Gegevens bevoegd gezag

Referentienummer	Datum ontvangst

Formulierversie
2017.01

Aanvraaggegevens

Ingediende aanvraag/melding

Aanvraagnummer	2734121
Aanvraagnaam	Watervergunningaanvraag Viking Link
Uw referentiecode	DEN34-1 / VKL-07-30-J800-002

Ingediend op	17-08-2017
Soort procedure	Reguliere procedure

Projectomschrijving	De hoogspanningsverbinding Viking Link bestaat uit twee offshore hoogspanningsleidingen (gelijkstroom) en een datakabel tussen Denemarken en het Verenigd Koninkrijk met een totale lengte van circa 635 kilometer. Viking Link doorkruist de territoriale wateren van twee landen (het Verenigd Koninkrijk en Denemarken) en de EEZ van vier landen (het Verenigd Koninkrijk, Nederland, Duitsland en Denemarken) en heeft een transportcapaciteit van 1400 MW.
Opmerking	Let op: Bij KvK nummer van de aanvrager zijn de KvK gegevens van gemachtigde ingevuld omdat de aanvrager een buitenlands bedrijf betreft (geen KvK beschikbaar). De aanvraag is voorbesproken met Rik Duijts.
Gefaseerd	Nee
Blokkerende onderdelen weglaten	Nee
Persoonsgegevens openbaar maken	Nee
Bijlagen die later komen	-
Bijlagen n.v.t. of al bekend	-

Bevoegd gezag

Naam:	Rijkswaterstaat
Bezoekadres:	Avenue Ceramique 125 6221 KV Maastricht
Postadres:	Service Center Vergunningen Rijkswaterstaat Postbus 4142 6202 PA Maastricht
Telefoonnummer:	088-7974300
E-mailadres:	omgevingsloket@rws.nl
Website:	www.rijkswaterstaat.nl
Contactpersoon:	Service centre vergunningen
Bereikbaar op:	ma - vr: 9:00 - 16:30 uur

Overzicht bijgevoegde modulebladen

Aanvraaggegevens

Aanvragergegevens

Locatie van de werkzaamheden

Werkzaamheden en onderdelen

Activiteiten op de Noordzee of het strand uitvoeren

- Waterstaatswerk of beschermingszone gebruiken

Bijlagen

Formulierversie
2017.01

Aanvrager bedrijf

1 Bedrijf

KvK-nummer	38020751
Vestigingsnummer	000007345658
Statutaire naam	National Grid Viking Link Ltd
Handelsnaam	-

2 Contactpersoon

Geslacht	☑ Man ☐ Vrouw
Voorletters	D.
Voorvoegsels	-
Achternaam	Bean
Functie	Project Manager

3 Vestigingsadres bedrijf

Adresregel 1	National Grid Viking Link Ltd.
Adresregel 2	31 Homer Road, Solihull
Adresregel 3	Birmingham, B91 3LT
Land	Grootbrittannië

4 Correspondentieadres

Adresregel 1	National Grid Viking Link Ltd.
Adresregel 2	31 Homer Road, Solihull
Adresregel 3	Birmingham, B91 3LT
Land	Grootbrittannië

5 Contactgegevens

Telefoonnummer	07771 290 724
Faxnummer	-
E-mailadres	david.bean@nationalgrid.com

Formulierversie
2017.01

Gemachtigde bedrijf

1 Bedrijf

KvK-nummer	38020751
Vestigingsnummer	000007345658
Statutaire naam	Witteveen+Bos
Handelsnaam	Witteveen+Bos

2 Contactpersoon

Geslacht	☐ Man ☑ Vrouw
Voorletters	E.J.
Voorvoegsels	-
Achternaam	Overbosch-de Graaf
Functie	adviseur vergunningen

3 Vestigingsadres bedrijf

Postcode	7411 SC
Huisnummer	2
Huisletter	-
Huisnummertoevoeging	-
Straatnaam	van Twickelostraat
Woonplaats	Deventer

4 Correspondentieadres

Postbus	233
Postcode	7400 AE
Plaats	Deventer

5 Contactgegevens

Telefoonnummer	0620945025
Faxnummer	-
E-mailadres	jolanda.overbosch@witteveenbos.com

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Locatie

1 Locatieaanduiding

Locatie waar de werkzaamheden plaatsvinden

- ☐ Adres
- ☐ Kadastraal perceelnummer
- ☑ Locatie op Noordzee, Waddenzee of IJsselmeer

2 Aanvulling locatieaanduiding

Coördinatenstelsel

- ☐ RD
- ☑ ETRS89 / WGS84

Invoerwijze

- ☑ Graden.decimale graden
- ☐ Graden.minuten.decimale minuten
- ☐ Graden.minuten.seconden.decimale seconden

Lengte: 004,8218276°

Breedte: 55,08998493°

3 Toelichting

Eventuele toelichting op locatie: Zie lijst met coordinaten in de bijlage bij deze vergunningaanvraag

Formulierversie
2017.01

Waterstaatswerk of beschermingszone gebruiken

Activiteiten op de Noordzee of het strand uitvoeren

1 Waterstaatwerk of beschermingszone gebruiken

Wilt u een bestaande vergunning wijzigen?	☐ Ja ☑ Nee
Wat is de geplande begindatum van deze activiteit?	01-01-2019
Geef eventueel een toelichting op de begindatum.	Exacte startdatum is nog niet bekend.
Wat is de geplande einddatum van deze activiteit?	01-01-2119
Geef eventueel een toelichting op de einddatum.	Vergunning wordt aangevraagd voor onbepaalde tijd
Omschrijf de activiteit die u wilt uitvoeren.	Realisatie van een hoogspanningsverbinding. De watervergunningaanvraag heeft betrekking op de aanleg, het gebruik en de verwijdering van twee kabels op zee (± 525kV) en een optische vezelkabel (datakabel). De voorgestelde zeekabelcorridor in de Nederlandse EEZ bestaat uit een corridor die 170 km lang en 450 meter breed is.
Waarom wilt u de activiteit uitvoeren?	De hoogspanningsverbinding zal de hoogspanningsnetten van Denemarken en het Verenigd Koninkrijk verbinden, waardoor uitwisseling van elektriciteit tussen de twee landen mogelijk wordt gemaakt.

Formulierversie
2017.01

Waterstaatswerk of beschermingszone gebruiken

Activiteiten op de Noordzee of het strand uitvoeren

1 Kabels of leidingen aanleggen

Welke activiteit(en) wilt u uitvoeren met betrekking tot kabels of leidingen?	☑ Aanleggen van kabels of leidingen in of nabij een oppervlaktewaterlichaam ☐ Aanleggen van kabels of leidingen in, op of nabij een waterkering ☐ Aanleggen van kabels of leidingen in, op of nabij een oppervlaktewaterlichaam en een waterkering
Past u bij de werkzaamheden een horizontaal gestuurde boring toe die een oppervlaktewaterlichaam, waterkering of beschermingszone doorkruist?	☐ Ja ☑ Nee
Welke kabels of leidingen wilt u aanleggen?	☐ Aanleggen van een vloeistofleiding ☐ Aanleggen van kabels ☐ Aanleggen van een warmtetransportleiding ☐ Aanleggen van kabels ten behoeve van telecom/televisie ☐ Aanleggen van een drukleiding ☑ Anders
Welke andere kabels of leidingen legt u aan?	Hoogspanningsverbinding

Formulierversie
2017.01

Bijlagen

Formele bijlagen

Naam bijlage	Bestandsnaam	Type	Datum ingediend	Status document
VKL-07-30-J800--003--Toelichting aanvraag	DEN34-1-17-004--076--VKL-07-30-J800--003-rapc01--Toelichting aanvraag watervergunning.pdf	Anders Situatietekening, kaart of foto Gegevens waterstaatswerk of beschermingszone gebruiken	2017-08-17	In behandeling
Bijlage 1. VKL-07-30-J800--004-rapd-MER	DEN34-1-17-004--068--VKL-07-30-J800-004-rapd-MER.pdf	Anders Situatietekening, kaart of foto Gegevens kabels of leidingen aanleggen Gegevens waterstaatswerk of beschermingszone gebruiken	2017-08-17	In behandeling
MER Annex I	Annex I.pdf	Anders	2017-08-17	In behandeling
MER Annex II	Annex II.pdf	Anders	2017-08-17	In behandeling
MER Annex III	Annex III.pdf	Anders	2017-08-17	In behandeling
MER Annex IV	Annex IV.pdf	Anders	2017-08-17	In behandeling
MER Annex V	Annex V.pdf	Anders	2017-08-17	In behandeling
MER Annex VI	Annex VI.pdf	Anders	2017-08-17	In behandeling
Bijlage 2.1 Kaart_RPL	Bijlage 2-1 Kaart_RPL_VKL--06-25--J700--004.pdf	Anders Situatietekening, kaart of foto Gegevens kabels of leidingen aanleggen Gegevens waterstaatswerk of beschermingszone gebruiken	2017-08-17	In behandeling
Bijlage 2.2 Coordinaten_RPL	Bijlage 2-2 Coordinaten_RP-L_VIKING_1_VKL--07-30--J800--005.pdf	Anders Situatietekening, kaart of foto Gegevens kabels of leidingen aanleggen Gegevens waterstaatswerk of beschermingszone gebruiken	2017-08-17	In behandeling
Bijlage 3 Survey Report	Bijlage 3 Survey Report_VKL-06-25-J700-004.pdf	Anders Situatietekening, kaart of foto	2017-08-17	In behandeling

Naam bijlage	Bestandsnaam	Type	Datum ingediend	Status document
		Gegevens kabels of leidingen aanleggen Gegevens waterstaatswerk of beschermingszone gebruiken		

Toelichting aanvraag Watervergunning

Viking Link - Nederland

VKL-07-30-J800-003

maart 2017

Medegefinancierd door de Europese Unie
De financieringsfaciliteit voor Europese verbindingen

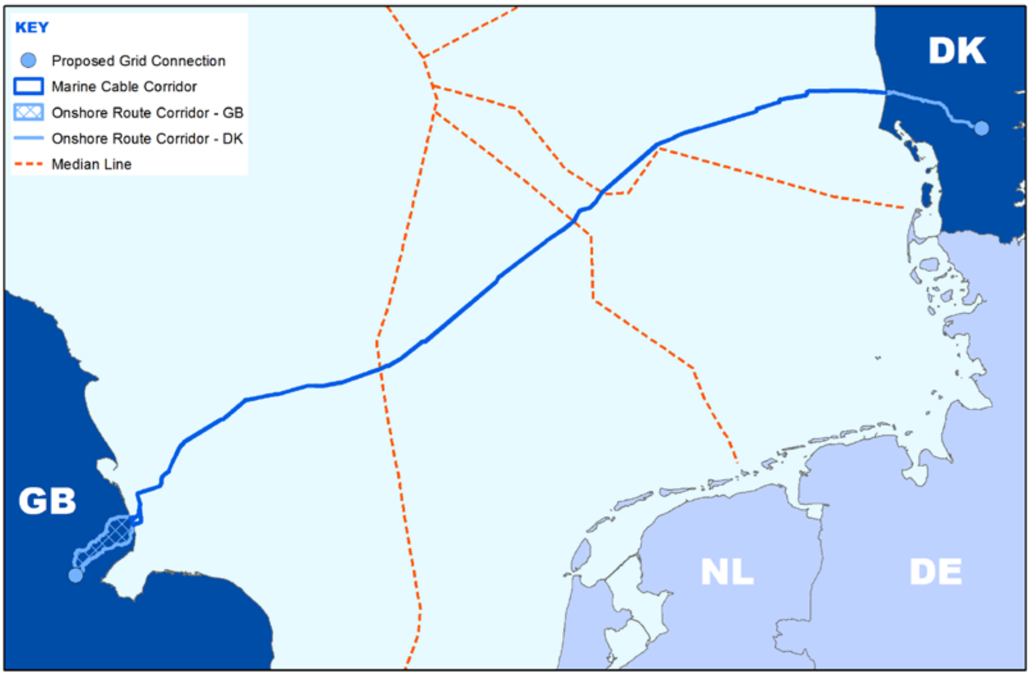
Inhoudsopgave

1 Inleiding

1.1 Viking Link - het project

1.1.1 Het projectvoorstel omvat de aanleg van een hoogspanningsgelijkstroomverbinding (High-Voltage Direct-Current, HVDC) met een capaciteit van 1400 megawatt (MW) tussen het Britse en Deense elektriciteitsnet. Het voorgestelde kabeltracé loopt van Bicker Fen in het graafschap Lincolnshire (Verenigd Koninkrijk) naar Revsing in Jutland (Denemarken).

1.1.2 Deze grensoverschrijdende kabelverbinding (interconnector) zal het territorium van vier Europese landen doorkruisen: het Verenigd Koninkrijk, Nederland, Duitsland en Denemarken. Het Nederlandse Milieueffectrapport heeft betrekking op het onderzeese deel van de voorgestelde Viking Link-corridor in de Nederlandse Exclusieve Economische Zone (EEZ), bestaande uit twee onderzeese HVDC-kabels, een optionele glasvezelkabel voor beheerdoeleinden, optionele steenbestorting, kabelmoffen en diverse materialen om kruisingen met andere onderzeese pijpleidingen/kabels te realiseren.



Afbeelding 1.1 Locatieoverzicht van de voorgestelde Viking Link Interconnector

1.2 De ontwikkelaar

1.2.1 Het Viking Link-project wordt gezamenlijk ontwikkeld door National Grid door middel van National Grid Viking Link Limited (NGVL) en Energinet.dk (ENDK), de Deense hoogspanningsnetbeheerder. Vergunningaanvrager is National Grid Viking Link Ltd.

1.3 Aanleiding, nut en noodzaak van het project

1.3.1 Het Viking Link-project sluit aan bij de doelstelling van de Europese Commissie om een geïntegreerde Europese energiemarkt te realiseren die een optimale prijs-kwaliteitverhouding biedt voor consumenten. De Viking Link-verbinding maakt efficiënter gebruik van hernieuwbare energiebronnen mogelijk en verbetert de leveringszekerheid van elektriciteit en de toegang tot hernieuwbare energiebronnen (duurzaam opgewekte elektriciteit). Daarmee komt het project de sociaal-economische situatie in zowel Denemarken als het Verenigd Koninkrijk ten goede.

1.3.2 De voordelen van de Viking Link-verbinding kunnen als volgt worden samengevat:

- Energiezekerheid: Door elektriciteitshandel tussen het Verenigd Koninkrijk en Denemarken mogelijk te maken, draagt de Viking Link-interconnector bij aan de leveringszekerheid en de diversiteit van het elektriciteitsaanbod in beide landen.
- Elektriciteitsprijzen: De grotere mogelijkheden voor het Verenigd Koninkrijk en Denemarken om handel te drijven op de Europese energiemarkten zullen bijdragen aan een drukkend effect op de groothandelsprijzen voor elektriciteit.
- Ondersteuning voor hernieuwbare energiebronnen: Om de nationale en internationale doelstellingen op het gebied van duurzame energie en klimaatverandering te behalen, wekken het Verenigd Koninkrijk en Denemarken meer energie op uit hernieuwbare energiebronnen, waaronder offshore-windenergie. De opwekking van windenergie is van nature wisselend, en interconnectoren bieden een effectieve manier om met deze vraag- en aanbodschommelingen om te gaan.

1.3.3 Het koppelen van de Britse en Deense elektriciteitsnetten door middel van een interconnector biedt de volgende specifieke voordelen voor beide landen:

- Denemarken maakt deel uit van de Nord Pool-elektriciteitsmarkt en beschikt over uitstekende verbindingen met Zweden, Duitsland en Noorwegen. Hiermee krijgt het Verenigd Koninkrijk toegang tot een goed ontwikkelde lagekostenmarkt waar de prijzen worden bepaald door een gediversifieerde energiemix uit geheel Scandinavië en Noord-Duitsland.
- Een kabelverbinding met het Verenigd Koninkrijk geeft Deense elektriciteitsproducenten toegang tot een markt met hoge prijzen, waardoor de waarde van het fluctuerende aanbod van in Denemarken opgewekte windenergie toeneemt.
- De Viking Link-interconnector geeft Denemarken en het Verenigd Koninkrijk toegang tot een diverser aanbod van energiebronnen, en biedt dus meer mogelijkheden om nieuwe elektriciteitsmarkten te betreden. De marktwerking van vraag en aanbod zal leiden tot lagere prijzen tijdens periodes van piekverbruik.

- De windenergieproductieniveaus in het Verenigd Koninkrijk en in Denemarken vertonen slechts een geringe onderlinge correlatie, en het is onwaarschijnlijk dat periodes van piekproductie zich gelijktijdig zullen voordoen in beide landen. Energieoverschotten kunnen dan eenvoudig via de interconnector worden getransporteerd naar locaties waar de vraag groter is. Dit ondersteunt de markt voor duurzame energie in beide landen, vermindert de noodzaak om elektriciteitsopwekking te beperken tijdens productiepieken, en heeft een gunstige invloed op de marktprijzen.

1.4 Project van gemeenschappelijk belang

1.4.1 Doordat het Viking Link project een PCI project is, is de Minister van Economische Zaken (EZ) de projectminister en het coördinerend bevoegd gezag. Het bevoegd gezag voor het nemen van dit uitvoeringsbesluit, de watervergunning, is het Ministerie van Infrastructuur en Milieu, Rijkswaterstaat Zee en Delta. De vergunning op basis van artikel 2.7 van de Wet natuurbescherming (gebiedsbescherming) wordt gecoördineerd voorbereid met deze watervergunning.

1.5 Wettelijk kader

1.5.1 De watervergunning wordt aangevraagd in het kader van artikel 6.5 onder c van de Waterwet, het gebruiken van een waterstaatswerk of beschermingszone in beheer bij het Rijk.

1.5.2 Omdat Viking Link een spanning heeft van meer dan 150 kV (namelijk 525 kV) en meer dan 5 km door gevoelig gebied loopt (het tracé doorkruist Natura 2000 gebied de Klaverbank met meer dan 5 km) is een m.e.r.-beoordeling vereist conform bijlage D, categorie 24.2 van het Besluit milieueffectrapportage. Om na te gaan of een m.e.r.-procedure doorlopen moet worden moet gelet worden op het volgende:

- belangrijke negatieve milieueffecten kunnen niet worden uitgesloten - een m.e.r.-procedure is van toepassing
- belangrijke negatieve milieueffecten kunnen worden uitgesloten - een m.e.r.-procedure is niet noodzakelijk

1.5.3 Om te voorkomen dat in een later stadium alsnog een m.e.r.-procedure van toepassing blijkt, is ervoor gekozen om een MER voor te bereiden voor het Viking Link project. Het MER is integraal onderdeel van deze watervergunningaanvraag en is toegevoegd in bijlage I.

1.6 Scope aanvraagdocument

1.6.1 Deze toelichting op de watervergunningaanvraag heeft betrekking op de aanleg, het gebruik en de verwijdering van twee kabels op zee (± 525kV) en een optische vezelkabel (datakabel).

1.6.2 De vergunning wordt aangevraagd voor onbepaalde tijd. Een uitgebreide omschrijving van de scope van het project is weergegeven in hoofdstuk 2. In bijlage II is een kaart van het tracé opgenomen.

1.7 Planning van het project

1.7.1 Er is nog geen overeenstemming over het schema voor aanvang van de installatie, maar de aanleg zal waarschijnlijk beginnen tussen 2019 en 2020. Over het algemeen vinden aanlegprojecten in Europese wateren in de zomer plaats, grofweg tussen april en oktober (hoewel Viking Link zich het recht voorbehoudt om eventueel het hele jaar door aan de aanleg te werken). Deze periode komt hoofdzakelijk voort uit de grote waarschijnlijkheid van ongunstige weersomstandigheden buiten deze periode. De planning zal ook worden beïnvloed door factoren als de vereiste ecologische compensatiemaatregelen, de vergunningsvoorwaarden voor de maximale arbeidsduur in het Natura 2000-gebied Klaverbank, de aanlevering van de kabel en de beschikbaarheid van schepen.

1.7.2 De planning voor de voornaamste stadia van het project wordt hieronder weergegeven in Afbeelding 1.2.

Afbeelding 1.2 Projectplanning

1.8 Leeswijzer

1.8.1 Hoofdstuk twee bevat een nadere projectbeschrijving en in hoofdstuk drie worden de verwachten emissies beschreven, vervolgens worden in hoofdstuk vier de milieueffecten van het voornemen toegelicht. Vervolgens wordt in hoofdstuk vijf het monitoringsplan beschreven; in hoofdstuk zes het veiligheid- en calamiteitenplan. Als laatste wordt in hoofdstuk zeven het verwijderingplan beschreven. Bij de toelichting zijn de volgende bijlagen toegevoegd:

Table 1.1 Lijst met bijlagen	
Nr.	**Titel**
1.	MER
2.	Kaart tracé en Lijst met coördinaten van het tracé (ETRS89)
3.	Cable route survey report

2 Project beschrijving

2.1 Inleiding

2.1.1 Dit hoofdstuk biedt een beschrijving van de mariene elementen van het voorgestelde project binnen de Nederlandse EEZ, van de mediaan Verenigd Koninkrijk/Nederland tot de mediaan Nederland/Duitsland. Het beschrijft de aspecten van het project met betrekking tot de aanleg, exploitatie (inclusief onderhoud en reparatie) en buitenbedrijfstelling van de zeekabels, waaronder:

2.1.2 **Aanleg**: Opties voor het aanlegproces van de zeekabel, waaronder de aan de aanleg voorafgaande onderzoeken, de diverse in te zetten schepen en de verschillende aanlegtechnieken die zouden kunnen worden toegepast bij het leggen, lassen en ingraven van de kabels.

2.1.3 **Exploitatie**: De fysieke kenmerken van de zeekabels, waaronder informatie over het ontwerp, werking, onderhoud en reparatie.

2.1.4 **Buitenbedrijfstelling**: De herstel- en ontmantelingsactiviteiten waarvan sprake is bij buitenbedrijfstelling van een gangbare zeekabel aan het einde van de operationele levensduur.

2.2 Overzicht

2.2.1 Het voorgestelde project betreft een hoogspanningsgelijkstroomverbinding (High Voltage Direct Current, HVDC) met een capaciteit van ca. 1400 megawatt (MW) waarmee elektriciteit zal worden overgedragen tussen de transportsystemen van Denemarken en het Verenigd Koninkrijk. Deze verbinding doorkruist de Exclusieve Economische Zones (EEZ) van het Verenigd Koninkrijk, Nederland, Duitsland en Denemarken.

2.2.2 Het project is zodanig geconfigureerd dat elektriciteit afwisselend in beide richtingen kan stromen, afhankelijk van vraag en aanbod in beide landen.

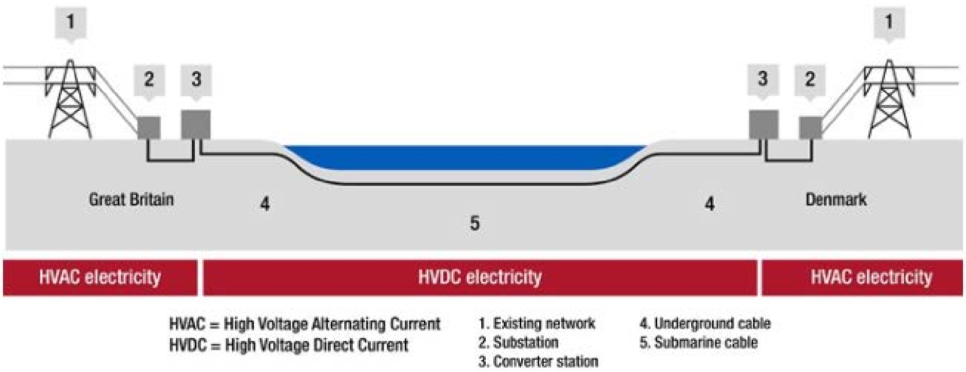
2.2.3 Het project betreft de bouw van een converterstation in Denemarken en het Verenigd Koninkrijk en de aanleg van zee- en landkabels tussen de converterstations in beide landen. De voorgestelde verbindingspunten zijn Bicker Fen in het graafschap Lincolnshire (Verenigd Koninkrijk) en Revsing in Jutland (Denemarken). De totale lengte van de zeekabel is 635 km, waarvan 170 km zich bevindt in Nederlandse wateren.

Tabel 2.1 Specificaties Viking Link	
Totale leng te offshore tracé	635 km
Lengte tracé in Nederlandse EEZ	170 km
Kabelcorridor (breedte)	450 meter
Trench (breedte)	1 meter
Voetafdruk trench (breedte)	5-15 meter
Voetafdruk kruispunten van kabels waar steenbestorting wordt toegepast (breedte)	tot 50 meter
Diepte kabel in de zeebodem[1]	één meter gronddekking

2.2.4 Een HVDC-verbinding vormt de meest efficiënte en effectieve manier om elektriciteit over deze afstand te transporteren. De hoogspanningsnetten in het Verenigd Koninkrijk en Denemarken maken gebruik van hoogspanningswisselstroom (High Voltage Alternating Current, HVAC). Voor het transport van elektriciteit door de zeekabel moet de hoogspanningswisselstroom eerst worden omgezet in hoogspanningsgelijkstroom (High Voltage Direct Current, HVDC). Nadat de elektriciteit over de zeebodems van het Verenigd Koninkrijk, Nederland, Duitsland en Denemarken is getransporteerd, wordt de HVDC bij de aanlandingspunten in het andere land weer omgezet in HVAC om daar verder te worden vervoerd.

2.2.5 De voorgestelde verbinding heeft de status van 'project van gemeenschappelijk belang' (Project of Common Interest, PCI) gekregen. Voor een PCI-project zijn de richtsnoeren voor de trans-Europese energie-infrastructuur (TEN-E), Verordening (EU) Nr. 347/2013 van toepassing.

2.2.6 Afbeelding 2.1 toont een schematische weergave van de Viking Link.



Afbeelding 2.1 Schematisch overzicht van de Viking Link

2.2.7 De voorgestelde zeekabelcorridor in de Nederlandse EEZ is vastgesteld aan de hand van voorbereidend technisch en onderzees onderzoek naar het kabeltracé en bestaat uit een corridor die 170 km lang en 450 meter breed is. Coördinaten van de hartlijn van het zeekabeltracé zijn opgenomen in Bijlage 2 van de watervergunning,

2.2.8 De vergunningaanvragen in elk land hebben betrekking op het zeekabeltracé. Daarbij moet worden opgemerkt dat hoewel het zeekabeltracé in de Nederlandse EEZ 450 meter breed is, er voor de uiteindelijke kabelconfiguratie slechts een klein deel van deze breedte nodig is voor de kabels en de aanleg ervan. Een representatieve breedte van de kabelsleuf is 1 meter, met een maximale voetafdruk voor de installatieapparatuur van ca. 5-15 meter, en tot 50 meter op kruispunten van kabels waar steenbestorting wordt toegepast. Voorgesteld wordt om de exacte positie van de zeekabels binnen het tracé na toekenning van de vergunningen maar voor aanvang van de aanleg definitief te bepalen. Dat maakt het mogelijk de uiteindelijk gelegde zeekabels te optimaliseren om uitdagingen op technisch en milieugebied te minimaliseren, onder meer het vermijden van niet-gesprongen explosieven (NGE).

2.3 Globale beschrijving van het kabelsysteem

2.3.1 Het zeekabelsysteem is een zogenaamd tweefasekabelsysteem. Tweefasesystemen transporteren elektriciteit door een gesloten circuit van twee naast elkaar gelegen HVDC-zeekabels. Op dit moment worden er twee typen HVDC-kabel voor het project overwogen: massa-geïmpregneerde kabels (Mass-Impregnated Non-Draining, MIND) en geëxtrudeerde kabels (Extruded Insulation). Het basisontwerp van de kabels is vergelijkbaar, met als voornaamste verschil de gebruikte isolatie. Deze kabels hebben doorgaans een diameter van 150 mm en een maximale bedrijfsspanning van ca. 525 kV.

2.3.2 De kabellegconfiguraties die voor elk rechtsgebied worden overwogen worden geschetst in tabel 2.2 hieronder.

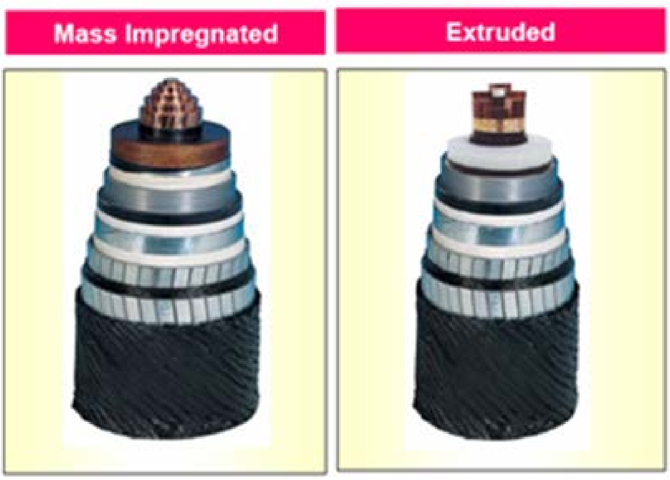
Tabel 2.2 Kabelconfiguratie voor elk rechtsgebied

Begrip	VK-sector	NL-sector	DU-sector	DE-sector
HVDC-kabelaanleg	Afzonderlijk gelegd of in het kader van één uitvoeringstraject. Kabels in dezelfde sleuf of tot 50 m uit elkaar.	Afzonderlijk gelegd of in het kader van één uitvoeringstraject, maar in dezelfde sleuf.		Afzonderlijk gelegd of in het kader van één uitvoeringstraject. Kabels in dezelfde sleuf of tot 50 m uit elkaar.
Aanleg glasvezelkabel	Kan tegelijk met de gebundelde HVDC-kabels worden gelegd.			
Kabellassen	Tussen de 12 en 30 zeekabellassen op de gehele onderzeese route.			

Tabel 2.2 Kabelconfiguratie voor elk rechtsgebied				
Begrip	**VK-sector**	**NL-sector**	**DU-sector**	**DE-sector**
Versterkers voor de glasvezelkabel	Te plaatsen om de circa 150 km vlakbij een kabellas om het optische signaal te versterken (niet binnen de begrenzing van de Klaverbank)			

Geëxtrudeerde kabel

2.3.3 Voor de geëxtrudeerde kabel wordt de isolatie geëxtrudeerd over een koperen of aluminium geleider. Deze wordt omhuld door een waterdichte mantel, meestal uit geëxtrudeerd naadloos lood, en door nog een beschermende plastic laag. De zeekabels hebben een extra laag in de vorm van draadwapening uit gegalvaniseerd staal die de treksterkte vergroot. Op deze manier is de kabel beter bestand tegen de belastingen van onderzeese aanleg. Dit is meestal een enkele laag van draden die spiraalsgewijs rond de kabel zijn gewonden en omhuld worden door een corrosiewerende mantel van met bitumen geïmpregneerd polypropyleengaren.



Afbeelding 2.2 Indicatieve HVDC-kabelopties

Massageïmpregneerde kabel (Mass Impregnated Non-Draining (MIND) Cable)

2.3.4 De MIND-kabel heeft een centrale uit hoeksteenvormige draden samengestelde afgeschermde koperen kern. De isolatie is van papier geïmpregneerd met hoogviskeuze minerale olie. Deze kabel staat niet onder druk zoals met een vloeistofgevulde kabel (laagviskeuze olie) en lekt daarom geen olie in geval van een kabelmantelbreuk. Dit zorgt voor mechanische sterkte gedurende de verwerking en installatie van de kabel en voor bescherming tegen beschadiging van buitenaf. De wapeningsdraden zijn ingebed in een laag gebituminiseerde jutedraden.

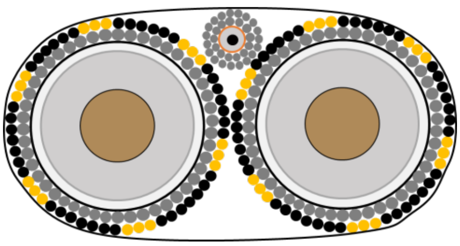
2.3.5 De kern van een massa-geïmpregneerde kabel heeft een concentrische constructie bestaande uit een centrale, uit hoeksteenvormige draden samengestelde afgeschermde koperen (of aluminium) geleider met lage weerstand afgeschermd met isolatielagen uit geïmpregneerd papier. Aan de buitenzijde heeft de kabel een diëlektrisch scherm bestaande uit halfgeleidend papier. De kabelkern is ingepakt in een loden mantel om de isolatie te beschermen tegen water; vervolgens is deze bedekt met een mantel van geëxtrudeerd polyethyleen tegen corrosie. Eén, en soms twee, wapeningslagen uit gegalvaniseerd staaldraad zijn spiraalvormig aangebracht. Dit zorgt voor mechanische sterkte gedurende de verwerking en installatie van de kabel en voor bescherming tegen beschadiging van buitenaf. De wapeningsdraden zijn ingebed in een laag gebitumineerde jutedraden.

Kabellegconfiguratie

2.3.6 In de Nederlandse EEZ zullen de zeekabels in dezelfde sleuf worden gelegd, hetzij apart of als gebundeld kabelpaar. Ook kan een glasvezelkabel voor besturings- en communicatiedoeleinden worden gelegd.

2.3.7 Er moet worden opgemerkt dat hoewel de zeekabelcorridor 450 m breed is, er slechts een klein deel van deze breedte (1 m) nodig is voor de aanleg van de kabels. Nadat de vergunningen zijn toegekend zal een gedetailleerd tracéonderzoek en optimalisatie plaatsvinden.

2.3.8 Afbeelding 2.3 toont een gangbare oplossing van twee bij elkaar gelegde HVDC-kabels en een glasvezelkabel.



Afbeelding 2.3 Dwarsdoorsnede kabelbundel

2.4 Aan de aanleg voorafgaande werkzaamheden

Onderzoeken

2.4.1 Langs het zeekabeltracé zijn mariene onderzoeken verricht ten behoeve van het technisch ontwerp en de uitgangskarakterisering van de kabel. Waarschijnlijk zal meer onderzoek vereist zijn om het kabeltracé binnen de brede corridor te optimaliseren. Het onderzoekswerk had betrekking op:

- Nearshore intergetijdeonderzoeken – MBES (Multi-Beam Echo Sounding), ondergrondprofilering, magnetometer, SSS (Side-Scan Sonar) en benthosmonstername
- Offshore geofysische onderzoeken – MBES, SSS, magnetometer, ondergrondprofilering, benthosmonstername
- Nearshore/offshore geotechnische onderzoeken – Vibrocorer-onderzoeken en diepsonderingen
- Onderzoeken met Remotely Operated Vehicles (ROV's) – MBES, video-opnames en filmfoto’s

- Benthosonderzoeken – beelden van de zeebodem, sedimentmonstername, waterprofilering en 2 m (onderzoeks) boomkor.

2.4.2 In onderstaande tabel 2.3 staan de belangrijkste bevindingen voorkomend uit het zeebodemonderzoek, in bijlage 3 is het zeebodem onderzoek toegevoegd.

Tabel 2.3 Resultaten zeebodemonderzoek Nederland		
Nederlandse EEZ	**KP reeks**	**KP 238.660 - KP 402.760**
Bathymetrie	Minimale diepte: Maximale diepte: Maximale hellingshoek:	41.2 m at KP 246 49.7 m at KP 280 ~1º voorbij KP 380, gemiddeld minder dan een 0,5 º
Geologische oppervlak gegevens	KP 238.600 - KP 268: Slibrijk fijn zand met af en toe slib/klei gevulde kanalen onder het zand oppervlak. KP 269 - KP 288: Geologisch oppervlak bestaat uit slib/klei met daarboven een dunne laag zand. KP 288 - KP 338: 1 tot 3 meter dikke laag met slibrijk fijn zand met daarin kleine hoeveelheden grind. KP 338 - KP 361: Overwegend zand KP 361 - KP 394: Overwegend zand met kleine hoeveelheden klei KP394 - KP 402.760: Overwegend slibachtige klei.	
Belemmeringen bij installatie	- 19 keien zijn in kaart gebracht in de Nederlandse sector. Maar één van deze keien bevindt zich binnen 100 meter van het tracé. Deze bevindt zich 7m noord-west van KP 376.057. - Een lijn van vier magnetische anomalieën snijdt het tracé bij KP 250.990. Vijf aaneengesloten magnetische anomalieën liggen dicht bij het tracé bij KP 344.400, en vier aaneengesloten magnetische anomalieën liggen dicht bij KP 356.900, inclusief een anomalie met hoge dichtheid. Deze reeksen van magnetische anomalieën kunnen oude kabels of vistuig zijn, echter is er geen overeenkomende data die dit kan bevestigen. - In totaal worden tien pijpleidingen en kabels gekruist: zie tabel 2.4.	

2.4.3 De aannemer die de kabels aanlegt zal voor aanvang van de kabelaanleg ook nog onderzoeken verrichten. Daartoe zullen waarschijnlijk de volgende onderdelen behoren: bathymetrie, SSS, ondiepe ondergrondprofilering en magnetometer. Het primaire doel van deze onderzoeken is te bevestigen dat er sinds de uitvoering van de zeeonderzoeken geen nieuwe belemmeringen zijn ontstaan, de zeebodemcondities van het voorgestelde zeekabeltracé te bevestigen en mogelijk NGE-onderzoek te verrichten. Daarnaast kunnen geotechnische onderzoeken worden verricht om de bodemcondities te verifiëren. De resultaten van zeebodemonderzoeken zorgen voor verfijning van de voorgestelde gronddekking en aanlegtechnieken voor de kabel. We wijzen erop dat in de Nederlandse nearshore en kustwateren doorgaans een minimale gronddekking van 1 m vereist is.

Tracévoorbereiding

2.4.4 De volgende tracévoorbereidingswerkzaamheden kunnen eventueel worden uitgevoerd voor aanvang van de aanleg van het zeekabelsysteem:

- Vrijmaken van het kabeltracé
- Vrijmaken van NGE (waarschijnlijk niet nodig)

2.4.5 Daarnaast is het mogelijk dat delen van de zeebodem met een hoog kleiaandeel worden voorbereid door het uitbaggeren van een sleuf waar de kabels in worden gelegd. Een alternatieve benadering voor deze delen zou zijn om een speciale ploeg te gebruiken – een oplossing die wellicht kosteneffectiever is.

2.4.6 Voor gebieden met grote stenen en/of zwerfkeien langs de route kan het nodig zijn om deze objecten uit de weg te halen zodat de zeeapparatuur in het tracé kan worden ingezet. Om een vrij traject voor de aanleg en ingraving van de kabel te realiseren, wordt een ploeg over de zeebodem getrokken die de zwerfkeien opzij duwt. Een baan van 5 tot 15 m breed zal worden vrijgemaakt van zwerfkeien.

Vrijmaken van het kabeltracé

2.4.7 Voor aanvang van de zeekabelinstallatie is het essentieel te waarborgen dat het kabeltracé vrij is van belemmeringen die de installatiewerkzaamheden kunnen hinderen. Afval op de zeebodem, zoals afgedankte werptrossen en netten of scheepskraandraden die mogelijk in zee zijn afgeworpen, communicatiekabels die niet meer in gebruik zijn en ander afval kan schadelijk zijn voor de graafmachine. Voor aanvang van de aanlegwerkzaamheden kan de zeekabelcorridor worden onderzocht met een magnetometer om te bepalen of er draden en kabels liggen die kunnen worden verwijderd.

2.4.8 Om de route te ontdoen van gedetecteerd en eventueel niet-gedetecteerd afval zal een klein vaartuig worden ingezet om dit te verwijderen in een operatie die wordt aangeduid met het begrip Pre-Lay Grapnel Run (PLGR). Het PLGR-schip vaart met een sleepkabel met daaraan een speciaal gevormde haak, een dreg, over de hartlijn van de kabelcorridor totdat het afval tegenkomt. De PLGR-dreg wordt zo ontworpen dat deze tot circa 1 m in de zeebodem dringt. De dreg heeft een maximale breedte van circa 200 mm.

2.4.9 Eventueel aangetroffen afval wordt aan dek gehaald om aan wal op gepaste wijze te worden afgevoerd. Oude communicatiekabels kunnen kilometers lang zijn. Het schip haalt een deel van de kabel los en verwijdert deze om een voldoende grote doorgang voor het ingraven te realiseren. Beide losse uiteinden van de resterende kabeldelen worden van gewichten voorzien (conform de door de International Cable Protection Committee (ICPC) gepubliceerde richtlijnen) om ze te beveiligen tegen verplaatsing alvorens men de kabeldelen weer naar de zeebodem laat zakken.

2.4.10 De PLGR-werkzaamheden kunnen gefaseerd worden uitgevoerd om voorafgaand aan elk kabelaanlegproject te waarborgen dat de route volledig vrij is van recent gedeponeerd afval.

2.5 Kabelaanleg

2.5.1 De kabels zullen over de gehele lengte worden ingegraven, behalve op plekken waar dit onmogelijk is, bijvoorbeeld bij kruisingen met bestaande kabels of pijpleidingen, of waar de gesteldheid van de zeebodem dit niet toelaat.

2.5.2 Binnen de Nederlandse EEZ bedraagt de voorgestelde aanlegdiepte (de afstand tussen de bovenzijde van de kabels en het onberoerde zeebodemoppervlak) van het kabelsysteem minimaal 1,0 m. Een eerste interpretatie van de gegevens uit zeebodemonderzoek voor de zeekabelcorridor wijst erop dat deze aanlegdiepte haalbaar lijkt met de momenteel verkrijgbare graafwerktuigen. De gronddekking van het kabelsysteem bedraagt 1 m.

2.5.3 Het zeebodemonderzoek omvatte een combinatie van niet-verstorend onderzoek over de hele lengte van het zeekabeltracé in de Nederlandse EEZ met verstorend onderzoek op specifieke locaties op de route. Daarom bestaat de mogelijkheid dat de feitelijke bodemcondities minder gunstig zullen zijn voor het ingraven van de kabel en dat een aanlegdiepte van 1 m zeer lokaal onmogelijk zal blijken. Men kan op onverwachte belemmeringen (zoals begraven keien of stukken harde klei) stuiten, wat voorkomen kan worden door middel van technisch tracé-onderzoek. Viking Link zal de begraafdiepte langs de route monitoren en gebieden waar 1,0 m begraafdiepte onmogelijk is als zodanig aanmerken.

2.5.4 Het kabelaanlegproces omvat de volgende elementen:

- kabelbescherming d.m.v. ingraven en eventueel aanbrengen van steenbestorting; en
- kruisingen van andere zeekabels en pijpleidingen.

2.5.5 Alle werkzaamheden worden uitgevoerd op 24-uursbasis om de overige scheepvaart zo min mogelijk te hinderen en om de efficiënte benutting van gunstige weersomstandigheden en tijd van ingezette schepen en werktuigen te maximaliseren. Met het oog op de scheepvaart- en operationele veiligheid zullen meldingen worden uitgebracht conform de wettelijk voorgeschreven procedures.

Kabelleggers

2.5.6 Het gebruik van specifieke hulpmiddelen, zoals kabelleggers, is afhankelijk van de onderneming waaraan het kabellegcontract wordt gegund en vervolgens van de beschikbaarheid van het betreffende vaartuig.

2.5.7 De bij het leggen van de kabel betrokken schepen zijn waarschijnlijk:

- Kabellegger: een kabellegger is een gespecialiseerd schip dat is ontworpen voor het transporteren en verwerken van lange lengtes zware elektriciteitskabels. Kabelleggers zijn uitgerust met dynamische-positioneringssystemen (DP-systemen) die het schip in staat stellen haar positie zeer nauwkeurig te handhaven, ongeacht de effecten van stromingen en wind.
- Wachtschip: waar dit nodig wordt geacht, zal de kabellegger worden vergezeld van een of meer wachtschepen. De wachtschepen zullen rond de kabellegger de wacht houden om te zorgen dat andere schepen uit de buurt van de installatie blijven om het risico van aanvaring te vermijden en de kabel te beschermen voordat deze wordt ingegraven.
- Steenstortschip: er zal steenbestorting worden aangebracht ter bescherming van delen van de zeekabels en voor kruisingen met bestaande kabels en pijpleidingen. Steenstortschepen hebben een grote hopper voor het transport van de rotsblokken en een mechanisme om deze ter plaatse te deponeren.

Kabelleggen

2.5.8 Het zeeoppervlak dat een kabellegformatie beslaat is afhankelijk van de vraag of er wordt gewerkt met gelijktijdig leggen en ingraven, dan wel of het ingraven na het leggen plaatsvindt. In het eerste geval kan de kabellegger de graafapparatuur inzetten. Dit kan ook worden gedaan door een ander schip dat er vlak achter vaart, waarmee in wezen één enkele formatie ontstaat. In het laatste geval kan het achteropkomende schip dat de kabel ingraaft zich op enige afstand, zelfs enkele dagen, achter de kabellegger bevinden, waarbij sprake is van twee aparte operaties die fysiek en eventueel in de tijd van elkaar gescheiden zijn.

2.5.9 Het benutte zeeoppervlak bestaat uit dat van het schip, of in geval van samenwerking de schepen, en de omringende veiligheidszone, hetgeen neerkomt op een ‘beperkt manoeuvreerbaar schip’. Een grote kabellegger is doorgaans tot 150 m lang. Het project staat in verbinding met andere vaartuigen en zal deze verzoeken op een ‘veilige’ afstand (bijv. 500 m) van de installatieschepen te blijven, zodat het werk ongehinderd kan doorgaan. Deze afstand is groter (mogelijk tot 2 km) als de kabellegger ankers heeft.

2.5.10 Het tijdseffect van de formatie is afhankelijk van het element met de laagste snelheid, doorgaans de ingraafformatie. Vanuit het perspectief van de overige scheepvaart zal deze stil lijken te liggen. Het kabelleggen verloopt met snelheden tussen de 100 en 300 m per uur.

Kabellassen

2.5.11 Omdat een kabellegger niet de gehele lengte aan kabel kan vervoeren die nodig is voor het volledige tracé, zal het nodig zijn de kabel in een aantal delen aan te leggen. Er zullen lassen nodig zijn om de delen samen te voegen, hoewel niet van tevoren kan worden bepaald hoeveel en op welke locaties er lassen zullen komen. Dit is pas mogelijk nadat een aannemer voor de installatie is aangewezen.

2.5.12 Kabellassen worden aan boord van de kabellegger gemaakt en nemen elk ongeveer een week in beslag. In die tijd ligt het schip waarschijnlijk verankerd om haar positie te handhaven. Zodra de kabellas aan boord van het schip is voltooid, wordt het kabelleggen weer voortgezet.

2.5.13 Voor het lasproces is voor beide kabeldelen extra kabellengte van tweemaal de waterdiepte nodig. Bij het neerlaten van de lassen op de zeebodem worden ze in een lusformatie gelegd, die vanwege haar vorm ‘omega’ wordt genoemd. De lusgrootte en -vorm worden geregeld terwijl de kabels op de zeebodem worden neergelaten om te waarborgen dat aan de vereiste minimumbuigradius van de kabel wordt voldaan.

2.5.14 Viking Link waarborgt dat eventuele kabellassen voor zover mogelijk niet zullen komen te liggen in gevoelige gebieden, zoals vaarwegen en ankergronden, waar langdurige ligging van de installatieformatie onwenselijk is. Op dit moment wordt verwacht dat er geen kabellassen zullen voorkomen binnen het Natura 2000-gebied Klaverbank.

Kruisingen van kabels en pijpleidingen

2.5.15 Viking Link kruist twee soorten infrastructuur van derden: buiten gebruik en in bedrijf. Kabels die buiten gebruik zijn worden meestal doorgesneden met toestemming van de eigenaar en worden beveiligd conform ICPC-richtlijnen.

2.5.16 Met eigenaren van in bedrijf zijnde kabels en pijpleidingen die door het project worden gekruist, worden kruisingsovereenkomsten gesloten. Alle partijen zijn geïnformeerd over de mogelijkheid van een kabelkruising.

2.5.17 Het fysieke ontwerp van de kruising kan variëren afhankelijk van onder meer de afmetingen, het type, de locatie en mate van ingraving van de te kruisen infrastructuur. Over het algemeen kruisen kabels andere infrastructuur via een ‘brug’ die uit een geaggregeerde afdekking van HDPE-kunststof of uit betonnen blokkenmatten bestaat. Dit gedeelte wordt vervolgens afgedekt met een beschermlaag van steenbestorting. Het ontwerp van een kruising voor elke te kruisen kabel/leiding vermeldt de voetafdruk van de impact op de zeebodem. De branchenorm is echter een 7 m brede brug over bestaande kabels.

2.5.18 De voetafdruk van kabelkruisingen is ca. 100 m (steenbestorting of betonnen blokkenmat langs de zeekabels) bij 30-50 m (breedte van brug over bestaande kabel of pijpleiding).

Kabelbescherming

2.5.19 Nadat de kabels op de zeebodem zijn gelegd, moeten ze worden ingegraven of op een andere manier worden beschermd tegen het risico van externe beschadiging door bijvoorbeeld ankers of visserijactiviteiten. De aard van de zeebodem langs de zeekabelcorridor varieert en kan bestaan uit zand, klei en grind. De keuze voor een bepaalde ingraaftechniek of beschermingsmethode hangt af van de gesteldheid van de zeebodem ter plaatse. In uitzonderlijke omstandigheden kan aanbrengen van steenbestorting nodig zijn.

2.5.20 Er zijn drie generieke typen werktuigen voor het leggen van kabels in de zeebodem:

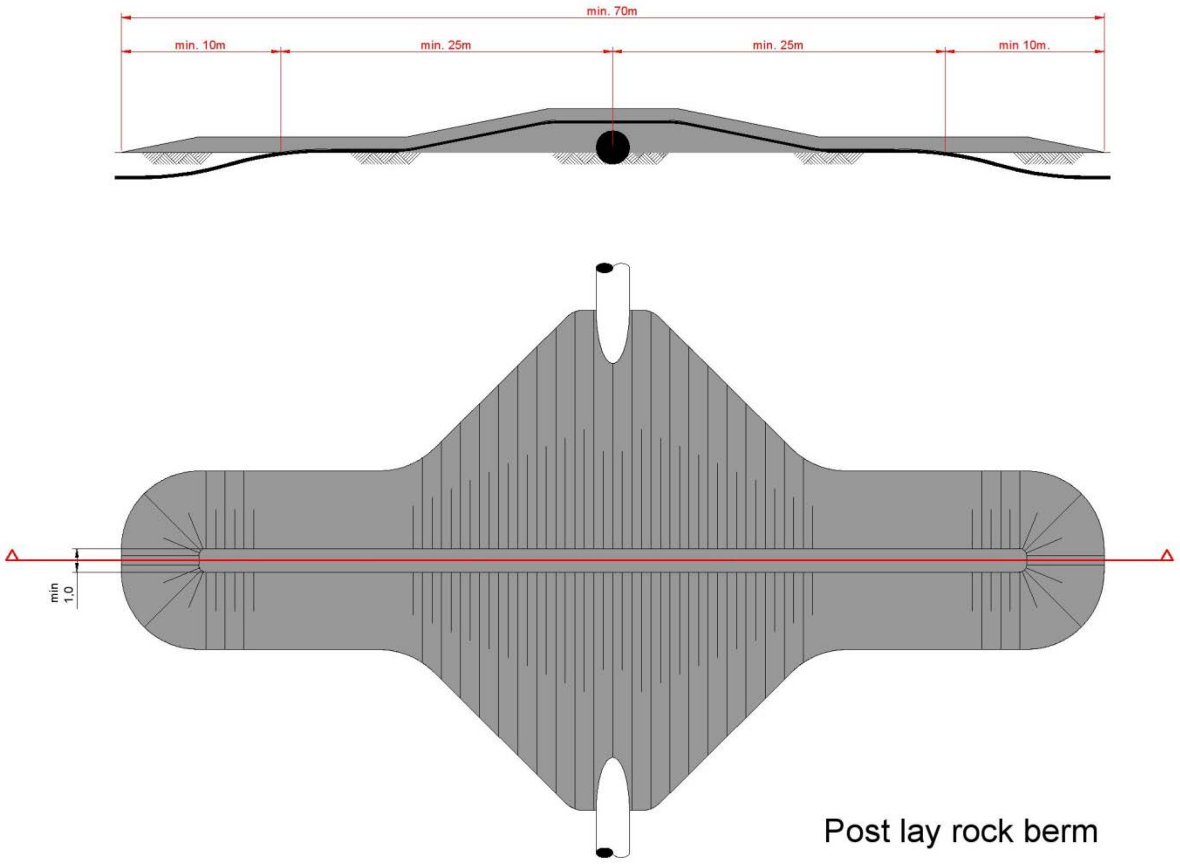
- Ploegen (gesleept): maken een open, V-vormige sleuf waarin de kabel wordt gelegd, en zijn geschikt voor de meeste soorten sediment, waaronder gesteente. De ploeg kan een sleuf tot 5 m breed (of breder) maken en de voetafdruk van de ploeg zelf kan tot ca. 10 m bedragen. Vanwege de grote omvang kunnen dergelijke werktuigen alleen worden gebruikt in water met een minimale diepte van 10 m.
- Inspuitingsmachines: zijn meestal zelfstuwende, op afstand bestuurbare voertuigen die vanaf de kabellegger of een ander ondersteuningsschip worden bestuurd. Inspuitingsmachines maken gebruik van waterstralen om de zeebodem onder de kabel los te maken, waardoor een sleuf gevuld met vloeibaar materiaal ontstaat. De kabel zakt door het eigen gewicht door het vloeibare materiaal heen in de sleuf of wordt in de sleuf geleid door een 'stinger' of 'depressor'. Het gebruik van waterstralen leidt tot iets meer troebelheid dan zou ontstaan bij een ploeg, die geen sediment verplaatst.
- Mechanische trenchers: zijn meestal gemonteerd op rupsbandvoertuigen en gebruiken kettingzagen of wielen gewapend met tanden uit wolfraam-koolstofstaal om een strakke sleuf te creëren. Deze machines zijn geschikt voor vrijwel elk type sediment, inclusief sedimenten met hoge schuifsterkte en zelfs moedergesteente. Een mechanische trencher maakt een sleuf van 0,5 tot 1 m breed.

2.5.21 Verwacht wordt dat de inspuitings- of ploegmethode zal worden gebruikt langs het Nederlandse deel van de kabelcorridor om een 1 meter brede sleuf te maken. Daarbij zullen werktuigen worden gebruikt met een voetafdruk van 2 meter aan weerszijden van de sleuf. Rekening houdend met een marge voor de verschillende graafwerktuigen wordt uitgegaan van een voetafdruk die 5-15 breed is.

2.5.22 Het aanbrengen van steenbestorting wordt toegepast om zeekabels te beschermen door deze af te dekken in een geprofileerde berm van breukstenen. De berm vormt een sterke beschermlaag en voorkomt eventueel aanstoten of vasthaken, en waarborgt tevens de stabiliteit doordat de kabel wordt afgeschermd van de zeestroming. De afmetingen van de berm en de benodigde gradatie van de bestorting zijn afhankelijk van de stroming en de golfbelasting.

2.6 Kabelkruisingen

2.6.1 Er worden kruisingsovereenkomsten gesloten met eigenaren van kabels en pijpleidingen die door het project worden gekruist. Alle partijen zijn geïnformeerd over de mogelijkheid van een kabelkruising. Deze overeenkomsten zetten het fysieke ontwerp van de kruising uiteen en beschrijven de rechten en verantwoordelijkheden van beide partijen om integriteitsbehoud van de kabels/leidingen te waarborgen. Afbeelding 2.4 hieronder toont een gangbaar ontwerp voor een kabelkruising.



Afbeelding 2.4 Schematische weergave van gangbare methode voor kabelkruising

2.6.2 Het project kruist in de Nederlandse sector tien kabels en pijpleidingen op negen kruisingslocaties zoals aangegeven in onderstaande tabel 2.4.

Tabel 2.4 Kabels en pijpleidingen in de Nederlandse sector die worden gekruist door Viking Link				
Kabel/pijpleiding	**KP-RPL**	**Eigenaar**	**Type**	**Status**
D18a-A - D15-A 8" Gas / 2" Methanol (Piggybacked) 398	398.454	ENGIE E&P Nederland B.V.	Pijpleidingen	In bedrijf
D15-FA - L10-AC 36"	398.454	Noordgastransport B.V.	Pijpleiding	In bedrijf
Sleipner - Zeebrugge 40"	368.560	Gassco	Pijpleiding	In bedrijf
Draupner - Dunkirk 42"	368.503	Gassco	Pijpleiding	In bedrijf
UK - Germany 6	344.093	BT	Glasvezelkabel	Buiten bedrijf
VSNL / TGN Northern Europe	303.515	Tata Communications	Glasvezelkabel	In bedrijf
A6A - F3FB1 20"	261.829	Wintershall AG	Pijpleiding	In bedrijf
A6A - F3FB1 4"	261.792	Wintershall AG	Pijpleiding	In bedrijf
Tyra-W - F03-FB 26"	247.700	Maersk Olie og Gas A/S	Pijpleiding	In bedrijf

2.6.3 Steenbestorting zal worden ontworpen met het oog op veilig gebruik van sleepnetten. Eventuele belemmeringen op de zeebodem als gevolg van projectgerelateerde werkzaamheden tijdens de aanlegfase, exploitatiefase (inclusief onderhoud en reparaties) en buitenbedrijfstellingsfase zullen worden verwijderd of veilig gemaakt voor vistuig dat wordt gebruikt in de boomkorvisserij.

3 Milieueffecten van het voornemen

3.1 Inleiding

3.1.1 Voor de Viking Link is een project-MER opgesteld die onderdeel uitmaakt van deze vergunningaanvraag. Het doel van de m.e.r. is om milieu- en natuurbelangen (naast andere belangen) een volwaardige rol te laten spelen bij de besluitvorming.

3.1.2 De effecten op milieu als gevolg van Viking Link zijn onderverdeeld in effecten tijdens de aanlegfase, gebruiksfase en verwijderingfase. Door het uitvoeren van werkzaamheden en het ruimtegebruik van het voornemen ontstaan mogelijk effecten, deze effecten zijn in het MER beschreven en beoordeeld. De effecten tijdens de aanleg en verwijderingfase zijn tijdelijk van aard. De effecten van de gebruiksfase zijn permanent. Op basis van wet- en regelgeving is een beoordelingskader ontwikkeld waarmee de effecten van het voornemen beoordeeld zijn. Het volledige MER is in bijlage I opgenomen.

3.1.3 In het MER zijn voor ecologie de verschillende alternatieven op verschillende deelaspecten beoordeeld. Het eerste deelaspect omvat gebiedsbescherming (Wet natuurbescherming), het tweede aspect soortenbescherming (Wet natuurbescherming) en het derde deelaspect omvat de Ecologische Hoofdstructuur (EHS) of Natuurnetwerk Nederland (NNN), hiernaast zijn ook de ecologisch waardevolle gebieden (Centrale oestergronden & Gasfonteinen) getoetst. Conform het beheer- en ontwikkelplan voor de rijkswateren (BPRW) is de Viking Link kabel getoetst aan de Kaderrichtlijn Mariene Strategie (KRM).

3.2 Resultaten MER

3.2.1 De belangrijkste conclusies van de beoordeling van de effecten op de fysieke, biologische en leefomgeving zijn als volgt:

- De belangrijkste effecten van het project betreffen naar verwachting kleine en tijdelijke negatieve effecten op zeebodemdieren tijdens de aanlegfase.
- De zeekabelcorridor loopt door het Natura 2000-gebied Klaverbank, dat is aangemerkt als habitattype H1170 (Riffen van open zee) en wordt gekenmerkt door delen met een hardere zeebodem en concentraties van zwerfkeien. De bevindingen van het voor het Viking Link-project uitgevoerde zeebodemonderzoek sluiten nauw aan bij eerdere kenschetsende onderzoeken van de Klaverbank. De verstoringen van de zeebodem zijn kleinschalig en alle gebieden met een harde ondergrond worden vermeden door optimalisering van het tracé. Hierdoor worden eventuele rechtstreekse effecten op gebieden met onderscheidende kenmerken beperkt. De toename van troebelheid is beperkt en heeft alleen betrekking op een klein gebied rond de zeekabelcorridor, waardoor er een verwaarloosbaar effect is op

rifkenmerken. Er worden daarom geen negatieve effecten verwacht op de instandhoudingsdoelstellingen van het Klaverbank-gebied.

- De twee kabels worden in dezelfde sleuf aangelegd en vervolgens in de zeebodem begraven, waardoor de verstorende effecten van elektromagnetische velden aanzienlijk worden verminderd. Er worden daarom slechts beperkte en lokale elektromagnetische emissies verwacht, die geen verstorende effecten zullen hebben op soorten die gevoelig zijn voor elektriciteit en/of magnetische velden.
- Het transporteren van stroom door de kabels zal warmte opwekken, maar dit zal slechts beperkt effect hebben op het sediment aan de oppervlakte. Dit opwarmeffect zou zeer lokaal en alleen in het sediment in de directe nabijheid van de begraven kabels optreden, en de omgevingstemperatuur van het zeewater zou bovendien dicht bij die van het zeebodemoppervlak blijven. Warmte-emissies worden tegengegaan door de kabel voldoende diep te begraven. Vanwege de gronddekking zullen verwarmingseffecten van de kabels waarschijnlijk geen gevolgen hebben voor infauna. Verstoring veroorzaakt door verwarmingseffecten afkomstig van kabels in verband met het project wordt daarom geacht niet te leiden tot een wijziging van de referentiesituatie voor zeebodemdieren.
- Eventuele negatieve effecten op de scheepvaartveiligheid of overige zeegebruikers zullen kortdurend, lokaal en niet significant zijn. Er is een risicobeoordeling uitgevoerd van de begraafdiepte, waarbij de gronddekking is bepaald op basis van een aanvaardbaar minimaal risiconiveau om blootlegging van de kabel te voorkomen en effecten op de scheepvaart en visserij te beperken.
- Er worden geen significante negatieve effecten verwacht op archeologische kenmerken of als gevolg van Niet-Gesprongen Explosieven. Er worden mitigerende maatregelen toegepast als er beschermde kenmerken worden ontdekt binnen de zeekabelcorridor tijdens aanleg- en reparatiewerkzaamheden.
- Er zijn geen andere projecten bekend binnen de Nederlandse, Britse of Duitse EEZ die interacties kunnen aangaan met het Viking Link-project, en er worden daarom geen cumulatieve effecten verwacht.
- De werkzaamheden tijdens de buitenbedrijfstellingsfase zullen grotendeels vergelijkbaar zijn met de aanlegfase, en er worden daarom geen sterke negatieve effecten verwacht als gevolg van het project.

3.3 KRW

3.3.1 Het Europese Parlement en de Raad van de Europese Unie hebben op 23 oktober 2000 de EU-Kaderrichtlijn Water (KRW) vastgesteld. Het doel van deze richtlijn is om aquatische ecosystemen te beschermen en duurzaam gebruik van water te bevorderen. Het tracé valt buiten het gebied waarvoor de Kaderrichtlijn Water geldt.

3.4 Marine Strategy Framework Directive (Europese Kaderrichtlijn Mariene Strategie, KRM)

3.4.1 De Europese Kaderrichtlijn Mariene Strategie (KRM) vereist dat Lidstaten de noodzakelijke maatregelen nemen om een goede milieutoestand (GMT) in hun mariene wateren te bewerkstelligen en/of te behouden. In de KRM wordt de goede milieutoestand voor de Noordzee beschreven met behulp van de volgende elf descriptoren.

- 1) Biodiversiteit: de biologische diversiteit wordt behouden. De kwaliteit en het voorkomen van habitats en de verspreiding en dichtheid van soorten zijn in overeenstemming met de heersende fysiografische, geografische en klimatologische omstandigheden.
- 2) Introductie van niet-inheemse soorten: door menselijke activiteiten geïntroduceerde niet-inheemse soorten komen voor op een niveau waarbij het ecosysteem niet verandert.
- 3) Visserij: populaties van alle commercieel geëxploiteerde soorten vis en schaal- en schelpdieren blijven binnen veilige biologische grenzen, en vertonen een opbouw qua leeftijd en omvang die kenmerkend is voor een gezond bestand.
- 4) Mariene voedselketens: alle elementen van de mariene voedselketens, voor zover deze bekend zijn, komen voor in normale dichtheden en diversiteit en op niveaus die de dichtheid van de soorten op lange termijn en het behoud van hun volledige voortplantingsvermogen garanderen.
- 5) Eutrofiëring: door de mens teweeggebrachte eutrofiëring is tot een minimum beperkt, met name de schadelijke effecten ervan zoals verlies van de biodiversiteit, aantasting van het ecosysteem, schadelijke algenbloei en zuurstofgebrek in de bodemwateren.
- 6) Integriteit van de zeebodem: integriteit van de zeebodem is zodanig dat de structuur en de functies van de ecosystemen gewaarborgd zijn en dat met name benthische ecosystemen niet onevenredig worden aangetast.
- 7) Hydrografische eigenschappen: permanente wijziging van de hydrografische eigenschappen berokkent de mariene ecosystemen geen schade.
- 8) Vervuilende stoffen: concentraties van vervuilende stoffen zijn zodanig dat geen verontreinigingseffecten optreden.
- 9) Vervuilende stoffen in vis: vervuilende stoffen in vis en andere visserijproducten voor menselijke consumptie overschrijden niet de grenzen die door communautaire wetgeving of andere relevante normen zijn vastgesteld.
- 10) Zwerfvuil op zee: de eigenschappen van, en de hoeveelheden zwerfvuil op zee veroorzaken geen schade aan het kust- en mariene milieu. Dit betreft tevens afbraakproducten als (micro)deeltjes van plastic. Het streven is om de hoeveelheid zwerfvuil op zee op termijn terug te brengen.
- 11) Energie: de toevoer van energie, waaronder onderwatergeluid, is op een niveau dat het mariene milieu geen schade berokkent. Door menselijke activiteiten veroorzaakte luide impulsgeluiden in de mariene omgeving met een lage en middelhoge frequentie, evenals continue geluiden met een lage frequentie, veroorzaken geen negatieve effecten voor ecosystemen.

