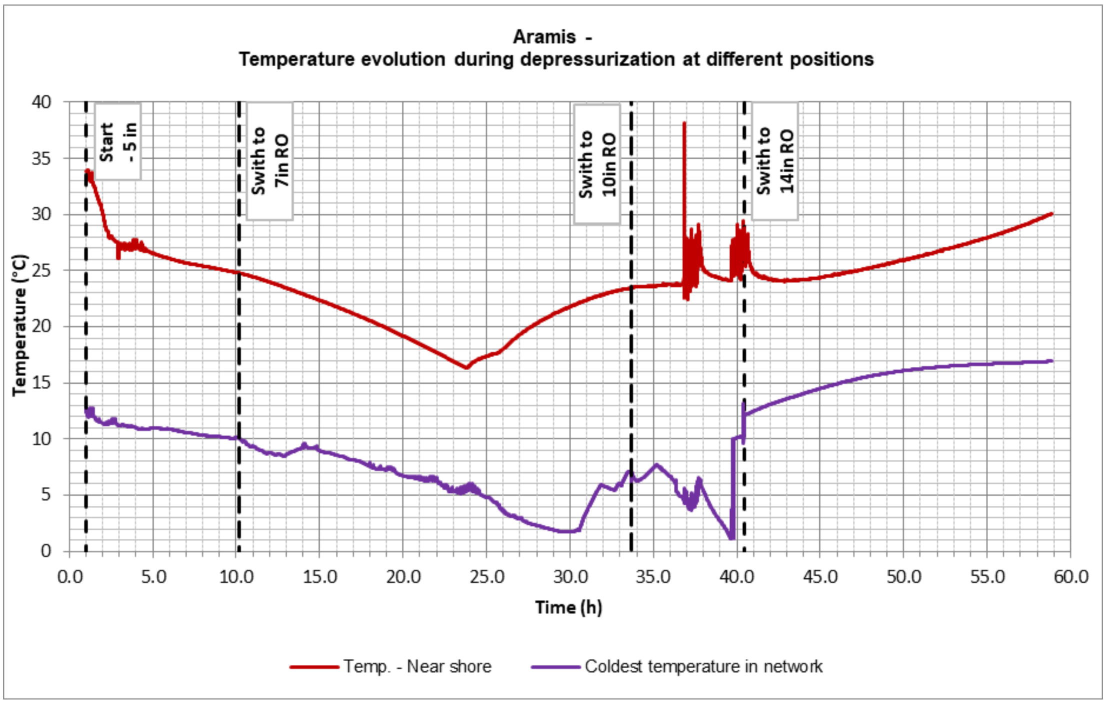

Figure 6-12: Temperature evolution at different positions upstream Restriction Orifices during depressurization

As presented on previous figures, proposed design keeps the temperatures high enough in order to avoid free water appearance and ice formation risks at 0°C and to avoid exceeding the design temperature of the trunkline. The minimum achieved temperature is 1°C for a few minutes to which a 5°C margin should be applied. A minimum temperature of -4°C should be considered at design.

The following table summarizes the peak rates of liquid and gas CO_2 expected downstream Restriction Orifice during the depressurization sequence. Both peak rates coincide at the same time, and they should be considered for the boot design and the dispersion study.

Peak liquid CO_2 (kg/s) ***10 % margin included***	**Peak gas CO_2 (kg/s)** ***10 % margin included***
708	705

Table 6-1: Peak quantity of CO_2 expected downstream Restriction Orifices during depressurization

It is worth reminding that the presented results of the depressurization are based on steady state warm conditions (warm inlet and summer ambient temperatures). In fact, it is more favorable to start the planned depressurization in warmer conditions as demonstrated in the Mollier diagram below where two starting points are presented one being colder than the other.

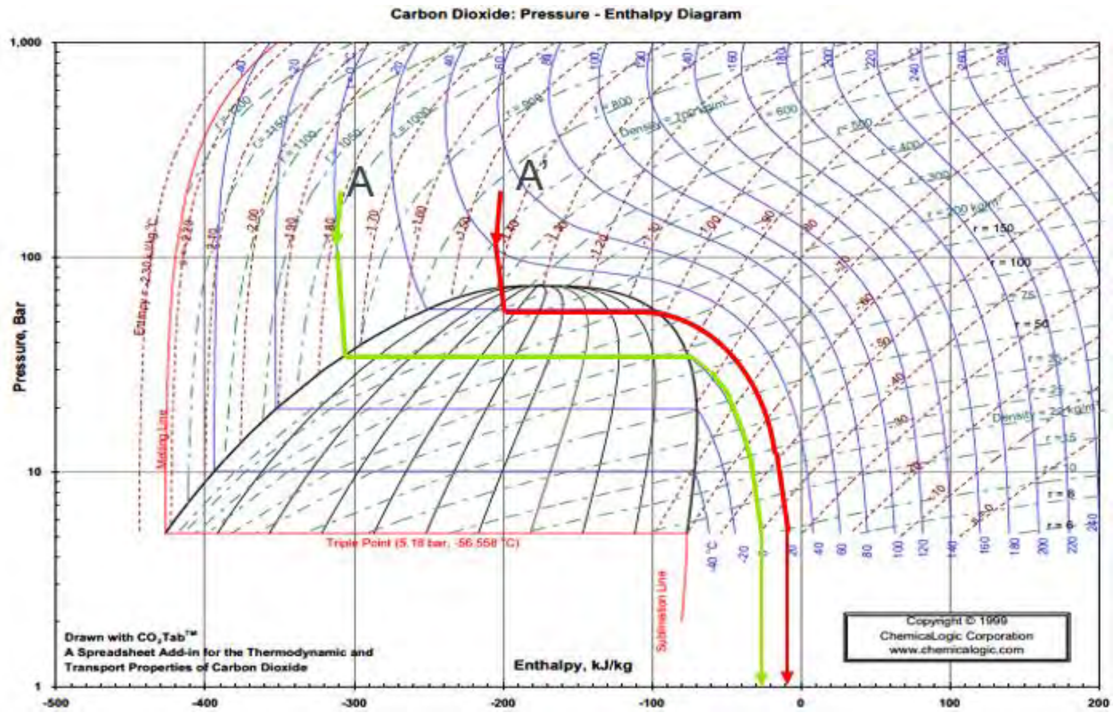

Figure 6-13: Comparison of cold and warm start of depressurization on the Mollier diagram

As observed on the figure above, the depressurization of relatively cold liquid phase CO_2 may lead to unacceptable low temperatures which could exceed the minimum design temperatures unless the conditions are controlled. When the start is at warmer conditions, the pipe is still warm thanks to the inertia and could help heat the vapor CO_2 which is also a way of controlling the minimum temperature in the system. When the system is in cold thermal equilibrium the depressurization could take longer time because it should be further sequenced with more intermediate RO sizes in order to control the temperature.

It is also worth mentioning that the probability of occurrence of such scenario where the system is in full thermal equilibrium with the ambient is very unlikely. The system is highly pressurized with liquid CO_2 and taking into account the thermal inertia even with a bare pipe and the thermal capacity of CO_2, which is very favourable, it would take days in order to be in the full thermal equilibrium which gives more flexibility in terms of operations.

Depressurization at cold temperatures with the system being in full equilibrium with the surroundings cold conditions is very unlikely to occur, and the results should not be significantly different compared to the ones presented in the present report, as illustrated on the diagram of Mollier for the CO_2, that is why it was not considered as the basis of the depressurisation design at least not at this phase of the study. As part of the Flow Assurance dossier to be developed at the next phase, the depressurization during winter conditions should be covered, what will allow verifying that the current design is still applicable even for colder temperatures.

7 UNCERTAINTIES & RISKS OF FLOW ASSURANCE STUDY

Main uncertainties & risks associated to present Flow Assurance study are listed and detailed here below:

- Reservoir Pressure:
  - The present study is considering an average reservoir pressure per year and not minimum reservoir pressure for start-up flowrates. This uncertainty also applies for late life conditions,
  - Flow Assurance study should be updated as soon as relevant information about expected reservoir pressures for the different panels will be better known,
- Well injectivity:
  - Should the injectivity not be equal to the target injection rate, then there is no guarantee to achieve the 22 MTPA injection rate through transport pipeline,
  - Flow Assurance study should be updated as soon as relevant information on well models and injectivities will be available for the different injection panels,
  - Range of injectivity (low injectivity, high injectivity, mid injectivity) should be considered as for other CCS projects to cover uncertainties at reservoir level,
- Inlet conditions & injection profile:
  - The inlet conditions to the transport pipeline (Pressure and Temperature) were provided at early stages of the project. Should any of these conditions be updated and/or modified, then a sensitivity study should be conducted in order to make sure of the feasibility of the selected concept,
  - Design temperature is based on combinations of different flowing conditions at terminal (22 MTPA – 56°C / 11 MTPA – 65°C). This design temperature assumes that Porthos premise will never deliver more than 11 MTPA. Should any upgrade of the Porthos facilities be considered in the future to get more emitters, then the design temperature of the pipeline might be a major bottleneck,
- CO_2 specifications and modelling:
  - CO_2 with impurities has been used as base case for all steady state and transient operations as there is at least 95% of CO_2 in the injected fluid. The considered fluid composition was based the Aramis Premises (Ref. [1]) and includes several assumptions (components ignored, others replaced with alike components...),
  - There are also some limitations in current commercial thermodynamic software, some impurities being not supported as Nox & Sox, while it is known today those impurities have strong impact on phase envelope of CO_2. Nox & Sox should not have a great impact on pressure drop (low impact on density and viscosity) but do have an impact on phase envelope and thus the risk of appearance of Two-phase flow and free water,
  - Since, the choice of the fluid could induce uncertainties on pressure drop calculations and depressurization key figures and although the different applied margins should cover these uncertainties, further sensitivity studies regarding CO_2 specifications should be conducted. Should the fluid composition be updated and/or modified, a feasibility study should be done in order to validate the selected concept,
- Depressurization operating philosophy,

  - Scenario of depressurization to be considered are unclear because of the lack of consolidated Basis of Design. Some scenario was discarded unanimity by project at the beginning and scenario came back at the end of the Flow Assurance study,

- Pipeline characteristics,
  - In the present study, most of the pipeline characteristics were provided by the pipeline specialists. Some of the cross-section details were based on assumptions, although validated by pipeline specialists could still induce uncertainties on the temperature profile of the transport system. Even though, the applied margins should cover these uncertainties, should there be any modifications in the pipeline characteristics, a feasibility study of the selected concept should be conducted.

- *Multiflash* and *OLGA* used versions,
  - Flow Assurance study has been carried out using *Multiflash 7.1* and *OLGA 2021.2*, the latest versions adequate with CO_2 fluids,
  - The version of *OLGA* used in present study may not capture all improvements related to CO_2 modeling and it is difficult to state if results are conservative or not.

8 CONCLUSIONS & WAY FORWARD

Based on the Flow Assurance study carried out in the frame of the pre-project study of the phase 1 of the Aramis project, no major showstoppers have been identified with the proposed pipe diameter. However, it appears that the injection of 22 MTPA might be highly challenging at the end of life, therefore highlighting the strong effect of the pressure build-up observed in the reservoir during field life. It is nevertheless important to keep in mind that depending on the pressure build-up in the reservoir, this plateau might be severely affected.

It is also worth mentioning that no concern is anticipated with regards to the transport pipeline operability.

The following way forward are nevertheless proposed to complete the Flow Assurance scope of work and further refine the design and the operating philosophy / strategy:

- The selected concept needs to be further studied and validated with updated Basis of Design (CO_2 specifications, Pipeline characteristics, Injection profile, Inlet conditions, Reservoir pressure evolution, Well models…),
- Further investigate the spurlines and BB04 pipelines diameters against updated injection profiles,
- Further develop the start-up sequence and associated operating philosophy (risks of hydrates, drying philosophy, Etc.),
- Further develop the hydrates mitigation strategy to cover well restart operations and initial start-up,
- Cover wells restart operating philosophy and procedures after both planned shutdown and abnormal shutdown followed by blowdown sequence in wells, especially the way Well Performance team intend to operate the different injection wells (respect of a certain drawdown for wellbore integrity management, full Injection Choke Valve opening instantaneously, well by well or all wells together, Etc.). Once this sequence of operations will be defined, then overall impact of the well restart sequence on the dynamic of the subsea network could be addressed,
- Develop hydrates remediation strategy considering the risks of hydrates formation in the transport and injection system during operating life,
- Further clarify the scenario of design of the pipeline with regards to the probability of occurrence. At this stage, a subsea trunkline at thermal equilibrium with surrounding sea water has been discarded by project unanimity and has not been considered by Flow Assurance team,
- Redevelop same scope considering pure CO_2, even if, from literatures, present assumptions are the most stringent,
- Develop the Flow Assurance dossier for the trunkline capturing the impact of the BB04 scope,
- Further develop the integrated model mimicking the different injection sites of all partners to fully capture the dynamic of the system and the impact of the different injection sites on each other.

9 APPENDIX

9.1 Steady state results

9.1.1 22 MTPA scenario

9.1.1.1 Pressure Profile

	Pipeline length (m)	Pressure (bara)	Pressure including margin (bara)
Onshore to MVL	0	180.97	180.97
	1894.00	180.52	180.47
Nearshore (including Micro-Tunnel part)	1917.20	180.54	180.49
	32569.63	174.51	173.86
A-ALT	32618.41	174.51	173.86
	126474.15	152.94	150.13
Section F ends with K14 PLET	126499.15	152.89	150.08
	162706.17	145.56	142.02
Section D ends with DHUB	162731.17	145.54	142.00
	196259.45	139.42	135.26
Section C ends with the PLEM	196272.28	139.40	135.25
	222489.78	140.48	136.43
PLEM to L4A ends with L4A platform	222515.83	140.39	136.33
	224417.70	136.31	131.84

9.1.1.2 Temperature Profile

	Pipeline length (m)	Temperature (C)
Onshore to MVL	0	49.99
	1894.00	49.77
Nearshore (including Micro-Tunnel part)	1917.20	49.77
	32569.63	43.12
A-ALT	32618.41	43.08
	126474.15	25.29
Section F ends with K14 PLET	126499.15	25.27
	162706.17	20.02
Section D ends with DHUB	162731.17	20.02
	196259.45	16.99
Section C ends with the PLEM	196272.28	17.00
	222489.78	16.33

PLEM to L4A ends with L4A platform	222515.83	16.38
	224417.70	15.78

9.1.2 5 MTPA scenario

9.1.2.1 Pressure Profile

	Pipeline length (m)	**Pressure (bara)**	**Pressure including margin (bara)**
Onshore to MVL	0	150.00	149.90
	1894.00	150.00	149.90
Nearshore (including Micro-Tunnel part)	1917.20	150.05	149.96
	32569.63	151.30	151.32
A-ALT	32618.41	151.35	151.38
	126474.15	150.37	150.31
Section F ends with K14 PLET	126499.15	150.37	150.31
	162706.17	150.28	150.21
Section D ends with DHUB	162731.17	150.28	150.21
	196259.45	146.78	146.36
Section C ends with the PLEM	196272.28	146.78	146.36
	222489.78	150.64	150.61
PLEM to L4A ends with L4A platform	222515.83	150.64	150.61
	224417.70	146.55	146.10

9.1.2.2 Temperature Profile

	Pipeline length (m)	**Temperature (C)**
Onshore to MVL	0	49.98
	1894.00	49.39
Nearshore (including Micro-Tunnel part)	1917.20	49.40
	32569.63	31.32
A-ALT	32618.41	31.20
	126474.15	17.59
Section F ends with K14 PLET	126499.15	17.59
	162706.17	17.41
Section D ends with DHUB	162731.17	17.41
	196259.45	16.62
Section C ends with the PLEM	196272.28	16.66
	222489.78	16.02
PLEM to L4A ends with L4A platform	222515.83	16.02
	224417.70	15.50

9.1.3 Sensitivity study 1

9.1.3.1 Pressure Profile

	Pipeline length (m)	Pressure (bara)	Pressure including margin (bara)
Onshore to MVL	0	180.97	180.97
	1894.00	180.53	180.48
Nearshore (including Micro-Tunnel part)	1917.20	180.54	180.49
	32569.63	174.59	173.94
A-ALT	32618.41	174.58	173.94
	126474.15	153.20	150.42
Section F ends with K14 PLET	126499.15	153.16	150.38
	162706.17	145.87	142.36
Section D ends with DHUB	162731.17	145.83	142.31
	196259.45	135.61	131.07

9.1.3.2 Temperature Profile

	Pipeline length (m)	Temperature (C)
Onshore to MVL	0	49.99
	1894.00	49.77
Nearshore (including Micro-Tunnel part)	1917.20	49.77
	32569.63	43.10
A-ALT	32618.41	43.06
	126474.15	24.90
Section F ends with K14 PLET	126499.15	24.88
	162706.17	19.86
Section D ends with DHUB	162731.17	19.85
	196259.45	17.32

9.1.4 Sensitivity study 2

9.1.4.1 Pressure Profile

	Pipeline length (m)	Pressure (bara)	Pressure including margin (bara)
Onshore to MVL	0	181.00	181.00
	1919.00	180.43	180.38

Nearshore (including Micro-Tunnel part)	1919.91	180.43	180.37
	32620.51	172.63	171.79
A-ALT	32621.81	172.55	171.70
	126576.34	145.30	141.73
Section F ends with DHUB	126576.36	145.30	141.74
	196399.47	127.92	122.62

9.1.4.2 Temperature Profile

	Pipeline length (m)	**Temperature (C)**
Onshore to MVL	0	65.00
	1919.00	64.80
Nearshore (including Micro-Tunnel part)	1919.91	64.80
	32620.51	55.06
A-ALT	32621.81	55.06
	126576.34	31.08
Section F ends with DHUB	126576.36	31.08
	196399.47	17.89

Aramis Pipeline Routing Desktop Study - Expected Site Conditions

Consultancy Report | Dutch Sector of the North Sea

R201644 03 | 10 February 2022

TotalEnergies

Document Control

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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.

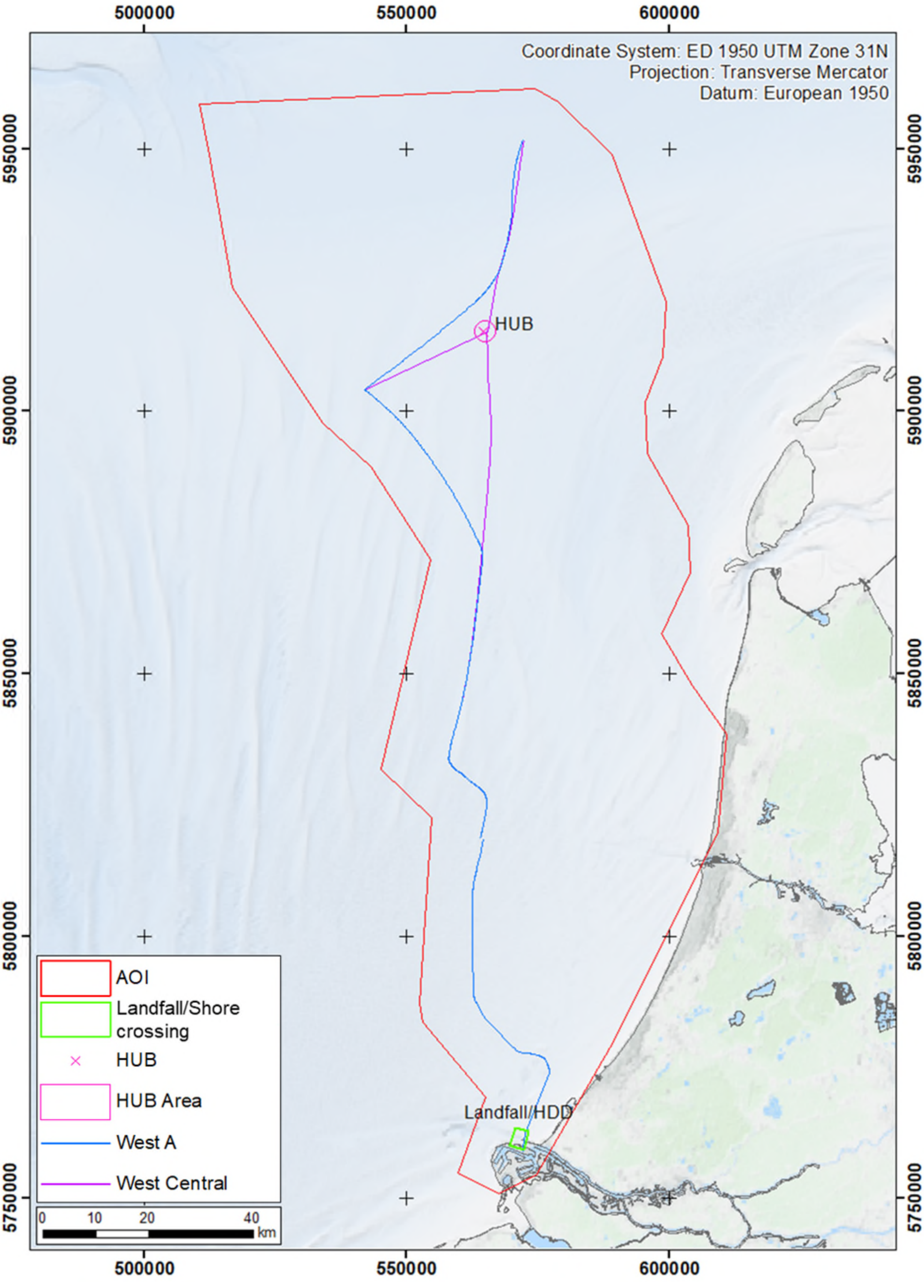
Please do not hesitate to contact us should you have any queries.

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.

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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.

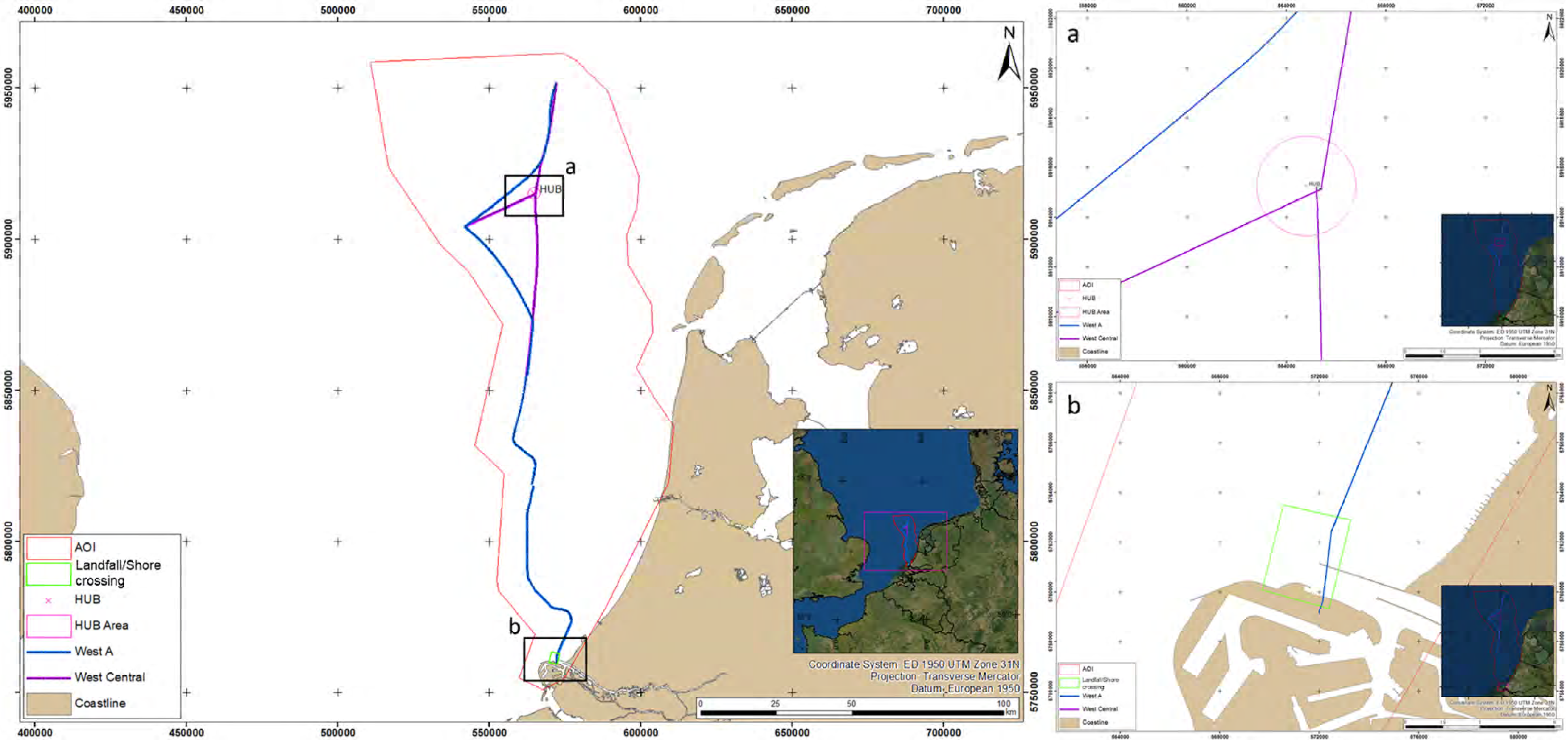

Figure 1.1: Extent of the AOI and definition of the Landfall/Shore crossing and Offshore Distribution HUB Areas

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.

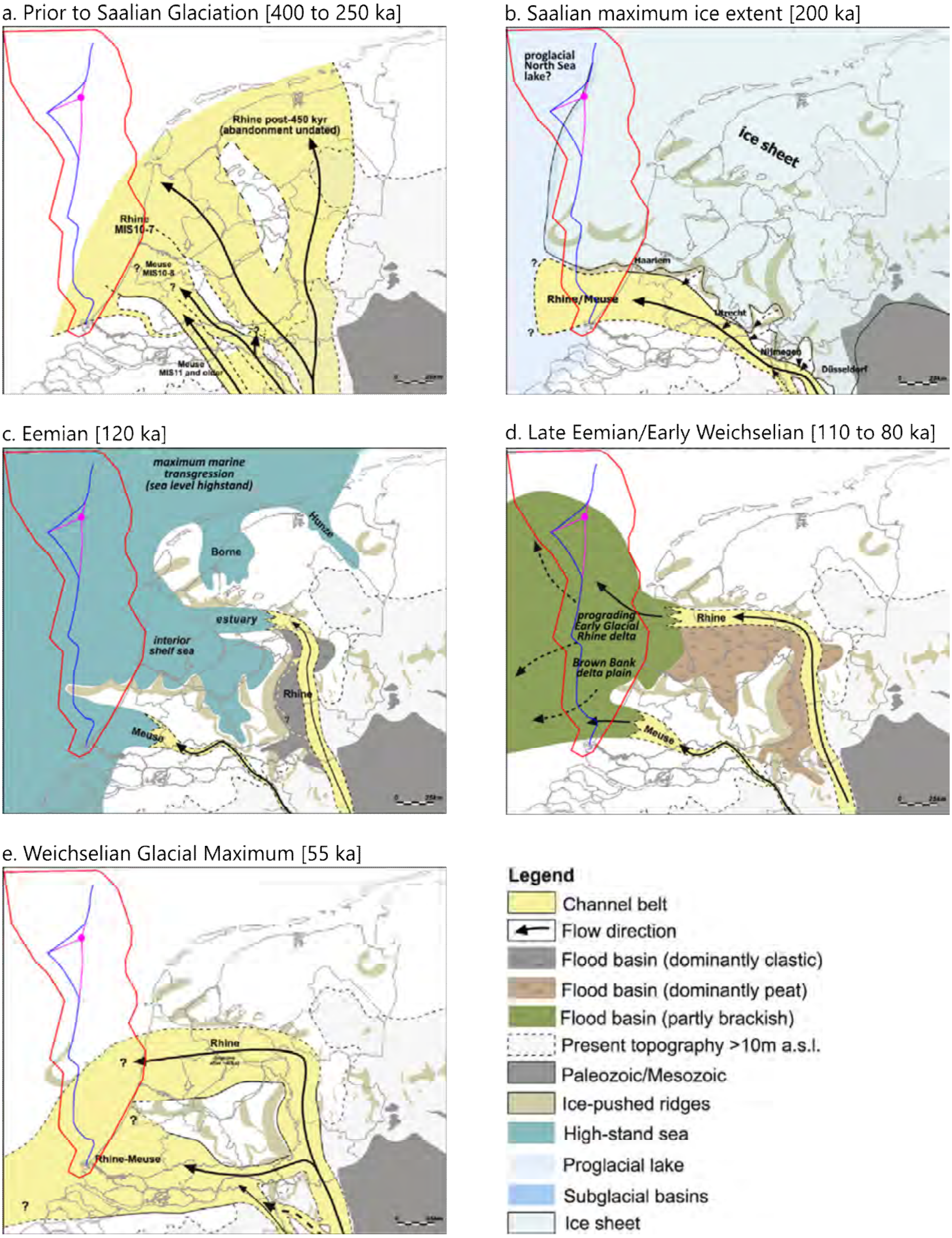

Figure 3.1: Paleo-geographical reconstructions of the Netherlands during the Middle to Late Pleistocene illustrated by five successive time frames. a) Rhine–Meuse drainage configuration prior to Saalian Glaciation. b) Maximum Saalian ice extent. c) Eemian interglacial maximum transgression during sea 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).

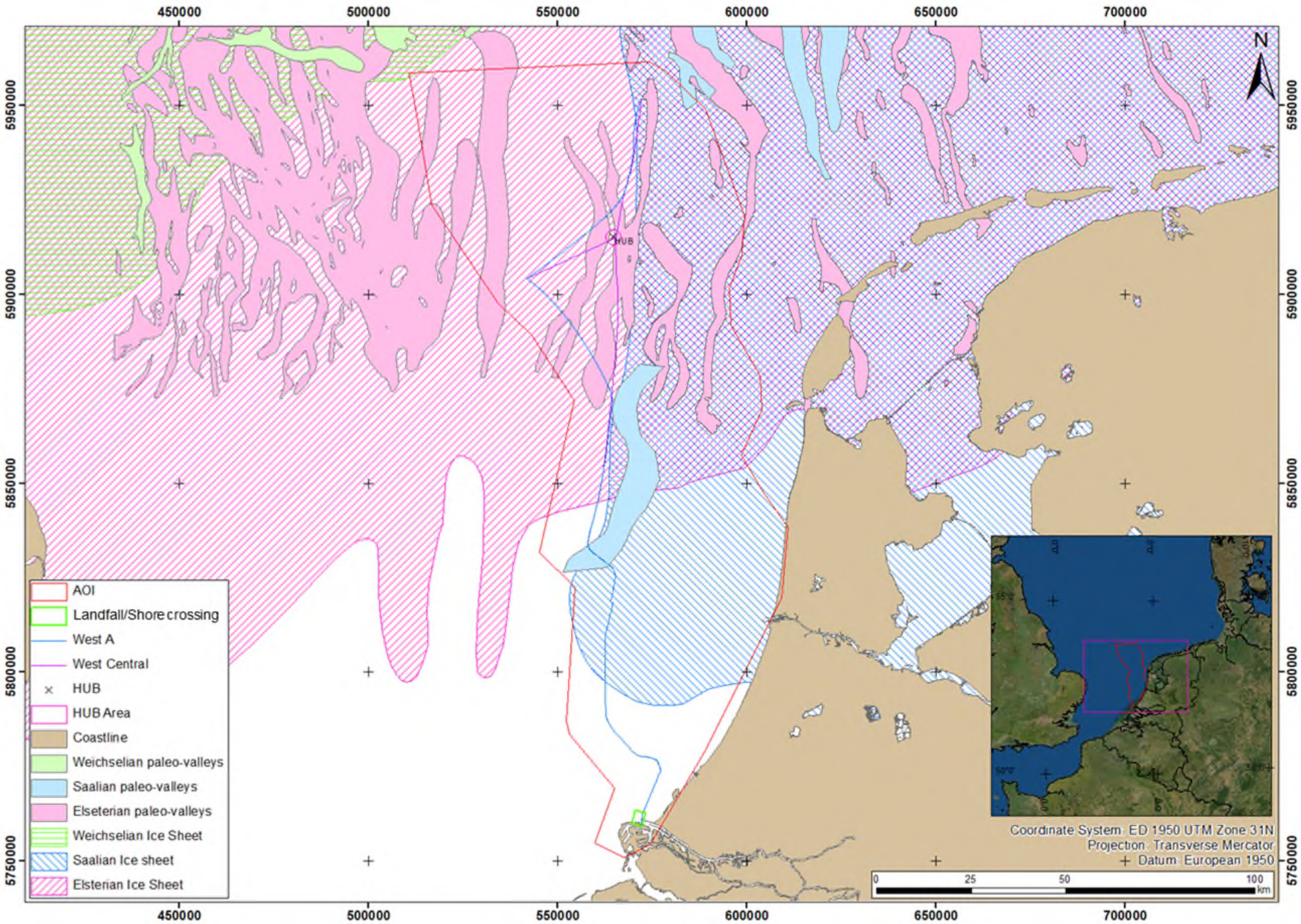

Figure 3.2: Maximum ice extent of the Pleistocene glaciations and associated paleo-valleys (Laban, 1995)

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.

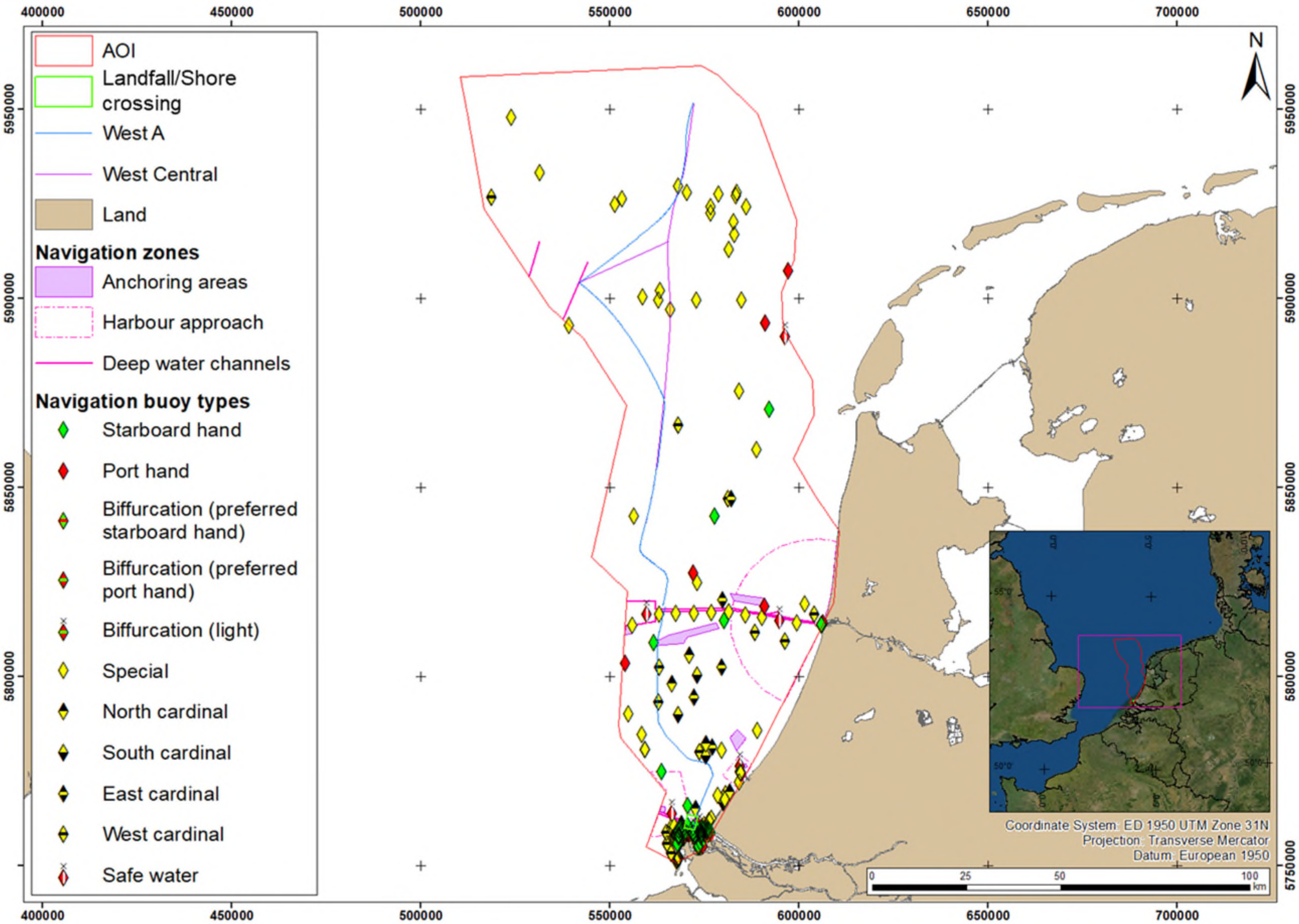

Figure 4.1: Navigation areas or infrastructures identified within the AOI

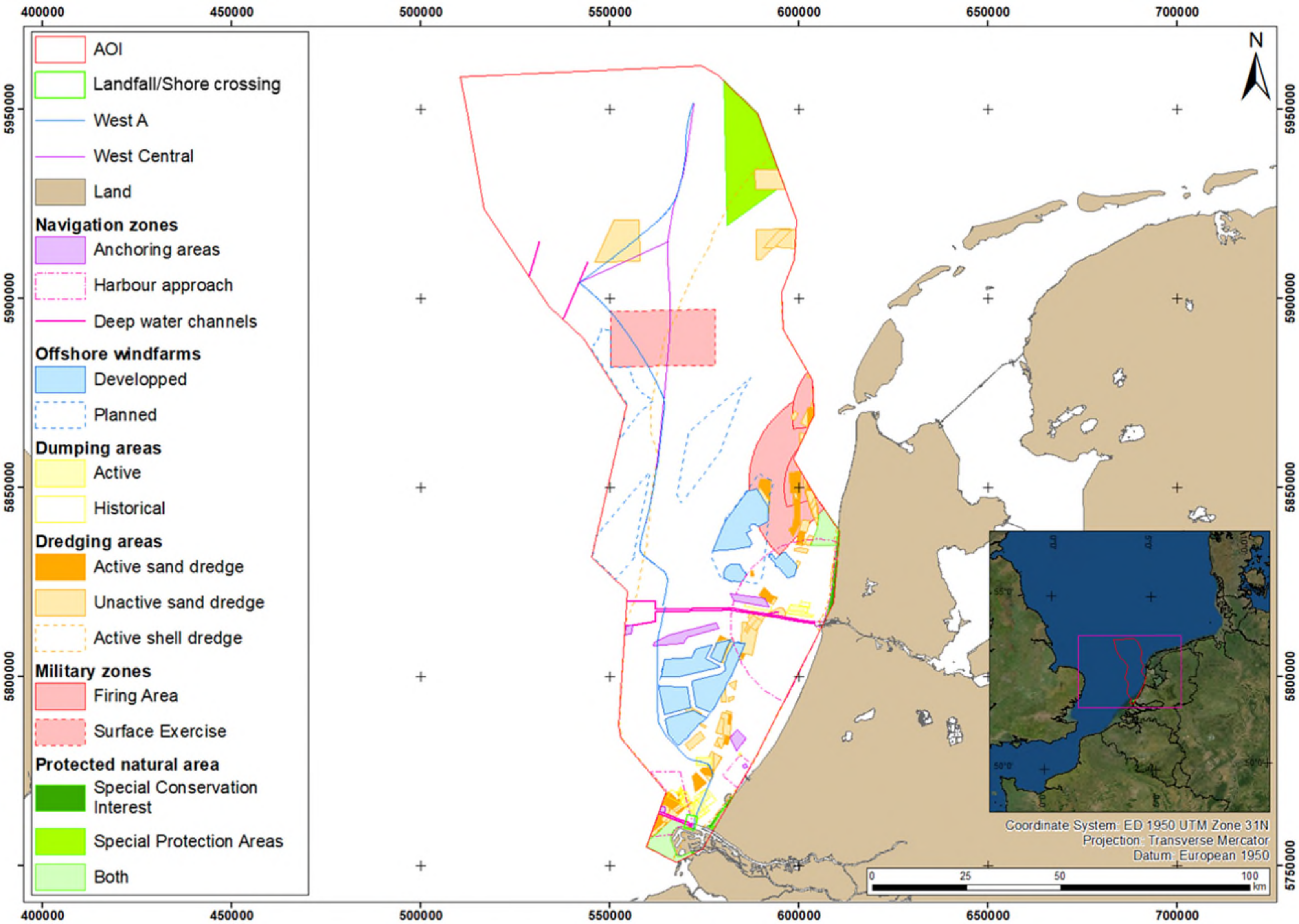

Figure 4.2: Restricted areas identified within the AOI

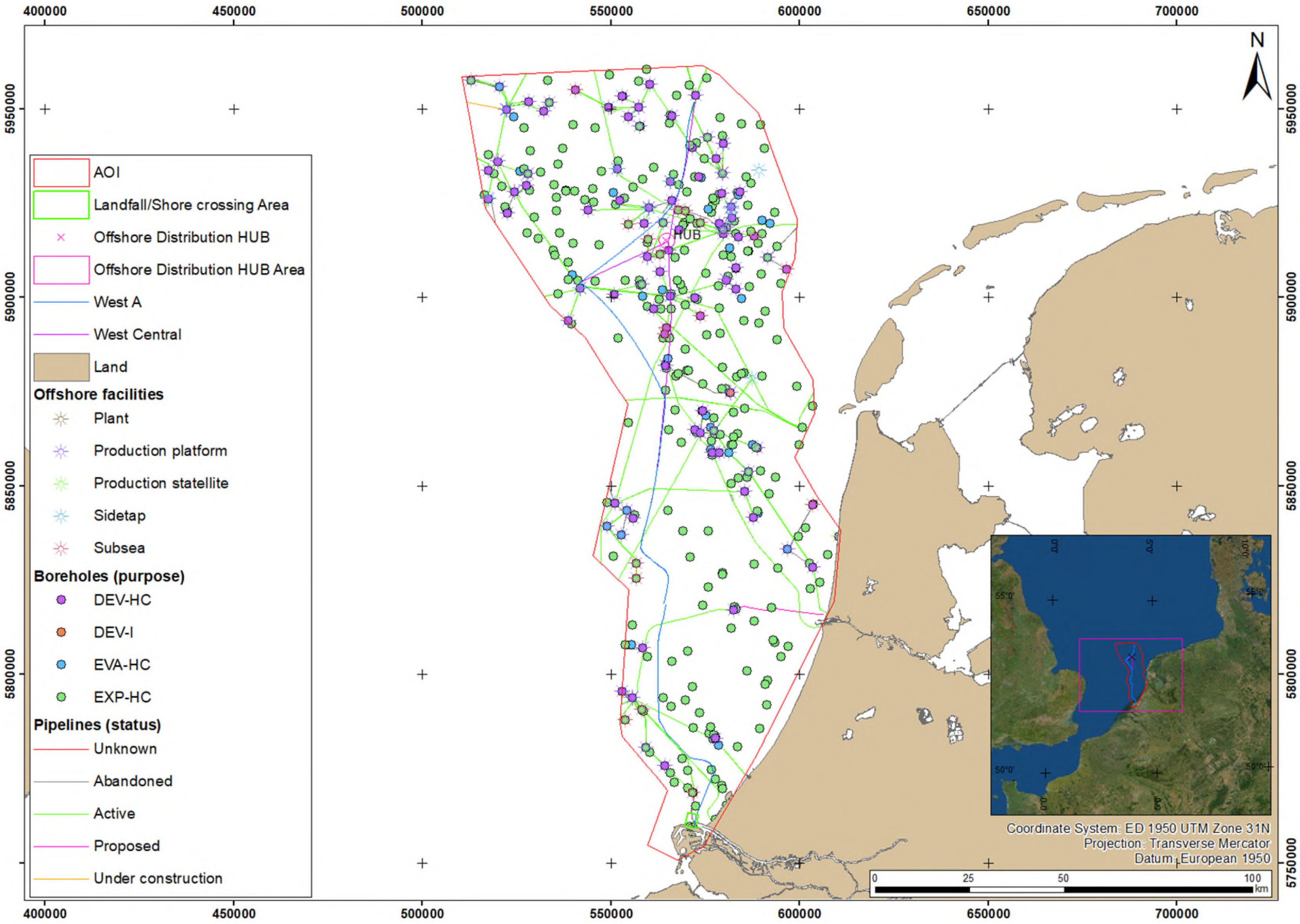

Figure 4.3: Oil and gas seafloor infrastructures identified within the AOI

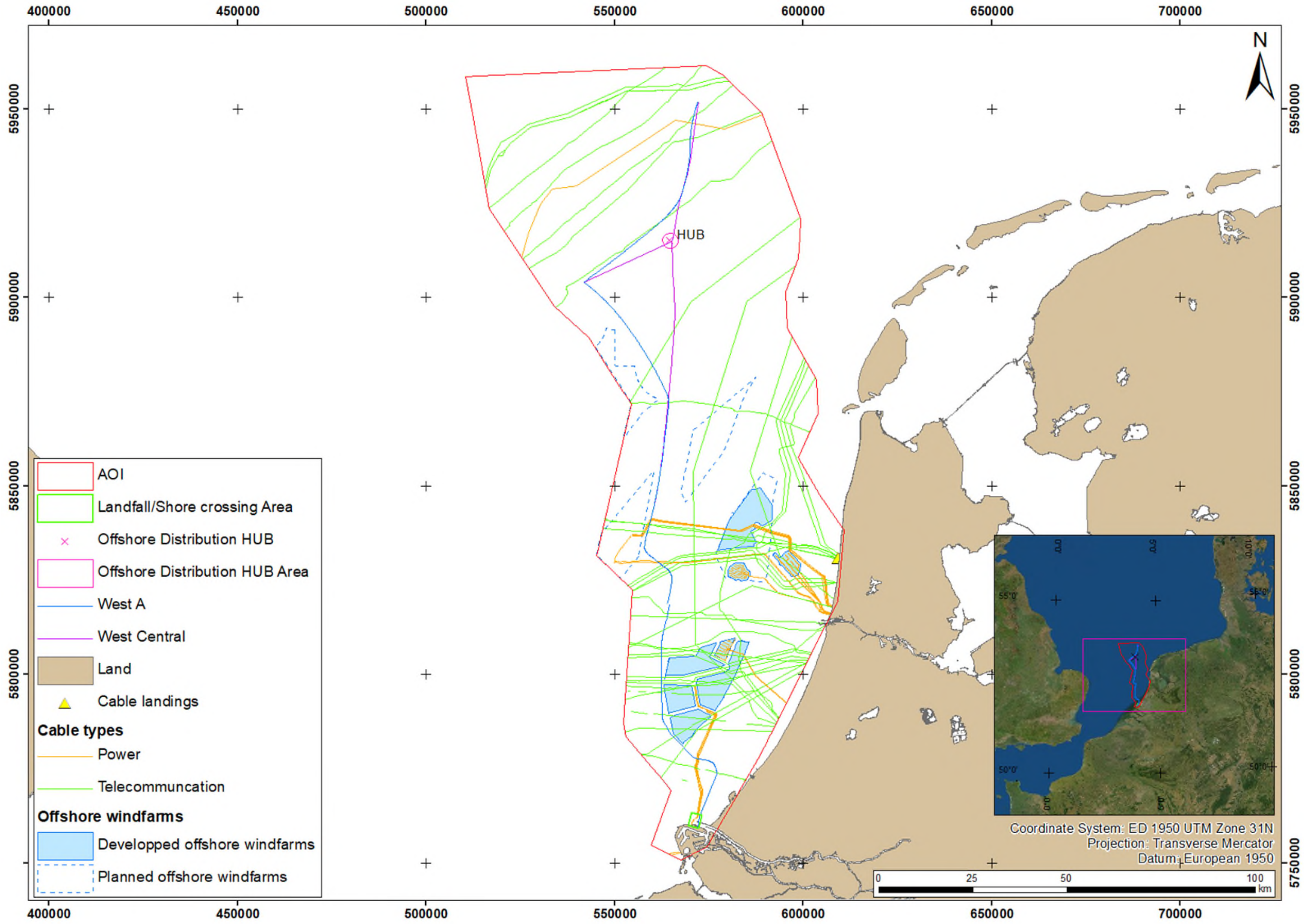

Figure 4.4: Cable and wind-energy related infrastructures identified within the AOI

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.

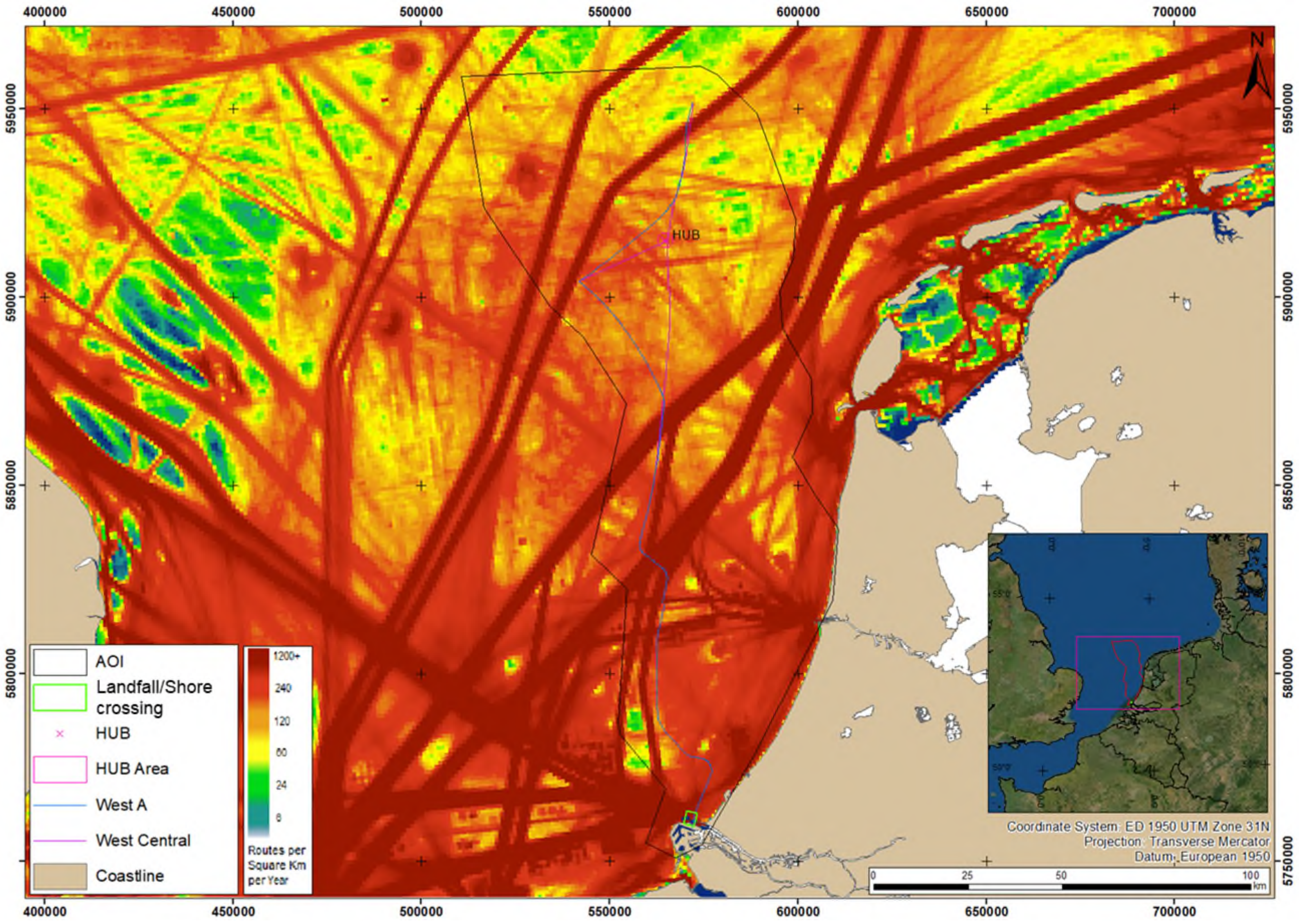

Figure 4.5: Total vessel routes density given as routes per km^2 per year for 2020 (EMODnet, 2022)

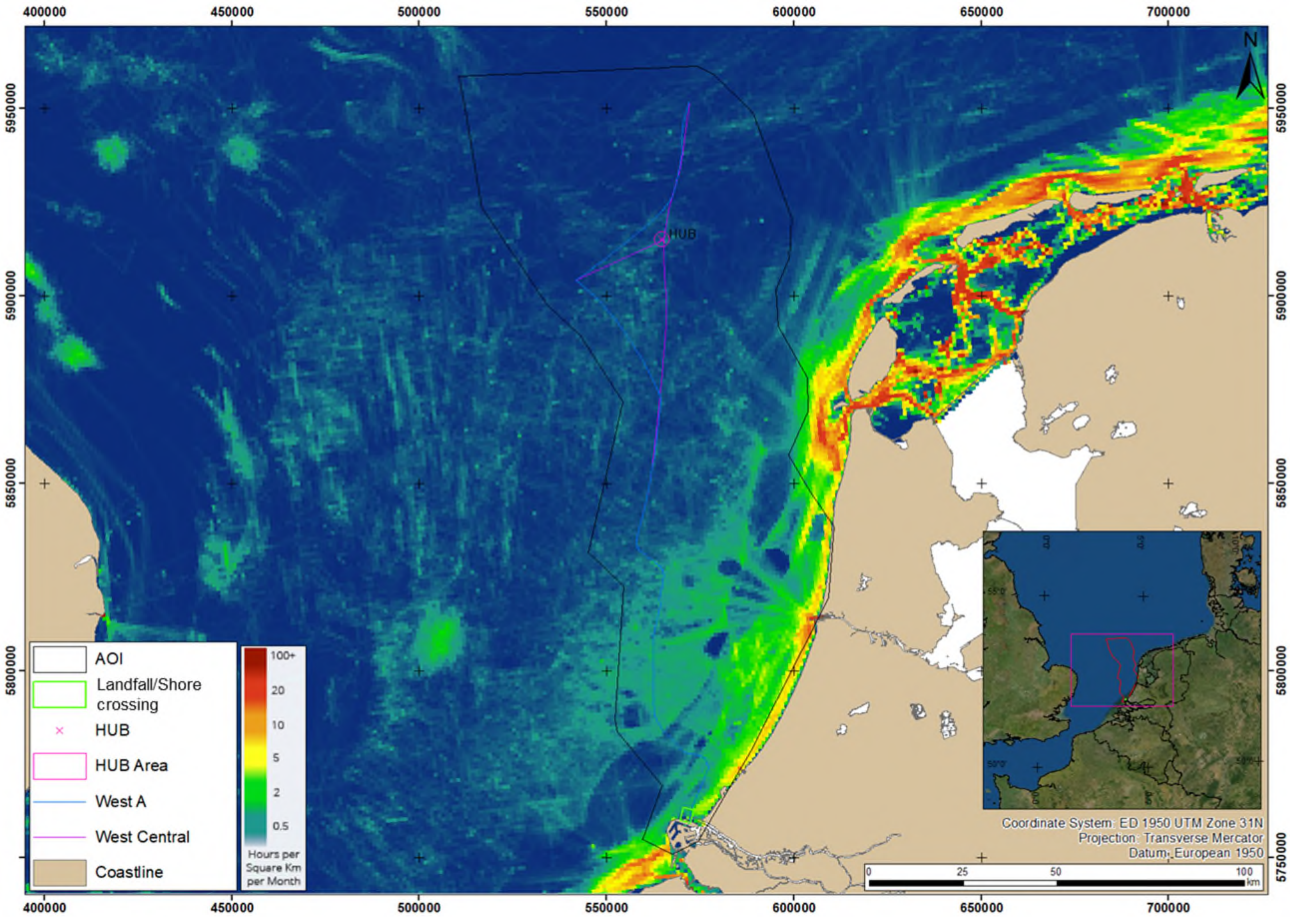

Figure 4.6: Average fishing activity density given in hours per km² per month for 2020 (EMODnet, 2022)

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.

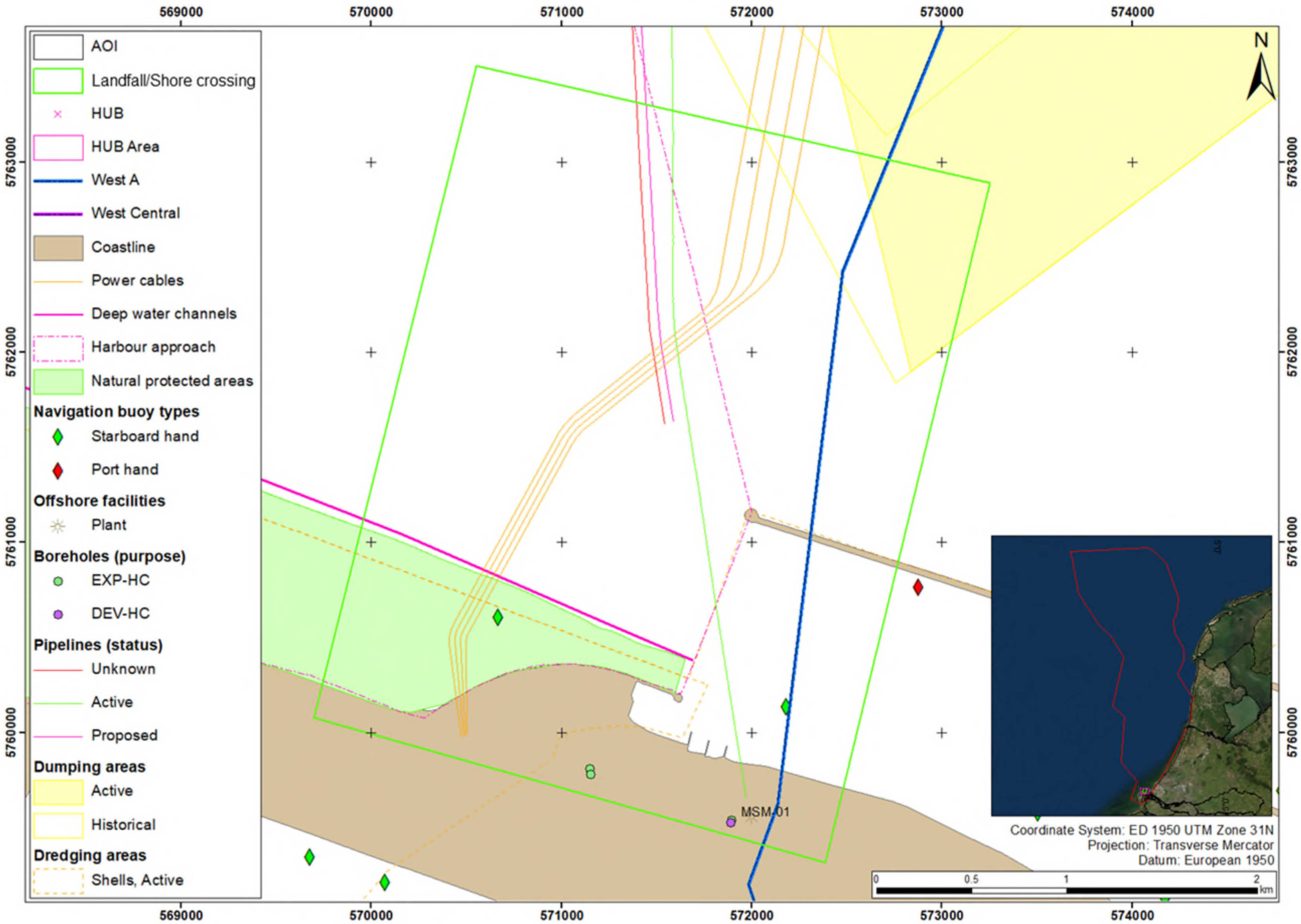

Figure 4.7: Site use across the Landfall/Shore crossing Area

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

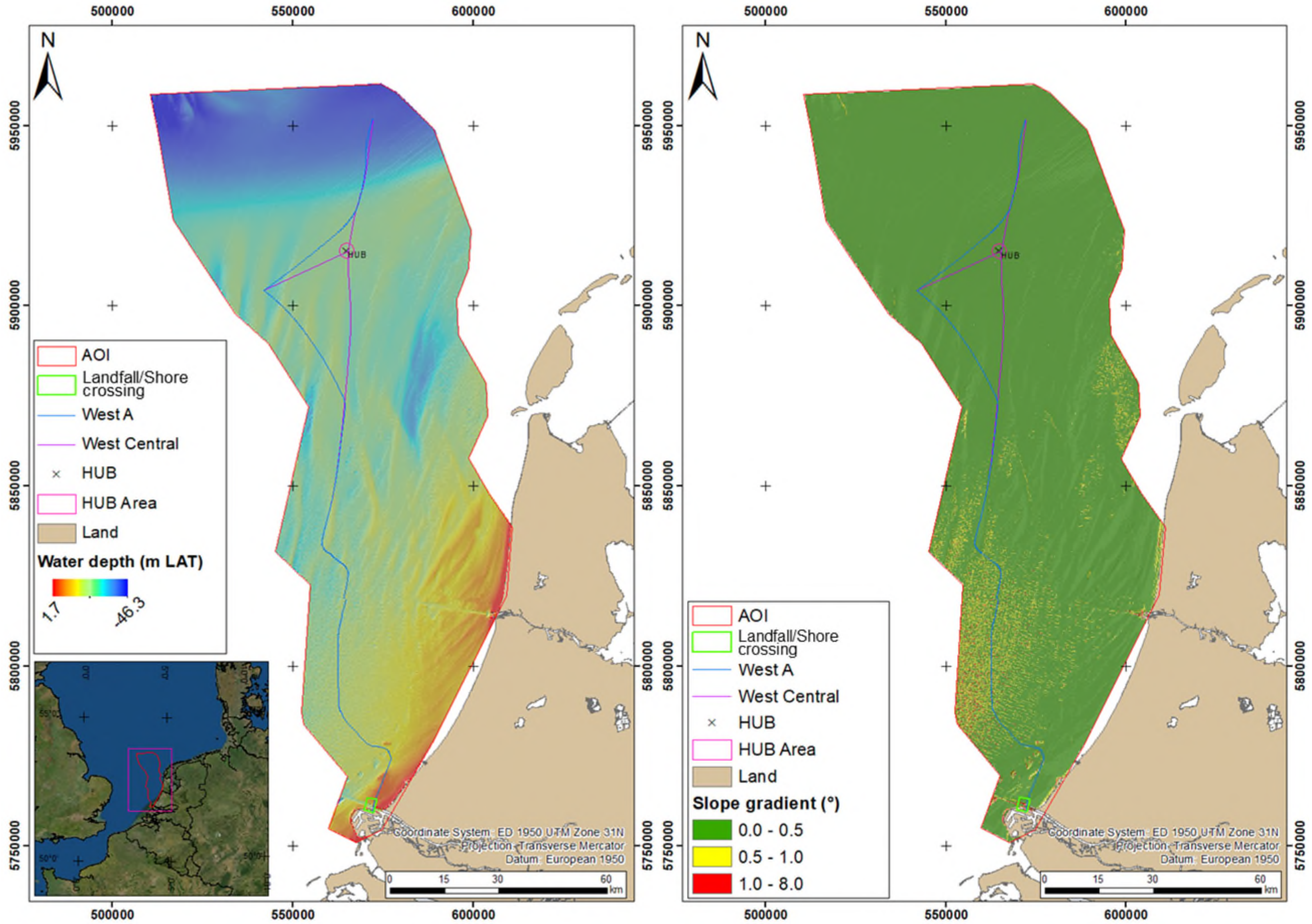

Figure 4.8: Left: bathymetric map and Right: slope gradient map of the entire AOI based on EMODnet 2020 data

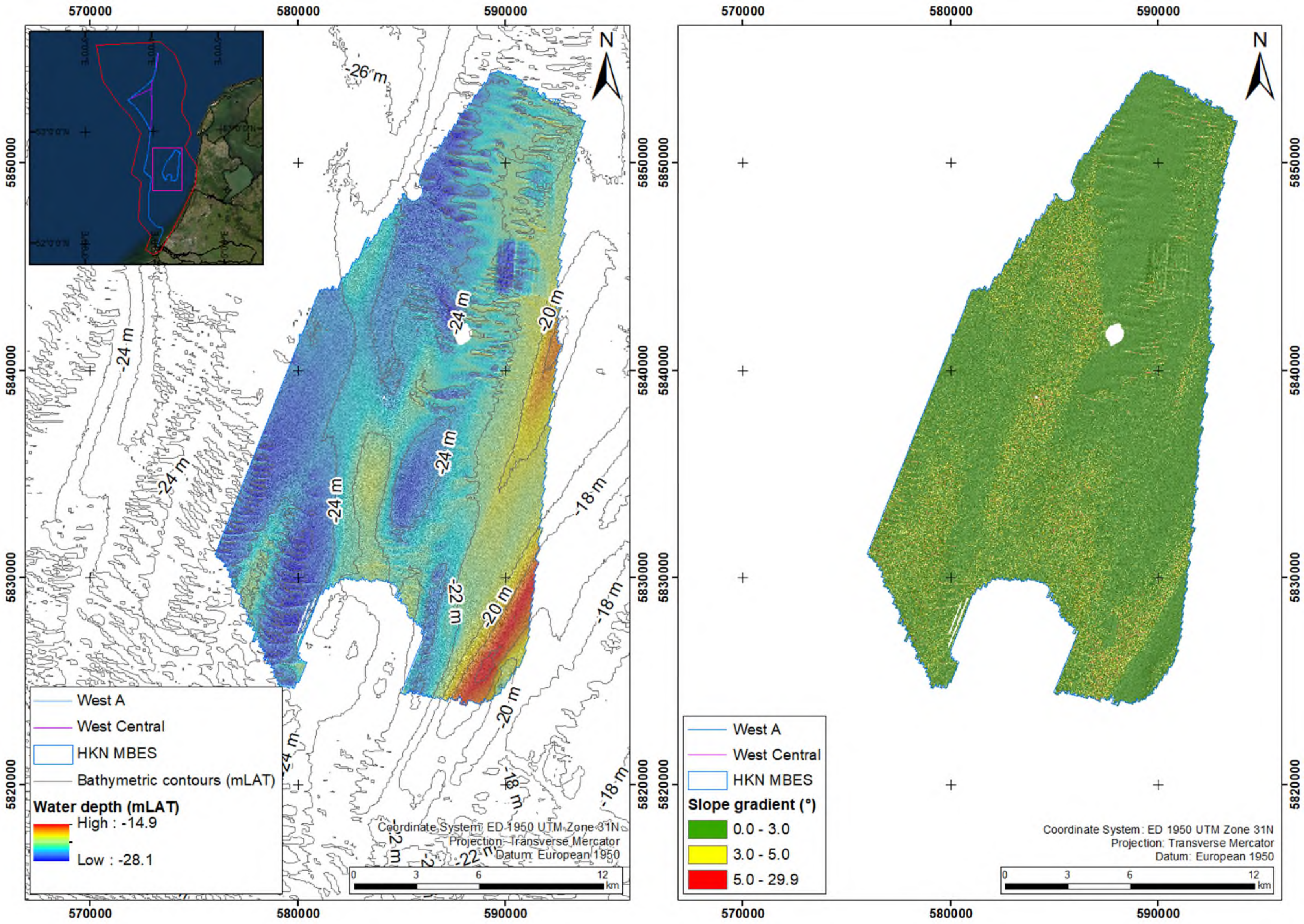

Figure 4.9: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (noord) WFZ area based on Fugro 2018 MBES data

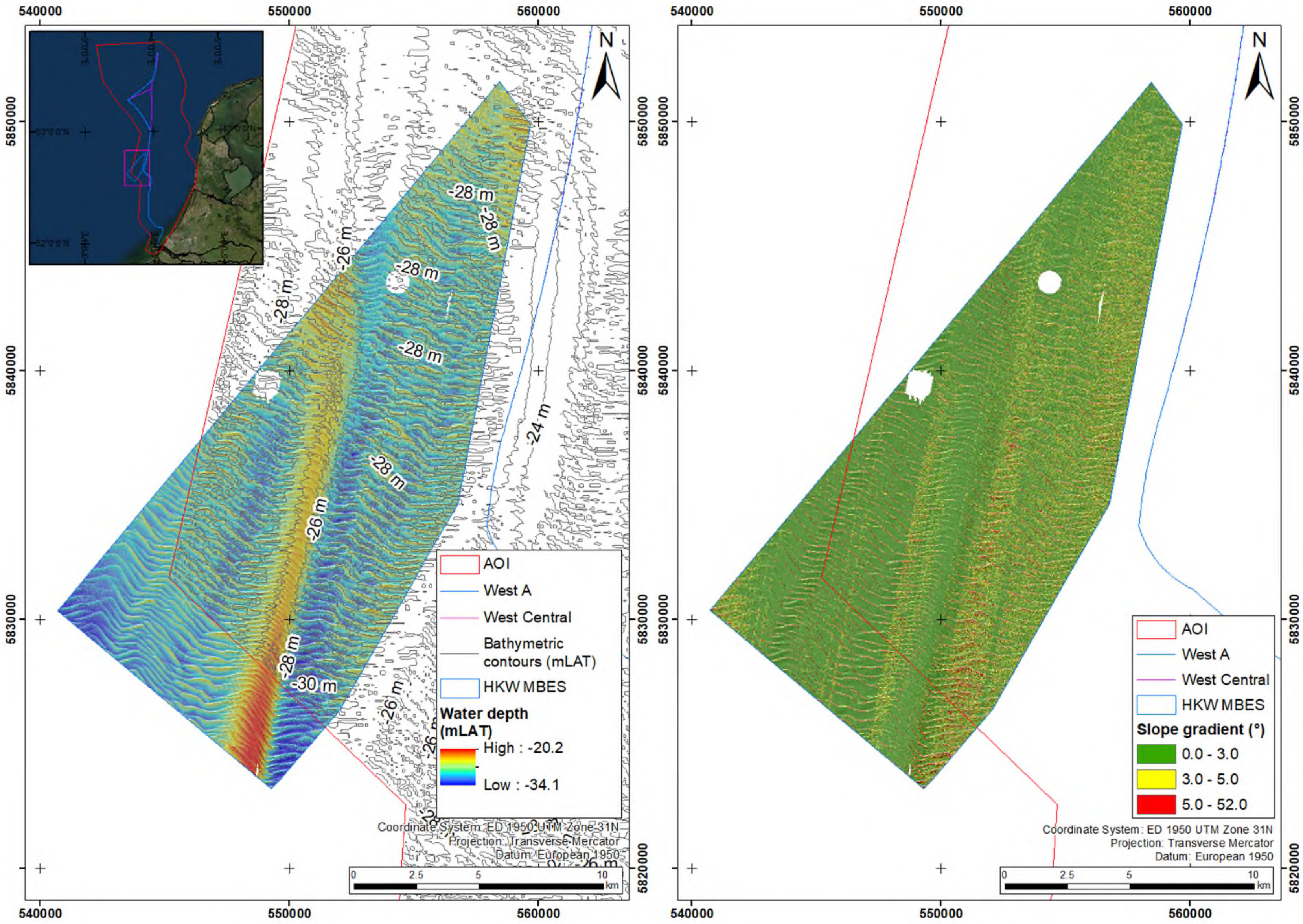

Figure 4.10: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (west) WFZ area based on Fugro 2019 MBES data

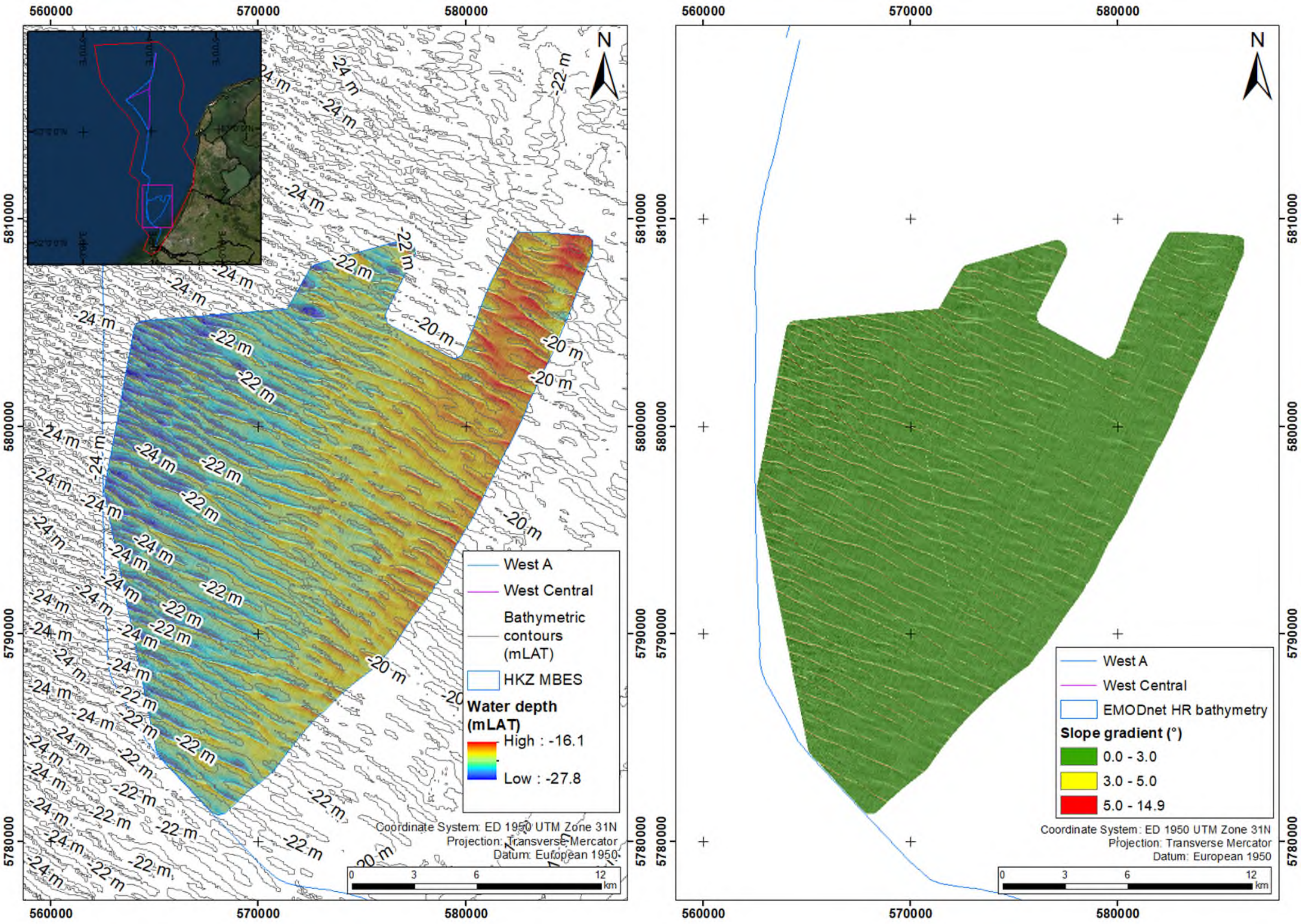

Figure 4.11: Left: bathymetric map and Right: slope gradient map of the Hollandse Kust (zuid) WFZ area based on Fugro 2016 MBES data

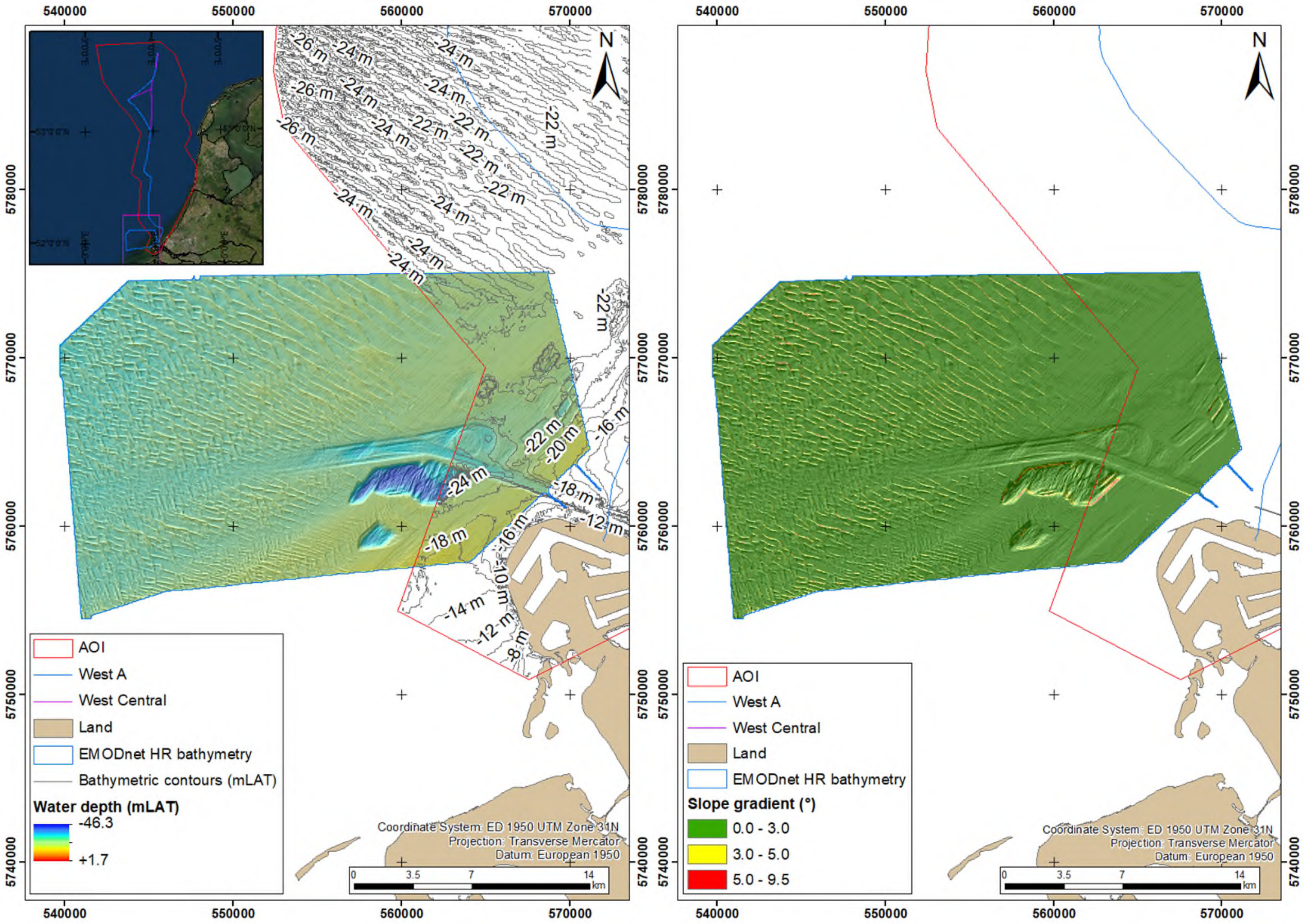

Figure 4.12: Left: bathymetric map and Right: slope gradient map of the Rotterdam approach area based on EMODnet 2020 high-resolution data

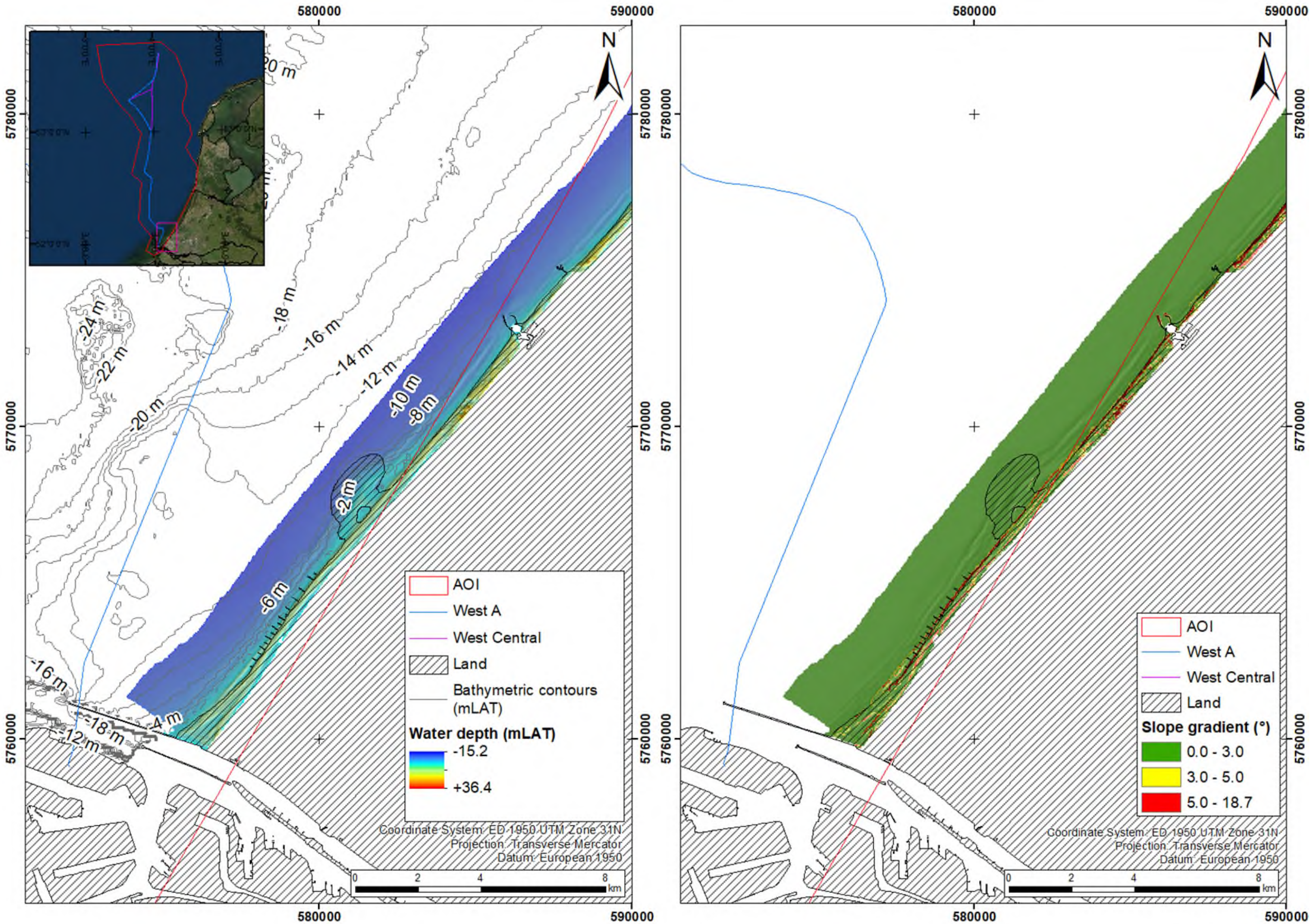

Figure 4.13: Left: bathymetric map and Right: slope gradient map of the southern coastal area based on EMODnet 2018 high-resolution data

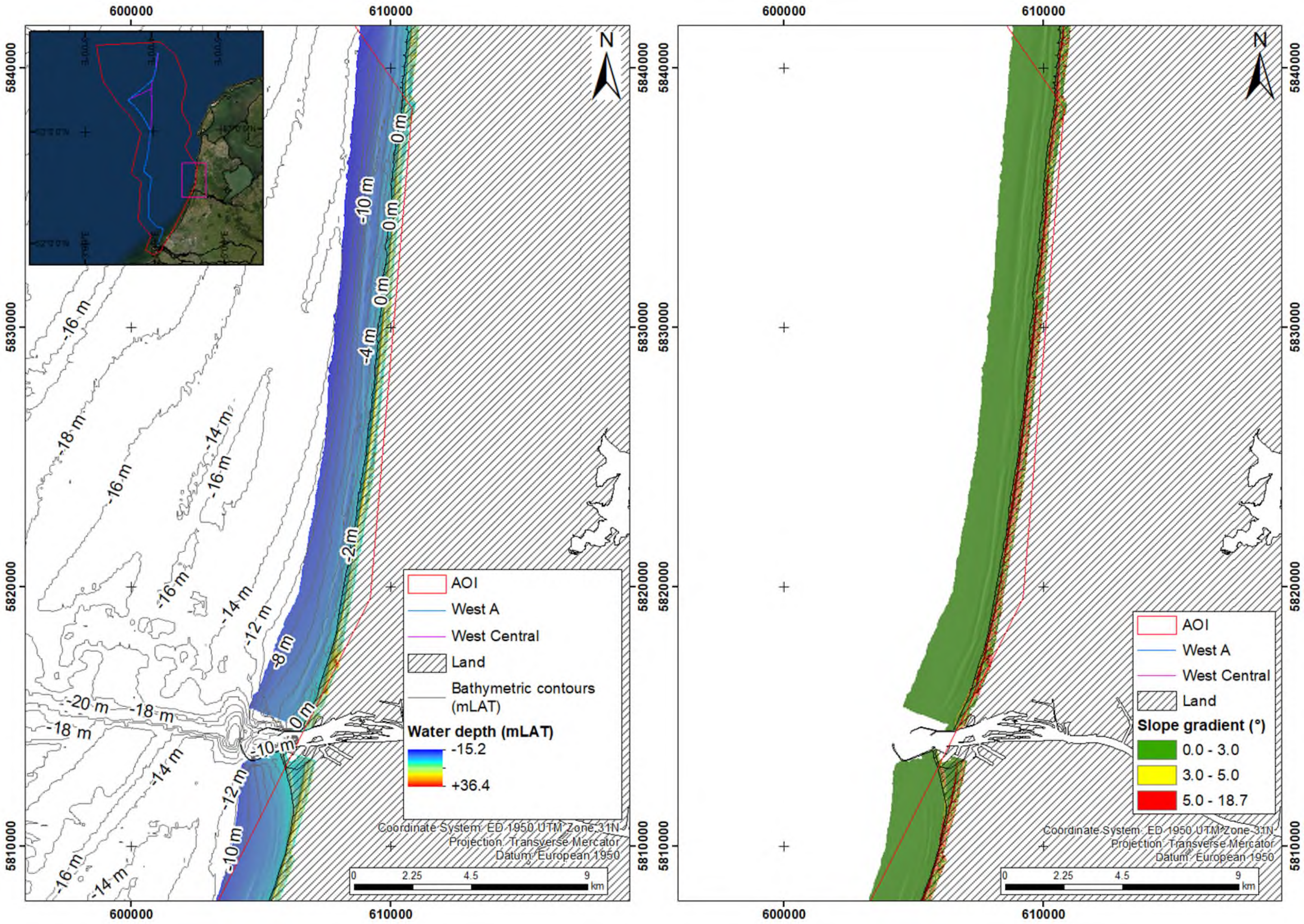

Figure 4.14: Left: bathymetric map and Right: slope gradient map of the northern coastal area based on EMODnet 2018 high-resolution data

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).

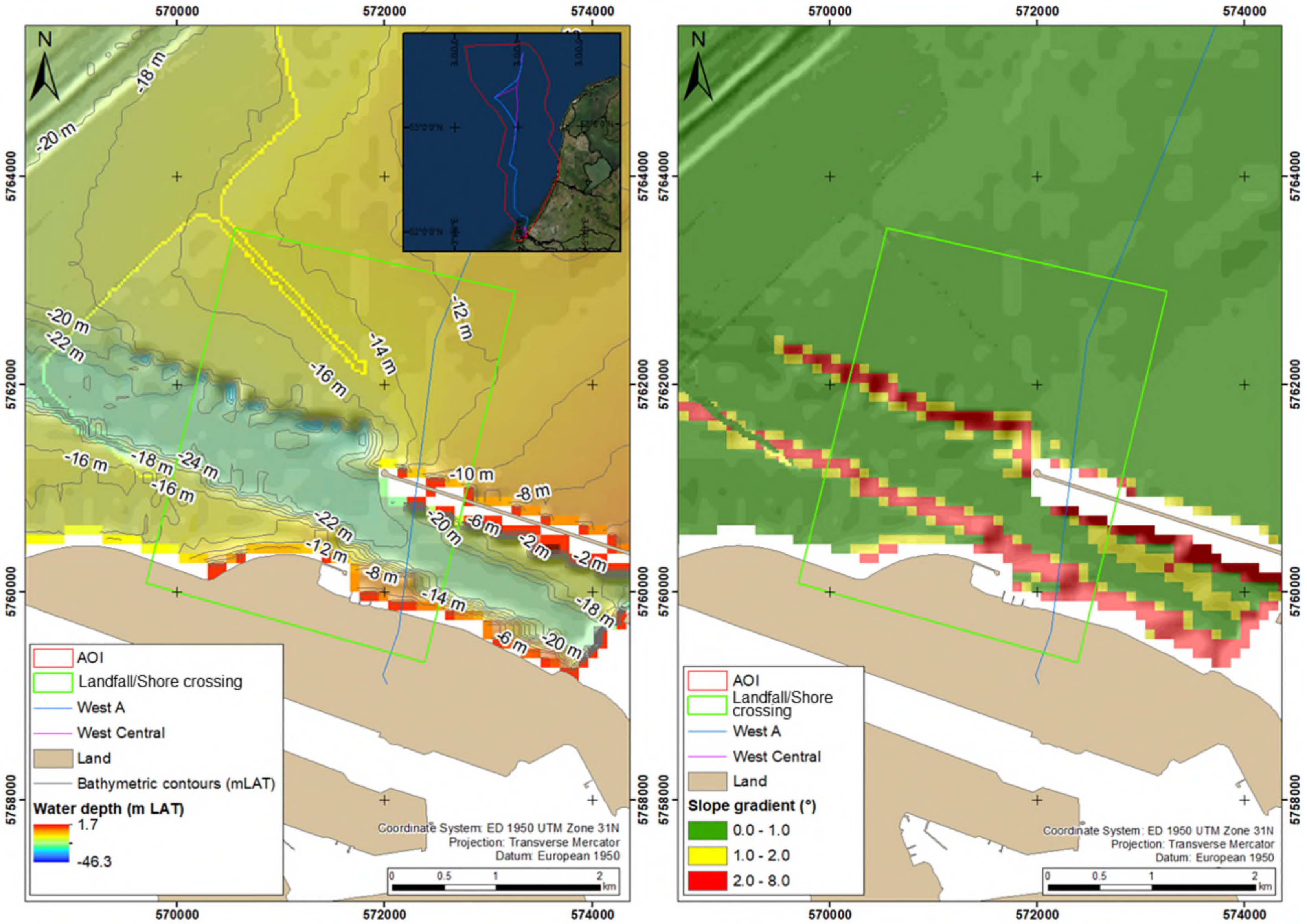

Figure 4.15: Left: bathymetric map and Right: Slope gradient map of the Landfall/Shore crossing Area based on the EMODnet 2020 data

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.

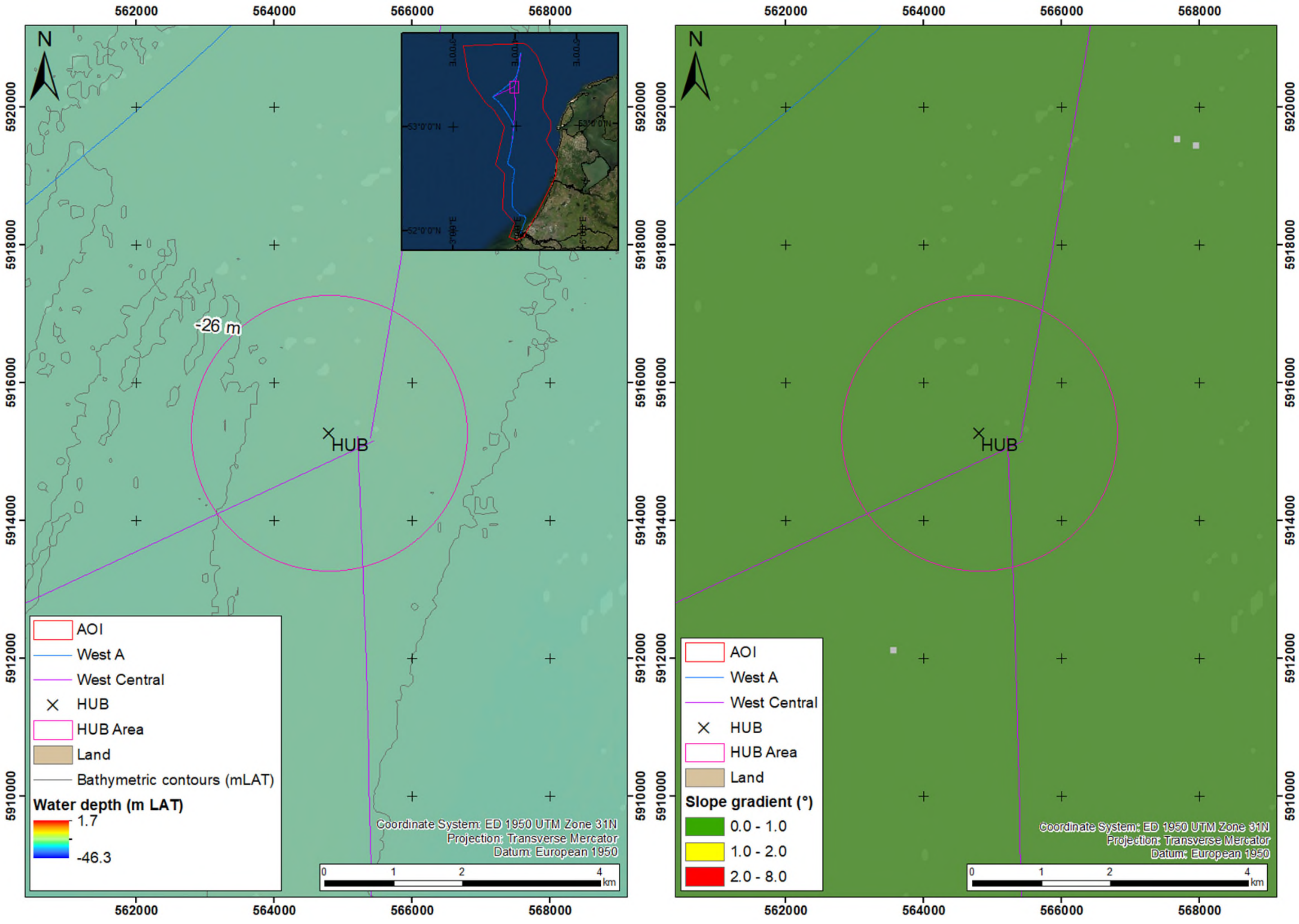

Figure 4.16: Left: bathymetric map and Right: slope gradient map of the Offshore Distribution HUB Area based on the EMODnet 2020 data

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.

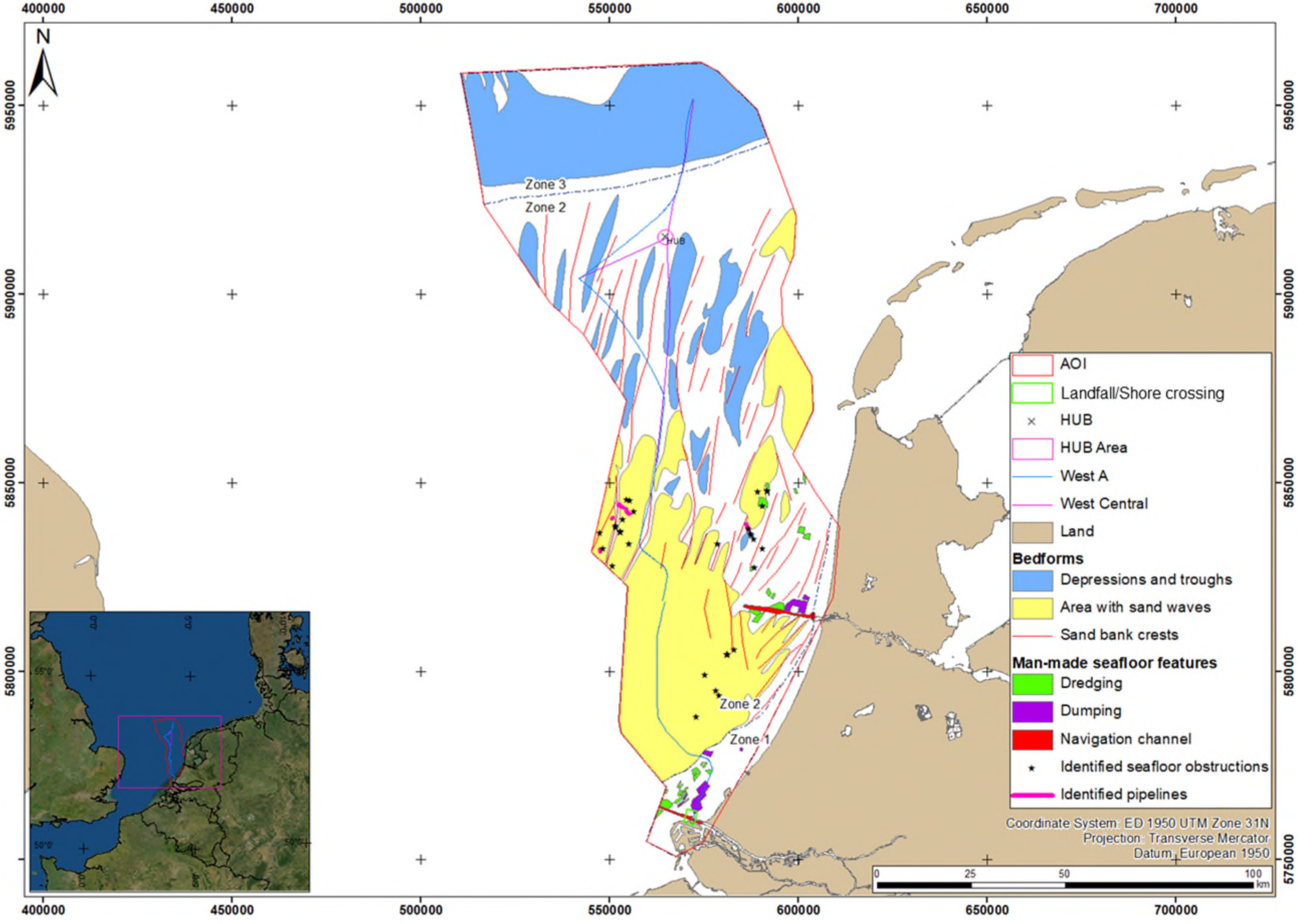

Figure 4.17: Map of the identified bedform and man-made seafloor features across the AOI

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).

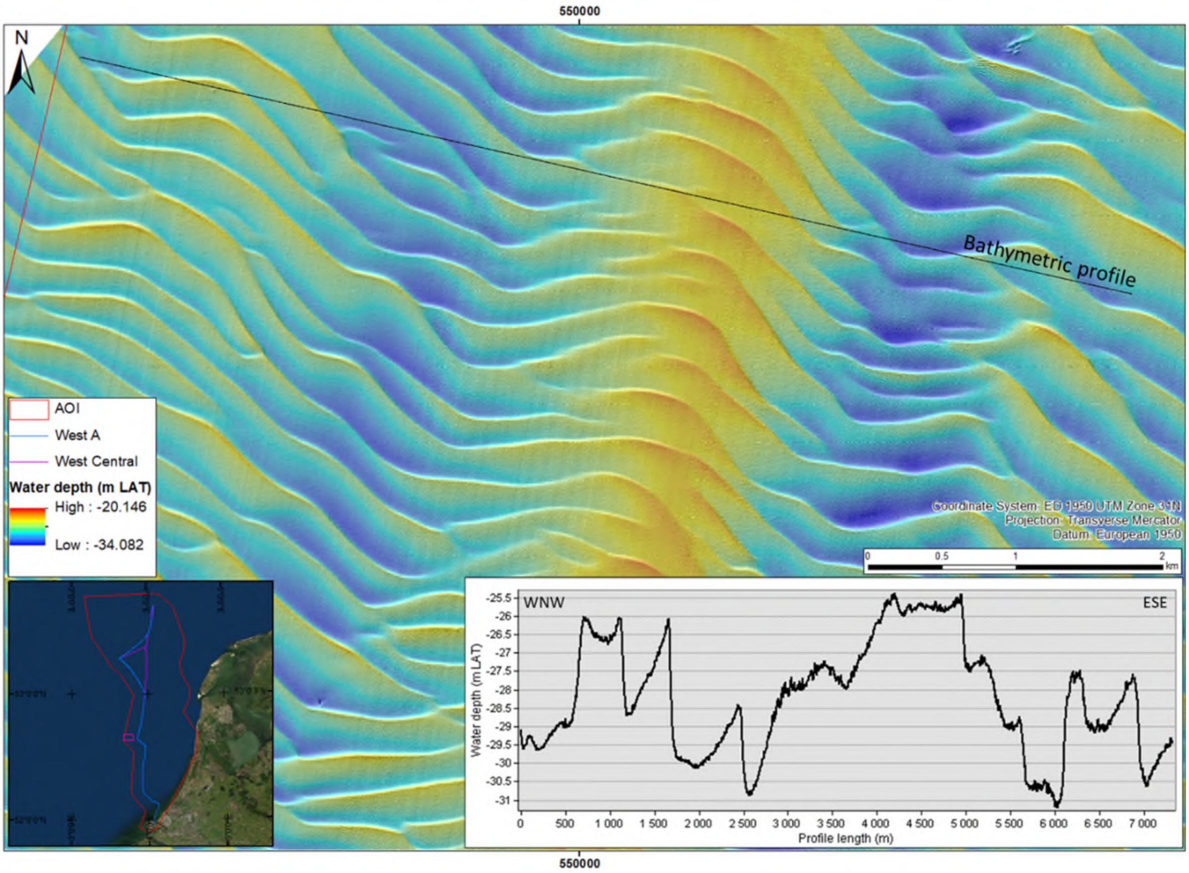

Figure 4.18: Example of sand banks with superimposed sand waves in the Hollandse Kust (west) WFZ as imaged on MBES bathymetry data. A bathymetric profile is given in a perpendicular direction to the sand banks.

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.

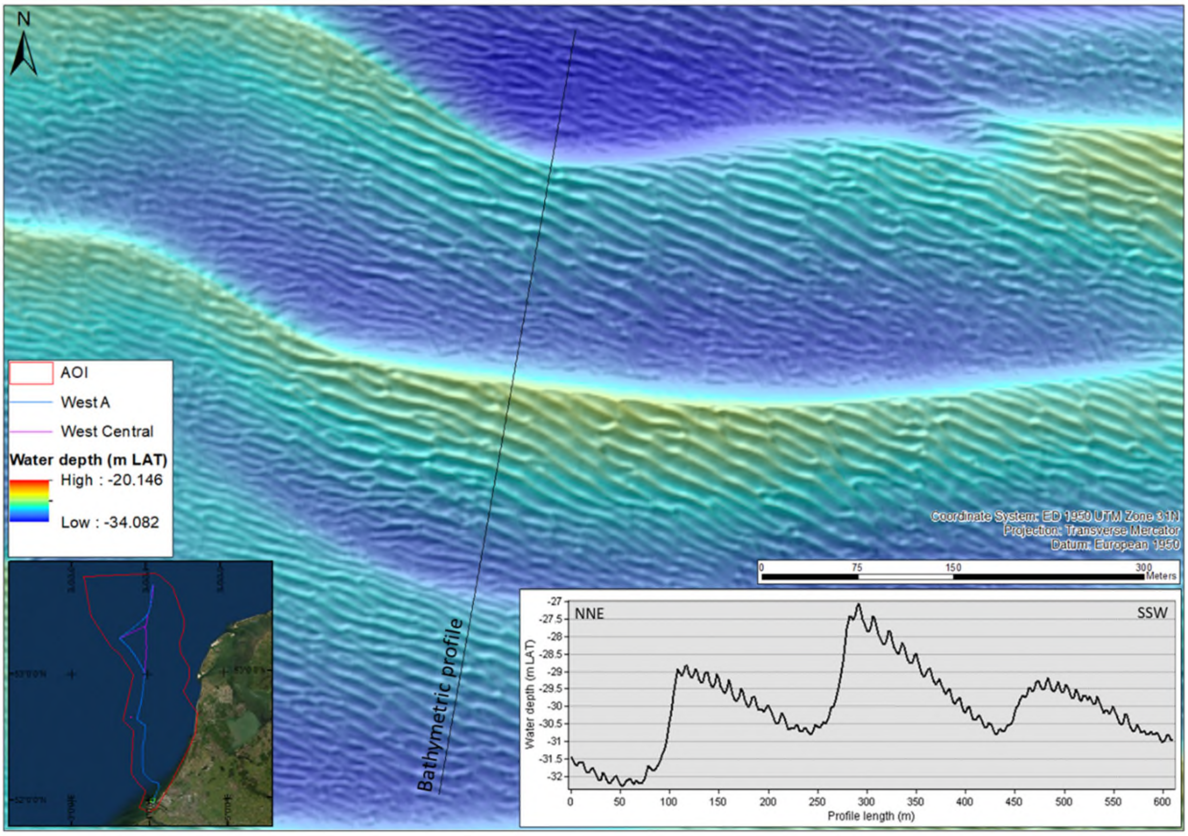

Figure 4.19: Example of sand waves with superimposed megaripples in the Hollandse Kust (west) WFZ as imaged on MBES bathymetry data. A bathymetric profile is given in a perpendicular direction to the sand waves.

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.

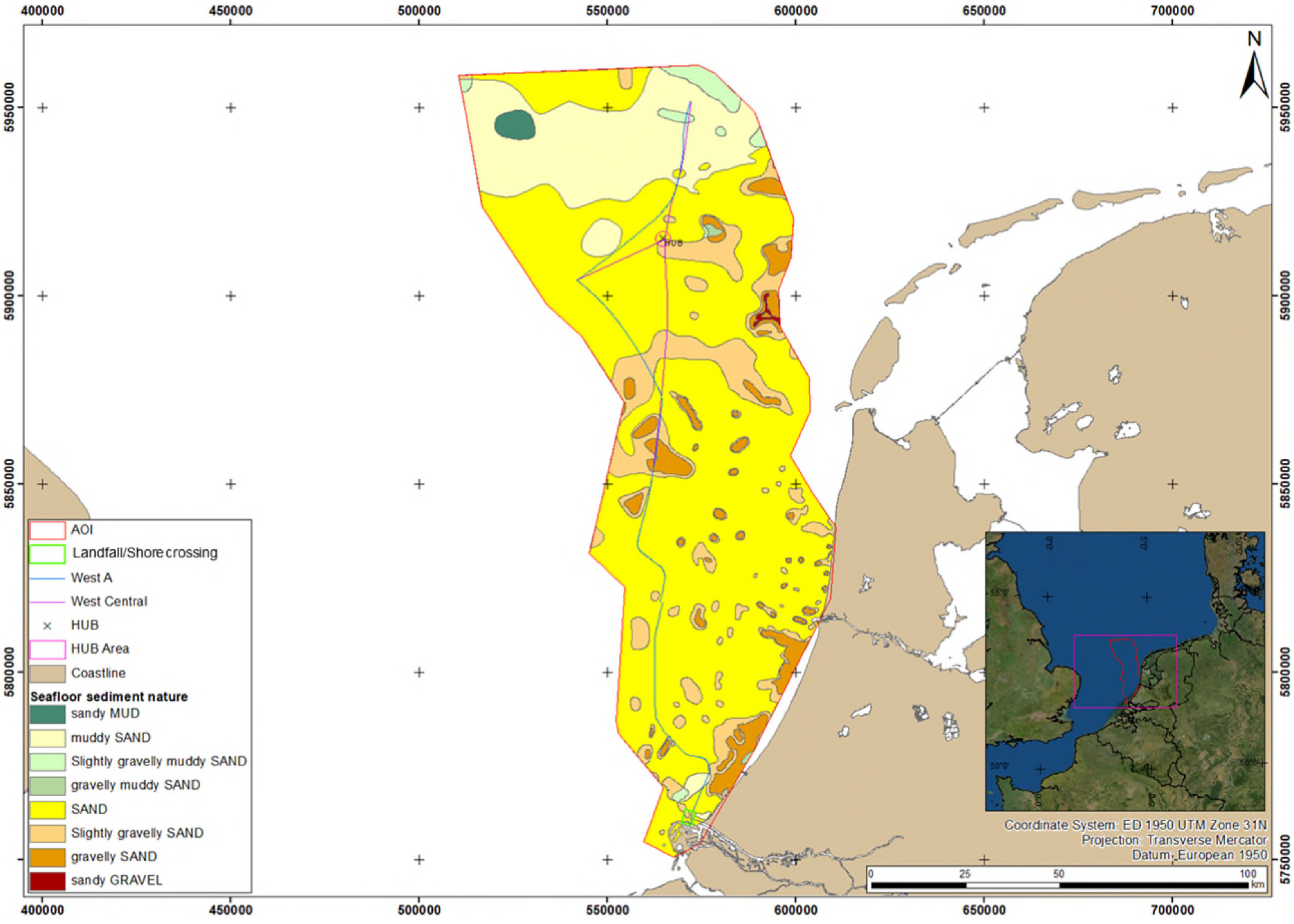

Figure 4.20: Surficial sediments across the AOI

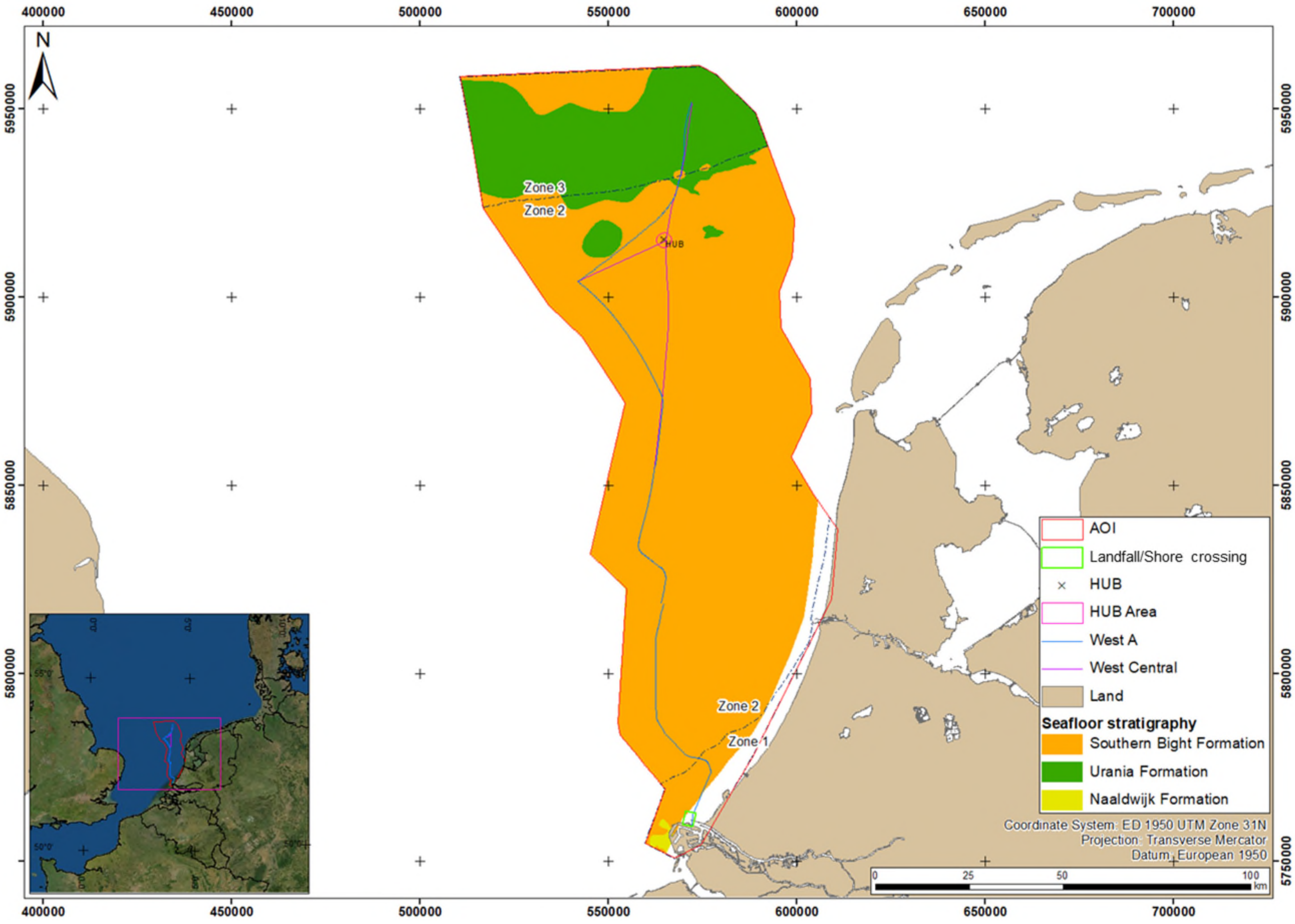

Figure 4.21: Surficial sediment stratigraphy across the AOI. Coverage is missing along the coastal area. In this area the Naaldwijk Formation is expected

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.

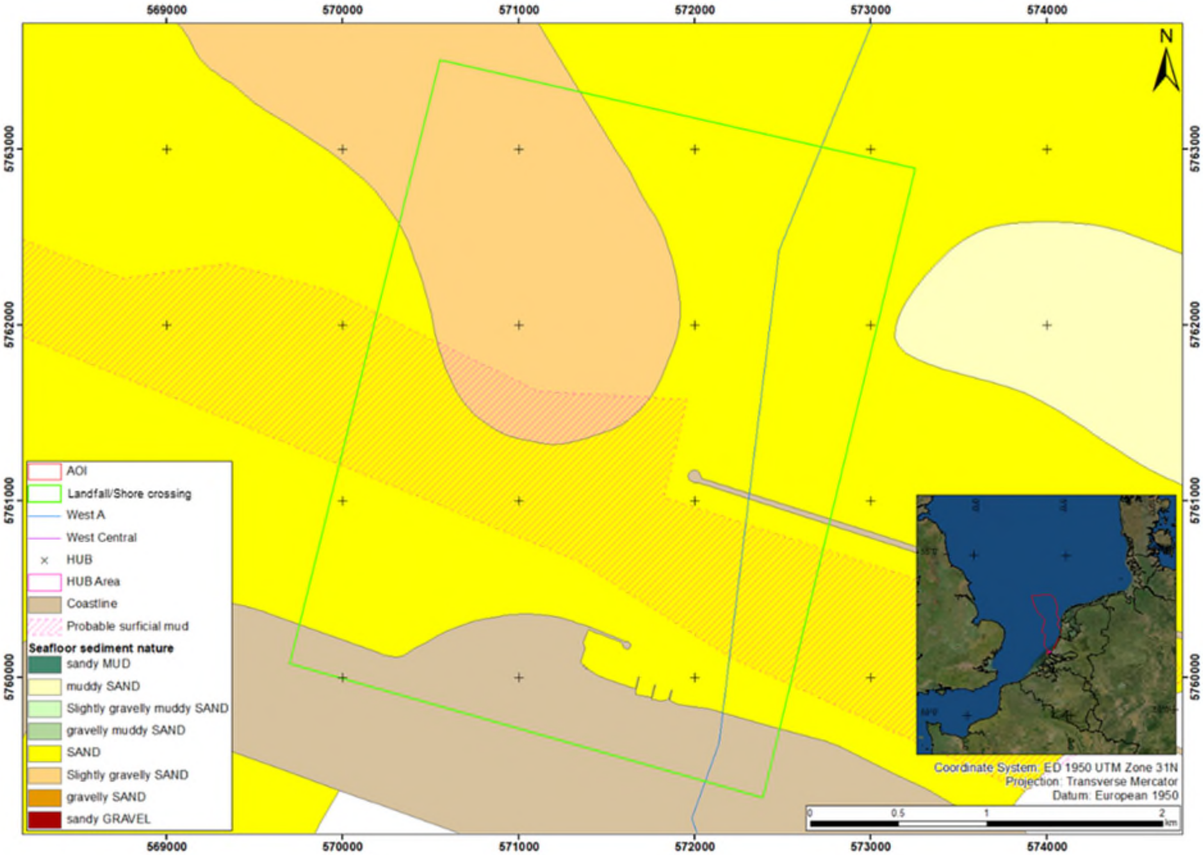

Figure 4.22: Surficial sediment nature across the Landfall/Shore crossing Area

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.

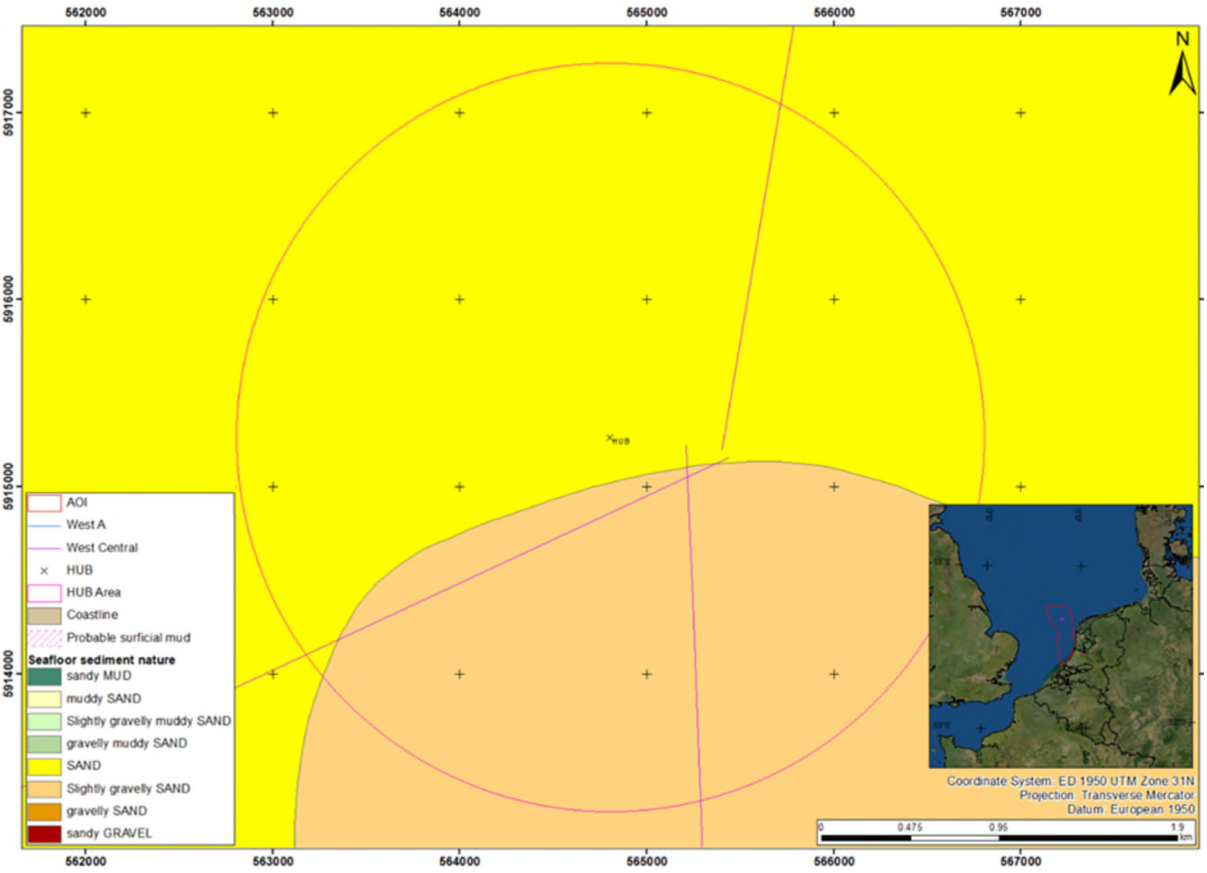

Figure 4.23: Surficial sediment nature across the Offshore Distribution HUB Area

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).

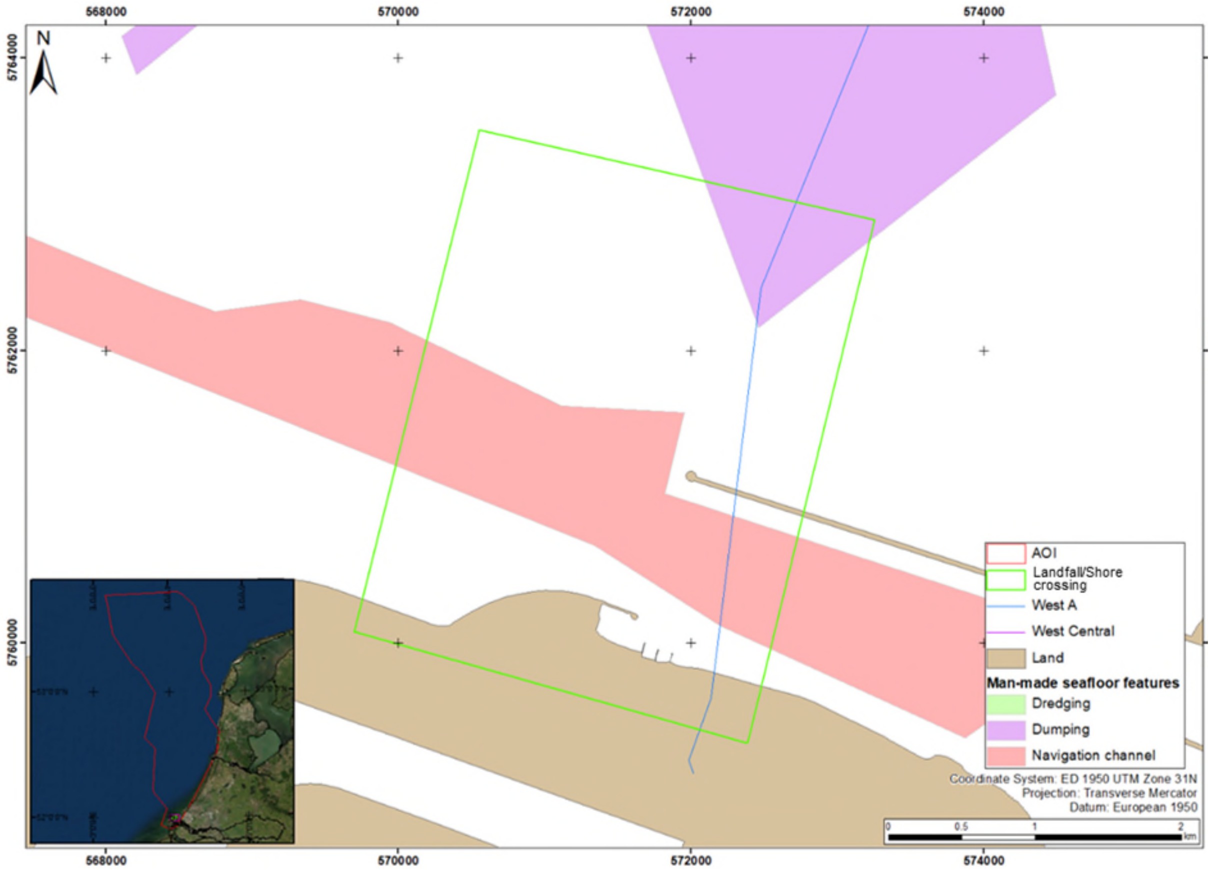

Figure 4.24: Surficial sediment nature across the Landfall/Shore crossing Area

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.

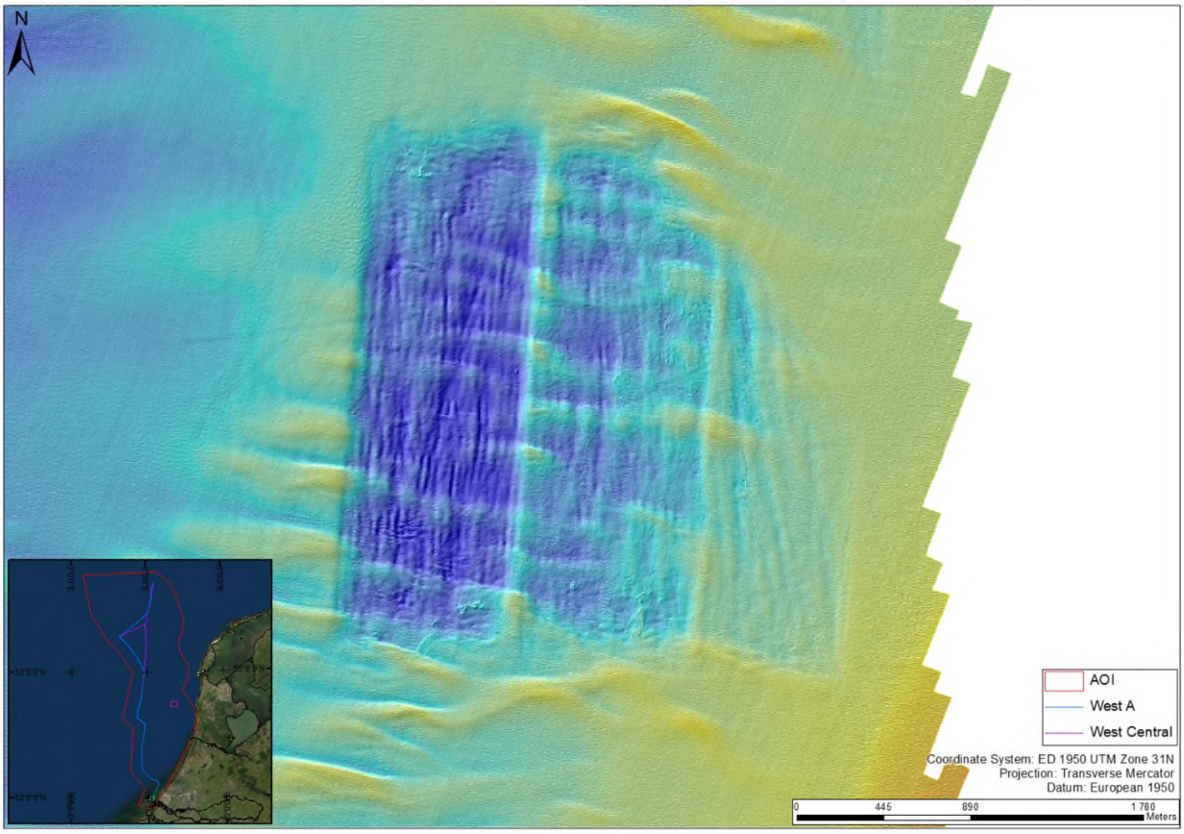

Figure 4.25: Former dredging area where sand waves are building back , as imaged in Hollandse Kust (noord) MBES bathymetry

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.

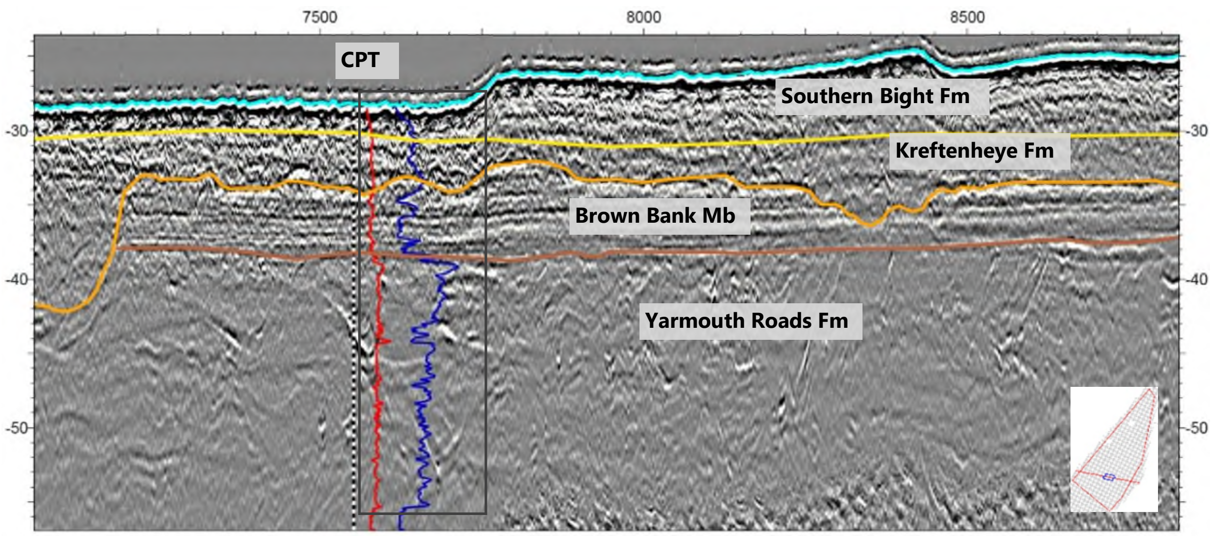

Figure 4.26: Example seismic reflection (2DUHR) cross section within the Hollandse Kust (west) WFZ (modified from Fugro, 2020). *Vertical scale is in metres reduced to LAT. The horizontal scale shows relative distance in metres along the seismic line. Width of the Cone Penetration Test (CPT) box shows 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

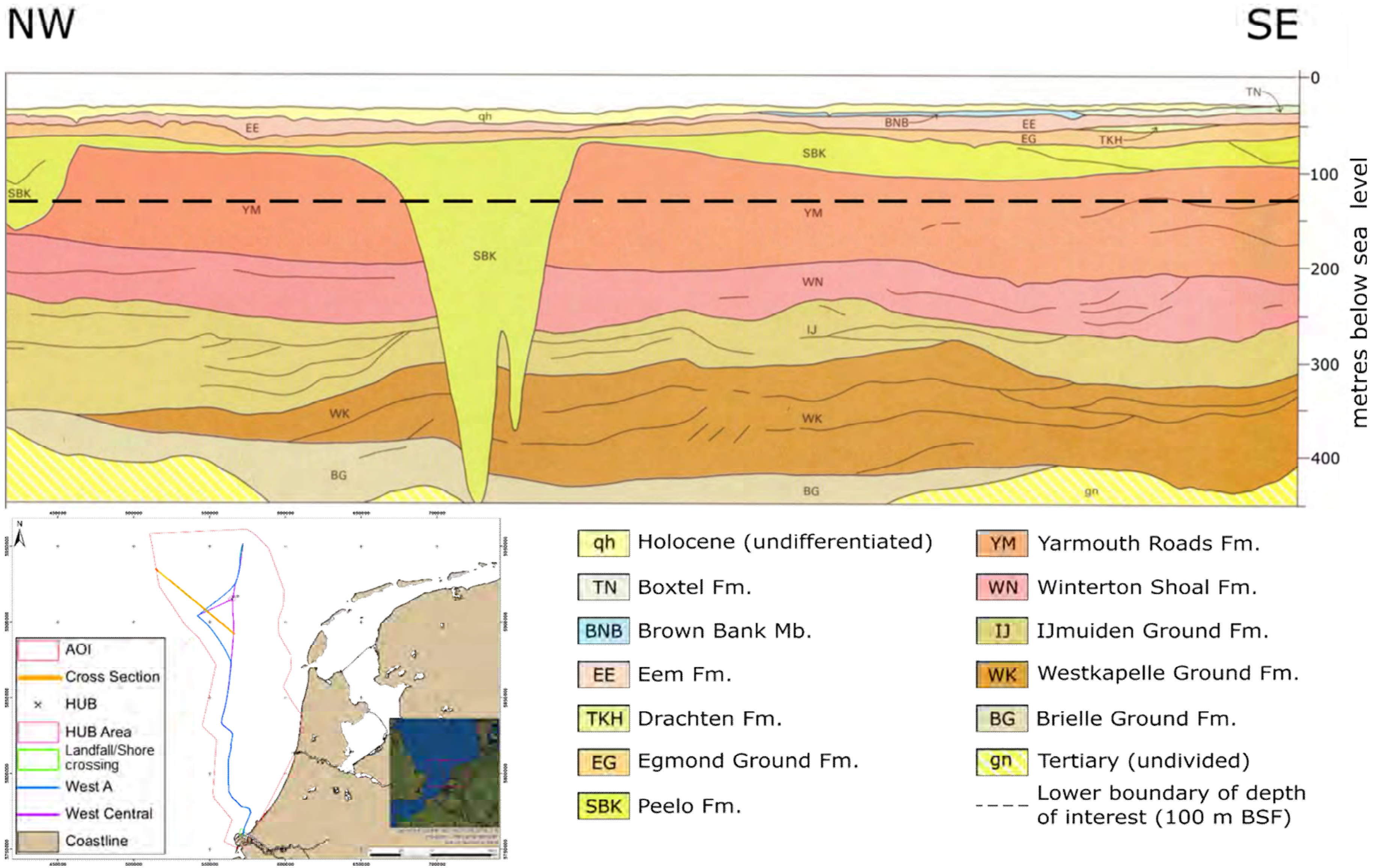

Figure 4.27: Schematic profile (with 50x vertical exaggeration) of the north-west part of the AOI. See the inset in the bottom left-hand corner for the location of the cross section (in orange). Modified after Cameron et al. (1986)

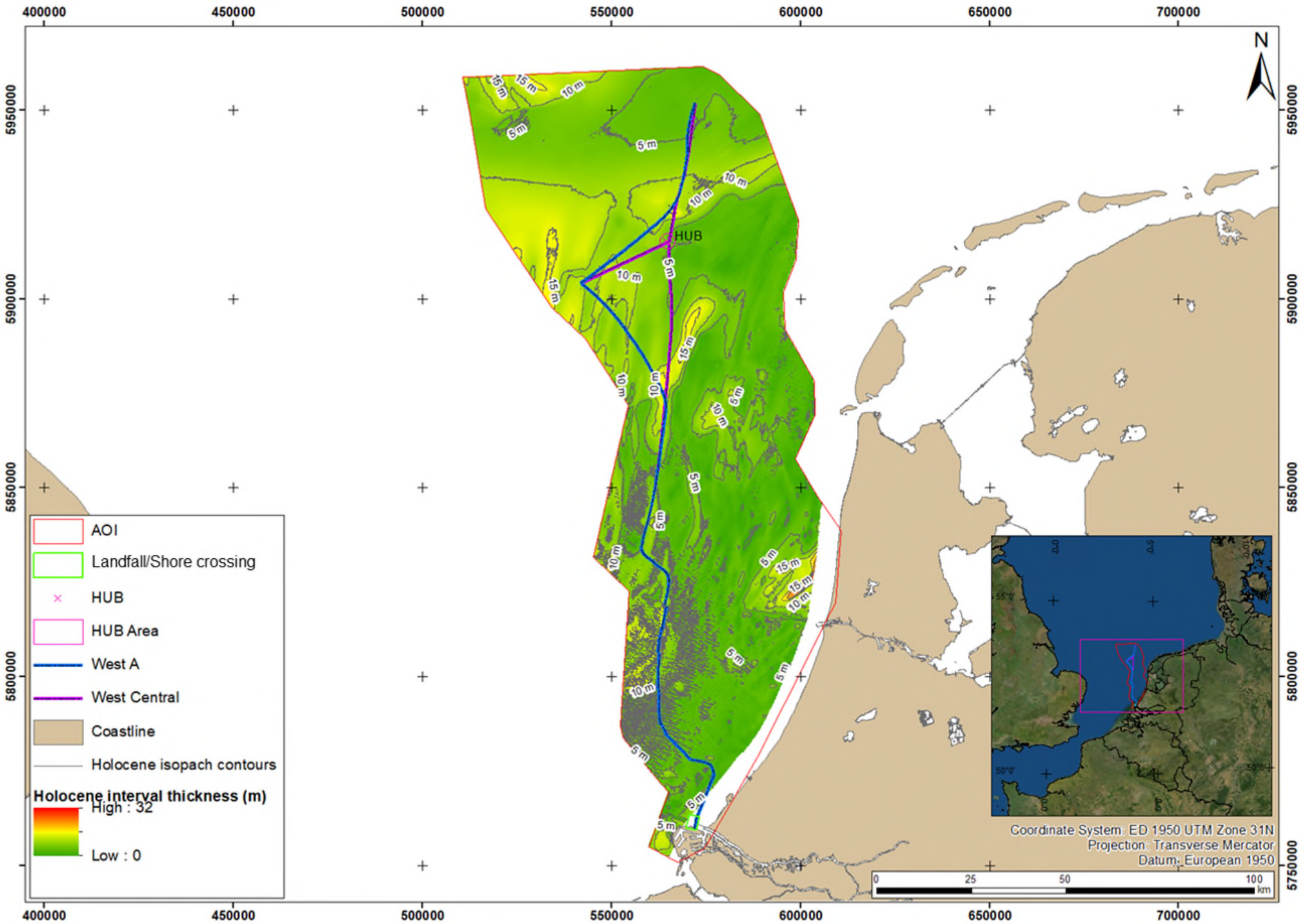

Figure 4.28: Expected thickness of the Holocene in the AOI

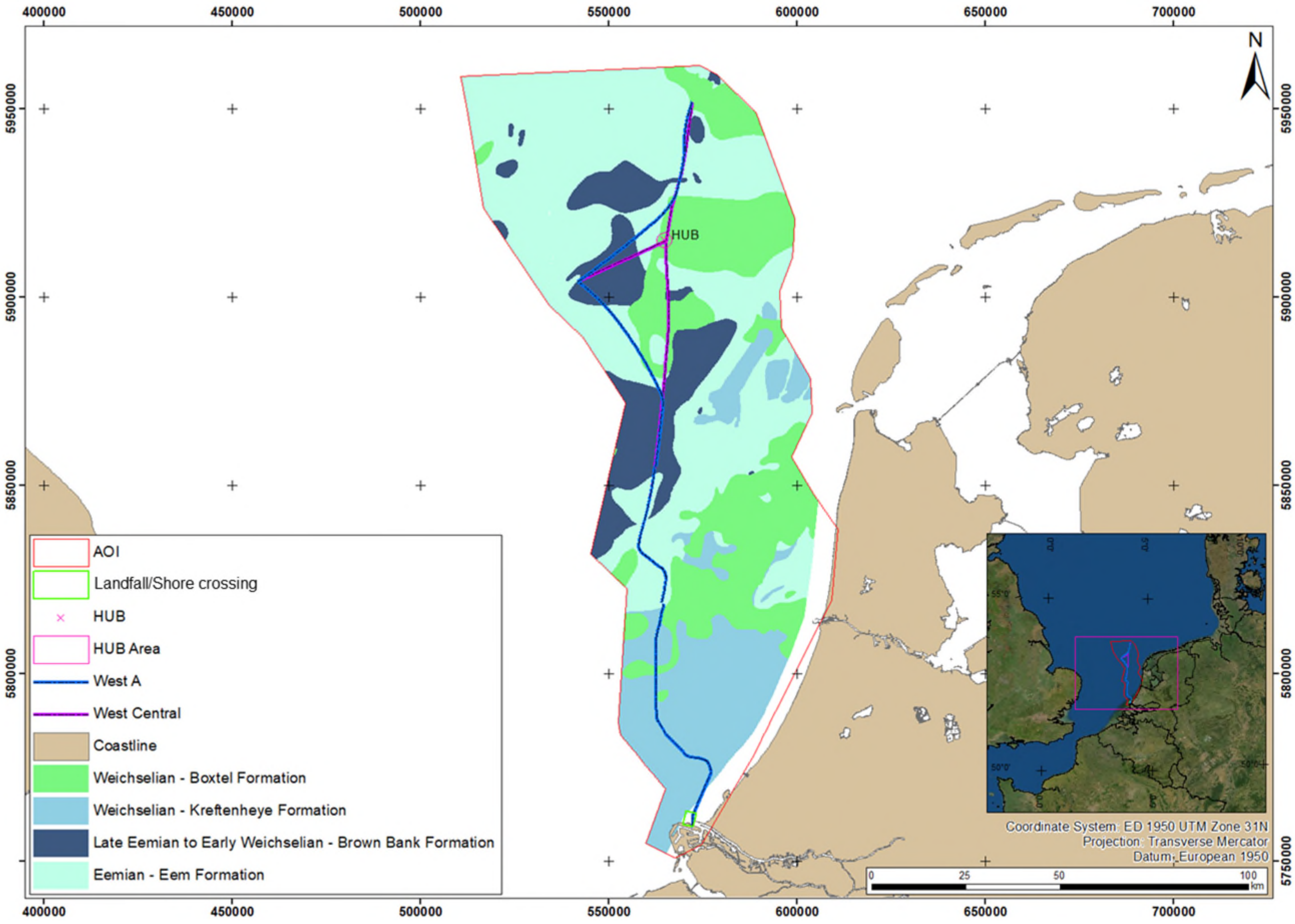

Figure 4.29: Distribution of the Late Pleistocene formations and members

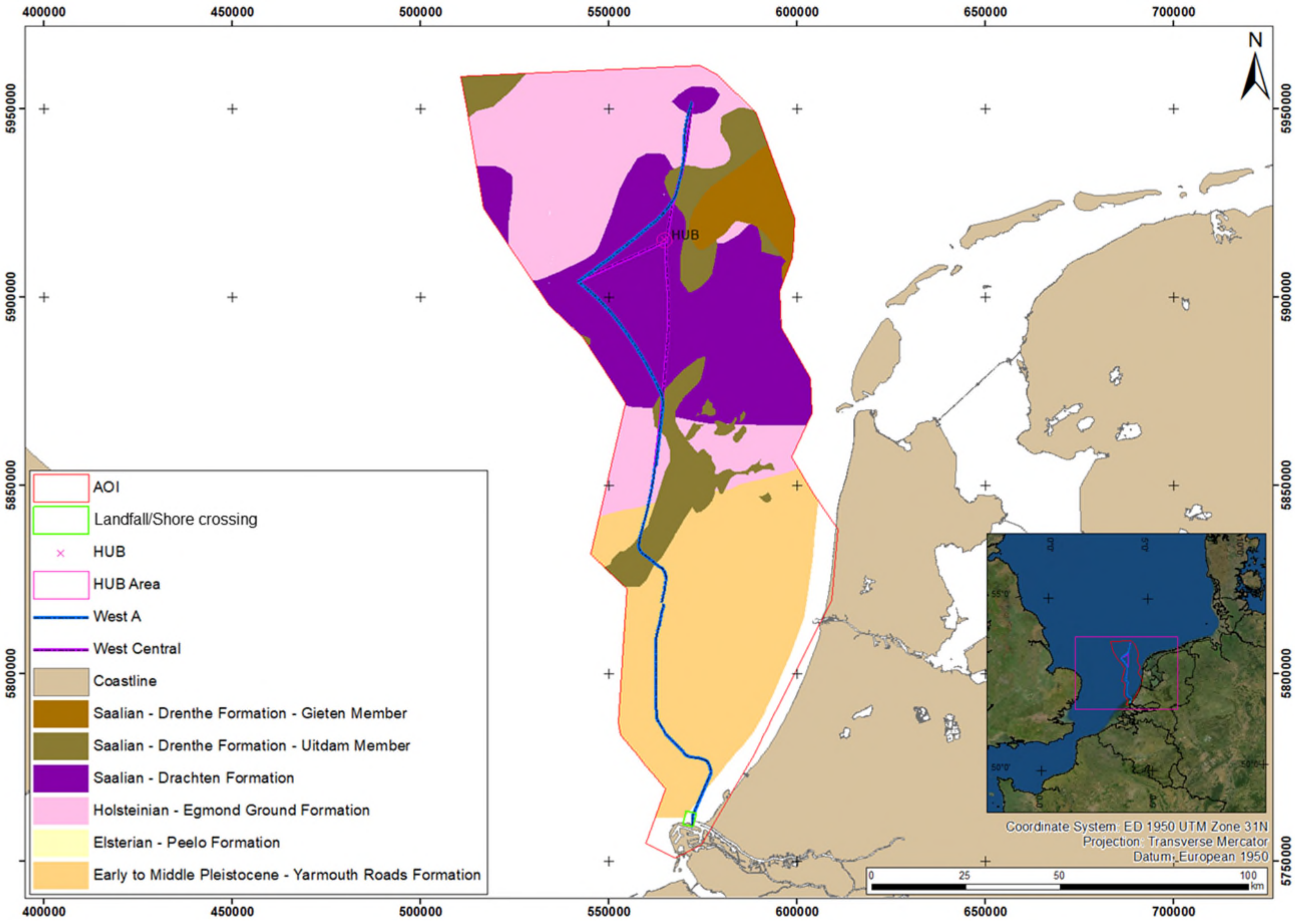

Figure 4.30: Distribution of the Early to Middle Pleistocene formations and members

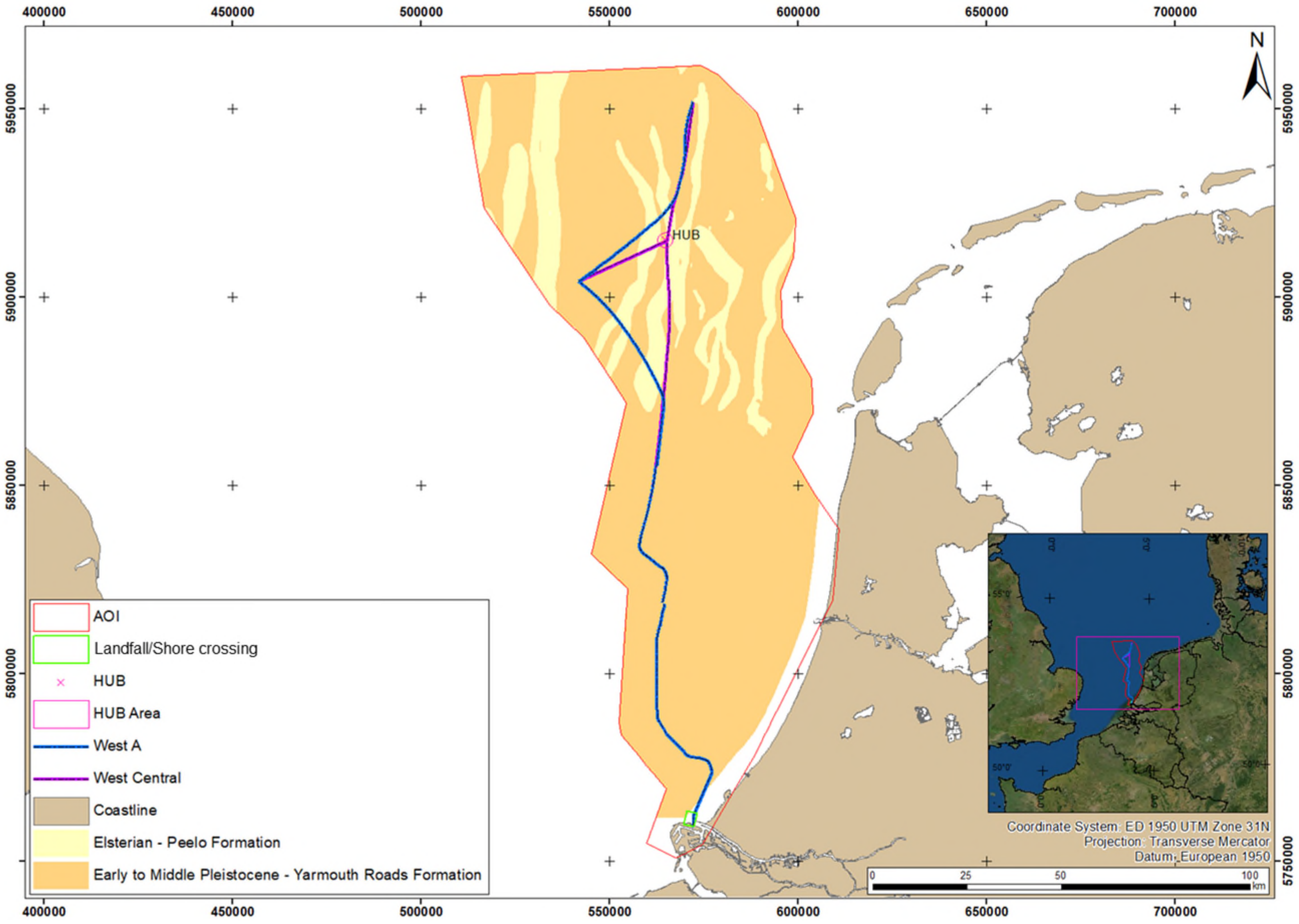

Figure 4.31: Distribution of the Early Pleistocene formations

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.

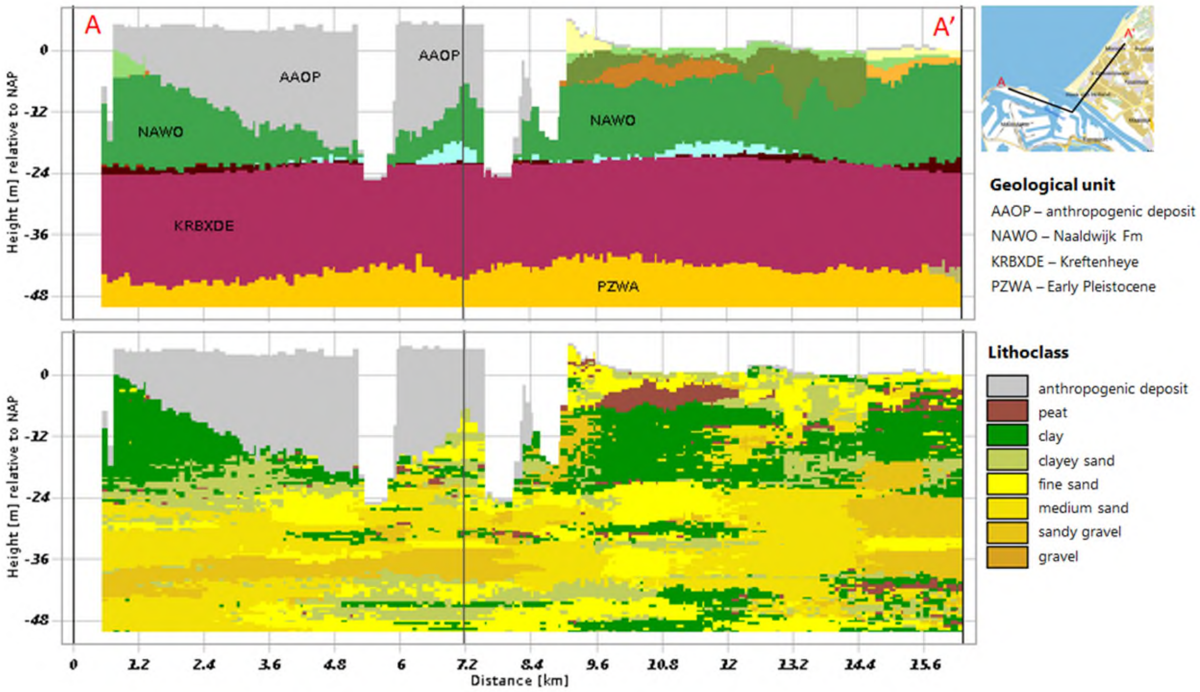

Figure 4.32: Synthetic ground models showing geological units (top image) and most probable lithologies (bottom image) in the vicinity of the Landfall/Shore crossing Area (source: DINOloket)

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.

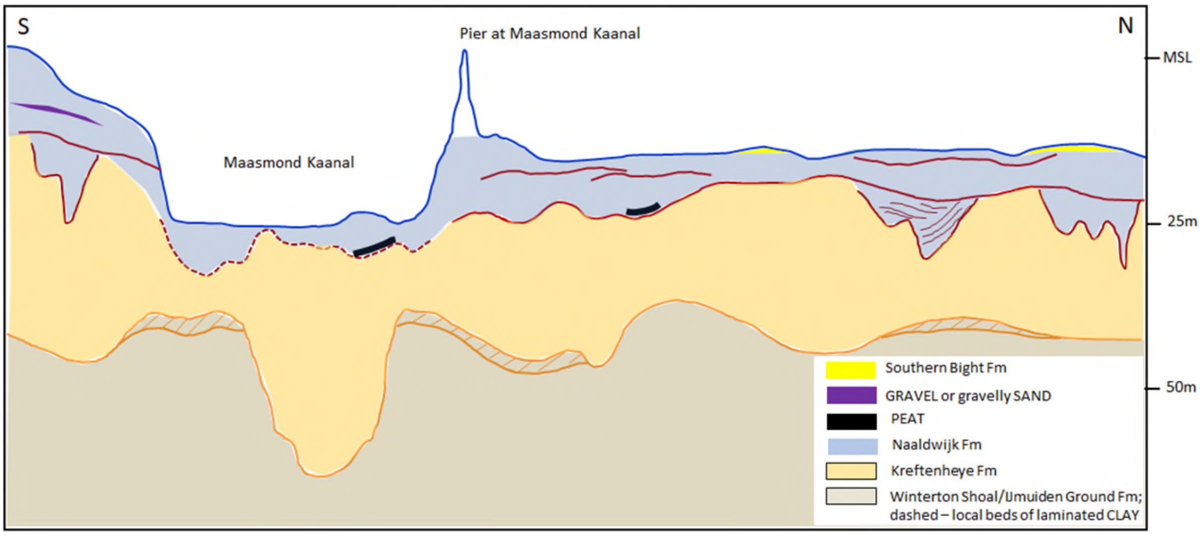

Figure 4.33: Schematic simplified cross section across the Maasmond Kanaal (based on geotechnical Fugro experience). Refer to Table 4.7 for detailed description of the units/geological formations

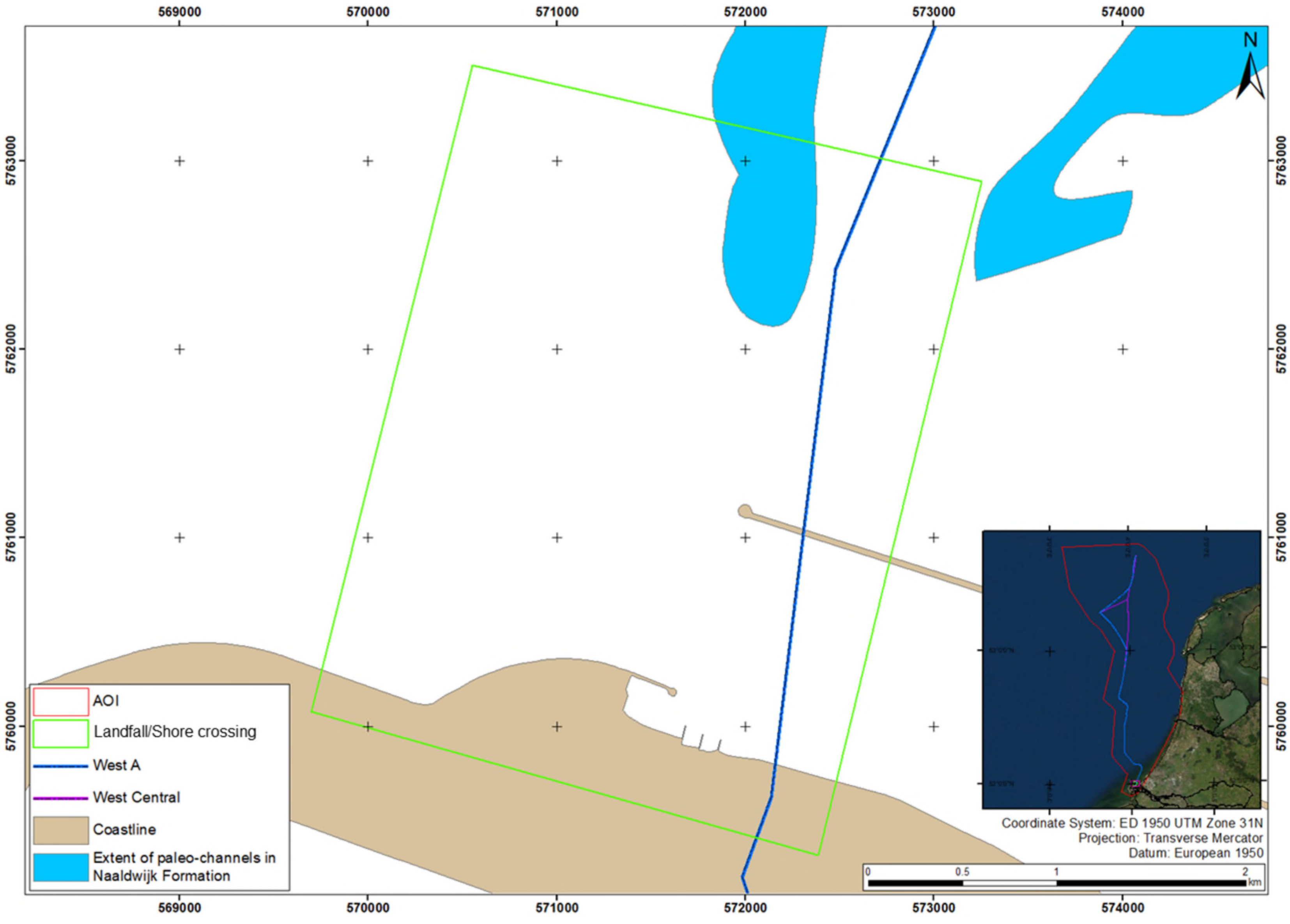

Figure 4.34: Distribution of the early Holocene (Naaldwijk Formation) paleo-channels in the Landfall/Shore crossing Area

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/m^3]	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.

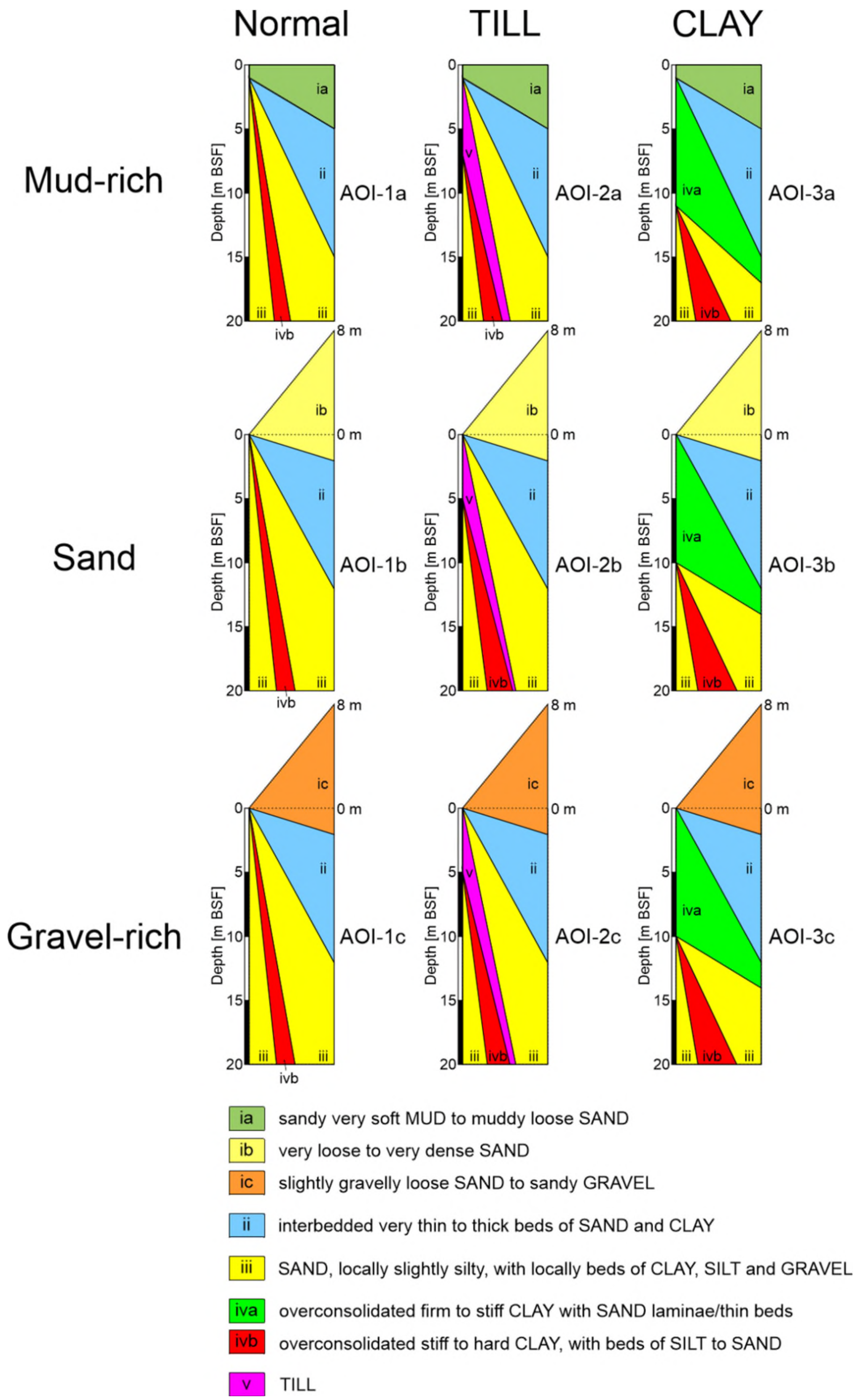

Figure 4.35: Predicted soil profiles across the AOI

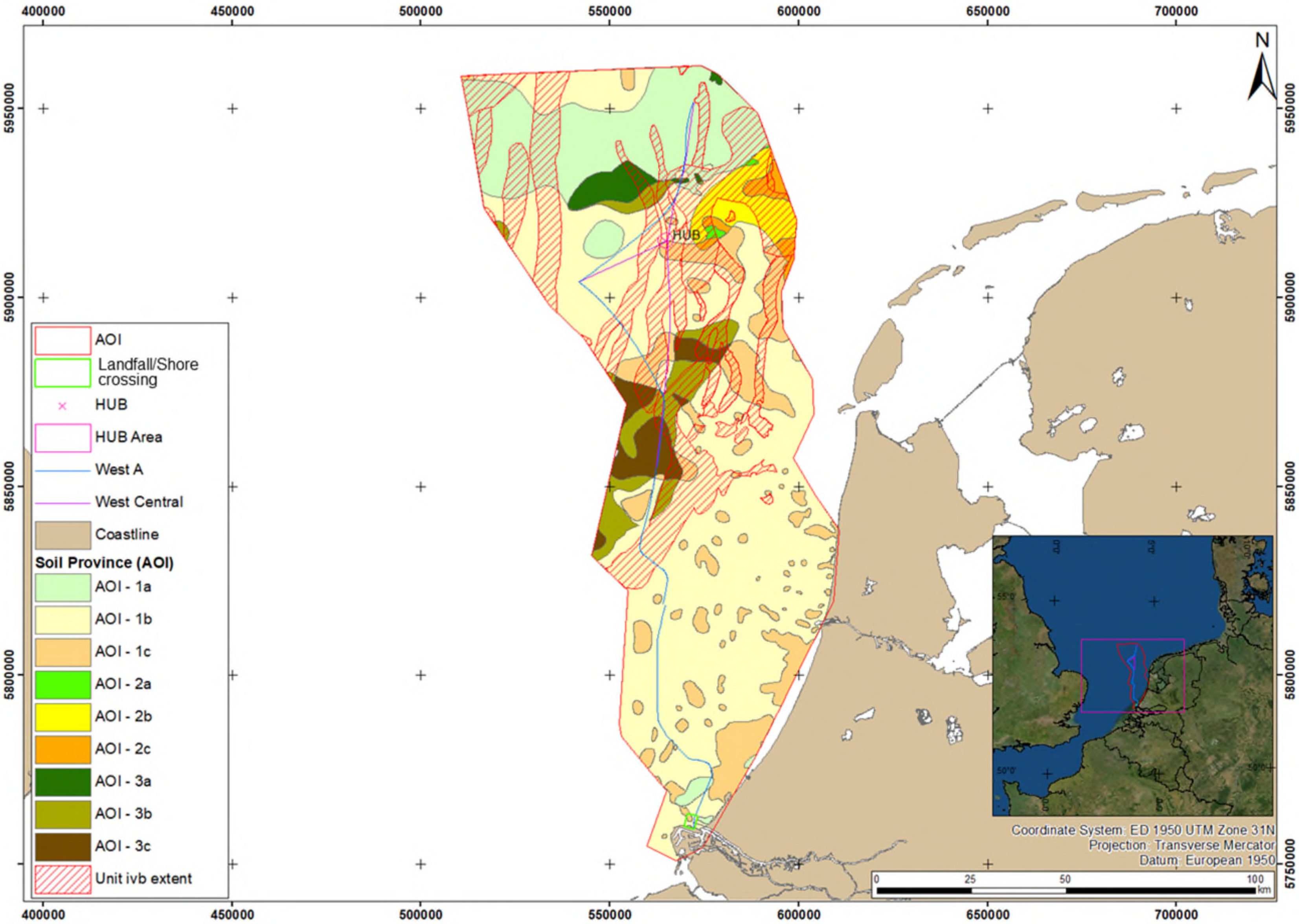

Figure 4.36: Soil province map across the AOI

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.

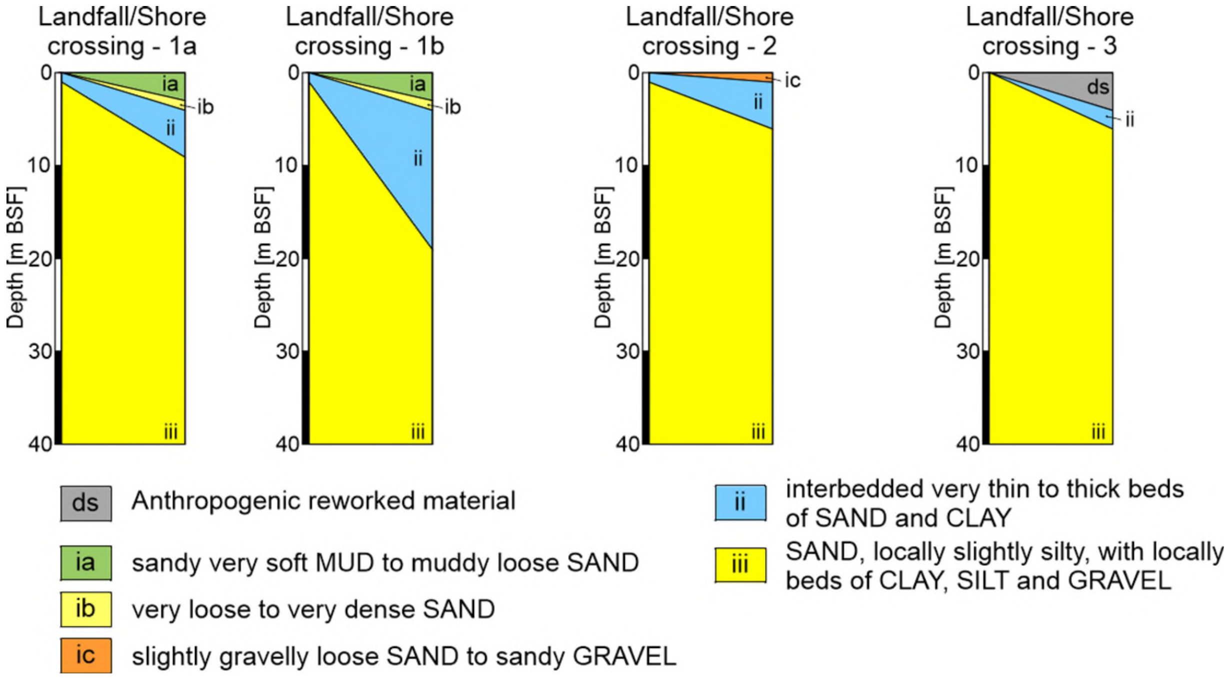

Figure 4.37: Predicted soil profiles across the Landfall/Shore crossing Area

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		

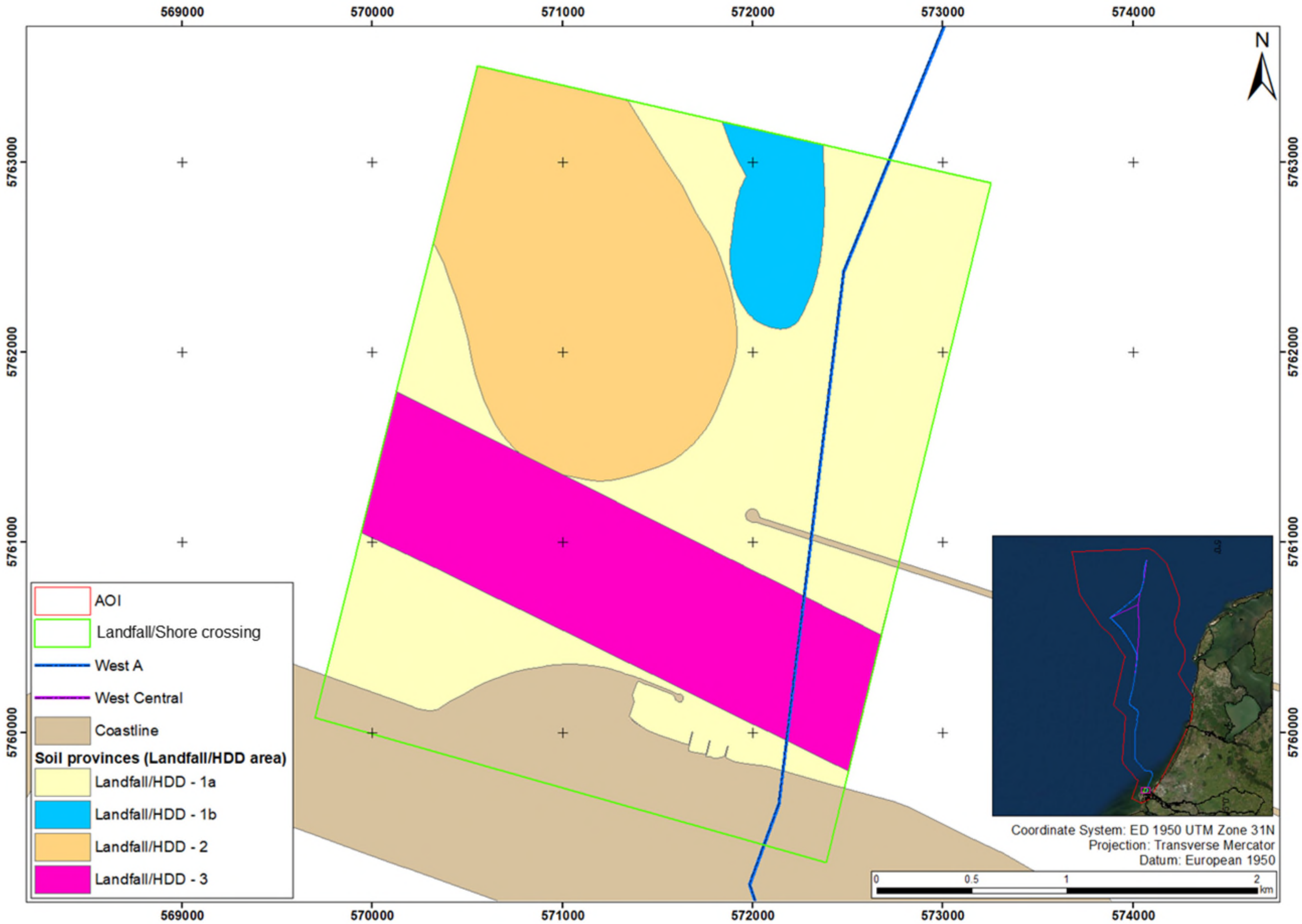

Figure 4.38: Soil province map across the Landfall/Shore crossing Area

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/m³]	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.

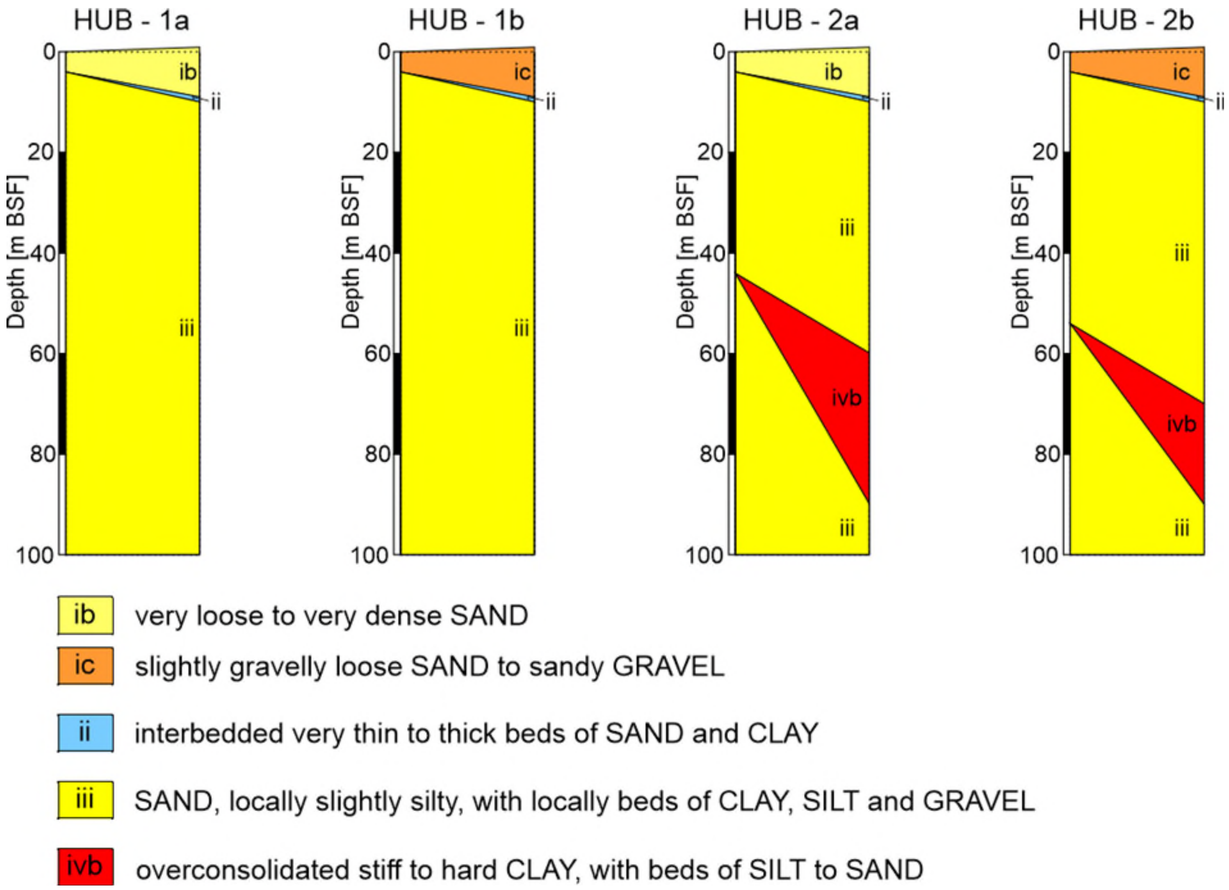

Figure 4.39: Predicted soil profiles across the Offshore Distribution HUB Area

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

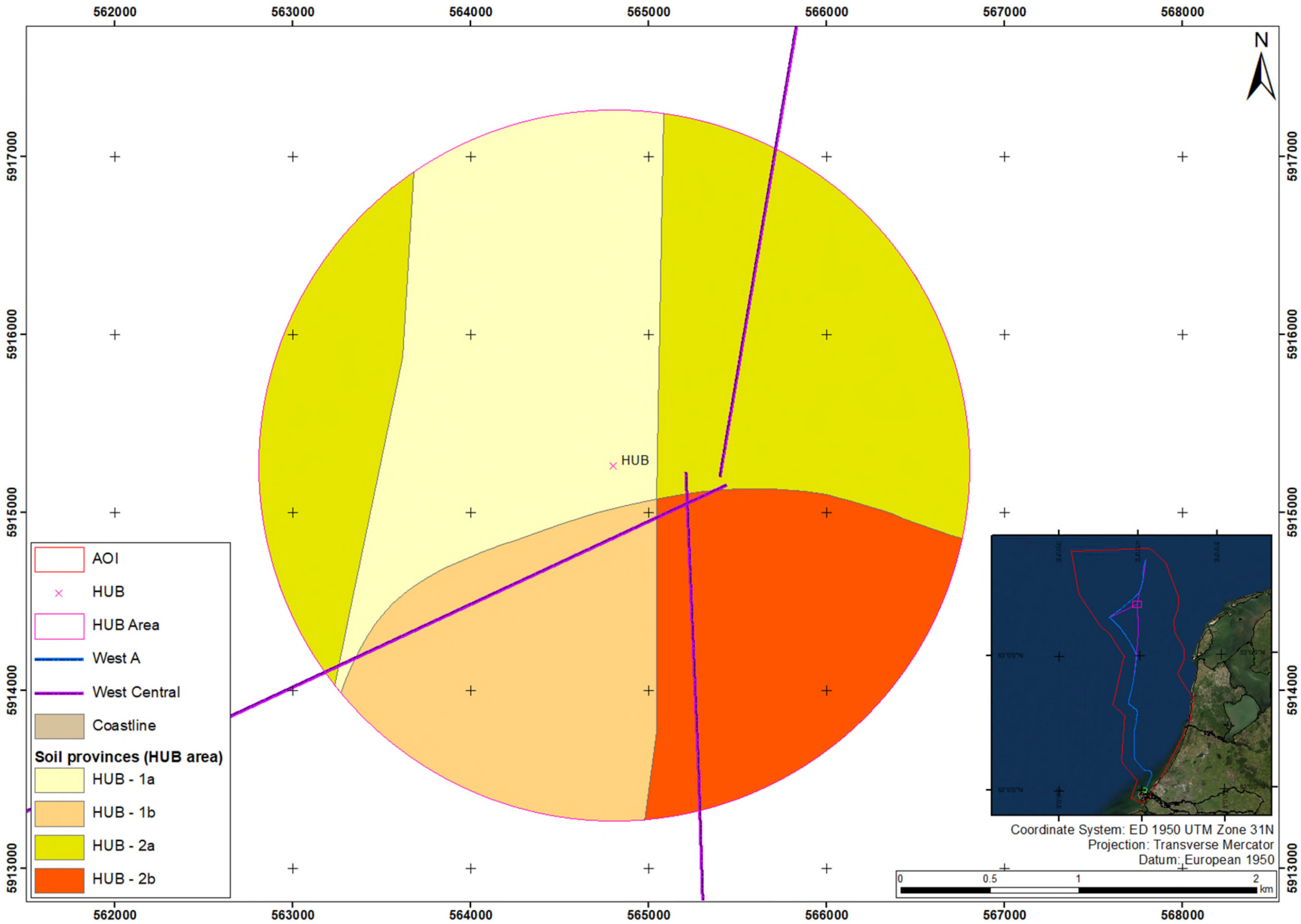

Figure 4.40: Soil province map across the Offshore Distribution HUB Area

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.

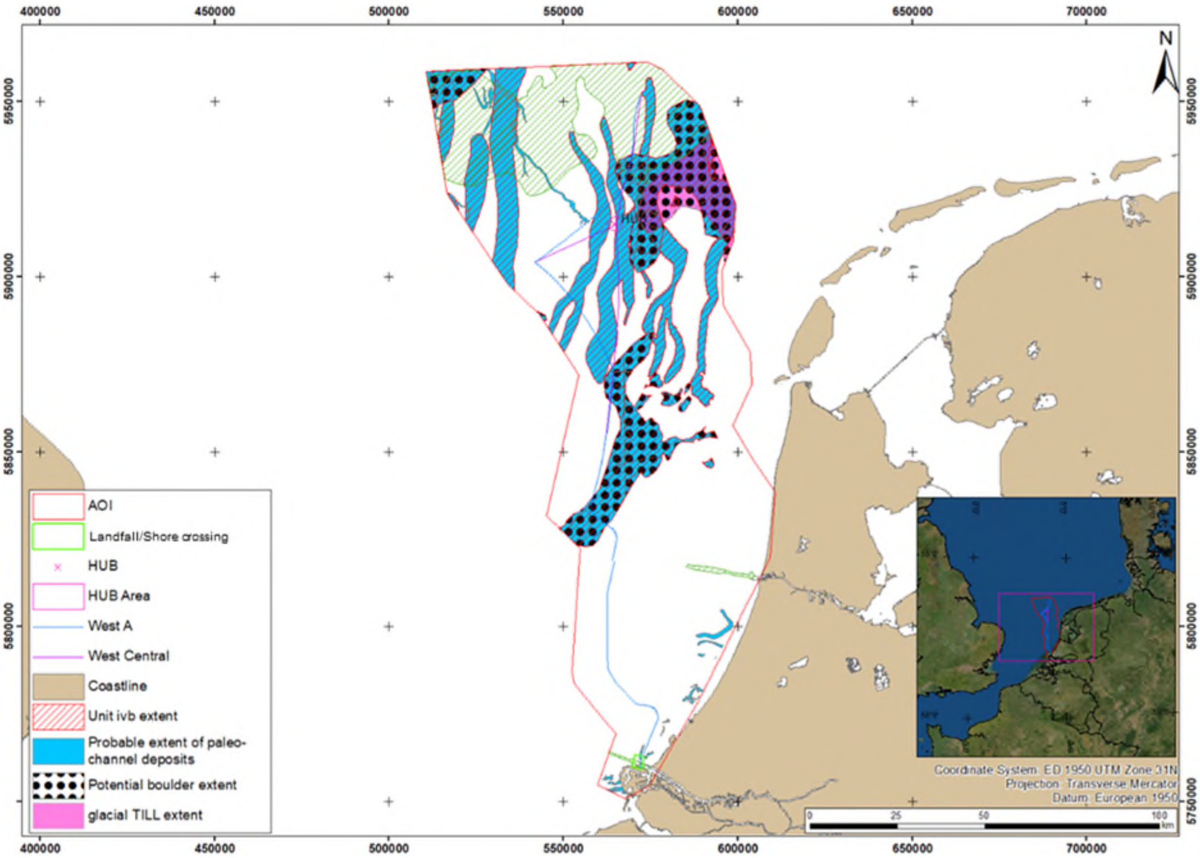

Figure 5.1: Map of identified soil constraints and potential geohazards across the AOI

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.

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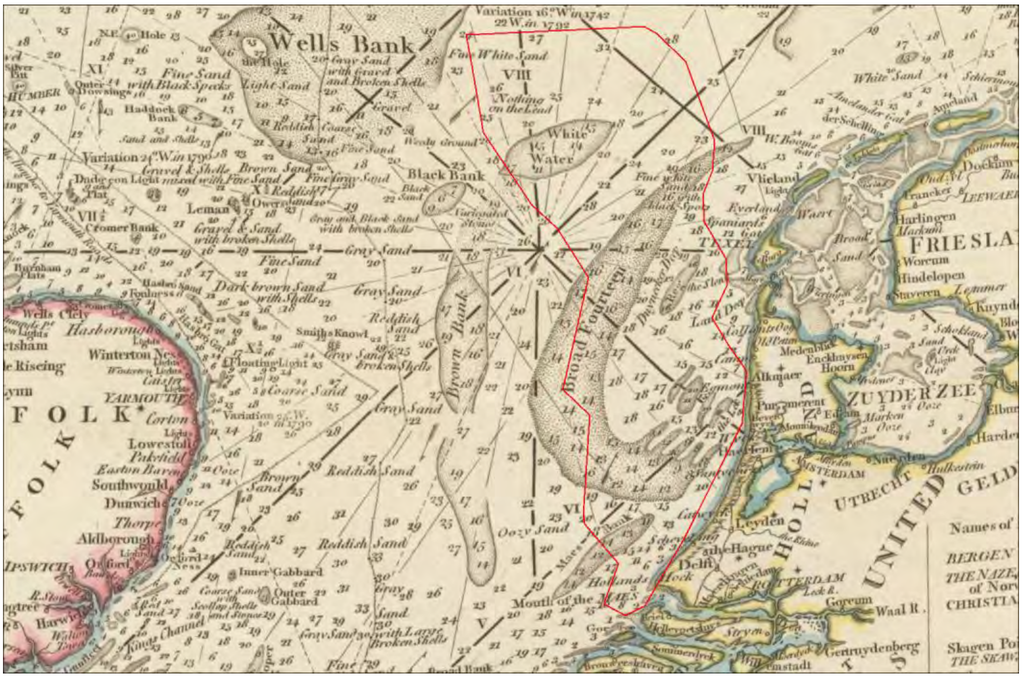
Appendix B

Archaeological Desktop Study

Periplus Archeomare

Archaeological Desk Study
Area of interests
Aramis pipelines



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[redacted] & [redacted]

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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.

<table>
<tr><th>Archaeological Expectancy</th><th colspan="2">Method</th><th>Goal</th><th>Remarks</th></tr>
<tr><td rowspan="4">Ship and aircraft wrecks</td><td rowspan="5">Geophysical</td><td>Side Scan Sonar</td><td>detect and map wreck sites</td><td>wrecks exposed at, or protruding from the seabed</td></tr>
<tr><td>Multibeam</td><td>characterize wreck sites morphologically;
detect (partially) buried wrecks by the occurrence of scours</td><td>in addition to side scan sonar</td></tr>
<tr><td>Sub-bottom Profiler</td><td rowspan="2">detect buried objects including possible ship wrecks and remains of aircraft</td><td rowspan="2">nature of the buried object cannot be determined directly</td></tr>
<tr><td>Magnetometer</td></tr>
<tr><td>Prehistoric settlements</td><td>Sub-bottom Profiler</td><td>map the Pleistocene landscape;
specify expectancy</td><td>supported by, and validated with drill data</td></tr>
</table>

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.

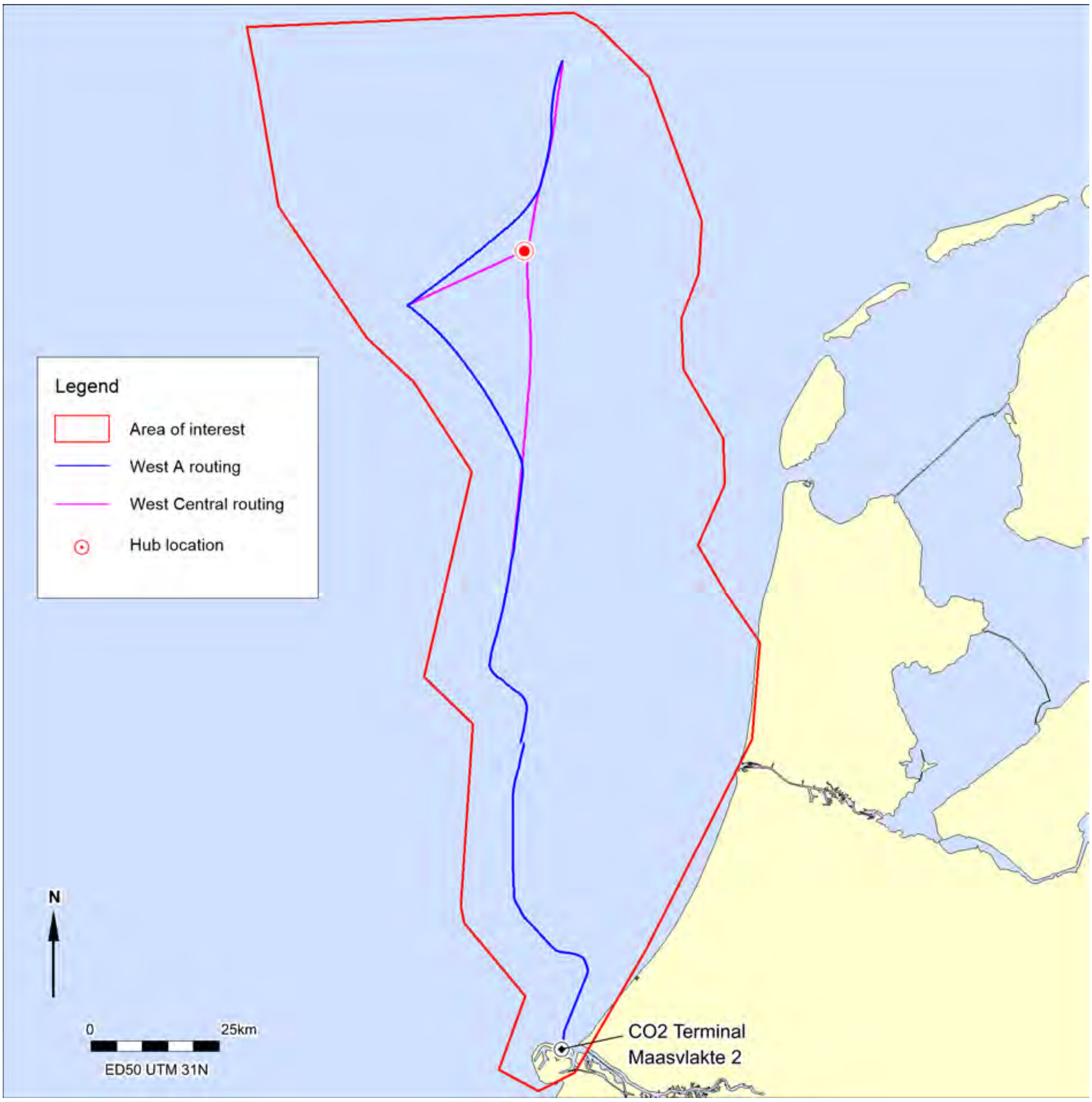

Figure 1. Location map of the area of interest

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.

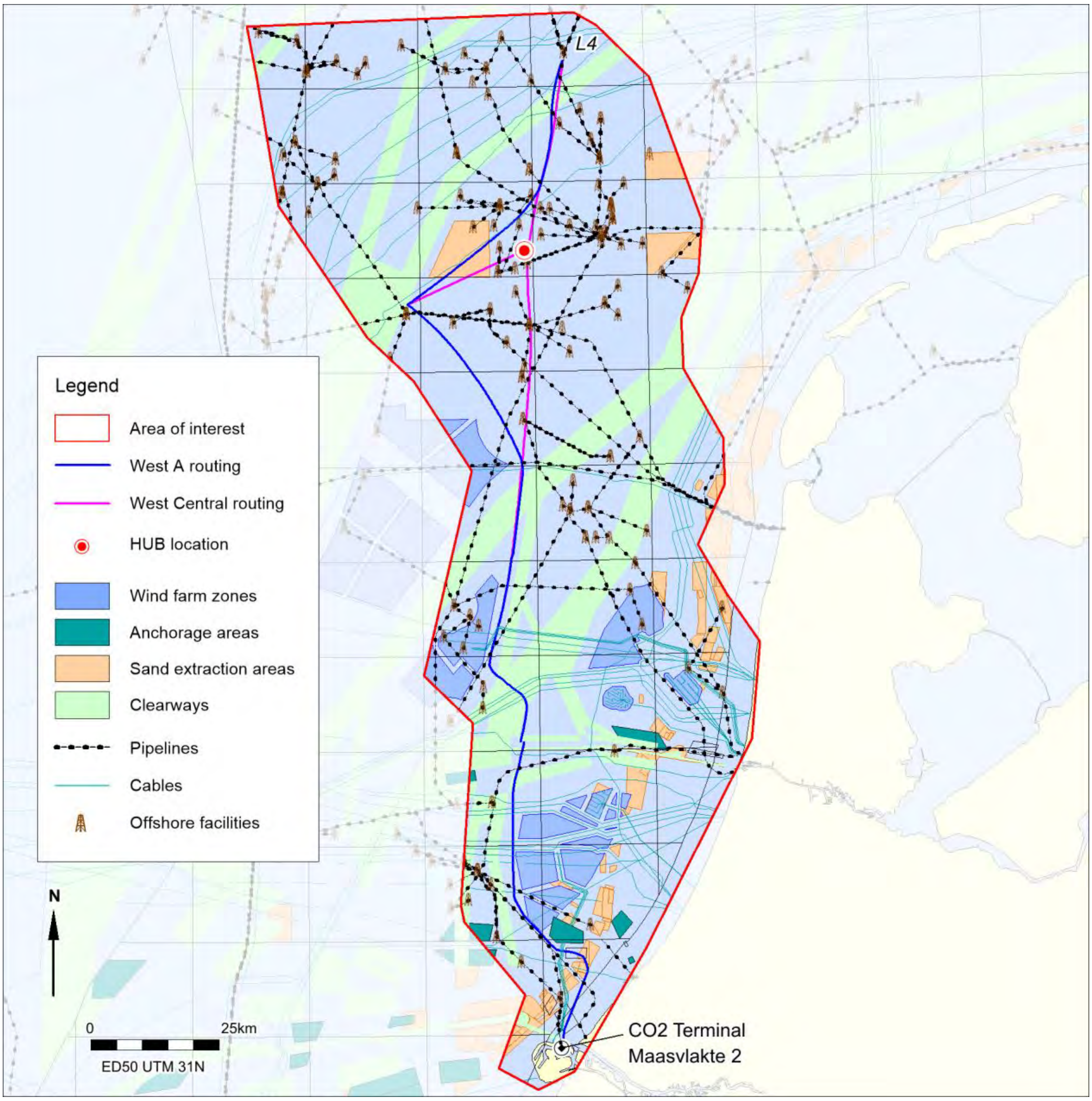

Figure 2. Overview of the area of interest in relation to other areas of use

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.

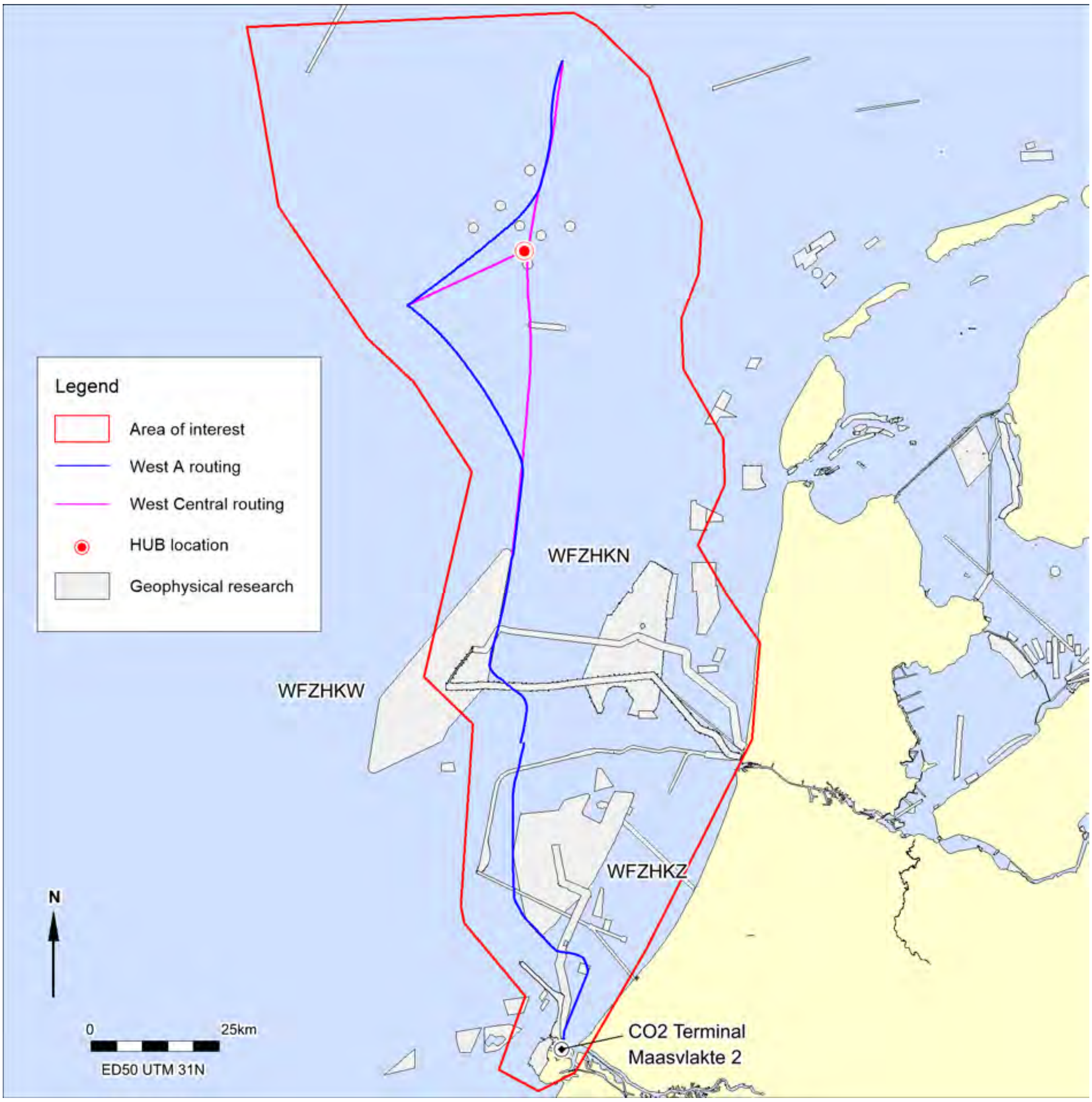

Figure 3 Previous conducted archaeological investigations in the area

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).

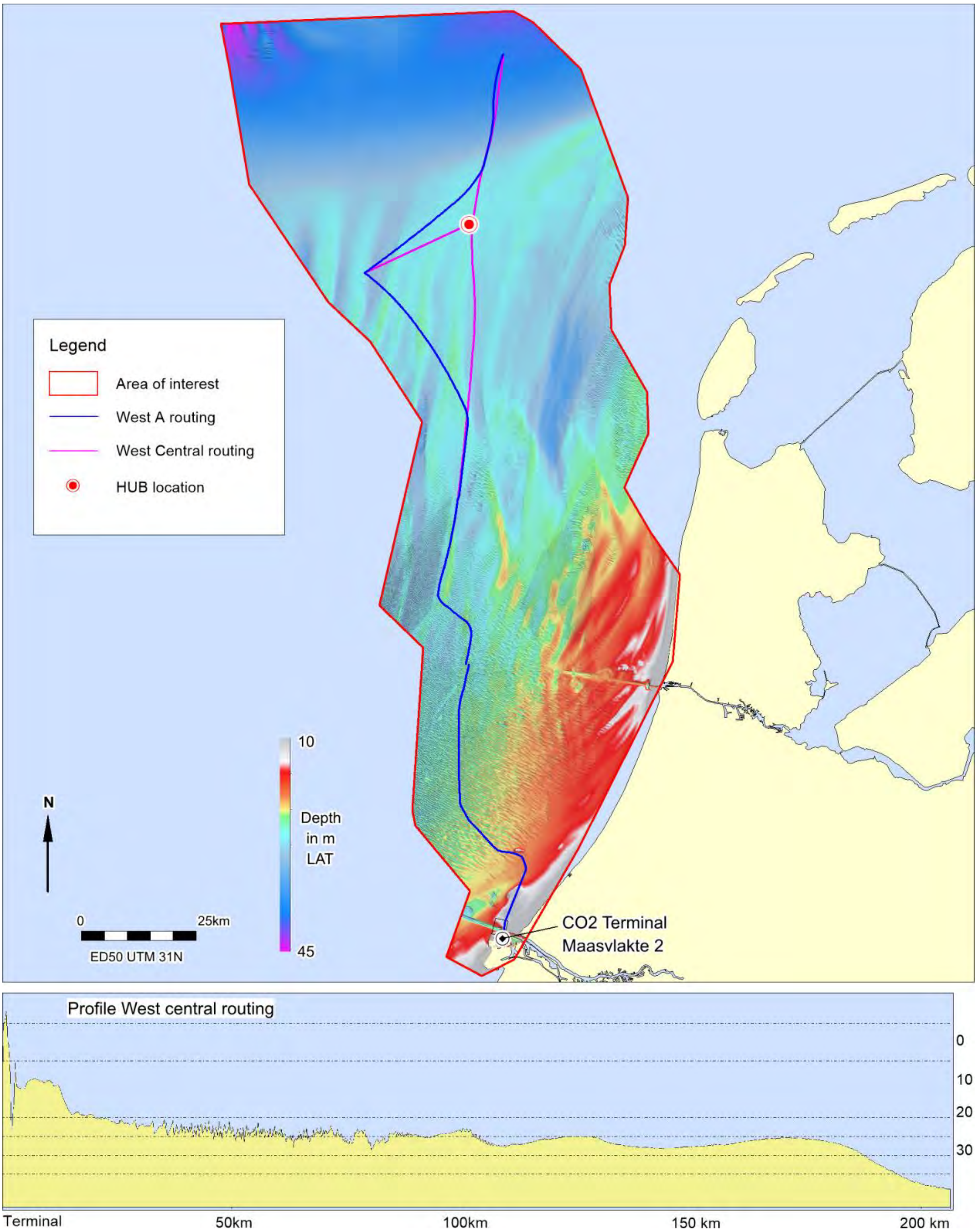

Figure 4. General bathymetry of the seabed and profile along the West central routing

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).

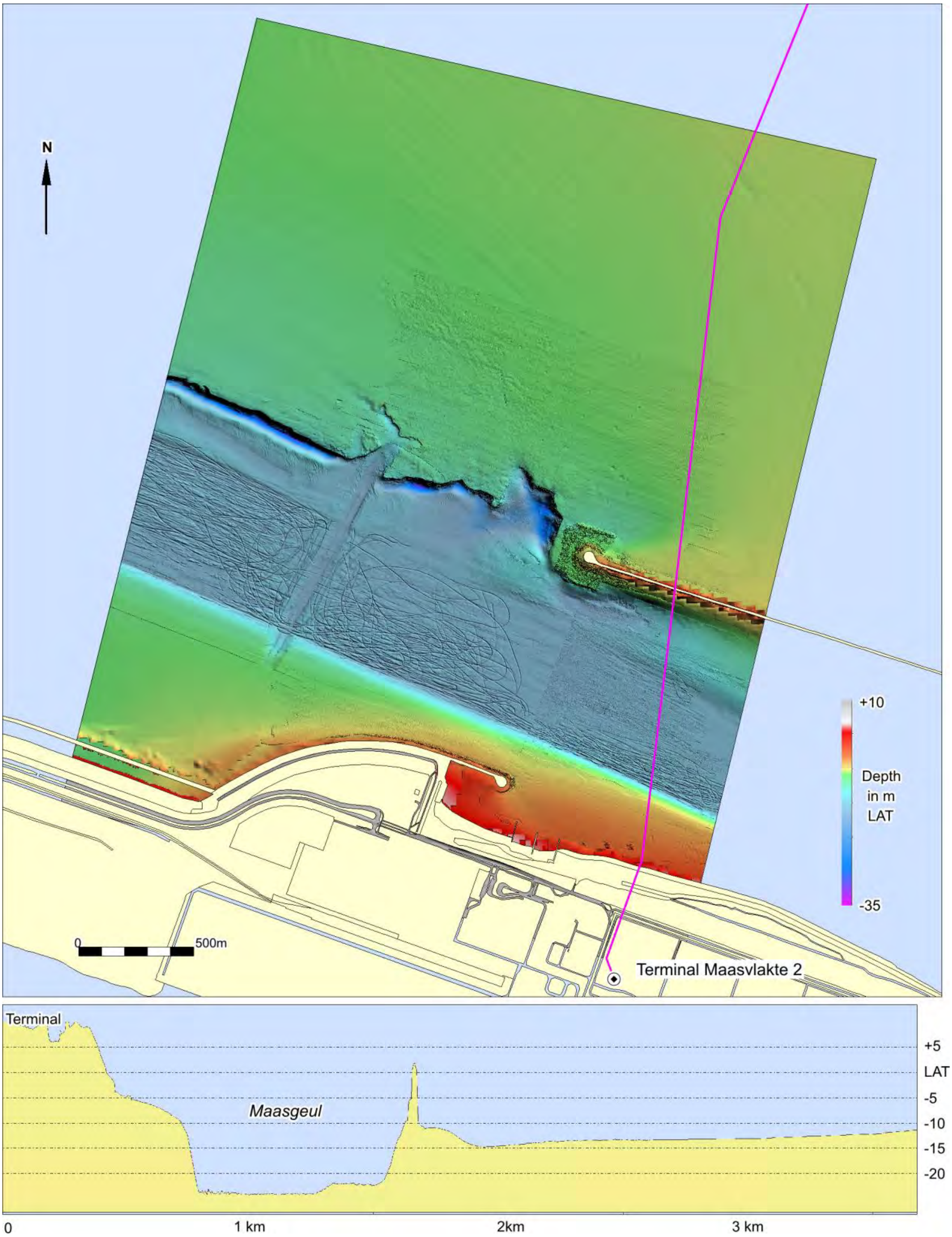

Figure 5. Bathymetry of the seabed in the landfall area

Seabed morphology

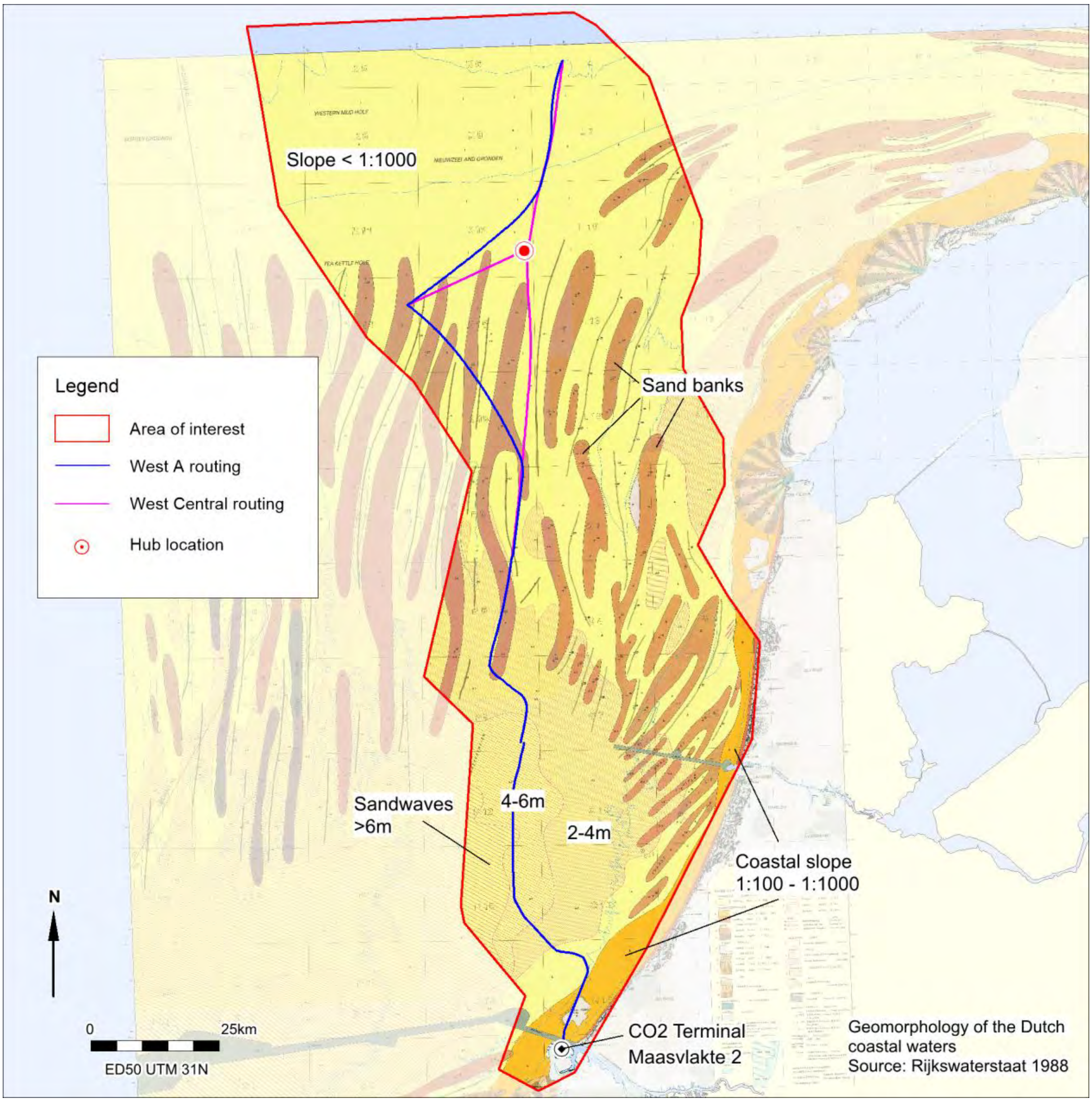

Figure 6. Geomorphology of the seabed

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.

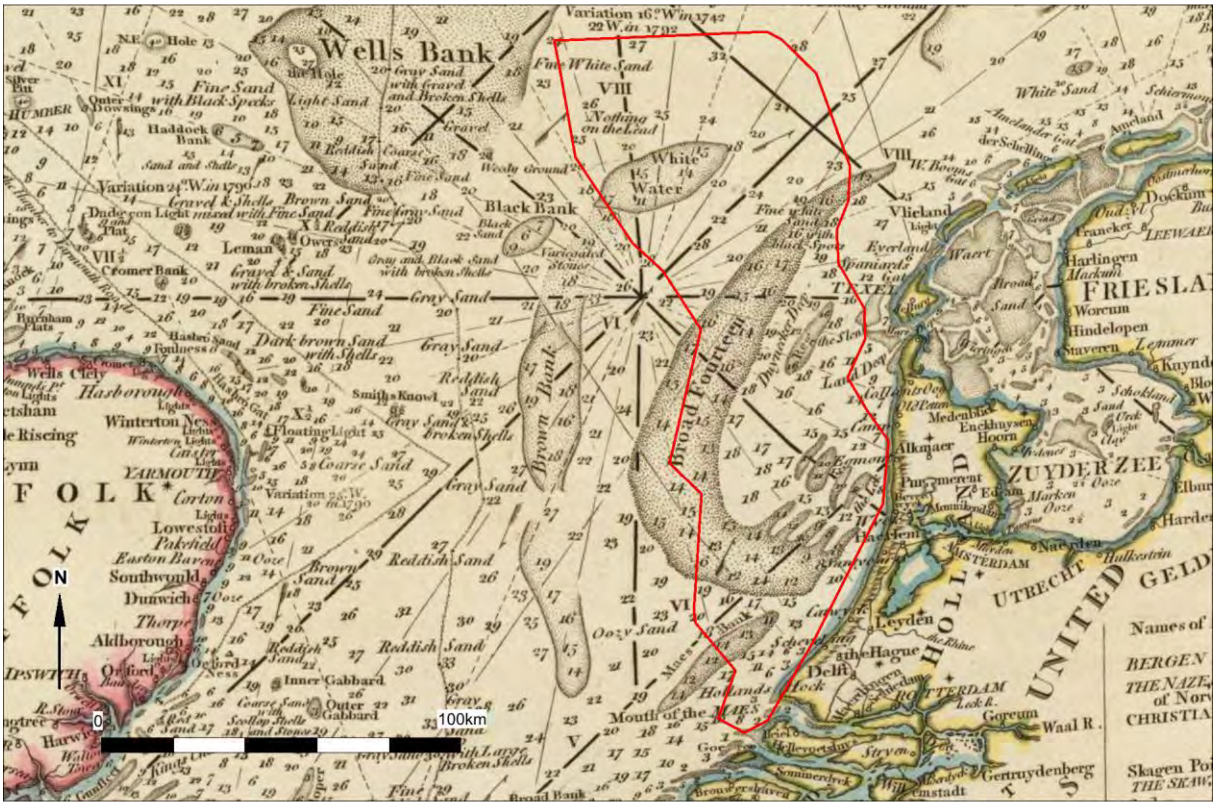

Figure 10. The area of interest on the historical map of 1777 (Faden)

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.

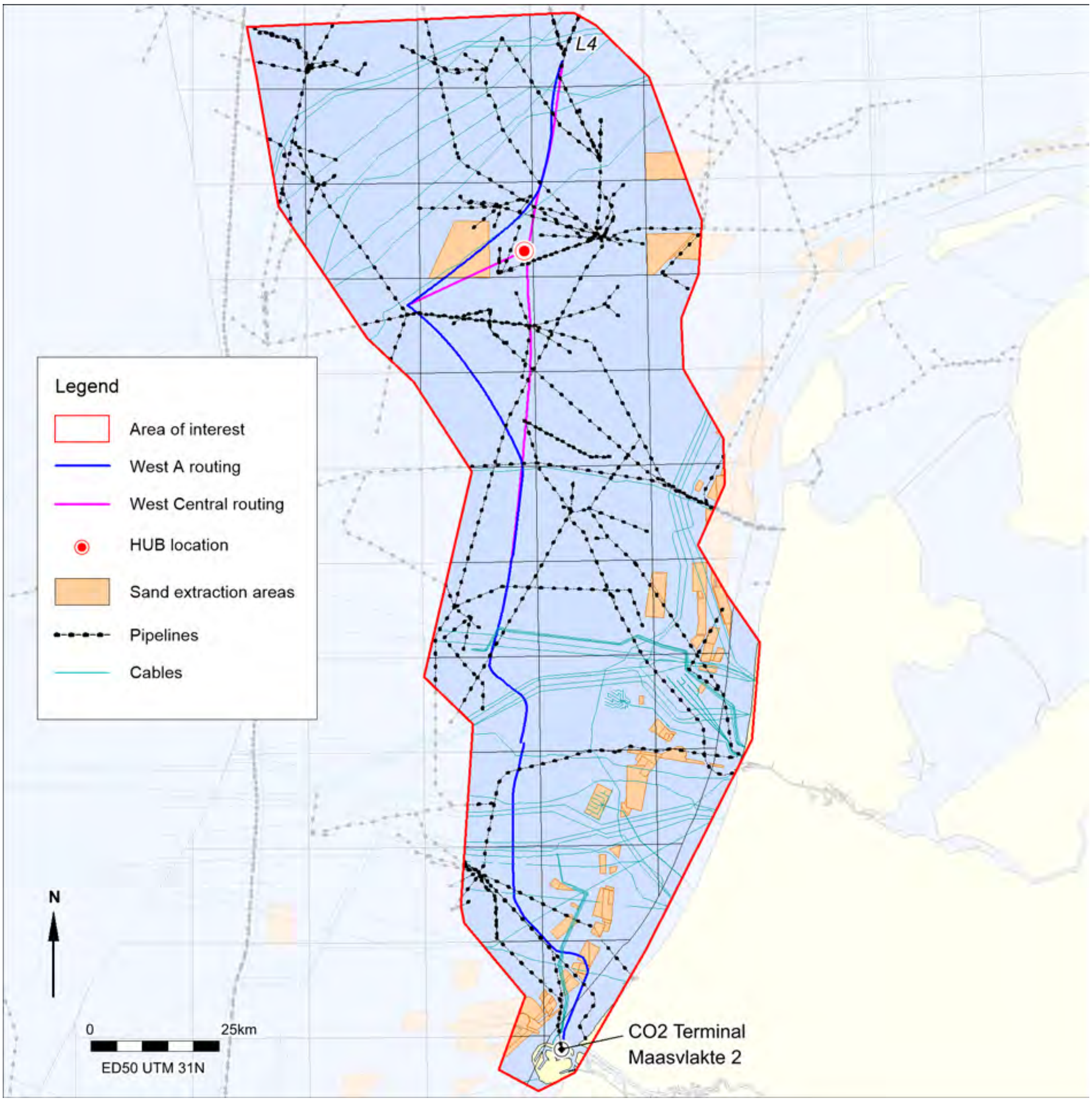

Figure 11. Pipelines, cables and sand extraction areas in the area

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).

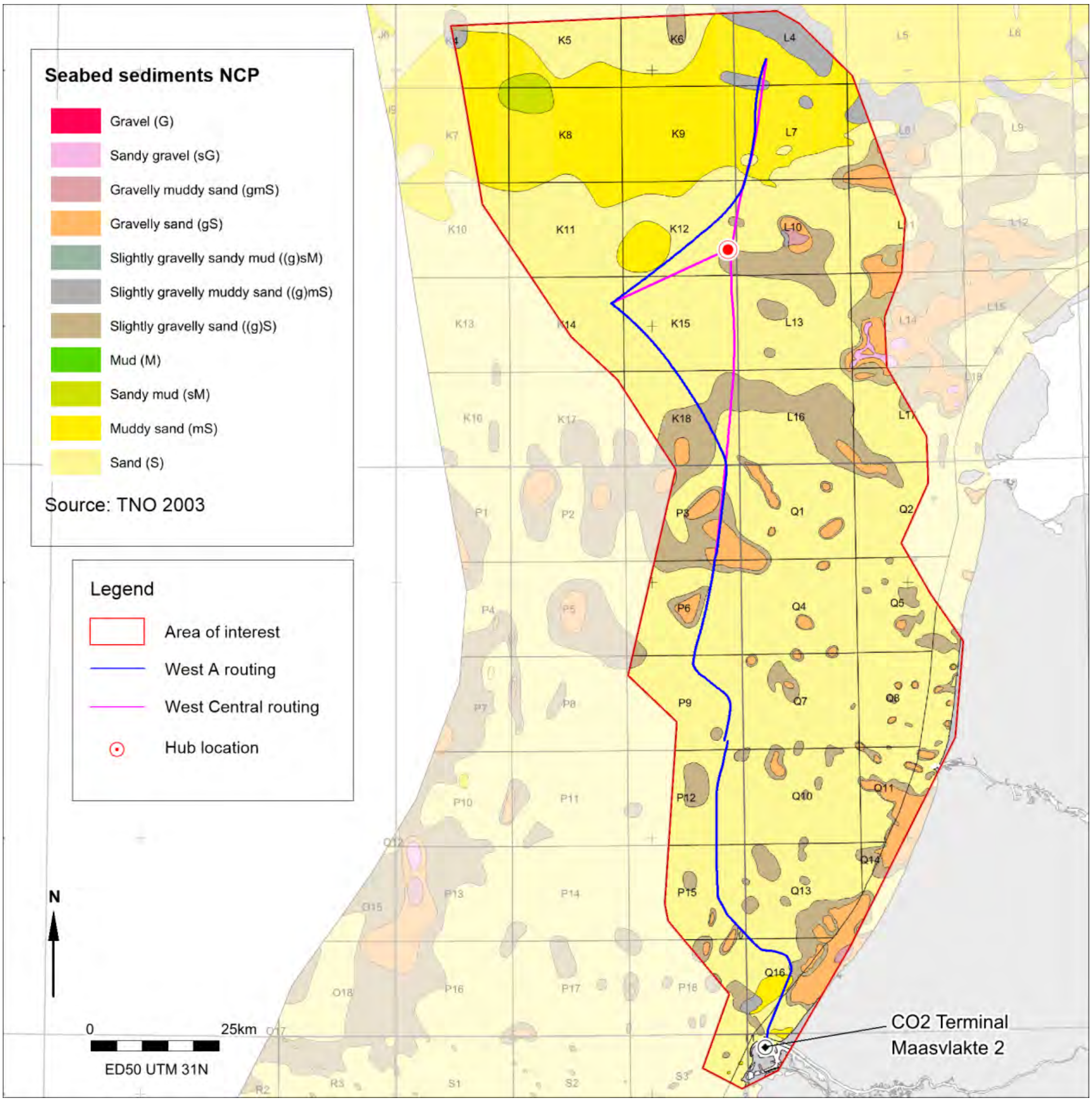

Figure 12. Seabed Sediments (Laban 2003)

Pleistocene Units

Figure 13 shows the different subcropping *Pleistocene* units in the area of interest[9].

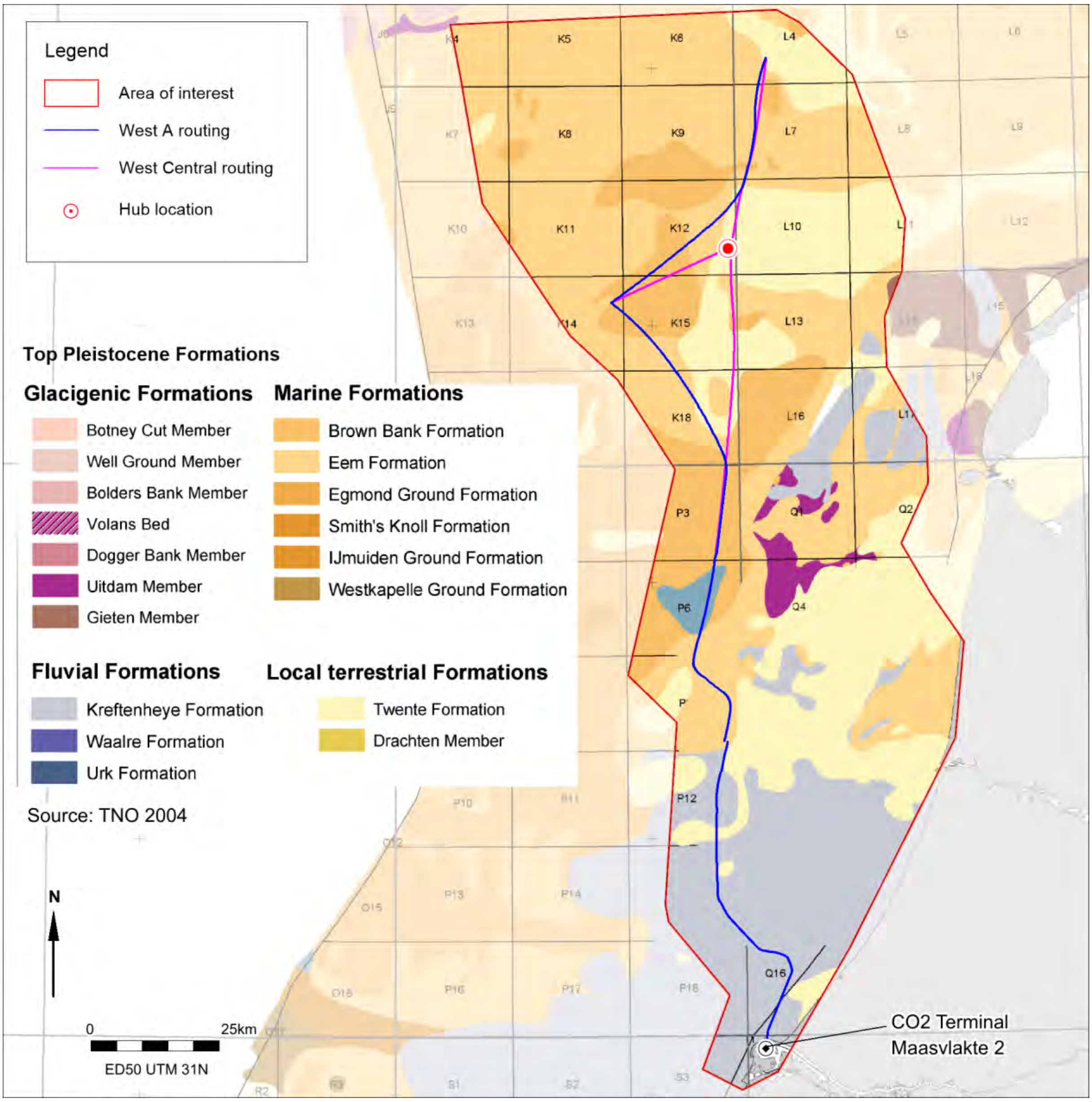

Figure 13. Subcropping Pleistocene formations

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.

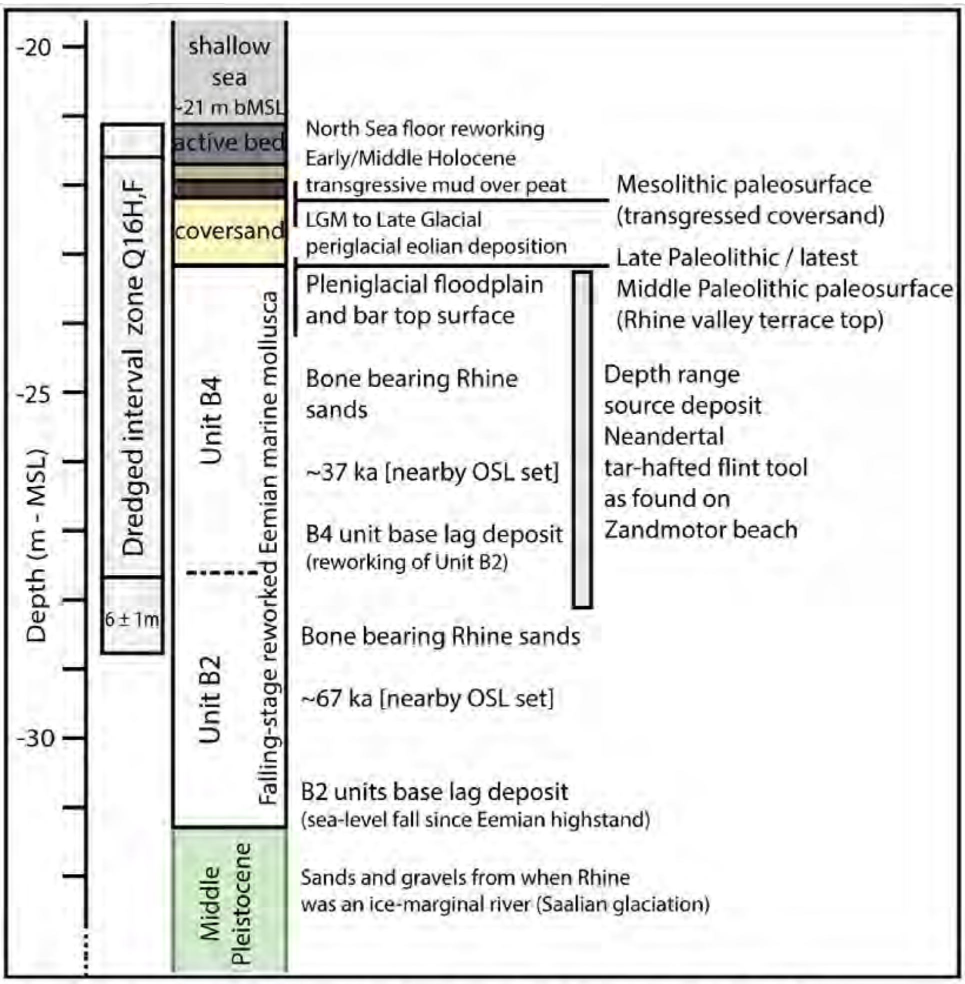

Fig. S2. Stratigraphy of the dredging area Q16. The upper 6-8 meters of the sedimentary column consist of: 1) a dynamic sheet of shelly sand of the active sea bed, 2) beds of Early-Middle Holocene transgressive tidal muds on basal peat, 3) Late Glacial eolian coversands containing Mesolithic materials (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.

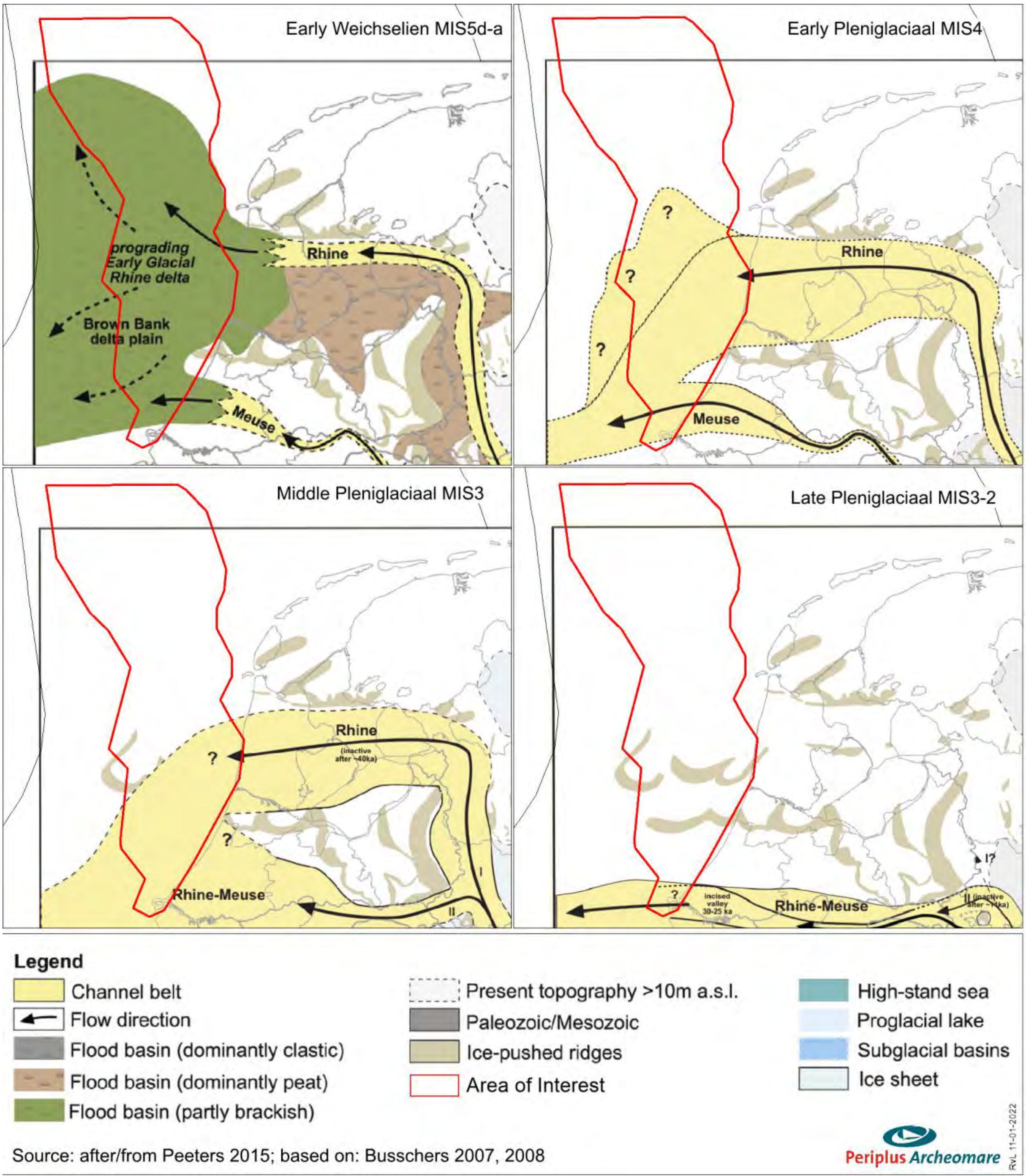

Figure 15. Paleogeographic maps of the Weichselian.

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]

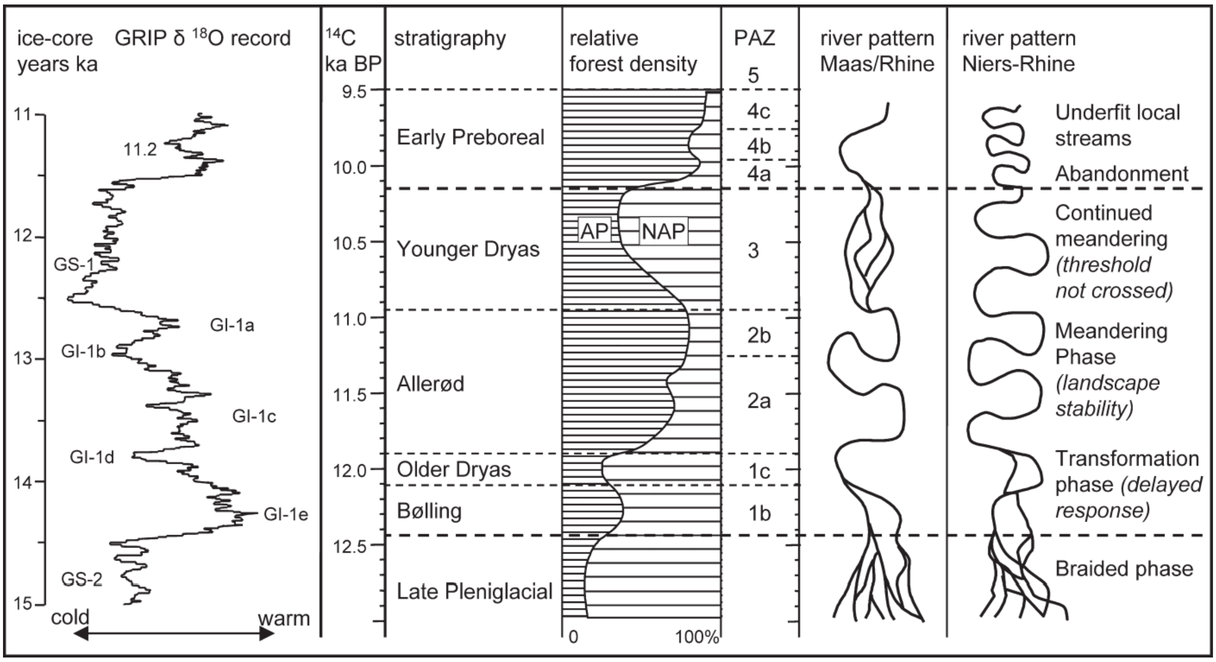

Figure 16. Late Glacial fluvial evolution of the Niers–Rhine and Maas in relation to climate and vegetation changes (from: Kasse 2005).

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.

<u>Boxtel Formation (Weichselian and Early *Holocene*)</u>

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.

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[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.

<u>Drachten Formation</u>

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).

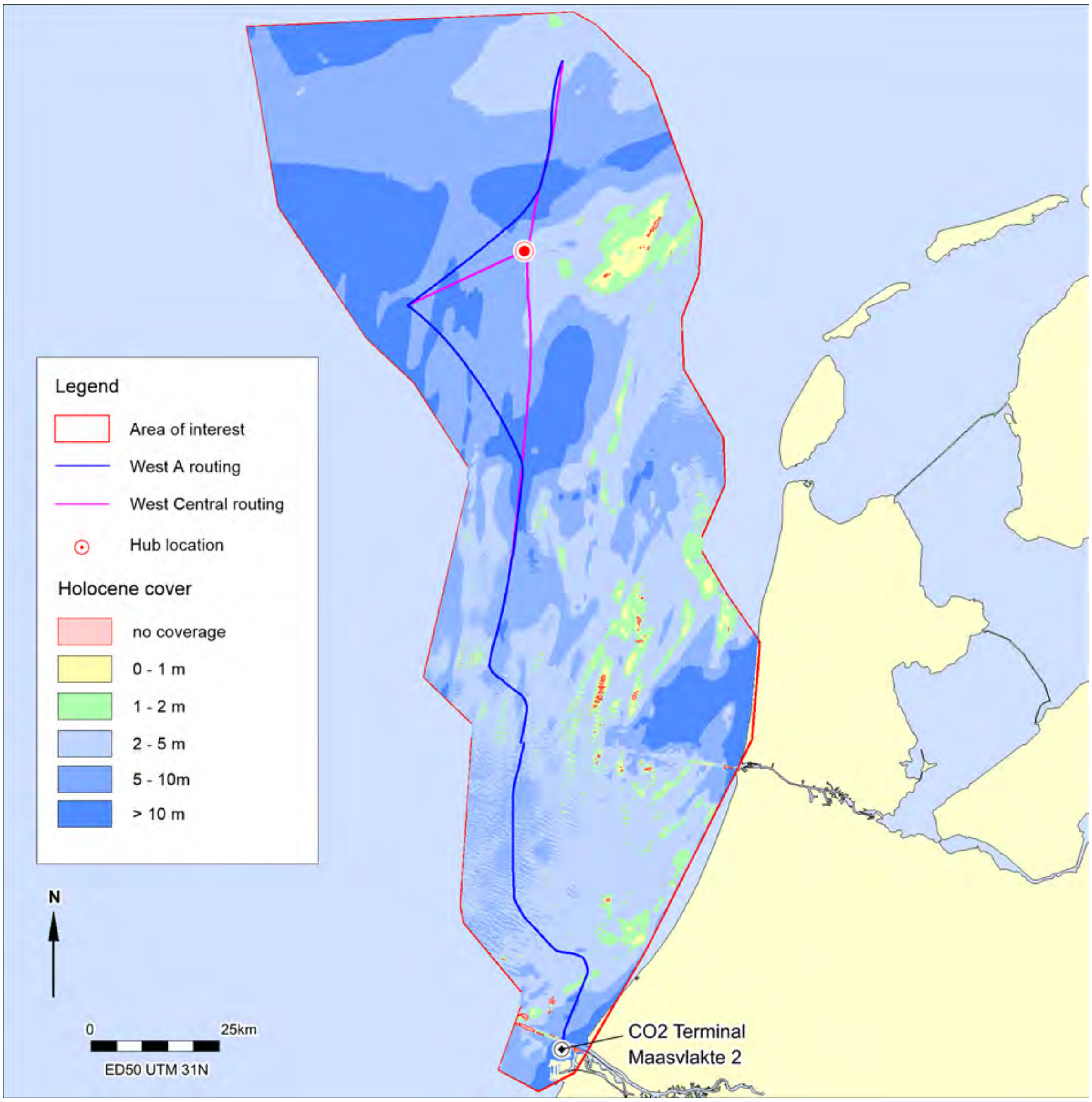

Figure 18. Thickness of Holocene cover

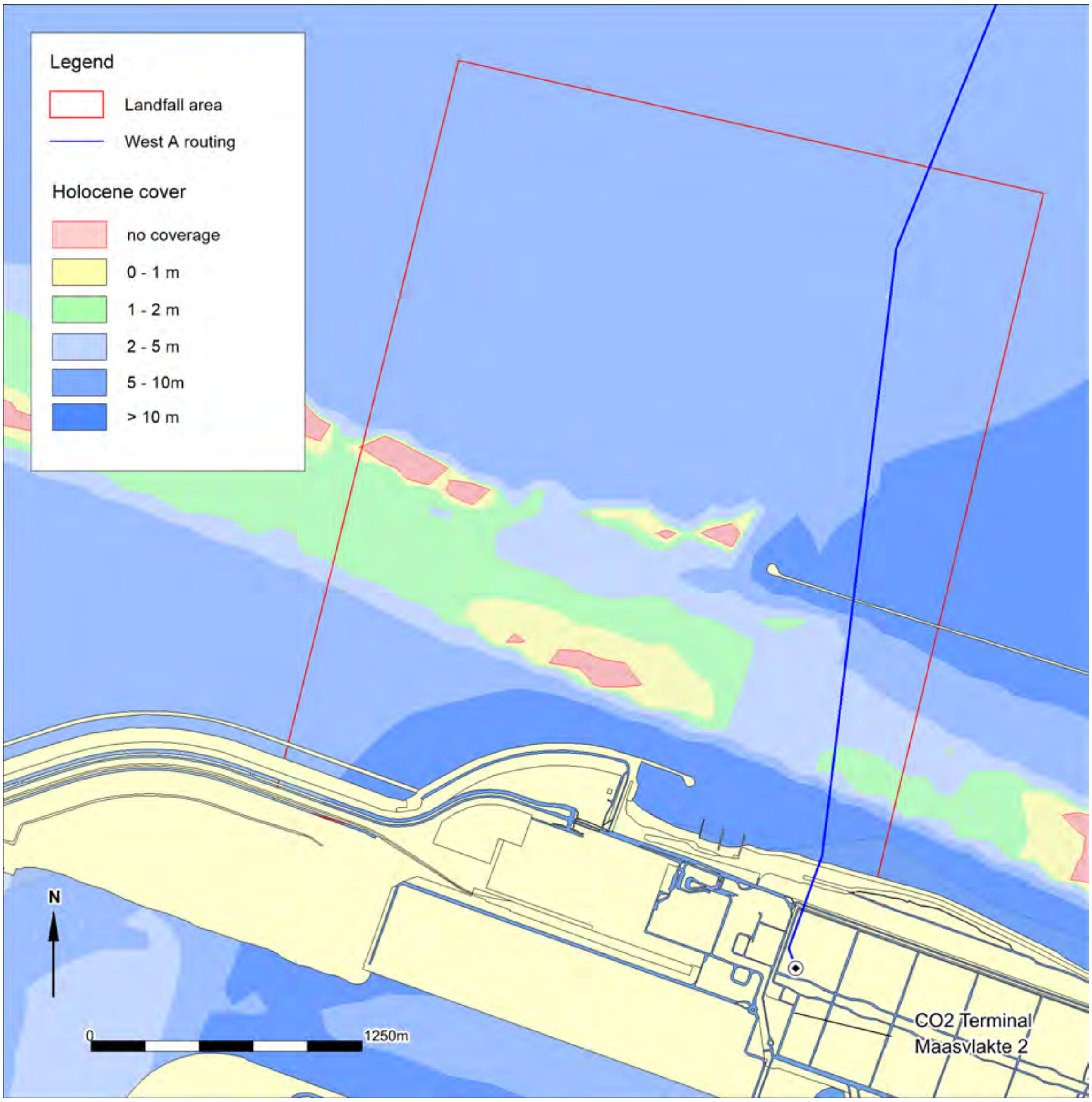

Figure 19. Holocene cover within the landfall area

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].

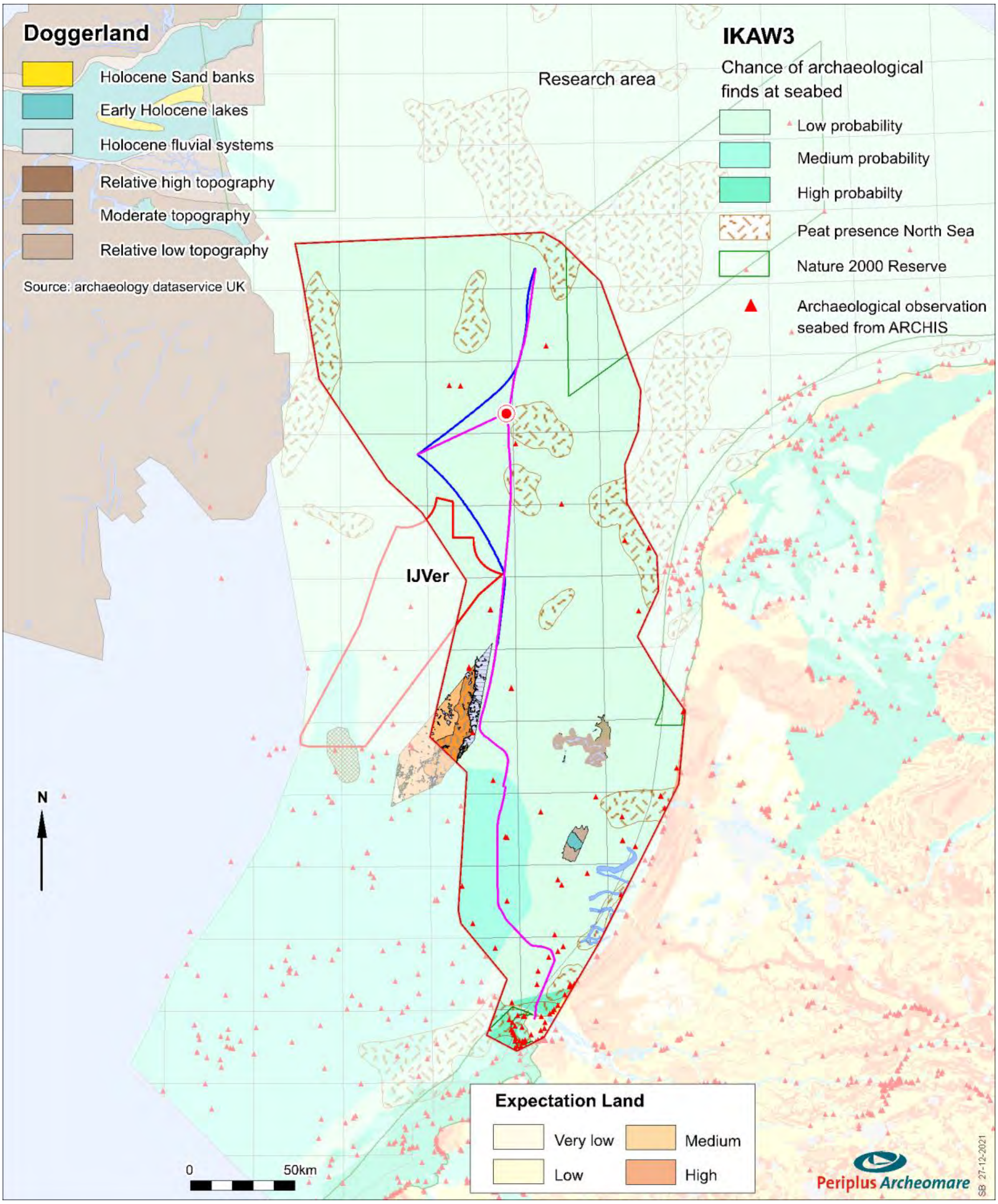

Figure 20. Overview indicative map of archaeological values (IKAW)

[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).

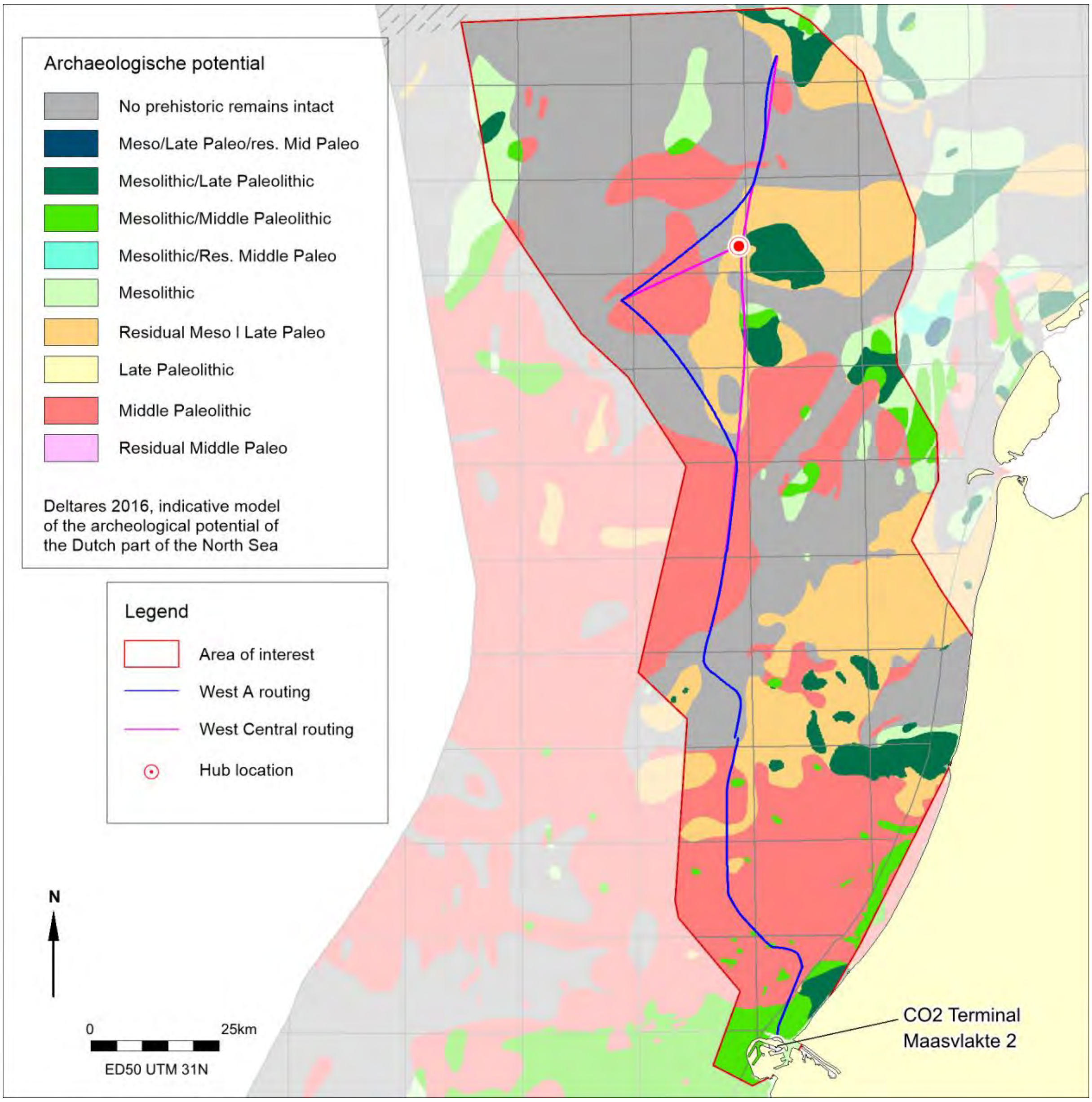

Figure 21. Archeological potential for prehistoric remains

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)

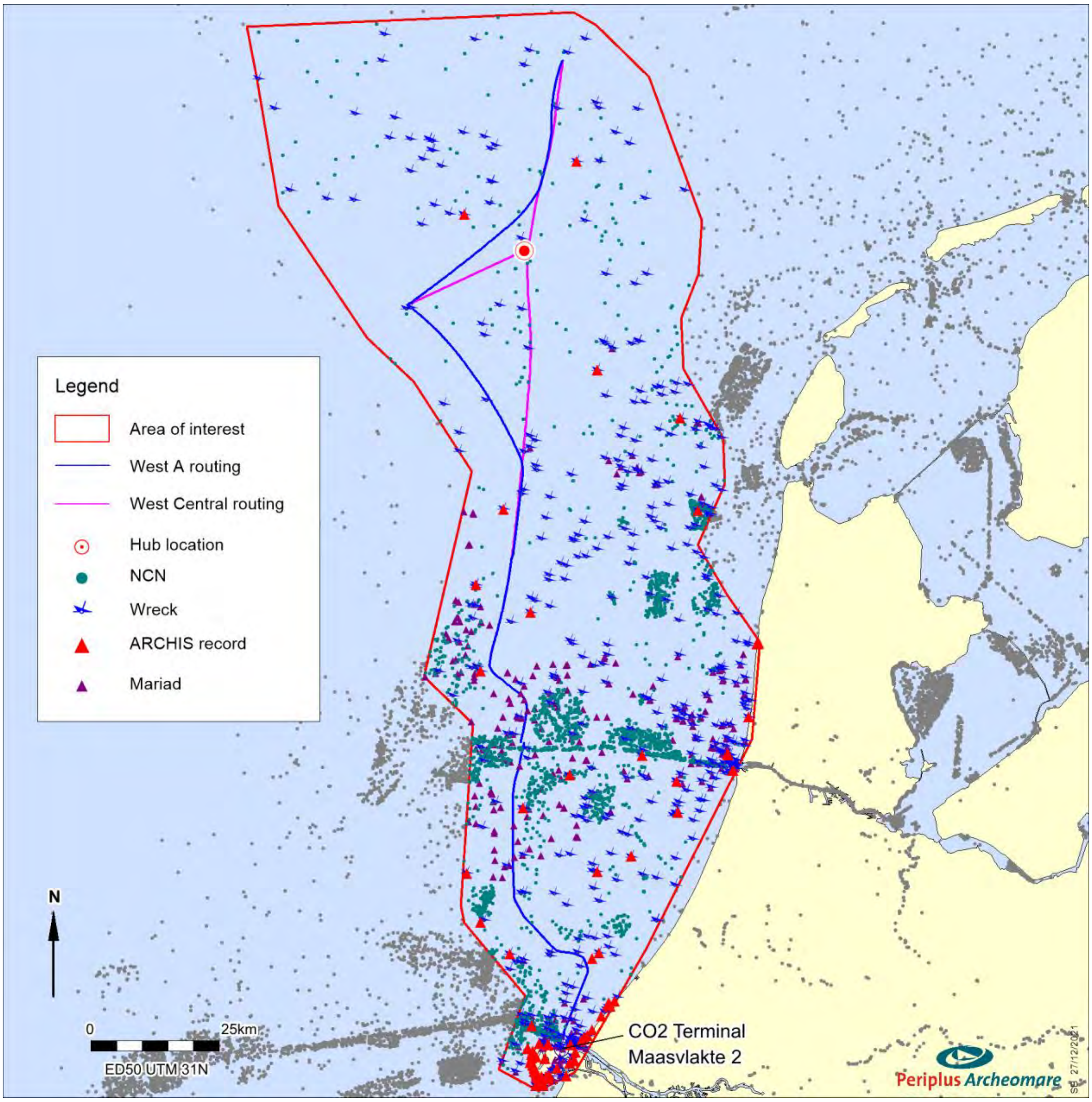

Figure 22. Overview of known objects and contacts in the area of interest

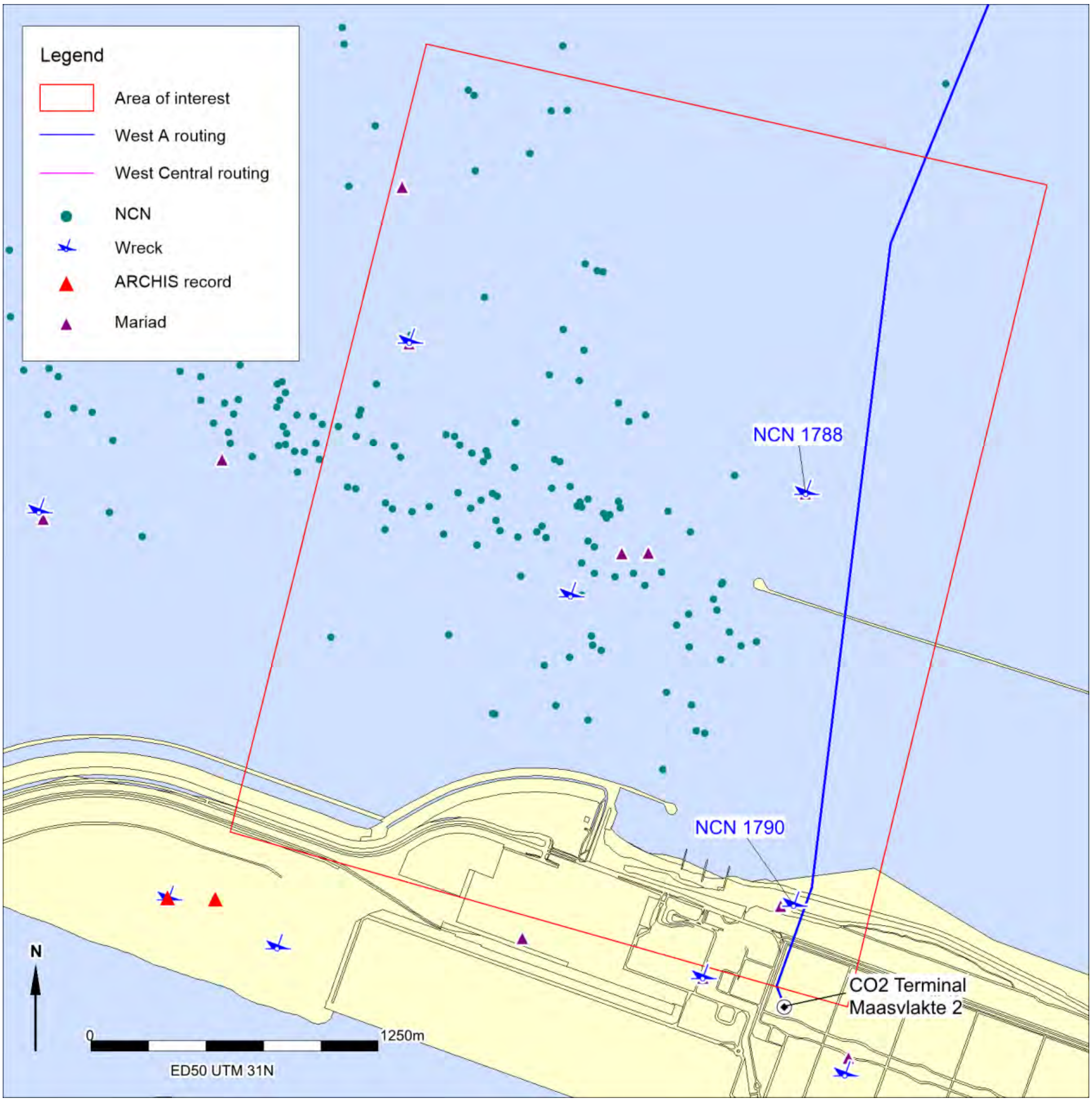

Figure 23. Overview of known objects and contacts in the landfall area

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).

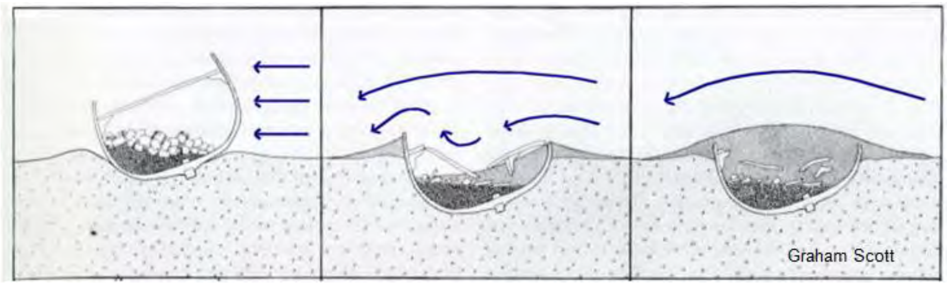

Figure 24. Example of wreck site formation (Graham Scott)

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.

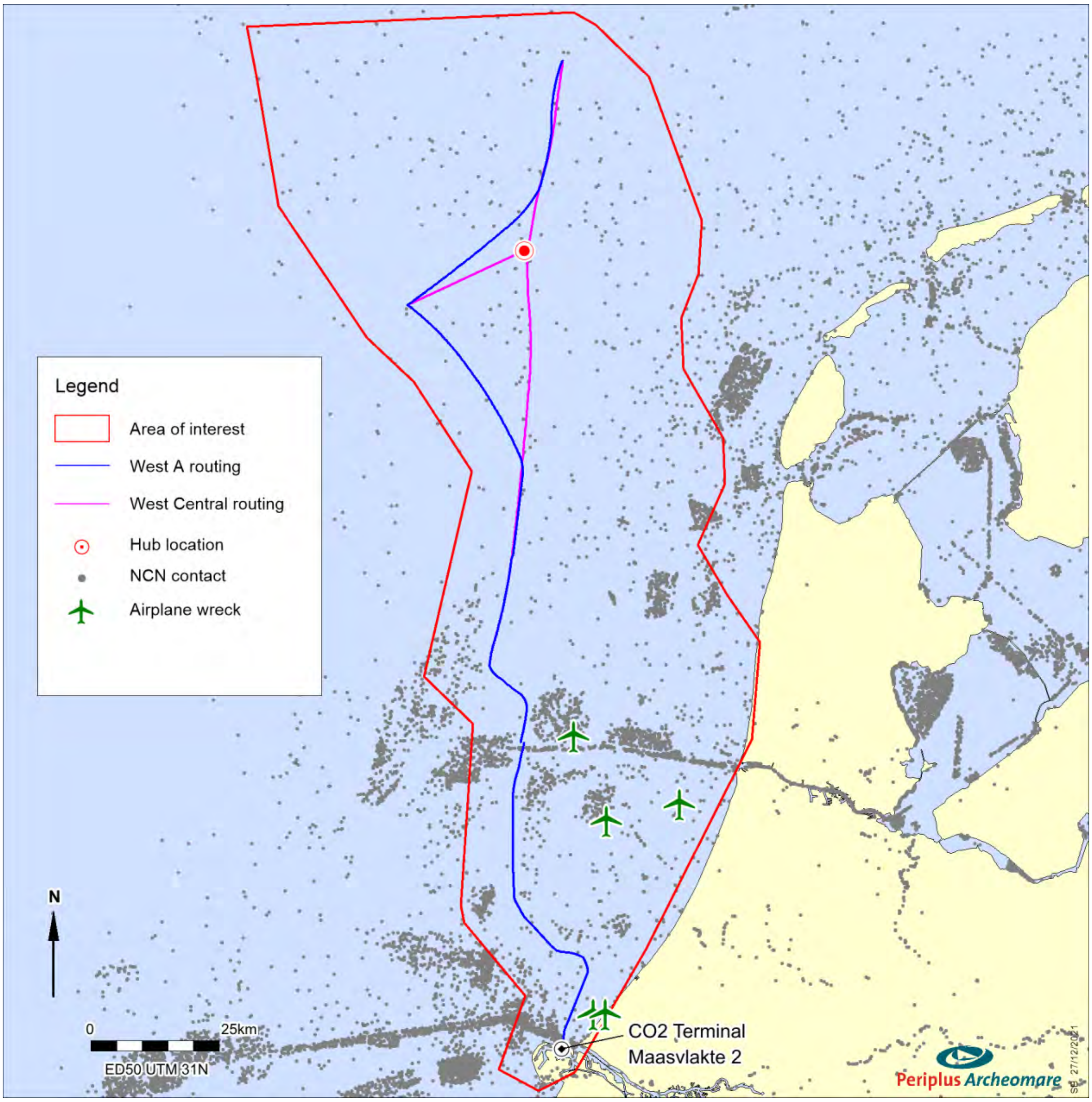

Figure 25. Known airplane wrecks within the area of interest

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.

<table>
<tr><th>Archaeological Expectancy</th><th colspan="2">Method</th><th>Goal</th><th>Remarks</th></tr>
<tr><td rowspan="4">Ship and aircraft wrecks</td><td rowspan="5">Geophysical</td><td>Side Scan Sonar</td><td>detect and map wreck sites</td><td>wrecks exposed at, or protruding from the seabed</td></tr>
<tr><td>Multibeam</td><td>characterize wreck sites morphologically;
detect (partially) buried wrecks by the occurrence of scours</td><td>in addition to side scan sonar</td></tr>
<tr><td>Sub-bottom Profiler</td><td rowspan="2">detect buried objects including possible ship wrecks and remains of aircraft</td><td rowspan="2">nature of the buried object cannot be determined directly</td></tr>
<tr><td>Magnetometer</td></tr>
<tr><td rowspan="3">Prehistoric settlements (camp sites)</td><td>Sub-bottom Profiler</td><td>map the Pleistocene landscape; specify expectancy</td><td>supported by, and validated with drill data</td></tr>
<tr><td rowspan="2">Geotechnical</td><td>Geological Drilling</td><td>determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy</td><td>designation of borehole and/or vibrocore locations for geo-archaeological research based on SBP data</td></tr>
<tr><td>Cone Penetration Test</td><td>determine lithostratigraphy</td><td>correlate with drilling data</td></tr>
</table>

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.

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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)

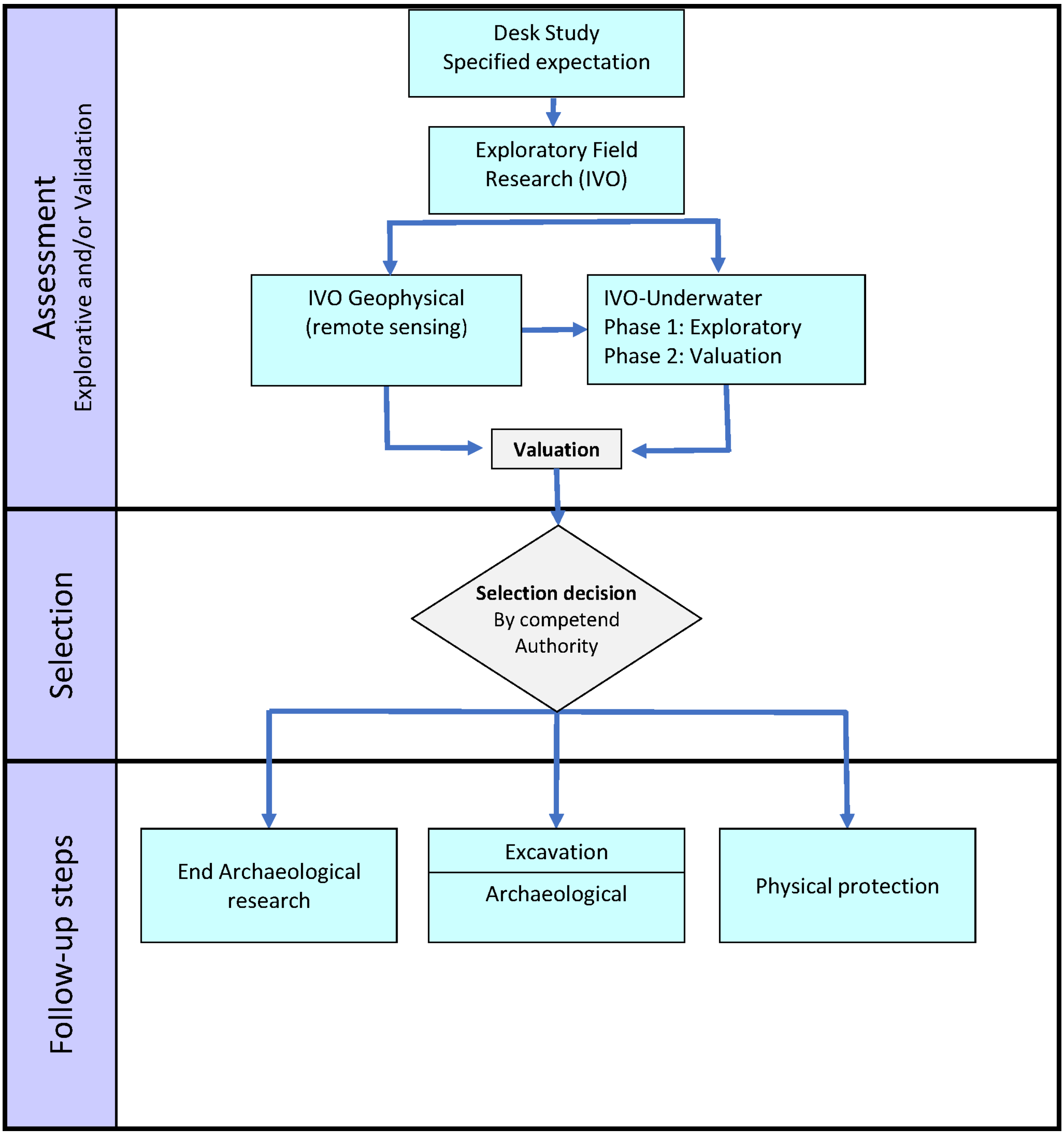
The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains are worth preserving. If the latter is the case, then there are 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
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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
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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.