3.4.2 De KRM heeft (nog) geen beoordelingskader. In de impactbeschrijving wordt daarom beschreven welke descriptoren in welke mate door het project kunnen worden beïnvloed.

Descriptor 1: Biodiversiteit

3.4.3 De habitat en de soorten die erin voorkomen, worden lokaal sterk beïnvloed door het graven van de sleuf. Ook komt er door het uitgraven van de zeebodem slib vrij in de waterkolom. De achteruitgang van de habitat zal echter maar tijdelijk zijn: de sleuf wordt deels weer opgevuld en zal in vier tot zes jaar door zeebodemfauna opnieuw worden gekoloniseerd; het opgeloste slib zal weer bezinken. Bovendien is het getroffen oppervlak verwaarloosbaar ten opzichte van de totale habitat die in de Noordzee beschikbaar is. Op de langere termijn is er daarom geen risico dat de goede milieutoestand wordt aangetast.

Descriptor 2: Introductie van niet-inheemse soorten

3.4.4 Waar kabels elkaar kruisen, wordt hard substraat aangebracht om ze te beschermen. Hard substraat is gevoelig voor de vestiging van niet-inheemse soorten, zoals onder meer biomonitoring van platforms heeft aangetoond. Dergelijke stukken hard substraat zouden dus als opstapje voor niet-inheemse soorten kunnen dienen. In dit geval bestaat het substraat echter uit zeer kleine brokstukken die waarschijnlijk deels door sediment zullen worden bedekt. Derhalve wordt niet verwacht dat de toegepaste bescherming tot een achteruitgang van de goede milieutoestand zal leiden.

Descriptor 3: Visserij

3.4.5 Visserijactiviteiten in het gebied zullen niet veranderen, er wordt derhalve geen impact op deze descriptor verwacht.

Descriptor 4: Mariene voedselketens

3.4.6 De mariene voedselketen kan worden aangetast doordat er tijdelijk minder prooidieren beschikbaar kunnen zijn door achteruitgang van de habitat en door troebelheid. De impact is echter hoofdzakelijk tijdelijk, en de voedselketen zal zich herstellen nadat de werkzaamheden zijn beëindigd. Er wordt daarom geen langetermijnimpact op de mariene voedselketen verwacht.

Descriptor 5: Eutrofiëring

3.4.7 Als gevolg van de activiteiten zullen geen extra voedingsstoffen in de omgeving terechtkomen. De goede milieutoestand zal daarom niet worden beïnvloed door een toegenomen eutrofiëring.

Descriptor 6: Integriteit van de zeebodem

3.4.8 Het graven van de sleuf heeft effect op de zeebodem en daarmee op de organismen die op en in de zeebodem leven (zie descriptor 1). De integriteit van de zeebodem zal worden aangetast door de kabelbescherming die wordt aangebracht waar kabels elkaar kruisen (zie ook descriptor 2). Vanwege het relatief kleine oppervlak en de tijdelijke aard van de werkzaamheden zullen de structuur en functies van de bodem en benthische ecosystemen echter niet negatief worden beïnvloed. De geplande activiteit leidt niet tot significante veranderingen met betrekking tot de uitgangs- c.q. referentiesituatie.

Descriptor 7: Hydrografische eigenschappen

3.4.9 Omdat het waarschijnlijk zeer lang gaat duren voordat de sleuf weer volledig met sediment is opgevuld, zullen de hydrografische eigenschappen van de bodem veranderen. Het effect zal echter alleen zeer lokaal zijn. Ook zal de troebelheid toenemen als gevolg van het graven van de sleuf, waardoor hydrografische kenmerken zullen veranderen. Dit effect zal echter niet alleen zeer lokaal maar ook tijdelijk zijn. Er kan vanuit worden gegaan dat er voor deze descriptor geen effect zal zijn op de goede milieutoestand.

Descriptor 8: Vervuilende stoffen

3.4.10 Zolang de werkzaamheden die vereist zijn om de kabel te leggen zorgvuldig en volgens internationale regels worden uitgevoerd, mag worden verwacht dat er geen vervuilende stoffen in de omgeving vrijkomen. De goede milieutoestand zal daarom niet worden beïnvloed door vrijkomende vervuilende stoffen.

Descriptor 9: Vervuilende stoffen in vis en visserijproducten

3.4.11 Zolang de werkzaamheden die vereist zijn om de kabel te leggen zorgvuldig en volgens internationale regels worden uitgevoerd, mag worden verwacht dat er geen vervuilende stoffen in de omgeving vrijkomen, en dat deze dus niet door vis en overige zeedieren waarop gevist wordt zullen worden opgenomen. De goede milieutoestand zal daarom niet worden beïnvloed door vrijkomende vervuilende stoffen.

Descriptor 10: Zwerfvuil op zee

3.4.12 Zolang de internationale afspraken over beheersing van scheepsafval worden nagekomen, mag worden verwacht dat de werkzaamheden niet zullen leiden tot meer afval in zee. De activiteit zal daarom geen effect hebben op de goede milieutoestand.

Descriptor 11.1: Elektromagnetische velden

3.4.13 In de context van de KRM kunnen elektromagnetische velden worden gezien als toevoer van energie. Doordat de elektromagnetische velden permanent aanwezig zullen zijn, kan niet worden uitgesloten dat ze een negatief effect op de goede milieutoestand zullen hebben. Hoewel geen effecten worden verwacht (zie de beschrijving van de effecten op Natura 2000-gebieden), zijn er op het gebied van elektromagnetische velden nog steeds leemten in kennis. In het kader van het Wind op Zee Ecologisch Programma (WOZEP) worden de effecten van elektromagnetische velden op dit moment onderzocht. Een eerste resultaat is dat het risico van effecten door elektromagnetische velden op het ecosysteem voor gelijkstroom veel hoger is dan voor wisselstroom doordat de velden continu stabiel zijn. Bovendien trekken de opgewekte elektromagnetische velden soms soorten aan die beschikken over elektromagnetische sensoren, zoals roggen en haaien, doordat ze denken te maken te hebben met prooien die elektrische velden opwekken. In sommige gevallen hebben zwakke elektromagnetische velden waarschijnlijk meer effecten dan sterke velden, doordat ze meer lijken op biologische elektromagnetische velden die van nature voorkomen. In de komende periode wordt hierover meer informatie verzameld.

Descriptor 11.2: Impulsgeluid en voortdurend geluid onderwater

3.4.14 In de context van de KRM kan deze descriptor aan verandering onderhevig zijn. De goede milieutoestand kan tijdelijk worden verstoord door meer onderwatergeluid als gevolg van extra scheepsverkeer, baggerwerkzaamheden en het aanbrengen van kabelbescherming op kabelkruisingen. Vanwege de tijdelijke aard van het werk zal de goede milieutoestand niet permanent achteruit gaan en worden de werkzaamheden vanuit het perspectief van de KRM niet als schadelijk gezien. Daarnaast worden door extra geluid ook descriptoren 1 (behoud van biodiversiteit) en 4 (voedselketens) geraakt, doordat sommige soorten het gebied tijdelijk zullen mijden. Dat zal geen permanent effect op de goede milieutoestand hebben, aangezien deze soorten in het gebied zullen terugkeren wanneer de werkzaamheden zijn afgerond.

Samenvatting van de KRM-beoordeling

3.4.15 Er worden beperkte en tijdelijke effecten op de descriptoren 1, 2, 4, 6, 7 en 11 verwacht, zoals hierboven beschreven. Er zijn geen effecten op de overige descriptoren. Alleen elektromagnetische velden kunnen mogelijk beperkte permanente effecten hebben. Wat betreft de KRM wordt op basis van de beschikbare kennis en informatie nog steeds verwacht dat de voorgestelde activiteit tot een licht negatieve verandering zal leiden ten opzichte van de uitgangssituatie (goede milieutoestand). Dit vanwege mogelijke effecten van elektromagnetische velden. Op dit moment is er een gebrek aan empirische effectstudies naar de gevolgen van elektromagnetische velden in de Noordzee voor bepaalde soorten. Om meer inzicht te krijgen in de effecten van elektromagnetische velden op soorten populaties, is uiteindelijk nader veldonderzoek vereist.

3.5 Emissies Viking Link

Elektromagnetisch (EM-)veld

3.5.1 Het aardmagnetisch veld vormt de achtergrond waarmee kunstmatige magnetische velden in interactie zijn en waartegen deze velden kunnen worden geëvalueerd. Het aardmagnetisch veld in de nabijheid van het kabelsysteem in de Nederlandse EEZ bedraagt naar verwachting circa 49,5 µT.

3.5.2 Zeekabels genereren magnetische velden door de elektrische stroom die zich door de kabels verplaatst. De sterkte van deze magnetische velden is direct afhankelijk van de hoeveelheid stroom. Het ontwerp van de kabels, inclusief loden mantel en gewapende kernen, voorkomt de verbreiding van elektrische (E-)velden in de omgeving. Deze materialen laten echter magnetische (B-)velden door, die daardoor wel, in feite ongehinderd, in de omgeving doordringen. Het B-veld zwakt af met het oplopen van de afstand (zowel horizontaal als verticaal) van de kabelgeleider. Lokaal kunnen er statische elektrische velden worden opgewekt wanneer zeewater (getijdestroom) of andere geleiders, zoals zeeorganismen, zich door het magnetische veld van de gelijkstroomkabel begeven. Elektrische velden zwakken af met het oplopen van zowel de horizontale als de verticale afstand van de kabelgeleider.

3.5.3 Binnen de Nederlandse wateren worden de zeekabels in dezelfde sleuf gelegd met een nominale tussenruimte van 0,2 m. De resulterende magnetische velden zullen zeer zwak zijn door de wederzijdse opheffing van de positieve en negatieve polen en de zich in tegengestelde richting verplaatsende stromen. De gronddekking kan het effectbereik van EM-velden beperken, maar in geringere mate dan de nabijheid van een kabel. Aan de hand van modellering is een raming gemaakt van de door het project opgewekte EM-veldsterkte. Aangenomen wordt dat de kabel conform de Nederlandse wetgeving een gronddekking van 1 m moet krijgen. Er zijn voorspellingen opgesteld van de opgewekte elektrische velden voor twee verschillende getijdestroomsnelheden: 0,5 m/s en 1.25 m/s, waarbij de resultaten van de hogere snelheid zijn gebruikt als meest ongunstige scenario (zie tabel 3.1).

Tabel 3.1 Verwachte maximale elektrische en magnetische velden van de Viking Link-zeekabel uitgaande van een gebundelde kabelconfiguratie (0,2 m tussenruimte)

Afstand vanaf kabel (m)	Elektrische-veldsterkte (µV/m)	Magneetveldsterkte (in µT)
0,5	238*	190
1,0	105	83,9
5,0	63,1	50,5
10	61,9	49,5

- * Een theoretische waarde omdat wordt verondersteld dat het veld onder de minimale gronddekking blijft.

3.5.4 De kabelconfiguratie van Viking Link elimineert directe opwekking van een elektrisch veld; door minimalisatie van het opgewekte magnetische veld minimaliseert de systeemconfiguratie ook de in het mariene milieu opgewekte elektrische velden.

Warmte-emissies

3.5.5 Het transport van gelijkstroom gaat gepaard met verliezen als gevolg van de interne weerstand in de geleider. Deze weerstand is evenredig aan de lengte van de kabels en is omgekeerd evenredig aan het oppervlak van de dwarsdoorsnede van de geleider (in dit geval de koperen of aluminium kabelkern). De weerstand is ook afhankelijk van de omgevingstemperatuur: de weerstand (en daarmee het warmteverlies) neemt toe naarmate de omgevingstemperatuur stijgt. De verloren energie wordt hoofdzakelijk omgezet in warmte, waardoor de temperatuur van de kabel en de omliggende zeebodem stijgt. De seizoensgerelateerde omgevingswatertemperatuur verandert langzaam, zodat de omliggende zeebodem dezelfde temperatuur heeft. Hierdoor is de temperatuur van het water en van het zeebodemoppervlak in de winter minimaal 3°C en in de zomer maximaal 17°C. Doordat de verliezen minder zijn bij lagere temperaturen, is het warmteverlies in de winter geringer dan in de zomer. Hoewel de gemiddelde omgevingstemperatuur ca. 10°C bedraagt, zijn de simulaties van de warmteafgifte uitgevoerd voor een behoudende temperatuur van 15°C (Brakelmann & Stammen, 2017).

Geluid

3.5.6 De offshore installatieformatie bestaat mogelijk uit twee vaartuigen: een schip dat de kabel legt en een schip dat de kabel ingraaft. De offshore formatie beweegt zich doorgaans voort met een snelheid van 100-300 m/uur per etmaal. Het door het leggen veroorzaakte geluid op een bepaalde locatie is over het algemeen van voorbijgaande aard en tijdelijk. Op laslocaties kan de installatieformatie zich echter gedurende 1 à 2 weken op één plaats bevinden. Het is in dit stadium nog niet mogelijk om laslocaties te specificeren, maar deze zullen naar verwachting allemaal op enige afstand uit de kust liggen.

3.5.7 In 2003 heeft het onafhankelijke onderzoeksorgaan COWRIE opdracht gegeven voor een onderzoek naar het geluid dat ontstaat bij het leggen van zeekabels. Tijdens het leggen van kabels bij het offshore-windpark North Hoyle zijn metingen verricht van de geluidsniveaus die ontstonden bij het ingraven van kabels in de zeebodem. De niveaus werden opgenomen op een afstand van 160 m van de graafwerkzaamheden met een hydrofoon op 2 m diepte; dit was noodzakelijk omdat op het moment van de metingen werd gewerkt in zeer ondiep water. Het geluidsdrukniveau van deze opname was 123 dB re 1m Pa. Het geluid als gevolg van het graafwerk bleek te bestaan uit een combinatie van breedbandgeluid, tonaal machinegeluid en overgangsgeluiden die waarschijnlijk samenhingen met brekend gesteente. Tijdens het onderzoek werd opgemerkt dat het geluid sterk variabel was en kennelijk afhing van de fysieke eigenschappen van het specifieke deel van de zeebodem waar op dat moment werd gewerkt. Analyse van de gegevens wijst uit dat bij een verondersteld transmissieverlies van 22 log (R) sprake is van een bronniveau van 178 dB re 1m Pa à 1 m. Met deze bron verrichte geluidsmodellering wijst vervolgens uit dat voor afstanden tot 5 km van de bron alle metingen lager zijn dan 70 dB_{ht} (met één specifieke uitzondering) en daarmee onder het niveau blijven waarop gedragsveranderingen zouden worden verwacht. Daarom wordt verwacht dat de effecten van geluid door het kabelleggen niet significant zullen zijn.

4 Kabelonderhoud en reparatie

4.1.1 Regelmatig onderhoudswerk aan de zeekabels na het leggen wordt niet verwacht. Er kan echter enig werk nodig zijn om de kabel ingegraven te houden ter bescherming tegen ongewenste interacties met andere zeegebruikers en mariene processen die schade zouden kunnen veroorzaken. De kabel en het leggen ervan worden ontworpen om eventuele onderhoudseisen zo beperkt mogelijk te houden.

4.1.2 Effecten van reparatie- en onderhoudswerkzaamheden zijn vergelijkbaar met de in deze beoordeling behandelde effecten van het kabelleggen, hoewel ze op kleinere schaal en meer gelokaliseerd gelden. Eventuele effecten zijn geringer dan die van het leggen van de kabel.

4.1.3 Routineonderzoek van een correct gelegde en afgeschermde zeekabel is normaliter niet vereist omdat zeekabels zijn ontworpen met het oog op minimaal onderhoud. Regelmatig onderzoek van kruisingen met pijpleidingen kunnen een vereiste zijn in een specifieke kruisingsovereenkomst voor de betreffende pijpleiding. Periodieke inspecties kunnen plaatsvinden om vast te stellen of de kabel blootligt of onder spanning staat.

4.1.4 Reparaties aan correct gelegde en afgeschermde zeekabels zijn zeldzaam maar vereisen directe interventie, die mogelijk tijdelijk effecten kunnen hebben voor het milieu en activiteiten van andere gebruikers van de zee. De meest voorkomende reden voor reparatie aan een zeekabel is door derden toegebrachte schade, meestal veroorzaakt door sleepnetschepen of ankers van handelsschepen. Dergelijke schade kan betrekking hebben op een specifieke locatie of op een wat langere afstand, afhankelijk van de energie van de interactie. De kabel kan lokaal beschadigd, over langere afstand ruw bewerkt, of uit de zeebodem getrokken zijn. De operationele details en de exacte configuratie van een reparatieformatie is afhankelijk van het type reparatie en de faciliteiten van de aannemer. Voor een reparatie dient meestal extra kabel te worden gelegd en moeten twee aanvullende kabellassen worden gerealiseerd (een eerste en een laatste). De aanvullende kabellengte in geval van puntschade kan gelijk zijn aan circa driemaal de waterdiepte ter plaatse en is langer als de kabels over grotere afstand beschadigd zijn. De aanvullende lengte van een gerepareerd kort kabelgedeelte houdt in dat de gerepareerde kabel niet in exact dezelfde positie en richting op de zeebodem kan worden teruggelegd. De overlengte zal in een lus op de zeebodem worden gelegd naast de oorspronkelijke route. De extra lassen en extra kabellengte zullen worden ingegraven, meestal met inspuitingsmachines die worden ingezet vanaf het reparatieschip zelf of vanaf een apart gespecialiseerd schip.

5 Veiligheids- en calamiteitenplan

5.1.1 Bij calamiteiten tijdens de aanleg van de kabel kunt u contact opnemen met Sat Chana (NGVL), die onder telefoonnummer +44 (0) 7789 480906 bereikbaar is of Jesper Dahl Vittrup (ENDK), die onder telefoonnummer +45 76224686 bereikbaar is.

5.1.2 Bij calamiteiten tijdens de gebruiksperiode van de kabel kunt u contact opnemen met de Centrale Meldkamer (CMK) van NGVL of ENDK. De telefoonnummers worden voor de start doorgegeven.

6 Verwijderingsplan

6.1.1 National Grid Viking Link (NGVL) en Energinet.dk erkennen het belang van het tijdig in aanmerking nemen van het buitenbedrijfstellingsproces. Mocht buitenbedrijfstelling aan de orde komen, dan zal deze operatie ook worden uitgevoerd conform het op dat moment geldende standaardprotocol binnen de industrie. Aan het eind van de levensduur van de kabel zullen de opties voor buitenbedrijfstelling worden geëvalueerd. In bepaalde gevallen kan de milieuvriendelijkste optie inhouden dat de kabels blijven liggen. Bij deze optie speelt de aansprakelijkheid een rol bij eventuele claims van vissers of andere derden die met de kabels in aanraking komen. Deze kwestie komt aan de orde in de planningsfase van de buitenbedrijfstelling van de kabel.

6.1.2 De doelstellingen van NGVL en Energinet.dk tijdens het buitenbedrijfstellingsproces zijn minimalisatie van zowel lange- als kortetermijneffecten voor het milieu in samenhang met de veilige bevaarbaarheid van de zee voor anderen. Op basis van de huidige regelgeving en beschikbare technologie stellen NGVL en Energinet.dk de volgende mate van buitenbedrijfstelling voor:

- kabelsysteem – verwijderen, dan wel veilig laten liggen, ingegraven tot onder het niveau van de natuurlijke zeebodem;
- matten – laten liggen;
- erosiebeschermingsmateriaal – laten liggen.

6.1.3 Indien kabels uit de zeebodem moeten worden verwijderd, dan is de volgende werkwijze gangbaar. De eerste fase zou zijn dat een deel van de ingegraven kabel wordt blootgelegd om ofwel een grijper direct op de kabel te plaatsen ofwel een ‘onderroller’ onder de kabel te plaatsen om deze over de gehele lengte te ontgraven. Deze lokale kabelontgraving vindt plaats met behulp van een inspuitingsmachine om een klein deel van de kabel bloot te leggen, of met een dreg om de kabel naar de oppervlakte te halen. Er zijn diverse soorten dreggen beschikbaar (zie paragraaf over ‘Pre-Lay Grapnel Runs’ (PLGR) hierboven, waaronder ‘de-trenching’ dreggen (de meest waarschijnlijke keuze) en andere, meer geavanceerde ‘cut-and-hold’ dreggen.

6.1.4 Wanneer een deel van de kabel blootligt, zijn er twee alternatieve methoden om de kabel in zijn geheel te ontgraven. De krachten bij het ‘uitpellen’ van de kabel zijn niet al te groot; er kan een grijper aan de kabel worden bevestigd om vervolgens een uiteinde van de kabel naar het bergingsschip op te halen. De kabelberging kan dan rechtstreeks plaatsvinden. Als alternatief kan een ‘onderroller’ worden ingezet die zich onder de volledige lengte van de ingegraven kabel door beweegt. Dit werktuig is via een staalkabel met een schip verbonden dat de kabel naar het niveau van de zeebodem optilt. Beide opties zorgen ervoor dat een kabeluiteinde aan boord van het bergingsschip kan worden gebracht. De kabelberging wordt dan voortgezet over de volledige lengte van de kabel, of kabeldelen worden apart afgesneden en opgeslagen. Het kabelbergingsproces komt in wezen neer op het omgekeerde van de aanleg, waarbij de werktuigen in tegengestelde richting werken en de kabel ofwel op haspels op het schip wordt opgerold of tijdens het bergen wordt opgeknipt in delen van ca. 1,5 m lang. Deze korte delen worden dan opgeslagen in (open) afvalcontainers aan boord van het schip om later te worden verwerkt conform de toepasselijke voorschriften voor hergebruik, recycling of afvalverwerking. Na terugkeer in de haven wordt de kabel op de kade uitgeladen.

6.1.5 Het kabeltracé wordt vervolgens onderzocht op eventueel achtergebleven delen. De uitkomsten daarvan worden gepresenteerd als bewijs van verwijdering. Tijdens de buitenbedrijfstelling van de kabel moet afvalmateriaal worden verwerkt, opgeslagen en afgevoerd conform de vanuit milieuoogpunt beste methode (o.b.v. de afvalhiërarchie) en conform de geldende wetgeving inzake afvalbeheer. Naar verwachting zal het buitenbedrijfstellingsprogramma overeenkomen met het programma tijdens aanleg, en zullen de schepen en doorlooptijden vergelijkbaar zijn met die in de aanlegfase.

Viking Link – Contact Us

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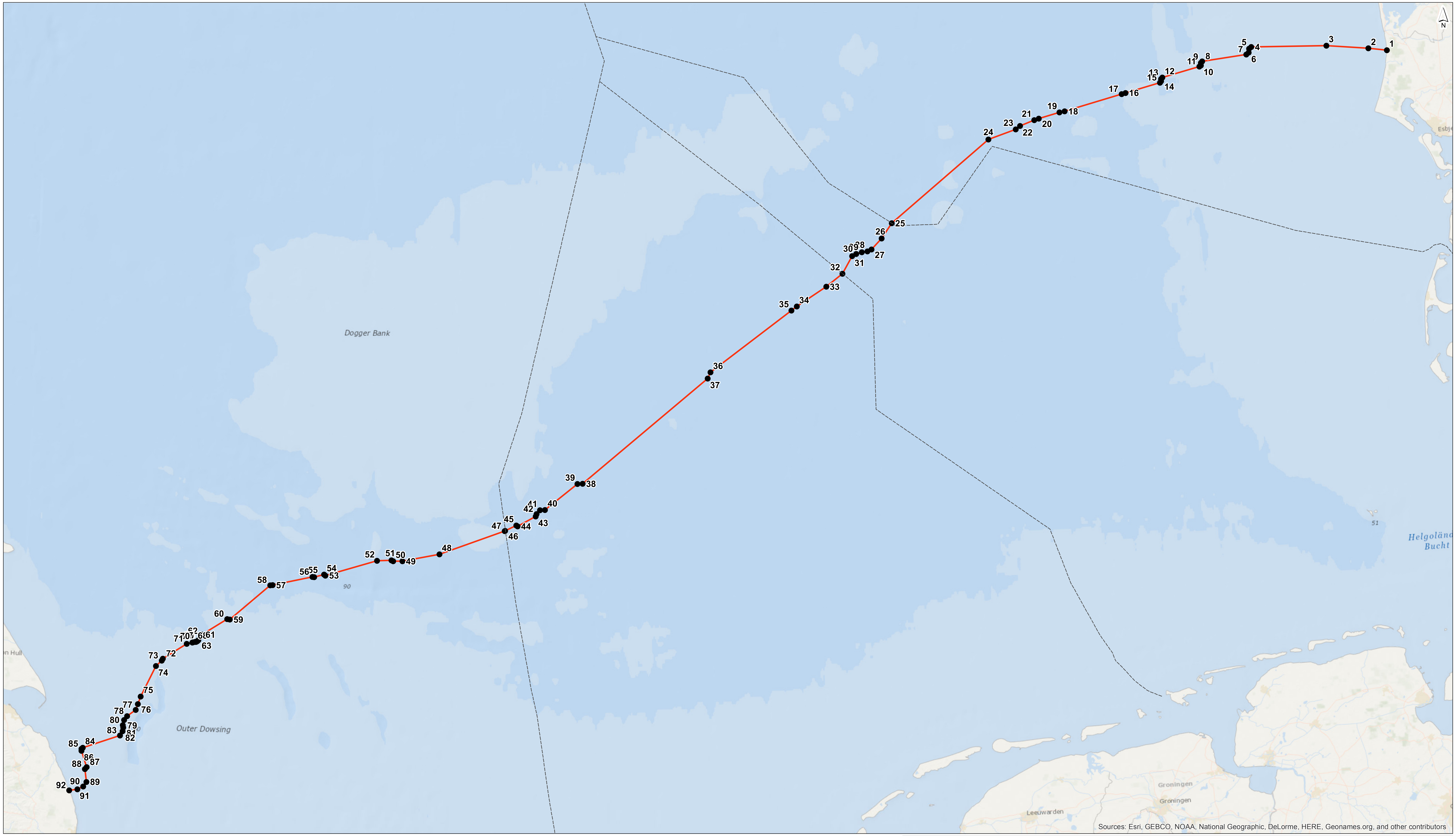

EEZ
RPL point
RPL line

drawn: C.Y. Vredevoort BSc
verified: A.T.W. van Breukelen MSc
approved: H.J.W. Albers-Schouten MA
version: DRAWING IN PROGRESS 1
date: 07-12-2016
drawing no: 0

Viking HVDC Interconnector

Preferred alternative RPL

client: national grid & energinet.dk
project: Viking HVDC Interconnector
project code: DEN34-1

page size: A2 landscape
scale: 1:973912

0 10 20 30 40 50 km

Witteveen + Bos

		ETRS_1989_UTM_Zone_31N		WGS 1984		
Point	KP	X (m)	Y (m)	Lat	Long	Remarks
1	0,000	824779,89350000000	6191987,07200000000	8,17861636175	55,76422756700	Denmark Landfall
2	7,084	817732,36370000000	6192707,30100000000	8,06758031456	55,77534828530	Denmark Waters
3	23,256	801593,97370000000	6193738,16000000000	7,81237170734	55,79490230240	Denmark Waters
4	51,987	772868,35380000000	6193178,64600000000	7,35501649149	55,80695124090	Denmark Waters
5	53,053	771983,05310000000	6192585,08700000000	7,34033976818	55,80213211420	Denmark Waters
6	54,553	771890,52940000000	6191087,11800000000	7,33737334154	55,78876311310	Denmark Waters
7	55,744	770953,33200000000	6190353,47600000000	7,32174132964	55,78271568110	Denmark Waters
8	72,837	754074,17510000000	6187657,61600000000	7,05078644074	55,76771150530	Denmark Waters
9	73,619	753523,58830000000	6187102,14900000000	7,04151693117	55,76302151540	Denmark Waters
10	74,589	753580,16560000000	6186133,50700000000	7,04151693082	55,75431001630	Denmark Waters
11	75,333	752978,90500000000	6185695,78300000000	7,03155548230	55,75070105360	Denmark Waters
12	90,170	738749,39900000000	6181493,66800000000	6,80169808613	55,72024944480	Denmark Waters
13	90,884	738273,20550000000	6180961,06800000000	6,79367062523	55,71570852340	Denmark Waters
14	91,734	738285,10090000000	6180111,26400000000	6,79312022331	55,70808361980	Denmark Waters
15	92,435	737855,01060000000	6179558,13500000000	6,78581048295	55,70333542770	Denmark Waters
16	106,169	724703,42720000000	6175601,14000000000	6,57371230077	55,67411809730	Denmark Waters
17	107,694	723241,67010000000	6175164,05800000000	6,55015914851	55,67087220900	Denmark Waters
18	130,542	701376,52020000000	6168534,82500000000	6,19822925662	55,62095517590	Denmark Waters
19	132,554	699409,58370000000	6168114,58600000000	6,16674021153	55,61799472640	Denmark Waters
20	140,843	691452,23100000000	6165792,84900000000	6,03896353000	55,60035705610	Denmark Waters
21	142,701	689705,97760000000	6165157,84800000000	6,01085120435	55,59534237770	Denmark Waters
22	148,538	684308,46680000000	6162935,34300000000	5,92382928748	55,57746998360	Denmark Waters
23	150,634	682641,58840000000	6161665,34000000000	5,89658469806	55,56670024440	Denmark Waters
24	161,826	672153,17110000000	6157759,57800000000	5,72803175129	55,53546003910	Denmark Waters
25	210,795	635155,24970000000	6125678,92800000000	5,12673270313	55,25903603250	Denmark Waters / German Waters
26	217,839	631281,57260000000	6119796,16200000000	5,06308604977	55,20725369550	German Waters
27	223,548	627378,96070000000	6115628,96600000000	4,99992274124	55,17085093460	German Waters
28	225,278	625802,23550000000	6114916,28000000000	4,97486727619	55,16485379820	German Waters
29	227,409	623708,26330000000	6114522,35800000000	4,94184498008	55,16184380160	German Waters
30	229,680	621533,61580000000	6113866,76400000000	4,90744979396	55,15649450260	German Waters
31	231,444	619975,27440000000	6113041,95600000000	4,88265771839	55,14946671700	German Waters
32	239,117	616271,92880000000	6106321,04200000000	4,82182760633	55,08998493330	German Waters / Dutch Waters
33	247,057	610054,08950000000	6101383,85100000000	4,72254646909	55,04705565200	Dutch Waters
34	260,662	598782,81700000000	6093763,83600000000	4,54357406667	54,98097188100	Dutch Waters
35	263,266	596719,06280000000	6092176,33300000000	4,51080304535	54,96711567440	Dutch Waters
36	302,225	565762,75090000000	6068522,53500000000	4,02196618533	54,75962713590	Dutch Waters
37	304,853	564651,49870000000	6066141,28100000000	4,00417048646	54,73837483210	Dutch Waters
38	367,480	516744,90250000000	6025803,24400000000	3,25780641775	54,37973606410	Dutch Waters
39	369,439	514786,98190000000	6025750,32700000000	3,22765969972	54,37932108380	Dutch Waters
40	385,361	502356,25946700000	6015801,00805000000	3,03619839336	54,29011162280	Dutch Waters
41	387,297	500425,18266800000	6015669,25193000000	3,00653174654	54,28893272200	Dutch Waters
42	389,266	499076,63930000000	6014233,96380000000	2,98581956742	54,27603242320	Dutch Waters
43	390,203	498797,85700000000	6013339,79310000000	2,98154178375	54,26799547730	Dutch Waters
44	398,150	491829,26430000000	6009519,08900000000	2,87464736696	54,23359297630	Dutch Waters
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46	403,465	487086,02550000000	6007788,74700000000	2,80195305847	54,21794384240	English Waters
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48	430,211	461903,25850000000	5998780,40900000000	2,41690837490	54,13573079530	English Waters
49	444,603	447757,45590000000	5996129,85800000000	2,20087764757	54,11066749250	English Waters
50	448,188	444172,69040000000	5996145,81900000000	2,14604723923	54,11043439900	English Waters
51	448,898	443550,48610000000	5996488,49400000000	2,13646698697	54,11344602790	English Waters
52	454,425	438026,65120000000	5996300,57700000000	2,05201719766	54,11112146290	English Waters
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63	531,992	369549,56490000000	5965892,05310000000	1,01807051951	53,82517182590	English Waters
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67	533,116	368638,24610000000	5965271,76490000000	1,00449896583	53,81937047540	English Waters
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79	575,862	341147,66800000000	5935312,02800000000	0,60260006153	53,54264754090	English Waters
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89	611,074	326731,22017300000	5911601,47067000000	0,39830866116	53,32518254710	English Waters
90	613,205	325509,42029400000	5909855,71764000000	0,38094434223	53,30910522660	English Waters
91	615,729	323231,41364800000	5908767,95987000000	0,34739778845	53,29858270000	English Waters
92	618,878	320114,39255200000	5908319,00148000000	0,30093424113	53,29350270510	English Landfall

FUGRO

VIKING LINK CABLE ROUTE SURVEY

NATIONAL GRID INTERCONNECTOR HOLDINGS LIMITED AND ENERGINET.DK.SOV

WPF CABLE ROUTE SURVEY REPORT

BOOK A: Text and Overview Chart

Survey Period 18 March to 6 September 2016
Fugro Document No.: J35045-R-IDRFA(03)

VikingLink

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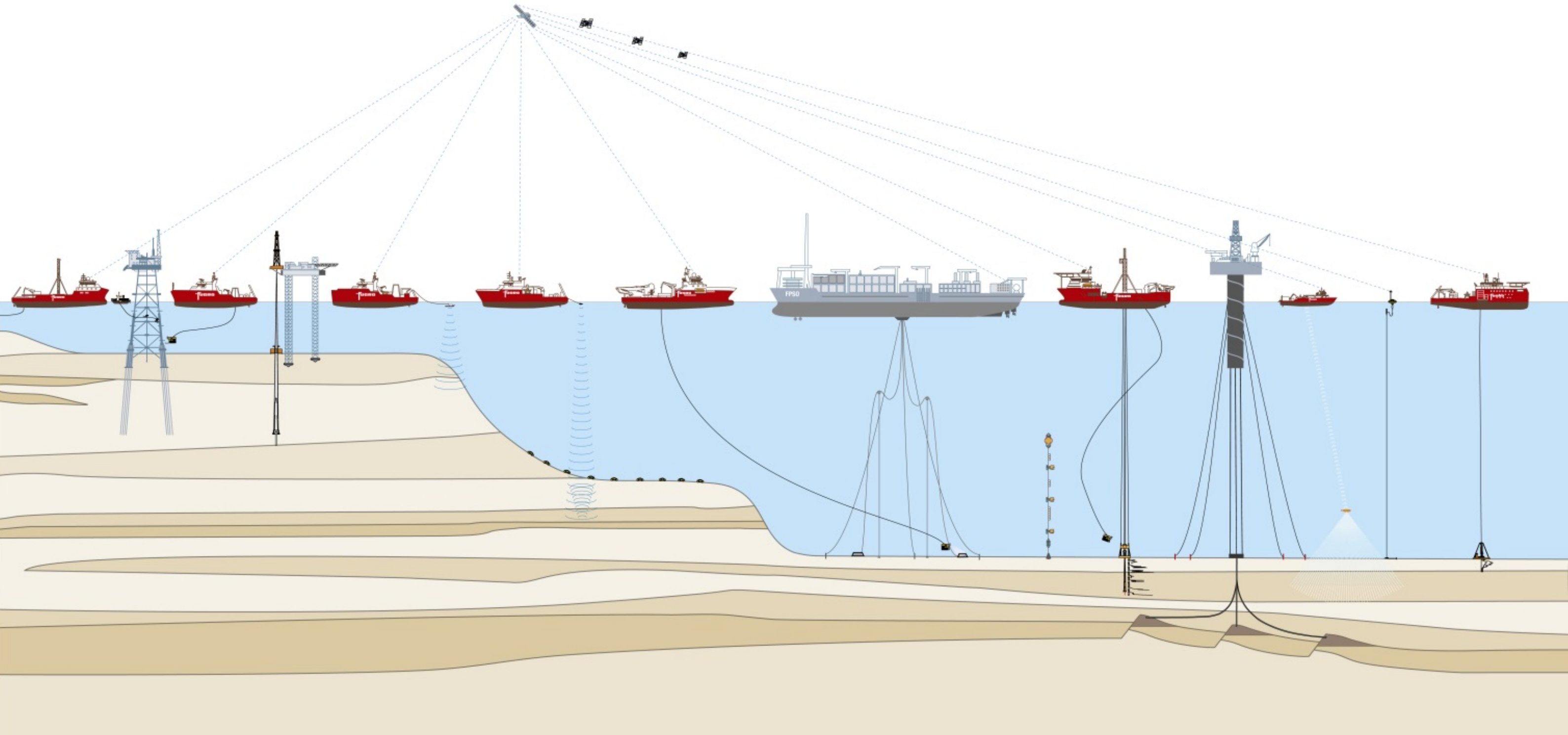
Co-financed by the European Union
Connecting Europe Facility

Revised Final



FUGRO

VIKING LINK CABLE ROUTE SURVEY

NATIONAL GRID INTERCONNECTOR HOLDINGS LIMITED AND ENERGINET.DK.SOV

WPF CABLE ROUTE SURVEY REPORT

BOOK A: Text and Overview Chart

Survey Period 18 March to 6 September 2016
Fugro Document No.: J35045-R-IDRFA(03)

Prepared for:

National Grid Interconnector Holdings Limited
1-3 Strand, London WC2N 5EH

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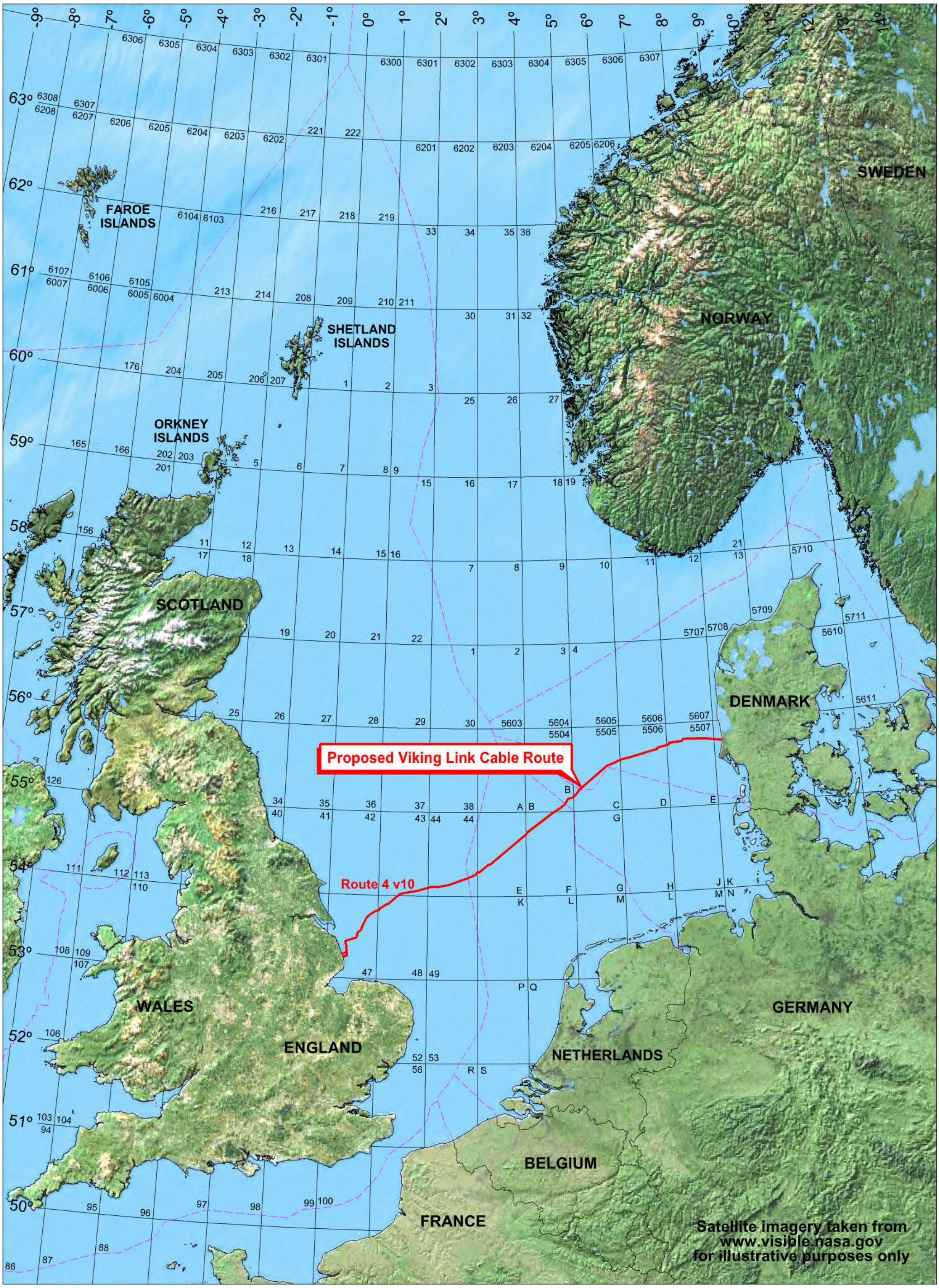
Co-financed by the European Union
Connecting Europe Facility

03	Revised Final Issue	Fugro	CAS/SA	GD	16 December 2016
02	Final Issue	Fugro	CAS/SA	GD	2 December 2016
01	Draft Issue for Client Review	Fugro	CAS/SA	GD	28 October 2016
Rev	**Description**	**Prepared**	**Checked**	**Approved**	**Date**



FRONTISPIECE

PROJECT DOCUMENT ARRANGEMENT

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ENGLAND – DENMARK HV CABLE ROUTE
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Operations Report
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Operations Report
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<tr><td colspan="4">Work Package C
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J35045-PEP2-D</td></tr>
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EXECUTIVE SUMMARY

Project Geodesy:	Ellipsoid: Datum: Semi major axis: Inverse Flattening: Projection: Grid: UTM Zone: Central Meridian: Latitude of Origin: False Easting: False Northing: Scale Factor on Central Meridian: Units:	European Terrestrial Reference System (ETRS) 1989 EPSG Code: 6258 GRS 1980 6 378 137.000 m 1/f=298.257222101 Transverse Mercator Universal Transverse Mercator 31 N 3° E 0° N 500 000 m 0 m 0.9996 Metre
Vertical Datum:	Lowest Astronomical Tide	
Route Revision:	20160623_Route_4_Rev10_ETRS89_UTM31N_RPL	

Cable Geotechnical Zonation (Section 8)	A cable geotechnical zonation was derived from the integration of geological, geophysical and geotechnical datasets. This forms a predictive model for geotechnical conditions to a depth of 3 m below seafloor (BSF) along the centreline of Route 4 (rev.10). The route has been categorised into seven cable geotechnical zones (see below), which are subdivided into 21 subzones. **Cable Geotechnical Zone 1** – Recent to early Holocene intertidal marine sediments (fine to medium SAND, SILT, extremely low strength CLAY and PEAT) to 3 m BSF *55.3% of Route 4 (rev.10)* **Cable Geotechnical Zone 2** – Recent to early Holocene marine sediments (coarse SAND and GRAVEL) to 3 m BSF *3.3% of Route 4 (rev.10)* **Cable Geotechnical Zone 3** – Recent to early Holocene marine sediments (mixed grain size SAND and GRAVEL containing inversions in relative density with depth) to 3 m BSF *6.6% of Route 4 (rev.10)* **Cable Geotechnical Zone 4** – Recent to early Holocene marine sediments overlying post-depositionally modified Late Quaternary sediments (granular sediments and low to extremely high strength CLAY) to 3 m BSF *1.8% of Route 4 (rev.10)* **Cable Geotechnical Zone 5** – Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments (granular sediments and predominantly high to extremely high strength CLAY) to 3 m BSF *30.2% of Route 4 (rev.10)* **Cable Geotechnical Zone 6** – Recent to early Holocene marine sediments overlying Middle to Late Quaternary marine sediments (very loose to very dense SAND and GRAVEL) to 3 m BSF *2.8% of Route 4 (rev.10)* **Cable Geotechnical Zone 7** – Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments overlying Upper Cretaceous chalk (granular sediments and high to extremely high strength CLAY and BEDROCK) *<0.1% of Route 4 (rev.10)*

Cable Installation Considerations Summary (Section 9)	A geomorphological assessment was completed for the corridor of Route 4 (rev. 10) appraising seabed relief with respect to cable installation. The following considerations were identified and are presented where they intersect the centerline of the proposed route on the alignment charts: ▪ Areas of potential sediment mobility ▪ Areas of numerous boulders ▪ Areas of subcropping to outcropping bedrock ▪ Seafloor gradients greater than 5 degrees These features were selected based on regions interpreted during the offshore data acquisition phase

ROUTE CONDITIONS

Danish Landfall	KP range: Alignment charts:	KP 0 – KP 2.388 001
Topography	Minimum Elevation: Maximum Elevation: Maximum Gradient Along Route:	0.0 m at KP 0.160 14.5 m at KP 0 22º at KP 0.080
Shallow Geology	Sand	
Onshore Installation Constraints	Significant features that might present a physical constraint to installation are the undulating sand dunes to KP 0.090	
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	0.0 m at KP 0.160 9.7 m at KP 2.388 2º from KP 0.500 to KP 0.650
Shallow Geology	Shallow sediments are expected to be SAND-prone to at least 3 m sub-seabed. The sub crop of these sands is interpreted to be CLAY/SILT-prone	
Nearshore Installation Constraints	Five boulders are mapped between KP 0.500 and KP 2.388 (alignment chart 1). Three of these boulders are immediately south of the route at KP 2.063, KP 2.093 and KP 2.218. There are four scattered magnetic anomalies within the Danish landfall zone, one is within 100 m of the route, positioned 11 m north of KP 0.548. The Harald Pipeline to Nybro runs near parallel to the route, it is positioned 270 m south of KP 0	

Danish EEZ	KP range: Alignment charts:	KP 2.388 – KP 210.795 001 - 048
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	9.7 m at KP 2.388 51.9 m at KP 170 >20º over short slopes on margins of scours, localised between KP 37 and KP 140.500
Shallow Geology	KP 2.388 – KP 44: loose silty fine SAND with subordinate GRAVEL over a sub crop of CLAY with rare SAND layers KP 44 – KP 47: CLAY with layers of SILT and SAND over a sub crop of CLAY with rare SAND layers KP 47 – KP 74: SAND over CLAY with rare SAND layers KP 74 – KP 210.560: loose silty fine SAND with subordinate GRAVEL over CLAY with rare SAND layers KP 121 – KP 127.850 and KP 144.330 – KP 198: sub crop of CLAY-prone channel infill	
Installation Constraints	A line of five magnetic anomalies intersects the route at KP 23.035 (alignment chart 6). Seven associated magnetic anomalies cross the route at KP 23.750 (alignment chart 6), four associated magnetic anomalies cross at KP 26.220 (alignment chart 6), five anomalies cross the route at KP 65.720 (alignment chart 15), three anomalies are north of the route at KP 66.075 (alignment chart 15) and six anomalies cross the route at KP	

	108.820 (alignment chart 25), these six anomalies are part of a field of sonar contacts. Four anomalies are immediately south of the route at KP 200 (alignment chart 45). These strings of magnetic anomalies may represent cable debris but there are no directly corresponding contacts on other data. There is a single magnetic anomaly on the route at KP 69.435 (alignment chart 16) and a sonar contact on the route at KP 125.315 (alignment chart 29). Boulders are on the route at KP 2.750, KP 2.858 and KP 2.896; boulders are numerous in this area. 12 existing pipelines and cables cross the route within the Danish EEZ. These are tabulated in Section 4.3.3.4

German EEZ	KP range: Alignment charts:	KP 210.795 – KP 238.117 048 - 054
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	40.3 m at KP 230 42.2 m at KP 210.795 and KP 215.300 <0.5°
Shallow Geology	Profiler data show numerous infilled channels within the German sector beneath a continuous 1 to 3 metre thick layer of silty SAND which extends from seabed. Sample and test data show that the sharply eroded channels are infilled with sandy SILT or CLAY. These channels are cut into dense silty SAND	
Installation Constraints	A line of three magnetic anomalies intersects the route at KP 221.250 (alignment chart 50), a line of four magnetic anomalies intersects the route at KP 222.030 (alignment chart 50), a line of four magnetic anomalies intersects the route at KP 226.530 (alignment chart 52). These strings of magnetic anomalies may represent cable debris but there are no corresponding contacts on other data. Two pipelines (no cables) cross the route within the German EEZ these are tabulated in Section 4.4.3.4	

Netherlands EEZ	KP range: Alignment charts:	KP 238.117 – KP 403.341 054 - 091
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	41.2 m at KP 243 56.1 m at KP 402.700 ~1° beyond KP 380, generally below 0.5°
Shallow Geology	KP 238.660 – KP 268: silty fine SAND with occasional SILT/CLAY filled channels below a surficial layer of SAND KP 268 – KP 288: shallow geology is SILT/CLAY prone with an unmappably thin layer of surficial SAND KP 288 – KP 338: 1 to 3 metre thick layer of silty fine SAND with subordinate GRAVEL and organic material subcropped by CLAY with rare SAND layers KP 338 – KP 361: subcrop of the uppermost SAND also becomes SAND prone KP 361 – KP 394: subcrop of the uppermost SAND unit is CLAY-prone KP 394 – KP 402.760: uppermost unit becomes SILT-prone subcrop is CLAY-prone	
Installation Constraints	19 boulders are mapped within the Dutch sector. Only one is within 100 m of the route. This is 7 m north-west of KP 376.057 (alignment chart 85). A line of four magnetic anomalies intersects the route at KP 250.990 (alignment chart 57). Five associated magnetic anomalies are close to the route at KP 344.400 (alignment chart 78), and four associated magnetic are close to KP 356.900 (alignment chart 80), including one of high intensity. These strings of magnetic anomalies may represent cable debris but there are no corresponding contacts on other data. Ten pipelines and cables cross the route within the Netherlands EEZ at nine crossing locations. These are tabulated within Section 4.5.3.4. There is a wellhead 9 m north-west	

	of KP 389.017 with associated spudcan depressions

UK EEZ	KP range: Alignment charts:	KP 403.341 – KP 618.20 (LF1 unless stated otherwise beyond KP 611.074) 091 - 141
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	4.6 m at KP 618.200 86.6 m at KP 472.740 ~10° at KP 475.500, similar dips on sand waves, locally from KP 474.900
Shallow Geology	KP 402.760 – KP 531.500: silty fine SAND with subordinate GRAVEL over CLAY with rare SAND layers KP 531.500 – KP 618.200: shallow geology is CLAY prone with only a thin veneer of sandy sediment at seabed, though locally sand waves are superimposed upon the upper surface of these CLAYS From KP 477 (alignment chart 108) to KP 485.500 (alignment chart 109) the shallow geological conditions are more complex and variable. The shallow sediments largely comprise infill of distinct channels	
Installation Constraints	Sand waves which occur beyond KP 469.120 (alignment chart 106) and are more numerous beyond KP 532.490 (alignment chart 120). The crests of sand waves are tabulated in Section 4.6.2. Inner and Outer Silver Pit erosive depressions. Numerous pebbles and boulders, especially beyond KP 535.440 on both LF options. Wrecks are located 142 m north-west of KP 404.779 (alignment chart 91), 233 m north-west of KP 419.159 and 200 m north-west of KP 419.398 (alignment chart 95). Seven associated magnetic anomalies cross the route at KP 528.650 (alignment chart 119). A line of five associated magnetic anomalies intersects the route at KP 618.140 (alignment chart 140). These may relate to cable debris though there are no corroborating observations in other data. 23 pipelines and cables cross the route within the UK EEZ at 20 crossing locations. These are tabulated within Section 4.6.3.4	

UK Landfall LF1	KP range: Alignment charts	KP 618.200 – KP 618.760 140 - 141
Topography	Minimum Elevation: Maximum Elevation: Maximum Gradient Along Route:	0.0 m at KP 618.420 12 m at KP 618.735 7º at KP 618.660 to KP 618.690
Shallow Geology	Sand	
Onshore Installation Constraints	Concrete sea wall with steel fencing at route end, groynes on beach	
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	0.0 m at KP 618.420 4.6 m at KP 618.200 4º at KP 618.430
Shallow Geology	Shallow sediments are expected to comprise CLAY with layers of SILT and SAND with a landward thickening veneer of silty SAND	
Nearshore Installation Constraints	There are a profusion of magnetic anomalies and sonar contacts within the landfall zone (alignment charts140 and 141)	

UK Landfall LF2	KP range: Alignment charts:	KP 611.074 – KP 622.659 LF2 139 - 141
Topography	Minimum Elevation: Maximum Elevation: Maximum Gradient Along Route:	0.0 m at KP 622.354 10 m at KP 622.659 7° at KP 622.592 to KP 622.617
Shallow Geology	Sand	
Onshore Installation Constraints	Concrete sea wall with steel fencing at route end, groynes on beach	
Bathymetry	Minimum Depth: Maximum Depth: Maximum Gradient Along Route:	0.0 m at KP 622.354 4.1 m at KP 622.200 1.6° from KP 622.354 to KP 622.200
Shallow Geology	Shallow sediments are expected to comprise CLAY with layers of SILT and SAND with a landward thickening veneer of silty SAND	
Nearshore Installation Constraints	There are five magnetic anomalies within the LF2 landfall area. One of these, at KP 622.372 is within 3 m of the route (LF2 alignment charts 140 and 141)	

BOOK STRUCTURE

BOOK A:	**Report Text and Overview Chart**
BOOK B:	DK EEZ, Alignment Charts 001 – 048
BOOK C:	DE and NL EEZ, Alignment Charts 048 – 091
BOOK D:	UK EEZ, Alignment Charts 091 – 141, Landfall and Aggregate Area Charts

CONTENTS

APPENDICES

TABLES IN THE MAIN TEXT

FIGURES IN THE MAIN TEXT

ABBREVIATIONS

AL1	Cefas Action Level 1
BAP	Biodiversity Action Plan
BLAST	Bringing Land and Sea Together (an EU initiative for unifying land, intertidal and marine data)
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CM	Central Meridian
CPI	Carbon Preference Index
CRP	Central Reference Point
CGZ	Cable Geotechnical Zone
CSC	Cable Soil Category
DE	Germany
DGPS	Differential Global Positioning System
DK	Denmark
DTU	Technical University of Denmark
DVR	Dansk Vertikal Reference
EEZ	Exclusive Economic Zone
ENDK	Energinet.dk SOV
EPSG	European Petroleum Survey Group
ERL	Effects Range Low
ETRS	European Terrestrial Reference System
EUNIS	European Nature Information System
FEED	Front End Engineering and Design
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HP	High Precision
HSE	Health, Safety and Environment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ITRF	International Terrestrial Reference Frame
JNCC	Joint Nature Conservation Committee
ka BP	Thousand years before present
KP	Kilometre Post
LAT	Lowest Astronomical Tide
LGM	Last Glacial Maximum
Ma BP	Million years before present
MBES	Multibeam echo sounder
MRU	Motion Reference Unit
MSL	Mean Sea Level
MV	Motor Vessel
NOAA	National Oceanic and Atmospheric Administration
NGIHL	National Grid Interconnector Holdings Limited
NL	The Netherlands
NS	Nearshore
ODN	Ordnance Datum Newlyn

OpCo	Operating Company
PGM	Permanent Ground Markers
PPE	Personal Protective Equipment
ppm	Parts Per Million
PRIMER	Plymouth Routines in Multivariate Ecological Research
Pr:Ph	Pristane Phytane Ratio
PSD	Particle Size Distribution
QC	Quality Control
ROV	Remotely Operated Vehicle
RPL	Route Position Listing
RTK	Real Time Kinematic
SVP	Sound Velocity Profiler
SVS	Sound Velocity Sensor
UCM	Unresolved Complex Mixture
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frame
WP	Work Package
WGS84	World Geodetic System 1984

British Geological Survey Formation Names

BCT	Botney Cut Formation
BDK	Bolders Bank Formation
BNB	Brown Bank Formation
CBK	Cleaver Bank Formation
DBK	Dogger Bank Formation
EEM	Eem Formation
EG	Egmond Ground Formation
ELW	Elbow Formation
MKH	Markham’s Hole Formation
qH	Quaternary Holocene (Undivided)
SBK	Swarte Bank Formation
SH	Sand Hole Formation
UCk	Upper Cretaceous Chalk
YM	Yarmouth Roads Formation

LIST OF DRAWINGS

Drawing No.	Description	Scale	Book	Issue
J35045-RO-Overview-500k	**Project Overview Chart**	**1:500**	**A**	**03**

Drawing No.	Description	KP Range	Scale	Book	Issue
J35045-AL-Chart-001-5k	Alignment Chart 1 of 141	0 - 4	1:5000	B	
J35045-AL-Chart-002-5k	Alignment Chart 2 of 141	4 - 9	1:5000	B	
J35045-AL-Chart-003-5k	Alignment Chart 3 of 141	9 - 13	1:5000	B	
J35045-AL-Chart-004-5k	Alignment Chart 4 of 141	13 - 18	1:5000	B	
J35045-AL-Chart-005-5k	Alignment Chart 5 of 141	18 - 23	1:5000	B	
J35045-AL-Chart-006-5k	Alignment Chart 6 of 141	23 - 27	1:5000	B	
J35045-AL-Chart-007-5k	Alignment Chart 7 of 141	27 - 31	1:5000	B	
J35045-AL-Chart-008-5k	Alignment Chart 8 of 141	31 - 36	1:5000	B	
J35045-AL-Chart-009-5k	Alignment Chart 9 of 141	36 - 41	1:5000	B	
J35045-AL-Chart-010-5k	Alignment Chart 10 of 141	41 - 45	1:5000	B	
J35045-AL-Chart-011-5k	Alignment Chart 11 of 141	45 - 50	1:5000	B	
J35045-AL-Chart-012-5k	Alignment Chart 12 of 141	50 - 54	1:5000	B	
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J35045-AL-Chart-015-5k	Alignment Chart 15 of 141	62 - 67	1:5000	B	
J35045-AL-Chart-016-5k	Alignment Chart 16 of 141	67 - 72	1:5000	B	
J35045-AL-Chart-017-5k	Alignment Chart 17 of 141	72 - 76	1:5000	B	
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J35045-AL-Chart-019-5k	Alignment Chart 19 of 141	80 - 84	1:5000	B	
J35045-AL-Chart-020-5k	Alignment Chart 20 of 141	84 - 89	1:5000	B	
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J35045-AL-Chart-022-5k	Alignment Chart 22 of 141	93 - 97	1:5000	B	
J35045-AL-Chart-023-5k	Alignment Chart 23 of 141	97 - 101	1:5000	B	
J35045-AL-Chart-024-5k	Alignment Chart 24 of 141	101 - 106	1:5000	B	
J35045-AL-Chart-025-5k	Alignment Chart 25 of 141	106 - 110	1:5000	B	
J35045-AL-Chart-026-5k	Alignment Chart 26 of 141	110 - 115	1:5000	B	
J35045-AL-Chart-027-5k	Alignment Chart 27 of 141	115- 120	1:5000	B	
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J35045-AL-Chart-029-5k	Alignment Chart 29 of 141	124 - 129	1:5000	B	
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J35045-AL-Chart-040-5k	Alignment Chart 40 of 141	172 - 177	1:5000	B	
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J35045-AL-Chart-050-5k	Alignment Chart 50 of 141	218 - 222	1:5000	C	
J35045-AL-Chart-051-5k	Alignment Chart 51 of 141	222 - 226	1:5000	C	
J35045-AL-Chart-052-5k	Alignment Chart 52 of 141	226 - 230	1:5000	C	
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J35045-AL-Chart-055-5k	Alignment Chart 55 of 141	239 - 243	1:5000	C	
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J35045-AL-Chart-058-5k	Alignment Chart 58 of 141	252 - 257	1:5000	C	
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J35045-AL-Chart-066-5k	Alignment Chart 66 of 141	289 - 293	1:5000	C	
J35045-AL-Chart-067-5k	Alignment Chart 67 of 141	293 - 298	1:5000	C	
J35045-AL-Chart-068-5k	Alignment Chart 68 of 141	298 - 302	1:5000	C	
J35045-AL-Chart-069-5k	Alignment Chart 69 of 141	302 - 306	1:5000	C	
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J35045-AL-Chart-073-5k	Alignment Chart 73 of 141	320 - 325	1:5000	C	
J35045-AL-Chart-074-5k	Alignment Chart 74 of 141	325 - 329	1:5000	C	
J35045-AL-Chart-075-5k	Alignment Chart 75 of 141	329 - 334	1:5000	C	
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J35045-AL-Chart-084-5k	Alignment Chart 84 of 141	370 - 375	1:5000	C	
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J35045-AL-Chart-102-5k	Alignment Chart 102 of 141	450 - 454	1:5000	D	
J35045-AL-Chart-103-5k	Alignment Chart 103 of 141	454 - 459	1:5000	D	
J35045-AL-Chart-104-5k	Alignment Chart 104 of 141	459 - 463	1:5000	D	
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J35045-AL-Chart-106-5k	Alignment Chart 106 of 141	468 - 472	1:5000	D	
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J35045-AL-Chart-108-5k	Alignment Chart 108 of 141	477 - 481	1:5000	D	
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J35045-AL-Chart-110-5k	Alignment Chart 110 of 141	485 - 490	1:5000	D	
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J35045-AL-Chart-125-5k	Alignment Chart 125 of 141	551 - 555	1:5000	D	
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J35045-AL-Chart-133-5k	Alignment Chart 133 of 141	583 - 588	1:5000	D	
J35045-AL-Chart-134-5k	Alignment Chart 134 of 141	588 - 593	1:5000	D	
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J3545-NU_01-1k	Plan Chart 1 of 3	Danish Landfall Topographic	1:1000	D	
J3545-NU_02-1k	Plan Chart 2 of 3	UK Landfall Topographic (LF1)	1:1000	D	
J3545-NU_02-1k	Plan Chart 3 of 3	UK Landfall Topographic (LF2)	1:1000	D	

Drawing No.	Description	Aggregate Extension	Scale	Book	Issue
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J35045-NU-BTY-2-10k	Plan Chart 2 of 4	Bathymetry - South	1:10000	D	
J35045-NU-SBF-1-10k	Plan Chart 3 of 4	Seabed Features - North	1:10000	D	
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1. INTRODUCTION

1.1 General Project Description

The Viking Link project concerns a planned High Voltage Direct Current (HVDC) electricity transmission interconnector, composed of a pair of buried submarine cables extending approximately 615 km between England and Denmark across the North Sea.

The project is being jointly developed by National Grid Interconnector Holdings Limited (NGIHL) and Energinet.dk SOV (ENDK). NGIHL/ENDK contracted Fugro to perform a Marine Survey for the submarine and underground landfall sections of the proposed interconnector. This includes defined Work Packages (WPs) covering Landfall, Nearshore and Offshore scopes of work. These sub-scopes, within the overall Marine Survey contract, will be carried out by a number of Fugro Operating Companies (OpCo), as detailed in the Project Execution Plan (J35045-PEP1).

1.2 Background

The purpose of the Viking Link project is to construct a submarine HVDC electricity transmission interconnector between England and Denmark. The planned cable layout is for a Danish landfall (KP 0) at Blaabjerg Strand, approximately 30 km north of Esbjerg and two English landfall areas, north of Anderby Creek, close to Skegness. These comprise a northern and southern offshore survey corridor providing four landfall options. From south to north these landfall options are named Alpha, Charlie, Delta and Echo. Offshore the main route is named Route 4. The survey route corridor is approximately 615 km long and 450 m wide.

The Route 4 survey plan is sub-divided into 15 survey blocks. Figure 1.1 shows the survey blocks for the selected survey route. Block lengths vary from 32 km to 54 km with most blocks between 45 km and 48 km long.

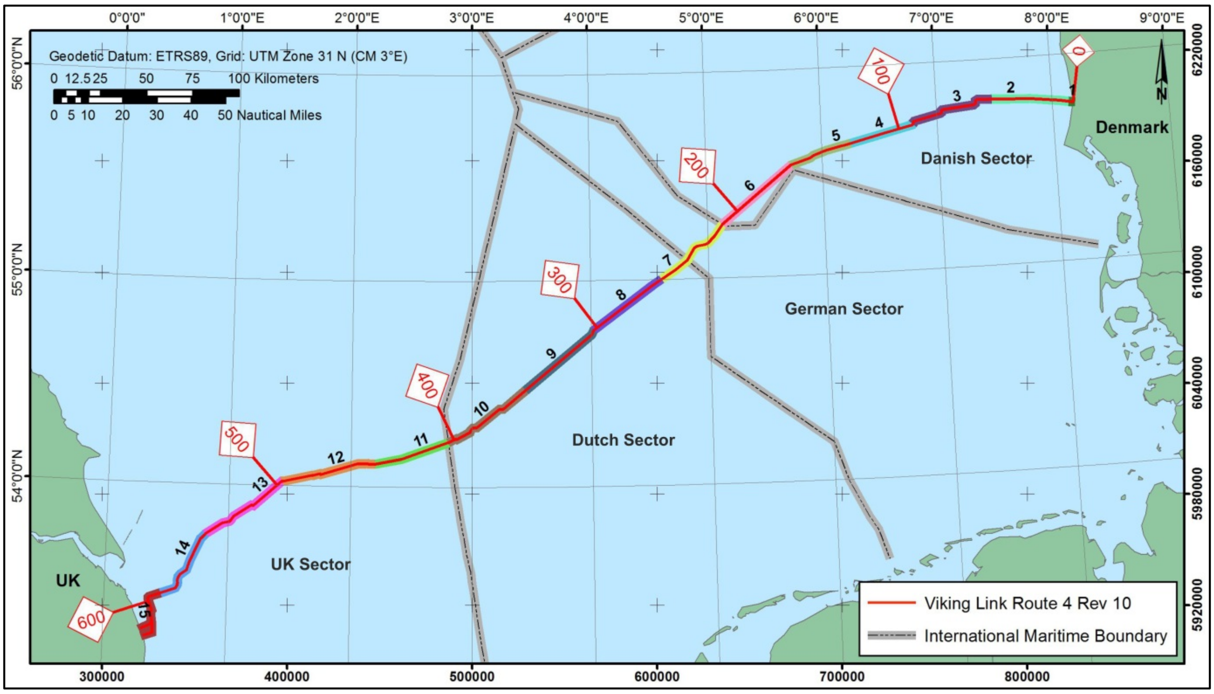


Figure 1.1: Viking Link Cable Route Overview

1.3 Project Objectives

The Viking Link cable route survey data consists of high-resolution topographic, bathymetric, seabed imagery and sub-seabed data (geophysical, geological, geotechnical and environmental) to support routing, FEED design and provide the basis for input to the construction tender process. The final results of the project will detail physical and environmental conditions from the seabed (or land surface) to a depth limit related to the available data.

Fugro was contracted to acquire survey data and to deliver a comprehensive integrated geophysical, geotechnical and environmental report. Four principal services are required to provide the range of information needed to inform routing, engineering and complete the consenting process. The headline objectives of the individual surveys are summarised in Table 1.1 and described in Sections 1.4 to 1.8.

Table 1.1: Headline Survey Objectives

GEOPHYSICAL
Undertake geophysical surveys along the route and in defined survey areas to determine: ■ Bathymetry ■ Seabed features and obstructions ■ Shallow geology
ENVIRONMENTAL (BENTHIC)
Undertake environmental surveys along the route ■ Map distribution and extent of marine benthic habitats ■ Benthic sampling for visual and chemical analysis
GEOTECHNICAL
Undertake geotechnical surveys along the route ■ Perform a sampling and testing programme along proposed cable route ■ Evaluate the nature and mechanical properties of seabed and intertidal sediments
UTILITY CROSSINGS
Undertake ROV surveys over identified pipe/cable crossings ■ Position intersection of Route Position Listing (RPL) and utility cable/pipeline ■ Status of utility (including depth of burial or height of exposure) and seabed at crossing

1.4 Survey Work Packages

The survey operations are structured into Work Packages (WP) as designated in Table 1.2:

Table 1.2: Work Package Designations

Work Package	Survey Operation
A	Onshore and Intertidal Activities
B	Geophysical Seabed Survey
C	Geotechnical Investigations (Nearshore and Offshore)
D	ROV investigations of crossing cables and pipelines
E	Benthic Investigations
F	Reporting and Data Delivery

WPA and B form the primary survey phases, the results of which provide planning input to WPC, D and E. WPF constitutes the reporting for all previously acquired Work Packages and laboratory testing, and the integration of the results from all Work Packages.

1.5 Geophysical Survey Objectives

The geophysical survey areas are split between WPA (onshore and intertidal survey area) and WPB (offshore survey area). The objectives of the geophysical surveys are to:

- Measure onshore and intertidal topography, bathymetry and surface morphology and identify the nature of the seabed sediments – in particular the height, length and slopes of sand waves;
- Identify the nature and thickness of superficial sediments and depth to bedrock, to a sub-seabed depth of 10 m where possible;
- Identify the distribution of subsea geological features such as areas of exposed bedrock or older formations;
- Identify the location, extent and nature of any impediments to the lay or burial of the proposed Viking Link cables such as wrecks, debris, rock outcrop, existing cables or pipelines, etc.;
- Determine geotechnical and benthic (environmental) sample locations.

1.6 Environmental (Benthic) Survey Objectives

The objectives of WPE, the environmental (benthic) investigation are to:

- Obtain environmental grab samples to correlate with potential marine habitats identified during the geophysical survey;
- Provide additional sampling conforming to German Exclusive Economic Zone (EEZ) requirements (for example, beam trawls);
- Recover samples for on-board and subsequent laboratory testing;
- Obtain video and still photography for benthic analysis.

1.7 Geotechnical Investigation Objectives

The objectives of WPC, the geotechnical investigation are to:

- Obtain and describe targeted samples of seabed materials to correlate with interpreted seismic reflectors;
- Recover targeted samples for on-board and subsequent laboratory testing;
- Test in-situ sediment properties at targeted locations.
- Obtain most tests and samples to a target depth of 3 m sub-seabed, and the remainder to a target depth of 6 m sub-seabed.

1.8 ROV Utility Crossing Investigation Objectives

The objectives of WPD, the ROV utility crossing investigation are to:

- Confirm the position and crossing angle of route/utility intersections across the 450 m survey corridor, and an additional 200 m to either side;

- Determine the burial status and depth of existing utilities;
- Determine the seabed features and conditions at each crossing.

1.9 Route Position Listing

The route position listing (RPL) details for the Viking Link cable route survey were supplied by Intertek in Excel spreadsheet and an ESRI shapefile format on 9 March 2016, prior to the start of the survey acquisition (file "20160309_DK_to_UK_Route_Rev3_ETRS89_UTM31N_RPL"). These formed the basis for the geophysical site and route surveys, from the Landfall in Denmark to the UK EEZ boundary (Point A). Subsequent revisions to the route led to "20160603_Route_4_Rev9_ETRS89_UTM31N" becoming the basis of the survey investigation and the crossing surveys.

A further revision to the RPL "20160623_Route_4_Rev10_ETRS89_UTM31N_RPL" this has been developed to accommodate the re-routing survey investigations and thus used for integrated reporting. Appendix A contains this latest revision of the proposed route.

1.10 Geodetic and Projection Parameters and Vertical Datum

1.10.1 Project Geodetic Parameters

The Viking Link project data are presented on the geodetic datum and map projection as defined in Table 1.3.

Table 1.3: Project Geodetic and Projection Parameters

ETRS89 (3D) [ETRS89-ITRF08]		
Global Navigation Satellite System (GNSS) Geodetic Parameters		
Datum:	International Terrestrial Reference Frame (ITRF) 2008 EPSG Code: 1061	
Ellipsoid:	GRS 1980	
Semi major axis:	a=6 378 137.000 m	
Inverse Flattening:	1/f=298.257222101	
Local Geodetic Datum Parameters		
Datum:	European Terrestrial Reference System (ETRS) 1989 EPSG Code: 6258	
Ellipsoid:	GRS 1980	
Semi major axis:	a=6 378 137.000 m	
Inverse Flattening:	1/f=298.257222101	
Datum Transformation Parameters from ITRF08 to ETRS89 (Coordinate Frame Rotation Convention)		
Shift dX 0.05373 m	Rotation rX -0.002214 arcsec	Scale difference 0.00264645 ppm
Shift dY 0.05093 m	Rotation rY -0.013392 arcsec	
Shift dZ 0.08790 m	Rotation rZ 0.021646 arcsec	EPSG Code: 41258
Project Projection Parameters		
Map Projection:	Transverse Mercator	
Grid System:	UTM Zone 31 N	
Central Meridian:	3° East	
Latitude of Origin:	0° North	
False Easting:	500 000 m	
False Northing:	0 m	
Scale Factor on Central Meridian:	0.9996	
Units:	Metre	
Note: The geodetic datum of Fugro's global GNSS correction data is ITRF2008, epoch 2016.331		

1.10.2 Vertical Datum

The vertical datum for this project is Lowest Astronomical Tide (LAT). All water depths; topographic mapping, factual results and charting are referenced to LAT and quoted in metres.

The land vertical datum for the UK is Ordnance Datum Newlyn (ODN) and for Denmark is Dansk Vertikal Reference 1990 (DVR90).

Table 1.4 lists UK vertical datum levels for selected Viking Link cable route locations, including the tie-in to ODN.

Table 1.4: Vertical Datum Levels for Selected Viking Link Cable Route Locations

Location	LAT [m]	MSL [m]	ODN [m]	Notes	MSL/LAT Separation [m]
UK N5 Landing	+0.1	+4.0	+3.8	Height above chart datum. Source: VORF (contains UKHO data © Crown copyright and database rights)	+3.9
UK N4 Landing	0.0	+3.8	+3.7		+3.8
Note: N4 landing = Original Southern Landfall near Skegness N5 landing = Original Northern Landfall near Mablethorpe					

Table 1.5 lists Danish, German and Netherlands vertical datum levels for selected Viking Link cable route locations, including the tie-in to DVR90.

Table 1.5: Other Levels Relative to Chart Datum

Location	LAT [m]	MSL [m]	DVR90 [m]	Notes	MSL/LAT Separation [m]
Esbjerg	-0.2	+1.1	+0.584	Height above chart datum. Source: Admiralty Tide Tables and http://www.gst.dk/media/gst/65263/Vejledning om højdesystemet.pdf	+1.3
DK Block 2/3 Interface	+40.3	+40.9	-	Height above ellipsoid in metres. Source: DTU13/ DTU13 + NL LAT Computation	+0.6
DK/DE EEZ Interface	+40.5	+40.9	-		+0.4
DE/NL EEZ Interface	+40.5	+41.0	-		+0.5
NL/UK EEZ Interface	+40.3	+41.6	-		+1.3

2. VESSELS AND DATA SOURCES

2.1 General

Work Package F (WPF) consists of the integration of datasets to form the cable route survey report (Figure 2.1). A wide variety of data sources were utilised in the development of this report. The following section gives a brief overview of these data, and also a brief summary of the various survey vessels and equipment used in their acquisition. For full details of each data set, including acquisition methodologies, resolution and limitations, please refer to the relevant work package operations report (see Page ii, Project Document Arrangement).

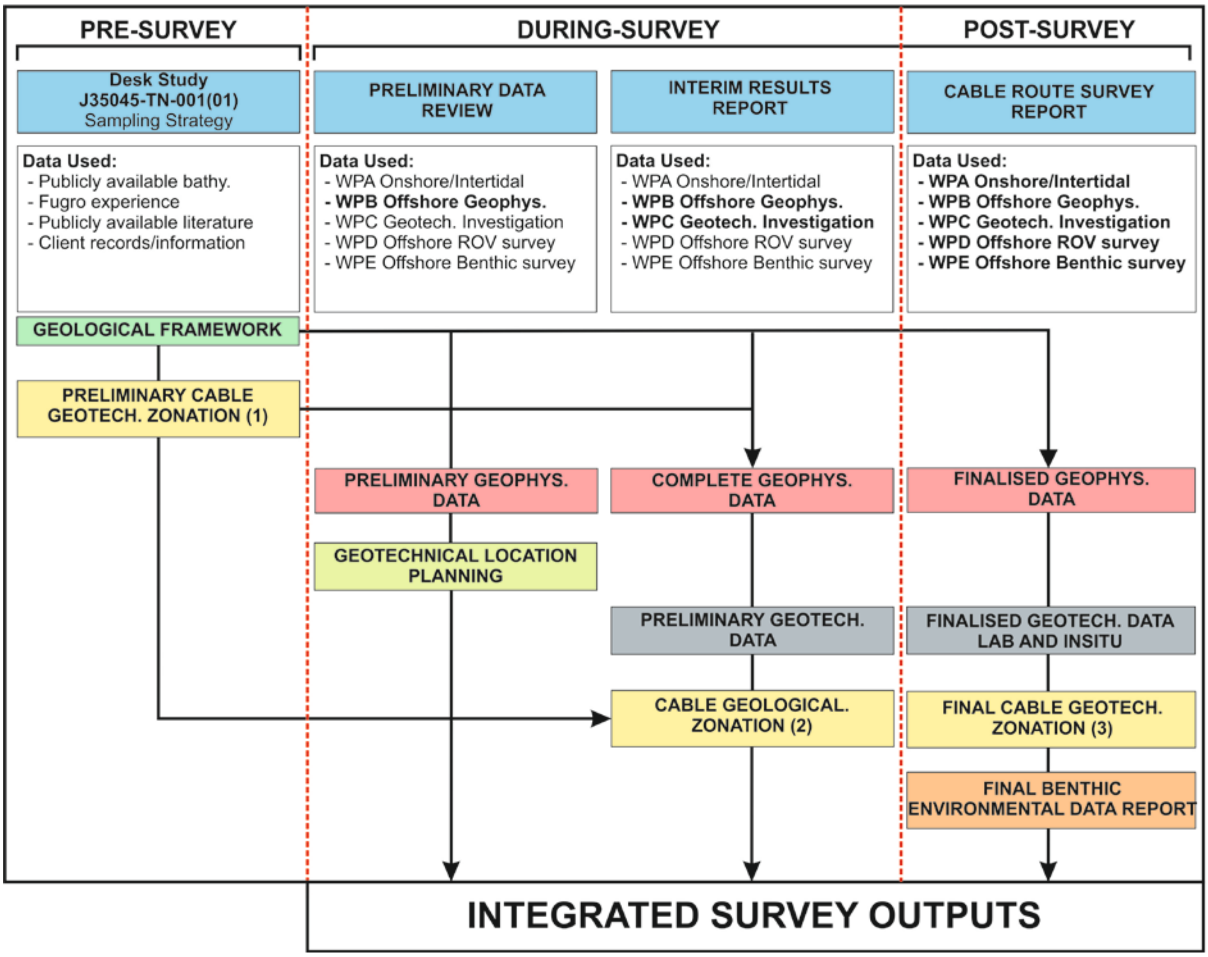


Figure 2.1: WP-F integrated reporting inputs (geophys. = geophysical; geotech. = geotechnical). 1, 2 and 3 refer to key stage gates in the integrated work flow

2.2 Survey Vessels and Equipment

Ten survey vessels, both Fugro-owned and third party, were used during marine survey operations. A number of these vessels conducted acquisition for more than one work package concurrently. The following section summarises these vessels and their survey equipment.

2.2.1 MV Fugro Meridian

The MV Fugro Meridian was utilised for the Work Package D Utility Crossings Survey from 2 May to 13 June 2016, and for a Work Package B Block 15 corridor extension from 4 to 6 June 2016.

Figure 2.2: MV Fugro Meridian

MV Fugro Meridian Survey Equipment	
Multibeam Echo Sounder	Kongsberg Simrad EM710
Single Beam Echo Sounder	Kongsberg Simrad EA500 Echo Sounder System (210 kHz/33 kHz)
Sidescan Sonar	Edgetech 4200 (300/600 kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	Geoaccoustic 5430A
Utility Crossings Survey Additional Equipment	
Remotely Operated Vehicle	Sea Eye Panther XT ROV, incorporating the following sensors:
Multibeam Echo Sounder	Reson SeaBat 7125 MBES
Pipe tracker	Teledyne TSS 440 Pipe and Cable System
Cable tracker	Teledyne TSS 350 Cable Tracker System

2.2.2 Valkyrie

The 12 m survey vessel Valkyrie was utilised for the nearshore element of the Work Package D Utility Crossings Survey from 9 to 13 June 2016, and Work Package A geophysical survey operations from 22 May to 12 June 2016.

Figure 2.3: Valkyrie

Valkyrie Survey Equipment	
Multibeam Echo Sounder	RESON 7125
Sidescan Sonar	EdgeTech 4125 (400/900 kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	STR 3.5 kHz pinger
Utility Crossings Survey Additional Equipment	
Sub-bottom Profiler (Pinger)	Innomar SES – 2000 parametric sub-bottom profiler

2.2.3 MV Fugro Frontier

The MV Fugro Frontier was utilised for Work Package B geophysical acquisition and Work Package E benthic survey acquisition from 18 March to 3 June 2016.

Figure 2.4: MV Fugro Frontier

MV Fugro Frontier Survey Equipment	
Multibeam Echo Sounder	2 x R2Sonic 2024 (400 kHz head)
Single Beam Echo Sounder	Kongsberg Simrad EA400 Echo Sounder System (210 kHz/33 kHz) with Reson TC2122 dual frequency hull-mounted transducer
Sidescan Sonar	Edgetech 4200 (300/600 kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	SES Sub-bottom Digital Transmitter system operating on CW between 2.5 kHz – 10 kHz with 4 × Massa TR-1075D transducers
Sub-bottom Profiler (Sparker)	Geo-Spark 200 source with CSP-N Power Supply and Geo-sense 8-element mini-streamer

2.2.4 MV Fugro Pioneer

The MV Fugro Pioneer was utilised for Work Package B geophysical acquisition and Work Package E benthic survey acquisition from 22 April to 22 May 2016. The vessel returned to the survey area to conduct additional work from 23 July to 29 July 2016.

Figure 2.5: MV Fugro Pioneer

MV Fugro Pioneer Survey Equipment	
Multibeam Echo Sounder	Kongsberg Simrad EM2040 Dual Head
Single Beam Echo Sounder	Kongsberg Simrad EA400 Echo Sounder System (210 kHz/33 kHz)
Sidescan Sonar	Edgetech 4200 (300/600 kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	Geoaccoustic 5430A
Sub-bottom Profiler (Sparker)	GSO 100 tip sparker with Geo-resources Geo-Sense mini-streamer

2.2.5 Geo Explorer

The third party survey vessel Geo Explorer was utilised for Work Package A geophysical acquisition from 10 May to 12 May 2016.

Figure 2.6: Geo Explorer

Geo Explorer Survey Equipment	
Multibeam Echo Sounder	Kongsberg EM3002D (Hull Mounted), 300 kHz
Sidescan Sonar	Klein sidescan sonar (100/500kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	3.5 kHz Massa pinger in a 2x1 array

2.2.6 RV Discovery

The RV Discovery was utilised for Work Package A geophysical acquisition and for Work Package E benthic survey operations from 8 June to 26 June 2016.

Figure 2.7: RV Discovery

RV Discovery Survey Equipment	
Multibeam Echo Sounder	Kongsberg EM2040 dual-head multibeam echo sounder
Sidescan Sonar	EdgeTech 4125 (400/900 kHz)
Magnetometer	Geometrics G882 caesium vapour with depth sensor
Sub-bottom Profiler (Pinger)	STR 3.5 kHz pinger

2.2.7 MV Markab

The MV Markab, a third party vessel, was utilised for Work Package C geotechnical operations from 15 April to 22 July 2016.

Figure 2.8: MV Markab

MV Markab Geotechnical Equipment	
High performance corer (HPC)	415 V, minimum 45 kVA power supply, 3 m to 6 m core barrel
Seacalf CPT	Roson Seabed Cone Penetrometer
Thermal conductivity cone	10 cm^2 probe Temperature sensor: PT1000, class A IEC60751 Maximum thrust 3 kN, equivalent pressure 100 MPa
Piezo CPT Cone	10 cm^2 probe Maximum thrust 100 kN Sensors for: cone resistance, sleeve friction, pore pressure, inclination

2.2.8 Jif Challenger

The survey vessel Jif Challenger, a third part vessel, was utilised for Work Package C geotechnical operations from 23 June to 29 June 2016.

Figure 2.9: Jif Challenger

Jif Challenger Geotechnical Equipment	
High performance corer (HPC)	415 V, minimum 45 kVA power supply, 3 m to 6 m core barrel
Seacalf CPT	Roson Seabed Cone Penetrometer
Thermal conductivity cone	10 cm^2 probe Temperature sensor: PT1000, class A IEC60751 Maximum thrust 3 kN, equivalent pressure 100 MPa
Piezo CPT Cone	10 cm^2 probe Maximum thrust 100 kN Sensors for: cone resistance, sleeve friction, pore pressure, inclination

2.2.9 Voe Earl

The third party vessel Voe Earl was utilised for Work Package C geotechnical operations from 25 July to 27 July 2016.

Figure 2.10: Voe Earl

Voe Earl Geotechnical Equipment	
High performance corer (HPC)	415 V, minimum 45 kVA power supply, 3 m to 6 m core barrel
Seacalf CPT	Roson Seabed Cone Penetrometer
Thermal conductivity cone	10 cm^2 probe Temperature sensor: PT1000, class A IEC60751 Maximum thrust 3 kN, equivalent pressure 100 MPa
Piezo CPT Cone	10 cm^2 probe Maximum thrust 100 kN Sensors for: cone resistance, sleeve friction, pore pressure, inclination

2.2.10 MV Meridian

The MV Meridian, a third party vessel, was utilised for Work Package E benthic survey operations from 21 August to 6 September 2016.

Figure 2.11: MV Meridian

2.2.11 Topographic Survey

The following equipment was used for the onshore topographic surveys conducted at the Danish and UK landfalls:

Requirement	Equipment
GPS receiver	Trimble R6 GPS receiver
Leveller	Trimble DINI digital leveller
Total station	Trimble S8 high-precision total station
Laser Scanner	Z+F 5010 C laser scanner

2.3 Geophysical Data Sources

2.3.1 Multibeam Swathe Bathymetry

Multibeam swathe bathymetry data were acquired throughout the marine survey corridor, along both the nearshore and offshore sections of the proposed route. The data were processed to 0.25 m, 0.5 m, 1 m and 5 m cell sizes; the 1 m cell size bathymetry model was used to produce bathymetric contours and a shaded relief image of the seabed displayed on the alignment charts. It was also used to inform the interpretation of seabed features and shallow geology.

2.3.2 Side Scan Sonar

High resolution and standard resolution side scan sonar data were acquired throughout the marine survey corridor, along both the nearshore and offshore sections of the proposed route. The data were acquired at frequencies of 600 kHz (high resolution) and 300 kHz (standard resolution). The data have a 75 m range throughout, and were used to identify point contacts and linear features on the seabed, as well as to interpret changes in seabed texture, including the presence of sediment ripples. The side scan sonar data were also used, in concert with the bathymetry and sub-bottom profiler data, to interpret larger scale geomorphological features on the seabed.

2.3.3 Sub-Bottom Profilers

A variety of sub-bottom profilers were used during the marine survey operations. The data from these sources was used to map geological layers to a maximum depth of approximately 25 m sub-seabed, but with an emphasis on the upper 5 m.

2.3.3.1 Pinger Sub-bottom Profiler

Pinger sub-bottom profiler data were acquired along all survey lines throughout the marine survey corridor. The pinger data were intended to provide the highest possible vertical resolution of the shallow sub-seabed geology.

2.3.3.2 Sparker Sub-bottom Profiler

Sparker sub-bottom profiler data were acquired along all survey lines on the offshore (Work Package B) section of the marine survey corridor. Sparker data provides a greater penetration than pinger data, at the cost of a slight decrease in vertical resolution.

2.3.4 Magnetometer

Marine magnetometer data were acquired along all nearshore and offshore survey lines. The data were interpreted to identify magnetic anomalies, this information was used to inform route planning during the marine survey. The data were also used to identify and verify the positions of charted pipelines and cables crossing the proposed route. It should be noted that due to the line spacing of the survey, the magnetometer data do not represent full coverage of the survey corridor. The nominal range of a magnetometer system is approximately 5.0 m to 7.5 m either side of the sensor.

2.4 Geotechnical Data Sources

2.4.1 Vibrocores

Vibrocores were collected at 420 locations on the proposed route. These were all taken along the line of the proposed route, unless offset to target a discrete location of interest. A total of 343 of the vibrocores had a target depth of 3 m, whilst a further 77 vibrocores had a target depth of 6 m. If sufficient penetration was not achieved at the first attempt, a maximum of two additional vibrocores were taken in the same area.

The acquired cores were transported to Fugro GeoConsulting Limited’s facility in Wallingford for logging and laboratory testing. A selection of particle size distribution tests and consolidated isotropically drained tests were subcontracted to the following laboratories:

- Geolabs Limited, Watford, UK;
- Fugro GeoServices Limited, Consett, UK;
- Fugro GeoServices BV, Leidschendam, NL;
- Fugro GeoServices BV, Arnham, NL;
- Fugro Consult Kft, Budapest, Hungary.

2.4.2 Cone Penetration Testing

Cone penetration tests were carried out at 417 locations on the proposed route. These were all taken along the line of the propose route, unless offset to target a discrete location of interest. A total of 344 of the CPTs had a target depth of 3 m, whilst a further 73 CPTs had a target depth of 6 m. If this was not achieved at the first attempt, a maximum of two additional CPTs were taken in the same area.

Cone penetration tests were carried out at the same locations as the vibrocores.

2.4.3 Thermal Conductivity Testing

In-situ thermal conductivity tests were carried out at 22 locations on the proposed route. These were all taken along the line of the proposed route, unless offset to target a discrete location of interest.

2.5 Environmental Data Sources

2.5.1 Seabed Video and Still Images

At each of 183 sites seabed video footage and still images were collected along predefined transects. Seabed video footage was collected at each station together with digital stills photographs taken throughout each transect. Where the video passed over sediment type boundaries, additional seabed video and stills were collected to provide sufficient footage for the analysis phase.

2.5.2 Fauna and Physio-Chemical Analysis Sampling

Seabed samples were collected using a Hamon Grab at a total of 189 sites. The samples were subject to an initial assessment on the survey vessel before transport to Fugro EMU’s facility in Portchester for laboratory testing.

2.6 Background Information

A wide variety of sources have been utilised to provide background information to this study, including data and information in the public domain and Fugro’s own experience in this and similar environments. A full list of background information used is presented in Section 11.

3. GEOLOGICAL FRAMEWORK

3.1 General

This section presents a summary of the geological setting of the proposed Viking Link cable route in the southern North Sea. The purpose of this section is to provide an overview of the recent geological history of the proposed route based on publicly available data. This was to guide the interpretation and integration of geophysical and geotechnical data.

3.2 Quaternary Evolutionary History of the Southern North Sea

The southern North Sea was affected by repeated glacial and interglacial cycles throughout the last 2.6 million years (Ma). It is generally agreed that the region was glaciated on at least three occasions in the past 550 000 years, during the Elsterian, Saalian and Weichselian glacial periods. While onshore the glacial limits are well-constrained, offshore boundaries are largely arbitrary and based on regional-scale datasets. The glacial stages, and the corresponding interglacial periods, have led to the creation of a complex stratigraphy in the southern North Sea. Figure 3.1 presents the global sea-level curve for the past 550 ka with the glacial and interglacial periods annotated.

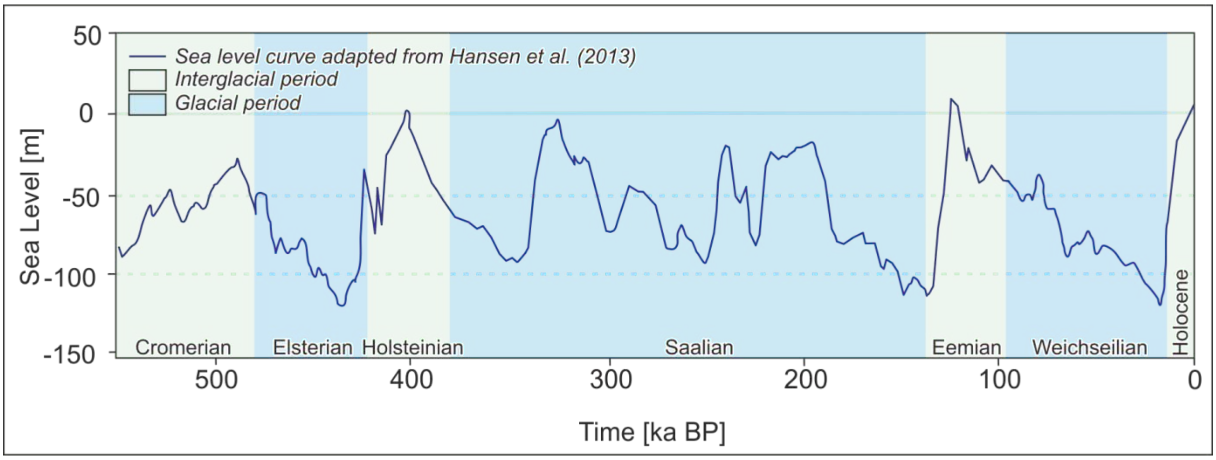


Figure 3.1: Global sea level curve for 550 000 years before present (BP) to present day. Adapted from Hansen et al. (2013) and Cohen and Gibbard (2010). Glacial periods generally correlate with a lowering of mean sea level. All depths referenced against present day sea level (0 m)

3.3 Early to Middle Pleistocene Cromerian Complex – 2.6 Ma to 478 ka BP

The southern North Sea in the early Pleistocene was characterised by marine conditions. Ongoing sealevel fall during this period led to the coastline retreating northwards and the deposition of prodelta sediments. Many of the major north-west European rivers drained into the southern North Sea region, including the proto-Thames, Rhine, Meuse and Elbe rivers.

As the coastline retreated, prodelta sediments were overlain by delta sediments and shallow marine/intertidal conditions prevailed across the southern North Sea, this led to the deposition of sands with abundant terrestrial material including plant debris, peat and wood. Figure 3.2 presents the interpreted depositional environments present during the Middle Pleistocene.

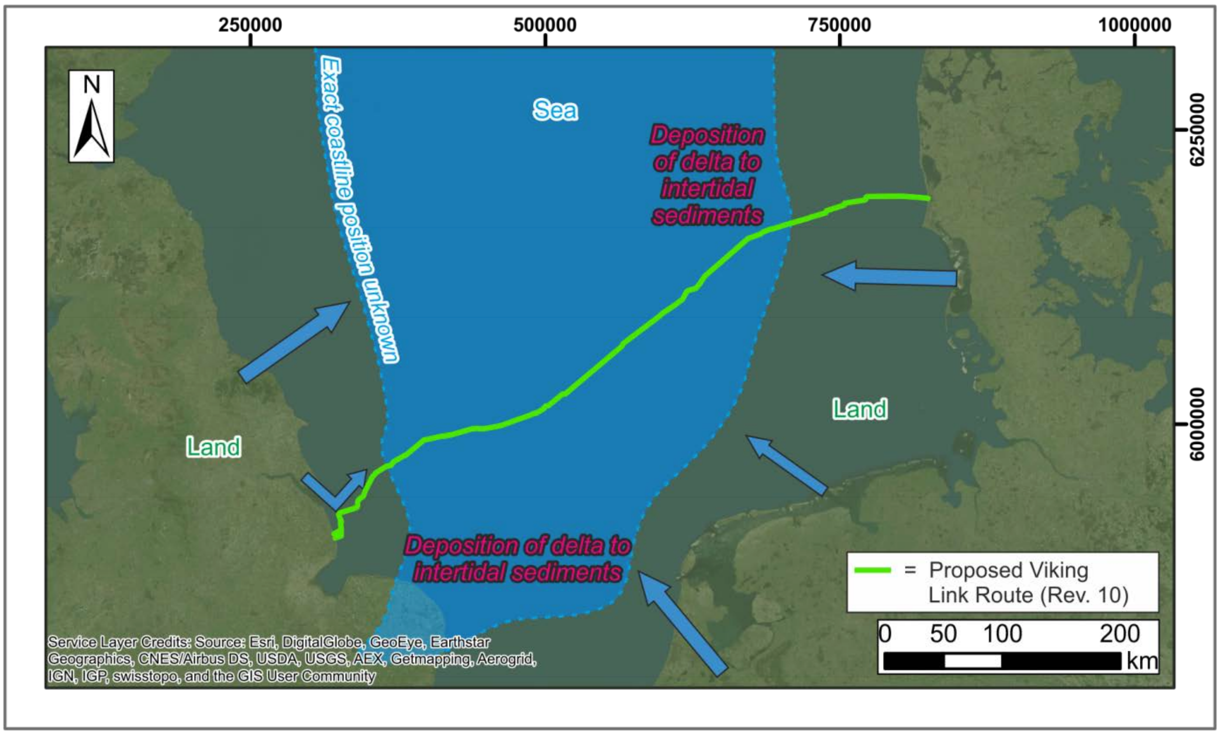


Figure 3.2: Interpreted depositional environments of the Middle Pleistocene Cromerian Complex approximately 780 ka BP. Adapted from Cameron et al. (1992)

3.4 Middle Pleistocene Elsterian Glacial Period - 478 ka to 424 ka BP

The Elsterian glacial period began approximately 478 ka BP (Cohen and Gibbard, 2010) and was the most extensive glacial period recorded across the region during the Quaternary period. At the climax of the Elsterian, the southern North Sea was entirely covered by ice sheets originating from across north-west Europe (Cameron et al., 1992; Graham et al., 2011). Large subglacial channels known as tunnel valleys were incised into the underlying chalk by hydrostatic water pressure at the height of the Elsterian glacial period. As the ice sheets began to retreat, the channels were progressively filled with clays, silts and sands which were subsequently overconsolidated by successive glacial stages. Figure 3.3 presents the ice front boundary and depositional environments present during the Elsterian.

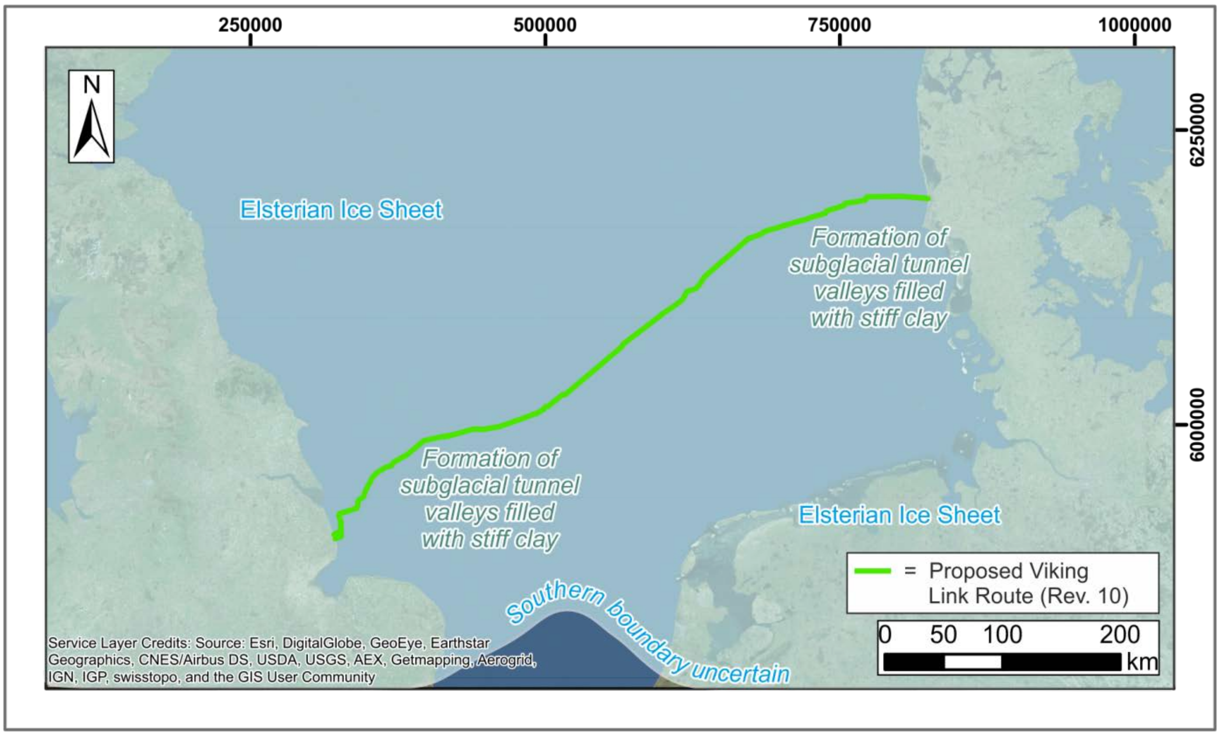


Figure 3.3: Interpreted depositional environments of the Middle Pleistocene Elsterian Glacial Period approximately 430 ka BP. Adapted from Cameron et al. (1992); Laban and van der Meer (2011)

3.5 Middle Pleistocene – Holsteinian and Saalian Periods 424 ka to 130 ka BP

Following the Elsterian, the Holsteinian interglacial was the start of global climate warming and ice sheet collapse. It is interpreted that during the Holsteinian the eastern part of the region became a shallow sea. The western part of the southern North Sea is interpreted to have been largely subaerially exposed, save for a large estuary or shallow marine environment in the vicinity of the Inner Silver Pit. Figure 3.4 presents the interpreted depositional environments towards the end of the Holsteinian interglacial period.

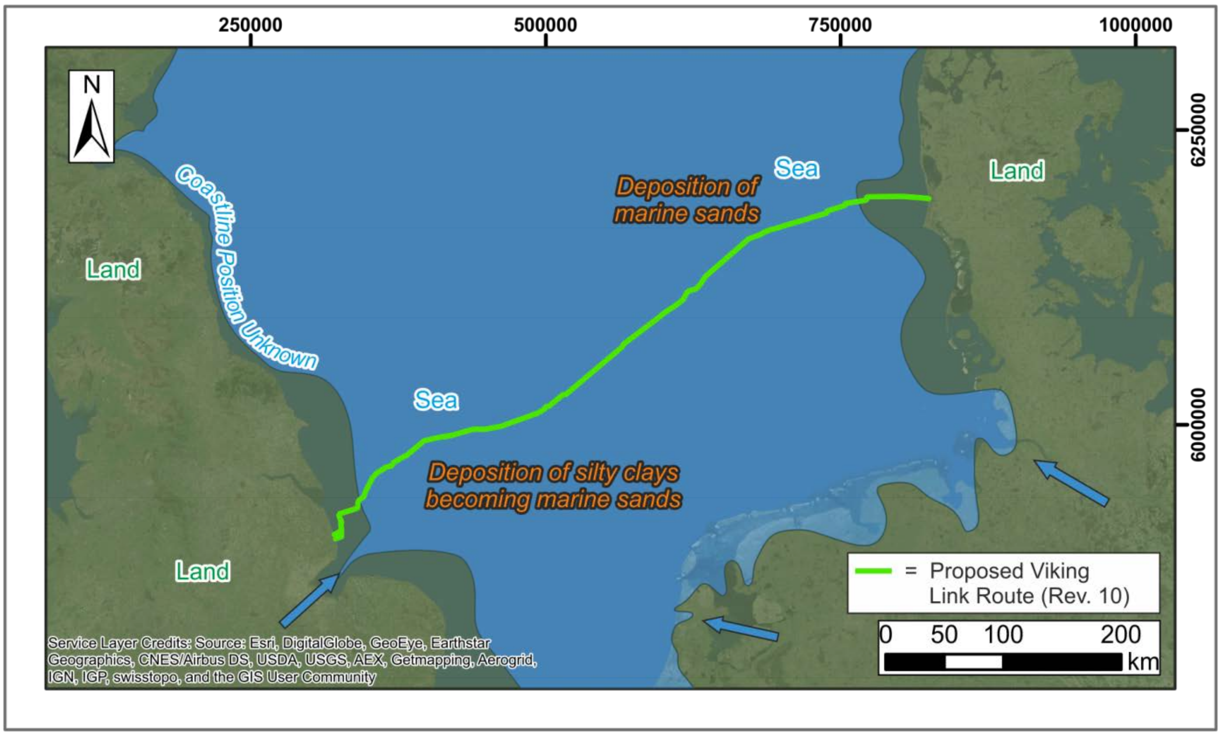


Figure 3.4 Interpreted depositional environments of the Middle Pleistocene Holsteinian Interglacial Period approximately 400 ka BP. Adapted from Cameron et al. (1992) and Tizzard et al. (2015)

Interglacial conditions prevailed until approximately 380 ka BP, when much of north-west Europe saw a return to glacial conditions during the Saalian. This stage, lasting for approximately 220 ka, is further refined into multiple stadial and interstadial stages. Figure 3.5 shows a demonstrative interpretation of conditions across the southern North Sea during the Saalian. It is thought Denmark and the surrounding regions were covered by a large ice sheet, with a western termination off the coasts of Norway and Denmark. The maximum ice extent across the southern North Sea is poorly documented as it has been mostly reworked by subsequent glacial processes during the Weichselian. It is thought that a large area of the southern North Sea remained either subaerially exposed or under glaciomarine conditions during the Saalian glacial period.

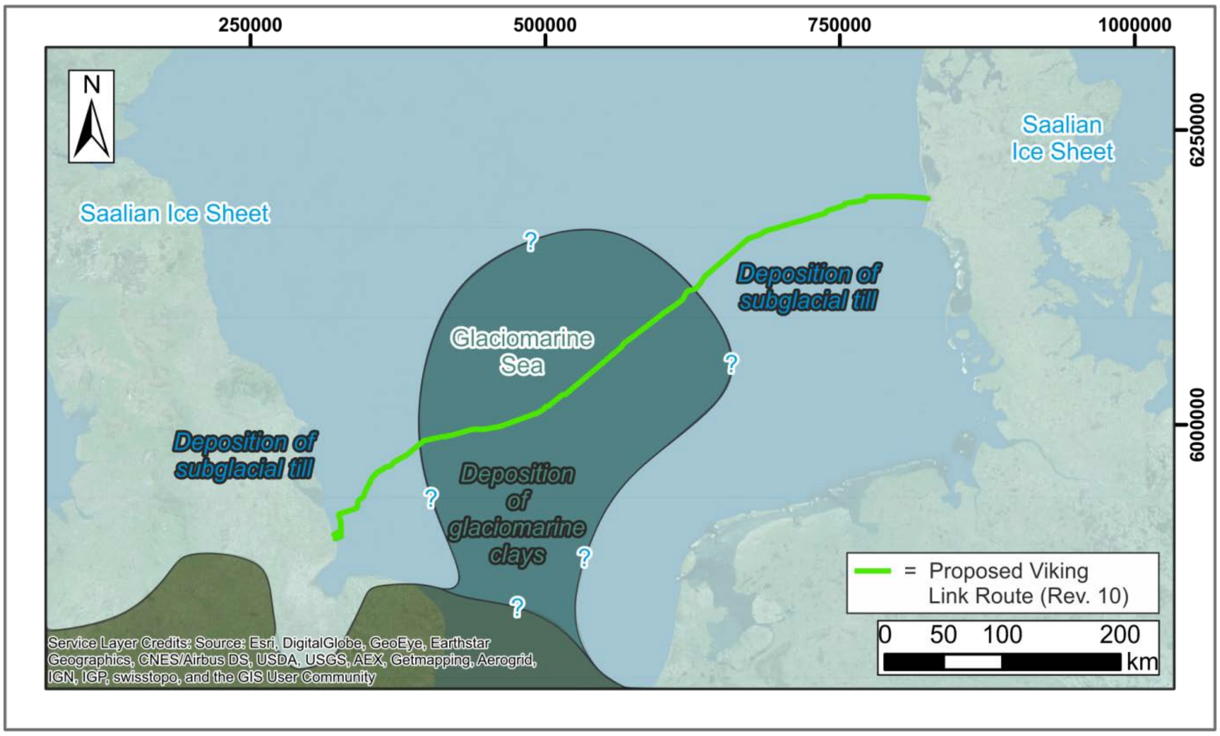


Figure 3.5: Interpreted depositional environments of the Middle Pleistocene Saalian Glacial Period between 380 ka BP and 110 ka BP. Adapted from Cameron et al., (1992)

3.6 Late Pleistocene – Eemian Interglacial and Weichselian Glacial Period 130 ka – 12 ka BP

The end of the Saalian once more saw an increase in global temperatures and the area became a shallow sea during the Eemian interglacial period. Marine conditions prevailed across eastern parts of the southern North Sea until the early Weichselian when the environment became a shallower, brackish sea of lower salinity. Figure 3.6 presents the interpreted depositional environments in the southern North Sea during this time.

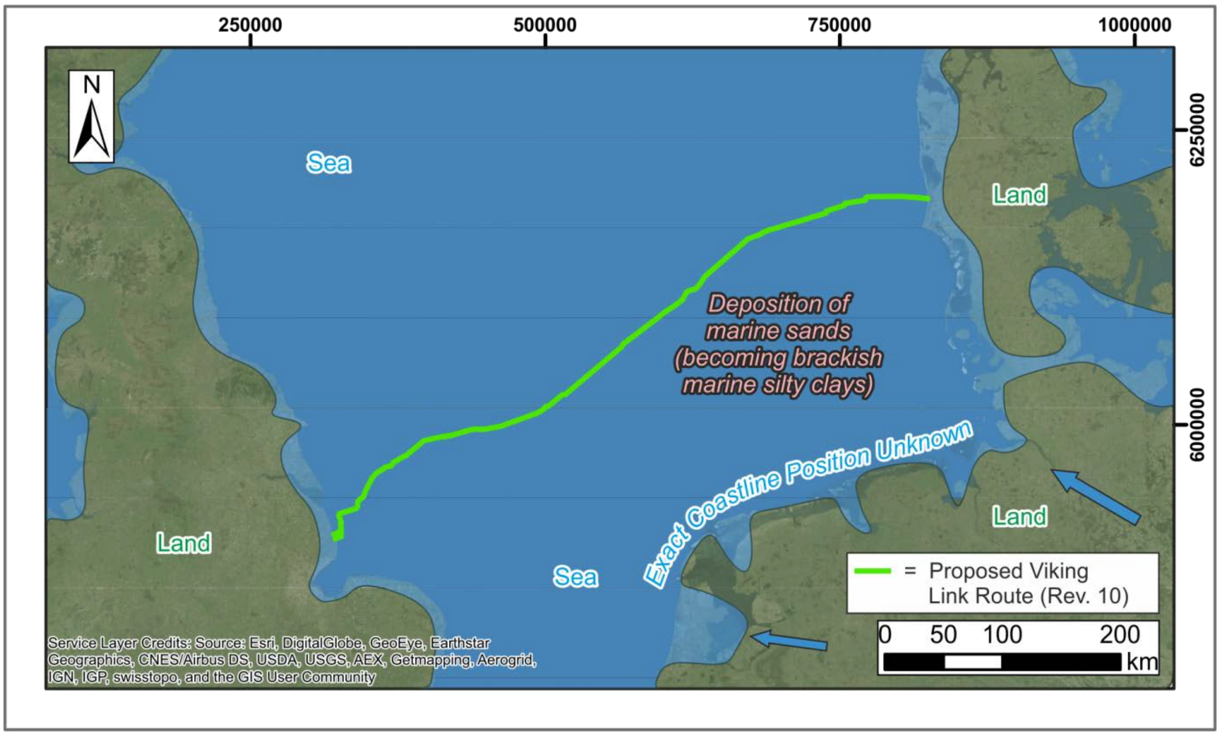


Figure 3.6: Depositional environments during Eemian Interglacial Period (approximately 130 ka BP). Adapted from Cameron et al., (1992), Bosch et al., (2000) and Miettinen et al., (2014)

A drop in global temperatures from approximately 110 ka BP caused a return to glacial conditions in north-west Europe. The Weichselian glacial period, between approximately 110 ka BP and 12 ka BP, is responsible for the most-extensive and best preserved Quaternary glacial units present across the southern North Sea. This was the last glacial event before present and is therefore known as the Last Glacial Maximum (LGM).

Recent studies suggest that the maximum extent of ice across much of north-western Europe was related to sudden warming periods and subsequent downwasting of the Weichselian ice sheets after approximately 21.7 ka BP (Bateman et al., 2011; Roberts et al., 2013). Downwasting, or thinning of glacial ice, can cause basal sliding of the ice where the ice-bed interface is lubricated by meltwater. This in turn may result in a glacier or lobe of ice extending beyond that of the glacial maximum. At least two of these downwasting events are thought to have occurred in conjunction with the North Sea Ice Lobe in the eastern UK (Bateman et al., 2011; Roberts et al., 2013; Busfield et al., 2015) and are likely to have occurred elsewhere in north-western Europe.

It is thought that much of the southern North Sea, south of approximately 55° N, was subaerially exposed prior to these downwasting events and the older Quaternary units were subaerially exposed. These units are likely to have been periglacially modified leading to the deposition of wind-blown sands or loess across the region and sub-aerial palaeochannels forming at the limits of the ice sheets.

The Heligoland Channel, which is a present-day bathymetric depression predominantly in the east of the region, was likely to be an erosional scour formed by the palaeo-Elbe river throughout the Weichselian. The palaeo-Elbe is interpreted to have drained the southern rim of the Weichselian ice sheet into a semi-enclosed glaciomarine basin.

Figure 3.7 presents the interpreted depositional environments across the southern North Sea during the LGM approximately 21.7 ka BP.

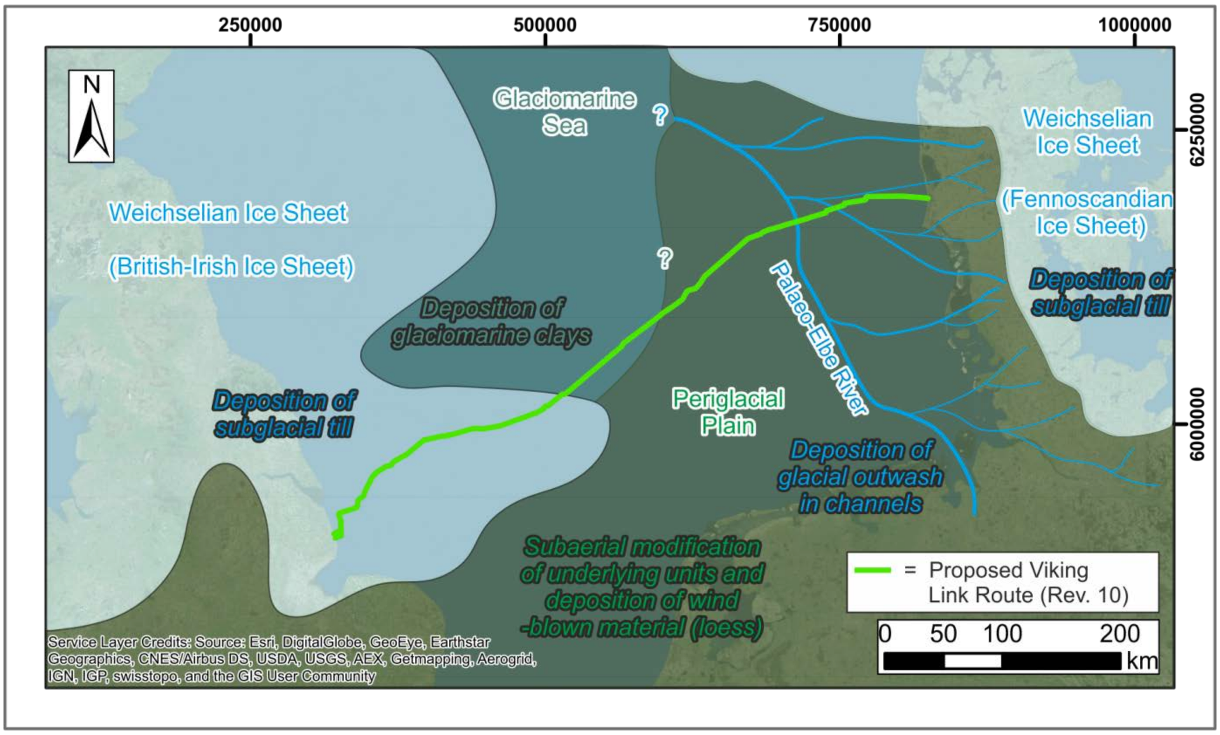


Figure 3.7: Depositional environments during the LGM approximately 21.7 ka BP. Adapted from Cameron et al., (1992); Gibbard & Clark, (2011); Graham et al., (2011), Houmark-Nielsen et al., (2005) and Konradi (2000)

3.7 Late Pleistocene to Early Holocene - 15 ka BP to 5 ka BP

After approximately 15 ka BP the British-Irish and Fennoscandian ice sheets were in their final stages of collapse. Former subglacial channels were likely conduits for meltwater, carving channels across the southern North Sea. These channels were up to 60 m deep towards the centre of the southern North Sea and exhibited substantial channel migration across several tens of kilometres. It is interpreted that some of these early meltwater channels may have eroded into the underlying geology forming the beginnings of the Outer Silver Pit (a present day seabed hollow) and other large scale incisions in the region.

Palaeochannels across the southern North Sea typically contain a range of sediments. These sediments record the changing environment from ice-proximal meltwater channels to subaerially exposed river channels and restricted lakes and backwaters throughout the Holocene.

As global sea-levels began to rise, the southern North Sea returned to marine conditions. The Dogger Bank, in addition to much of the region, was subaerially exposed. Peat offshore represents the transition from intertidal or estuarine conditions to submerged marine conditions. Figure 3.8 presents the interpreted depositional environments across the region approximately 8.7 ka BP.

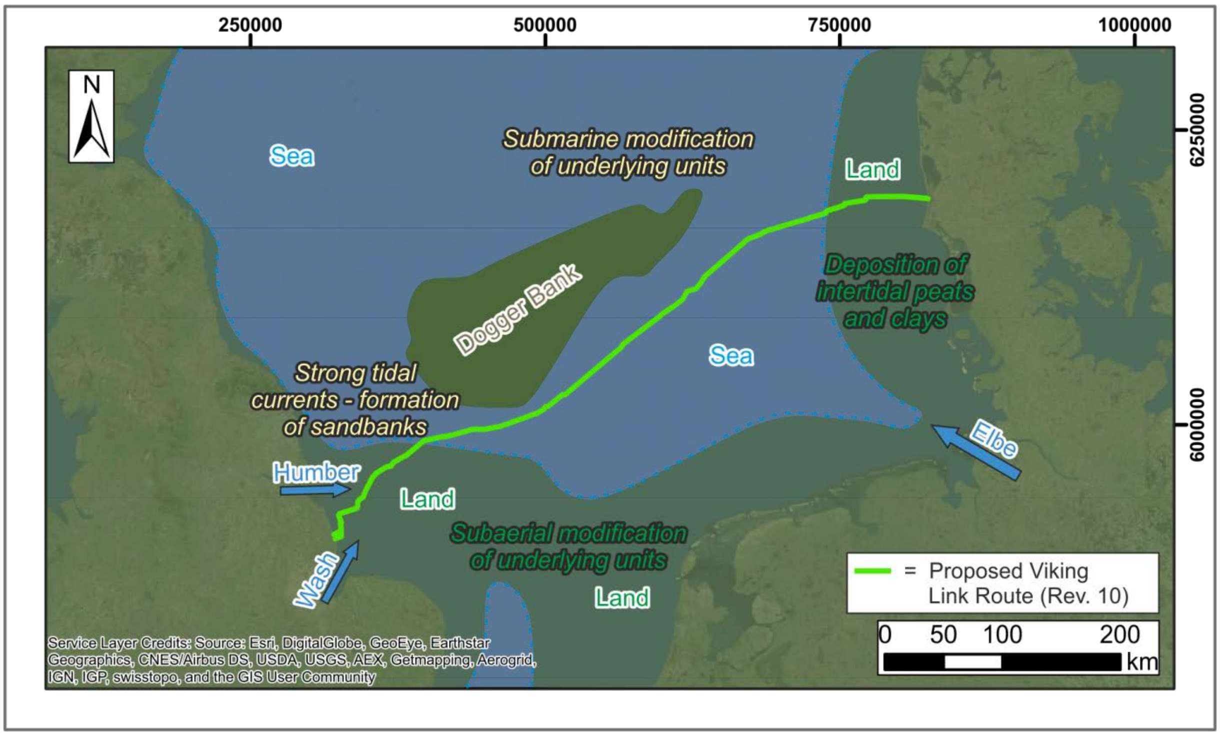


Figure 3.8: Depositional environments approximately 8.7 ka BP. Adapted from Cameron et al., (1992); Konradi, (2000) and Gaffney et al., (2007)

In the east of the southern North Sea, deposition in the palaeo-Elbe River and associated estuary changed from fluvial sediments to marine silts. This transition is interpreted to have occurred around 11 ka BP, as dated in deep core samples acquired between the Heligoland Channel and the Dogger Bank (Konradi, 2000). Sea level at this time was around 70 m below current LAT.

Around the same time, shallow, tidally influenced marine conditions approximately 10 ka BP to 9 ka BP continued the erosion of the Outer Silver Pit to a depth of around 85 m below current lowest astronomical tide (LAT), some 40 m below the level of the surrounding seabed. This environment is interpreted based on the preservation of large dune bedforms in the Outer Silver Pit known as the Sand Hills group (discussed in more detail in Section 9) (Gaffney et al., 2007).

3.8 Late Holocene – 5 ka BP to Present

The prevailing marine environment of deposition throughout the late Holocene is consistent with the conditions of the present day southern North Sea. The tops of preserved Pleistocene deposits were reworked by marine processes and were deposited as a gravel lag or bedforms and sandbanks in the strongly tidally influenced marine basin. Sediments in shallow coastal areas are often highly mobile and large scale bedforms such as dune bedforms are commonplace, particularly in inshore areas on the periphery of the basin. In the UK sector, strong waves, currents and tides have left the underlying bedrock, typically Cretaceous Chalk, exposed at or just below the seabed. Figure 3.9 shows the present day features of the southern North Sea.

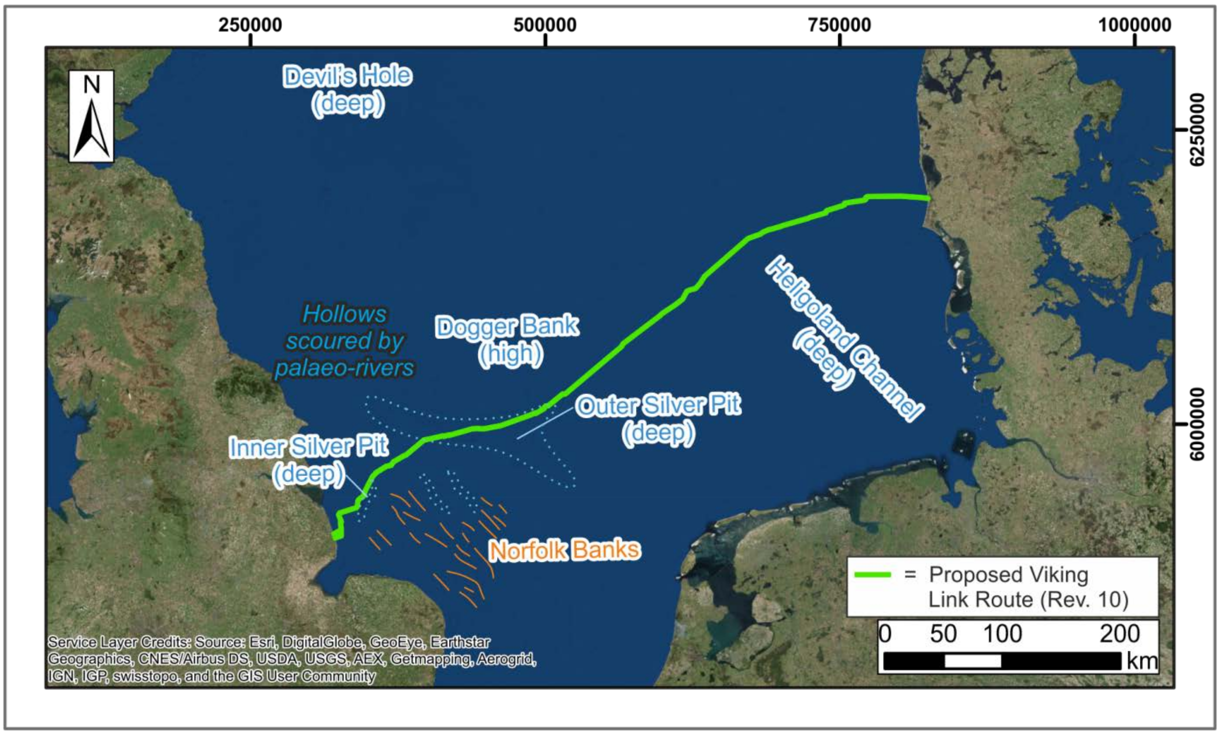


Figure 3.9: Present day features of the southern North Sea

3.9 Route Specific Geological Framework

This section presents a summary of the shallow geological formations interpreted to be present along the proposed Viking Link cable route in the southern North Sea. This geological framework is derived from interpretation of geophysical and geotechnical data collected along the proposed route supplemented by publicly available data, literature and knowledge of the regional sedimentary environment. The purpose of this section is to provide an overview of geological conditions and characteristic descriptions along the route to provide context to the more detailed information in other parts of this report. Table 3.1 summarises the geological formations identified within the depth of interest in addition to a description of their depositional environment, generalised geotechnical description and other characteristics.

British Geological Survey (BGS) nomenclature for geological formations is applied to the whole route, where applicable. Where a geological formation does not have associated BGS terminology this is indicated in the text.

Table 3.1: Summary of Interpreted Geological Formations along the Viking Link Cable Route

Name* (BGS Acronym)	Age	Depositional Environment	Typical Thicknesses** [m]	Geotechnical Description	Characteristics
Holocene sediments (undifferentiated) (qH)	0 – 5 ka (Recent Holocene)	Marine	0 – 5 (20)	Loose slightly clayey slightly gravelly fine to coarse SAND with shell fragments Slightly to very sandy subangular to subrounded fine to coarse GRAVEL of mixed lithology with fine to medium gravel-sized shell fragments	Sandy gravel and gravel in the UK sector including reworked sand, gravel lag deposits and recently deposited silts and clays. Comprises gravelly veneer deposits < 2 m thick and sandy mobile sediments. Thickest deposits up to 15 m thick associated with mobile bedforms and large sandbanks in coastal areas. Sand, silty and clayey sand in Dutch, German and Danish sectors from 1 – 20 m thick. Holocene marine sediments represent the present-day marine environment and processes across the southern North Sea
Elbow Formation (ELW)	5 – 11 ka (Holocene)	Brackish Marine	2 – 6 (12)	Very loose to medium dense fine SAND with closely to medium spaced laminae of silty SAND and CLAY or extremely low strength CLAY Spongy pseudo-fibrous PEAT	Interbedded fine sand and clay layers with local basal layer of peat deposited in an intertidal environment. Patchy distribution across the North Sea. Peat in this facies often occurs as a strong irregular reflector on seismic profiles, close to seabed, and may cause acoustic blanking of underlying units. This unit represents a change from subaerial exposure in the early Holocene to being inundated by marine conditions
Palaeochannels†	5 – 11 ka (Holocene)	Fluvial	1 – 15 (20)	Loose to very dense gravelly fine to medium SAND	Formed in the early Holocene, this formation comprises a mixed fill of clay, silt, sand, gravel and organic matter (peat, gyttja). Localised channel deposits, may sample into Botney Cut Formation and Pleistocene to Holocene palaeo-Elbe deposits† Palaeo-Elbe deposits comprising sandy silt material representing estuarine environment during the early Holocene up to 17 m thick. Palaeochannels represent surface water drainage channels in an otherwise subaerially exposed environment
Botney Cut Formation (BCT)	8 – 15 ka (Weichselian to Holocene)	Glaciofluvial /Subglacial	0 – 30 (60)	Very soft to stiff, low to high strength slightly gravelly reddish brown CLAY with interbeds of sand, silt and gravel	Low to extremely high strength diamicton with layers of gravel, sand, silt or clay. Organic matter, including peat, may also be present in upper units. May appear well-bedded in seismic records and incising older units, and usually exhibits a strong basal reflector. This formation represents change from a subglacial to glacifluvial environment present at the end of the last glacial period
Twente Formation (TN)	*8 – 50 ka (Weichselian to Holocene)*	*Periglacial Aeolian*	*1 – 10 (25)*	*Loose to very dense well-sorted fine to medium SAND*	*Well-sorted fine to medium sand with occasional gravel. Not likely to be easily differentiated from underlying or overlying marine sand units. Top boundary may be defined by a layer of weak clay and/or the presence of peat. This unit represents wind-blown sediments deposited in a periglacial environment during the last glacial maximum and early Holocene*
Bolders Bank Formation (BDK)	15 – 22 ka (Weichselian)	Glacial	7 – 15 (20)	Firm to stiff high strength to very high strength reddish brown to brownish grey sandy gravelly CLAY with gravel, cobbles and boulders	Medium strength to extremely high strength greyish brown to brown clay containing clasts with a range of lithologies. Occasional boulder sized erratics and lenses of well sorted sand and gravel. Internal channels comprising granular material may also be present. Generally strong, level or gently undulating basal reflector, generally acoustically chaotic. The till deposited at the base of a grounded ice sheet during the LGM. Where the unit interfingers the Dogger Bank Formation, the units represent a fluctuating margin between a grounded ice sheet and glaciomarine conditions during the LGM
Dogger Bank Formation (DBK)	15 – 50 ka (Weichselian)	Glaciomarine (Weichselian)	7 – 15 (40)	Firm high strength olive grey to grey silty CLAY with gravel and cobbles	Medium strength to extremely high strength olive grey clay with well-developed stratification, containing dropstones and high silt component. May have well-ordered internal reflectors or appear acoustically chaotic, with strong, level basal reflector. Represents a glaciomarine environment during the LGM. Where the unit interfingers the Bolders Bank Formation, the units represent a fluctuating margin between a grounded ice sheet and glaciomarine conditions during the LGM
Brown Bank Formation (BNB)	*60 – 115 ka (Eemian)*	*Brackish Marine /Lacustrine*	*0 – 20*	*Silty CLAY*	*Low strength clay with abundant bioturbation. Expected to be finely laminated, which may be represented by weak internal reflectors in seismic data*
Eem Formation (EEM)	*60 – 115 ka (Eemian)*	*Marine*	*0 – 20*	*Medium dense to very dense coarse SAND with shells and shell fragments*	*Shelly marine sands with localised muddy sands and muds on western edges. Acoustically structureless or weakly bedded, occurs as a blanket deposit. Often indistinguishable acoustically or geotechnically from the underlying Egmond Ground Formation, where both are present*
Cleaver Bank Formation (CLV)	*115 – 380 ka (Saalian)*	*Glaciomarine*	*2 – 8*	*Stiff high strength laminated dark grey CLAY with angular gravel*	*Tabular body of clay interpreted to be glaciomarine/proglacial in origin. Transitions eastwards into the Borkumriff Formation.*
Egmond Ground Formation (EG)	380 – 397 ka *(Holsteinian)*	Marine	8 – 20	Dense to very dense dark grey very gravelly coarse SAND with traces of shell fragments	Dense to very dense sand with silt or clay interbeds. Acoustically structureless or weakly bedded, occurs as a blanket deposit
Sand Hole Formation (SH)	*397 – 425 ka (Holsteinian)*	*Estuarine/ Intertidal/ Marine*	*0 – 20*	*Silty CLAY*	*Laminated clays with parallel, even reflectors on seismic profiles. Confined close to the Inner Silver Pit. Lower units associated with a cold, restricted marine environment. Upper units containing higher sand content and represent an estuarine or shallow coastal environment*

Name* (BGS Acronym)	Age	Depositional Environment	Typical Thicknesses** [m]	Geotechnical Description	Characteristics
Swarte Bank Formation (SBK)	425 – 478 ka (Elsterian)	Subglacial	5 – 450	Very stiff very high strength CLAY with medium to thick beds of medium dense sand and with cobbles and boulders	Overconsolidated very high strength to ultra-high strength grey diamictons with rare lenses of coarse-grained sand. Generally strong basal reflector dipping sharply. Internally sometimes may appear weakly-structured or sometimes structureless
Yarmouth Roads Formation (YM)	478 – Early Pleistocene	Fluvial/ Intertidal	160	Medium dense to very dense fine to medium SAND with gravel and with rare laminae to thin beds of clay	Interbedded sand and silt with muddy interbeds. Sometimes contains plant debris, peat and wood. Stacked, inclined parallel to sub-parallel reflectors present in seismic data
Upper Chalk (UCk)	Upper Cretaceous	Marine	-	Structureless weathered CHALK to extremely weak to weak low to medium density CHALK (CIRIA Grade C5 to A1)	Highly variable weathered chalk present at or close to the seabed close to the UK coastline where Quaternary sediments (including seabed sediments) are thin or absent

Notes:

* Geological formations listed as per British Geological Survey (BGS) nomenclature
** Thicknesses approximated based on BGS and other public literature
† No formal nomenclature
ka = thousand years ago
LGM = Last Glacial Maximum
CIRIA grade from Lord et al. (2002)
Geological units in *italics* were not positively identified on the Viking Link route but are interpreted as a possibility based on publicly available reference material. Geotechnical descriptions for these units are based on those provided by the BGS.