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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 Probable	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.
Naval mines (WWII)	Probable Certain	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’	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.
Aerial bombs	Certain Probable	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.
Rockets	Certain Probable	3 inch rocket with 25 lbs or 60 lbs (SAP) warhead	
Under water ammunition	Certain Probable	18 inch torpedo Mk XV Depth charge	

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.

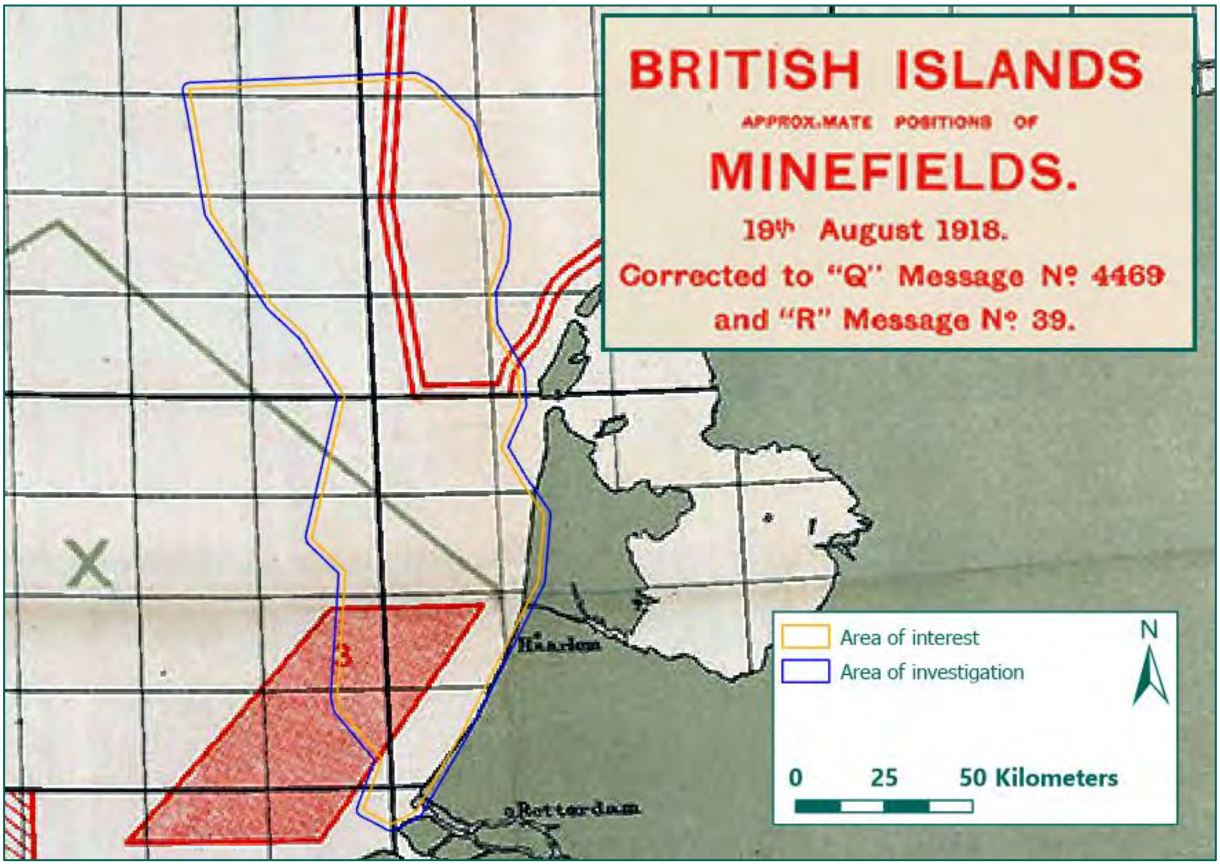


Figure 2: Cutout of the map *British Islands. Approximate position of minefields*, *19th August 1918,* showing minefields around the British Islands (Source: Library of Congress).

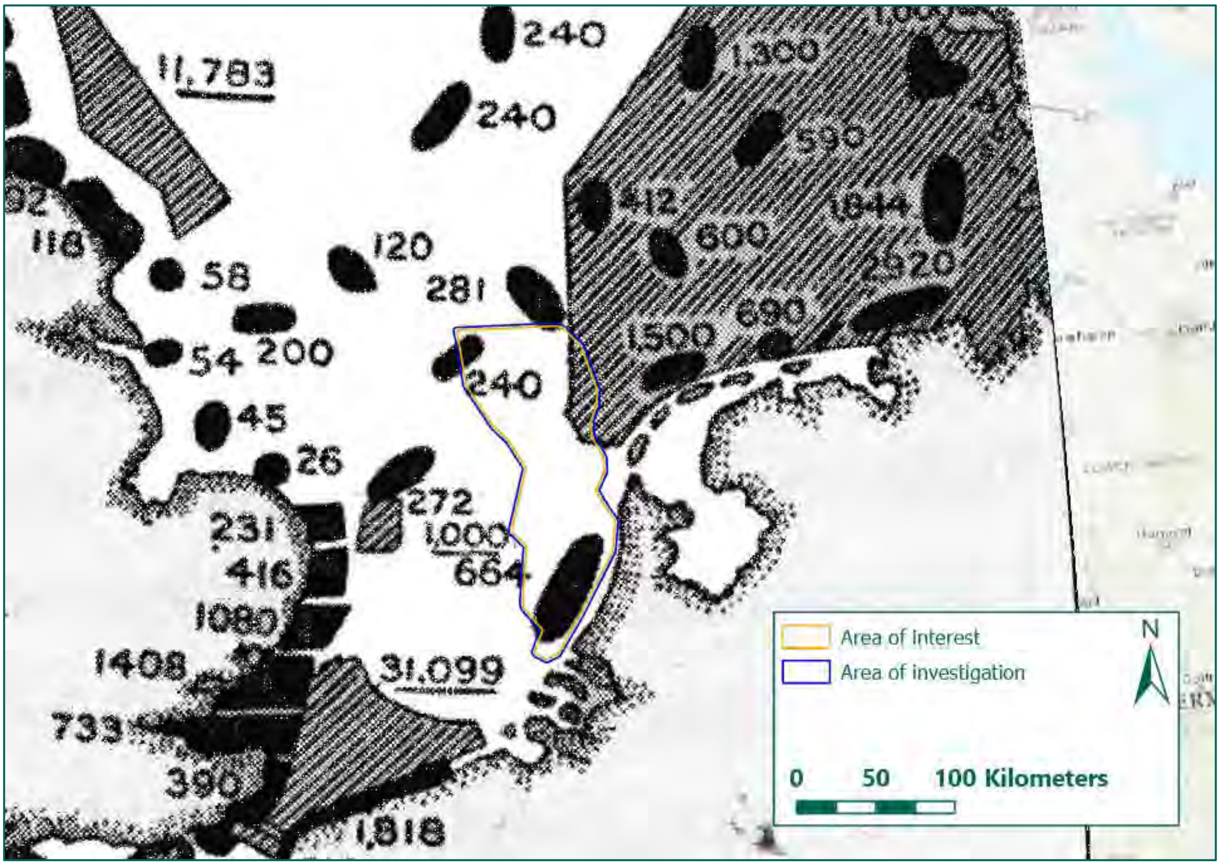


Figure 3: British, German and American mines laid during the First World War (Source: Literature CRO 62).

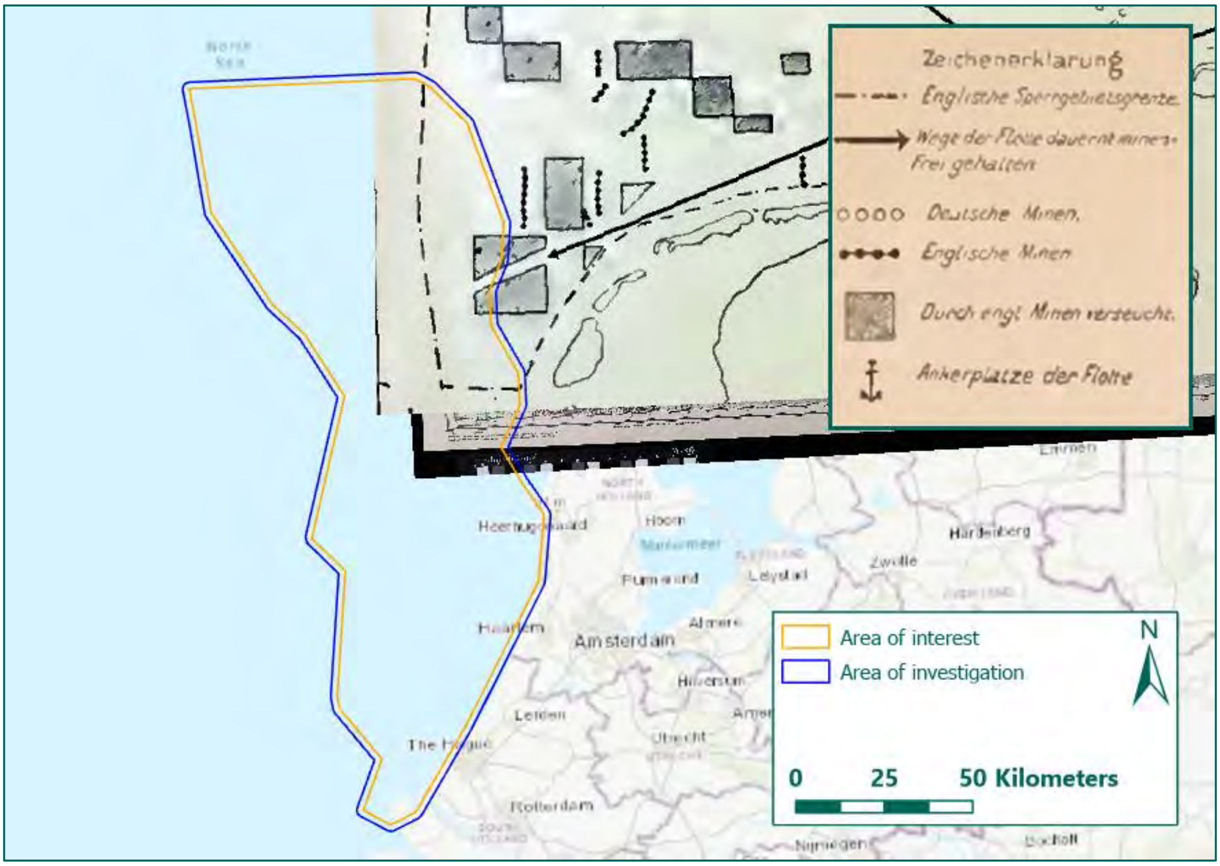


Figure 4: Details about minefields near the Dutch coast (Source: Literature SCH 288)

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.

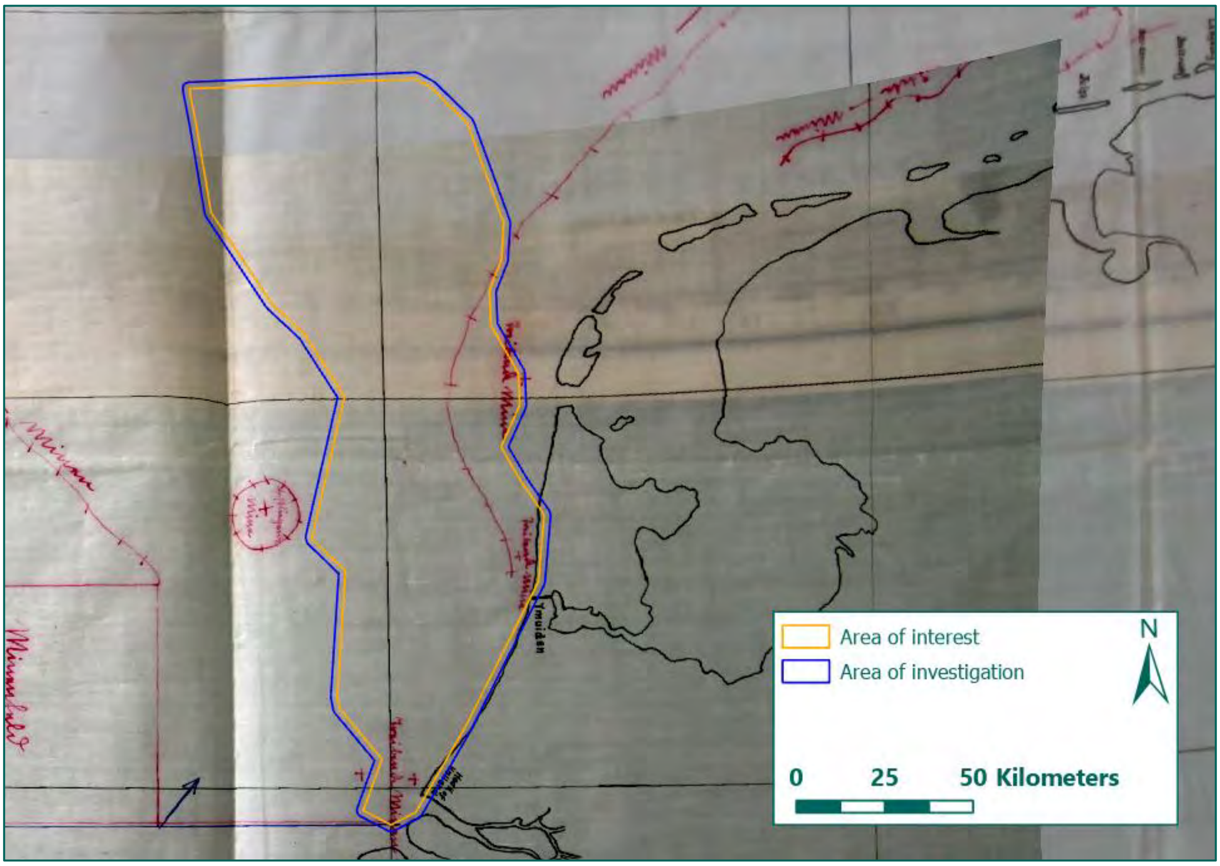


Figure 5: German map showing the suspected Allied minefield, according to the situation of March 1915 (Source: BaMa, RM 5/4721K).

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.

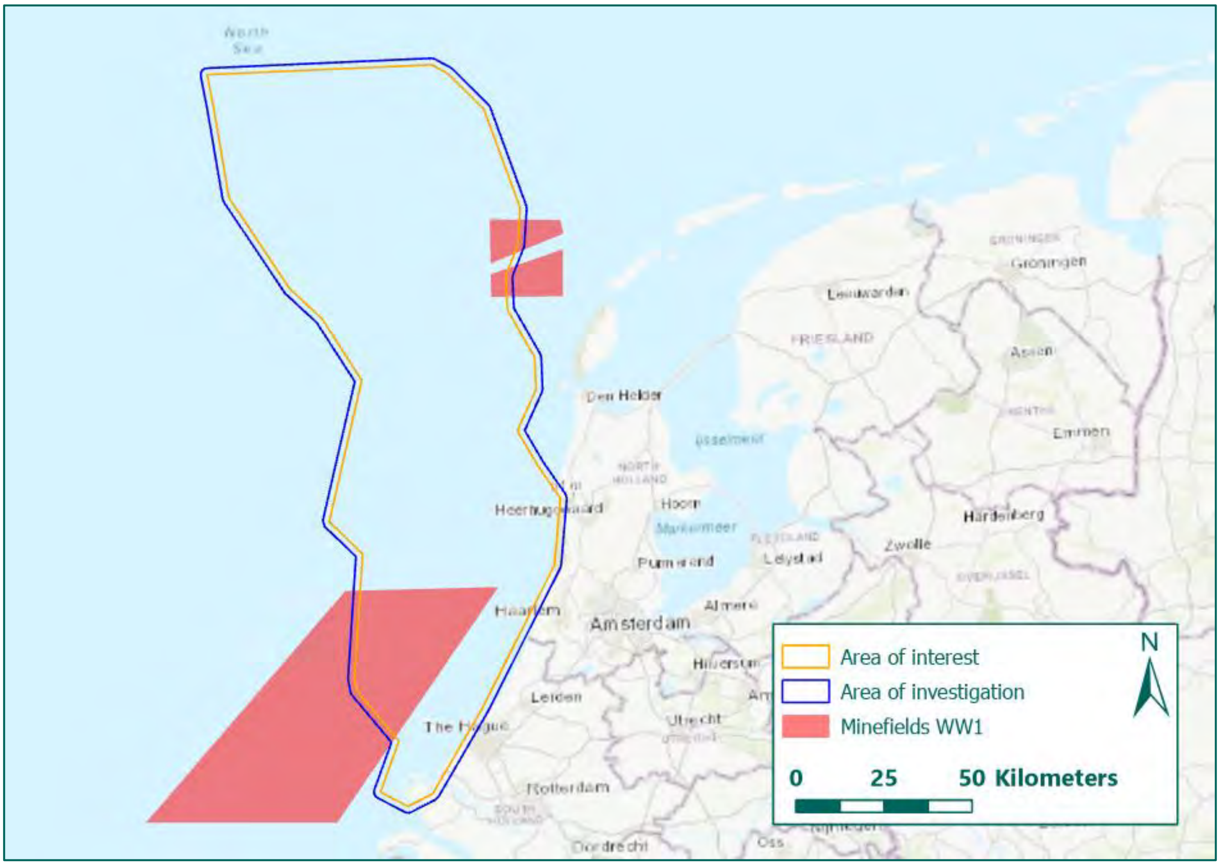


Figure 6: British and German minefields during WW1 (Source basemap: ESRI).

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.

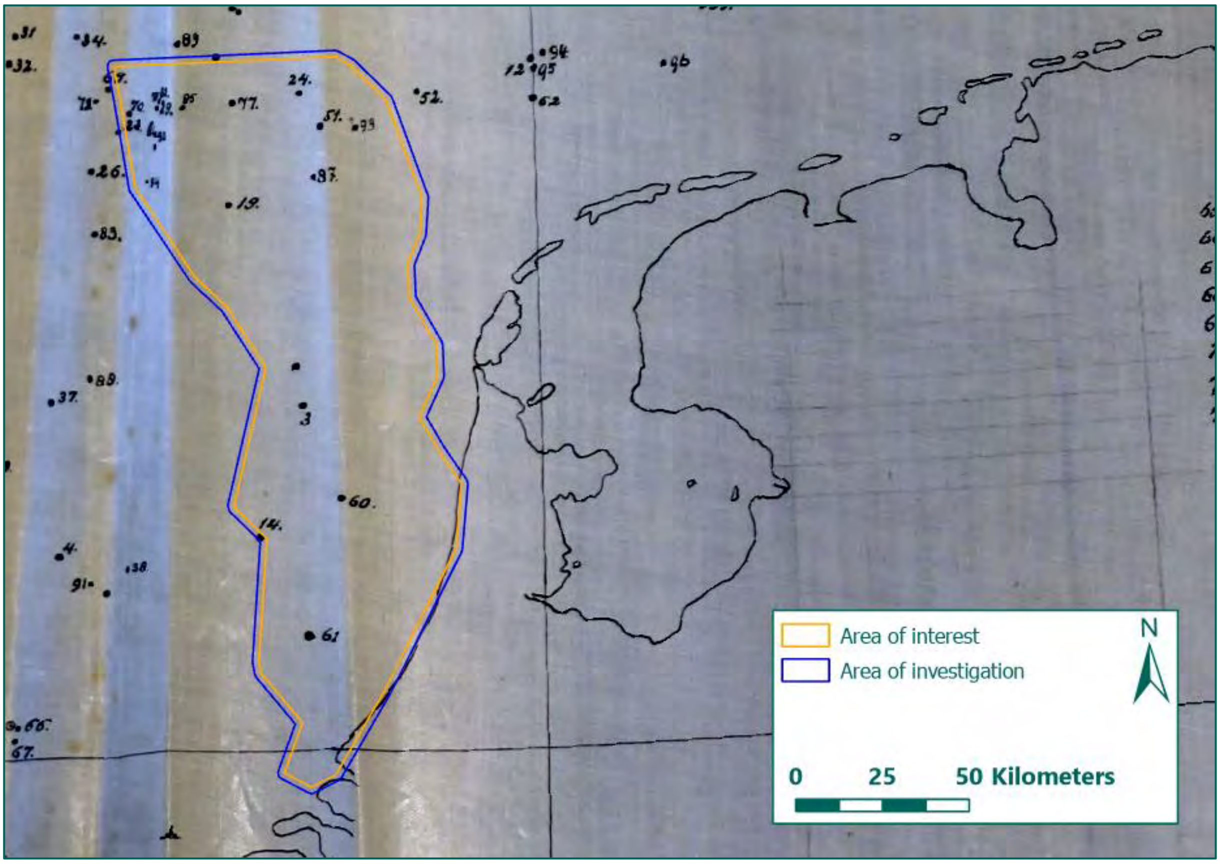


Figure 7: Map showing locations where Dutch ships ran onto mines during 1914-1916 (Source: NA, 2.05.32.09, file 44).

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.

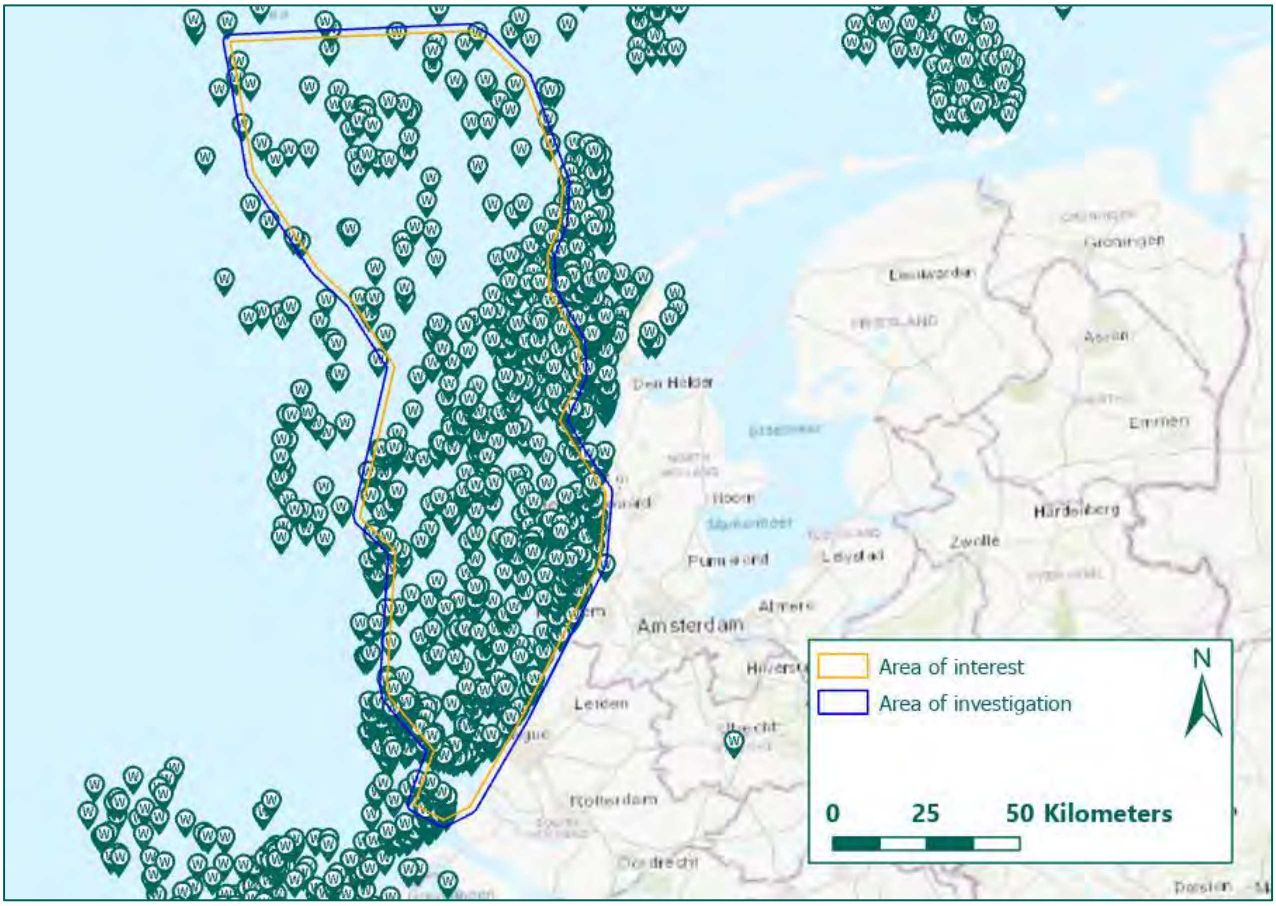


Figure 8: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

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.

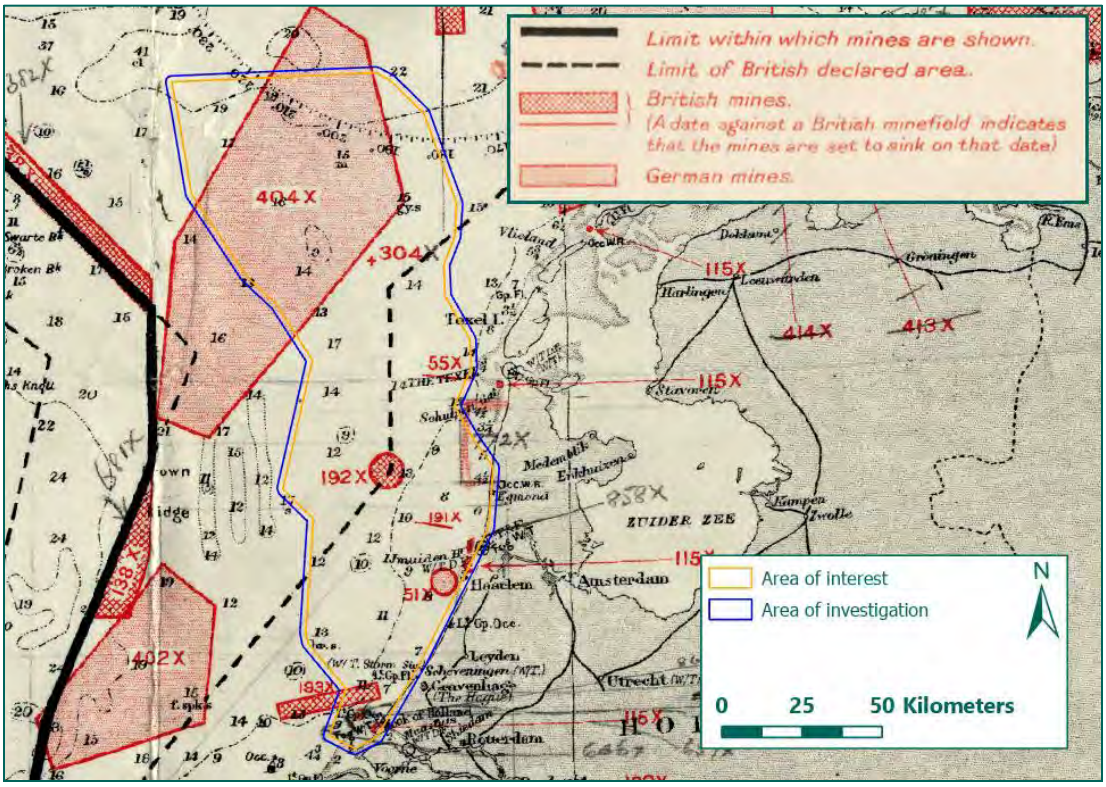


Figure 9: British map showing German and British minefields (Source: TNA, ADM 239/304).

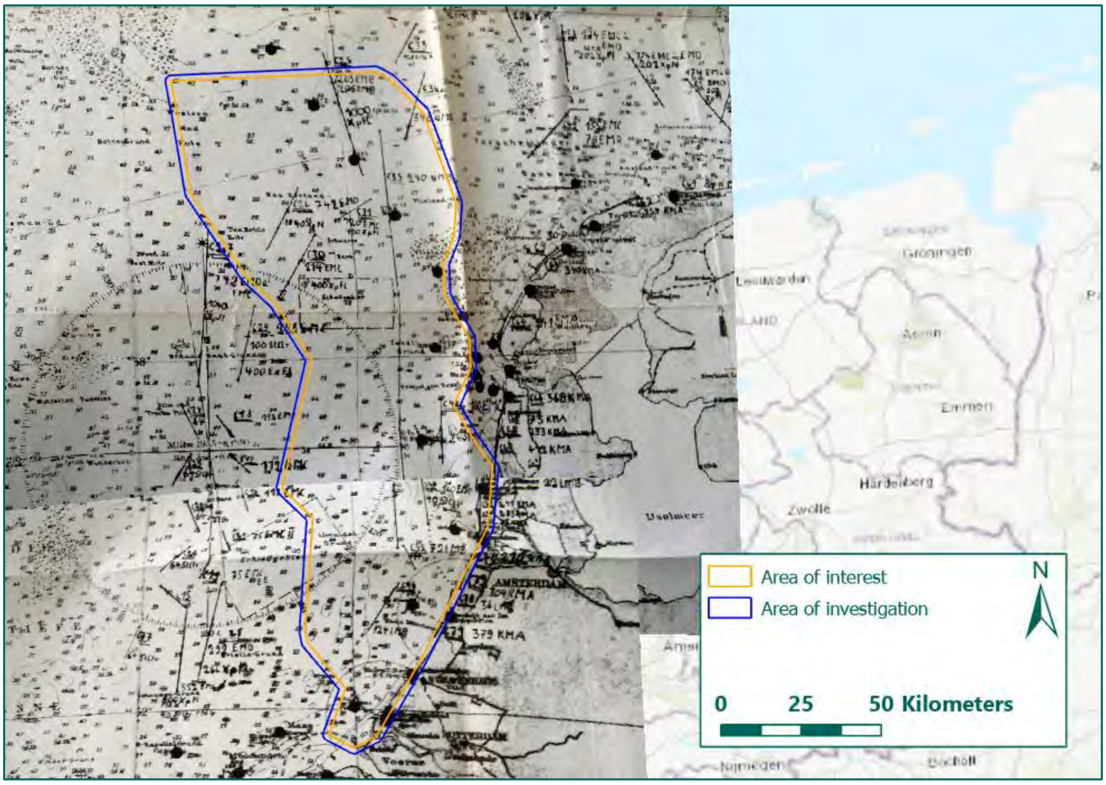


Figure 10: Naval chart showing numbered German minefields. Multiple minefields are present in the area of interest. (Source: BAMA, ZA 5/27).

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’.

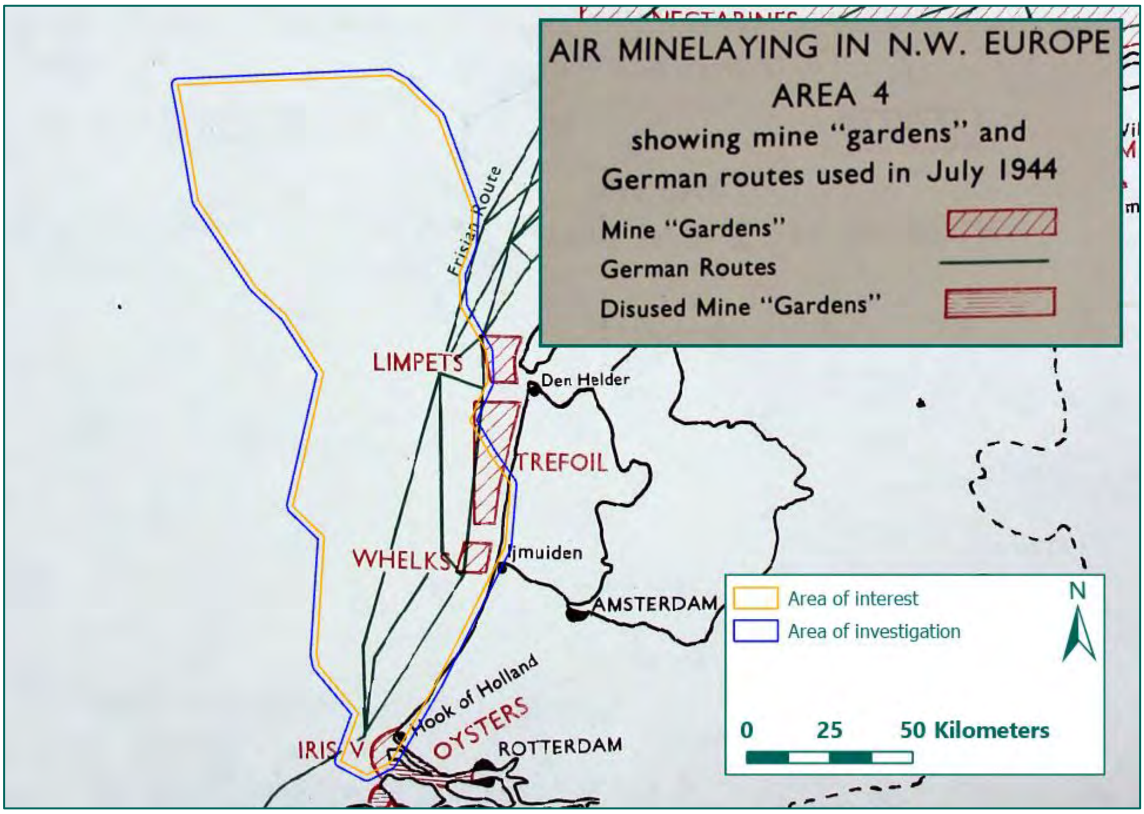


Figure 11: British ‘Gardens’ within the area of investigation (Source: TNA, ADM 234/561).

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.

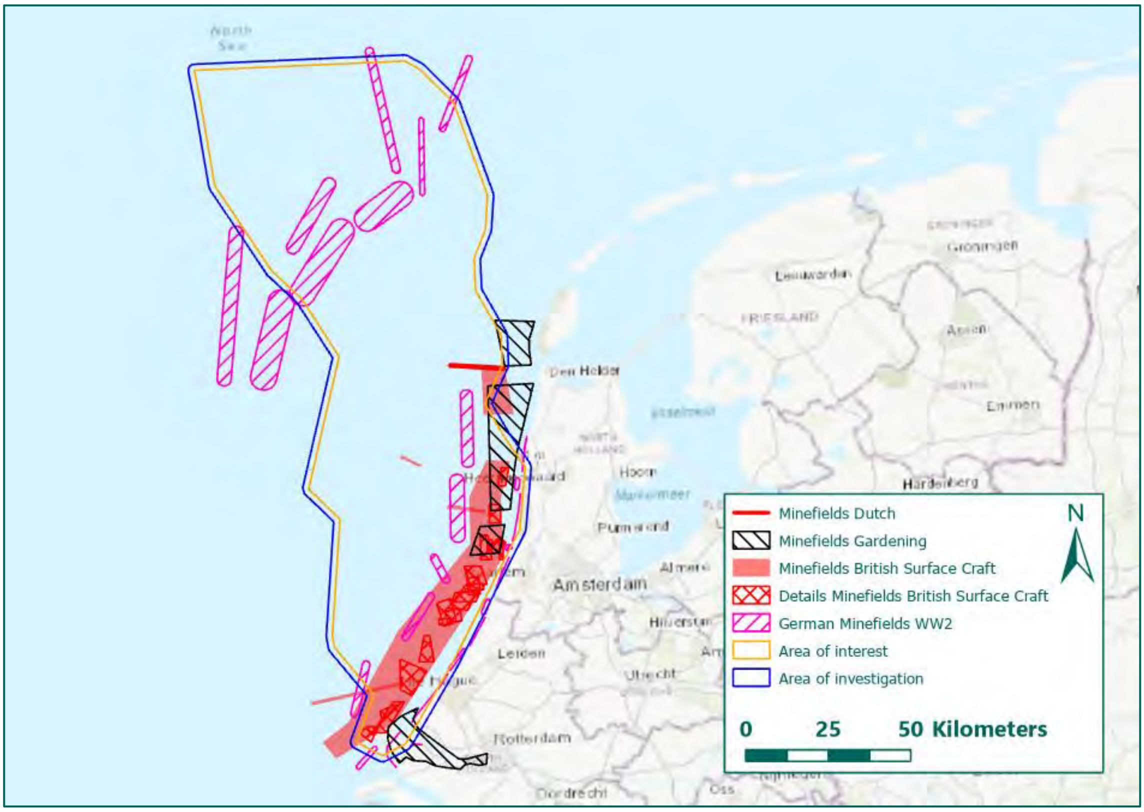


Figure 12: Minefields in WW2 (Source basemap: ESRI).

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).

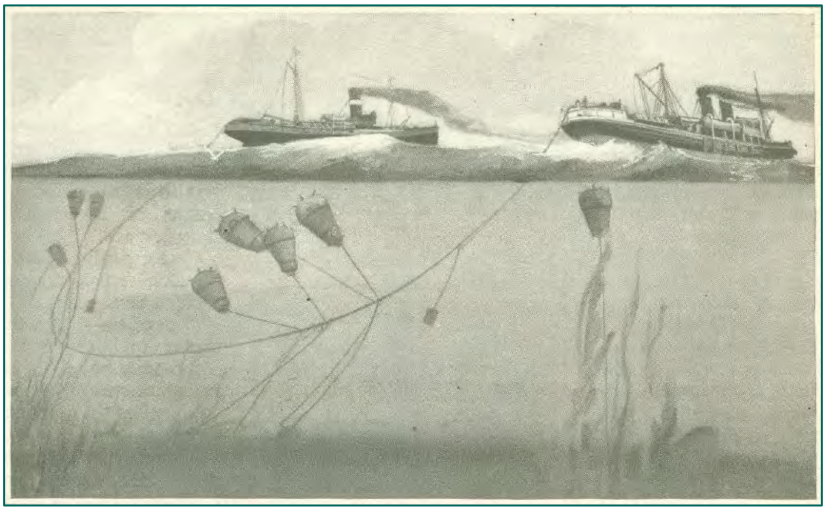


Figure 13: Post WWI-mine sweeping. (Source: http://www.digitalhistoryproject.com/2012/06/submarine-mines-in-world-war-i-byleland.html)

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).

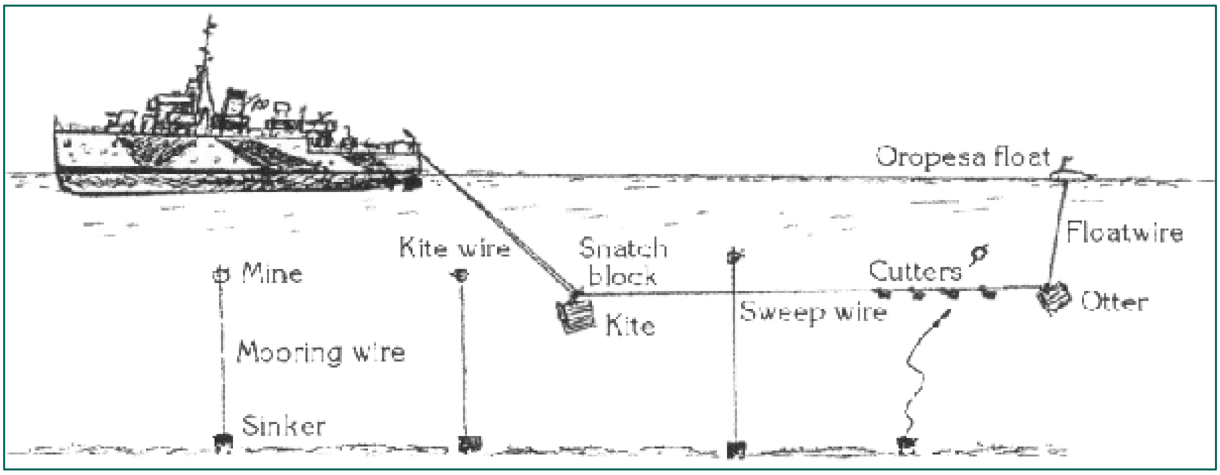


Figure 14: Oropesa sweeping (source: 'The 'Art' of Minesweeping', 27 May 2013, http://www.minesweepers.org.uk/sweeping.htm, consulted 2 August 2019).

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.

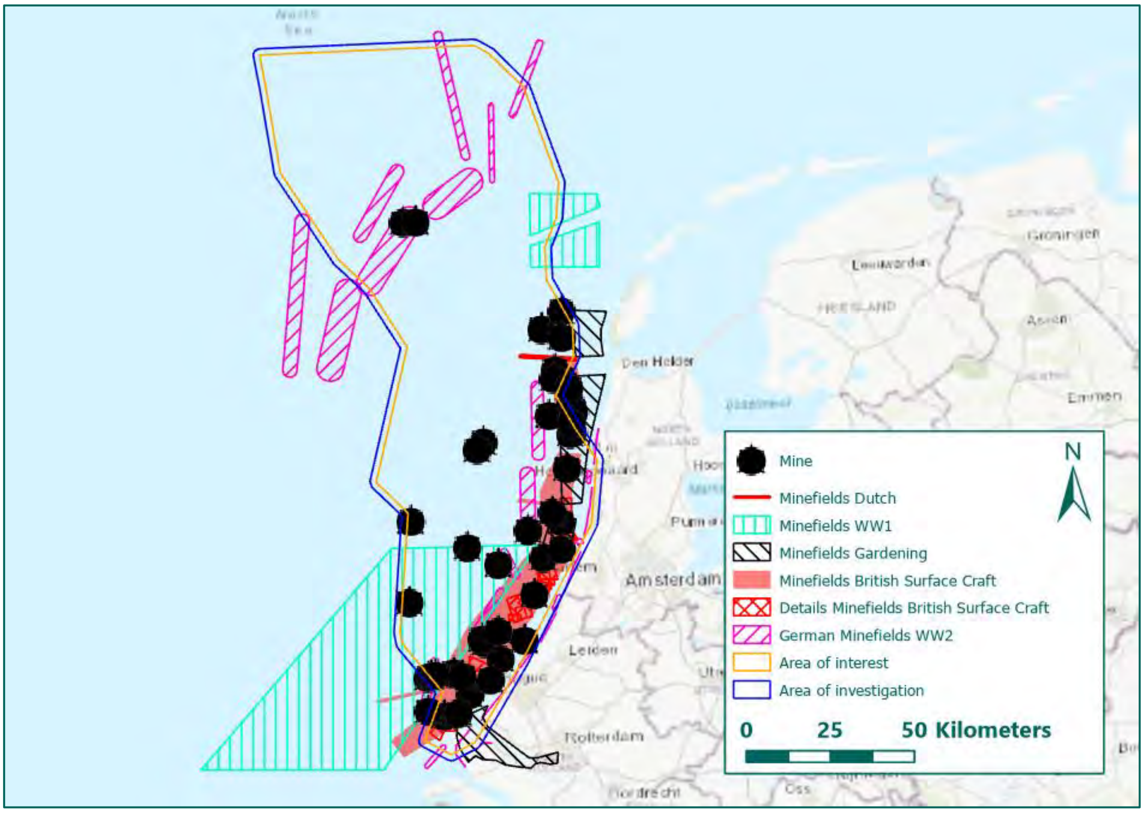


Figure 16: Locations of known minefields and locations where the Dutch Coastguard cleared mines (Source basemap: ESRI).

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.

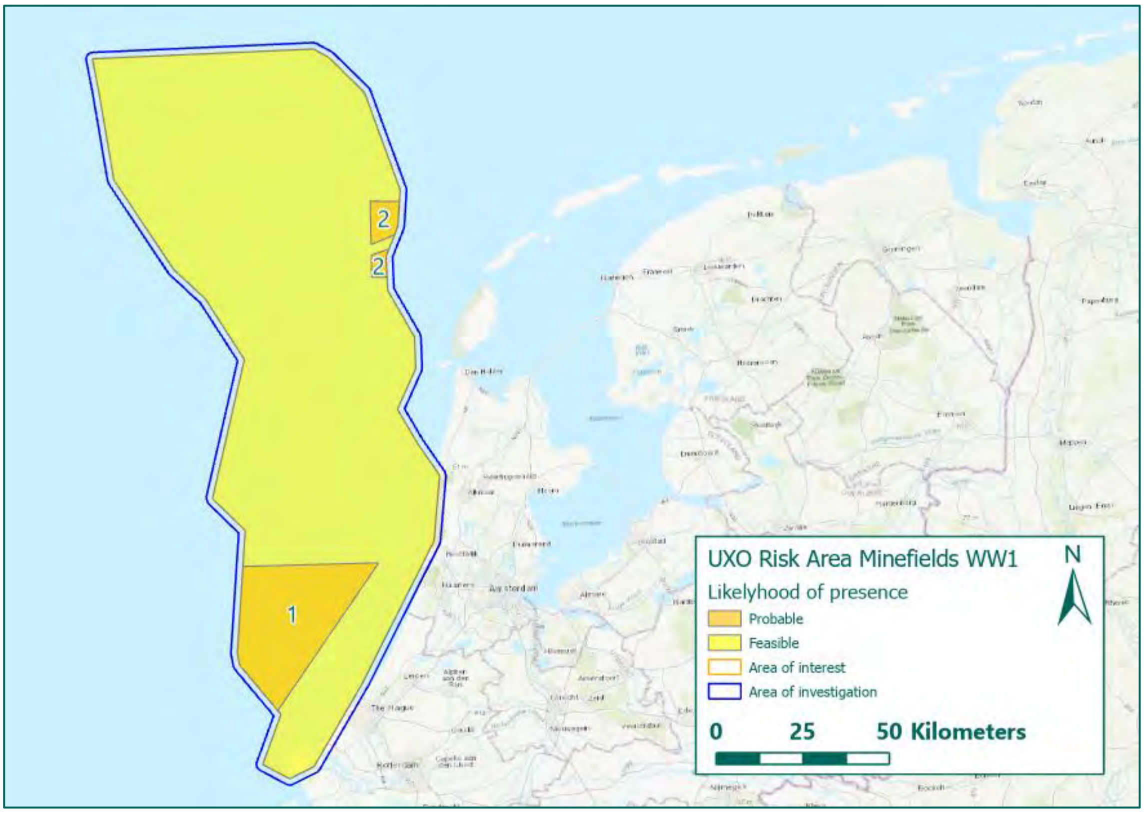


Figure 17: Likelihood of presence of UXO as result of the WW1 minefields. (Source basemap: ESRI).

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.

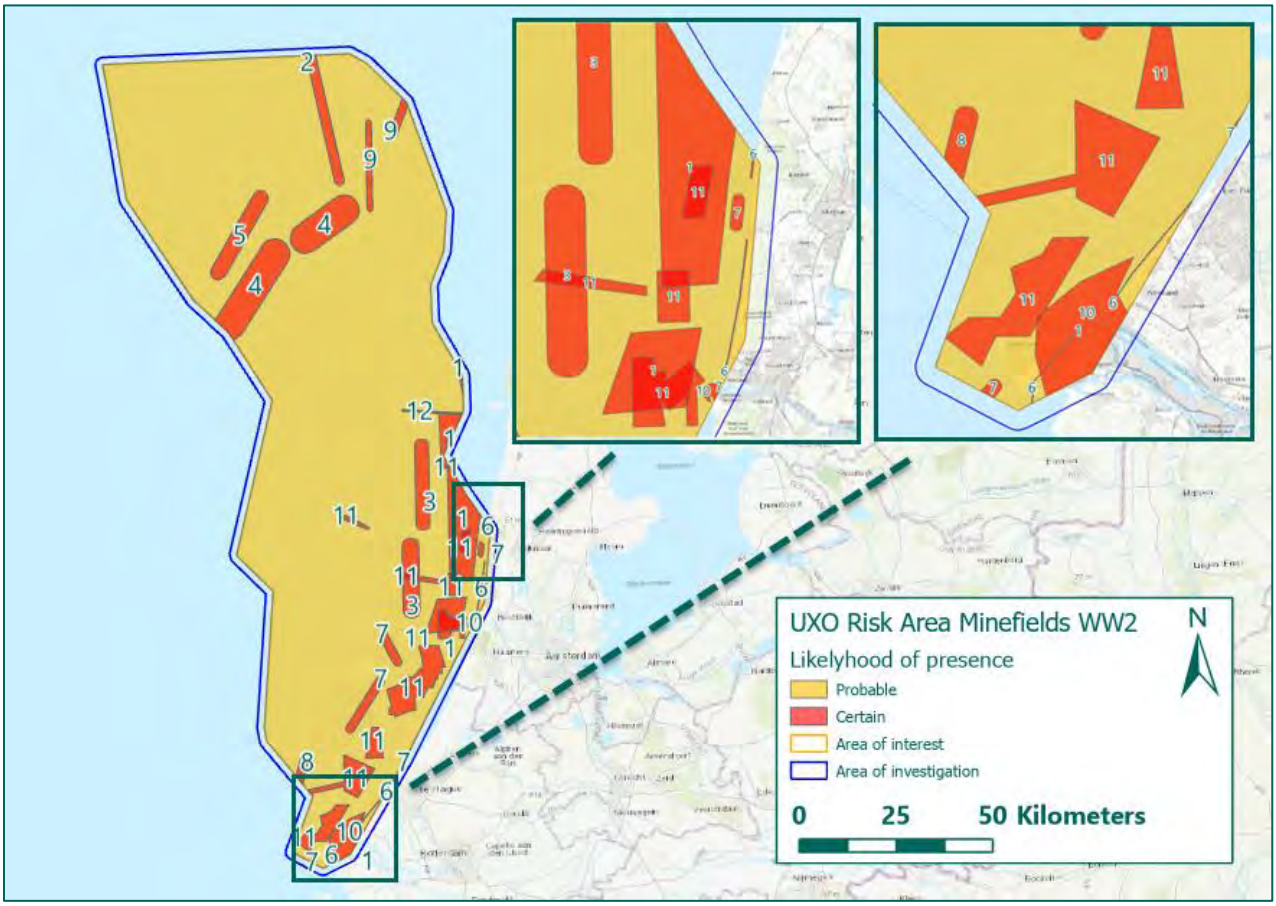


Figure 18: Likelihood of presence of UXO as result of the WW2 minefields. (Source basemap: ESRI).

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.

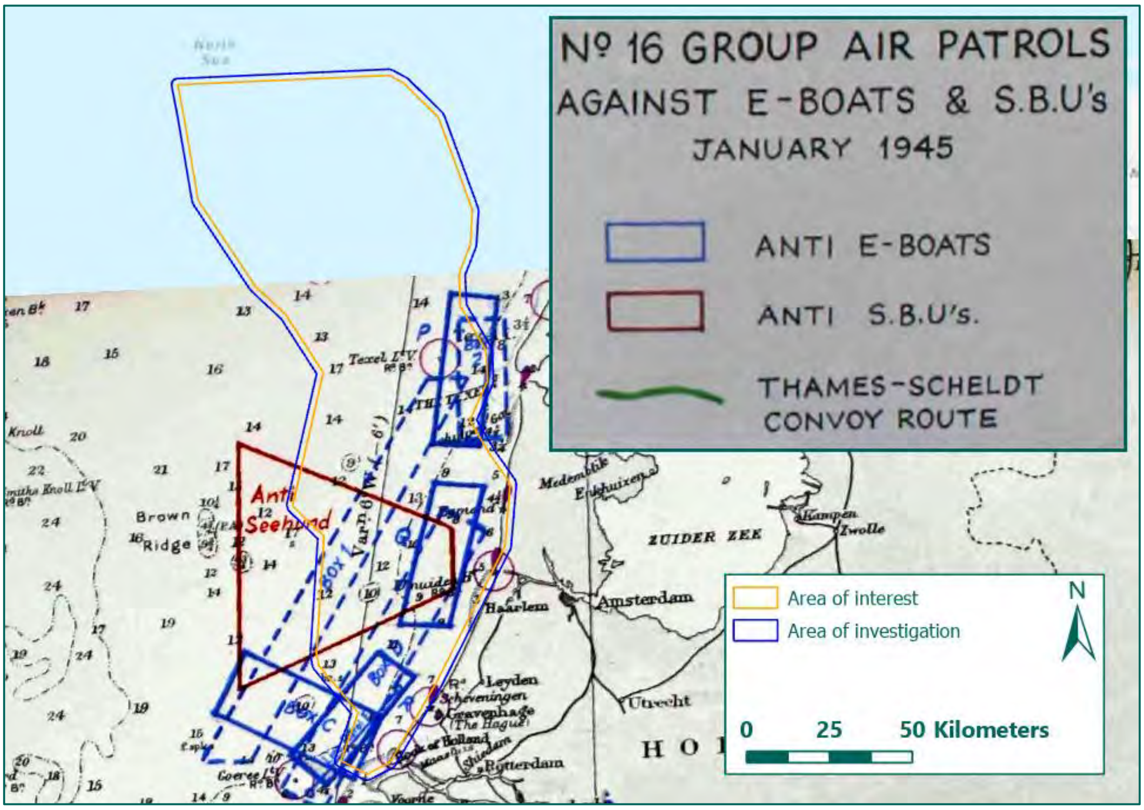


Figure 19: Coastal Command, No.16 Group, Air Patrols against E-Boats & S.B.U.'s January 1945 (Source: CAB 101/324).

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.

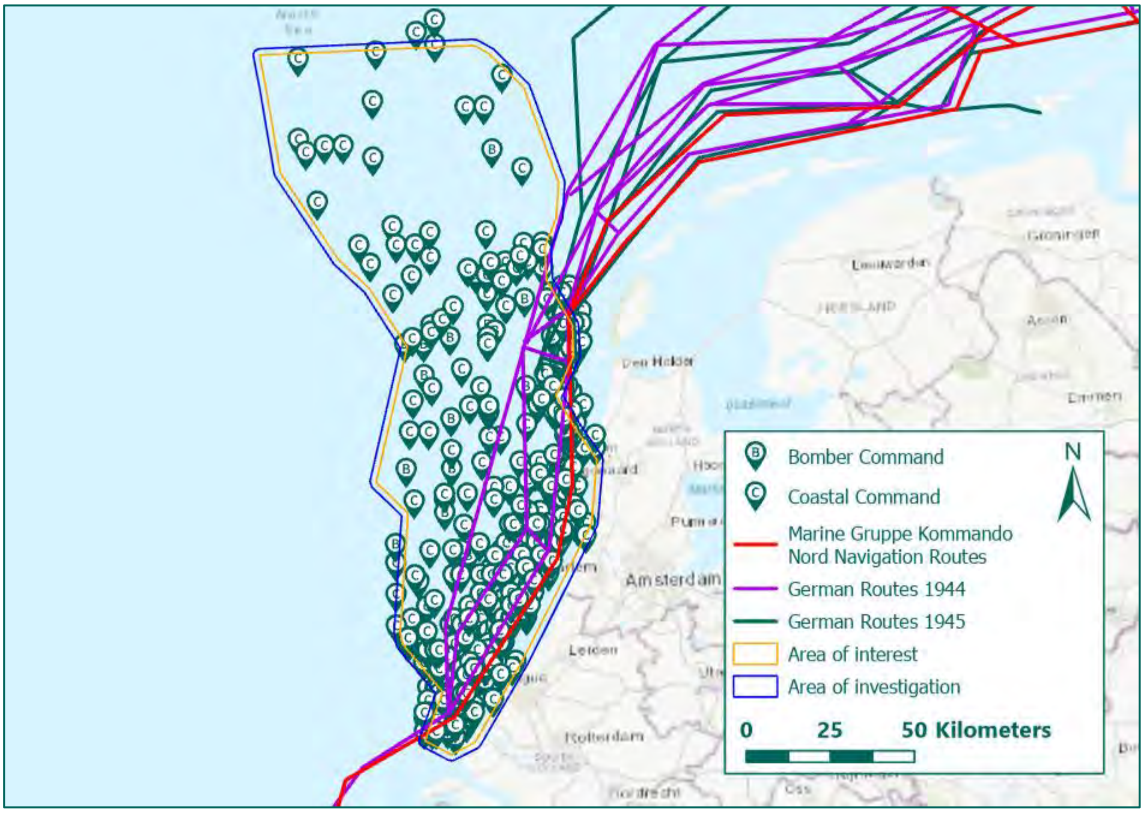


Figure 20: Attacks made by Coastal Command and Bomber Command, and relevant German convoy routes (Source basemap: ESRI).

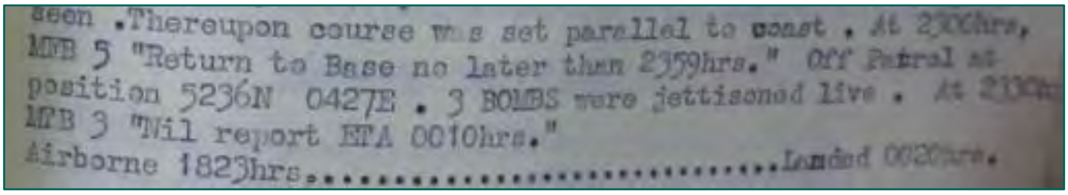
Since more than 500 attacks took place in the area of investigation, it is expected that UXO remain. Air strikes on ships were carried out with aerial bombs, depth charges, torpedoes, and 3 inch rockets with a 60 lbs warhead semi armour piercing (SAP). The definition of the UXO risk area and the calibres 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.



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.

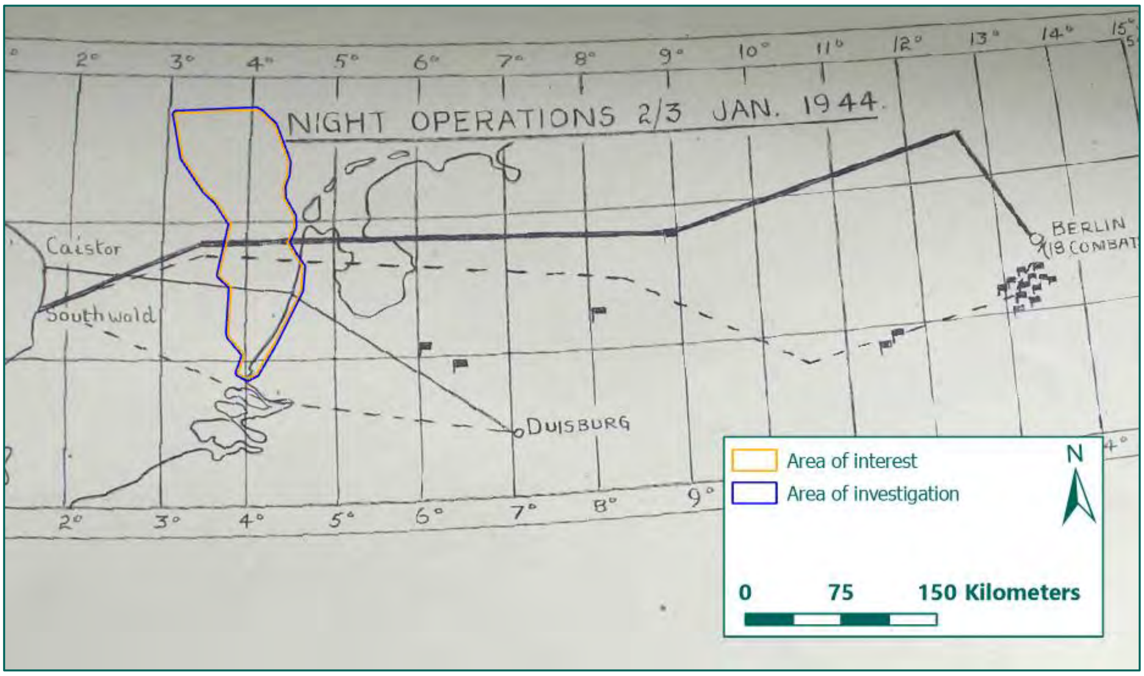


Figure 22: Example of a flight path over the area of investigation of bombers from Bomber Command, 2/3 January 1944 (Source, TNA, AIR 24/264).

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.

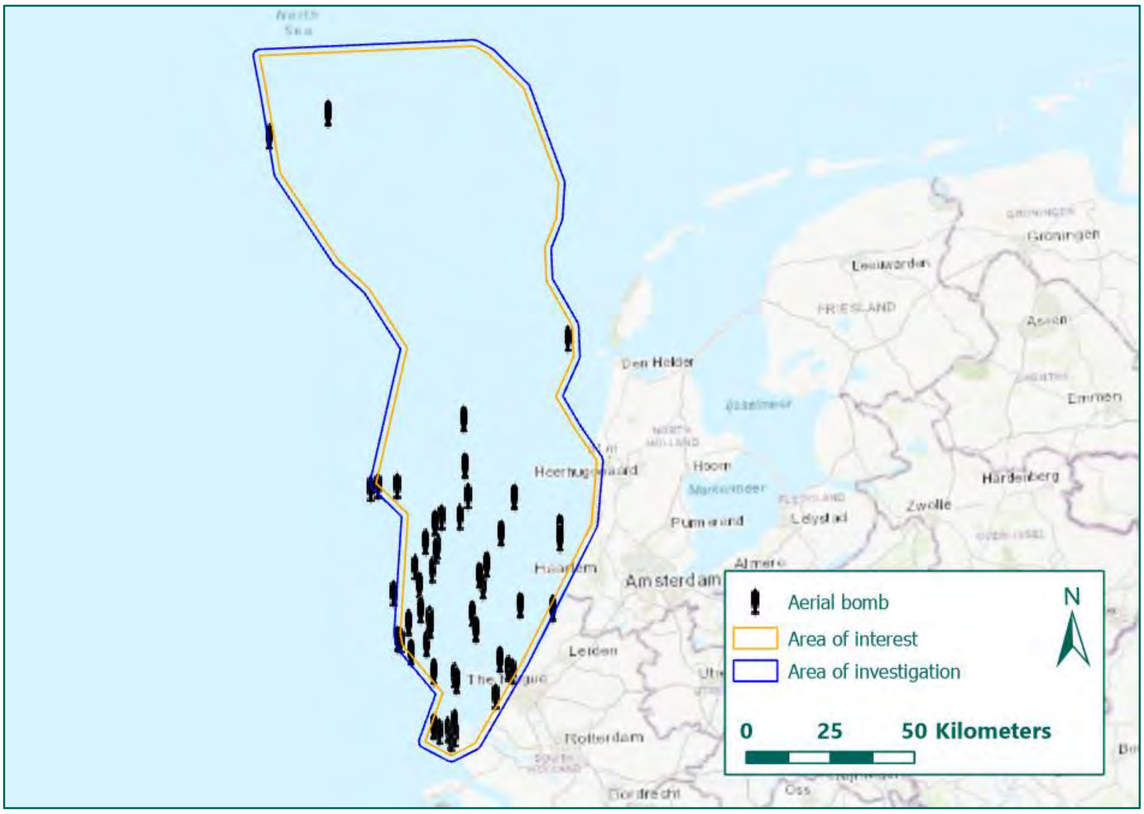


Figure 23: Cleared aerial bombs within the area of investigation (Source basemap: ESRI).

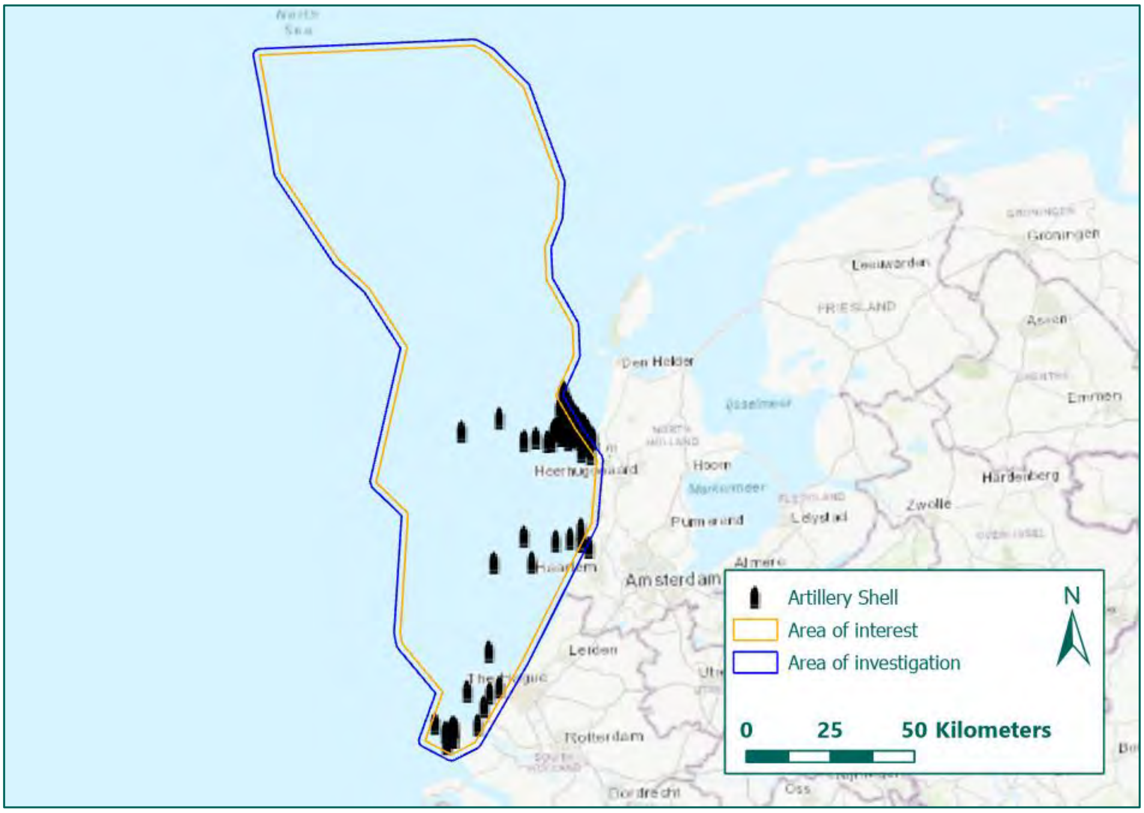


Figure 24: Cleared artillery shells within the area of investigation (Source basemap: ESRI).

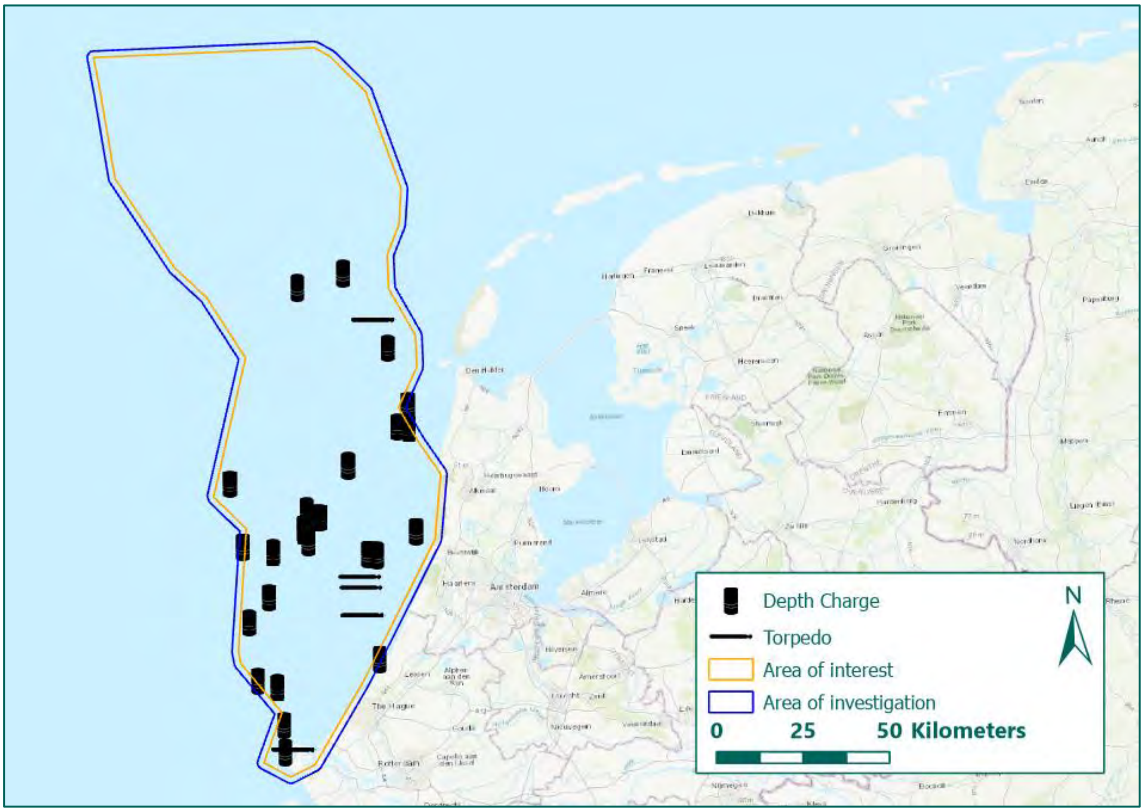


Figure 25: Cleared torpedoes and depth charges within the area of investigation (Source basemap: ESRI).

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.

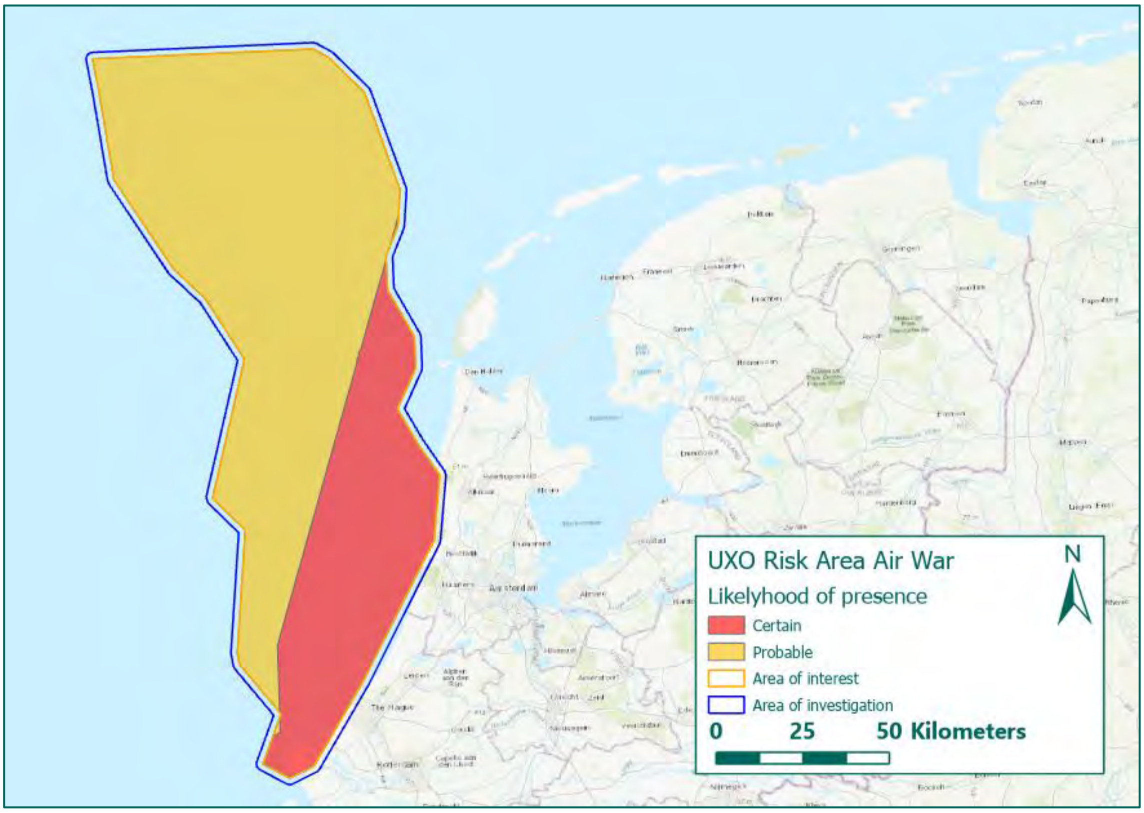


Figure 26: Likelihood of presence of UXO as result of the air war. (Source basemap: ESRI).

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

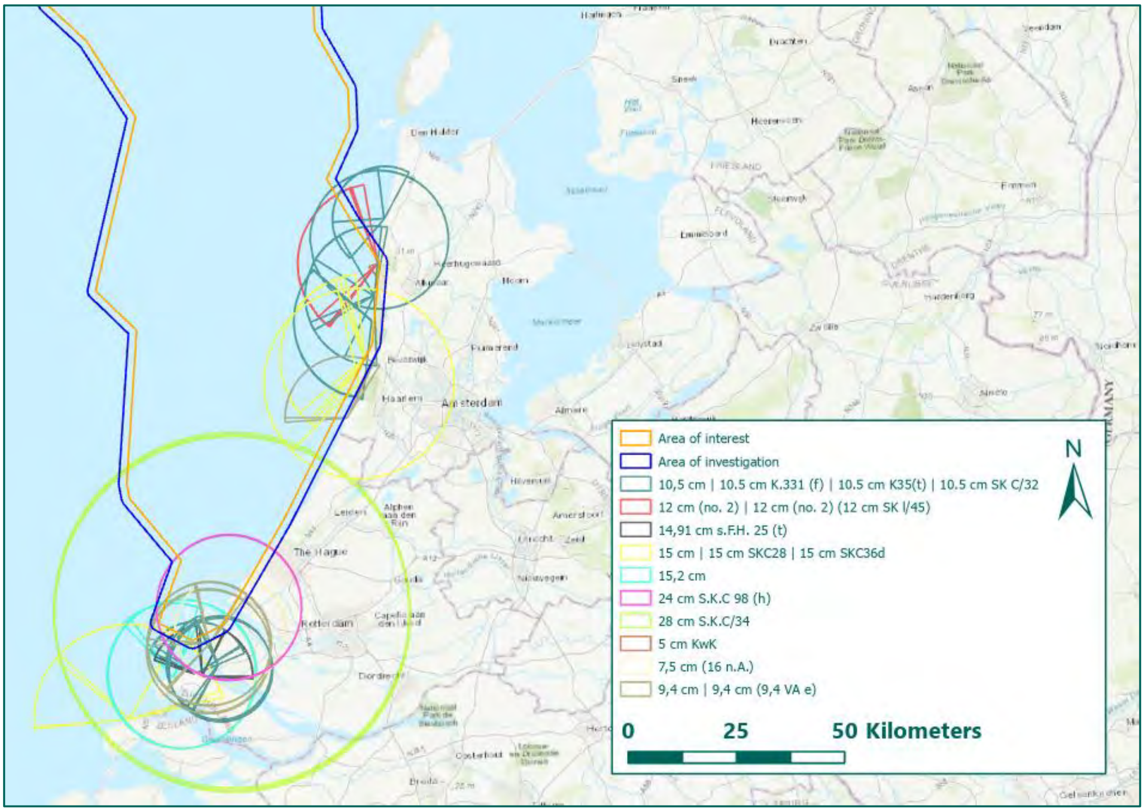


Figure 28: Locations and range of coastal guns near the area of investigation (Source basemap: ESRI).

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.

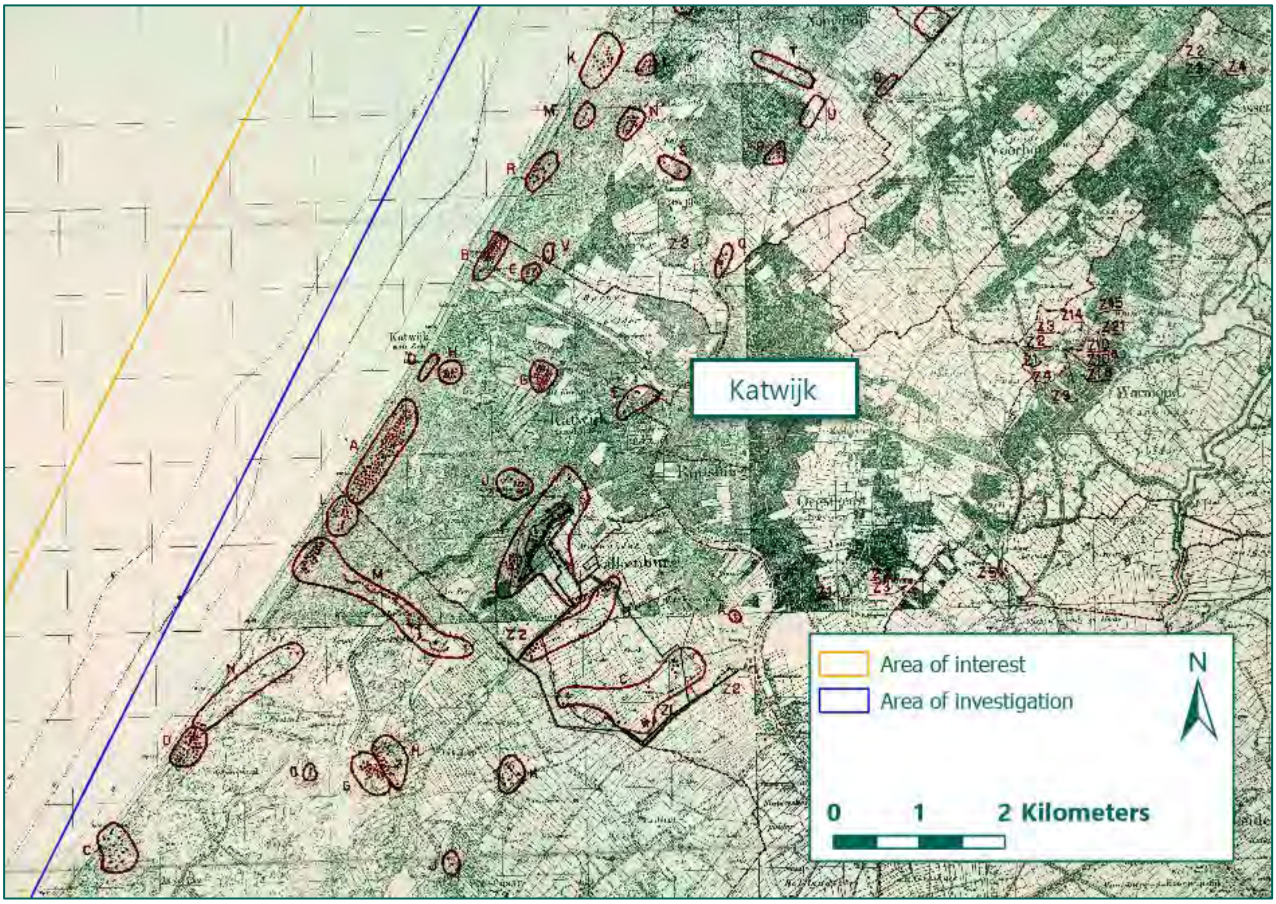


Figure 29: Cutout from a 'Blokkaart' showing the contours of military Infrastructure (Source: Nationaal Archief, 'Blokkaart' 275 3G).

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.

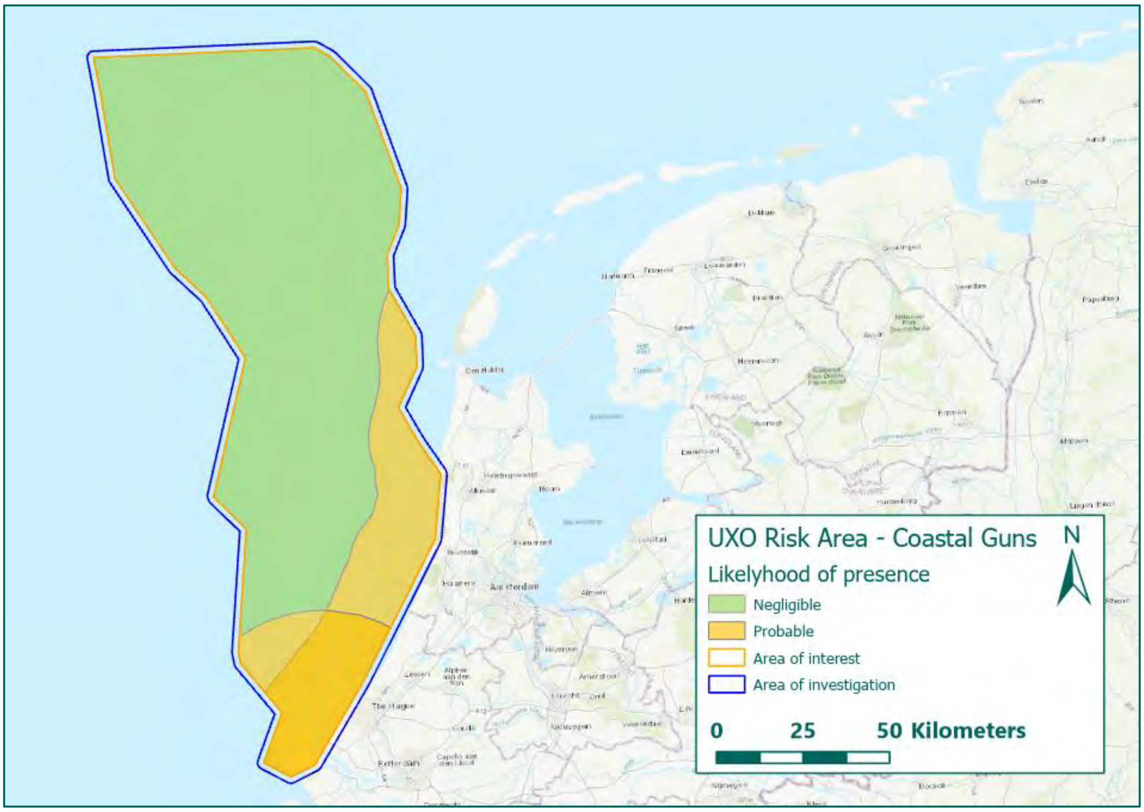


Figure 30: Likelihood of presence of UXO as result of the presence of coastal guns. (Source basemap: ESRI).

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.

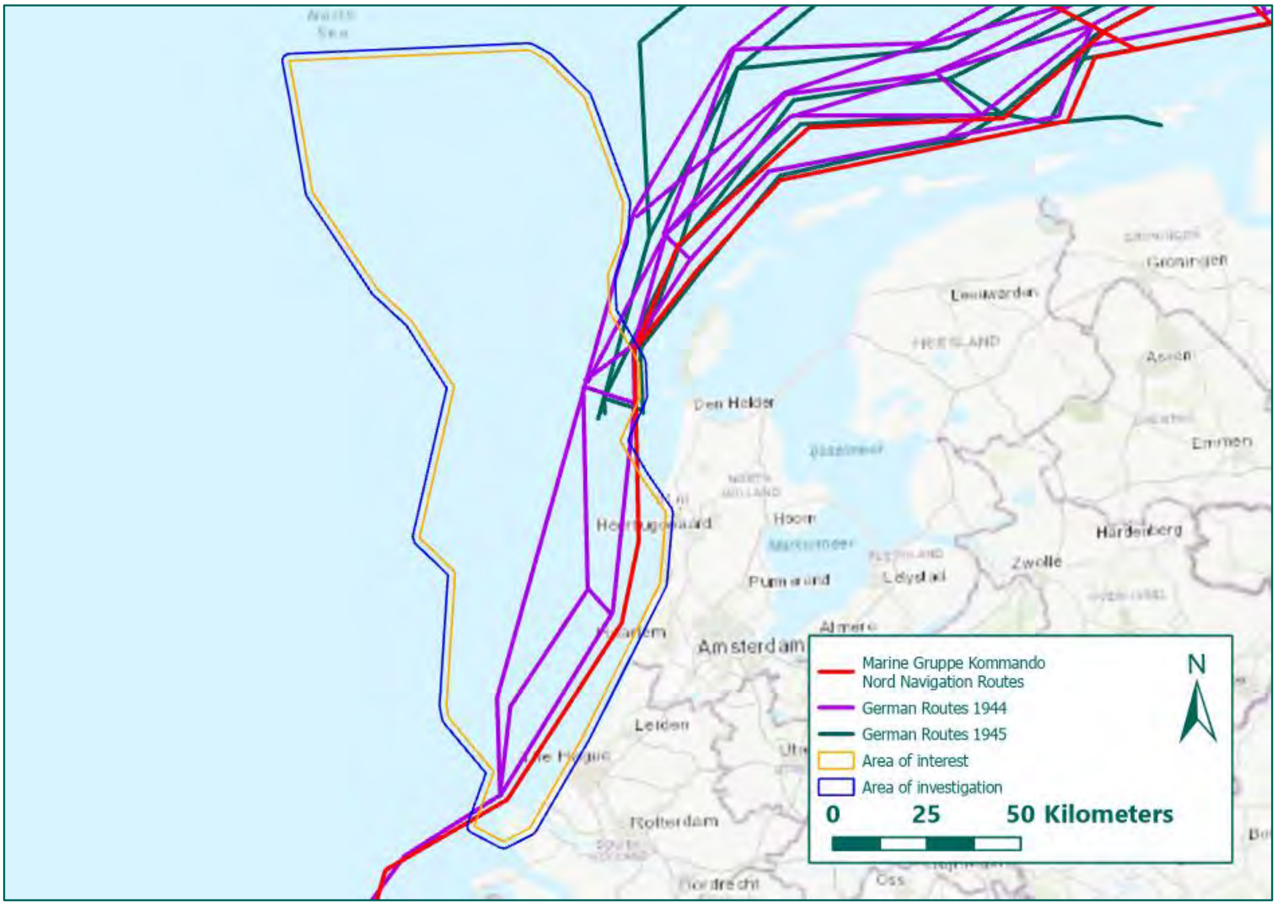


Figure 31: Convoy route "Weg Rot" and the quadrants used by the German navy. (Source basemap: ESRI).

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.

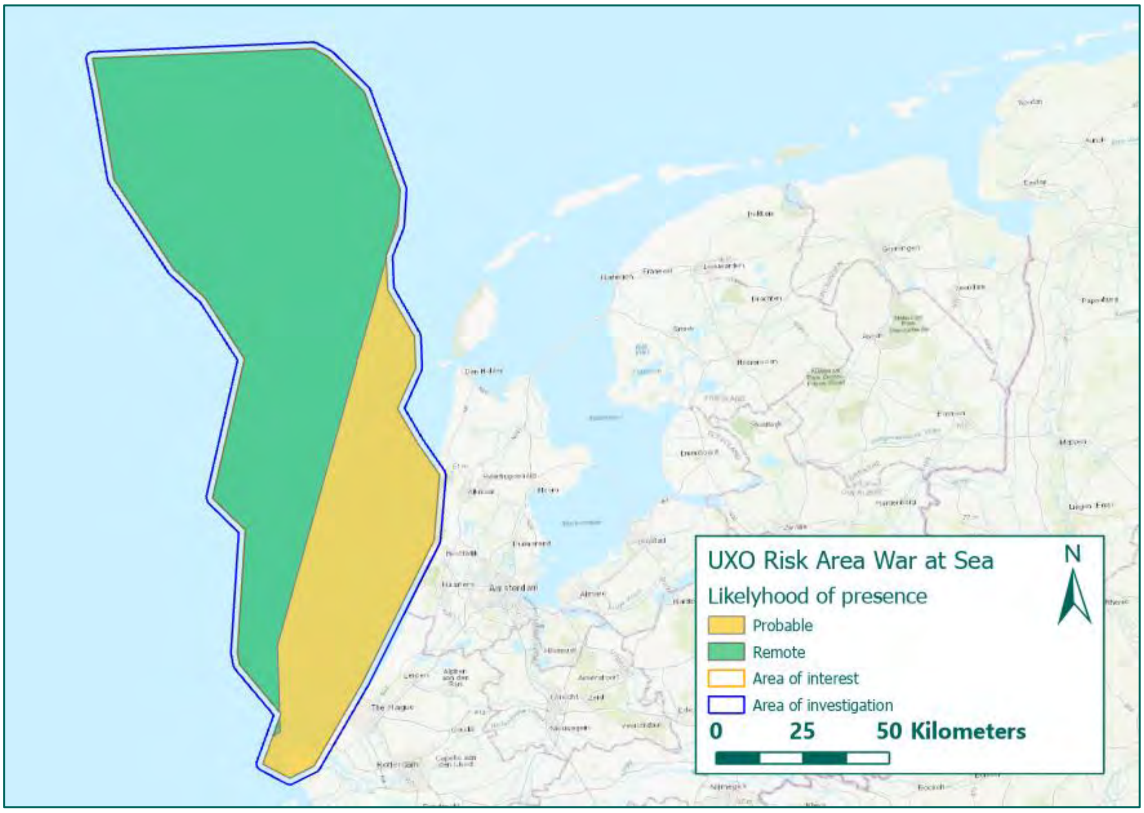


Figure 32: UXO risk area caused by surface craft battles. (Source basemap: ESRI).

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.

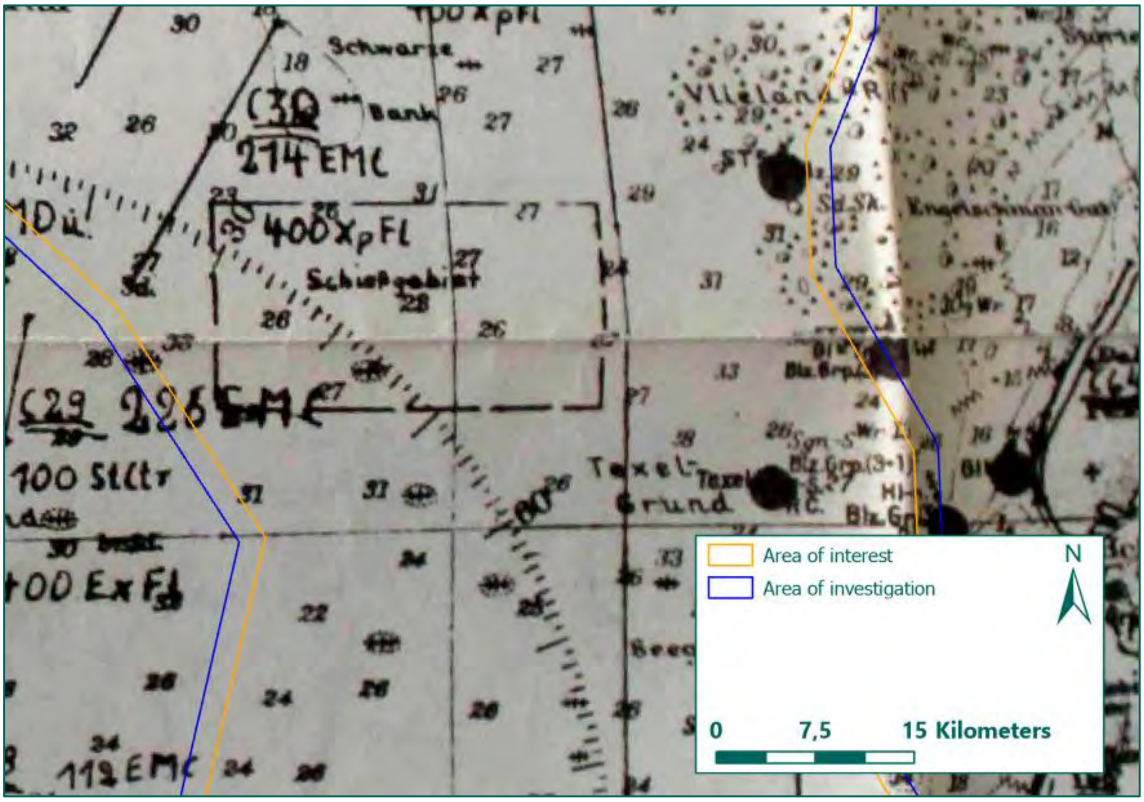


Figure 33: German map showing minefields and a 'Schieβgebiet' ('Shooting area') within the area of analysis (Source: BAMA, ZA 5/27).

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.

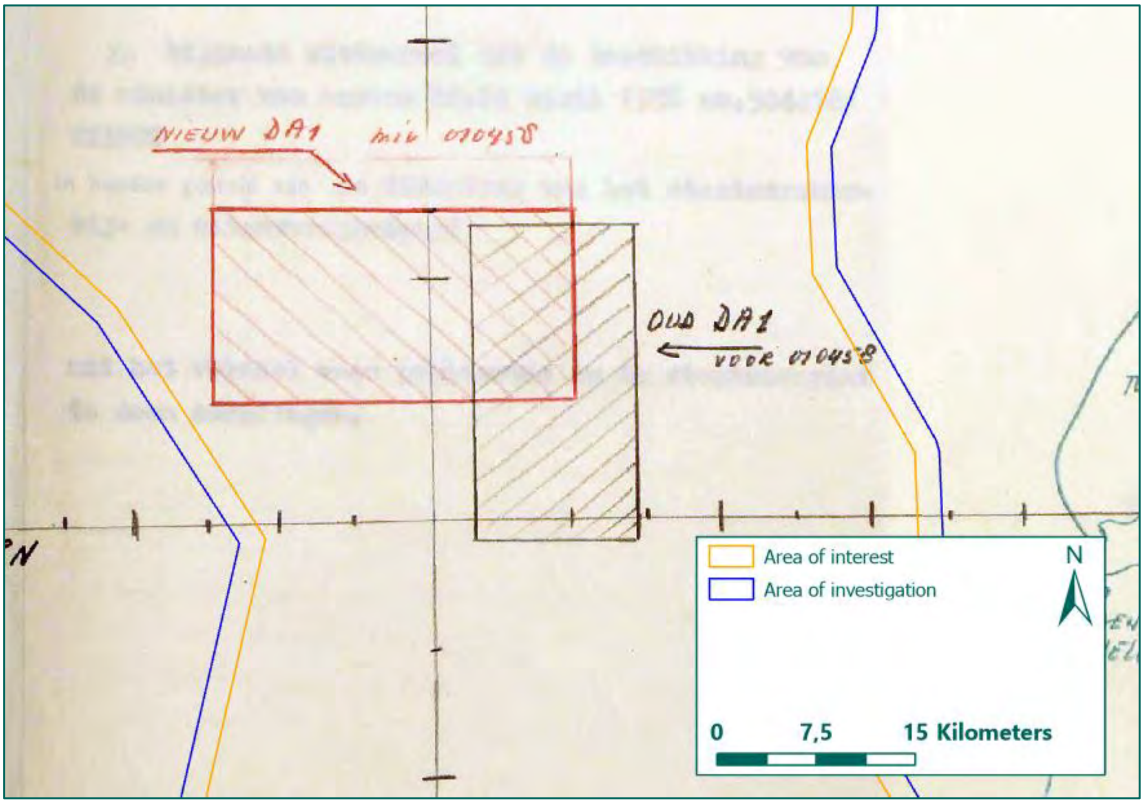


Figure 34: maps showing the location of a Dutch military exercise area within the area of investigation (Source: Nationaal Archief Toegang 2.12.56, folder 939).

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.

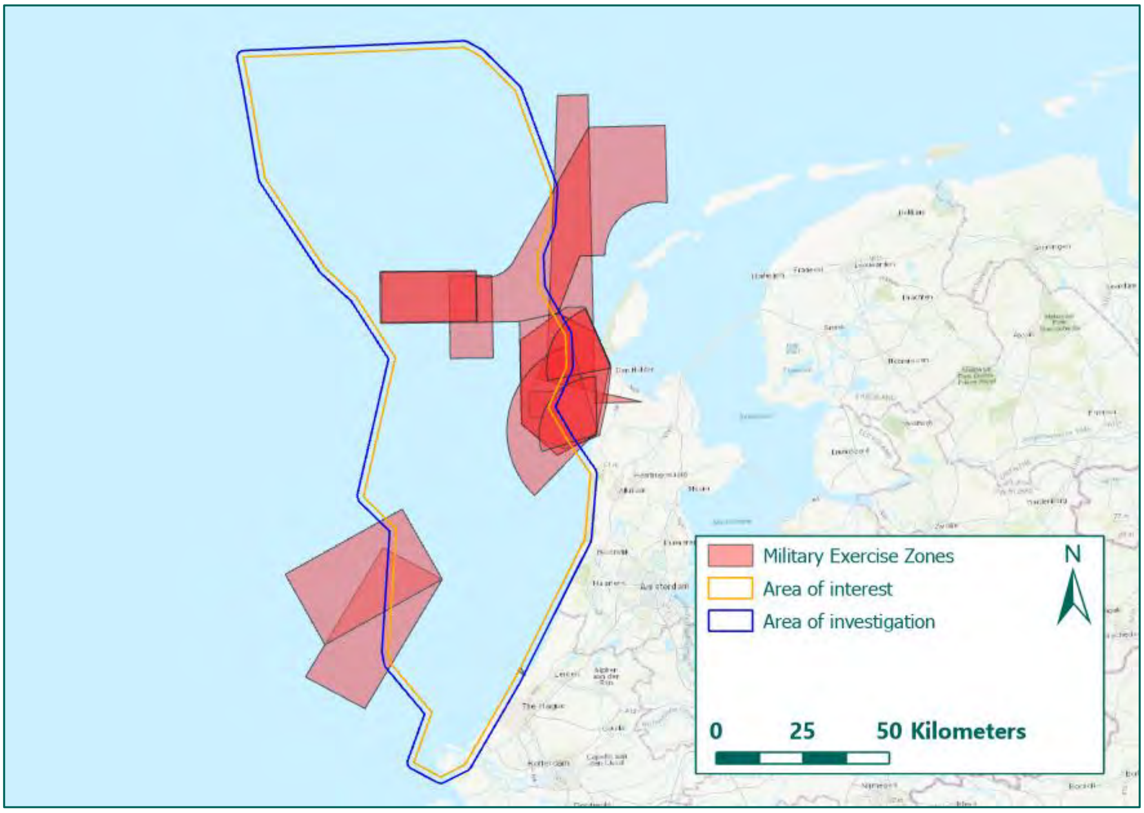


Figure 35: Military exercise zones within the area of investigation (Source basemap: ESRI)

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.

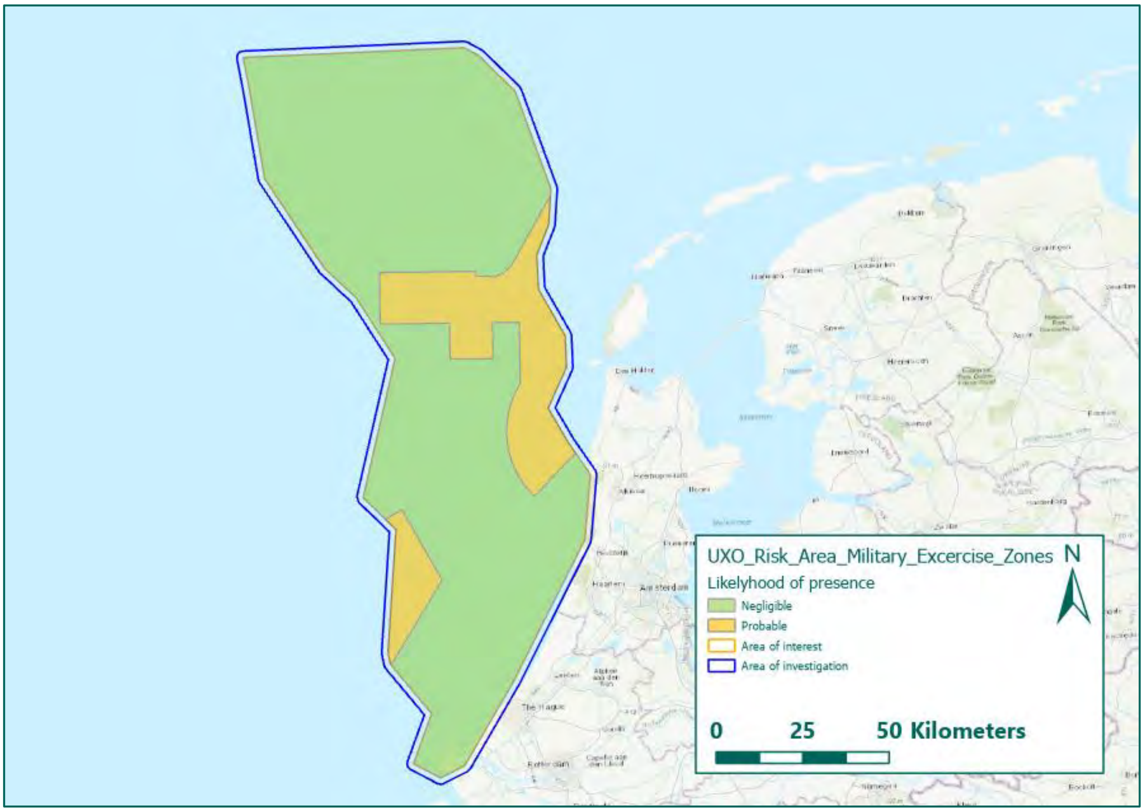


Figure 36: Likelihood of presence of UXO as result of the presence of coastal guns. (Source basemap: ESRI).

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.

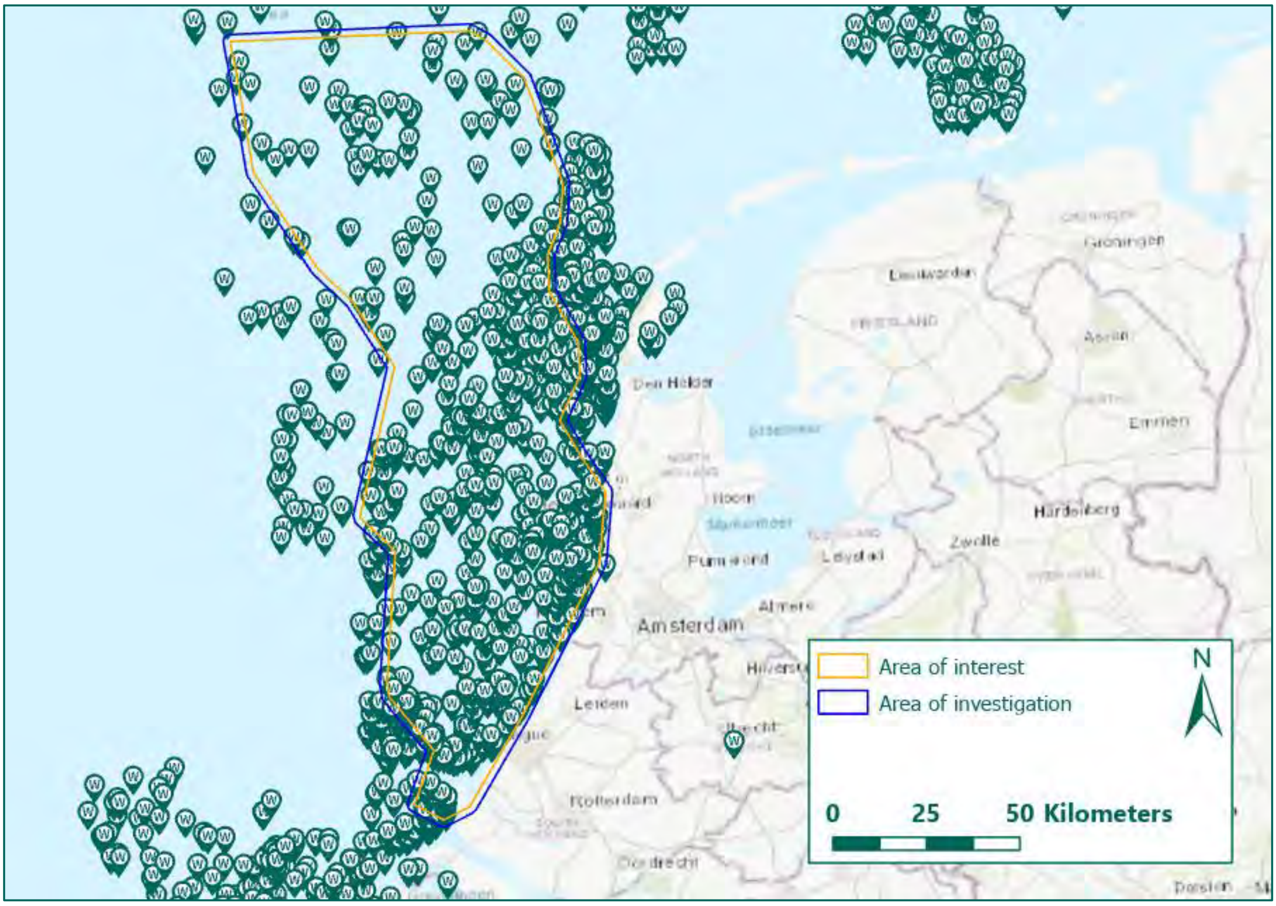


Figure 37: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

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.

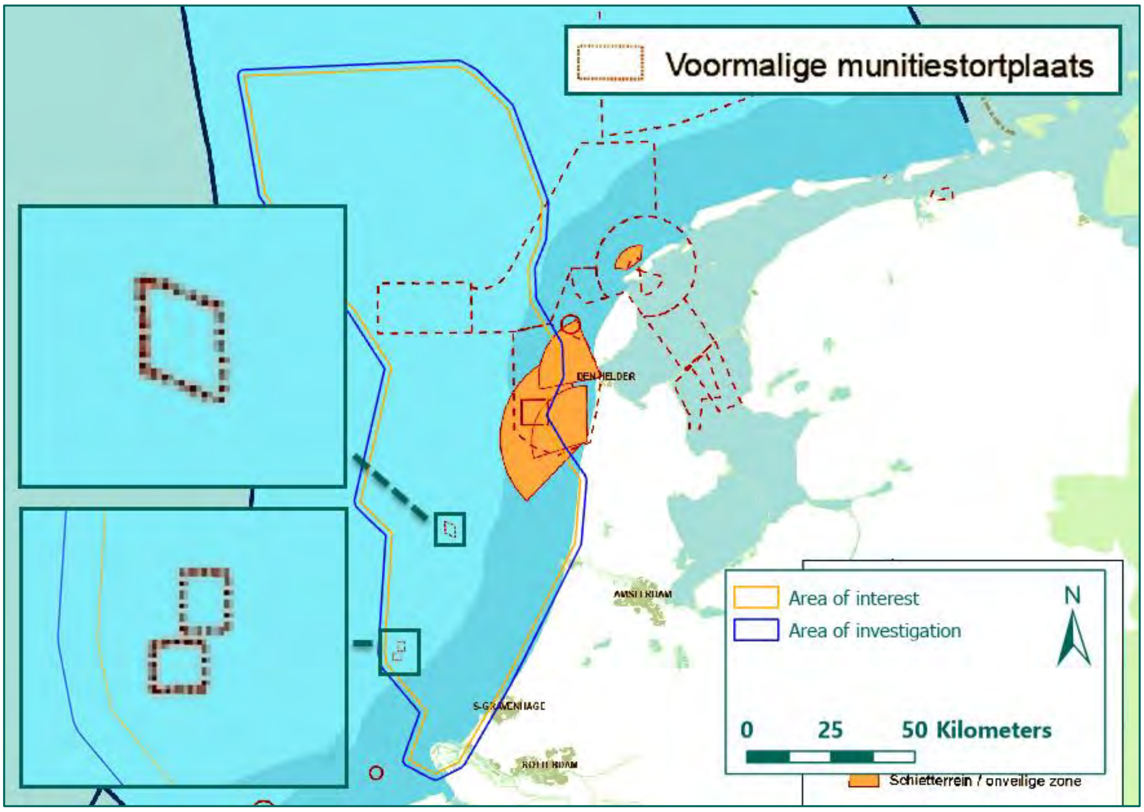


Figure 38: Map showing the military usage of parts of the North Sea, including munition dumping sites (Source: NZL).

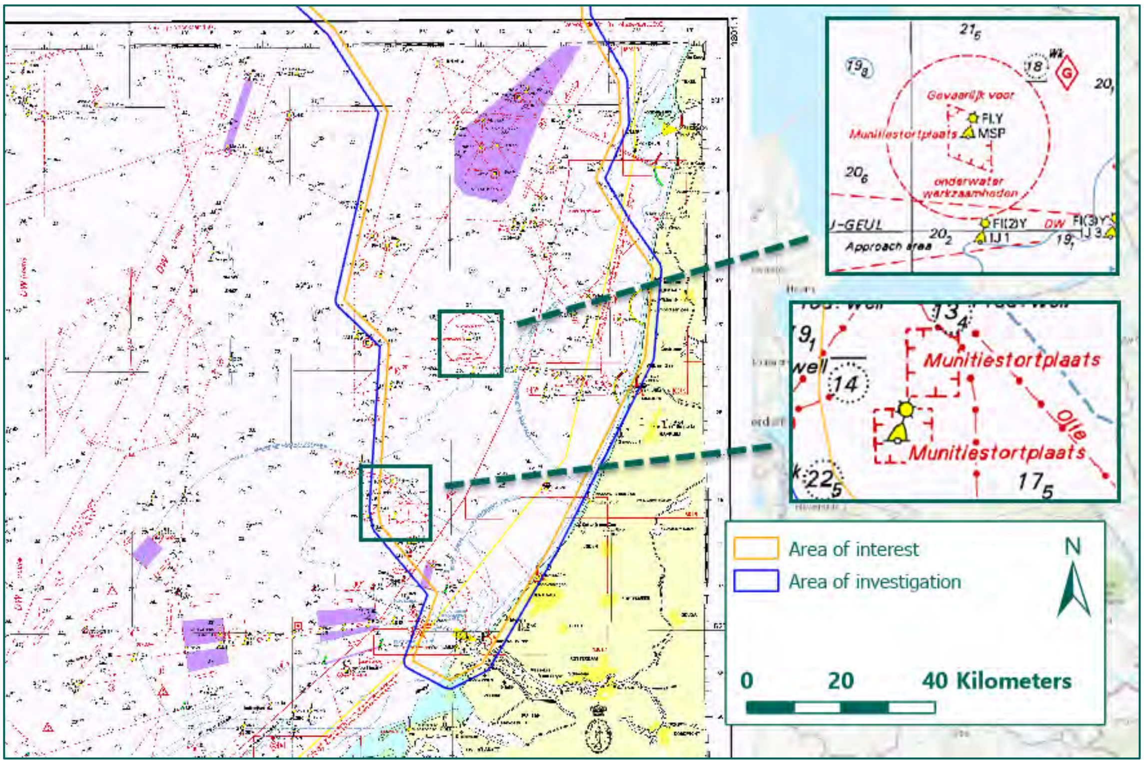


Figure 39: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

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.

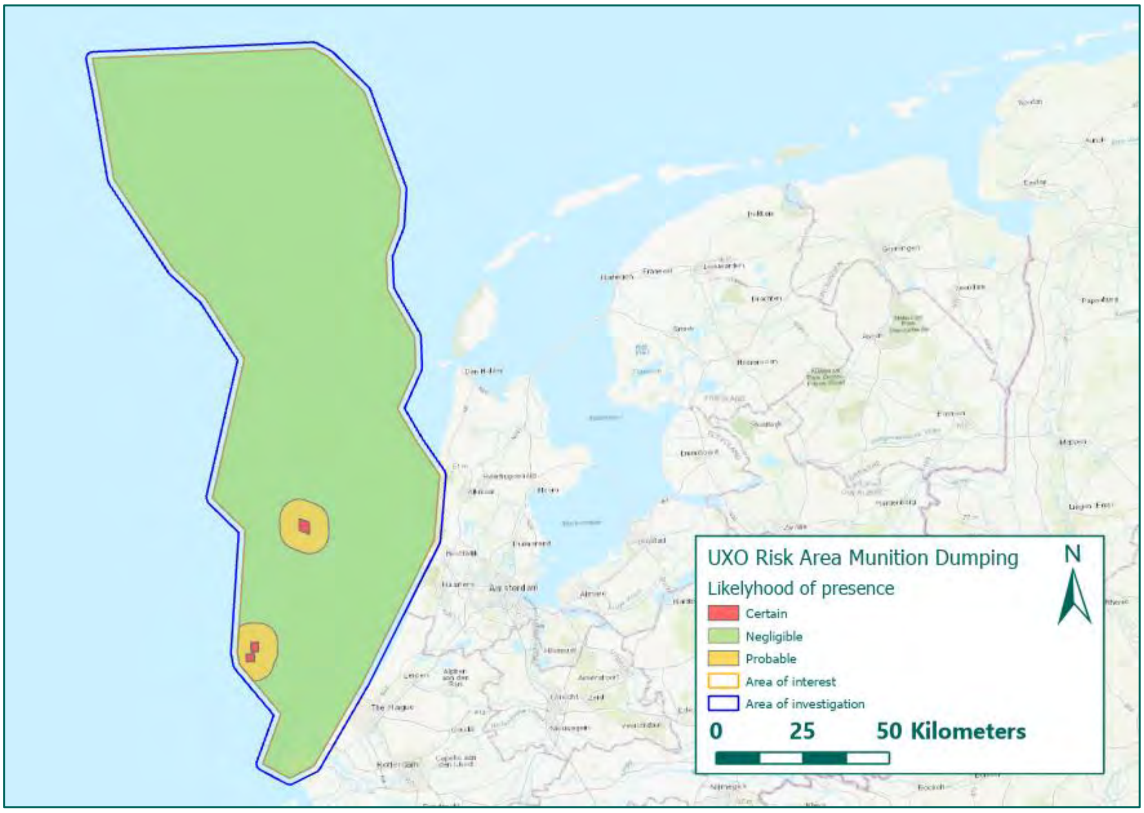


Figure 40: UXO risk area due to munition dumping. (Source basemap: ESRI).

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:

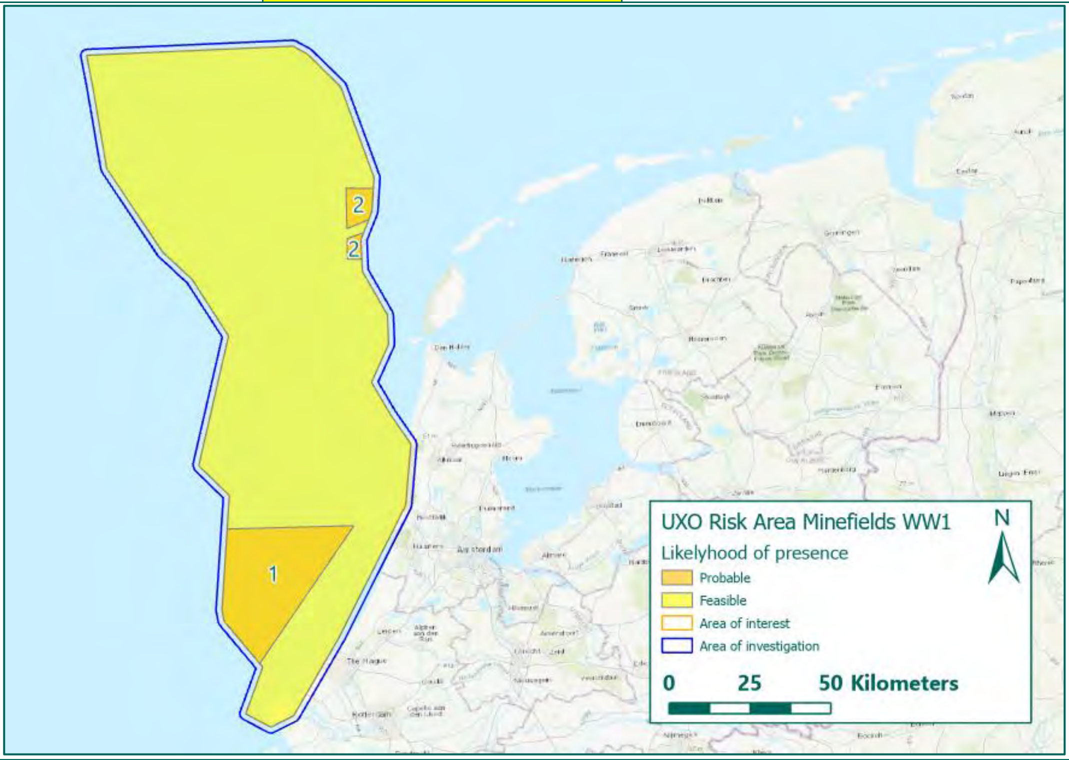
- It is not possible to pinpoint exact locations of war-related events at sea. This problem is partly solved by defining a large area of investigation. Events that took place within this area could have led to a UXO risk area.
- Compared to land, the North Sea offers few reference points. Therefore, 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.

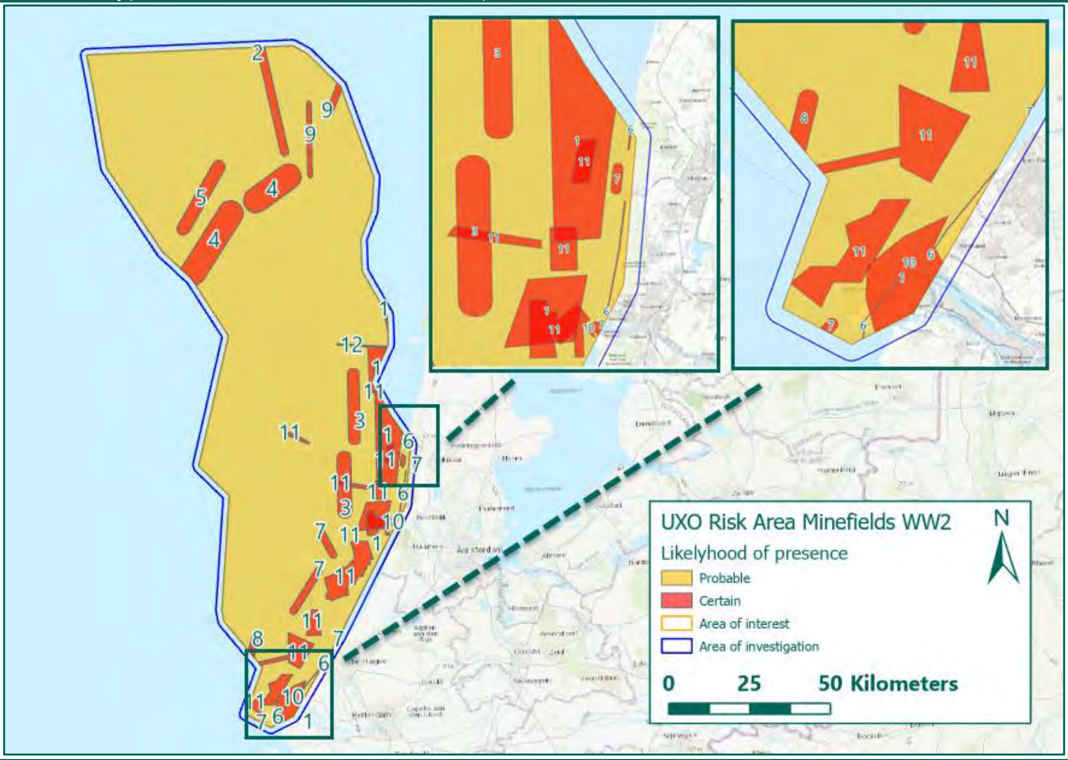
UXO Risk Area as a result of the naval mines (paragraph 4.1)

UXO (sub)type and calibre	Likelihood of presence	Demarcation
Naval Mines WW1: German E-Mine moored contact mines, British Vickers / British Elia and H Mark II moored contact mines	Probable	Within the boundaries of known minefields.
	Feasible	Outside the boundaries of known minefields.



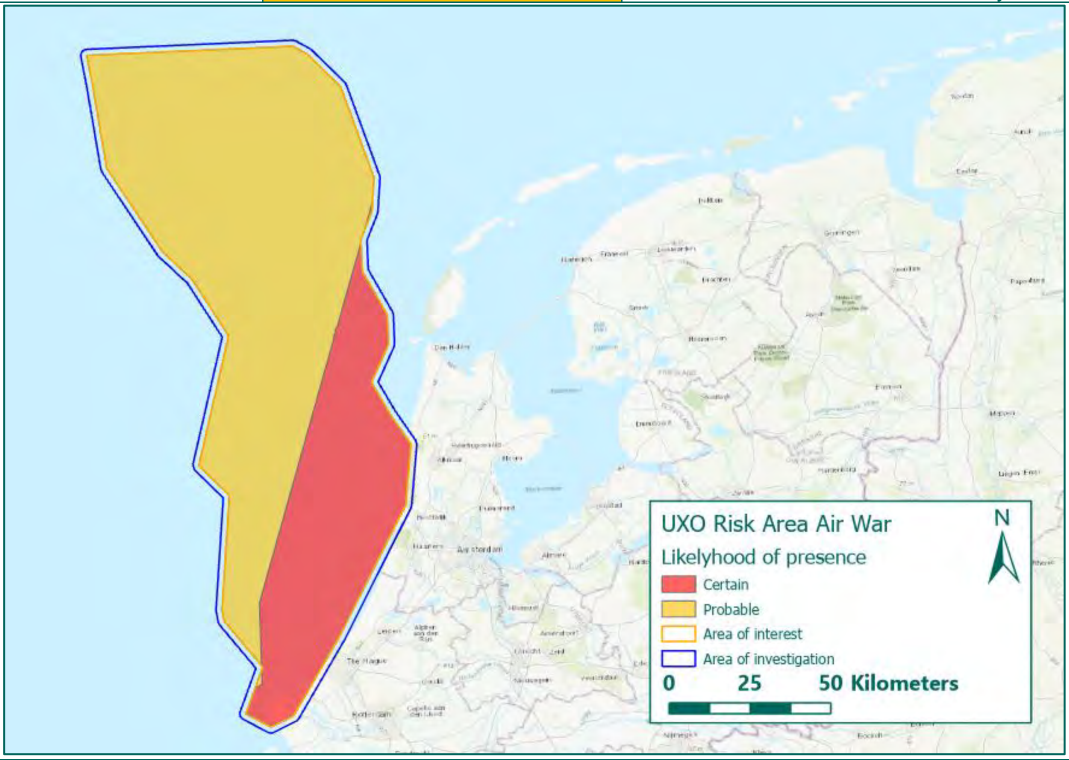
UXO (sub)type and calibre	Likelihood of presence	Demarcation
Naval mines WWII: British Mk I-IV ground mines and British Mk VII- VIII and Mk XIV German EMB, EMC, EMD, UMA, RMA, KMA contact mines German LMB Ground mines German Exploding Floats (and also non explosive sweep obstructors) Dutch Model 1921 '2e soort'	Certain	Within the boundaries of known minefields.
	Probable	Outside the boundaries of known minefields.

UXO (sub)type and calibre	Likelihood of presence	Demarcation



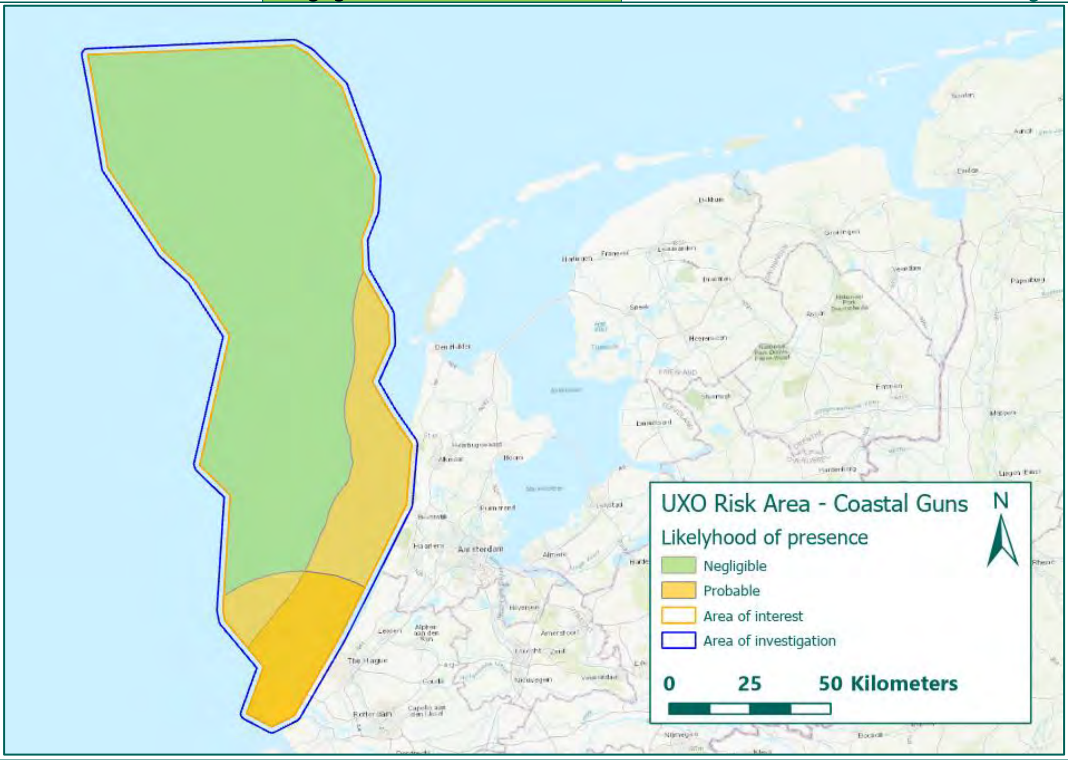
UXO Risk Area as a result of the air war (paragraph 4.2)

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.



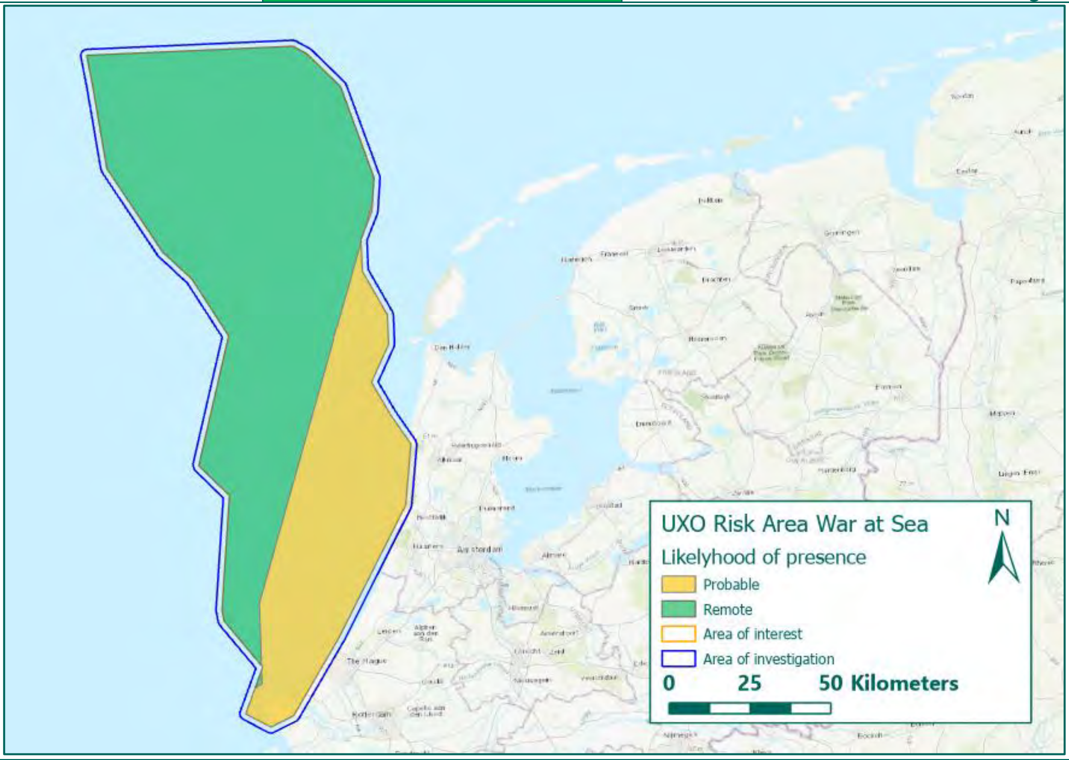
UXO Risk Area as a result of the coastal guns (paragraph 4.3)

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.



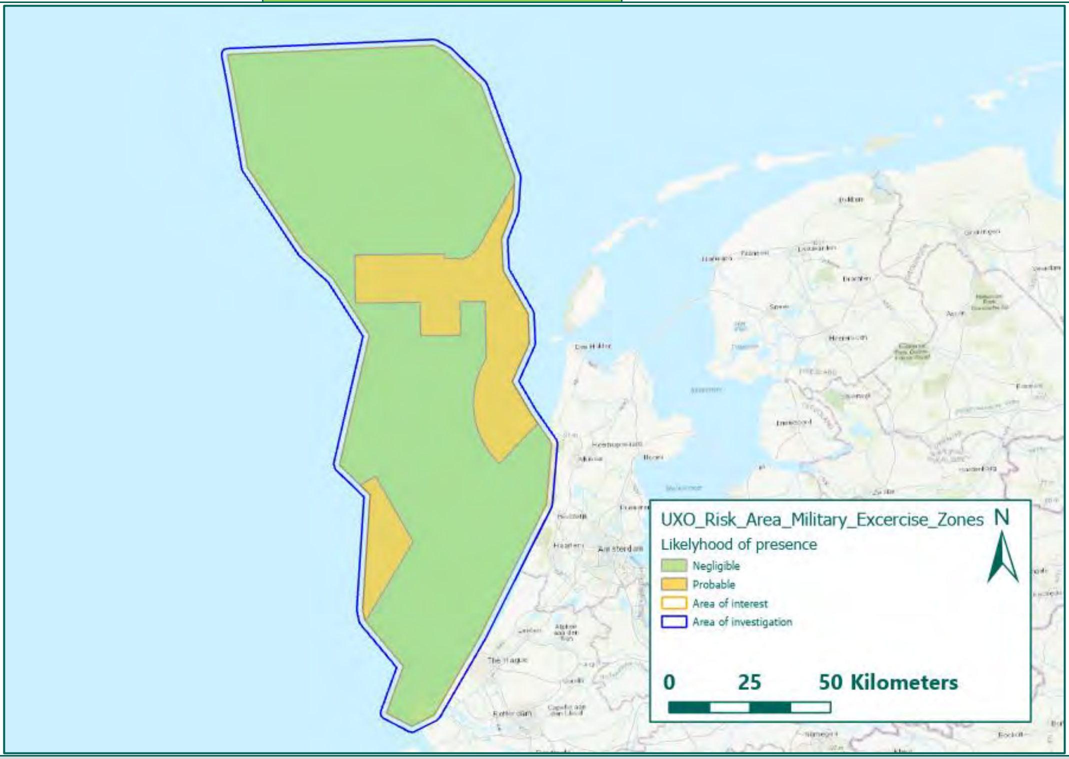
UXO Risk Area as a result of the war at sea (paragraph 4.4)

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.



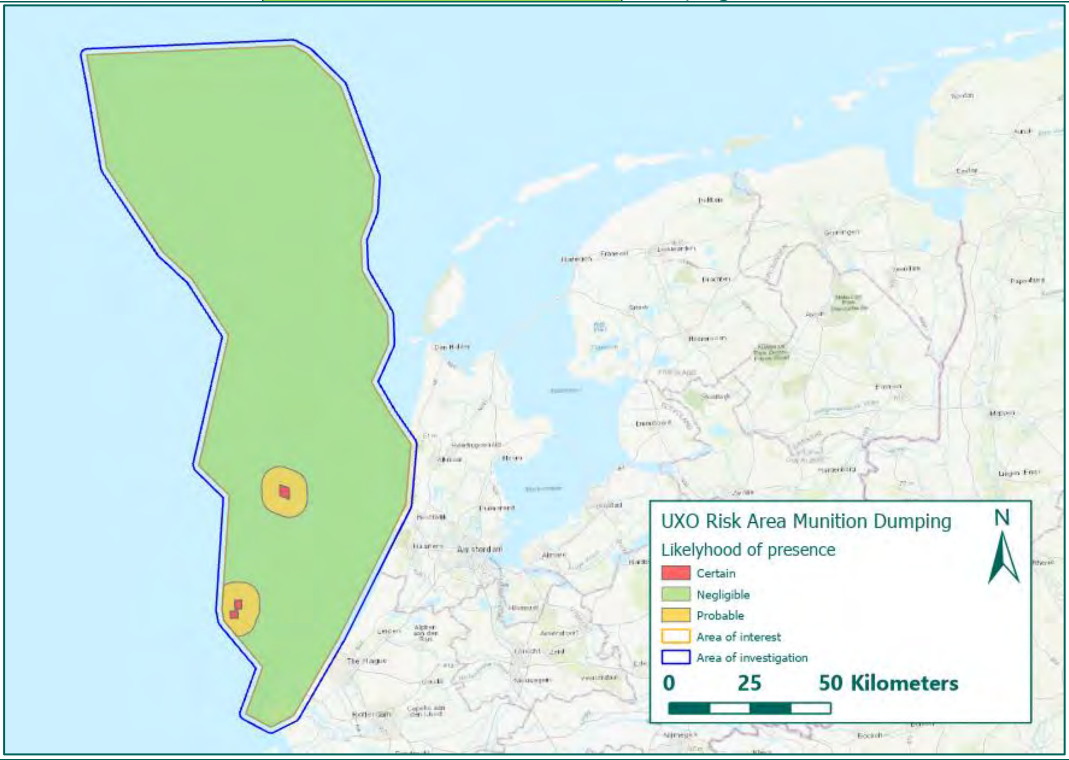
UXO Risk Area as a result of military exercises (paragraph 4.5)

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).