4. ROUTE CONDITIONS

4.1 General

This report section contains a synopsis of the findings of the survey as presented in the upper panels of the alignment charts: the Cable Geotechnical Zone Parameters shown in the lower panel are discussed in Section 7 of this report.

The description of the route is split on the basis of national Exclusive Economic Zones (EEZ), the findings of work package E have also been sub-divided and reported this way (Section 5). All quoted KPs are as per revision 10 of the route. All quoted water depths are metres below Lowest Astronomical Tide (LAT).

The Danish sector extends from KP 0 to KP 210.795, the German sector from KP 210.795 to KP 239.117, the Dutch sector from KP 239.117 to KP 403.341 and the UK sector from KP 403.341 to the end of the route at KP 618.735 (LF1).

The Danish landfall section between KP 0 and KP 2.388 and the UK landfalls have been separately described.

4.2 Danish Landfall

4.2.1 General

The Danish landfall sector of the route encompasses KP 0 to KP 2.388. The route is orientated east to west within this area with an elevation range of +14.5 m close to KP 0 to 9.7 m below LAT at KP 2.388. The Danish landfall is covered by the plan view landfall chart (Appendix G) and the first alignment chart (alignment chart 1).

4.2.2 Topography

The onshore area extends for 250 metres from the Beach Manhole (BMH) at KP 0 to approximately KP 0.250 where the water depth is 1 m.

The route initially passes across sand dunes between KP 0 and KP 0.070. The terrain here undulates with elevations between 14.5 m and 10.5 m. There is a pronounced break of slope at the junction of the dunes and beach at KP 0.070, elevation reduces from approximately 10 m to 2 m over 20 m of the route. Dip reaches 22° at KP 0.080.

The beach slopes gently from KP 0.090 (the foot of the dunes) to KP 0.175. The beach is almost flat beyond this point to KP 0.250.

There is a 250 m data gap between the topographic survey data and nearshore marine data, this gap occurs between approximately KP 0.250 and KP 0.500.

4.2.3 Bathymetry

Nearshore bathymetry data extend from KP 0.500 to the limit of the route described in this section, KP 2.388. Seabed dip is greatest between KP 0.500 and KP 0.650 where water depth increases from 2 m to 4 m, gradient reaches 2° over this section of the route. Beyond KP 0.650 to KP 2.388 the seabed slopes very gently to the west with the water depth increasing from 2 m to 9.7 m.

4.2.4 Seabed Features

4.2.4.1 Seabed sediments

From KP 0.500 seabed sediments comprise very loose to loose silty fine SAND with shell fragments and GRAVEL ribbons to KP 2.388.

4.2.4.2 Bedforms/sediment mobility/natural obstructions

The seabed is generally smooth. Despite the lack of bedforms the morphology of the beach/intertidal zone will respond to storm events.

Five boulders are mapped between KP 0.500 and KP 2.388 (alignment chart 1). Three of these boulders are immediately south of the route at KP 2.063, KP 2.093 and KP 2.218.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.2.4.3 Debris

There are four scattered magnetic anomalies within the Danish landfall zone, one is within 100 m of the route, positioned 11 m north of KP 0.548.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.2.4.4 Existing infrastructure

The Harald Pipeline to Nybro runs near parallel to the route, it is positioned 270 m south of KP 0 and 300 m south of KP 0.500, it gradually diverges from the route with increasing KP.

4.2.5 Shallow Geology

Shallow sediments are expected to be SAND-prone to at least 3 m sub-seabed. The sub crop of these sands is interpreted to be CLAY/SILT-prone.

4.3 Danish EEZ

4.3.1 General

The offshore Danish portion of the planned route extends from the margin of the landfall zone at KP 2.388 (where the water depth is 9.7 m) to KP 210.795, the boundary between the Danish and German sectors. The water depth at this point is 42.2 m. The Danish offshore portion of the route is 208.407 kilometres long, excluding chainage within the landfall zone (an additional 2.388 kilometres).

The Danish sector of the route is covered by alignment chart numbers 1 to 48. These alignment charts should be referred to for any planning decisions that might be influenced by this report as they show the complete interpretation while this narrative makes approximations and omissions to provide a general illustration of conditions along the route.

The heading of the route is approximately east to west at the eastern extremity of the Danish sector, with increasing KP the route heading becomes approximately north-east to south-west from KP 160 to the western limit of the Danish sector.

4.3.2 Bathymetry

Water depths within the Danish portion of the route range from 9.7 m (at the eastern junction with the landfall area at KP 2.388) to a maximum of 51.9 m below LAT. Water depths generally increase with ascending KP to the maximum depth of 51.9 m at approximately KP 170 (alignment chart 39). Beyond this point water depths decrease to a minimum of 41.7 m at KP 207 (alignment chart 47). The Danish sector of the route transects the eastern flank of the southern North Sea basin and it is the regional pattern of westerly basinward dip that describes the gross bathymetric trend over the initial 170 kilometres of the route.

There are numerous smaller scale bathymetric variations. The most pronounced are interpreted to be related to erosive scouring. These scours drive bathymetric variation of between 2 m and 3 m and are likely relict features. Dips locally reach ~20° at the margins of these scours though over very short slopes. East of this zone of bathymetric variation (KP 2.500 to KP 27) the seabed is relatively smooth but is interpreted to have been subject to widespread planation through regional erosion.

Table 4.1: Bathymetric Anomalies Danish EEZ

Origin of Bathymetric Anomaly	Relief [m]	Chart Number	KP
Subtle contra-regional upslope	-4	7-8	27 to 34
Undulating seabed: scoured	+/-2	9-11	37 to 46.200
Undulating seabed: scoured	+/-2	14	59 to 60
Undulating seabed: scoured	+/-2	14-15	62 to 63.250
Undulating seabed: scoured	+/-2	15-16	64.500 to 68.500
Undulating seabed: scoured	+/-2	17-18	72 to 77.750
Undulating seabed: scoured	+/-3	19-20	81 to 84.800
Undulating seabed: scoured	+/-2	21-23	90.400 to 98.500
Undulating seabed: scoured	+/-2	23-24	101 to 102
Undulating seabed: scoured	+/-2	26-27	113.610 to 118
Undulating seabed: scoured	+/-1-2	32	137 to 140.500

4.3.3 Seabed Features

4.3.3.1 Seabed sediments

From KP 2.388 seabed sediments comprise very loose to loose silty fine SAND with shell fragments to KP 9.765. From KP 9.765 to KP 36.510 seabed sediments consist of SAND. Sediments are consistently SAND-prone to KP 115.615 and are generally classified as very loose to loose silty fine SAND with shell fragments; variations are concentrated in the areas of scouring detailed in the table above (Table 4.1). From KP 115.615 to KP 169.080 seabed sediments are CLAY-prone, beyond KP 169.080 seabed sediments are very loose to loose silty fine SAND with shell fragments.

4.3.3.2 Bedforms/sediment mobility/natural obstructions

The seabed is generally smooth except for the areas of scour detailed in the table of bathymetric anomalies (Table 4.1). A sediment mobility assessment was not included as part of this project. Erosion, affecting seabed morphology, may occur during extreme tidal or storm events.

Numerous boulders are mapped between KP 2.388 and KP 3 (alignment chart 1) three boulders are on the route at KP 2.750, KP 2.858 and KP 2.896. Boulders are also present around KP 46.100 (alignment chart 11), KP 75.500 to KP 76 (alignment chart 18) and KP 115.500 (alignment chart 27).

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.3.3.3 Debris

There are numerous debris items within the Danish sector.

A line of five magnetic anomalies intersects the route at KP 23.035 (alignment chart 6). Seven associated magnetic anomalies cross the route at KP 23.750 (alignment chart 6), four associated magnetic anomalies cross at KP 26.220 (alignment chart 6), five anomalies cross the route at KP 65.720 (alignment chart 15), three anomalies are north of the route at KP 66.075 (alignment chart 15), six anomalies cross the route at KP 108.820 (alignment chart 25), these six anomalies are part of a field of sonar contacts. Four anomalies are immediately south of the route at KP 200 (alignment chart 45). These strings of magnetic anomalies may represent cable debris but there are no directly corresponding contacts on other data.

There is a single magnetic anomaly on the route at KP 69.435 (alignment chart 16) and a sonar contact on the route at KP 125.315 (alignment chart 29).

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.3.3.4 Existing infrastructure

Table 4.2: Existing Infrastructure Danish EEZ

Name	Crossing Number	Chart Number	KP	Status
CANTAT3	46	11	49.157	Out of service cable
Arendal-Westerland No. 1	45	12	51.938	Out of service cable
Harald to Nybro 24’’ Gas	44	12	53.606	In service pipeline
TAT 14 Seg. N	42	16	68.580	In service cable
Tyra TE-E to Nybro 30’’ Gas	41	17	74.258	In service pipeline
Gorm E to Frederica 20’’ Oil	40	21	91.442	In service pipeline
Arendal-Westerland No. 2	39	23	97.992	In service cable

Name	Crossing Number	Chart Number	KP	Status
Europipe 2 42'' Gas	38	25	106.812	In service pipeline
NorNed	37	30	131.572	In service cable
Atlantic Crossing 1 Seg. A	36	33	141.864	In service cable
Pangea	35	34	149.190	In service cable
TAT 10 Seg. C	34	36	155.321	In service cable

Further details of these infrastructure crossings are contained within report J35045-R-RESD.

12 existing cables and pipelines cross the route in the Danish sector. The Arendal-Westerland No. 2 in-service cable was not found during survey; the position for the crossing in Table 4.2 is derived from the cable's database position.

4.3.4 Shallow Geology

From the boundary with the Danish landfall section at KP 2.388 the shallow geology comprises loose silty fine SAND with subordinate GRAVEL over a sub crop of CLAY with rare SAND layers. The uppermost SAND is generally over 3 m thick to KP 44 (alignment chart 10). From KP 44 to KP 47 CLAY with layers of SILT and SAND is present immediately below the seabed sediments. A thick lens of SAND occurs between KP 47 and KP 56.500 (alignment charts 11 to 13) this package reaches a maximum thickness of 5 m at KP 52. Beyond KP 56.500 the uppermost SAND is generally less than 3 m thick and subcropped by CLAY with rare SAND layers to KP 74 (alignment chart 17). From KP 74 the sub crop becomes SAND prone, though this is denser than the upper SAND.

Between KP 121 and KP 127.850 (alignment charts 28 and 29) and between KP 144.330 (alignment chart 33) and KP 198 (alignment chart 45) the upper SAND is sub cropped by CLAY-prone channel infill.

4.3.4.1 Peat

Table 4.3: Peat within the Danish EEZ

KP range profiler	Min. Depth BSF profiler [m]	Geotech. Station	Description	Chart No.
14.620	No seismic response	B02-09-VC	Spongy pseudo-fibrous very dark grey PEAT	4
56.780 – 57.920	1.5	B03-06-VC	Spongy fibrous very dusky red PEAT	13
58.550 – 58.720	0.5	Not sampled	-	14
60.160 – 60.310	1	Not sampled	-	14
60.400 – 60.540	1	Not sampled	-	14
92.180 – 92.620	1.5	B03-28-VC	Very dark brown spongy pseudo-fibrous PEAT with traces of coarse gravel-sized pockets of fine to medium sand	21

KP range profiler	Min. Depth BSF profiler [m]	Geotech. Station	Description	Chart No.
92.650 – 92.750	1.5	B03-28-VC	Very dark brown spongy pseudo-fibrous PEAT with traces of coarse gravel-sized pockets of fine to medium sand	22
197.690 – 198.090	4	B06-19-VC	Spongy fibrous very dark grey PEAT	45
201.660 – 202.180	4	B06-24-VC	Spongy fibrous very dark brown PEAT	46
207.550 – 207.750	2	B06-30-VC	Spongy fibrous very dark brown PEAT	47
207.870 – 208.130	1.5	B06-30-VC	-	47

Peat generally has high reflection amplitude on the profiler records. In some areas (detailed in the table above) it has been interpreted purely on the basis of seismic appearance. In other areas it has been proved by geotechnical samples.

4.4 German EEZ

4.4.1 General

The German portion of the planned route extends from the boundary with the Danish sector at KP 210.795 (where the water depth is 42.2 m) to KP 239.117; the boundary between the German and Dutch sectors, the water depth at this point is 41.7 m. The German portion of the route is 28.322 kilometres long.

The German sector of the route is covered by alignment chart numbers 48 to 54. These alignment charts should be referred to for any planning decisions that might be influenced by this report as they show the complete interpretation while this narrative makes approximations and omissions to provide a general illustration of conditions along the route.

The heading of the route is approximately north-east to south-west throughout the German sector.

4.4.2 Bathymetry

The water depths across the German sector range from 40.3 m at KP 230 (alignment chart 52) to 42.2 m below LAT at KP 210.795 (alignment chart 48) and KP 215.300 (alignment chart 49).

The seabed across the German sector describes a very gently sloping subtle mound. The apex of this mound is at approximately KP 230 but seabed dips are very subdued throughout the sector. Seabed dip is below 0.5° except for the immediate surroundings of a pipe crossing at KP 218.261.

4.4.3 Seabed Features

4.4.3.1 Seabed sediments

Seabed sediments are consistent throughout the German sector and comprise very loose to loose silty fine SAND with shell fragments. Geotechnical data show that these surficial sands are approximately 0.5 m thick.

4.4.3.2 Bedforms/sediment mobility/natural obstructions

The seabed is smooth. While a sediment mobility assessment has not been carried out for this project the lack of bedforms is an indication that the seabed sediments are not generally subject to migration. There is also no evidence for erosion (scours).

Four boulders are mapped within the German sector.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.4.3.3 Debris

There is a single item of debris within the German sector but this is toward the margins of the corridor at KP 220.513. There are two sonar contacts and numerous magnetic anomalies.

A line of three magnetic anomalies intersects the route at KP 221.250 (alignment chart 50), a line of four magnetic anomalies intersects the route at KP 222.030 (alignment chart 50), a line of four magnetic anomalies intersects the route at KP 226.530 (alignment chart 52). These strings of magnetic anomalies may represent cable debris but there are no corresponding contacts on other data.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.4.3.4 Existing infrastructure

Europipe 1 (a 40 inch gas pipeline) crosses the route at KP 218.261 (alignment chart 50). This pipeline is in service and is owned/operated by Gassco. Norpipe (a 36 inch gas pipeline) crosses the route at KP 222.900 (alignment chart 51). This pipeline is in service and is owned/operated by Gassco.

Table 4.4: Existing Infrastructure German EEZ

Name	Crossing Number	Chart Number	KP	Status
Europipe 1	33	50	218.261	In service pipeline
Norpipe	32	51	222.900	In service pipeline

4.4.4 Shallow Geology

Profiler data show numerous infilled channels within the German sector beneath a continuous 1 to 3 metre thick layer of silty SAND which extends from seabed.

Sample and test data show that the sharply eroded channels are infilled with sandy SILT or CLAY. These channels are cut into dense silty SAND.

4.4.4.1 Peat

Table 4.5: Peat within the German EEZ

KP range profiler	Min. Depth BSF profiler [m]	Geotech. Station	Description	Chart No.
211.930 – 212.200	5	Not sampled	-	48
212.400 – 213.300	4	B07-02-VC	Spongy fibrous very dark greyish brown PEAT	48
220.150 – 220.480	0.5	Not sampled	-	50
220.930 – 221.480	0.5	Not sampled	-	50
221.960 – 222.100	0.5	B07-08-VC	Spongy fibrous very dark brown PEAT	50
231.080 – 231.330	0.5	B07-18-VC	Spongy fibrous dark brown PEAT	53
234.960 – 235.860	0.5	B07-22-VCA	Firm fibrous very dark brown PEAT - from 1.15 m to 1.60 m with extremely closely spaced to very closely spaced thin to thick laminae of fine sand	54
236.660 – 237.300	0.5	B07-24-VC	Spongy fibrous very dark greyish brown to black PEAT	54
237.480 – 237.880	0.5	B07-25-VC	Spongy fibrous dark greyish brown PEAT	54

Peat generally has high reflection amplitude on the profiler records. In some areas (see table above) it has been interpreted purely on the basis of seismic appearance. In other areas it has been proved by geotechnical samples.

4.5 Netherlands EEZ

4.5.1 General

The Netherlands portion of the planned route extends from the boundary with the German sector at KP 239.117 (where the water depth is 41.6 m) to KP 403.341, the boundary between the Netherlands and UK sectors the water depth at this point is 55.6 m. The Netherlands offshore portion of the route is 164.224 kilometres long.

The Dutch sector of the route is covered by alignment chart numbers 54 to 91. These alignment charts should be referred to for any planning decisions that might be influenced by this report as they show the complete interpretation while this narrative makes approximations and omissions to provide a general illustration of conditions along the route.

The heading of the route is approximately north-east to south-west throughout the Dutch sector.

4.5.2 Bathymetry

Water depths within the Netherlands EEZ range from 41.2 m at KP 243 (alignment chart 55) to a maximum of 56.1 m below LAT at KP 402.700, close to the boundary with UK waters.

The route transects the central part of the North Sea within the Dutch sector. In overview water depths increase with ascending KP to 49.7 m at KP 280 (alignment chart 64). Beyond KP 280 to the boundary with the UK sector at KP 403.341 bathymetric trends are primarily defined by a broad subtle bank with 12 m of relief.

The seabed is very smooth within the Netherlands EEZ with dips generally below 0.5°, locally reaching approximately 1° beyond KP 380 (alignment chart 86).

4.5.3 Seabed Features

4.5.3.1 Seabed sediments

Seabed sediments are consistent throughout the Netherlands EEZ and comprise very loose to loose silty fine SAND with shell fragments.

4.5.3.2 Bedforms/sediment mobility/natural obstructions

The seabed is smooth. 19 boulders are mapped within the Netherlands EEZ. Only one is within 100 m of the route. This is 7 m north-west of KP 376.057 (alignment chart 85).

While a sediment mobility assessment has not been carried out for this project the lack of bedforms is an indication that the seabed sediments are not generally subject to migration. There is also no evidence for erosion (scours).

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.5.3.3 Debris

There are 35 debris items within the Netherlands EEZ.

A line of four magnetic anomalies intersects the route at KP 250.990 (alignment chart 57). Five associated magnetic anomalies are close to the route at KP 344.400 (alignment chart 78), and four associated magnetic anomalies are close to KP 356.900 (alignment chart 80), including one of high intensity. These strings of magnetic anomalies may represent cable debris but there are no corresponding contacts on other data.

There are six magnetic anomalies close to the wellhead at KP 389.017 (alignment chart 88) though these are all interpreted to have been generated by the wellhead. The wellhead is discussed in Section 4.5.3.4.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.5.3.4 Existing infrastructure

Table 4.6: Existing Infrastructure Netherlands EEZ

Name	Crossing Number	Chart Number	KP	Status
Tyra-W to F03-FB 26'' Gas Pipeline	31	56	247.700	In service pipeline
A6A to F3FB1 4'' Condensate Pipeline	30	60	261.792	In service pipeline
A6A to F3FB1 20'' Gas Pipeline	29	60	261.829	In service pipeline
VSNL/TGN Northern Europe	28	69	303.515	In service cable
UK – Germany 6	27	78	344.093	Out of service
Draupner to Dunkirk 42'' Gas Pipeline	26	83	368.503	In service pipeline
Sleipner to Zeebrugge 40'' Gas Pipeline	25	83	368.560	In service pipeline
D15-FA to L10-AC 36'' Gas Pipeline	24	87	387.817	In service pipeline
D18a-A to D15-A 8'' Gas/2'' Methanol	23	90	398.454	In service pipeline

Further details of these infrastructure crossings are contained within report J35045-R-RESD.

Drilling has taken place immediately north-west of the route at KP 389 (alignment chart 88). There are spud can marks in the seabed and an associated sonar contact (and high magnitude magnetic anomaly) which represents a wellhead standing clear of the seabed. There is high confidence in this interpretation as the wellhead contact is in the correct position relative to the spud can marks. The wellhead is 9 m north-west of KP 389.017.

4.5.4 Shallow Geology

From the eastern limit of the Dutch sector at KP 239.117 to KP 268 (alignment chart 61) the shallow geology predominantly comprises silty fine SAND with occasional SILT/CLAY filled channels below a surficial layer of SAND. From KP 268 to KP 288 (alignment chart 65) shallow geology is SILT/CLAY prone with an unmappably thin layer of surficial SAND.

From KP 288 to KP 338 (alignment chart 76) the shallow geology is characterised by a mapped 1 to 3 metre thick layer of silty fine SAND with subordinate GRAVEL and organic material. This is subcropped by CLAY with rare SAND layers. Beyond KP 338 to KP 361 (alignment chart 81) the subcrop of the uppermost SAND also becomes SAND prone: profiler records show some structural complexity with numerous infilled channels, though sediment types remain quite consistently SAND-prone.

From KP 361 the subcrop of the uppermost SAND unit is CLAY-prone. An important change takes place at KP 394 (alignment chart 89) where the uppermost mapped unit becomes SILT-prone to the boundary with the UK sector at KP 403.341.

4.5.4.1 Peat

Table 4.7: Peat within the Netherlands EEZ

KP range profiler	Min. Depth BSF profiler [m]	Geotech. Station	Description	Chart No.
239.490 – 239.810	1	B07-28-VC	Spongy fibrous black PEAT	55
240.260 – 240.290	1	Not sampled	-	55
263.070 – 263.330	1	B08-10-VC	Spongy fibrous very dark brown PEAT with medium to coarse gravel-sized pockets of dark grey fine sand	60
263.560 – 263.600	1	Not sampled		60
267.910 – 268.560	1	B08-16-VC	Spongy PEAT with closely spaced thick laminae of grey silty clay	61
335.320 – 336.930	1.5	B09-20-VC	Very dark brown spongy fibrous PEAT with few coarse gravel-sized to cobble-sized wood fragments - with slight H2S odour	76
337.800 – 338.200	1.5	B09-20-VC		

Peat generally has high reflection amplitude on the profiler records. In some areas (see table above) it has been interpreted purely on the basis of seismic appearance. In other areas it has been proved by geotechnical samples.

4.6 UK EEZ

4.6.1 General

The offshore UK portion of the planned route extends from the boundary with the Dutch sector at KP 403.341 (where the water depth is 55.6 m) to the junction with the UK landfall section, the western extremity of the offshore route at KP 618.200. The UK offshore portion of the route is 214.859 kilometres long, the total UK route chainage is 215.394 kilometres.

The UK sector of the route is covered by alignment chart numbers 91 to 141. These alignment charts should be referred to for any planning decisions that might be influenced by this report as they show the complete interpretation while this narrative makes approximations and omissions to provide a general illustration of conditions along the route.

The heading of the route is approximately north-east to south-west throughout the UK sector though in greater detail the route arcs to the north and the route has an increasingly southerly heading with increasing KP.

The route splits into northern (LF1) and southern (LF2) landfall branches at KP 611.074 (alignment chart 139). Unless stated otherwise this text describes conditions along the northern landfall option (LF1).

There are a profusion of magnetic anomalies displayed on alignment chart 136 between KP 597.500 and KP 601. The vast majority of these are low magnitude and only present on areas covered by wing lines. These anomalies are interpreted to be due to an error in instrument calibration, operation or function rather than representing a debris field.

4.6.2 Bathymetry

Water depths across the area range from 86.6 m to 4.6 m below LAT.

Water depths generally increase with ascending KP from the junction with the Dutch sector at KP 403.341 (where the water depth is 55.6 m) to the base of the Outer Silver Pit where water depths reach 86.6 m at KP 472.740 (alignment chart 107).

The Outer Silver Pit is a large scale seabed depression which, on the route, has approximately 10 metres of negative relief. This feature effectively marks the onset of the western flank of the North Sea Basin, from this point water depths generally decrease with ascending KP to the limit of the offshore UK sector at KP 618.200 (alignment chart 140) where the water depth is 4.6 m. Water depth abruptly decreases beyond this point to the UK landfall.

There are numerous other bathymetric features. The route crosses the deepest part of the Inner Silver Pit between approximately KP 549.500 and KP 551.200, water depth reaches 40 m within this feature, approximately 10 m below the surrounding seabed (alignment charts 124 and 125).

Other bathymetric variations are related to large scale bedforms, one of which is so large that it required a reroute (and therefore is not present on revision 10 of the route).

Seabed dip reaches ~10° on the Outer Silver Pit, dips of similar magnitude occur on the flanks of sand waves.

Table 4.8: Bathymetric Anomalies UK EEZ

Origin of Bathymetric Anomaly	Relief [m]	Chart Number	KP
Sand Wave Crest	+2	106	469.120
Sand Wave Crest	+1	106	469.550
Erosive hollow: Outer Silver Pit	-10	105-107	472.740
Sand Wave Crest	+2-3	107	474.900
Sand Wave Crest	+2-3	107	475.120
Sand Wave Crest	+2-3	107	475.970
Undulating Seabed	+/-4	108-109	477 to 484
Sand Wave Crest/ridge	+1	108	477.880
Ridge	+2	108	481.540
Sand Wave Crest	+1	115	512.280
Sand Wave Crest	+1-2	120	532.490
Sand Wave Crest	+2-3	122	539.470
Sand Wave Crest	+2-3	122	539.590
Sand Wave Crest	+2-3	122	539.620
Sand Wave Crest	+3	122	542.400

Origin of Bathymetric Anomaly	Relief [m]	Chart Number	KP
Numerous Sand Wave Crests	+1-2	123	542.850 to 543.350
Sand Wave Crest	+1	123	544.920
Sand Wave Crest	+1	123	546.390
Sand Wave Crest	+3	123	546.700
Erosive hollow: Inner Silver Pit	-10	124-125	549.500 to 551.200
Undulating Seabed	+/-4	131-137	577.500 to 602.500
Numerous Sand Wave Crests	+1-3	137	603.140 to 605.400
Numerous Sand Wave Crests	+1-4	139-140 (LF1)	613.040 to 614.350

Small scale bathymetric variation is driven by mobile bedforms, ripples. These intermittently occur from KP 501.180 (alignment chart 113) to the end of the UK offshore sector.

The offshore portion of the LF2 route option almost immediately passes up a 3° slope on an asymmetric bank where water depth decreases by 2.5 m at KP 611.450. Beyond this point to KP 614 the water depth is approximately 12 m though the seabed relief is, in detail, quite irregular. Water depth gently decreases to 5.6 m by KP 621.850. This is the base of the beach slope which dips at up to 4° to the zero isobath at KP 622.350.

4.6.3 Seabed Features

4.6.3.1 Seabed sediments

Seabed sediments comprise very loose to loose silty fine SAND with shell fragments from KP 402.760 to KP 501.180 (alignment chart 113). Beyond KP 501.180 seabed sediments consist of SAND and SAND with PEBBLES. Beyond KP 535.440 sediments comprise SAND with PEBBLES and BOULDERS.

CHALK bedrock is at or very close to exposure between KP 550.500 and KP 551.054 (alignment charts 124 and 125) within the Inner Silver Pit. Sediments become SAND-prone beyond this point with variable proportions of PEBBLES and BOULDERS from KP 566.860 (alignment chart 128) on both landfall route options.

4.6.3.2 Bedforms/sediment mobility/natural obstructions

Sand wave areas are tabulated in the bathymetry section. Smaller scale ripples intermittently occur from KP 501.180 to the end of the UK offshore sector. PEBBLES and BOULDERS are too numerous to be individually mapped beyond KP 566.860 (alignment chart 128), and are of particularly high density beyond KP 621 on the LF2 part of the route.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.6.3.3 Debris

Wrecks are located 142 m north-west of KP 404.779 (alignment chart 91), 233 m north-west of KP 419.159 and 200 m north-west of KP 419.398 (alignment chart 95).

There are numerous debris items within the offshore UK sector.

Seven associated magnetic anomalies cross the route at KP 528.650 (alignment chart 119). A line of five associated magnetic anomalies intersects the route at KP 618.140 (alignment chart 140). These may relate to cable debris though there are no corroborating observations in other data.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.6.3.4 Existing infrastructure

23 cables and pipelines, all of which are in-service, cross the route within the UK sector at 20 crossing locations. Table 4.9 lists the KP of the crossing points. Further details of these infrastructure crossings are contained within report J35045-R-RESD.

Table 4.9: Existing Infrastructure UK EEZ

Name	Crossing Number	Chart Number	KP	Status
Ketch to Murdoch 18'' Gas/3'' Methanol	22	97	429.858	In service pipeline
Tampnet/Norsea Com-1 Seg.3	21	98	435.334	In service cable
Schooner to Murdoch 16'' Gas/3'' Methanol	20	101	448.513	In service pipeline
Theddlethorpe to Murdoch MD 26'' Gas	19	107	475.366	In service pipeline
Theddlethorpe to Murdoch MD 3'' Methanol	18	107	475.388	In service pipeline
Esmond to Bacton 24'' Gas	17	108	479.916	In service pipeline
Shearwater to Bacton 34'' Gas (SEAL)	16	112	496.287	In service pipeline
Babbage to West Sole 12'' Gas	15	117	517.510	In service pipeline
West Sole to Easington 16'' Gas	14	124	547.675	In service pipeline
West Sole to Easington 24'' Gas	13	124	547.788	In service pipeline
Amethyst C1D to Amethyst A1D Power	12	128	565.084	In service cable
Amethyst C1D to Amethyst A1D 12'' Gas	11	128	565.142	In service pipeline
Amethyst C1D to Easington Power	10	128	566.583	In service cable
Amethyst C1D to Easington 30'' Gas	9	128	566.630	In service pipeline
Theddlethorpe to Murdoch MD 26'' Gas	7	137	605.501	In service pipeline
Theddlethorpe to Murdoch MD 4'' Methanol	6	138	605.521	In service pipeline
Pickeral A to Theddlethorpe 24'' Chemical	5	138	605.630	In service pipeline
Loggs PP to Theddlethorpe 36'' Gas	4	138	605.728	In service pipeline
Loggs PP to Theddlethorpe 4'' Methanol	3	138	605.748	In service pipeline
Viking AR to Theddlethorpe 28'' Gas/3'' Methanol	2	138	607.422	In service pipeline

4.6.4 Shallow Geology

From the eastern extremity of the UK sector at KP 403.341 to KP 531.500 (alignment chart 120) the shallow geology predominantly comprises silty fine SAND with subordinate GRAVEL over CLAY with rare SAND layers. Geotechnical data indicate that this uppermost SAND-prone unit is generally at least 2 m thick, though in some areas it is not possible to discern the base of this unit in profiler records. Beyond KP 428 (alignment chart 96) to KP 464 (alignment chart 105) the uppermost SAND is over 3 m thick.

From KP 477 (alignment chart 108) to KP 485.500 (alignment chart 109) the shallow geological conditions become more complex and variable. The seabed becomes undulating in this area and the shallow sediments largely comprise infill of distinct channels.

From KP 531.500 the shallow geology is CLAY prone with only a thin veneer of sandy sediment at seabed, though locally sand waves are superimposed upon the upper surface of these CLAYS.

4.6.4.1 Peat

Table 4.10: Peat within the UK EEZ

KP range profiler	Min. Depth BSF profiler [m]	Geotech. Station	Description	Chart No.
602.660 – 602.810	1	B15-05-VC	Spongy fibrous PEAT, with coarse gravel sized fragments of very dark brown wood	137
603.750 – 603.960	1			
604.570 – 604.990	2.5			

Peat generally has high reflection amplitude on the profiler records. In some areas (see table above) it has been interpreted purely on the basis of seismic appearance. In other areas it has been proved by geotechnical samples.

4.7 UK Landfall LF1

4.7.1 General

The LF1 UK landfall sector of the route encompasses KP 618.200 to KP 618.735. The route is orientated east-north-east to west-south-west within this area with an elevation range of 4.6 m below LAT at KP 618.200 to +12.0 m at KP 618.735. This area is covered by the plan view landfall chart 2 (LF1) and alignment charts 140 and 141. The following text refers to the northern LF1 route option.

4.7.2 Topography

The onshore area extends for 315 metres from the Beach Manhole (BMH) at KP 618.735 to the 0 m isobath at approximately KP 618.420.

The Beach Manhole (BMH)/western end of the route is located on the sea wall at an elevation of approximately 9 m. The area immediately west of the sea wall comprises the Sandylands golf course. East of the sea wall the beach dips steeply from an elevation of 9 m to 5 m over the course of just 33 m, an average gradient of 7° (KP 618.693 to KP 618.660).

From KP 618.643 the beach slopes gently from an elevation of 5 m to 1 m at KP 618.509, beyond this point, to an elevation of 0.5 m at KP 618.410, the seabed is flat.

4.7.3 Bathymetry

Bathymetry data extend from KP 618.420 to the limit of the route described in this section, KP 618.200. Seabed dip is greatest between KP 618.410 and KP 618.307 where water depth increases from -0.5 m to 4 m, gradient averages 2.5° and exceptionally reaches 4° at KP 618.430. Beyond KP 618.307 to KP 618.200 the seabed slopes very gently with the water depth increasing from 4 m to 4.6 m.

4.7.4 Seabed Features

4.7.4.1 <u>Seabed sediments</u>

Seabed sediments are SAND-prone with numerous PEBBLES and BOULDERS.

4.7.4.2 <u>Bedforms/sediment mobility/natural obstructions</u>

The seabed is generally smooth except for the PEBBLES and BOULDERS which comprise the seabed sediments. Boulders are far more numerous immediately east of the landfall zone.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

The beach profile is expected to respond to extreme storm and tidal events.

4.7.4.3 <u>Debris</u>

There are a profusion of magnetic anomalies and sonar contacts within the landfall zone (alignment charts 140 and 141).

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

4.7.4.4 <u>Existing infrastructure</u>

A concrete sea wall with steel fencing is present at the route end, and groynes occur on the beach.

4.7.5 Shallow Geology

Shallow sediments are expected to comprise CLAY with layers of SILT and SAND with a landward thickening veneer of silty SAND.

4.8 UK Landfall LF2

4.8.1 General

The LF2 UK landfall sector of the route encompasses KP 622.200 to KP 622.659. The route is orientated east-north-east to west-south-west within this area with an elevation range of 4.1 m below LAT at KP 622.200 to +10 m at KP 622.659. This area is covered by the plan view landfall chart 3 (LF2) and alignment chart 141 (LF2).

4.8.2 Topography

The onshore area extends for 305 metres from the Beach Manhole (BMH) at KP 622.659 to the 0 m isobath at approximately KP 622.354.

The Beach Manhole (BMH)/western end of the route is located on the eastern flank of the sea wall at an elevation of approximately 10 m. Anderby Marsh nature reserve, characterised by marsh and flooded meadows, is positioned immediately west of the sea wall.

East of the sea wall the beach dips steeply between KP 622.592 and KP 622.617 from an elevation of 8 m to 5 m over the course of just 25 m, an average gradient of 7°.

From KP 618.592 the beach slopes gently from an elevation of 5 m to 0 m at KP 622.354.

4.8.3 Bathymetry

Bathymetry data extend from KP 622.354 to the limit of the route described in this section, KP 622.200. Seabed dip is consistent at 1.6°, water depth increases from west to east from 0 m to 4.1 m.

4.8.4 Seabed Features

4.8.4.1 Seabed sediments

Seabed sediments are SAND-prone with numerous PEBBLES and BOULDERS.

4.8.4.2 Bedforms/sediment mobility/natural obstructions

The seabed is generally smooth except for the PEBBLES and BOULDERS which comprise the seabed sediments.

Tables of point contacts have been supplied digitally; details of these products are contained in Appendix D of this report.

The beach profile is expected to respond to extreme storm and tidal events.

4.8.4.3 Debris

There are five magnetic anomalies within the LF2 landfall area. One of these, at KP 622.372 is within 3 m of the route (alignment chart 141 LF2).

4.8.4.4 Existing infrastructure

A concrete sea wall with steel fencing is present at the route end, and groynes occur on the beach.

4.8.5 Shallow Geology

Shallow sediments are expected to comprise CLAY with layers of SILT and SAND with a landward thickening veneer of silty SAND.

4.9 Magnetometer Contacts (UXO Risk Mitigation)

NGIL and Energinet commissioned a desk based UXO (unexploded ordnance) risk mitigation plan completed by OrdTek Ltd (OrdTek, 2016). The results of this study are listed in Table 4.11 and visually presented in Figure 4.1. The classes of proposed risk mitigation measures for UXO for KP are included in the digital deliverables for the magnetometer contacts.

Table 4.11: Proposed Risk Mitigation Measure (OrdTek, 2016)

Start KP*	End KP*	Proposed Risk Mitigation Measure (Class)
0.000 (DK landfall)	2.338	Procedural and reactive mitigation
2.388	140.500	UXO survey: Potential for buried objects
140.500	256.300	Use existing geophysical data
256.300	474.00	Use existing geophysical data
474.000	531.200	UXO survey: Potential for buried objects
531.200	UK landfall	UXO survey: Potential for buried objects and boulder/cobbles

Notes:
* Kilometre Post (KP) referenced to Route 4 (v.10)
Table information from OrdTek (2016) supplied by Energinet (email: Jens Colberg-Larsen, 3 November 2016)

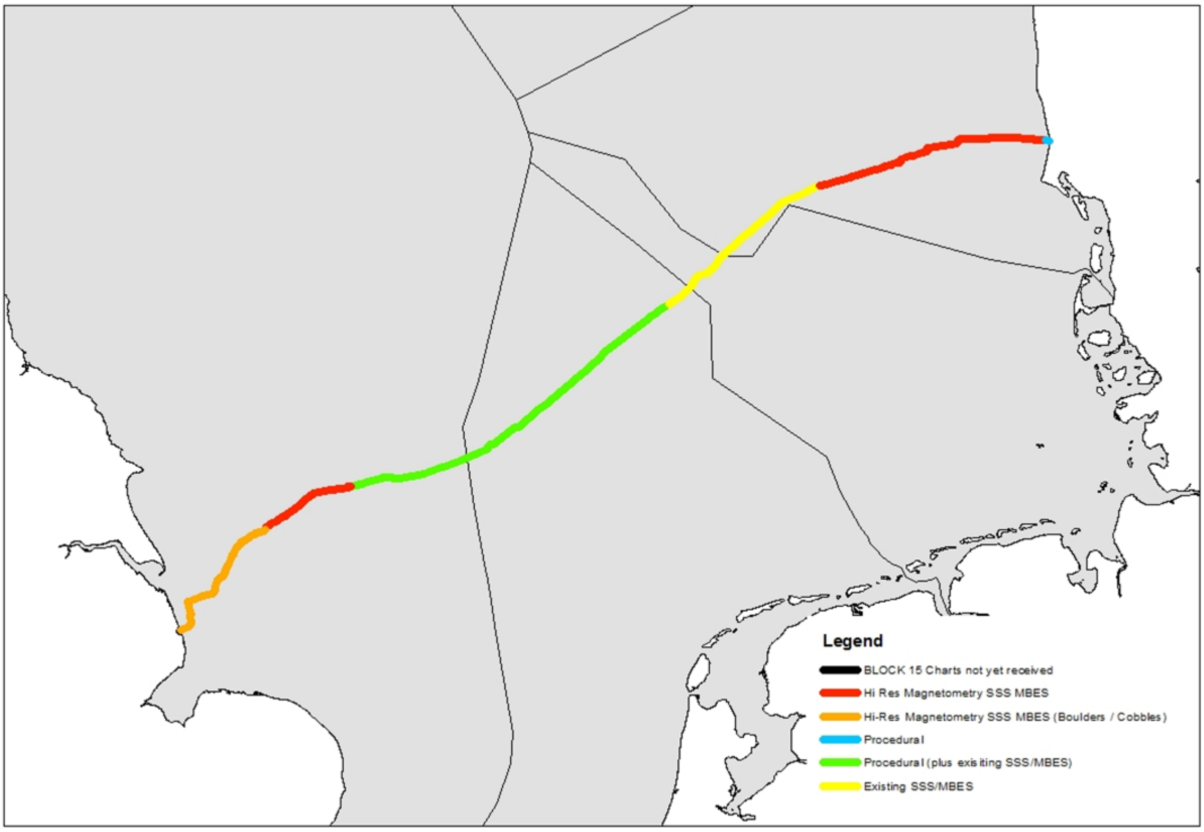


Figure 4.1: OrdTek (2016) UXO proposed risk mitigation map

5. ENVIRONMENTAL ASSESSMENT

5.1 General

This section presents the key findings of the benthic survey carried out at the following stations along the Viking Link cable route. The results for the stations sampled are presented for the four sectors as follows:

- 92 stations within the UK sector[1];
- 36 stations within the Dutch sector[2];
- 40 stations within the German sector;
- 45 stations within the Danish sector[3].

The only habitat of concern identified within the sectors was the mussel beds identified between KP 569.700 and KP 570.635 (alignment chart 129). Details of the mussel beds and other habitats identified can be found within the following sections and the four Benthic Results Report volumes.

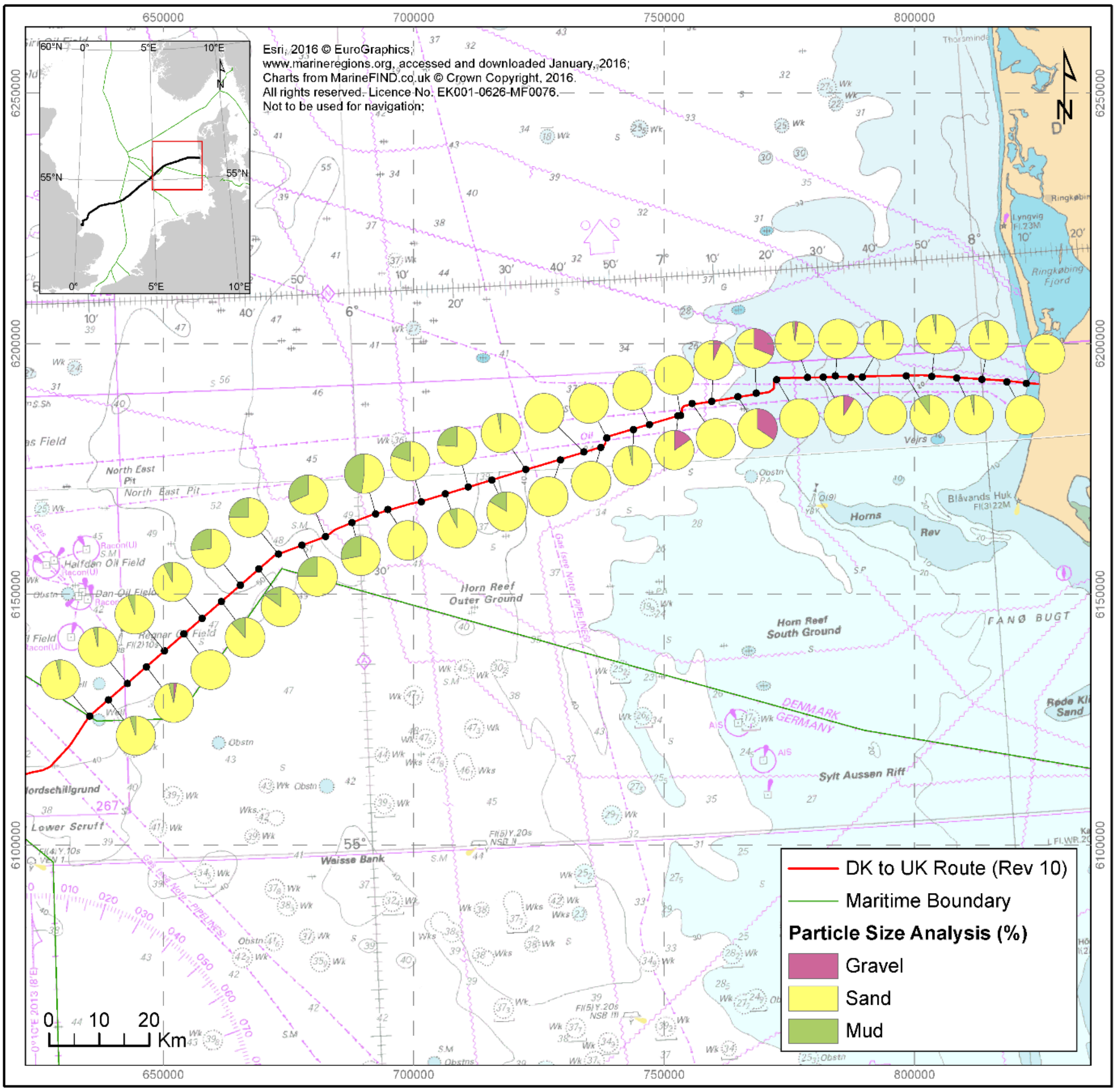
J35045-R-RESE.1 UK sector
J35045-R-RESE.2 Dutch sector
J35045-R-RESE.3 German sector
J35045-R-RESE.4 Danish sector

[1] Within the UK sector, hard substrates and low visibility restricted sampling. In total, 82 video transects, 66 grabs (resulting from 62 physico-chemical samples [with an additional 2 particle size samples where full physico-chemical samples were not successfully acquired] and 64 faunal samples) and 68 water quality profile datasets were successfully collected. Full details can be found in the Benthic Operations Report (J35045-R-OPSE) and the UK Benthic Results Report (J35045-R-RESE.1).
[2] In addition to one video transect rerun.
[3] In addition to four video transect reruns.

5.2 Danish Sector

5.2.1 Seabed Sediment Conditions

Sediments within the Danish sector were dominated by the sand fraction, with some variation in the gravel and mud fractions present at each station. Coarser material was only observed from the video analysis in patches along six transects (2FTR10, 3FTR11, 3FTR11A, 3FTR13, 3FTR17 and 4FTR26). Figure 5.1 presents the spatial distribution of the sediments within the Danish sector.



Map Document: (\\EMU-FS1.ad.emuenv.co.uk\GIS-DATA\Q160701_VikingLink_Benthic_2016\3_Plots\2_Draft\Denmark\Q160701_DM_Sediments.mxd)
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Figure 5.1: Spatial distribution of sediments using Folk (1954) classifications along the cable route within the Danish sector (from PSD analysis)

5.2.2 Sediment Chemistry

Metal concentrations were all below the Cefas AL1 values, except copper at one station, and all below the OSPAR ERL values and all total hydrocarbon concentrations were below the Cefas AL1 values; therefore, are considered to be of little concern with respect to possible effects on the marine environment, in the context of the disposal of dredged material. In addition, the total hydrocarbons are lower than typical range for offshore North Sea surface sediments (Sheahan et al., 2001).

CPI values indicate a slight dominance of biogenic alkanes, with the presence some n-alkanes typically related to petrogenic inputs (McDougall, 2000; Russell et al., 2005). Pr:Ph ratios are high indicating that the sediments are not likely to be contaminated. This finding is supported by evidence of only small UCM humps on the gas chromatograms (Brassell and Eglinton, 1980; McDougall, 2000).

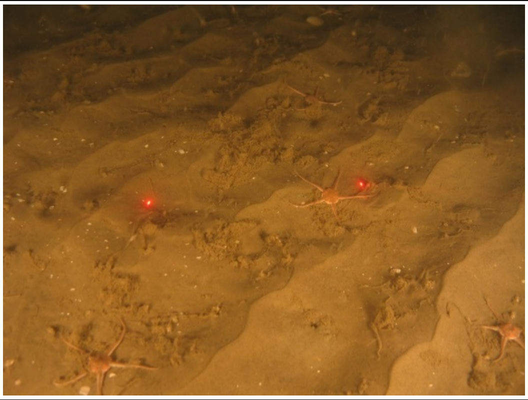
5.2.3 Macrobenthic Communities

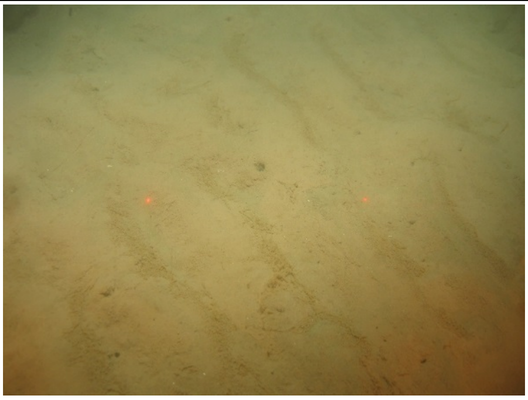
The video analysis revealed four main habitats within the Danish sector; these are presented within Table 5.1.

Observed epifauna was generally sparse throughout the Danish sector. Three species of echinoderms (common starfish *Asterias rubens*, sandstar *Astropecten irregularis* and brittle star *Ophiura ophiura*), crabs (masked crab *Corystes cassivelaunus,* hermit crabs Paguridae and the identified species *Pagurus bernhardus* and the genus *Liocarcinus*) were the most commonly observed epifauna.

Areas of seabed with coarser material hosted different taxa and dominances than the areas of rippled sand. The most dominant taxa were common starfish *Asterias rubens,* hydroid/bryozoan turf, edible crab *Cancer pagurus*, polychaetes *Spirobranchus* sp., hydroid/bryozoan meadow, hornwrack Flustra foliacea, dead man's fingers *Alcyonium digitatum*, hermit crabs Paguridae, bryozoan crusts, gobies Gobiidae and anemone *Metridium dianthus.*

Table 5.1: Examples of the Main Habitats Encountered Along the Cable Route within the Danish sector

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
2FTR03	Rippled sand with shell fragments and occasional burrows. Empty *Ensis* sp. shells and *Echinocardium cordatum* tests present	*Ophiura ophiura* Actiniaria *Asterias rubens* *Ophiura albida* Hydroid/bryozoan turf *Liocarcinus* sp. Pleuronectiformes Gobiidae *Pomatoschistus* sp.	

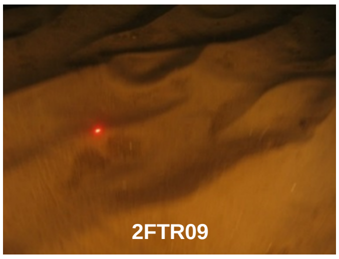
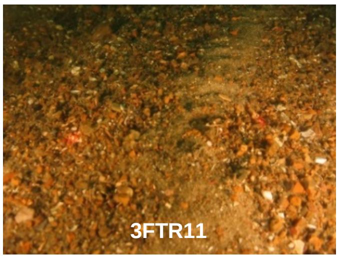
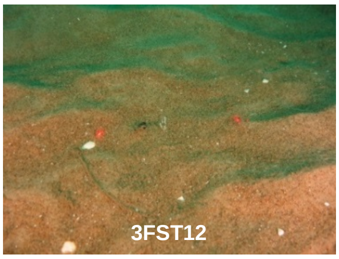
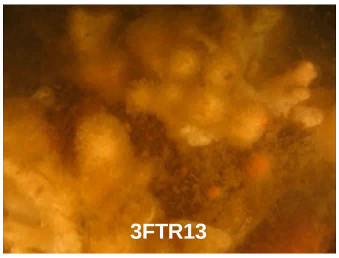
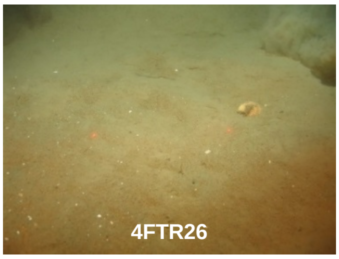
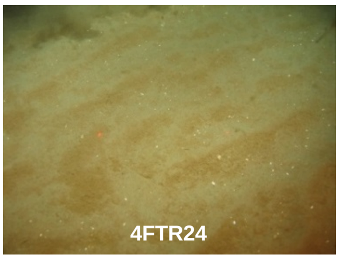
Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
Part of 3FTR11	Coarse mixed sediment (gravel, sand, pebbles and cobbles). Empty *Ensis* sp. shells present	*Urticina felina* *Alcyonium digitatum* *Spirobranchus* sp. *Metridium dianthus* Bryozoan crusts Hydroid/bryozoan turf *Flustra foliacea* Hydroid/bryozoan meadow *Liocarcinus* sp. Actiniaria *Asterias rubens* Cirripedia Paguridae	
Part of 3FTR11	Rippled gravelly sand	*Asterias rubens* Gobiidae	
4FTR28	Rippled silty sand/sandy silt with burrows	Polychaete tubes *Asterias rubens* *Astropecten irregularis* *?Callionymus* sp. *Ophiura ophiura* *Corystes cassivelaunus* *Echinocardium cordatum* (recorded from grab sample field records)	

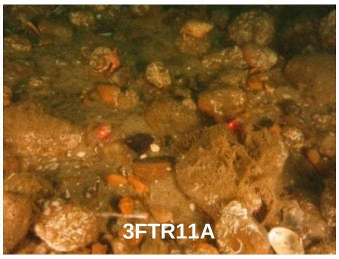
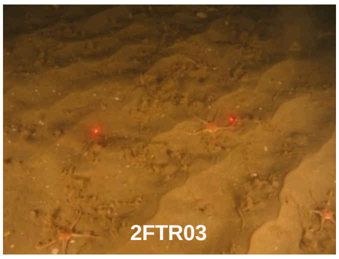
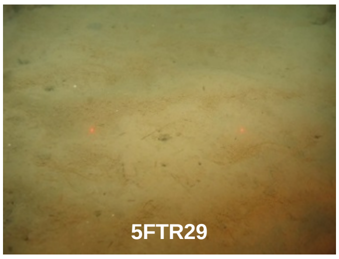
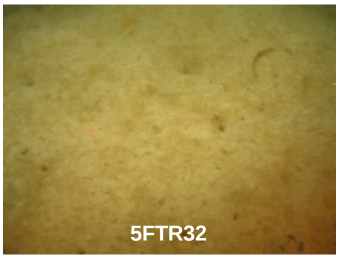
The enumerated benthic fauna from grab samples comprised a total of 182 taxa, represented by 4865 individuals.

Annelida were dominant in terms of taxa diversity, accounting for 75 taxa, equivalent to 41 % of the benthic diversity. Echninodermata were the most dominant also in terms of abundance with 2064 individuals (42% of the benthic abundance).

Combined with the video analysis, which identified epifaunal communities and seabed conditions not captured within the singular grab along each transect, 11 EUNIS biotopes were identified within the Danish sector. These biotopes included three Level 5 biotopes, four Level 4 biotope complexes, two Level 3 habitat complexes and three Level 5 biotope mosaics. These biotopes are presented within Table 5.2, with the distribution of the biotopes presented within Figure 5.2.

Table 5.2: Biotopes Recorded from the Survey Along the Cable Route within the Danish sector

EUNIS (2016) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.13 Infralittoral coarse sediments	2FST09, 3FST19	e	
A5.14 Circalittoral coarse sediment	Part of 3FTR11	*	
A5.145 *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel	2FST10, 3FST12, 3FST14, 3FST15	d	
A5.145 *Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel ***with*** A5.444 *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	Part of 3FTR13	*	
A5.2 Sublittoral sand	3FST13 Part of 2FTR10, Part of 3FTR11, Part of 3FTR11A, Parts of 3FTR14, Part of 3FTR17, Part of 4FTR26	d†	
A5.242 *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand	2FST01, 2FST02, 2FST04, 2FST05, 2FST06, 2FST07, 2FST08, 3FST16, 3FST17, 3FST18, 3FST20, 3FST21, 4FST22, 4FST23, 4FST24, 4FST25, 4FST28, 5FST30	b	

EUNIS (2016) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.242 *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand ***with*** A5.444 *Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment	3FST11A	b	
A5.242 *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand ***with*** A5.137 Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand	2FST03	b	
A5.26 Circalittoral muddy sand	4FST27, 5FST29, 6FST41, 6FST42, 6FST43, 6FST44, 6FST45	a	
A5.351 *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	4FST26, 5FST31, 5FST32, 5FST33, 5FST34, 5FST35, 6FST36, 6FST37, 6FST38, 6FST39, 6FST40	a	
A5.44 Circalittoral mixed sediment	Part of 2FTR10, Part of 3FTR11, Part of 4FTR26	*	

Notes:
* = Not included in grab analysis, partial video transects only.
† = In addition to partial video transects
# = Faunal group derived from multivariate analysis (PRIMER)

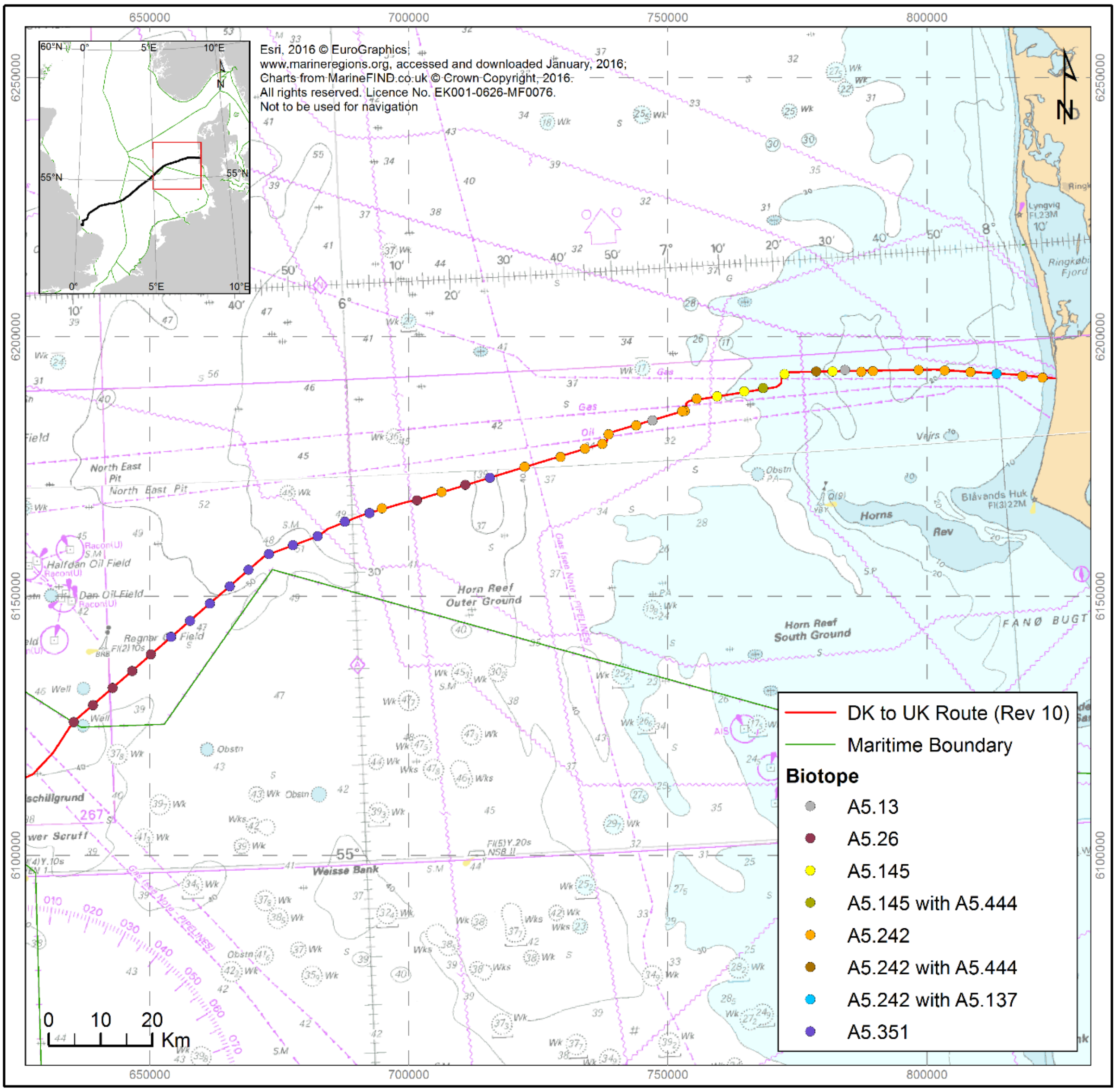


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Figure 5.2: Distribution of biotopes along the cable route within the Danish sector (from grab stations)

5.2.4 Species and Habitats of Conservation Interest

Two species of fish (solenette and dab) and one species of shellfish (Norway lobster) which were recorded in the current survey are on the IUCN Red List for Threatened Species. All three of these species are listed as species of 'least concern'.

One ocean quahog individual (80 mm) was recorded in a grab sample from Station 4FTR26, and empty ocean quahog shells were recorded from a total of three transects (4FTR22, 4FTR23 and 6FTR42). This is important as the species is listed on the OSPAR 'List of Threatened and Declining Habitats and Species', due to its slow growth and maturation rates, low fecundity and sporadic recruitment and vulnerability to physical disturbance or substratum loss.

Six patches of coarse material were investigated as possible Annex I habitat Cobble Reef. Due to the absence of medium to high concentrations of cobbles and boulders, three patches were designated ‘Not Reef’ and three as ‘Low’ resemblance to stony reef.

5.2.5 Water Profiles

Results of the water column profiles indicated well mixed layers of water across the survey area, typical of the shallow parts of the southern North Sea, where seawater remains well mixed throughout the year owing to strong tidal action (North Sea Task Force, 1993). Water quality profiles were fairly similar throughout the Danish sector survey area.

5.3 German Sector

5.3.1 Seabed Sediment Conditions

Sediments across the German sector survey area were dominated by sand with minor gravel and mud fractions, and shell fragments noted from the video footage. The spatial distribution of the particle size distribution (PSD) analysis results are presented within Figure 5.3.

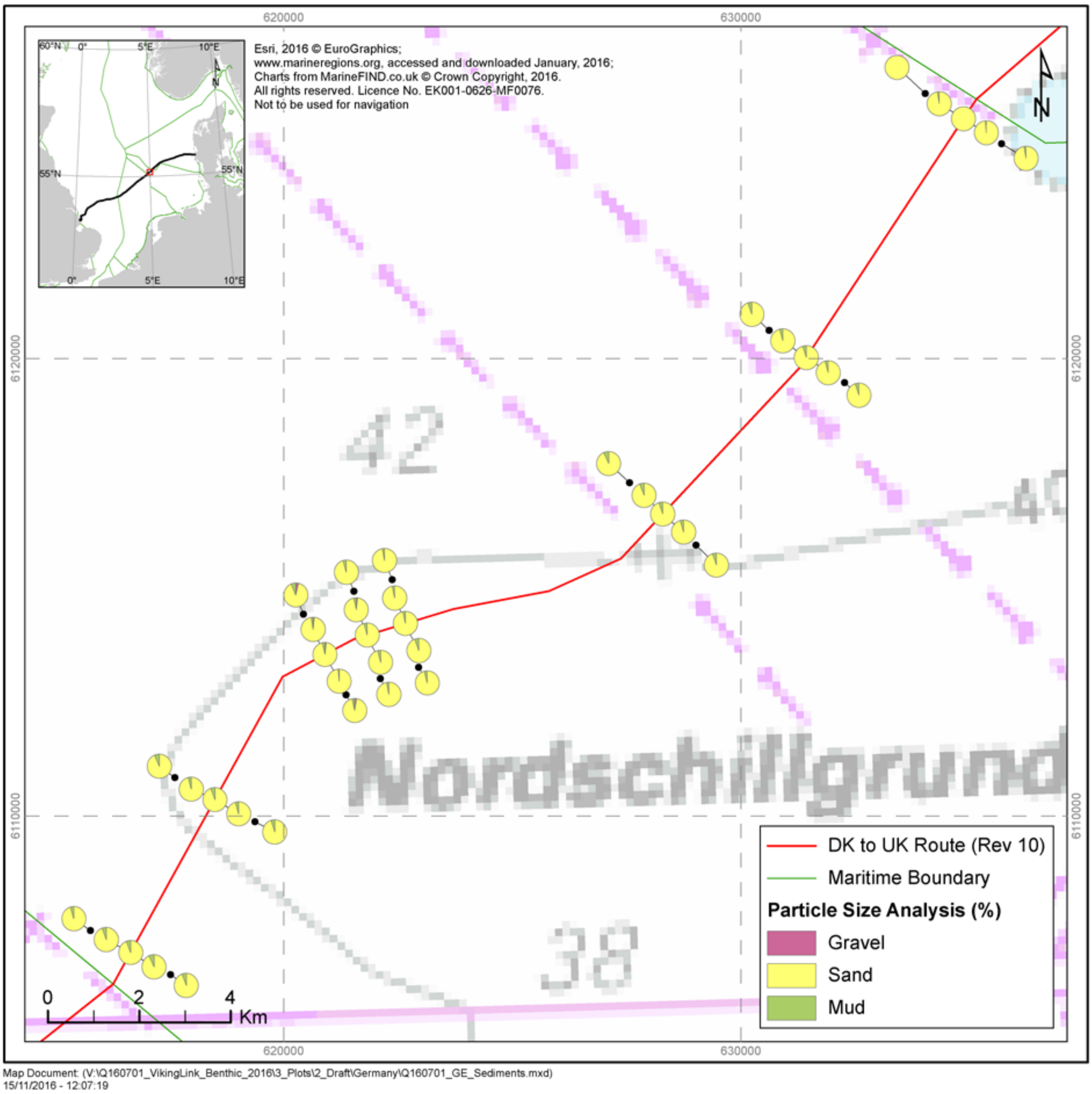
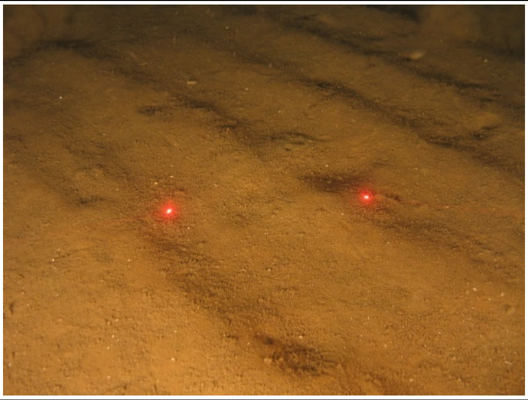


Figure 5.3: Spatial distribution of sediments using Folk (1954) classifications along the cable route within the German sector (from PSD analysis)

5.3.2 Macrobenthic Communities

The video analysis found sparse fauna throughout the German sector. Two species of starfish (sand star *Astropecten irregularis* and common starfish *Asterias rubens)* and hermit crab Paguridae were the most commonly observed epifauna and were encountered throughout all the observed seabed habitats. Polychaete tubes were also observed at each site. However, it was unclear from the video footage and stills alone whether polychaetes were present within these tubes. The masked crab *Corystes cassivelanus*, common hermit crab *Pagurus bernhardus (*some of which were recorded with the hydroid, *Hydractinia echinata* living on their shells), dragonet, *Callionymus* sp., hydroid/bryozoan turf and unidentified flat fish Pleuronectiformes, made up the other taxa within the top ten encountered species (Table 5.3).

Table 5.3: Examples of the Main Habitats Encountered Along the Cable Route within the German sector

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
7MTR34	Rippled silty sand with burrows. *Echinocardium cordatum* tests present.	Polychaete tubes *Buglossidium luteum* Paguridae *Astropecten irregularis* *Asterias rubens* Pleuronectiformes *Callionymus* sp. *Luidia sarsi* Gadidae	

The enumerated fauna from the grab samples comprised 179 taxa, represented by 22 428 individuals.

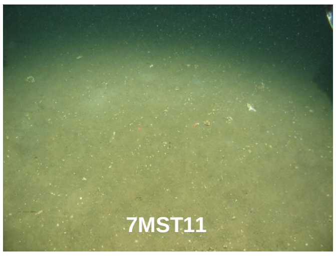
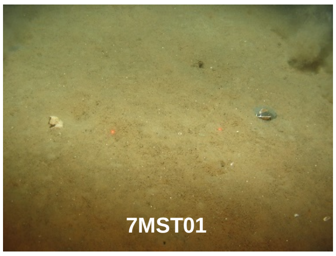
Annelida were dominant in terms of taxa composition, accounting for 57 taxa, equivalent to 32 % of the benthic diversity; they were followed by Crustacea (55 taxa, 31 %) and Mollusca (47 taxa, 26 %), whereas Echinodermata and "Other Taxa" comprised, respectively, 7 % (12 taxa) and 4 % (8 taxa) of the benthic faunal diversity. However, Echinodermata were the most dominant in terms of abundance with 11,302 individuals (50 % of the benthic abundance), followed by the Annelida (4,221 individuals, 19 %) and Mollusca (3,840 individuals, 17 %). Crustacean and "Other Taxa" comprised 5 % (1,222 individuals) and 8 % (1,843 individuals) of the benthic abundance respectively.

Within the trawl samples, fish species made up the majority of the taxa (37 % of the total) and biomass (70 % of the total), however, with regards taxonomic abundance, echinoderms were the most numerous (66 % of total). The most numerous and frequently occurring species included common starfish *Asterias rubens*, starfish species *Luidia sarsii,* sandstar *Astropecten irregularis,* solenette *Buglossidium luteum*, scaldfish *Arnoglossus laterna*, dab *Limanda limanda* and plaice *Pleuronectes platessa.* Multivariate analysis was carried out on the trawl samples and identified two groups with the primary reasoning for the split was the difference in abundances. Overall, all the species recorded are associated with sand dominated sediments and were generally comparable between trawls.

Combined with the video analysis, which identified epifaunal communities and seabed conditions not sampled by the singular grab along a transect, a total of two EUNIS biotopes were identified for the German sector. These biotopes were Level 5 biotope '*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud' (A5.351) (23 stations) and Level 3 biotope 'Circalittoral sandy mud' (A5.26) (17 stations). Table 5.4 presents the biotopes recorded, with Figure 5.4 presenting the distribution of the biotopes recorded from within the German sector.

The biotopes have also been assessed alongside the sidescan sonar (Figure 5.5), which found little, or no variation, in reflectivity indicating a uniform seabed with homogenous sediments. The findings of the acoustic data have been corroborated by the video footage and stills image, particle size distribution, macrofaunal grab, and trawl sample analyses, and fits with the linked nature of the two biotopes.

Table 5.4: Biotopes Recorded from the Survey Along the Cable Route within the German sector

EUNIS (2016)	Stations	Faunal Group#	Representative Underwater Photograph
A5.26 Circalittoral muddy sand	7MST11, 7MST12, 7MST14 to 7MST17, 7MST19, 7MST20, 7MST23, 7MST24, 7MST32, 7MST34, 7MST36 to 7MST40	a b c	
A5.351 *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	7MST01 to 7MST10, 7MST13, 7MST18, 7MST21, 7MST22, 7MST25 to 7MST31, 7MST33, 7MST35	d	

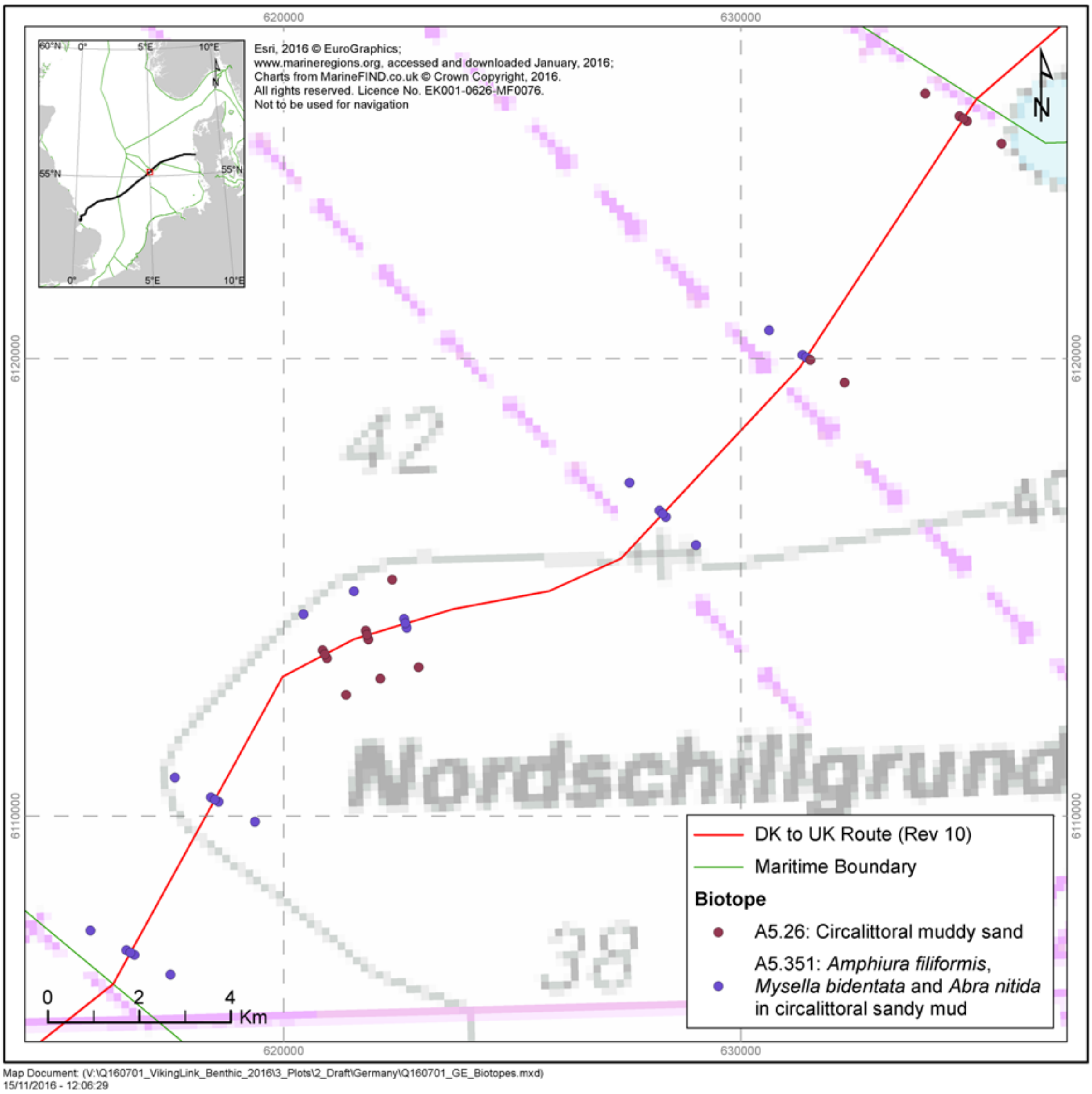


Figure 5.4: Distribution of biotopes along the cable route within the German sector

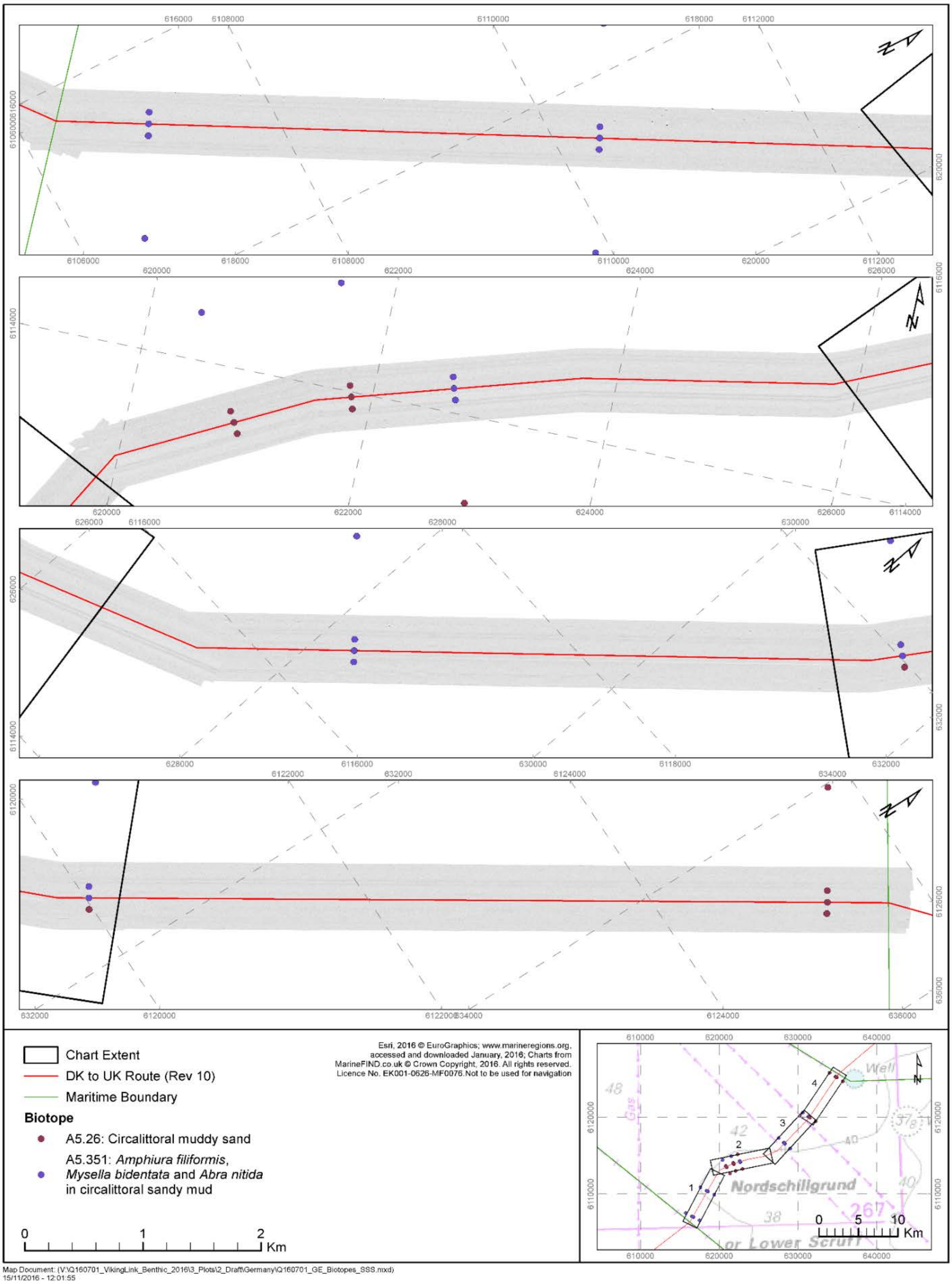


Figure 5.5: Sidescan sonar overlaid with biotopes along the cable route within the German sector

5.3.3 Species and Habitats of Conservation Interest

No Annex I habitats or OSPAR threatened and/or declining habitats were recorded within the German sector.

A total of 11 juveniles of the ocean quahog *Arctica islandica* were recorded from the 120 grab samples collected within the Germany survey array. This is important as the species is listed on the OSPAR 'List of Threatened and Declining Habitats and Species', due to its slow growth and maturation rates, low fecundity and sporadic recruitment and vulnerability to physical disturbance or substratum loss.

A total of 11 species of fish recorded in the current survey are on the IUCN red list for threatened species. One of these species (Dover sole *Solea solea*) is listed as 'data deficient', with the remaining species listed as species of 'least concern'.

This included two sandeels *Ammodytes* recorded at Stations 7MST20 and 7MST26. Of the species which could be identified under this genus, lesser sandeel *Ammodytes marinus* are listed UK Biodiversity Action Plan (BAP) priority species (JNCC, 2016). Sandeels are of ecological importance for providing food for many bird species, including guillemots, razorbrill and terns.

5.3.4 Water Profiles

Results of the water column profiles indicated a medium to strong thermocline and oxygen boundary column was observed at all stations, with warmer, more oxygen saturated and often more saline waters at the surface. Dissolved oxygen percentiles were near/or at saturation at the time of survey, with no indication of oxygen depletion. The stratification and values of the variables measured were similar to those typical of the southern North Sea.

5.4 Dutch Sector

5.4.1 Seabed Sediment Conditions

Sediments across the Dutch sector were predominantly sands with varying proportions of gravel, and mud. Coarser material was observed from the video analysis in patches along three transects (10PTR06, 10PTR08 and 10PTR09). Figure 5.6 presents the spatial distribution of the sediments from the PSD analysis within the Dutch sector.

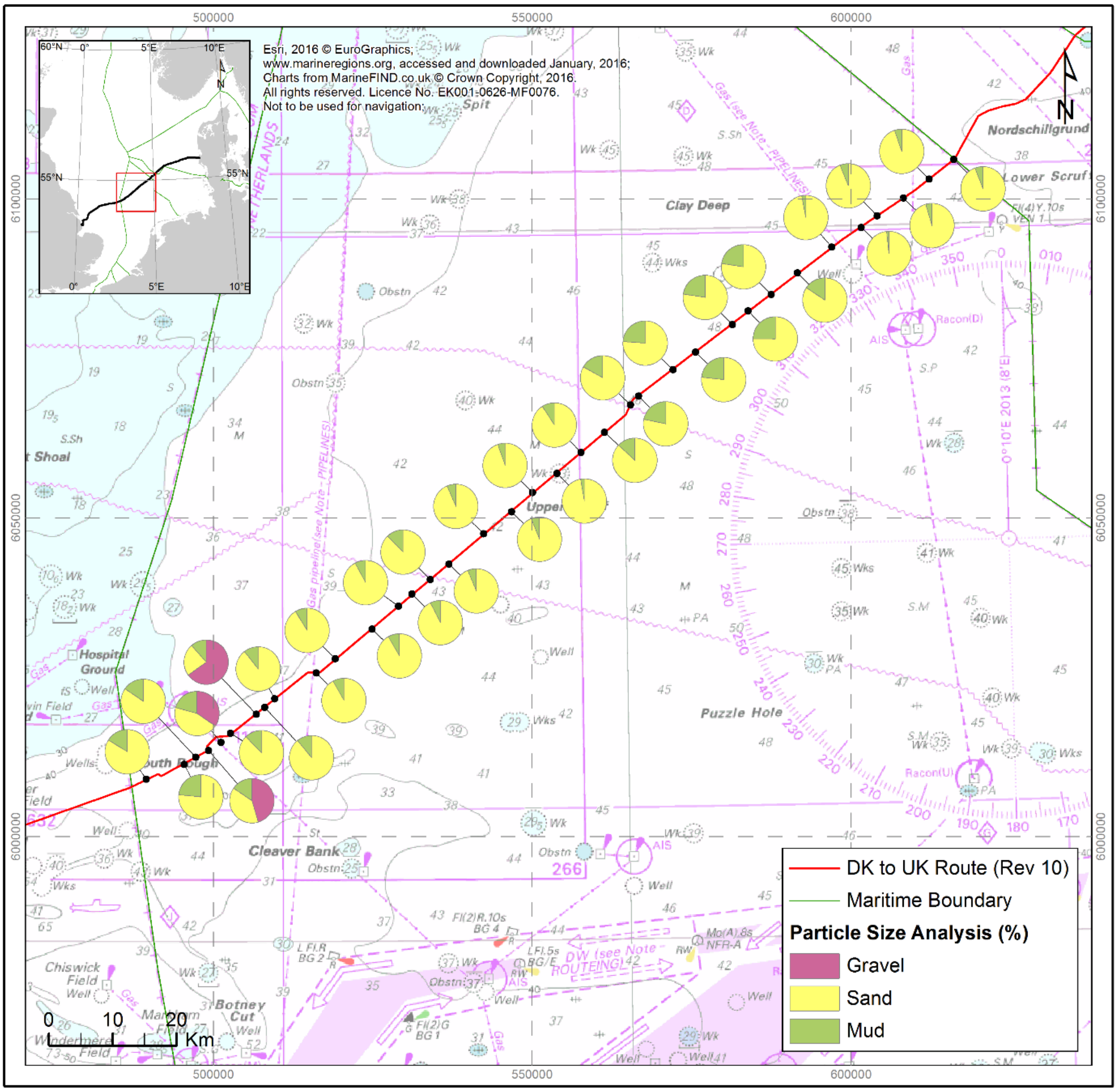


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Figure 5.6: Spatial distribution of sediments using Folk (1954) classifications along the cable route within the Dutch sector (from PSD Analysis)

5.4.2 Sediment Chemistry

Within the Dutch sector, all the metal concentrations were all below the Cefas AL1 values and OSPAR ERL values and all total hydrocarbon concentrations were below the Cefas AL1 values; therefore, are considered to be of little concern with respect to possible effects on the marine environment. In addition, the total hydrocarbons are lower than the typical range for offshore North Sea surface sediments (Sheahan et al., 2001).

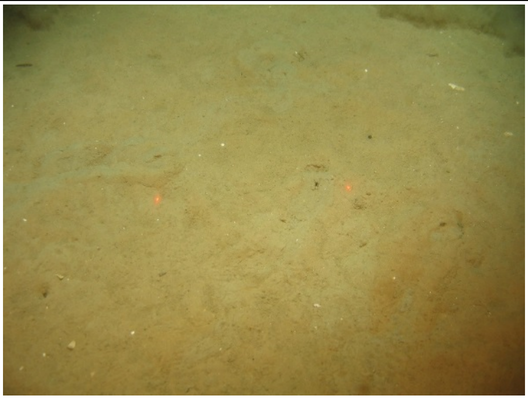
CPI values indicate a slight dominance of biogenic alkanes, with the presence some n-alkanes typically related to petrogenic inputs (McDougall, 2000; Russell et al., 2005). Pr:Ph ratios are high indicating that the sediments are not likely to be contaminated. This finding is supported by only slight evidence of UCM humps on the gas chromatograms (Brassell and Eglinton, 1980; McDougall, 2000).

5.4.3 Macrobenthic Communities

The video analysis found three main habitat types within the Dutch sector, these are presented within Table 5.5. Observed epifauna from the video footage was generally sparse throughout the Dutch sector. Two species of starfish (sand star *Astropecten irregularis* and common starfish *Asterias rubens)*, and hermit crab Paguridae, were the most commonly observed epifauna and were encountered throughout all the observed seabed habitats. The masked crab *Corystes cassivelanus*, sea potato *Echinocardium cordatum*, and brittlestars Ophiuridae were also observed.

Areas of coarser sediments were found with a greater diversity and abundance of epifauna species, which included dead man's fingers, *Alcyonium digitatum*, brittlestars, *Ophiothrix fragilis*, Dahlia anemone, *Urticina felina* and hydroid/bryozoan turf.

Table 5.5: Examples of the Main Habitats Encountered Along the Cable Route within the Dutch sector

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
7FTR46	Silty sand with shell fragments and occasional burrows *Echinocardium cordatum* tests present	*Echinocardium cordatum* Polychaete tubes Hydroid/bryozoan turf *Corystes cassivelaunus* Paguridae *Hydractinia echinata* *Asterias rubens* *Astropecten irregularis* Pleuronectiformes	
8PTR08	Silty sand with burrows. *Echinocardium cordatum* tests present	Polychaete tubes *Astropecten irregularis* Gadidae *Liocarcinus* sp. *Pagurus bernhardus* *Merlangius merlangus* *Luidia sarsi* *Asterias rubens* Ophiuridae	

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
10PTR09	Gravelly sandy silt/silty sand with pebbles and small cobbles	*Urticina felina* Ascidiacea *Ophiothrix fragilis* Hydroid/bryozoan turf *Alyconium digitatum* *Pagurus bernhardus* *Asterias rubens* Gastropod eggs *Spirobranchus* sp. *Cancer pagurus*	

The enumerated fauna from the grab samples comprised 172 taxa, represented by 3 542 individuals.

Annelida were dominant in terms of taxa composition, accounting for 46 % of the infaunal diversity. Crustacea followed (24 %), then Mollusca (18 %), then Echinodermata (8 %) and finally other taxa (3 %). The taxa grouped into the ‘other’ category were Sipuncula, Cephalorhyncha, Nermertea, Platyhelminthes, Cnidaria and Foraminifera.

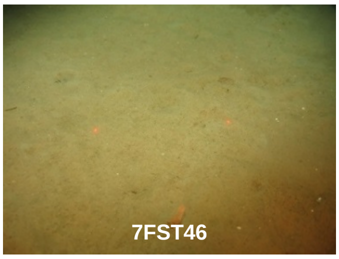
In terms of abundance, Echinodermata were dominant, accounting for 45 % of the infaunal abundance. This was accounted for by one brittlestar species, *Amphiura filiformis*, with a recorded abundance of 1,398 individuals within the Dutch sector stations. Annelida followed with 24 % of the total taxa abundance, Mollusca with 22 %, then Crustacea (8 %) and other taxa (2 %).

Combined with the video analysis, which identified epifaunal communities and seabed conditions not sampled by the singular grab along a transect, three EUNIS biotopes were identified for the Dutch sector. These biotopes were ‘*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud’ (A5.351), ‘Circalittoral sandy mud’ (A5.26) and ‘circalittoral mixed sediment’ (A5.44). The three patches of coarser material identified from video analysis were designated ‘circalittoral mixed sediment’.

‘*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud’ (A5.351) was the most common biotope observed across the Dutch sector, followed by ‘circalittoral sandy mud’. Table 5.6 presents the biotopes recorded, with Figure 5.7 presenting the distribution of the biotopes recorded from within the Dutch sector.

Many of the most abundant species observed during the current survey are common species throughout the North Sea. *Spiophanes bombyx*, *Pholoe* sp., *Amphiura filiformis* and *Goniada maculata* are species with the highest occurrence within the North Sea as a whole (Heip & Craemeersch, 1995).

Table 5.6: Biotopes Recorded from the Survey Along the Cable Route within the Dutch sector

EUNIS (2016) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.351 *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	7FST46, 7FST47, 7FST48, 7FST49, 8PST01, 8PST03, 8PST04, 8PST05, 8PST06. 8PST07, 8PST08, 8PST09, 9PST01, 9PST02, 9PST03, 9PST04, 9PST08, 10PST01, 10PST03, 10PST04, 10PST05, 10PST06, 10PST07, 10PST08, 10PST09, 10PST10, 10PST11, 10PST12	g, f, d, e, a†	
A5.26 Circalittoral muddy sand	8PST02, 8PST04, 9PST05, 9PST06, 9PST07, 9PST09, 9PST10, 9PST11, 10PST02	b	
A5.44 Circalittoral mixed sediment	Part of 10PTR06, Part of 10PTR08, Parts of 10PST09	*	

Notes:
= Faunal group derived from multivariate analysis (PRIMER)
† = In addition to partial video transects
* = Not included in grab analysis, partial video transects only

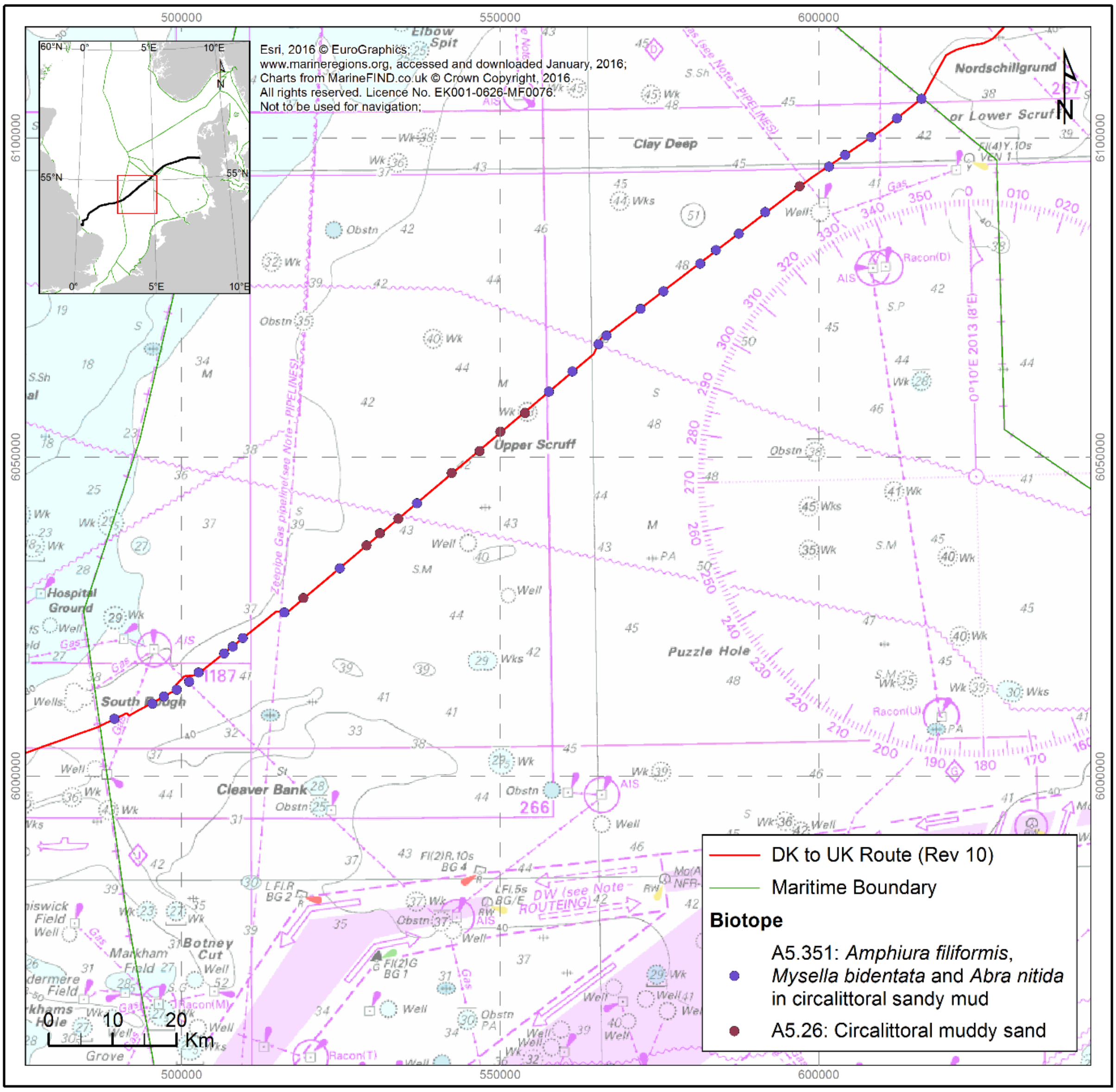


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Figure 5.7: Distribution of biotopes along the cable route within the Dutch sector (from grab samples)

5.4.4 Species and Habitats of Conservation Interest

An area known as the Central Oyster Grounds is present within the Dutch sector. Although the area is not formally protected, it has been identified as an area of high biodiversity and biomass. This area is known not to sustain native oyster populations but does support populations of the OSPAR protected ocean quahog. Only one juvenile ocean quahog was identified from a grab sample. Ocean quahog are listed as declining by OSPAR. During the current study, species diversity and biomass recorded from the grab samples within the Central Oyster Grounds were found to be generally comparable to the stations outside of this area.

Three patches of coarse material were investigated as possible, Annex I habitat Cobble reef. Due to the absence of medium to high concentrations of cobbles and boulders, all three patches were designated 'Not Reef'.

Three species of fish (plaice, solenette and whiting) and one species of shellfish (Norway lobster) recorded in the current survey are on the IUCN red list for threatened species. All four of these species are listed as species of 'least concern'.

5.4.5 Water Profiles

Water quality profiles were similar throughout the Dutch sector survey area. A medium to weak stratification of the water column was observed at the majority of stations, with warmer, more oxygen saturated and often more saline waters at the surface. The depth to which stratification was observed varied with total water depth recorded at each station but occurred between approximately 10 m to 34 m.

The stratified water column is typical of the water column conditions observed during the summer months in the deeper areas of the Dutch North Sea (Noordzeeloket, 2012).

5.5 UK Sector

5.5.1 Seabed Sediment Conditions

Results of grab samples analysis showed that the survey area within the UK sector comprised a mixed range of sediment types from well sorted sands to very poorly sorted muddy sandy gravel. A broad pattern of sediment distribution was identified, with more heterogeneous sediments characterising nearshore stations whereas offshore stations comprised predominantly muddy sand.

The spatial distribution of the particle size distribution (PSD) analysis results are presented within Figure 5.8.

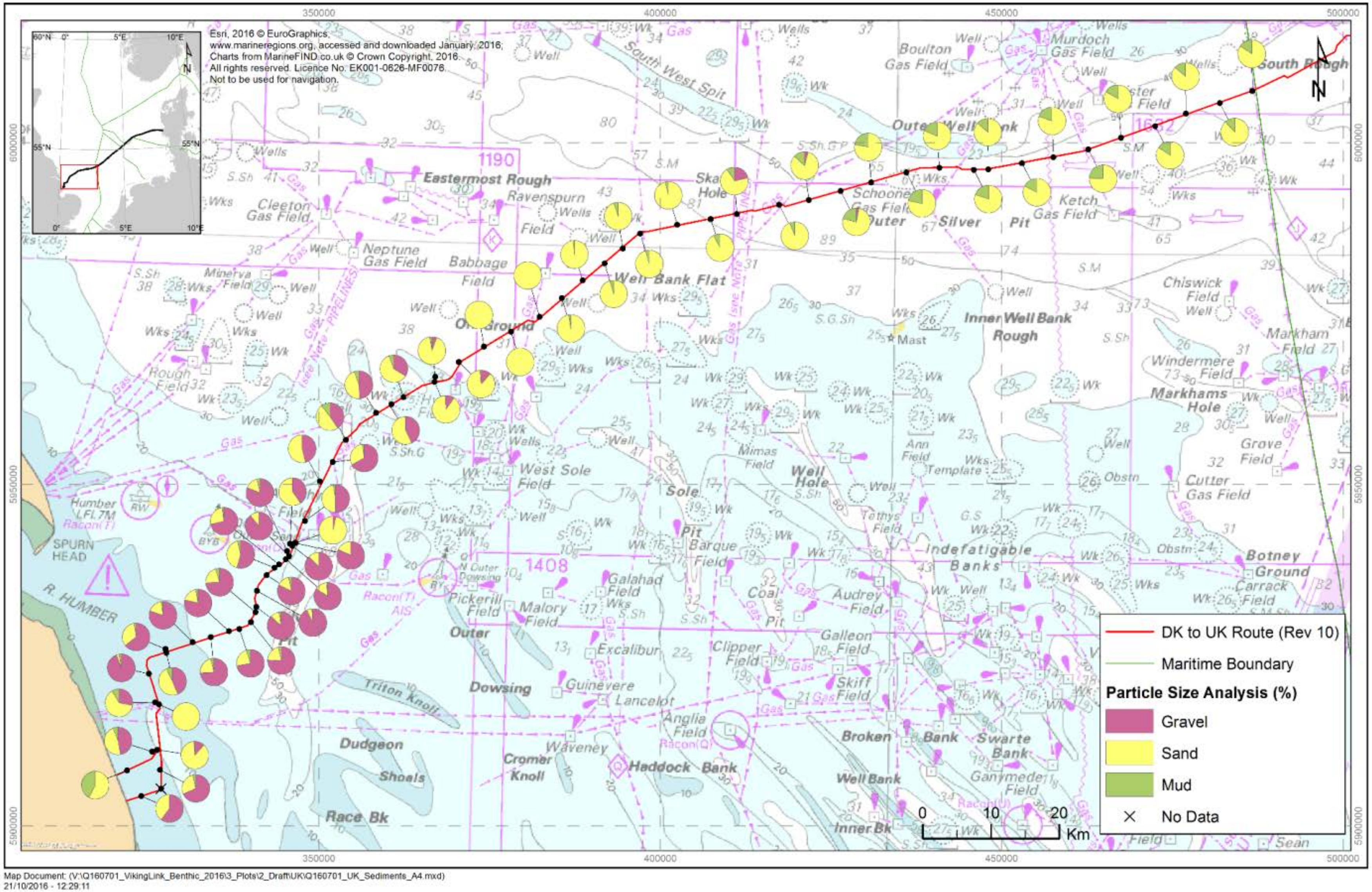


Figure 5.8: Spatial distribution of sediments using Folk (1954) classifications along the cable route within the UK sector (from PSD analysis)

5.5.2 Sediment Chemistry

Within the UK sector, all metal concentrations except copper and arsenic were below the Cefas (Centre for Environment, Fisheries and Aquaculture Science) (2003) Action Level 1 (AL1) and Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Effects Range Low (ERL) values. Copper exceeded the Cefas AL1 and OSPAR ERL value at one station (15DST06) close to the UK coast. Concentrations of arsenic were above the Cefas AL1 value of 20 $\mu g g^{-1}$ at Station 15DST08.

All total hydrocarbon concentrations within the UK sector were below the Cefas AL1 values and, therefore, are considered to be of little concern with respect to possible effects on the marine environment. In addition, the total hydrocarbons are low relative to the typical range for offshore North Sea surface sediments (Sheahan et al., 2001).

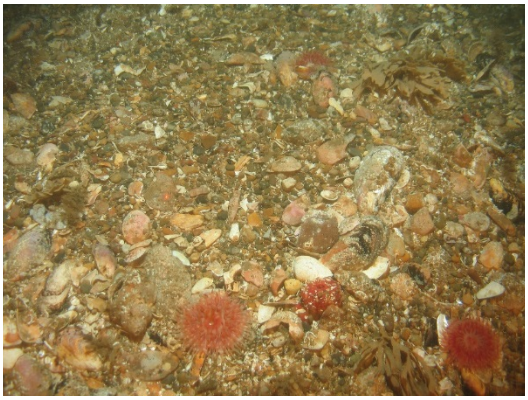
The UK carbon preference index (CPI) values indicate a dominance of biogenic alkanes, with the presence some n-alkanes typically related to petrogenic inputs (McDougall, 2000; Russell et al., 2005). The UK pristane phytane ratios (Pr:Ph) are high indicating that the sediments are not likely to be contaminated, however, the ratios do decrease closer to the UK coast (McDougall, 2000). This finding is supported by the more pronounced nature of unresolved complex mixture (UCM) humps towards the UK coastline, indicating contamination of the sediment (Brassell and Eglinton, 1980; McDougall, 2000).

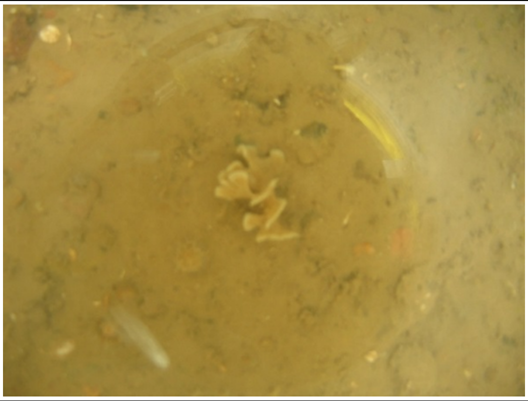
5.5.3 Macrobenthic Communities

Analysis of the video footage showed the presence of two major habitats within the UK sector survey area, one featuring predominantly sandy sediments, characteristic of the offshore stations, and one featuring highly heterogeneous seabed sediment, comprising a mix of coarse sand and gravel, including pebbles, cobbles and boulders, and characteristic of the nearshore stations. The epibiotic communities reflected the sediment complexity, with the offshore sandier sediments hosting lower faunal diversity represented mainly by fish, echinoderms, crustaceans and molluscs, with sessile epifauna being absent or scarce. The nearshore coarser sediments comprised a rich and diverse epibenthic community which included a variety of sessile epifauna. The main habitats recorded from video analysis are presented within Table 5.7.

The epibiotic communities recorded by the seabed video footage were broadly comparable to those reported for the shallower sediment areas of the southern North Sea (Callaway et al., 2002 and Jennings et al., 1999). Characteristic epibenthic species included crustaceans, such as *Pisidia longicornis* and species of *Macropodia* and *Liocarcinus*, together with molluscs, such as *Crepidula fornicata*, *Gibbula* and *Calliostoma ziziphynum*. Other notable motile species included echinoderms such as *Asterias rubens* and *Crassoster papposus*. Sessile colonial epifauna comprised bryozoans, notably, *Flustra. foliacea* which occurred densely at selected stations, and *Alcyionium*, together with cnidarians of the *Hydrallmania* and *Nemertesia* genera.

Table 5.7: Examples of the Main Habitats Encountered Along the Cable Route within the UK sector

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
11PTR01	Rippled silty sand with burrows.	Polychaete tubes Decapoda *Astropecten irregularis* Pisces	
13FTR09	Rippled shelly coarse sand with a small proportion of gravel. *Echinocardium cordatum* tests present.	*Lanice conchilega* Ammodytidae *Asterias rubens* *Ophiura albida* Gobiidae Pleuronectiformes *Callionymus* sp. *Echiichthys vipera* Hydroid/bryozoan turf	
14FTR15	Mixed coarse sediments. Sandy Shelly gravel with pebbles and occasional cobbles and small boulders. High proportion of empty Mytilidae shells present.	*Urticina* sp. Cirripedia *Spirobranchus* sp. Bryozoan crusts Corallinaceae Hydroid/bryozoan turf *Urticina felina* *Alcyonium digitatum* *Hydrallmania falcata* *Crepidula fornicata* *Chaetopterus variopedatus* Actiniaria *Flustra foliacea* *Abietinaria abietina* *Calliostoma zizyphinum* *Crossaster papposus* *Liocarcinus* sp.	
14FTR18	Sandy gravel and pebbles with occasional cobbles and boulders. Empty Mytilidae shells present.	*Spirobranchus* sp. Bryozoan crusts Hydroid/bryozoan turf Cirripedia *Calliostoma zizyphinum* Paguridae *Urticina felina* *Crossaster papposus* *Echinus esculentus* *Flustra foliacea* *Macropodia* sp. Gobiidae *Necora puber*	

Station	Sediment Description	Conspicuous Species	Representative Underwater Photograph
14FTR23	Mixed coarse sediment. Sandy gravel and pebbles. Occasional cobbles and boulders.	*Flustra foliacea* *Sabella* sp. Caridea *Sabellaria spinulosa* (crusts) Paguridae Hydroid / bryozoan meadow Actiniaria *Spirobranchus* sp. *Crepidula fornicata* *Dendrodoa grossularia* *Polycarpa sp.* *Crossaster papposus* *Urticina felina* *Necora puber* *Pagurus bernhardus* Cirripedia *Henricia* sp. Polyplacophora Ascidiacea *Ebalia* sp. *Gibbula* sp. Galatheidae *Botrylloides leachi* Corallinaceae *Agonus cataphractus* Porifera *Cancer pagurus* *Liocarcinus* sp. *Calliostoma zizyphinum* *Maja brachydactyla* *Dysidea fragilis* *Hydrallmania falcata* *Echinus esculentus* Hydroid/bryozoan turf Plumariidae *Asterias rubens*	
15DTR09	Silt/clay with sand and occasional cobble and gravel.	Actiniaria *Flustra foliacea* Hydroid/bryozoan turf *Spirobranchus* sp. Hydroid/bryozoan meadow	

Results of the biological analyses indicated the presence of fairly rich and diverse invertebrate benthic communities, the occurrence and distribution of which was associated with the sediment type, as indicated by the results of the correlation analyses (BIOENV).

The enumerated benthic fauna from grab samples comprised a total of 382 taxa, represented by 35,483 individuals. These included 12 taxa of solitary epifauna comprising 11,907 individuals.

Annelida were dominant in terms of taxa composition, accounting for 41 % of the infaunal diversity; they were followed by Crustacea (25 %) and Mollusca (22 %).

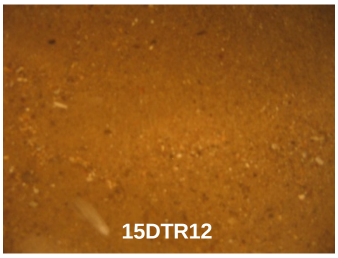
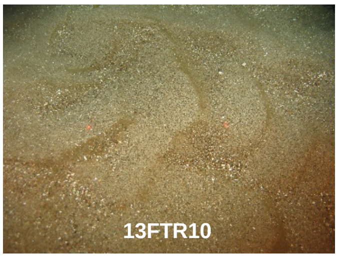
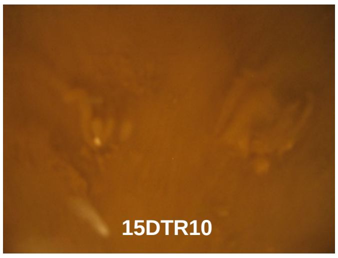
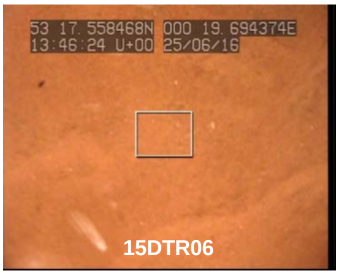
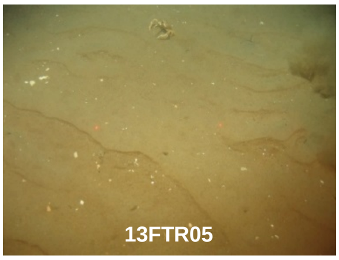
The annelids were dominant also in terms of abundance (36 %), followed by the crustaceans (28 %) and other taxa (15 %). Mollusca comprised 11 % of the infaunal abundance and Echinodermata 9 %.

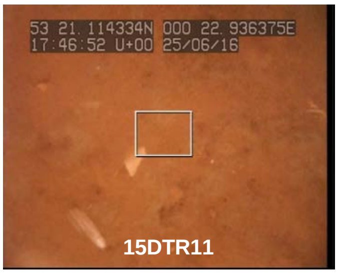
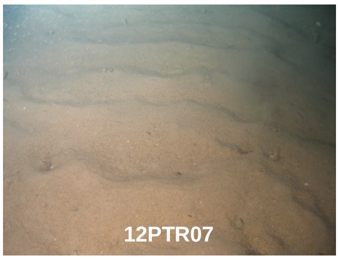
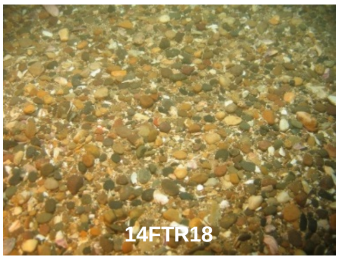
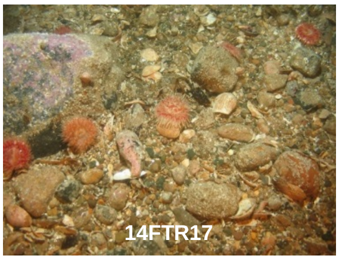
Combined with the video analysis, which identified epifaunal communities and seabed conditions not sampled by the singular grab along a transect, 12 European Nature Information System (EUNIS) biotopes (EEA, 2016) and Joint Nature Conservation Committee (JNCC) biotopes (Connor et al, 2004) were identified for the UK sector. Table 5.8, with Figure 5.9 presenting the distribution of the biotopes recorded from the grab samples collected within the UK sector.

The epibiotic communities reflected the sediment complexity, with the offshore sandier sediments hosting lower faunal diversity represented mainly by fish, echinoderms, crustaceans and molluscs, with sessile epifauna being absent or scarce.

The nearshore coarser sediments comprised a rich and diverse epibenthic community, which included a variety of sessile epifauna.

Table 5.8: Biotopes Recorded from the Survey Along the Cable Route within the UK sector

EUNIS (2016) / JNCC (2015) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.1 / SS.SCS Sublittoral coarse sediment	15DTR12	*	
A5.133 / SS.SCS.ICS.MoeVen *Moerella* spp. with venerid bivalves in infralittoral gravelly sand	13FST10, 13FST15, 14PST02_RR, 14PST03_RR, 15DST03	B2	
A5.133 / SS.SCS.ICS.MoeVen *Moerella* spp. with venerid bivalves in infralittoral gravelly sand ***with*** A5.444 / SS.SMX.CMx.FluHyd *Flustra foliacea* and *Hydrallmania falcata* on tide swept circalittoral mixed sediment	15DST10	B2†	
A5.2 / SS.SSa Sublittoral sands	15DTR04, 15DTR07	*	
A5.24 / SS.SSa.IMuSa Infralittoral muddy sand	15DST06	A	
A5.242 / SS.SSa.IMuSa.FfabMag *Fabulina fabula and Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand	12PST09, 12PST10, 13FST01, 13FST02, 13FST03, 13FST04, 13FST05, 13FST06, 13FST07, 13FST08, 13FST09	A1	

EUNIS (2016) / JNCC (2015) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.3 / SS.SMu Sublittoral mud	15DTR11	*	
A5.351 / SS.SMu.CSaMu.AfilMysAnit *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	11PST01, 11PST02, 11PST03, 11PST04, 11PST05, 11PST06, 11PST07, 11PST08, 11PST09, 12PST01, 12PST02, 12PST03, 12PST04, 12PST05, 12PST06, 12PST07, 12PST08	A2	
A5.44 / SS.SMx.CMx Circalittoral mixed sediment	Part of 14FTR18	*	
A5.44 / SS.SMx.CMx Circalittoral mixed sediment ***with*** A5.444 / SS.SMX.CMx.FluHyd *Flustra foliacea* and *Hydrallmania falcata* on tide swept circalittoral mixed sediment	Part of 14FTR16, Part of 14FTR17	*	
A5.444 / SS.SMX.CMx.FluHyd *Flustra foliacea* and *Hydrallmania falcata* on tide swept circalittoral mixed sediment	Part of 13FTR11, Part of 14FTR22, 15DTR01	*	
A5.445 / SS.SMx.CMx.OphMx *Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediments	14PTR44	*	

EUNIS (2016) / JNCC (2015) Biotope	Stations	Faunal Group#	Representative Underwater Photograph
A5.611 / SS.SBR.PoR.SspiMx *Sabellaria spinulosa* on stable circalittoral mixed sediment	14PST04_RR, 14FST23A	B1	
A5.611 / SS.SBR.PoR.SspiMx *Sabellaria spinulosa* on stable circalittoral mixed sediment ***with*** A5.444 / SS.SMX.CMx.FluHyd *Flustra foliacea* and *Hydrallmania falcata* on tide swept circalittoral mixed sediment	13FST11, 13FST12, 13FST13, 14PST14, 14PST15, 14PST16, 14PST17, 14PST18, 14PST19, 14PST22, 14PST23, 14PST24, 14PST25, 14PST26, 14PST27, 14PST28, 14PST29, 14PST30, 14PST31, 15DST02, 15DST05, 15DST08, 15DST09, 15MST13, 15MST15	B1†	
A5.62 / SS.SBR.SMus Sublittoral mussel beds on sediment	14PST20, 14PST21, 14PTR35, 14PTR36, 14PTR41, 14PTR42, 14PTR43	*	

Notes:
* = Not included in grab analysis, partial video transects only.
† = In addition to partial video transects
‡ = Individual sample faunal grouping
# = Faunal group derived from multivariate analysis (PRIMER)

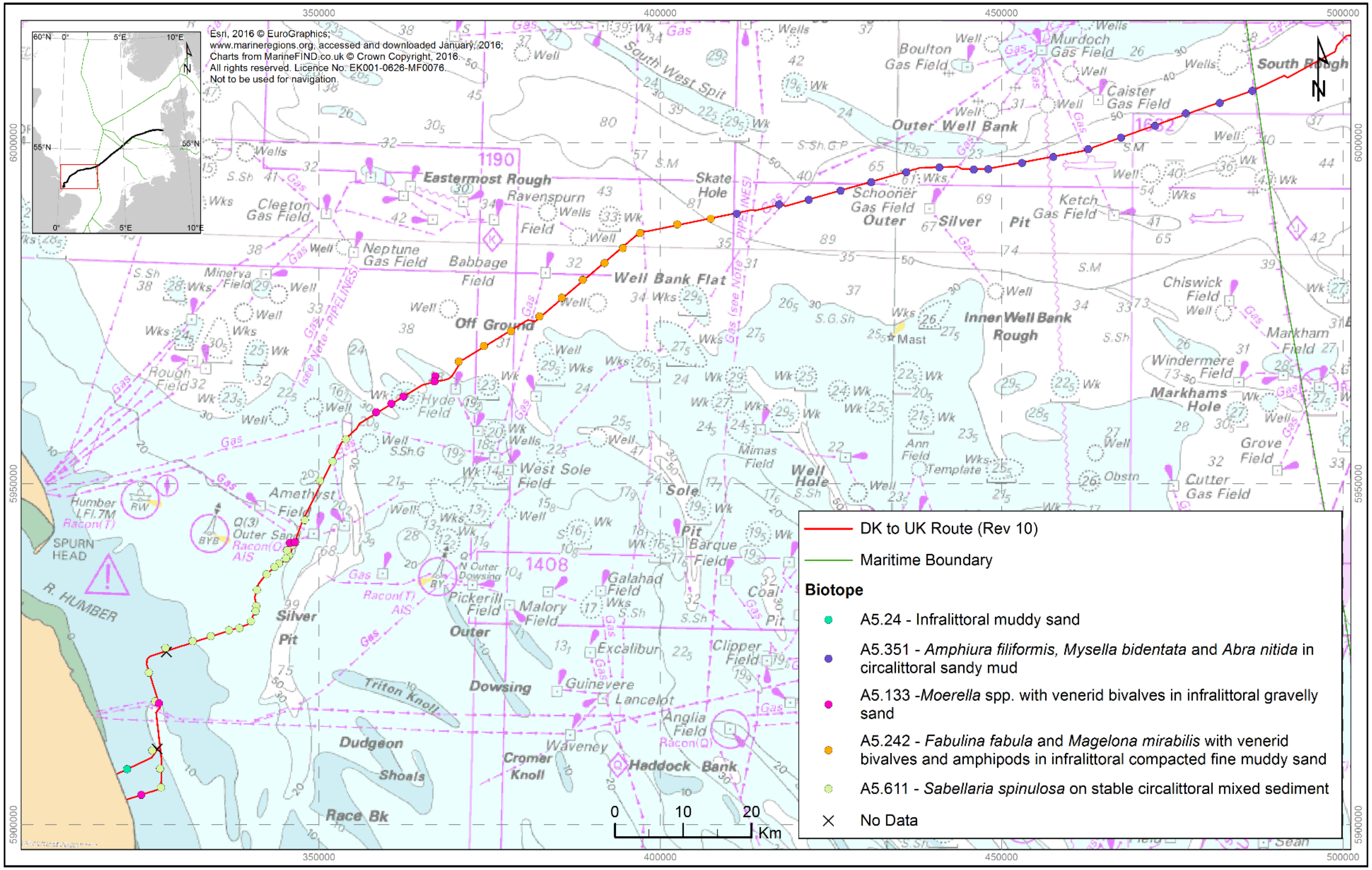


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Figure 5.9: Distribution of biotopes along the cable route within the UK sector (from grab samples)

5.5.4 Species and Habitats of Conservation Interest

A total of six stations were observed with high abundances of *Sabellaria spinulosa* recorded from the video footage analysis. Thin and thick crusts of *Sabellaria spinulosa* were recorded from these stations. The tubes were not upright, consolidated or intertwined. Therefore, all six stations have been classified as 'Not Reef'.

A total of 16 stations were analysed in order to ascertain the resemblance to stony reef. Five stations were classified as 'Not Reef', whilst a further 11 stations were classified as 'Low' resemblance to a stony reef. It should be noted that these elevations were at the lower end of the stony reef resemblance scales, as were the percentage cobbles and boulder composition.

Sublittoral mussel beds on (sublittoral) sediment (A5.62) is a new UK BAP Priority Habitat (Blue mussel beds on sediment). Sublittoral mussel beds are contained within the Annex I feature reefs (biogenic). An area of mussel bed was recorded within the UK sector (Alignment chart 125).

Four species of fish (plaice, sole, solenette and whiting) and one species of shellfish (Norway lobster) recorded in the current survey are on the IUCN red list for threatened species. All of these species are listed as species of 'least concern', with the exception of sole, which is considered 'data deficient'.

In addition, sand eels of the Ammodytidae family were recorded from the video footage at five stations. Lesser sandeel *Ammodytes marinus* are listed UK Biodiversity Action Plan (BAP) priority species (JNCC, 2016). However, it is not possible to distinguish sand eel species using just video footage.

5.5.5 Water Profiles

Results of the water column profiles indicated well mixed layers of water across the survey area, which are typical of the shallow parts of the southern North Sea, where seawater remains well mixed throughout the year owing to strong tidal action. Values of the variables measured showed mean values typical of the southern North Sea. Dissolved oxygen percentiles were near/or at saturation at the time of survey, with no indication of oxygen depletion.

6. CABLE GEOLOGICAL ZONATION

6.1 General

This section describes the cable geological zonation along the proposed Viking Link route. This zonation provides a high-level overview of the assemblages of geological formations which can be expected within specific KP ranges along the route. This cable geological zonation was updated from that presented in the earlier stages of the project (Fugro, 2016a), finalised through analysis of geophysical and geotechnical data.

The geological cable route zonation provides a summary of the geological formations and predicted geotechnical conditions along the route to a depth of 3 m below seabed (BSF). This was carried out by assessing sub-bottom profiler data and bathymetry data, in conjunction with knowledge of the regional geological framework (Section 3), and geotechnical data.

The cable geological zones provide rationale for the interpretation of geotechnical variation presented in Section 7, especially in areas where lateral variability of soil conditions, such as caused by glacial till, is expected to be extremely high.

Table 6.1 and Figure 6.1 summarise the updated cable geological zones and Sections 6.2 to 6.7 discuss each zone in more detail.

Table 6.1: Updated Cable Geological Zonation along the Viking Link Cable Route

Zone	Kilometre Post Range and Percentage	Identified Geological Formations	Generalised Soil Conditions	Key Considerations
A	(Danish landfall) 0 to 136.5 (22.1%) 199.7 to 266.35 (10.8%)	Holocene marine deposits (clay, silt and sand) overlying Elbow Formation Early Holocene Palaeochannels Undifferentiated pre-Holocene deposits (dense sand and high-strength clay)	Loose to very dense clayey SAND with Medium to high strength SILT/CLAY and Possible localised PEAT	▪ Largely comprising very loose granular material and weak clay overlying dense to very dense sand ▪ Highly variable soils (including extremely low to high strength clays, changes and inversions in density, organic material and coarse material) infilling palaeochannels ▪ Coarse material including boulders, cobble and gravel may be present at seabed ▪ Sediment mobility, the presence of scour and mobile bedforms ▪ Localised areas of sub-cropping high strength clays ▪ Localised areas of organic material (peat) below seafloor
B	136.5 to 199.7 (10.2%) 399.5 to 464 (10.4%)*	Holocene marine deposits (silt and sand) Palaeo-Elbe Estuary deposits (silt, sand and clay) Outer Silver Pit Estuary (?) deposits (silt, sand and clay)	Loose silty SAND/sandy SILT overlying Low strength organic-rich CLAY and Possible localised PEAT	▪ Localised areas of organic material (peat) below seafloor ▪ Sediment mobility, the presence of scour and mobile or relict bedforms
C	266.25 to 399.5 (21.6%)	Holocene marine deposits (silt and sand) Elbow Formation Early Holocene Palaeochannels Botney Cut Formation Bolders Bank Formation Dogger Bank Formation Cleaver Bank Formation	Loose to dense clayey gravelly SAND with Low to high strength sandy SILT/CLAY and Possible localised PEAT	▪ Variable thickness of Holocene materials ▪ High to extremely high strength clay and very dense sand associated with glacially derived sediments ▪ Highly variable soils (including extremely low to high strength clays, organic material and coarse material) infilling palaeochannels ▪ Coarse material including boulders, cobble and gravel may be present at seabed associated with and within clay units
D	393.0 to 394.5 (0.2%)‡ 398.0 to 399.5 (0.2%)‡ 403.0 to 404.0 (0.2%)‡ 464 to 486 (3.6%)	Holocene marine deposits (silt, sand and gravel) Early Holocene Palaeochannels Swarte Bank Formation Yarmouth Roads Formation	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY	▪ High to ultra-high strength clay (Swarte Bank Formation) and very dense silty gravelly sand or high strength clay (Yarmouth Roads Formation) ▪ Coarse material including boulders, cobble and gravel may be present at seabed and within clay units ▪ Sediment mobility, the presence of relict bedforms, locally high seabed gradients ▪ Highly variable soils (including extremely low to high strength clays, organic material and coarse material) infilling Holocene palaeochannels
E	486 to 549 (10.2%)	Holocene marine deposits (sand and gravel) Early Holocene Palaeochannels Bolders Bank Formation	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY and Possible localised PEAT	▪ Variable thickness in Holocene materials ▪ High to very-high strength clay and very dense sand ▪ Coarse material including boulders, cobble and gravel may be present at seafloor and within clay units ▪ High sediment mobility, the presence of mobile bedforms and possibility of scour ▪ Highly variable soils (including extremely low to high strength clays, changes and inversions in density, organic material and coarse material) infilling palaeochannels
F	549 to 618.735 (UK landfall) (11.3%)	Holocene marine deposits (sand and gravel) Elbow Formation Early Holocene Palaeochannels Bolders Bank Formation Egmond Ground Formation Upper Cretaceous Chalk	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY with BEDROCK (Chalk) and Possible localised PEAT	▪ Localised chalk bedrock of all CIRIA grades ▪ High to extremely high strength clay and very dense sand ▪ Coarse material including boulders, cobble and gravel present at seafloor and within clay units ▪ High sediment mobility, the presence of mobile bedforms and possibility of scour ▪ Highly variable soils (including extremely low to high strength clays, changes and inversions in density, organic material and coarse material) infilling palaeochannels

Notes
* Geological Zone B and Zone C contain very localised subcrops of Geological Zone D
† Not mapped but inferred to be present based on regional literature
‡ Localised subcrop of these sediments within Geological Zone B and Zone C
Palaeochannels are identified across the length of the cable route and contain a range of fill materials, strengths and densities. The presence of peat or other organic-rich sediments within channels is also possible

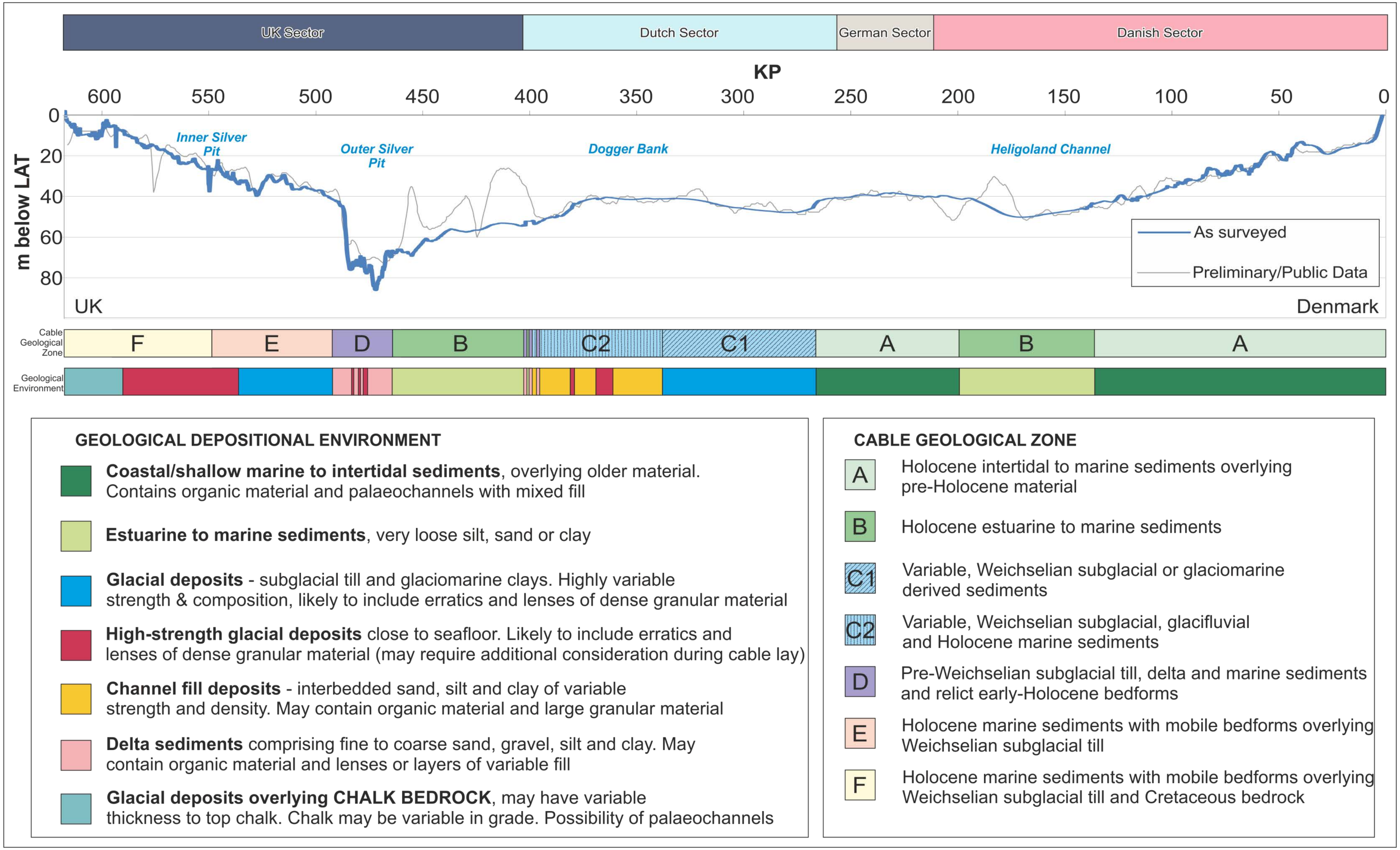


Figure 6.1: Cable Geological Zonation

6.2 Zone A – Intertidal to Marine Sediments

Zone A occurs between KP 0 and KP 136.500 and between KP 199.700 and KP 266.300. This zone is characterised by the sandy Holocene sediments associated with recent marine processes and older shallow marine to intertidal environments. These sediments are interpreted to overlie undifferentiated pre-Holocene deposits associated with wind-blown material and older marine environments.

The surficial sediments and intertidal to marine sediments are predominantly composed of fine to medium-grained sands with variable silt content. Medium beds of silt were sampled at various geotechnical locations. Shells and shell fragments are often noted in core logs, associated with both sandy and silty layers.

Peat was sampled and imaged locally in Zone A and exhibits a spongy, pseudo-fibrous texture. The peat also has an odour of hydrogen sulphide (H_2S). This was identified offshore in several geotechnical locations (e.g. B02-09-VC) and this suggests high organic matter content suggestive of anaerobic conditions similar to peat bogs onshore Denmark. The peat and associated clay layers, represent change from an intertidal environment to fully submerged marine conditions associated with the marine transgression.

A number of palaeochannels are present within Zone A. Geotechnical data from these channels describe variable sediments from extremely low to high strength clay and very loose to very dense fine to coarse sand. These channels were cut during periods of subaerial exposure during the late Pleistocene/early Holocene and are intrinsically linked to the estuarine environments, in Zone B outlined in Section 6.3.