Likelihood of Occurrence	Hazard Severity				
	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

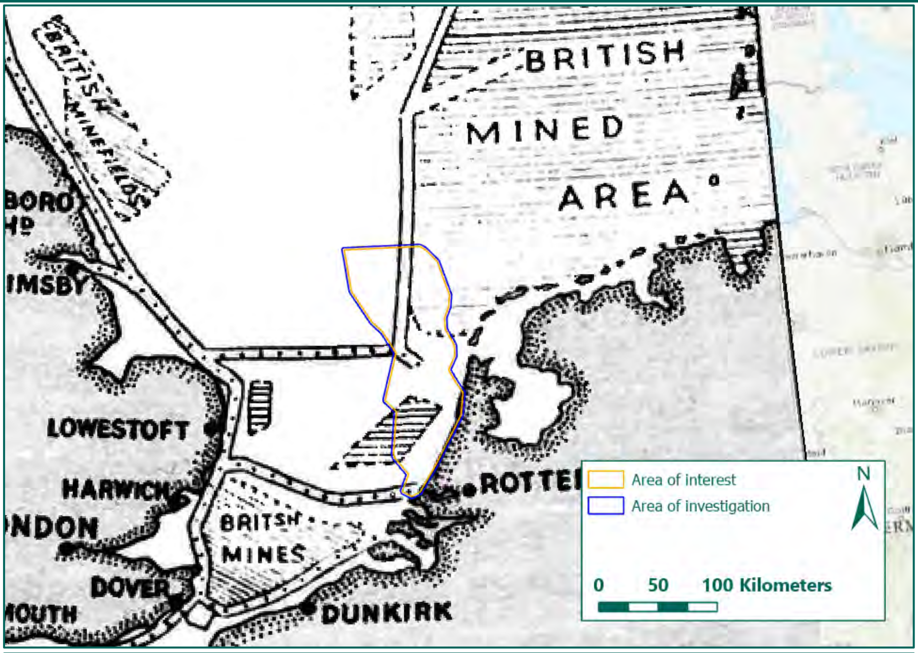
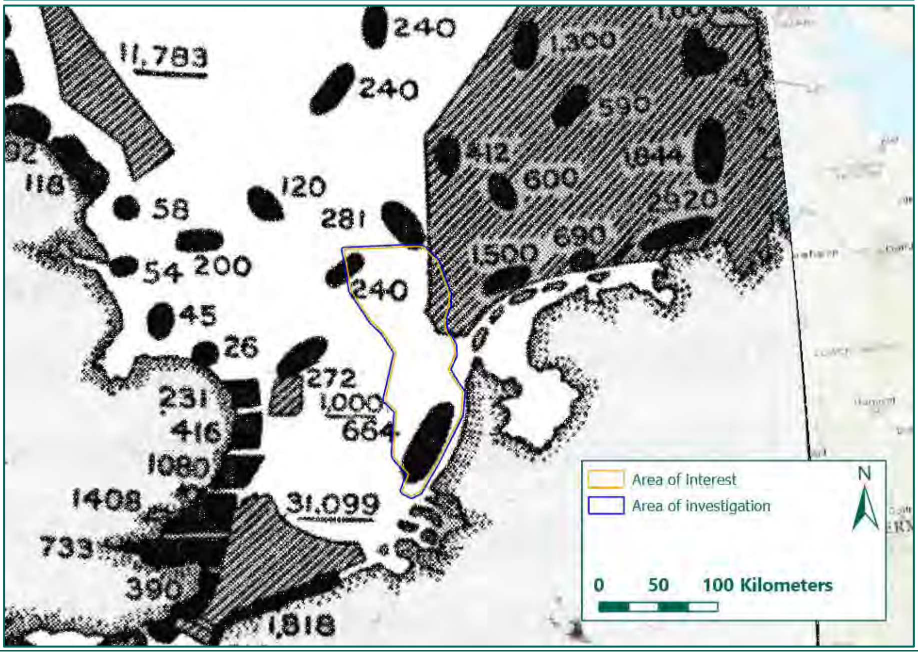
Table 4: Reference to literature.

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

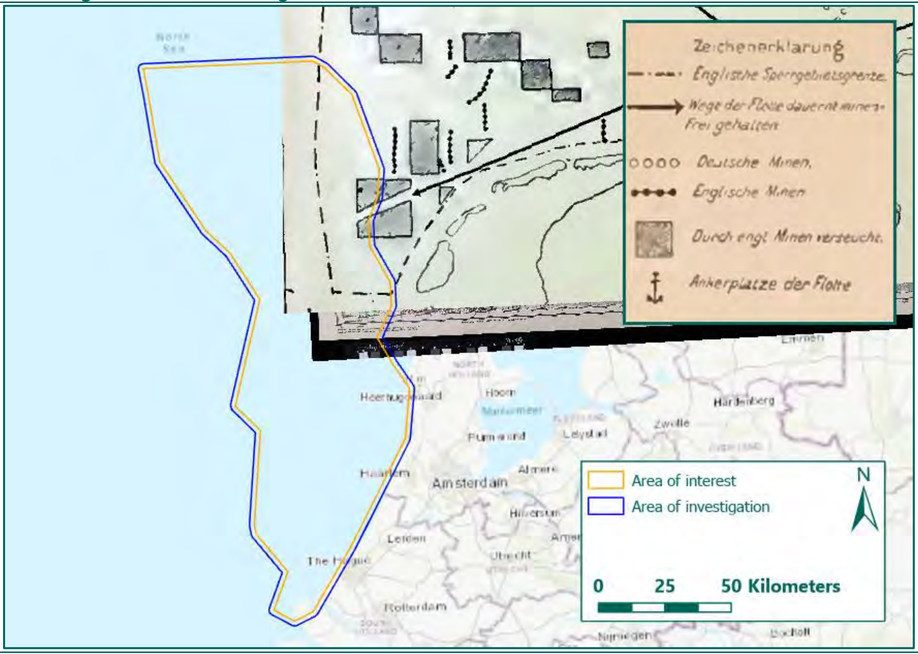
Date / year	Event	Source	Page
	was manned mainly by Royal Navy personnel and fishermen and consisted of 14,500 men and 700 officers at its peak. A particular danger when clearing dense fields was what was known as 'counter mining'. This occurred when exploding one mine would set off others in the vicinity – 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

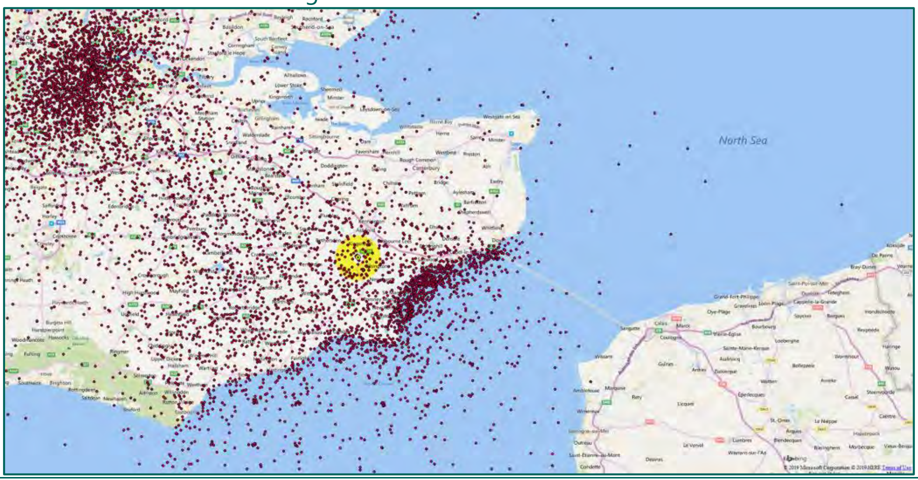
When the inevitability of the Second World War became clear in August 1939, the allied and non-aligned armies of the countries surrounding Germany once again mobilized to prepare for an imminent attack. While serious naval threats were not foreseen, preparations also took place on the coast and the sea. Coastal guns were once again installed, and vital waterways were mined.

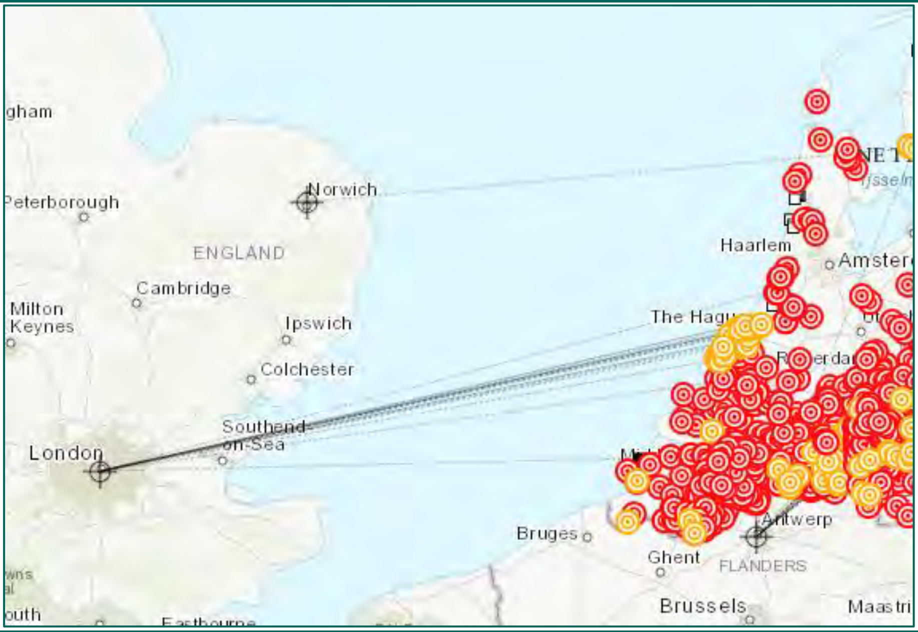
The North Sea became the frontline between Great-Britain and occupied mainland Europe. Fast attack craft from the Royal Navy coastal forces attacked German shipping close to the coast and laid mines to further hamper German navigation of the North Sea. Patrolling allied aircraft attacked convoys, submarines 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:

Date / year	Event	Source	Page
1944-1945	V1 and V2 bombs hitting the UK 	V2	-
	Locations of V1 bombs hitting the UK and the North Sea near Kent. 	AAS	-
	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.	VER	-

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

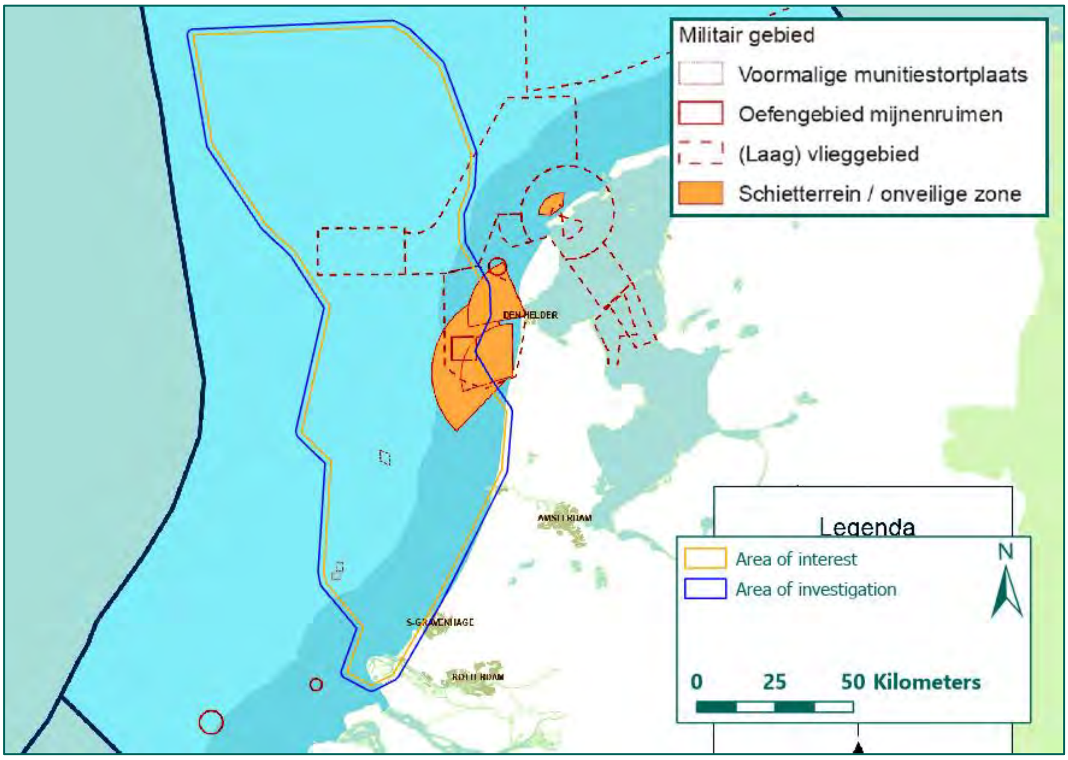


Figure 43: Map showing the military usage of parts of the North Sea (Source: NZL).

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.

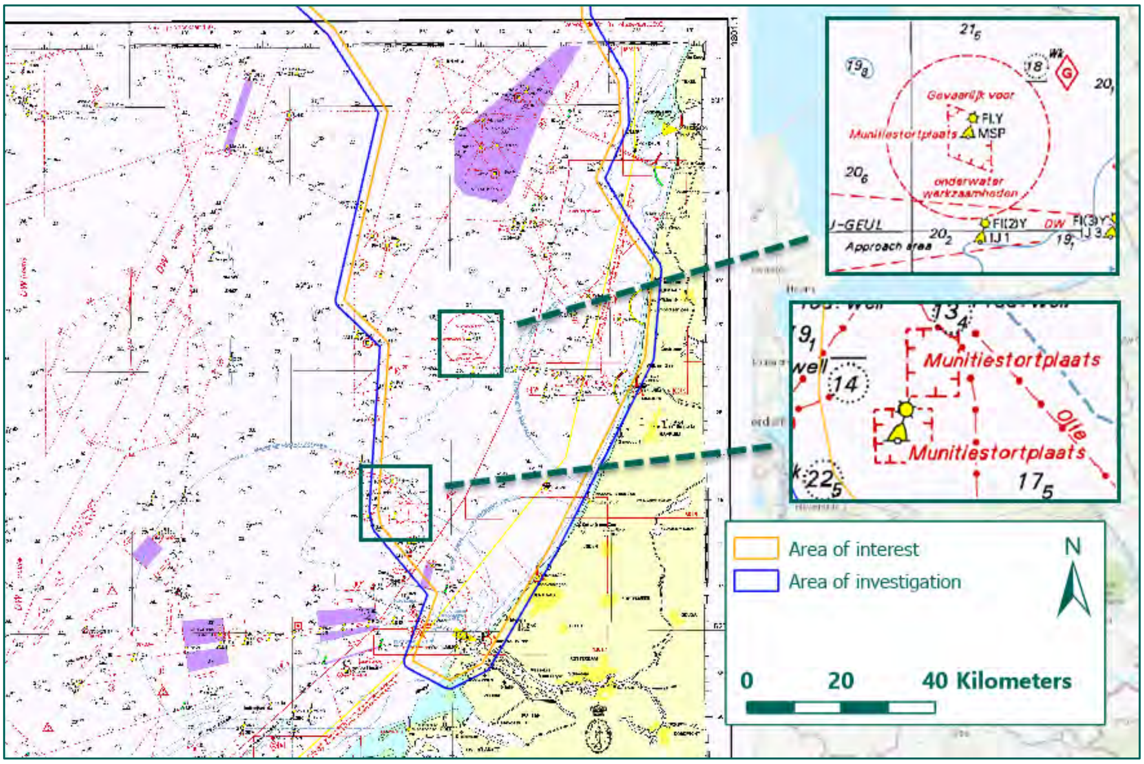


Figure 44: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

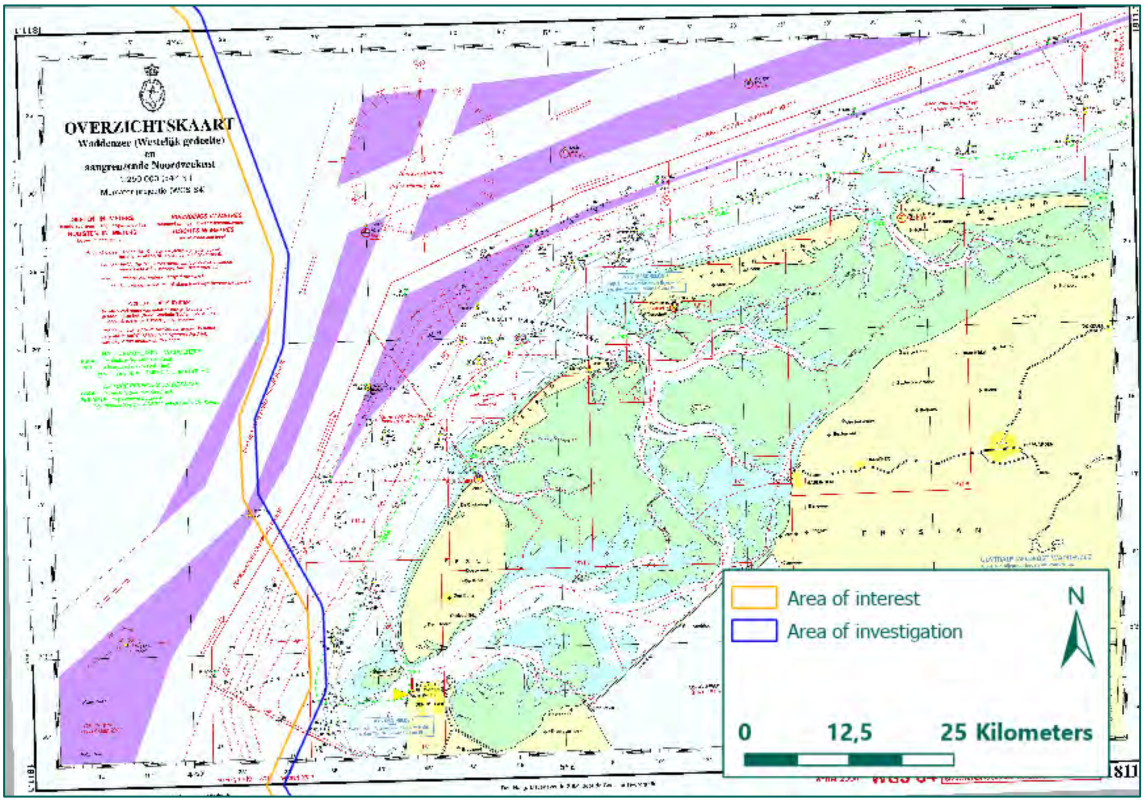


Figure 45: Naval chart (Source: Royal Netherlands Navy Hydrographic service).

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:

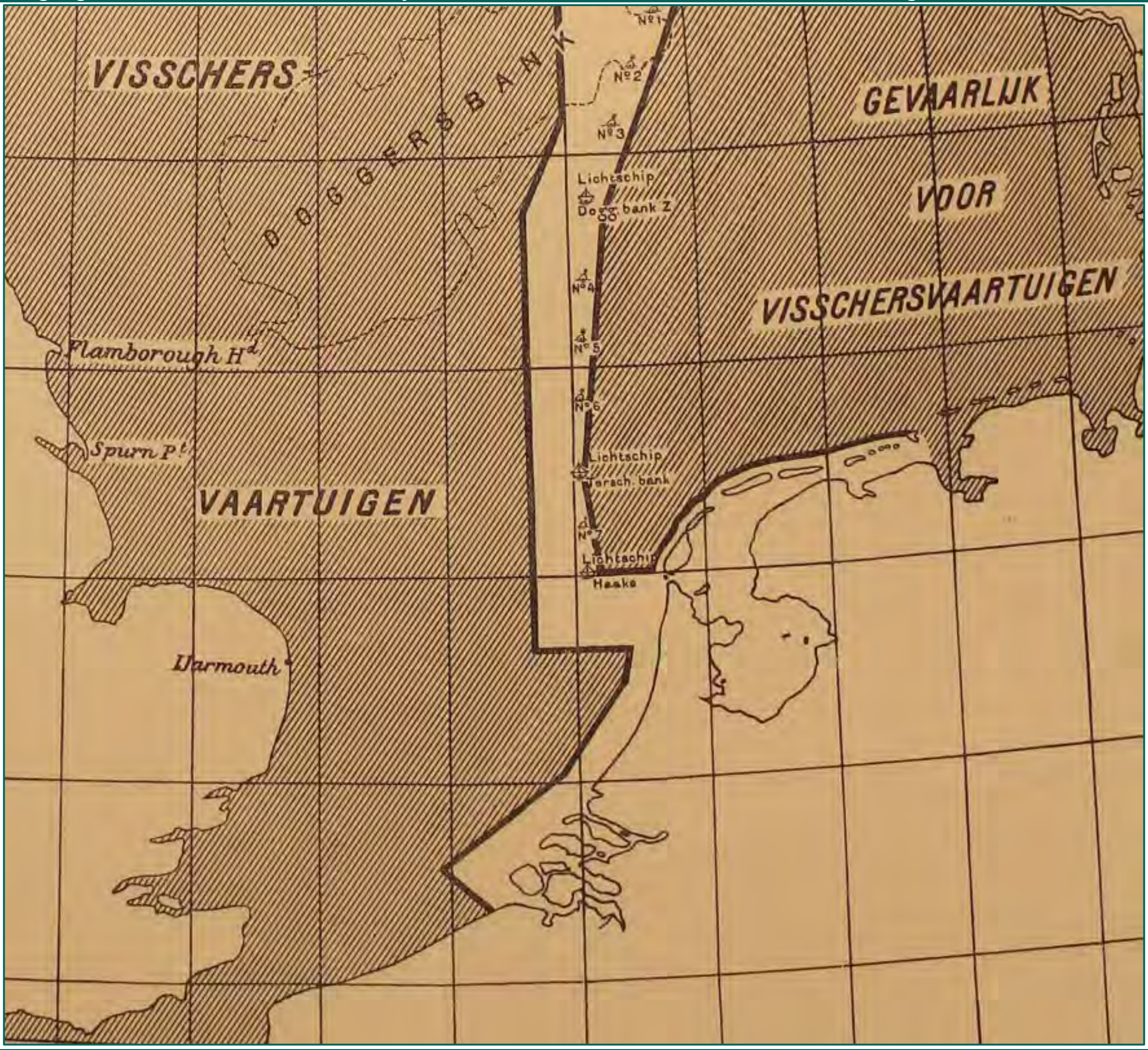
	51° 35′ N.B.	2° 57′ O.L.
naar	52° 2′ N.B.	3° 52′ O.L.
„	52° 28′ N.B.	4° 22′ O.L.
„	52° 40′ N.B.	4° 25′ O.L.
„	52° 40′ N.B.	3° 40′ O.L.
„	54° 45′ N.B.	3° 40′ O.L.
„	55° 10′ N.B.	4° 0′ O.L.
„	56° 0′ N.B.	4° 0′ O.L.
„	56° 0′ N.B.	4° 50′ O.L.

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

$\frac{52^\circ - 05' N,}{03^\circ - 40' E}$ $\frac{52^\circ - 25' N,}{04^\circ - 00' E}$ $\frac{52^\circ - 10' N,}{03^\circ - 25' E}$ $\frac{52^\circ - 30' N}{03^\circ - 25' E}$

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 "Stereomat[illegible]lage Erfprins.
   Gebied begrensd door Kaap Hoofd naar

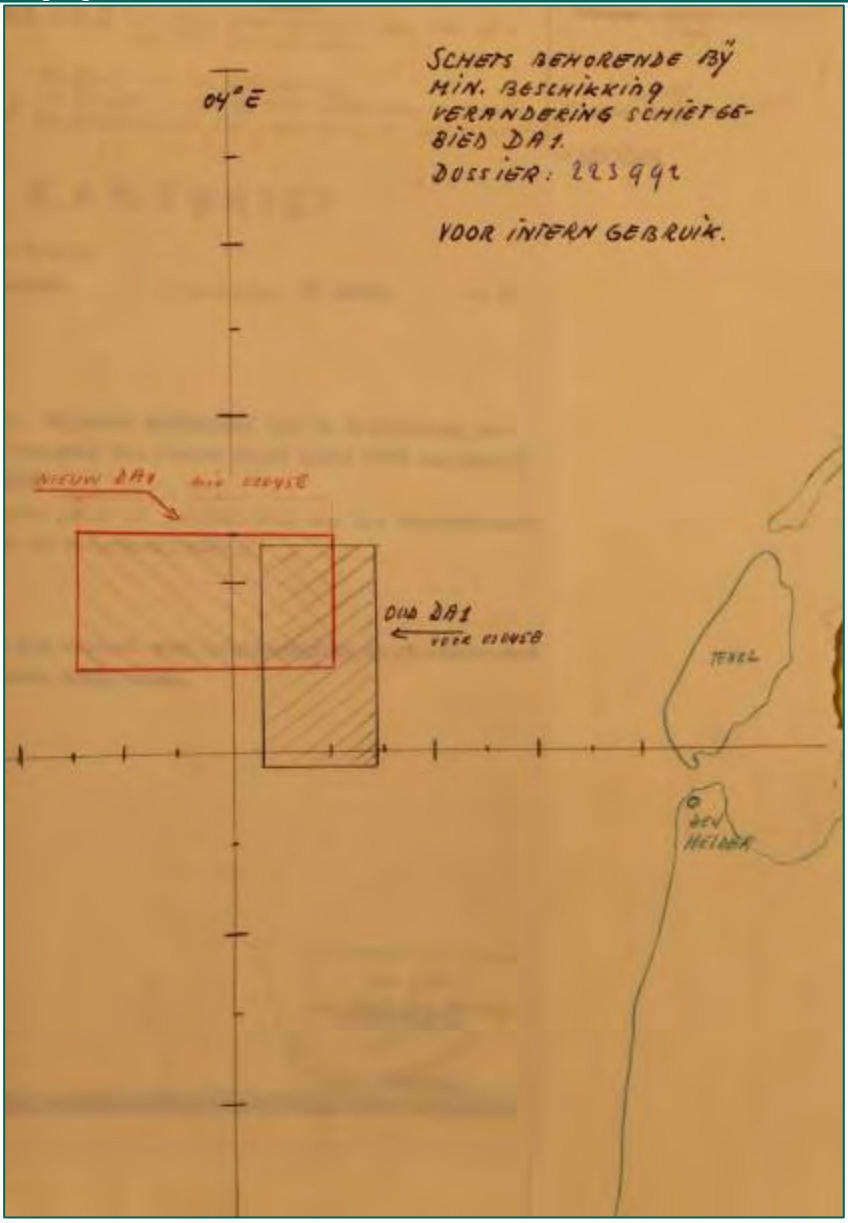
$\frac{52^\circ - 52' N}{4^\circ - 40' E}$ naar $\frac{52 - 52 N}{4^\circ - 52' E}$ naar $\frac{52 - 56 N}{4^\circ - 28' E}$

naar $\frac{53^\circ - 0' N}{4^\circ - 28' E}$ naar $\frac{53^\circ - 4' N}{4 - 32' E}$ naar $\frac{53^\circ - 4' N}{4^\circ - 40' E}$

naar Kaap Hoofd.

Old en new site of DA1:

Toegang 2.12.56: Marine na 1945



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.

DA 1 (Den Helder I)

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)

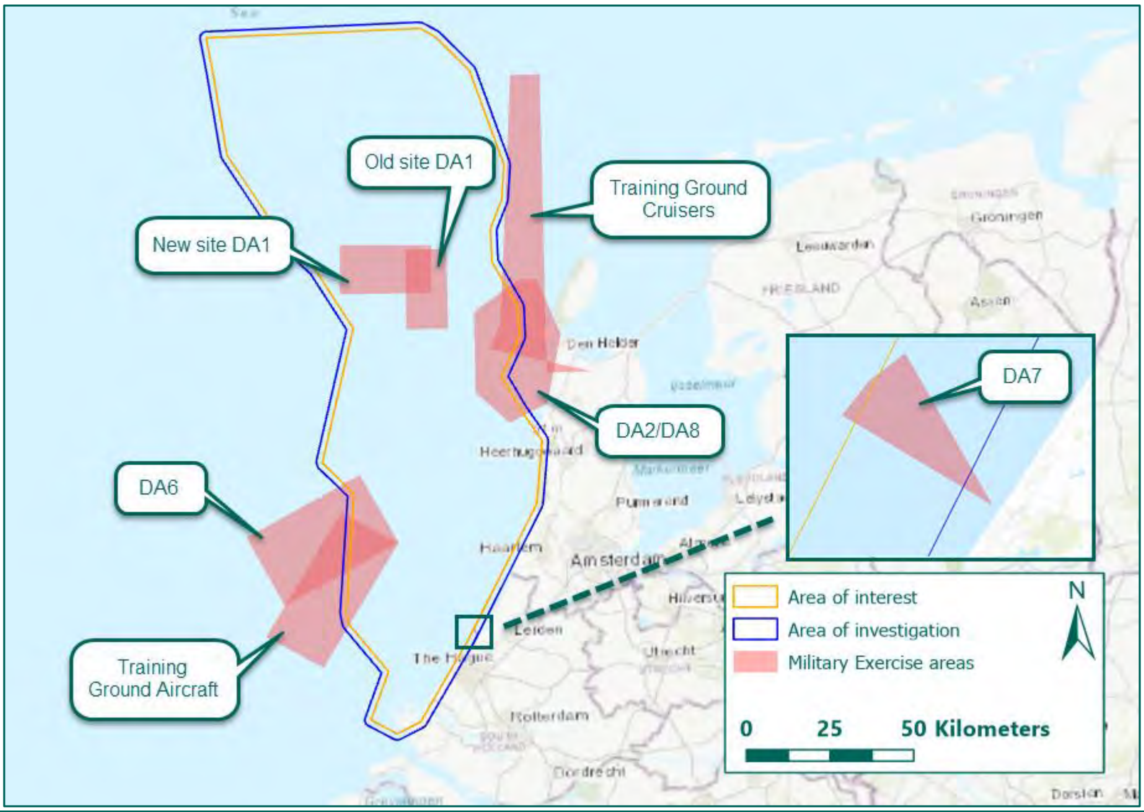
Het gebied, begrensd door een lijn, welke de volgende posities verbindt:
52.58.00 N — 04.44.00 O; 52.47.00 N — 04.40.00 O;
52.44.00 N — 04.30.00 O; 52.49.00 N — 04.21.00 O;
53.02.00 N — 04.21.00 O; 53.07.00 N — 04.33.00 O en
53.07.00 N — 04.38.00 O,
tot een hoogte van 10.000 meter.

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.

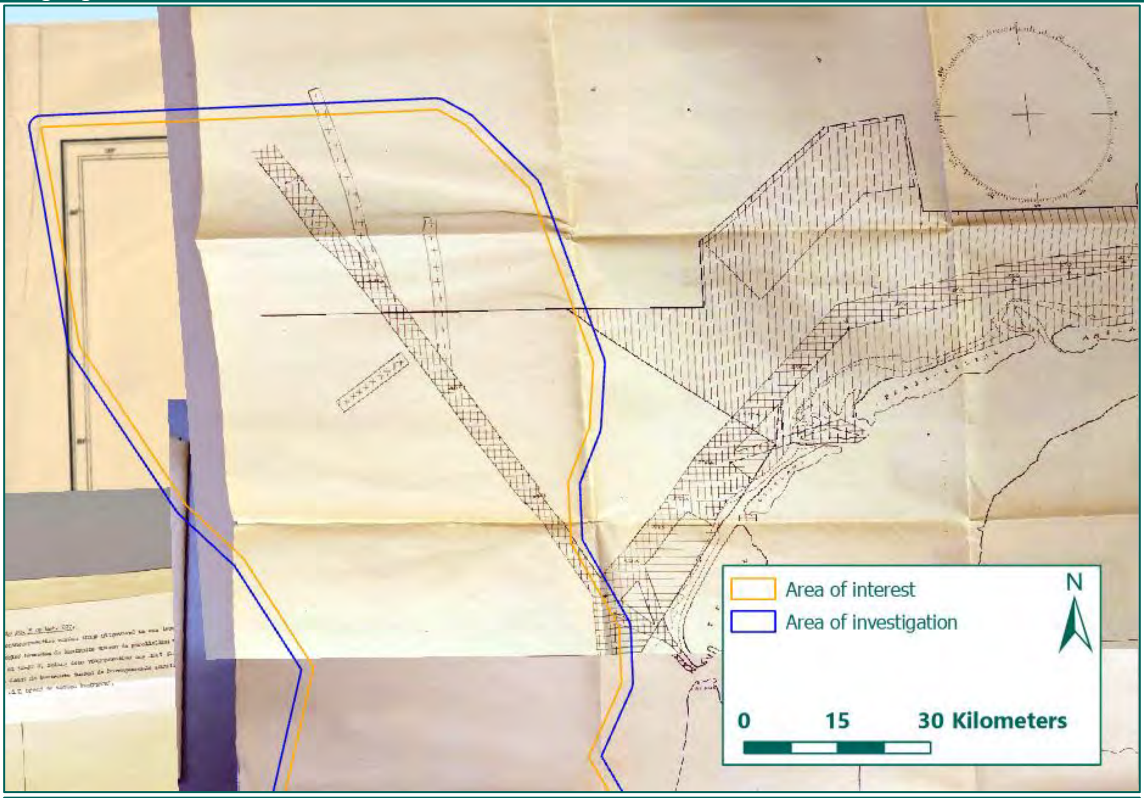
DA 7 (Wassenaarse slag)

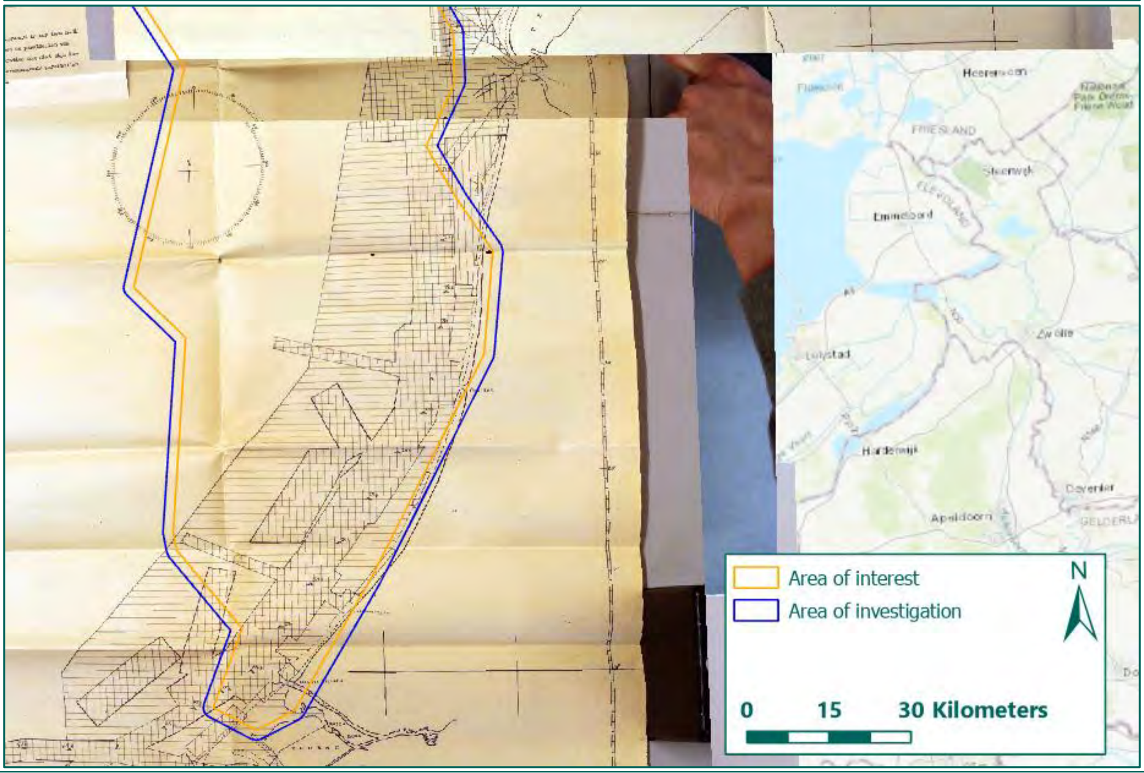
Een sector uit de positie 52.09.48 N — 04.20.45 O, in de richting 300° rechtwijzend door 315° naar 330° rechtwijzend, met een straal van 1,4 zeemijlen, tot een hoogte van 500 meter.

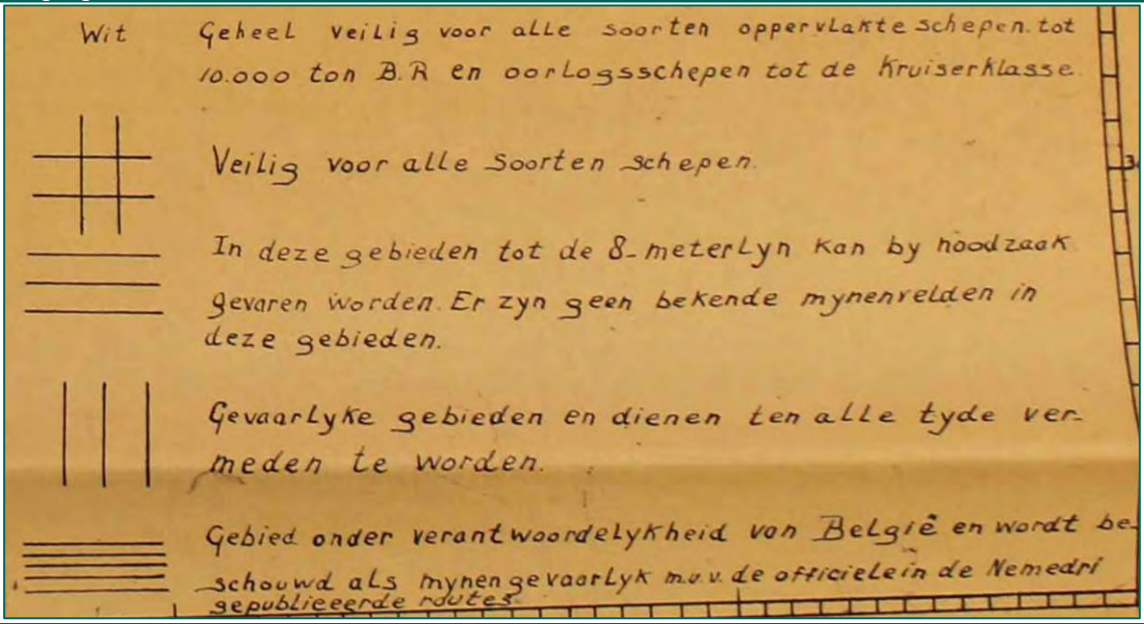


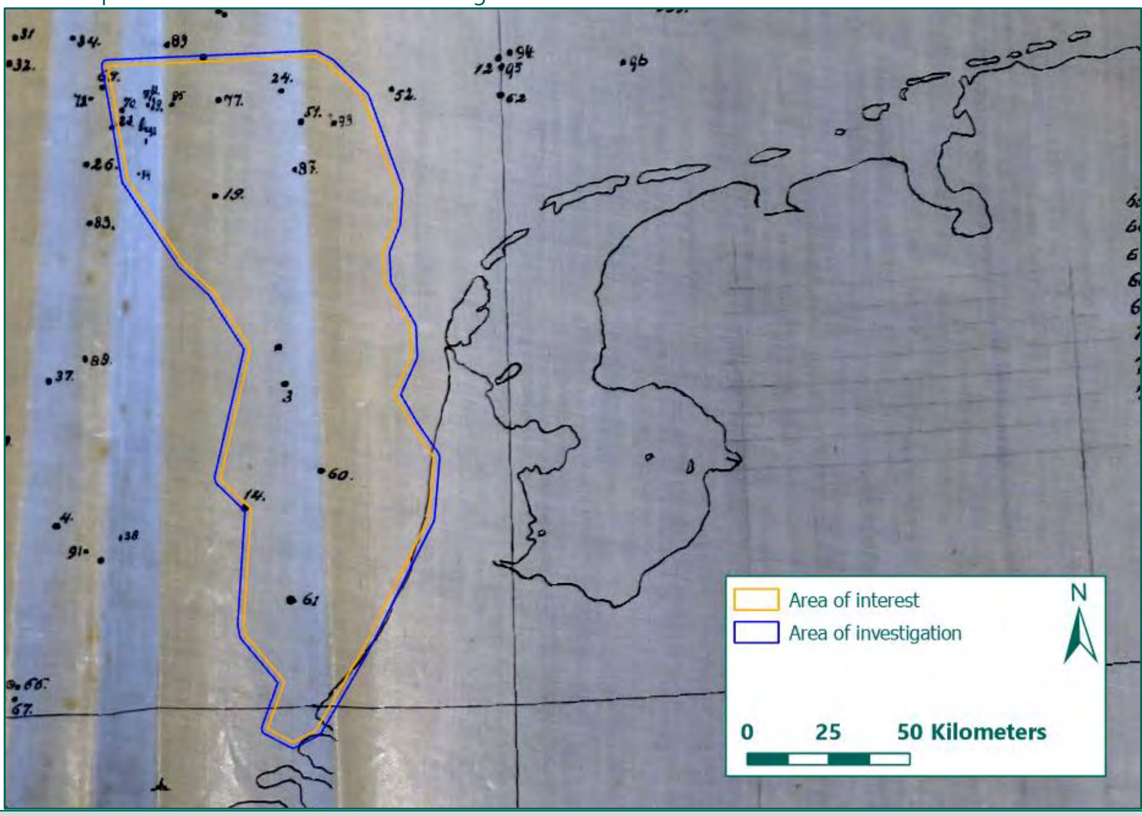
Inventaris 1882	Situatiekaarten van mijnen voor de Nederlandse kust. 1949-1950

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.

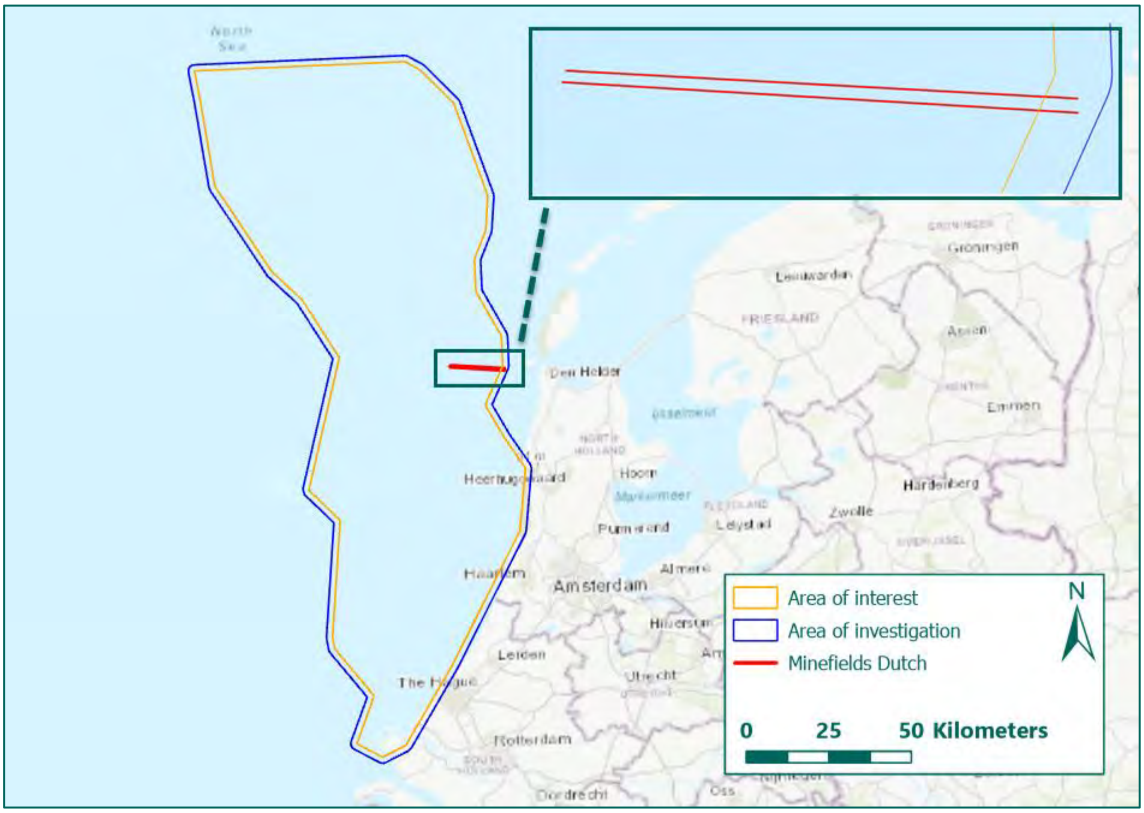


Figure 46: Dutch minefields within the Area of investigation (Source: NIMH 092).

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.

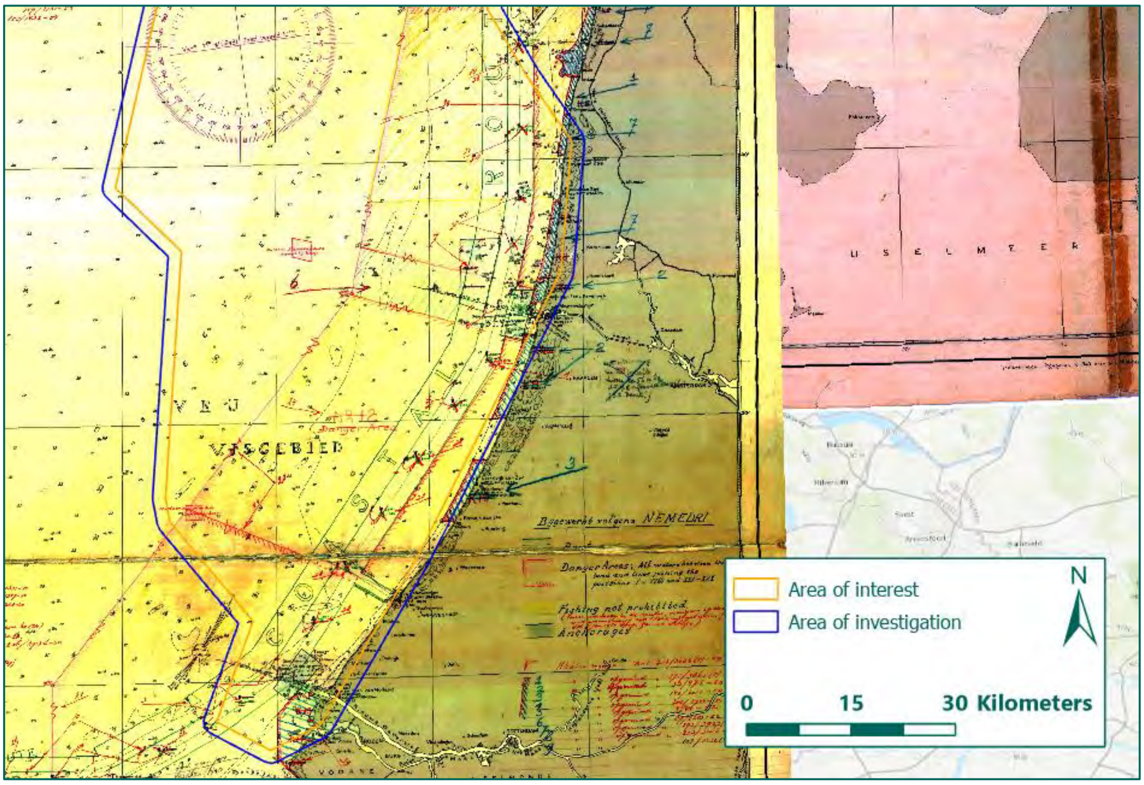


Figure 48: Map offer information on minesweeping after the Second World War (Source: Navy Museum NEMEDRI 227 West-Hinder tot Texel).

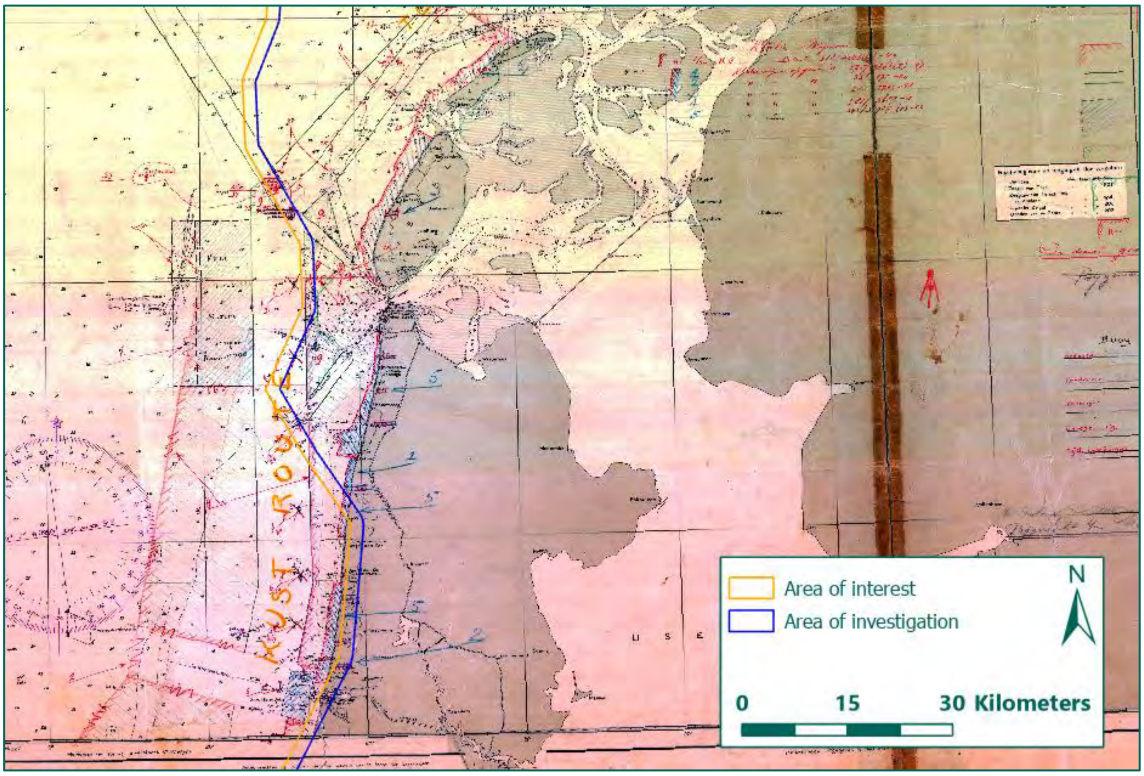


Figure 49: Map offer information on minesweeping after the Second World War (Source: Navy Museum NEMEDRI 226 IJmuiden tot de Weser).

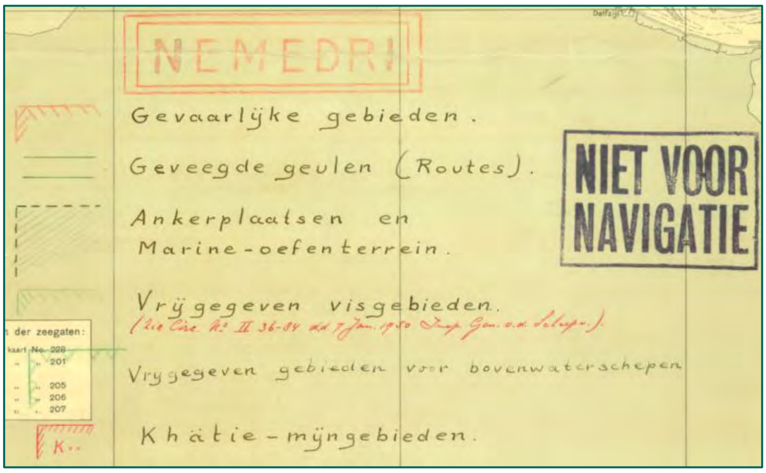


Figure 50: Legend of NEMERDI maps (Source: Navy Museum NEMEDRI 226 IJmuiden tot de Weser).

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.

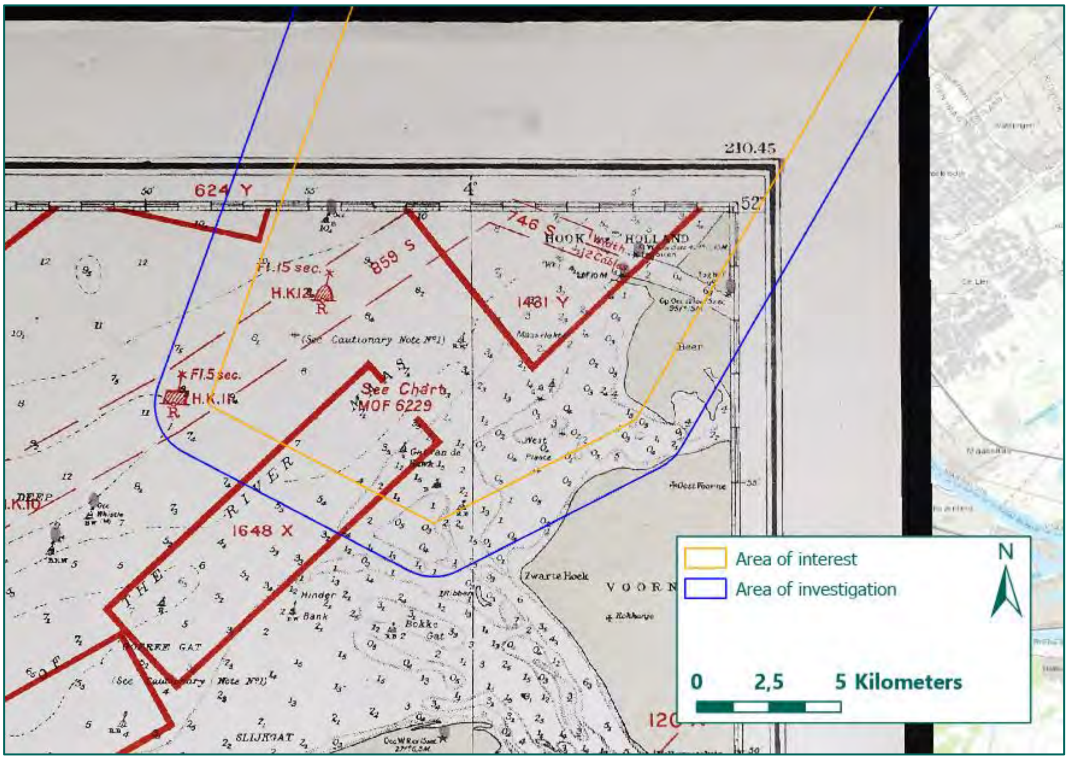


Figure 51: OCB MO F6550 Dunkerque to Hook of Holland, 1945. The red squares indicate minefields (Source: UKHO, Shelf 35).

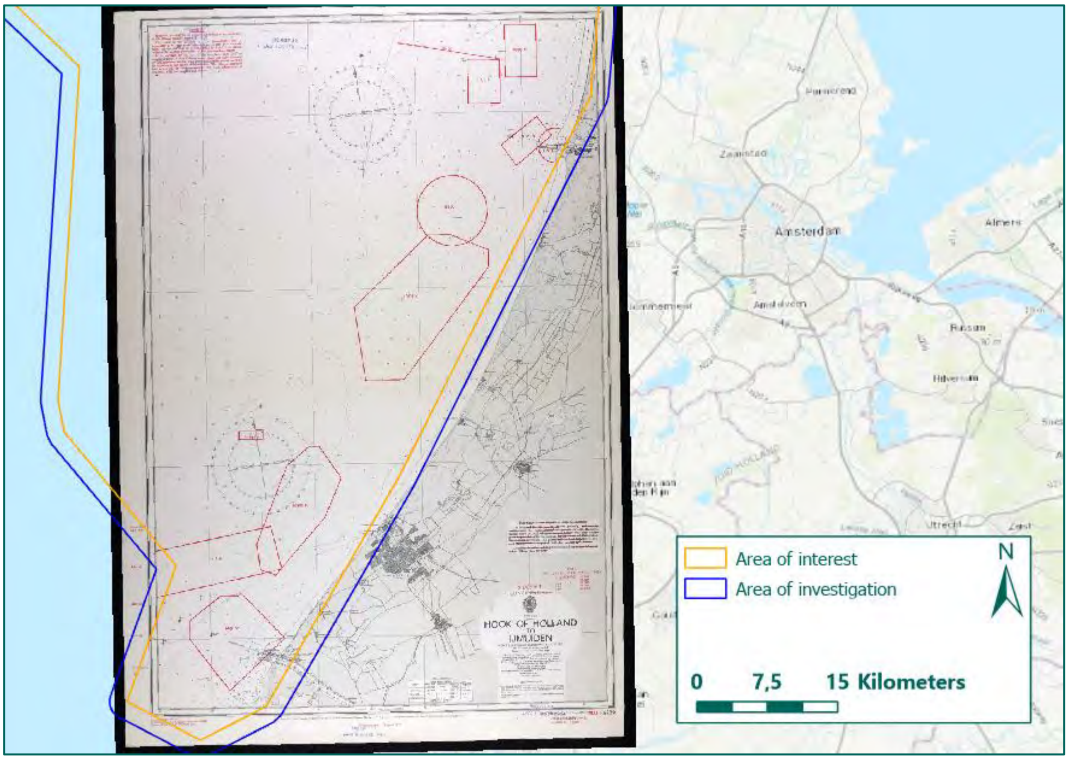


Figure 52: OCB MO F6229 Hook of Holland 1944. The red squares indicate minefields (Source: UKHO, Shelf 35).

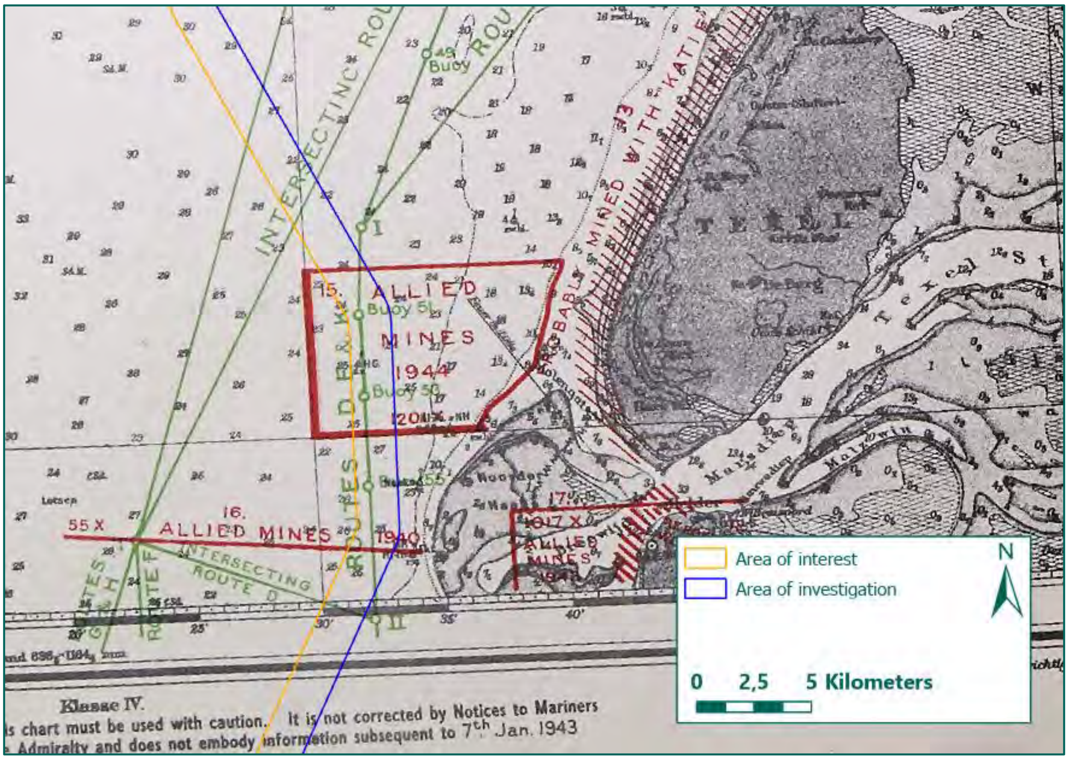


Figure 53: OCB MO 6590 Texel Bis Cuxhaven 1945. The red squares indicate minefields, green lines indicate convoy routes (Source: UKHO, Shelf 35).

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).

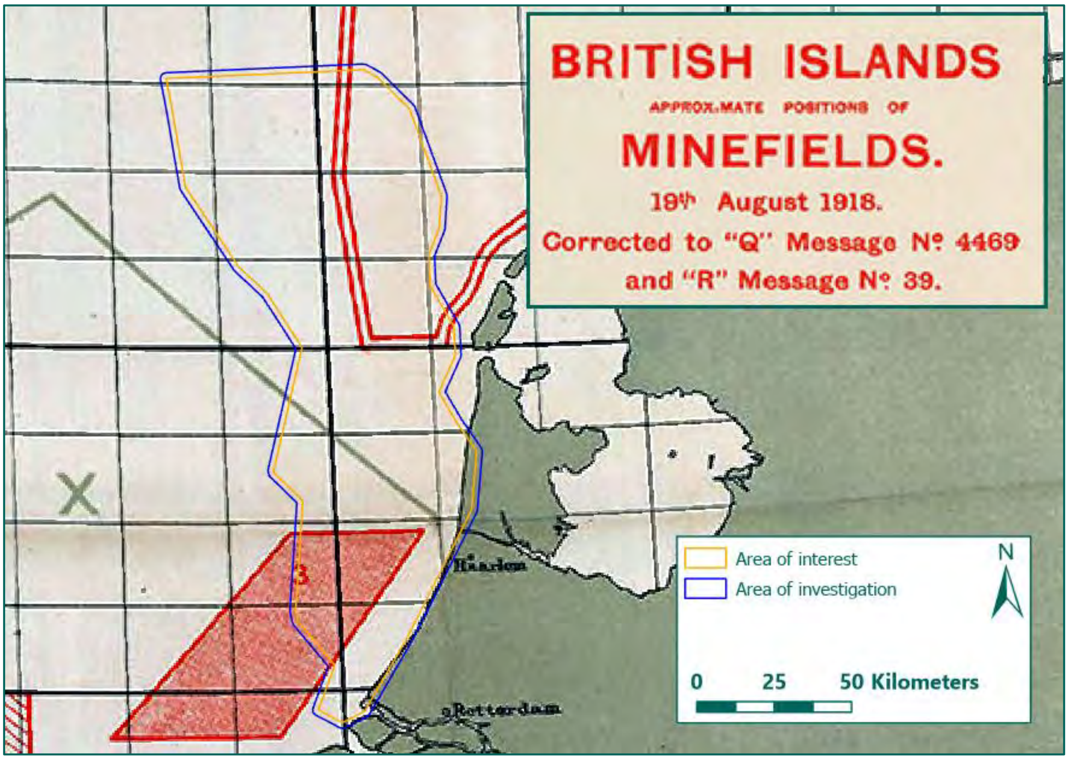


Figure 55: Minefields in the North Sea during 19 August 1918 (Source basemap: LOC).

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.

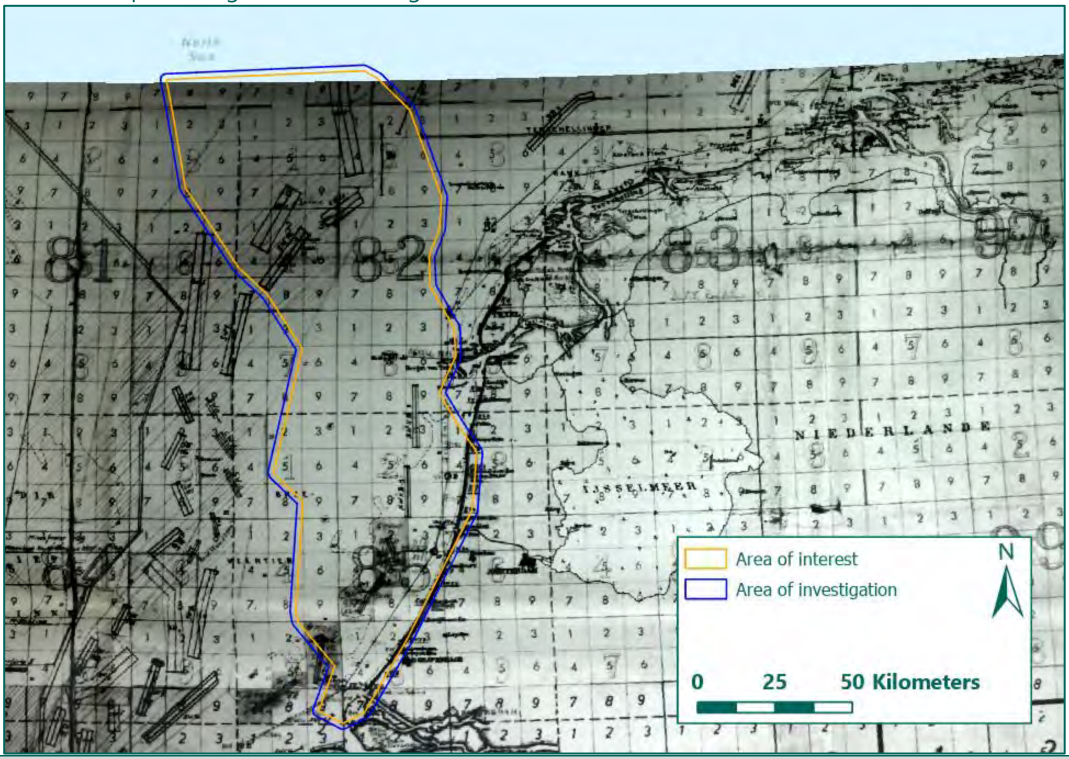
Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers (ADM)	
ADM 1/18996	Results of British minelaying offensive.
General information about total amount of laid/dropped mines, 3rd September 1939 – 5th May 1945: MINES LAID IN ENEMY WATERS By Fast Minelayers and Destroyers 11,100 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:

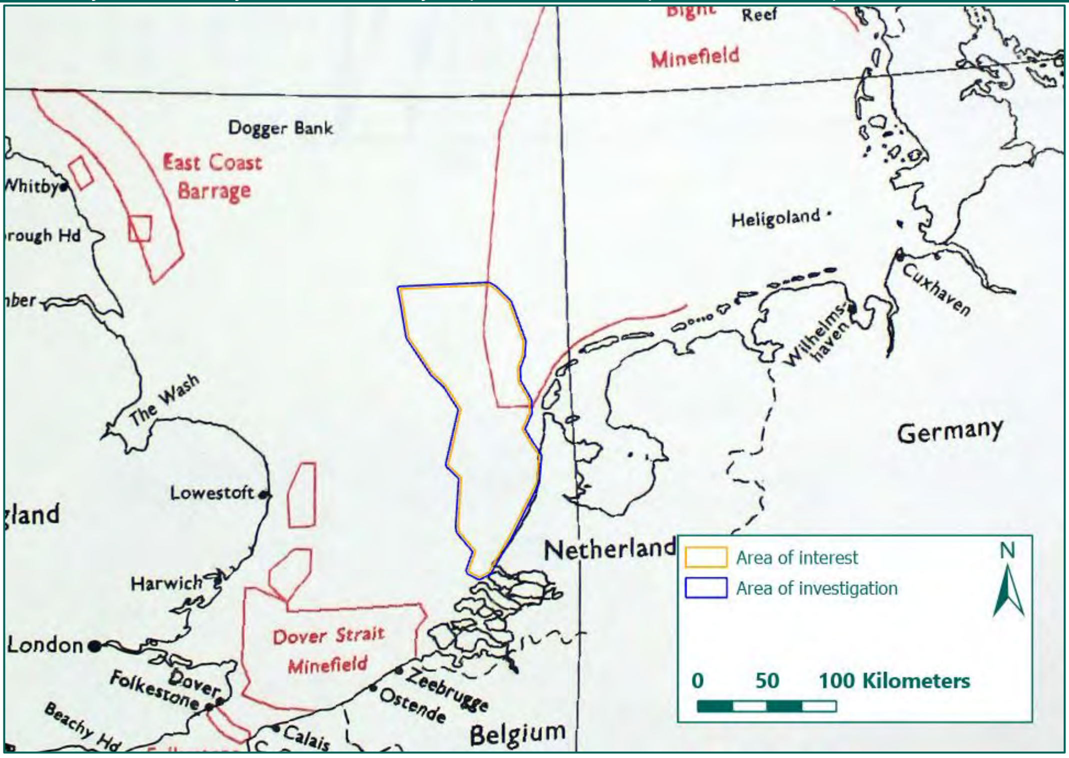


ADM 234/561	British mining operations 1939-1945: Vol 2.

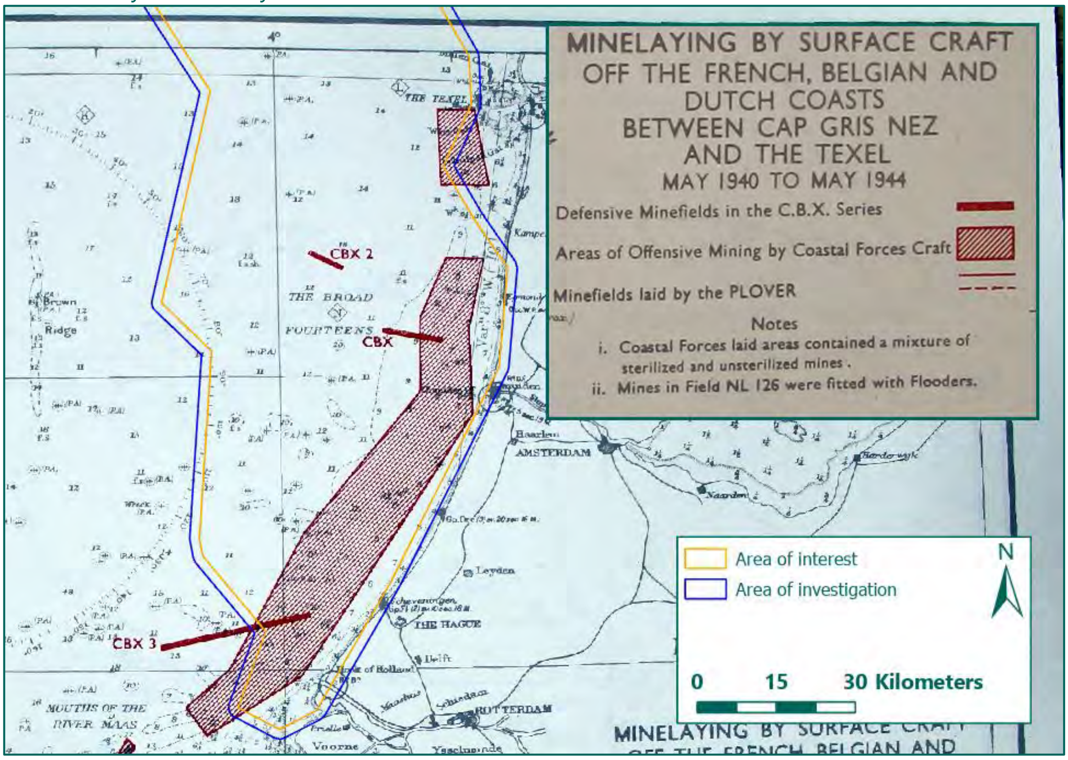
Relevant information:

- 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)

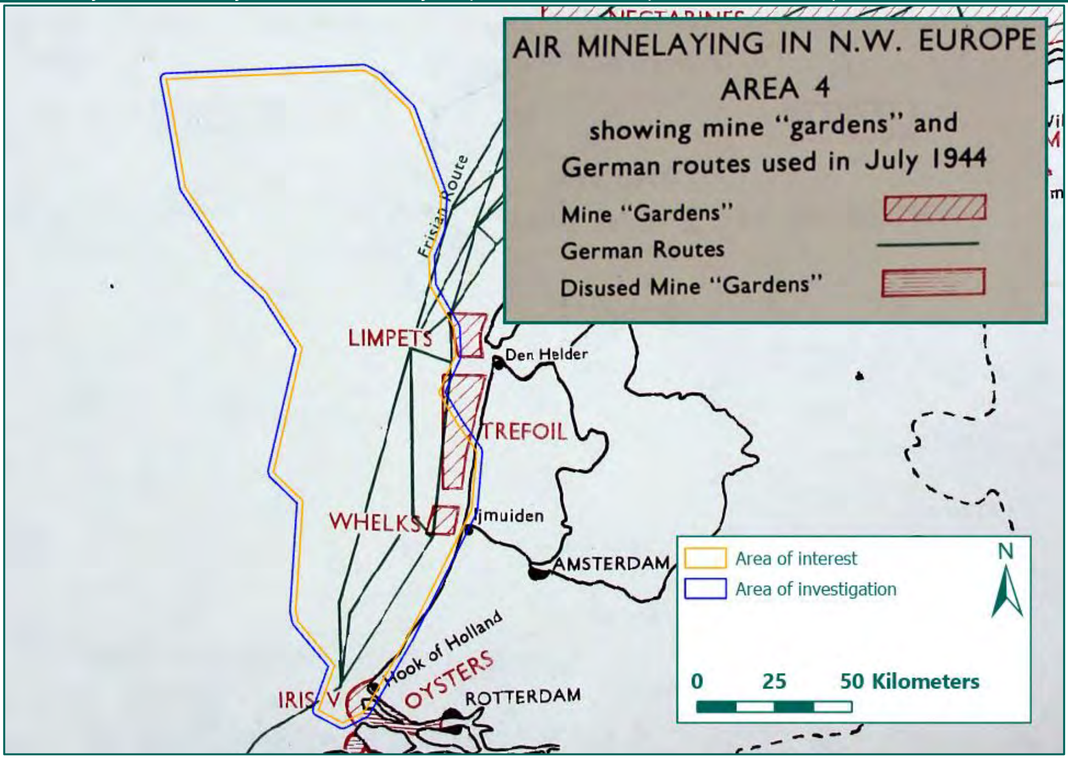


- Map showing:
  Minelaying by surface craft off the French, Belgian and Dutch Coasts between Cap Gris Nez and The Texel, May 1940 – May 1944:

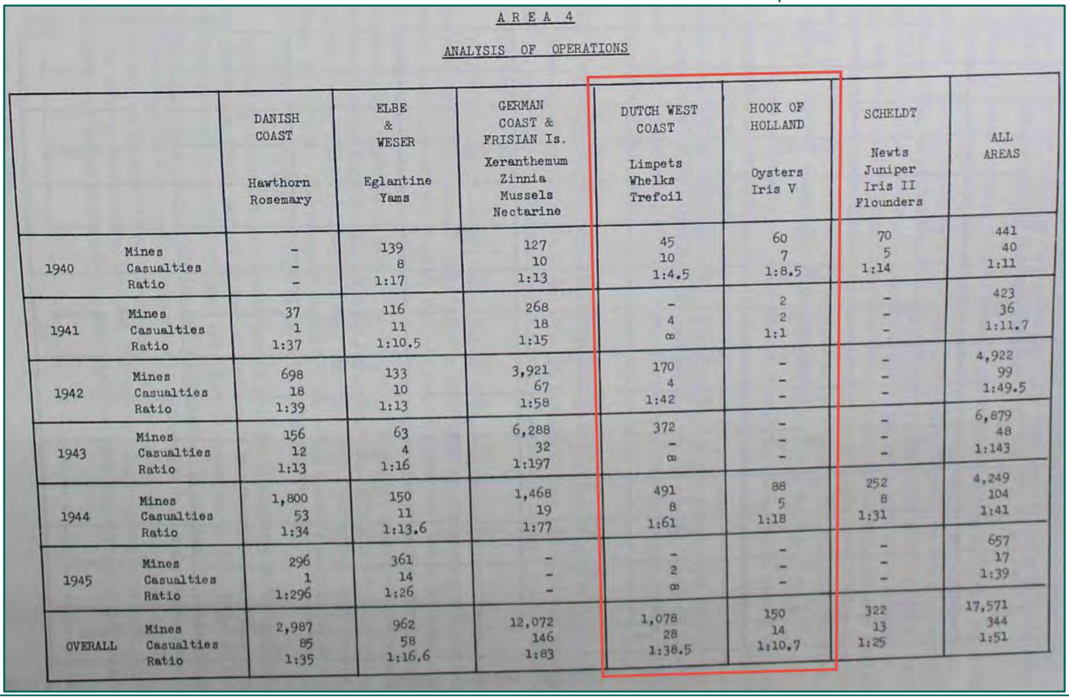


- Map showing:
  Air Minelaying in NW Europe:

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

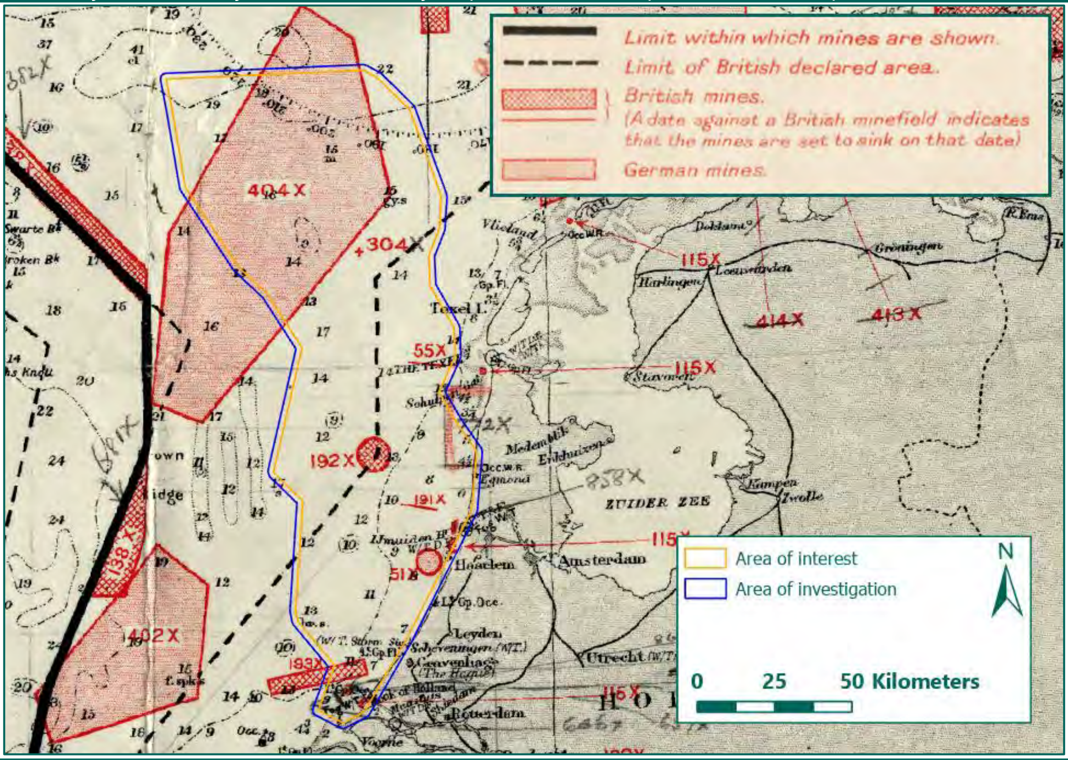
		DANISH COAST Hawthorn Rosemary	ELBE & WESER Eglantine Yams	GERMAN COAST & FRISIAN Is. Xeranthemum Zinnia Mussels Nectarine	DUTCH WEST COAST Limpets Whelks Trefoil	HOOK OF HOLLAND Oysters Iris V	SCHELDT Newts Juniper Iris II Flounders	ALL AREAS
1940	Mines Casualties Ratio	- - -	139 8 1:17	127 10 1:13	45 10 1:4.5	60 7 1:8.5	70 5 1:14	441 40 1:11
1941	Mines Casualties Ratio	37 1 1:37	116 11 1:10.5	268 18 1:15	- 4 ∞	2 2 1:1	- - -	423 36 1:11.7
1942	Mines Casualties Ratio	698 18 1:39	133 10 1:13	3,921 67 1:58	170 4 1:42	- - -	- - -	4,922 99 1:49.5
1943	Mines Casualties Ratio	156 12 1:13	63 4 1:16	6,288 32 1:197	372 - ∞	- - -	- - -	6,879 48 1:143
1944	Mines Casualties Ratio	1,800 53 1:34	150 11 1:13.6	1,468 19 1:77	491 8 1:61	88 5 1:18	252 8 1:31	4,249 104 1:41
1945	Mines Casualties Ratio	296 1 1:296	361 14 1:26	- - -	- 2 ∞	- - -	- - -	657 17 1:39
OVERALL	Mines Casualties Ratio	2,987 85 1:35	962 58 1:16.6	12,072 146 1:83	1,078 28 1:38.5	150 14 1:10.7	322 13 1:25	17,571 344 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)

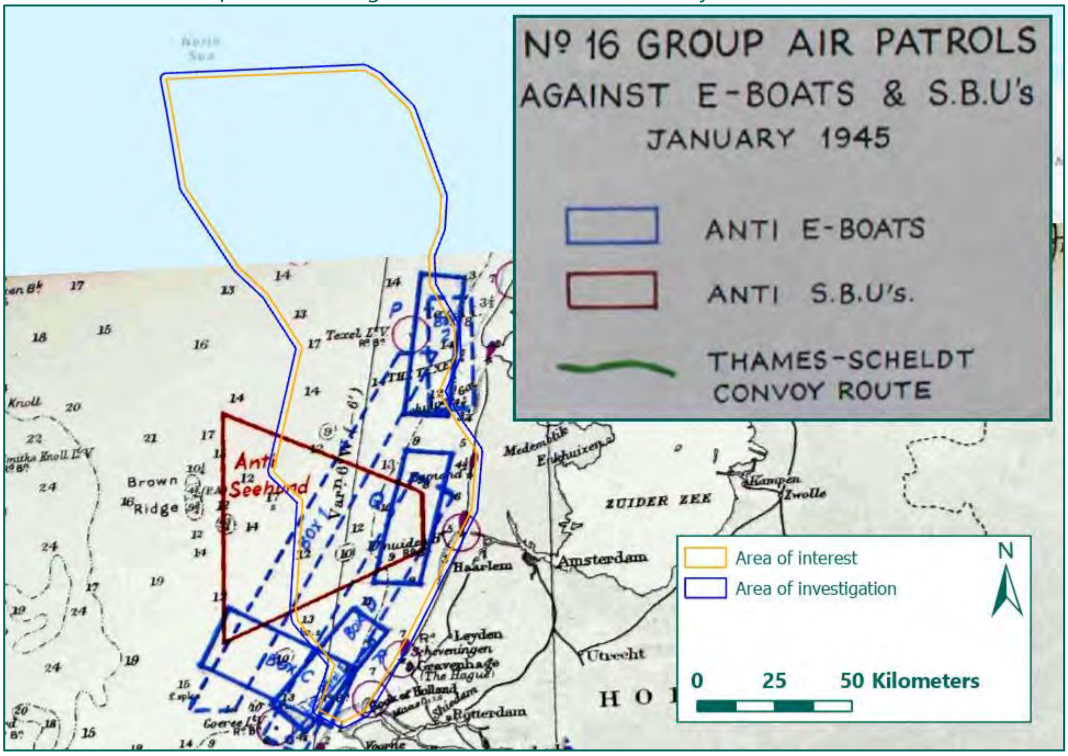


Cabinet and its committees (CAB)

Cabinet and its committees (CAB)	
CAB 101/324	Air Offensive Against Enemy Shipping and Bomber Command Minelaying Operations, 1 September 1944 - 5 May 1945

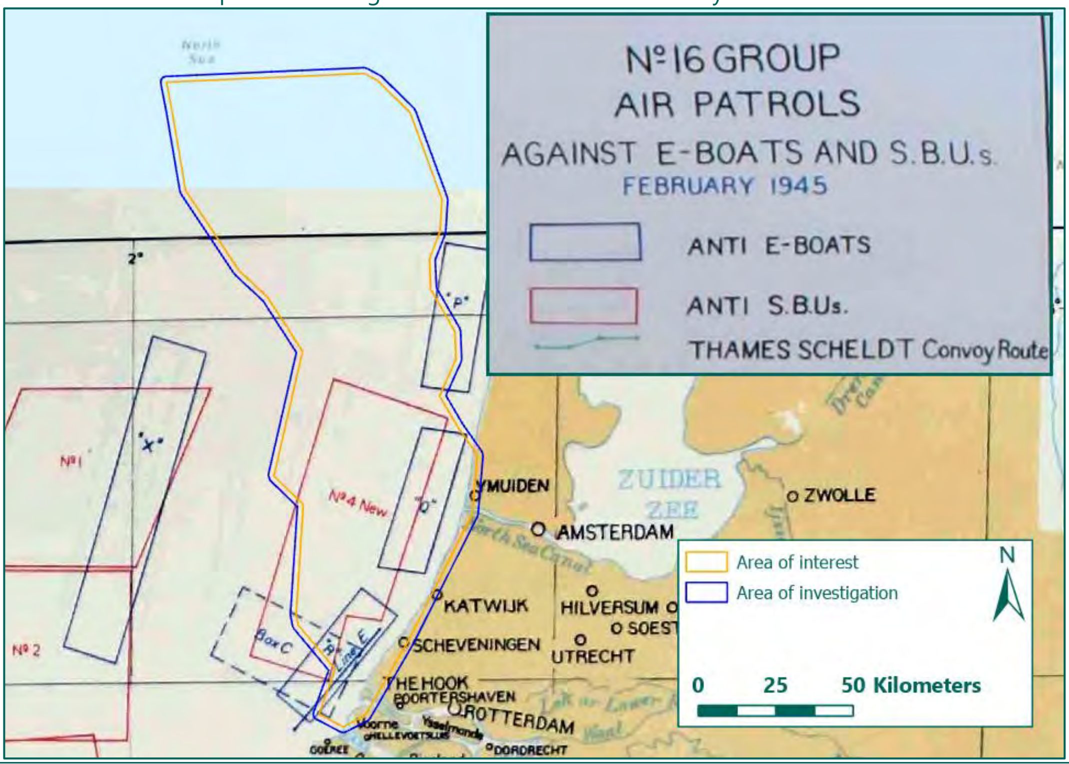
Relevant information:

- No.16 Group Air Patrols against E-Boats & S.B.U.'s January 1945.



Relevant information:

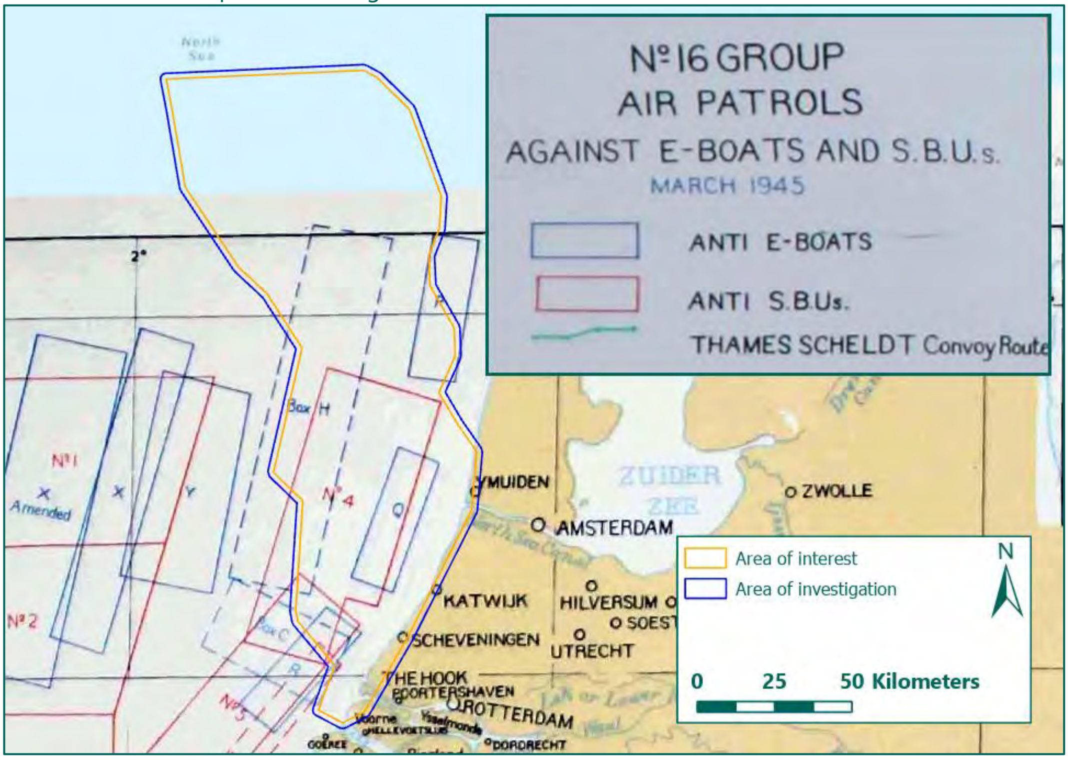
- No.16 Group Air Patrols against E-Boats & S.B.U.'s February 1945.



Cabinet and its committees (CAB)

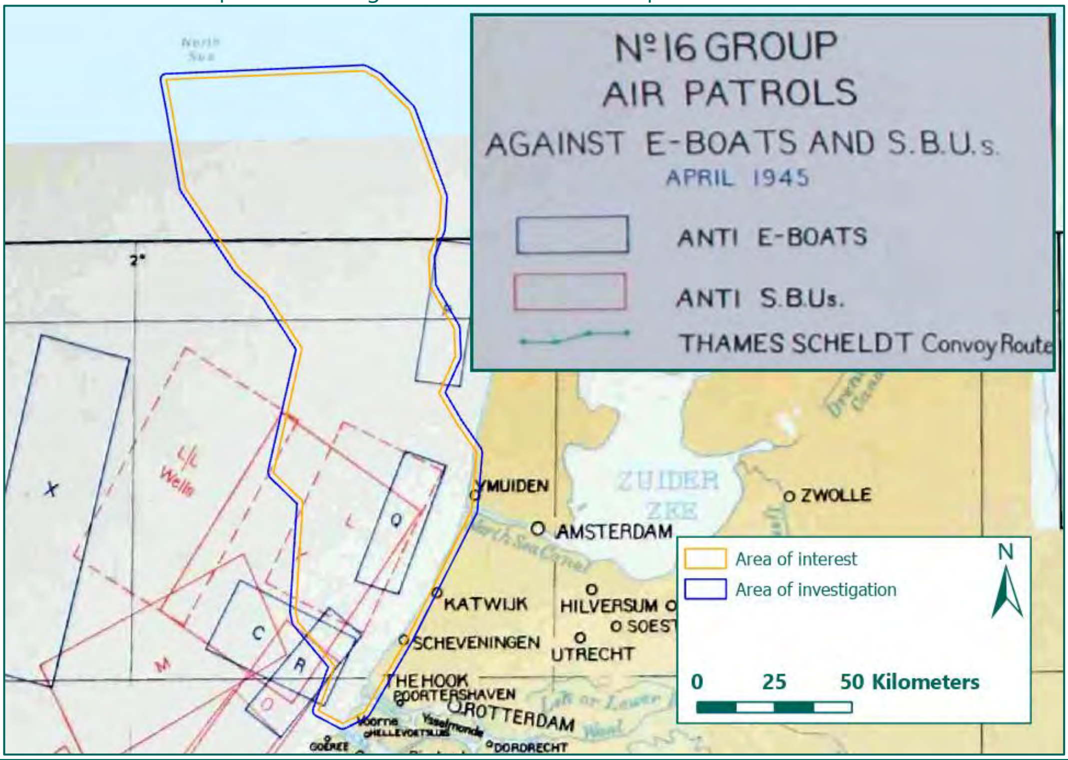
Relevant information:

- 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

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.

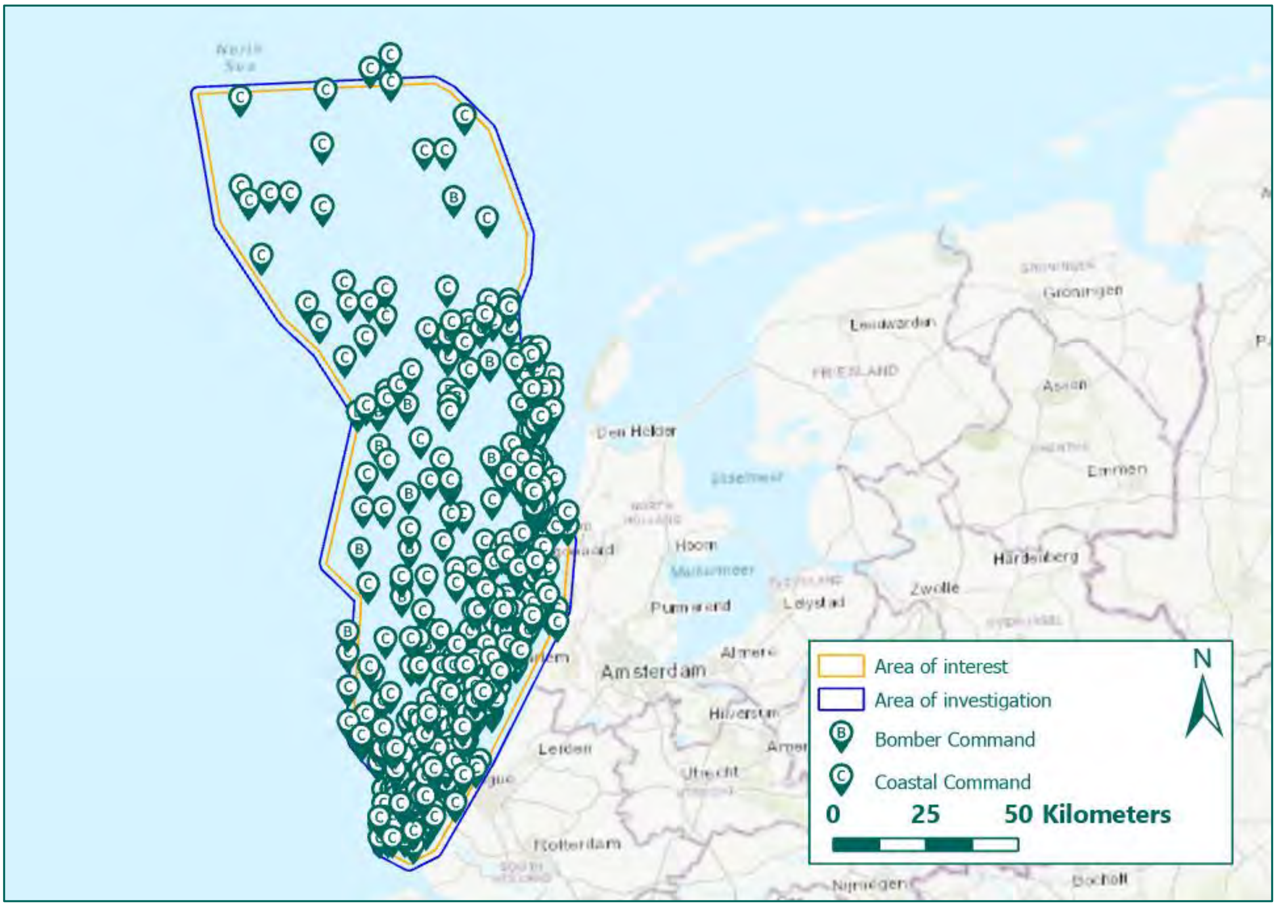


Figure 56: Locations of attacks, jettisons, crashes and relevant observations from Bomber Command and Coastal Command (Source basemap: ESRI).

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.

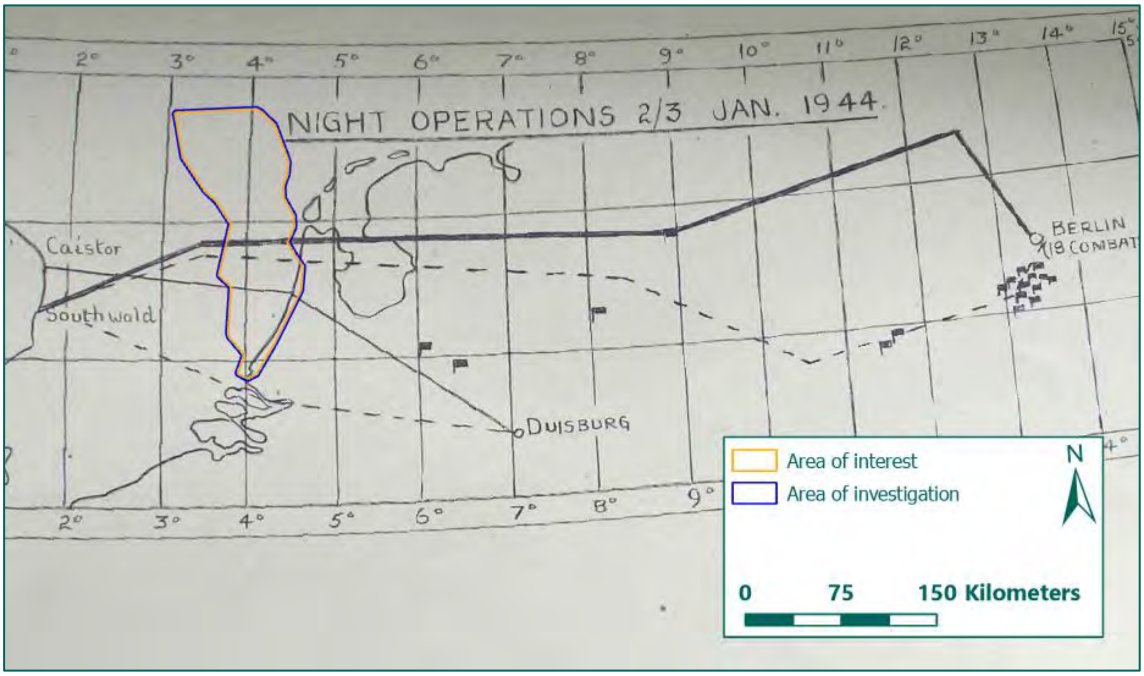


Figure 57: Example of a flight path over the area of investigation of bombers from Bomber Command, 2/3 January 1944 (Source, TNA, AIR 24/264).

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.

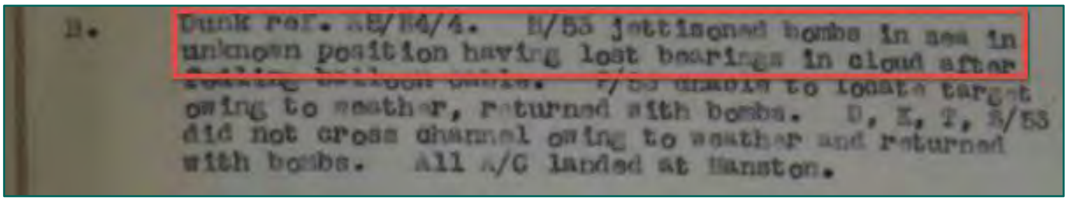

B. Dunk ref. AB/B4/4. H/53 jettisoned bombs in sea in unknown position having lost bearings in cloud after [illegible] F/53 unable to locate target owing to weather, returned with bombs. D, E, T, S/53 did not cross channel owing to weather and returned with bombs. All A/C landed at Manston.

Figure 1: Blenheim Bomber jettisoned its bombs at an unknown position in the Northsea (Bron: TNA, AIR 24/375).

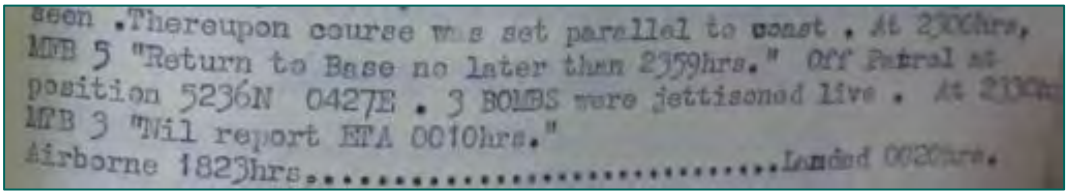

seen .Thereupon course was set parallel to coast . At 2300hrs, MFB 5 "Return to Base no later than 2359hrs." Off Patrol at position 5236N 0427E . 3 BOMBS were jettisoned live . At 2300hrs MFB 3 "Nil report ETA 0010hrs."
Airborne 1823hrs.................................Landed 0020hrs.

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 arm ed with 5 x 500lb
bom bs 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 arm ed with torpedoes 10ft setting.
Patrol carried out. At 0250 MTB 1 'Nil sighting' and VHF MT
Beaufighters 'Nothing'. At 0258 2 bom bs 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.

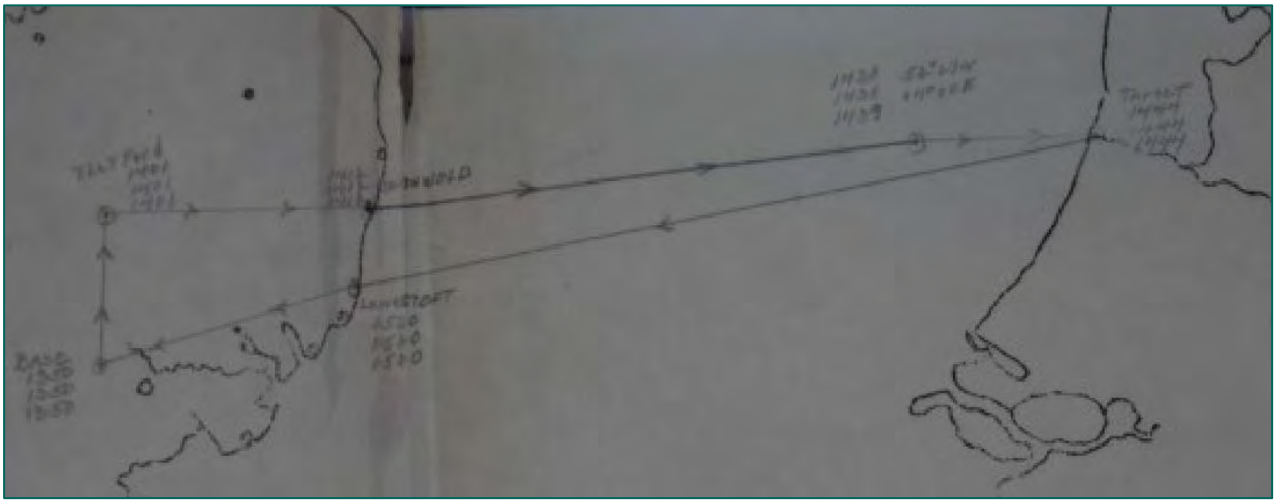


Figure 60: The flightpath of aircraft of USAAF on 26 March 1944 (Source: NARA Box RG18, Box 1388).

No further files have been consulted with regards of the area of investigation. Consulting these sources is outside the scope of this research.

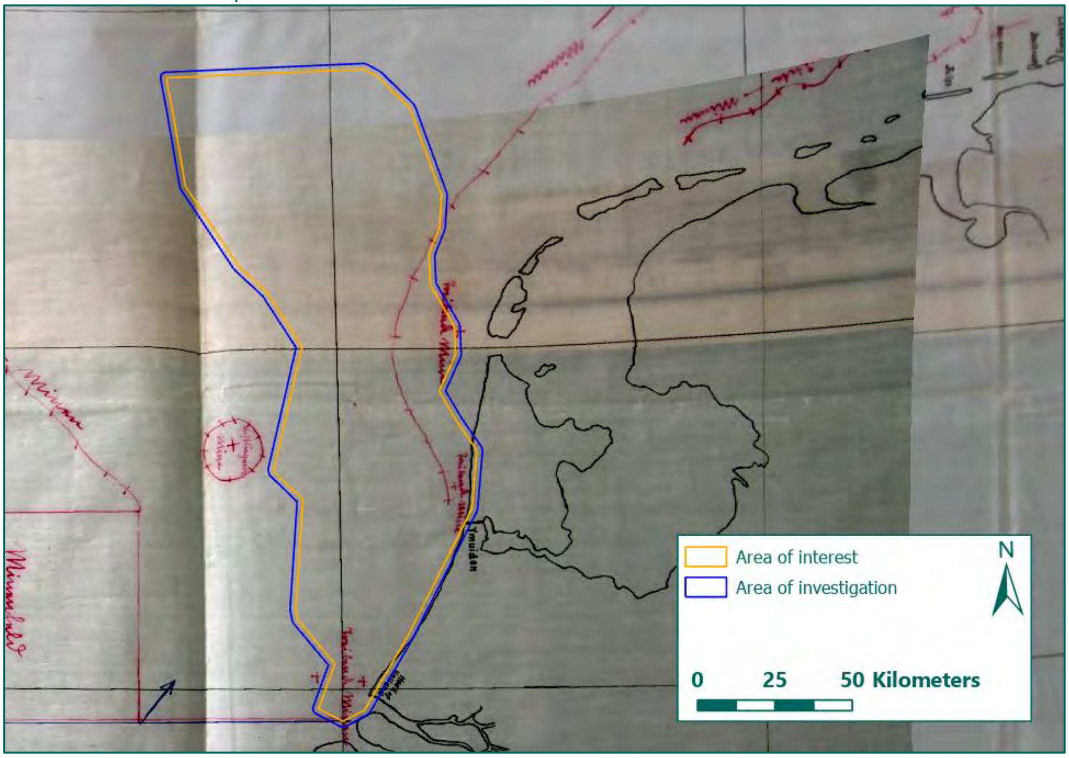
Bundesarchiv-Militärarchiv (BAMA)

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:

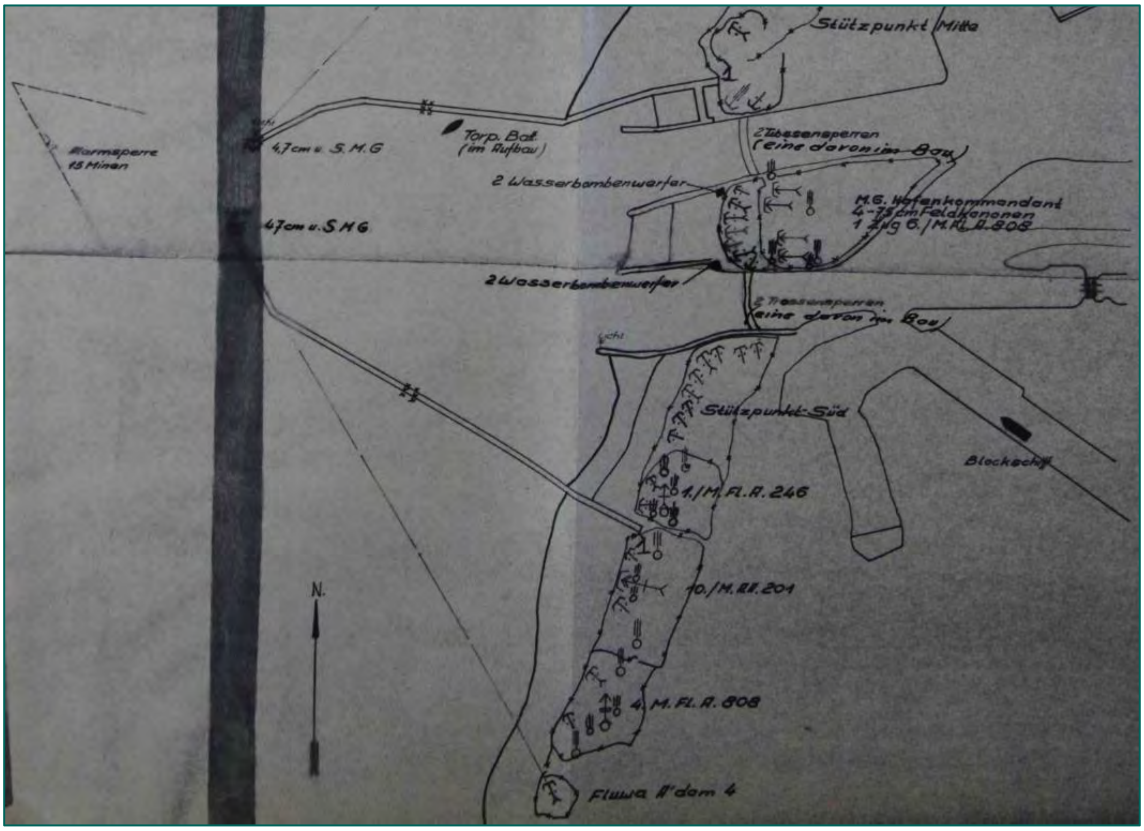
RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.	
The Admiralty of the Imperial Navy was the highest level of command of the German Navy during the First World War. Record Group RM5 contains documents from the admiralty. The following documents are considered relevant for the area of investigation.	
RM 5/4721K	Kommando der Hochseestreitkräfte: "Zusammenstellung der bisher bekannten Minensperren und minenverdächtigen Gebiete". Druck, 3.3.1915
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.	

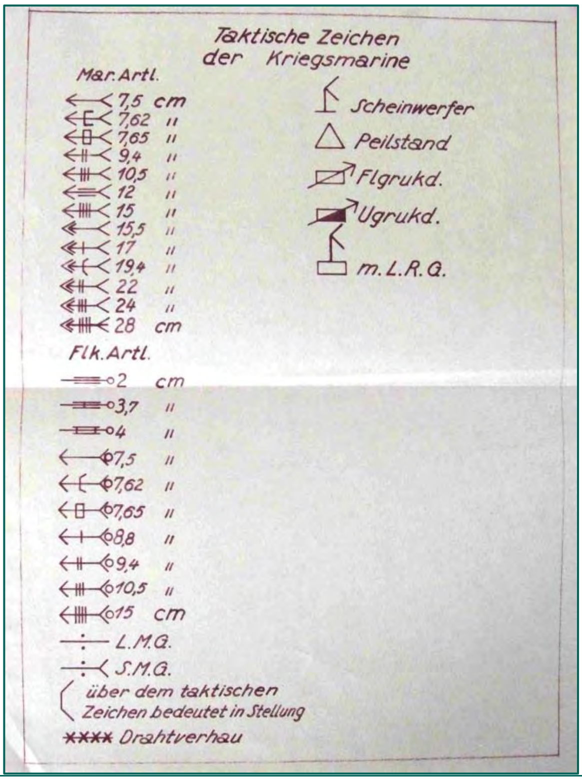


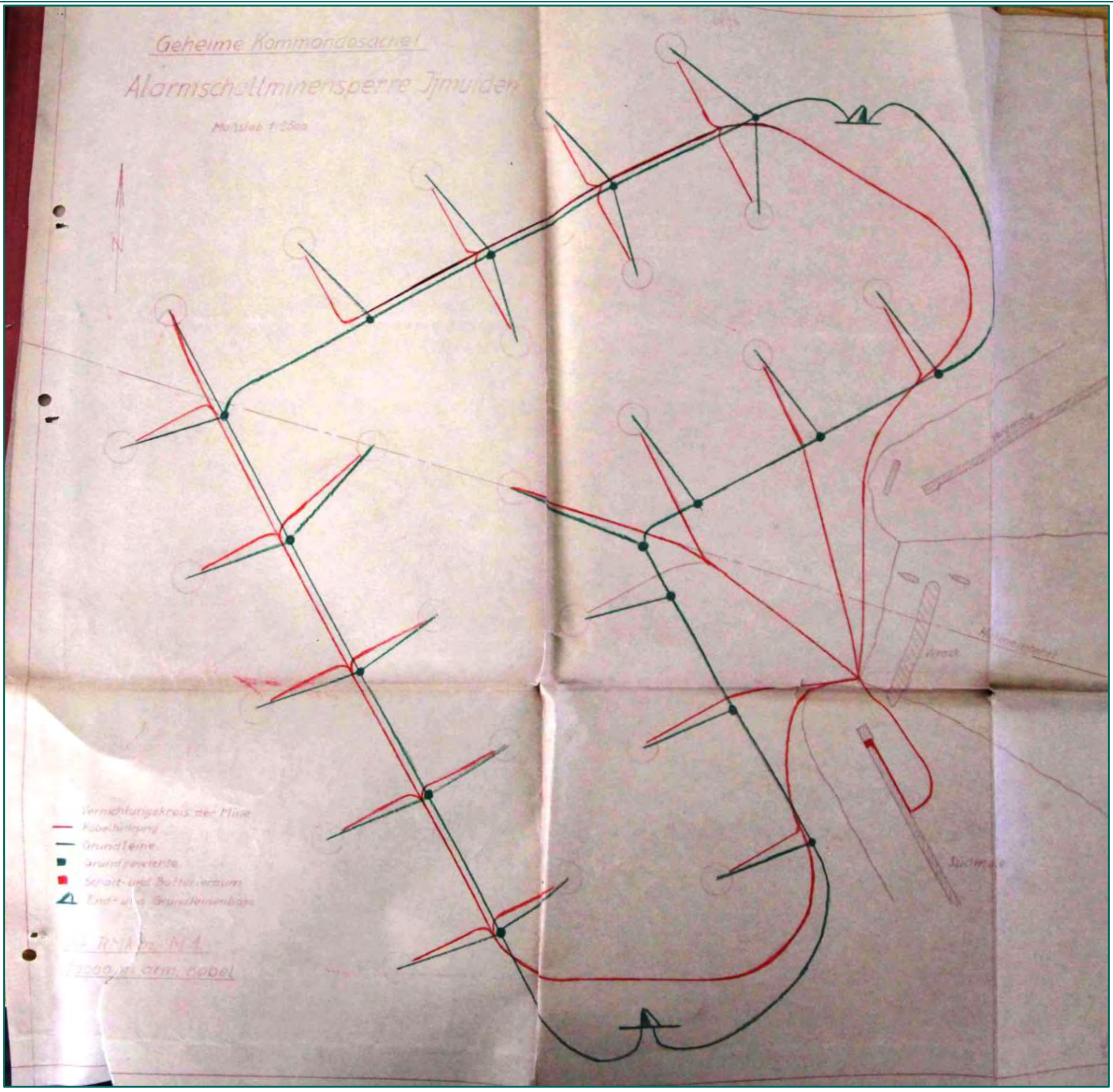
Within the area of investigation the map shows 'Treibende Minen' (Contact mines).	

RM 35-I: Marinegruppenkommando Ost – Nord der Kriegsmarine.	
The *Marinegruppenkommando Ost – Nord* operated as the commander of the units that had to secure the East and North Sea.	
RM 35-I/277	Minenlage Nord (M.L.N.) 1. Mai 1942 - 1. Okt. 1943

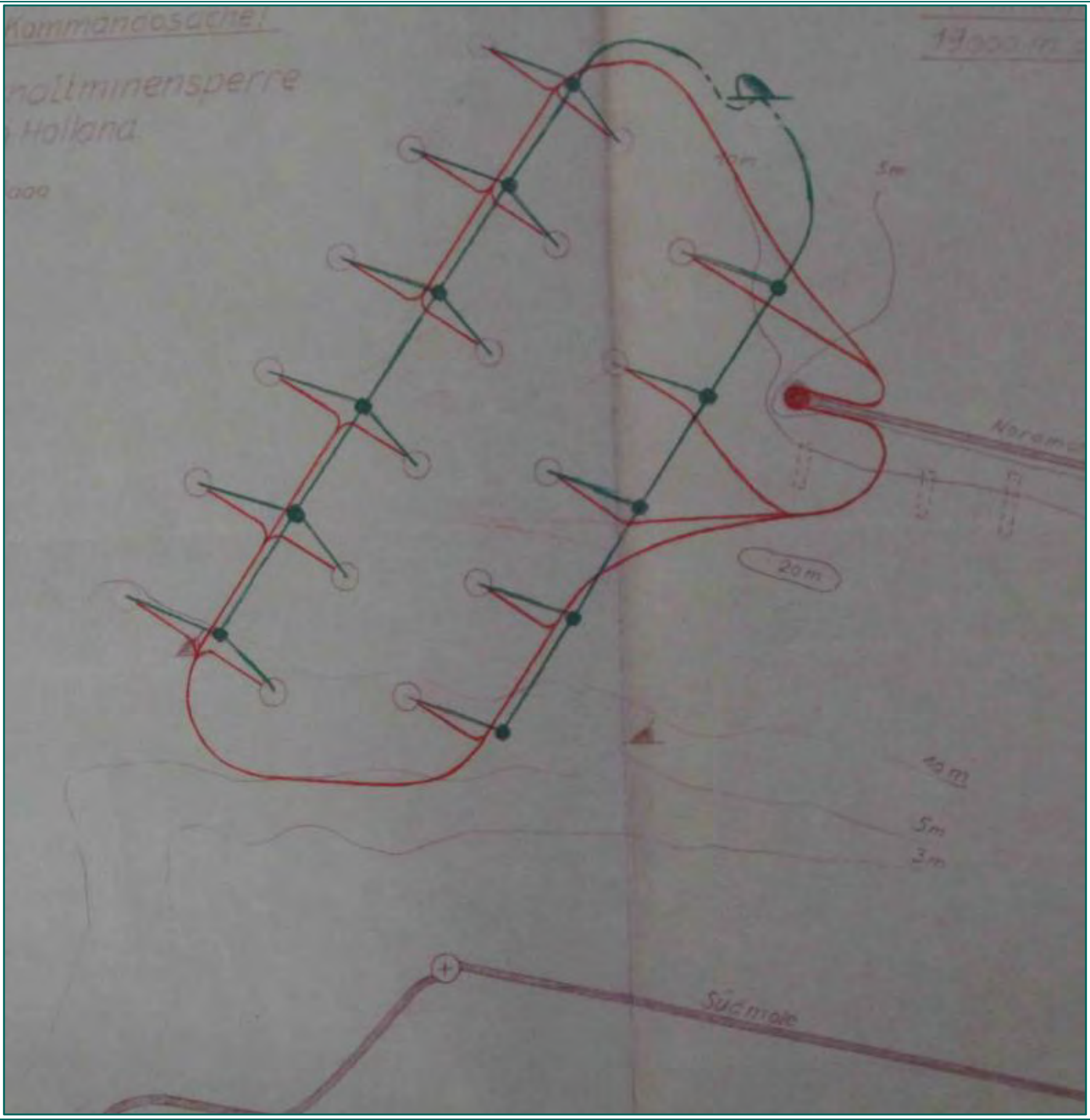
Map showing the defences of IJmuiden harbour. A warning minefield is situated in front of the port entrance. The minefield consisted of 24 RMA magnetic ground mines. The mines had a remote controlled detonator and each mine was coupled to a device on land. This gave the German defender the option to turn the mines on and off.



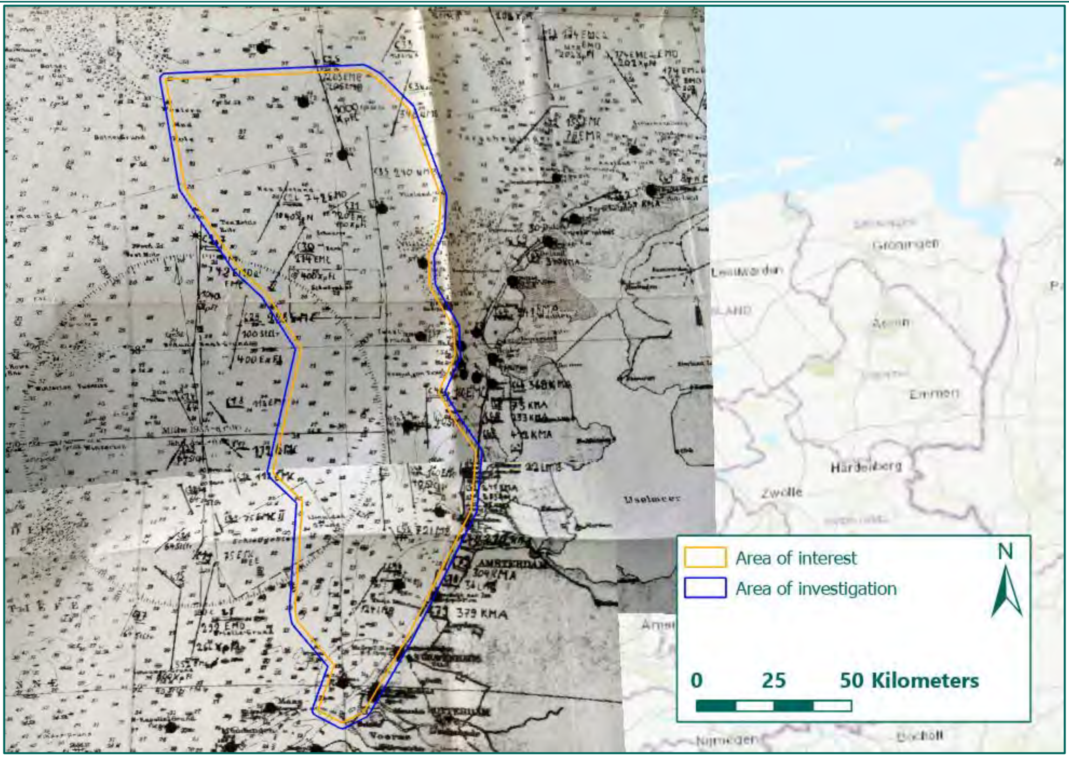




Map showing a minefield consisted of 17 RMA magnetic ground mines at the Hoek van Holland.



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 XpFl		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 XpFl		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 XpFl		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 ExFl		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 XpFl		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 XpFl		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 340 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 accurate	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 accurate	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 accurate	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 mibe 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 BMC	DM1	G M	 10	180 180	1 1	165	Mean mine spacing 90 yds. Arming delay 24 hours. BMC 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.

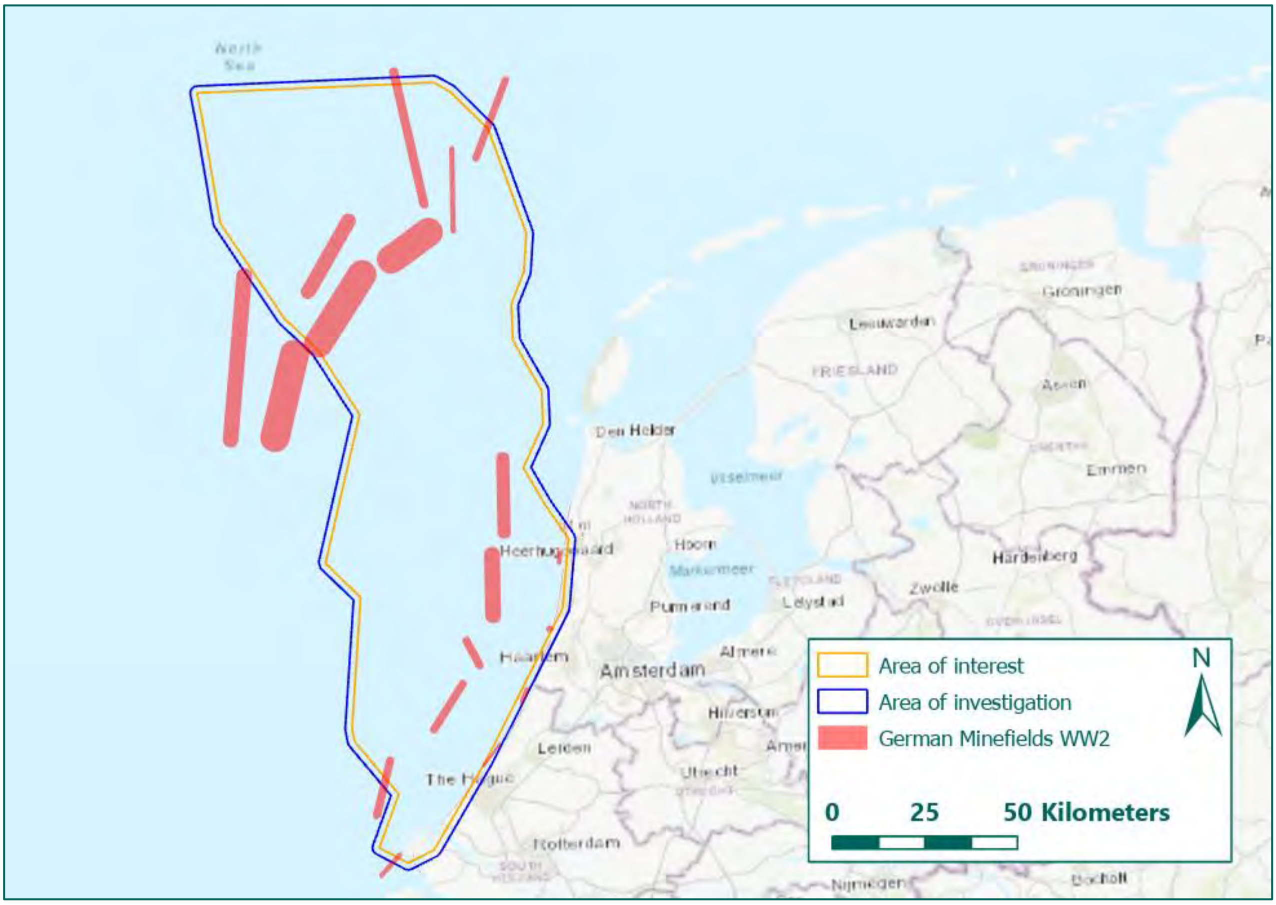


Figure 61: German Minefields within the Area of investigation (Source basemap: ESRI).

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

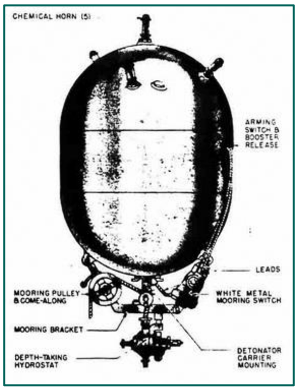
[7] *Einheidsmine* – Type B, Contact mine
[8] Exploding floats, *Sprengboje*
[9] *Einheidsmine* – Type D, Contact mine
[10] *Einheidsmine* – Type C, Contact mine
[11] Static cutters/Static Conical Sweep Obstructor, *Reisboje*
[12] *U-Bootabwehrmine* – Type B, Contact Mine
[13] *Luft Mine* – Type B, Influence Mine

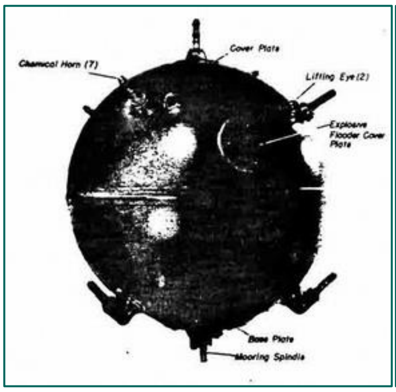
Number	Amount of mines	Rows	
		Amount	Spacing
C46	124 x LMB	2	Unknown
C47	160 x EMC, 40 x StCtr	3	Unknown
C48	160 x EMC, 40 x StCtr	3	Unknown
C67	412 x KMA[14]	2	Unknown
C69	KMA (unknown amount)	2	Unknown
C70	75 x KMA	2	Unknown
C71	285 x KMA	2	Unknown
C72	304 x KMA	2	Unknown
C73	210 x KMA	2	Unknown
C78	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

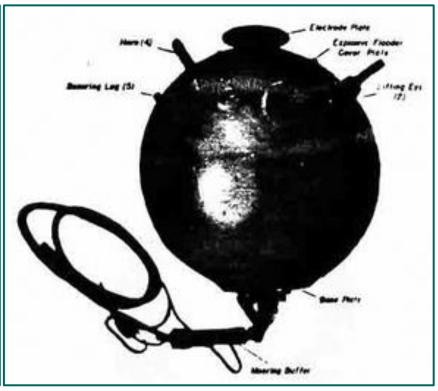
[14] Küstenmine – Type A, Contactmine
[15] Regulare Mine – Type A, Contactmine

German Mines (and sweep obstructors) within the area of investigation)

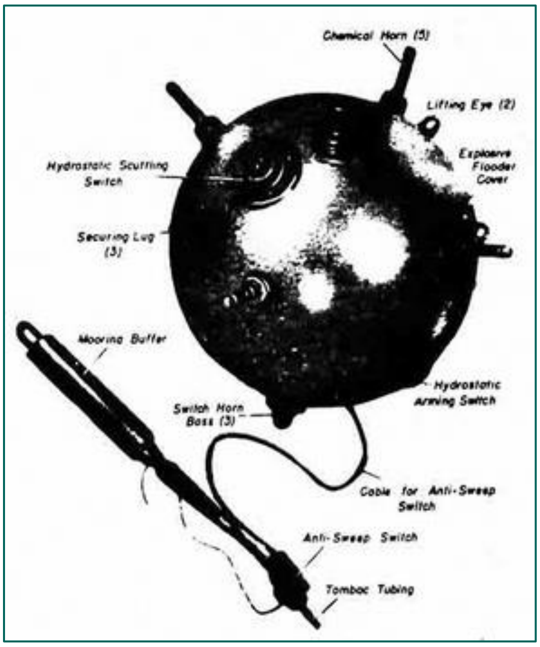
Einheidsmine – Type B, C and D Contact mine



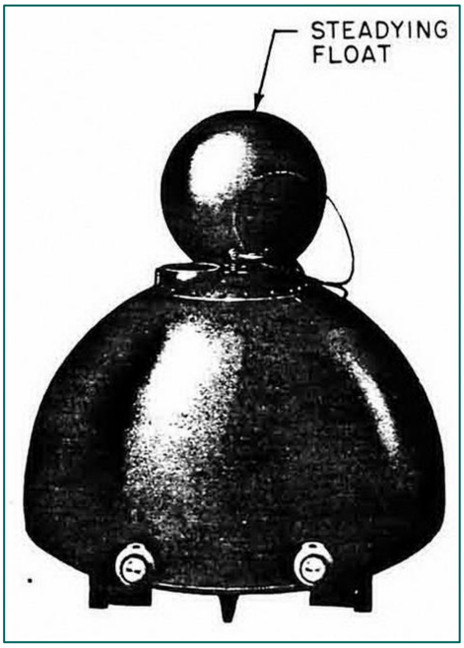




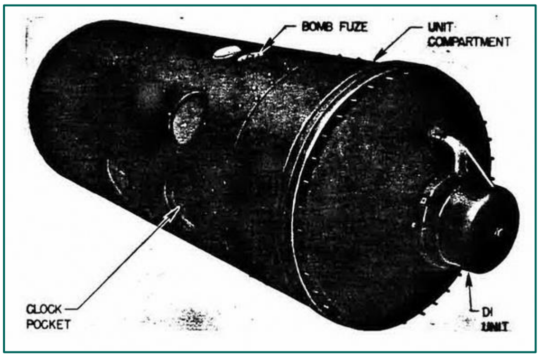
U-Bootabwehrmine – Type A, Contact Mine



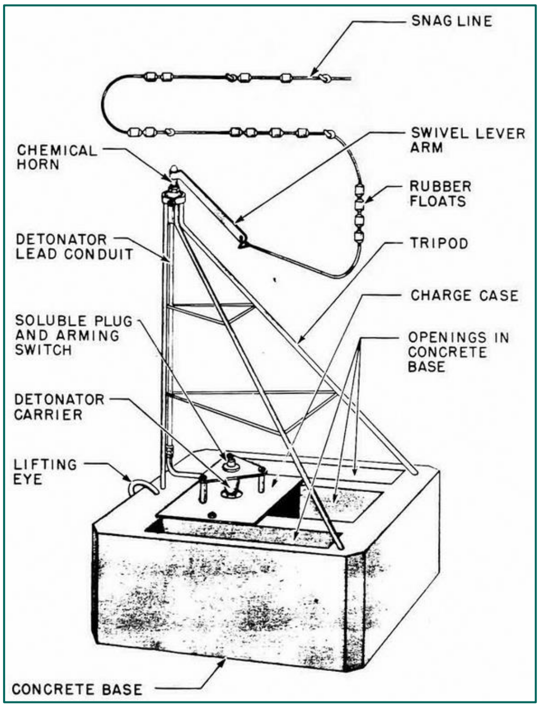
Regulare Mine – Type A, Contactmine

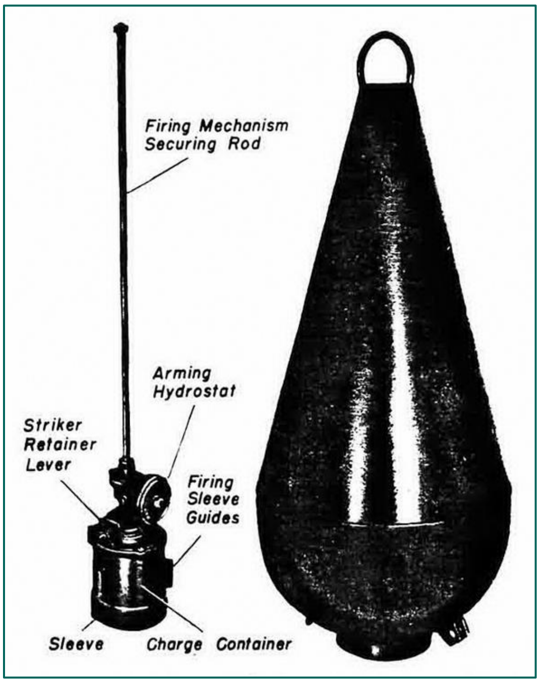


<table>
<tr><th colspan="2">German Mines (and sweep obstructors) within the area of investigation</th></tr>
<tr><td>Luft Mine – Type B, Influence/Ground Mine



</td>
<td>Küstenmine – Type A, Contactmine


</td></tr>
<tr><td>Exploding floats, *Sprengboje* (Explosive)


</td>
<td>Static cutters/Static Conical Sweep Obstructor, *Reisboje* (Non explosive)

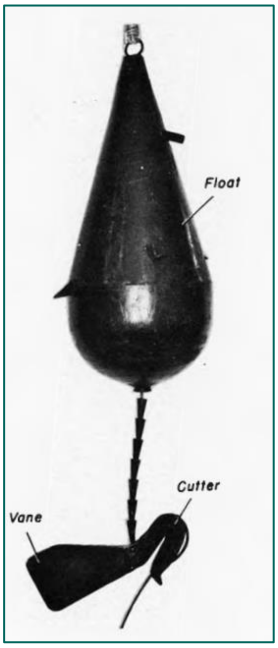

</td></tr>
</table>

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.

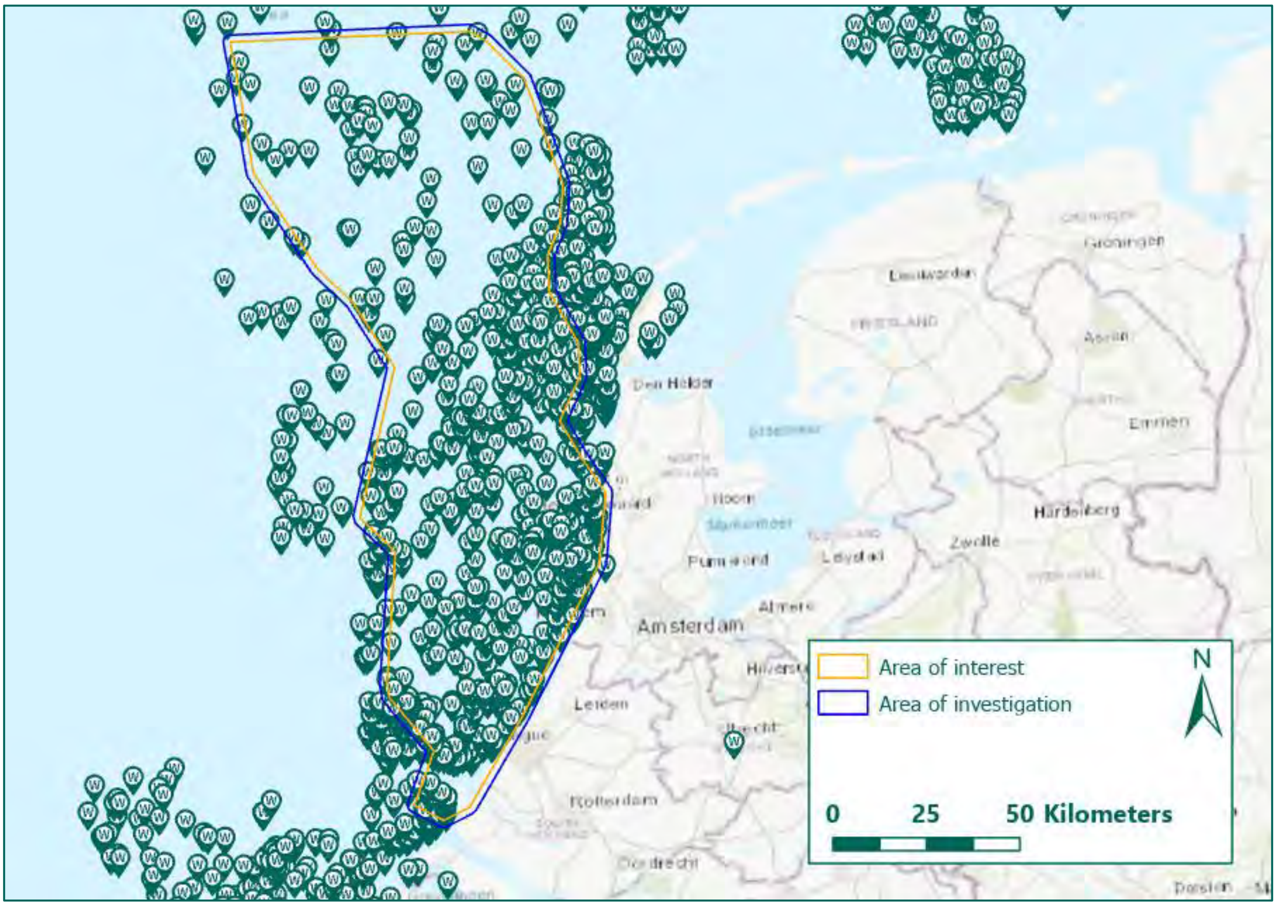


Figure 62: Overview of wrecks within the area of interest according to HP39 (Source: HP39).

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.

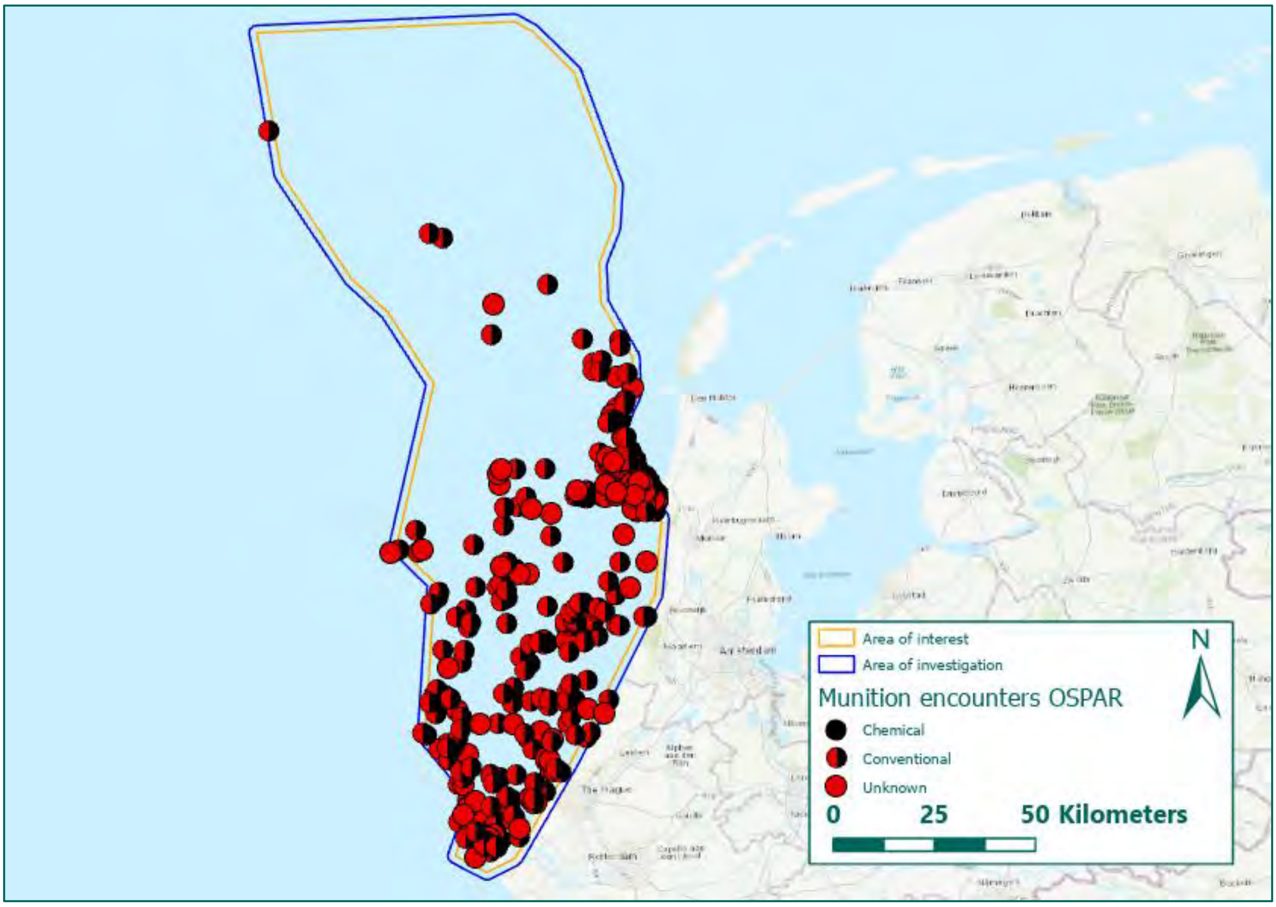


Figure 63: Overview OSPAR ammunition encounters within the area of interest (Source: OSPAR).

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.

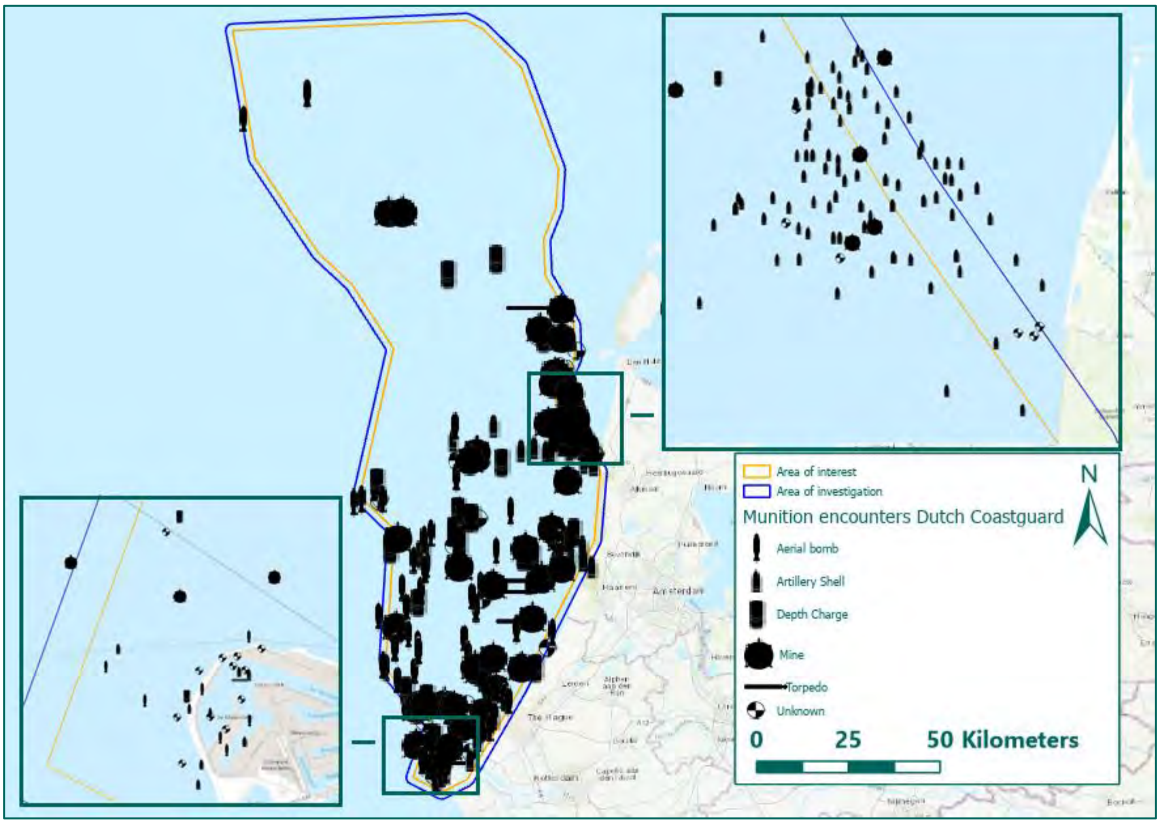


Figure 64: Overview of UXO lifted by the Dutch Coastguard (Source basemap: ESRI).

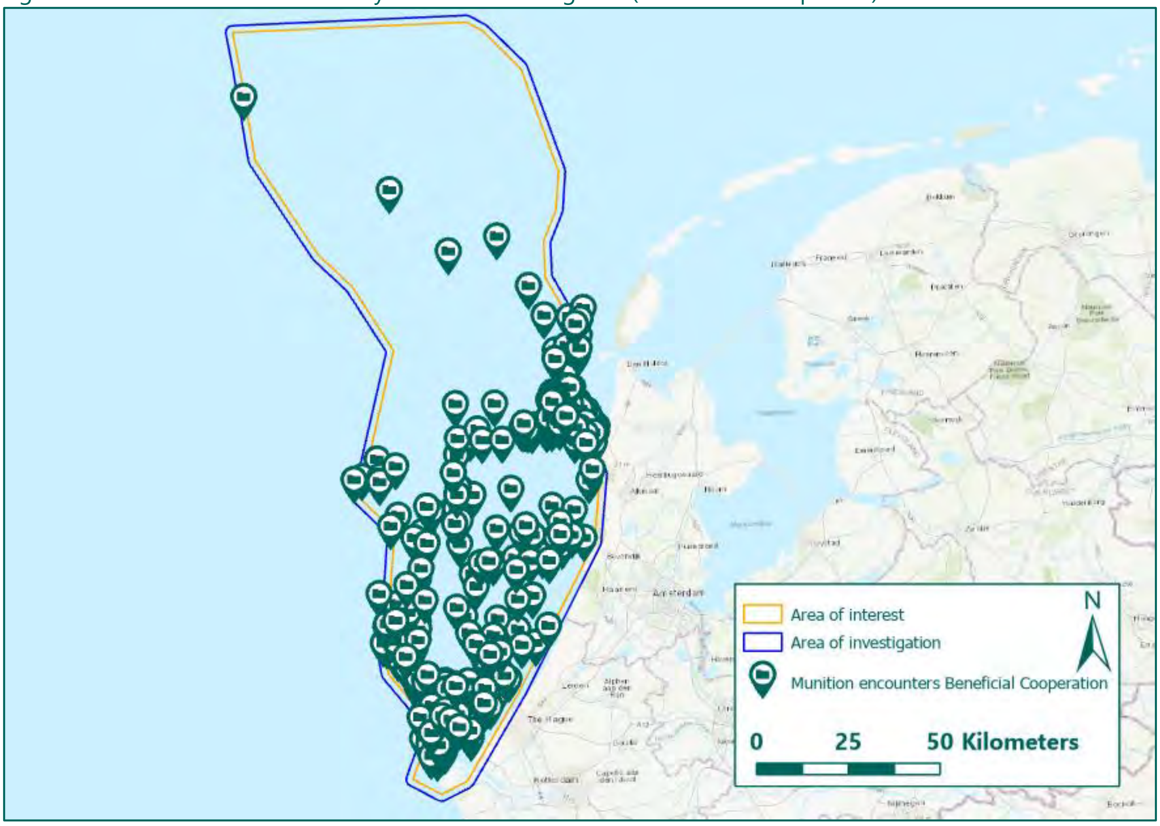
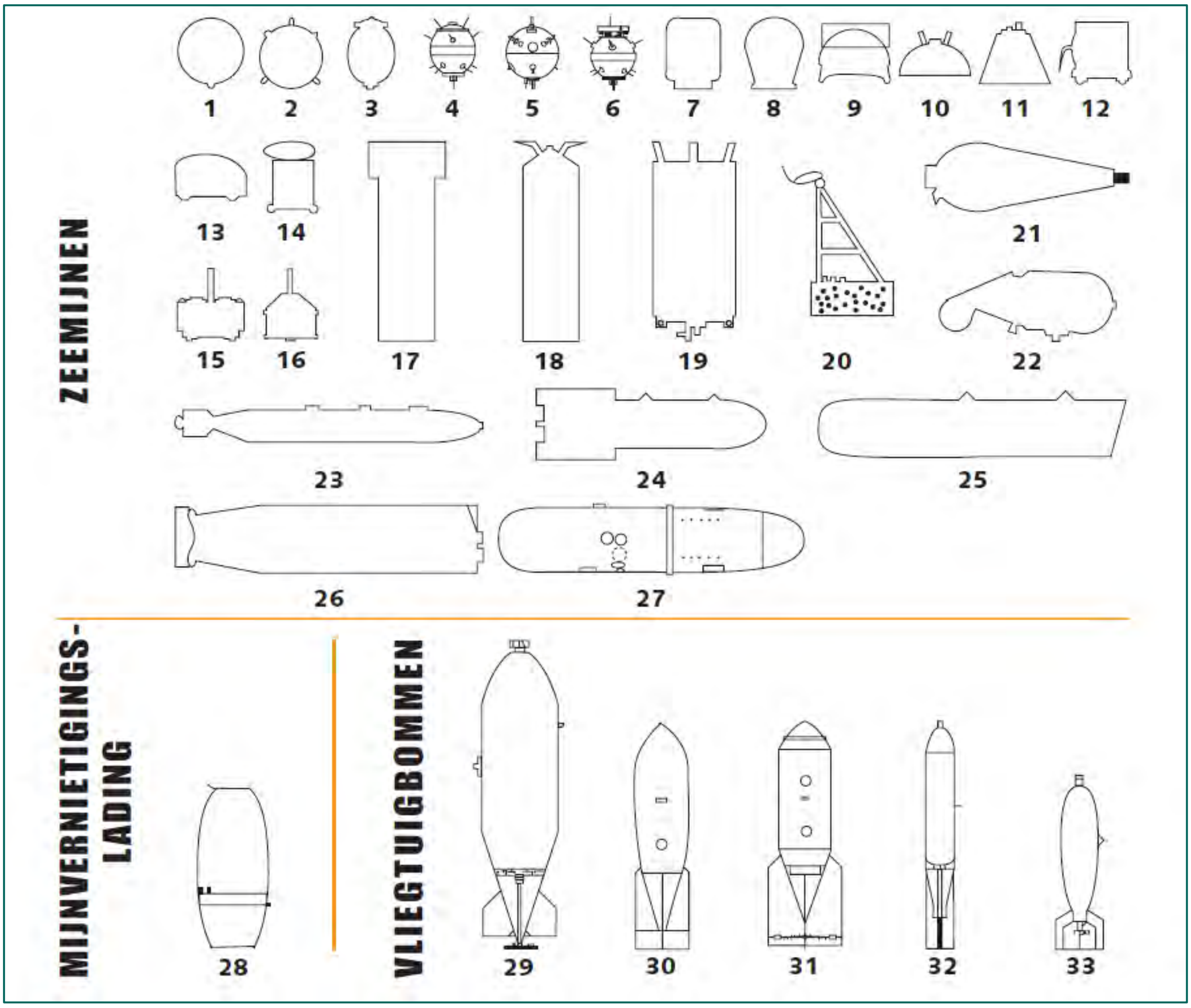


Figure 65: Overview of UXO lifted by the Beneficial Cooperation (Source basemap: ESRI).


ZEEMIJNEN
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MIJNVERNIETIGINGS-
LADING
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VLIEGTUIGBOMMEN
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33

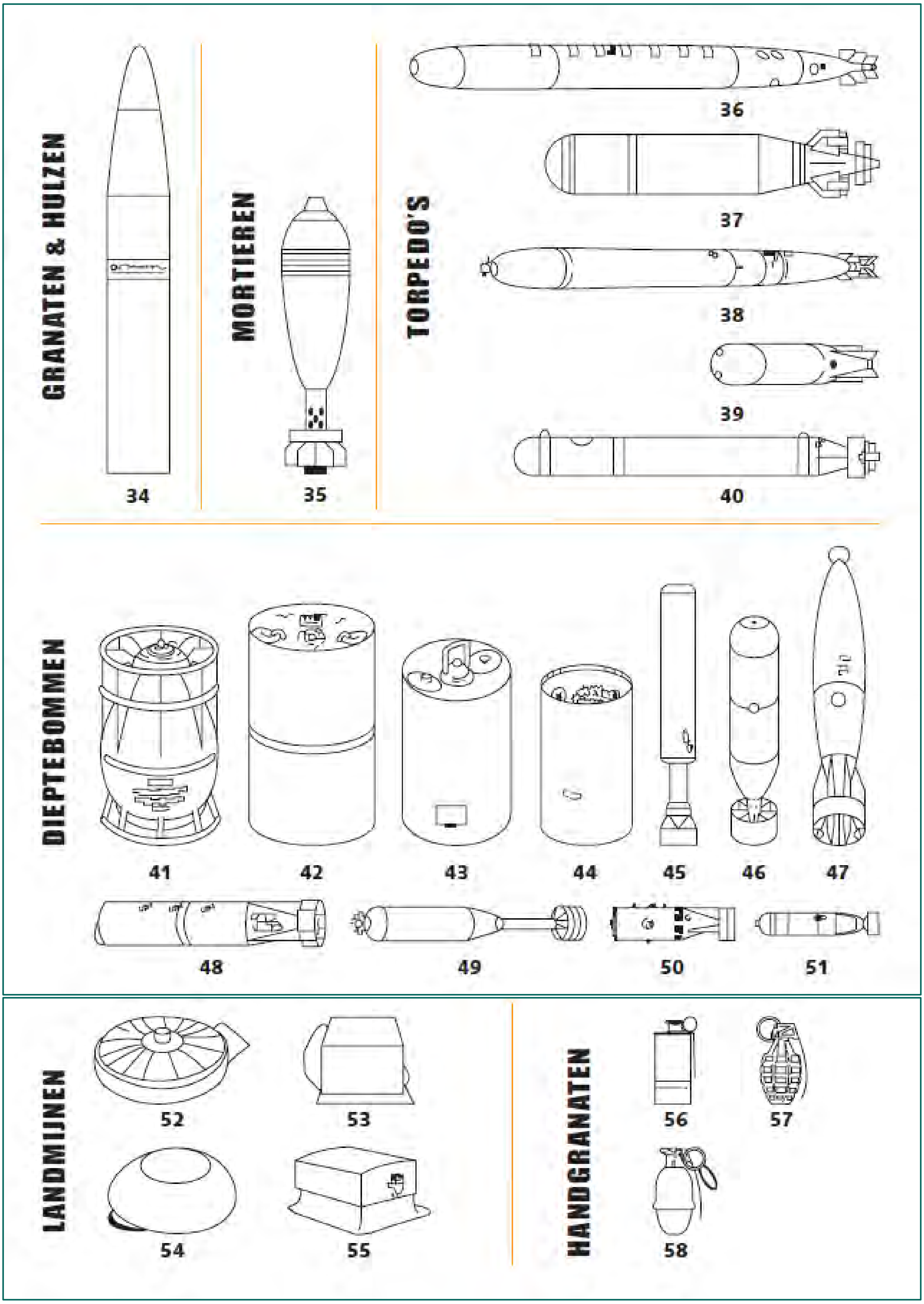

Figure 66: 'Explosievenkaart' (Explosives chart) of the Dutch Coastguard. This chart is used to help identify UXO (Source: Dutch Coastguard).

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.

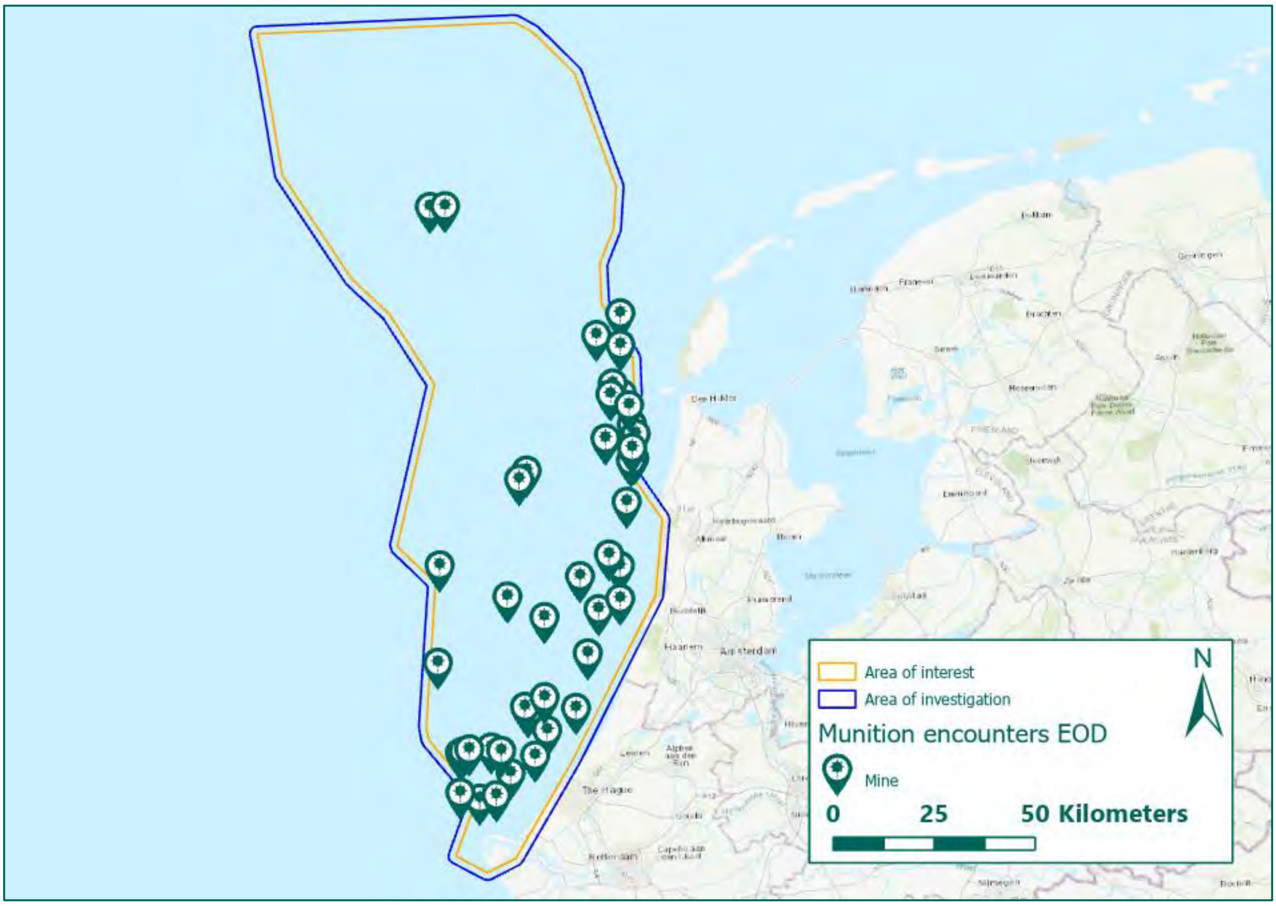

Figure 67: Overview of UXO lifted by the Dutch EOD (Source basemap: ESRI).

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] 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]

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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.

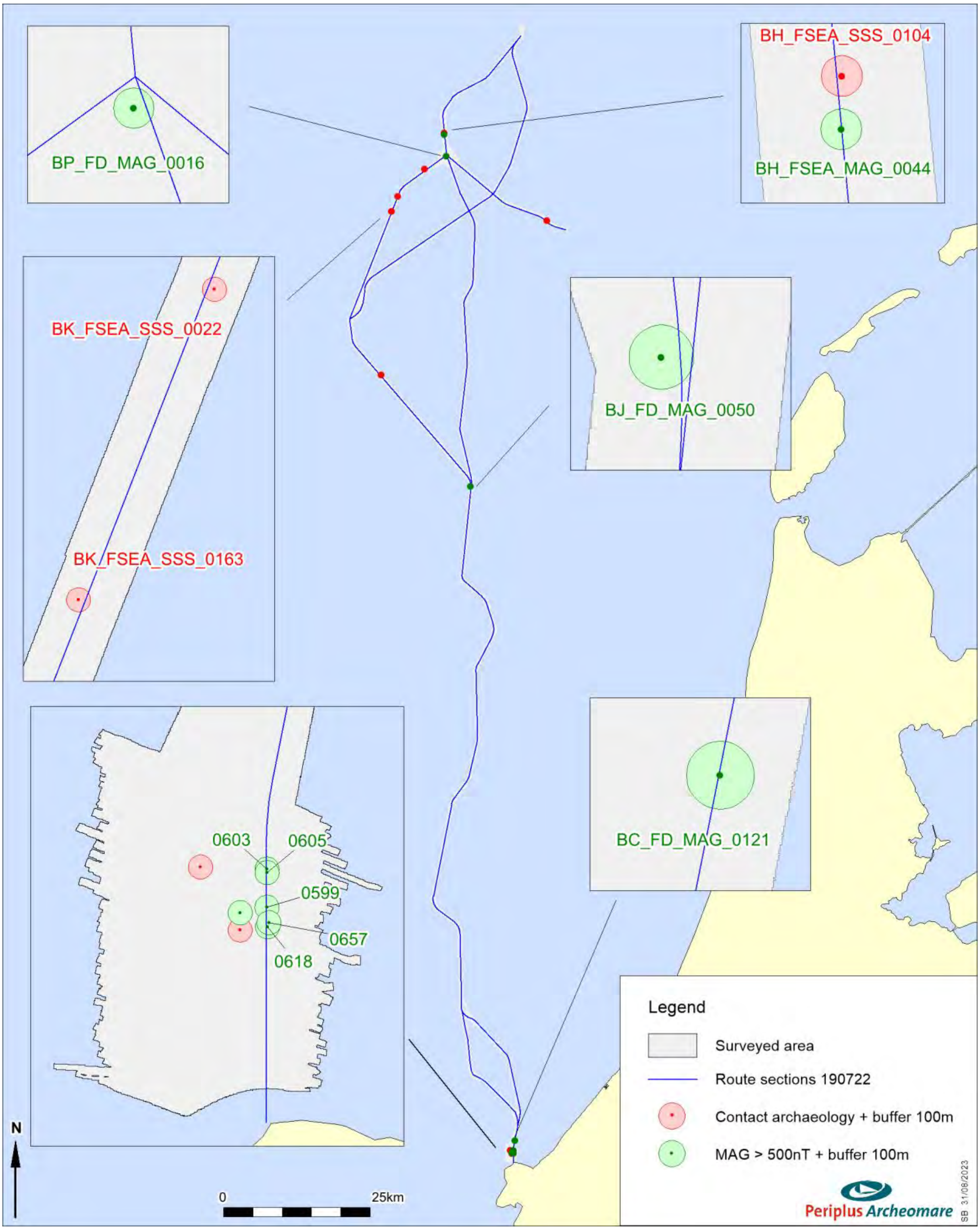

Figure 1. Overview of the potential archaeological targets within 100 meters of the proposed route

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].

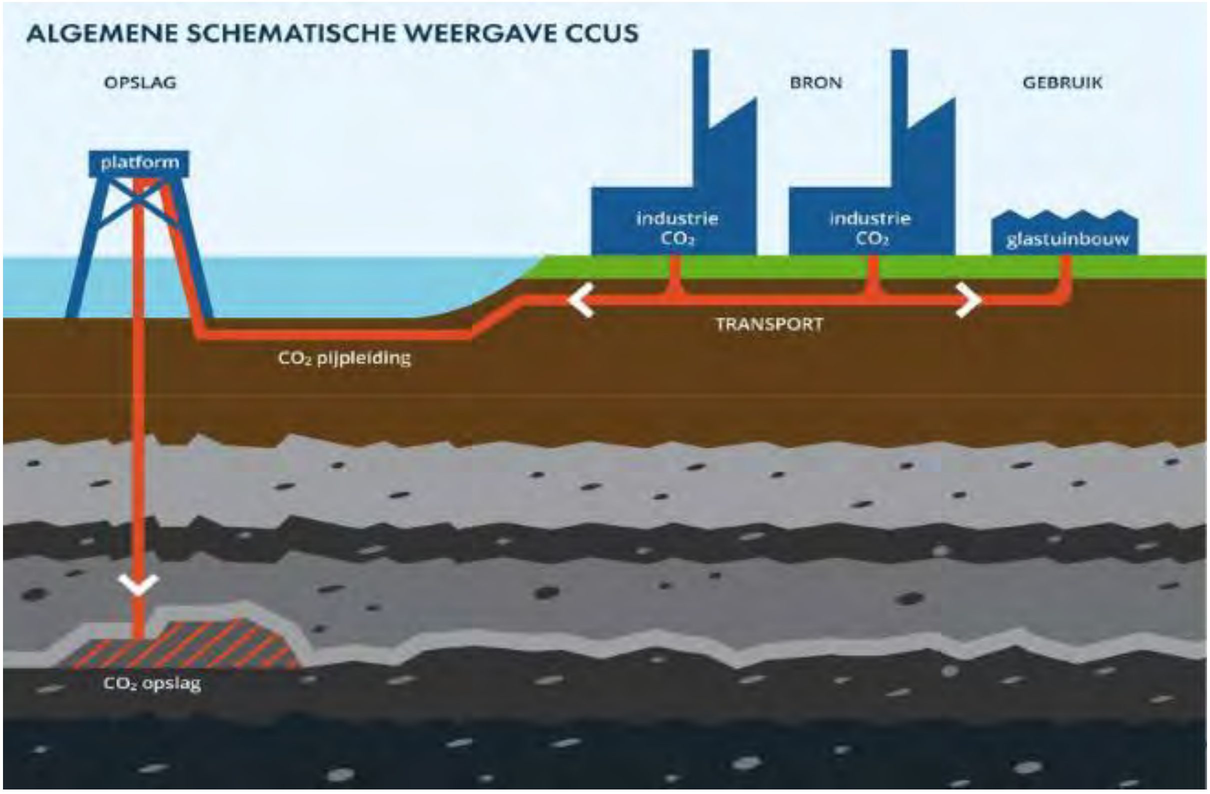

Figure 3: Schematic representation of the transport and storage system.

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.

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[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

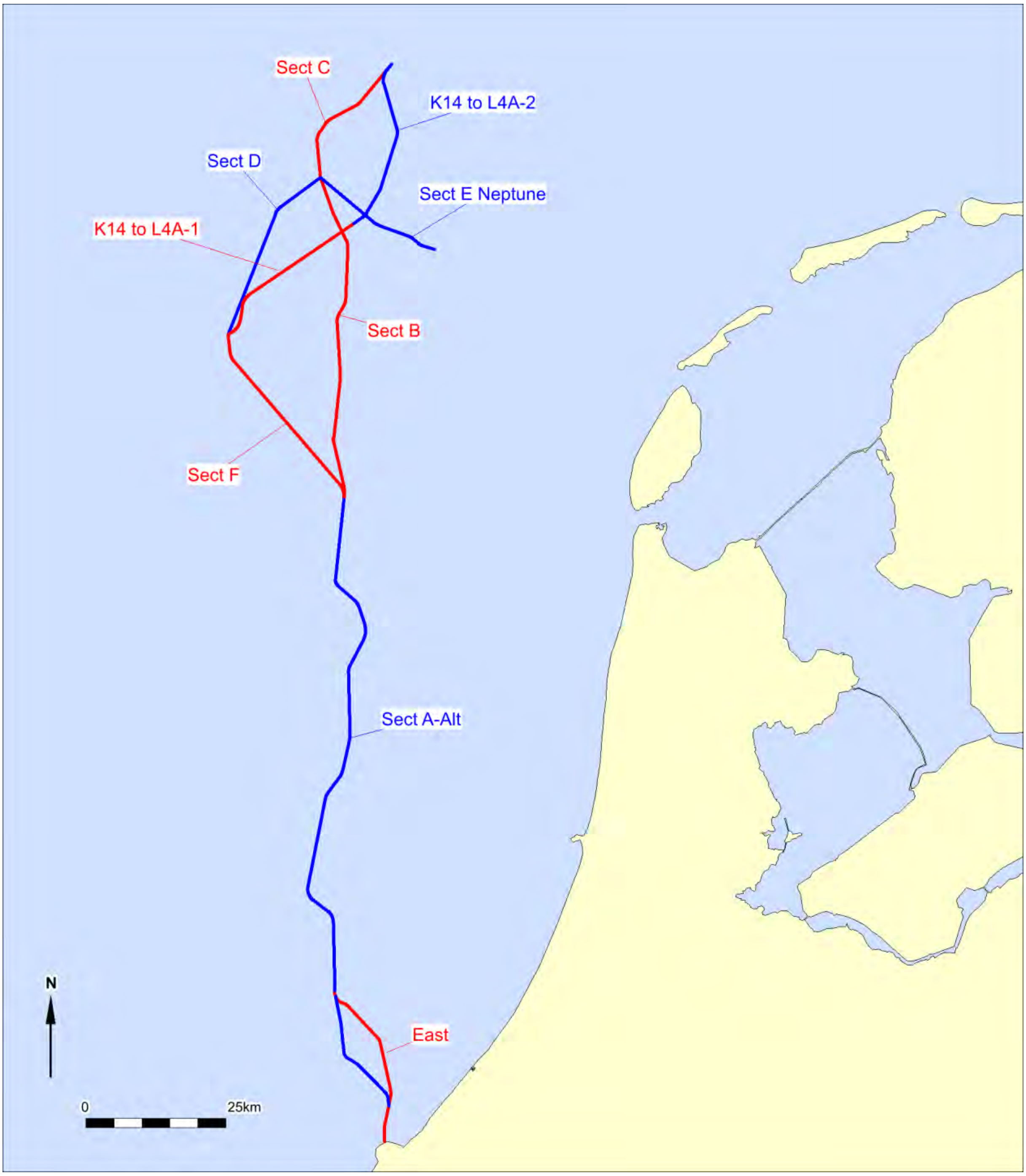

Figure 4. Sections bathymetric profiles based on the multibeam recordings (source data: Fugro 2022)

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.

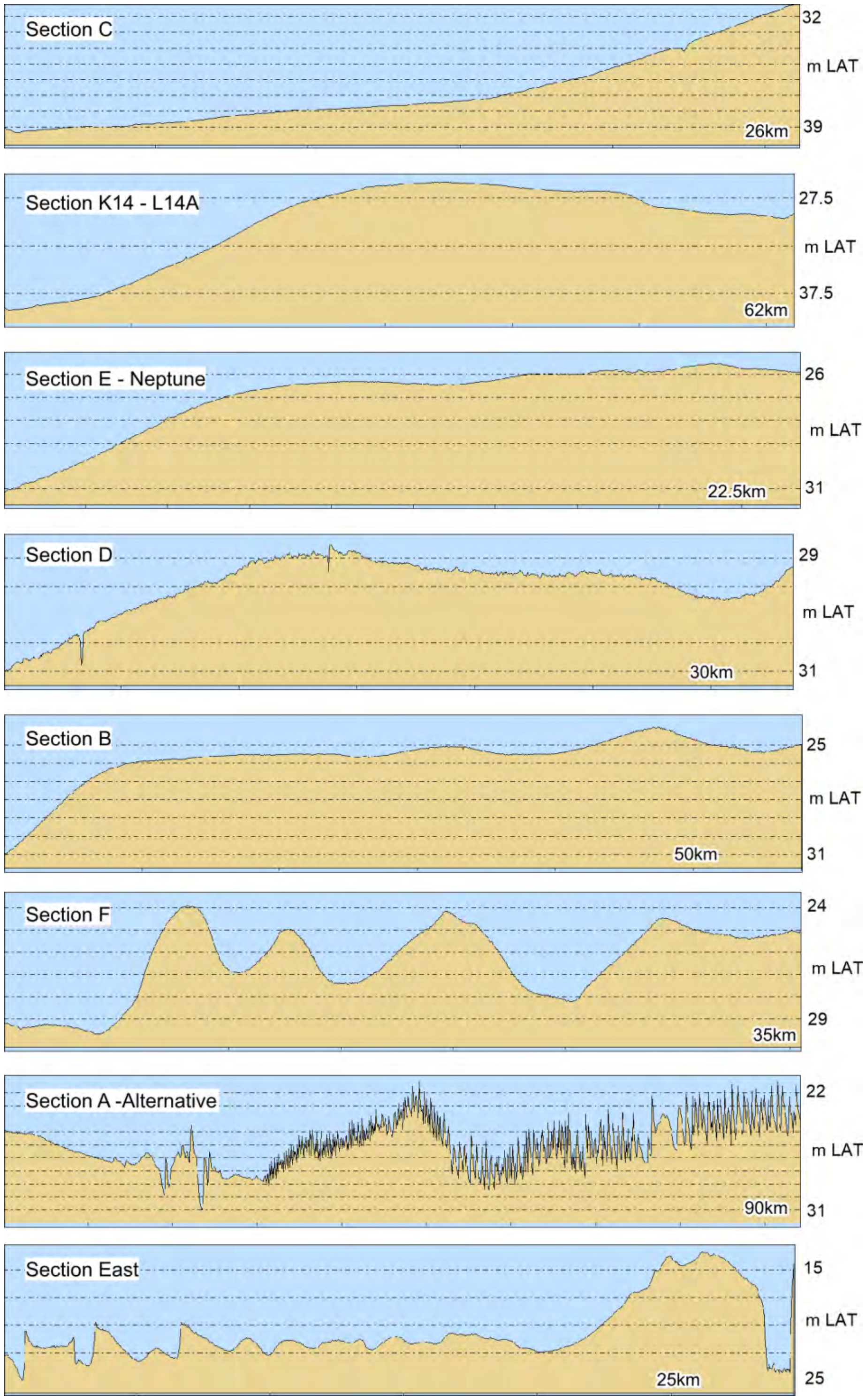

Figure 5. The seabed profiles along the different sections from north to south.

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.

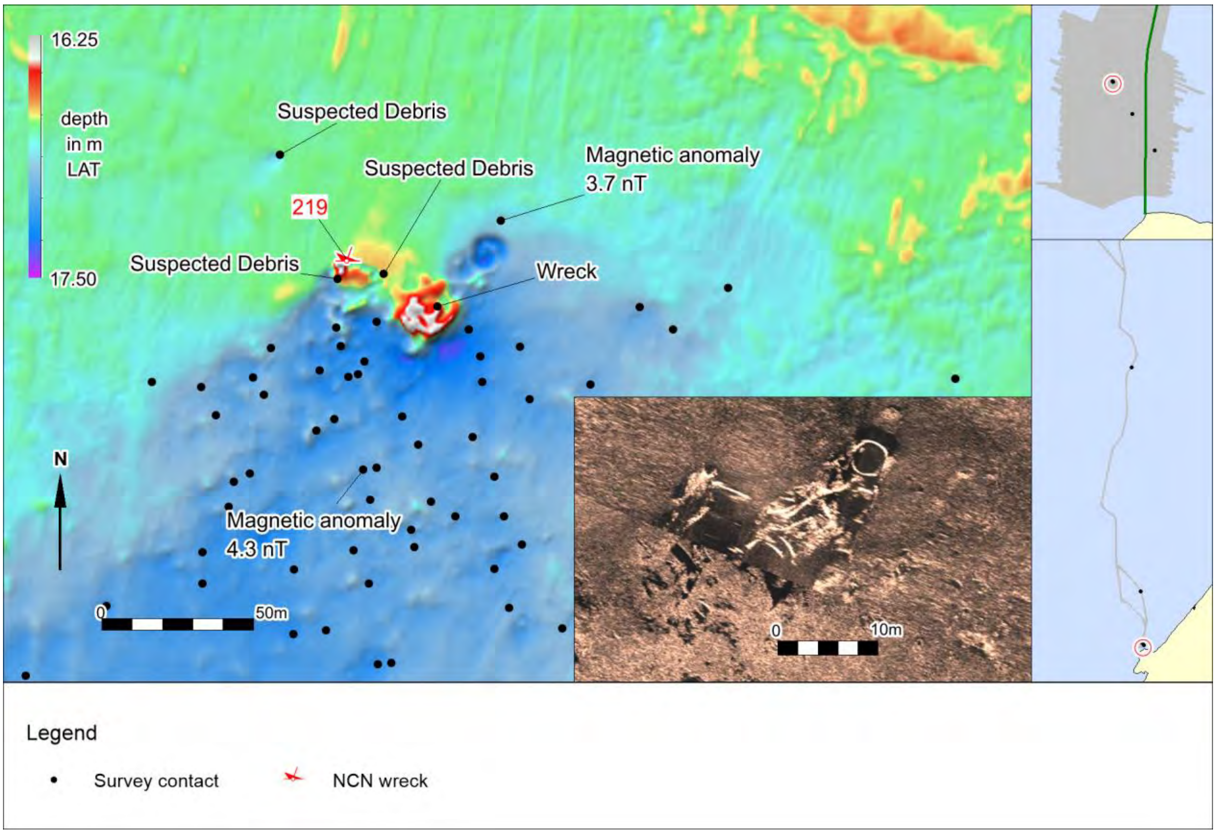

Figure 6. Multibeam image of NCN 219

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.

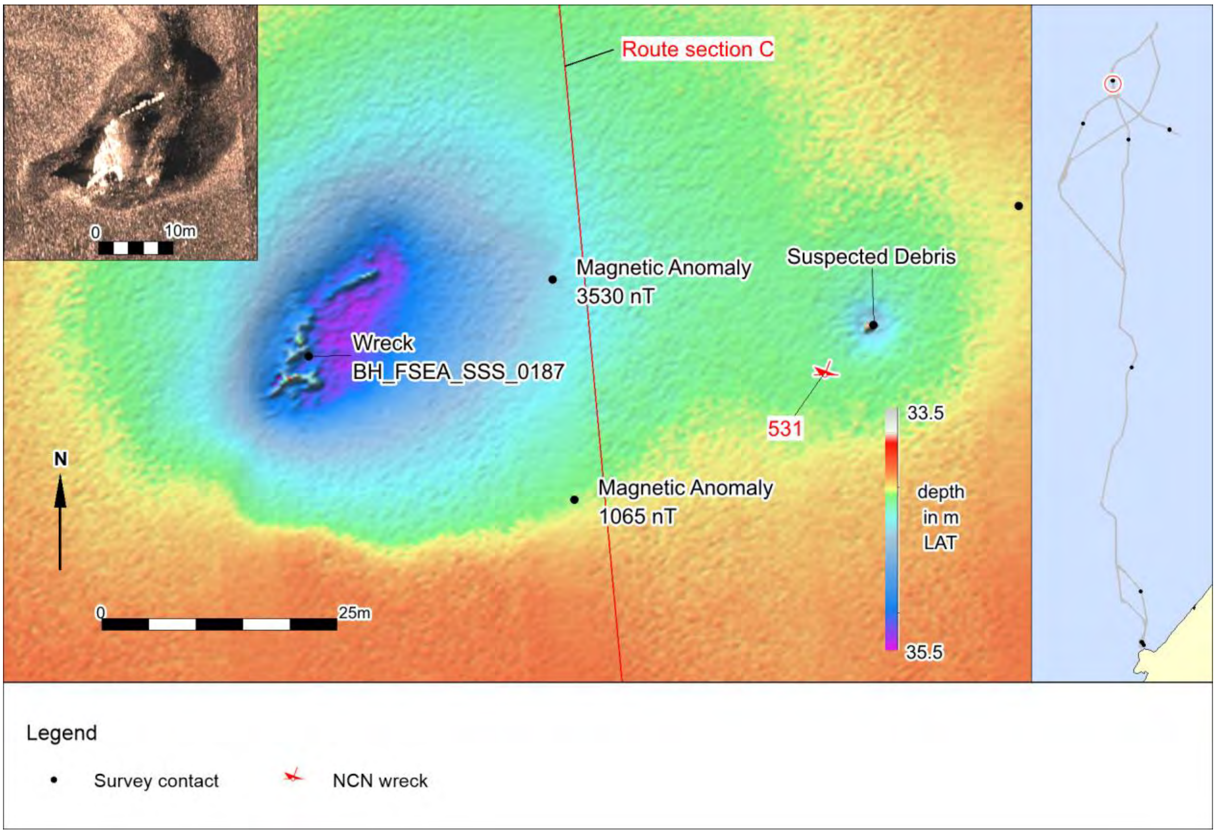

Figure 7. Sonar and multibeam image of NCN 531

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.

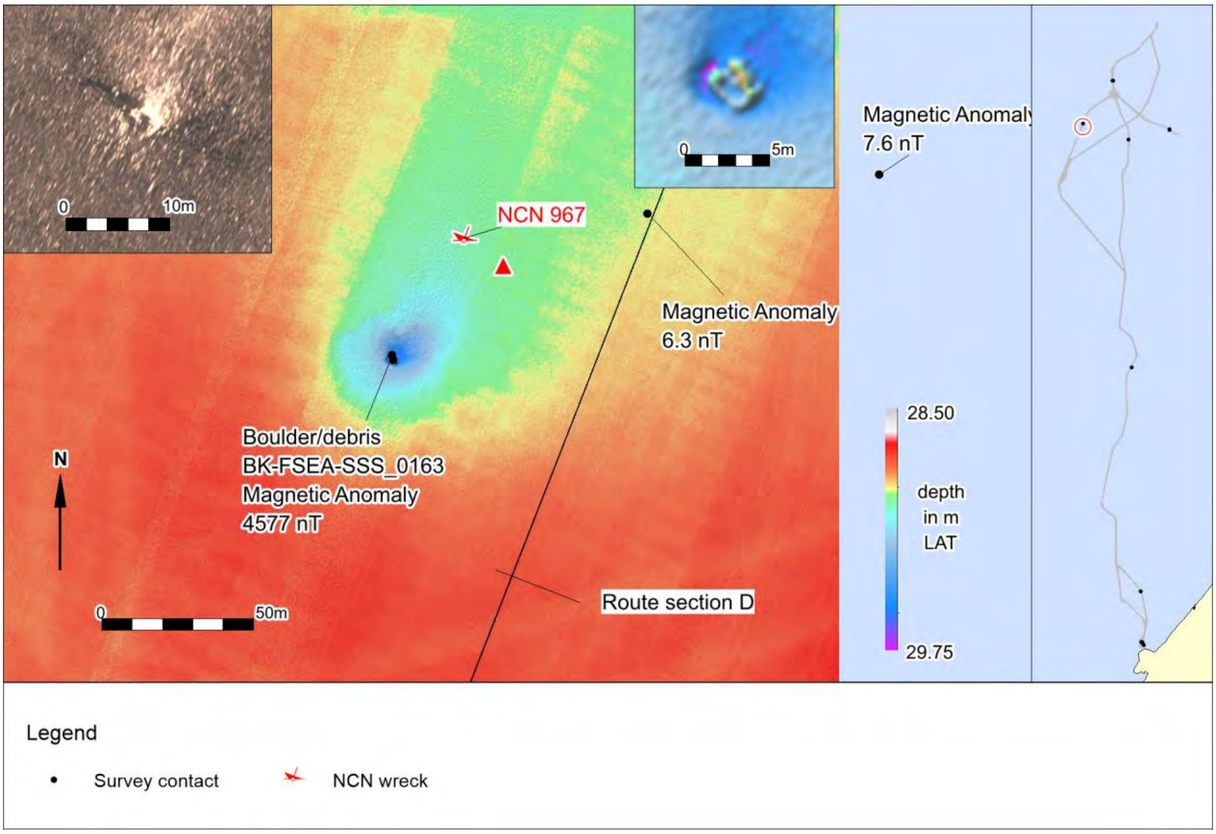

Figure 8. Sonar and multibeam image of NCN 967

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.

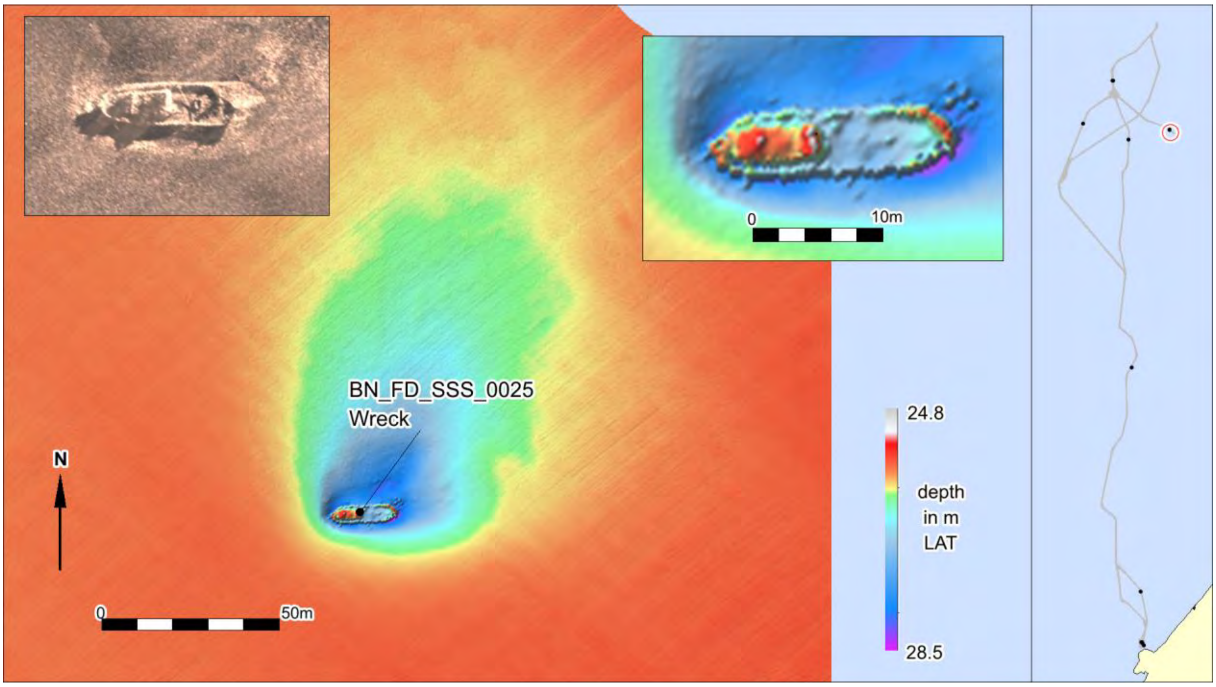

Figure 9. Sonar and multibeam image of contact BN_FD_SSS_0025

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.

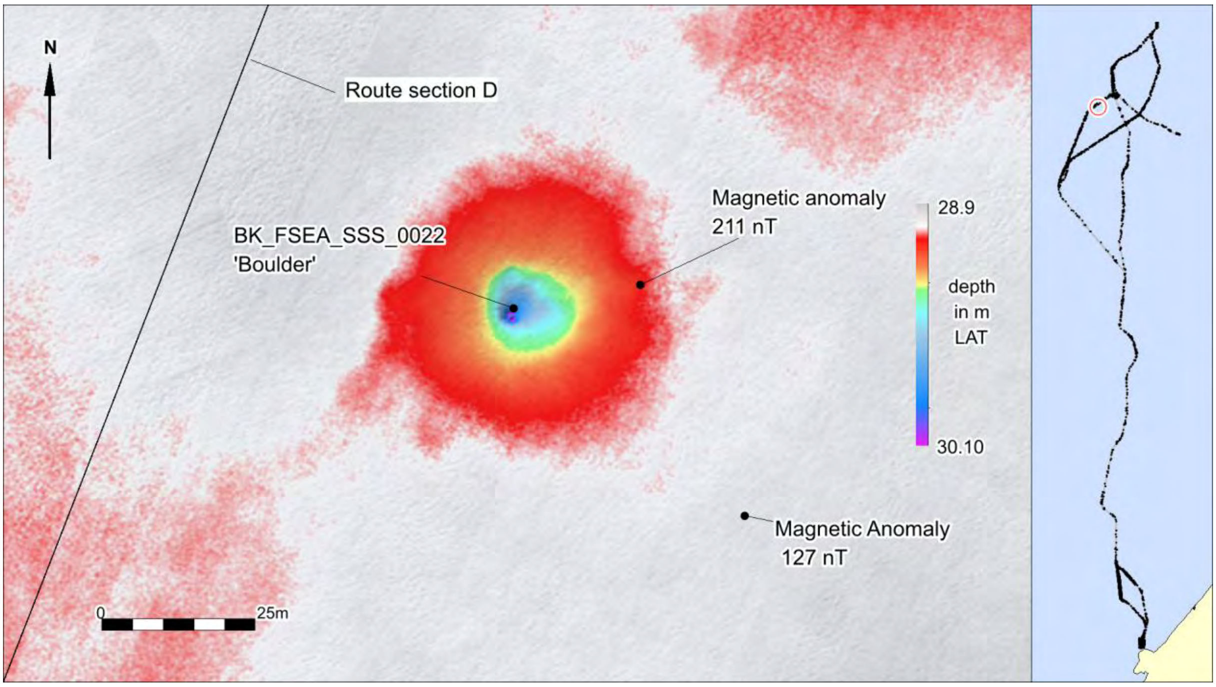

Figure 10. Multibeam image of survey contact BK-FSEA-SSS-022

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.

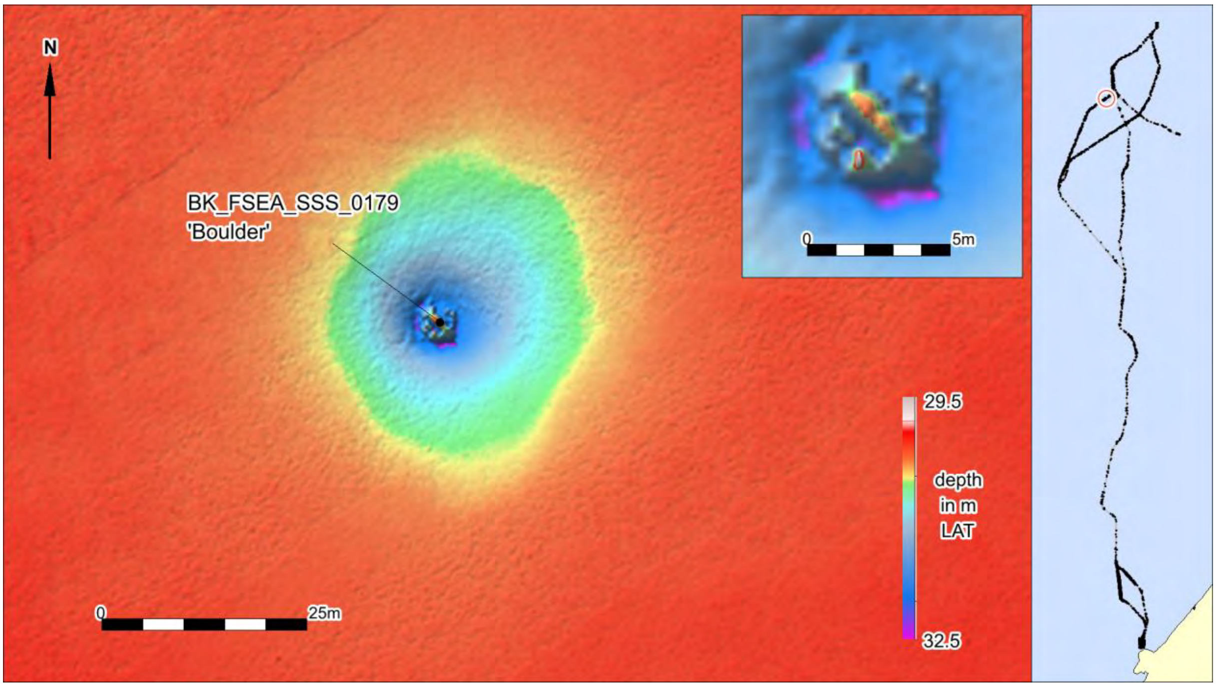

Figure 11. Multibeam image of survey contact BK-FSEA-SSS-0179

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.

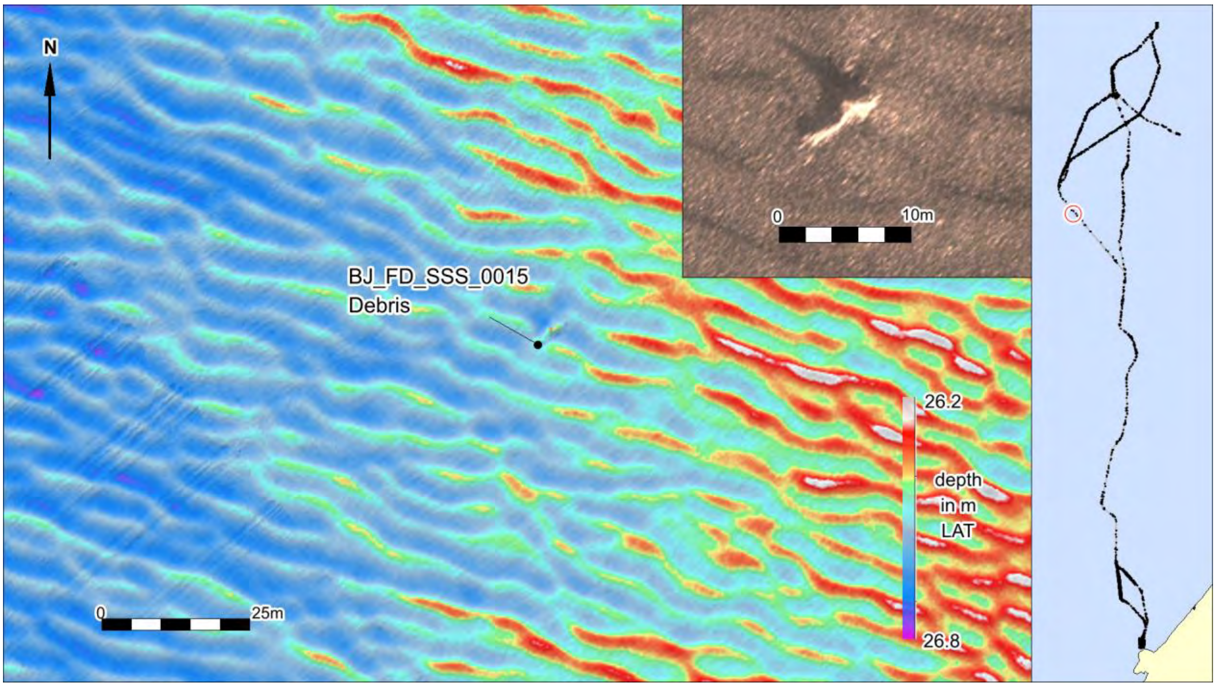

Figure 12. Sonar and multibeam image of survey contact BJ-FD-SSS-015

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.

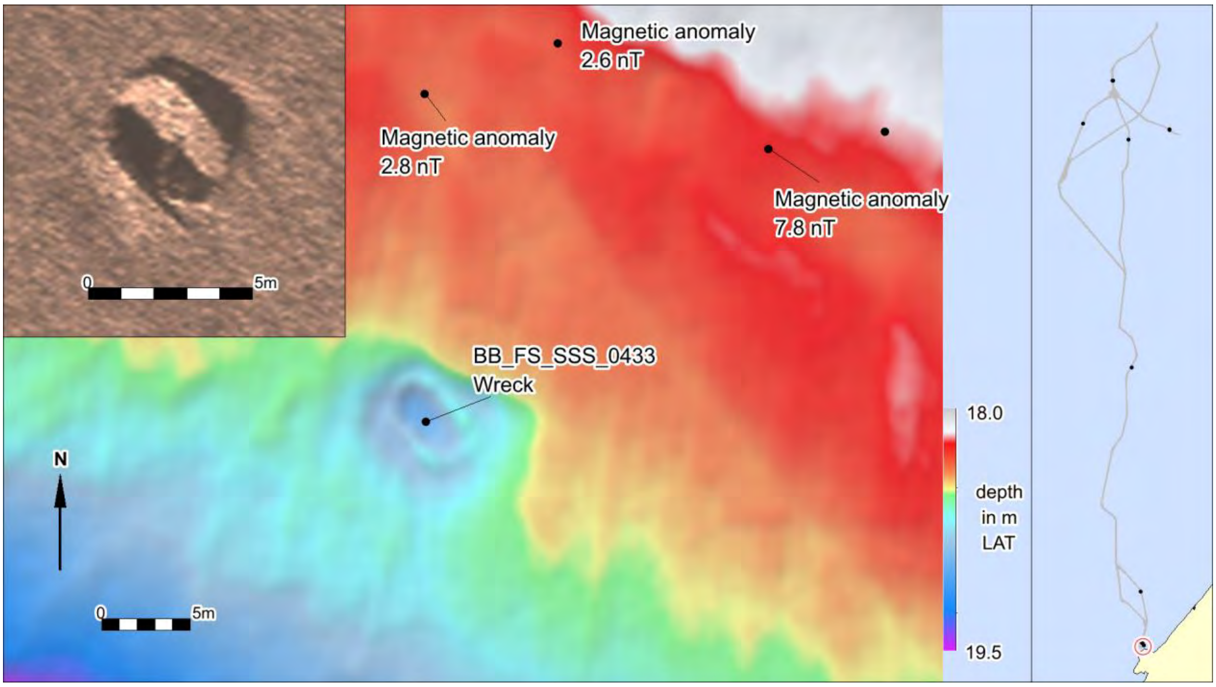

Figure 13. Multibeam image of survey contact BB-FS-SSS-0433

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

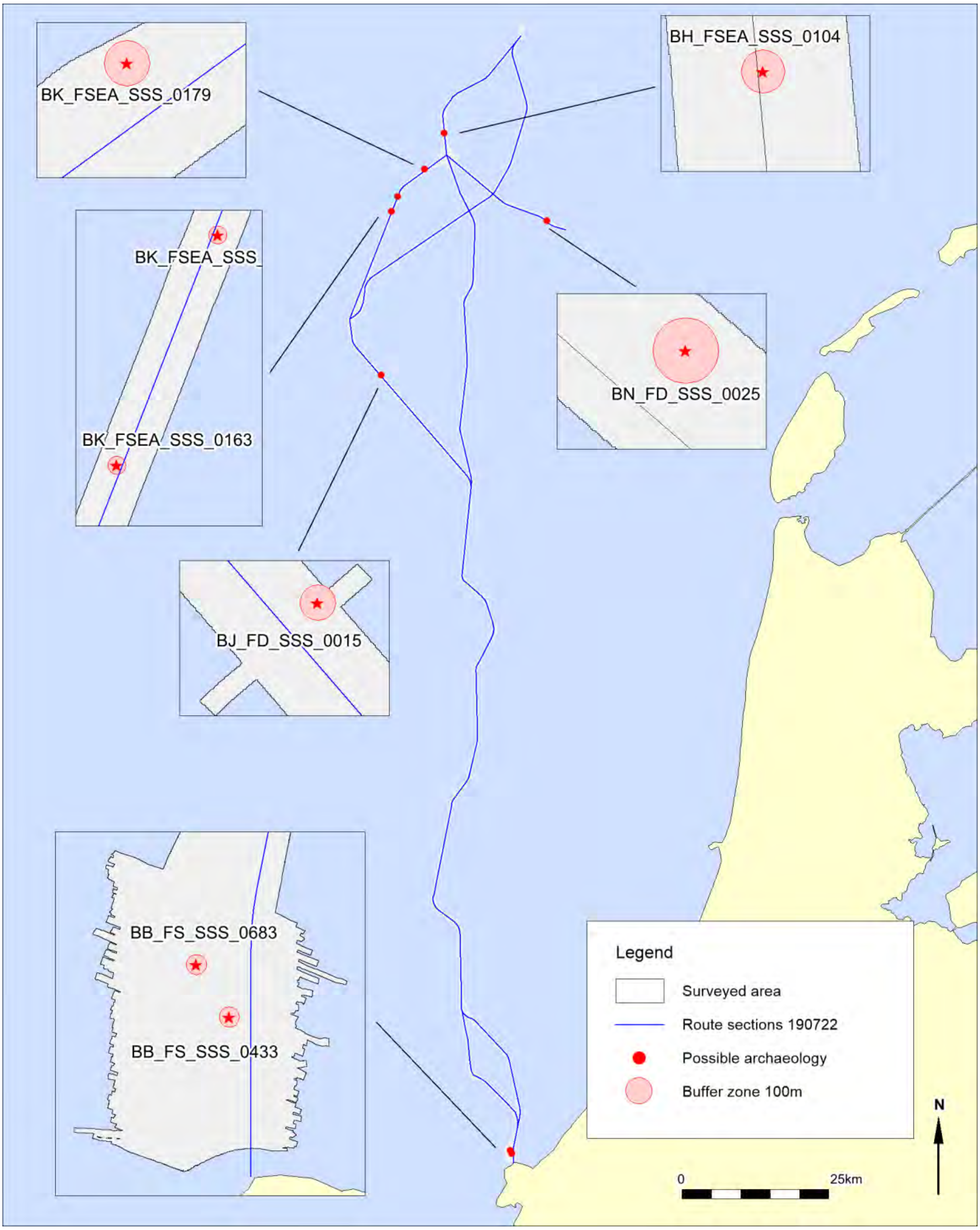

Figure 14. Overview of all side scan sonar / multibeam contacts with an archaeological expectation

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.

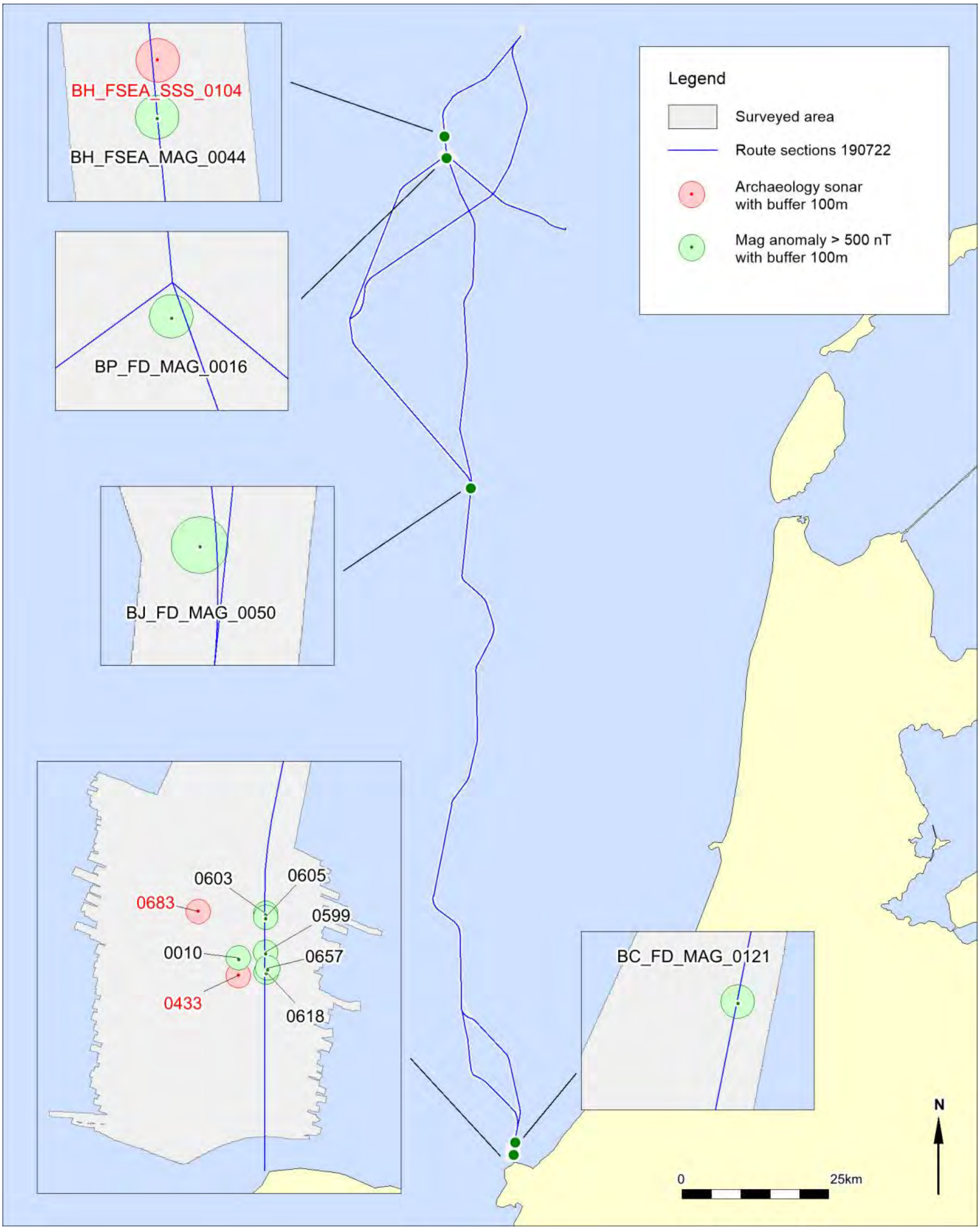

Figure 16. Magnetic anomalies larger than 500nT not related to known objects, infrastructure or objects found with side scan sonar.

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.

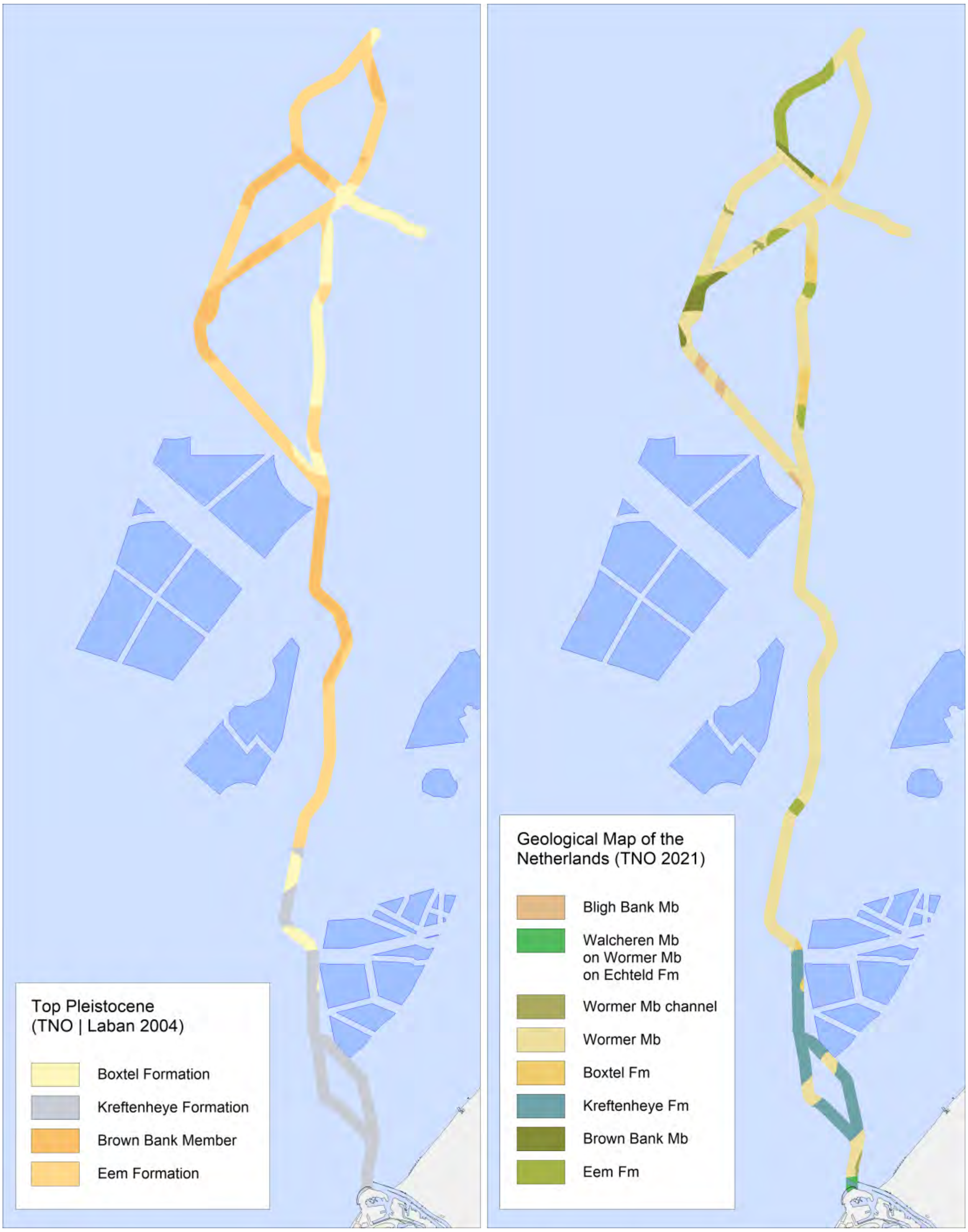

Figure 17. Subcropping Pleistocene units within 2000-meter corridor along the optional Aramis routes according to the 2004 Top Pleistocene Map and 2021 Geological map of the Netherlands; wind farm sites displayed to provide some spatial context.

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		Seismic Signature and Character of the Base	Distribution	Lithology[1]	Geological Formation / *Member*	Depositional Environment
		Top	Base					
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.

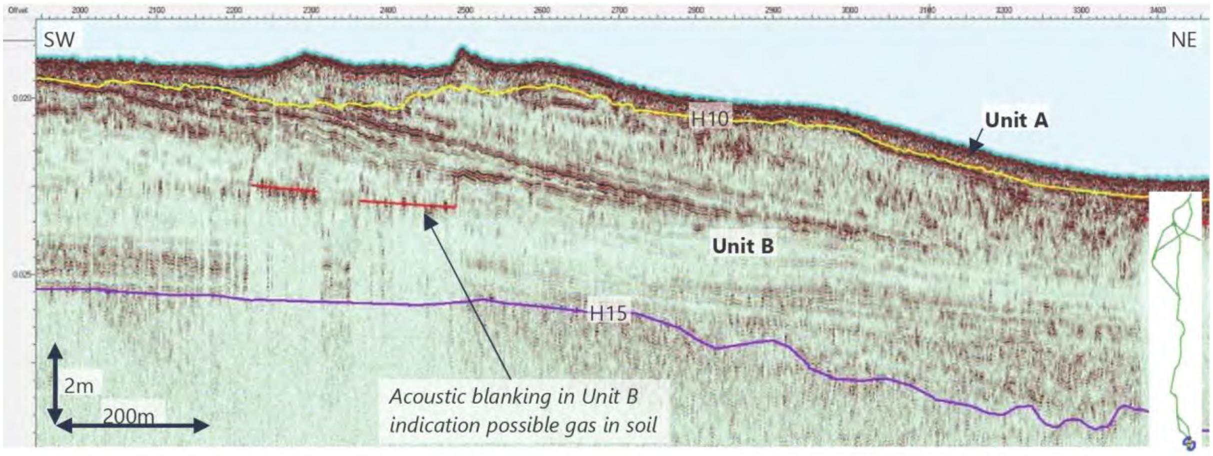

Figure 0.12: SBP data example of acoustic blanking in Unit B. (Line SBP_TA3C2020P1)

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.

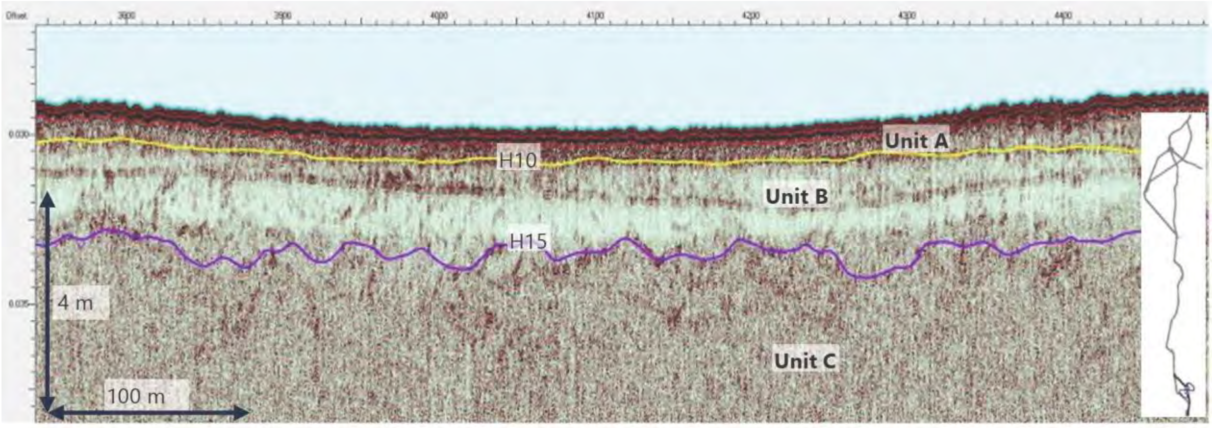

Figure 0.9: SBP data example of route section Export Route East MT. (Line SBP_TA3C2016P2)

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.

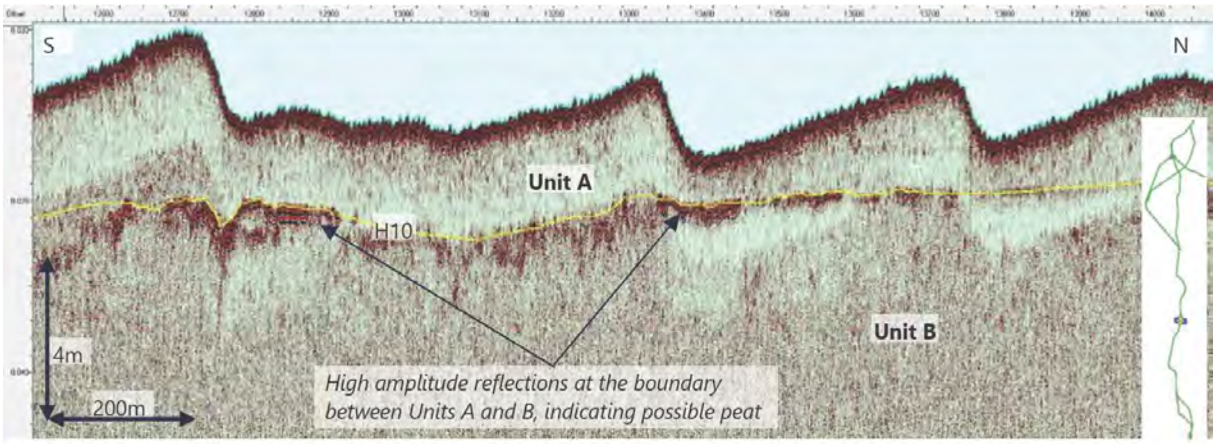

Figure 0.11: SBP data example of anomalies indicating possible peat in Unit B. (Line SBP_TA3E2134P1)

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.

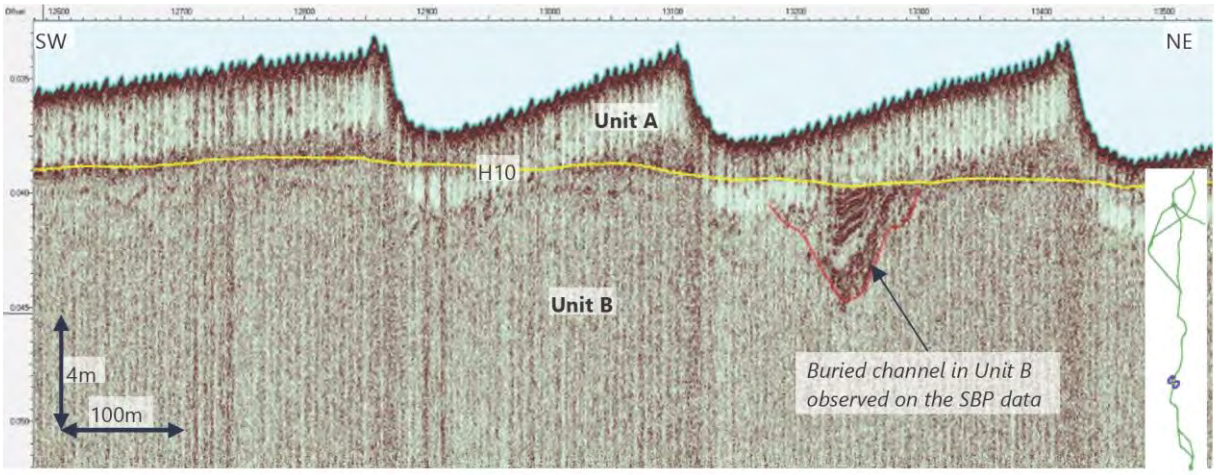

Figure 0.10: SBP data example of buried channels in Unit B. (Line SBP_TA3D2118P1)

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.

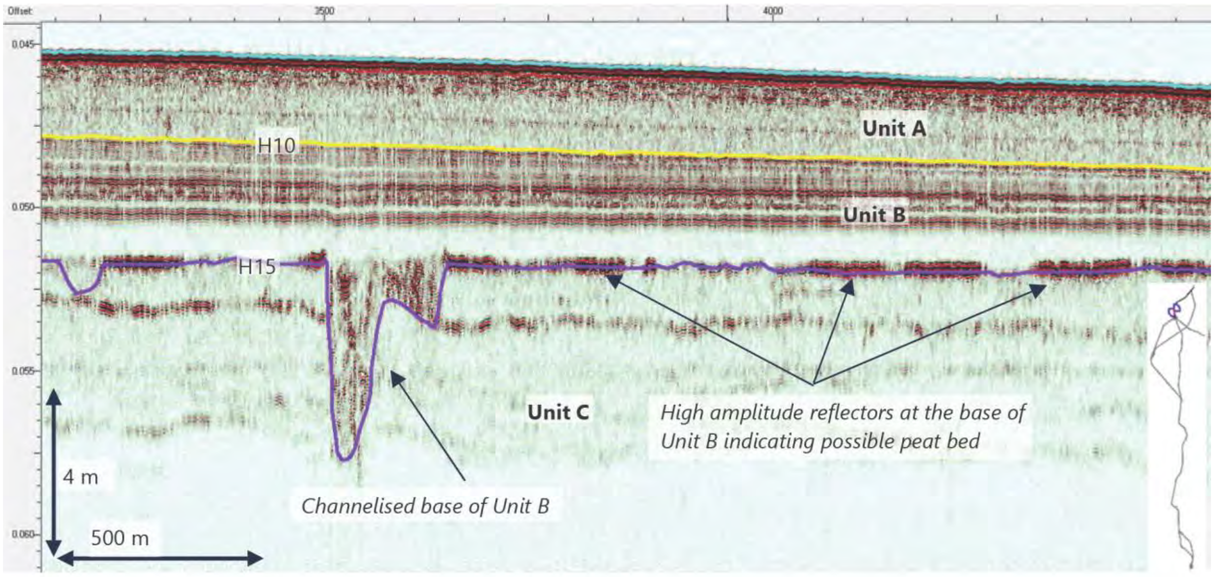

Figure 0.8: SBP data example of route section C. (Line SBP_TA3H23321P1_1)

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.

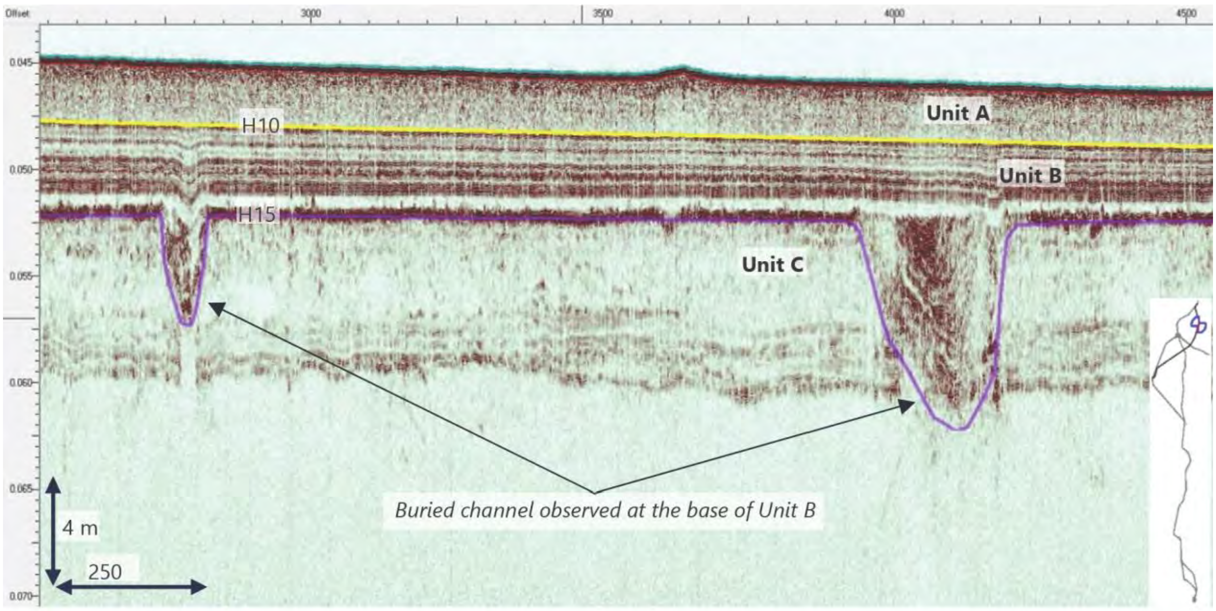

Figure 13.7: SBP data example of route section K14-L4A. (Line SBP_TA3M2321P1_1)

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.

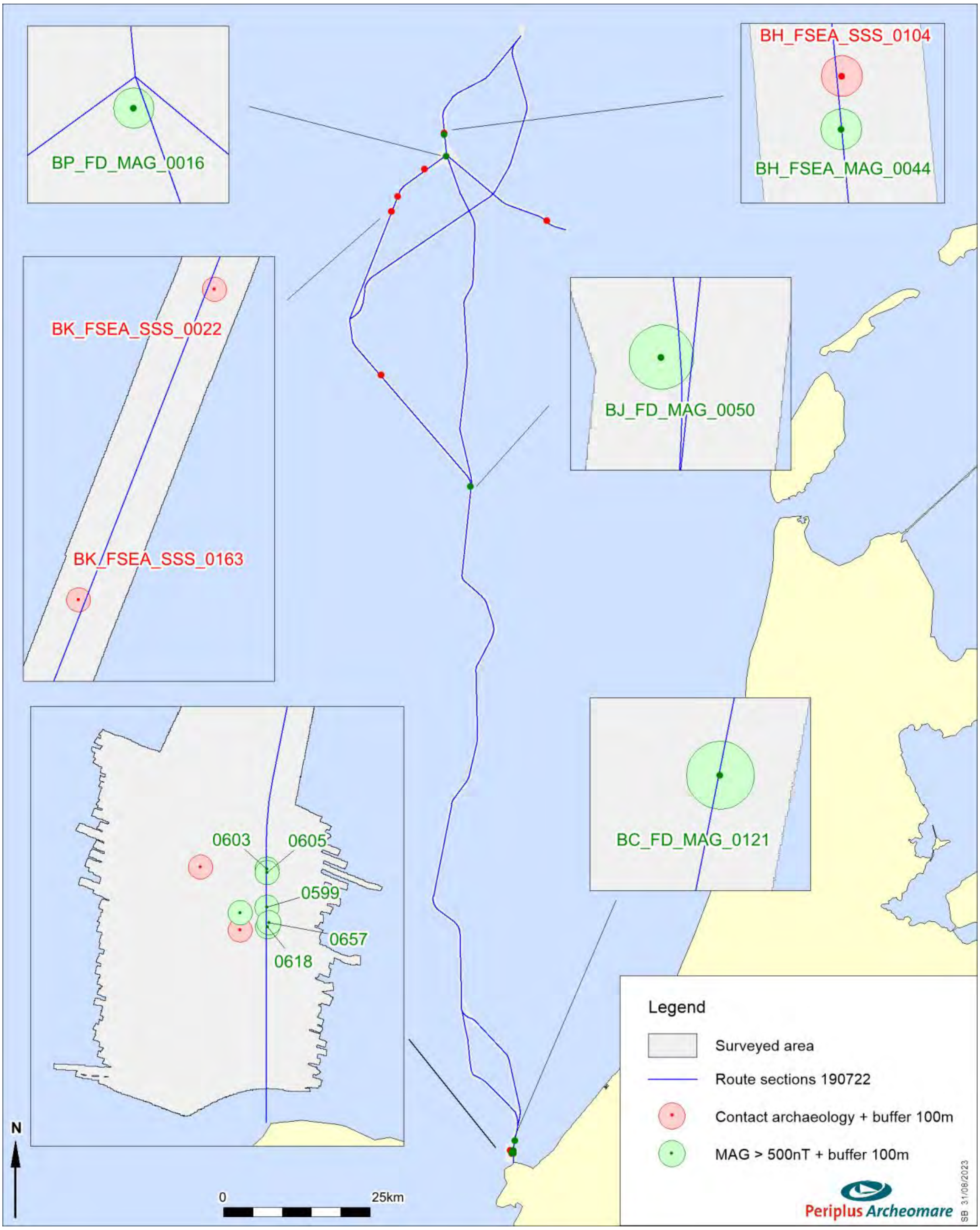

Figure 24. Overview of the potential archaeological targets within 100 meters of the proposed route

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.

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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.

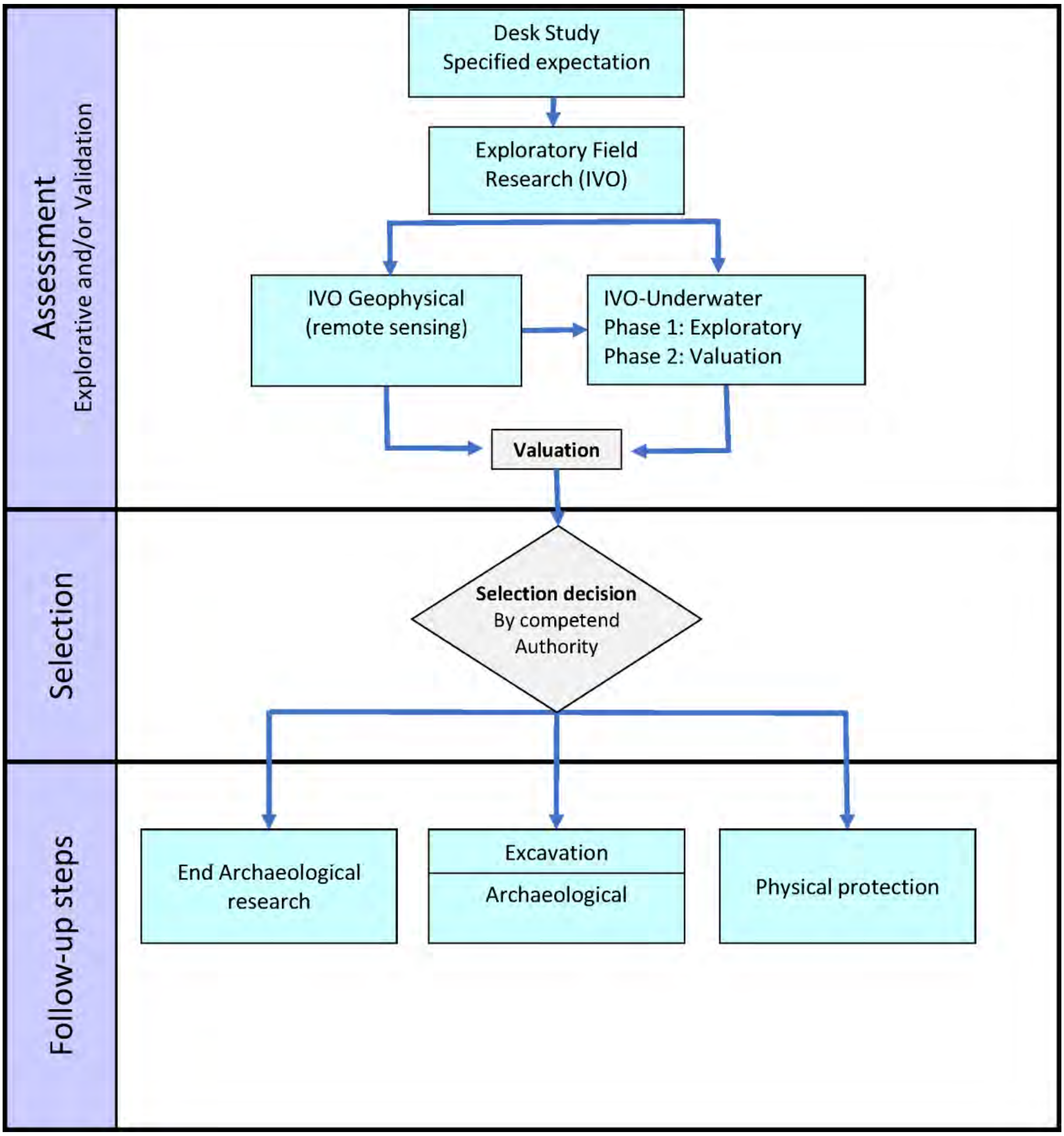
   IF as site is identified as an archaeological object or structure then the next phase must be carried out:

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:

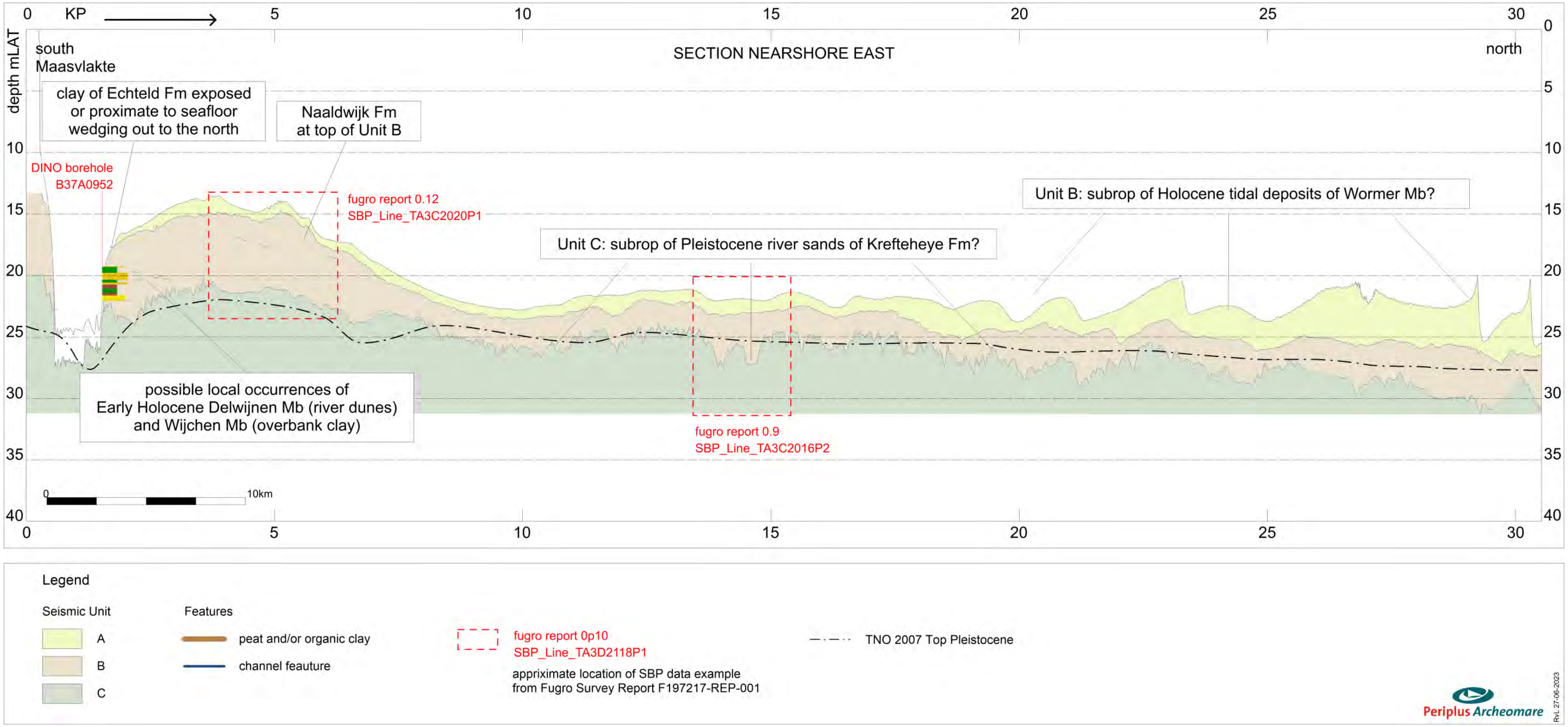
5. **Archaeological excavation**
   The archaeological remains are excavated under supervision of a senior maritime archaeologist. All remains need to be documented, registered, and conserved. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

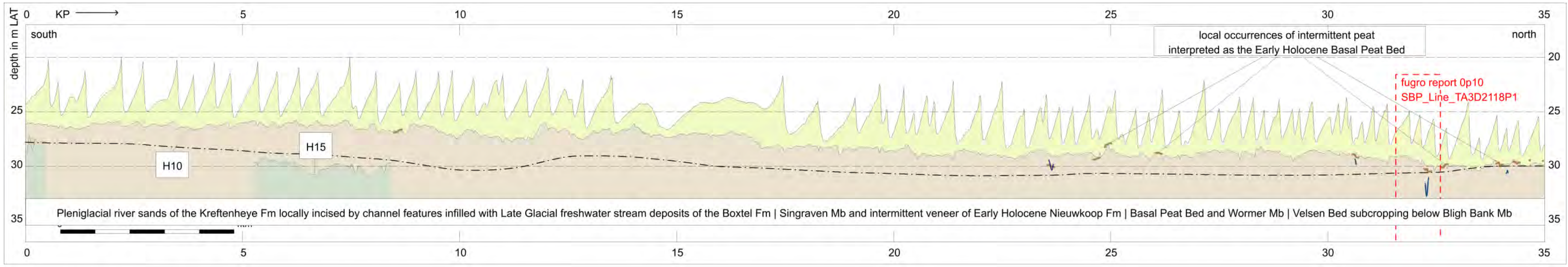
The phases described above contain a number of decision points that are dependent on the detected archaeological objects. The figure below shows these moments schematically.

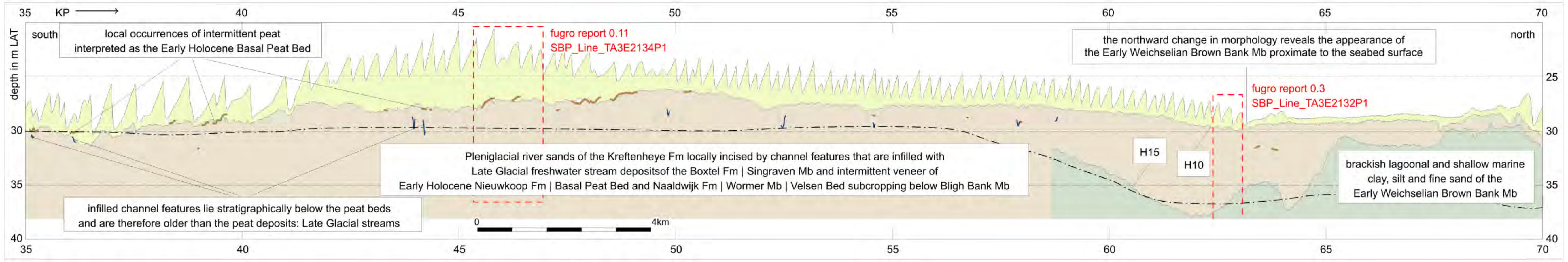


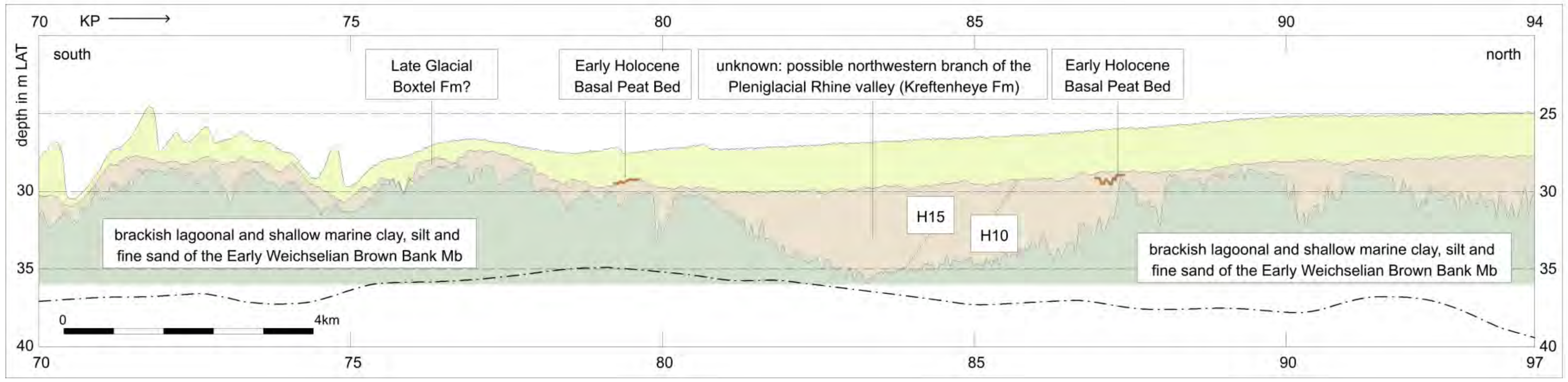
Appendix 3. X-sections

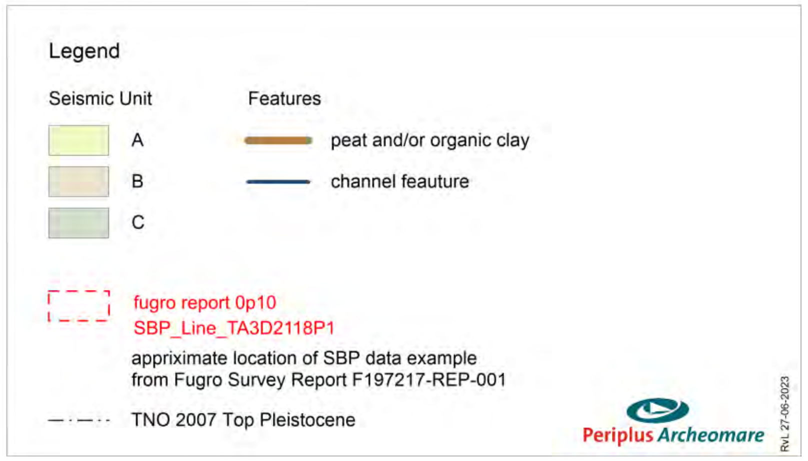
Section Nearshore East, A, B and C

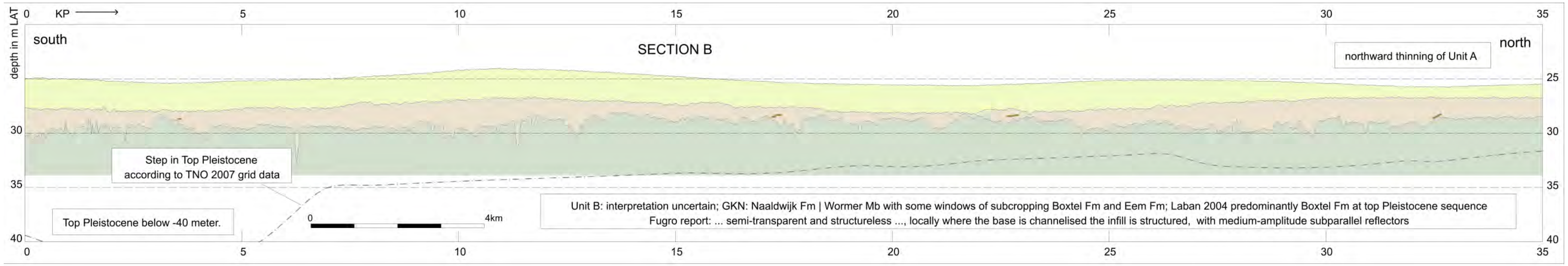

0 KP 5 10 15 20 25 30
depth mLAT
south
Maasvlakte
SECTION NEARSHORE EAST
north
clay of Echteld Fm exposed or proximate to seafloor wedging out to the north
Naaldwijk Fm at top of Unit B
DINO borehole B37A0952
fugro report 0.12
SBP_Line_TA3C2020P1
Unit B: subrop of Holocene tidal deposits of Wormer Mb?
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

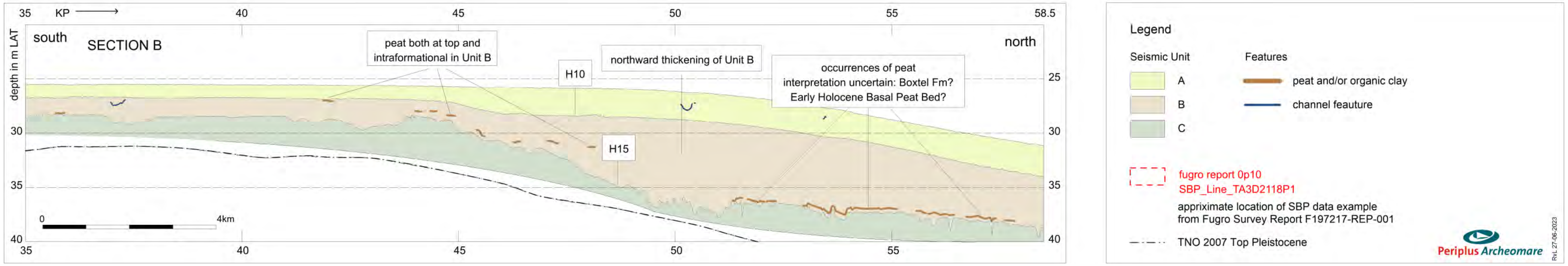

KP
depth in m LAT
south
north
local occurrences of intermittent peat interpreted as the Early Holocene Basal Peat Bed
fugro report 0p10
SBP_Line_TA3D2118P1
H15
H10
Pleniglacial river sands of the Kreftenheye Fm locally incised by channel features infilled with Late Glacial freshwater stream deposits 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

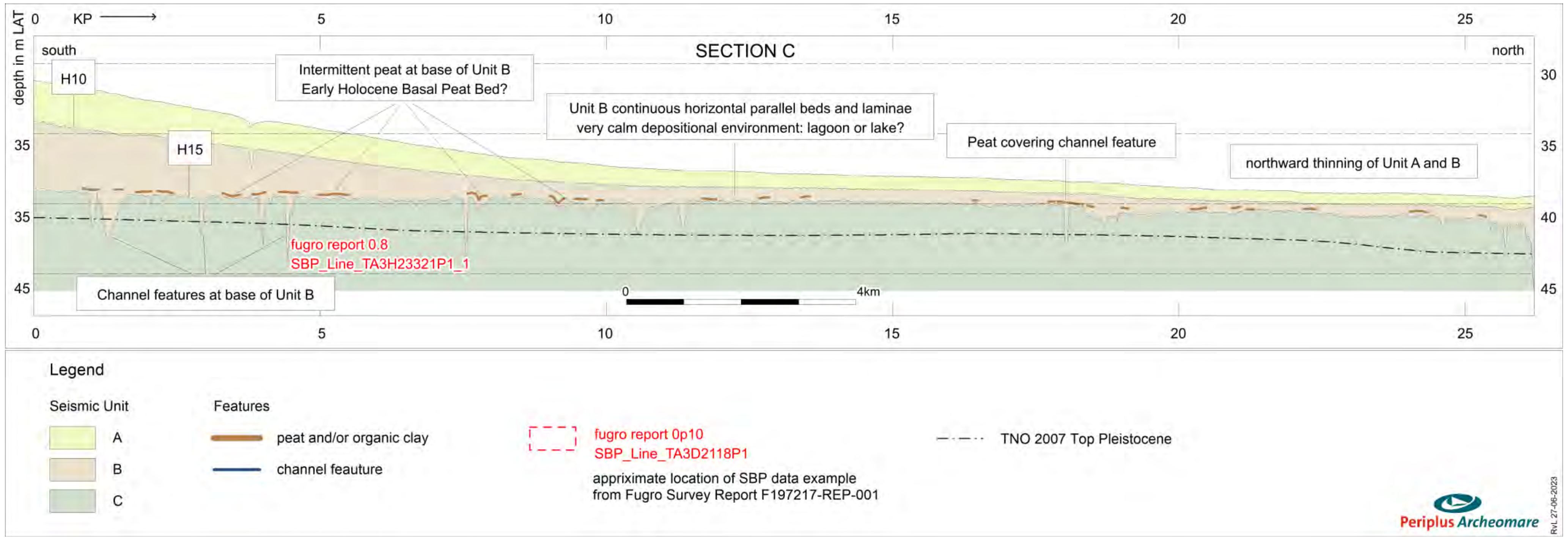

KP
depth in m LAT
south
north
local occurrences of intermittent peat interpreted as the Early Holocene Basal Peat Bed
fugro report 0.11
SBP_Line_TA3E2134P1
the northward change in morphology reveals the appearance of the Early Weichselian Brown Bank Mb proximate to the seabed surface
fugro report 0.3
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
H15
H10
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


KP
depth in m LAT
south
north
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
H15
H10
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
0
4km


Legend
Seismic Unit
Features
A
peat and/or organic clay
B
channel feauture
C
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


depth in m LAT
KP
south
SECTION B
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
0 5 10 15 20 25 30 35
25 30 35 40


35 KP 40 45 50 55 58.5
depth in m LAT
south
SECTION B
north
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
0
4km
25 30 35 40
Legend
Seismic Unit
Features
A
B
C
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
Rvl. 27-06-2023


0 KP 5 10 15 20 25
depth in m LAT
south
SECTION C
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
30 35 40 45
Legend
Seismic Unit
Features
A
B
C
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
Rvl. 27-06-2023

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.

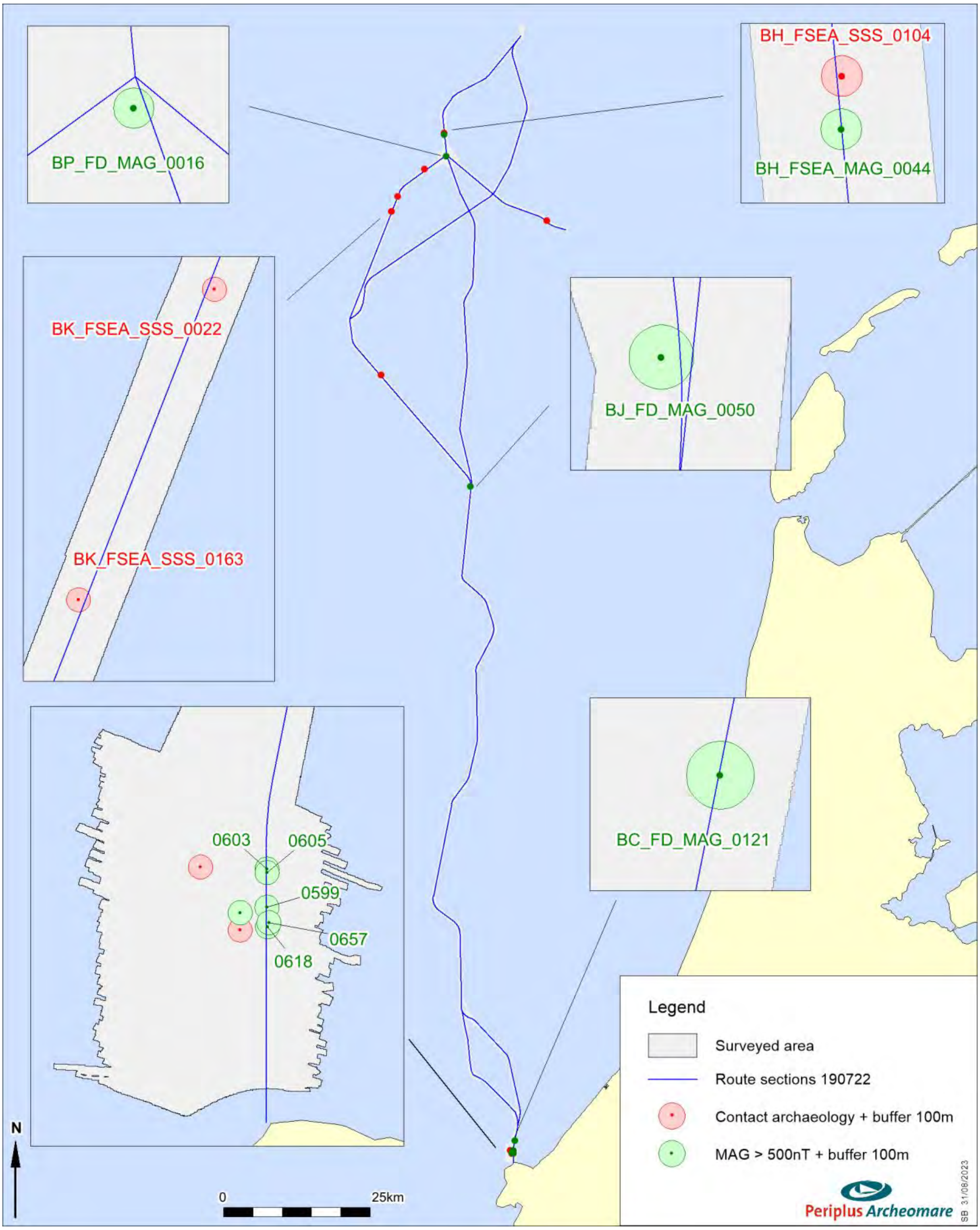
Magnetische afwijkingen

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.

Rijksdienst voor het Cultureel Erfgoed
Ministerie van Onderwijs, Cultuur en Wetenschap

> Retouradres Postbus 1600 3800 BP Amersfoort

[redacted]

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Contactpersoon
[redacted]

Datum 21 augustus 2023
Betreft 22A030-01 Geofysisch conceptrapport Aramis

[redacted]

Hierbij deel ik mede dat de Rijksdienst voor het Cultureel Erfgoed (RCE) het conceptrapport Aramis geofysisch van d.d. 03-08-2023 met referentienummer 22A030-01 goedkeurt.

Dit advies is verzorgd door:
[redacted]

Mochten er naar aanleiding van dit advies nog vragen zijn, neem dan gerust contact op via de contactgegevens aan de rechterzijde.

Met vriendelijke groet,

[redacted]

PARTICIPATIEPLAN

ARAMIS-INITIATIEF

Fase milieueffectrapportage t/m voorkeursalternatief

Herziene versie

Oktober 2023

Documentnummer

NL-ARM-PFE-B10-ENV-GEA-0299

INHOUDSOPGAVE

ALGEMEEN

Voor u ligt het geactualiseerde participatieplan van het Aramis-initiatief (hierna: Aramis). Het plan is opgesteld door Aramis in afstemming met CO_2next en het ministerie van Economische Zaken en Klimaat (EZK). In het participatieplan leest u hoe u en andere belanghebbenden worden geïnformeerd over en betrokken bij het Aramis-project.

Bij elke fase van het project actualiseren initiatiefnemers TotalEnergies, Shell, Energie Beheer Nederland (EBN) en Gasunie het participatieplan. Dat doen zij op basis van voortschrijdend inzicht, ontwikkelingen in het project, gesprekken met stakeholders, reacties op het participatieplan en een evaluatie van de voorgaande periode.

- De eerste versie van het participatieplan is samen met de kennisgeving *Voornemen en Voorstel Participatie voor het project Aramis* (kennisgeving van het V&P)[1] gepubliceerd in januari 2022.
- Naar aanleiding van gesprekken met stakeholders en reacties op de kennisgeving van het V&P is in juni 2022 een tweede versie van het plan gepubliceerd, gelijktijdig met de publicatie van de conceptversie van de Notitie Reikwijdte en Detailniveau (concept-NRD).
- In november 2022 werd de derde versie uitgebracht, die in het teken stond van de definitieve Notitie Reikwijdte en Detailniveau (NRD).
- Deze vierde versie van het participatieplan omvat het tijdvak juni 2023 tot eind 2023. In deze periode wordt de Integrale Effectenanalyse (IEA) opgesteld (onder behoud van het concept-milieueffectrapport (MER) fase 1), die de basis vormt voor de keuze van een voorkeursalternatief (VKA).

Het MER wordt medio 2024 samen met de ontwerpbesluiten ter inzage gelegd. Dan is er weer mogelijkheid tot reageren. Begin 2024 zal het participatieplan opnieuw worden geüpdatet, waarbij de mogelijkheid van reageren en de wijze waarop dit kan expliciet worden vermeld.

De invoering van de nieuwe Omgevingswet per 1 januari 2024 is een van de aanleidingen van deze nieuwe update. Aangezien de vergunningaanvragen na 1 januari 2024 worden ingediend, verandert de RCR-planning (Rijkscoördinatieregeling) en wijzigen daarmee ook de inspraakmomenten en de bijbehorende terminologie. Met deze update wordt u hiervan op de hoogte gebracht.

LEESWIJZER

- Hoofdstuk 1 introduceert het Aramis-project en de rol van EZK in de te volgen procedure.
- Hoofdstuk 2 licht de doelen, uitgangspunten en het kader van het participatieplan toe.
- Hoofdstuk 3 beschrijft hoe de participatie aan het MER en de IEA tot en met de VKA er concreet uitziet.
- Hoofdstuk 4 geeft een overzicht van alle geplande participatiemomenten.

Voor aanvullende informatie ziet u een verwijzing naar websites en documenten.

[1] https://www.rvo.nl/sites/default/files/2021/12/Notitie-Voornemen-en-Voorstel-Participatie-CCS-Aramis.pdf

1. INLEIDING

1.1 OVER ARAMIS

Het klimaat verandert snel door de toename van CO_2- en andere broeikasgassen in de atmosfeer. In het Klimaatakkoord van Parijs zijn ambitieuze doelen vastgelegd om de CO_2-uitstoot te verlagen. Hierin is afgesproken de opwarming van de atmosfeer te beperken tot maximaal 2°C, maar bij voorkeur onder 1,5°C te houden. Het vormt een grote uitdaging om de uitstoot zodanig te verlagen dat de klimaatdoelstellingen voor 2050 worden behaald.

Verduurzaming van de industrie is een van de maatregelen om CO_2-uitstoot te verminderen. De komende decennia wordt het aandeel van fossiele brand- en grondstoffen in productieprocessen afgebouwd. Voor deze transitie is tijd nodig: het is niet mogelijk in één keer volledig fossielvrij te worden en alle industriële processen om te zetten naar groene waterstof en/of groene stroom.

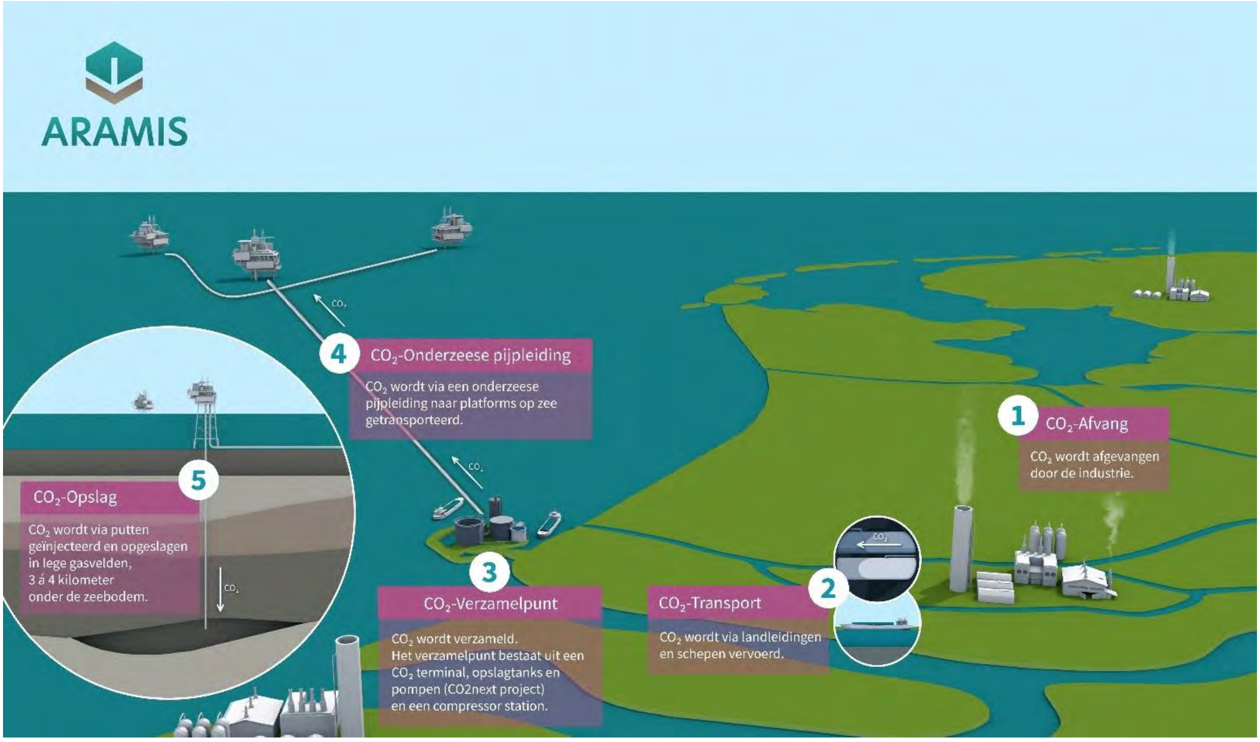
Totdat het gebruik van fossiele brandstoffen in industriële processen tot nul is gereduceerd, kan CO_2-uitstoot fors worden verminderd door afvang en ondergrondse opslag van vrijkomende CO_2. Deze techniek wordt Carbon Capture and Storage (CCS) genoemd en vermindert de hoeveelheid broeikasgassen die in de atmosfeer terechtkomt.

Rapportages van het Intergovernmental Panel on Climate Change (IPCC) en het Internationale Energie Agentschap (IEA)[2] laten zien dat – zolang er onvoldoende alternatieven zijn – permanente CO_2-opslag noodzakelijk is voor moeilijk te verduurzamen industrie. In de Klimaatnota 2022 en de Klimaat- en Energieverkenning (KEV) 2023 staat aangegeven dat het grootste gedeelte van de industriële CO_2-reductie tot 2030 uit CCS zal komen. De overheid ziet het afvangen en opslaan van CO_2 als een belangrijke (overgangs)technologie en stimuleert daarom CO_2-opslag onder de Noordzee.

De opslag van de afgevangen CO_2 is voorzien in lege gasvelden diep onder de zeebodem. Om de bij de industrie afgevangen CO_2 naar deze opslaglocaties te brengen, wordt een nieuwe, open transportinfrastructuur ontwikkeld. ‘Open’ betekent dat andere partijen de mogelijkheid hebben om op de CCS-keten aan te sluiten, zowel aan de voorkant (de afvang) als aan de achterkant (de opslag).

Bij een open CO_2-transportinfrastructuur zijn veel verschillende partijen betrokken, elk met een eigen rol en elk met een eerder of later moment waarop zij aansluiten. Samen vormen deze partijen de integrale CCS-keten: van de afvang van CO_2 tot permanente opslag in lege gasvelden diep onder de Noordzee. De keten bestaat veelal uit zelfstandige onderdelen, die voor een goed functionerend geheel nauw op elkaar moeten zijn afgestemd (zie afbeelding 1).

[2] IPPC rapportage 2022, Mitigation of Climate change



Afbeelding 1. Overzicht componenten van de CCS-keten, waar het Aramis-initiatief onderdeel van uitmaakt.

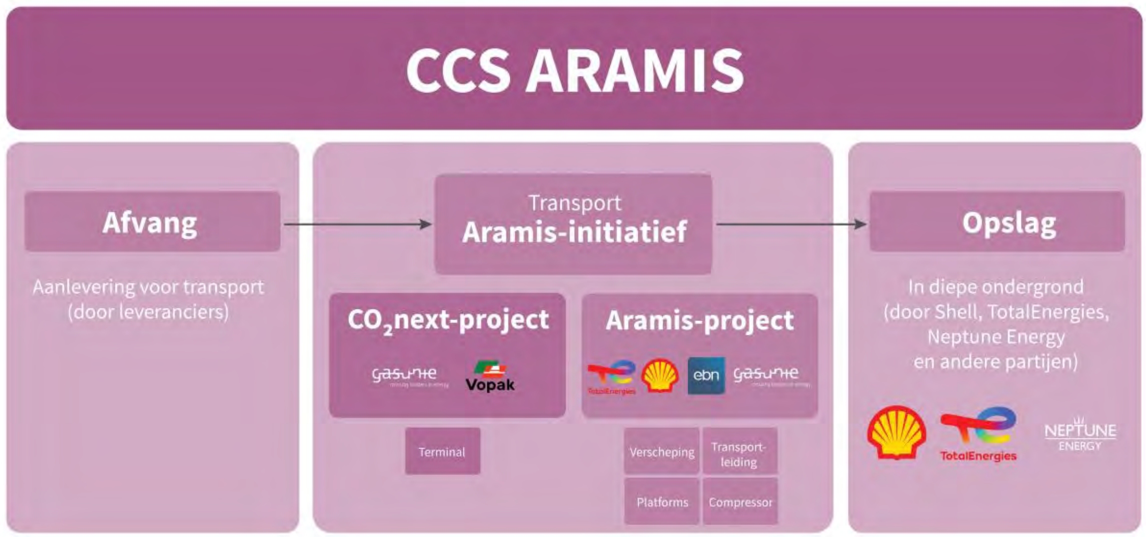
1. CO_2-afvang bij industrie en geschikt maken voor transport;
2. CO_2-transport naar de Maasvlakte via Porthos-landleiding, binnenvaart en zeevaart;
3. CO_2-verzamelpunt op de Maasvlakte met terminal en compressorlocatie. De terminal omvat steigers, tanks voor tijdelijke opslag van per schip aangevoerde CO_2, en hogedrukpompen voor levering aan de zeeleiding (CO_2next-project). De compressorlocatie ontvangt CO_2 via de landleiding en brengt dit op druk voor het transport per zeeleiding;
4. CO_2-transport door de centrale CO_2-zeeleiding naar platforms op de Noordzee;
5. Platform met leidingen vanaf de centrale CO_2-zeeleiding en met putten naar lege gasvelden diep onder de Noordzee.

Aramis heeft betrekking op het transport van CO_2 (onderdeel 2) naar het CO_2-verzamelpunt (onderdeel 3) en het transport via een zeeleiding naar de platforms op zee (onderdeel 4). In de CCS-keten van afvang, transport en opslag richt Aramis zich op het transportdeel: de CO_2-transportinfrastructuur. De CO_2-afvang (onderdeel 1) en de CO_2-opslag (onderdeel 5) vallen weliswaar buiten Aramis, maar vormen een samenhangend geheel met Aramis. Zodoende worden deze onderdelen in het verlengde van Aramis beschreven.

De transportinfrastructuur biedt andere partijen de mogelijkheid om op de CCS-keten aan te sluiten, zowel aan de voorkant (de afvang) als aan de achterkant (de opslag). Aramis voorziet daarmee in een cruciaal onderdeel van de CCS-keten. Het is niet mogelijk om op voorhand aan te geven welke partijen zich aansluiten en wanneer. Dat is inherent aan de aard van een open infrastructuur, die is gericht op toekomstige uitbreiding en aanpassing.

1.2 PROJECTORGANISATIE EN INITIATIEFNEMERS

Afbeelding 2 geeft weer hoe de verschillende onderdelen van Aramis zich verhouden tot elkaar en tot de Aramis-CCS-keten.



Afbeelding 2. Aramis binnen de Aramis-CCS-keten.

TotalEnergies, Shell, Energie Beheer Nederland (EBN) en Gasunie zijn de initiatiefnemers van de ontwikkeling van de Aramis- CO_2-transportinfrastructuur. Zij zijn zelf verantwoordelijk voor de compressie van CO_2 die afkomstig is van de landleiding, de centrale CO_2-zeeleiding en de platforms.

Door verschillende bedrijven zal CO_2 worden afgevangen. Vervolgens verzorgen verschillende leveranciers de aanlevering van CO_2 via leiding (gas) of schip (vloeibaar) naar het CO_2-verzamelpunt. Op het verzamelpunt worden de terminalfaciliteiten verzorgd door CO_2next. In CO_2next werken Gasunie en Koninklijke Vopak samen aan de bouw van een nieuwe CO_2-terminal op de Maasvlakte.

De aanleg van de centrale CO_2-zeeleiding is onderdeel van het Aramis-project, evenals de bouw van het compressorstation op het verzamelpunt. Voor het overige (steigers, tanks voor tijdelijke opslag van per schip aangevoerde CO_2, en hogedrukpompen voor levering aan de zeeleiding) valt het verzamelpunt onder CO_2next.

De opslagpartijen (onder meer Shell, TotalEnergies en Neptune Energy) zijn verantwoordelijk voor de opslag van CO_2, inclusief het transport vanaf hun platforms naar de ondergrondse reservoirs.

1.3 ROL VAN HET MINISTERIE EN KORTE TOELICHTING OP DE PROCEDURE

Het ministerie van Economische Zaken en Klimaat (EZK) en Aramis werken nauw samen aan dit project en hebben hierin elk een eigen taak en rol.

Rollen van EZK

Voordat Aramis en CO_2next kunnen worden gerealiseerd, is er een ruimtelijk besluit nodig en moeten de vereiste vergunningen zijn verleend. EZK coördineert de besluitvorming van energieprojecten met een nationaal belang. Dit heet nu nog de Rijkscoördinatieregeling (RCR). Onder de nieuwe Omgevingswet die op 1 januari 2024 ingaat heet dit projectprocedure. Aangezien de vergunningaanvragen na 1 januari 2024 worden ingediend, hebben we het hier verder over de projectprocedure.