In addition to bedforms (comprising coarse granular material) bathymetry data indicate seabed scour associated with cohesive, clay-rich material between approximately KP 37 and KP 102. Figure 6.2 shows a profile and bathymetry data example of some of these features. While most geotechnical data suggest that these features are covered with a layer of sandy or gravelly material, extremely low to high strength clay is identified in some vibrocore locations (notably B03-11-VC and B03-17-VC). This clay is interpreted by GEUS (2016) to represent planar deposits of Weichselian outwash material and subcropping tills and diamicton of Saalian age with varying degrees of weathering.

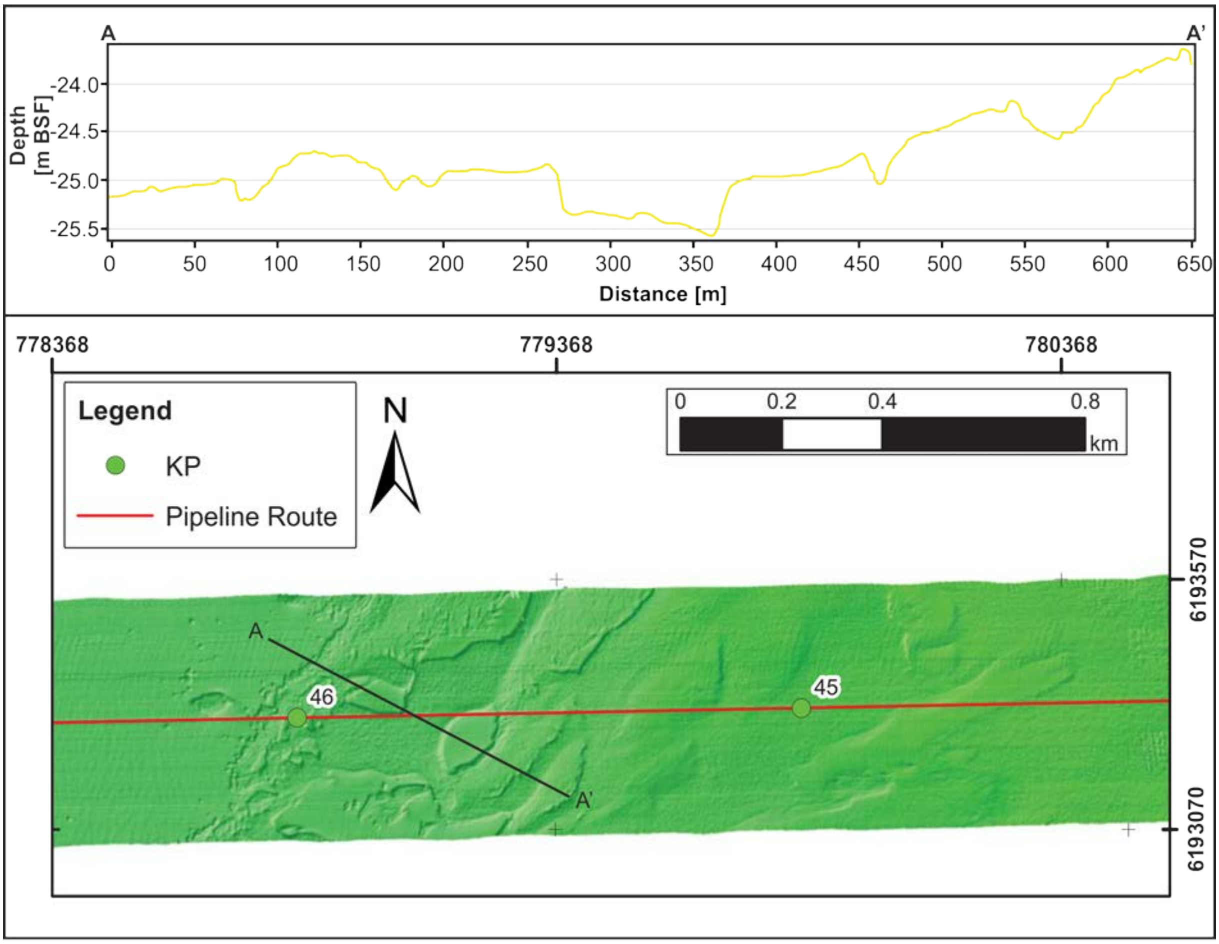


Figure 6.2: Example of erosional features from Zone A. Top: Bathymetry profile. Bottom: Colour shaded bathymetry

Towards the western limits of Zone A between KP 199 and KP 266, SBP data display inclined reflectors which are interpreted to represent the migration of palaeochannels on the margins of the Palaeo-Elbe estuary (Section 6.3). Geotechnical data from these sections suggest little change from the silty or sandy material elsewhere in Zone B. SBP data suggest that this material was deposited overlying the Dogger Bank Formation (a geological formation which is interpreted to be prevalent in Zone C). Figure 6.3 shows a SBP example of sandy sediments and peat. Therefore, although the Palaeo-Elbe and associated distributaries have migrated over time, based on the sampled geotechnical data, soil conditions can be considered homogenous.

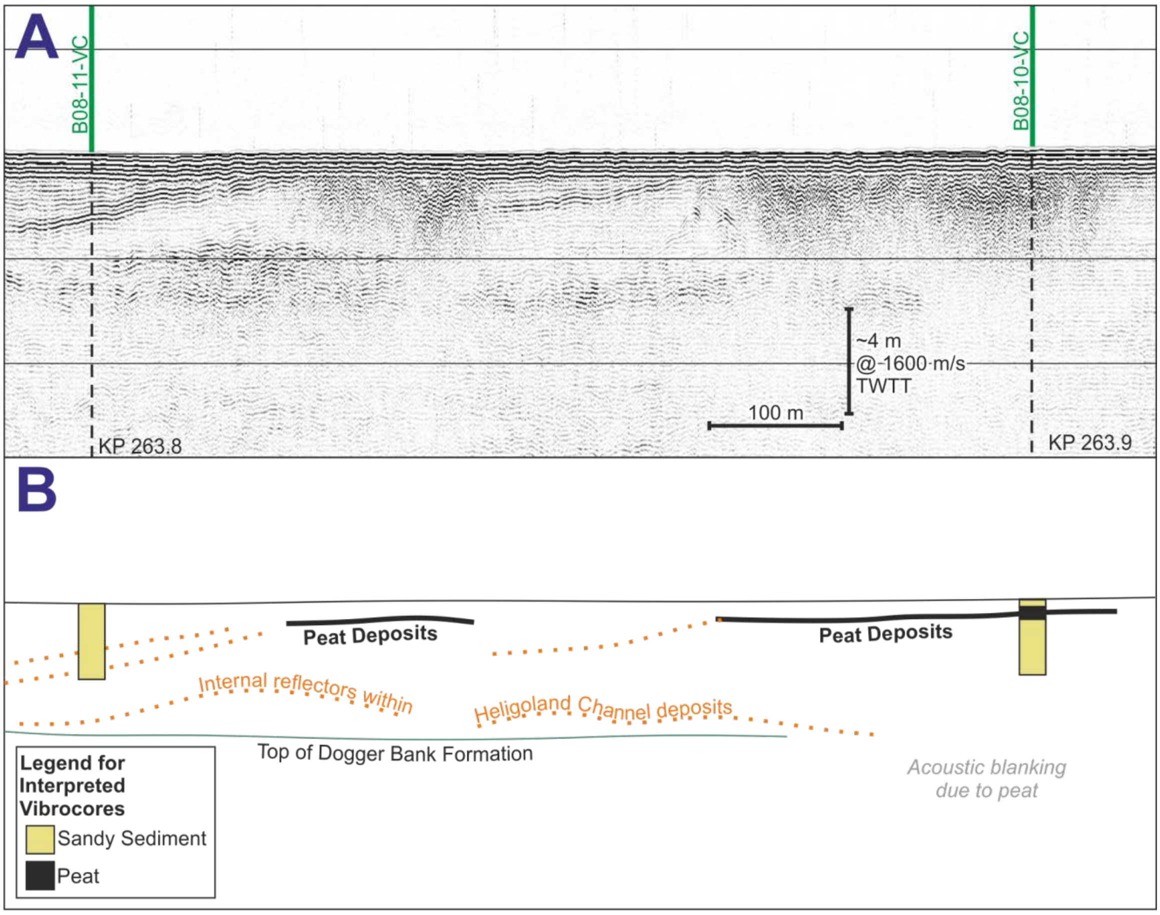


Figure 6.3: Peat in vibrocores (A: SBP data; B: schematic interpreted SBP)

6.3 Zone B – Estuarine to Marine Sediments

From KP 136.500 to KP 199.700 and KP 399.500 to KP 464 the route's lithology is characterised by silt or fine to medium sand overlying extremely low strength clay. These sediments are interpreted to have been deposited in an estuarine environment at the mouth of the palaeo-Elbe river and around the north-eastern margins of the Outer Silver Pit during the late Pleistocene and early Holocene. SBP data for these sections exhibit a well-bedded channel fill unit between KP 136.500 and KP 199.700. Geotechnical data suggest a silt-rich fill with high quantities of organic matter and layers of extremely low strength clay. Acoustic blanking is present between KP 143 and KP 198, suggesting the presence of biogenic gas (Figure 6.4).

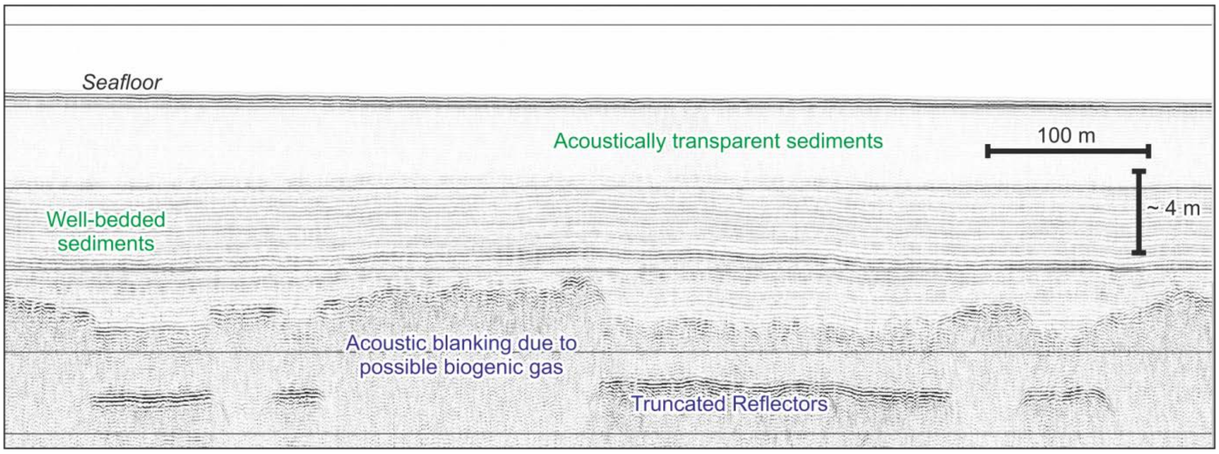


Figure 6.4: SBP data example showing expression of shallow gas

6.4 Zone C – Variable Glacially Derived Sediments

Zone C covers a variable region of seabed between KP 266.300 and KP 399.500 where a broad range of sediments are interpreted to be present from geophysical and geotechnical data. Beneath a thin veneer of sandy sediment, palaeochannels are filled with variable material from the end of the LGM, and high-strength clay deposits from previous glacial periods also exist. Due to the variability in Zone C it is divided into two subzones as described in Sections 6.4.1 and 6.4.2.

6.4.1 Subzone Zone C1

Between KP 266.300 and KP 338 the geology in the uppermost 3 m is characterised by a thin layer of Holocene material (including peat) overlying glacial deposits comprising medium to high strength silty clay (Figure 6.5). At some geotechnical locations laminae of clayey silt were identified. It is interpreted that these sediments are the Dogger Bank Formation, glaciomarine sediments deposited during the Weichselian glacial period. Geotechnical test results indicate undrained shear strengths of approximately 80 kPa to 120 kPa which are typical for samples in this region.

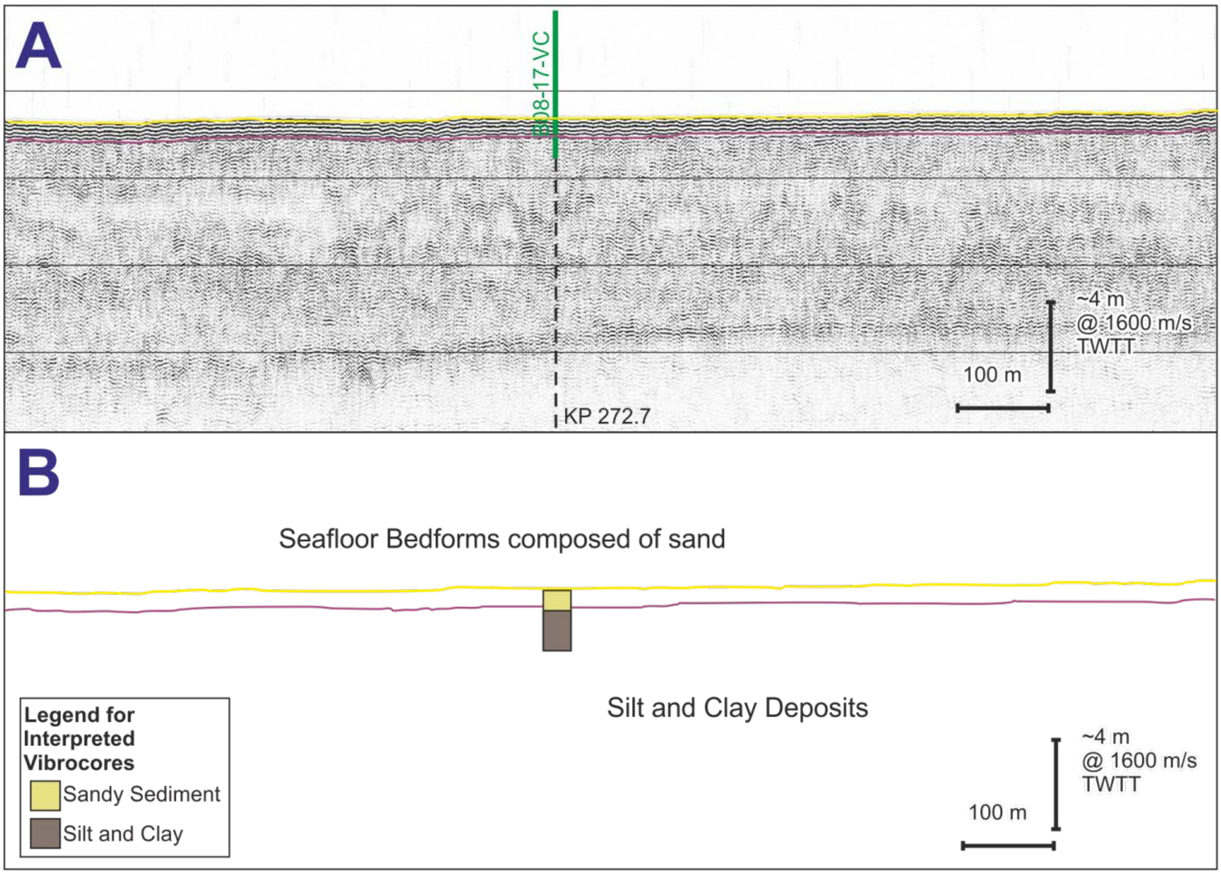


Figure 6.5: SBP data example showing the acoustic character of the Dogger Bank Formation (A: SBP data, B: schematic interpreted SBP)

6.4.2 Subzone Zone C2

The remainder of Zone C, between KP 338 and KP 399.500, is characterised as Subzone C2 which comprises extensive palaeochannels, up to 8 km wide, and contain variable fill materials to variable depths of incision. These are interpreted to have been originally incised at the end of the LGM when ice retreated and was subsequently filled with Botney Cut Formation and more recent sediment. Geotechnical data suggest that the channels are often covered by Holocene marine sediments up to 3 m thick which also contain low strength clay. Due to the environment of deposition of these channel fills, it is possible that fill sediments may contain organic matter such as peat. Figure 6.6 shows a SBP data example from one of the Botney Cut Formation channels.

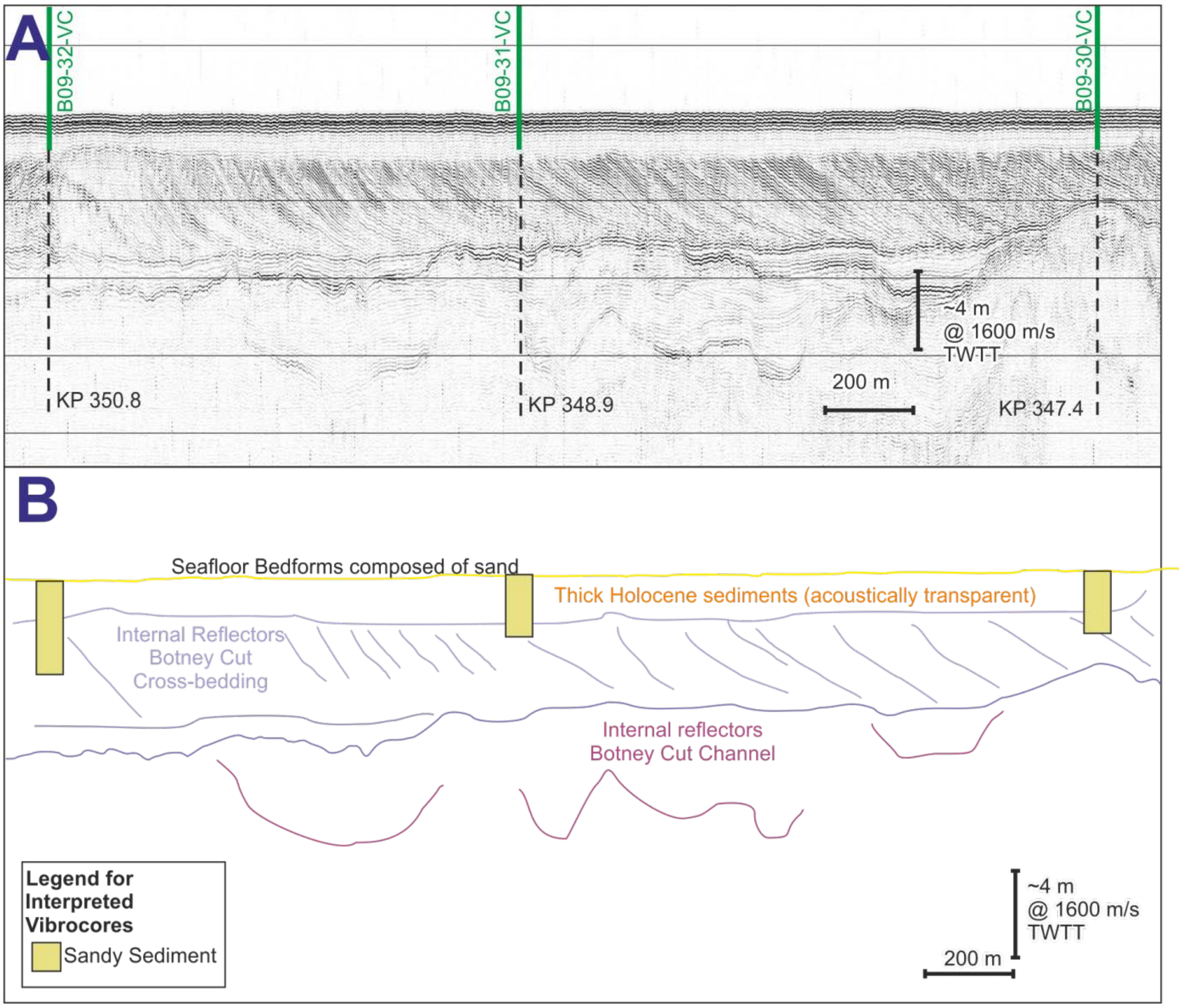


Figure 6.6: SBP data example of area of Botney Cut Formation with thick layer of sandy Holocene sediments (A: SBP data, B: schematic interpreted SBP)

Sub- to outcrops of Bolders Bank Formation and Dogger Bank Formation are present in Zone C. These areas are characterised by extremely high strength gravel-rich clays and are interpreted to have been resistant to erosion, potentially due to subtle differences in subglacial depositional history. Locations where glacial till is present at or close to seabed are a potential constraint to installation of the cable and are discussed in greater detail in Section 7.

Interpretation of profiler data in this section highlights an area of glacially-derived clay close to seabed that is potentially highly variable. It is possible that this area was an area of interfingering between the Dogger Bank Formation and Bolders Bank Formation units. Geotechnical samples suggest differences in clay origin between grey and olive grey clays often associated with the Dogger Bank Formation and the brown and reddish brown of the Bolders Bank Formation.

Two areas of early to middle Pleistocene Yarmouth Roads Formation is present in this zone within the depth of interest (Table 6.2).

6.5 Zone D – Exposed Pre-Weichselian Material

The majority of Zone D is located between KP 464 and KP 485.700, comprising an area where Holocene silty gravelly sand of variable thickness overlie high to ultra-high strength clays and medium dense to very dense sands.

The Outer Silver Pit is a bathymetric depression south of the Dogger Bank, which incises older, underlying geological formations. The depression is incised to a depth of approximately 85 m below LAT. It is interpreted that meltwater channels at the end of the LGM scoured this hollow following the approximate direction of Elsterian tunnel valleys, with tidal action maintaining the hollow following inundation. This erosion has left the base of Elsterian tunnel-valley Swarte Bank Formation and Cromerian delta plain sediments of the Yarmouth Roads Formation at seafloor or very close to exposure beneath a veneer of Holocene sediments.

In addition to the main area of Zone D, the dense to very dense sand of the Yarmouth Roads Formation is also locally present in small areas of subcrop. Table 6.2 summarises the extent of these isolated outlying areas. These subcrops, beneath a layer of Holocene sediment, account for less than 0.7% (4.4 km) of the total length of the cable route.

Table 6.2 Outlying occurrences of Zone D

KP Range	Within Zone	Geotechnical Locations
393.0 - 394.5	C	B10-25-CPT/VC
398.0 - 399.5	C	B10-27-CPT/VC, B10-28-CPT/VC
403.0 - 404.4	B	B11-01-CPT/VC

The bottom of the Outer Silver Pit is incised by more recent (early Holocene) channels. Large features interpreted to be relict bedforms of the Sand Hills Group are also present. These bedforms are discussed in more detail in Section 9.

6.6 Zone E – Subglacial Till

Zone E is located between KP 485.700 and KP 549 and is predominantly characterised by the presence of the Bolders Bank Formation. This medium strength to extremely high strength clay is covered by a layer of sand and gravel of variable thickness (typically less than 1 m). In places the Bolders Bank Formation is incised or removed entirely by Palaeochannels. These channels contain a variable mixed fill. Boulders may be present at or below the seabed or within Zone E eroded from the Bolders Bank Formation.

Seabed sediments are interpreted to be mobile across this zone. Bedforms range in size from small to medium (according to the Ashley (1990) classification scheme); less than 0.5 m high with a wavelength of 10 m to 15 m. Figure 6.7 shows a bathymetry data example of slightly asymmetric bedforms approximately 0.35 m in height with a wavelength of approximately 15 m. Between KP 532 and KP 547, very large mobile bedforms up to 12 m high are present in the vicinity of the cable route (Section 9.5).

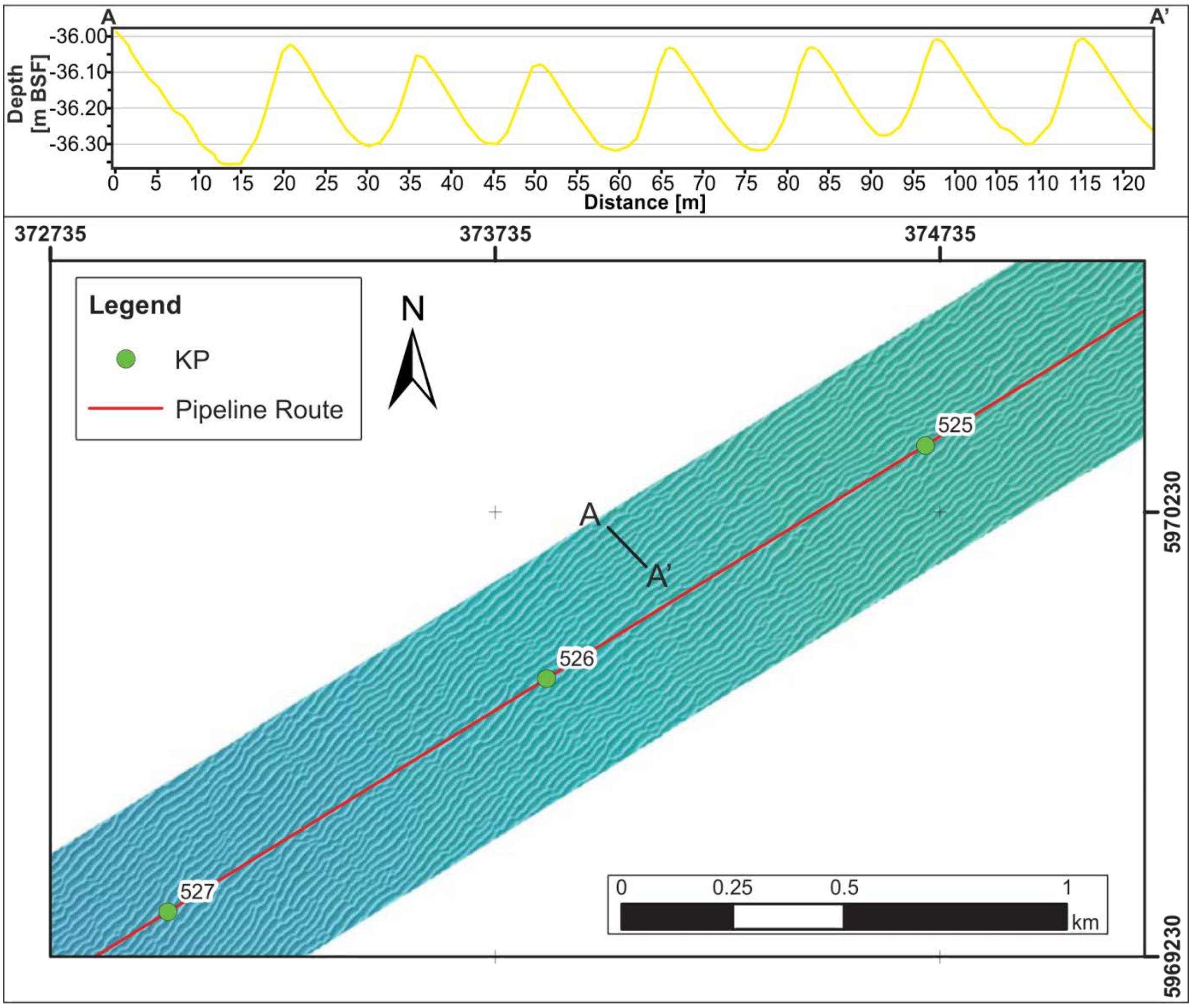


Figure 6.7: Bathymetry data example of small to medium-sized bedforms. Bedform size classified according to Ashley (1990)

6.7 Zone F – Subglacial Till and Bedrock

Zone F is located between KP 549 and the UK landfall (KP 618.735) and is characterised by a thin layer of coarse granular material (sands and gravels) overlying clay of the Bolders Bank Formation. This zone comprises chalk bedrock close to seabed. The strength of the chalk bedrock in this region is known to be extremely variable. Chalk has been sampled in the northern limit of the Inner Silver Pit (KP 549.800 - to KP 551.200); this particular location is discussed in more detail in Section 9.10.

One location, B14-03-CPT/VC, was interpreted to sample the very dense gravelly sand of the Egmond Ground Formation. The extent of this formation is limited to the immediate vicinity of the Inner Silver Pit, where overlying formations have been incised to expose the Egmond Ground Formation at seafloor.

Large bedforms, including sandbanks and dunes, are present across this region and are known to be highly mobile (Section 9.5).

7. CABLE GEOTECHNICAL ZONATION

7.1 General

This section presents the cable geotechnical zonation (CGZ) along the proposed route centreline. The cable geotechnical zonation approach is based on Fugro experience working with cable installation contractors to derive a geotechnical classification system. For the Viking Link project, this scheme has also had input from Primo Marine to best constrain the specific geotechnical conditions of interest for this cable installation programme.

A cable geotechnical zonation is derived from the integration of geological, geophysical and geotechnical datasets, and forms a predictive model which demarcates differing geotechnical conditions. The output of the cable geotechnical zonation, is a prediction of soil conditions to a depth of 3 m BSF along the route.

To derive the cable geotechnical zones, the soil conditions were first simplified to generate cable soil categories (CSC) and then divided based on analysis of the sub-bottom profiler (SBP) interpretation. In areas of indistinct or laterally discontinuous geophysical data, the cable geological zonation, as interpreted in Section 5, was used as the basis for the selection of cable geotechnical zones with priority given to the proximal geotechnical data.

7.2 Methodology

The creation of a cable geotechnical zonation for the cable route involved the following steps:

i. Assessment of sampled soil conditions from both vibrocore and CPT results, and a review of these in conjunction with the knowledge derived from the cable geological zonation (Section 5);
ii. Unitisation of sampled soil conditions along the cable route;
iii. Simplification of the unitised soil conditions into CSCs, and then into predicted soil profiles to 3 m BSF;
iv. Review of significant changes in stratigraphy (i.e. sand to clay or sand to bedrock) identified within the sample locations against mapped reflectors within the SBP data (Figure 7.1);
v. Interpolation of the predicted soil profiles based on the geophysical datasets;
vi. Creation of cable geotechnical zones with specific KP ranges along the Route 4 (rev.10). centreline.

7.3 Cable Geotechnical Zonation Limitations

The definition of zone boundaries is based on integration of multiple datasets and interpretation performed as a result of these. The zones selected capture the most appropriate summary of soil conditions based on the data available. In some areas engineering geological judgement was used to define zones, particularly where data are less comprehensive or interpretations are uncertain.

It is anticipated that soil conditions will vary more widely than indicated, particularly laterally close to interpreted zone boundaries.

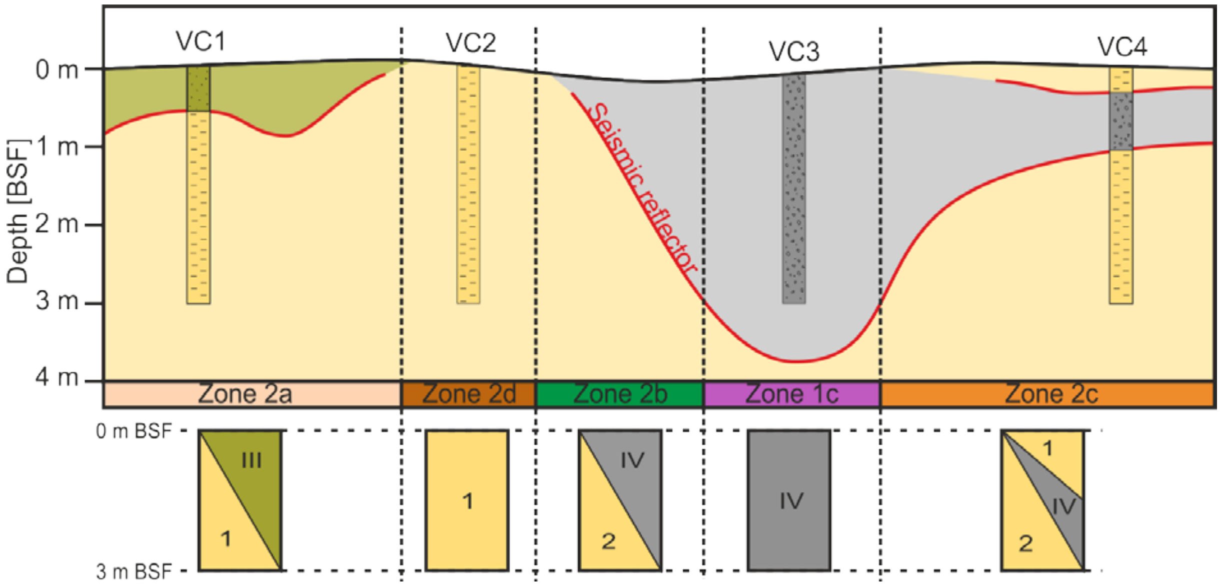


Figure 7.1: Conceptual schematic of the integration of geotechnical and geophysical data to create a cable geotechnical zonation along the centreline of a proposed route (after Mason and Smith, 2016)

7.4 Cable Soil Categories

To simplify the soil units encountered along the export routes, the sampled and tested conditions were divided into cable soil categories (CSCs) to 3 m BSF across the site. These were developed by Fugro with cable installation contractors and summarise the main soil types to provide key information to inform future engineering. The CSCs used for the Viking Link project are presented in Table 7.1.

The CSCs were agreed upon by Fugro and Primo Marine following a meeting held on 6 October 2016.

Table 7.1: Cable Soil Categories (CSCs)

Description*	Cable Soil Category (CSC)
Extremely low to very low strength (0 kPa to 20 kPa) CLAY/SILT	1
Low to medium strength (20 kPa to 75 kPa) CLAY/SILT	2
High strength (75 kPa to 150 kPa) CLAY/SILT	3
Very high to extremely high strength (150 kPa to >600 kPa) CLAY/SILT	4
BEDROCK	5
SILT (drained)	I†
Fine to medium grained SAND (0.06 mm to 0.6 mm)	II†
Coarse grained SAND (0.6 mm to 2 mm)	III†
GRAVEL (2 mm to 60 mm)	IV†
PEAT	V

Notes:
* = Strength and grain-size categorisation according to BS 5930: 1999 (2010)
† = Density of sand is denoted by following modifiers:

a – Very loose to loose (<5 % to 35 %)	
b – Medium dense to dense (35 % to 85 %)	
c – Very dense (< 85%)	

7.5 Definition of Cable Soil Categories as Geological Formations

The cable soil categories can be approximated to represent the geological formations which are present along the route, based on the discussion in Sections 3 and 5. Table 7.2 presents a correlation between the BGS geological formation and the interpreted cable geotechnical zones.

Table 7.2: Correlation of Cable Soil Categories and Geological Formations

Cable Soil Category	Description*	Geological Formation(s)**
1	Extremely low to very low strength (0 kPa to 20 kPa) CLAY/SILT	Holocene sediments Palaeochannels Elbow Formation Botney Cut Formation
2	Low to medium strength (20 kPa to 75 kPa) CLAY/SILT	Bolders Bank Formation(weathered) Dogger Bank Formation(weathered)
3	High strength (75 kPa to 150 kPa) CLAY/SILT	Bolders Bank Formation Dogger Bank Formation *Brown Bank Formation* *Sand Hole Formation* Swarte Bank Formation
4	Very high to extremely high strength (150 kPa to >600 kPa) CLAY/SILT	
5	BEDROCK	Upper Cretaceous Chalk
I	SILT (drained)	Holocene sediments Elbow Formation Palaeochannels Botney Cut Formation *Aeolian sediments* *Eem Formation* Egmond Ground Formation Yarmouth Roads Formation *Markham's Hole Formation*
II	Fine to medium grained SAND (0.06 mm to 0.6 mm)	
III	Coarse grained SAND (0.6 mm to 2 mm)	
IV	GRAVEL (2 mm to 60 mm)	
V	PEAT	Palaeochannels Elbow Formation

Notes:
* = Strength and grain-size categorisation according to BS 5930: 1999 (2010)
** Geological formations listed as per British Geological Survey nomenclature
Geological units in *italics* were not positively identified on the Viking Link route but are interpreted as a possibility based on publicly available reference material

7.6 Cable Geotechnical Zones

Seven cable geotechnical zones were selected for the project with associated sub-zones; these are introduced in Table 7.3, with further detailed descriptions in Sections 7.6.1 to 7.6.7. A full geotechnical zone versus KP listing is presented in Table 7.4.

Table 7.3 lists factors which need to be considered when appraising each of the zones for the purposes of cable design and future installation activities. It should be noted that the geotechnical zones presented are for the purposes of summarising the geotechnical conditions along the route and are related but separate from the cable geological zones in Section 5.

Figure 7.2 presents an overview of the cable geotechnical zone profiles for reference.

Figure 7.3 to Figure 7.10 display the approximate extents of each CGZ (including sub-zones) on a route overview map for reference. Section 7.3 details the limitations of the cable geotechnical zonation process.

Table 7.3: Cable Geotechnical Zone (CGZs) Summary

CGZ	Description	Percentage of Route Applicable*	Number of sub-zones	Considerations
1	Recent to early Holocene intertidal to marine sediments (fine)	55.3%	5	▪ Increasing relative density (D_r) profiles from surface ▪ Extremely low strength, estuarine sediments within 3 m BSF ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
2	Recent to early Holocene marine sediments (coarse)	3.3%	1	▪ Increasing relative density profiles from surface ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
3	Recent to early Holocene marine sediments (mixed)	6.6%	3	▪ Changes in grain size with increasing depth ▪ Relative density inversions and cut-backs with increasing depth ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
4	Recent to early Holocene marine sediments overlying post-depositionally modified Late Quaternary sediments	1.8%	3	▪ Overconsolidated sediments, sub-aerially exposed ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor

CGZ	Description	Percentage of Route Applicable*	Number of sub-zones	Considerations
5	Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments	30.2%	6	▪ Overconsolidated sediments with coarser inclusions, glacial till ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
6	Recent to early Holocene marine sediments overlying Middle to Late Quaternary marine sediments	2.8%	2	▪ Expected to be Egmond Ground and/ or Yarmouth Roads Formation ▪ Unrecorded cobbles and boulders at seafloor
7	Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments overlying Upper Cretaceous bedrock	<0.1%	1	▪ Exposed Upper Cretaceous CHALK, sampled in the Silver Pit region ▪ Unrecorded cobbles and boulders at seafloor ▪ Could be expected to occur elsewhere along the route, particularly in the UK sector associated with glaciotectonics

Notes:
CGZ= cable geotechnical zone
BSF = below seafloor
* Route 4 (rev.10)

Table 7.4: Cable Geotechnical Zone (CGZs) Listing

Route	CGZ	Start KP	End KP	Distance [km]
DK to LF1	1b	0	3.2	3.20
	1b	3.2	4.5	1.30
	1d	4.5	7.5	3.00
	1b	7.5	9.4	1.90
	3a	9.4	12.25	2.85
	1b	12.25	13.15	0.90
	1d	13.15	15.6	2.45
	1b	15.6	23.68	8.08
	4a	23.68	23.85	0.17
	1b	23.85	26.5	2.65
	3a	26.5	31.8	5.30
	1b	31.8	34	2.20
	1b	34	37.5	3.50
	1b	37.5	38.5	1.00
	2a	38.5	42.25	3.75
	1b	42.25	43	0.75
	3a	43	44.8	1.80
	1e	44.8	45.95	1.15
	4d	45.95	48.2	2.25
	1b	48.2	51.2	3.00
	3c	51.2	54.5	3.30
	2a	54.5	56.5	2.00
	1e	56.5	59.1	2.60
	2a	59.1	59.4	0.30
	2a	59.4	60	0.60
	2a	60	62.35	2.35
	4d	62.35	63	0.65
	1b	63	64.1	1.10
	3c	64.1	66.45	2.35
	3d	66.45	67.75	1.30
	3a	67.75	72.9	5.15
	1b	72.9	75.6	2.70
	2a	75.6	79	3.40
	1b	79	80.75	1.75
	1b	80.75	84.6	3.85
	2a	84.6	88.85	4.25
	1b	88.85	89.05	0.20

Route	CGZ	Start KP	End KP	Distance [km]
	2a	89.05	90.75	1.70
	1d	90.75	93.25	2.50
	1e	93.25	94.75	1.50
	1d	94.75	96.35	1.60
	1b	96.35	101	4.65
	4a	101	104.05	3.05
	1b	104.05	113	8.95
	4d	113	115	2.00
	4d	115	115.65	0.65
	1b	115.65	118.8	3.15
	1a	118.8	121.5	2.70
	1b	121.5	124	2.50
	4a	124	125	1.00
	1c	125	127.75	2.75
	1d	127.75	132.5	4.75
	1b	132.5	135	2.50
	4c	135	135.45	0.45
	3d	135.45	135.8	0.35
	4c	135.8	136.5	0.70
	1b	136.5	140	3.50
	2a	140	142.1	2.10
	1b	142.1	144	1.90
	1c	144	181.5	37.50
	1a	181.5	193.5	12.00
	1b	193.5	195.75	2.25
	3a	195.75	198.65	2.90
	1b	198.65	200.2	1.55
	1d	200.2	203	2.80
	1b	203	206	3.00
	3a	206	215.9	9.90
	1d	215.9	218.5	2.60
	1b	218.5	220.5	2.00
	1d	220.5	221.3	0.80
	1d	221.3	222.2	0.90
	1d	222.2	223	0.80
	1d	223	224	1.00
	1d	224	224.75	0.75
	1b	224.75	227.5	2.75

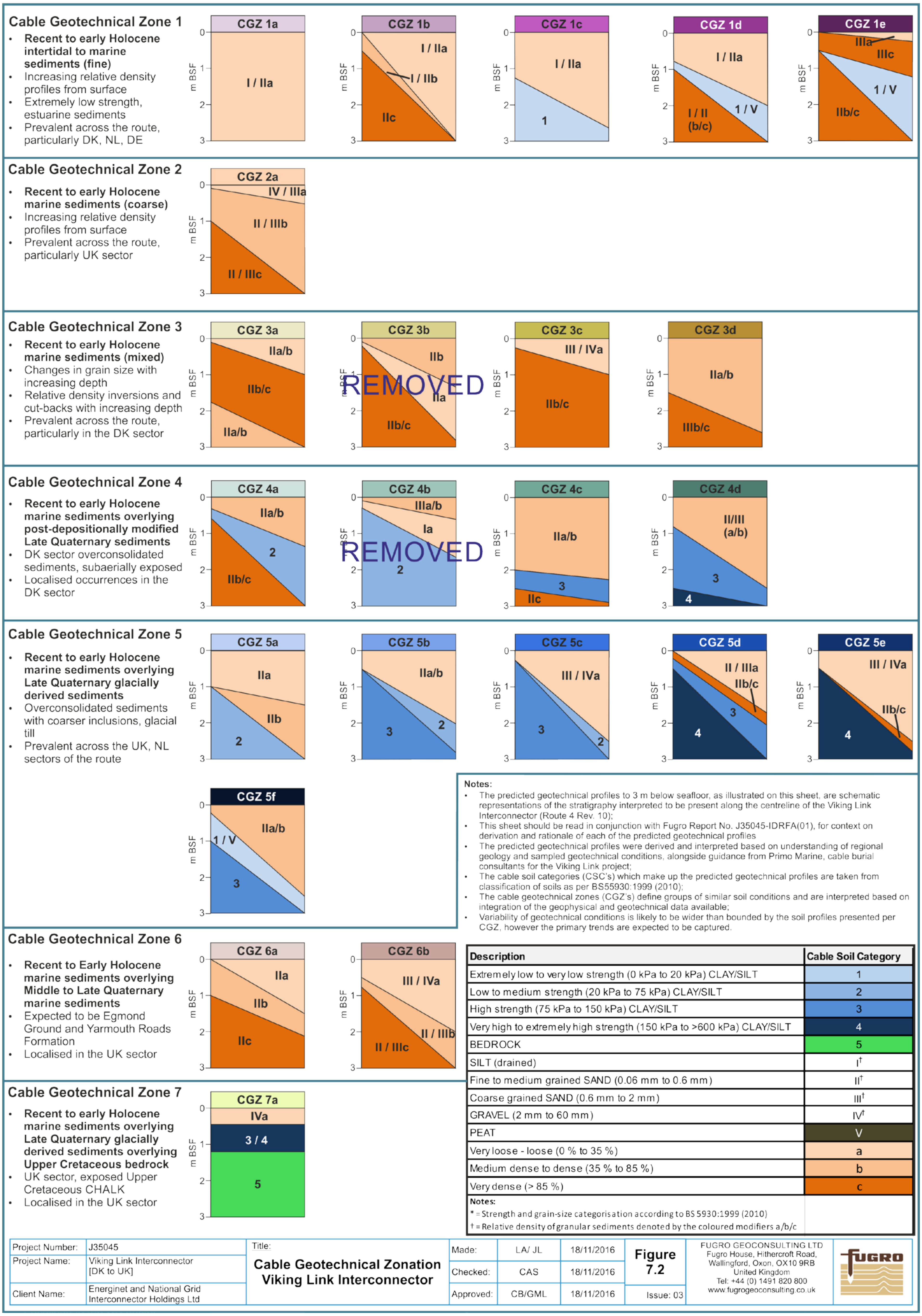
Route	CGZ	Start KP	End KP	Distance [km]
	3a	227.5	229.65	2.15
	1b	229.65	231	1.35
	1d	231	231.7	0.70
	3a	231.7	233	1.30
	1d	233	240.9	7.90
	1d	240.9	241.1	0.20
	1b	241.1	241.2	0.10
	1d	241.2	241.4	0.20
	1b	241.4	241.6	0.20
	1d	241.6	241.8	0.20
	1b	241.8	242.8	1.00
	1d	242.8	243.1	0.30
	1b	243.1	252	8.90
	1d	252	255	3.00
	1b	255	262.95	7.95
	1d	262.95	263.3	0.35
	1b	263.3	266.25	2.95
	5f	266.25	270	3.75
	5b	270	303.5	33.50
	5f	303.5	309.5	6.00
	1c	309.5	311.5	2.00
	1b	311.5	325.5	14.00
	5b	325.5	338	12.50
	1d	338	350.5	12.50
	1c	350.5	361	10.50
	5d	361	367.5	6.50
	1a	367.5	367.75	0.25
	5d	367.75	369	1.25
	1a	369	379	10.00
	5d	379	380.75	1.75
	1c	380.75	385.5	4.75
	1b	385.5	387	1.50
	1c	387	392.8	5.80
	1d	392.8	394.5	1.70
	1c	394.5	398.25	3.75
	6b	398.25	399.5	1.25
	1c	399.5	403.1	3.60
	1d	403.1	404.4	1.30

Route	CGZ	Start KP	End KP	Distance [km]
	1c	404.4	429.5	25.10
	1a	429.5	464.2	34.70
	6b	464.2	464.80	0.60
	1a	464.8	465.45	0.65
	6a	465.45	468.00	2.55
	6b	468	470.00	2.00
	6b	470	471.20	1.20
	6b	471.2	472.20	1.00
	6a	472.2	473.00	0.80
	6b	473	473.20	0.20
	6a	473.2	474.45	1.25
	6b	474.45	477.90	3.45
	5e	477.9	479.30	1.40
	6b	479.3	479.45	0.15
	5e	479.45	480.70	1.25
	5c	480.7	481.00	0.30
	5e	481	482.10	1.10
	6b	482.1	483.75	1.65
	5b	483.75	485.10	1.35
	6a	485.1	485.65	0.55
	1b	485.65	487.20	1.55
	5e	487.20	488.50	1.30
	5d	488.5	490.80	2.30
	5e	490.8	492.40	1.60
	5e	492.4	493.30	0.90
	5d	493.3	496.50	3.20
	1a	496.5	499.15	2.65
	5b	499.15	502.20	3.05
	5a	502.2	502.30	0.10
	5b	502.3	502.70	0.40
	5e	502.7	505.50	2.80
	5b	505.5	506.40	0.90
	5c	506.4	506.70	0.30
	5e	506.7	510.25	3.55
	5b	510.25	512.90	2.65
	5d	512.9	514.90	2.00
	1b	514.9	517.30	2.40
	5b	517.3	520.20	2.90

Route	CGZ	Start KP	End KP	Distance [km]
	1b	520.2	525.30	5.10
	5d	525.3	532.35	7.05
	1e	532.35	532.60	0.25
	5b	532.6	534.70	2.10
	2a	534.7	534.90	0.20
	5b	534.9	536.50	1.60
	5e	536.5	539.20	2.70
	5d	539.2	539.35	0.15
	5c	539.35	539.65	0.30
	5d	539.65	539.90	0.25
	5e	539.9	544.15	4.25
	5a	544.15	546.30	2.15
	5e	546.3	550.20	3.90
	7a	550.2	550.65	0.45
	6a	550.65	551.15	0.50
	5e	551.15	568.50	17.35
	5d	568.5	570.00	1.50
	5e	570	572.90	2.90
	5d	572.9	573.80	0.90
	5e	573.8	574.50	0.70
	5c	574.5	579.10	4.60
	5f	579.1	580.65	1.55
	5e	580.65	581.10	0.45
	5c	581.1	586.00	4.90
	5b	586	587.25	1.25
	5d	587.25	590.30	3.05
	5b	590.3	594.50	4.20
	5f	594.5	598.60	4.10
	3c	598.6	599.05	0.45
	5f	599.05	599.80	0.75
	3c	599.8	600.60	0.80
	5f	600.6	601.60	1.00
	3c	601.6	602.55	0.95
	5f	602.55	603.70	1.15
	1b	603.70	605.45	1.75
	5f	605.45	614.45	9.00
	5c	614.45	615.00	0.55
	5f	615	615.15	0.15

Route	CGZ	Start KP	End KP	Distance [km]
	5c	615.15	616.70	1.55
	5f	616.7	616.85	0.15
	5c	616.85	618.80	1.95
Split to LF2	5f	611.1	613.00	1.90
	5c	613	617.50	4.50
	1b	617.5	617.60	0.10
	5c	617.60	620.20	2.60
	2a	620.20	620.30	0.10
	5c	620.30	622.45	2.15

Notes:
CGZ = Cable Geotechnical Zone
KP = Kilometre Point



Notes:

- The predicted geotechnical profiles to 3 m below seafloor, as illustrated on this sheet, are schematic representations of the stratigraphy interpreted to be present along the centreline of the Viking Link Interconnector (Route 4 Rev. 10);
- This sheet should be read in conjunction with Fugro Report No. J35045-IDRFA(01), for context on derivation and rationale of each of the predicted geotechnical profiles
- The predicted geotechnical profiles were derived and interpreted based on understanding of regional geology and sampled geotechnical conditions, alongside guidance from Primo Marine, cable burial consultants for the Viking Link project;
- The cable soil categories (CSC's) which make up the predicted geotechnical profiles are taken from classification of soils as per BS55930:1999 (2010);
- The cable geotechnical zones (CGZ's) define groups of similar soil conditions and are interpreted based on integration of the geophysical and geotechnical data available;
- Variability of geotechnical conditions is likely to be wider than bounded by the soil profiles presented per CGZ, however the primary trends are expected to be captured.

Description	Cable Soil Category
Extremely low to very low strength (0 kPa to 20 kPa) CLAY/SILT	1
Low to medium strength (20 kPa to 75 kPa) CLAY/SILT	2
High strength (75 kPa to 150 kPa) CLAY/SILT	3
Very high to extremely high strength (150 kPa to >600 kPa) CLAY/SILT	4
BEDROCK	5
SILT (drained)	I†
Fine to medium grained SAND (0.06 mm to 0.6 mm)	II†
Coarse grained SAND (0.6 mm to 2 mm)	III†
GRAVEL (2 mm to 60 mm)	IV†
PEAT	V
Very loose - loose (0 % to 35 %)	a
Medium dense to dense (35 % to 85 %)	b
Very dense (> 85 %)	c

Notes:
* = Strength and grain-size categorisation according to BS 5930:1999 (2010)
† = Relative density of granular sediments denoted by the coloured modifiers a/b/c

Figure 7.2: Cable Geotechnical Zones, predicted soil profiles to 3 m below seafloor

7.6.1 CGZ 1

CGZ 1 is composed of recent to early Holocene intertidal to marine sediments and is interpreted to be present along 55.3% of the route. CGZ 1 is split into five sub-zones which represent various configurations of fine sand, silt and extremely low strength to very low strength clay with peat and organic material to 3 m BSF.

Figure 7.3 illustrates the definition of the sand and silt dominated sub-zones of CGZ 1 (1a and 1b) along the route. In contrast, Figure 7.4 illustrates the definition of extremely low strength clay and peat dominated sub-zones of CGZ 1 (1c, 1d and 1e) along the route; refer to Table 7.1 for cable soil category definitions.

7.6.2 CGZ 2

CGZ 2 is composed of recent to early Holocene marine sediments and is interpreted to be present along 3.3% of the route. CGZ 2 has one sub-zone which represents coarse sand and gravel increasing in relative density with depth to 3 m BSF.

Figure 7.5 illustrates the definition of the coarse sand and gravel dominated CGZ 2 (2a) along the route; refer to Table 7.1 for cable soil category definitions.

7.6.3 CGZ 3

CGZ 3 is composed of recent to early Holocene marine sediments and is interpreted to be present along 6.6% of the route. CGZ 3 is split into three sub-zones which represent various configurations of fine sand overlying coarse sand, coarse sand and gravel overlying fine sand and relative density inversions with depth to 3 m BSF.

A fourth sub-zone, CGZ 3b, was initially proposed based on preliminary data (J35045-R-IDRFA(01)). For this report, CGZ 3b was removed following detailed review of finalised geotechnical logs, full laboratory results and derivation of geotechnical parameters (Section 8).

Figure 7.6 illustrates the definition of CGZ 3 (3a, 3c and 3d) along the route; refer to Table 7.1 for cable soil category definitions.

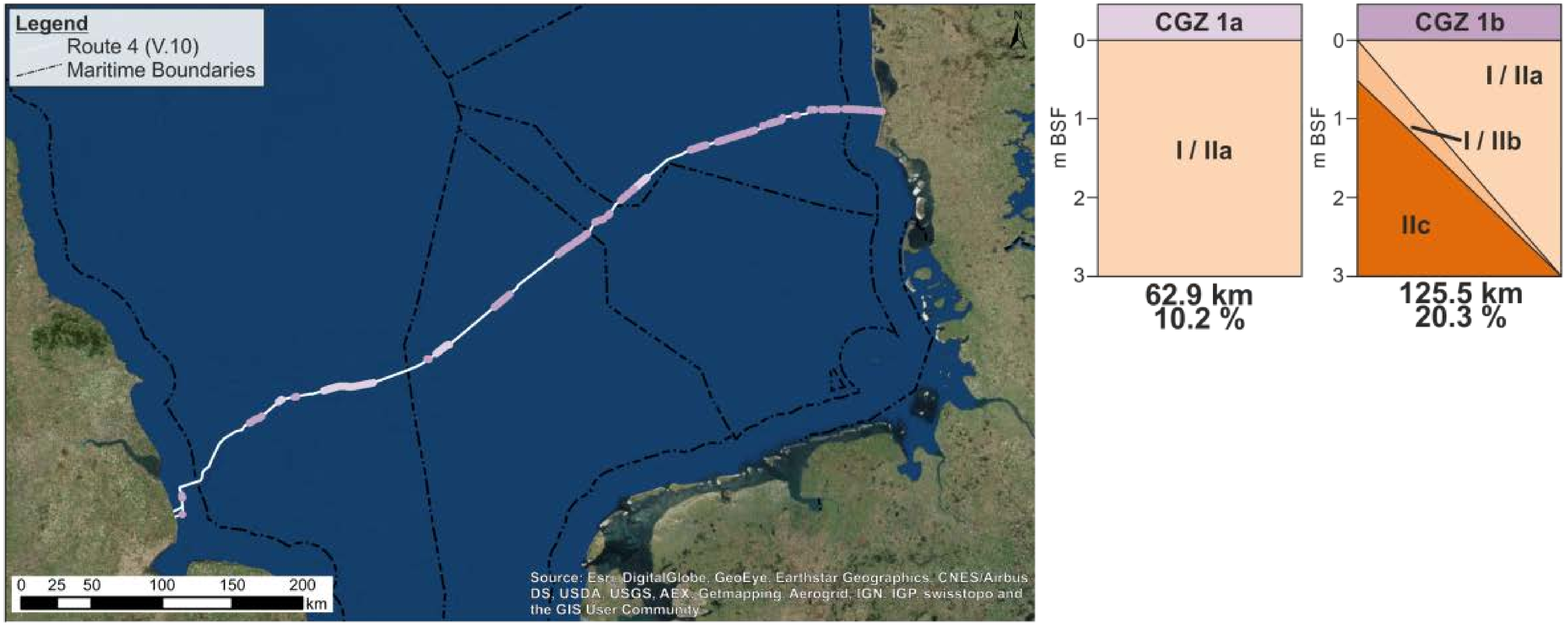


Figure 7.3: Extents of CGZ 1a and 1b

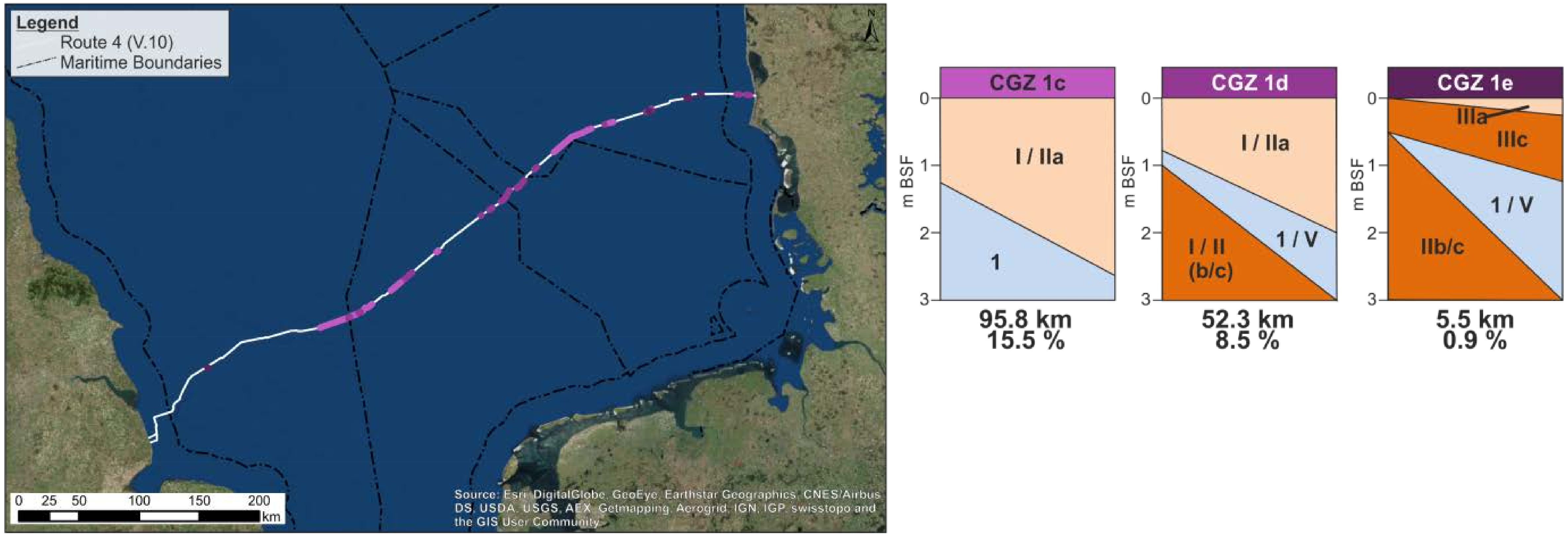


Figure 7.4: Extents of CGZ 1c, 1d and 1e

Figure 7.5: Extents of CGZ 2a

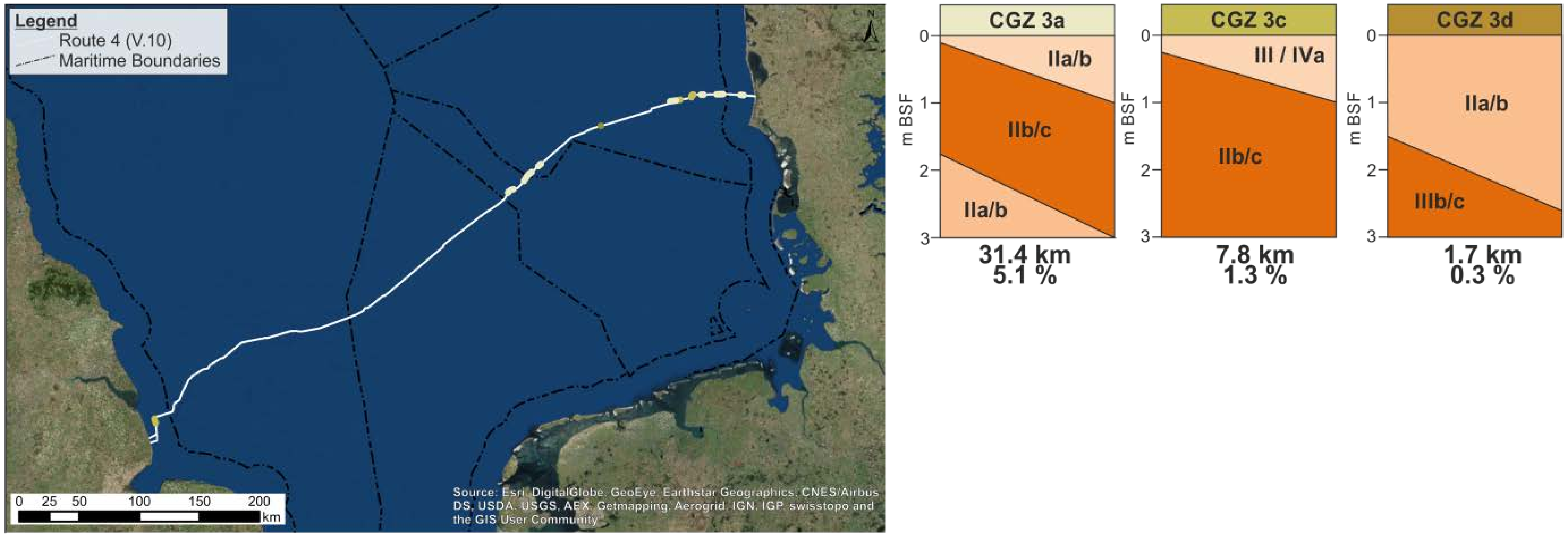


Figure 7.6: Extents of CGZ 3a, 3c and 3d

7.6.4 CGZ 4

CGZ 4 is composed of recent to early Holocene marine sediments overlying post-depositionally modified Late Quaternary Sediments and is interpreted to be present along 1.8% of the route. CGZ 4 is split into four sub-zones which represent various configurations of fine sands, silts and low to extremely high strength clay to 3 m BSF.

A fourth sub-zone, CGZ 4b, was initially proposed based on preliminary data (J35045-R-IDRFA(01)). For this report, CGZ 4b was removed following detailed review of finalised geotechnical logs, full laboratory results and geotechnical parameters (Section 8).

Figure 7.7 illustrates the definition of CGZ 4 (4a, 4c and 4d) along the route; refer to Table 7.1 for cable soil category definitions.

7.6.5 CGZ 5

CGZ 5 is composed of recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments and is interpreted to be present along 30.2% of the route. CGZ 5 is split into six sub-zones which represent various configurations of fine and coarse sand, extremely low strength clay and peat up to extremely high strength clay to 3 m BSF.

Figure 7.8 illustrates the definition of CGZ 5 (5a, 5b, 5c, 5d and 5e) along the route; refer to Table 7.1 for cable soil category definitions.