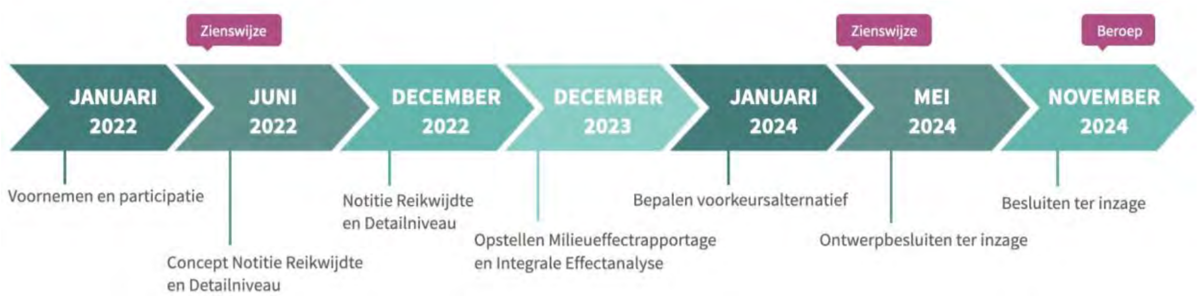
EZK coördineert de projectprocedure, waarbij de verschillende benodigde besluiten (vergunningen en eventueel ontheffingen) gelijktijdig worden genomen in afstemming met de overheden. Het gaat dan om zowel het ruimtelijk besluit als de uitvoeringsbesluiten. De coördinatie betekent ook dat alle stukken tegelijk ter inzage worden gelegd. Tegen de definitieve besluiten kan beroep worden aangetekend. Er is een beperkt aantal momenten waarin om een reactie wordt gevraagd, of men een zienswijze of beroep kan indienen.

Het ruimtelijk besluit wordt genomen door de minister voor Klimaat en Energie in overeenstemming met het ministerie van Binnenlandse Zaken en Koninkrijksrelaties. Het ruimtelijke besluit (in de nieuwe Omgevingswet: projectbesluit) wijzigt de huidige bestemmingen. Ook zijn er omgevingsvergunningen nodig, waaronder bouwvergunningen voor installaties op het verzamelpunt en voor de aanpassingen aan de platforms.

Andere vergunningen vallen onder de verantwoordelijkheid van andere bevoegde gezagen, bijvoorbeeld gemeente Rotterdam, Rijkswaterstaat en het ministerie van Landbouw, Natuur en Voedselkwaliteit (LNV). Vergunningen voor de afvang en opslag van CO_2 vallen buiten Aramis en worden aangevraagd door de opslagpartijen.

Nieuwe Omgevingswet en projectprocedure

Op 1 januari 2024 treedt de nieuwe Omgevingswet in werking. De formele besluiten voor Aramis worden niet voor deze datum genomen. Het ruimtelijk besluit van het Rijk heet onder de Omgevingswet niet meer rijksinpassingsplan (zoals in de Wet ruimtelijke ordening), maar projectbesluit. Aramis doorloopt de projectprocedure zoals weergegeven in afbeelding 3.



Afbeelding 3. Overzicht procedurestappen en tijdlijn.

Voornemen en voorstel participatie

Met de publicatie van de kennisgeving *Voornemen en Voorstel Participatie voor het project Aramis* (kennisgeving van het V&P) in de *Staatscourant* op 6 januari 2022 ging de projectprocedure officieel van start. EZK ontving zes reacties naar aanleiding van de kennisgeving. Op 19 en 24 januari 2022 heeft Aramis werksessies georganiseerd voor stakeholders van de Maasvlakte en de Noordzee. Bijlage 1 beschrijft de reacties en op welke manier die zijn gebruikt voor het actualiseren van dit participatieplan.

Concept-NRD

Bijlage 2 bevat het verslag van de stakeholdersessie op 21 juni 2022 waar de inhoud van de concept-NRD (Notitie Reikwijdte en Detailniveau) is besproken. In reactie op dit concept zijn acht zienswijzen ingediend. Op basis van deze zienswijzen is bekeken welke aanvullingen er nodig waren in de definitieve NRD. De definitieve NRD is in december 2022 vastgesteld.
Zowel de beantwoording van de vragen als de definitieve NRD is terug te vinden op de website van de RVO (https://www.rvo.nl/sites/default/files/2022-11/Vaststelling-NRD-en-Nota-van-Antwoord-concept-NRD-Aramis.pdf).

De inspraakprocedure heeft geresulteerd in twee aanpassingen aan de concept-NRD:

1. Als gevolg van de zienswijze van Neptune Energy worden de opslagfaciliteiten en bijbehorende infrastructuur van Neptune Energy als gelijkwaardig meegenomen in het MER, conform de opslagfaciliteiten voor TotalEnergies en Shell;
2. Het tracé van de zeeleiding is verder geoptimaliseerd, wat heeft geleid tot drie alternatieven en een variant, die alle in het MER worden getoetst.

IEA en MER

De volgende stap in het proces vindt momenteel plaats en behelst de voorbereidingen voor één integraal MER (fase 1 en fase 2 in één MER): een inventarisatie van de milieueffecten aan de hand van bureaustudies, onderzoeken en surveys. Op basis van de eerste resultaten van de milieuonderzoeken, evenals de aspecten kosten, omgeving, techniek en toekomstvastheid, stelt Aramis een Integrale Effectenanalyse (IEA) op. Deze analyse van de effecten van de verschillende routealternatieven en -varianten biedt tevens een uitgebreide analyse van zaken als de ruimtelijke inpassing. De resultaten van alle milieuonderzoeken worden samengevoegd in het MER, die naar verwachting in december 2023 gereed is. Het MER onderbouwt zowel de vergunningaanvragen als het projectbesluit en wordt in 2024 bij de ontwerpbesluiten ter inzage gelegd.

In overeenstemming met de minister van Binnenlandse Zaken en Koninkrijksrelaties kiest de minister voor Klimaat en Energie op basis van de IEA het voorkeursalternatief (VKA). Over het VKA vindt afstemming plaats met andere overheden en belangenorganisaties. Het VKA wordt gepubliceerd op de website van de RVO: Bureau Energieprojecten. Het VKA vormt de grondslag voor het ruimtelijk besluit (projectbesluit) en de vergunningen. Naar verwachting worden in het derde kwartaal van 2024 alle besluiten in ontwerp ter inzage gelegd, waarop ieder die dat wenst een zienswijze kan indienen. De zienswijzen worden betrokken bij het opstellen van de definitieve besluiten, waartegen beroep openstaat.

2 DOELEN EN KADER VAN PARTICIPATIE

2.1 DOELEN VAN PARTICIPATIE

Participatie gaat in brede zin over het betrekken van belanghebbenden en belangstellenden bij een project (zie de uitleg van de participatieladder in paragraaf 2.3). Dit participatieplan loopt vooruit op de nieuwe Omgevingswet door naast de wettelijk geregelde inspraak op het projectbesluit (formele procedure) een bredere betrokkenheid te organiseren. Aramis betrekt ieder die dat graag wil bij het project en handelt daarmee nu al in de geest van de aankomende wet. Hiermee hebben wij de volgende doelen voor ogen:

1. We willen burgers, bedrijven en maatschappelijke organisaties op een passende wijze bereiken;
2. We willen hun vragen, kansen en zorgen kennen en begrijpen;
3. We willen bij de ontwikkeling van het project rekening houden met ieders belangen;
4. We willen heldere keuzes maken en daarbij duidelijk laten zien hoe we omgaan met belangen, aandachtspunten, kansen en zorgen vanuit de omgeving.

Bij het behalen van deze doelen zijn we altijd bereid tot een constructieve dialoog. Onze projectorganisatie gaat uiteraard zorgvuldig om met persoonsgegevens, conform de AVG.

2.2 UITGANGSPUNTEN VAN PARTICIPATIE

We vinden het belangrijk dat participatie met betrekking tot Aramis begrijpelijk, betrouwbaar en toegankelijk is. Om te zorgen dat onze participatieaanpak zo goed mogelijk aansluit op de informatiebehoefte en wensen van belanghebbenden en belangstellenden, hanteren we de volgende uitgangspunten:

- We communiceren duidelijk, begrijpelijk en op maat;
- We bieden verschillende communicatiemiddelen aan, zodat iedereen de mogelijkheid heeft om onze informatie tot zich te nemen en indien gewenst met ons in dialoog te gaan;
- We communiceren tijdig en proactief;
- We kiezen voor een toegankelijke vorm die interactie en deelname aan inspraak stimuleert;
- We zijn goed bereikbaar en we reageren snel op vragen, klachten en verzoeken;
- We koppelen inhoud, toon en vorm aan elkaar, zodat we iedereen zo passend mogelijk bereiken.

2.3 KADER VAN PARTICIPATIE: HIER GAAT HET WEL/NIET OVER

Voor geslaagde participatie moet het duidelijk zijn waar belanghebbenden en belangstellenden wel en niet over kunnen meepraten en waar zij wel en geen invloed op hebben. De volgende drie vragen spelen hierbij een belangrijke rol: *waarom* we dit project willen doen, *waar* we dit project willen doen en *hoe*. Dit participatieplan maakt onderscheid tussen deze vragen en geeft per vraag de mate van participatie aan. Participatie kent namelijk verschillende gradaties, zoals hierna weergegeven in de participatieladder. Hoe hoger op de ladder, hoe meer invloed. Toch is ook op de onderste trede (informeren) sprake van participatie. Participatie is dus een heel breed concept.

Afbeelding 4. Participatieladder.

Waarom we dit willen doen?
De vraag waarom we Aramis willen uitvoeren is een vraag over nut en noodzaak van het initiatief. Aramis sluit aan op het regeringsbeleid, zoals geformuleerd in de brief van het kabinet aan de Tweede Kamer van 10 december 2021. In deze brief staat dat het afvangen, transporteren en opslaan van CO_2 een belangrijke (overgangs)technologie vormt voor de verduurzaming van Nederland en essentieel is om de CO_2-reductiedoelstelling voor 2030 te halen[3]. Ook in het Klimaatakkoord wordt verwezen naar CCS als een van de oplossingen om deze reductiedoelstelling te halen. Zie de Notitie Reikwijdte en Detailniveau (NRD) voor meer informatie over het Europese en Nederlandse klimaatbeleid en de rol van CCS hierin.

PARTICIPATIENIVEAU: INFORMEREN

Waar we dit willen doen?
De vraag waar we Aramis willen uitvoeren heeft betrekking op alternatieven en varianten van onder andere het tracé. De procedure voor de ruimtelijke inpassing, evenals de voorbereiding van het voorkeursalternatief, krijgt vorm in nauwe cocreatie met bevoegde instanties en betrokkenen bij andere activiteiten en ontwikkelingen in de buurt van Aramis. Met hen wordt ook gesproken over de gevolgen van de aanleg van onderdelen van het initiatief. Dit participatieplan beschrijft de verschillende manieren die belanghebbenden en belangstellenden hebben om hun suggesties kenbaar te maken. Ieder heeft de mogelijkheid om alternatieven aan te dragen, waarna deze worden afgewogen en mogelijk meegenomen. De uiteindelijke besluitvorming over het voorkeursalternatief is een taak van de ministers van EZK en BZK.

PARTICIPATIENIVEAUS: CONSULTEREN EN ADVISEREN

Hoe we dit willen doen?
De vraag hoe we Aramis willen uitvoeren is met name relevant in de dialoog met belanghebbenden en betrokkenen in de buurt van het project. Participatie draait hier om de gevolgen voor enerzijds de directe leef- en werkomgeving van mensen, en anderzijds de bedrijfsvoering van ondernemingen op de Maasvlakte en de Noordzee. Het gaat dus vooral om de impact van Aramis tijdens de uitvoering en ingebruikname. Naarmate het project zich verder ontwikkelt, concreter wordt en de uitvoering nadert, neemt de betrokkenheid van stakeholders in de directe omgeving toe. Gesprekken verplaatsen we dan naar lokaal niveau. Onderwerpen die hierbij aan bod komen zijn bijvoorbeeld de planning (start en duur) en uitvoering (tijdelijke overlast van bouwactiviteiten en veiligheid).

PARTICIPATIENIVEAU: CONSENSUS

[3] https://open.overheid.nl/repository/ronl-8fded76b-4d2c-4e79-817d-06bb14d9bb3a/1/pdf/kamerbrief-over-stand-van-zaken-ccs.pdf

3 PARTICIPATIEAANPAK

We betrekken graag personen en partijen bij Aramis wanneer het project hun belangen beïnvloedt, wanneer zij zich inhoudelijk betrokken voelen en/of wanneer zij belangrijk zijn voor de realisatie van Aramis. Hierbij onderscheiden we de volgende groepen:

- Burgers: mensen die dicht bij het project wonen of verblijven en om die reden vragen of zorgen hebben of anderzijds geïnteresseerd zijn. Wij denken dan vooral aan omwonenden;
- Bedrijven in de omgeving: bedrijven die dicht in de buurt van het project gevestigd zijn of daar werkzaamheden uitvoeren, zoals buurbedrijven op de Maasvlakte en op de Noordzee;
- Inhoudelijk betrokkenen: maatschappelijke organisaties en stakeholders die zich, los van de locatie, inhoudelijk betrokken voelen. Dit zijn bijvoorbeeld vertegenwoordigers van de scheepvaart, kustwacht, visserij, kabelexploitanten en operators van windparken. Wij denken verder aan ngo's die zich sterk maken voor natuur en milieu. Ook kennisinstellingen en organisaties die zich bezighouden met klimaat en CCS horen hierbij;
- Bestuursorganen: overheden op landelijk, provinciaal en lokaal niveau, zoals de provincie Zuid-Holland, gemeenten, Rijkswaterstaat (kruising zeewering, zandwinning, scheepvaart) en het waterschap Hollandse Delta. Ook semipublieke instellingen zoals ProRail, TenneT en Havenbedrijf Rotterdam zijn belangrijke stakeholders;
- Offshore storage-operators: operators van platforms op de Noordzee die in de toekomst wellicht toegang willen tot de CO_2-transportinfrastructuur van Aramis.

Deze personen en partijen hebben keuze uit individuele gesprekken en groepsbijeenkomsten, zowel online als live. De mate van participatie (informeren, consulteren, adviseren of verkrijgen van consensus) wordt vastgelegd en duidelijk gecommuniceerd. Zo willen wij een brede vertegenwoordiging van de samenleving bereiken en iedereen passend bedienen. Het is onze hoop dat deze werkwijze leidt tot meer betrokkenheid en meer waardering voor en acceptatie van Aramis.

We bieden de volgende informatiekanalen om geïnformeerd te blijven (informeren):
- Publicaties in de *Staatscourant* en huis-aan-huisbladen;
- Informatie op de websites van Aramis, CO_2next en Bureau Energieprojecten;
- (In)formele bijeenkomsten: (online) informatiebijeenkomst/seminar/kennissessie;
- Digitale nieuwsbrief;
- Persoonlijke of geclusterde gesprekken.

We bieden de volgende manieren om betrokken te blijven (consulteren of adviseren):
- (Online) informatiebijeenkomst;
- Bestuurlijke, regionale en landelijke overleggen;
- Persoonlijke of geclusterde gesprekken;
- Schriftelijke reactie op plannen.

Hieronder lichten we deze kanalen toe voor de periode vanaf het vaststellen van het milieueffectrapport (MER) en de Integrale Effectenanalyse (IEA) tot de publicatie van de ontwerpbesluiten.

3.1 MANIEREN OM GEÏNFORMEERD TE BLIJVEN (INFORMEREN)

In deze en de volgende paragraaf leest u hoe wij personen en partijen in de komende periode bij Aramis willen betrekken. Bijlage 3 beschrijft welke stappen in eerdere fases zijn genomen.

a. Publicaties Staatscourant en huis-aan-huisbladen
Formele stappen in de projectprocedure worden vooraf gepubliceerd in de *Staatscourant* en in huis-aan-huisbladen. Naar verwachting wordt in het derde kwartaal van 2024 de terinzagelegging van de ontwerpbeschikkingen in de *Staatscourant* gepubliceerd, waarop zienswijzen kunnen worden ingediend. Eind 2024/begin 2025 volgt naar verwachting de publicatie in de *Staatscourant* dat de definitieve besluiten op de vergunningaanvragen ter inzage liggen voor beroep.

b. Websites Aramis, CO_2next en Bureau Energieprojecten
Iedereen heeft toegang tot onze websites www.aramis-ccs.com/nl en CO2next.nl. Hier delen wij regelmatig updates en mijlpalen, waarbij we verwijzen naar de officiële documenten op de website van Bureau Energieprojecten. Het is voor iedereen mogelijk om een reactie achter te laten. De websites vermelden ook de e-mailadressen en telefoonnummers voor rechtstreeks contact. Wanneer het MER, de IEA en de (ontwerp)besluiten gereed zijn, worden die op de website van Bureau Energieprojecten gepubliceerd.

c. (In)formele bijeenkomsten: (online) informatiebijeenkomsten en symposia
In de komende periode worden de milieuonderzoeken uitgevoerd. Tijdens eerdere sessies hebben verschillende stakeholders aandachtspunten (eisen en wensen) aangedragen. Op basis van deze aandachtspunten bespreken we de tussentijdse resultaten van de milieuonderzoeken met de stakeholders. Zo kunnen we stakeholders met zorgen en vragen, bijvoorbeeld over geluid, Natura 2000-gebieden, veiligheid, gezondheid of de impact op de omgeving, specifiek en gedetailleerd informeren. Eventueel vindt er een informatiebijeenkomst of symposium plaats. Vooraf peilen we hiervoor de interesse en informatiebehoefte bij stakeholders. Bij voldoende interesse bepalen we een datum, die we tijdig aan de stakeholders kenbaar maken.

d. Digitale nieuwsbrief
Zo'n vier tot vijf keer per jaar verschijnt een nieuwsbrief waarvoor iedereen zich via onze website kan aanmelden. De aankomende nieuwsbrieven staan gepland voor september en november. Deze planning staat niet vast en hangt onder andere af van de vraag of er voldoende nieuws is om te communiceren.

e. Persoonlijke of geclusterde gesprekken
De komende periode vinden zowel individuele als geclusterde gesprekken plaats met de diverse stakeholders. Deze gesprekken kunnen het gehele Aramis-initiatief tot onderwerp hebben, dus inclusief het onderdeel waarvoor CO_2next verantwoordelijk is. Maar het is ook mogelijk dat het gesprek zich beperkt tot uitsluitend het deel waarvoor Aramis of CO_2next verantwoordelijk is. Dit is afhankelijk van het onderwerp en de organisatie waarmee het gesprek plaatsvindt, bijvoorbeeld omliggende bedrijven, gemeenten, ngo's, Kamerleden enzovoort.

Tijdens deze gesprekken worden de eisen en wensen van de gesprekspartners zo concreet mogelijk gemaakt. Eisen en wensen die betrekking hebben op het tracé en de exacte ligging worden in deze fase meegenomen, eisen en wensen die betrekking hebben op de uitvoering volgen in een later realisatiecontract.

De Integrale Effectenanalyse (IEA) brengt de effecten in kaart die de verschillende alternatieven hebben op milieu, kosten, omgeving, techniek en toekomstvastheid. Hier krijgen de opgehaalde eisen en wensen hun beslag. Belanghebbenden worden geïnformeerd over de uitkomsten van de IEA en geconsulteerd over de beoogde voorkeursalternatieven voor het Aramis initiatief.

3.2 MANIEREN OM BETROKKEN TE BLIJVEN (CONSULTEREN/ADVISEREN)

a. (Online) informatiebijeenkomst
In de komende periode vinden de milieuonderzoeken plaats. Aramis organiseert dan een of meer MER-kennissessies met als onderwerp: wat houden deze milieuonderzoeken precies in en wat zijn de eerste bevindingen?

b. Bestuurlijke, regionale en landelijke overleggen
Aramis en EZK vinden het belangrijk om direct betrokken overheden, adviesorganen en belangenorganisaties te betrekken bij de besluitvorming over het project. Voor zowel de ruimtelijke procedure als de uitvoeringsvergunningen vinden afstemmingsoverleggen plaats. Zo wordt in het Noordzeeoverleg met enige regelmaat een update gegeven van de onderzeese routealternatieven van Aramis en het overleg dat daarover heeft plaatsgevonden. Deze updates hebben tot doel de aanwezige organisaties mee te nemen in de totstandkoming van de IEA en het VKA, de basis voor het (ruimtelijk) projectbesluit. Daarnaast worden ook andere regionale overheden en belangenorganisaties geïnformeerd over het project.

c. Stakeholders
Aramis is in een eerder stadium geïntroduceerd bij onder meer programmamanagers, regioadviseurs, beleidsadviseurs en projectleiders van ministeries (EZK Wind-op-zee, Landbouw, Natuur en Voedselkwaliteit (LNV), Defensie, Binnenlandse Zaken en Koninkrijksrelaties (BZK), Infrastructuur en Waterstaat (IenW)), de Rijksdienst voor het Cultureel Erfgoed (RCE), lokale gemeenten (Rotterdam, Voorne aan Zee), de provincie (Zuid-Holland), Veiligheidsregio Rotterdam-Rijnmond (VRR), water(veiligheid)beheerders (waterschap Hollandse Delta, RWS Zee & Delta, Kustwacht), omgevingsdiensten (DCMR, ODH), wegbeheerder (RWS WNZ), railbeheerder (ProRail), belangengroepen (Deltalinqs, KVNR, Element NL, Nexstep, de Nederlandse Vissersbond, Nederlands Loodswezen, H-vision, NWEA, Verontruste Burgers van Voorne), ngo's (Bellona, Stichting de Noordzee, Natuur & Milieu, Greenpeace, Milieufederatie Zuid-Holland, Vogelbescherming, WNF), raakvlakprojecten (Porthos, Eneco), kabel- en pijpleidingeigenaren (TenneT, Stedin), offshore operators (o.a. Neptune Energy, Petrogas) en bedrijven op de Maasvlakte (Havenbedrijf Rotterdam, MOT, Euromax). Met deze stakeholders worden een-op-een- of clustergesprekken gevoerd.

d. Schriftelijke reactie op plannen
Iedereen krijgt in 2024 de mogelijkheid om schriftelijk een reactie te geven op het ontwerpbesluit en op het MER. De publicatie van het ontwerpbesluit staat gepland voor het derde kwartaal van 2024 en men heeft dan zes weken de tijd om te reageren. Aramis brengt de stakeholders te zijner tijd op de hoogte van de publicatie, zodat zij in de gelegenheid zijn om tijdig een zienswijze op het ontwerpbesluit (inclusief het MER) in te dienen.

4. PARTICIPATIEKALENDER

4.1 PARTICIPATIEKALENDER

De onderstaande tabel geeft op hoofdlijnen de stappen van besluitvorming en participatie weer conform de projectprocedure (zie paragraaf 1.3 hierboven). In de tabel staat wanneer officiële documenten worden gepubliceerd en ter inzage worden gelegd, en wanneer ieder die dat wil kan meedenken, bijdragen en inspreken.

PROCESSTAP	WIJZE VAN PARTICIPATIE	STATUS
Voornemen en voorstel participatie (januari 2022)	**Informeren, consulteren en adviseren** EZK en Aramis hebben de brede omgeving van overheden, bevoegde instanties, inwoners, bedrijven en professionele stakeholders geïnformeerd over het projectvoornemen en de voorgestelde invulling van participatie. Iedereen kon een formele reactie geven met betrekking tot: 1. andere oplossingen voor de geschetste opgave, bijvoorbeeld andere manieren om CCS toe te passen (denk aan alternatieven en varianten); 2. andere voorstellen voor de wijze waarop derden worden betrokken. Alle verzamelde reacties zijn waar mogelijk verwerkt in de concept-NRD (Notitie Reikwijdte en Detailniveau). Participatie-instrumenten: • Publicatie in Staatscourant en huis-aan-huisbladen; • Openbare informatiebijeenkomst.	**Gereed**
Inventarisatie alternatieven en varianten en het beoordelingskader (januari-mei 2022)	**Consulteren en adviseren** EZK en Aramis hebben andere overheden, bevoegde instanties en belangenorganisaties geconsulteerd om op verschillende manieren mee te denken, informatie aan te leveren over tracé-alternatieven, en varianten en aandachtspunten aan te dragen voor de NRD en het MER. Participatie-instrumenten: • Geïntegreerde interactieve werksessies; • Een-op-een- of clustergesprekken; • Nieuwsbrief Aramis.	**Gereed**
Concept Notitie Reikwijdte en Detailniveau (concept-NRD) (juni 2022)	**Informeren, consulteren en adviseren** Iedereen kon een formele zienswijze indienen over de vragen: • of de participatie beter kan; • of er iets ontbreekt bij de onderzoeken; • of de juiste onderdelen worden onderzocht; • of er andere tracé-alternatieven en/of -varianten onderzocht moeten worden. Waar relevant zijn deze meegenomen in de definitieve NRD. Participatie-instrumenten: • Publicatie in Staatscourant en huis-aan-huisbladen; • Publicatie op www.rvo.nl/onderwerpen/bureau-energieprojecten;	**Gereed**

	• Websites Aramis en CO_2next; • Raadpleging Commissie MER; • Een-op-een- of clustergesprekken; • Formele en informele informatiebijeenkomst op 21 juni 2022; • Nieuwsbrief Aramis.	
Vaststellen definitieve NRD (december 2022)	**Informeren** EZK en Aramis hebben de brede omgeving geïnformeerd over de definitief vastgestelde NRD. Participatie-instrumenten: • Publicatie op www.rvo.nl/onderwerpen/bureau-energieprojecten; • Websites Aramis en CO_2next; • Nieuwsbrief Aramis.	**Gereed**
Integrale Effectenanalyse (IEA) (december 2023)	**Informeren, consulteren en adviseren** EZK en Aramis consulteren de brede omgeving over de afwegingen van de IEA op basis van de aspecten milieu, kosten, omgeving, techniek en toekomstvastheid. Participatie-instrumenten onder andere: • Publicatie op www.rvo.nl/onderwerpen/bureau-energieprojecten; • Websites Aramis en CO_2next; • Overleggen (door EZK); • Een-op-een- of clustergesprekken; • Nieuwsbrief Aramis.	*Gepland*
Keuze voorkeursalternatief (VKA) (januari 2024)	**Informeren, consulteren en adviseren** EZK en Aramis raadplegen decentrale overheden en andere departementen over het VKA. De minister van EZK bepaalt op basis van dit advies het voorkeursalternatief. Participatie-instrumenten onder andere: • Een-op-een- of clustergesprekken met belanghebbenden; • Overleggen (door EZK); • Websites Aramis en CO_2next; • Nieuwsbrief Aramis.	*Gepland*

Milieueffectrapport (MER) als onderdeel van de vergunningaanvragen (eind 2024)	**Informeren, consulteren en adviseren** EZK en Aramis consulteren de brede omgeving over het MER. Reageren op het MER is mogelijk bij de terinzagelegging van de ontwerpbesluiten (zie de stap Publicatie ontwerp-projectbesluit en ontwerp-vergunningen hieronder). Participatie-instrumenten onder andere: • Resultaten van het MER zullen aan het eind worden gedeeld; • Een-op-een- of clustergesprekken met belanghebbenden; • Websites Aramis en CO_2next; • Nieuwsbrief Aramis.	*Gepland*
Publicatie ontwerp-projectbesluit en ontwerp-vergunningen (eind 2024)	**Informeren en horen** De bevoegde instanties stellen op basis van de aanvragen van Aramis het ontwerp-projectbesluit en de ontwerp-vergunningen op. EZK publiceert het ontwerp-projectbesluit en de ontwerp-vergunningen, inclusief het MER. Iedereen die dat wil kan een formele zienswijze indienen. De commissie van de m.e.r. geeft een advies over het MER. Participatie-instrumenten onder andere: • Publicatie in Staatscourant en huis-aan-huisbladen; • Publicatie op www.rvo.nl/onderwerpen/bureau-energieprojecten; • Openbare informatiebijeenkomst(en); • Een-op-een- of clustergesprekken met belanghebbenden; • Websites Aramis en CO_2next; • Nieuwsbrief Aramis.	*Gepland*
Publicatie definitief projectbesluit en definitieve vergunningen (eind 2024/begin 2025)	**Informeren en beroep** EZK publiceert het definitief projectbesluit en de definitieve vergunningen. Iedereen kan reageren op het projectbesluit en de vergunningen door hiertegen beroep in te stellen. Participatie-instrumenten onder andere: • Publicatie in Staatscourant en huis-aan-huisbladen; • Publicatie op www.rvo.nl/onderwerpen/bureau-energieprojecten; • Hoger beroep; • Websites Aramis en CO_2next; • Nieuwsbrief Aramis.	*Gepland*
Onherroepelijk projectbesluit en vergunningen (zonder beroep)	Uitspraak Raad van State na behandeling van mogelijke beroepen.	n.t.b.

4.2 WE HOREN GRAAG UW REACTIE OP DIT PARTICIPATIEPLAN

Zoals in paragraaf 1.1 aangeven, actualiseren we het participatieplan minstens eenmaal per projectfase. Het volgende participatieplan verschijnt naar verwachting in het voorjaar van 2024, voorafgaand aan de publicatie van het projectbesluit.

Heeft u vragen of suggesties voor verbetering van dit plan? Wij horen graag van u!
U kunt uw reactie per e-mail sturen naar: info@aramis-ccs.com.

BIJLAGES

BIJLAGE 1 SAMENVATTING INBRENG STAKEHOLDERS

Het doel van de stakeholderparticipatie is het ophalen van informatie, gebiedskennis, aandachtspunten, ideeën en kansen uit de omgeving. Zo hebben er sinds zomer 2021 kennismakingsgesprekken met stakeholders, één-op-één overleggen en persoonlijk contact met verschillende belanghebbenden plaatsgevonden. Van 7 januari tot 17 februari 2022 heeft de notitie 'Voornemen en Voorstel Participatie' ter inzage gelegen. In die periode was het mogelijk om te reageren door een schriftelijke reactie te geven op deze notitie. Er zijn zes reacties binnengekomen bij EZK. Er is formeel een antwoord gegeven op deze reacties via de nota van antwoord die is opgesteld door EZK in afstemming met het Aramis initiatief. Deze nota van antwoord is tegelijkertijd met de concept NRD en dit Participatieplan gepubliceerd.

Daarnaast werden er op 19 en 24 januari 2022 werksessies met verschillende stakeholders op respectievelijk 'land' en op 'zee' georganiseerd en heeft het ministerie van Economische Zaken en Klimaat op 26 januari 2022 een informatieavond gehouden. Een aantal aanwezigen bij de informatieavond heeft aangegeven de Aramis nieuwsbrief te willen ontvangen: zij hebben inmiddels de eerste Aramis nieuwsbrief ontvangen en worden op de hoogte gehouden door volgende nieuwsbrieven. Tijdens de verschillende gesprekken en werksessies zijn de plannen toegelicht en is er veel gebiedskennis verzameld. In het onderstaande wordt een samenvatting van aandachtspunten gegeven die door stakeholders zijn benoemd. Hierbij is onderscheid gemaakt tussen het onderdeel 'aanlanding en landdeel' (A) en het onderdeel 'zeedeel' (B). Daarnaast volgt een lijst van geraadpleegde stakeholders per onderdeel.

1 Samenvatting aandachtspunten Maasvlakte – aanlanding en landdeel

Omgevingsveiligheid, geluid & stikstof depositie
Veel partijen stellen vragen over omgevingsveiligheid, geluid en stikstofdepositie door de aanleg en aanwezigheid van de terminal en het compressor station, pompen en andere installaties. Ook over het 'entry' punt van de micro-tunnel (één van de twee voorlopige aanlandingslocaties op de Maasvlakte) stellen partijen vragen met het oog op het risico op calamiteiten, aangezien de 'vuurwerk ompak' locatie op de Prinses Maximaweg zich nabij bevindt. Verder wordt voor de stikstofdepositie in relatie tot scheepvaartbewegingen (ten behoeve van de vloeibare intake van CO_2) aandacht gevraagd.

Overslag CO_2 na aanlanding per schip
De terminalfaciliteiten, bestaande uit de overslag van CO_2 van schepen, tijdelijke opslag en verpomping van vloeibaar CO_2 naar de zeeleiding worden door CO_2next uitgevoerd.

Aanlanding vanuit zee op Maasvlakte
Voor de aanlanding van de pijpleiding vanuit zee naar de Maasvlakte zijn twee opties in beeld. Ten eerste via een Horizontale boring (HDD) onder de harde zeewering of ten tweede via een micro-tunnel die op diepte ligt onder de Maasgeul. De stakeholders vragen aandacht voor het feit dat beide aanlegmethodes ook op het land van de Maasvlakte permanente ruimte en werkterreinen behoeven. Hiervoor is tijdige afstemming met meerdere stakeholders, onder meer Port of Rotterdam van belang.

De suggestie wordt gedaan om een overleg te hebben met de stakeholders die gebiedskennis hebben over de aanlanding middels een HDD op de Maasvlakte. De beschikbare ruimte is beperkt gezien de ligging van TenneT kabels (Net op zee HKZ), de voorziene ligging van de Porthos CO_2 leiding, de aanwezige leidingenstrook op de Maasvlakte en het voorziene windpark van Eneco op de zeewering.

Een van de opties, een microtunnel, zou mogelijkheden en kansen kunnen bieden voor medegebruik zoals het 'Net op zee' van TenneT voor nog toekomstige windparken.
Ongeacht de aanlandingsopties wordt aandacht gevraagd voor dat de scheepvaart in de Maasgeul geen hinder mag ondervinden.

Andere functies en industrie op de Maasvlakte
In veel gesprekken komt naar voren dat de industrie volcontinu in bedrijf is. De dagelijkse werkzaamheden moeten 24/7 door kunnen gaan tijdens de aanlegfase van de projecten. Ook dient de toegang van hulpdiensten te allen tijde zijn gegarandeerd. Eveneens dient de bereikbaarheid van de kazerne van de Gezamenlijke Brandweer aan de Prinses Maximaweg 24/7 gegarandeerd te blijven.
De leiding komt deels binnen en buiten de leidingenstrook te liggen. Dit vergt afstemming met zowel Port of Rotterdam als het Leidingenbureau van gemeente Rotterdam. De krappe ligging in de leidingenstrook en de drukte in de ondergrond zijn aandachtspunten.

Autoriteiten en andere stakeholders – aanlanding en landdeel
Autoriteiten: Het Ministerie van EZK, DCMR, ProRail regio Randstad-Zuid, Gemeente Rotterdam (RO, leidingenbureau Rotterdam), Veiligheidsregio Rotterdam-Rijnmond, Rijkswaterstaat (WNZ, Zee & Delta), Omgevingsdienst Haaglanden, Provincie Zuid-Holland
Ngo's: Vereniging Natuurmonumenten Zuid Holland, Natuur- en Milieufederatie Zuid-Holland
Kabel en pijplijn eigenaren: TenneT
Industrie & Business & andere projecten Maasvlakte: Deltalinqs, Havenbedrijf Rotterdam, Divisie Havenmeester van het Havenbedrijf Rotterdam, Eneco, Euromax, Gate terminal, Porthos , MOT, ProRail, ECT Rotterdam
Scheepvaart: het Nederlands Loodswezen
Overige: Gezamenlijke brandweer Prinses Maxima kazerne

1 Samenvatting aandachtspunten - zeedeel

Zeeleiding op of in de zeebodem
Partijen hebben vragen over de installatie van de zeeleiding op of in de zeebodem. Dit heeft te maken met verschillende belangen van verschillende stakeholders. Zo dient de leiding overvisbaar te zijn en moet scheepvaartveiligheid gegarandeerd zijn in geval van (nood)ankeren boven de leiding. Daarnaast zijn er vragen over de gevolgen van meerdere leidingen en kabels die gekruist worden in de aanlooproute voor de scheepvaart; ontstaan er dan niet lokale verondiepingen op de zeebodem als gevolg van de kruisingsconstructies op de zeebodem? Nautische partijen vragen verder om het beperken van hinder voor de scheepvaart door het vermijden van ankergebieden en het zoveel mogelijk haaks kruisen van hoofdvaarroutes en geulen. Daarnaast wordt er aandacht gevraagd voor het mogelijke effect van CO_2 lekkage op het milieu. Ook is er sprake van de aanwezigheid van mogelijke obstakels op de zeebodem (zoals wrakken en mogelijk WO II resten).

Andere functies op de Noordzee
Partijen geven aan dat er nieuwe windparken op zee worden gepland. Dit heeft mogelijk ook gevolg voor een militair oefengebied op zee dat verplaatst moeten worden. Partijen vragen of er bij de tracering van de leiding rekening wordt gehouden met deze ontwikkelingen. Dit betekent ook nieuwe hoogspanningskabels van het net op zee, waarin in de tracering rekening gehouden moet worden (t.a.v. minimumafstanden en kruisingen).
Andere olie- en gasoperators hebben interesse getoond voor het eveneens aansluiten op de centrale leiding, zodat ook van hun opslagmogelijkheden gebruik gemaakt kan worden. Voor deze groep van stakeholders is op 9 maart 2022 een aparte bijeenkomst georganiseerd.
Partijen vragen aandacht voor andere gebruiksfuncties op de drukke Noordzee; zoals zandwinning. Deze gebieden dienen zo veel mogelijk vermeden te worden.
Met de stakeholders zijn twee tracé opties (Opties A en B) in het noordelijke deel op zee besproken. Alleen vanuit de toekomstige windpark belangen is er een voorkeur uitgesproken voor route-optie A omdat deze route-optie minder impact heeft op het toekomstige windenergiegebied. Overige partijen hebben geen onderscheidende aandachtspunten per tracé optie aangegeven.

Natuurversterkende maatregelen en andere kansen
In de contacten met partijen werden ook kansen benoemd voor de Noordzee; zoals het natuur-inclusief aanleggen van de benodigde infrastructuur op de zeebodem en een eventuele koppeling met andere CCS projecten.

Autoriteiten en andere stakeholders - zeedeel
Autoriteiten: Ministerie van EZK, Rijkswaterstaat (Zee & Delta), Ministerie van LNV, Ministerie van Defensie/ Dienst der Hydrografie, Ministerie van I en W
Ngo's: Vereniging Natuurmonumenten Zuid Holland, Natuur- en Milieufederatie Zuid-Holland, Stichting de Noordzee, Natuur & Milieu
Kabel en pijplijn eigenaren: TenneT, Stedin
Industrie & Business: Divisie Havenmeester van het Havenbedrijf Rotterdam
Scheepvaart: het Nederlands Loodswezen, Scheepvaart Adviesgroep Noordzee, KVNR
Visserij: Nederlandse Vissersbond, Voormalig VisNED
Olie en gas: Element NL
Zandwinning: LaMER
Overig: Kustwacht

Terugkoppeling werksessies
In de terugkoppeling naar deze stakeholders hebben we initieel een korte reactie gegeven op alle aandachtspunten. Hierin is aangeven dat we contact opnemen om een afspraak te maken en in individuele gesprekken hun aandachtspunten verder willen bespreken. Het Aramis initiatief heeft na de werksessie contact gehad met het Havenbedrijf Rotterdam, Euromax, Deltalinqs (bij de Klimaattafel) en DCMR. Op 7 april 2022 is er ook een gezamenlijk gesprek geweest met de gemeente Rotterdam, EZK, Gate terminal, MOT, Aramis en CO_2next over de aanpak voor het wijzigen van het huidige bestemmingsplan van Gate terminal en MOT en de rol van de bevoegde gezagen. Er is een vervolgoverleg ingepland om helderheid te verschaffen aan de te volgen procedure. Alle reacties zijn als input meegewogen voor de concept NRD en het technisch ontwerp waar we momenteel mee bezig zijn.

BIJLAGE 2 VERSLAG STAKEHOLDERSESSIE 21 JUNI 2022

Onderwerp	Stakeholderbijeenkomst Aramis en CO_2next
Project	Aramis
Datum bijeenkomst	21 juni 2022
Plaats	Hoek van Holland
Bijlage(n)	Presentatie Aramis
Aanwezig	Ministerie van EZK, EZK Wind-op-zee, TenneT, RWS, Koninklijke Vereniging van Nederlandse Reders, Kustwacht, Neptune, Carbon Collectors, Noordgastransport, Porthos, AECOM, Buis Consultancy, TNO, Port of Rotterdam (nautisch beheer), Omgevingsdienst Haaglanden, DCMR, Provincie Zuid- Holland, RWS (WNZ), LNV, Veiligheidsregio Rotterdam -Rijnmond.

Verslag stakeholderbijeenkomst

Algemeen

Op 21 juni jl. heeft een stakeholderbijeenkomst plaatsgevonden. Het doel van de bijeenkomst was het ophalen van informatie, gebiedskennis, aandachtspunten voor het MER ideeën, zorgen, wensen en kansen uit de omgeving. Onderstaand het verslag van de bijeenkomst.

Plenaire opening

Er wordt gestart met een toelichting op de concept Notitie Reikwijdte en Detailniveau en de stand van zaken van Aramis. Er wordt aangegeven wat de planning is en op welke momenten er nog ruimte is voor participatie.

Thematafels

Na het plenaire gedeelde wordt er uiteen gegaan in drie thematafels: de Maasvlakte, de Aflanding en de Noordzee.

Samenvatting aandachtspunten Maasvlakte

Aan deze tafel gingen vragen onder meer over:

- technisch gerelateerde zaken zoals de aanleg van pijpleidingen: land-trace's en de constante flow van de CO_2 in relatie tot een flexibel aanbod van de CO_2
- de schepen: emissieloos bouwen, stikstofdepositie en duur van het bouwen, soort schepen, capaciteit steigers, en aanbod walstroom
- het bevoegd gezag voor het deel van de aanlanding en de Maasvlakte (in dit geval gecoördineerd door EZK).
- de situatie met betrekking tot het compressorstation en de relatie tussen Aramis, Porthos en CO_2next.
- de scope tussen Aramis emitters en andere emitters, als ook over de capaciteit en prioritering voor de opslagvelden en voldoende beschikbaarheid van schepen voor de aan- en afvoer van vloeibare CO_2.
- punten in relatie tot de veiligheid, zoals het meenemen van de windturbines in de risicoanalyse, de gevolgen voor Hoek van Holland, aanvaringsrisico's, tankrisico's, de ligging van de brandweer kazerne bij een verkeerde wind.

Samenvatting aandachtspunten Aflanding
Aan deze tafel is onder andere gevraagd naar de technische uitdaging in dit project, en de beschikbare ruimte in relatie tot de beoogde Porthos leiding. Verder hebben TenneT en Porthos vooral hun ervaringen gedeeld, opgedaan bij eerdere aanleg van leidingen in het gebied, respectievelijk bij de voorbereiding daarop. Zo is uitdrukkelijk meegegeven aandacht te hebben in het vervolgtraject voor aanwezige niet gesprongen explosieven, archeologische waarden, bodemgesteldheid, stabiliteit van de zeewering, en beschermde soorten. Dit zowel uit technisch oogpunt als voor wat betreft de benodigde vergunningen en toestemmingen en de tijd die daarmee gemoeid is. Aangeboden wordt waar mogelijk gegevens van bijvoorbeeld boringen te delen, zonder daarbij de eigen verantwoordelijkheid van Aramis uit het oog te verliezen. Vanuit Nautisch Beheer van Port of Rotterdam wordt aandacht gevraagd voor het veilig en ongestoord doorgang vinden van de scheepvaart en de eisen die daaraan worden gesteld. In dat kader is als aandachtspunt meegegeven dat het Port of Rotterdam niet altijd duidelijk is op welke wijze de verschillende initiatiefnemers in de Maasmond met elkaar samenwerken.

Samenvatting aandachtspunten Noordzee
Aan deze tafel werd de ligging van de leiding toegelicht aan de hand van een tracétekening. Daarna is er de mogelijkheid gegeven aan de aanwezigen om te reageren op deze tekening.

Veel van de ingebrachte punten waren suggesties ter verbetering van de ligging van de leiding en het kaartmateriaal.

- EZK Wind-op-zee merkt op dat de zoekgebieden voor Hollandse Kust Zuidwest en Noordwest vervallen. Deze moeten nog van de tracétekening worden afgehaald.
- De Kustwacht geeft aan dat in de bepaling van de tracékeuze aandacht moet zijn voor multifunctioneel ruimtegebruik, bijvoorbeeld gaswindgebieden en bijbehorende aanvliegroutes en defensie oefengebied.
- De Kustwacht geeft als suggestie dat bestaande pijpleidingen gevolgd kunnen worden om een corridor te creëren.
- Neptune Energy geeft aan dat de Riser Tower of site tap op ‘gelijke’ afstand van hun velden moet liggen als van de velden van TotalEnergies en Shell.
- De Kustwacht geeft aan dat de leiding overvisbaar moet zijn, geen ankerplekken mag kruisen en zoveel mogelijk parallel moet liggen aan de vaarroutes.
- EZK Wind-op-zee ziet graag dat de leiding wordt gelegd buiten de (beoogde) windgebieden.

Daarnaast worden er verschillende punten ingebracht ter verbetering van de c-NRD en om mee te nemen in het MER:

- EZK Wind-op-zee vindt dat de ruimtelijke keuzes voor de ligging van het tracé nog beter omschreven mogen worden in de c-NRD.
- Neptune Energy voegt daaraan toe dat ze graag nog beter de mogelijkheden voor toekomstige aan- en aftakkingen op de leiding omschreven zien.
- De Kustwacht geeft aan dat er in het MER onderzocht moet worden wat het effect van lekkage is.

KNVR geeft tot slot de tip om MARIN te benaderen voor meer informatie over hun onderzoek naar de mogelijkheden om windmolens te beschermen tegen op drift geraakte schepen, omdat de uitkomsten hiervan ook nuttig voor Aramis kunnen zijn.

De middag is afgerond met een plenaire terugkoppeling, waarbij de gevoerde gesprekken per thematafel zijn samengevat, en is benadrukt dat op meerdere momenten in het vervolg van het proces participatie mogelijk is. Aramis zal de opgehaalde informatie verwerken in het MER en zal het gesprek van de thematafels voort zetten met de verschillende stakeholders.

BIJLAGE 3 AFGERONDE ACTIES VAN PARTICIPATIE (UIT H3)

MANIEREN OM GEÏNFORMEERD TE BLIJVEN (INFORMEREN)

a. Publicaties Staatscourant en huis-aan-huis bladen
Op 9 juni 2022 is in de Staatscourant (en in diezelfde week ook in huis-aan-huis bladen) gepubliceerd dat de concept NRD en dit participatieplan ter inzage lagen voor reacties. Op 2 december 2022 is in de Staatscourant gepubliceerd dat de definitieve NRD is vastgesteld.

b. Websites projecten Aramis, CO_2next en Bureau Energieprojecten
Op 10 juni 2022 is de concept NRD gepubliceerd op de website van Bureau Energieprojecten. Hierop kon iedereen de concept NRD en het geactualiseerde participatieplan inzien. Iedereen had de mogelijkheid tot het indienen van een zienswijze. Er zijn acht zienswijze ingediend die formeel zijn beantwoord. Op 2 december 2022 is de definitieve NRD inclusief de nota van antwoord gepubliceerd op de website van Bureau Energieprojecten.

c. (In)formele bijeenkomsten: Informatiebijeenkomst, symposium en kennissessies
Op 21 juni 2022 hebben EZK en het Aramis initiatief een formele informatiebijeenkomst gehouden, ten tijde van de terinzagelegging van de concept NRD. We hebben de concept NRD toegelicht, welke alternatieven en varianten we in het MER gaan onderzoeken, hoe we dat gaan doen en in welk detailniveau. Tijdens deze bijeenkomst waren projectleden van het Aramis initiatief aanwezig om vragen over het project en de concept NRD te beantwoorden. Medewerkers van EZK waren ook aanwezig om vragen over de procedure te beantwoorden.

Naast de formele bijeenkomst heeft Aramis een informele bijeenkomst georganiseerd voor alle (zakelijke) stakeholders. Doel was om de deelnemers van deze bijeenkomst te informeren over de status van het project aan de hand van de concept NRD en om alle vragen die er leven te beantwoorden. Met deze bijeenkomst heeft het Aramis initiatief ook voldaan aan de verplichting van een openbare raadpleging die volgt uit de PCI-status (Project of Common Interest).

d. Digitale nieuwsbrief
We hebben eind april 2022 de eerste nieuwsbrief en in juli 2022 de tweede nieuwsbrief uitgebracht. De eerste twee nieuwsbrieven waren in het Nederlands. De derde nieuwsbrief (in het Engels) is in november 2022 verspreid en de vierde in april 2023. Alle nieuwsbrieven zijn toegankelijk via de Aramis website.

e. Persoonlijk of geclusterde gesprekken
Afgelopen periode zijn individuele en ook geclusterde gesprekken met de diverse stakeholders gevoerd. Uitkomsten daarvan zijn en worden verwerkt in Dialog.

MANIEREN OM BETROKKEN TE BLIJVEN (INFORMEREN/CONSULTEREN/ADVISEREN)

a. Informatiebijeenkomst
Tijdens de informatiebijeenkomst op 21 juni 2022 konden de aanwezigen op een laagdrempelige manier in gesprek gaan met projectmedewerkers van het Aramis initiatief en het ministerie van EZK. Ook was het voor de aanwezigen mogelijk tijdens deze bijeenkomst een mondelinge reactie (zienswijze) in te dienen. Uiteindelijk zijn er acht schriftelijke reacties ingediend op de concept NRD.

b. Bestuurlijke en landelijke overleggen
Het Aramis initiatief en het ministerie van EZK vinden het belangrijk om gemeenten, provincie en andere bestuursorganen actief te betrekken bij de besluitvorming over het project.

Het Aramis initiatief en het ministerie van EZK betrekken bestuurlijke partners van de gemeenten, de provincie Zuid-Holland en andere departementen met betrekking tot de Noordzee actief bij het besluitvormingsproces van het projectbesluit. Bestuurders van deze partners worden bij elke formele zienswijze periode op de hoogte gehouden van de voortgang in een op te richten Bestuurlijk Overleg (BO), geïnitieerd door EZK.

Op 15 november 2022 heeft het eerste coördinatieoverleg vergunningen plaatsgevonden. Dit is een tweemaandelijks overleg met alle bevoegde gezagen in het kader de vergunningen onder de Rijkscoördinatieregeling (RCR).

c. Persoonlijke of geclusterde gesprekken
Wij hebben het project al eerder geïntroduceerd o.a. aan programma-managers, regioadviseurs, beleidsadviseurs en projectleiders van ministeries (EZK Wind, Landbouw, Natuur en Voedselkwaliteit (LNV), Rijksdienst voor het Cultureel Erfgoed (RCE) , Defensie, Binnenlandse Zaken en Koninkrijksrelaties (BZK), Infrastructuur en Waterstaat (IenW)), lokale gemeenten (Rotterdam, Brielle, Westvoorne), Provincie (Zuid-Holland), VRR, water(veiligheid)beheerders (Waterschap Hollandse Delta, RWS Zee & Delta, Kustwacht), omgevingsdiensten (DCMR, ODH), wegbeheerder (RWS WNZ), railbeheerder (ProRail), belangengroepen (Deltalinqs, KVNR, Element NL, Bellona, Nexstep, de Nederlandse Vissersbond, Stichting de Noordzee, Nederlands Loodswezen, H-vision, NWEA, Verontruste Burgers van Voorne), ngo's (Natuur & Milieu, Greenpeace, Milieufederatie Zuid-Holland), raakvlakprojecten (Porthos, Eneco), kabel- en pijpleiding eigenaren (TenneT, Stedin), offshore operators (o.a. Neptune Energy , Petrogas) en bedrijven op de Maasvlakte (Havenbedrijf Rotterdam, MOT, Euromax). Dit ambtelijke en persoonlijke contact zetten wij voort in deze komende fase.

Hieronder staat een overzicht met welke belanghebbenden en over welke onderwerpen wij spreken.

- Havenbedrijf Rotterdam: de aanlanding, uitwerking verschillende tracés en locatie alternatieven en varianten in het havengebied;
- Provincie Zuid-Holland: de ruimtelijke kwaliteit (o.a. openheid en natuur) van het gebied in relatie tot het tracé en locatiealternatieven en -varianten, vergunningen;
- RWS Zee & Delta en Kustwacht: nautische veiligheid, het kruisen van scheepvaartroutes, de tracering en locatie alternatieven en varianten, vergunningen op zee;
- RWS WNZ: uitwerking van tracé- en locatiealternatieven en varianten bij kruising van waterkeringen, hoofdwatergangen, aandachtspunten van diverse uitvoeringsmethodes en vergunningen;
- Waterschap Hollandse Delta, DCMR en ODH: benodigde water vergunningen, vergunningen in het kader van de wet algemene bepalingen omgevingsrecht en natuurvergunningen en ontheffingen;
- Gemeente Rotterdam: voor de benodigde vergunningenoverzicht en rol van bevoegde gezag en invloed op CCS op de energietransitie;
- TenneT, Stedin: raakvlakken projecten en invloeden van tracé- en locatiekeuzes, met name bij de kruising van de waterkering (TenneT) en energievoorziening en beschikbare ruimte in de Leidingenstrook (Stedin);
- Eneco: raakvlakken en veiligheidsrisico's van windmolens op de Maasvlakte;

- MOT, ECT Rotterdam, Euromax: impact op 24/h bedrijfsvoering en overlast (geluid, trillingen);
- Ministeries: raakvlakken (toekomstige) windparken op de Noordzee zoals Lagelander, impact op het milieu en visserij, raakvlakken (toekomstige) zandwinningsgebieden, gebieden van hoge cultuur-historische waarde en vergunningen;
- Wij informeren de bij ons bekende maatschappelijke organisaties (Milieufederatie Zuid-Holland, Natuur & Milieu, Greenpeace, Milieudefensie en Stichting de Noordzee) rechtstreeks over het project en de procedures. In de studies die we uitvoeren voor de vergunningen en het milieueffectrapport (MER) besteden we nadrukkelijk aandacht aan milieu, natuur en andere belangrijke maatschappelijke waarden. Daarnaast onderzoeken we met Stichting de Noordzee, Natuur & Milieu, het Koninklijk Nederlands Instituut voor Onderzoek der Zee, de Wageningen University & Research en het Nederlandse Organisatie voor Wetenschappelijk Onderzoek of we het project Aramis natuurversterkend kunnen aanleggen;
- Porthos: afstemming omgevingsmanagement en aansluiting op Porthos;
- Commissie MER: afstemming en advies voor concept NRD en MER;
- ProRail: impact op kruising van en werken nabij het spoor (veiligheid en bedrijfsvoering);
- Veiligheidsregio's: veiligheidsrisico's in het havengebied en de nabije omgeving (toegangswegen);
- Het Aramis initiatief is meermalen aangeschoven bij het Noordzeeoverleg (NZO). De NZO-leden zijn: de ministeries (Infrastructuur en Waterstaat, Economische Zaken en Klimaat, en Landbouw, Natuur en Voedselkwaliteit), Energiesector (Nederlandse Wind Energie Associatie, TenneT, Element NL, Energie Beheer Nederland), Zeevaartsector (Branche Organisatie Zeehavens, Koninklijke Vereniging Nederlandse Rederijen, Havenmeesters), natuur en milieuorganisaties (WNF Nederland, Greenpeace (geen permanent lid), Stichting De Noordzee, Vogelbescherming Nederland, Natuur & Milieu) en Voedsel&Visserij (NetVisWerk en Producentenorganisaties Urk & Delta Zuid). Het project Aramis informeert regelmatig over de stand van zaken tijdens dit NZO-overleg. Aanwezigen van dit overleg wordt gevraagd om input te leveren vanuit hun organisatie, bijv. over scheepvaartbelemmering op zee of kruising Maasgeul, gevoelige infrastructuur op de zeebodem, raakvlak (toekomstige) windmolenparken, impact op natuur, onderwater geluid, etc.);
- NEa (Nederlandse Emissieautoriteit): onafhankelijke autoriteit voor toezicht op de uitstoot van broeikasgassen;
- Er is een gezamenlijke bijeenkomst geweest waarin het project Aramis gepresenteerd werd aan alle operators en waar operators kenbaar konden maken of men wilde aansluiten, en zo ja, wanneer. Met operators met concrete belangstelling en betrokkenheid zijn er individuele overleggen gevoerd;
- Eind 2021 is door CO_2next een Open Season proces gestart. Het primaire doel van het Open Season was het verkrijgen van een beter inzicht in het marktpotentieel. Dit is mede van belang voor de vergunningaanvraag waarin de eindsituatie dient te worden omschreven. Bovendien is waardevolle informatie verzameld voor het verdere engineering proces zodat al vroegtijdig kan worden nagedacht over bijvoorbeeld tie-in point en over-dimensionering. Een secundair doel van het Open Season proces was om te voldoen aan de criteria voor Open Access en Non-discriminatory Access. Hierdoor wordt gerechtvaardigd dat er een of enkele launching customers zijn.

In een intensieve samenwerking en onder speciale voorwaarden kan met deze launching customers de keten worden opgezet. In een volgende fase zouden andere partijen dan onder de dan geldende voorwaarden kunnen aansluiten.

d. Schriftelijke reactie op de plannen geven
Iedereen heeft in 2022 de mogelijkheid gehad een schriftelijke reactie te geven op de concept NRD (een zienswijze indienen). Er zijn acht zienswijzen ingediend. Al deze zienswijzen zijn gebundeld (zienswijzebundel) en in de nota van antwoord is een toelichting gegeven of en hoe deze zijn meegenomen bij het opstellen van de definitieve NRD of in het verdere proces.

Het Aramis initiatief heeft advies aan de commissie MER op de concept NRD gevraagd. Dit advies is op de site van de commissie op 18 augustus 2022 gepubliceerd. Het ministerie van EZK heeft op basis van de ingekomen zienswijzen en het advies van de commissie MER de definitieve NRD vastgesteld en gepubliceerd op 2 december 2022.

RAPPORT

Natuurtoets Aramis CCS soortenbescherming

Natuurtoets in het kader van de Omgevingswet

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2005

Status: Definitief/1

Datum: 9 februari 2024

ARAMIS	CCS-ARAMIS Project
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2005 Document title Nature report species Revision Final 4.0

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Titel document: Natuurtoets Aramis CCS soortenbescherming

Sub titel: Natuurtoets in het kader van de Omgevingswet
Referentie: ARM-PFE-B10-ENV-EIA-2005
Status: 1/Definitief
Datum: 9 februari 2024
Projectnaam: Aramis CCS
Projectnummer: BH8744

Classificatie
Projectgerelateerd

Inhoud

Afkortingenlijst

ADD	Acoustic Deterrent Device
Bal	Besluit Activiteiten Leefomgeving
CCS	Carbon Capture and Storage
EEZ	Exclusieve Economische Zone
HbR	Havenbedrijf Rotterdam
HSD	Hydro Sound Damper
MER	Milieueffectrapportage
MMO	Marine Mammal Observer
MOT	Maasvlakte Olie Terminal
NCP	Nederlands Continentaal Plat
NDFF	Nationale Databank Flora en Fauna
Ow	Omgevingswet
PAM	Passive Acoustic Monitoring
PTS	Permanent Threshold Shift
TTS	Temporary Threshold Shift
Wnb	Wet natuurbescherming

1. Inleiding

Voor u ligt het detailrapport soortenbescherming, onderdeel van het het MER voor het Aramis initiatief.

Dit detailrapport heeft betrekking op soortenbescherming. Hierbij zijn de mogelijke effecten op onder de Omgevingswet beschermde soorten beschreven. Het rapport dient tevens als onderlegger voor de vergunningaanvraag.

De effecten op onder de Omgevingswet beschermde Natura 2000-gebieden zijn in een andere rapportage beschreven, te lezen in detailrapport gebiedsbescherming.

Dit detailrapport bevat een gedetailleerde beschrijving en beoordeling van de effecten in de aanleg- en gebruiksfase 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.

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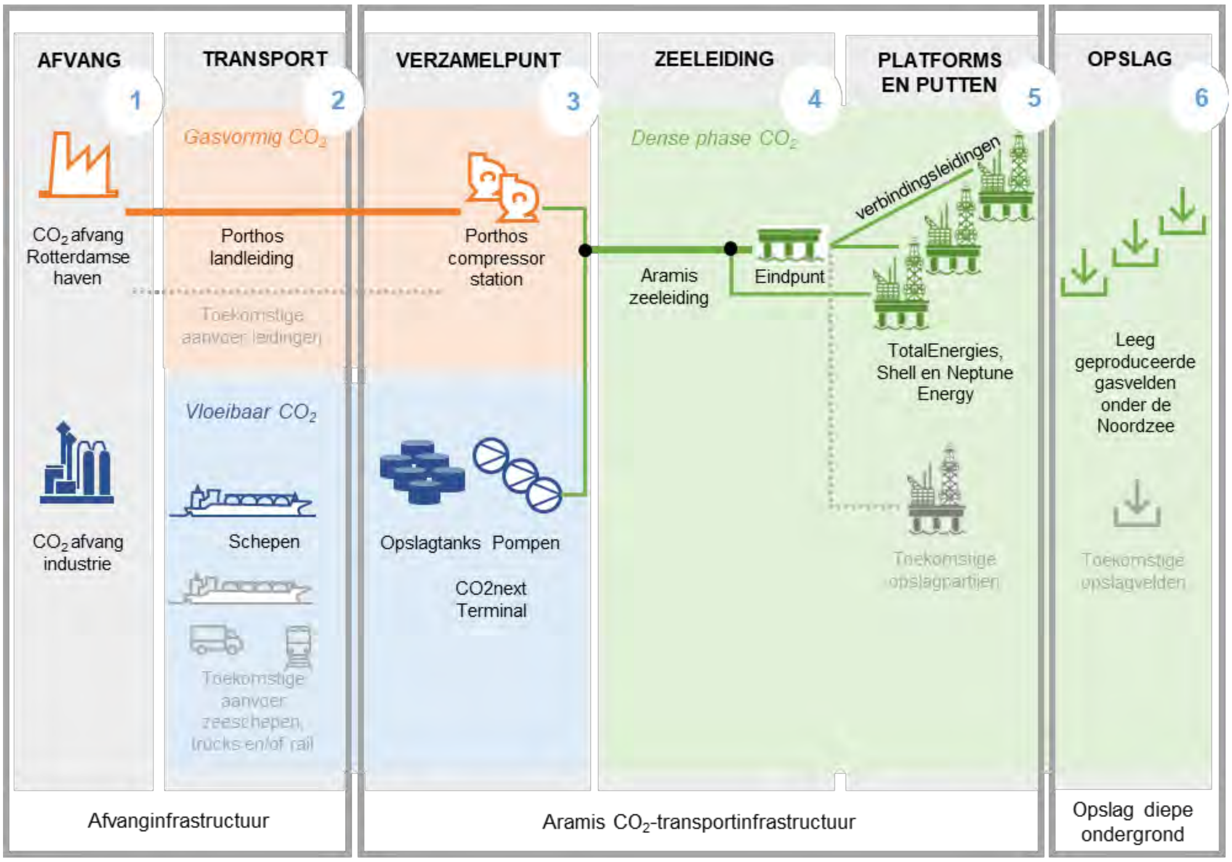
CO_2-opslag diepe ondergrond

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

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

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.

Het voorkeursalternatief (VKA) voor de onderdelen van het Aramis initiatief staat weergeven in Tabel 1-1. Op basis van het VKA zijn effecten op beschermde flora en fauna beoordeeld. Het VKA is dan ook leidend voor de effectbeoordeling.

Tabel 1-1. Alternatieven voor ketenonderdelen van het Aramis initiatief.

Ketenonderdeel	Voorgenomen activiteit (voorkeursalternatief)	Alternatieven
Locatie van de terminal	Op het MOT-terrein, ten zuidoosten van de meest oostelijke opslagtanks voor aardolie.	Op het GATE Tank 5 terrein ten noordoosten van de Yukonhaven.
Kruising Maasgeul	Tunnel vanaf Haaievin bij Edisonbaai.	Direct pipe-techniek nabij de kruising met de Porthos-zeeleiding.
Tracé van de zeeleiding	Westelijke route 2 langs K14-platform.	Westelijke route 1.
		Centrale route.
Type eindpunt op zee	Platform installatie als eindpunt.	Eindpunt op de zeebodem.

Een uitgebreide beschrijving van het Aramis initiatief is opgenomen in het deelrapport technische beschrijving en het hoofdrapport MER.

Voor de realisatie van de Aramis CO_2-infrastructuur zijn meerdere vergunningen nodig. Bij een deel van de vergunningen geldt een m.e.r.-plicht, wat inhoudt dat een milieueffectrapportage opgesteld moet worden ter onderbouwing van de vergunningsaanvragen. Voor het verkrijgen van deze vergunningen is een project-MER nodig. Tevens zal voor de aanleg van de Aramis CO_2-infrastructuur het huidige bestemmingsplan gewijzigd moeten worden. Hiervoor is een besluit over de planologische inpassing nodig. Dit besluit is tevens m.e.r.-plichtig, middels een Plan-MER. Het Plan-MER is in deze gecombineerd met het Project-MER. Het plan kan alleen worden vastgesteld, als gedeputeerde staten voor het project een vergunning kan verlenen. Dit is alleen mogelijk indien uit de Soortentoets de zekerheid is verkregen dat het plan, onderscheidenlijk het project, de gunstige staat van instandhouding van beschermde flora en fauna niet zal aantasten. Om deze onderzoeksvraag te beantwoorden is onderhavige Soortentoets opgesteld.

1.2 Fasering en uitbreidingsmogelijkheden

De CCS-keten wordt stapsgewijs uitgebreid. In het MER zijn drie fases onderscheiden: startsituatie, eerste uitbreidingssituatie en eindsituatie. De capaciteit per fase is gegeven in Tabel 1-2.

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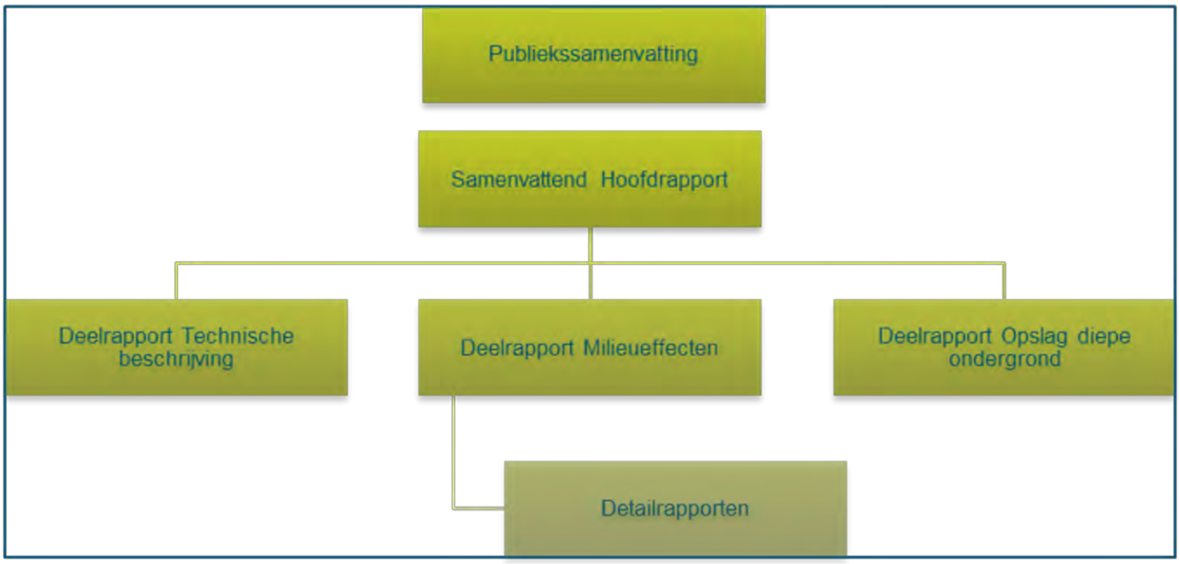
Tabel 1-2. Capaciteit per fase.

Fase	Capaciteit (Mton CO_2 per jaar)	Toelichting
Startsituatie	5	Deze capaciteit is gebaseerd op de huidige vraag van CO_2-leveranciers naar opslagcapaciteit.
Eerste uitbreidingssituatie	14	Deze waarde is gebaseerd op een verwachte groei van de vraag naar CO_2-transportcapaciteit binnen enkele jaren na de startsituatie.
Eindsituatie	22	Deze waarde is gebaseerd op een verwachte maximale vraag naar CO_2-transportcapaciteit voor opslag van CO_2 in leeggeproduceerde gasvelden op zee.

1.3 Opbouw van het MER en dit detailrapport

Voor het Aramis initiatief is een MER 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 Soortenbescherming. 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 hoofdstuk 2 is het wettelijke kader opgenomen. Vervolgens is in hoofdstuk 3 de onderzoeks- en beoordelingsmethodiek beschreven. In hoofdstuk 4 is de fasering van het project kort toegelicht, ook is het plangebied beschreven. In hoofdstuk 5 is per soortgroep beschreven welke beschermde of bedreigde soorten in of nabij het plangebied voorkomen of verwacht kunnen worden. In hoofdstuk 6 zijn de voorzorgs- en mitigerende maatregelen voor de voorkomende soorten uitgewerkt. In hoofdstuk 7 wordt een samenvatting van de bevindingen gegeven en wordt er getoetst aan wet- en regelgeving voor soortenbescherming.

2. Wettelijk & ruimtelijk natuurbeschermingskader

In Nederland wordt voor behoud en herstel van biodiversiteit de natuur via twee sporen beschermd, namelijk het wettelijk spoor en het planologisch spoor geregeld in de Wet op de Ruimtelijke Ordening. In de wetgeving zijn de Europese habitat- en vogelrichtlijnen geïmplementeerd. Dit omvat de soortenbescherming van inheemse flora en fauna en specifiek gebiedsbescherming van Natura 2000-gebieden. Daarnaast is bescherming van overige nationaal beschermde soorten en houtopstanden in het buitengebied wettelijk geregeld.

Bescherming van natuurgebieden en andere specifieke gebieden met bijzondere natuurwaarden zoals weidevogelleefgebieden in agrarisch gebied is planologisch vastgelegd in nationaal, provinciaal en gemeentelijk niveau in omgevingsverordeningen en/of omgevingsplan. De planologische bescherming van gebieden heeft ruimtelijk gezien overlap met de wettelijk beschermde natuurwaarden.

Natuurwaarden en biologische diversiteit zijn per 1 januari 2024 beschermd via de Omgevingswet. In deze wet worden alle wetten voor de leefomgeving opgenomen, waaronder de Wet natuurbescherming (Wnb) en Wet op de Ruimtelijke Ordening (RO) waarin de planologische bescherming van natuur is geregeld.

Dit rapport geeft een algemene indruk van het plangebied en de daar mogelijk voorkomende onder de Omgevingswet beschermde soorten. Het doel van het rapport is een QuickScan Soortenbescherming. Uit de QuickScan volgt of er in het kader van soortenbescherming vervolgstappen zoals het uitvoeren van een aanvullend onderzoek en een aanvraag van een omgevingsvergunning noodzakelijk zijn.

2.1 Wettelijke bescherming natuur

De Wnb (vigerend 2017-2023) en bijbehorende wetsartikelen zijn als algemene rijksregels opgenomen in het Besluit activiteiten leefomgeving (Bal) van de omgevingswet (vigerend per 1 januari 2024). De werking van de Wnb ten aanzien van natuur wijzigt hierdoor niet.

De omgevingswet omvat rijksregels die de volgende algemene doelen hebben:

- het beschermen en ontwikkelen van de natuur;
- het behouden en herstellen van biologische diversiteit;
- het doelmatig beheren, gebruiken en ontwikkelen van de natuur en het verzekeren van een samenhangend beleid gericht op het behoud en beheer van waardevolle landschappen.

Deze algemene doelenbepaling beoogt actieve soortenbescherming anders dan de vorm van passieve soortenbescherming via de verbodsbepalingen gericht op een nalaten. De opdracht aan bestuursorganen is om actief beleid te voeren teneinde een gunstige staat van instandhouding van de soorten te bereiken. Deze verplichting om aan actieve soortenbescherming te doen, vloeit voort uit de Vogel- en Habitatrichtlijn.

De zorgplicht van het Wnb is in het Bal nader geconcretiseerd in een specifieke zorgplicht voor Natura 2000 (art. 11.6) en inheemse soorten (art. 11.27).

Specifieke zorgplicht

(art. 11.6 Natura 2000-activiteit; art 11.27 Flora en fauna activiteit)

1) Degene die een *Natura 2000 of flora en fauna activiteit* verricht en weet of redelijkerwijs kan vermoeden dat die activiteit nadelige gevolgen kan hebben voor het belang, is verplicht:

a) alle maatregelen te nemen die redelijkerwijs van diegene kunnen worden gevraagd om die gevolgen te voorkomen;

b) voor zover die gevolgen niet kunnen worden voorkomen: die gevolgen zoveel mogelijk te beperken of ongedaan te maken; en

c) als die gevolgen onvoldoende kunnen worden beperkt: die activiteit achterwege te laten voor zover dat redelijkerwijs van diegene kan worden gevraagd.

De Omgevingswet en bijbehorende Bal regelt activiteiten die met natuur te maken hebben. Deze natuuractiviteiten gaan over dieren en planten in het wild en gebieden waarin ze leven. In het Bal zijn drie beschermingstypen met een eigen toetsingskader te onderscheiden:

- Natura 2000-gebieden;
- Flora en fauna (inheems);
- Houtopstanden (buiten de bebouwde kom).

In deze rapportage wordt getoetst aan het toetsingskader voor flora en fauna.

Het bevoegd gezag, voor het al dan niet verlenen van vergunningen en/of vrijstellingen, is de provincie of de rijksoverheid. Bij wie de bevoegdheid ligt is vastgelegd in het Besluit natuurbescherming artikel 1.3. De rijksoverheid blijft het bevoegd gezag voor onder andere de rijks- en spoorwegen, grote wateren en defensieterreinen. Voor dit project is de minister van LNV het bevoegd gezag.

2.2 Toetsingskader Flora en fauna

De kern van de bescherming van inheemse soorten is dat de gunstige 'staat van instandhouding' van in het wild levende planten- en diersoorten wordt beschermd en behouden. Deze bescherming volgt ook direct uit de Europese Habitat- en Vogelrichtlijn die verder met soorten is aangevuld met voor Nederland bijzondere en bedreigde soorten. Een activiteit mag geen blijvende negatieve invloed hebben op de staat van instandhouding van soorten (SvI). Dat houdt in dat de soort ook op langere termijn kan blijven bestaan. Het effect is afhankelijk van de omvang van het project en moet beoordeeld worden op lokaal, regionaal en/of landelijk niveau.

Anders dan bij de gebiedsbescherming is bij inheemse flora en fauna het leefgebied beschermd. Dat kan overal zijn en is niet strikt verbonden aan een natuurgebied.

Rijksregels

De bescherming van inheemse soorten was tot 1 januari 2024 in de Wet natuurbescherming (hoofdstuk 3) geregeld en is nu geregeld in Bal § 11.2. Het beschermingsregime van soorten en verbodsbepalingen is hierdoor niet gewijzigd (Tabel 2-1).

Voor de inheemse soorten gelden verschillende beschermingsregimes. Deze zijn:

- Vogelrichtlijnsoorten — Ow Bal § 11.2.2 (voorheen Wnb § 3.1 Wnb)
- Habitatrichtlijnsoorten — Ow Bal § 11.2.3 (voorheen Wnb § 3.2 Wnb)
- Andere soorten — Ow Bal § 11.2.4 (voorheen Wnb § 3.3 Wnb)

De bescherming van Vogel- en Habitatrichtlijnsoorten kent een zwaardere bescherming dan de andere soorten die van nationaal belang zijn. De andere soorten betreffen soorten die van nationaal belang zijn en onder druk staan (o.a. Rode lijst). Voor de inheemse soorten die niet in de bijlagen van de Omgevingswet zijn opgenomen geldt de specifieke zorgplicht (Ow Bal § 11.27).

Tabel 2-1. Soortenbescherming: overzicht verbodsartikelen Wet natuurbescherming (Wnb), wordt vervangen door Omgevingswet met Besluit activiteiten leefomgeving (Ow Bal). HR: Habitatrichtlijn. VR: Vogelrichtlijn. N.v.t.: Niet van toepassing.

Verbodsbepalingen Vogelrichtlijn Ow Bal art.11.37	Verbodsbepalingen Habitatrichtlijn Ow Bal art.11.46	Verbodsbepalingen Andere soorten Ow Bal art. 11.54
Bal art. 11.37 1a. Het is verboden opzettelijk van nature in Nederland in het wild levende vogels van soorten als bedoeld in artikel 1 van de Vogelrichtlijn te doden of te vangen.	**Bal art 11.46 1a** Het is verboden in het wild levende dieren HR IV soorten (Verdrag Bern en Bonn) in hun natuurlijk verspreidingsgebied opzettelijk te doden of te vangen.	**Bal art. 11.54 1a** Onverminderd artikel 3.5, eerste, vierde en vijfde lid, is het verboden in het wild levende dieren, genoemd in Wnb bijlage A/Bal bijlage IX onder A, opzettelijk te doden of te vangen.
Bal art. 11.37 1b Het is verboden opzettelijk nesten, rustplaatsen en eieren van vogels als bedoeld in het eerste lid te vernielen of te beschadigen, of nesten van vogels weg te nemen.	**Bal art 11.46 1d** Het is verboden de voortplantingsplaatsen of rustplaatsen van dieren als bedoeld in het eerste lid te beschadigen of te vernielen.	**Bal art. 11.54 1b** Onverminderd artikel 3.5, eerste, vierde en vijfde lid, is het verboden de vaste voortplantingsplaatsen of rustplaatsen opzettelijk te beschadigen of te vernielen.

Verbodsbepalingen Vogelrichtlijn Ow Bal art.11.37	Verbodsbepalingen Habitatrichtlijn Ow Bal art.11.46	Verbodsbepalingen Andere soorten Ow Bal art. 11.54
Bal art. 11.37 1c Het is verboden eieren van vogels als bedoeld in het eerste lid te rapen en deze onder zich te hebben.	**Bal art. 11.46 1c** Het is verboden eieren van dieren als bedoeld in het eerste lid in de natuur opzettelijk te vernielen of te rapen.	N.v.t.
Bal art. 11.37 1d Het is verboden vogels als bedoeld in het eerste lid opzettelijk te storen. **Bal art. 11.37 3** Het verbod geldt niet als de storing niet van wezenlijke invloed is op de staat van instandhouding van de desbetreffende vogelsoort.	**Bal art 11.46 1b** Het is verboden dieren als bedoeld in het eerste lid opzettelijk te verstoren.	N.v.t.
N.v.t.	**Bal art. 11.46 1e**. Het is verboden planten HR (en Verdrag van Bern) in hun natuurlijke verspreidingsgebied opzettelijk te plukken en te verzamelen, af te snijden, te ontwortelen of te vernielen.	**Bal art. 11.54 1c** Onverminderd artikel 3.5, eerste, vierde en vijfde lid, is het verboden vaatplanten genoemd in Wnb bijlage B/ Bal bijlage IX onder B, in hun natuurlijke verspreidingsgebied opzettelijk te plukken en te verzamelen, af te snijden, te ontwortelen of te vernielen.

Toelichting bescherming broedvogels en jaarrond beschermde vogels (11.37 lid 1b Bal)

Via de Europese vogelrichtlijn zijn alle Europese wilde vogels door de wet zelfs uitdrukkelijk als beschermde diersoort aangewezen. Strenge bescherming geldt voor:

- Broedvogels;
- Jaarrond beschermde vogels.

Het verstoren van broedende vogels en hun nesten tijdens de broedtijd is verboden, tenzij de storing niet van wezenlijke invloed is op de staat van instandhouding van de vogelsoort.

Nesten of holten die ieder jaar opnieuw gebruikt worden of ook buiten het seizoen van belang zijn voor de instandhouding van de soort, vallen ook buiten het broedseizoen onder de definitie van ‘vaste rust- of verblijfplaatsen’. Deze nesten zijn jaarrond beschermd tenzij ze permanent verlaten zijn. In 2009 heeft Dienst Regelingen een aangepaste lijst jaarrond beschermde vogelnesten gepubliceerd met onderverdeling in vijf categorieën. Deze categorieën zijn in onderstaand kader toegelicht.

Vogelnesten die het gehele jaar door zijn beschermd

Op de volgende categorieën gelden de verbodsbepalingen van artikel 11.37 lid 1b Bal het *gehele* jaar:

1. Nesten die, behalve gedurende het broedseizoen als nest, buiten het broedseizoen in gebruik zijn als vaste rust- en verblijfplaats (voorbeeld: steenuil).
2. Nesten van koloniebroeders die elk broedseizoen op dezelfde plaats broeden en die daarin zeer honkvast zijn of afhankelijk van bebouwing of biotoop. De (fysieke) voorwaarden voor de nestplaats zijn vaak zeer specifiek en limitatief beschikbaar (voorbeeld: roek, gierzwaluw en huismus).
3. Nesten van vogels, zijnde geen koloniebroeders, die elk broedseizoen op dezelfde plaats broeden en die daarin zeer honkvast zijn of afhankelijk van bebouwing. De (fysieke) voorwaarden voor de nestplaats zijn vaak zeer specifiek en limitatief beschikbaar (voorbeeld: ooievaar, kerkuil en slechtvalk).
4. Vogels die jaar in jaar uit gebruik maken van hetzelfde nest en die zelf niet of nauwelijks in staat zijn een nest te bouwen (voorbeeld: boomvalk, buizerd en ransuil).
5. Nesten die niet jaarrond beschermd vanwege voldoende flexibiliteit, tenzij er sprake is van zwaarwegende feiten of ecologische omstandigheden, die jaarronde bescherming van de nesten eisen.

Bron: DLG 2009. Landelijke lijst. Provincies kunnen deze lijst aangepast hebben gebaseerd op provinciale omstandigheden.

Vrijstellingsmogelijkheden 'andere soorten'

Voor de 'andere soorten' van artikel art. 11.54 Bal kunnen provincies en het ministerie van LNV een algemene vrijstelling van de ontheffingsplicht vaststellen middels een verordening. De provincie is doorgaans het bevoegd gezag voor het al dan niet verlenen van vergunningen. Wanneer het ruimtelijke ingrepen betreft waarmee grote nationale belangen zijn gemoeid, is het rijk in de vorm van de minister voor Natuur en Stikstof bevoegd gezag en gelden de nationale regels. Het bevoegd gezag voor dit project is de minister voor Natuur en Stikstof. In Tabel 2-2 zijn de door LNV vrijgestelde soorten weergegeven.

Tabel 2-2. Overzicht van de soorten met een algemene vrijstelling

Vrijgestelde soorten Minister van LNV	
Aardmuis	Hermelijn
Bastaardkikker	Huisspitsmuis
Bosmuis	Kleine watersalamander
Bruine kikker	Konijn
Bunzing	Meerkikker
Dwergmuis	Ree
Dwergspitsmuis	Rosse woelmuis
Egel	Veldmuis
Gewone bosspitsmuis	Vos
Gewone pad	Hazelworm
Haas	

Toetsing van een activiteit aan flora en fauna

Om te kunnen beoordelen of een activiteit leidt tot overtreding van een verbodsbepaling, moet enerzijds de aanwezigheid van wettelijk beschermde soorten worden bepaald en moet anderzijds worden bepaald of de activiteit leidt tot overtreding van verbodsbepalingen en/of hierdoor de SvI van de soort in gevaar wordt gebracht (zie kader). Dit is eerst in de vorm van een Quickscan. In beginsel moet met voorzorgsmaatregelen ervoor worden gezorgd dat de functionaliteit van het leefgebied niet wordt aangetast en soorten niet worden verwond of gedood. Lukt dat niet, dan moeten mitigerende en/of compenserende maatregelen genomen worden en is een omgevingsvergunning nodig.

De Staat van Instandhouding van een soort wordt niet in gevaar gebracht wanneer:
- uit onderzoek blijkt dat de soort op de locatie kan blijven bestaan, ook op de lange termijn;
- het natuurlijk verspreidingsgebied van die soort niet kleiner wordt of snel kleiner gaat worden;
- het leefgebied groot genoeg is en zal blijven bestaan. Of als het op een alternatieve plek wordt ingericht. Zo blijven de populaties van de soort op lange termijn bestaan.

De beoordeling van de SvI van Europees beschermde soorten (VR en HR) vindt op plaatselijk en regionaal populatieniveau plaats. Voor de andere soorten gebeurt dit op landelijk niveau.

Uit de quickscan flora en fauna kan naar voren komen dat de activiteit leidt tot overtreding van verbodsbepalingen en/of dat er onvoldoende gegevens zijn en dat nader gericht veldonderzoek op basis van onderzoeksprotocollen nodig is. Vervolgens vindt opnieuw een effectbeoordeling plaats van de activiteit op basis van deze onderzoeksgegevens.

Voor het verkrijgen van een omgevingsvergunning worden de benodigde gegevens veelal vastgelegd in een projectplan (voorheen activiteitenplan). Het projectplan omvat onder meer de beschrijving en het belang van de activiteit, de soorten waarvoor een vergunning wordt aangevraagd, de onderzochte alternatieven, de mitigerende en/of compenserende maatregelen.

Omgevingsvergunning, gebiedsontheffing gedragscodes en belang

Voor soorten van de Vogelrichtlijn en Habitatrichtlijn kan alleen een omgevingsvergunning worden verleend op basis van de in deze richtlijnen genoemde belangen (bijvoorbeeld openbare veiligheid of dwingende reden van groot openbaar belang) en dat de staat van instandhouding van de soort niet in gevaar wordt gebracht.

In specifieke gevallen geldt een vrijstelling van ontheffingsplicht als ruimtelijke ontwikkelingen, beheer en onderhoudswerkzaamheden en bestendig beheer uitgevoerd worden volgens een goedgekeurde gedragscode. De specifieke zorgplicht (Ow Bal art. 11.27) blijft wel te allen tijde van toepassing.

Voor grotere gebieden en terugkerende activiteiten over een langere periode kan een gebiedsontheffing aangevraagd worden. Dit gebeurt onder meer op basis van een Soorten Management Plan (SMP) op basis waarvan de staat van instandhouding van soorten door het treffen van maatregelen minimaal behouden blijft alsook verbetert.

<u>Omgevingsvergunning Havenbedrijf Rotterdam</u>
Het havenbedrijf Rotterdam heeft het Managementplan beschermde soorten voor de omgang met beschermde flora en fauna in het havengebied, in het kader van ruimtelijke ontwikkeling, inrichting, bestendig gebruik, beheer en onderhoud[2]. Dit betreft een gebiedsgerichte ontheffing gebaseerd op de volgende goedkeuringsbesluiten:

- Goedkeuringsbesluit gedragscode (RVO/2020/61, geldig t/m 31 augustus 2025);
- Ontheffing (FF/75C/2013/0027, inclusief toegekende wijziging in mei 2017 met kenmerk FF/75c/2013/0027A, geldig t/m december 2023) op basis van het Managementplan beschermde soorten Havengebied Rotterdam 2015' en inclusief de toegekende wijziging april 2021 met kenmerk ODH-2021-00052289.

Dit managementplan heeft betrekking op beschermde soorten die voorkomen in het beheergebied van het havenbedrijf en bundelt alle voorwaarden van zowel de gedragscode voor bestendig gebruik, beheer en onderhoud, als die in de gebiedsontheffing waarin de bescherming van soorten bij ruimtelijke ontwikkeling of inrichting is geregeld.

Het managementplan van het havenbedrijf Rotterdam is eind vorig jaar verlopen, en is hierna weer met één jaar verlenging vergund tot en met 23 december 2024 (Omgevingsdienst Haaglanden, 2023). Het havenbedrijf Rotterdam heeft inmiddels een nieuwe gebiedsontheffing aangevraagd gebaseerd op een nieuw managementplan. Deze is gebaseerd op (vrijwel) dezelfde werkprotocollen als in het huidige managementplan. De aanvraag ligt momenteel ter goedkeuring bij het bevoegd gezag. De verwachting is dat de nieuwe gebiedsontheffing dit jaar wordt verleend met een geldigheid van tien jaar (Persoonlijke communicatie, Robbert Wolf, Adviseur Natuur & Milieu Havenbedrijf Rotterdam N.Z., 29-01-2024). Het uitgangspunt in deze beoordeling is dat er bij Aramis gewerkt kan worden onder de aanstaande gebiedsontheffing.

De type ruimtelijke ingrepen zoals beoogd voor het project Aramis, vallen onder "Activiteiten in het kader van ruimtelijke ontwikkeling of inrichting verbonden aan de gebiedsontheffing:

- Aanleggen van infrastructuur (kabels en leidingen, wegen, spoorlijnen);
- Realiseren van gebouwen, bouwwerken en installaties (waaronder ook kademuren).

Als eis vanuit de vrijstelling en ontheffing, is het nodig dat er ecologische werkprotocollen (werkbeschrijvingen) uit het managementplan worden gehanteerd voor de praktische uitvoering. In het geval van ruimtelijke ontwikkeling is het nodig om deze werkprotocollen per project apart in een beschrijving op te nemen, waarbij de locatiespecifieke omstandigheden en een kaart extra worden toegevoegd. Er moet altijd nog een kaart worden geraadpleegd wáár de beschermde soorten zich bevinden. Dit kan via de Havenscan, de Natuurwijzer van HbR via de online ArcGis kaart, of volgt uit een (aanvullend) veldbezoek of actuele onderzoeksrapportage.

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[2] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam.*

In geval van strikt beschermde soorten waarvoor de gebiedsontheffing van kracht is, dienen werkzaamheden altijd te worden uitgevoerd na goedkeuring van HbR en onder begeleiding van een erkende ecoloog. Hiervan dient verslag uitgebracht te worden in woord en beeld aan HbR, in verband met de periodieke evaluatie van het gebruik van de ontheffing.

Soorten van de Rode lijst & Provinciale aandachtsoorten (bedreigd -gevoelig- kwetsbaar)
In Nederland zijn nog diverse soorten en soortgroepen die bedreigd worden, en op de zogenaamde Rode lijst[3] staan, die niet actief beschermd worden door de natuurwet- en regelgeving. Een voorbeeld zijn de verschillende insectengroepen zoals bijen, sprinkhanen en krekels, haften en steenvliegen waarvan een groot deel bedreigd worden. Deze groepen zijn voor bestuiving van planten en als voedselvoorziening voor soorten hoger in de voedselpiramide van essentieel belang. De egel is een voorbeeld van een nog vrij algemene soort die qua verspreiding in de afgelopen tien jaar met 50% is gedaald door verstedelijking, versnippering en wijziging in landbouwkundig gebruik.

Om de negatieve trend in biodiversiteit te keren volgt uit de Omgevingswet dat er voor alle inheemse soorten waaronder soorten van de Rode Lijst of lokale aandachtsoorten een nadrukkelijke zorgplicht voor geldt. Provincies besteden extra aandacht voor regionale soorten (zoals aandachtsoorten) en gebieden en stellen subsidies beschikbaar. Vanuit de Europese Unie wordt gewerkt aan een Europese strategie voor biodiversiteit met een wetsvoorstel met bindende hersteldoelen.

De opgave voor biodiversiteitsherstel gaat verder dan de huidige wet- en regelgeving en is een actieve oproep om gezamenlijk het tij van daling in biodiversiteit te keren. Dit is in het onderstaande kader toegelicht.

Biodiversiteitsherstel
Op nationaal en provinciaal niveau wordt in de Nationale omgevingsvisie (2020) ingestoken op bescherming en versterking van biodiversiteit en duurzaam benutten van het natuurlijk kapitaal. Biodiversiteit en natuurlijk kapitaal moeten een integraal onderdeel zijn van visies op stedelijke en infrastructurele ontwikkelingen, klimaatadaptatie, waterbeheerplannen, omgevingsvisies (Natuurambitie NL/Natuurpositief 2019). Natuur moet niet alleen binnen natuurgebieden versterkt worden, maar overal. Dit betreft in steden, op het platteland en in de grote wateren (Nationale agenda natuurbeleid).

Diverse partijen onderschrijven de urgentie voor biodiversiteitsherstel en zijn partner van het Deltaplan Biodiversiteitsherstel (https://www.samenvoorbiodiversiteit.nl/). Royal HaskoningDHV is partner van het Deltaplan.

[3] Een Rode lijst is een overzicht van soorten die uit Nederland zijn verdwenen of dreigen te verdwijnen op basis van zeldzaamheid en/of negatieve trend. De lijst wordt periodiek vastgesteld door de Minister van Economische Zaken: zie https://minez.nederlandsesoorten.nl/soorten. De indeling is verdwenen, ernstig bedreigd, bedreigd, kwetsbaar, gevoelig.

3. Beschrijving onderzoeks- en beoordelingsmethodiek

Om na te gaan wat het belang is van het plangebied voor de wettelijk beschermde soorten die in of nabij het plangebied voorkomen, zijn de volgende stappen doorlopen:

3.1 Inventarisatie van beschermde soorten

Landdeel

Het landdeel betreft het in hoofdstuk 4 nader beschreven verzamelpunt op de Tweede Maasvlakte, waar aanlegsteigers voor schepen, opslagtanks en andere installaties als hogedrukpompen zullen worden gerealiseerd. Het voorkomen van soorten op dit landdeel is gebaseerd op verspreidingsgegevens van de Nationale Databank Flora en Fauna (NDFF) en informatie uit de database van de monitoring van Bureau Stadsnatuur. Op 3 januari 2023 zijn verspreidingsgegevens van beschermde soorten opgevraagd uit de NDFF voor het plangebied en enkele kilometers rondom het plangebied van de afgelopen tien jaar. Bureau Stadsnatuur heeft in het kader van het Managementplan beschermde soorten jaarlijks onderzocht op verschillende terreinen in het havengebied. Daarbij zijn ook de gegevens van het broedvogelmonitoringsprogramma opgenomen. Deze gegevens zijn geraadpleegd middels de Natuurwijzer (2023 update) van het havenbedrijf. Door deze verspreidingsgegevens te raadplegen, is inzicht verkregen in de aanwezige beschermde soorten in of in de directe omgeving van het plangebied. Op 17 januari en 16 februari 2023 is aanvullend op het voorgaande door twee ter zake kundige ecologen van RHDHV (een expert op het gebied van Natuurwetgeving en -beleid, en een marien ecoloog) een oriënterend veldbezoek aan het landdeel gebracht. Het terrein is al lopende onderzocht op het voorkomen van soorten en/of geschikte biotopen. Hierbij zijn het terrein waar de installaties gebouwd worden gecontroleerd, inclusief het dijklichaam en de achterliggende Maasgeul (visueel vanaf de dijk). Aan de hand van de verspreidingsgegevens en de veldbezoeken is beoordeeld voor welke beschermde soorten geschikt leefgebied aanwezig is in het plangebied.

Zeedeel

Op basis van literatuuronderzoek is het voorkomen van beschermde soorten in het zeedeel van het plangebied in kaart gebracht en zijn de effecten van de geplande activiteiten van het Aramis project op deze soorten bepaald. Op 16 februari 2023 is door twee ter zake kundige ecologen van RHDHV een aanvullend veldbezoek aan het landdeel gebracht, waarbij met name de focus lag op het waarnemen van zeehonden (zie Bijlage 1 voor de verslagen van de veldbezoeken). Ook is de Natuurwijzer (2023 update) geraadpleegd, waarin waarnemingen van zeehonden zijn geregistreerd voor het havengebied van Rotterdam.

Daarnaast is er in de periode van 11 juli 2022 t/m 24 januari 2023 onderzoek gedaan door Fugro naar vogelsoorten in het plangebied (Fugro, 2023). Resultaten uit dit onderzoek zijn gebruikt als onderbouwing van het wel of niet voorkomen van vogelsoorten in of nabij het plangebied op zee.

3.2 Effectbeoordeling soorten

Aan de hand van de verspreidingsgegevens is beoordeeld voor welke beschermde soorten er geschikt leefgebied aanwezig is in het plangebied. Door middel van een analyse van het project in relatie tot de biotoopeisen van de beschermde soorten uit het plangebied is beoordeeld welke negatieve effecten de voorgenomen werkzaamheden kunnen hebben op de mogelijk in het plangebied voorkomende beschermde soorten. Indien de onderzoeksresultaten voldoende zekerheid geven over het voorkomen van beschermde soorten, zijn de mogelijke (negatieve) effecten van de voorgenomen ingreep op deze soorten bepaald. De resultaten van het onderzoek zijn voor het landdeel en het zeedeel beschreven.

In deze stap is voor het landdeel ook gekeken in hoeverre het voornemen afbreuk doet aan de gestelde randvoorwaarden opgenomen in de bestaande ontheffingen (Wnb) van het Havenbedrijf Rotterdam N.V, samengevat in het document: Managementplan beschermde soorten Havenbedrijf Rotterdam 2021[4].

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[4] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam.*

3.3 Vervolgstappen

De conclusies uit het onderzoek zijn beschreven. Ook zijn de te nemen vervolgstappen beschreven, zoals het nemen van voorzorgs- of mitigerende maatregelen. Indien de aanwezigheid van beschermde soorten op basis van het onderzoek is aangetoond, is bepaald of overtredingen van verbodsbepalingen te verwachten zijn, en of een omgevingsvergunning in het kader van de Ow, noodzakelijk is.

4. Plangebied en afbakening Aramis initiatief

De eerste twee fasen vinden gedeeltelijk gelijktijdig plaats (Tabel 4-1). In de startsituatie worden twee aanlegsteigers aangelegd. De aanlegsteigers zijn ontworpen voor schepen met volumes variërend van 2.200 m^3 tot 12.000 m^3 en een maximale lengte van 165 m. Door de snelle ontwikkeling van vloeibare CO_2-tankers is het mogelijk dat in de toekomst schepen met een maximale lengte van 200 m worden ontwikkeld voor volumes van 18.000 tot 30.000 m^3. Afhankelijk van de ontwikkeling van dergelijk grote schepen zal in de eerste uitbreidingssituatie ofwel één extra grote aanlegsteiger worden aangelegd of zullen er twee extra aanlegsteigers komen voor schepen tot 150 m.

Voor de beoordeling wordt uitgegaan van twee aanlegsteigers. Hetzelfde geldt voor de pompen. Na de eerste uitbreiding is verdere uitbreiding tot de eindsituatie voorzien. Voor alle fases worden nu vergunningaanvragen voorbereid. Het MER beschrijft en toetst de effecten van de eerste twee fasen. In het deelrapport Technische Beschrijving zijn de aanleg en het gebruik van deze fasen expliciet beschreven. Voor de eindsituatie zullen te zijner tijd waar nodig vergunningen worden aangevraagd met aanvullend milieuonderzoek.

Tabel 4-1. Fasering uitbreiding CCS-keten.

Fase	Ketenonderdelen Aramis initiatief	Overige onderdelen CCS-keten	Capaciteit (Mton CO_2 per jaar)	Ingebruikname
Startsituatie	Transport per schip, terminal, compressorstation, zeeleiding en platforms TotalEnergies, Shell.	Afvang, transport Porthos-landleiding, opslag in diepe ondergrond.	5	2028
Eerste uitbreidingssituatie	Uitbreiding transport per schip, terminal en compressorstation, platforms Neptune Energy en mogelijk andere operators.	Aanvullende afvang en transport, uitbreiding opslaglocaties in diepe ondergrond.	14	2028 - 2032
Eindsituatie	Uitbreiding transport, terminal en compressorstation en platforms op zee tot maximale capaciteit van de zeeleiding.	Uitbreiding afvang en transport en aanvullende opslag in de diepe ondergrond en uitbreiding CO2Next.	22	Na 2028

In de startsituatie wordt de afgevangen CO_2 aangeleverd met binnenvaartschepen en de Porthos landleiding. Voor de opslag wordt gebruik gemaakt van de platforms van Shell en TotalEnergies. In de eerste uitbreidingssituatie vindt aanvullend transport naar het verzamelpunt plaats met extra schepen en met de Porthos landleiding en wordt het verzamelpunt uitgebreid met steigers, compressoren, pompen en opslagcapaciteit. Neptune Energy is als extra opslagpartij onderdeel van de eerste uitbreidingssituatie, waarbij de verwachting is dat ze gelijktijdig starten met de partijen in de startsituatie.

Toekomstige initiatieven, na de eerste uitbreiding, behoren niet tot het Aramis initiatief. Maar de opzet van de CO_2-transportinfrastructuur is wel zodanig flexibel en ruim, dat er voldoende ruimte is voor toekomstige uitbreiding, tot een maximale capaciteit van 22 Mton CO_2 per jaar. Voorbeelden van mogelijke toekomstige ontwikkelingen zijn:

- Aanvullend transport naar het verzamelpunt met extra landleidingen, schepen of via spoor- en weg;
- Verdere uitbreiding van de terminal en het compressorstation;
- Nieuwe platforms en/of opslagvelden;

- Uitvoeren van seismisch onderzoek (e.g. nullijnonderzoek)[5];
- Het Aramis initiatief biedt op termijn ook de mogelijkheid om CO_2 uit het buitenland te verwerken;
- Het verzamelpunt biedt na uitbreiding mogelijkheden voor hergebruik van CO_2, aangeduid als CCUS (Carbon Capture, Utilisation and Storage)[6].

Om toekomstige uitbreidingen mogelijk te maken is de zeeleiding gedimensioneerd op de maximale uiteindelijke capaciteit. Overige onderdelen zijn of uit te breiden (terminal en compressorstation) of aan te koppelen (toevoerleidingen op land en verbindingsleidingen naar nieuwe platforms/opslagvelden). Om de terminal en het compressorstation in de toekomst uit te kunnen bereiden, is nu extra ruimte gereserveerd. Voor het aankoppelen van leidingen op land en op zee zijn verbindingspunten voorzien.

Voor een gedetailleerde en volledige omschrijving van alle onderdelen wordt verwezen naar het apart bijgeleverde technische beschrijvingsdocument (Deelrapport Technische Beschrijving, 2023).

4.1 Locatie

Het plangebied, welke beschouwd wordt ten behoeve van de onderhavige Soortentoets, bestaat uit twee deelgebieden:

- Het **landdeel**, bestaande uit het Rotterdamse havengebied, en Maasvlakte (Figuur 4-1).
- Het **zeedeel**, bestaande uit de Noordzee, het passeren van de Voordelta en de Maasgeul, Noordzeekustzone, Klaverbank, Bruine Bank en Friese Front (Figuur 4-2).

Landdeel
De Aramis transportleiding op de Maasvlakte is gepland in de leidingstrook van Leidingenbureau Rotterdam en wordt beheerd door het Havenbedrijf Rotterdam (HbR). De Maasvlakte is onderdeel van het Rotterdamse havengebied. Het gebied is ontwikkeld door zand vanuit zee aan te brengen tot een hoogte van ongeveer vijf meter +NAP. Aan de noordwestzijde van de Maasvlakte bevindt zich ook een harde zeewering ter bescherming tegen golfslag.

Het uitgangspunt in deze Soortentoets is dat het compressorstation van Porthos (groen omlijnd) vergund is en dat de fundering er al staat. Voor de aanlegfase van Aramis wordt er enkel mechaniek bijgeplaatst en er is geen sprake van extra ruimtebeslag. Voor de gebruiksfase geldt dat het compressorstation is uitgevoerd als onbemand station dat op afstand bestuurd wordt door de centrale commandopost van Porthos. Indien noodzakelijk kan het station ook lokaal bediend worden. Voor onderhouds- en controlewerkzaamheden zullen er technici aanwezig zijn.

Het leidingwerk van de terminal naar het Porthos compressorstation is bovengronds voorzien over het MOT terrein. De CO2next terminal is gepland aan de oostzijde van de MOT. Hier vindt permanent ruimtebeslag plaat in verband met installatie van ofwel bolvormige (*spheres*) ofwel langwerpige (*bullets*) opslagtanks.

Het overige leidingwerk is ondergronds voorzien, het in Figuur 4-1 in groen weergegeven deel komt in de aanwezige leidingstrook. Het in rood weergegeven deel is een nieuwe leiding ingegraven voor het al vergunde Porthos project. De bodem wordt in de aanlegfase open gegraven en nadien weer gedicht. Er is geen sprake van permanent ruimtebeslag. De in Figuur 4-1 weergegeven jetties vragen niet om ruimtebeslag op land. Wel zullen er in de gebruiksfase meer schepen aanleggen dan in de huidige situatie.

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[5] Seismische surveys als noodzakelijke baseline en monitoringsverplichting vanuit de CO2 opslagvergunningen worden qua impact behandeld in het MER en specifiek in het achtergrondrapport onderwatergeluid.
[6] De terminal biedt de mogelijkheid CO2 door te voeren naar derde partijen, naast Aramis. Daarmee kan CO2 aan andere opslagpartijen worden geleverd of ingezet worden voor hergebruik (CCUS, Carbon Capture, Utilisation and Storage).

Figuur 4-1. Locaties van het compressor station, de terminal en de pijplegroute.

Voor de gebruiksfase geldt dat er calamiteiten kunnen optreden. Er is rekening gehouden met gemiddeldééns in de vijftien jaar een calamiteit waarbij een relief van CO_2 plaats vindt bij de nieuw te installeren aanlegsteigers. Er ontstaat dan een luchtstroom die onder hoge druk naar buiten spuit. Dit geeft een verstorend geluid en een grote concentratie CO_2. Een hoge concentratie CO_2 kan verstikkend werken zowel voor mens als dier. Omdat het gaat om een calamiteit is deze relief niet beoordeeld en behandeld als uitgangspunt in deze soortentoets. Hetzelfde geldt voor de relief valve die wordt geplaatst op het centrale eindpunt (zee-deel).

Zeedeel
Het gemeentelijke bestemmingsplan van de gemeente Rotterdam eindigt na één kilometer vanaf de kust, zodat het leidingtracé onder de Maasgeul in het bestemmingsplan moet worden opgenomen. De twaalf mijls-zone (zeemijlen[7]) geeft de territoriale grens van Nederland aan. Voorbij deze zone bevindt zich de exclusieve economische zone (EEZ), een gebied dat zich tot 200 zeemijl (370,4 km) buiten de kust uitstrekt.

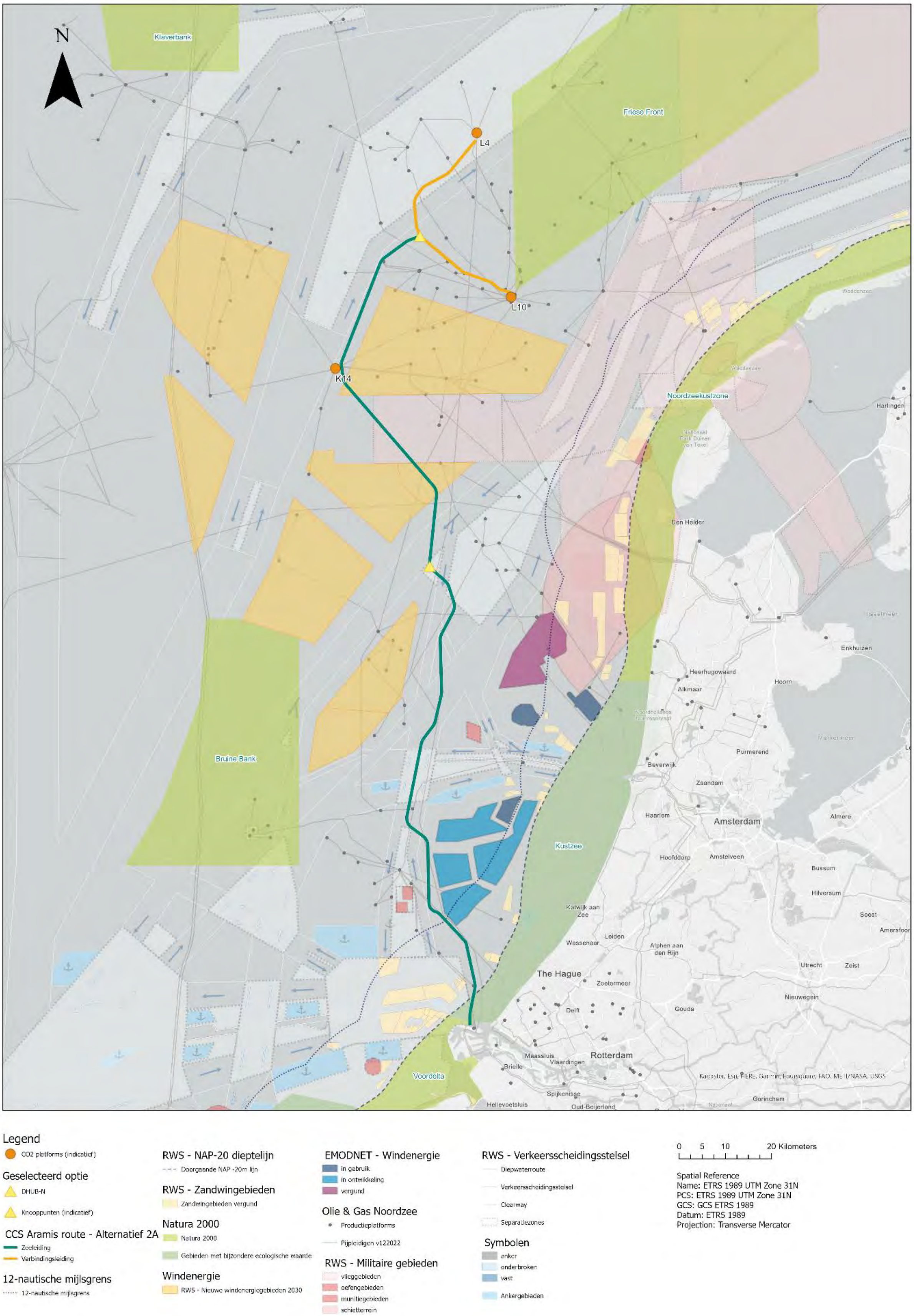
De transportroute van CO_2 schepen gaat via binnenlands waterbinnenwater en/of kustwateren. De zeeleiding bevindt zich deels binnen de territoriale wateren en het grootste gedeelte in de EEZ. De platforms bevinden zich binnen de EEZ. De EEZ wordt ook aangeduid als het Nederlands Continentaal Plat (NCP).

Direct ten noorden van de Maasvlakte bevindt zich de vaargeul naar de Rotterdamse haven. Deze wordt aangeduid als de Maasgeul (gelegen in de Maasmond) en is circa 30 meter diep. De diepte van het geplande traject van de zeeleiding is maximaal 31 m. De zeeleiding bevindt zich op de Noordzee en zodoende dient Aramis rekening te houden met de andere functies op de Noordzee. Relevante andere functies bestaan uit scheepvaart, visserij en militaire oefenruimte. Daarnaast worden in toenemende mate windturbines op de Noordzee ontwikkeld. Ook zijn delen van de Noordzee aangewezen als Natura2000-gebied. De afstanden van de pijpleiding en platforms ten opzichte van de Natura 2000-gebieden is weergegeven in Tabel 4-2.

[7] *Een zeemijl komt overeen met 1,852 kilometer.*

Tabel 4-2. Overzicht minimale afstanden van de platforms en zeeleiding tot de Natura 2000-gebieden.

Type infrastructuur	Afstand tot Natura 2000-gebieden in km				
	Voordelta	Bruine Bank	Noordzeekust-zone	Friese Front	Klaverbank
Platform L4-A	192	116	69	7,8	53
Platform L10-zuid	156	87	41	1,6	77
Platform K14-FA	143	58	70	43	68
Eindpunt	170	91	65	20	53
Zeeleiding Alternatief 1A West	0	23	37	2,1	40



Figuur 4-2. Overzicht van Aramis initiatief met aanwezige Natura 2000-gebieden.

4.2 Overzicht activiteiten

In Tabel 4-3 zijn de werkzaamheden samengevat uit de technische beschrijving die worden meegenomen in de Soortentoets (Deelrapport Technische Beschrijving, 2023).

Tabel 4-3. Overzicht van de te beoordelen activiteiten van het Aramis initiatief.

Activiteit		**Verstoringsfactoren**	**Technische aandachtspunten van belang bij de toetsing**
Pijpleiding leggen	Baggeren zeeleiding inclusief twee alternatieven: Microtunnel en Direct Piping [1].	Vertroebeling, oppervlakteverlies, beweging/optiek, verandering dynamiek substraat, onderwatergeluid.	▪ Diameter leiding is circa 80 cm. ▪ Het volume grondverzet als gevolg van de baggerwerkzaamheden wordt grotendeels gebruikt om de gebaggerde sleuf weer dicht te maken (voor microtunneling: 1.967 m^3, voor direct piping: 706.756 m^3) een deel wordt afgevoerd naar een stortplaats op zee (voor microtunneling: 53 m^3, voor direct piping: 996 m^3).
	Aftoppen zandgolven met sleephopperzuiger.	Vertroebeling, verandering dynamiek substraat, onderwatergeluid/trillingen.	▪ Zes weken vóór de installatie van de zeeleiding worden de zandgolven afgetopt. ▪ Opties zijn ter plaatse storten, elders storten of nuttig gebruiken als suppletie- of ophoogzand.
	Leggen zee- en verbindingsleidingen.	Vertroebeling, oppervlakteverlies, beweging/optiek, verandering dynamiek substraat, onderwatergeluid/trillingen.	**Verbindingsleidingen** ▪ Ieder platform wordt met een verbindingsleiding (spurline) verbonden aan de zeeleiding, via het noordelijke distributieplatform of één van de connectiepunten van de zeeleiding. ▪ K14-FA; Er komt een 800 m lange 16” (circa 40 cm diameter) verbindingsleiding naar het connectiepunt. ▪ L4-A: Er komt een 24 km lange 20” (circa 50 cm diameter) verbindingsleiding naar het noordelijke distributieplatform van de zeeleiding. ▪ L10-zuid: Er komt een 24 km lange 20” (circa 50 cm diameter) verbindingsleiding naar het noordelijke distributieplatform van de zeeleiding. ▪ Verbindingsleiding wordt (gedeeltelijk) ingegraven en, bij kruisingen met andere leidingen, gedeeltelijk afgedekt met stortsteen.

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Activiteit		Verstoringsfactoren	Technische aandachtspunten van belang bij de toetsing
			Zeeleiding ▪ Het tracé van de zeeleiding loopt vanuit de doorkruising met de Maasgeul in noordelijke richting naar het eindpunt dat zich ongeveer op 230 kilometer afstand in noordelijke richting op de Noordzee bevindt. ▪ Gemiddelde aanleg één km per dag. ▪ De leiding wordt opgebouwd uit leidingsegmenten met een lengte van ongeveer twaalf meter. De leidingsegmenten worden met bevoorradingsschepen vanuit het depot aan wal naar het pijpenlegschip aangevoerd en op zee op het pijpenlegschip overgeladen. Op het pijpenlegschip wordt steeds een nieuw segment aan de opgebouwde leiding gelast.
	Ingraven of begraven zee- en/of verbindingsleidingen.	Vertroebeling, oppervlakteverlies, beweging/optiek, verandering dynamiek substraat, onderwatergeluid/trillingen.	▪ 70 kilometer vanaf de kruising met de Maasgeul wordt de zeeleiding ingegraven in de zeebodem, met dekking van circa 1 meter. De kruising van de Maasgeul vindt plaats door middel van microtunneling/direct piping (zie Activiteit Baggeren zeeleiding inclusief twee alternatieven: Microtunnel en Direct Piping). ▪ Voor kruisingen van shipping lanes en zandgolven wordt mogelijk eerst een sleuf gebaggerd voor een verdiepte aanleg, als de benodigde ingraafdiepte te groot is voor een ingraafmachine (trencher).
	Rock dump kruisingen.	Vertroebeling, oppervlakteverlies, beweging/optiek, verandering dynamiek substraat, onderwatergeluid.	▪ Naar verwachting gaat dit om circa 45 kruisingen van gemiddeld 500 meter lengte waar stenen worden gestort bij bestaande leidingen/ kabels. De verwachting is dat na het storten van het steen geen verdere stortingen nodig zijn gedurende de levensduur van het Aramis initiatief.

Activiteit		Verstoringsfactoren	Technische aandachtspunten van belang bij de toetsing
Scheepvaart en helikoptervluchten	Schepen, langer op één locatie, baggerschip, pijplegschip, bevoorradingsschepen, trenchschip, begeleidingsschepen, helikopters.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	Bijlage 2: Scheepvaart- en helikopterbewegingen.
Platform en putten L4-A	Nieuwe putten boren bij de sloten van L4-A3 en L4-A4.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ 100 dagen per put.
	Aanpassen platform L4-A.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ Verwijderen van compressie- en accommodatiemodules met een heavy lift vaartuig ▪ Aanbrengen van de riser (beschermd met staalconstructie) langs een van de staanders van het platform ▪ Plaatsen productiemanifold, injectie- en meteringskid ▪ Plaatsen van voorzieningen voor de duurzame energievoorziening (e.g. zonnepanelen. windturbines) ▪ Aanbrengen van entree punten waar personeel vanaf onderhouds- en inspectieschepen (Walk-to-Work (W2W) vessels) op het platform kan komen ▪ Aanpassen en waar nodig vervangen van de leidingen op het platform.
Platforms en putten nabij K14-FA en bij L10-zuid	Plaatsen platforms K14-FA en L10-zuid (inclusief heien verankeringspalen).	Oppervlakteverlies, versnippering leefgebied, onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ Plaatsen nieuw platform duurt totaal 7 dagen. ▪ 4 verankeringspalen; diameter 1 - 1.7 m; diepte 35 - 60 m. ▪ Heien verankeringspalen duurt circa twee-drie dagen per locatie.
	Heien conductors voor putten.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ K14-FA; 40-80 m diepte, vier of zes conductors, drie dagen per 4-6 conductors, diameter is 0,76 m.

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Activiteit		Verstoringsfactoren	Technische aandachtspunten van belang bij de toetsing
			▪ L10-zuid; 40-80 m diepte, vier of zes conductors, drie dagen per vier-zes conductors, diameter is 0,76 m. ▪ L4-A; 2 conductors. ▪ Het heien van een conductor duurt circa zes uur (hei energie bedraagt circa 90 kJ).
	Boren putten.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ K14-FA; in totaal 400 dagen boorwerkzaamheden vanaf een zelfheffend booreiland, 4 nieuwe injectieputten Shell, 2500 m diepte bovenste deel put. ▪ L10-zuid; 100 dagen per put, vier-zes nieuwe putten. ▪ L4-A; 2 nieuwe putten en twee sidetracks.
Centrale eindpunt	Heiwerkzaamheden centrale eindpunt.	Onderwatergeluid/trillingen, verstoring door licht, verstoring door beweging/optiek.	▪ Diameter twee m, lengte 45 m. ▪ Vier of zes verankeringspalen. ▪ Drie dagen per vier-zes verankeringspalen.
Lozingen	Lozing van boorvloeistof en boorgruis.	Verontreiniging, vertroebeling, verandering dynamiek.	▪ K14-FA: De restanten van de boorvloeistof en het boorgruis worden volgens de gangbare praktijk op zee geloosd bij de desbetreffende put. Het gaat om circa 10.371 ton waterbasisboorgruis, en 7.909 ton waterbasis boorvloeistof (in totaal voor alle putten). Er wordt ongeveer 6.500 ton schoon regen- en spoelwater van de dekken en 250 ton sanitair afval (septic tank) op zee geloosd (in totaal). ▪ L10-zuid: De lozing van schoon regen- en spoelwater bedraagt 6.500 ton en voor het sanitaire afval 250 ton (in totaal). Water wordt tot beneden de wettelijk vastgestelde concentraties ontdaan van koolwaterstoffen en vervolgens geloosd. Geloosd water voldoet aan de emissie eisen van H9 van de mijnbouwregeling (30 ppm olie in water). Bij de werkzaamheden aan platform L10-zuid worden nieuwe putten geboord, waarbij Water Based Mud (WBM)-houdende boorvloeistof

Activiteit		Verstoringsfactoren	Technische aandachtspunten van belang bij de toetsing
			wordt gebruikt. Het gaat om circa 1.700 tot 2.000 ton waterbasisboorgruis en 1.700 tot 3.500 ton waterbasis boorvloeistof per put (vier-zes putten). De boorvloeistof en het boorgruis worden volgens de gangbare praktijk op zee geloosd. ▪ L4-A: het gaat in totaal om 2.000 ton waterbasisboorgruis en 1.900 ton waterbasis boorvloeistof. ▪ Het onderste deel van de putten wordt geboord met boorvloeistof op lage toxiciteit oliebasis (LTOBM, Low toxicity oil based mud). Deze boorvloeistof en boorgruis worden afgevoerd naar land.
Terminal	Aanleg aanlegsteigers (jetties) en vaarbewegingen in de aanlegfase.	Onderwatergeluid/trillingen, oppervlakteverlies.	▪ In de startsituatie worden twee aanlegsteigers aangelegd. De aanlegsteigers zijn ontworpen voor schepen met volumes variërend van 2.200 m^3 tot 12.000 m^3 en een maximale lengte van 165 m. ▪ Het heien van fundering bij de aanlegsteigers geeft onderwatergeluid. Dit vindt plaats binnen het Yangtzekanaal en staat niet in direct contact met de Noordzee. Vaarbewegingen in de aanlegfase, onderdeel van verkeer in de Maasgeul en in het Yangtzekanaal.
Leidingtracé	Aanleg onshore leiding.	Oppervlakteverlies.	▪ Het leidingwerk van de terminal naar het Porthos compressor station is bovengronds voorzien over het MOT terrein. De CO2next terminal is gepland aan de oostzijde van de MOT. ▪ Vanaf het compressorstation wordt de leiding in de bestaande leidingstrook ondergronds geplaatst naast andere leidingen, waaronder de Porthos-zeeleiding. Hiervoor moet de leidingstrook bij de expansieloops en over de hele lengte langs de Aziëweg worden verbreed.

Activiteit		Verstoringsfactoren	Technische aandachtspunten van belang bij de toetsing
Compressorstation	Aanpassingen aan het compressorstation.	Oppervlakteverlies.	▪ Gasvormig CO2 wordt aangeleverd via de Porthos landleiding aan het compressorstation. ▪ Tijdens de bouwfase van het Porthos compressorstation zal er een verbrede fundering worden aangelegd voor de toekomstige plaatsing van de compressoren voor Aramis, Het compressorstation wordt uitgebreid met drie extra compressoren voor Aramis.

[1] In dit rapport wordt gesproken over de microtunnel. Maar mogelijk wordt in plaats van de microtunnel boortechniek (over delen van de tunnel) gebruik gemaakt van een iets ander boortechniek, de segmented tunnel boortechniek of een hybride vorm. Daar waar dat tot verschillen in milieueffecten leidt, is dat aangegeven in de MER en Soortentoets.

5. Aanwezigheid en beoordeling van beschermde natuurwaarden

Hieronder is per soortgroep beschreven welke beschermde of bedreigde soorten in of nabij het plangebied voorkomen of verwacht kunnen worden. De voorkomende soorten en effectbeoordeling in of nabij het plangebied voor het land-deel zijn beschreven in paragraaf 5.1 en voor het zee-deel in paragraaf 5.2. In hoofdstuk 6 is voor de optredende negatieve effecten beschreven hoe deze te voorkomen dan wel te verzachten zijn, en of het aanvragen van een omgevingsvergunning noodzakelijk is of dat gewerkt kan worden conform een vigerende gedragscode.

5.1 Voorkomende soorten en effectbeoordeling (land)

5.1.1 Vaatplanten

Voorkomen
Er zijn binnen het plangebied in de NDFF en de Natuurwijzer waarnemingen bekend van glad biggenkruid (*Hypochaeris glabra*). Glad biggenkruid wordt zeer algemeen aangetroffen in de leidingstrook, langs het MOT terrein en op verschillende plaatsen in de berm in het plangebied. Het voorkomen van beschermde vaatplanten in en nabij het plangebied is daarmee aangetoond. Het is bekend dat glad biggenkruid wijdverspreid en plaatselijk massaal voor komt in halfopen vegetaties in bermen en leidingstroken op het terrein van het havenbedrijf[8].

Glad biggenkruid is een éénjarige soort die zich telkens opnieuw vanuit zaad moet ontwikkelen en die zowel in het voor- als najaar kiemt. Daardoor is behoud en bescherming van glad biggenkruid veel meer een zaak van het beschermen van de zaadbank in de bodem en een geschikt leef- en vestigingsmilieu dan van de bescherming van individuele exemplaren.

Effectbeoordeling
Als gevolg van de werkzaamheden kunnen tijdelijk standplaatsen van glad biggenkruid worden geschaad. Mogelijk gaan als gevolg van de nieuwe ruimtelijke inrichting ook permanent groeilocaties verloren. Hetgeen leidt tot overtreding van artikel 11.54 1a en 1b van het Bal. Aanvullende maatregelen zijn noodzakelijk.

Vervolgstappen
Om aan te sluiten op de gebiedsontheffing van het havenbedrijf, dienen de werkzaamheden te worden uitgevoerd volgens de werkprotocollen zoals vastgelegd in het Managementplan van het havenbedrijf. De noodzakelijke maatregelen zijn toegelicht in paragraaf 6.1. Als aan alle eisen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk.

5.1.2 Grondgebonden (land)zoogdieren

Voorkomen
Er zijn binnen het plangebied in de NDFF en de Natuurwijzer waarnemingen van de volgende land-zoogdieren bekend: bever (*Castor fiber*), bunzing (*Mustela putorius*), haas (*Lepus europaeus*), konijn (*Oryctolagus cuniculus*) en veldmuis (*Microtus arvalis*). Het voorkomen van andere nationaal beschermde soorten als vos (*Vulpes vulpes*) of ree (*Capreolus capreolus*) is tevens niet uitgesloten. Het voorkomen van zeezoogdieren wordt in paragraaf 5.2.2 behandeld.

Van de in de literatuur vermelde soorten, valt de bever onder het beschermingsregime van de Habitatricht-lijn. Bevers hebben hun leefgebied in het overgangsgebied tussen land en water zoals moerassen, langs beken, rivieren en meren. De aanwezigheid van bossen of bosschages op de oevers is een vereiste. De soort is voor zover bekend alleen zwemmend waargenomen. De waarneming van de bever betreft vrijwel zeker een zwervend exemplaar op zoek naar een geschikt leefgebied. Voor de bever is in of nabij het plangebied geen geschikt leefgebied aanwezig. Dit komt voornamelijk door de verharde oevers en het

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[8] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam.*

ontbreken van houtopstanden. Het plangebied maakt geen onderdeel uit van het leefgebied van de bever. Overtreding van de verbodsbepalingen van de Ow is voor deze soort uitgesloten.

De overige soorten betreffen nationaal beschermde soorten. Het aanwezige biotoop in het plangebied betreft lage begroeiing die hoofdzakelijk uit gras bestaat. In de directe omgeving van het plangebied is ook weinig beschutting aanwezig waardoor het plangebied en de directe omgeving hiervan voor veel grondgebonden zoogdieren als bunzing, haas, ree en veldmuis hooguit marginaal leefgebied betreft. Negatieve effecten en daarmee een overtreding van de Ow ten aanzien van deze soorten kunnen op voorhand uitgesloten worden.

Konijnen komen echter veel voor in en rondom het plangebied en hebben op verschillende plaatsen een hol. Hetzelfde geldt voor de vos. De soort wordt ook veel waargenomen door personeel dat aanwezig is op het terrein. Mogelijk heeft ook de vos een hol in of nabij het plangebied.

Effectbeoordeling
Als gevolg van de beoogde aanlegwerkzaamheden kunnen verblijfplaatsen van meer algemeen voorkomende beschermde zoogdieren als konijnen en vossen beschadigd of vernietigd worden, daarbij kunnen ook mogelijk dieren worden gedood. Hetgeen leidt tot overtreding van artikel 11.54 1a en 1b van het Bal. Aanvullende maatregelen zijn noodzakelijk.

Het plangebied vormt echter geen essentieel leefgebied voor konijn of vos, in de directe omgeving is voldoende uitwijkmogelijkheid. Ruimtebeslag in de gebruiksfase is beperkt en na inrichting kan het plangebied vrijwel dezelfde ecologische functie vervullen als voorheen. Permanent negatieve effecten worden op voorhand uitgesloten.

Vervolgstappen
Omdat konijn en vos zijn opgenomen in de lijst van vrijgestelde soorten (AMvB RN art 3.31), hoeft voor de optredende negatieve effecten en daarmee overtreding van verbodsbepalingen, geen omgevingsvergunning te worden aangevraagd. Negatieve effecten op konijn en vos en hun leefomgeving moeten wel zoveel als mogelijk voorkomen dan wel beperkt worden. De noodzakelijke maatregelen zijn toegelicht in paragraaf 6.1.

5.1.3 Vleermuizen

Voorkomen
Er zijn binnen het plangebied waarnemingen in de NDFF en in de Natuurwijzer bekend van vleermuizen. Dit betreffen de gewone dwergvleermuis (*Pipistrellus pipistrellus*) en ruige dwergvleermuis (*Pipistrellus nathusii*). Daarnaast worden ook soorten als laatvlieger (*Eptesicus serotinus*), en myotis-soorten als meervleermuis (*Myotis dasycneme*) en watervleermuis (*Myotis daubentonii*) vermeld.

Vleermuizen maken op verschillende manieren gebruik van het landschap. Vleermuizen hebben vaste rust- en verblijfplaatsen in gebouwen of bomen. Ze maken gebruik van lijnvormige structuren in het landschap om zich te oriënteren en zich daarlangs te verplaatsen tussen verblijfplaatsen en foerageergebieden.

Omdat er voor de werkzaamheden op land geen gebouwen gesloopt of bomen gekapt worden, zijn effecten op rust- en/of verblijfplaatsen van vleermuizen binnen het plangebied op voorhand uitgesloten. In het plangebied ontbreekt het aan lange aaneengeschakelde, lijnvormige elementen als bomenrijen. Een functie als vliegroute voor vleermuizen over land is daarom tevens uitgesloten. Mogelijk komen er wel passerende individuen voor langs de zuidelijke oever (het Yangtzekanaal). De noordelijke oever is door de aanwezigheid van windmolens niet geschikt om veilig langs te vliegen. De zuidelijke oever is echter niet essentieel, gezien de aanwezige uitwijkmogelijkheden in de direct omgeving, zoals bijvoorbeeld de overkant van het Yangtzekanaal. Aanwezigheid van essentiële vliegroutes is daarom uitgesloten. De begroeiing in het plangebied is schraal en bestaat geheel uit grassen en kruiden. Deze vegetatie heeft een lage aantrekkende werking op insecten. Daarbij wordt het plangebied door de aanwezige lantaarnpalen grotendeels verlicht. Het plangebied biedt dan ook hooguit marginaal geschikt foerageergebied voor vleermuizen.

Effectbeoordeling
Het plangebied en de directe omgeving daarvan voorziet op grond van de geraadpleegde verspreidingsgegevens en de aanwezige habitats niet in essentieel leefgebied of verblijfsmogelijkheden van krachtens de Ow beschermde vleermuizen. Negatieve tijdelijke en/of permanente effecten en een overtreding van de Ow ten aanzien van vleermuizen kunnen uitgesloten worden.

5.1.4 Vogels

Voorkomen
Uit de verspreidingsgegevens van de NDFF is gebleken dat in het plangebied of in de omgeving daarvan waarnemingen bekend zijn van verschillende soorten broedvogels welke jaarrond of niet-jaarrond beschermde nesten kunnen hebben. Deze soorten zijn vaak overvliegend, maar ook rustend of foeragerend waargenomen. Tijdens het veldbezoek zijn de volgende vogelsoorten waargenomen: ekster (*Pica pica*), houtduif (*Columba palumbus*) en kauw (*Corvus monedula*) en verschillende meeuwensoorten. Op basis van de NDFF-data is het aannemelijk dat soorten zoals de drieteenmeeuw (*Rissa tridactyla*), dwergmeeuw (*Hydrocoloeus minutus*), kokmeeuw (*Chroicocephalus ridibundus*), stormmeeuw (*Larus canus*), kleine mantelmeeuw (*Larus fuscus*) en zilvermeeuw (*Larus argentatus*) voorkomen.

Vogels kunnen op verschillende manieren gebruik maken van het plangebied: als broedlocatie, plek om te foerageren of om te rusten. In het plangebied zijn geen bomen, waardoor jaarrond beschermde nesten van boombroedende soorten als roek, buizerd en boomvalk op voorhand uitgesloten zijn. Door het ontbreken van gebouwen is tevens het voorkomen van jaarrond beschermde nesten van gebouwbroedende soorten als huismus of gierzwaluw uitgesloten.

Vanwege het grotendeels ontbreken van opgaande beplanting zijn de vrijwel kale terreinen alleen geschikt voor grondbroeders. Deze hebben geen van allen een jaarrond beschermd nest. Zo is bijvoorbeeld de kleine mantelmeeuw op vergelijkbare locaties in de Maasvlakte een talrijke broedvogelsoort, net als de zilvermeeuw en visdief. De toenemende aanwezigheid van de vos maakt het plangebied en omgeving steeds minder geschikt voor grondbroedende vogels. Verder zouden opportunistische en voor verstoring relatief ongevoelige soorten (zonder jaarrond beschermd nest) als kauw, houtduif en ekster wel in de nabijheid van het plangebied kunnen broeden, bijvoorbeeld op het terrein ten noorden van het plangebied waar nog enige opgaande begroeiing aanwezig is.