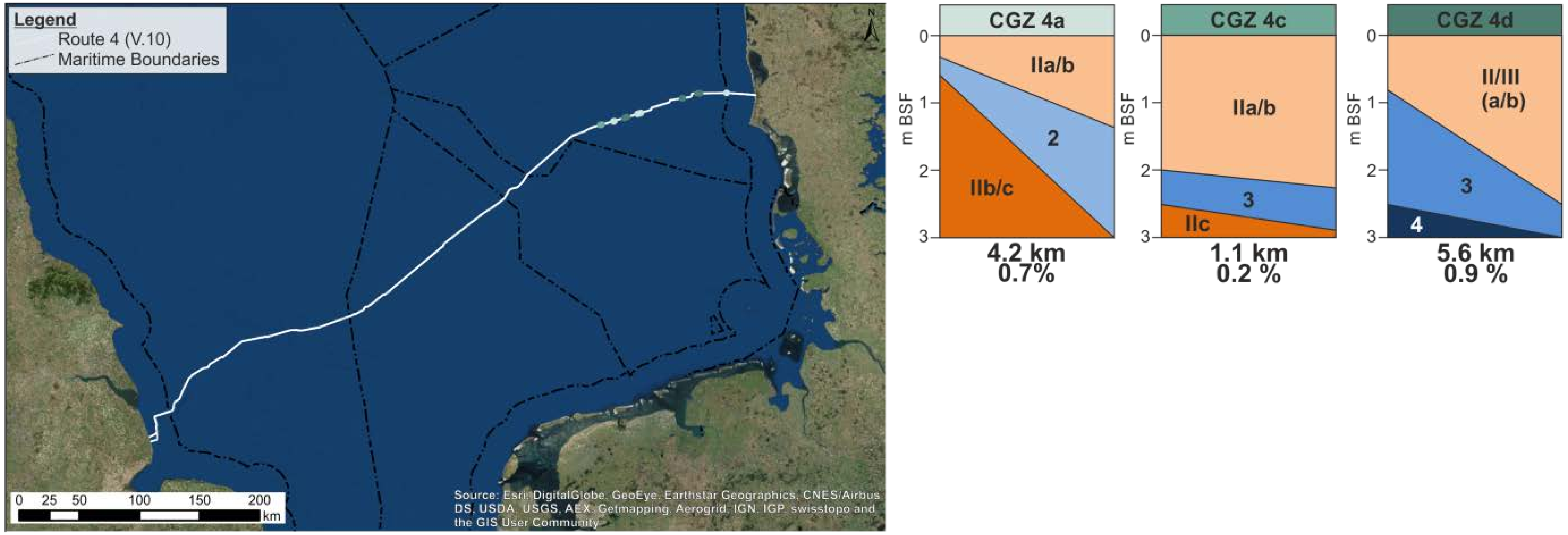


Figure 7.7: Extents of CGZ 4a, 4c and 4d

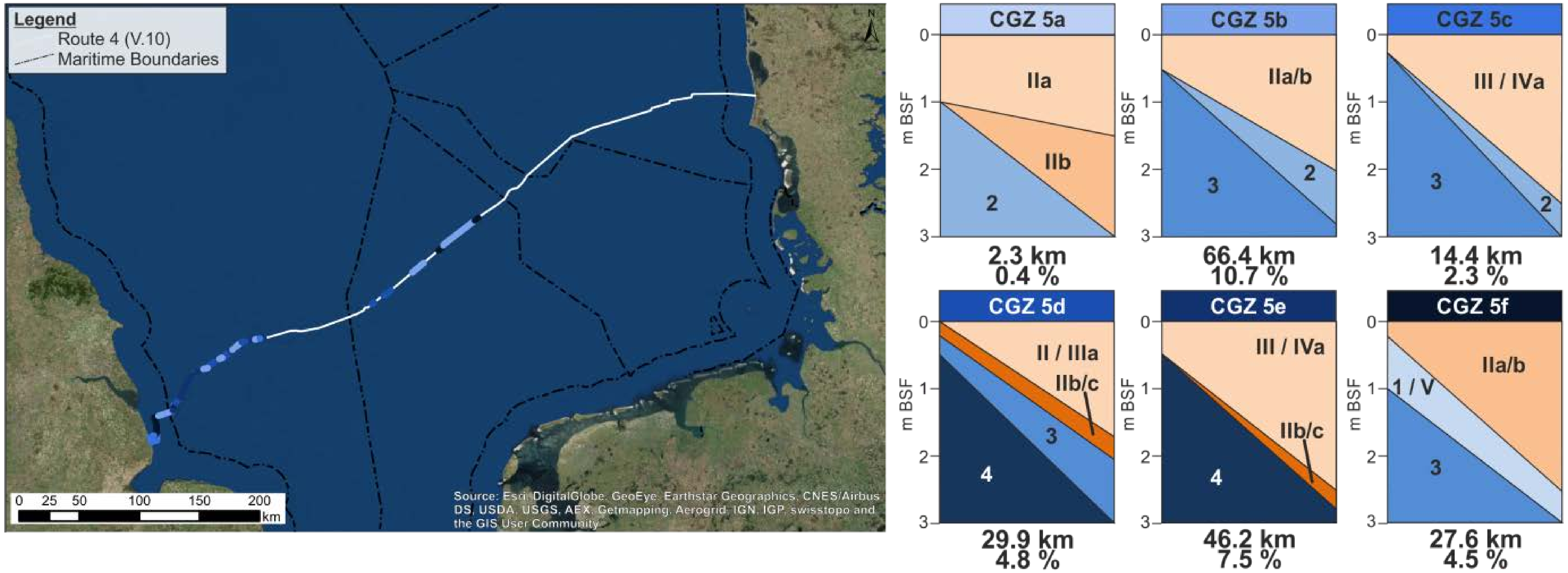


Figure 7.8: Extents of CGZ 5a, 5b, 5c, 5d, 5e and 5f

7.6.6 CGZ 6

CGZ 6 is composed of recent to early Holocene marine sediments overlying Middle to Late Quaternary marine sediments and is interpreted to be present along 2.8% of the route. CGZ 6 is split into two sub-zones which represent various configurations of fine and coarse sand increasing in relative density with depth to 3 m BSF.

Figure 7.9 illustrates the definition of CGZ 6 (6a and 6b) along the route; refer to Table 7.1 for cable soil category definitions.

7.6.7 CGZ 7

CGZ 7 is composed of recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments overlying Upper Cretaceous bedrock and is interpreted to be present for less than 0.1% of the route. CGZ 7 has one sub-zone which considers 3 m BSF of fine sand, high to extremely high strength clay and bedrock.

Figure 7.10 illustrates the definition of CGZ 7 (7a) along the route; refer to Table 7.1 for cable soil category definitions.

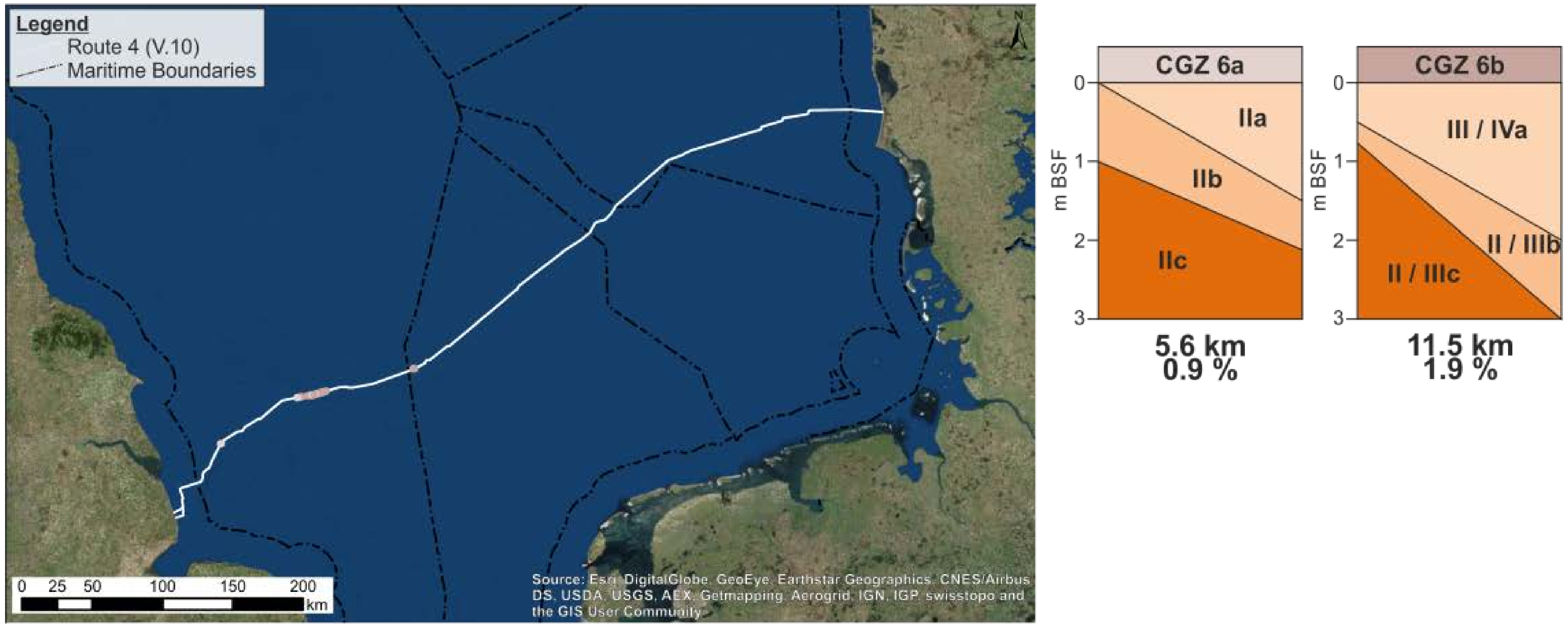


Figure 7.9: Extents of CGZ 6a and 6b

Figure 7.10: Extents of CGZ 7a

8. CABLE GEOTECHNICAL ZONATION PARAMETERS

8.1 General

This section presents the geotechnical parameters for each of the cable geotechnical zones (CGZ) defined in Section 5. The parameters for each cable soil category (CSC) interpreted to be present within each CGZ are derived from laboratory test data and site-specific geotechnical data (e.g. CPT).

The geotechnical parameters listed in Table 8.1 are discussed in this section and are presented on Alignment Charts 1 to 141 (Volume B, C and D of this report) and landfall chart:

Table 8.1: Geotechnical Parameters Presented per Cable Geotechnical Zone

Symbol	Description	Unit	Comments
s_u	Undrained shear strength	kPa	▪ See Section 8.2.1
q_c	Cone resistance	MPa	▪ Values for cone resistance are based on the results of all CPTs for that zone, with LE, BE and HE interpreted based on engineering geological judgement
$ɣ'$	Submerged unit weight	kN/m^3	▪ Values for submerged unit weight are based on statistical derivation from direct laboratory measurements and are presented to the nearest 0.5 kN/w^3
w	Moisture content	%	▪ Values for moisture content are based on statistical derivation from direct laboratory measurements and are presented to the nearest 1%
I_p	Plasticity index	%	▪ Values for plasticity index are based on statistical derivation from direct laboratory measurements and are presented to the nearest 1%
s_t	Sensitivity	-	▪ Values for sensitivity are based on statistical derivation from direct laboratory measurements and are presented to the nearest 0.1 ▪ No values for sensitivity are presented as no remoulded tests were undertaken for the project
-	Fines content	%	▪ Values for fines content are based on statistical derivation from direct laboratory measurements and are presented to the nearest 1%
Dr	Relative density	%	▪ See Section 8.2.1
$Φ'$	Effective angle of internal friction	°	▪ Values for friction angle are based on statistical derivation from direct laboratory measurements, corroborated with CPT-derived relative density ranges according to API (2001) ▪ An increase of 5 degrees on the HE for GRAVEL is taken into account ▪ Consideration should be given to the measured values recorded in laboratory tests (Appendix XX), the density of data was too low to use in the derivation of parameters
K	Thermal resistivity	mK/W	▪ See Section 8.2.2

Notes:
- = No unit applies

Low estimate (LE), best estimate (BE) and high estimate (HE) values are presented for each geotechnical parameter and represent the likely range of parameter values expected along Route 4 (rev.10).

It should be noted that within some CGZs, limited geotechnical data are available for some cable soil categories. As a result, data is grouped at the overarching CGZ (e.g. CGZ 1) level, and only where applicable and enough data points are present sorted by subzone (e.g. CGZ 1a, 1b).

Figure 8.1 illustrates a geotechnical parameter table and how it appears on the alignment charts.

CGZ 1a																															
Cable Geotechnical Category	Depth	Undrained Shear Strength s_u [kPa]			Submerged Unit Weight γ' [kN/m³]			Moisture Content w [%]			Plasticity Index I_p [%]			Sensitivity s_t [-]			Fines Content [%]			Relative Density Dr [%]			Effective Angle of Internal Friction Φ' [°]			Thermal Resistivity R [mK/W]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
I / IIa	0.00	-	-	-	8.0	9.5	11.0	18	25	32	-	-	-	-	-	-	1	10	19	0	2	35	20	-	25	0.39	0.46	0.56
	3.00																			0	15	35						

Figure 8.1: Example Geotechnical Parameter Table for Cable Geotechnical Zone 1a

8.2 Derived Parameter Data

This section describes the derivation and considerations for selected geotechnical parameters presented in this report and on the charts. Care should be taken to make note of all considerations mentioned when using the geotechnical parameter bounds for engineering purposes.

Where possible, a statistical approach (DNV, 2012) was used to derive geotechnical parameter bounds, particularly for basic classification testing. Engineering geological judgement was used in the derivation of appropriate values for relative density, undrained shear strength and cone resistance.

8.2.1 Undrained Shear Strength and Relative Density

The selection of undrained shear strength and relative density values are crucial for the purpose of selecting the possible equipment which can be used for the installation of the cable. The selection of appropriate CSCs, alongside Primo Marine (Table 7.1, meeting 6 October 2016) provides the basis for the ranges of undrained shear strength and relative density.

The CSCs were interpreted at each location based on engineering geological judgement and an understanding of the ranges of undrained shear strength and relative density which are expected in each geological formation. This approach allows data points which can be considered erroneous or influenced by the variability in soil conditions to be screened. Minor peaks in undrained shear strength or relative density may occur for the following reasons:

i. Minor constituents of the sediment, (e.g. gravel) resulting in peaks or spikes in q_c ;
ii. Thin sedimentary layers (less than 20 cm) which cannot be fully reconciled using CPT data, i.e. incorrect high initial q_c high final q_c based on interpretation of CPT results;
iii. Secondary constituents of the sediment (e.g. sand or silt), affecting the readings of handheld torvanes or pocket penetrometers creating high or low, unrepresentative undrained shear strength readings.

Figure 8.2 illustrates the selection of CSCs at location B08-18 and B10-11. N_{kt} factors (15 and 20) were used to derive undrained shear strength of cohesive (clay) soils from CPT data. These are considered typical for North Sea soils, based on Fugro experience. Relative density of cohesionless soils was estimated from CPT data using the relationships proposed by Jamiolkowski et al. (2003). For more information on the use of CPT and laboratory test data refer to the Geotechnical Laboratory Report (J35045-R-RESF).

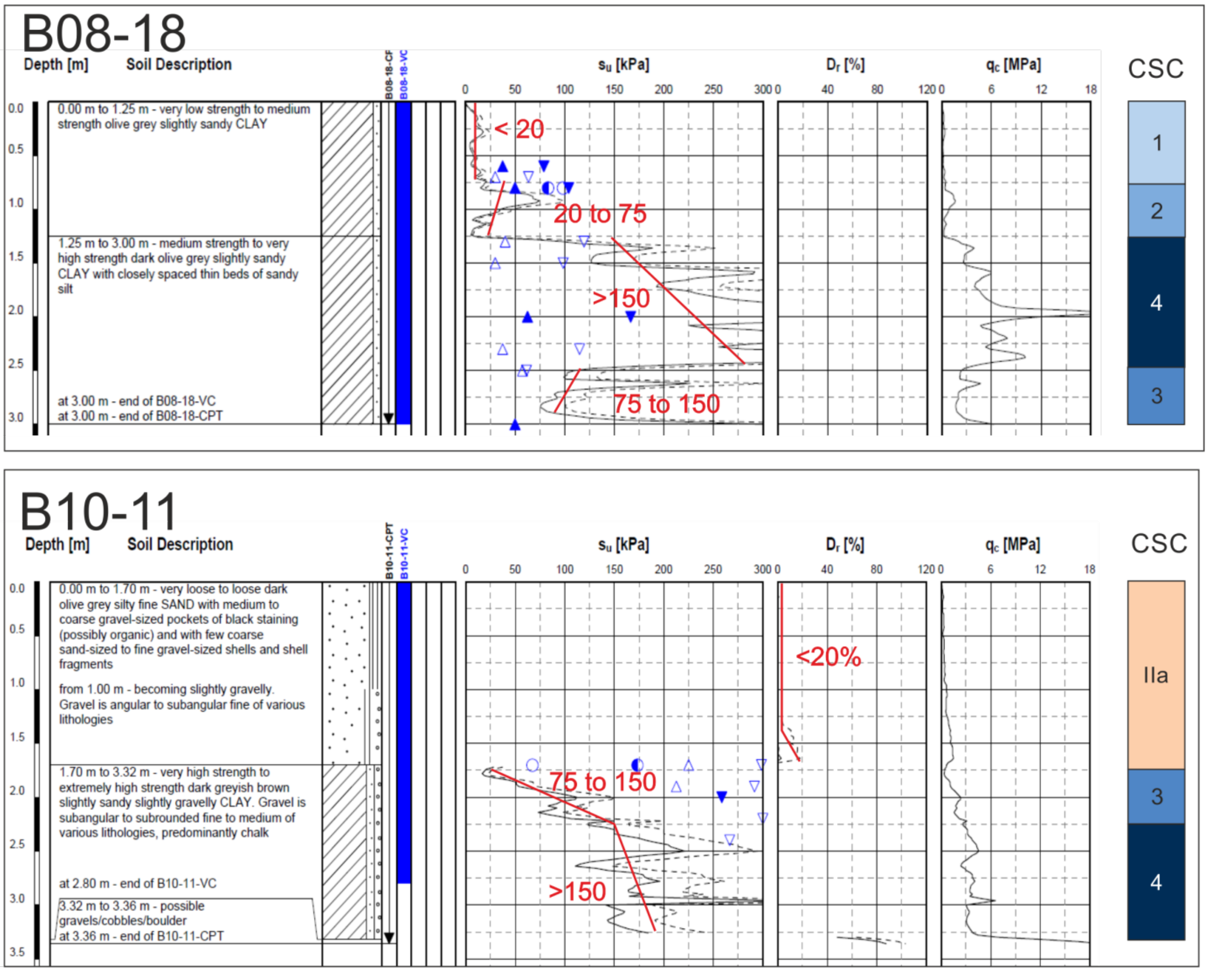


Figure 8.2: (Top) Location B08-18 and (Bottom) B10-11 with annotated generalised shear strength and relative density profiles with interpreted Cable Soil Categories (CSCs) to the left

8.2.2 Thermal Resistivity Data

Thermal resistivity has the potential for significant impacts on design of the cable and requirements for trenching and backfill materials. A total of 663 thermal resistivity tests were completed as in-situ, field or laboratory based experiments according to ASTM D5334-14; the overall mean of the results was 0.5 $m.K/W$. This section documents outliers (those which fall greater than 2 standard deviations away from the mean) and indicates possible reasons for these results. Table 8.2 lists these outlier test results, locations, their respective CSC and also CGZ.

Table 8.2: Thermal Resistivity Outlier Test Results

Location	Depth [m BSF]	Soil Type	CSC	CGZ	Thermal Resistivity [m.K/W]	Remarks
B02-09-VC	1.1	PEAT	V	1d	1.555	▪ Field test
B02-14-VC	1.1	SILT	2	4a	1.034	▪ Field test
B02-14-VCA	1.1	SILT	2	4a	1.136	▪ Field test
B02-14-VCB	1.1	SILT	2	4a	1.425	▪ Field test
B02-24-VC	1.0	SAND	Ic	3c	1.318	▪ Laboratory test ▪ Low moisture content (2%)
B02-31-VC	1.0	SAND	IIb	3a	1.905	▪ Laboratory test ▪ Reconstituted sample
B03-07-VC	1.1	SAND	IIc	1e	1.188	▪ Field test
B03-11-VC	1.1	SAND	IIc	3c	0.961	▪ Field test
B03-12-VC	1.5	SAND	IIc	1b	2.105	▪ Laboratory test ▪ Reconstituted sample
B03-16-VC	1.1	SAND	IIc	3a	1.131	▪ Field test
B03-18-VC	1.1	SAND	IIc	3a	1.082	▪ Field test
B05-03-VC	1.5	PEAT	V	1d	1.202	▪ Laboratory test
B05-03-VC	1.1	CLAY	1	1d	0.909	▪ Field test
B05-04-TC	0.99	CLAY	2	1d	1.000	▪ In-situ test
B06-24-VC	1	CLAY	1	1c	0.936	▪ Laboratory test ▪ Reconstituted sample
B06-25-VC	1.1	CLAY	1	1d	0.960	▪ Field test
B07-07-VC	2.5	CLAY	1	1c	0.929	▪ Laboratory test ▪ Low submerged unit weight ($4.42\ \mathrm{kN}/m^3$)
B07-07-VC	1.1	CLAY	1	1c	0.923	▪ Field test
B07-08-TC	1.2	CLAY	V	1d	0.926	▪ In-situ test
B07-08-VC	1.1	PEAT	V	1d	0.990	▪ Field test
B07-25-VC	2.5	SAND	IIa	1b	1.282	▪ Laboratory test ▪ Low submerged unit weight ($1.38\ \mathrm{kN}/m^3$)
B07-40-VC	1.5	SAND	IIc	1b	0.990	▪ Laboratory test ▪ Reconstituted sample ▪ Low submerged unit weight ($3.54\ \mathrm{kN}/m^3$)
B08-10-TC	1.14	PEAT	V	1b	1.299	▪ In-situ test
B08-10-VC	1.1	PEAT	V	1b	1.445	▪ Field test
B12-38-VC	1.1	SAND	IIc	6b	0.887	▪ Field test
B14-17-VC	1.1	GRAVEL	IVc	5e	1.289	▪ Field test

Notes:
VC = vibrocore, TC = insitu thermal conductivity probe
CSC = Cable Soil Category (see Table 7.1), CGZ = Cable Geotechnical Zone (see Section 7)
Field test = test performed when core was recovered to deck using hand-held needle probe
Insitu test = test performed by insitu thermal conductivity probe
Laboratory test = test performed at Fugro laboratories

Several variants on the thermal resistivity laboratory test types were performed; these are stated in the Geotechnical Laboratory Report (J35045-R-RESF) and listed below:

- Undisturbed (TC) – performed offshore and onshore at 1.0 m BSF;
- Saturated (TC_{sat}) – performed onshore when the sample was considered to have dried out;
- Reconstituted (TC_{rec}) – performed on sands, reconstituted to a minimum dry density as determined from minimum/ maximum density test results;

- Remoulded (TC_{rem}) – performed on clays or silts, remoulded tests were performed at natural water content.

High recorded thermal resistivity values could be attributed to the following reasons:

i. Presence of peat (CSC V) or high organic content sediments;
ii. Variants in sample preparation: particularly for the laboratory based tests where low moisture contents and/ or density values were recorded based on saturated, reconstituted or remoulded samples;
iii. Equipment related inconsistency, for sediments with a high variability in sediment type (i.e. multiple secondary constituents).

For comparison, several locations which utilised the various test methods (field, laboratory and insitu) were compared. Table 8.3 lists a selection of these results. Comparison between the results shows a number of examples with good agreement between the test methods and others with a wider scatter in terms of absolute results. It therefore it should be considered that the number of outliers within the dataset is not unexpected given its size and the nature of the test methods being utilised.

Table 8.3: Thermal Resistivity Results – Test Comparison

Location	Depth [m BSF]	Soil Type	CSC	Test Type	Thermal Resistivity [m.K/W]
B04-08	1.1	SAND	IIa	In situ test	0.44
	1.1	SAND	IIa	Field test	0.66
	1.5	SAND	IIc	Laboratory test (rec.)	0.40
	1.5	SAND	IIc	Laboratory test	0.33
B05-22	1.0	CLAY	1	In situ test	0.43
	1.1	CLAY	1	Field test	0.64
	1.0	CLAY	1	Laboratory test	0.63
B06-31	1.0	SAND	IIa	In situ test	0.39
	1.1	SAND	IIa	Field test	0.64
	1.5	SAND	IIb	Laboratory test	0.36
	1.5	SAND	IIb	Laboratory test	0.38
B08-10	1.14	PEAT	V	In situ test	1.30
	1.1	PEAT	V	Field test	1.45
	1.5	SAND	IIb	Laboratory test (rec.)	0.47
	1.5	SAND	IIb	Laboratory test	0.45

Notes:
BSF = Below seafloor
CSC = Cable Soil Category (see Table 7.1)
Field test = test performed when core was recovered to deck using hand-held needle probe
Insitu test = test performed by insitu thermal conductivity probe
Laboratory test = test performed at Fugro laboratories
Rec = Reconstituted

Individual locations with anomalously high thermal resistivity values should be reviewed on a case-by-case basis, particularly in areas of PEAT (see Section 8.2.3), but consideration should also be given to the discussion in this section on possible reasons for the outlier values.

8.2.3 Locations Containing Peat/Organic Material

Sample locations which contain peat or organic material are understood to be of particular concern for the installation of a buried power cable. Table 8.4 contains details on soil layers which have been described as containing 'PEAT' and their relative thicknesses. Figure 8.3 presents an overview of these locations referenced against the route and the country boundaries.

Table 8.4: Geotechnical Locations Containing Peat Along Route 4 (rev.10)

Location	Top Depth BSF [m]	Thickness [m]	Description
B02-09-VC	0.90	0.24	Spongy pseudo-fibrous very dark grey PEAT
B03-06-VC	1.35	0.55	Spongy fibrous very dusky red PEAT
B03-28-VC	2.15	0.45	Very dark brown spongy pseudo-fibrous PEAT with traces of coarse gravel-sized pockets of fine to medium sand
B06-19-VC	4.50	0.15	Spongy fibrous very dark grey PEAT
B06-24-VC	3.32	0.07	Spongy fibrous very dark brown PEAT
B06-30-VC	0.60	0.05	Spongy fibrous very dark brown PEAT
B07-02-VC	4.35	0.15	Spongy fibrous very dark greyish brown PEAT
B07-08-VC	1.40	0.5	Spongy fibrous very dark brown PEAT
B07-18-VC	1.45	0.3	Spongy fibrous dark brown PEAT
B07-22-VCA	1.15	0.65	Firm fibrous very dark brown PEAT - from 1.15 m to 1.60 m with extremely closely spaced to very closely spaced thin to thick laminae of fine sand
B07-24-VC	0.70	0.15	Spongy fibrous very dark greyish brown to black PEAT
B07-25-VC	2.40	0.6	Spongy fibrous dark greyish brown PEAT
B07-28-VC	0.60	0.2	Spongy fibrous black PEAT
B08-10-VC	0.50	0.5	Spongy fibrous very dark brown PEAT with medium to coarse gravel-sized pockets of dark grey fine sand
B08-10-VC	1.05	0.15	Spongy fibrous dark brown PEAT with traces of fine gravel-sized to medium gravel-sized pockets of plant material
B08-16-VC	0.30	0.3	Spongy PEAT with closely spaced thick laminae of grey silty clay
B09-20-VC	1.10	0.13	Very dark brown spongy fibrous PEAT with few coarse gravel-sized to cobble-sized wood fragments - with slight H2S odour
B15-05-VC	3.55	0.25	Spongy fibrous PEAT, with coarse gravel sized fragments of very dark brown wood.
B15-06-VC	1.05	0.55	Very dark brown spongy fibrous PEAT, with coarse gravel sized fragments of wood

It is important to note that peat may be more widespread than where it has been sampled. This is expected particularly where it is associated with early Holocene clays, deposited during the subsequent marine transgression. This episode may have buried or partially removed peat in some areas.

Figure 8.3: Occurrences of Peat along Route 4 (rev. 10), denoted as orange circles at 19 locations

9. GEOMORPHOLOGICAL FEATURES AND PROCESSES

9.1 General

In addition to the review of geotechnical conditions along the centreline of Route 4 (rev.10), (Section 7), consideration was given to the geomorphology of the seabed and its potential impact on cable installation and burial. Four main types of geomorphological feature were selected:

i. Areas of subcropping to outcropping bedrock;
ii. Areas of numerous boulders;
iii. Areas of seabed dip greater than 5 degrees;
iv. Areas of potential sediment mobility.

The features listed above, in Table 9.3 and discussed in this section are presented on Alignment Charts 1 to 141, relative to the centreline. For discussion of the seabed features interpreted across the route corridor, refer to Section 4.

The Integration Team of Fugro, responsible for this report, reviewed the data during acquisition. As part of this review, potential areas for rerouting consideration were identified and passed to the Viking Link team as a technical note (Fugro 2016b). The contents of the technical note are presented within this section, and where appropriate, updated to reflect current understanding.

9.2 Areas of Subcropping to Outcropping Bedrock

Two possible areas of subcropping to outcropping bedrock were identified during the course of the geophysical survey operations and data interpretation, one of these being subsequently ground truthed by geotechnical sampling:

i. KP 90.590 to KP 90.620;
ii. KP 549.770 to 551.240.

The first instance of sub to outcropping bedrock was discounted following further investigation of seafloor character. The second occurrence containing outcropping chalk was sampled at B14-02 and is located in the Inner Silver Pit, a surface channel extending from the Wash (eastern UK) which has eroded into the underlying geological formations. For further discussion on this feature, including illustrations refer to Section 9.10.

This instance of sub to outcropping bedrock total 1.47 km, approximately 0.23%, of Route 4 (rev.10). Other instances of sub- to outcropping bedrock cannot be discounted in the UK Sector, especially in areas where geophysical profiler data quality or penetration is poor.

Instances of extremely high strength subcropping glacial till are demarcated based on cable geotechnical zones containing cable soil category 4 (CGZ 4d, 5d, 5e, 7a). If deemed appropriate, ‘Areas of Subcropping to Outcropping Bedrock’ can be updated to include these areas of sub- to outcropping glacial till with shear strength greater than 150 kPa.

9.3 Areas of Numerous Boulders

Numerous side-scan sonar contacts were interpreted as boulders. These measure in excess of 0.1 m in any axis. Areas of numerous boulders were defined based on the offshore interpretation and relates to areas where boulder density exceeds 1%.

Route 4 (version 10) centreline crosses 9.150 km of areas of numerous boulders. This equates to 8.300 km or 1.3% of DK to LF1, and an additional 0.850 km of Point D to LF2. Most of these areas are in the UK Sector between KP 540 and landfall. The density of boulder contacts interpreted in the UK sector can be attributed to cobbles, boulders and associated debris eroded from the underlying glacial till. The varying densities reflect the potential for surface sediment mobility and changes in underlying till composition.

9.4 Seafloor Gradients Greater than 5 Degrees

Areas of seafloor with gradients greater than 5 degrees require consideration for the progress of seafloor installation equipment such as jet-sledges. The Southern North Sea is predominantly flat and featureless and the majority of the route in the Danish, German and Dutch Sectors contains seafloor gradients not exceeding 2 degrees. Areas where dip does exceed 5 degrees generally correspond with bedforms such as sand waves.

The total length of route with seabed dip beyond 5 degrees is 0.79 km (0.13% of the route).

9.5 Areas of Potential Sediment Mobility

Along the cable route the potential for sediment mobility is proved by the presence of bedforms. Sediment mobility is an important consideration for cable installation in order to prevent damage to cables post-lay from scour, free-spanning or undesired burial. A sediment mobility assessment has not been undertaken as part of this study.

While large portions of the route are featureless, bedforms were identified on approximately 21% of the route. During the completion of the survey several large sediment waves were routed around, for further discussion on this please see Sections 9.6 and 9.9.

Table 9.1 summarises the bedforms present along the route, which can be divided into three groups based on sediment type, anticipated activity and size. Table 9.2 summarises Ashley's Bedform Classification Scheme (1990).

Table 9.1: Summary of Bedforms Along the Viking Link Cable Route

Sector	KP Ranges	Associated Sediment Type	Bedform Size (Ashley 1990)	Active/ Relict	Remarks
DK	37.0 – 102.0	Silt, fine to medium sand	Small to large	Active	Patchy distribution within KP range. Interpreted to be associated with siltier sediments with underlying clay
UK	467.8 – 483.6	Fine to coarse sand	Medium to large	Relict	Part of the Sand Hills Group, formed in the early Holocene and relict following continued sea level rise
UK	501.1 – 618.8	Fine to coarse sand	Ripples to very large dunes	Active	Patchy distribution within KP range. Highly mobile due to strong tidal currents.

Table 9.2: Classification of Dune Bedforms According to Ashley (1990)

Dimension	Classification				
	Ripple	Small	Medium	Large	Very Large
Wavelength (m)	<0.6	0.6 - 5	5-10	10-100	>100
Height (m)	<0.075	0.075 – 0.4	0.4 – 0.75	0.75 – 5	>5

In the Danish sector, sediment mobility is evidenced by localised areas of bedforms and scour features related to erosion. The features comprise scour pits/depressions and asymmetrical ridges some of which may be relict bedforms. These features are surrounded by smooth, low lying featureless seafloor which is interpreted to be a regional planation surface.

Sediment mobility in the UK sector is discussed in more detail in Section 9.9. Evidence for sediment mobility in each national sector is described in Section 4 of this report.

Table 9.3: Summary of Geomorphological Features and Associated Potential Considerations for Cable Installation

Geomorphological Feature	Description	Distribution along Route 4v10	Cable Installation Considerations
Areas of subcropping to outcropping bedrock	• Irregular seafloor morphology • Competent lithologies (bedrock, weathered bedrock) subcropping to outcropping at seafloor on subbottom geophysical data	1.47 km (0.23%)	• At the boundary with older strata, a step increase in various geotechnical parameters and a change in sediment type is expected, particularly related to weathered bedrock • The presence of hard seabed material may also act as a focus for benthic communities. These may be environmentally protected and may result in a requirement for avoidance
Areas of numerous boulders	• Interpretation of the side scan sonar data indicates density of seabed boulders (over 0.1 m in height) is greater than 1%	9.15 km (1.5 %)	• Boulders may present a direct obstruction to cable installation techniques and may pose problems during spoil removal as they may block suction tubes, or may be immobile if large enough • Hard seabed material such as boulders may act as a focus for benthic communities. These may be environmentally protected and may result in a requirement for avoidance
Seafloor gradients greater than 5 degrees	• Often associated with the presence of subcropping older strata and bedforms	0.79 km (0.13%)	• Steep slopes may pose cable spanning and flexing issues
Areas of potential sediment mobility	• Areas of very loose to loose sediment (typically fine to coarse sand) which have the potential for mobility though general near bed current activity or storm activity • Typically sinuous, discontinuous ridges (or dunes) up to 12 m in height (UK Sector) • Also found as large ripple fields of average 0.5 m height and 25 m wavelength (UK Sector) • Pits, scours associated with siltier/clay sediments in DK sector	195.71 km (21.0%)	• Potential migration of sediment waves may result in exposure, spanning, and/or increased burial of the cable • Increased likelihood of sediment removal and cable exposure during the cable's engineering lifetime

Notes:
BSF = Below seafloor
* = 100% is defined as the total length of Route 4 (rev.10)

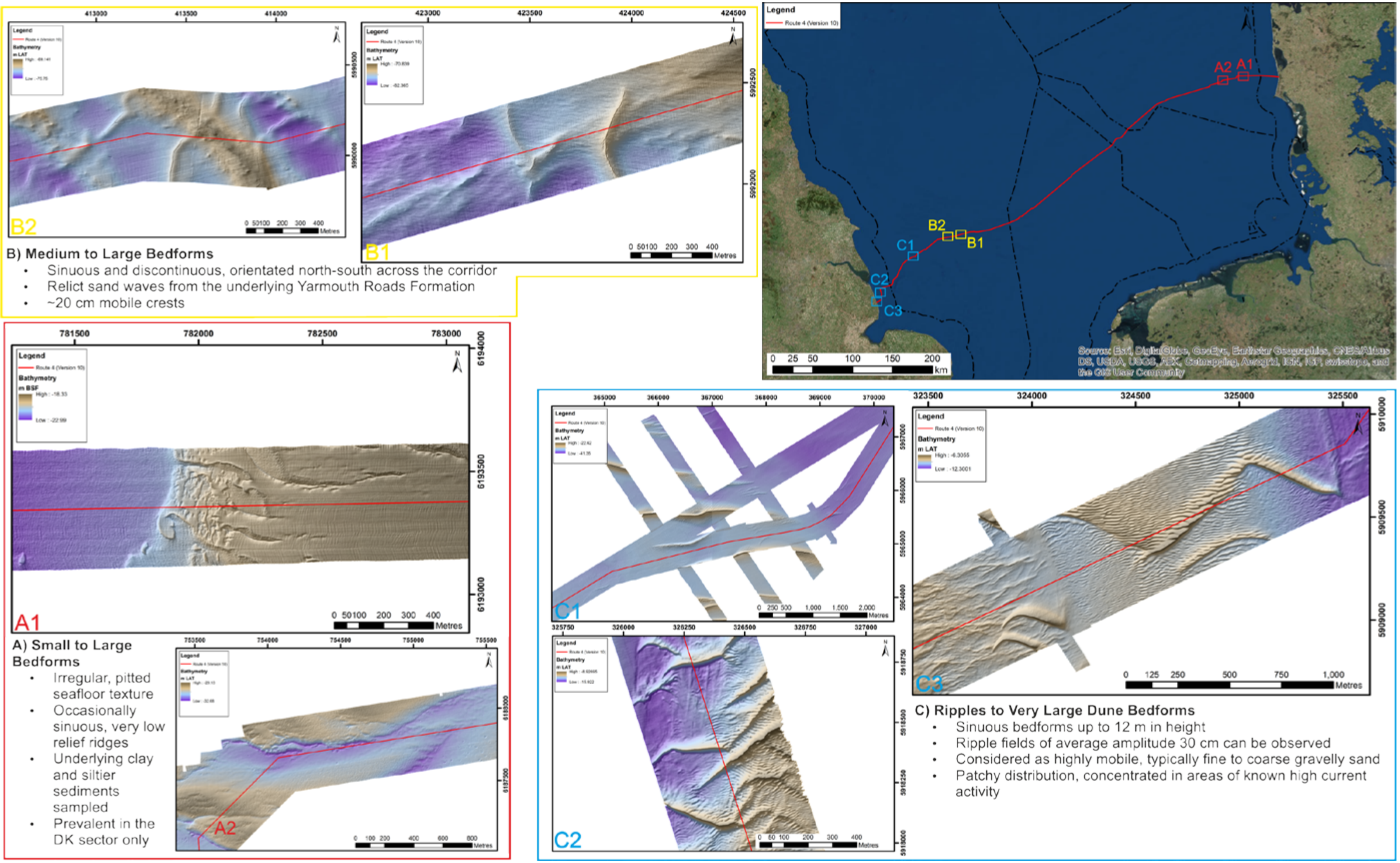


Figure 9.1: Examples of areas of potential sediment mobility along Route 4 (rev.10)

9.6 Routing Considerations (Fugro, 2016b)

This section provides commentary on the seabed and shallow subseabed features which, based on the view of the Integration Team of Fugro, required consideration for future routing, cable engineering and cable installation. The contents of this section were reported to Viking Link during the course of survey operations by means of a technical note (Fugro. 2016b). In some cases this has led to re-routing taking place.

Table 9.4 lists the features for consideration and the current status of any further investigations which are taking place on these features. Sections 9.7 to 9.11 discuss these features in order of increasing KP.

Table 9.4: Seabed and Sub seabed Features for Routing Consideration

First Chart No.	KP Start*	KP End*	Cable Geological Zone	Cable Geotechnical Zone	Description	Mitigation
82	361.3	369.0	C	5b/ 5e	Sub to outcropping competent strata	No action
86	379.0	380.8	C	5e	Sub to outcropping competent strata	No action
87	386.8	389.3	C	5e	Sub to outcropping competent strata	Re-route (Fugro Frontier, June 2016)
105	467.2	482.9	D	6	Relict sediment waves	Acquire more data to assess reroute (completed Fugro Frontier, July 2016)
113	501.0	545.9	E/ F	1	Sediment waves, mobile bedforms	Re-route (Fugro Frontier, June 2016)
124	548.9	550.9	E/ F	7	Sub to outcropping chalk strata	Acquire more data to assess reroute (completed Fugro Frontier, July 2016)
124	-	-	E/ F	7	Possibility of Sub to outcropping chalk strata	No action
128	565.0*	575.0*	F	N/A	Mussel bed	Acquire more data to assess reroute (acquired Fugro Frontier, July 2016)
137	602.0	611.0	F	1	Sediment waves, mobile bedforms	No action

Notes:
The proposed mitigation takes into account the clients responses to the issues raised in Fugro (2016b). 'No action' is stated where no follow up response (via Technical Queries, TQ's or similar) has been initiated
* Approximate location only, benthic inspection work with additional winglines
CGZ = cable geotechnical zone, and refers to the predominant classification in Section 7.6

9.7 Sub to Out Cropping Competent Strata

The British Geological Survey (Cameron et al., 1992) identifies several isolated instances of sub- to outcropping Bolders Bank Formation within Block 10. These are typically rounded or lenticular in shape, orientated east-west and less than 5 km in diameter. Sections 9.7.1 and 9.7.2 discuss three cases of sub to outcropping Bolders Bank Formation on the proposed route.

9.7.1 KP 361.300 to KP 369 and KP 379 to KP 380.800

Figure 9.2 and Figure 9.3 illustrates a sub-bottom profiler data example and the bathymetric profile where competent strata were identified close to seabed within possible trenching depth. This strata is interpreted to be part of the Bolders Bank Formation, interpreted as CGZ 5b or 5e containing very high to extremely high strength clay. This feature has little, if any, bathymetric relief and is surrounded by a widespread Botney Cut Formation channel (typically low strength (approximately 20 kPa) sandy clay to silty sand) as charted by the British Geological Survey (BGS, 2016).

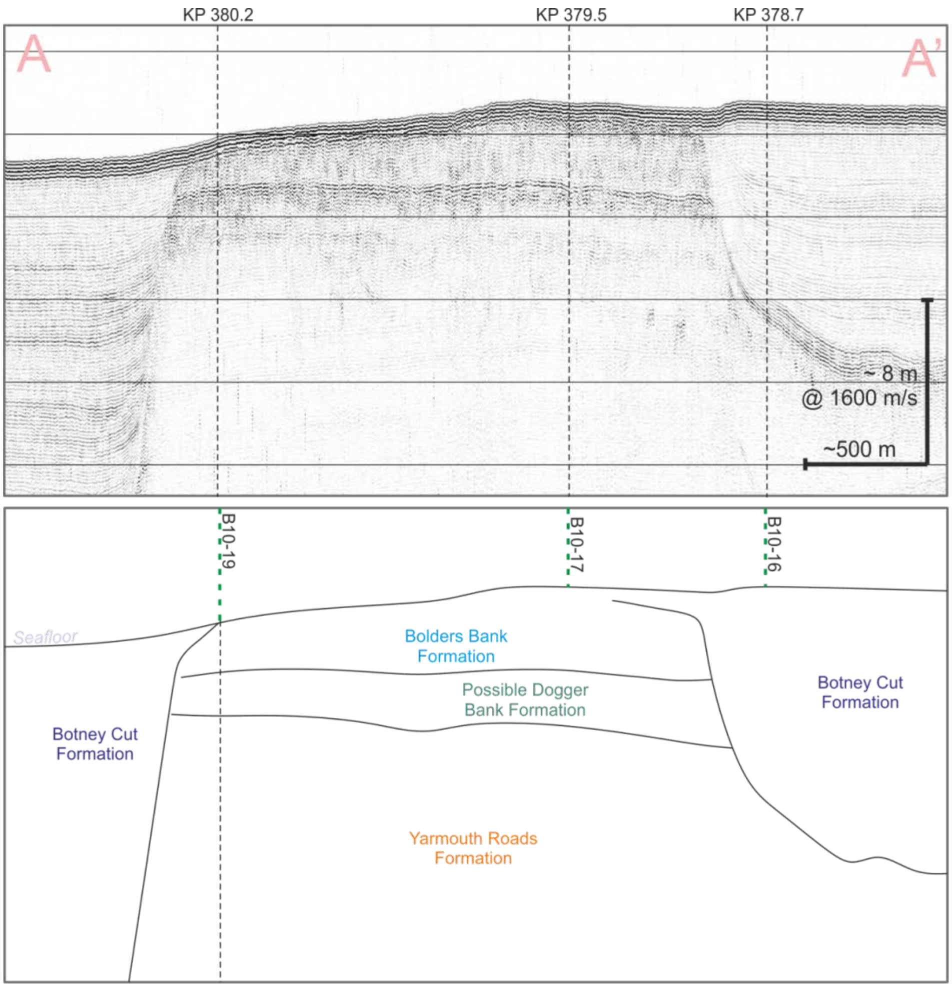


Figure 9.2: Profile in area of subcropping competent strata. Top: SBP data, Base: schematic interpreted SBP

Locations B10-17 and B10-18 were sited on the subcropping strata and index testing on the vibrocore samples indicate undrained shear strengths of up to 400 kPa. This compares to locations outside the feature sampling the interpreted Botney Cut Channel Formation (B10-16 and B10-19) which are composed of clayey silt to silty sand.

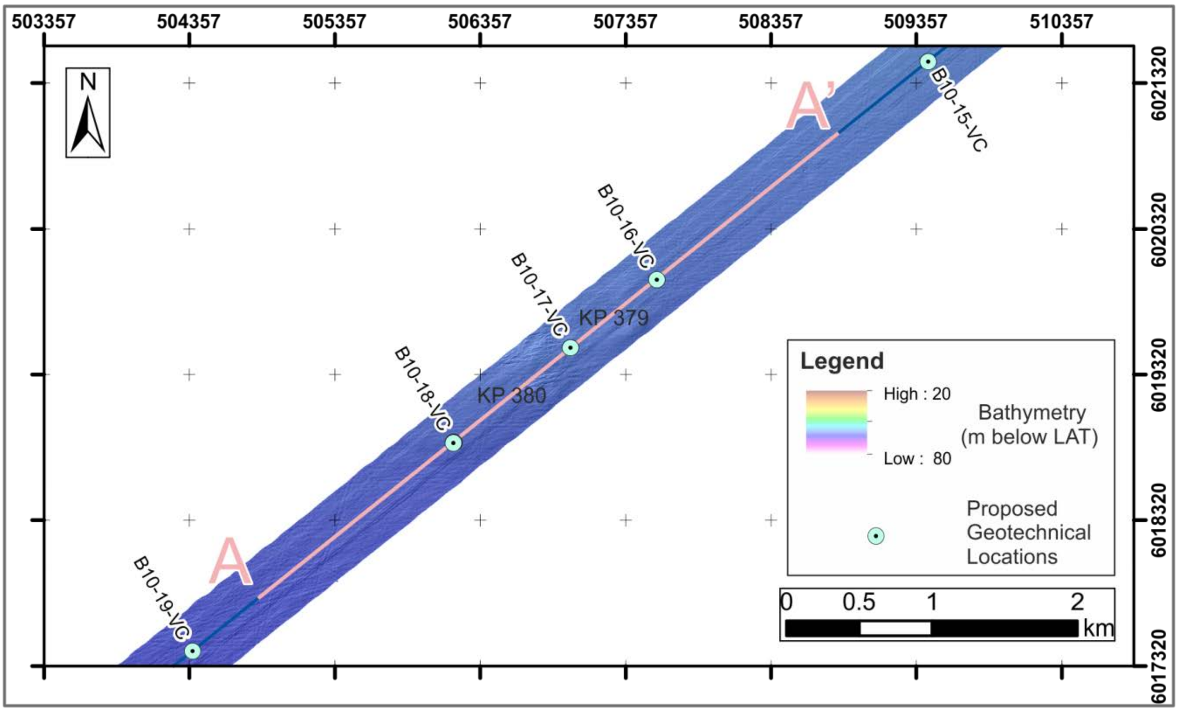


Figure 9.3 Bathymetry in area of subcropping competent strata

9.7.2 KP 386.800 to KP 389.300

Figure 9.4 and Figure 9.5 illustrate a bathymetric profile and SBP data example where a 3 km wide, 6 m high mound was identified. This mound is interpreted to represent an area of sub- to outcropping older, more competent strata surrounded by a widespread Botney Cut Formation channel, interpreted as CGZ 5e containing high to very high strength clay (75 kPa to greater than 150 kPa). Numerous sidescan sonar contacts are observed on the feature; these are interpreted as cobbles and boulders derived from glacial till.

Geotechnical locations B10-22 and B10-23 were sited on the mound and index testing on the vibrocore samples indicate undrained shear strengths of up to 450 kPa. This compares to locations outside the feature sampling the interpreted Botney Cut Channel Formation (B10-21 and B10-24) which are composed of silty to clayey organic-rich sand.

The proposed Viking Link cable route was modified to avoid this particular outcrop; other areas of sub-cropping Bolders Bank Formation were identified (Section 9.7.1) and should be considered during installation of the cable.

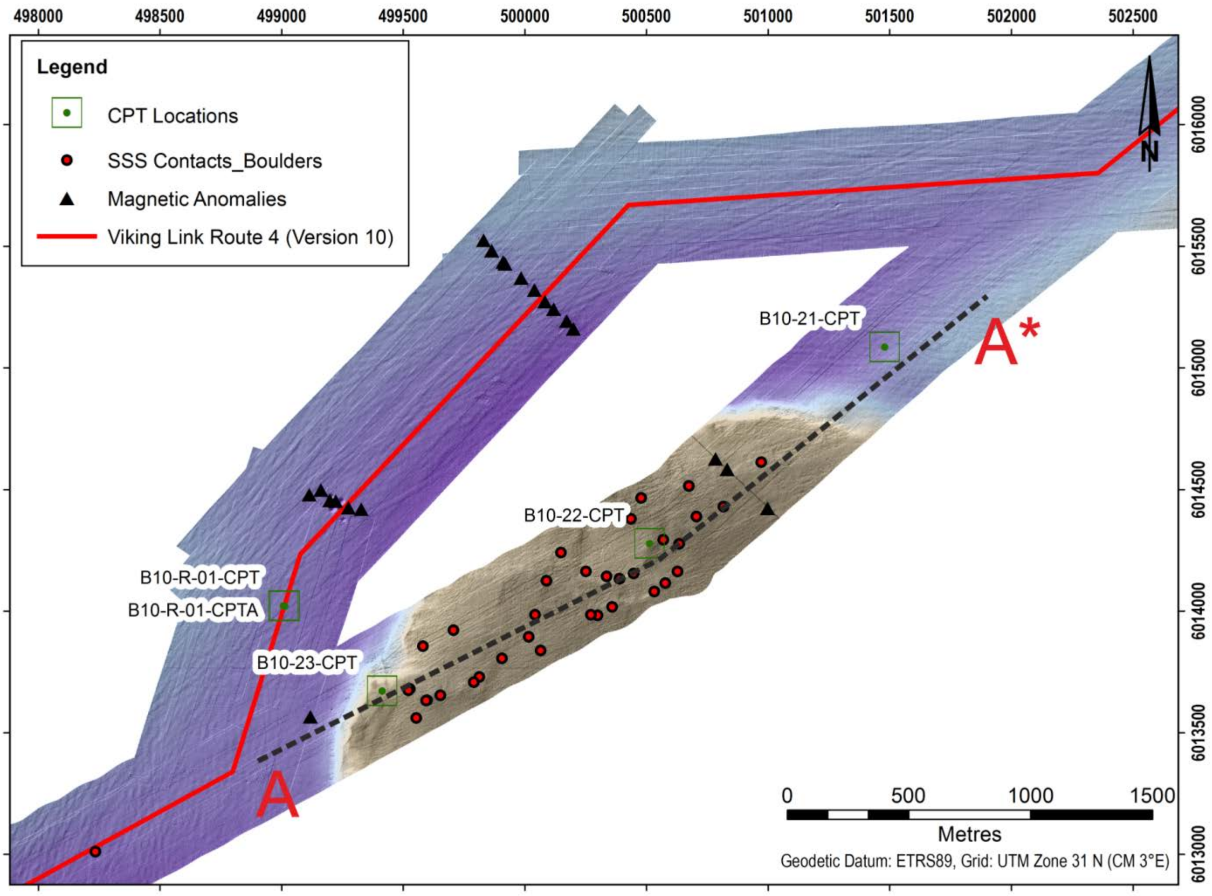


Figure 9.4: Sub to outcropping Bolders Bank Formation mound (KP 386.800 to KP 389.300), re-routed Route 4 (rev.10) presented

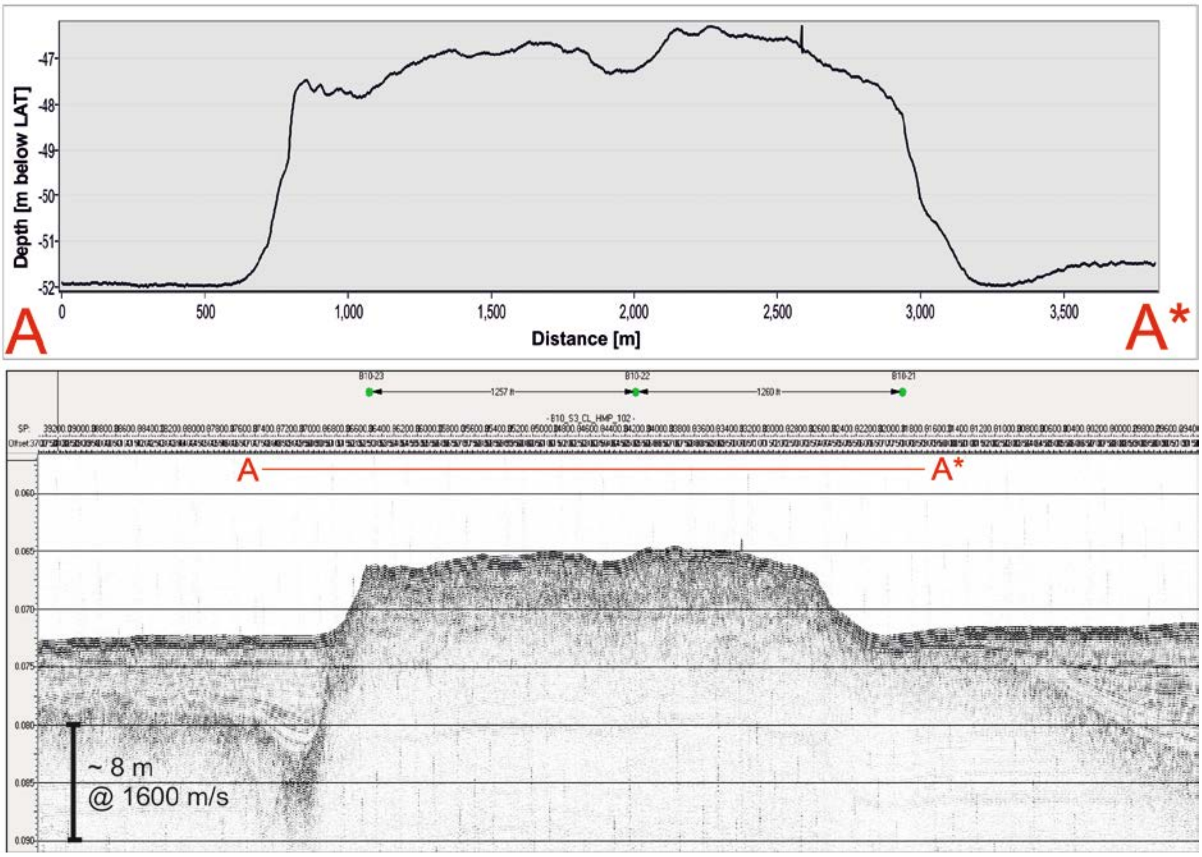


Figure 9.5: Sub to outcropping Bolders Bank Formation mound (KP 386.800 to KP 389.300). Top: cross section from 1 m bin-size MBES bathymetry. Bottom: SBP pinger survey line

9.8 Relict Bedforms (KP 467.500 to KP 482.900)

Sinuous, discontinuous ridges, typically orientated north to south, were identified over an approximately 15 km stretch of the route in the UK sector. These appear partially buried on MBES and SBP and are often associated with irregular, blocky seabed and exhibit a small (< 20 cm) ridge superimposed on, or just offset from, ridge crests facing north to west.

Originally interpreted to be glacially derived bedforms (eskers), a more detailed investigation into these features suggests that they are likely to be relict sandbank bedforms. It is interpreted that these features formed between 9000 years and 8700 years BP. In literature they are referred to as the Sand Hills group (Cameron et al., 1992; Gaffney et al., 2007). At this time the Outer Silver Pit was flooded during the early stages of an early Holocene marine transgression. The Outer Silver Pit, recently incised by meltwater, acted as a strait between sub-aerially exposed Dogger Bank and the mainland. It is interpreted that the area was hydrodynamically dominated by strong tidal currents. As sea levels continued to rise the features became relict and no longer controlled by metocean processes. The small remnant ridges at the present-day seabed may be the legacy a storm event, or other meteorological surge, which temporarily caused mobility of a surface layer of sediment.

Geotechnical data suggest that these bedforms comprise mainly shelly sand, likely to be at least in part derived from the underlying Yarmouth Roads Formation, which is present at or just below the seabed (CGZ 6). Rough seabed in the surrounding vicinity is thought to represent more competent layers of the Yarmouth Roads Formation which were more resistant to erosion during the subsequent glacial stages and Holocene marine transgression.

Figure 9.6 shows an example SBP pinger line through these features sampling undrained shear strengths of clay up to 250 kPa (CSC 4). Figure 9.7 illustrates a bathymetric image of the interpreted bedforms features.

Further geophysical data acquisition was undertaken to widen the survey corridor based on the observation of these features.

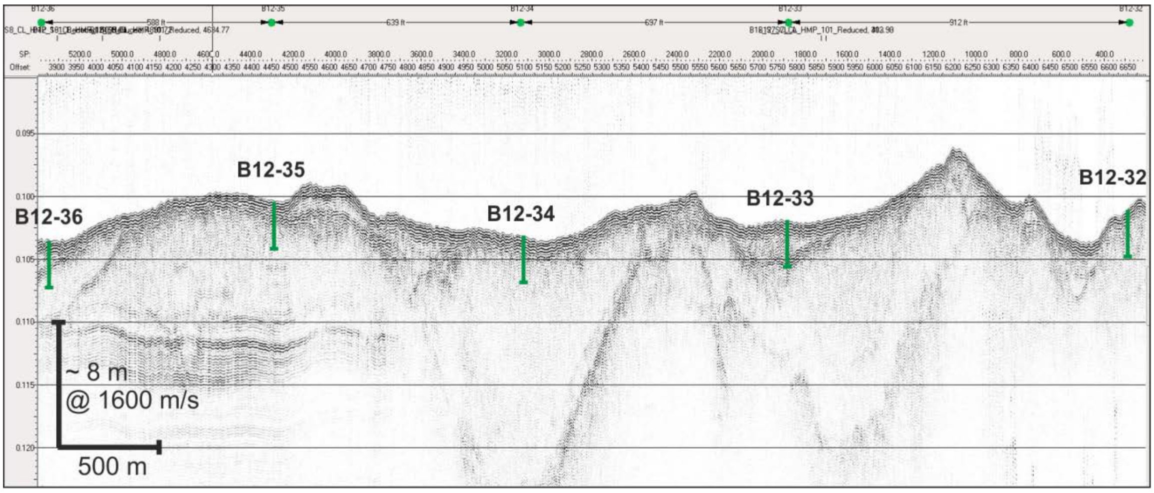


Figure 9.6: SBP pinger survey line through three features interpreted as relict bedforms. Each mound is superimposed on an underlying older strata subcrop

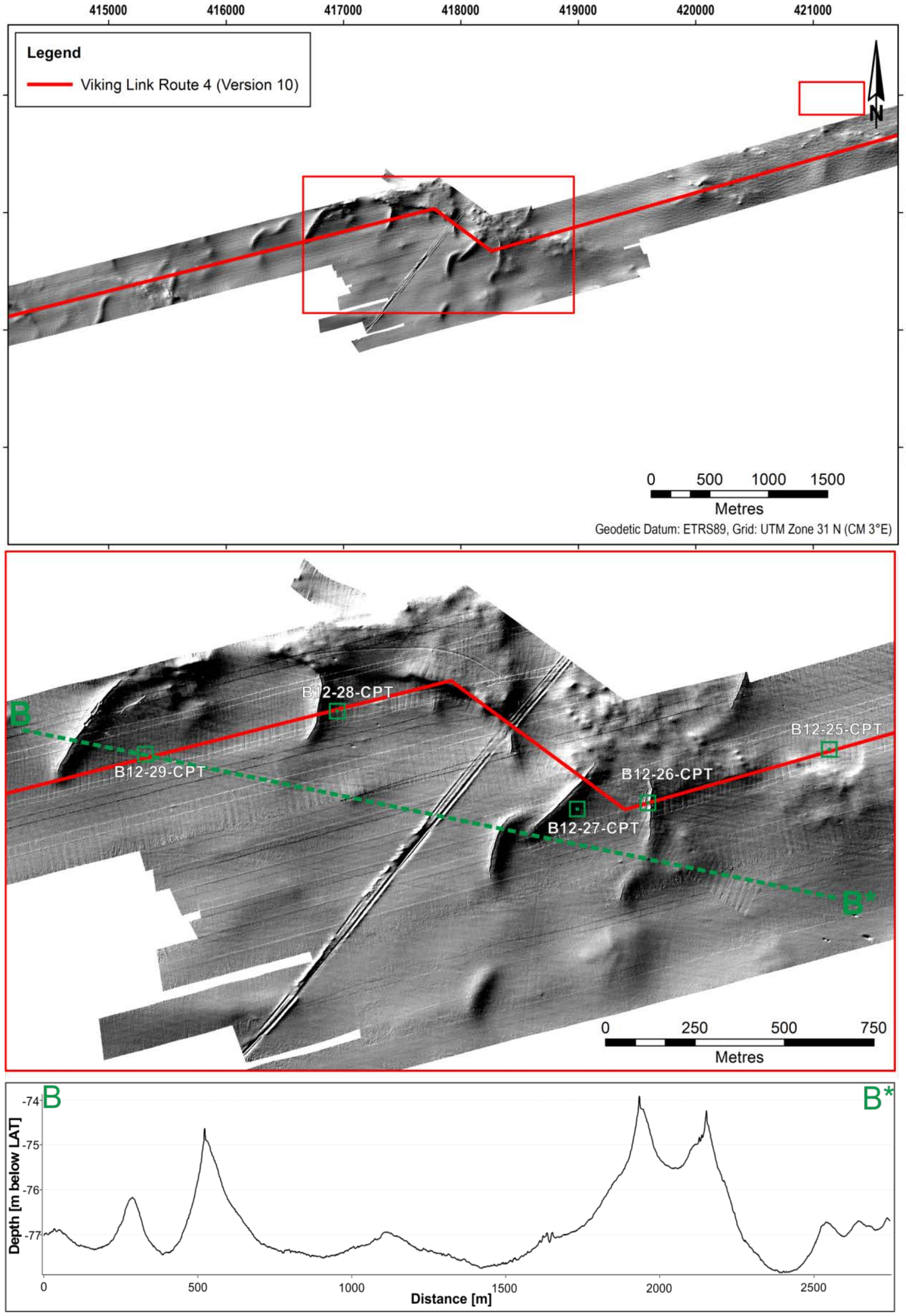


Figure 9.7: Interpreted relict sandbank bedforms, in Block 12 (KP 467.200 to KP 482.900). Top: hillshaded bathymetry (illumination from the north-west). Middle: zoom-in hillshaded bathymetry with annotated features. Bottom: cross section from 1 m bin-size MBES bathymetry line of section in top image

9.9 Sediment Waves and Mobile Bedforms (KP 501 to KP 545.900)

A distinctive seabed character was identified in the UK sector which can be attributed to mobile sediments arranged into sediment banks, waves and ripples. Between KP 501 and KP 545.900 there is an area of 0.25 m high ripples orientated north-east to south-west, parallel to the direction of the proposed cable route. These cease abruptly at KP 533.200, giving over to flat areas of seabed and larger sediment waves up to 12 m high.

Figure 9.8 illustrates a SBP survey line through the largest sediment wave. This region (Figure 9.9) contains a mobile Holocene veneer of sand- and gravel-sized sediments overlying medium strength clay of the Bolders Bank Formation. This in turn overlies either chalk or other older, more competent, strata (Section 6.6).

Route 4 (rev.10) was modified to avoid this feature and other large bedforms in the region. It is interpreted that this bedform is non-mobile following analysis of historical datasets from the area.

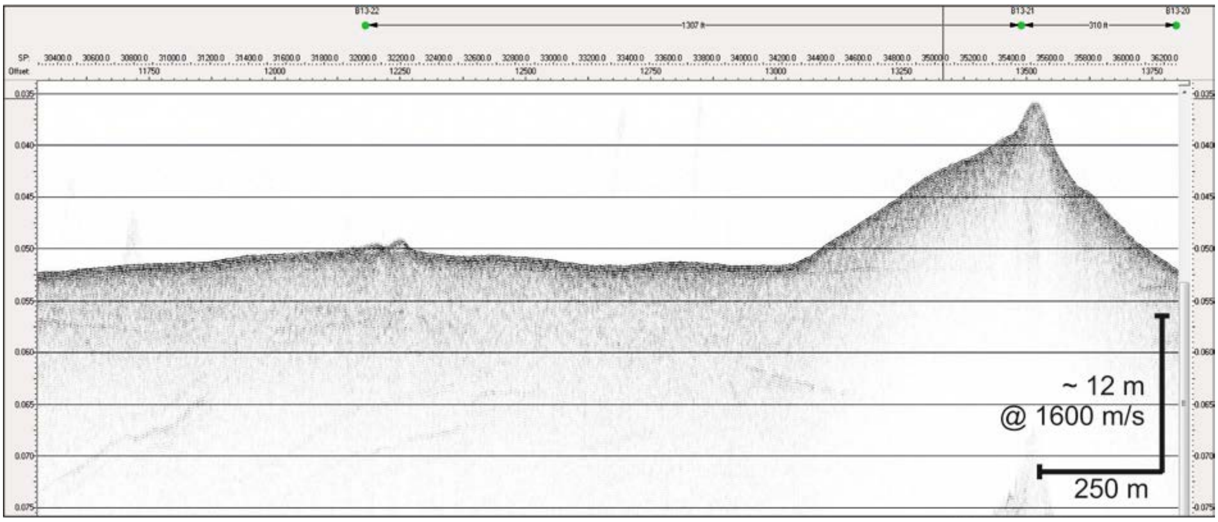


Figure 9.8: SBP pinger survey line across 12 m sediment wave (also imaged in Figure 9.9) Depth to base of interpreted Holocene veneer easily defined on the pinger dataset, note the dipping reflectors to the left of the image interpreted to represent subcropping chalk or older strata. This feature is not on the cable route centreline following rerouting

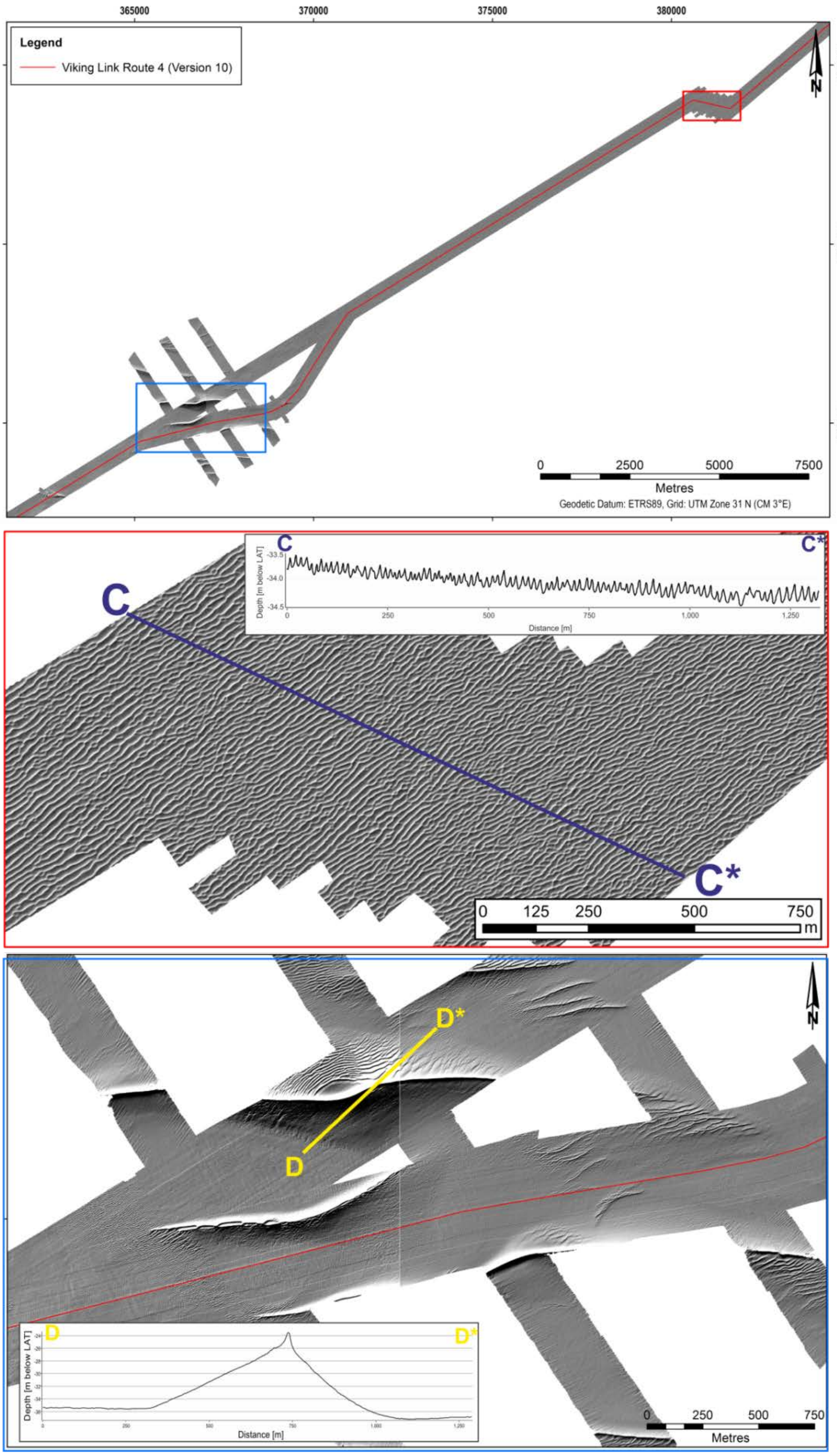


Figure 9.9: Mobile bedforms in Block 13. Middle: Sediment ripples approx. 25 cm high (approximately KP 517.000 to KP 518.000). Bottom: 12 m sediment wave (off route)

9.10 Sub- to Outcropping Chalk (KP 548.900 to KP 550.900)

Chalk bedrock outcropping at or just below seabed was identified between KP 548.900 and KP 550.900 on geophysical data and sampled at B14-02. The chalk at seabed is associated with a seabed channel. This bathymetric depression is the northern expression of the Inner Silver Pit, which is interpreted to be the historic channel of a river flowing north from the Wash, eastern England. Figure 9.10 shows the bathymetry of the depression and associated geotechnical locations and also a section of sub-bottom profiler data through the channel.