Effectbeoordeling
Het plangebied vormt een, als gevolg van aanwezigheid van de vos inmiddels suboptimaal, geschikt leef- en broedgebied voor enkele grondbroedende vogels zonder jaarrond beschermd nest. Wanneer de aanlegwerkzaamheden worden uitgevoerd in het broedseizoen worden bij het vergraven van grond mogelijk nesten vernietigd of beschadigd. Daarnaast kunnen broedende vogels in het plangebied en de directe omgeving daarvan worden verstoord. Wanneer broedende vogels daardoor voortijdig het nest verlaten, geldt dit eveneens als het opzettelijk vernietigen of beschadigen van nesten en eieren van vogels. Dit is een overtreding van artikel 11.37 1a, 1b en 1d van het Bal. Aanvullende maatregelen zijn noodzakelijk.

Het plangebied vormt geen essentieel biotoop voor broedvogels, in de directe omgeving is voldoende uitwijkmogelijkheid. Ruimtebeslag in de gebruiksfase is beperkt en na inrichting kan het plangebied vrijwel dezelfde ecologische functie vervullen als voorheen. Permanent negatieve effecten worden uitgesloten.

Vervolgstappen
Negatieve effecten op broedvogels moeten voorkomen worden. Dat kan door bepaalde werkzaamheden en activiteiten in tijd en ruimte daarop afgestemd te plannen of specifieke mitigerende maatregelen te treffen. De noodzakelijke maatregelen zijn toegelicht in paragraaf 6.1.

5.1.5 Vissen

Voorkomen
De werkzaamheden worden op land uitgevoerd. Permanent watervoerende elementen ontbreken binnen het plangebied. Op basis van het ontbreken van oppervlaktewateren (zoals plassen, vijvers, etc.) kan het voorkomen van beschermde vissen worden uitgesloten.

Effectbeoordeling
In het plangebied (land-deel) komen geen wettelijk beschermde vissen voor. Negatieve effecten en een overtreding van de Ow worden op voorhand uitgesloten.

5.1.6 Amfibieën

Voorkomen
Er zijn in het noordoostelijk deel van het plangebied in de NDFF en in de Natuurwijzer waarnemingen bekend van de rugstreeppad (*Epidalea calamita*). De soort is waargenomen bij een daar aanwezig waterbassin en komt verspreid over het terrein van het havenbedrijf op meerdere locaties voor[9]. Het voorkomen van de rugstreeppad in het plangebied is daarmee aannemelijk. Voor de rugstreeppad is in en nabij het plangebied geschikt leefgebied aanwezig. Het waterbassin vormt potentieel geschikt voortplantingsbiotoop. In de directe omgeving zijn geschikte overwinteringsplaatsen zoals open zandige locaties en elementen waar amfibieën onder kunnen schuilen aanwezig. De met dicht gras begroeide delen van het plangebied zijn niet geschikt als leefgebied van de soort. De rugstreeppad is echter in staat, indien er geschikte omstandigheden ontstaan, snel een gebied te koloniseren.

Effectbeoordeling
De beoogde aanlegwerkzaamheden kunnen leiden tot het tijdelijk beschadigen en/of vernietigen van verblijfplaatsen en het verwonden en/of doden van individuen van de rugstreeppad. Mogelijk gaat als gevolg van de nieuwe ruimtelijke inrichting ook permanent geschikt leefgebied verloren. Hetgeen leidt tot overtreding van artikel 11.46 1a, 1b en 1d van de Ow het Bal. Aanvullende maatregelen zijn noodzakelijk.

Vervolgstappen
Om aan te sluiten op de gebiedsontheffing van het havenbedrijf, dienen de werkzaamheden te worden uitgevoerd volgens de werkprotocollen zoals vastgelegd in het Managementplan van het havenbedrijf. Indien aan alle eisen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk. De noodzakelijke maatregelen zijn toegelicht in paragraaf 6.1.

5.1.7 Reptielen

Voorkomen
In de ruime omgeving van het plangebied zijn in de NDFF-waarnemingen bekend van de beschermde zandhagedis (*Lacerta agilis*). De zandhagedis is sterk gebonden aan duin- en heidegebieden. De waarnemingen van de soort zijn dan ook gedaan in het duingebied van Hoek van Holland en het duingebied bij Oostvoorne. Voor de zandhagedis geschikt biotoop, zoals open zandige locaties is aanwezig binnen het plangebied. Echter, verbinding met bestaande populaties waarvan onder anderen aan de overzijde van de Nieuwe Waterweg ontbreekt, waardoor aanwezigheid van de soort redelijkerwijs kan worden uitgesloten.

Effectbeoordeling
In het plangebied komen geen wettelijk beschermde reptielen voor. Negatieve effecten en een overtreding van de Ow worden op voorhand uitgesloten.

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[9] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam.*

Royal HaskoningDHV

5.1.8 Ongewervelde soorten

Voorkomen
Er zijn in het plangebied in de NDFF en in de Natuurwijzer geen waarnemingen bekend van beschermde ongewervelde diersoorten. Voor de meeste soorten geldt dat het voorkomen op basis van de aanwezige biotopen (voor vrijwel al de zwaarder beschermde soorten ongeschikt) en de algemene verspreidingsgegevens uitgesloten is. Individuen van de grote vos (dagvlinder) (*Nymphalis polychloros*) kunnen incidenteel wel aangetroffen worden. Dit is een zeer mobiele soort. Voor de grote vos geschikte waardplanten als iep, zoete kers, populier en wilgensoorten ontbreken echter in het plangebied. Vaste voortplantingsplaatsen of rustplaatsen van de soort worden daarom op voorhand uitgesloten.

Effectbeoordeling
Het plangebied en de directe omgeving daarvan voorziet op grond van de geraadpleegde verspreidingsgegevens en de aanwezige habitats niet in essentieel leefgebied of verblijfsmogelijkheden van krachtens de Ow beschermde ongewervelden. Negatieve tijdelijke en/of permanente effecten en een overtreding van de Ow ten aanzien van ongewervelden kunnen op voorhand uitgesloten worden.

5.1.9 Samenvatting voorkomende beschermde soortgroepen (land-deel)

Op basis van de uitkomsten van het onderzoek, is het voorkomen van de in het onderstaande overzicht opgenomen soorten te verwachten of niet uitgesloten (Tabel 5-1). Het gaat om: glad biggenkruid, algemeen voorkomende beschermde zoogdieren (konijn en vos), vleermuizen, broedvogels en de rugstreeppad. Er is beoordeeld of en zo ja op welke wijze de projectuitvoering kan leiden tot negatieve effecten op deze soorten. Ten aanzien van vleermuizen zijn negatieve effecten op voorhand uitgesloten. Voor de overige soorten/soortgroepen geldt dat niet.

Glad biggenkruid en de rugstreeppad vallen onder het Managementplan beschermde soorten van het havenbedrijf. Om te kunnen voldoen aan gebiedsontheffing van het havenbedrijf, dient gewerkt te worden conform de bijbehorende werkprotocollen. Onderdeel hiervan is dat voorafgaand aan de werkzaamheden het plangebied nader onderzocht wordt op het voorkomen van leefgebiedsfuncties van glad biggenkruid en de rugstreeppad. Vanuit de bevindingen van dit onderzoek kunnen noodzakelijke vervolgstappen worden genomen, zoals mogelijk het inrichten van compenserend leefgebied. Indien aan alle eisen uit de werkprotocollen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk.

Voor algemeen voorkomende beschermde zoogdieren en broedvogels geldt dat ze niet vallen onder het Managementplan beschermde soorten, maar dat overtreding van de Ow dient te worden voorkomen door het nemen van voorzorgsmaatregelen. Deze voorzorgsmaatregelen dienen samen met de maatregelen uit het Managementplan ten aanzien van glad biggenkruid en de rugstreeppad op genomen te worden in een project specifiek ecologisch werkprotocol. De werkzaamheden kunnen pas worden uitgevoerd na goedkeuring van het havenbedrijf en dienen plaats te vinden onder begeleiding van een erkend ecoloog.

Tabel 5-1. Overzicht van de te verwachten beschermde soorten (land).

Soortgroep	Aanwezig	Effectbeoordeling – negatieve effecten?	Vervolgstappen
Vaatplanten	Glad biggenkruid.	Ja, wanneer standplaatsen vergraven worden, dit is een overtreding van de verbodsbepalingen.	Er dient gewerkt te worden conform de werkprotocollen uit het “Managementplan beschermde soorten Havenbedrijf Rotterdam”. Het aanvragen van een projectspecifieke omgevingsvergunning is niet noodzakelijk.
Grondgebonden zoogdieren	Algemeen voorkomende beschermde soorten als: konijn en vos.	Ja, verstoring van leefgebied tijdens de uitvoering van de	Negatieve effecten moeten zoveel als mogelijk voorkomen dan wel beperkt worden. De te nemen maatregelen om effecten zo veel als mogelijk te beperken

		werkzaamheden, doden en/of verwonden.	dan wel uit te sluiten dienen uitgewerkt te worden in een ecologisch werkprotocol.
Vleermuizen	Verschillende soorten waaronder gewone en ruige dwergvleermuis, laatvlieger en watervleermuis.	Nee, er worden geen negatieve effecten op vleermuizen verwacht. Er is geen sprake van een overtreding van de verbodsbepaling en het uitvoeren van nader onderzoek naar het voorkomen is niet aan de orde.	Geen verdere vervolgstappen.
Algemene broedvogels	Soorten als: kleine mantelmeeuw zilvermeeuw, visdief, kauw, houtduif en ekster.	Ja, aanwezige broedende vogels kunnen door de werkzaamheden verstoord worden, indien gewerkt wordt tijdens het broedseizoen is ecologische begeleiding vereist.	Negatieve effecten moeten voorkomen worden. De te nemen maatregelen dienen uitgewerkt te worden in een ecologisch werkprotocol.
Amfibieën	Rugstreeppad.	Ja, de rugstreeppad kan het plangebied koloniseren. Indien de juiste omstandigheden voor het voorkomen van de rugstreeppad ontstaan gedurende de werkzaamheden moeten mitigerende maatregelen genomen worden.	Er dient gewerkt te worden conform de werkprotocollen uit het “Managementplan beschermde soorten Havenbedrijf Rotterdam”. Het aanvragen van een projectspecifieke omgevingsvergunning is niet noodzakelijk.

5.2 Voorkomende soorten en effectbeoordeling (zee)

5.2.1 Vissen

In het plangebied komen volgens verspreidingsgegevens de beschermde vissen houting en steur voor (Sportvisserij Nederland, 2023; Winter et al., 2014). Andere beschermde vissen zoals de grote modderkruiper en kwabaal zijn zoetwatervissen en komen niet voor op zee.

Voorkomen – Houting
De houting (*Coregonus oxyrinchus*) verdween in de 20^{e} eeuw uit onze rivieren en kustwateren. Door herintroductie van de soort tussen 1999 en 2006 worden er inmiddels weer incidenteel houtingen in rivieren en de Waddenzee gevangen. Door gebrek aan open verbindingen met de Noordzee groeit in Nederland een groot deel van de houtingen op in het IJsselmeer en blijven daar ook als volwassen dieren (Winter et al., 2014).

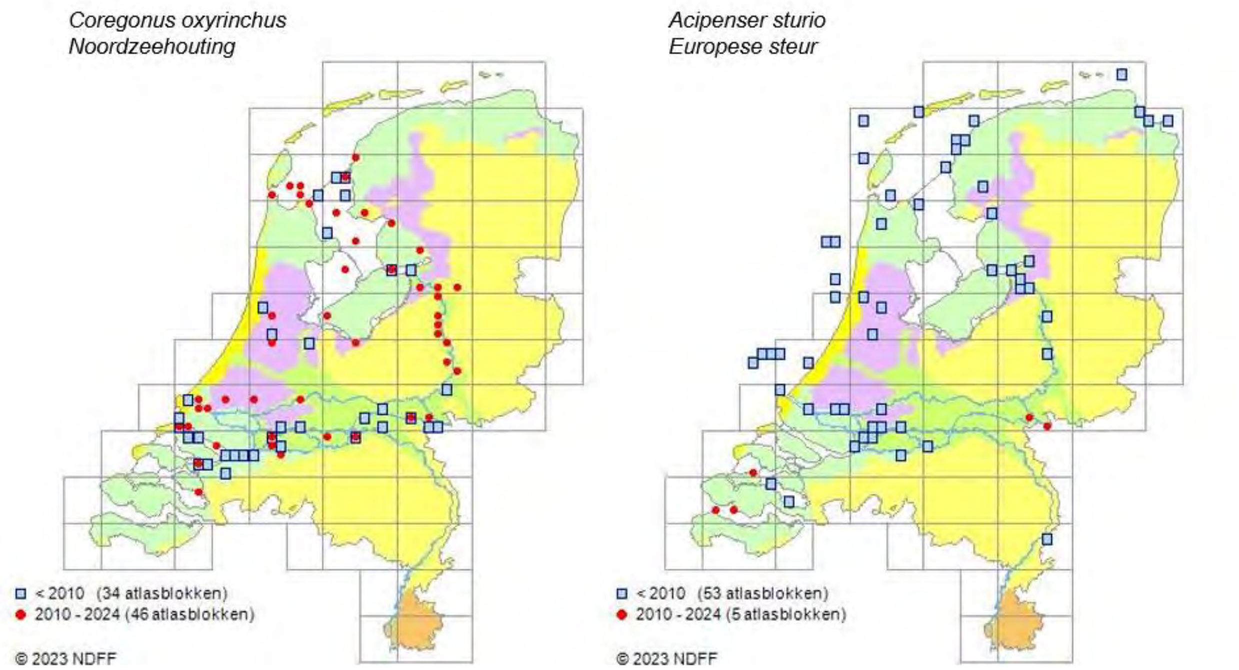
Rond november trekt de Noordzeehouting de rivieren op om zich voort te planten. Er wordt gepaaid boven kiezel- of zandbodems met een matige stroming. De eitjes komen aan het begin van het voorjaar uit. De jonge Noordzeehouting laten zich in de loop van de zomer afzakken richting riviermondingen en de kustzone. Juveniele Noordzeehoutingen voeden zich vooral met zoöplankton. Grotere Noordzeehoutingen eten daarnaast ook insectenlarven, scheldieren, kreeftachtigen en kleine vissen (RAVON, n.d.-b).

Geschikt voortplantingsbiotoop is verder stroomopwaarts van de rivieren te vinden en ontbreekt binnen het plangebied. Volwassen individuen kunnen incidenteel passerend of foeragerend voorkomen in het plangebied (Figuur 5-1). Ook kunnen oudere juvenielen langskomen onderweg naar de Noordzee.

Voorkomen – Steur
In onderzoek van Daan (2000) is geconcludeerd dat de Atlantische steur (*Acipenser sturio*) is verdwenen in de Noordzee. Afgelopen jaren zijn in diverse Europese rivieren steuren uitgezet. Specifiek in Nederland zijn in 2012, 47 individuen uitgezet in de Nieuwe Maas en de Rijn ter hoogte van Kekerdom en in 2015 nog eens 53 individuen in de Rijn nabij de Duitse grens. In juni 2023 zijn er ook in de Biesbosch 29 jonge steuren uitgezet. Al deze dieren zijn naar zee getrokken. Er zijn daarna enkele meldingen bekend van vangsten van steuren in de Delta (Sportvisserij Nederland, 2023).

Voor de voortplanting trekt de steur in het voorjaar de rivieren op waarbij vele honderden kilometers kunnen worden afgelegd. De paai geschied in diepe snelstromende delen op een bodem bestaande uit grof grind en stenen. Jonge steuren zakken de rivier af als ze een aantal jaar oud zijn om op te groeien in het estuarium waarna ze uitzwerven over de kustwateren. Hier voeden ze zich met kreeftachtigen, wormen, schelpdieren en vissen die ze opsporen met behulp van de bekdraden (RAVON, n.d.-a).

Geschikt voortplantingsbiotoop is verder stroomopwaarts van de rivieren te vinden en ontbreekt binnen het plangebied. De soort is ook pas recent weer geïntroduceerd, waardoor de kans dat de steur passerend of foeragerend voorkomt in het plangebied verwaarloosbaar klein is. Negatieve effecten op de soort worden daarom op voorhand uitgesloten.



Figuur 5-1. Verspreidingskaarten van de noordzeehouting (Coregonus oxyrinchus) en Europese steur (Acipenser sturio). Blauwe blokken zijn waarnemingen voor 2010. De rode stippen zijn waarnemingen tussen 2010-2023. Bron: www.verspreidingsatlas.nl.

Effectbeoordeling
De beoogde activiteiten in de aanlegfase (boren, heien, baggeren, trenchen en pijpen leggen) vinden plaats in een drukbevaren gebied. In totaal worden er in de aanlegfase ruim 2.000 extra scheepvaartbewegingen verwacht ten behoeve van de eerdergenoemde activiteiten. In de gebruiksfase vinden ook scheepvaartbewegingen plaats vanuit de havens van Den Helder, Rotterdam en Amsterdam naar de platforms voor onderhoud. Jaarlijks worden er 325 scheepvaartbewegingen verwacht in de gebruiksfase.

Vissen zijn zeer mobiel en hebben genoeg uitwijkmogelijkheden om het onderwatergeluid te vermijden, mocht dit als te verstorend worden ervaren. Door alle vaardrukte is er al een verhoogd achtergrondgeluid en zodoende al een hoge mate van verstoring aanwezig, waardoor de extra scheepvaartbewegingen van het Aramis initiatief in zowel de aanleg- als de gebruiksfase minimaal zullen bijdragen aan extra verstoring van vissen in het plangebied (zie Passende Beoordeling, RHDHV, 2023b).

Voor impulsgeluiden, zoals afkomstig van het heien in de aanlegfase, is de situatie anders omdat dit niet tot het reguliere achtergrondgeluid behoort en bovendien tot acute schade bij vissen kan leiden. Vissen met een zwemblaas kunnen gevoelig zijn voor dit type geluidsverstoring. De aanwezigheid van een zwemblaas nabij of verbonden met het binnenoor zorgt ervoor dat deze vissen gevoeliger zijn voor geluid, doordat variaties in waterdruk worden omgezet in waterbeweging (trillingen). Op deze manier bereikt in totaal meer waterbeweging het binnenoor, en kan daar schade aanrichten. De Temporary Threshold Shift (TTS)-waarde voor deze vissen zou kunnen liggen rond de 186 dB SELcum (Popper and Hawkins (2019). Dit toont aan dat de drempel voor vissoorten die gevoelig zijn voor onderwatergeluid hoger ligt dan voor bijvoorbeeld zeezoogdieren. Uit meerdere studies blijkt dan ook dat vissen na blootstelling aan impulsgeluid geen, of weinig schade oplopen (Debusschere et al., 2014; van der Knaap et al., 2021, 2022). Daarnaast zijn vissen zeer mobiel waardoor ze voor de meeste werkzaamheden relatief eenvoudig kunnen uitwijken. Mede door de standaardvoorzieningen die worden getroffen bij aanvang van de heiactiviteiten, zoals soft starts, is doding of verwonding van vissen door impulsgeluiden uitgesloten.

Door het baggeren, trenchen, het storten van steen bij kruisingen van infrastructuur, en de lozing van boorgruis vindt daarnaast beschadiging van bodemhabitats, vertroebeling van de waterkolom en sedimentatie plaats. Het leefgebied van de houting kan hierdoor tijdelijk aangetast worden door oppervlakteverlies en vertroebeling van de waterkolom. Omdat de meeste werkzaamheden slechts op één plaats tegelijk plaatsvinden, de effecten zich beperken tot naar verwachting hooguit een paar 1000 m^2 betreft de verstoring op ieder moment slechts een zeer klein oppervlak in vergelijking met omringende vergelijkbare habitats. Door de tijdelijke aard van de activiteiten en doordat er voldoende uitwijkmogelijkheden zijn in de directe omgeving, zijn negatieve effecten op de houting uitgesloten. Bovendien zijn de effecten van met name sedimentatie het meest relevant voor juvenielen, eitjes en larven en dat deel van de levenscyclus wordt stroomopwaarts in rivieren doorgebracht. Dit betekent dat de vissen tijdens de meest kwetsbare levensfasen niet aanwezig zullen zijn in of nabij het plangebied.

Het voornemen leidt niet tot overtreding van de Ow. Het aanvragen van een omgevingsvergunning voor de houting of de steur is niet aan de orde.

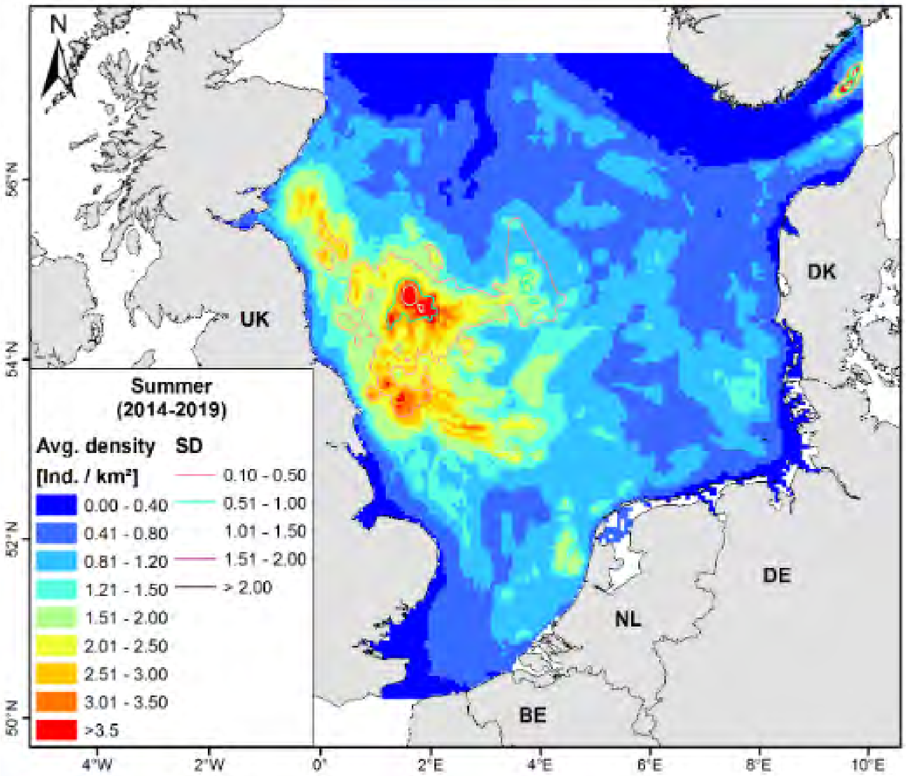
5.2.2 Zeezoogdieren

Het plangebied overlapt met de verspreiding van de beschermde zeezoogdieren bruinvis (*Phocoena phocoena*) en de gewone en grijze zeehond (*Phoca vitulina* en *Halichoerus grypus*).

Bruinvis
Voorkomen
Bruinvissen komen veel voor langs de kust, maar hebben ook een voorkeur voor relatief ondiepere wateren van het NCP (Figuur 5-2) (Redeker & van Doorn, 2019). Jonge bruinvissen worden tussen mei en juli voornamelijk in beschut, ondiep water geboren, een enkele keer op open zee (Geelhoed & van Polanen Petel, 2011a).

Jonge bruinvissen eten vooral grondels. Volwassen bruinvissen eten bij voorkeur vette vis als haring, zandspiering en makreel en anders kabeljauwachtigen, zoals wijting (Leopold, 2015). Voor zowel het zoeken naar voedsel, als ook voor navigatie en communicatie onderling gebruiken de dieren echolocatie. De soort gebruikt korte klikklanken met een hoge frequentie en een smalle bandbreedte (Møhl & Andersen, 1973).

De bruinvis is doorgaans het gehele jaar aanwezig in de Noordzee, maar migreert in de loop van de zomer voornamelijk naar het noorden (Soldaat & Poot, 2019). De zomerperiode (juni-augustus) is tevens ook de voortplantingsperiode van de bruinvis (Ecomare, 2023). Voor zover bekend zijn voortplantingsplaatsen van bruinvissen gelegen in het centrale en Duitse deel van de Noordzee (BfN, 2017; Ministerie van Economische Zaken, 2014). Hieruit wordt afgeleid dat geschikte voortplantingsplaatsen voor bruinvissen op het NCP ontbreken. Het tijdelijk beschadigen of vernielen van vaste voortplantingsplaatsen van de bruinvis is daarmee op voorhand uitgesloten (Bal artikel 11.46 1d van de Ow). Echter, kan wel worden aangenomen dat bruinvissen passerend of foeragerend in het plangebied voorkomen.



Figuur 5-2. Verwachte bruinvis dichtheden in de Noordzee in de zomer (Gillis et al., 2020).

Effectbeoordeling

Oppervlakteverlies. Ter plekke van de heilocaties, de putten en het leidingtracé zal de zeebodem vergraven worden en tijdelijk of permanent ongeschikt zijn als leefgebied voor bodembewonende soorten die als prooi voor bruinvissen kunnen dienen. In de aanlegfase betreft dit voornamelijk het tijdelijke effect voor de aanleg van de leidingen. Voor de aanleg van de nearshore zeeleiding wordt met behulp van een trencher een gleuf gegraven van maximaal twee m diep, zes m breed aan de bovenkant van de gleuf en twee m breed aan de onderkant van de gleuf. Het gaat om de eerste 70 kilometer vanaf de kruising met de Maasgeul waar de zeeleiding wordt ingegraven in de zeebodem, met een dekking van circa één meter. Na de aanlegfase zal de zeebodem ter plekke van de leidingen en overige tijdelijk aangetaste waterbodem zich weer herstellen. Het gaat daardoor om een tijdelijk oppervlakteverlies.

De aanleg van de zeeleiding *op* de zeebodem betreft een permanent oppervlakteverlies. Het permanente effect betreft ter plekke van de constructies circa tien ha op de zeebodem (Passende Beoordeling, RHDHV, 2023b). Sommige soorten zullen al vrijwel meteen weer gebruik maken van het verstoorde gebied, herstel van met name langzaam groeiende sessiele soorten kan jaren duren. Voor de bruinvis is het vooral van belang dat prooidieren al snel na de aanlegfase weer gebruik kunnen maken van het verstoorde gebied, omdat het mobiele vissoorten betreft. Voor de bruinvis zal het verstoorde gebied dus waarschijnlijk al na enkele dagen of weken weer op een vergelijkbare manier als vóór de ingreep bruikbaar zijn als foerageergebied. Significant negatieve effecten van oppervlakteverlies op de bruinvis zijn uitgesloten.

Vertroebeling. Bij het baggeren en trenchen kan vertroebeling optreden. Zeezoogdieren maken over het algemeen vaker gebruik van troebele wateren met name om te foerageren en veel soorten hebben goedontwikkelde sonarsystemen die hun functioneren in een troebele omgeving mogelijk maakt (Au et al., 2000). Troebel water komt onder natuurlijke omstandigheden ook voor op het NCP met name door wind en stromingen. De bruinvis is beperkt gevoelig voor vertroebeling (Tamis et al., 2011) en de troebele wolk zal enkel lokaal aanwezig zijn, waardoor effecten van vertroebeling op de bruinvis zijn uit te sluiten.

Sedimentatie. De werkzaamheden zorgen voor sedimenten in de waterkolom die vervolgens op de bodem neerslaan en daar een sedimentlaagje vormen. Door de aanleg van de nearshore zeeleiding (tot 70 km vanaf de doorkruising van de Maasgeul) treedt sedimentatie op met een maximale toename in sedimentdikte van 0,20 mm aan weerszijden van de leiding (zie Detailrapport zeebodem, RHDHV, 2023a). Ook bij de lozing van boorgruis kan sedimentatie optreden. Op basis van een modelstudie van de lozing van boorgruis van 12 putten bij platform N05-A (Royal HaskoningDHV, 2020) is een inschatting gemaakt van de verspreiding van het boorgruis op de boorlocatie van de nieuwe putten van het Aramis initiatief. Uit de modelstudie van N05-A bleek dat het meeste sediment van het boorgruis direct zou vallen onder het boorplatform op de zeebodem door de grove korrelgrootte, waarbij een laag van maximaal 23 cm per boring zou ontstaan. Het fijnere boorgruis zou door de eb- en vloedbeweging over een groter gebied worden verspreid. Binnen een straal van 90 m rondom de boorlocatie zou de extra sedimentatie per boring groter zijn dan 1,5 cm in een *worst case*-situatie. Dit sediment zou, afhankelijk van het aantal zware stormen, maanden tot jaren na de boorwerkzaamheden nog aanwezig zijn nabij de platformlocatie. Buiten een straal van 105 m rond het platform zou geen tot een verwaarloosbaar kleine hoeveelheid extra sedimentatie zichtbaar zijn.

Er zal geen sprake zijn van bedekking van prooien van de bruinvis (o.a. juvenielen en larven van de zandspiering en haring) door verhoogde sedimentatie. Bij extreme omstandigheden (bijvoorbeeld storm) is de zandspiering bovendien in staat om zich te verplaatsen of in te graven. Het is daarom aannemelijk dat die soort bij een toename van een aantal centimeter sediment in de directe omgeving van de boorlocatie geen direct effect ondervinden vanwege zijn mobiliteit en aanpassingsvermogen (Tulp et al., 2016). Directe en indirecte significant negatieve effecten van sedimentatie op de bruinvis zijn uit te sluiten.

Licht. De activiteiten ten behoeve van de aanleg van de aanlegsteigers, de offshore activiteiten (heien, boren, zeeleiding en verbindingsleidingen leggen) en de inzet van schepen voor het onderhoud aan de platforms leiden tot een toename in lichtuitstraling en scheepvaart- en helikopterbewegingen. Doordat verlichting op schepen beperkt blijft tot de vereiste navigatieverlichting, wordt ervan uitgegaan dat de toename in lichtuitstraling - en dan met name lichtuitstraling onderwater - zeer beperkt tot nauwelijks toeneemt. Significant negatieve effecten van licht op de bruinvis zijn uit te sluiten.

Beweging en optiek. In het geval van verstoring door aanwezigheid (optische verstoring) is vaak moeilijk onderscheid te maken tussen de verstoring die optreedt door het visueel waarnemen van onder andere schepen, of dat eventueel vluchtgedrag te wijden is aan geluid dat met de scheepvaartbewegingen gepaard gaat. Voor diersoorten die zich boven het wateroppervlak bevinden, zoals watervogels, treedt vaak in eerste instantie optische verstoring op. Hierdoor vermijden deze soorten mogelijk het plangebied voordat geluidsverstoring kan optreden. Omdat geluid verder propageert in water dan in lucht en de bruinvis zich voornamelijk in de waterkolom begeeft, is het voor de bruinvis aannemelijker dat deze in eerste instantie het plangebied verlaten door geluidsverstoring dan door optische verstoring van schepen. Er wordt daarmee niet verwacht dat bruinvissen hinder ondervinden van een toename in scheepvaart- en helikopterbewegingen (RHDHV, 2023b). Effecten van geluid worden hieronder beoordeeld.

Geluid. De beoogde activiteiten in de aanlegfase (boren, heien, baggeren, trenchen en pijpleidingen leggen) leiden tot een verhoogd geluidsniveau binnen het plangebied. Bruinvissen zijn gevoelig voor geluidsverstoringen vanaf 140 dB (Heinis et al., 2019). Op basis van de geluidsverstoringscontouren is voor werkzaamheden waar impulsgeluid bij vrijkomt, waaronder het heien van de conductorpijpen, het centrale eindpunt en de platformverankeringspalen, vastgesteld dat deze overlapt met het leefgebied van de bruinvis (Passende Beoordeling, RHDHV, 2023b).

Omdat zeezoogdieren zoals bruinvissen mobiel zijn en zich verplaatsen binnen én buiten diverse Natura 2000-gebieden, zijn effecten van onderwatergeluid op de gehele populatie in de Noordzee beoordeeld (zie Passende Beoordeling, RHDHV, 2023b). Voor Nederland wordt in het Kader Ecologie en Cumulatie (KEC) 4.0 een maximaal ecologisch toelaatbare reductie van 5% van de Nederlandse populatie bruinvissen gehanteerd, die momenteel wordt geschat op 62.771 individuen op het NCP (Heinis et al., 2022). Op basis van de Interim Population Consequences of Disturbance Model (iPCOD) formule is berekend dat voor de verschillende activiteiten van het Aramis initiatief een range van 10.665 – 18.016 bruinvisverstoringsdagen oplevert, wat resulteert in een populatiereductie van 4,5 – 8,4 bruinvissen (Tabel 5-2). In de berekening wordt uitgegaan van de worst case situatie dat activiteiten met effecten op onderwatergeluid vlak na elkaar plaatsvinden, waardoor mogelijk tussentijds herstel van de populatie niet wordt verwacht. De populatiereductie die door alle activiteiten met impulsgeluid van het Aramis initiatief tijdens de aanlegfase in de Noordzee plaatsvinden komt neer op maximaal 0,007 tot 0,013% en valt daarmee binnen de maximaal toelaatbare reductie (5%). Voor een gedetailleerde beschrijving van de berekeningen wordt verwezen naar de Passende Beoordeling (RHDHV, 2023b).

Tabel 5-2. Aantal bruinvisverstoringsdagen per activiteit en de totale populatiereductie van alle activiteiten met impulsgeluid opgeteld, berekend uit aantal verstoorde bruinvissen per dag maal het aantal verstoringsdagen en de iPCOD formule.

Activiteit		Aantal dagen voor activiteit	Aantal verstorings-dagen	Verstoord oppervlak in km^2	Gemiddelde dichtheid per km^2 o.b.v. locatie activiteit	Verstoorde dieren per dag	Aantal bruinvis-verstorings-dagen	Populatie-reductie (aantal dieren)
Heien aanlegsteigers fase 1	-	50	51	9	0,81	7,29	372	0,1
Heien aanlegsteigers fase 2	-	50	51	9	0,81	7,29	372	0,1
Heien verankeringspal en nieuwe platforms	Per platform	3	4	610	1,20 – 2,0	732 – 1.220	2.926 – 4.880	1,2 – 2,2
	Totaal [1]	6	8	610	1,20 – 2,0	732 – 1.220	5.853– 9.760	2,7 – 4,9
Heien conductorpijpen nieuwe putten	Per put	0,5	1,5	94	1,20 – 2,0	114 – 188	171 - 376	0,04 - 0,1
	Totaal [2]	7	10	94	1,20 – 2,0	114 – 188	1.140 - 2.632	0,4 - 1,1
Heien centrale eindpunt	-	3	4	610	1,20 – 2,0	732 – 1.220	2.928 – 4.880	1,2 – 2,2
Totaal	-	-	-	-	-	-	10.665 – 18.016	4,5 – 8,4

[1]: In totaal 2 nieuwe platforms; (1) L10-zuid en (2) K14-FA.
[2]: Platform K14-FA; 4-6 nieuwe injectieputten. Platform L10-zuid; 4-6 nieuwe injectieputten. Platform L4-A; 2 nieuwe injectieputten (L4-A3 en L4-A4). Worst-case; 14 nieuwe injectieputten.

Er is geen sprake van permanente gehoorschade (PTS) als gevolg van de werkzaamheden. Verstoring door onderwatergeluid kan echter niet worden uitgesloten, omdat bruinvissen het plangebied voor een langere periode mogelijk zullen mijden door de toename in geluid. Zo is bepaald dat bruinvissen bij het heien van het centrale eindpunt het plangebied kunnen mijden tot op 14 km van de heilocatie (Tabel 5-3). Daarnaast wordt bij het heien van de verankeringspalen voor de platforms en het centrale eindpunt de geluidsnorm (SELss 164 dB re 1µPa2s op 750 m van de heilocatie), zoals gehanteerd in de kavelbesluiten voor het offshore windpark IJmuiden, overschreden met 7 dB (RHDHV, 2023b).

Tabel 5-3. Overzicht berekende effecten PTS en mijding zeezoogdieren en vissen.*

Geluidbron	Diersoort	Drempel PTS SEL in dB re 1 µPa2s	Veilige afstand (m) voor PTS bij verblijf van 3 uur	Drempel mijding SPL in dB re 1 µPa bij verhoogd achtergrondgeluid	Mijding op afstand in m mits verhoogd achtergrondgeluid
Pijpleggen	Bruinvis	173	<10	130	<10
	Zeehond	201	<10	130	2.300
	Vissen	207	<10	150	n.v.t.
Aanleg verbindingsleiding(en) voor de spurlines	Bruinvis	173	<10	130	<10
	Zeehond	201	<10	130	2.300
	Vissen	207	<10	150	n.v.t.
Baggeren	Bruinvis	173	<10	130	<10
	Zeehond	201	<10	130	2.300
Heavy lift schip	Bruinvis	173	<10	130	<10
	Zeehond	201	<10	130	2.300
Injectieputten boren	Bruinvis	173	<100	130	10.000
	Zeehond	201	<100	130	10.000
Machinegeluid (gerelateerd aan werkzaamheden platform)	Bruinvis	173	<100	130	10.000
	Zeehond	201	<100	130	10.000
	Vissen	207	<100	150	n.v.t.
Aanlegsteigers heien	Bruinvis	155	3.000	-	3.300 (Verstoringsoppervlak in haven: 9 km^2)
	Zeehond	185	1.350	-	3.300 (Verstoringsoppervlak in haven: 9 km^2)
Verankeringspalen nieuwe platforms	Bruinvis	-	-	-	13.934
	Zeehond	-	-	-	8.574
Conductorpijpen nieuwe putten	Bruinvis	-	-	-	5.500
	Zeehond	-	-	-	4.100
Heien centrale eindpunt	Bruinvis	-	-	-	13.938
	Zeehond	-	-	-	8.577

**Voor het bepalen en beoordelen van eventuele effecten van heiwerk op zeezoogdieren in de Noordzee sluiten we aan bij het Kader Ecologie en Cumulatie (KEC). In de tbael betreft dat de drie laatstgenoemde geluidbronnen. De bijbehorende gepresenteerde mijdingsafstand is gebaseerd op een geluiddosis (SELSS) en niet op een geluiddrukniveau (SPL), zoals wordt gebruikt voor geluidbronnen die continu van karakter zijn. Verder is PTS in de berekeningen rond KEC niet relevant. Om deze redenen bevat de tabel niet voor alle geluidbronnen gegevens over het aspect PTS en mijding uitgedrukt in SPL.*

De effecten zoals hierboven beschreven hebben alleen betrekking op impulsgeluid. Het verstoorde oppervlak is in werkelijkheid groter, doordat bij veel werkzaamheden zoals het baggeren en leggen van de pijpleiding, het boren of aanpassen van de putten en de benodigde schepen om de platforms aan te leggen continu onderwatergeluid vrijkomt. Ook in de gebruiksfase worden extra schepen ingezet voor onderhoud aan de platforms (circa 325 extra scheepvaartbewegingen).

Kijkende naar de werkzaamheden die rond de platforms in de Noordzee plaatsvinden in de aanlegfase, worden er circa één tot twee jaar achter elkaar, intensief werkzaamheden uitgevoerd. Het is aannemelijk dat bruinvissen het verstoorde gebied voor langere tijd zullen mijden. Dit kan effect hebben op individuele bruinvissen en kan daarnaast de staat van instandhouding op populatieniveau negatief beïnvloeden, omdat:

- Er sprake is van een langere periode waarin verstoring plaatsvindt (één tot twee jaar in de aanlegfase en aansluitend in de gebruiksfase) waardoor een deel van het leefgebied een verminderde foerageerfunctie heeft.
- Activiteiten waar geluid bij vrijkomt mogelijk opeenvolgend of tegelijkertijd plaatsvinden. Doordat de activiteiten op verschillende locaties vlakbij elkaar plaatsvinden, kan dit negatieve invloed hebben op de uitwijkmogelijkheden van bruinvissen.

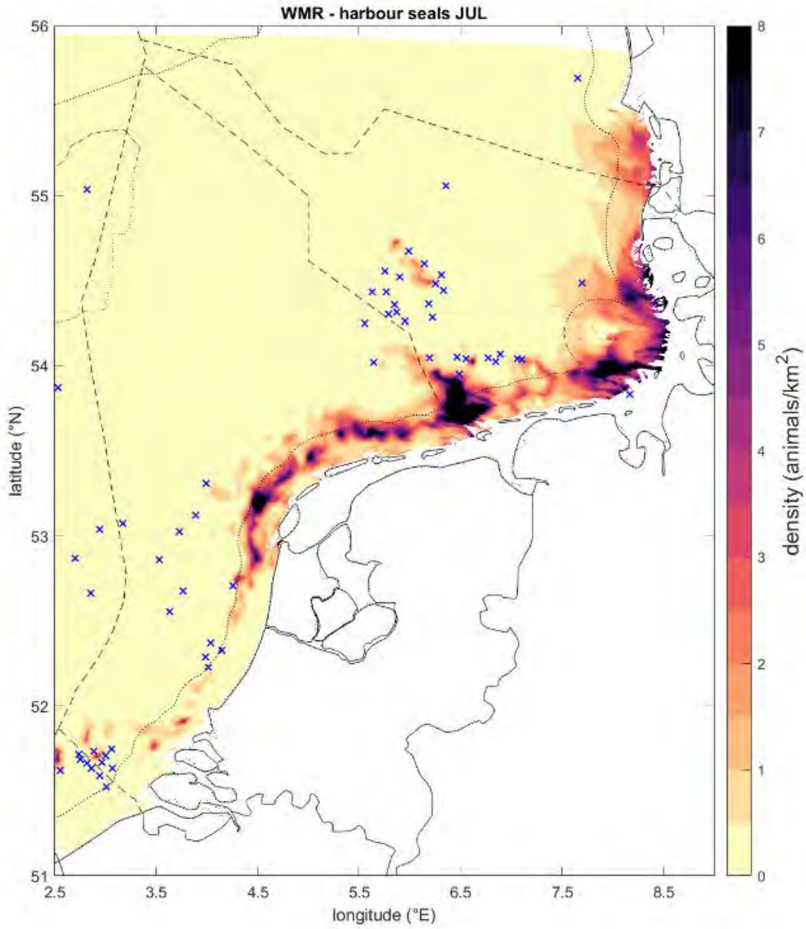
Verstoring van de bruinvis is niet uit te sluiten voor de heiwerkzaamheden (aanlegfase), de inzet van schepen (aanleg- en gebruiksfase) en het gebruik van een Acoustic Deterrent Device (ADD) (aanlegfase). Dit is een overtreding van artikel 11.46 1b van het Bal.

Door het nemen van standaardvoorzieningen zoals een soft start zullen individuen van bruinvissen in het gebied minimaal tot 500 meter van de geluidsbron worden verjaagd. Hierdoor wordt voorkomen dat bruinvissen (gehoor)schade oplopen (Temporary Threshold Shift (TTS) en Permanent Threshold Shift (PTS)). De soft start is onderdeel van het heien en dient ervoor om veel directere negatieve effecten op de soort te voorkomen. De aanvang van een soft start dient niet geïnterpreteerd te worden als opzettelijk verstoring en is daarmee geen overtreding van Bal artikel 11.46 1b van de Ow.

Vervolgstappen
Het feit dat op meerdere locaties in de Noordzee zal worden gewerkt en verspreid over een langere periode met verschillende vormen van verstoring en diverse verstoringsoppervlakten, wijzen uit dat significant negatieve effecten voor de bruinvispopulatie in de Noordzee niet kunnen worden uitgesloten. Voor het verstoren van de bruinvis door de werkzaamheden dient een omgevingsvergunning aangevraagd te worden. Aanvullende mitigatie is nodig om significant negatieve effecten op populatieniveau te kunnen uitsluiten (zie Hoofdstuk 6).

Gewone en grijze zeehond
Voorkomen – Gewone zeehond
De gewone zeehond leeft voornamelijk in getijdengebieden waar plekken aanwezig zijn die bij eb droogvallen (Figuur 5-3). Deze plekken zijn vooral te vinden langs zandige kusten en rotskusten, maar ook op met wier bedekte riffen, kiezelsteenstranden, zandplaten en stenen. Ze hebben een sterke voorkeur voor rustige plekken, zonder menselijke aanwezigheid. Tijdens hoog water zwemmen gewone zeehonden naar andere (diepere) delen om te foerageren. Hierdoor kunnen ze ook in het plangebied op open zee voorkomen, hetzij minder frequent dan in de kustzone. Een enkele keer komt een gewone zeehond (tijdelijk) voor bij riviermondingen of zelfs in (zoete) binnenwateren (Zoogdiervereniging, n.d.). Individuen van de gewone zeehond kunnen het plangebied passeren.

Het is bekend dat gewone zeehonden rusten en mogelijk ook jongen krijgen op de strandjes (bij o.a. Edison Baai) in de buurt van de Maasvlakte (Bijlage 1; Hoekstein et al., 2022). Ook de zandplaat Noorderhaaks die vlakbij de haven van Den Helder is gelegen, wordt veel door zeehonden gebruikt om te rusten, pups te zogen en te verharen.



Figuur 5-3. Gemiddelde populatiedistributie van de gewone zeehond op het Nederlands Continentaal Plat in juli op basis van Aarts (2021). Verkregen uit Heinis et al. (2022).

Voorkomen – Grijze zeehond

De grijze zeehond komt voor langs de oostelijke en westelijke kusten van de Atlantische oceaan. De grijze zeehond foerageert op zee, vooral op platvissen. Grijze zeehonden krijgen hun jongen in de periode november tot en met februari op droogblijvende platen of stranden. De pups van grijze zeehond kunnen in tegenstelling tot de pups van gewone zeehond niet direct zwemmen na hun geboorte. De grijze zeehond verhaart in de periode maart-april. Ook in deze periode zijn ze gebonden aan permanent droogliggende platen, stranden en duinen.

Een deel van het plangebied op open zee kan door zeehonden worden gebruikt om te foerageren. Grijze zeehonden kunnen tot ver uit de kust zoeken naar voedsel (Ministerie van Economische Zaken, 2014b). Daarnaast kunnen individuen van de gewone zeehond mogelijk passerend voorkomen in het plangebied. Het is bekend dat gewone zeehonden rusten en mogelijk ook jongen krijgen op de strandjes (bij o.a. Edison Baai) rondom de Tweede Maasvlakte (Bijlage 1; Hoekstein et al., 2022). Ook de zandplaat Noorderhaaks die vlakbij de haven van Den Helder is gelegen, wordt veel door zeehonden gebruikt om te rusten, pups te zogen en te verharen.

Effectbeoordeling

Oppervlakteverlies. Ter plekke van de heilocaties, de putten en het leidingtracé zal de zeebodem vergraven worden en tijdelijk of permanent ongeschikt zijn als leefgebied voor bodembewonende soorten die als prooi voor zeehonden kunnen dienen. In de aanlegfase betreft dit voornamelijk het tijdelijke effect voor de aanleg van de leidingen. Voor de aanleg van de nearshore zeeleiding wordt met behulp van een trencher een gleuf gegraven van maximaal twee m diep, zes m breed aan de bovenkant van de gleuf en twee m breed aan de onderkant van de gleuf. Het gaat om de eerste 70 kilometer vanaf de kruising met de Maasgeul waar de zeeleiding wordt ingegraven in de zeebodem, met een dekking van circa één meter. Na de aanlegfase zal de zeebodem ter plekke van de leidingen en overige tijdelijk aangetaste waterbodem zich weer herstellen. Het gaat om een tijdelijk oppervlakteverlies.

De aanleg van de zeeleiding *op* de zeebodem betreft een permanent oppervlakteverlies. Het permanente effect betreft ter plekke van de constructies circa tien ha op de zeebodem (RHDHV, 2023b). Sommige soorten zullen al vrijwel meteen weer gebruik maken van het verstoorde gebied, herstel van met name langzaam groeiende sessiele soorten kan jaren duren. Voor de zeehond is het vooral van belang dat prooidieren al snel na de aanlegfase weer gebruik kunnen maken van het verstoorde gebied, omdat het mobiele vissoorten betreft. Voor de zeehond zal het verstoorde gebied dus waarschijnlijk al na enkele dagen of weken weer op een vergelijkbare manier als voor de ingreep bruikbaar zijn als foerageergebied. Significant negatieve effecten van oppervlakteverlies zijn uit te sluiten.

Licht. De activiteiten ten behoeve van de aanleg van de aanlegsteigers, de offshore activiteiten (heien, boren, zeeleiding en verbindingsleidingen leggen) en de inzet van schepen voor het onderhoud aan de platforms leiden tot een toename in lichtuitstraling en scheepvaart- en helikopterbewegingen. Lichtverstoring is met name relevant voor zeehonden die zich boven het water bevinden op ligplaatsen. In de Voordelta zijn verschillende ligplaatsen van volwassen zeehonden aanwezig. Zeehonden zijn gevoelig voor verstoring op hun ligplaatsen en in hun foerageergebied. Verstoring leidt in eerste instantie tot een verhoogde alertheid. Langdurige verstoring kan leiden tot een verandering van het gebruik van het leefgebied, of tot het verlaten van het gebied (Reijnders et al., 2000). Over specifieke effecten van licht op rustende zeehonden is weinig bekend. Wel is bekend dat zeehonden over het algemeen erg gevoelig zijn voor (kunstmatige) verlichting. Gelet op de aanwezigheid van een aantal zeehonden op de strandjes van het noordelijke deel van de Voordelta en de hoge lichtemissie op de Maasvlakte, kan er vanuit worden gegaan dat bij de in het gebied aanwezige zeehonden gewenning is opgetreden ten aanzien van de aanwezigheid van kunstlicht. De extra lichtuitstraling door de inzet van constructieschepen in de Voordelta is minimaal in vergelijking met de achtergrondverlichting en bovendien tijdelijk, waardoor verstorende effecten op rustende zeehonden in de buurt van de Maasvlakte kunnen worden uitgesloten.

Rustende of zogende zeehonden op Noorderhaaks kunnen mogelijk verstoord raken door lichtuitstraling van uitvarende schepen die de haven van Den Helder uitvaren en de Noordzeekustzone doorkruisen. Vanuit het havengebied van Den Helder zullen ten behoeve van het Aramis initiatief maximaal 2.064 extra scheepvaartbewegingen plaatsvinden in de aanlegfase in één-twee jaar (maximale toename van 128% t.o.v. huidige scheepvaart Den Helder). De toename in scheepvaart kan leiden tot verstoring van rustende of zogende zeehonden op Noorderhaaks. In een studie van Bouma et al. (2010) bleek echter dat de 41 onderzochte passages van baggerschepen langs Noorderhaaks niet leidden tot gedragsveranderingen van rustende zeehonden. De afstanden tussen de ligplaatsen van de zeehonden en de schepen die werden onderzocht lagen tussen de 600 en 1.200 m, wat vergelijkbaar is met de afstanden tussen de schepen van het Aramis initiatief en de ligplaatsen van de zeehonden op Noorderhaaks. Het wordt daarom niet verwacht dat de zeehonden op Noorderhaaks hun ligplaatsen zullen verlaten als gevolg van de toename in scheepvaartverkeer. Bovendien vinden er in het gebied tussen Den Helder en Texel veel menselijke activiteiten plaats, waardoor de zeehonden waarschijnlijk door gewenning minder gevoelig zijn voor verstoring dan in andere gebieden waar geen of in beperkte mate menselijke activiteiten plaatsvinden. Zeehonden op Noorderhaaks zullen geen hinder ondervinden van lichtuitstraling als gevolg van dit project.

Beweging en optiek. Zeehonden zijn ook gevoelig voor verstoring door beweging van objecten en personen. De aanwezigheid van de zeehonden in de buurt van de drukbevaren routes zijn een indicatie van gewenning waarbij zeehonden ook bij verstoring de rustplekken bij de Tweede Maasvlakte blijven benutten. Door de spreiding van de extra scheepvaartbewegingen over een lange periode en de minimale toename van scheepvaartbewegingen (maximaal 80 in de aanlegfase) ten opzichte van het huidige drukbevaren verkeersbeeld in de haven van Rotterdam kunnen effecten door bewegingen van voorbijgaande schepen worden uitgesloten. Er zal ook geen sprake van optische verstoring van rustende, zogende en foeragerende zeehonden op of nabij Noorderhaaks in de kustzone. Zeehonden zijn door gewenning hoogstwaarschijnlijk minder gevoelig voor verstoring door schepen (zie *Effecten van licht*). Zeehonden zullen geen hinder ondervinden van een toename in scheepvaart- en helikopterbewegingen als gevolg van dit project.

Vertroebeling. Bij het baggeren en trenchen kan vertroebeling optreden. Zeezoogdieren vestigen zich over het algemeen vaker in troebele wateren en veel soorten gebruiken goedontwikkelde sonarsystemen om de omgeving te verkennen (Au et al., 2000). De studie van McConnell et al. (1999) toonde aan dat er geen verschil in foerageergedrag bestond tussen één blinde en verschillende niet-blinde grijze zeehonden in de Noordzee. Deze resultaten wijzen erop dat zicht niet essentieel is voor overleving van zeehonden of de mogelijkheid tot foerageren. Het is dus niet te verwachten dat vertroebeling van het water de zeehonden beïnvloedt in het vangen van hun prooi; ook blinde dieren kunnen zich doorgaans goed in het wild redden (Brasseur, 2007). Indirecte effecten van vertroebeling op zeezoogdieren zijn complex om te definiëren. In de literatuur wordt benoemd dat baggeren over het algemeen resulteert in verminderde biomassa, soortenrijkdom en soortendiversiteit van prooien, afhankelijk van de omgeving en het tijdsverloop van de activiteit. Zeezoogdieren zijn echter in staat om te compenseren voor kleinschalige veranderingen in de aanwezigheid van prooien. Dit doen ze door (tijdelijk) over te gaan op andere prooisoorten, zich te verplaatsen naar alternatieve foerageergebieden of de foerageertijd te verlengen (Todd et al., 2015). Significant negatieve effecten van vertroebeling op de zeehond zijn uitgesloten.

Sedimentatie. De werkzaamheden zorgen voor sedimenten in de waterkolom die vervolgens op de bodem neerslaan en daar een sedimentlaagje vormen. Door de aanleg van de nearshore zeeleiding (tot 70 km vanaf de doorkruising van de Maasgeul) treedt sedimentatie op met een maximale sedimentatie waarde van 0,20 mm aan weerszijden van de leiding (zie Detailrapport zeebodem, RHDHV, 2023a). Ook bij de lozing van boorgruis kan sedimentatie optreden. Op basis van een modelstudie van de lozing van boorgruis van twaalf putten bij platform N05-A (Royal HaskoningDHV, 2020) is een inschatting gemaakt van de verspreiding van het boorgruis op de boorlocatie van de nieuwe putten van het Aramis initiatief. Uit de modelstudie van N05-A bleek dat het meeste sediment van het boorgruis direct zou vallen onder het boorplatform op de zeebodem door de grove korrelgrootte, waarbij een laag van maximaal 23 cm per boring zou ontstaan. Bij de twaalf boringen zou de extra sedimentatie binnen een straal van 105 m rond het platform groter dan 1,5 cm zijn. Daarbuiten zou geen tot een verwaarloosbaar kleine hoeveelheid extra sedimentatie zichtbaar.

De grijze en gewone zeehond eten met name vis, zoals zandspiering en haring. Haring is een mobiele pelagische soort die zich eenvoudig kan verplaatsen bij verstoring. De zandspiering is een rondvis die zowel pelagisch als nabij de bodem voorkomt. De soort paait op zandige bodems, maar ook op fijn grind (tussen 0.35-1.3 mm). Het paaien gebeurt bij voorkeur langs de randen van grote zandbanken en op toppen van kleine zandbanken, met een stroomsnelheid van ongeveer één m/s. De eieren worden in de bodem gelegd (Wright et al., 2000). Paai- en opgroeigebieden kunnen schade ondervinden van bodemberoering en/of sedimentatie. Bij extreme omstandigheden (bijvoorbeeld storm) is de zandspiering echter in staat om zich te verplaatsen of in te graven; de soort zal dus bij een toename van een aantal millimeters sediment geen direct effect ondervinden vanwege zijn mobiliteit (Tulp et al., 2016). Zeezoogdieren zijn bovendien in staat om te compenseren voor kleinschalige veranderingen in de aanwezigheid van prooien. Dit doen ze door (tijdelijk) over te gaan op andere prooisoorten, zich te verplaatsen naar alternatieve foerageergebieden of de foerageertijd te verlengen (Todd et al., 2015). Significant negatieve effecten door sedimentatie zijn uit te sluiten.

Geluid. De beoogde activiteiten (boren, heien, baggeren, trenchen en pijpleidingen leggen) leiden tot een verhoogd geluidsniveau binnen het plangebied. Impulsgeluid kan mogelijk fysieke of fysiologische effecten veroorzaken, bestaande uit tijdelijke- of permanente gehoordrempelverschuiving en in het ergste geval verwondingen. Hoe dichter zeezoogdieren zich bevinden bij de geluidsbron, hoe groter de verstoring zal zijn, waarbij permanente gehoorschade (PTS) het meest ingrijpende effect is, daarna tijdelijke gehoordrempelverschuiving (TTS) en vermijding en gedragsverandering. Fysieke schade zoals PTS en TTS worden niet verwacht door de inzet van een soft start procedure bij het heien die in het standaard werkprotocol wordt opgenomen.

De verstoringsoppervlakten voor zeehonden variëren per activiteit tussen de 54 en 314 km² (zie voor meer details de Passende Beoordeling, RHDHV, 2023b). De percentages van verstoorde zeehonden in Tabel 5-4 geven een indicatie weer van de verstoring, maar zijn niet goed bij elkaar op te tellen. In de praktijk zijn de dichtheden op open zee lager en is het aannemelijk dat individuen meermaals worden verstoord door dezelfde of verschillende activiteiten. Ervan uitgaande dat activiteiten kort na elkaar uitgevoerd gaan worden, zullen zeehonden het gebied voor een langere periode mijden. Aangezien de werkzaamheden één tot twee jaar zullen duren, kan de mijdingsperiode ook oplopen tot een vergelijkbare periode. Dit is het worst-case scenario. Het is namelijk ook mogelijk dat ook hier gewenning optreedt en de effecten veel beperkter zullen uitvallen.

Tabel 5-4. Percentages verstoorde gewone en grijze zeehonden ten gevolge van de voorgenomen activiteiten.

Activiteit		**Gewone zeehonden**		**Grijze zeehonden**	
		Totale Nederlandse populatie	Verstoorde dieren (%)	Totale Nederlandse populatie	Verstoorde dieren (%)
Injectieputten boren	Per put	9.245	1,96	8.038	1,70
	Totaal [1]	9.245	27,38	8.038	23,78
Heien verankeringspalen nieuwe platforms	Per verankeringspaal	9.245	1,43	8.038	1,24
	Totaal [2]	9.245	11,46	8.038	9,95
Heien conductorpijpen nieuwe putten	Per put	9.245	0,34	8.038	0,29
	Totaal [1]	9.245	4,71	8.038	4,09
Heien centrale eindpunt	-	9.245	1,43	8.038	1,24

[1]: Platform K14-FA; 4-6 nieuwe injectieputten. Platform L10-zuid; 4-6 nieuwe injectieputten. Platform L4-A; 2 nieuwe injectieputten (L4-A3 en L4-A4). Worst-case; 12-14 nieuwe injectieputten.
[2]: In totaal 2 nieuwe platforms; (1) L10-zuid en (2) K14-FA.

Het plangebied op open zee kan door zeehonden gebruikt worden om te foerageren. Grijze zeehonden kunnen tot ver uit de kust zoeken naar voedsel (Ministerie van Economische Zaken, 2014a). Het foerageergebied neemt door de verstoring daarom mogelijk af. Er zijn anderzijds voldoende uitwijkmogelijkheden voor gewone en grijze zeehonden om te foerageren. Daarbij zijn de nabijgelegen gebieden Noordzeekustzone en de Waddenzee belangrijkere gebieden voor de gewone zeehond en grijze zeehond dan de open zee (Aarts, 2021; Aarts et al., 2016, Figuur 5-3), anders dan voor bruinvissen. Door de activiteiten wordt er daarom geen essentieel foerageergebied van de grijze of gewone zeehond aangetast op zee.

Op basis van een geluidscontour van de voorgenomen hei-activiteiten is vastgesteld dat er gedurende de uitvoering geen overlap is met de rustplaatsen van zeehonden in de Voordelta of andere gebieden op de Noordzee. Wel kunnen zeehonden die rusten, pups zogen of foerageren in de kustzone mogelijk verstoord raken door het geluid van de schepen die worden ingezet voor het Aramis initiatief. Een deel van de schepen van het Aramis initiatief zal via de scheepvaartroute de Noordzeekustzone doorkruisen (maximaal 2.064 extra schepen, toename van maximaal 128% t.o.v. huidige verkeersbeeld scheepvaart), waardoor een direct effect van geluid kan optreden. De zandplaat Noorderhaaks wordt veel door zeehonden gebruikt om te rusten, pups te zogen en te verharen. Daarbij is het belangrijk dat ze in de buurt van de plaat kunnen foerageren. De wateren nabij Noorderhaaks zijn essentieel foerageergebied.

Alhoewel het gaat om een drukke scheepvaartroute waar de schepen van het Aramis initiatief doorheen zullen varen, is de mogelijke toename in onderwatergeluid heel groot. Dit betekent dat extra geluidsverstoring kan optreden en de periode dat ze kunnen foerageren nabij Noorderhaaks wordt verkleind. Essentieel foerageergebied gaat hiermee tijdelijk verloren. Daarbij zal de toename in onderwatergeluid door de inzet van schepen in de aanlegfase voor een langere periode van één-twee jaar aanwezig zijn, wat betekent dat de zeehonden voor een langere periode worden verstoord. Ook in de gebruiksfase worden extra schepen ingezet, waardoor de werkelijke periode waarin geluidsverstoring optreedt langer is dan één-twee jaar.

Verstoring van de rust- en voortplantingsplaats van de gewone en grijze zeehond op en nabij Noorderhaaks is niet uit te sluiten. Dit is een overtreding van artikel 11.54 1b van het Bal.

Vervolgstappen
Voor het verstoren van de rust- en voortplantingsplaats van de gewone en grijze zeehond door de inzet van extra schepen dient een omgevingsvergunning aangevraagd te worden. Aanvullende mitigatie is nodig om significant negatieve effecten op populatieniveau te kunnen uitsluiten (zie Hoofdstuk 6).

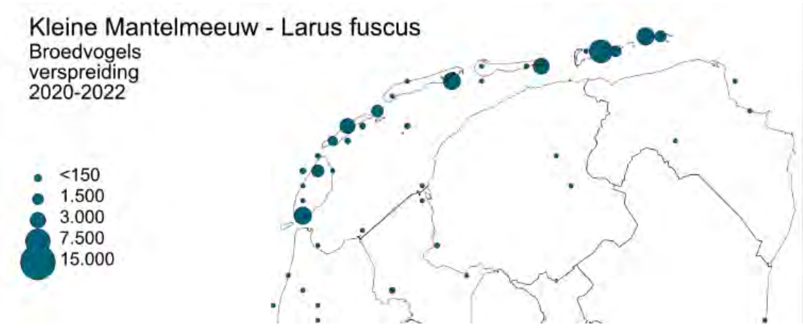
5.2.3 Vogels

Voorkomen
Vogels kunnen op verschillende manieren gebruikmaken van het plangebied: als broedlocatie, plek om te foerageren of om te rusten.

Voor algemeen voorkomende vogels als de drieteenmeeuw (*Rissa tridactyla*) geldt bijvoorbeeld dat ze op installaties of constructies kunnen broeden (Camphuysen & Leopold, 2007; Christensen-Dalsgaard et al., 2019). Drieteenmeeuwen nestelen al vanaf het jaar 2000 op enkele olieplatforms in de Zuidelijke Noordzee (Camphuysen & De Vreeze, 2005). Het broedseizoen valt voor de drieteenmeeuw doorgaans tussen midden-mei en augustus. Uit de voorbereidende milieusurvey van Fugro blijkt dat in de periode van 11 juli 2022 t/m 24 januari 2023 in totaal 388 drieteenmeeuwen zijn waargenomen op het Aramis traject (doorkruising Maasgeul, tracé zeeleiding, putten, platforms) op 249 verschillende telmomenten (Figuur 5-7). Drieteenmeeuwen zijn voornamelijk waargenomen ter hoogte van het tracé van de nearshore zeeleiding. Meer noordelijk – ter hoogte van de (beoogde) locatie van de bestaande en nieuw-te-realiseren platforms – zijn drieteenmeeuwen in kleinere aantallen waargenomen (maximaal zeven per telmoment). Drieteenmeeuwen kunnen broedend voorkomen op het bestaande platform L4-A.

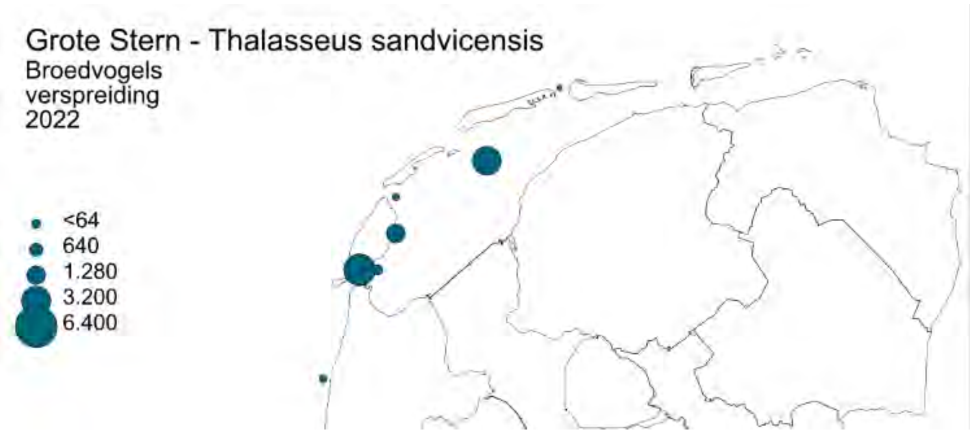
In de periode van 11 juli 2022 t/m 24 januari 2023 is de zeekoet (*Uria aalge*) in totaal 560 keer waargenomen in het plangebied en de daarvan in de buurt gelegen gebieden (Fugro, 2023). In de nabijheid is een vaste rustplaats aanwezig van de zeekoet, waar de vogels ronddobberen op het water (Friese Front). Kenmerkend voor de zeekoet is het gebruik van het Friese Front door ruiende mannetjes met hun jongen in de nazomer. De afstand tot de kust, en daarmee de relatieve rust, in combinatie met het hoge voedselaanbod maakt het Friese Front een aantrekkelijk rust- en foerageergebied voor de zeekoet. De zeekoet kan voorkomen in het plangebied en omliggende gebieden op zee.

De kleine mantelmeeuw (*Larus fuscus*) broedt in alle landen rondom de Noordzee. De kleine mantelmeeuw is een koloniebroeder. De grootste kolonies in Nederland bevinden zich in het Deltagebied en de Waddeneilanden. Op ieder Waddeneiland wordt gebroed, zo ook op de zuidelijke punt van Texel, in de buurt van het plangebied (Sovon, n.d.-a) (Figuur 5-4). De nesten kunnen zich in verschillende habitats bevinden zoals open duin, schorren/kwelders, industriegebieden, opspuitterreinen en eilandjes in afgesloten zeearmen (Ministerie van LNV, 2008b). De kleine mantelmeeuw foerageert op zee op vis, en richt zich voornamelijk op visafval achter boten. Het is bekend dat ze foerageren tot op vele tientallen kilometers afstand van de broedkolonie, en zelfs afstanden tot 200 km zijn ook bekend (Ministerie van LNV, 2008b). Tussen maart en mei trekken de kleine mantelmeeuwen richting de Nederlandse broedgebieden, de broedtijd start rond eind april. (Vogelbescherming, n.d.-b). De kleine mantelmeeuw is een zomergast op de Noordzee, tijdens de winter is deze soort minimaal aanwezig. In augustus komt de kleine mantelmeeuw voor op bijna het hele NCP, met uitzondering van het meest noordelijke gebied (Fijn et al., 2022). De broedvogel kleine mantelmeeuw kan foeragerend voorkomen in het plangebied op zee. Ook broedt de kleine mantelmeeuw in de kustzone waar in de buurt schepen uitvaren vanuit de haven van Den Helder.



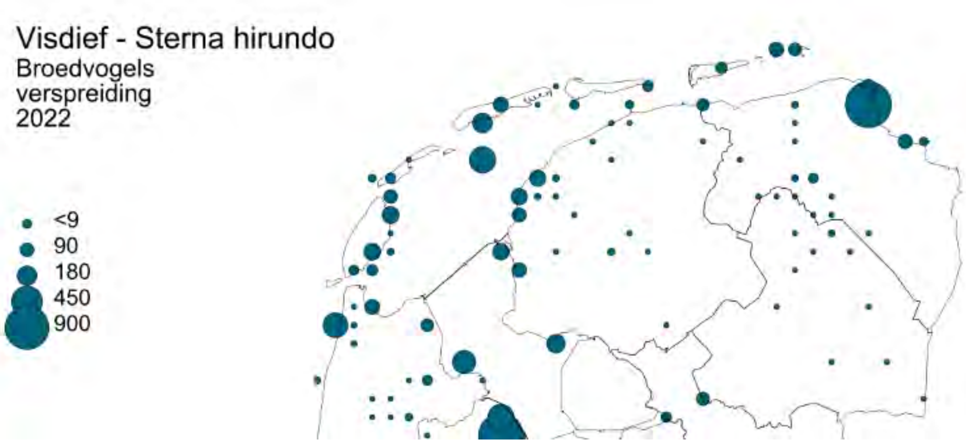
Figuur 5-4. Verspreiding van de kleine mantelmeeuw als broedvogel op de Waddeneilanden in 2020-2020 (www.sovon.nl).

De grote stern (*Thalasseus sandvicensis*) is eveneens een koloniebroeder in alle landen rondom de Noordzee. De omvang van de kolonies is groot, er komen slechts een klein aantal van deze kolonies voor in Nederland. De broedkolonies bevinden zich voornamelijk in het Deltagebied en op de Waddeneilanden. In het Waddengebied wordt voornamelijk gebroed op Texel, een grote kolonie bevindt zich op de zuidelijke punt (Figuur 5-5) (Fijn et al., 2021). De broedkolonies bevinden zich voornamelijk op kale of schaarsbegroeide eilanden. Vaak bevat het broedgebied randbegroeiing, dit gebruiken de kuikens als schuilplaats. De broed start rond eind april en begin mei. Er wordt gefoerageerd in de kustzone van de Noordzee en in geulen in de Waddenzee. De grote stern voedt zich voornamelijk met vis, bij voorkeur op een afstand tussen 15 – 40 km van de nestplaats (Ministerie van LNV, 2008a). Er wordt echter ook op ruime afstand van de broedkolonie vis gevangen; soms ver op zee (Vogelbescherming, n.d.-c). In het rapport van Fijn et al. (2022) wordt gerapporteerd dat bij monitoringsvluchten tot ruim 100 km uit de kust trekkende grote sterns werden waargenomen op het NCP, maar daarbuiten vrijwel niet meer. De broedvogel grote stern kan foeragerend voorkomen in het plangebied op zee. Ook broedt de grote stern in de kustzone waar in de buurt schepen uitvaren vanuit de haven van Den Helder.



Figuur 5-5. Verspreiding van de broedvogel grote stern in het Waddengebied in 2022 (www.sovon.nl).

De visdief (*Sterna hirundo*) is ook een koloniebroeder. Het broedhabitat omvat rustige, schaars begroeide plekken nabij visrijke wateren langs de kust. Ook langs de binnenwateren wordt door de visdief gebroed. Bij voorkeur wordt op plaatsen gebroed die niet toegankelijk zijn voor grondpredatoren (Vogelbescherming, n.d.-a). Er bevinden zich verschillende broedkolonies op de Waddeneilanden, zo ook op Texel nabij het plangebied (Sovon, n.d.-b) (Figuur 5-6). De visdief eet kleine vissen, deze worden meestal gevangen op 5-10 km afstand van de kolonie. Soms zoekt de visdief zijn prooi op meer dan 30 km van de broedplaats (Ministerie van LNV, 2008c). De visdief broedt in Nederland meestal vanaf mei tot begin juni. Vanaf begin juli vertrekken groepen visdief richting het zuiden, ze volgen hierbij graag de kustroute (Vogelbescherming, n.d.-a). De visdief is het talrijkst in de kustzone, maar is ook aanwezig op andere delen van het NCP. De visdief trekt in augustus weg van de Noordzee. Er werden grote getallen visdief waargenomen ten noordwesten van de Waddeneilanden. De afstand tot de kust was hierbij meer dan 100 km (Fijn et al., 2022). De broedvogel visdief kan foeragerend voorkomen in het plangebied op zee. Ook broedt de visdief in de kustzone waar in de buurt schepen uitvaren vanuit de haven van Den Helder.



Figuur 5-6. Verspreiding van de broedvogels visdief in het Waddengebied in 2022 (www.sovon.nl).

Effectbeoordeling

Licht en optische verstoring. De schepen die worden ingezet bij de aanleg van de nearshore zeeleiding en de aanleg van het tunnelwerk (microtunneling of direct piping) stralen licht uit. Ook het uitvaren van schepen vanuit de haven van Den Helder kan effect hebben op de broedvogels kleine mantelmeeuw, grote stern en visdief. Verstoring door licht en beweging kan leiden tot gedragsverandering van vogels. Lichtuitstraling en beweging treden meestal gelijktijdig op en zodoende kunnen deze doorgaans als één verstoringsbron worden beschouwd. Om deze reden worden de effecten van licht en beweging door de inzet van schepen als één verstoringsbron beoordeeld voor vogels.

Fliessbach et al. (2019) deden onderzoek naar de response van 26 zeevogels in de Duitse Noordzee en Baltische Zee op verstoring door schepen. Op basis van de indicatoren ‘soorten schuwheid’, ‘energiekosten voor vluchten’, ‘potentieel voor uitwijken’ werd als onderdeel van het onderzoek een Disturbance Vulnerability Index (Verstoringsgevoeligheidsindex; DVI) berekend. Een score dichtbij 0 betekent dat de vogel niet gevoelig is voor verstoring door schepen, terwijl een score van 100 een grote gevoeligheid weergeeft. De drieteenmeeuw (DVI-score: 9.3), kleine mantelmeeuw (DVI-score: 6.7), visdief (DVI-score: 3.9), grote stern (DVI-score: 6.7) en zeekoet (DVI-score: 19.5) zijn niet erg gevoelig voor verstoring door scheepvaart. Er is geen sprake van een effect op de overleving of voortplanting van deze vogelsoorten als gevolg van de projectgerelateerde scheepvaart.

De drieteenmeeuw kan daarnaast worden verstoord door beweging en licht als gevolg van de werkzaamheden aan platform L4-A. Er is weinig informatie beschikbaar over de mate waarin een drieteenmeeuw die op een platform broedt verstoring ervaart. Het is wel bekend dat de drieteenmeeuwen op platforms waarschijnlijk nestlocaties kiezen met minder verstoring door mensen (Thompson, 2021). In relatie tot recreatie wordt de verstoringsgevoeligheid van de drieteenmeeuw beschreven als klasse ‘middelgroot’ met een geschatte vluchtafstand van 250 m. Na verstoring is de drieteenmeeuw redelijk snel terug op zijn oorspronkelijke verblijfplaats (Krijgsveld et al., 2022). Omdat de drieteenmeeuw die broedt op een platform gewend is aan lichtuitstraling en beweging op platforms en de soort redelijk snel terugkeert na verstoring, zijn significant negatieve effecten van licht en beweging op de drieteenmeeuw uit te sluiten.

Vertroebeling en sedimentatie. Vertroebeling en sedimentatie kan ontstaan door de lozing van boorgruis en bagger- en trenchactiviteiten.

Uit onderzoek naar Texelse kleine mantelmeeuwen bleek dat het dieet van de kleine mantelmeeuw een sterke binding had met commerciële visserij, natuurlijke prooidieren op afstand van vissersschepen werden vermoedelijk vooral binnen de 20 meter dieptelijn opgepikt van het wateroppervlak (Camphuysen et al., 2008). Omdat de kleine mantelmeeuw voornamelijk vis en zwemkrabben oppikt van het wateroppervlak, zal vertroebeling en sedimentatie in de waterkolom geen grote rol spelen in het foerageersucces. Significant negatieve indirecte en directe effecten van sedimentatie en vertroebeling op de kleine mantelmeeuw zijn uitgesloten.

Duikende vogels zoals de grote stern, visdief en zeekoet daarentegen kunnen duiken tot dieptes waar vertroebeling voorkomt. Wanneer deze soorten duiken in water waar de troebele pluim aanwezig is, kan dit leiden tot een verminderd vangsucces. Uit een studie van grote sterns die foerageren in de broedtijd nabij de kolonie van De Petten op Texel bleek dat bij de optimale zichtdiepte van ongeveer 1,75 meter de kans op vangen van prooivis ongeveer 60% is. Wanneer het zicht vermindert naar 0,4 meter is deze kans ongeveer 30% (Baptist & Leopold, 2007). In de Westerschelde bleek uit onderzoek dat de visdief een significant hoger vis- en foerageersucces heeft in water met een doorzicht van meer dan 180 cm (Brenninkmeijer et al., 2002). Zicht is hiermee een belangrijk zintuig voor de grote stern en visdief in het vangen van prooien. Door vertroebeling kan het foerageersucces van de broedvogels afnemen.

Zeekoeten eten vooral rondvis, maar ook incidenteel platvis, inktvis, borstelwormen en kleine kreeftachtigen, die ze duikend vangen (Ministerie van LNV, 2008d). Daardoor kan de zeekoet ook een negatief effect ervaren door vertroebeling en sedimentatie. Het verstoringsoppervlak door de lozing van boorgruis bij de putten van platforms L4-A en L10-zuid is echter dermate beperkt in oppervlakte (in een straal van 150 m om de put, 70.685 m^2 verstoringsoppervlak per put) dat er genoeg areaal overblijft voor de duikende vogels om te foerageren. Dit betekent dat minder dan 0,1% van het NCP tijdelijk wordt beïnvloed als gevolg van sedimentatie. De verstoring door vertroebeling is per locatie bovendien van korte duur. Significant negatieve indirecte en directe effecten van sedimentatie en vertroebeling op de broedvogels zijn uitgesloten.

Geluid. Tijdens de verschillende fases van de voorgenomen activiteit wordt geluid geproduceerd door de inzet van schepen en helikopters, het heien van conductors en het boren van putten.

Helikopters zorgen van alle soorten vliegverkeer voor de grootste mate van verstoring van vogels, dit heeft te maken met de grote hoeveelheid lawaai die ze maken, en omdat ze relatief laag vliegen en relatief langzaam vliegen (Krijgsveld et al., 2008). Recentelijk werd de akoestische ecologie van de zeekoet onderzocht, hierbij is gevonden dat de frequenties van het gehoor en de vocalisatie van de zeekoet overlappen met veel antropogene geluidsbronnen, wat aangeeft dat de soort gevoelig is voor verstoring door een scala aan geluidstypen (Smith et al., 2023). Deze overlap omvat, in verschillende mate; geluidsbronnen in de lucht zoals verkeerslawaai, menselijke spraak en vliegtuigen die overvliegen.

Hoe snel de geluid producerende verstoringsbron zich verplaatst en de voorspelbaarheid van de route is van invloed op de mate van verstoring. Omdat bijvoorbeeld een vliegtuig het gebied sneller weer verlaten heeft, reageren vogels weliswaar eerder op een vliegtuig dan op een schip, maar is de verstoring in het algemeen van kortere duur (Krijgsveld et al., 2008). Wanneer het geluid een bepaalde mate van voorspelbaarheid heeft en de vogels het niet als een bedreiging ervaren, dan is het te verwachten dat er gewenning optreedt. Zolang helikopters en schepen vooral gebruik maken van vaste vlieg- en vaarroutes, worden er daarom geen significant negatieve effecten van helikopter- en scheepvaartgeluid op vogels verwacht.

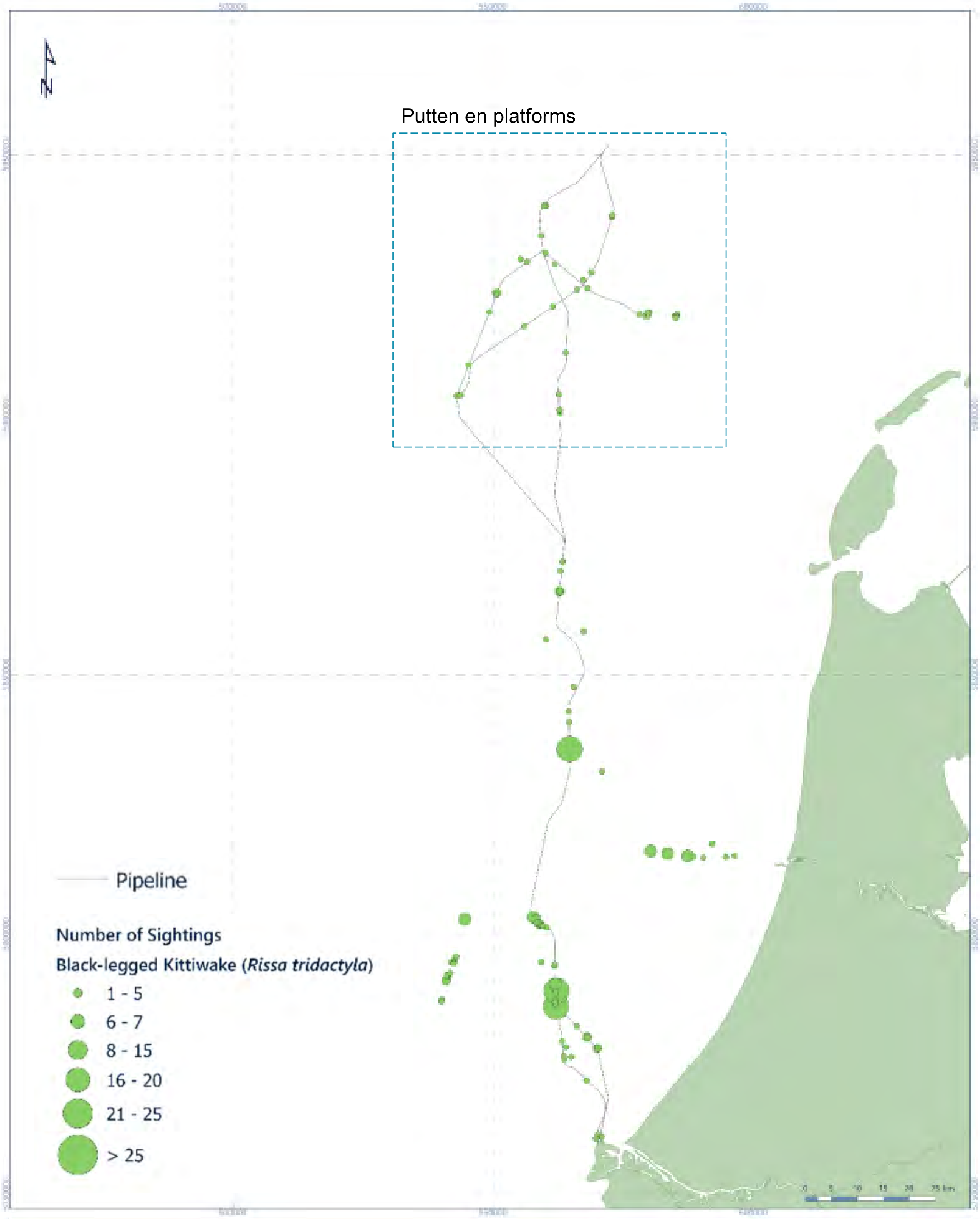
Het heien van de conductors van de putten, het boren van de putten en het heien van de verankeringspalen van de platforms leidt tot impulsief onderwatergeluid. De zeekoet is in de ruiperiode (juli-augustus) gevoelig voor dit type verstoring, omdat de soort dan niet kan vliegen en minder mobiel is. Met name de toename in impulsief onderwatergeluid door heiwerkzaamheden kan verstorende effecten hebben op deze duikende soort (Anderson Hansen et al., 2020). Het rust- en foerageergebied van de zeekoet is echter groot genoeg voor de zeekoet om te zwemmen naar alternatief gebied (oppervlakte Friese Front; circa 2.880 km^2). Bovendien is bekend van de zeekoet dat hij platforms vermijdt, wat betekent dat er geen grote groepen zeekoeten in de buurt van de platforms aanwezig zullen zijn. De enkele zeekoeten die wel voorkomen binnen de verstoringscontouren van de heiwerkzaamheden, kunnen tijdig wegzwemmen naar alternatief gebied dankzij de inzet van een soft start bij de heiwerkzaamheden. De jongen van de zeekoet zijn eveneens in staat om weg te zwemmen van de verstoringsbron. Ook de broedvogels kleine mantelmeeuw, visdief en grote stern kunnen tijdens foerageertrips op open zee uitwijken naar alternatief foerageergebied bij verstoring door hei- en boorwerkzaamheden. De overleving en voortplanting van de zeekoet, kleine mantelmeeuw, visdief en grote stern komen niet in gevaar door de hei- en boorwerkzaamheden. Er is geen sprake van overtreding van de verbodsbepalingen.

Platform L4-A zal daarnaast worden aangepast zodat het platform en bijbehorende putten geschikt zijn voor CO_2-opslag. Bij de werkzaamheden aan het platform L4-A komt machinegeluid vrij. Wanneer werkzaamheden bij het bestaande platform L4-A worden uitgevoerd in het broedseizoen worden mogelijk nesten van de drieteenmeeuw vernietigd of beschadigd die op het platform aanwezig zijn. Wanneer broedende vogels daardoor voortijdig het nest verlaten, geldt dit als het opzettelijk vernietigen of beschadigen van nesten en eieren van vogels.

Dit is een overtreding van Bal artikel 11.37 1a, 1b en 1d van de Ow. Door het nemen van voorzorgsmaatregelen kan voorkomen worden dat negatieve effecten op vogels optreden.

Vervolgstappen

Negatieve effecten op de broedvogel drieteenmeeuw moeten voorkomen worden gedurende de broedperiode (tussen midden-mei en augustus). De te nemen maatregelen dienen uitgewerkt te worden in een op het werk toegespitst ecologisch werkprotocol. Een voorzet voor de noodzakelijke voorzorgsmaatregelen is beschreven in Hoofdstuk 6.



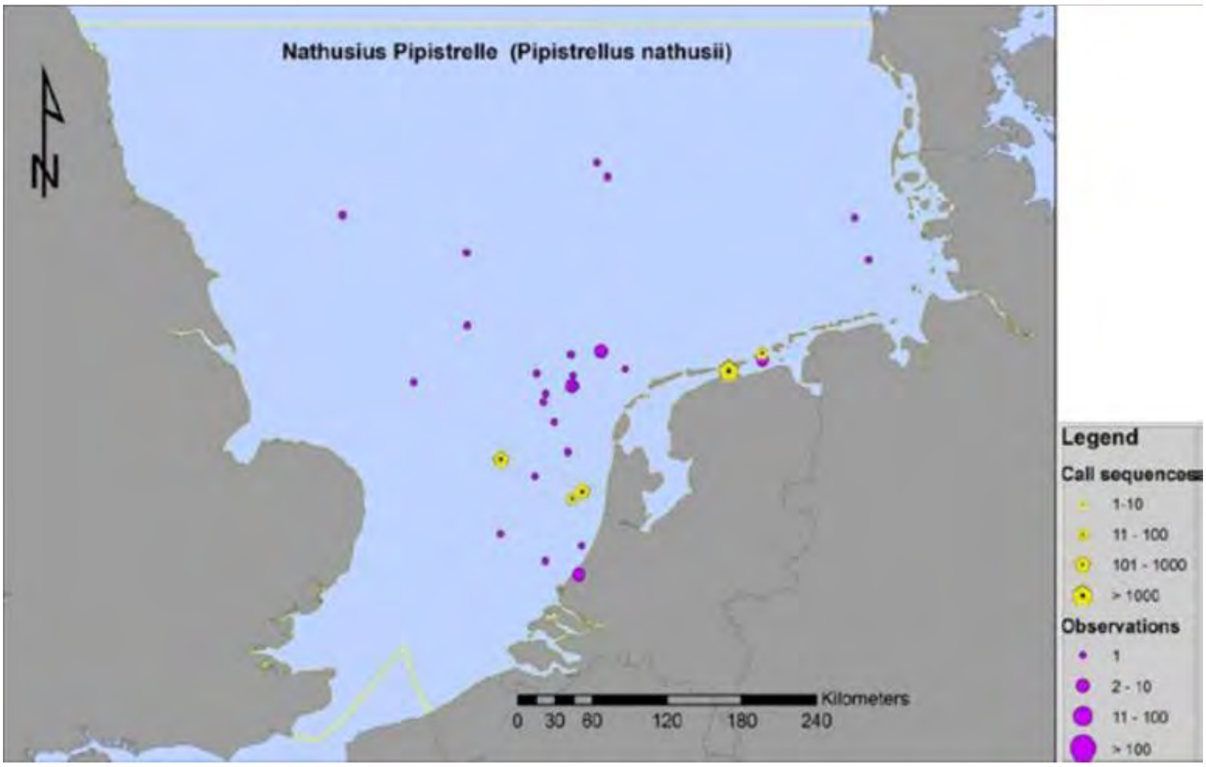
Figuur 5-7. Verspreiding van de drieteenmeeuw in het plangebied (Fugro, 2023).

5.2.4 Vleermuizen

Voorkomen
In de kuststreek komen diverse vleermuissoorten voor, waaronder ruige en gewone dwergvleermuis (*Pipistrellus nathusii en Pipistrellus pipistrellus*), rosse vleermuis (*Nyctalus noctula*), watervleermuis (*Myotis daubentonii*) en meervleermuis (*Myotis dasycneme*) (Figuur 5-8). Vleermuizen hebben hun verblijfplaatsen op land en foerageren daar ook (Lagerveld et al., 2022). De voornaamste dagelijkse vliegbewegingen (los van migratie) vinden dan ook plaats boven land. Hierdoor worden verblijfplaatsen in het plangebied (zee-deel) op voorhand uitgesloten.

Van grofweg maart tot en met november maken vleermuizen vanuit hun verblijfplaatsen foerageertochten. In de winterperiode gaan ze in winterslaap en foerageren ze nagenoeg niet. De maximale foerageerafstand vanaf de kust boven zee van de watervleermuis, rosse vleermuis en meervleermuis ligt doorgaans onder de tien km (RVO, 2014b, 2014a), alhoewel voor rosse vleermuis ook uitschieters tot 18 km zijn waargenomen (Lagerveld & Mostert, 2023). Het voorkomen van vleermuizen binnen het plangebied (op 35 km uit de kust) tijdens foerageertochten vanaf vaste verblijfplekken op land is daarom eveneens uitgesloten.

De migrerende rosse vleermuis en ruige dwergvleermuis trekken in de herfst naar plaatsen met een zacht zeeklimaat (Rydell et al., 2010). Van met name de ruige dwergvleermuis is bekend dat individuen van deze soort in het voor- en najaar van Noord-Holland over de Noordzee naar Groot-Brittannië trekt (Boshamer & Bekker, 2008; Fleming et al., 2003). De najaarstrek lijkt volgens Lagerveld et al. (2019) iets sterker te zijn dan de voorjaarstrek. Het is onduidelijk of de vleermuizen alleen ’s nachts trekken of dat zij ook bij daglicht over de Noordzee migreren. In Lagerveld, Wilkes, et al. (2023) is geobserveerd dat trekkende vleermuizen de overtocht vaak niet in één nacht kunnen maken en de dag spenderen op offshore structuren. Er bestaan momenteel nog veel kennisleemtes over de populatiegrootte, het gedrag en de migratie van vleermuizen over de Noordzee. Deze staan gepland om in het meerjarenprogramma van WOZEP 2024-2030 ingevuld te worden. Op basis van de huidige literatuur is het onduidelijk in hoeverre ruige dwergvleermuizen en rosse vleermuizen vaste trekroutes volgen.



Figuur 5-8. De verspreiding van de ruige dwergvleermuis (Pipistrellus nathusii) (Rijkswaterstaat, 2015).

Effectbeoordeling
Het plaatsen van de nieuwe platforms L10-zuid en K14-FA en de inzet van extra schepen zullen leiden tot een toename in lichtuitstraling. Vleermuizen migreren en foerageren meestal in de nacht (Lagerveld, Geelhoed, et al., 2023) en zijn gevoelig voor lichtuitstraling (Voigt et al., 2017, 2018). Van migrerende vleermuizen, zoals van de van de genera *Pipistrellus, Nyctalus* and *Eptesicus,* is bekend dat zij worden aangetrokken door offshore structuren (e.g., platforms en windturbines) vanwege het hoge aantal insecten dat wordt aangetrokken tot het licht (Ahlén et al., 2009; Lagerveld, Geelhoed, et al., 2023). Of dit echter al honderden constructies met verlichting ook van toepassing is op migrerende vleermuizen die bij deze structuren verwacht kunnen worden is onbekend. De nieuwe inrichting kan daardoor potentieel leiden tot verstoring van vliegbeweging. Er zijn echter al honderden constructies met verlichting op de Noordzee (platforms, boeien, windturbines, schepen, etc.) en van een effect daarvan op migratie is vooralsnog geen aanwijzing. De extra platforms en schepen kunnen worden beschouwd als een kleine toename in lichtverstoring ten opzichte van de achtergrondverstoring. Het is daarmee onwaarschijnlijk dat de nieuwe structuren tot een relevante aantrekking van vleermuizen zal leiden en daardoor hinder zou kunnen veroorzaken.

Het voornemen leidt niet tot het opzettelijk verstoren van rosse vleermuizen en ruige dwergvleermuizen. Er is geen sprake van overtreding van de verbodsbepalingen van de Ow.

5.2.5. Samenvatting voorkomende beschermde soortgroepen (zee-deel)

Op basis van de uitkomsten van het onderzoek, is het voorkomen van de in het onderstaande overzicht opgenomen soorten te verwachten of niet uitgesloten (Tabel 5-5). Uit de beschrijving van het voorkomen van beschermde soorten blijkt dat in het plangebied en in de nabijheid van het plangebied de volgende soortgroepen voorkomen of voor kunnen komen: beschermde zeezoogdieren, vleermuizen, broedvogels en vissen. Er is beoordeeld of en zo ja op welke wijze de projectuitvoering kan leiden tot negatieve effecten.

Tabel 5-5. Overzicht van de te verwachten beschermde soorten (zee).

Soortgroep	Aanwezig	Effectbeoordeling – negatieve effecten?	Vervolgstappen
Zeezoogdieren	Bruinvis.	Heiwerkzaamheden en het daarbij gebruik van ADDs leidt tot een overtreding van de verbodsbepaling (artikel 11.46 1b).	Voor de bruinvis dient een Omgevingsvergunning te worden aangevraagd op basis van artikel 11.46 1b van het Bal. Voor de gewone zeehond en grijze zeehond dient een Omgevingsvergunning te worden aangevraagd op basis van artikel 11.54 1b van het Bal. In de aanvraag van de omgevingsvergunning dient een activiteitenplan te worden opgesteld met daarin aanvullende mitigatie.
	Gewone zeehond, grijze zeehond.	De toename in scheepsactiviteit door het Aramis initiatief nabij essentieel foerageergebied Noorderhaaks voor zeehonden leidt tot een overtreding van de verbodsbepaling (artikel 11.54 1b).	
Vissen	Houting en steur.	Er worden geen verbodsbepalingen overtreden. Een omgevingsvergunning in het kader van de Ow is niet nodig.	Geen verdere vervolgstappen.

Vogels	Broedvogelsoorten op zee (drieteenmeeuw, grote stern, visdief en kleine mantelmeeuw).	Er worden geen verbodsbepalingen overtreden. Een omgevingsvergunning in het kader van de Ow is niet nodig.	Geen verdere vervolgstappen, mits er tijdens het broedseizoen niet aan een platform wordt gewerkt waar drieteenmeeuwen broeden.
Vleermuizen	Rosse vleermuis en ruige dwergvleermuis.	Er worden geen verbodsbepalingen overtreden. Een omgevingsvergunning in het kader van de Ow is niet nodig.	Geen verdere vervolgstappen.

6. Voorzorgsmaatregelen en mitigerende maatregelen

Onderstaande zijn de voorzorgs- en mitigerende maatregelen voor de voorkomende soorten uitgewerkt.

6.1 Land-deel

Op basis van de uitkomsten van het onderzoek, is het voorkomen van de volgende beschermde soorten te verwachten: glad biggenkruid, algemeen voorkomende beschermde zoogdieren (konijn en vos), vleermuizen, broedvogels en de rugstreeppad. Ten aanzien van vleermuizen zijn negatieve effecten op voorhand uitgesloten. Voor de overige soorten/soortgroepen geldt dat niet.

Glad biggenkruid en de rugstreeppad vallen onder het Managementplan beschermde soorten van het havenbedrijf. Om te kunnen voldoen aan gebiedsontheffing van het havenbedrijf, dient gewerkt te worden conform de bijbehorende werkprotocollen. Indien aan alle eisen uit de werkprotocollen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk.

Voor algemeen voorkomende beschermde zoogdieren en broedvogels geldt dat ze niet vallen onder het Managementplan beschermde soorten, maar dat overtreding van de Ow dient te worden voorkomen door het nemen van voorzorgsmaatregelen. Onderstaande zijn de noodzakelijke maatregelen toegelicht.

Deze voorzorgsmaatregelen dienen samen met de maatregelen uit het Managementplan ten aanzien van glad biggenkruid en de rugstreeppad opgenomen te worden in een project specifiek ecologisch werkprotocol. De werkzaamheden kunnen pas worden uitgevoerd na goedkeuring van het havenbedrijf en dienen plaats te vinden onder begeleiding van een erkend ecoloog.

Vaatplanten
De werkzaamheden kunnen mogelijk leiden tot vernietiging van aanwezige standplaatsen van beschermde vaatplanten, specifiek gaat het om glad biggenkruid. Dit is een overtreding van de verbodsbepalingen van de Ow. Om aan te sluiten op de gebiedsontheffing van het havenbedrijf, dienen de werkzaamheden te worden uitgevoerd volgens de werkprotocollen zoals vastgelegd in het Managementplan van het havenbedrijf. De bijbehorende noodzakelijke maatregelen zijn:

- Groeiplaatsen worden buiten de werkzaamheden gehouden en zo min mogelijk betreden.
- Rond de periferie van de groeiplaats moet bij graafwerkzaamheden een beschermingszone met een straal van tenminste 5 meter worden ingesteld waar niet wordt gewerkt. Deze maatregel is voor de duidelijkheid niet van toepassing bij het uitvoeren van het reguliere periodieke maaibeheer buiten de kwetsbare periode.
- Men dient ervoor te zorgen dat de groeiplaats voldoende zonlicht kan blijven ontvangen. Toenemende beschaduwing door het planten van bomen of door andere oorzaken moet worden tegengegaan.
- Onder begeleiding van een deskundige – wanneer werkzaamheden plaatsvinden binnen de groeiplaatsen van de beschermde soort.
- Aanwezige groeiplaatsen worden aangegeven op kaartmateriaal welke te allen tijde op de werklocatie aanwezig dient te zijn.
- Bij gebruik van zwaar materieel moeten rijplaten worden gebruikt om te voorkomen dat de bovenste zode kapot wordt gereden en een voedselrijke en voor veel beschermde (en overige) soorten ongeschikte bodem achterblijft.
- Indien een (deel van een) terrein met glad biggenkruid zal verdwijnen, zal een deskundig ecoloog beoordelen of een toplaag met glad biggenkruid moet worden verplaatst naar een nieuwe plek in de nabije omgeving. Het is afhankelijk van de omgeving, of deze maatregel nodig is, of niet. Een deskundig ecoloog moet dit beoordelen en de details zoals dikte van de af te graven toplaag bepalen.
- In depot zetten van een toplaag met glad biggenkruid mag ten hoogste 3 maanden duren, maar bij voorkeur korter. Een deskundig ecoloog zal hierbij betrokken moeten zijn om randvoorwaarden te bepalen.
- Een ecoloog beoordeelt jaarlijks of de hoeveelheid te verdwijnen leefgebied van glad biggenkruid niet in strijd komt met de lokale gunstige staat van instandhouding. Wanneer via de Havenscan

wordt gesignaleerd dat de lokale gunstige staat van instandhouding van glad biggenkruid in het geding komt, kan niet meer van de gebiedsontheffing gebruik gemaakt worden voor wat betreft ruimtelijke ontwikkeling.
- Na voltooiing van het werk wordt er niet met gras ingezaaid.
- HbR zal de omliggende openbare ruimte waar HbR het beheer over voert, dusdanig inrichten en beheren, dat ruim voldoende areaal een gunstig milieu heeft voor glad biggenkruid[10].

Om te kunnen voldoen aan gebiedsontheffing van het havenbedrijf, dient voorafgaand aan de werkzaamheden het plangebied nader onderzocht te worden op het voorkomen van groeiplaatsen van glad biggenkruid. Het is noodzakelijk om dit in het juiste seizoen te doen, wanneer deze bloeien. Glad biggenkruid bloeit van juni tot oktober en is dan goed te onderscheiden van verwante soorten die ook in het gebied voor kunnen komen. Vanuit de bevindingen van dit aanvullende onderzoek kunnen noodzakelijke vervolgstappen worden genomen, zoals mogelijk het inrichten van compenserende groeilocaties om de gunstige staat van instandhouding van de soort te kunnen borgen. Als aan alle eisen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk.

Grondgebonden (land)zoogdieren
Het voorkomen van de nationaal beschermde soorten konijn en vos is niet uitgesloten. Door de werkzaamheden kunnen negatieve effecten optreden, welke leiden tot een overtreding van de verbodsbepalingen. De minister van LNV heeft konijn en vos vrijgesteld van ontheffingsplicht bij ruimtelijke ingrepen (AMvB RN art 3.31), waardoor het aanvragen van een omgevingsvergunning ten aanzien van deze soorten niet noodzakelijk is. Er dient echter wel rekening gehouden te worden met de zorgplicht. Negatieve effecten dienen daarom alsnog (zoveel mogelijk) voorkomen te worden. Dit kan middels het nemen van de algemene maatregelen geadviseerd in het kader van de zorgplicht. In dit geval houdt dit op hoofdlijnen in:

- Het werken in één richting, waardoor aanwezige dieren de kans krijgen de werkzaamheden te ontvluchten. Geef deze dieren daarvoor ook de tijd en ruimte.
- Indien door het werk holen (verblijfplaatsen) worden aangetast en/of vernietigd mag dit alleen plaatsvinden onder ecologische begeleiding en buiten de kwetsbare voortplantingsperiode (globaal van januari tot juli).

Broedvogels
Indien de werkzaamheden op land worden uitgevoerd in het broedseizoen van vogels, bestaat een kans op verstoring van binnen de invloedsfeer aanwezige in gebruik zijnde nesten. Dit is een overtreding van de verbodsbepalingen. Het is niet mogelijk om hiervoor een omgevingsvergunning te verkrijgen. Het heeft daarom de voorkeur de grondverplaatsing op land zo mogelijk buiten het broedseizoen uit te voeren. Het broedseizoen valt voor de meeste soorten tussen half maart en half augustus. Ook daarbuiten is het mogelijk dat broedende vogels worden aangetroffen. Indien de werkzaamheden wel in het broedseizoen worden uitgevoerd, moeten de volgende maatregelen in acht genomen worden:

- De werkzaamheden voorafgaand aan het broedseizoen te beginnen en, voor zover mogelijk, min of meer continue door te laten gaan gedurende het broedseizoen. Hierdoor blijft er steeds sprake van verstoring waardoor verstoringsgevoelige soorten zich niet zullen vestigen. Het grote voordeel van deze methode is, dat de verstoringsafstand “automatisch” bepaald wordt. Vogels zullen uit eigen beweging een nestplaats kiezen buiten hun specifieke verstoringsafstand. Nadeel is dat de continue activiteiten (zowel in tijd als in ruimte) lastig te realiseren is en deze maatregel geen 100% garantie geeft dat zich toch geen vogels vestigen.
- De werkzaamheden ecologisch te laten begeleiden zodat gewerkt wordt buiten de verstoringsafstand van aanwezige broedgevallen. In dit geval wordt door een ter zake kundige in de gaten gehouden waar vogels broeden en wel of juist niet gewerkt kan worden. Nadeel van deze methode is dat als zich een broedgeval voordoet, de planning en werkzaamheden aangepast moeten worden.

[10] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam. Pagina 32.*

- Voorafgaand aan de werkzaamheden dient een erkend ecoloog het plangebied te inspecteren op broedgevallen. Bij afwezigheid van broedende vogels, kan het werkgebied worden vrijgegeven. Tijdens het broedseizoen geldt een dergelijke vrijgave maar voor een paar dagen. Indien er geen gebruik van gemaakt wordt dient daarna opnieuw geïnspecteerd te worden.

Amfibieën
De beoogde aanlegwerkzaamheden kunnen leiden tot het tijdelijk beschadigen en/of vernietigen van verblijfplaatsen en het verwonden en/of doden van individuen van de rugstreeppad. Mogelijk gaat als gevolg van de nieuwe ruimtelijke inrichting ook permanent geschikt leefgebied verloren. Dit is een overtreding van de verbodsbepalingen van de Ow. Om aan te sluiten op de gebiedsontheffing van het havenbedrijf, dienen de werkzaamheden te worden uitgevoerd volgens de werkprotocollen zoals vastgelegd in het Managementplan van het havenbedrijf. De bijbehorende noodzakelijke maatregelen zijn:

- Onder begeleiding van een ecologisch deskundige dient voorafgaand aan werkzaamheden het projectgebied ontoegankelijk gemaakt te worden voor rugstreeppadden door het plaatsen van paddenschermen en het dempen van potentiële voortplantingswateren nadat door een ter zake kundige is vastgesteld dat deze op dat moment niet in gebruik zijn.
- Paddenschermen bestaan in principe uit staand worteldoek van 50 centimeter hoog dat vijftien centimeter wordt ingegraven en wordt verankerd aan paaltjes.
- De voorzieningen die getroffen zijn om het gebied ontoegankelijk te maken moeten zodanig beheerd worden dat ze hun functie te allen tijde kunnen vervullen. Omgewaaide of omvergereden paddenschermen dienen zo spoedig mogelijk te worden hersteld.
- Na hevige regenval ontstane plassen, volgelopen wielsporen of greppels, dienen zo snel mogelijk weer te worden gecontroleerd op activiteit (aanwezigheid van eisnoeren en larven, imago's) van de soort en daarna te worden gedempt.
- Voor de rugstreeppad is vervangend leefgebied gerealiseerd op de Maasvlakte (hierna betiteld als 'mitigatielocaties'), bestaande uit zes in elkaars nabijheid gelegen clusters van drie voortplantingspoelen en landhabitat bestaand uit zandige greppels, zandhopen en stenen.
- Wanneer geen geschikte landhabitat in de buurt (op minder dan twee kilometer afstand) aanwezig is en/of het risico op herkolonisatie van het werkterrein groot is, moeten dieren verplaatst worden naar één van de voor de soort ingerichte mitigatielocaties op de Maasvlakte.
- Wanneer ook voortplantingswater verdwijnt moet voorafgaand aan het grondwerk tijdig nieuw, al dan niet tijdelijk, door te soort te gebruiken water zo dicht mogelijk bij het te verdwijnen water gegraven worden. Pas wanneer (bijvoorbeeld om bodemtechnische redenen) geen geschikt voortplantingswater kan worden gerealiseerd en/of het risico op herkolonisatie van het werkterrein daardoor groot is, mogen dieren verplaatst worden naar één van de voor de soort ingerichte mitigatielocaties op de Maasvlakte.
- Als werkzaamheden niet uitgesteld kunnen worden tot buiten de voortplantingsperiode, dan moet er voordat de werkzaamheden aanvangen gezocht worden naar eisnoeren en larven en imago's. Bij het aantreffen hiervan moeten deze, indien mogelijk, verplaatst worden naar geschikt gebied in de directe omgeving waar geen werkzaamheden voorzien zijn en, wanneer dit ontbreekt of het risico op herkolonisatie van het werkterrein te groot is (in geval van imago's), naar een van de mitigatielocaties op de Maasvlakte.
- De aangelegde alternatieve leefgebieden en verbindingszones voor de rugstreeppad dienen zodanig onderhouden te worden dat de functie van voortplantingswater, dan wel dagrust- of winterrustplaats, behouden blijft. Hiertoe dient het bestaande beheerplan, dat door Dienst Regelingen is goedgekeurd, als geldende richtlijn.
- Gezien het mobiele karakter van rugstreeppadden dient ook zorgvuldig te worden omgesprongen met potentiële voortplantingswateren. Potentiële voortplantingswateren worden bij werkzaamheden mogelijk als gevolg van onwetendheid vernield. Dergelijke potentiële voortplantingswateren dienen door een deskundige op het gebied van amfibieën in kaart te worden gebracht, voor zover die informatie nog niet uit de jaarlijkse monitoring die in opdracht van HbR wordt uitgevoerd kan worden afgeleid[11].

[11] *Bureau Stadsnatuur, juli 2021.Managementplan beschermde soorten Havenbedrijf Rotterdam 2021. In opdracht van Port of Rotterdam. Pagina 48.*

Om te kunnen voldoen aan gebiedsontheffing van het havenbedrijf, dient voorafgaand aan de werkzaamheden het plangebied nader onderzocht te worden op het voorkomen van leefgebiedsfuncties van de rugstreeppad. Het is noodzakelijk om dit in het juiste seizoen te doen wanneer deze dieren actief zijn. Rugstreeppadden kunnen grofweg in de periode april tot en met begin augustus onderzocht worden. Vanuit de bevindingen van dit aanvullende onderzoek kunnen noodzakelijke vervolgstappen worden genomen, zoals mogelijk het inrichten van compenserend leefgebied om de gunstige staat van instandhouding van de soort te kunnen borgen. Indien aan alle eisen van het managementplan kan worden voldaan is het aanvragen van een omgevingsvergunning niet noodzakelijk.

6.2 Zee-deel

In de omgeving van het plangebied komen mogelijk beschermde vissen, zeezoogdieren, vogels en vleermuizen voor. Het voornemen kan leiden tot negatieve effecten op zeezoogdieren, vogels en vleermuizen op zee. Het overtreden van verbodsbepalingen uit de Ow ten aanzien van deze soortgroepen moet voorkomen worden door het nemen van maatregelen. Indien dit niet mogelijk is, dient een omgevingsvergunning te worden aangevraagd. Onderstaande is dit nader toegelicht.

Vissen

Voorzorgsmaatregelen
Om de verstoring van vissen uit voorzorg te voorkomen dienen de volgende voorzorgsmaatregelen te worden uitgevoerd:

- Bij alle hei-activiteiten wordt een ADD (Acoustic Deterrent Device) in combinatie met een soft start toegepast. Voor het heien van conductors met de drill en drive methode zal dit ook worden toegepast. Een ADD is een apparaat dat in het water wordt gehangen en specifieke, onschadelijke geluidsignalen produceert met een afschrikkende werking op vissen. Op deze manier wordt eventueel in het directe plangebied aanwezige vissen de gelegenheid gegeven het plangebied te verlaten. Er wordt gebruik gemaakt van één of meer ADD's met een bereik van minimaal 500 m gedurende een half uur voor en tijdens het heien,
- De soft start dient minimaal 30 minuten lang te duren en te beginnen met vijf minuten op circa 20% van de slagenergie, aansluitend kan de slagenergie geleidelijk naar 90% worden opgehoogd. Na 30 minuten zijn eventueel aanwezige vissen ver genoeg weggezwommen om geen gehoorschade op te lopen.

Zeezoogdieren

Voorzorgsmaatregelen
Om directe verstoringseffecten op zeezoogdieren zoveel mogelijk te beperken dienen de volgende voorzorgsmaatregelen te worden uitgevoerd:

- Bij alle hei-activiteiten wordt een ADD (Acoustic Deterrent Device) in combinatie met een soft start toegepast. Voor het heien van conductors met de drill en drive methode zal dit ook worden toegepast. Een ADD is een apparaat dat in het water wordt gehangen en specifieke, onschadelijke geluidsignalen produceert met een afschrikkende werking op zeezoogdieren. Op deze manier wordt eventueel in het directe plangebied aanwezige zeezoogdieren de gelegenheid gegeven het plangebied te verlaten. Er wordt gebruik gemaakt van één of meer ADD's met een bereik van minimaal 500 m gedurende een half uur voor en tijdens het heien;
- De soft start dient minimaal 30 minuten lang te duren en te beginnen met vijf minuten op circa 20% van de slagenergie, aansluitend kan de slagenergie geleidelijk naar 90% worden opgehoogd. Na 30 minuten zijn eventueel aanwezige zeezoogdieren ver genoeg weggezwommen om geen gehoorschade op te lopen;
- Om effecten van geluid door (hei)werkzaamheden te mitigeren wordt er gebruik gemaakt van een Marine Mammal Observer (MMO) en Passive Acoustic Monitoring (PAM). Wanneer het donker is, of de weersomstandigheden een visuele monitoring ineffectief maken, zal er alleen akoestisch gemonitord worden (PAM), hiermee worden clicks van bruinvissen tot 500 m opgevangen.

Mitigerende maatregelen
Voor het verstoren van het leefgebied van de bruinvis en de gewone en grijze zeehond dient een omgevingsvergunning aangevraagd te worden. Daarnaast is aanvullende mitigatie nodig om significant negatieve effecten op populatieniveau te kunnen uitsluiten:

- Bij de hei-werkzaamheden dienen geluidsbeperkende maatregelen genomen te worden (bijvoorbeeld door gebruik te maken van een HSD Systeem/bubbelscherm) of een werkwijze waarbij relatief weinig onderwatergeluid zal optreden om effecten op de populatie bruinvissen te voorkomen (het geluidsniveau moet onder de 164 dB liggen op 750 meter afstand);
- Er dient zoveel mogelijk gebruik gemaakt te worden van stille schepen om continu onderwatergeluid te minimaliseren.

Vogels

Indien de werkzaamheden op zee worden uitgevoerd in het broedseizoen van vogels, bestaat een kans op verstoring van binnen de invloedsfeer aanwezige in gebruik zijnde nesten op het bestaande platform L4-A. Het is een overtreding van de verbodsbepalingen om rustende en broedende vogels te verstoren. Het is niet mogelijk om hiervoor een omgevingsvergunning te verkrijgen, waardoor het voorkomen van negatieve effecten gedurende de aanlegfase noodzakelijk is. Dit kan door:

- De werkzaamheden bij platform L4-A buiten het broedseizoen van de drieteenmeeuw uit te voeren. Het broedseizoen van de drieteenmeeuw duurt van midden-mei t/m augustus.

Indien dit niet mogelijk is, dienen de volgende maatregelen te worden uitgevoerd;

  - De werkzaamheden voorafgaand aan het broedseizoen te laten beginnen en in een, voor zover mogelijk, constante intensiteit te laten doorgaan gedurende het broedseizoen. Het grote voordeel van deze methode is, dat de verstoringsafstand “automatisch” bepaald wordt. Vogels zullen uit eigen beweging een nestplaats kiezen buiten hun specifieke verstoringsafstand. Nadeel is dat de constante intensiteit (zowel in tijd als in ruimte) lastig te realiseren is.

  - De werkzaamheden uit te voeren in het broedseizoen onder ecologische begeleiding. Er moet in dit geval gecontroleerd worden door een gecertificeerd persoon of er geen broedende drieteenmeeuwen voorkomen op of onder het platform. Voorafgaand aan de werkzaamheden dient een erkend ecoloog het plangebied te inspecteren op broedgevallen. Bij afwezigheid van broedende vogels, kan het werkgebied worden vrijgegeven. Vanuit praktische overwegingen kan deze inspectie ook via een videoverbinding uitgevoerd worden waarbij de ecoloog niet op de locatie aanwezig is, maar wel aanstuurt waar gefilmd moet worden.

Vleermuizen

Voorzorgsmaatregelen
Om verstoring van vleermuizen uit voorzorg te voorkomen dienen de volgende voorzorgsmaatregelen te worden uitgevoerd:

- Werkzaamheden zoveel als mogelijk bij daglicht uitvoeren[12]. Met name tijdens de voor vleermuizen belangrijk periode (voorjaarstrek, najaarstrek en dicht bij land ook in de zomer).
- De verlichting zoveel mogelijk beperken in aantal, intensiteit en draaiuren door bijvoorbeeld gebruik te maken van bewegingssensors en tijdklokken en afschermen van lichtbundels.
- De verlichting op het platform en de schepen wordt gericht op de activiteit om lichtuitstraling naar de omgeving te voorkomen.
- Voor transportbewegingen van en naar het platform dient waar mogelijk gebruik gemaakt te worden van bestaande scheepvaartroutes en zoveel mogelijk bij daglicht (tenminste in de actieve periode van de vleermuizen).

[12] Offshore werkzaamheden vinden in veel gevallen 24/7 plaatst. De inzet van bepaalde machines (o.a. boormachines) vraagt om continue activiteit. Deze maatregel geldt dan ook voornamelijk voor activiteiten op land.

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6.3 Overige maatregelen uitvoering - zorgplicht

Voor iedere plant- en diersoort geldt de zorgplicht, los van een vrijstelling of omgevingsvergunning. Schade aan dier- of plantensoorten moet te allen tijde worden voorkomen zover redelijkerwijs mogelijk is. Voor de uitvoeringsfase is aantal algemene voorzorgsmaatregelen beschreven op basis waarvan verstoring en doding van soorten veelal wordt voorkomen:

- De werkzaamheden worden zover mogelijk overdag, tussen zonsopgang en zonsondergang uitgevoerd[13]. Veel algemene en beschermde diersoorten zijn vooral actief gedurende de vroege ochtend, late avond en nacht.
- Indien ’s nachts gewerkt wordt, wordt verlichting toegepast die enkel gericht is op de bouwlocatie.
- De werkzaamheden worden bij voorkeur buiten de kwetsbare periode uitgevoerd. De kwetsbare periode betreft hoofdzakelijk de voortplantingsperiode. Voor een aantal diergroepen/soorten betreft dit ook de winter(rust)periode wanneer dieren minder actief zijn met vergrote kans op doding.
- De aannemer maakt enkel gebruik van de ruimte die noodzakelijk is voor het uitvoeren van de werkzaamheden en ontziet daarbij plaatsen met begroeiing en/of beplanting zoveel mogelijk. Zo wordt onnodige verstoring van dieren en planten voorkomen.

Deze maatregelen worden locatie-specifiek uitgewerkt in een Ecologisch werkprotocol dat voorafgaand aan de werkzaamheden wordt opgesteld en waarvan alle relevante betrokkenen kennisgenomen moeten hebben en dat nagevolgd dient te worden.

[13] *Offshore werkzaamheden vinden in veel gevallen 24/7 plaatst. De inzet van bepaalde machines (o.a. boormachines) vraagt om continue activiteit. Deze maatregel geldt dan ook voornamelijk voor activiteiten op land.*

7. Samenvatting bevindingen en toetsing wet- en regelgeving voor soortenbescherming

7.1 Landdeel

Binnen het plangebied kunnen verschillende beschermde soorten voorkomen. Het gaat om: glad biggenkruid, algemeen voorkomende zoogdieren, broedvogels en de rugstreeppad. Voor de meeste van deze soorten geldt dat een overtreding van de Ow voorkomen kan worden door het nemen van voorzorgsmaatregelen zoals beschreven in hoofdstuk 6. Voor glad biggenkruid en de rugstreeppad geldt dat niet. Als gevolg van de werkzaamheden kunnen tijdelijk standplaatsen van glad biggenkruid worden geschaad. Mogelijk gaan als gevolg van de nieuwe ruimtelijke inrichting ook permanent groeilocaties verloren. De beoogde aanlegwerkzaamheden kunnen daarnaast leiden tot het tijdelijk beschadigen en/of vernietigen van verblijfplaatsen en het verwonden en/of doden van individuen van de rugstreeppad.

Om aan te sluiten op de gebiedsontheffing van het havenbedrijf, dienen de werkzaamheden te worden uitgevoerd volgens de werkprotocollen zoals vastgelegd in het Managementplan van het havenbedrijf.

De voorzorgsmaatregelen dienen samen met de maatregelen uit het Managementplan ten aanzien van glad biggenkruid en de rugstreeppad opgenomen te worden in een project specifiek ecologisch werkprotocol. De werkzaamheden kunnen pas worden uitgevoerd na goedkeuring van het havenbedrijf en dienen plaats te vinden onder begeleiding van een erkend ecoloog.

7.2 Zeedeel

Binnen het plangebied op zee kunnen verschillende beschermde soorten voorkomen. Het gaat om: vissen (houting en steur), zeezoogdieren (bruinvis, gewone zeehond en grijze zeehond), broedvogels en migrerende vleermuizen (rosse vleermuis en ruige dwergvleermuis).

Voor de vissoorten geldt dat een overtreding van de Ow op voorhand kan worden uitgesloten, omdat het plangebied niet overlapt met essentieel leefgebied van de houting en steur.

Voor zeezoogdieren is geconcludeerd dat de effecten van onderwatergeluid leiden tot een overtreding van de verbodsbepalingen. Voor de bruinvis betreft dit opzettelijke verstoring door de effecten als gevolg van heiwerkzaamheden en het daarbij gebruik van ADDs. Dit is een overtreding van artikel 11.46 1b van het Bal. In het geval van de gewone zeehond en grijze zeehond betreft dit de verstoring die optreedt door de toename in scheepvaartbewegingen nabij het essentieel foerageergebied Noorderhaaks. Dit is een overtreding van artikel 11.54 1b van het Bal.

Voor broedvogels (i.e., drieteenmeeuwen) geldt dat er mogelijk verstoring optreedt bij rustende of broedende vogels tijdens werkzaamheden op het platform L4-A. Dit type overtreding is niet vergunbaar onder de Ow. Door het nemen van maatregelen, zoals voorgesteld in paragraaf 6.2, wordt een dergelijke overtreding van de Ow voorkomen.

Voor migrerende vleermuissoorten (rosse vleermuis en ruige dwergvleermuis) is geconcludeerd dat nieuwe constructies en daarbij horende lichtverstoring geen relevante effecten teweegbrengen die migratie verhinderen. Het is daarnaast momenteel ook niet bekend of migrerende vleermuizen vaste trekroutes gebruiken. De conclusie luidt dat er voldoende uitwijkmogelijkheden bestaan voor vleermuizen tijdens de overtocht. Het voornemen leidt niet tot het opzettelijk verstoren van de rosse vleermuis en ruige dwergvleermuis. Overtreding van de Ow is daarmee uitgesloten.

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8. Literatuur

Aarts, G. (2021). *Memo “Estimated distribution of grey and harbour seals” for KEC 4.0*. Wageningen Marine Research.

Aarts, G., Cremer, J., Kirkwood, R., van der Wal, J. T., Matthiopoulos, J., & Brasseur, S. (2016). *Spatial distribution and habitat preference of harbour seals (Phoca vitulina) in the Dutch North Sea*. https://library.wur.nl/WebQuery/wurpubs/fulltext/400306

Ahlén, I., Baagøe, H. J., & Bach, L. (2009). Behavior of Scandinavian bats during migration and foraging at sea. *Journal of Mammalogy*, *90*(6), 1318–1323.

Anderson Hansen, K., Hernandez, A., Mooney, T. A., Rasmussen, M. H., Sørensen, K., & Wahlberg, M. (2020). The common murre (Uria aalge), an auk seabird, reacts to underwater sound. *The Journal of the Acoustical Society of America*, *147*(6), 4069–4074.

Au, W. W. L., Popper, A. N., & Fay, R. R. (2000). *Hearing by whales and dolphins*. Springer New York, NY, USA:

Baptist, M. J., & Leopold, M. (2007). *De relatie tussen zichtdiepte en vangstsucces van de Grote Sterns van De Petten, Texel*. IMARES.

BfN. (2017). *Die Meeresscchutzgebiete in der deutschen ausschließlichen Wirtschaftszone der Nordsee: Beschreibung und Zustandsbewertung*.

Boshamer, J., & Bekker, J. (2008). Nathusius’ pipistrelles (Pipistrellus nathusii) and other species of bats on offshore platforms in the Dutch sector of the North Sea. *Lutra 2008 51 (1): 17-36, 2008.*

Bouma, S., Lengkeek, W., van den Boogaard, B., & Waardenburg, H. (2010). Reageren zeehonden op de Razende Bol op langsvarende baggerschepen. *Bureau Waardenburg Report*, *09–291*.

Brasseur, S. M. (2007). *Zeezoogdieren in de Eems, cumulatieve effecten van de activiteiten rond de ontwikkeling van de Eemshaven*. IMARES.

Brenninkmeijer, A., Doeglas, G., & de Fouw, J. (2002). Foerageergedrag van sterns in de westelijke Westerschelde in 2002. *Rapport Altenburg En Wymenga*.

Camphuysen, C., & De Vreeze, F. (2005). De Drieteenmeeuw als broedvogel in Nederland. *Limosa*, *78*(2), 65.

Camphuysen, C., & Leopold, M. (2007). Drieteenmeeuw vestigt zich op meerdere platforms in Nederlandse wateren. *Limosa*, *80*(4), 153–156.

Camphuysen, C., van Dijk, J., Witte, H., & Spaans, N. (2008). De voedselkeuze van Kleine Mantelmeeuwen en Zilvermeeuwen en andere indicaties die aanwijzingen geven over het ruimtegebruik van deze vogelsoorten in de Noord-Hollandse kustwateren. *NIOZ Rapport*, *12*.

Christensen-Dalsgaard, S., Dehnhard, N., Moe, B., Systad, G. H. R., & Follestad, A. (2019). *Unmanned installations and birds. A desktop study on how to minimize area of conflict*.

Daan, N. (2000). De Noordzee-visfauna en criteria voor het vaststellen van doelsoorten voor het natuurbeleid. *Nederlands Instituut Voor Visserijonderzoek RIVO. Rapport C031/00*.

Debusschere, E., De Coensel, B., Bajek, A., Botteldooren, D., HOstens, K., Vanaverbeke, J., Vandendriessche, S., Van Ginderdeuren, K., Vincx, M., & Degraer, S. (2014). *In Situ Mortality Experiments with Juvenile Sea Bass (Dicentrarchus labrax) in Relation to Impulsive Sound Levels Caused by Pile Driving of Windmill Foundations. PLoS ONE, 9(10), e109280.*

Ecomare. (2023). Bruinvissen. *Verdiep/Leesvoer/Dieren*. https://www.ecomare.nl/verdiep/leesvoer/dieren/bruinvissen/

Fijn, R., van Bemmelen, R., de Jong, J., Arts, F., Beuker, D., Rebolledo, E. B., Engels, B., Hoekstein, M., van der Horst, Y., & Leemans, J. (2022). *Verspreiding, abundantie en trends van zeevogels en zeezoogdieren op het Nederlands Continentaal Plat in 2020-2021*.

Fleming, T., Eby, H., Kunz, T., & Fenton, M. (2003). Fleming, T. H., Eby, P., Kunz, T. H., & Fenton, M. B. (2003). Ecology of bat migration. *Bat Ecology, 156, 164-65.*

Fliessbach, K. L., Borkenhagen, K., Guse, N., Markones, N., Schwemmer, P., & Garthe, S. (2019). A ship traffic disturbance vulnerability index for Northwest European seabirds as a tool for marine spatial planning. *Frontiers in Marine Science*, *6*, 192.

Fugro. (2023). *Aramis Pipeline Route Geophysical, Geotechnical and Environmental Survey*.

Geelhoed, S. C. V., & van Polanen Petel, T. (2011). *Zeezoogdieren op de Noordzee; Achtergronddocument bij Natuurverkenning 2011*.

Gillis, A., Ramirez-Martinez, N., Nachtsheim, D., & Siebert, U. (2020). *Update of distribution maps of harbour porpoises in the North Sea. Institute for Terrestrial and Aquatic Wildlife (ITAW).*

Heinis, F., De Jong, C., Von Benda-Beckmann, A., & Water, S. (2022). *Framework for Assessing Ecological and Cumulative Effects 2021 (KEC 4.0)–marine mammals.*

Heinis, F., De Jong, C., Von Benda-Beckmann, S., & Binnerts, S. (2019). *Kader Ecologie en Cumulatie – 2018 Cumulatieve effecten van aanleg van windparken op zee op bruinvissen.*

Hoekstein, M. S. J., Sluijter, M., & van Straalen, K. D. (2022). *Watervogels en zeezoogdieren in de Zoute Delta 2020/2021* (Rijkswaterstaat, Centrale informatievoorziening Rapport BM 20.03. Deltamilieu Projecten Rapportnr. 2022-01.). Deltamilieu Projecten, Vlissingen.

Krijgsveld, K. L., Klaassen, B., & Van der Winden, J. (2022). *Verstoring van vogels door recreatie. Literatuurstudie van verstoringsgevoeligheid en overzicht van maatregelen. Deel 1 hoofdrapport & deel 2 soortbesprekingen*. Uitgave Vogelbscherming Nederland.

Krijgsveld, K., Smits, R., & Van der Winden, J. (2008). Update literatuurstudie naar de reacties van vogels op recreatie. *Buro Waardenburg, Culemborg*.

Lagerveld, S., Geelhoed, S. C., Bittner, O., Wilkes, T., Noort, B., van Puijenbroek, M., van der Wal, J. T., Verdaat, H., Keur, M., & Steenbergen, J. (2023). *Spatiotemporal occurrence of bats at the southern North Sea 2017-2020*. Wageningen Marine Research.

Lagerveld, S., Janssen, R., Stienstra, K., Boshamer, J., Van Puijenbroek, M., Noort, B., & Geelhoed, S. C. V. (2022). *Home range and habitat use of common noctules in the Dutch coastal zone* (C057/21). Wageningen Marine Research.

Lagerveld, S., & Mostert, K. (2023). Are offshore wind farms in the Netherlands a potential threat for coastal populations of noctule? *Lutra*, *66*(1), 39–53.

Lagerveld, S., van der Wal, J. T., Vries, V., Verdaat, H., Sonneveld, C., van der Meer, J., Brabant, R., & Noort, B. (2019). *Bats at the southern North Sea in 2017 & 2018* (p.). Wageningen Marine Research. https://library.wur.nl/WebQuery/wurpubs/557366

Lagerveld, S., Wilkes, T., van Puijenbroek, M. E., Noort, B. C., & Geelhoed, S. C. (2023). Acoustic monitoring reveals spatiotemporal occurrence of Nathusius' pipistrelle at the southern North Sea during autumn migration. *Environmental Monitoring and Assessment*, *195*(9), 1016.

Leopold, M. (2015). *Eat and be eaten. Porpoise diet studies*.

McConnell, B., Fedak, M., Lovell, P., & Hammond, P. (1999). Movements and foraging areas of grey seals in the North Sea. *Journal of Applied Ecology*, *36*(4), 573–590.

Ministerie van Economische Zaken. (2014). *Profieldocument H1351 Bruinvis (Phocoena phocoena)*.

Ministerie van Economische Zaken. (2014a). Profieldocument H1364 Grijze zeehond (Halichoerus grypus). *Https://Www.Natura2000.Nl/Sites/Default/Files/Profielen/Profielen_HRSoorten_Actueel/Profiel_soort_H1364_2014.Pdf*.

Ministerie van LNV. (2008a). *Profieldocument Grote stern (A191)*. https://www.natura2000.nl/sites/default/files/profielen/Profielen_Vogels_Actueel/Profiel_vogel_A191.pdf

Ministerie van LNV. (2008b). *Profieldocument Kleine mantelmeeuw (A183)*. https://www.natura2000.nl/sites/default/files/profielen/Profielen_Vogels_Actueel/Profiel_vogel_A183.pdf

Ministerie van LNV. (2008c). *Visdief (Sterna hirundo) (A193)*. https://www.natura2000.nl/sites/default/files/profielen/Profielen_Vogels_Actueel/Profiel_vogel_A193.pdf

Ministerie van LNV. (2008d). *Zeekoet (Uria aalge) (A199)*. https://www.natura2000.nl/sites/default/files/profielen/Profielen_Vogels_Actueel/Profiel_vogel_A199_2014.pdf

Møhl, B., & Andersen, S. (1973). *Echolocation: High-frequency component in the click of the Harbor*.

Omgevingsdienst Haaglanden. (2023). *Beschikking (wijziging) Wet natuurbescherming—Soortenbescherming*.

RAVON. (n.d.-a). *Europese steur Acipenser sturio*. https://www.ravon.nl/Soorten/Soortinformatie/europese-steur

RAVON. (n.d.-b). *Noordzeehouting Coregonus oxyrinchus*. https://www.ravon.nl/Soorten/Soortinformatie/noordzeehouting

Redeker, M., & van Doorn, F. (2019). *Bruinvissen in de Noordzee*. www.indenoordzee.nl/noordzee-bruinvissen/%0D

Reijnders, P. J. H., Brasseur, S. M., & Brinkman, A. G. (2000). *Habitatgebruik en aantalsontwikkelingen van gewone zeehonden in de Oosterschelde en het overige Deltagebied*. Alterra.

RHDHV. (2023a). *Detailrapport zeebodem, inclusief morfologie, archeologie en niet gesprongen explosieven (ARM-PFE-B10-ENV-EIA-2025)*.

RHDHV. (2023b). *Passende Beoordeling Aramis CCS* (BH8744-WM-RP-220614–0926). Royal HaskoningDHV.

Rijkswaterstaat. (2015c). *Kader Ecologie en Cumulatie t.b.v. Uitrol windenergie op zee (2015c). Deelrapport B: Bijlage Imares onderzoek: Cumulatieve effecten op vogels en vleermuizen.*

Royal HaskoningDHV. (2020). *Vertroebelingsstudie platform N05-A*.

RVO. (2014a). *Soortenstandaard Rosse vleermuis (Nyctalus noctula)* (RVO-S08-401/BF15896). Rijksdienst voor Ondernemend Nederland. https://www.rvo.nl/sites/default/files/2015/01/Soortenstandaard%20Rosse%20vleermuis.pdf

RVO. (2014b). *Soortenstandaard Watervleermuis (Myotis daubentonii)* (RVO-S09-401/BF15896). Rijksdienst voor Ondernemend Nederland. https://www.rvo.nl/sites/default/files/2015/01/Soortenstandaard%20watervleermuis.pdf

Rydell, J., Bach, L., Dubourg-Savage, M.-J., Green, M., Rodrigues, L., & Hedenström, A. (2010). Bat mortality at wind turbines in northwestern Europe. *Acta Chiropterologica*, *12*(2), 261–274.

Smith, A. B., Fischer-McMorrow, I., Kolbeinsson, Y., Rasmussen, M., Shero, M. R., McElwaine, J. N., Jones, O. R., & Mooney, T. A. (2023). Sensitive aerial hearing within a noisy nesting soundscape in a deep-diving seabird, the common murre Uria aalge. *Marine Ecology Progress Series*, *714*, 87–104.

Soldaat, L., & Poot, M. J. M. (2019). *Analyse bruinvisgegevens en evaluatie monitoring Noordzee—Kwaliteitsborging IHM 2019*.

Sovon. (n.d.-a). *Kleine Mantelmeeuw—Larus fuscus—Lesser Black-backed Gull*. https://stats.sovon.nl/stats/soort/5910

Sovon. (n.d.-b). *Visdief—Sterna hirundo—Common Tern*. https://stats.sovon.nl/stats/soort/6150

Sportvisserij Nederland. (2023). *Steur na uitzet direct vertrokken uit de Biesbosch*.

Tamis, J. E., Karman, C. C., de Vries, P., & Klok, C. (2011). *Offshore olie-en gasactivitetiten en Natura 2000. Inventarisatie van mogelijke gevolgen voor de instandhoudingsdoelen van de Noordzee*.

Thompson, D. (2021). *Advice note—Seabrid Survey Methods dor Offshore Installations: Black-legged kittiwakes. JNCC*.

Todd, V. L., Todd, I. B., Gardiner, J. C., Morrin, E. C., MacPherson, N. A., DiMarzio, N. A., & Thomsen, F. (2015). A review of impacts of marine dredging activities on marine mammals. *ICES Journal of Marine Science*, *72*(2), 328–340.

Tulp, I., Tien, N., & van Damme, C. (2016). *PMR Monitoring natuurcompensatie Voordelta: Ontwikkeling vis in de Voordelta na instelling bodembeschermingsgebied ter compensatie van de aanleg Tweede Maasvlakte*. Wageningen Marine Research.

van der Knaap, I., Reubens, J., Thomas, L., Ainslie, M. A., Winter, H. V., Hubert, J., Martin, B., & Slabbekoorn, H. (2021). Effects of a seismic survey on movement of free-ranging Atlantic cod. *Current Biology*, *31*(7), 1555–1562.

van der Knaap, I., Slabbekoorn, H., Moens, T., Van den Eynde, D., & Reubens, J. (2022). Effects of pile driving sound on local movement of free-ranging Atlantic cod in the Belgian North Sea. *Environmental Pollution*, *300*, 118913. https://doi.org/10.1016/j.envpol.2022.118913

Vogelbescherming. (n.d.-a). *Common Tern, Sterna hirundo—Sterns (Sternidae)*. https://www.vogelbescherming.nl/ontdek-vogels/kennis-over-vogels/vogelgids/vogel/visdief

Vogelbescherming. (n.d.-b). *Lesser Black-backed Gull, Larus fuscus—Meeuwen (Laridae)*. https://www.vogelbescherming.nl/ontdek-vogels/kennis-over-vogels/vogelgids/vogel/kleine-mantelmeeuw

Vogelbescherming. (n.d.-c). *Sandwich Tern, Sterna sandvicensis—Sterns (Sternidae)*. https://www.vogelbescherming.nl/ontdek-vogels/kennis-over-vogels/vogelgids/vogel/grote-stern

Voigt, C. C., Rehnig, K., Lindecke, O., & Pētersons, G. (2018). Migratory bats are attracted by red light but not by warm-white light: Implications for the protection of nocturnal migrants. *Ecology and Evolution*, *8*(18), 9353–9361.

Voigt, C. C., Roeleke, M., Marggraf, L., Pētersons, G., & Voigt-Heucke, S. L. (2017). Migratory bats respond to artificial green light with positive phototaxis. *PLoS One*, *12*(5), e0177748.

Winter, H., Griffioen, A., & Van Keeken, O. (2014). *De Vismigratierivier: Bronnenonderzoek naar gedrag van vis rond zoet-zout overgangen*. IMARES.

Wright, P., Jensen, H., & Tuck, I. (2000). The influence of sediment type on the distribution of the lesser sandeel, Ammodytes marinus. *Journal of Sea Research*, *44*(3–4), 243–256.

Zoogdiervereniging. (n.d.). *Gewone zeehond*. https://www.zoogdiervereniging.nl/zoogdiersoorten/gewone-zeehond

Bijlage 1. Verslagen veldbezoeken

Veldbezoek 17 januari 2023

Uitvoeringsomstandigheden

Locatie	Maasvlakte
Uitgevoerd door:	Royal HaskoningDHV
Datum:	17 januari 2023
Tijd:	14.00-16.00 uur
Temperatuur	4ºC
Bewolking	onbewolkt
Wind	0-1 Bft
Luchtvochtigheid	onbekend

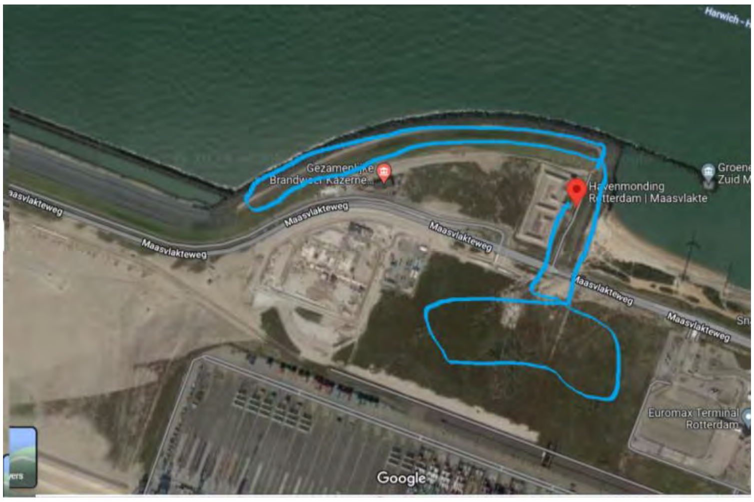
Doel van het onderzoek, onderzoeksmethode

Eerste veldonderzoek om te kijken of en welke dieren aanwezig zijn in het gebied. De hieronder beschreven soorten zijn gebaseerd op waarnemingen die ter plekke zijn gedaan en dit veldverslag kan daarmee niet als volledige inventarisatie worden gezien. Mogelijk zijn in andere seizoenen (of op andere momenten van de dag) andere soorten waarneembaar.

Bij Havenmonding Rotterdam Maasvlakte geparkeerd. Via het pad aan de onderkant van de dijk naar de windmolens gelopen. Daar de dijk opgegaan en via de bovenkant van de dijk teruggelopen. Vervolgens via het strand naar het open veld in het midden gelopen. Daar via rechts naar achter met een bocht naar links gelopen (zie blauwe lijn foto).

Kenschets van het terrein

Industriegebied met gras stroken. Er loopt een 80-weg, waar veel vrachtwagens op rijden. De waterkant is afgeschermd met grote rotsen waar zeehonden niet op kunnen. Op het strand waren auto/quad sporen. In het veld in het midden was een plek waar een soort struikengroei was. Verder was de vegetatie laag.



Waarnemingen

Veel graaf en holsporen van konijnen. Het rode vlak was een grote konijnenburcht, maar zit ook op het veld (ook rood omkaderd, TER INDICATIE).

Daarnaast veel konijnen waargenomen links van het rode vlak en in veld onder het rode vlak. In het veld onder het rode vlak zijn ook predator sporen (botten) en poep van een vos waargenomen. Er is dus ook een vos aanwezig in het gebied.

Geen zeehonden waargenomen. De waterkant is afgeschermd met grote rotsen dus het is niet waarschijnlijk dat ze daarop gaan liggen. Op het strand lagen er ook geen zeehonden. Daar waren wel auto/quad sporen, dus er is ook verstoring. Mensen laten hun hond uit op de dijk.

Veel aalscholvers en meeuwen waargenomen. Ook een aantal eksters en een raaf. Geen broedlocaties waargenomen.






Veldbezoek 16 februari 2023

Uitvoeringsomstandigheden

Locatie:	Maasvlakte
Uitgevoerd door:	Royal HaskoningDHV
Datum:	16 februari 2023
Tijd:	15.00-16.00 uur
Temperatuur	9ºC
Bewolking	bewolk en na een tijdje motregen
Wind	4-5 Bft op de jetty locatie
Luchtvochtigheid	onbekend

Doel van het onderzoek, onderzoeksmethode

Aanvullend (tweede) veldonderzoek om te kijken/welke dieren kunnen aanwezig zijn in het gebied MOT & GATE terrein en rond Beereiland. De hieronder beschreven soorten zijn gebaseerd op waarnemingen die ter plekke zijn gedaan en dit veldverslag kan daarmee niet als volledige inventarisatie worden gezien. Mogelijk zijn in andere seizoenen (of op andere momenten van de dag) andere soorten waarneembaar.

Vanuit GATE is met een medewerker (Daniel) over het terrein gereden en gewandeld. Hij kon meer vertellen over wat medewerkers dagelijks allemaal zien. We zijn begonnen bij het GATE gebouw. Vervolgens met uitzicht op het Beer eiland naar het zuiden gereden (zie blauwe lijn in een Google Maps screenshot hieronder). Vervolgens is er gekeken bij de uitlaatstroom waar de aanlegsteigers komen (zie blauwe dikke lijn bij drie witte opslag tankers).

Kenschets van het terrein

De Maasvlakteweg is een 80 km weg met aan de zeekant een begroeide berm met bomen en struiken. Aan de MOT kant is er een klein dijkje waarachter de opslagvaten staan. Bij het GATE terrein is er aan de waterkant een stuk strand. De waterkant gaat erna over in grote stenen, waar zeehonden niet op kunnen. Op het zuidelijkste punt is een afgesloten stuk gras met laag struikengroei. Op het terrein zijn meerdere grasgebieden met veel lage vegetatie. Bij de GATE opslagvaten is de waterkant afgeschermd met rotsen. Daar zijn ook grasgebieden aanwezig.

Waarnemingen

Bij het opkomen van het terrein stond al een: “pas op overstekende vossen” - bord. Geen vossen gezien, Daniel vertelde dat er wel veel zitten (hier is ook beeldmateriaal van beschikbaar). De holen van de vossen zouden langs de Maasvlakteweg zitten. Ook een buizerd waargenomen boven het gebied.

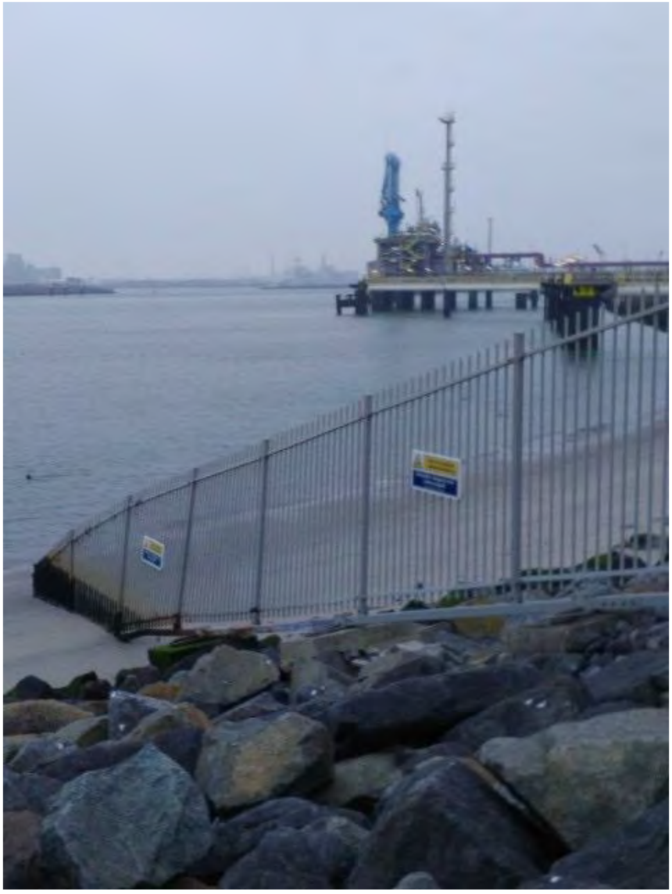
Naast het GATE gebouw zijn zowel zeehonden in het water waargenomen als rustend op het strand. Tijdens het veldbezoek waren er tussen de zes en negen zeehonden visueel zichtbaar, waarvan twee of drie grijze zeehonden en zes tot zeven gewone zeehonden. Daniel kon ons vertellen dat er soms 30 tot 40 zeehonden kunnen zitten. Bij de zeehonden op het strand en op het GATE terrein zijn ook scholeksters en meeuwen waargenomen (grote of kleine mantelmeeuw of grijze meeuw).

De zichtbare kant van het Beereiland was beschermd met grote stenen, waar zeehonden niet op kunnen rusten.

Op het zuidelijke uiteinde was een open graslandschap waar konijnen liepen. Daarnaast vertelde Daniel dat er veel vogels broeden in dat gebied. Nu waren deze niet te zien.

Bij de GATE opslagvaten langs de koelwateruitstroom waren ook konijnen. Daarnaast lagen er veel lege schelpen en krabben resten wat aangeeft dat vogels (meeuwen) daar foerageren. Er waren meeuwen en scholeksters te zien. De waterkant was beschermd met grote stenen.

Daniel kon ons vertellen dat er erg veel konijnen, hazen en vossen op het gehele GATE en MOT terrein zitten. Eerst was er ook een hert, maar die zit nu op het Beereiland volgens Daniel. Vooral in de zomer zijn er veel zeehonden aanwezig en (broed)vogels. De vossen, konijnen en hazen krijgen ook jongen in het gebied. Buizerds en wellicht andere roofvogels komen ook voor in het gebied.




Let op!!
overstekende
vossen

Royal HaskoningDHV

Bijlage 2. Scheepvaart- en helikopterbewegingen

	Type schip/ helikopter	Activiteit	Aantal schepen/ helikopters	Aantal bewegingen	Duur activiteit (in dagen)
Direct piping	Baggerschip	Baggerwerkzaamheden bij in en bij de Maasgeul.	1	2	41,29
	Pijplegschip	Intrekken van zeeleiding door direct pipe casing.	1	2	0,37
	Support vessel	Schoonmaken, intern inspecteren en testen van de leiding.	1	2	5,58
Totaal	-	-	3	6	47
Microtunneling	Baggerschip	Baggerwerkzaamheden bij in en bij de Maasgeul.	1	2	5,99
	Pijplegschip	Intrekken van zeeleiding door microtunnel.	1	2	1,15
	Support vessel	Schoonmaken, intern inspecteren en testen van de leiding.	1	2	6,84
Totaal	-	-	3	6	14
Aanleg zeeleiding	Support vessel	Controleren van de route door de aannemer vóór aanvang van alle constructie activiteiten.	1	2	3,41
	Baggerschip	Zeebed correcties om de pijpleg route te verbeteren.	1	2	14,49

	Pijplegschip	Intrekken van offshore zeeleiding.	1	2	7
	Pijplegschip	Doorleggen van zeeleiding naar het eindpunt.	1	2	50,69
	Pipe carrier	Bevoorrading pijplegschip.	3	6	50,69
	Support vessel	Kruising met bestaande infrastructuur.	1	2	11,97
	Transport barge + sleepboot	Speciaal transport voor toekomstige aansluitingen.	2	2	3
	Support vessel	Volgschip voor veilige aanleg zeeleiding.	1	2	50,17
	Support vessel	Schoonmaken, intern inspecteren en testen van de leiding.	2	4	32,3
	Support vessel	Stenen storten.	1	2	13,27
	Trencher	Begraven van de zeeleiding.	1	2	71,72
	Survey schip	Laatste inspectie.	1	2	3,41
Totaal	-	-	15	30	312
Werkzaamheden platform K14-FA (Shell)	Work to work vessel	Varen van en naar het platform.	1	80	N.A.
	Diving support vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	10
	Supply support vessel	Varen van en naar het platform.	1	10	N.A.
	Standby/survey vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	25
	Heavy lifting vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	17
	Transport barge + Tug	Varen van en naar het platform / Werkzaamheden bij het platform.	1	19	12
	Pipelaying vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	8

	Trenching + rockdump vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	7
	Helikopter	Beweging van en naar het platform.	1	50	N.A.
Totaal	-	-	9	169	N.A.
Werkzaamheden putten K14-FA (Shell)	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	12	N.A.
	Drilling supply vessel	Varen van en naar het platform.	1	229	N.A.
	Standby vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	400
	Drilling with Jackup	Werkzaamheden bij het platform.	1	2	400
Totaal	-	-	4	245	400
Werkzaamheden platform L10-zuid (Neptune)	Work to work vessel	Varen van en naar het platform.	1	4	N.A.
	Diving support vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	8
	Heavy lifting vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	9
	Pipelaying vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	7
Totaal	-	-	4	10	N.A.
Werkzaamheden putten L10-zuid (Neptune)	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	2	N.A.
	Drilling supply vessel	Varen van en naar het platform.	1	276	N.A.
	Standby vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	420
	Drilling with Jackup	Werkzaamheden bij het platform.	1	2	420
	Helikopter	Beweging van en naar het platform.	1	300	N.A.
Totaal	-	-	5	582	420
Werkzaamheden platform L4-A (Total Energies)	Heavy lifting vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	N.A.
	Supply vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	114	N.A.
	Standby vessel	Varen van en naar het platform.	1	2	132
	Diving support vessel	Varen van en naar het platform.	1	2	14
	Work to work vessel (crew change)	Varen van en naar het platform.	1	60	N.A.

	Pipelaying vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	15
	Support vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	7
	Rockdump vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	1
	DSV (metrology centrale eindpunt + L4-A)	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2	14
	Helikopter	Beweging van en naar het platform.	1	76	N.A.
Totaal	-	-	9	264	132
Werkzaamheden putten L4-A (Total Energies)	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	2	N.A.
	Drilling supply vessel	Varen van en naar het platform.	1	816	N.A.
	Drilling with Jackup	Werkzaamheden bij het platform.	1	2	408
	Helikopter	Beweging van en naar het platform.	1	234	N.A.
Totaal	-	-	4	1.054	408
Gebruiksfase – Total Energies	Walk to walk vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	144 (per jaar)	-
	Standby vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2 (per jaar)	-
	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	5 (per jaar)	-
	Supply vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	3 (per jaar)	-
	WS barge	Varen van en naar het platform / Werkzaamheden bij het platform.	1	4 (per jaar)	-
Totaal	-	-	5	158 (per jaar)	-
Gebruiksfase - Neptune	Walk to walk vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	48 (per jaar)	-
	Standby vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2 (per jaar)	-
	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	5 (per jaar)	-
	Supply vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	3 (per jaar)	-
	WS barge	Varen van en naar het platform / Werkzaamheden bij het platform.	1	4 (per jaar)	-
Totaal	-	-	5	62 (per jaar)	-

Gebruiksfase - Shell	Walk to walk vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	91 (per jaar)	-
	Standby vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	2 (per jaar)	-
	Mobilisatie/ Demobilisatie	Varen van en naar het platform.	1	5 (per jaar)	-
	Supply vessel	Varen van en naar het platform / Werkzaamheden bij het platform.	1	3 (per jaar)	-
	WS barge	Varen van en naar het platform / Werkzaamheden bij het platform.	1	4 (per jaar)	-
Totaal	-	-	5	105 (per jaar)	-

RAPPORT

Nautische Veiligheid

MER Aramis CO2 transportinfrastructuur

Klant: Aramis

Referentie: ARM-PFE-B10-ENV-EIA-2007

Status: Definitief/01

Datum: 9 februari 2024

ARAMIS	**CCS-ARAMIS Project**
	Environment Impact Assessment – Baseline report
	Document No. ARM-PFE-B10-ENV-EIA-2007 Document title Nautical safety report Revision Final 4.0

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Enhancing Society Together

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Titel document:	Nautische Veiligheid
Sub titel:	MER Aramis CO2 transportinfrastructuur
Referentie:	ARM-PFE-B10-ENV-EIA-2007
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 Nautische veiligheid bij het MER voor het Aramis initiatief (kortweg Aramis). Het Aramis initiatief bestaat uit de aanleg en exploitatie van een open CCS-infrastructuur. Hiermee 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 het milieuthema nautische veiligheid. Hierbij zijn de mogelijke risico's vanuit nautisch perspectief beschreven.

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

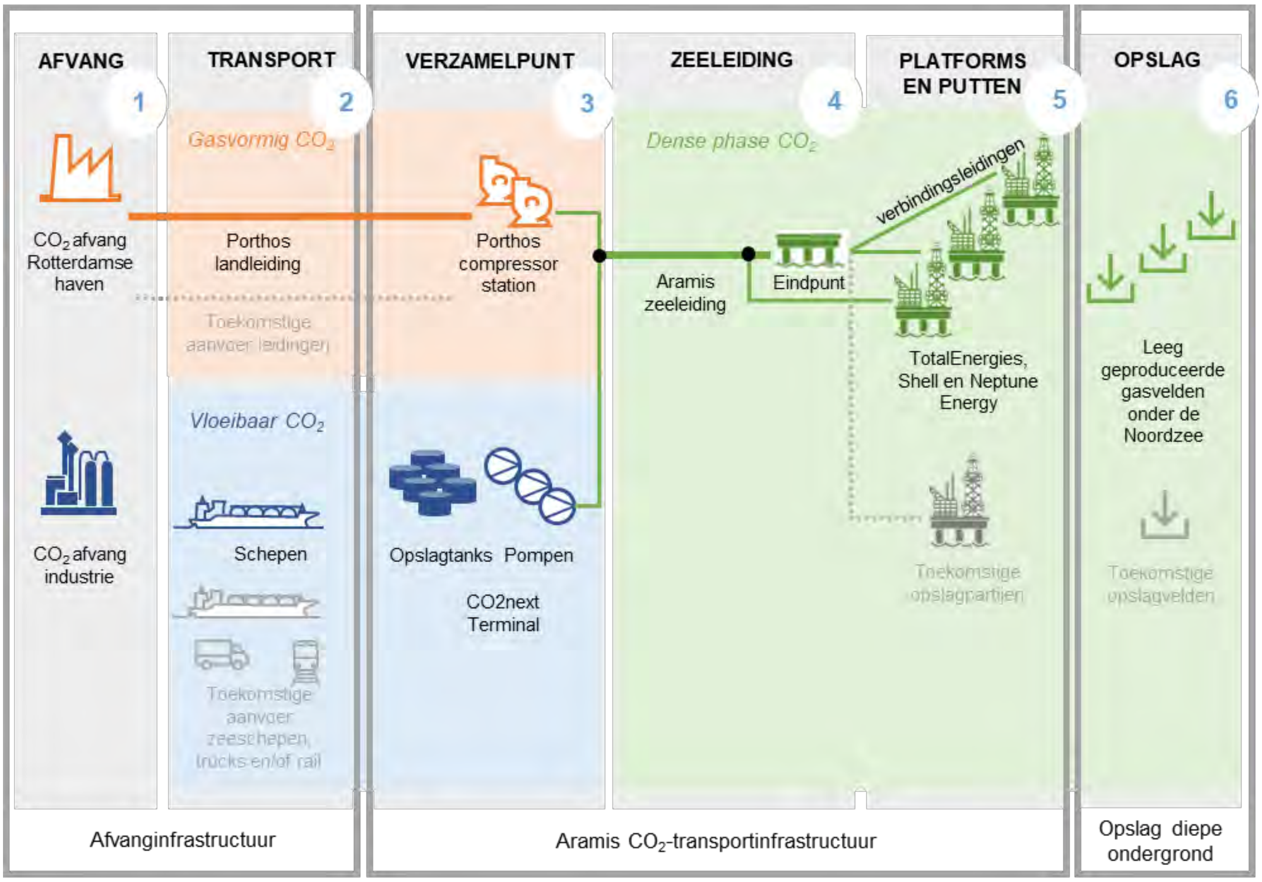
1. CO_2-afvang bij industrie, en geschikt maken voor transport;
2. CO_2-transport naar het verzamelpunt op de Maasvlakte, middels de Porthos landleiding of per schip;

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.

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

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 thema Nautische Veiligheid

Bij het milieuthema nautische veiligheid worden risico's in beeld gebracht. Andere milieuthema's hebben veelal betrekking op milieueffecten, dat wil zeggen gevolgen die zullen optreden ten gevolgen van activteiten. Bij nautische veiligheid wordt in beeld gebracht wat de kans en gevolgen van een gebeurtenis zijn. Dat wordt voor de eenduidigheid met de andere thema's als effect omschreven.

Voor het milieuthema nautische veiligheid zijn de aspecten *scheepvaart, aanvaring (van de buisleiding, van de steiger, van het platform, van derden, door derden)* van belang. Daarnaast is ook het *falen van de buisleiding* een aspect dat onderdeel is van nautische veiligheid.

Voor het aspect Nautische Veiligheid is daarom gekeken naar:

1. Verscheping in de omgeving Rotterdam
    a. Doorvaart van CO_2 zeeschepen in de Maasgeul;
    b. Doorvaart van CO_2 binnenvaart door Rotterdam;
    c. Afmeren;
    d. Verlading;
    e. Effecten van (gebruik van) de marine terminal van CO_2next.
2. Zeedeel Leiding
    a. Aanlanding in Rottterdam;
    b. kruising van de Maasgeul;
    c. Zeeleiding tracé (op de zeebodem en ingegraven) naar het distributieplatform;
    d. Verbindingsleidingen (op zeebodem en deels ingegraven) van het distributieplatform naar de injectieplatforms
    e. Kruisingen van pijpleidingen en kabels;
    f. Kruisingen met navigatiegebieden.
3. Platforms
    a. Distributieplatform;
    b. Nieuwe platforms (Neptune Energy en Shell);
    c. Connectie op bestaand platform (TotalEnergies).

Zowel de aanlegfase als de operationele fase is beschouwd.

1.2.1 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 nautische veiligheid worden beschreven. Daarbij wordt onderscheid gemaakt tussen de aanlegfase en gebruiksfase, en worden de mogelijke effecten van een incident beschreven; namelijk bijvoorbeeld:

- De aanlegfase bestaat uit de aanleg van de terminal, het aanpassen van het compressorstation, plaatsen van de buisleiding op en in de zeebodem) en het installeren en aanpassen van platforms.
  - De effecten tijdens de aanleg betreffen het hinderen van de scheepvaart en de risico's van een aanvaring. Bij inspectie, reparaties en/of herbegraven zijn vergelijkbare effecten op de scheepvaart te verwachten als bij de aanleg.

- 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.
  - De effecten tijdens de gebruiksfase zijn met name het beschadigen van de buisleiding en platforms door ongecontroleerde aanvaring van schepen (met name derden)

Een verdere uiteenzetting van de effecten tijdens aanleg en gebruiksfase kan gevonden worden in hoofdstuk 3.2.
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.

1.2.2 Relevante milieuaspecten

Voor het milieuthema nautische veiligheid zijn met name de volgende potentiële gebeurtenissen relevant:

- Aanvaring van platforms en aanmeervoorzieningen
- Beschadiging van buisleidingen

Voor meer details wordt verwezen naar de tekst in hoofdstuk 1.2 en de gedetailleerde effect inventarisatie in hoofdstuk 3.2.

Dit detailrapport beschrijft de milieueffecten van de potentiële gebeurtenissen.

Cumulatie
De term cumulatie wordt gebruikt voor het opstapelen van effecten veroorzaakt door verschillende gebeurtenissen. Door dit opstapelen kunnen de *gezamenlijke* effecten groter zijn dan die van een enkel gebeurtenissen.

1.2.3 Relevante alternatieven en varianten

In het MER zijn verschillende alternatieven en varianten onderzocht. Deze alternatieven en varianten zijn voor het milieuthema nautische veiligheid niet allemaal relevant. In Tabel 1-1 zijn de relevante varianten opgenomen.

Tabel 1-1. Relevante alternatieven en varianten voor het aspect nautische veiligheid.

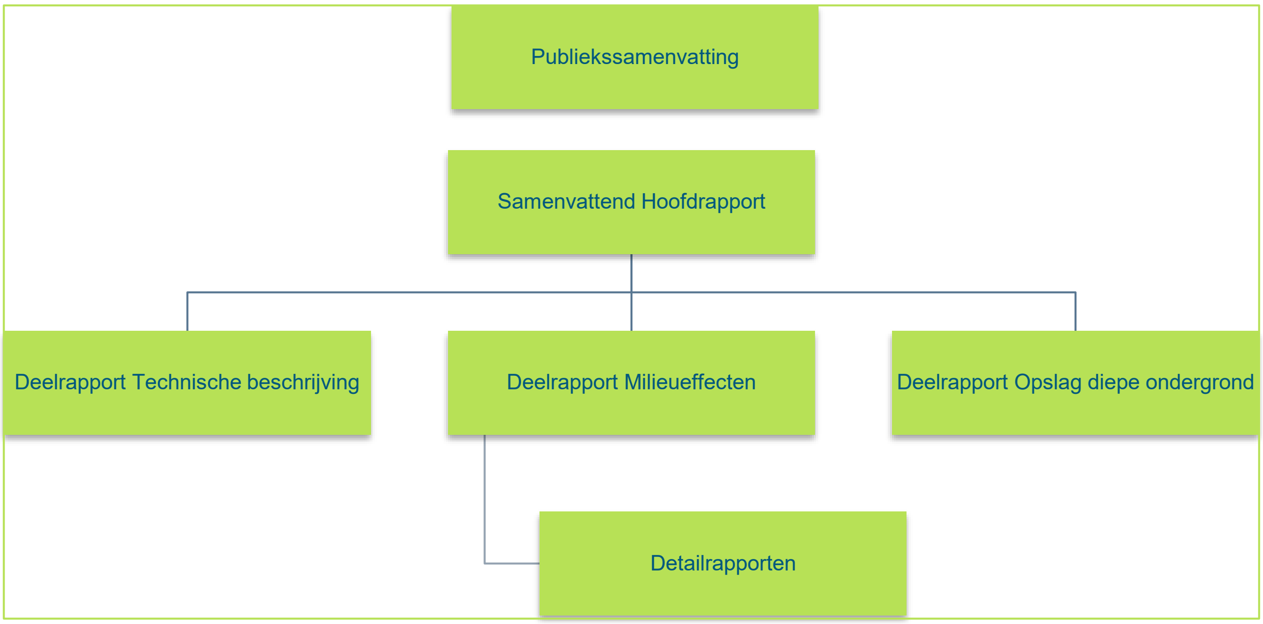
Locatie	Voorgenomen activiteit	Alternatief/ variant
Locatie van de terminal	Op het MOT-terrein, ten zuidoosten van de meest oostelijke opslagtanks voor aardolie	Tank 05 locatie bij Gate, ten oosten van de Yukonhaven
Kruising Maasgeul	Microtunnel vanaf haaienvin bij Edisonbaai	Direct Pipe boring nabij kruising Porthos leiding
Leiding tracé	Tracé volgens figuur 4.5	NA

Een uitgebreide beschrijving van al de alternatieven en varianten is opgenomen in het deelrapport Technische beschrijving bij het MER.

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.

Het voorliggende rapport is het detailrapport nautische veiligheid. 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 deelrapport beschrijft in het volgende hoofdstuk allereerst welk kader van beleid, wet- en regelgeving van toepassing is voor het thema Nautische Veiligheid. 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 dent 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, inclusief onderhoudswerkzaamheden en onvoorziene situaties
- tijdens de aanleg en ontmanteling.

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 bevat hoofdstuk 9 een opsomming van alle ontbrekende informatie voor het thema Nautische Veiligheid en een voorstel voor hoe de effecten op Nautische Veiligheid gemonitord kunnen worden.

Royal HaskoningDHV

2 Beleid, wet- en regelgeving

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

2.1 Wettelijk kader

Deze paragraaf beschrijft het wettelijk kader voor het thema van dit deelrapport, inclusief alle criteria specifieke wettelijke kaders. Dit wordt weergegeven in onderstaande tabel.

Tabel 2-1. Wettelijk kader scheepvaart en veiligheid

Omgevingswet (2024)	Per 1 januari 2024 zijn de bepalingen van de Waterwet opgenomen in de Omgevingswet. De normen voor de primaire waterkeringen zijn vastgelegd als omgevingswaarde in het Besluit kwaliteit leefomgeving.
Arbeidsomstandighedenbesluit (2023)	Dit besluit stelt eisen aan de opsporing van niet-gesprongen explosieven. In artikel 4.10 van het Arbobesluit is bepaald dat bedrijven die werkzaamheden samenhangende met het opsporen van Niet-Gesprongen Explosieven (NGE) verrichten in het bezit dienen te zijn van een 'procescertificaat opsporen conventionele explosieven dat is afgegeven door onze minister of een certificerende instelling'. De certificatieplicht geldt per 2007. In artikel 4.17f van de Arboregeling wordt als grondslag voor certificatie van opsporingsbedrijven verwezen naar het werkveldspecifieke certificatieschema voor het systeemcertificaat opsporing conventionele explosieven (WSCSOCE), zoals opgenomen in bijlage XII van de Arboregeling.
Noordzeeakkoord (2020) (waaronder OSPAR5, ASCOBANS6, Kaderrichtlijn Mariene Strategie);	Met het Noordzeeakkoord (NZA) geven overheid en stakeholders samen invulling aan de opgaven voor de Noordzee, zoals aan de natuur-, voedsel- en energietransities op de Noordzee. Ook wordt met het NZA een bijdrage geleverd aan de invulling van het klimaatakkoord. De afspraken, ook over de winning van fossiele energie, zijn gemaakt in het licht van de afspraken van COP-Parijs.
Regeling provinciale risicokaart	Provincies maken en beheren de Risicokaart. Dit is wettelijk verankerd in de Wet Veiligheidsregio's. In een ministeriële regeling zijn nadere, algemeen verbindende voorschriften voor de Risicokaart opgenomen. Op de risicokaart staan kwetsbare objecten en risicovolle situaties. Bevat o.a. maximale waterhoogte bij dijkdoorbraak.

2.2 Beleidskader

Deze paragraaf beschrijft het beleidskader voor het thema van dit deelrapport, inclusief alle criteria specifieke beleidskaders. Dit wordt weergegeven in onderstaande tabel.

Tabel 2-2. Beleidskader scheepvaart en veiligheid

CS-OOO (2021)	Certificatieschema voor het managementsysteemcertificaat Opsporen van ontplofbare oorlogsresten. Certificatie van opsporingsbedrijven vindt plaats op basis van het Certificatieschema opsporen ontplofbare oorlogsresten (CS-OOO). Het CS-OOO heeft per 1 januari 2021 het zogenoemde WSCS-OCE vervangen. Het certificatieschema heeft betrekking op het opsporen van ontplofbare oorlogsresten die in de (water)bodem zijn achtergebleven tijdens en na de Eerste en Tweede wereldoorlog.

Nationaal Water Programma 2022-2027 (2022)	Het Nationaal Water Programma 2022–2027 (NWP) geeft een overzicht van de ontwikkelingen binnen het waterdomein en legt nieuw ontwikkeld beleid vast. Er wordt omschreven hoe er wordt gewerkt aan schoon, veilig en voldoende water dat klimaatadaptief en toekomstbestendig is. Het NWP beschrijft de nationale beleids- en beheerdoelen op het gebied van o.a. waterveiligheid en scheepvaart.
Programma Noordzee 2022-2027 (2022)	Het Programma Noordzee 2022-2027 richt zich op het bereiken van een duurzaam en veilig gebruik van de Noordzee dat bijdraagt aan de maatschappelijke, economische en ecologische doelstellingen van Nederland. Het plan is als bijlage onderdeel van het Nationaal Water Programma 2022-2027 en bevat onder andere nieuw beleid over het in stand houden en verder ontwikkelen van hoofdinfrastructuur (o.a. scheepvaartroutes).
Recente aanwijzingen van Natura 2000-gebieden op Noordzee, zoals Bruine Bank.	

2.3 Relevantie wet- en regelgeving voor criteria en beoordeling

In deze paragraaf wordt van een aantal beleidskaders aangegeven hoe deze de criteria en beoordeling daarvan beïnvloeden.

2.3.1 Programma Noordzee 2022-2027

Voor het goed kunnen functioneren en de toekomstbestendigheid van de zeehavens zijn voldoende ankergebieden van voldoende grootte essentieel. Aangrenzend aan deze ankergebieden wordt voldoende manoeuvreerruimte (c.q. voldoende afstand tot windparken) voor zeeschepen in stormsituaties vrijgehouden. Dit is belangrijk voor schepen die niet langer veilig ten anker kunnen liggen. Zij hebben voldoende ruimte nodig om snelheid te kunnen maken ter wille van de manoeuvreerbaarheid. gedurende de storm. In verkeersscheidingsstelsels, diepwaterroutes, ankergebieden, precautionary area's en clearways gaat scheepvaart vóór ander gebruik.

2.3.2 Relevante wet- en regelgeving voor waterkeringen

Waterkeringen (dijken, dammen en andere verhogingen die water kunnen keren) beschermen het Nederlandse land en haar bewoners tegen hoogwater van de zee of de binnenwateren. Waterkeringen zijn verdeeld in primaire, secundaire en regionale waterkeringen. Elke waterkering heeft een bepaalde normering die beschrijft hoe hevig de situatie is waartegen deze waterkering minimaal bestand moet zijn. Ook heeft elke waterkering een beschermingszone waarbinnen beperkte functies kunnen plaatsvinden. De normeringen en beschermingszones kunnen per waterkering verschillen, en staan beschreven in nationaal, provinciaal en regionaal (waterschappen) beleid. Deze staan tot 1 januari 2024 beschreven in de Waterwet, de provinciale omgevingsverordeningen van de provincies. Inmiddels zijn deze opgenomen in de Omgevingswet, Omgevingsregeling, Besluit kwaliteit leefomgeving en, voor zover al vastgesteld, de Waterschapsverordeningen[2].

De relevante zeewering voor Aramis wordt door RWS beschouwd als een primaire zeewering. Deze ligt echter buitendijks en helpt dus niet mee om overstromingen te voorkomen.

Het aanleggen van kabels, leidingen en tunnels mag niet leiden tot een vermindering van de veiligheid van een waterkering. In principe doorkruist elk mogelijk concept minimaal een waterkering. Dit gebeurt in de regel door middel van een boring onder de kering door, om eventuele effecten op de waterkering

[2] *Waterschappen moeten op 1 januari 2026 een waterschapverordening hebben vastgesteld*

zoveel mogelijk te minimaliseren. Tijdens het vormgeven van het concept, moet per tracé worden meegenomen wat de specifieke normeringen en beschermingszones van een waterkering zijn. Voor het abstractieniveau van dit deelrapport echter, is slechts de hoeveelheid kruisingen met een waterkering van belang.

2.3.3 Gronddekking kabels en leidingen vanuit Rijkswaterstaat

Indien het begraven van leidingen en kabels nodig is en toegepast, hanteert Rijkswaterstaat een minimale gronddekking op de kabel of leiding ten opzichte van de actuele bodem.

Rijkswaterstaat hanteert hiervoor de volgende categorieën en gronddekkingen:

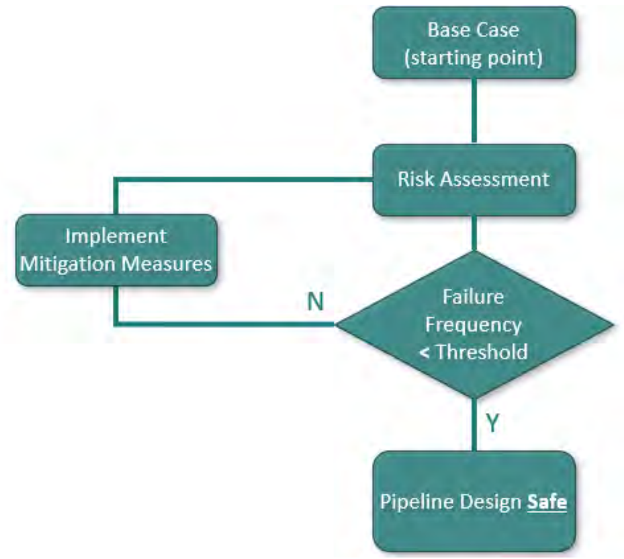
- Gronddekking buiten vaarwegen ≥ 1 meter;
- Gronddekking in vaarwegen ≥ 2,5 meter;
- Gronddekking kruising vaarwegen ≥ 2,5 meter

2.3.4 Normering

Het project wordt uitgevoerd conform onder andere de volgende relevante NEN- normen, waardoor de optredende risico’s aanzienlijk worden gemitigeerd. Het recht wordt voorbehouden om gelijkwaardige normen toe te passen.

- NEN 3650-1 (2020) – Eisen voor buisleidingsystemen – Deel 1: Algemene eisen
- NEN 3650-2 (2020) - Eisen voor buisleidingsystemen – Deel 2: Aanvullende eisen voor leidingen van staal
- NEN 3651 (2020) - Aanvullende Eisen voor buisleidingen in of nabij belangrijke waterstaatswerken
- NEN 3655 (2020) - Veiligheidsbeheerssysteem (VBS) voor buisleidingsystemen voor het transport van gevaarlijke stoffen – Functionele eisen
- NEN 3656 (2022) - Eisen voor stalen zeeleidingsystemen.

De toe te passen methode is dat een risico assessment wordt uitgevoerd als onder deel van ontwerp. Het ontwerp wordt zo aangepast dat de risico’s acceptabel zijn, omdat voldaan wordt aan de grenswaarde genoemd in de (NEN) normen. Deze methodiek is als volgt grafisch weergegeven.



3 Beschrijving onderzoeks- en beoordelingsmethodiek

Dit hoofdstuk beschrijft de aanpak waarmee de milieueffecten worden bepaald en beoordeeld. De beoordeling maakt gebruik van een risico inventarisatie.

In het kader van het vervolg van de studie wordt hier het onderscheid gemaakt tussen effecten en risico's.

De effecten zijn de gevolgen van het ontwikkelen, bouwen en opereren van de elementen binnen het kader van de Aramis m.e.r. Deze effecten worden in dit rapport geïnventariseerd en beoordeeld.

Risico is de kans dat een potentieel gevaar resulteert in een daadwerkelijk incident en de ernst van het letsel of de schade die dit tot gevolg heeft. In het kader van deze studie wordt het risico gebruikt om tot een beoordeling van het effect te komen.

3.1 Onderzoeksmethodiek

Onafhankelijk van de ontwerpen en uitgevoerde studies heeft een team van (Maritieme) Veiligheidsexperts op basis van de geplande activiteiten en onderdelen een interne effect-inventarisatie gemaakt, waarin ook de relevante nautische risico's zijn onderkend.

De effecten zijn gekwalificeerd en voor elk relevant effect is onderzocht

- hoe het project omgaat met het risico in ontwerp en uitvoering;
- Welke alternatieven zijn onderzocht;
- Welke mitigerende maatregelen zijn voorgesteld;
- Hoe bovenstaande is vastgelegd in studies.

Voor elk niet voldoende gemitigeerd effect is een voorstel gedaan voor verdere mitigatie.

Wijze van bepalen en beoordelen van effecten Nautische Veiligheid
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. Hierbij passen we een zeven-punts scoreschaal toe van plussen en minnen zoals hieronder voor elk beoordelingscriterium weergegeven. Op die manier worden de effecten voor alle relevante milieuthema's bepaald en beoordeeld.

Tabel 2-1. Maatlat effectbeoordeling Nautische Veiligheid

Effect	Omschrijving
+ + +	Sterk positief effect, groot van omvang en zodanig dat een overschrijding van normen wordt opgeheven
+ +	Positief effect, relatief groot of in een kritische periode of gebied
+	Licht positief effect, relatief beperkt, tijdelijk of lokaal
0	Geen effect
-	Licht negatief effect, relatief beperkt, tijdelijk of lokaal
- -	Negatief effect, relatief groot of in een kritische periode of gebied, mitigatie in de vorm van nader onderzoek naar risico's is nodig

- - -	Zeer negatief effect, zodanig dat milieueffect buiten de normen van regelgeving en beleid valt, nader onderzoek naar risico's in nodig en mitigerende maatregelen moeten worden toegepast
Nvt	Niet van toepassing

3.2 Nautische risico's

3.2.1 Terminal en scheepvaart

Met scheepvaart wordt hier bedoeld de schepen die CO_2 aanleveren in Rotterdam. Het gaat hier om zowel binnenvaart schepen als zeevaartschepen. Voor de zeevaart wordt het traject vanaf de Maasgeul tot aan de aanlegplaats beschouwd, voor de binnenvaart is het traject in de haven van Rotterdam naar de aanlegplaats beschouwd.

Aanlegfase
In de aanlegfase worden de steigers gebouwd, veelal gebruik makend van drijvend materieel.

Tabel 3-2. Effect inventarisatie terminal Aanlegfase

Nummer	Aspect	Effect	Risico
1.1.1	Marine terminal	Ongecontroleerd drijvend bouwmaterieel	Rammen van derden met als gevolg materiele schade, stremming van het Beerkanaal of Yangtzekanaal
1.1.2		Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer	Rammen door derden met als gevolg materiele schade, stremming van het Beerkanaal of Yangtzekanaal
1.1.3		Rammen van bouwmaterieel of mariene constructies door derden	Rammen door derden met als gevolg materiele schade, stremming van het Beerkanaal of Yangtzekanaal

Gebruiksfase
In de gebruiksfase meren CO_2 zeeschepen en CO_2 binnenvaartschepen aan de steigers aan, waarna zij CO_2 verladen. De steigers liggen aan de rand van het Yangtzekanaal, de doorgaande ingang naar de Tweede Maasvlakte.

Tabel 3-3. Effect inventarisatie terminal Gebruiksfase

Nummer	Aspect	Effect	Risico
1.2.1	Doorvaart CO_2 zeeschepen	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	Rammen van andere schepen, met als gevolg lekken CO_2, materiele schade, milieutechnische schade en economische schade door stremming van de Nieuwe Waterweg, het Beerkanaal of Yangtzekanaal
1.2.2		Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	Rammen van assets, zoals buisleidingen, steigers en oevers, met als gevolg lekken CO_2, materiele schade, milieutechnische schade en economische schade door stremming van de Nieuwe Waterweg, het Beerkanaal of Yangtzekanaal

Nummer	Aspect	Effect	Risico
1.2.3	Doorvaart CO_2 binnenvaart	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	Rammen van andere schepen, met als gevolg materiele schade, milieutechnische schade en economische schade door stremming Nieuwe Waterweg
1.2.4		Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	Rammen van assets, zoals buisleidingen, steigers en oevers, met als gevolg materiele schade, milieutechnische schade en economische schade door stremming Nieuwe Waterweg
1.2.5	Afmeren van CO_2 zee schepen of CO_2 binnenvaart	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	Rammen van andere schepen, met als gevolg materiele schade, milieutechnische schade en economische schade door stremming van het Beerkanaal of Yangtzekanaal
1.2.6	Verlading van CO_2	Verlies van CO_2 product tijdens de verlading door proces fouten, ondeugdelijk materiaal of brekende afmeerlijnen, bijvoorbeeld door passerende schepen of stroming uit uitlaat	Verlies van product met als gevolg milieuschade of persoonlijk gevaar
1.2.7	Marine terminal	Rammen van de constructie door derden	Rammen door derden met als gevolg materiele schade, stremming van het Beerkanaal of Yangtzekanaal

3.2.2 Zeeleidingen

Aanlegfase

De effecten tijdens de aanleg betreffen het hinderen van de scheepvaart en de risico's van een aanvaring. Bij inspectie, reparaties en/of herbegraven zijn vergelijkbare effecten op de scheepvaart te verwachten als bij de aanleg.

Tabel 3-4. Effect inventarisatie zeeleidingen Aanlegfase

Nummer	Aspect	Effect	Risico
2.1.1	Aanlanding pijpleiding op Maasvlakte	Aanlegwerkzaamheden doorkruising leiding tasten stabiliteit waterkering aan	Overstroming, economische schade voor herstel werkzaamheden
2.1.2	Kruising van de Maasgeul	Beschadigen bestaande pijplijnen door: a. gestuurde boring b. Drijvend materieel verankering c. Spudpalen/ heien d. Baggeren	Milieuschade, Economische schade voor herstel werkzaamheden Economische schade door onbruikbaar zijn van pijpleiding
2.1.3		hinderen doorgaand scheepvaartverkeer, bijvoorbeeld door verankeringen voor drijvend materieel of druktesten leiding	Rammen door derden met als gevolg materiele schade, Geplande stremming van de Nieuwe Waterweg, met als gevolg economische schade voor Haven van Rotterdam

Nummer	Aspect	Effect	Risico
2.1.4		Rammen van bouwmaterieel of mariene constructies, inclusief ontvangstschacht, door derden	Rammen door derden met als gevolg materiele schade, stremming van de Nieuwe Waterweg Beschadigen ontvangstschacht, met potentieel vollopen van tunneldeel. Personele risico's.
2.1.5		Ongecontroleerd drijvend bouwmaterieel	Rammen van derden met als gevolg materiele schade, stremming van de Nieuwe Waterweg
2.1.6	Zeeleiding tracé tot distributieplatform	Beschadigen bestaande- Niet bekende- pijpleidingen door baggeren of verankering drijvend materieel	Milieuschade, Economische schade voor herstel werkzaamheden Economische schade door onbruikbaar zijn van pijpleiding
2.1.7	Kruisingen van pijpleidingen en kabels	Beschadigen bestaande pijpleidingen en kabels door baggeren, verankering drijvend materieel of kruisingswerkzaamheden	Milieuschade, Economische schade voor herstelwerkzaamheden Economische schade door onbruikbaar zijn van pijpleiding
2.1.8	Kruisingen met navigatiegebieden	Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer	Rammen door derden met als gevolg materiele schade, Geplande stremming van de navigatiegebieden, met als gevolg economische schade voor Haven van Rotterdam
2.1.9		Rammen van bouwmaterieel of mariene constructies door derden	Rammen door derden met als gevolg materiele schade, stremming van de navigatiegebieden
2.1.10		Ongecontroleerd drijvend bouwmaterieel	Rammen van derden met als gevolg materiele schade, stremming van navigatiegebieden

Gebruiksfase

De zeeleiding heeft een zeker faalkans (*falen buisleiding)*. Indien de CO_2 vrijkomt onderwater, dan zal zich een zogenaamde "bubble plume" vormen. De effecten van de zeeleiding op de visserij wordt bepaald door de kans op een ongeval door contact van vissersgerei en ankers met de transportleiding (*schade buisleiding door netten en ankers*).

Tabel 3-5. Effect inventarisatie zeeleidingen Gebruiksfase

Nummer	Aspect	Effect	Risico
2.2.1	Aanlanding in Rotterdam	Lekken primaire waterkering door doorkruising van de leiding	Overstroming, economische schade voor herstel werkzaamheden
2.2.2	Kruising van de Maasgeul	Verankeringen voor drijvend materieel tijdens onderhoud hinderen doorgaand scheepvaartverkeer	Rammen door derden met als gevolg materiele schade, Geplande stremming van de Nieuwe Waterweg, met als gevolg economische schade voor Haven van Rotterdam

Nummer	Aspect	Effect	Risico
2.2.3	Zeeleiding tracé tot distributieplatform Zeeleiding tracé to platforms	Falen van de buisleiding door: a. Corrosie b. Te hoge druk in de pijplijn	Zinkend schip van derden door verlies van hydrostatische druk
2.2.4		Beschadigen van de buisleiding door: a. Zinken schip na rammen of anderszins b. Slepen van ankers c. Slepen van vissers gerei d. Gevallen lading e. Aanraking door kiel schip of bouwmaterieel	Milieuschade, Economische schade voor herstel werkzaamheden Economische schade door onbruikbaar zijn van pijpleiding Zinkend schip van derden door verlies van hydrostatische druk Reputatieschade en obstructie
2.2.5	Kruisingen van pijpleidingen en kabels	Beoogd tracé interfereert met bestaande infrastructuur	Verplaatsen bestaande infrastructuur, verlengd vergunningen traject, reputatieverlies, obstructie
2.2.6	Kruisingen met navigatiegebieden	Beoogd tracé interfereert met bestaande navigatiegebieden	Verplaatsen bestaande navigatiegebieden, verlengd vergunningen traject, reputatieverlies, obstructie

3.2.3 Platformen; distributieplatform, nieuwe en bestaande platforms

De nautische veiligheid heeft betrekking op het risico van aanvaring van het platform. Tijdens werkzaamheden op het platform bevinden zich schepen bij het platform. Deze kunnen tegen het platform komen, wat wordt aangeduid als driften (of aandrijven). In de gebruiksfase varen schepen rond het platform. Als deze tegen het platform komen, wordt dit als rammen omschreven.

Aanlegfase

Tabel 3-6. Effect inventarisatie platformen Aanlegfase

Nummer	Aspect	Effect	Risico
3.1.1	Nieuwe platforms (Neptune Energy en Shell)	Schade aan het platform bij - de load out (Door vallende kraan , vallende objecten), - transport (Door zinkend transport schip, overbelaste constructie) of - installatie (Door botsend installatieschip, overbelaste constructie)	Schade aan platform, vertraging project
3.1.2	Distributieplatform Connectie bestaande en nieuwe platforms	Schade aan het platform bij connectie (Door botsend installatieschip, overbelaste constructie)	Schade aan platform, vertraging project
3.1.3	Veranderingen aan bestaande platforms	Schade aan het platform door extra functionaliteit van CO_2 transport over het platform, overbelaste constructie	Schade aan platform, vertraging project

Gebruiksfase

Tijdens de gebruiksfase worden de platforms ge-serviced, gebruik makend van Offshore Support Vessels (OSV's). De platforms zijn gesitueerd in de drukbevaren Noordzee. Er bestaat daarom een risico dat de platforms worden aangevaren en beschadigd door ongecontroleerde schepen.

Tabel 3-7. Effect inventarisatie platformen Gebruiksfase

Nummer	Aspect	Effect	Risico
3.2.1	Distributieplatform Nieuwe platforms (Neptune Energy en Shell) Connectie op bestaande platforms (Shell Total en distributieplatform)	Platform faalt door aanvaring service schip	Platform buiten gebruik, met als gevolg verlies van operability Aramis, of opslagcapaciteit bij opslagpartij. Service schip beschadigd
3.2.2		Platform faalt door aanvaring schip van derden	Platform buiten gebruik, met als gevolg verlies van operability Aramis, of opslagcapaciteit bij opslagpartij. Schip van derden beschadigd
3.2.3		Impact van service operaties op marine leven	Additionele milieuschade door toename aantal scheepsbewegingen
3.2.4		Service schepen botsen met derden (Scheepvaart, platforms, windpark)	Materiele schade,

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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 en de situatie die ontstaat als gevolg van alle autonome ontwikkelingen; de referentiesituatie. Daarna wordt de toekomstige situatie gecreëerd door Aramis geschetst.

4.1 Huidige situatie en autonome ontwikkeling

Verschillende activiteiten vinden plaats op de Noordzee:

- Scheepvaart (navigatie)
- Windparken
- Offshore platformen
- Visserij
- Kabels en pijpleidingen

De Noordzee is een van de drukst bevaren zeeën ter wereld. Een deel van de scheepvaart verlaat of komt de haven van Rotterdam binnen via de Maasgeul. Het deel van de scheepvaart met een grote diepgang vaart enkele tientallen kilometers westwaarts om vervolgens naar het zuiden of noorden af te buigen. Scheepvaart met een kleinere diepgang met bestemming IJmuiden, Hamburg of andere havens in de omgeving slaat al eerder af in noordelijke richting. Hier bevindt zich ook een verkeersscheidingsstelsel (het Maas Noord VSS).

Figuur 4-1: Overzicht van de geplande pijpleidingen nabij landingspunt Source: Imagery from © 2022 Microsoft Corporation © 2022 Maxar © CNES (2022) Distribution Airbus DS, assets from drawing ARM-CPT-BB3-PLR-LAY-0045

De Tennet kabels en TAQA gas pijplijn zijn bestaand.

De zeescheepvaart, welke de Rotterdamse haven binnenvaart, passeert onder andere het scheepvaartkanaal de Maasgeul. Dit is een regelmatig gebaggerd kanaal met een breedte van circa 1km. Door de intensieve bevaring en het belang van de Maasgeul voor de haven van Rotterdam is het van groot belang dat stremmingen tot een minimum beperkt blijven.

Het gebied is intensief gebombardeerd in WWII en achtergelaten niet-ge explodeerde bommen (NGE) moeten verwacht worden.

Nabij het landingspunt op de Maasvlakte zijn de volgende bestaande en geplande assets geïdentificeerd:

- Tennet Power kabels. Deze worden geïnstalleerd, gebruik maken van de HDD methode bij de oeverkruising. Ze worden begraven ter plaatse van de Maasgeul.
- 26 Inch gas pijplijn (TAQA Energy B.V.) aan de oostzijde,

Autonome ontwikkeling
Voor het Aramis initiatief relevante autonome ontwikkelingen betreffen in ieder geval:

- Ontwikkeling van het Porthos project;
  - Voorgestelde Porthos (CO_2) pipeline aan de westzijde van het Aramis tracé
- Ontwikkeling aanlanding van TenneT kabels en nieuwe installaties;
- Beëindigen aardgasproductie in de geselecteerde opslagvelden;
- Windparken op zee (bijvoorbeeld IJmuiden Ver Beta, Gamma en Nederwiek Beta);

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- Verwachte toename scheepvaart komende 40 jaar door verder ontwikkeling van de Maasvlakte (Alexiahaven en Amaliahaven).

4.2 Geplande Aramis ontwikkeling

In het Deelrapport Technische beschrijving zijn de technische aspecten van het Aramis initiatief inclusief de aanlegfase beschreven. Relevant voor het milieuaspect Nautische Veiligheid zijn:

- De terminal met de bijbehorende scheepsvaart
- De leidingen op of in de zeebodem en de kruisingen met de waterkering
- De platforms

Onderstaand wordt op deze elementen ingegaan.

4.2.1 Terminal en scheepvaart

Het aantal jaarlijks verwachte schepen, weergegeven in tabel 4-1, welke de basis is van de beoordeling in dit rapport, is gebaseerd op de stand per 1 November 2023 en is als volgt.

Gedurende de verder ontwikkeling van het project wordt het aantal scheepsbewegingen aangepast aan bijvoorbeeld de aanwezige stikstofruimte. In het geval de aantallen schepen significant afwijken van de getoetste hoeveelheden, zal een nieuwe toetsing moeten plaatsvinden.

Tabel 4-1. Aantal CO2next schepen per jaar

		Start	Eerste uitbreiding	Maximaal
Capaciteit Terminal		5.4 mtpa	10 mtpa	15 mtpa
#vessel arrivals				
	2,1k-barge	6	6	6
	6k-barge			
	7,5k-barge	431	431	431
	11,7k-barge	207	739	1059
	16k-coaster (Export)	76	76	83
	Totaal	720	1252	1579

De CO_2 zeeschepen zullen door de Maasgeul de haven van Rotterdam binnenvaren en direct door het Beerkanaal naar de locatie van de steigers koers vatten. Het verkeer in de haven wordt gereguleerd door de Havenautoriteit. Het totaal aantal zeeschepen dat de haven van Rotterdam aandoet is gemiddeld 80 per dag.

Het plan is de terminal te ontwikkelen op het terrein van de Maasvlakte Olie Terminal (MOT), of als alternatief op het huidige terrein van Gate terminal. Het is de bedoeling dat de activiteiten van Gate terminal en MOT ongestoord kunnen blijven doorgaan. Aan de zuidzijde van het terrein wordt ruimte gereserveerd voor het aanmeren van schepen.

De aanlandingsactiviteit wordt als voorgenomen activiteit gerealiseerd door de aanleg van steigers, die parallel aan de zuidoever van het Gate terminalterrein met het Yangtzekanaal gaan lopen. Voor de vergunningaanvragen wordt uitgegaan van 3 steigers. De eindsituatie is 3 of 4 steigers.

Indien een alternatieve locatie wordt gebruikt voor de terminal, zal dit niet leiden tot een wijziging van de locatie van de steigers, zoals weergegeven in onderstaande figuur.

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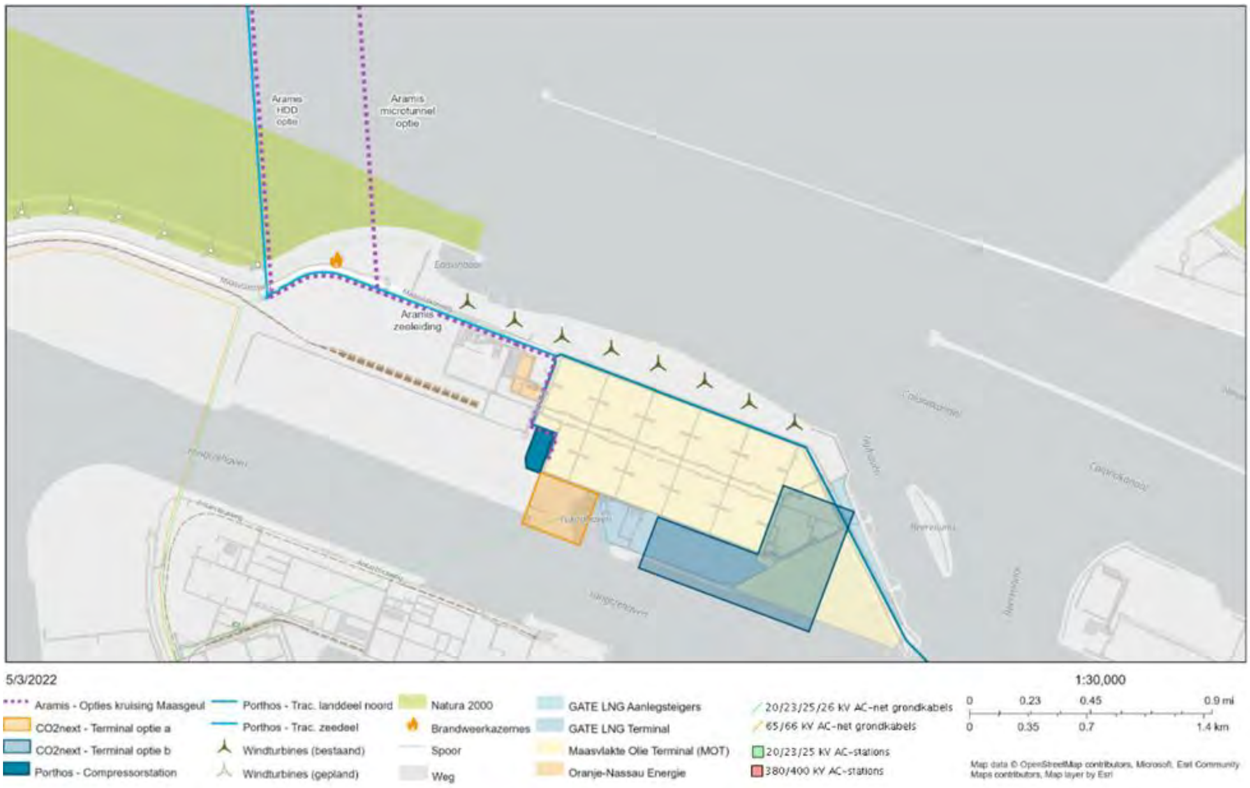
Figuur 4-2. Overzicht van de locatie van CO2next.

4.2.2 Zeeleidingen

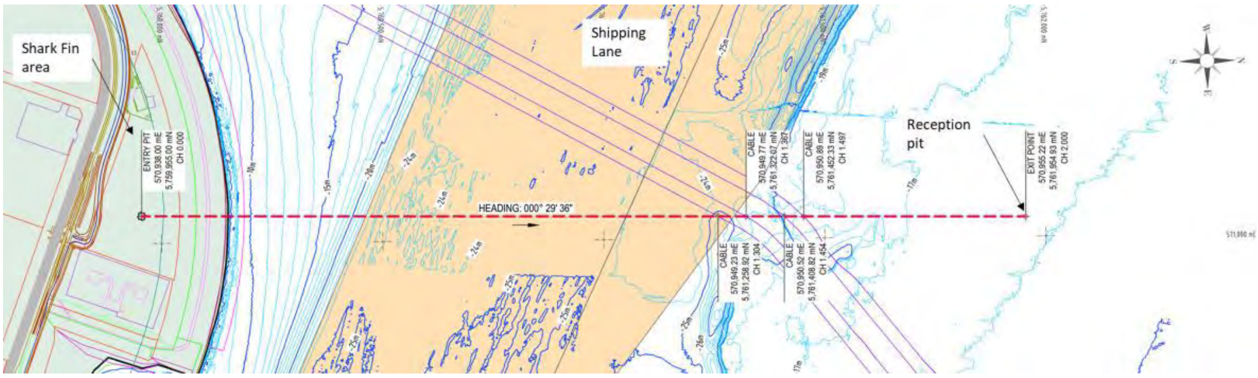
Er is gekozen voor de diameter die dermate groot is dat in de toekomst tot 22 Mton CO_2 per jaar kan worden getransporteerd. In het ontwerp wordt uitgegaan van een diameter van 32 inch (circa 80 cm). De druk in de leiding is 140 tot 180 bar, met ontwerpdruk van 200 bar. De CO_2 wordt in vloeibare vorm (dense phase) getransporteerd. De druk en temperatuur in de zeeleiding wordt aangestuurd vanaf het compressorstation en de hogedrukpompen bij de terminal.

Het zeedeel van de Aramis leiding bevindt zich vanaf de Maasvlakte in voornamelijk noordwaartse richting.



Figuur 4-3. Overzicht locatie aanlanding Aramis zeeleiding

Direct voor de kust van de Maasvlakte bevindt zich de Maasgeul. Deze vaargeul is bestemd voor (zee-) schepen van en naar de Rotterdamse haven.



Figuur 4-4. Overzicht van de kruising van de Maasgeul. Bron: "Mircotunnel Trajectory - North Option Plan View & Profile" Uit scope of work document 416010-00257 - ARM-CPT-BB3-PLR-REP-0047_1.0

De zeeleiding scope is weergegeven in onderstaande figuur.

Figuur 4-5. Overzicht zeeleiding tracé CCS Aramis

4.2.3 Platformen; distributieplatform, nieuwe en bestaande platforms

Er komt een nieuw platform aan het uiteinde van de zeeleiding, het distributieplatform. Verder gaan Shell en Neptune Energy een nieuw platform plaatsen, terwijl TotalEnergies gebruik maakt van een bestaand platform.

De platformen zullen ge-serviced worden met OSV's.

Autonoom zal er op de Noordzee ook rekening gehouden moeten worden met een toename van het aantal schepen. Rondom offshore mijnbouwinstallaties is een veiligheidszone van 500 m aanwezig. Hierbinnen is geen enkele activiteit is toegestaan, tenzij ten bate van de mijnbouw activiteit.

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5 Milieuaspecten Gebruiksfase, inclusief onderhoud, calamiteiten

Dit hoofdstuk gaat per Aramis onderdeel in op de effecten op het thema Nautische veiligheid, zoals die verwacht worden tijdens het gebruik van de CCS-keten.

In dit hoofdstuk wordt de nautische veiligheid getoetst voor de gebruiksfase. De effecten zijn genummerd conform de aanduiding in hoofdstuk 3.

5.1 Terminal en scheepvaart

Effect 1.2.1 - Doorvaart CO_2 zeeschepen – rammen van schepen (0)
Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten

De risicobepaling is gebaseerd op de MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande CO_2 faciliteiten middels een desktopstudie is bepaald.

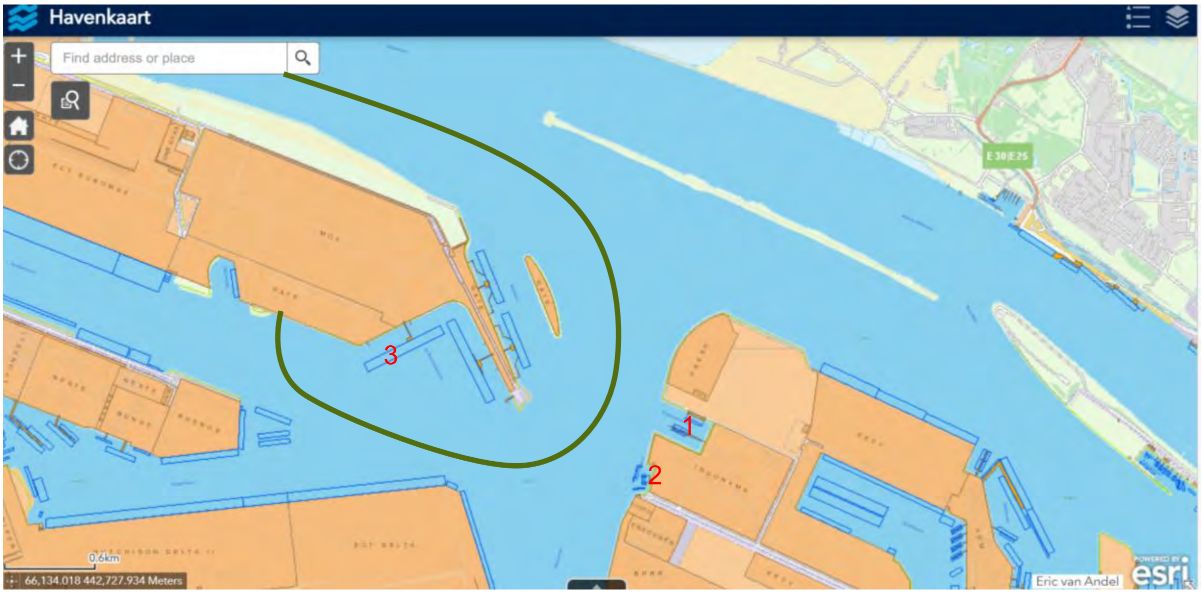
In deze studie is het aantal scheepvaart bewegingen in het Yangtzekanaal bepaald middels AIS data. Deze AIS data geeft aan dat er momenteel (2020) circa 330 schepen per dag passeren (120 zeeschepen en 210 binnenvaart). Autonome ontwikkelingen zullen verder leiden tot een significante vermeerdering. Het totaal aantal zeeschepen dat de haven van Rotterdam binnen vaart is circa 80 per dag.

Omdat de intensiteit van de CO2next zeeschepen te verwaarlozen is in vergelijking met het totaal aantal schepen in de haven van Rotterdam, het Beerkanaal en de Yangtzehaven wordt het effect als nihil (0) ingeschaald.

Effect 1.2.2 - Doorvaart CO_2 zeeschepen – rammen van assets (-)
Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten

Met betrekking tot de doorvaart naar de Maasvlakte, het aantal incidenten in de haven van Rotterdam (Zeevaart en Binnenvaart) per jaar is circa 140, wat neerkomt op ongeveer 0,05% van de scheepsbewegingen in Rotterdam. Het aantal zeeschepen dat de CO2next terminal aan zal doen bedraagt maximaal 83 per jaar. In de te volgen route is het aantal obstakels en belendende terminals gering.

Met betrekking tot de manoeuvre naar de steiger:
De volgende faciliteiten zijn kwetsbaar (Zie ook figuur 5-1):
1. Indorama jetty in de Tenesseehaven
2. Loodswezen faciliteiten in de Pistoolhaven
3. MOT faciliteiten in de 8^{e} Petroleum haven en LNG Gate activiteiten in de Yukonhaven



Figuur 5-1. Schets van aanvaarmanoeuvre zeeschepen naar CO2next steigers

De route is vanuit nautisch oogpunt uitdagend, hoewel het een bestaande route is, die gecontroleerd wordt door de Havenauthoriteit.

In de brief HBR-2244094 (3-3-2022) geeft de havenmeester aan dat hij het risico van aanvaren acceptabel vindt, gebaseerd op de huidige ervaringen en uitgevoerde studies.

Maatregelen
Aangeraden wordt om de volgende voorzorgsmaatregelen in te stellen:

- Door middel van Real Time Simulaties het risico voor de specifieke te verwachten schepen inschatten
- Operationele grenzen bepalen
- Training

Met deze maatregelen wordt het effect als licht negatief beschouwd (-). Er zijn voorzorgsmaatregelen benodigd in de voorbereiding, waarmee de effecten afdoende beperkt worden.

Effect 1.2.3 - Doorvaart CO_2 binnenvaartschepen – rammen van schepen (0)
Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten

Informatie is afkomstig uit MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande CO_2 faciliteiten middels een desktopstudie is bepaald.

In deze studie is het aantal scheepvaart bewegingen in het Yangtzekanaal bepaald middels AIS data. Deze AIS data geeft aan dat er momenteel (2020) circa 330 schepen per dag passeren (120 zeeschepen en 210 binnenvaart). Autonome ontwikkelingen zullen verder leiden tot een significante vermeerdering.

De binnenvaart schepen zullen door het Hartelkanaal of de Nieuwe Waterweg door de haven van Rotterdam varen, om vervolgens door het Beerkanaal naar de locatie van de steigers koers te vatten. Het verkeer in de haven wordt gereguleerd door de Havenauthoriteit. Het totaal aantal binnenvaartschepen dat de haven van Rotterdam dagelijks aandoet is gemiddeld 275 per dag.

Omdat de intensiteit van de CO2next binnenvaartschepen te verwaarlozen is (Maximaal circa 4,5 per dag) op het totaal aantal schepen in de haven van Rotterdam en het Beerkanaal wordt het effect als nihil (0) ingeschaald.

Effect 1.2.4 - Doorvaart CO_2 zeeschepen – rammen van assets (-)
Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten

Met betrekking tot de doorvaart naar de Maasvlakte, het aantal incidenten in de haven van Rotterdam (Zeevaart en Binnenvaart) per jaar is circa 140, wat neerkomt op ongeveer 0,05% van de schepen die Rotterdam aandoen.

Het aantal binnenvaart schepen dat de CO2next terminal aan zal doen bedraagt 1496 per jaar. In de te volgen route binnen de haven van Rotterdam zit een groot aantal obstakels en belendende terminals. Desondanks is de route vanuit nautisch oogpunt voor binnenvaartschepen niet uitdagend. Het is een bestaande route die dagelijks door vele schepen wordt bevaren, zonder noemenswaardige incidenten.

Met betrekking tot de manoeuvre naar de steigers, verwezen wordt naar brief HBR-2244094 (3-3-2022) waarin de havenmeester aangeeft dat hij het risico van aanvaren acceptabel vindt, gebaseerd op de huidige ervaringen en uitgevoerde studies.

Het effect wordt als licht negatief ingeschat (-), wat aangeeft dat voorzorgsmaatregelen benodigd zijn in de voorbereiding, maar dat verwacht wordt dat de effecten daarmee afdoende gemitigeerd zullen kunnen worden. Zie voor de voorzorgsmaatregelen de beschrijving bij Effect 1.2.2.

Effect 1.2.5 - Afmeren van CO2 zee schepen of CO_2-binnenvaart (0)
Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten

Informatie afkomstig uit de brief HBR-2244094 (3-3-2022) waarin de havenmeester aangeeft dat hij het risico van aanvaren acceptabel vindt, gebaseerd op de huidige ervaringen en uitgevoerde studies.

De finale benadering van de afmeervoorzieningen wordt niet als uitdagend gezien. Het volgen van een normaal ontwerp proces, inclusief Real Time Simulatie van de afmeerprocedure zal verder bevestigen dat er geen zorgen zijn met betrekking tot de nautische veiligheid. Het effect wordt als nihil ingeschat (0).

Effect 1.2.6 - Verlading van CO_2 (0)
Verlies van CO_2-product tijdens de verlading door proces fouten, ondeugdelijk materiaal of brekende afmeerlijnen, bijvoorbeeld door passerende schepen of stroming uit uitlaat

De veiligheid van het verladen van CO_2 op de steiger is geen onderdeel van de Nautische veiligheidsaspecten, behalve daar waar het gaat om de stabiliteit van het afmeersysteem. Specifieke aspecten voor de situatie in de Yangtze haven zijn:

- Hydraulische belastingen ten gevolge van passerende schepen
- Stromingen ter plaatse van de koelwater uitlaat

Informatie is afkomstig uit studie D10054101:43 (19-5-2022) van ARCADIS en naar 33932.600/v2 (8-2-2022) van MARIN, waarin het afmeersysteem is geconfirmeerd middels Dynamische Mooring Analysis (DMA), rekening houdend met passerende schepen en stromingen uit het uitlaatsysteem.
In overleg met de havenautoriteit zouden voorzorgsmaatregelen zoals een snelheidsbeperking ingesteld kunnen worden.

Deze effecten zijn goed te voorspellen in gedetailleerde studies en vormen daarom geen significante bedreiging voor het afmeersysteem. Het effect wordt als nihil ingeschat (0).

Effect 1.2.7 - Marine terminal - Rammen van de constructie door derden (-)
Informatie is afkomstig uit MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande ligplaatsen voor Liquid CO_2 (LCO2) schepen middels een desktopstudie is bepaald.

In deze studie is het aantal scheepvaart bewegingen in het Yangtzekanaal bepaald middels AIS data. Deze AIS data geeft aan dat er momenteel (2020) circa 330 schepen per dag passeren (120 zeeschepen en 210 binnenvaart). Autonome ontwikkelingen zullen verder leiden tot een significante vermeerdering.

Verwezen wordt naar brief HBR-2244094 (3-3-2022) waarin de havenmeester aangeeft dat hij het risico van aanvaren acceptabel vindt, gebaseerd op de huidige ervaringen en uitgevoerde studies.

In de MARIN studie worden de risico’s ingeschat als soortgelijk aan de risico’s in een studie uitgevoerd in 2011 voor toendertijd geplande ligplaatsen voor LNG schepen. De praktijk in de laatste 10 jaar bevestigt het gemodelleerde beeld.

Omdat autonome ontwikkelingen zullen leiden tot een toename van het aantal scheepsbewegingen in het Yangtzekanaal wordt geadviseerd, in navolging van de voorwaarde van de havenmeester, om een Risico studie en effectenstudie voor de situatie 2040/2050 uit te voeren.

Ondanks de uitgevoerde studies, wordt het risico van aanvaring van de steiger door derden vooralsnog als significant ingeschat en daarom licht negatief gescoord (-). Verdere probabilistische analyse, zoals gepland te worden uitgevoerd in 2023, zal uitwijzen in hoeverre het risico gemitigeerd zal moeten worden.

5.2 Zeeleidingen

Effect 2.2.1 - Aanlanding in Rotterdam (0)
Lekken primaire waterkering door doorkruising van de leiding.

De zeewering wordt door RWS beschouwd als een primaire zeewering. Deze ligt echter buitendijks en helpt dus niet om overstromingen te voorkomen. Er mag vanuit gegaan worden dat het ontwerp en de constructie van de aanlanding voldoende adequaat zal zijn. Aangezien het haventerrein boven het waterniveau ligt, is er geen risico van overstroming (0).

Effect 2.2.2 - Kruising van de Maasgeul (0)
Verankeringen voor drijvend materieel tijdens onderhoud hinderen doorgaand scheepvaartverkeer

Er wordt vanuit gegaan dat er geen uitwendig onderhoud nodig is gedurende de levensduur van de buisleiding en het effect is daarom nihil (0).

Effect 2.2.3 - Zeeleiding tracé tot distributieplatform (0)
Falen van de buisleiding door:
a. Corrosie

b. Te hoge druk in de pijplijn

Volgens de MER Porthos, I&BBF8260R001.D0.1, datum 1-9-2020, heeft de zeeleiding een zekere faalkans. De kans op falen wordt voor circa 50% bepaald door corrosie en materiaal defecten en voor 25% door impact van bijvoorbeeld ankers. De faalkans van niet-begraven transportleidingen over zee, met een diameter kleiner dan 24 inch is circa 5,0 * 10-5 per km per jaar. De Aramis pijplijn is 32” en kent een soortgelijk risico van falen.

Indien de CO_2 vrijkomt onderwater, dan zal zich een zogenaamde “bubble plume” vormen. Deze bubble plume zal de uitstromingssnelheid van het CO_2 reduceren en voorkomen dat er jet dispersie optreedt. De intensieve menging van CO_2 bij vrijkomen met het zeewater zal ervoor zorgen dat vrijgekomen CO_2 direct de temperatuur aanneemt van het zeewater. Daarnaast kan een gedeelte van het CO_2 in het water oplossen. Bij kleinere waterdieptes zal de “bubble plume” leiden tot verminderde dichtheid van het water en potentieel instabiliteit van een schip.

De kans dat een (vissers-) schip zich direct boven een falende buisleiding zal bevinden wordt als zeer klein ingeschat, tenzij het (vissers-) schip zelf de oorzaak is van het falen. Het wordt daarnaast niet waarschijnlijk geacht dat het plaatselijke verlies van hydrostatische druk zal leiden tot verlies van stabiliteit van een (Vissers-) schip (0).

Effect 2.2.4 Zeeleiding tracé tot distributieplatform (--)
Beschadigen van de buisleiding door:
a. Zinken schip na rammen of anderszins
b. Slepen van ankers
c. Slepen van vissers gerei
d. Gevallen lading
e. Aanraking door kiel schip of bouwmaterieel

Het risico op een ongeval is aanwezig bij beschadiging van de buisleiding door aanvaring door de scheepvaart.

In 2011 heeft MARIN voor een soortgelijk project uitgevoerd (CO_2 opslag met een buisleiding vanaf de Maasvlakte), ref. 24114.620/3B, gedateerd 22 februari 2011. Daarin is onderzoek gedaan naar de kans op een incident met de buisleiding door passerende scheepvaart.

De kans op een incident is bepaald met ongevalskansmodules van het SAMSON model (Safety Assessment Model for Shipping and Offshore on the North Sea). Het model is ontwikkeld voor Rijkswaterstaat Noordzee en wordt gebruikt om de kansen en consequenties van alle type ongevallen op zee te schatten. Ook wordt het SAMSON model gebruikt om de impact van deze ongevallen op het veiligheidsniveau te voorspellen. Voor de berekeningen wordt gebruik gemaakt van een verkeersdatabase die de dichtheid, samenstelling en het gedrag van het scheepvaartverkeer beschrijft.

Het verkeer op zee wordt onderverdeeld in twee groepen, namelijk het ‘routegebonden’ en het ‘niet routegebonden’ verkeer (R-schepen en N-schepen). Het routegebonden verkeer bevat de scheepsbewegingen van de koopvaardijschepen, die op weg zijn van haven A naar haven B. Het niet routegebonden verkeer bevat de scheepsbewegingen van de schepen die een missie ergens op zee hebben, zoals visserij, bevoorradingsvaart, werkvaart en recreatievaart.
De vier hoogste ongevalfrequenties zijn:

- Vissende vissersschepen die over de buisleiding varen;
- Anker haakt achter de buisleiding;

- Containers vallen overboord op de buisleiding;
- Schip zinkt op buisleiding (wel of niet als gevolg van een aanvaring).

Tabel 5-1. Frequenties gebeurtenissen voor elk deel van de zeeleiding

Tabel 4-1 Frequentie per gebeurtenis voor elk deel van de pijpleiding

Pijp	Van		Naar		Lengte	Passages over pijp			Gezonken op pijp na een aanvaring			Gezonken op pijp zonder aanvaring		
	NB	OL	NB	OL		aantal/km/jaar			aantal/km/miljoen jaar			aantal/km/miljoen jaar		
Sectie	° '	° '	° '	° '	km	R-schip	N-schip	Totaal	R-schip	N-schip	Totaal	R-schip	N-schip	Totaal
1	5208	356	5208	357	0.446	0	89	89	0.000	0.593	0.593	0.000	0.256	0.256
2	5208	357	5204	403	10.383	878	301	1179	1.556	1.128	2.684	1.426	0.517	1.943
3	5204	403	5202	403	3.496	0	706	706	0.000	1.868	1.868	0.000	0.827	0.827
4	5202	403	5200	402	2.575	0	699	699	0.000	1.651	1.651	0.000	0.707	0.707
5	5200	402	5159	402	2.380	27253	699	27952	39.098	1.649	40.748	32.699	0.707	33.406
Totaal					19.280	3837	472	4309	5.664	1.384	**7.048**	4.804	0.616	**5.420**

Tabel 4-2 Frequentie per gebeurtenis voor elk deel van de pijpleiding (vervolg)

Pijp	Container overboord op pijp			Dek lading op pijp			Anker op pijp			Anker haakt achter pijp			Vissend vissersschip vaart over pijp
	aantal/km/miljoen jaar			aantal/km/miljoen jaar			aantal/km/miljoen jaar			aantal/km/miljoen jaar			aantal/km/jaar
Sectie	R-schip	N-schip	Totaal	R-schip	N-schip	Totaal	R-schip	N-schip	Totaal	R-schip	N-schip	Totaal	Vissersschip
1	0.000	0.000	0.000	0.000	0.006	0.006	0.000	0.076	0.076	0.000	0.272	0.272	57
2	20.787	0.000	20.787	0.129	0.018	0.148	0.401	0.171	0.572	4.166	0.574	4.741	67
3	0.000	0.000	0.000	0.000	0.037	0.037	0.000	0.327	0.327	0.000	0.913	0.913	90
4	0.000	0.000	0.000	0.000	0.034	0.034	0.000	0.306	0.306	0.000	0.773	0.773	78
5	62.678	0.000	62.678	4.205	0.034	4.239	12.916	0.305	13.221	140.784	0.772	141.555	78
Totaal	18.932	0.000	**18.932**	0.589	0.026	0.614	1.810	0.232	2.042	19.623	0.680	**20.302**	74

De frequenties die samenhangen met R-schepen zijn uitsluitend relevant voor trajecten in de directe nabijheid van navigatiekanalen. Op die lokaties zullen mitigerende maatregelen getroffen worden zoals bijvoorbeeld het begraven van de buisleiding.

Op andere lokaties wordt er mitigerende maatregelen getroffen om het risico te verminderen van zinkende schepen en vallende lading, zoasl bijvoorbeeld het aanhouden van een minimale afstand van 1 nautical mile tussen de vaarweg en het tracé van de zeeleiding De inschatting binnen het kader van dit rapport is dat de kans op vallende lading buiten de vaargeul verwaarloosbaar is. Begraven zou een passende mitigerende maatregel zijn.

Voor de N-schepen is met name de frequentie van passerende vissende vissersschepen van belang. Op basis van de analyse van MARIN voor het soortgelijke project, worden alle andere risico's als beperkt ingeschaald.

Voor het risico van beschadigingen ten gevolge van vissende vissersschepen, waarbij de slepende netten de pijpleiding beschadigen, (Er passeren circa 80 vissende schepen/ km/ jaar) wordt geadviseerd aanvullende maatregelen te treffen.

In afwachting van deze studie en op basis van de MARIN studie wordt het risico op beschadiging vooralsnog als hoog ingeschat en daarom negatief gescoord (- -).

Opgemerkt wordt dat er een risico gedreven aanpak in het ontwerp zal worden toegepast waarin de risico's geïnventariseerd worden en het ontwerp aangepast totdat de risico's acceptabel zijn in overeenstemming met de geldende (NEN) normen.

Effect 2.2.5 - Kruisingen van pijpleidingen en kabels (0)
Beoogd tracé interfereert met bestaande infrastructuur

Het traject van de buisleiding is bepaald, rekening houdend met de bestaande infrastructuur. Informatie is afkomstig uit rapport 416010-00257 - ARM-CPT-BB3-PLR-REP-0066_1, 05 April 2023, Routing.

Informatie is afkomstig uit rapport 416010-00257 - ARM-CPT-BB3-PLR-REP-0048_2, van datum 19 March 2023; Crossing inventory.
Het totaal aantal kruisingen van pijpleidingen is 47, exclusief Neptune Energy aansluiting.

Tabel 5-2. Aantal kruisingen pijpleidingen

Section	Type 1	Type 2	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Total
NS HDD	1		1	1				2	1	6
A	5				1	9	1	7	5	28
C		2	1				1		2	6
D		1			1				1	3
F			3		1					4
Total	6	3	5	1	3	9	2	9	9	47

De kruisingen zijn onderverdeeld in 10 typen.

Tabel 5-3. Definitie typen kruisingen

Crossed infrastructure	Aramis buried	Aramis on seabed
Pipeline buried, < 16-inch	Type 1	Type 2
Pipeline on seabed, 16 to 24-inch	Type 3	Type 4
Pipeline on seabed, 24 to 36-inch	Type 5	Type 6
cable buried	Type 7	Type 8
cable abandoned/OOS	Type 9 cut and remove section	Type 10 no action

Voor elk type is een ontwerp gemaakt, waarin op gecontroleerde wijze de kruising tot stand gebracht kan worden.

De impact van het traject wordt daarom als nihil beschouwd (0).

Effect 2.2.6 - Kruisingen met navigatiegebieden (0)
Beoogd tracé interfereert met bestaande navigatiegebieden
Het traject van de buisleiding is bepaald, rekening houdend met bestaande infrastructuur, zoals het Verkeers Scheidings Stelsel en bestaande pijpleidingen en kabels. Informatie is afkomstig uit rapport 416010-00257 – ARM-CPT-BB3-PLR-REP-0066_1, 05 April 2023, Routing.

Er wordt een bufferzone tussen de navigatieroute en de leidingen tracé aangehouden van minimaal 1 nm. Daarnaast wordt de navigatieroute gekruist met een minimale hoek van 30 graden.

Figuur 5-2: Alternatieve leidingen tracés nabij BBL gaspijplijn

Ter plaatse van de BBL gas pijplijn zijn er twee alternatieve routes gedefinieerd. De rode route is de gekozen route. De alternatieve (Gele) route is niet geprefereerd met name omdat in die route meer leidingen worden gekruisd.

Het traject van de buisleiding is bepaald, rekening houdend met de bestaande infrastructuur en vaarroutes. De impact van het traject wordt daarom als nihil beschouwd (0).

5.3 Platforms; distributieplatform, nieuwe en bestaande platforms

Tijdens de gebruiksfase worden de platforms ge-serviced, gebruik makend van Offshore Support Vessels (OSV's). De platforms zijn gesitueerd in de drukbevaren Noordzee. Er bestaat daarom een risico dat de platforms worden aangevaren en beschadigd door ongecontroleerde schepen.

Effect 3.2.1 - Platform faalt door aanvaring service schip (-)
Informatie is afkomstig uit:

- rapport A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment.
- A07 External Hazards Assessment, K6CC, March 2023

- Abbott risk consulting, ARC-001-231-R004, April 2022, TEPNL Passing Vessel Collision Study L4A

In deze rapporten worden de risico's van rammen door "Infield" schepen (Schepen direct betrokken bij de operatie van de platforms) bepaald. De geschiedenis geeft aan dat met dit soort schepen de risico's van rammen relatief groot zijn:

- De schepen zijn per definitie regelmatig in de nabijheid van de platforms
- De afmeting van de schepen is relatief groot
- De schepen hebben een relatief grote aankomstsnelheid

Veel operaties worden uitgevoerd met walk-to-work vessels (W2W), welke voorzien zijn van 3D bewegingscompensatie voor de kranen en loopbruggen. Ook jack up platforms (JUP) kunnen gebruikt worden, welke een stabiel platform bieden. W2W vessels zijn self propelled, terwijl JUP's door sleepboten naar hun positie worden gebracht.

Door meer betrouwbaar materieel en betere veiligheidsprocedures is het aantal incidenten over de afgelopen jaren significant afgenomen. De kans op impact wordt uitgerekend als 1/150 jaar, wat hoger is dan voor passerende schepen. De impact energie is echter, door de lage snelheid, lager.

Voorzorgsmaatregelen kunnen bestaan uit bijvoorbeeld

- Instellen van operationele beperkingen
- Ontwerpen van afmeervoorziening welke geen invloed heeft op de product verlading
- Emergency ShutDown faciliteiten
- Training
- Adequaat liftplan
- Collision risk management plan, inclusief remote monitoring
- Remote operations waar mogelijk
- Platform voldoende sterk ontwerpen;
- Kwetsbare elementen zoals conductors en stijgpijp beschermen door constructie

Al met al, met name door de mogelijke goede voorbereiding en de geringe gevolgen, wordt het effect van aanvaring en beschadiging door werkschepen als klein ingeschat (-).

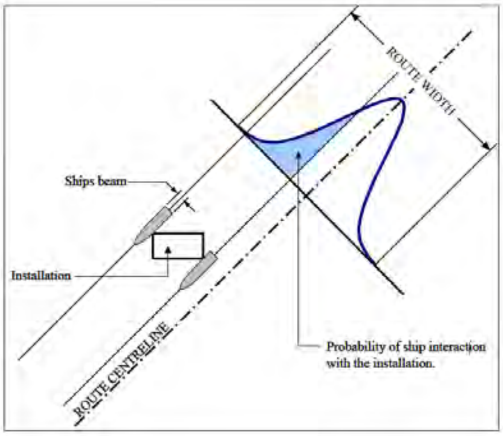
Effect 3.2.2 - Platform faalt door aanvaring schip van derden (--)
Informatie is afkomstig uit:

- rapport A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment.
- A07 External Hazards Assessment, K6CC, March 2023
- Abbott risk consulting, ARC-001-231-R004, April 2022, TEPNL Passing Vessel Collision Study L4A

In deze rapporten worden de risico's van rammen van de platforms door verschillende schepen geanalyseerd:

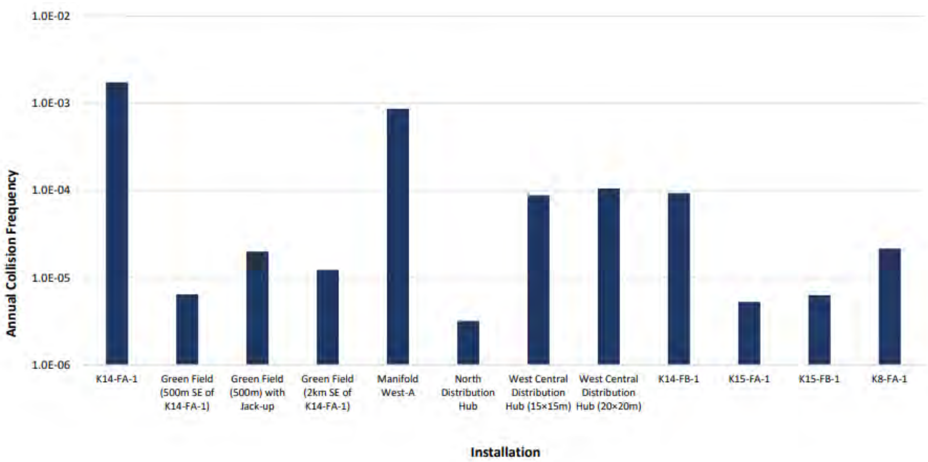
1. Passerende schepen
2. Passerende driftende schepen
3. Passerende vissersschepen

Ad 1:
Het programma COLLRISK is gebruikt om de risico's op aanvaring van de offshore platforms door derden te bepalen. Het model is erop gebaseerd dat de aanvaring frequentie proportioneel is met het volume en de nabijheid van naburige schepen. Historische data laat zien dat de meest waarschijnlijke oorzaak van het rammen van schepen ligt in menselijke fouten.
In het model is de verkeersintensiteit, gemiddelde positie en standaarddeviatie van de scheepsvaartroutes gebruikt om het ram risico van de platforms te bepalen.



Figuur 5-3: Definitieschets standaarddeviatie scheepvaartroute

De hoogste bepaalde frequentie is een kans op voorkomen van 1 op de 570 jaar. Platform K14-F-1A en Manifold West A hebben de hoogste kans op aanvaring.



Figuur 5-4: Kans op aanvaring Aramis platformen (Bron: rapport A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment)

Het centrale platform is nog in ontwikkeling. Meer studie is nodig om de exacte risico's en effecten van passerende schepen op het centrale platform in kaart te brengen. In afwachting van deze studie is het effect op significant ingeschat.

Ad 2.
Het programma COLLRISK is gebruikt om de risicos op aanvaring van de offshore platforms door derden te bepalen. De module voor driftende schepen gaat ervan uit dat de motor moet falen voordat een schip

gaat driften. Het model houdt rekening met de mogelijkheid dat schepen meerder motoren kunnen hebben.

De hoogste bepaalde frequentie is een kans op voorkomen van 1 op de 6800 jaar.

Ad 3.
De activiteiten door vissers schepen zijn niet-routine activiteiten en kunnen daarom niet met COLLRISK worden gesimuleerd. Het gebruikte model benut AIS data om de kans te bepalen dat vissersschepen in de buurt van de platforms komen, met het risico op rammen als gevolg.

De hoogst gevonden frequentie dat een vissersschip een platform raakt is eens per 12.000 jaar.

Aangezien een aantal platforms relatief dicht bij de VSS liggen, is de kans op rammen daardoor relatief hoog. De mogelijke voorzorgsmaatregelen om rammen te voorkomen, zoals NAVAIDS, lichten voor zichtbaarheid vanuit platforms, lijken beperkt, alhoewel de veiligheidsafstand van 500m bijdraagt aan de vermindering van het risico. Er zijn wel maatregelen mogelijk om de nadelige gevolgen te mitigeren, zoals bijvoorbeeld robuust constructief ontwerp of implementatie van Emergency Shutdown Systems.

Met name vanwege de onzekerheden en nog niet definitieve studies omtrent het centrale platform wordt het effect als significant ingeschat (--).

Effect 3.2.3 - Impact van service operaties op marine leven (0)
Het aantal additionele service schepen is beperkt, in vergelijking tot het aantal schepen op de Noordzee. De effecten zijn daarom nihil (0).

Effect 3.2.4 - Service schepen botsen met derden (Scheepvaart, platforms, windpark) (0)
Het aantal service activiteiten per platform wordt ingeschat als volgt (Referentie rapport A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment).

Tabel 5-4. Service activiteiten per platform

Type of Operation	Vessel type	Typical Vessel	Number of Days over 15 Years	Annual Hours
Planned	W2W / Support vessel	Kasteelborg / Kroonborg	299	239
	Stimulation vessel	Island Captain / Island Centurion	48	38
	Supply Vessel	VOS Patience	100*	27
Unplanned	50% W2W / 50% using synergy with other works (i.e., no additional visits)	Kasteelborg / Kroonborg	30	24
	50% W2W / 50% using synergy with other works (i.e., no additional visits)		30	24

*The number of supply vessel visits is based on information provided by the client. Visits are conservatively assumed to take an average of four hours.

Het aantal additionele service schepen is beperkt, in vergelijking tot het huidig aantal schepen op de Noordzee. De effecten zijn daarom nihil (0).

5.4 Samenvatting en conclusies

Tabel 5-5. Samenvatting effectbeoordeling Gebruiksfase

Nummer	Aspect	Effect	Effectbeoordeling	Gebruikte studie
1.2.1	Doorvaart zeeschepen	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten, met als gevolg rammen van schepen	(0)	AIS Data, MARIN studie 33932.601_v1 7-3-2022 Data Website HbR Inschatting CO2next schepen
1.2.2		Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten, met als gevolg rammen van assets	(-)	brief HBR-2244094 (3-3-2022) Data website HbR
1.2.3	Doorvaart binnenvaart	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten, met als gevolg rammen van schepen	(0)	AIS Data, MARIN studie 33932.601_v1 7-3-2022 AIS Data Data website HbR Inschatting CO2next schepen
1.2.4		Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten, met als gevolg rammen van assets	(-)	HBR-2244094 (3-3-2022) Data website HbR
1.2.5	Afmeren	Uit de koers lopen door ondeugdelijk materiaal of menselijke fouten	(0)	HBR-2244094 (3-3-2022) Expert judgement
1.2.6	Verlading	Verlies van CO_2 product tijdens de verlading door proces fouten, ondeugdelijk materiaal of rammen door derden	(0)	D10054101:43 (19-5-2022) van ARCADIS 33932.600/v2 (8-2-2022) MARIN
1.2.7	Marine terminal	Rammen van de constructie door derden	(-)	HBR-2244094 (3-3-2022) MARIN studie 33932.601_v1 7-3-2022
2.2.1	Aanlanding in Rotterdam	Lekken primaire waterkering door doorkruising van de leiding	(0)	Expert judgement
2.2.2	Kruising van de Maasgeul	Verankeringen voor drijvend materieel tijdens onderhoud hinderen doorgaand scheepvaartverkeer	(0)	Expert judgement
2.2.3	Zeeleiding tracé tot distributieplatform Zeeleiding tracé to platforms	Falen van de buisleiding door: a. Corrosie b. Te hoge druk in de pijplijn	(0)	MER Porthos, I&BBF8260R001.D0.1, datum 1-9-2020
2.2.4		Falen van de buisleiding door: a. Zinken schip na clash of anderszins b. Draggen van ankers c. Draggen van vissers netten d. Gevallen lading e. Aanraking door kiel schip	(- -)	MARIN ref. 24114.620/3, 22 februari 2011

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Nummer	Aspect	Effect	Effectbeoordeling	Gebruikte studie
2.2.5	Kruisingen van pijpleidingen en kabels	Beoogd tracé interfereert met bestaande infrastructuur	(0)	416010-00257 – ARM-CPT-BB3-PLR-REP-0066_1, 05 April 2023, Routing. 416010-00257 – ARM-CPT-BB3-PLR-REP-0048_2, 19 March 2023; Crossing inventory
2.2.6	Kruisingen met navigatiegebieden	Beoogd tracé interfereert met bestaande navigatiegebieden	(0)	416010-00257 – ARM-CPT-BB3-PLR-REP-0066_1, 05 April 2023, Routing.
3.2.1	Distributieplatform Nieuwe platforms (Neptune Energy en Shell) Connectie op bestaande platforms	Platform faalt door aanvaring service schip	(-)	A4863-SHE-CRA-1, 1 juni 2022, Vessel collision risk A07 External Hazards Assessment, K6CC, March 2023 ARC-001-231-R004, April 2022, TEPNL L4A
3.2.2		Platform faalt door aanvaring schip van derden	(--)	A4863-SHE-CRA-1, 1 juni 2022, Vessel collision risk A07 External Hazards Assessment, K6CC, March 2023 ARC-001-231-R004, April 2022, TEPNL L4A
3.2.3		Impact van service operaties op marine leven	(0)	Expert judgement
3.2.4		Service schepen botsen met derden (Scheepvaart, platforms, windpark)	(0)	A4863-SHE-CRA-1, 1 juni 2022, Vessel collision risk

De belangrijkste aandachtspunten zijn:

- De LCO_2 schepen zullen moeten manoeuvreren door de druk bevaren Rotterdamse haven. Dit is niet ongebruikelijk, maar zal wel met de nodige afstemming gepand moeten worden.
- De platforms zijn kwetsbaar voor passerende schepen, als ook serviceschepen.
- Het aantal passerende schepen in het Yangtzekanaal zal autonoom verder groeien, met significante kans op aanvaring van de CO2next steigers. De afgemeerde CO2next schepen dienen fysiek of operationeel beschermd te worden tegen aanvaring.
- Met name de vissersschepen hebben een redelijke kans om de buisleiding te beschadigen op lokaties waar de buisleiding niet begraven is.

6 Milieuaspecten aanlegfase en ontmantelingsfases

Dit hoofdstuk gaat per Aramis onderdeel in op de effecten op het thema nautische veiligheid, zoals die verwacht worden tijdens de aanleg en de ontmanteling van de CCS-keten. Waar nodig wordt onderscheid gemaakt naar de startfase en de eerste uitbreidingsfase. Tevens bevat het hoofdstuk een doorkijk naar de effecten (Consequenties) die verwacht worden voor de eindfase.

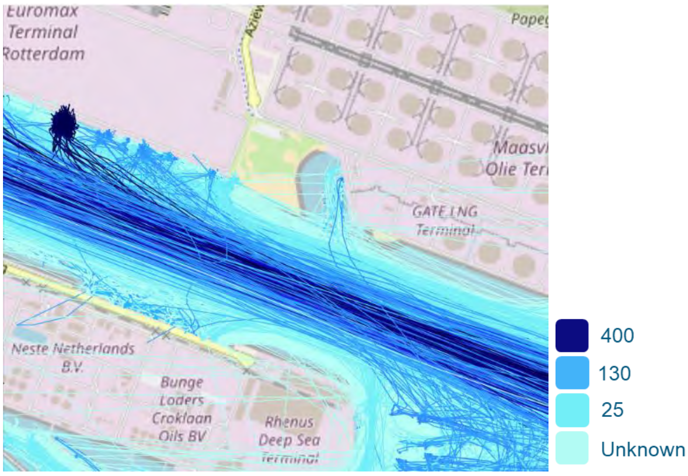
6.1 Terminal en scheepvaart

De effecten tijdens de aanleg betreffen het hinderen van de scheepvaart en de risico's van een aanvaring. Bij inspectie, reparaties en/of herbegraven zijn vergelijkbare effecten op de scheepvaart te verwachten als bij de aanleg.

Effect 1.1.1 - Ongecontroleerd drijvend bouwmaterieel (-)
Informatie is afkomstig uit MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande CO_2 faciliteiten middels een desktopstudie is bepaald.

De breedte van het Yangtzekanaal is circa 500m, waarvan 300m beschikbaar is voor doorvaart. Het Yangtzekanaal biedt daarom relatief weinig ruimte voor drijvend materieel, terwijl de normale scheepvaart doorgang zal moeten hebben. In het geval van ongecontroleerd drijvend materieel, zal er redelijke kans zijn dat de doorgaande scheepvaart daar hinder van zal ondervinden.

Een overzicht van de huidige scheepvaart bewegingen in het Yangtzekanaal gebaseerd op AIS data. Deze AIS data geeft aan dat er momenteel (2020) circa 330 schepen per dag passeren (120 zeeschepen en 210 binnenvaart). Autonome ontwikkelingen zullen leiden tot een significante vermeerdering.



Figuur 6-1: Overzicht scheepvaartbewegingen in de nabijheid van Gate terminal, in een periode van 4 weken in 2023, colour-coded op scheepslengte

De werkmethodiek van de aanleg van de CO2next steigers zal hier rekening mee moeten houden, door voorzorgsmaatregelen te treffen in bijvoorbeeld extra verankeringen of het gebruik van Jack up platformen (JUP), welke niet verankerd zijn maar op spudpalen staan, danwel de inzet van sleepboten.

Het effect wordt licht negatief gescoord (-).

Effect 1.1.2 - Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer (0)
Informatie is afkomstig uit MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande CO_2 faciliteiten middels een desktopstudie is bepaald.
Het Yangtzekanaal biedt relatief weinig ruimte voor drijvend materieel, terwijl de normale scheepvaart doorgang zal moeten hebben. Drijvend materieel wordt vaak op ankers vastgelegd, waar hier beperkte ruimte voor is.
Mitigerende maatregelen zouden kunnen inhouden dat de constructiemethode van de steigers aangepast wordt, bijvoorbeeld door vanaf de oever uit te bouwen, of middels het gebruik van JUP's.

Daarmee zal de beperking van het scheepsvaartverkeer in het Yangtze kanaal tot een minimum beperkt kunnen worden, en dit effect is daarom neutraal gescoord (0).

Effect 1.1.3 - Rammen van bouwmaterieel of mariene constructies door derden (-)
Informatie is afkomstig uit MARIN studie 33932.601_v1 van 7 maart 2022, waarin het aanvaarrisico van de geplande CO_2 faciliteiten middels een desktopstudie is bepaald.

Het Yangtzekanaal biedt relatief weinig ruimte voor drijvend materieel, terwijl de normale scheepvaart doorgang zal moeten hebben. In het geval van ongecontroleerde scheepvaart, zal er redelijke kans zijn dat zij de in aanbouw zijnde faciliteiten rammen.

Een overzicht van de huidige scheepvaart bewegingen in het Yangtzekanaal gebaseerd op AIS data. Deze AIS data geeft aan dat er momenteel (2020) circa 330 schepen per dag passeren (120 zeeschepen en 210 binnenvaart). Autonome ontwikkelingen zullen leiden tot een significante vermeerdering.

De werkmethodiek van de CO2next steigers zal hier rekening mee moeten houden, bijvoorbeeld door mitigerende maatregelen te treffen in bijvoorbeeld extra beschermende maatregelen, zoals boeien of sleepboot bescherming of operationele beperkingen van de scheepvaart in overleg met de Havenauthoriteit.

Het effect wordt licht negatief gescoord (-).

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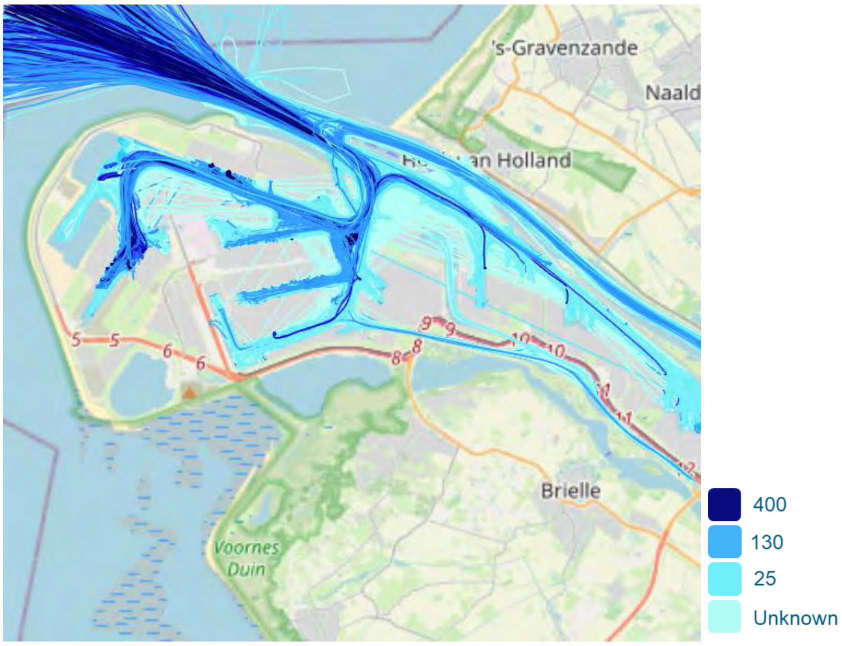
6.2 Zeeleidingen

Informatie is afkomstig uit “Overall Method Statement Construction Activities Aramis” gedateerd 11 Mei 2023, waarin globaal de constructiemethodiek van de zeeleiding wordt beschreven.

Effect 2.1.1 - Aanlanding pijpleiding op Maasvlakte (0)
Aanlegwerkzaamheden doorkruising leiding tasten stabiliteit waterkering aan.

Bij adequaat ontwerp en de uitvoering van de aanlanding zal er geen risico zijn voor instabiliteit van de oever. Aangezien het haventerrein boven het waterniveau ligt, is er geen risico van overstroming.

De drukte van de Maasgeul wordt weergegeven in de volgende figuur.



Figuur 6-2: Overzicht scheepvaartbewegingen in de Maasgeul (four weeks 2023), colour-coded by vessel length

In principe zullen de werkzaamheden voor de aanleg van een kruising op het land gedaan worden, van waaruit onder de waterkering en de Maasgeul geboord zal worden.

Het effect wordt als verwaarloosbaar gescoord (0).

Effect 2.1.2 - Kruising van de Maasgeul - Beschadigen bestaande pijplijnen (0)
Beschadigen bestaande pijplijnen door:

a) gestuurde boring
b) Drijvend materieel verankering
c) Spudpalen/ heien
d) Baggeren

De locatie van de bestaande leidingen is bekend en daar zal in de constructie rekening mee gehouden worden. Wel zal er NGE onderzoek (Onderzoek naar niet gesprongen oorlogsresten/ explosieven) uitgevoerd moeten worden voorafgaand aan de aanleg van de leiding.

De kans dat er onbekende leidingen beschadigd raken wordt als nihil ingeschat (0).

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Effect 2.1.3 - Kruising van de Maasgeul - hinderen doorgaand scheepvaartverkeer (0) / (--)
Hinderen doorgaand scheepvaartverkeer bijvoorbeeld door verankeringen voor drijvend materieel of druktesten leiding

Er zijn twee alternatieven voor de kruising van de Maasgeul, welke beide uitgaan van een gestuurde boring.

In de varianten met tunnel boringen ligt de geboorde buisleiding circa 10 m diep onder het diepste punt van de vaargeul en heeft daardoor geen impact op de scheepvaart en geen risico op aanvaring van de buisleiding. Een tijdelijk werkschip om de transportleiding en eventuele kabel te begeleiden die onder de Maasgeul wordt getrokken bij de boring onder de Maasgeul, zal ten noorden van de Maasgeul liggen. Gezien de vaste ligging van dit werkvaartuig is effect op het scheepvaartverkeer in de Maasgeul niet te verwachten. Scheepvaart ondervindt daarom nagenoeg geen hinder voor de aanleg van de leiding onder de Maasgeul door en worden de effecten als nihil beschouwd (0).

Voor de Direct Pipe uitvoeringsmethode wordt er een sleuf gegraven door de Maasgeul . Het verkeer in de Maasgeul zal daardoor enige tijd hinder ondervinden. Door een slimme planning waarbij de vaargeul niet volledig wordt afgesloten en geen gebruik gemaakt wordt van brede ankerlijnen, zal het effect nog enigszins beperkt kunnen worden. Tevens is het van belang dat de mogelijke stremming goed wordt gecommuniceerd aan de scheepvaart en loodsen, voorafgaand aan de werkzaamheden. Het effect wordt desalniettemin als hoog ingeschat en daarom negatief gescoord (- -).

Effect 2.1.4 - Kruising van de Maasgeul – rammen materiaal (-) / (0)
Rammen van bouwmaterieel of mariene constructies, inclusief ontvangstschacht, door derden

Voor de gestuurde boring, zal er een ontvangstschacht worden aangelegd ten noorden van de Maasgeul. Deze ontvangstschacht zal enkele weken in bedrijf zijn, voordat de buisleiding aan beide zijden aangesloten is. De ontvangstschacht ligt buiten de Maasgeul. Hoewel de werkzaamheden gecontroleerd worden uitgevoerd en er mitigerende maatregelen kunnen worden ingesteld om de schacht te beschermen, zoals bijvoorbeeld een beschermingsconstructie of permanente wachtschepen, wordt het effect als licht negatief gescoord (-). De reden is het grote aantal schepen dat passeert en de grote potentiële consequenties (Overlijden).

Voor het Direct pipe alternatief is dit geen issue (0).

Effect 2.1.5 - Kruising van de Maasgeul – Ongecontroleerd drijvend bouwmaterieel (0)
Tijdens de aanleg van de transportleiding zullen werkvaartuigen in de Maasmond aanwezig zijn. De werkzaamheden zijn van tijdelijke aard. Maatregelen zullen worden ingesteld in overleg met de Havenmeester zodanig dat de kans op rammen nihil zal zijn (0).

Effect 2.1.6 – zeeleiding tracé – beschadiging leidingen (0)
Beschadigen bestaande, niet bekende, pijpleidingen door baggeren of verankering drijvend materieel

Het werkvaartuig dat de transportleiding legt, start de werkzaamheden ten noorden van de Maasgeul in het geval van de microtunnel optie. De drukke Maasgeul scheepvaartroute zal dus niet gekruist worden.

Voor de Direct Pipe optie wordt de Maasgeul wel gekruist.

Informatie is afkomstig uit rapport 416010-00257 - ARM-CPT-BB3-PLR-REP-0048_2, van datum 19 March 2023; Crossing inventory. Er is een inventarisatie gemaakt van de kruisingen op het tracé van de buisleiding, gebaseerd op Noordzeeloket, https://www.noordzeeloket.nl/en/up-date-atlas/.

De buisleiding zal worden begraven op de lokaties waar een navigatiekanaal wordt gekruist, of op de lokaties waar zand duinen kunnen zorgen voor constructieve instabiliteit. De totale lengte van de buisleiding die begraven zal worden is 110 km (105 km Sectie A, 5 km Sectie C),

- lengte 10 km, startend bij de aanlanding; reden scheepvaartactiviteiten
- lengte 75 km, start bij platform P18-A, reden zand duinen
- lengte 20 km, reden ondiep water scheepvaartactiviteiten
- Lengte 5 km, sectie C, reden diepwater scheepvaartactiviteiten

De locatie van de bestaande leidingen is bekend en daar zal in de constructie rekening mee gehouden worden. De kans dat er onbekende leidingen beschadigd raken wordt als nihil ingeschat (0).

Effect 2.1.7 – Kruisng leidingen en kabels (0)
Beschadigen bestaande pijpleidingen en kabels door baggeren, verankering drijvend materieel of kruisingswerkzaamheden
Informatie is afkomstig uit rapport 416010-00257 - ARM-CPT-BB3-PLR-REP-0048_2, van datum 19 March 2023; Crossing inventory.

Het totaal aantal kruisingen van pijpleidingen is 47, exclusief Neptune Energy aansluiting.

Tabel 6-1. Aantal kruisingen pijpleidingen

Section	Type 1	Type 2	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Total
NS HDD	1		1	1				2	1	6
A	5				1	9	1	7	5	28
C		2	1				1		2	6
D		1			1				1	3
F			3		1					4
Total	6	3	5	1	3	9	2	9	9	47

De kruisingen zijn onderverdeeld in 10 typen.

Tabel 6-2. Definitie typen kruisingen

Crossed infrastructure	Aramis buried	Aramis on seabed
Pipeline buried, < 16-inch	Type 1	Type 2
Pipeline on seabed, 16 to 24-inch	Type 3	Type 4
Pipeline on seabed, 24 to 36-inch	Type 5	Type 6
cable buried	Type 7	Type 8
cable abandoned/OOS	Type 9 cut and remove section	Type 10 no action

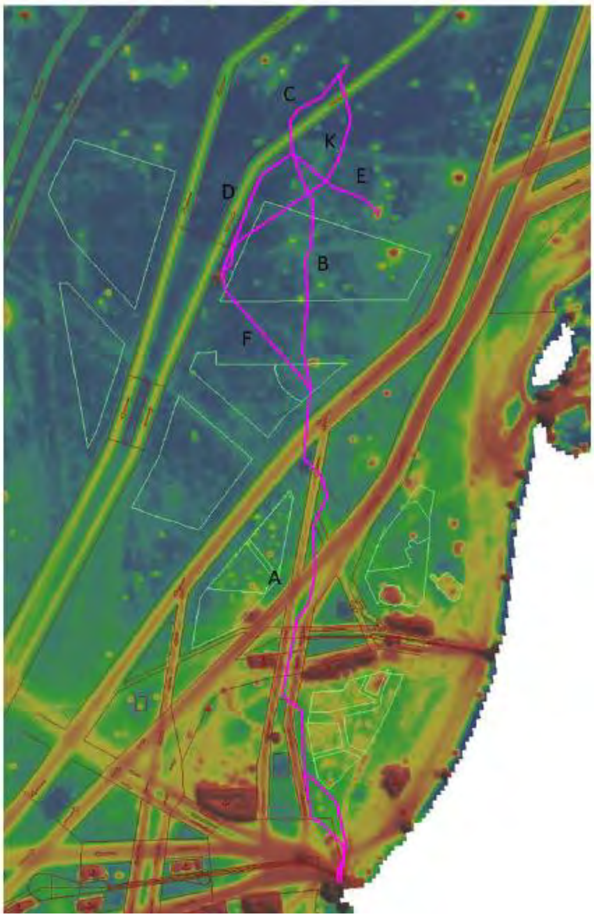
Voor elk type is een ontwerp gemaakt, waarin op gecontroleerde wijze de kruising tot stand gebracht kan worden. De kans op schade aan bestaande leidingen wordt daarom als nihil ingeschat (0).

Effect 2.1.8 - Kruisingen met navigatiegebieden (-)
Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer.

Het tracé kruist meerdere Verkeers Scheiding Stelsels (VSS). Het tracé kruist, naast de Maasgeul, 6 maal een navigatieroute en grenst op 2 lokaties aan een navigatieroute.

Het leggen van een ingegraven buisleiding zal gedaan worden door een combinatie van een legschip en een ingraafmachine. Afhankelijk van het type ingraafmachine, wordt de ingraafmachine begeleid door een ingraafschip of heeft deze een eigen aandrijving. In de effectbepaling wordt uitgegaan van een combinatie met een geschatte lengte van maximaal 2.000 m. De snelheid waarmee gevaren wordt is geschat op 3 km per dag.

Veelal zijn de hoeken van het werkvaartuig en het VSS niet haaks, en zal naar schatting maximaal 50% door het werkvaartuig worden ingenomen. Gezien de korte afstand en de werksnelheid, zal deze hinder naar verwachting gedurende een dag plaats vinden en is daarom licht negatief gescoord (-).



Figuur 6-3: Overzicht scheepvaartbewegingen in de Noordzee

Effect 2.1.9 – Kruising navigatiegebieden – rammen materieel (0)
Rammen van bouwmaterieel of mariene constructies door derden

Tijdens de aanleg van de transportleiding zullen werkvaartuigen in de VSS aanwezig zijn. Aanwezigheid van een guardvessel of sleepboot als begeleiding kan een goede voorzorgsmaatregel zijn. De werkzaamheden zijn van tijdelijke aard. Maatregelen zullen worden ingesteld in overleg met de Havenmeester en Kustwacht zodanig dat de kans op rammen nihil zal zijn (0).

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Effect 2.1.10 – Kruising navigatiegebieden - ongecontroleerd drijvend bouwmaterieel (0)
Tijdens de aanleg van de transportleiding zullen werkvaartuigen in de VSS aanwezig zijn. De werkzaamheden zijn van tijdelijke aard. Maatregelen zullen worden ingesteld in de constructie methodes zodanig dat de kans op losbreken nihil zal zijn (0).

Aanwezigheid van een sleepboot als begeleiding kan een goede mitigerende maatregel zijn.

6.3 Platforms; distributieplatform, nieuwe en bestaande platforms

Effect 3.1.1 - Nieuwe platforms (Neptune Energy en Shell) – (0)
Schade aan het platform bij:

- de load out (Door vallende kraan , vallende objecten);
- transport (Door zinkend transport schip, overbelaste constructie) of;
- installatie (Door botsend installatieschip, overbelaste constructie).

Informatie is afkomstig uit document 27.1726-GMT-210, offshore installation manual- Volume 1, Installation Manual for the D18a-A platforms van Seaway Heavy Lifting, waarin de installatie van 4 platforms wordt beschreven, inclusief:

- Transport;
- Pre-installatie activiteiten;
- Jacket installatie;
- Topsides installatie en;
- Commissioning.

Deze methodologie is beschreven voor daadwerkelijk in 2013 geïnstalleerde platforms. Er wordt vanuit gegaan dat een soortgelijke methodologie zal worden opgesteld voor de Aramis en Neptune platforms, waarbij de geleerde lessen uit 2013 zullen worden meegenomen.

Hoewel de activiteiten, door bijvoorbeeld de gewichten en de complexiteit van de activiteiten als risicovol beschouwd kunnen worden, is in de methodologie duidelijk dat de risico's onder controle zijn en afdoende gemitigeerd. De risico's op beschadiging van de platforms wordt daarom als nihil (0) beoordeeld.

Effect 3.1.2 – Distributieplatform - Connectie bestaande en nieuwe platforms (0)
Schade aan het platform bij connectie door botsend installatieschip, overbelaste constructie

Informatie is afkomstig uit het rapport A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment. In dit rapport wordt het risico van rammen door "Infield" schepen (Schepen direct betrokken bij de operatie van de platforms) bepaald. De geschiedenis geeft aan dat met dit soort schepen de risico's van rammen relatief groot zijn:

- De schepen zijn per definitie regelmatig in de nabijheid van de platforms.
- De afmeting van de schepen is relatief groot.
- De schepen hebben een relatief grote aanmeersnelheid.

Veel operaties worden uitgevoerd met walk-to-work vessels (W2W), welke voorzien zijn van 3D bewegingscompensatie voor de kranen en loopbruggen. Ook jack up platforms (JUP) kunnen gebruikt worden, welke een stabiel platform bieden. W2W vessels zijn self propelled, terwijl JUP's door sleepboten naar hun positie worden gebracht.

Door meer betrouwbaar materieel en betere veiligheidsprocedures is het aantal incidenten over de afgelopen jaren significant afgenomen. De kans op impact wordt uitgerekend als 1/150 jaar, wat hoger is dan voor passerende schepen. De impact energie is echter, door de lage snelheid, lager.

Mitigerende maatregelen kunnen bestaan uit bijvoorbeeld

- Instellen van operationele beperkingen;
- Goed liftplan.

Al met al, met name door de tijdelijke natuur en de mogelijke goede voorbereiding, inclusief het instellen van operationele restricties, wordt het effect van aanvaring en beschadiging door werkschepen als nihil ingeschat (0).

Effect 3.1.3 - Veranderingen aan bestaande platforms (0)
Schade aan het platform door extra functionaliteit van CO_2-transport over het platform, overbelaste constructie

De extra functionaliteit bestaat bijvoorbeeld uit een riser, pompen, etc. Er wordt geadviseerd een technische inspectie uit te voeren op het platform, waarbij ook de onderhoudsrapporten worden beschouwd.

De aanpassing van de constructie zal worden ontworpen, rekening houdend met de huidige staat van het platform en de benodigde versterking. De kans op schade aan de constructie door de extra belasting wordt daarom als nihil ingeschat (0).

6.4 Samenvatting en conclusies

Tabel 6-3. Samenvatting effectbeoordeling Constructiefase

Nummer	Aspect	Effect	Effect-beoor-deling	Gebruikte studie
1.1.1	Marine terminal	Ongecontroleerd drijvend bouwmaterieel	(-)	AIS data, MARIN studie 33932.601_v1 van 7 maart 2022
1.1.2		Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer	(0)	AIS data, MARIN studie 33932.601_v1 van 7 maart 2022
1.1.3		Rammen van bouwmaterieel of mariene constructies door derden	(-)	AIS data MARIN studie 33932.601_v1 van 7 maart 2022
2.1.1	Aanlanding in Rotterdam	Lekken waterkering door doorkruising van de leiding Impact op doorgaand scheepvaartverkeer	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.2	Kruising van de Maasgeul	Beschadigen bestaande pijplijnen door: a. gestuurde boring	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)

Nummer	Aspect	Effect	Effect-beoor-deling	Gebruikte studie
		b. Drijvend materieel verankering c. Spudpalen/ heien d. Baggeren		
2.1.3		Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer Tunnel Direct pipe	(0) (- -).	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.4		Rammen van bouwmaterieel of mariene constructies, inclusief ontvangstschaft, door derden Tunnel Direct Pipe	(-) (0).	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.5		Ongecontroleerd drijvend bouwmaterieel	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.6	Zeeleiding tracé tot distributieplatf orm Zeeleiding tracé tot platforms	Beschadigen bestaande- Niet bekende- pijpleidingen door baggeren of verankering drijvend materieel	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023) 416010-00257 – ARM-CPT-BB3-PLR-REP-0048_2, van datum 19 March 2023; Crossing inventory
2.1.7	Kruisingen van pijpleidingen en kabels	Beschadigen bestaande pijpleidingen door baggeren, verankering drijvend materieel of kruisingswerkzaamheden	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023) 416010-00257 – ARM-CPT-BB3-PLR-REP-0048_2, 19 March 2023; Crossing inventory
2.1.8	Kruisingen met navigatiegebie den	Verankeringen voor drijvend materieel hinderen doorgaand scheepvaartverkeer	(-)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.9		Rammen van bouwmaterieel of mariene constructies door derden	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
2.1.10		Ongecontroleerd drijvend bouwmaterieel	(0)	Overall Method Statement Construction Activities Aramis, (11 Mei 2023)
3.1.1	Nieuwe platforms (Neptune Energy en Shell)	Schade aan het platform bij de load out (Door vallende kraan, vallende objecten), transport (Door zinkend transport schip, overbelaste constructie) of installatie (Door botsend installatieschip, overbelaste constructie)	(0)	Constructie methode installatie platform 27.1726-GMT-210, 14 juni 2013

Nummer	Aspect	Effect	Effect-beoor-deling	Gebruikte studie
3.1.2	Distributie-platform Connectie op bestaande platforms	Schade aan het platform bij connectie (Door botsend installatieschip)	(0)	A4863-SHE-CRA-1, gedateerd 1 juni 2022, Aramis project, Vessel collision risk assessment
3.1.3		Schade aan het platform door extra functionaliteit, overbelaste constructie	(0)	Expert judgement

De belangrijkste aandachtspunten zijn:

- De CO2next steigers worden geconstrueerd direct naast het drukbevaren Yangtzekanaal. Mitigerende maatregelen dienen te worden genomen om de invloed van het drijvend bouwmaterieel op de passerende schepen te minimaliseren. Daarnaast dienen de te bouwen constructies fysiek of operationeel beschermd te worden tegen aanvaring.
- De Maasgeul is drukbevaren. Elke belemmering, bijvoorbeeld door de bouwactiviteiten van de aanlanding zullen impact hebben.
- Voor de gestuurde boring, benodigd voor de kruising van de Maasgeul, is een ontvangstschacht nodig. De eventuele consequenties van aanvaring van deze ontvangstschacht zijn zeer groot.
- Het doorgaand verkeer in de VSS dient beschermd te worden voor impact van verankeringen van drijvend materieel.

7 Milieuaspecten van Aramis als integraal systeem

In voorgaande hoofdstukken zijn de milieueffecten beschreven die de verschillende onderdelen van het Aramis initiatief teweegbrengen. Sommige aspecten zijn echter afhankelijk van het presteren van het systeem als geheel. Deze aspecten zijn in dit hoofdstuk beschreven.

Voor het aspect Nautische Veiligheid zijn geen aspecten met betrekking tot het integraal systeem geïdentificeerd. Dit hoofdstuk is daarom opzettelijk leeg gelaten.

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.

De levering van CO_2 vanaf leveranciers naar het verzamelpunt, zal deels plaatsvinden in gasvorm via de Porthos landleiding en deels in vloeibare vorm via schepen. In het MER is onderzoek gedaan naar de nautische veiligheid voor de schepen nabij de terminal, vanaf het heersende verkeersbeeld. Buiten de Aramis scope, maar wel ten gevolge van Aramis, vindt er het laden van de schepen bij de leverancier plaats en het transport vanaf de leverancier tot aan de haven van de terminal.

Het laden en transport heeft betrekking op CO_2 schepen, wat relatief nieuw is. De veiligheid bij het laden en transporteren, zowel de barges als de coasters zal door de leveranciers in beeld moeten worden gebracht en valt dus buiten de scope van dit MER.

Een deel van de transport en de constructie van 2 barges vindt plaats door de partijen betrokken bij Aramis. Deze activiteiten vallen echter niet onder de scope van de Aramis MER.

9 Leemten in kennis en voorstel voor monitoring

Dit beschrijft of en zo ja welke leemten in kennis er zijn voor de besluitvorming over het Aramis initiatief. Daarnaast bevat het een voorstel voor welke milieu-aspecten gemonitord moeten worden.

9.1 Leemten in kennis

Voorafgaand aan de werkzaamheden zal in overleg met de (Rijks)Havenmeester van Rotterdam, de Kustwacht en de directie Noordzee van RWS bepaald worden welke veiligheidsmaatregelen in acht genomen dienen te worden. Dit zal moeten gebeuren met de dan heersende kennis en ervaring.

Hiermee zullen eventuele negatieve effecten als hinder en aanvaarrisico's zoveel mogelijk worden vermeden.

Rapportages die later beschikbaar komen

- MARIN rapport 'Effecten scheepvaartveiligheid (DHUB en leidingen)' met hierin oa. een indicatie van de aanvarings-/ aandrijvingskansen en drijfvermogen bij lekkage leiding

10 Samenvatting bevindingen en toetsing wet- en regelgeving

De samenvattingen van de bevindingen en toetsing zijn gegeven in hoofdstuk 5 en 6 en worden omwille van uniformiteit hier niet herhaald.

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.

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