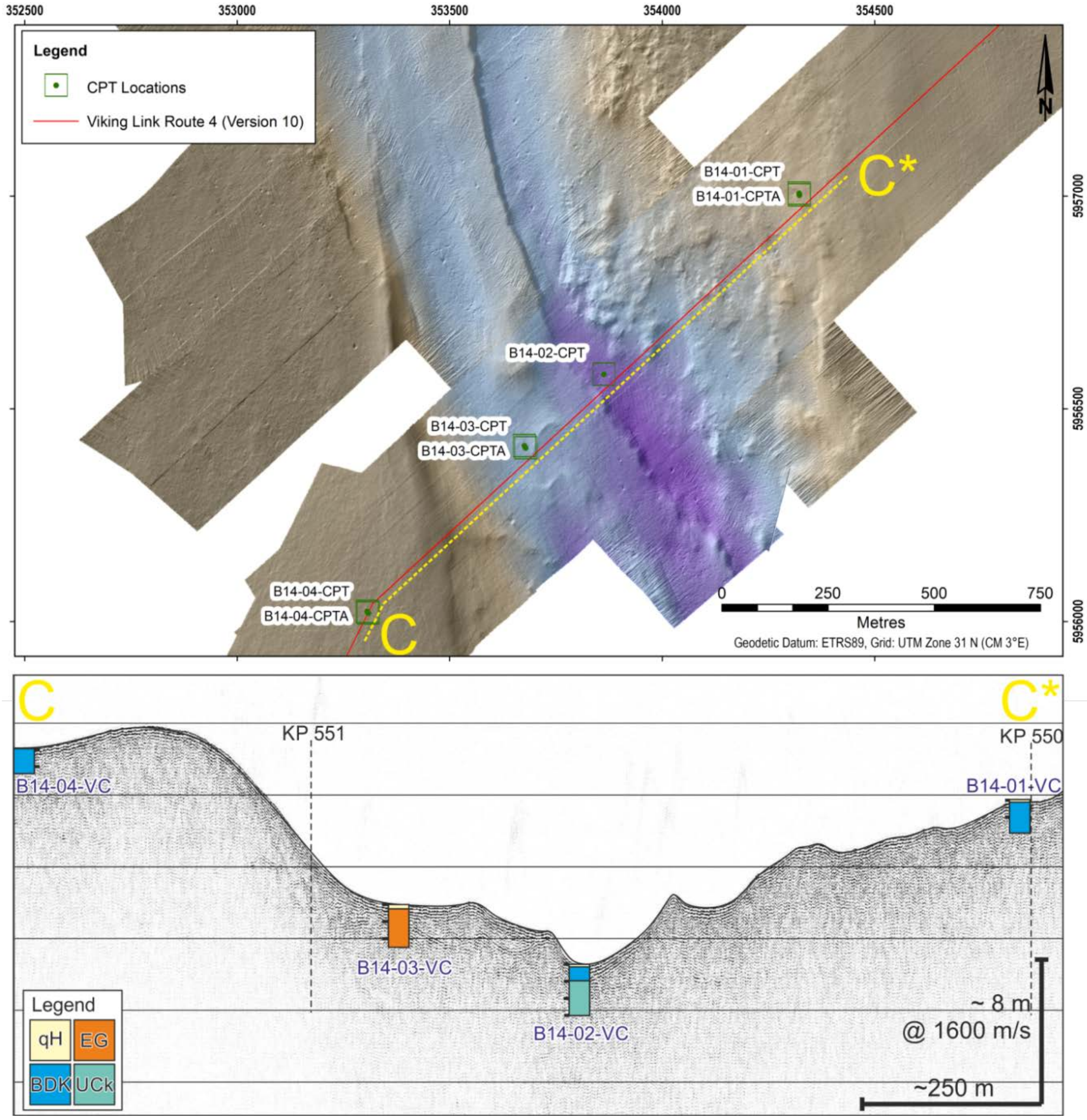


Figure 9.10 Top: Outcropping chalk at seabed. Bottom: Seismic data section across Silver Pit channel. Vibrocores interpreted based on expected geology in this location from preliminary offshore core logs. qH = Holocene, EG = Egmond Ground, BDK = Bolders Bank, UCk = Upper Chalk Group

9.11 Sub- to Outcropping Chalk: UK Sector

Areas of potentially sub- to outcropping chalk with limited glacial till cover were identified during preliminary geotechnical location selection in the UK sector. It is possible that these areas are of ecological and environmental significance.

The presence of exposed bedrock and gravel or cobbles at seabed, adjacent to areas of highly mobile bedforms, demonstrates strong metocean conditions within this block and adequate cable protection in this environment will be crucial as, depending on bedrock strength, conventional trenching may not be an option.

The sub-bottom profiler data is inconclusive with respect to clearly defining the presence of chalk versus stiff to hard clay such of the Bolders Bank Formation.

It is important to note that the only location that sampled chalk was B14-02, the remainder of the sample and test locations did not sample any bedrock.

9.12 Mussel Bed (KP 569.700 to 570.635)

Blue mussels *Mytilus edulis* were recorded along the Video Transects 14FTR20 and 14FTR21 as frequent to common. Due to the density of the mussels, these have been classified as mussel beds.

Additional transects were undertaken and analysed in order to delimit the extent of the mussel bed. Areas of live mussels have been presented in Figure 9.11, along with areas of empty shells and areas where no shells or live mussels were evident (defined as “Not Bed”).

The ecological importance of mussel beds is in their role in coastal sediment dynamics, acting as a food source for other organisms, and providing an enhanced area of biodiversity in an otherwise sediment-dominated environment (UK BAP, 2008). Sublittoral mussel beds are classified as a UK BAP Priority Habitat (Blue mussel beds on sediment), contained within Annex I feature reefs (biogenic), which is also a Marine Conservation Zone (MCZ) broad scale habitat, and listed within the MSFD Predominant Habitat: Shallow sublittoral rock and biogenic reef.

More details on the mussel beds can be found within UK Benthic Results Report (J35045-R-RESE.1).

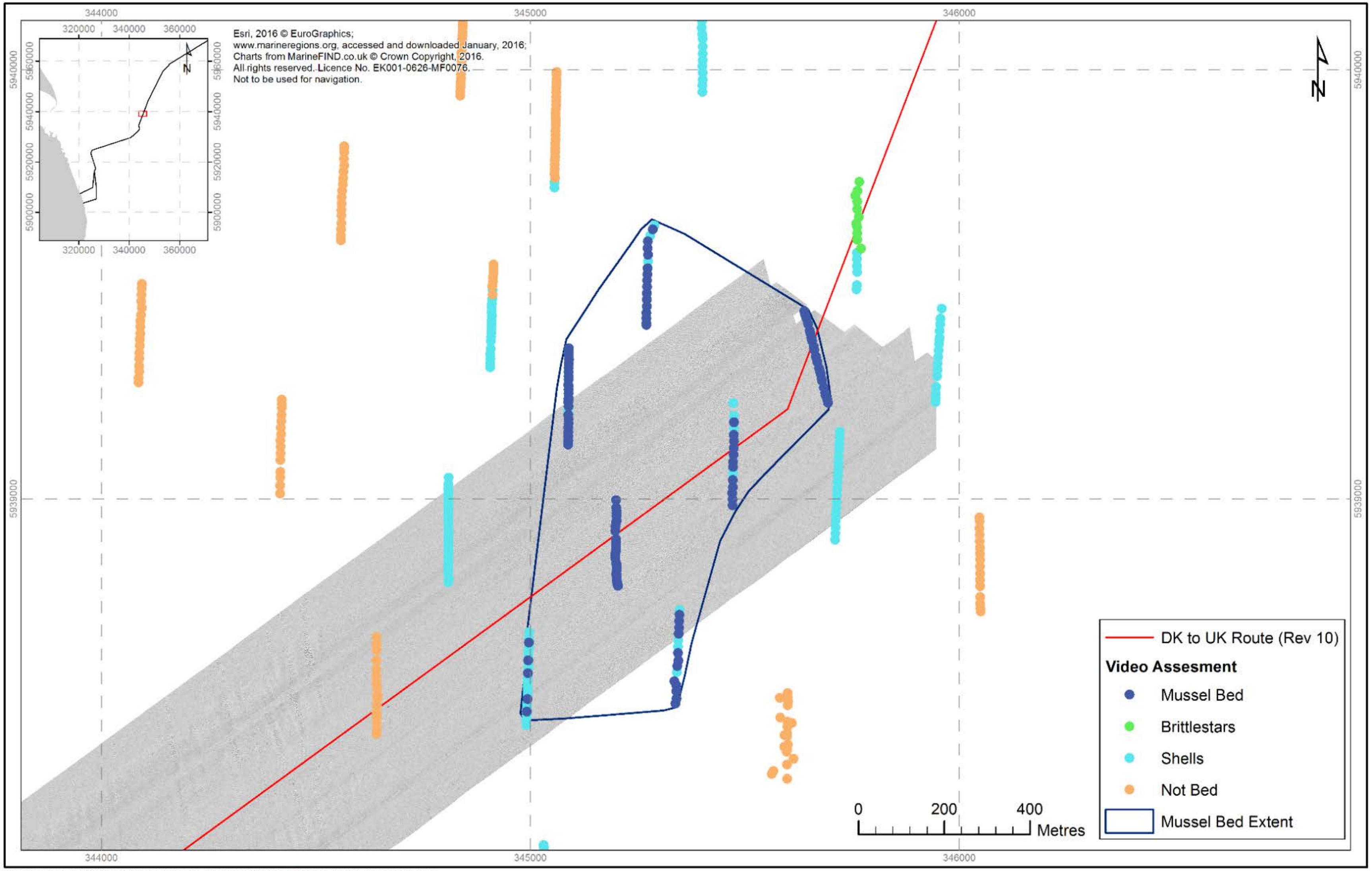


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Figure 9.11: Mussel bed extents

9.13 Sediment Waves and Mobile Bedforms (KP 602.000 to KP 611.000)

A distinctive seabed character was identified in the UK sector which can be attributed to mobile sediments arranged into sediment banks, waves and ripples. Between KP 602.000 and KP 611.00 an area of bedforms can be observed orientated approximately east-west, perpendicular to the direction of the proposed cable route. The bedforms are ripple- to small dune-sized (between 0.05 m and 0.30 m height with a wavelength of approximately 5 m to 9 m) and largely symmetrical, suggesting low net sediment transport, and morphology dictated by tidal processes. However, asymmetrical large dune-sized bedforms are also present (from approximately 0.60 m to 3.00 m height with a wavelength of up to 150 m). It is not known if these bedforms are fully mobile or if their mobility is restricted to seasonal strong currents and storm events.

Geotechnical location B15-06-CPT/VC suggests that the bedforms comprise very loose silty fine to medium sand, over a layer of very low strength clay and peat overlying more competent clay. It is likely that the peat and low strength clay is part of the Elbow Formation, and the more competent clay is a weathered surface of the Bolders Bank Formation. Figure 9.12 shows a geophysical cross-section containing this geotechnical location.

It is not possible from shallow seismic data to interpret the full extent of peat in this area, but it can be observed that in the North Sea, peat is often preserved:

- Within Palaeochannels; and
- Beneath sandbanks and bedforms.

Both of these features are present at this location; however peat is also present in location B15-05-CPT/VC above the channel fill deposits. It is therefore interpreted that the peat may be preserved anywhere within this section of mobile bedforms.

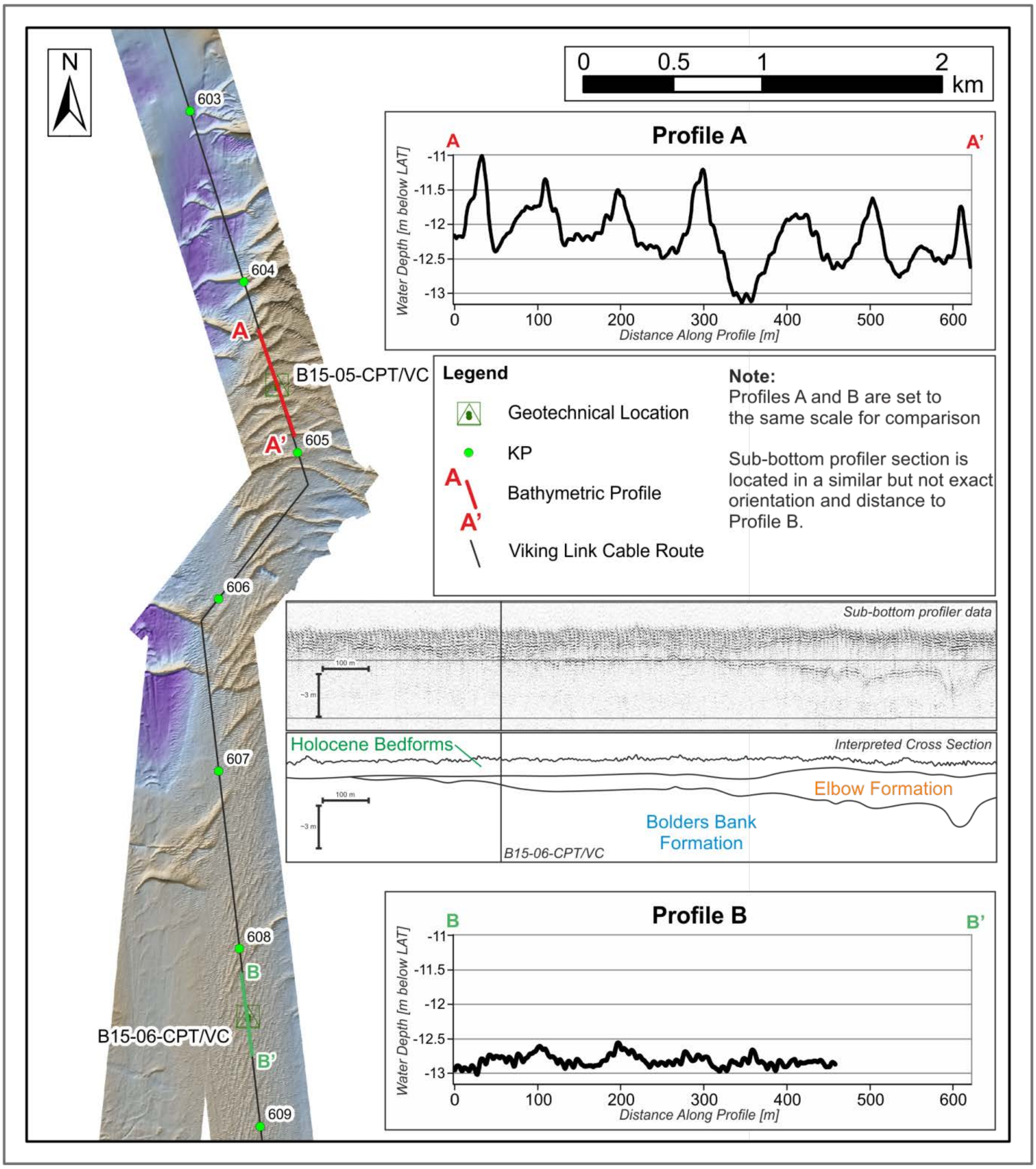

Figure 9.12: Sediment waves and mobile bedforms (KP 602 to KP 611)

10. CONCLUSIONS

10.1 General

This section presents some conclusions of the cable route survey. A detailed synopsis of the survey results can be found in the executive summary, this set of conclusions focuses on exceptional factors which might affect planning and broad characterisation of typical conditions. The content of this section should not be directly used for planning.

10.2 Geological Framework

The geology across the Viking Link cable corridor has been affected by numerous glacial and interglacial cycles throughout the Quaternary, particularly within the last 550 ka. This has led to deposition taking place in a wide range of environments, including glacial and periglacial, fluvial, estuarine, deltaic and marine. In turn these diverse sediments have been affected by post-depositional processes including desiccation, overconsolidation, erosion and reworking. Ten geological formations, as described by the British Geological Survey, were identified from geophysical and geotechnical data along the route ranging from Upper Cretaceous Chalk to recent surficial sediments.

10.3 Route Conditions

The Danish land section is approximately 250 m long and comprises an unexceptional sandy terrain with an 8 m high bank of sand dunes between KP 0 and KP 0.070 the only feature of note.

The offshore Danish sector (ending KP 210.795) is characterised by a generally gently sloping SAND/SILT seabed. The atypical feature of this area is the seabed scouring which has generated numerous short, steep slopes. It is beyond the scope of this study to comment on the conditions leading to scour in this area or how frequently scour might occur. Owners/operators of existing seabed infrastructure in the areas affected by scour may be able to advise on this matter: 12 existing cables and pipelines cross the route in the Danish sector. Water depths in the Danish sector reach a maximum of 51.9 m. Shallow geology consists of a generally 1 m to 3 m thick layer of SAND over CLAY with SAND or dense SAND. Peat layers were regularly found in Danish and German sector vibrocores.

The German Sector is only 28.322 km long with less than 2 m variation in water depth. Surface sands overly dense silty SAND with sharply eroded channels infilled with SILT or CLAY. Two pipelines cross the route in the German sector.

The Dutch sector extends from KP 239.117 to KP 403.341. Water depth ranges from 41.2 m at KP 243 to a maximum of 56.1 m at KP 402.700. The seabed is very smooth with dip rarely reaching 1°. The most notable feature of this route sector is a steel wellhead standing clear of the seabed 9 m north-west of KP 389.017. The shallow geological sequence consists of a discontinuous layer of SAND over dense SAND or CLAY with peat found in vibrocores to KP 338.200.

9 cables and pipelines cross the route within the Dutch sector.

The UK sector of the route runs from KP 403.341 to the western extremity of the route, the UK landfall. The route splits into northern (LF1) and southern (LF2) route options at KP 611.704. A combination of large scale sand waves, ancient erosion features (Inner and outer Silver Pits) and glacially influenced geology means that the UK sector shows greater bathymetric and geological variation than the remainder of the route.

Water depth reaches a maximum of 86.6 m at the base of the Outer Silver Pit at KP 472.740; seabed dips reach ~10° in this area. CHALK bedrock is at or close to outcrop with the axis of the Inner Silver Pit at KP 551.

The glacial tills contain numerous boulders which are particularly densely distributed over the westernmost 50 kilometres of the route.

20 cables and pipelines, all of which are in-service, cross the route within the UK sector.

The LF1 route ending is positioned on a concrete seawall at an elevation of 9 m, a golf course lies to the west. The LF2 option also terminates on a seawall with a nature reserve to the west. The beaches at both landfall options are sand-prone and unexceptional.

10.4 Environmental Assessment

10.4.1 Seabed Sediment conditions

Results of grab samples analysis showed that the survey area within the UK sector comprised a mixed range of sediment types from well sorted sands to very poorly sorted muddy sandy gravel. A broad pattern of sediment distribution was identified, with more heterogeneous sediments characterising nearshore stations whereas offshore stations comprised predominantly muddy sand. Sediments across the Dutch sector were predominantly sands with varying proportions of gravel, and mud, with coarser material observed along three transects to the west of the sector. Sediments across the German sector survey area were dominated by sand with minor gravel and mud fractions, and shell fragments. Sediments within the Danish sector were dominated by the sand fraction, with some variation in the gravel and mud fractions present at each station, with coarser material observed f along six transects to the east of the sector.

10.4.2 Sediment Chemistry

Across the chemistry samples, most metal concentrations were below the Cefas (Centre for Environment, Fisheries and Aquaculture Science) (2003) Action Level 1 (AL1) and Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) Effects Range Low (ERL) values and all total hydrocarbon concentrations were below the Cefas AL1 values, therefore, are considered to be of little concern with respect to possible effects on the marine environment. The high pristane phytane ratios (Pr:Ph) across the cable route indicate that the sediments are not likely to be contaminated.

10.4.3 Macrobenthic Communities

Within the UK sector survey area, the epibiotic communities reflected the sediment complexity, with the offshore sandier sediments hosting lower faunal diversity represented mainly by fish, echinoderms, crustaceans and molluscs, with sessile epifauna being absent or scarce. The nearshore coarser sediments comprised a rich and diverse epibenthic community which included a variety of sessile epifauna.

Sparsely distributed fauna was recorded throughout the Netherlands, Germany and Danish sectors with species of starfish (sand star *Astropecten irregularis* and common starfish *Asterias rubens)* and hermit crab Paguridae included within the most commonly observed epifauna. Areas of coarser sediments in the Dutch sector were found with a greater diversity and abundance of epifauna species, which included dead man's fingers, *Alcyonium digitatum*, brittlestars, *Ophiothrix fragilis*, Dahlia anemone, *Urticina felina* and hydroid/bryozoan turf.

Within the UK sector, Annelida were dominant in terms of taxa composition and abundance. Along the rest of the cable route, Annelida were dominant in terms of taxa composition, however, in terms of abundance, Echinodermata were the most dominant, with a high percentage attributed from the abundance of one brittlestar species *Amphiura filiformis.*

Within the trawl samples collected in the German sector, fish species made up the majority of the taxa (37% of the total) and biomass (70% of the total), however, with regards taxonomic abundance, echinoderms were the most numerous (66% of total). Overall, all the species recorded are associated with sand dominated sediments and were generally comparable between trawls.

Combined with the video analysis, which identified epifaunal communities and seabed conditions not sampled by the singular grab along a transect, a total of 22 European Nature Information System (EUNIS) biotopes (EEA, 2016) were identified along the cable route, of which the most common were "*Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud" (A5.351) (present within all sectors) and *"Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand" (A5.242) (present within the UK and Danish sectors).

10.4.4 Species and Habitats of Conservation Interest

An area of mussel bed was recorded within the UK sector (Alignment chart 125). Sublittoral mussel beds on (sublittoral) sediment (A5.62) is a new UK BAP Priority Habitat (Blue mussel beds on sediment). Sublittoral mussel beds are contained within the Annex I feature reefs (biogenic).

Within the UK sector, a total of six stations were observed with high abundances of *Sabellaria spinulosa*, however, they were classified as 'Not Reef'.

Stony reef assessment was carried out at 16 UK, 3 Netherlands and 6 Danish sector stations, of which 11 UK and 3 Danish sector stations were classified as "low" resemblance to stony reef.

An area known as the Central Oyster Grounds is present within the Dutch sector. Although the area is not formally protected, it has been identified as an area of high biodiversity and biomass. This area is known not to sustain native oyster populations but does support populations of the OSPAR protected ocean quahog. Only one juvenile ocean quahog was identified from a grab sample. Ocean quahog are listed as declining by OSPAR. During the current study, species diversity and biomass recorded from the grab samples within the Central Oyster Grounds were found to be generally comparable to the stations outside of this area.

In addition, 11 juvenile ocean quahogs were recorded in the Germany grab samples, one ocean quahog individual (80 mm) in the Denmark grab samples and empty ocean quahog shells in three Danish sector video transects. This is important as the species is listed on the OSPAR 'List of Threatened and Declining Habitats and Species', due to its slow growth and maturation rates, low fecundity and sporadic recruitment and vulnerability to physical disturbance or substratum loss.

Across the cable route, 11 species of fish and one species of shellfish (Norway lobster) recorded in the current survey are on the IUCN red list for threatened species. All of these species are listed as species of 'least concern', with the exception of Dover sole, which is considered 'data deficient'.

In addition, sand eels of the Ammodytidae family were recorded in the UK and German sectors, which have potentiall to be the lesser sandeel *Ammodytes marinus,* a UK Biodiversity Action Plan (BAP) priority species (JNCC, 2016).

10.4.5 Water Profiles

Within the UK and Danish sectors, the water column profiles indicated well mixed layers of water. Within the Dutch sector, a medium to weak stratification of the water column was observed at the majority of stations, with warmer, more oxygen saturated and often more saline waters at the surface. In the German sector, the water column profiles indicated a medium to strong thermocline and oxygen boundary column was observed at all stations, with warmer, more oxygen saturated and often more saline waters at the surface.

10.5 Cable Geological Zonation

A cable geological zonation was completed to provide a high level overview of geological formations and depositional environments (and subsequently prediction of geotechnical conditions) along the cable route to a depth of 3 m below seafloor. The geological zonation was based on bathymetry and sub-bottom profiler data, and later integrated with geotechnical data (Section 7). The geological zonation provides a rationale for the geotechnical conditions encountered along the route. Table 10.1 summarises the six geological zones identified during this project.

Table 10.1: Cable Geological Zonation along the Viking Link Cable Route

Zone	Kilometre Post Range and Percentage	Identified Geological Formations	Generalised Soil Conditions
A	(Danish landfall) 0 to 136.5 (22.1%) 199.7 to 266.35 (10.8%)	Holocene marine deposits (clay, silt and sand) overlying Elbow Formation Early Holocene Palaeochannels Undifferentiated pre-Holocene deposits (dense sand and high-strength clay)	Loose to very dense clayey SAND with Medium to high strength SILT/CLAY and Possible localised PEAT
B	136.5 to 199.7 (10.2%) 399.5 to 464 (10.4%)*	Holocene marine deposits (silt and sand) Palaeo-Elbe Estuary deposits (silt, sand and clay) Outer Silver Pit Estuary (?) deposits (silt, sand and clay)	Loose silty SAND/sandy SILT overlying Low strength organic-rich CLAY and Possible localised PEAT

Zone	Kilometre Post Range and Percentage	Identified Geological Formations	Generalised Soil Conditions
C	266.25 to 399.5 (21.6%)	Holocene marine deposits (silt and sand) Elbow Formation Early Holocene Palaeochannels Botney Cut Formation Bolders Bank Formation Dogger Bank Formation Cleaver Bank Formation	Loose to dense clayey gravelly SAND with Low to high strength sandy SILT/CLAY and Possible localised PEAT
D	393.0 to 394.5 (0.2%)‡ 398.0 to 399.5 (0.2%)‡ 403.0 to 404.0 (0.2%)‡ 464 to 486 (3.6%)	Holocene marine deposits (silt, sand and gravel) Early Holocene Palaeochannels Swarte Bank Formation Yarmouth Roads Formation	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY
E	486 to 549 (10.2%)	Holocene marine deposits (sand and gravel) Early Holocene Palaeochannels Bolders Bank Formation	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY and Possible localised PEAT
F	549 to 618.8 (UK landfall) (11.3%)	Holocene marine deposits (sand and gravel) Elbow Formation Early Holocene Palaeochannels Bolders Bank Formation Egmond Ground Formation Upper Cretaceous Chalk	Loose to dense SAND and GRAVEL with Low to high strength sandy CLAY with BEDROCK (Chalk) and Possible localised PEAT

Notes
* Geological Zone B and Zone C contain very localised subcrops of Geological Zone D
† Not mapped but inferred to be present based on regional literature
‡ Localised subcrop of these sediments within Geological Zone B and Zone C
Palaeochannels are identified across the length of the cable route and contain a range of fill materials, strengths and densities. The presence of peat or other organic-rich sediments within channels is also possible

10.6 Cable Geotechnical Zonation

A cable geotechnical zonation integrates geological, geophysical and geotechnical datasets acquired to form a predictive model of geotechnical conditions along the proposed route. These are designed to be applicable to future design and installation activities.

The output of the cable geotechnical zonation was the prediction of soil conditions to a depth of 3 m below seafloor (BSF) along the centreline of the Route. These consist of seven primary geotechnical zones, subdivided into 21 subzones and demarcate geotechnical conditions listed in Table 10.2.

Geotechnical parameters were derived for each of the cable geotechnical zones, namely: undrained shear strength, moisture content, submerged unit weight, fines content, plasticity index, relative density, effective angle of internal friction and thermal resistivity.

Table 10.2: Cable Geotechnical Zone (CGZs) Summary

CGZ	Description	Percentage of Route Applicable*	Number of sub-zones	Considerations
1	Recent to early Holocene intertidal to marine sediments (fine)	55.3%	5	▪ Increasing relative density (D_r) profiles from surface ▪ Extremely low strength, estuarine sediments within 3 m BSF ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
2	Recent to early Holocene marine sediments (coarse)	3.3%	1	▪ Increasing relative density profiles from surface ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
3	Recent to early Holocene marine sediments (mixed)	6.6%	3	▪ Changes in grain size with increasing depth ▪ Relative density inversions and cut-backs with increasing depth ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
4	Recent to early Holocene marine sediments overlying post-depositionally modified Late Quaternary sediments	1.8%	3	▪ Overconsolidated sediments, sub-aerially exposed ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
5	Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments	30.2%	6	▪ Overconsolidated sediments with coarser inclusions, glacial till ▪ Locally variable channel infill deposits, including unmapped coarse sand/gravel lag deposits or extremely low to very low strength clay/peat ▪ Unrecorded cobbles and boulders at seafloor
6	Recent to early Holocene marine sediments overlying Middle to Late Quaternary marine sediments	2.8%	2	▪ Expected to be Egmond Ground and/ or Yarmouth Roads Formation ▪ Unrecorded cobbles and boulders at seafloor
7	Recent to early Holocene marine sediments overlying Late Quaternary glacially derived sediments overlying Upper Cretaceous bedrock	<0.1%	1	▪ Exposed Upper Cretaceous CHALK, sampled in the Inner Silver Pit region ▪ Unrecorded cobbles and boulders at seafloor ▪ Could be expected to occur elsewhere along the route, particularly in the UK sector associated with glaciotectonics

Notes:
CGZ= cable geotechnical zone
BSF = below seafloor
* Route 4 (rev.10)

10.7 Geomorphological Features and Processes

Geophysical and geotechnical data were reviewed for geomorphological features and processes judged to be of particular potential significance to operations. Any areas for rerouting consideration were identified and communicated to the Viking Link team as a technical note. As a result, some areas of sub- to outcropping competent strata and very large bedforms were routed around. In addition, further data were collected for micro-routing around mussel beds, relict and mobile bedforms.

Table 10.3 summarises the four main geomorphological features which should be considered and reviewed in conjunction with the supplied survey results. These features are presented on the alignment charts relative to the centreline.

Table 10.3: Summary of Geomorphological Features and Associated Potential Considerations for Cable Installation

Geomorphological Feature	Description	Distribution along Route 4v10	Cable Installation Considerations
Areas of subcropping to outcropping bedrock	• Irregular seafloor morphology • Competent lithologies (bedrock, weathered bedrock) subcropping to outcropping at seafloor on subbottom geophysical data	1.50 km (0.24%)	• At the boundary with older strata, a step increase in various geotechnical parameters and a change in sediment type is expected, particularly related to weathered bedrock • The presence of hard seabed material may also act as a focus for benthic communities. These may be environmentally protected and may result in a requirement for avoidance
Areas of numerous boulders	• Interpretation of the side scan sonar data indicates density of seabed boulders (over 0.1 m in height) is over approximately 75 per/km^2 • Interpolation completed using a GIS-based gridding algorithm	9.150 km (1.5%)	• Boulders may present a direct obstruction to cable installation techniques and may pose problems during spoil removal as they may block suction tubes, or may be immobile if large enough • Hard seabed material such as boulders may act as a focus for benthic communities. These may be environmentally protected and may result in a requirement for avoidance
Seafloor gradients greater than 5 degrees	• Often associated with the presence of subcropping older strata and bedforms	0.79 km (0.13%)	• Steep slopes may pose cable spanning and flexing issues
Areas of potential sediment mobility	• Areas of very loose to loose sediment (typically fine to coarse sand) which have the potential for mobility though general near bed current activity or storm activity • Typically sinuous, discontinuous ridges (or dunes) up to 12 m in height (UK Sector) • Also found as large ripple fields of average 0.5 m height and 25 m wavelength (UK Sector) • Pits, scours associated with siltier/clay sediments in DK sector	195.71 km (21.0%)	• Potential migration of sediment waves may result in exposure, spanning, and/or increased burial of the cable • Increased likelihood of sediment removal and cable exposure during the cable's engineering lifetime

Geomorphological Feature	Description	Distribution along Route 4v10	Cable Installation Considerations
Mussel Beds	• Dense aggregations of blue mussels *Mytilus edulis* recorded on video transects and presence within grab samples • Characteristics assessed, resulting in classification as mussel bed • Extents of mussel bed identified through analysis of additional video transects	0.94 km (0.15%)	• Mussel beds classified under UK BAP Priority Habitats, Annex I features, Marine Conservation Zones and MSFD Predominant Habitats
Notes: BSF = Below seafloor * = 100% is defined as the total length of Route 4 (rev.10)			

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APPENDICES

A. ROUTE POSITION LISTINGS

Route Position Listings: Route 4, Revision 10 (LF1 and LF2)

Geodetic Datum: ETRS89 Grid: UTM Zone 31 N (CM 3°E)					Route Revision : Route 4, Rev 10 (Landfall 1)	
Point	KP	Easting [m]	Northing [m]	Latitude	Longitude	Remarks
1	0.000	824 779.894	6 191 987.072	55.764228°N	8.178616°E	Denmark Landfall
2	7.084	817 732.364	6 192 707.301	55.775348°N	8.067580°E	
3	23.256	801 593.974	6 193 738.160	55.794902°N	7.812372°E	
4	51.987	772 868.354	6 193 178.646	55.806951°N	7.355016°E	
5	53.052	771 983.053	6 192 585.087	55.802132°N	7.340340°E	
6	54.553	771 890.529	6 191 087.118	55.788763°N	7.337373°E	
7	55.743	770 953.332	6 190 353.476	55.782716°N	7.321741°E	
8	72.837	754 074.175	6 187 657.616	55.767712°N	7.050786°E	
9	73.619	753 523.588	6 187 102.149	55.763022°N	7.041517°E	
10	74.589	753 580.166	6 186 133.507	55.754310°N	7.041517°E	
11	75.333	752 978.905	6 185 695.783	55.750701°N	7.031555°E	
12	90.170	738 749.399	6 181 493.668	55.720249°N	6.801698°E	
13	90.884	738 273.206	6 180 961.068	55.715709°N	6.793671°E	
14	91.734	738 285.101	6 180 111.264	55.708084°N	6.793120°E	
15	92.435	737 855.011	6 179 558.135	55.703335°N	6.785810°E	
16	106.169	724 703.427	6 175 601.140	55.674118°N	6.573712°E	
17	107.694	723 241.670	6 175 164.058	55.670872°N	6.550159°E	
18	130.542	701 376.520	6 168 534.825	55.620955°N	6.198229°E	
19	132.554	699 409.584	6 168 114.586	55.617995°N	6.166740°E	
20	140.843	691 452.231	6 165 792.849	55.600357°N	6.038964°E	
21	142.701	689 705.978	6 165 157.848	55.595342°N	6.010851°E	
22	148.538	684 308.467	6 162 935.343	55.577470°N	5.923829°E	
23	150.634	682 641.588	6 161 665.340	55.566700°N	5.896585°E	
24	161.826	672 153.171	6 157 759.578	55.535460°N	5.728032°E	
25	210.795	635 155.250	6 125 678.928	55.259036°N	5.126733°E	
26	217.839	631 281.573	6 119 796.162	55.207254°N	5.063086°E	
27	223.548	627 378.961	6 115 628.966	55.170851°N	4.999923°E	
28	225.278	625 802.235	6 114 916.280	55.164854°N	4.974867°E	
29	227.409	623 708.263	6 114 522.358	55.161844°N	4.941845°E	
30	229.680	621 533.616	6 113 866.764	55.156495°N	4.907450°E	
31	231.444	619 975.274	6 113 041.956	55.149467°N	4.882658°E	
32	239.117	616 271.929	6 106 321.042	55.089985°N	4.821828°E	
33	247.057	610 054.090	6 101 383.851	55.047056°N	4.722546°E	
34	260.662	598 782.817	6 093 763.836	54.980972°N	4.543574°E	
35	263.266	596 719.063	6 092 176.333	54.967116°N	4.510803°E	
36	302.225	565 762.751	6 068 522.535	54.759627°N	4.021966°E	
37	304.853	564 651.499	6 066 141.281	54.738375°N	4.004170°E	
38	367.480	516 744.903	6 025 803.244	54.379736°N	3.257806°E	
39	369.439	514 786.982	6 025 750.327	54.379321°N	3.227660°E	

Geodetic Datum: ETRS89 Grid: UTM Zone 31 N (CM 3°E)					Route Revision : Route 4, Rev 10 (Landfall 1)	
Point	KP	Easting [m]	Northing [m]	Latitude	Longitude	Remarks
40	385.361	502 356.259	6 015 801.008	54.290112°N	3.036198°E	
41	387.296	500 425.183	6 015 669.252	54.288933°N	3.006532°E	
42	389.266	499 076.639	6 014 233.964	54.276032°N	2.985820°E	
43	390.202	498 797.857	6 013 339.793	54.267995°N	2.981542°E	
44	398.150	491 829.264	6 009 519.089	54.233593°N	2.874647°E	
45	398.740	491 338.168	6 009 847.161	54.236533°N	2.867104°E	
46	403.464	487 086.025	6 007 788.747	54.217944°N	2.801953°E	
47	403.643	486 925.419	6 007 710.999	54.217241°N	2.799493°E	
48	430.211	461 903.259	5 998 780.409	54.135731°N	2.416908°E	
49	444.603	447 757.456	5 996 129.858	54.110667°N	2.200878°E	
50	448.188	444 172.690	5 996 145.819	54.110434°N	2.146047°E	
51	448.898	443 550.486	5 996 488.494	54.113446°N	2.136467°E	
52	454.425	438 026.651	5 996 300.577	54.111121°N	2.052017°E	
53	474.980	418 257.505	5 990 673.559	54.057798°N	1.751205°E	
54	475.585	417 770.670	5 991 033.393	54.060954°N	1.743672°E	
55	479.509	413 966.943	5 990 069.313	54.051670°N	1.685847°E	
56	480.195	413 283.328	5 990 123.225	54.052040°N	1.675393°E	
57	495.770	398 022.395	5 987 011.278	54.021288°N	1.443413°E	
58	496.671	397 122.810	5 986 958.361	54.020634°N	1.429706°E	
59	516.998	381 644.654	5 973 782.085	53.898948°N	1.198683°E	
60	518.057	380 612.777	5 974 020.210	53.900850°N	1.182894°E	
61	529.397	370 958.312	5 968 071.122	53.845098°N	1.038545°E	
62	530.131	370 541.897	5 967 466.309	53.839561°N	1.032474°E	
63	531.992	369 549.565	5 965 892.053	53.825172°N	1.018071°E	
64	532.477	369 211.613	5 965 544.319	53.821963°N	1.013087°E	
65	532.708	369 017.207	5 965 419.867	53.820796°N	1.010189°E	
66	532.930	368 816.779	5 965 323.937	53.819884°N	1.007187°E	
67	533.116	368 638.246	5 965 271.765	53.819370°N	1.004499°E	
68	533.409	368 351.425	5 965 214.553	53.818784°N	1.000169°E	
69	534.291	367 481.422	5 965 068.453	53.817251°N	0.987025°E	
70	534.496	367 279.477	5 965 032.693	53.816878°N	0.983975°E	
71	536.707	365 137.607	5 964 484.401	53.811402°N	0.951703°E	
72	547.484	355 962.822	5 958 830.891	53.758164°N	0.815105°E	
73	548.355	355 526.258	5 958 076.827	53.751271°N	0.808841°E	
74	551.357	353 318.385	5 956 042.102	53.732379°N	0.776348°E	
75	564.434	347 517.889	5 944 322.002	53.625456°N	0.694250°E	
76	567.572	346 430.231	5 941 378.546	53.598703°N	0.679269°E	
77	569.896	345 599.422	5 939 208.538	53.578970°N	0.667799°E	
78	573.946	342 328.472	5 936 820.833	53.556554°N	0.619643°E	
79	575.862	341 147.668	5 935 312.028	53.542648°N	0.602600°E	
80	577.921	340 619.635	5 933 321.158	53.524608°N	0.595652°E	

Geodetic Datum: ETRS89 Grid: UTM Zone 31 N (CM 3°E)					**Route Revision : Route 4, Rev 10 (Landfall 1)**	
Point	**KP**	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**	**Remarks**
81	578.815	340 813.306	5 932 448.196	53.516827°N	0.599015°E	
82	580.269	340 568.199	5 931 015.212	53.503884°N	0.596050°E	
83	582.203	339 594.435	5 929 344.539	53.488584°N	0.582236°E	
84	597.265	325 271.346	5 924 684.616	53.442181°N	0.369177°E	
85	597.853	324 850.233	5 924 274.857	53.438362°N	0.363071°E	
86	598.621	324 778.078	5 923 510.286	53.431473°N	0.362412°E	
87	605.190	326 756.904	5 917 245.606	53.375873°N	0.395605°E	
88	606.157	326 160.518	5 916 484.700	53.368845°N	0.387068°E	
89	611.074	326 731.220	5 911 601.471	53.325183°N	0.398309°E	Point D
90	613.204	325 509.420	5 909 855.718	53.309105°N	0.380944°E	
91	618.735	320 518.724	5 907 472.639	53.286040°N	0.307472°E	UK Landfall (LF1)

Geodetic Datum: ETRS89 Grid: UTM Zone 31 N (CM 3°E)					**Route Revision : Route 4, Rev 10 (Landfall 2)**	
Point	**KP**	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**	**Remarks**
89	611.074	326 731.220	5 911 601.471	53.325183°N	0.398309°E	Point D
90	613.260	326 984.974	5 909 430.216	53.305768°N	0.403299°E	
91	617.352	326 901.360	5 905 338.456	53.268998°N	0.404275°E	
92	622.659	321 850.309	5 903 710.262	53.252706°N	0.329531°E	UK Landfall (LF2)
Note: Route 4, Rev10 Landfall 2 shares common positions with Route 4, Rev10 Landfall 1 up to Point D (KP 611.074)						

B. GUIDELINES ON USE OF REPORT

GUIDELINES ON USE OF REPORT

This report and the assessment carried out in connection with the report (together the 'Services') were compiled and carried out by Fugro GeoConsulting Limited ('Fugro') for National Grid Interconnector Holdings Limited/ Energinet DK SOV (the 'Client') in accordance with the terms of a contract between Fugro and the Client. The Services were performed by Fugro with the skill and care ordinarily exercised by a reasonable geotechnical specialist at the time the Services were performed. Further, and in particular, the Services were performed by Fugro taking into account the limits of the scope of works required by the Client, the time scale involved and the resources, including financial and manpower resources, agreed between Fugro and the Client.

Other than that expressly contained in paragraph one above, Fugro provides no other representation or warranty whether express or implied, in relation to the Services.

The Services were performed by Fugro exclusively for the purposes of the Client. Fugro is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless expressly provided in writing, Fugro does not authorise, consent or condone any party other than the Client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and Fugro disclaims any liability to such party. Any such party would be well advised to seek independent advice from a competent geotechnical specialist and / or lawyer.

It is Fugro's understanding that this report is to be used for the purpose described in Section 1 (Introduction) of this report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, and/or should the Client's proposed development or use of the site change (including in particular any change in any design and/or specification relating to the proposed use or development of the site), this report may no longer be valid or appropriate and any further use of or reliance upon the report in those circumstances by the Client without Fugro's review and advice shall be at the Client's sole and own risk. Should Fugro be requested, and Fugro agree, to review the report after the date hereof, Fugro shall be entitled to additional payment at the then existing rates or such other terms as may be agreed between Fugro and the Client.

The passage of time may result in changes (whether man-made or otherwise) in site conditions and changes in regulatory or other legal provisions, technology, methods of analysis, or economic conditions which could render the report inaccurate or unreliable. The information, recommendations and conclusions contained in this report should not be relied upon if any such changes have taken place or after a period of two years from the date of this report or such other period as maybe expressly stated in the report, without the written agreement of Fugro. In the absence of such written agreement of Fugro, reliance on the report after any such changes have occurred or after the period of two years has expired shall be at the Client's own and sole risk. Should Fugro agree to review the report after the period of two years has expired, Fugro shall be entitled to additional payment at the then existing rates or such other terms as may be agreed between Fugro and the Client.

The observations, recommendations and conclusions in this report are based solely upon the Services which were provided pursuant to the contract between the Client and Fugro. Fugro has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the Client and Fugro. Fugro is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services.

Where the Services have involved Fugro's interpretation and/or other use of any information (including documentation or materials, analysis, recommendations and conclusions) provided by third parties (including independent testing and/or information services or laboratories) or the Client and upon which Fugro was reasonably entitled to rely or involved Fugro's observations of existing physical conditions of any site involved in the Services, then the Services clearly are limited by the accuracy of such information and the observations which were reasonably possible of the said site. Unless otherwise stated, Fugro was not authorised and did not attempt to independently verify the accuracy or completeness of such information, received from the Client or third parties during the performance of the Services. Fugro is not liable for any inaccuracies (including any incompleteness) in the said information, the discovery of which inaccuracies required the doing of any act including the gathering of any information which it was not reasonably possible for Fugro to do including the doing of any independent investigation of the information provided to Fugro save as otherwise provided in the terms of the contract between the Client and Fugro.

The soil and ground conditions information provided in the Services are based solely on evaluations of soil and ground condition samples and in situ tests at determined sample test locations and elevations. That information cannot be extrapolated to any area or elevation outside those locations and elevations unless specifically so stated in the report. In the light of the information available to Fugro, the soil and ground conditions information are considered appropriate for use in relation to the geotechnical design and installation aspects of the structures addressed in the report, but they may not be appropriate for the design of other structures.

C. WP-D UTILITY CROSSINGS SURVEY

C.1 OVERVIEW

The following presents a summary of the existing pipeline and cable crossings inspected during the Work Package D Utility Crossing Survey, along with any planned cable or pipelines. Identification numbers were assigned to each of the utility crossing as part of the Desk Top Study. These crossing numbers were used to reference each of the surveys conducted during the utility crossing survey. A number of changes to the program resulted in an inconsistent numbering, with some duplicate crossing numbers. Consequently the crossing numbers were revised post-survey and all results files and text have been updated to reflect these revised numbers. Both the original and revised crossing numbers are listed below.

Geodetic Datum: ETRS89 Grid: UTM Zone 31N (CM 3°E)								
Name	Type	Sector	Original Crossing No.	Updated Crossing No.	Xing_Type	Easting	Northing	KP
Entry corridor Triton Knoll export cable	Planned Cable	UK	1	01	Planned corridor database position	326 915.6	5 906 035.3	616.655
Exit corridor Triton Knoll export cable	Planned Cable	UK	1	01	Planned corridor database position	326 949.2	5 907 681.3	615.009
Viking AR to Theddlethorpe 28" Gas / 3" Methanol (Piggybacked)	Pipeline	UK	2_3	02	As-found	326 307.3	5 915 228.5	607.422
Loggs PP to Theddlethorpe 4" Methanol line	Umbilical	UK	5	03	As-found (based on small number of targets)	326 405.2	5 916 796.9	605.748
Loggs PP to Theddlethorpe 36" Gas pipeline	Pipeline	UK	5	04	As-found	326 425.0	5 916 822.1	605.728
Pickeral A to Theddlethorpe 24" Chemical pipeline	Pipeline	UK	6	05	As-found	326 485.8	5 916 899.8	605.630
Theddlethorpe to Murdoch MD 4" Methanol line	Umbilical	UK	8	06	As-found (based on small number of targets)	326 550.2	5 916 981.9	605.526
Theddlethorpe to Murdoch MD 26" Gas pipeline	Pipeline	UK	8	07	As-found	326 565.7	5 917 001.6	605.500
Entry corridor Hornsea export cable	Planned Cable	UK	1	08	Planned corridor database position	340 813.3	5 932 448.2	578.815
Exit corridor Hornsea export cable	Planned Cable	UK	1	08	Planned corridor database position	340 619.6	5 933 321.2	577.921
Amethyst A2D to Easington 30" Gas pipeline	Pipeline	UK	2	09	As-found	346 756.8	5 942 262.4	566.630
Amethyst A2D to Easington Power cable	Umbilical	UK	3	10	As-found	346 773.1	5 942 306.4	566.583
Amethyst C1D to Amethyst A1D 12" Gas pipeline	Pipeline	UK	4	11	As-found	347 272.6	5 943 658.1	565.142
Amethyst C1D to Amethyst A1D Power cable	Umbilical	UK	5	12	As-found	347 292.8	5 943 712.8	565.084

Geodetic Datum: ETRS89 Grid: UTM Zone 31N (CM 3°E)								
Name	**Type**	**Sector**	**Original Crossing No.**	**Updated Crossing No.**	**Xing_Type**	**Easting**	**Northing**	**KP**
West Sole to Easington 24" Gas pipeline	Pipeline	UK	6	13	As-found	355 810.3	5 958 567.5	547.788
West Sole to Easington 16" Gas pipeline	Pipeline	UK	7	14	As-found	355 867.1	5 958 665.5	547.675
Babbage to West Sole 12" Gas Export pipeline	Pipeline	UK	8	15	As-found	381 146.1	5 973 897.2	517.510
Shearwater to Bacton 34" Gas pipeline (SEAL)	Pipeline	UK	9	16	As-found	397 505.5	5 986 980.9	496.287
Esmond to Bacton 24" Gas pipeline	Pipeline	UK	10	17	As-found	413 561.3	5 990 101.3	479.916
Theddlethorpe to Murdoch MD 4" Methanol line	Umbilical	UK	11	18	As-found	417 929.0	5 990 916.3	475.388
Theddlethorpe to Murdoch MD 26" Gas pipeline	Pipeline	UK	12	19	As-found	417 946.6	5 990 903.3	475.366
Schooner to Murdoch 16" Gas / 3" Methanol (Piggybacked)	Pipeline	UK	13-14	20	As-found	443 888.1	5 996 302.5	448.513
Tampnet / Norsea Com-1 Seg. 3	Cable	UK	15	21	As-found	456 868.1	5 997 837.0	435.334
Ketch to Murdoch 18" Gas / 3" Methanol (Piggybacked)	Pipeline	UK	16-17	22	As-found	462 235.6	5 998 899.0	429.858
D18a-A to D15-A 8" Gas / 2" Methanol (Piggybacked)	Pipeline	Dutch	18-19	23	As-found	491 576.0	6 009 688.3	398.454
D15-FA to L10-AC 36" Gas pipeline	Pipeline	Dutch	20	24	As-found	500 068.9	6 015 290.0	387.817
Sleipner to Zeebrugge 40" Gas pipeline (Zeepipe)	Pipeline	Dutch	21	25	As-found	515 665.7	6 025 774.1	368.560
Draupner to Dunkirk 42" Gas pipeline (Franpipe (formerly Norfra))	Pipeline	Dutch	22	26	As-found	515 722.8	6 025 775.6	368.503
UK - Germany 6	Cable	Dutch	23	27	As-found	534 635.0	6 040 867.0	344.093
VSNL / TGN Northern Europe	Cable	Dutch	24	28	As-found	565 217.4	6 067 353.8	303.515
A6A to F3FB1 20" Gas pipeline	Pipeline	Dutch	25	29	As-found	597 858.3	6 093 052.7	261.829
A6A to F3FB1 4" Condensate pipeline	Pipeline	Dutch	26	30	As-found	597 887.1	6 093 074.8	261.792
Tyra-W to F03-FB 26" Gas pipeline	Pipeline	Dutch	27	31	As-found	609 521.7	6 101 023.9	247.700
Norpipe 36" Gas pipeline	Pipeline	German	28	32	As-found	627 821.7	6 116 101.7	222.900
Europipe 1 40" Gas pipeline	Pipeline	German	29	33	As-found	630 992.8	6 119 487.8	218.261
TAT 10 Seg. C	Cable	Danish	30	34	As-found	678 249.3	6 160 029.7	155.321

Geodetic Datum: ETRS89 Grid: UTM Zone 31N (CM 3°E)								
Name	**Type**	**Sector**	**Original Crossing No.**	**Updated Crossing No.**	**Xing_Type**	**Easting**	**Northing**	**KP**
Pangea	Cable	Danish	31	35	As-found (Not located at crossing)	683 789.9	6 162 540.2	149.190
Atlantic Crossing 1 (Seg. A)	Cable	Danish	32	36	As-found	690 492.9	6 165 444.0	141.864
NorNed	Cable	Danish	33	37	As-found	700 369.4	6 168 319.6	131.572
Europipe 2 42" Gas pipeline	Pipeline	Danish	34	38	As-found	724 087.2	6 175 416.9	106.812
Arendal-Westerland No 2	Cable	Danish	35	39	Database position (not found)	732 533.7	6 177 957.1	97.992
Gorm E to Frederica 20" Oil pipeline	Pipeline	Danish	36	40	As-found	738 281.0	6 180 403.3	91.442
Tyra TE-E to Nybro 30" Gas pipeline	Pipeline	Danish	37	41	As-found	753 560.9	6 186 463.4	74.258
TAT 14 Seg. N	Cable	Danish	38	42	As-found	758 277.8	6 188 329.0	68.580
NordLink	Planned Pipeline	Danish	39	43	Planned database position	770 387.7	6 190 263.1	56.316
Harald to Nybro 24" Gas pipeline	Pipeline	Danish	40	44	As-found	771 948.9	6 192 032.6	53.606
Arendal-Westerland No 1	Cable	Danish	41	45	As-found	772 916.6	6 193 179.6	51.938
CANTAT3	Cable	Danish	42	46	As-found	775 697.5	6 193 233.8	49.157

Notes:
1. Route KP's and crossing coordinates based on Route Position Listing '20160623_Route_4_Rev10_ETRS89_UTM31N'
2. Coordinates and KP's are based on as-found positions unless otherwise stated.

D. DIGITAL DELIVERABLES

The hard drive contains a complete set of the electronic deliverables for the Viking Link Cable Route Survey.

The majority of datasets have been archived in a single zip file, with the following naming convention:

"VL_*name of datset_issue date_revision number"*

It has not been possible to archive some of the larger datasets. These are provided in their native form, and subdivided into the individual survey blocks to which they belong. Figure D.1 below shows an overview of the Viking Link proposed route, and also the survey blocks used to manage data acquisition and processing.

Table D.1 presents a register of all datasets provided on this hard drive. For reference, the unzipped size of each dataset is also given.

This hard drive does not include final PDF copies of all project reports; these will be submitted on a further set of electronic deliverables which will be issued on completing of the project in early 2017.

During review of the enclosed datasets it was observed that the number of survey lines vary from sensor to sensor, and also that the number of tracks for a particular sensor do not necessarily match the number of data files supplied for that sensor. The reasons for these discrepancies are:

i. Trackplots have different numbers of line features for each sensor because the tracks are based on the logged files and not all sensors were logged for all lines. For example, during the running of infill lines for bathymetry, towed sensors would only be deployed if required, in order to reduce the risk of snagging fishing gear.
ii. New data files are automatically created for each sensor throughout the acquisition of each line. This is so that the resulting data files do not become too large. Therefore, there will normally be more than one file per line and particularly so for long lines. This occurs at different rates for each sensor because not all data files are populated at the same rate. For example, sidescan sonar, multibeam and sub-bottom profile sensors all create much larger files than magnetometer sensors, and so will create new files more frequently. This happens in order to improve file stability, to ensure that the file sizes are manageable and not so large that they cause the processing software to crash upon import.
iii. Trackplots have different number of line features vs number of logged files because track plots have been provided for processed files only. Therefore, if the data file was not processed, due to reduced data quality for example, then the corresponding track plot has not been provided to the client. This will result in the number of acquired data files outnumbering the number of track line features.

It should be noted that throughout the survey, data were named in accordance with their corresponding survey line. Where more than one data file has been acquired along one survey line, this will be denoted by a suffix to the file name, for instance "_001", "_002" etc.

Figure D.1: Overview of Viking Link Cable Route Survey

Table D.1: Deliverables Register

Unique Folder ID	Work Package	Description	File Type(s)	Size on Disk
FIP5000	A	Elevation – processed / full density Ungridded terrain elevations	XYZ	4 KB
FIP5001	A	Elevation Contours Topographic contours 0.25 m intervals	ESRI SHP Polyline	6 KB
FIP5002	A	Elevation - point Topographic points	CSV	3 KB
FIP5003	B	Bathymetry – processed / full density Bathymetry ungridded	XYZ	637.5 GB
FIP5004	B	Bathymetry – processed / gridded Bathymetry gridded 0.25m resolution	XYZ	154.1 GB
FIP5005	B	Bathymetry – processed / gridded Bathymetry gridded 0.25m resolution	ESRI GRID	34.7 GB
FIP5006	B	Bathymetry – processed / gridded Bathymetry gridded 1.00 m resolution	XYZ	9.9 GB
FIP5007	B	Bathymetry – processed / gridded Bathymetry gridded 1.00 m resolution	ESRI GRID	2.2 GB
FIP5008	B	Bathymetry – processed / gridded Bathymetry gridded 5.00 m resolution	XYZ	421.5 MB
FIP5009	B	Bathymetry – processed / gridded Bathymetry gridded 5.00 m resolution	ESRI GRID	21.8 GB
FIP5010	B	Elevation Contours Bathymetry contours 0.50 m intervals	ESRI SHP Polyline	52.3 MB
FIP5011	B	Track – vessel / platform Vessel Track - Central Reference Point	ESRI SHP Polyline	10.0 MB
FIP5012	B	Track – vessel / platform Vessel Track - MBES Starboard	ESRI SHP Polyline	9.6 MB
FIP5013	B	Track – vessel / platform Vessel Track - MBES Port	ESRI SHP Polyline	10.4 MB
FIP5014	B	SSS - constituent data High Frequency Raw Data with corrected NAV	XTF	683.4 GB
FIP5015	B	SSS - constituent data Low Frequency Raw Data with corrected NAV	XTF	319.9 GB
FIP5016	B	SSS - constituent data Navigation Files	CSV	269.0 MB
FIP5017	B	SSS - mosaic High Frequency SSS Mosaic	GEOTIFF	2.3 GB
FIP5018	B	SSS - mosaic Low Frequency SSS Mosaic	GEOTIFF	5.6 GB
FIP5019	B	Track – vessel / platform Vessel Track - SSS	ESRI SHP Polyline	89.6 MB
FIP5020	B	Seabed Features - point	ESRI SHP Point	37.4 MB
FIP5021	B	Magnetometer / gradiometer - processed Magnetometer Measurements	CSV	3.0 GB
FIP5022	B	Track – vessel / platform Vessel Track - Magnetometer	ESRI SHP Polyline	69.0 MB
FIP5023	B	Point contact - Maggy MAG Anomaly Target List	ESRI SHP Point	0.2 KB
FIP5024	B	Geophysical data - shallow High Frequency SBP (Pinger)	SEGY	99.8 GB
FIP5025	B	Geophysical data - shallow Medium Frequency SBP (Sparker)	SEGY	21.1 GB
FIP5026	B	Track – vessel / platform Vessel Track - Pinger	ESRI SHP Polyline	9.0 MB

Unique Folder ID	Work Package	Description	File Type(s)	Size on Disk
FIP5027	B	Track – vessel / platform Vessel Track - Sparker	ESRI SHP Polyline	6.2 MB
FIP5028	B	Elevation profile Interpreted horizons from SBP	CSV	1.0 GB
FIP5029	B	Isopach Grid (thickness) base Holocene	ESRI GRID	21.2 GB
FIP5030	B	Isopach Grid (thickness) base Holocene	XYZ	123.0 MB
FIP5031	B	Isopach Grid (thickness) base Holocene	GEOTIFF	3.6 GB
FIP5032	B	Depth Grid (elevation LAT) base Holocene	ESRI GRID	21.2 GB
FIP5033	B	Depth Grid (elevation LAT) base Holocene	XYZ	56.7 MB
FIP5034	B	Depth Grid (elevation LAT) base Holocene	GEOTIFF	3.6 GB
FIP5035	B	Depth Grid (elevation BSB) base Holocene	ESRI GRID	21.2 GB
FIP5036	B	Depth Grid (elevation BSB) base Holocene	XYZ	56.7 MB
FIP5037	B	Depth Grid (elevation BSB) base Holocene	GEOTIFF	3.9 GB
FIP5069	B	Geophysical data - Processed backscatter data	ESRI GRID	654 MB
FIP5038	B	Location(s) - sampled/ installed Grab sample locations / results	CSV	37 KB
FIP5039	C	Location(s) - sampled/ installed Geotechnical sample locations - Core	CSV / ESRI SHP Point	0.1 KB
FIP5041	C	Location(s) - sampled/ installed Geotechnical sample locations - CPT	CSV / ESRI SHP Point	0.1 KB
FIP5043	C	Factual logs Laboratory test schedule, overview and results tables (geotechnical)	XLS/XLSX	2.0 MB
FIP5044	C	Factual logs CPT tests, Core tests and Laboratory tests	AGS	10.7 MB
FIP5068	C	Location(s) – sampled / installed Geotechnical sample locations - Thermal Conductivity	CSV / ESRI SHP Point	9 B
FIP5052	D	Elevation profile Infrastructure depth of burial coordinates (5 point files)	XLSX	32 KB
FIP5053	D	Point contact - Other Events table	XLSX	24 KB
FIP5054	D	Location(s) - as found As found crossing locations	ESRI SHP Point	0.3 KB
FIP5055	D	Video ROV Video	CODEC	64.1 MB
FIP5056	E	Benthic classification - point	ESRI SHP Point	200 KB
FIP5057	E	Benthic classification - line	ESRI SHP Polyline	66 KB
FIP5058	E	Benthic classification - area features	ESRI SHP Polygon	37 KB
FIP5060	E	Factual logs Laboratory test schedule, overview and results tables (benthic)	XLS/XLSX	720 KB
FIP5061	E	Video Camera video	CODEC	78.7 MB

Unique Folder ID	Work Package	Description	File Type(s)	Size on Disk
FIP5062	E	Photographic stills images	JPEG	5.1 MB
FIP5063	E	Track – vessel / platform Photographic stills fixes	ESRI SHP Point	3.3 MB
FIP5064	E	Track – vessel / platform Benthic video track	ESRI SHP Polyline	12 B
FIP5065	E	Track – vessel / platform Vessel Track - Beam Trawl COG	ESRI SHP Polyline	5 B
FIP5066	E	Track – vessel / platform Vessel Track - Benthic Grab Sample Locations	ESRI SHP Point	15 B
FIP5067	E	Track – vessel / platform Vessel Track - Benthic Water Quality Profiling Locations	ESRI SHP Point	10 B
FIP5046	F	Seabed features - linear	ESRI SHP Polyline	1.2 MB
FIP5047	F	Seabed features - area	ESRI SHP Polygon	0.9 MB
FIP5048	F	Sediment area - primary seabed surface geology	ESRI SHP Polygon	1.0 MB
FIP6000	Various	Final Reports – all work packages	PDF	TBC

Notes:
Unique Folder ID numbers were assigned to some data items that have subsequently been omitted or merged with another dataset. These folders have been omitted from the above table.

E. ONSHORE GROUND MARKERS AND STATION DESCRIPTIONS

E.1 UK STATION DESCRIPTIONS

E.1.1 Establishment of Reference Points for UK Landfalls

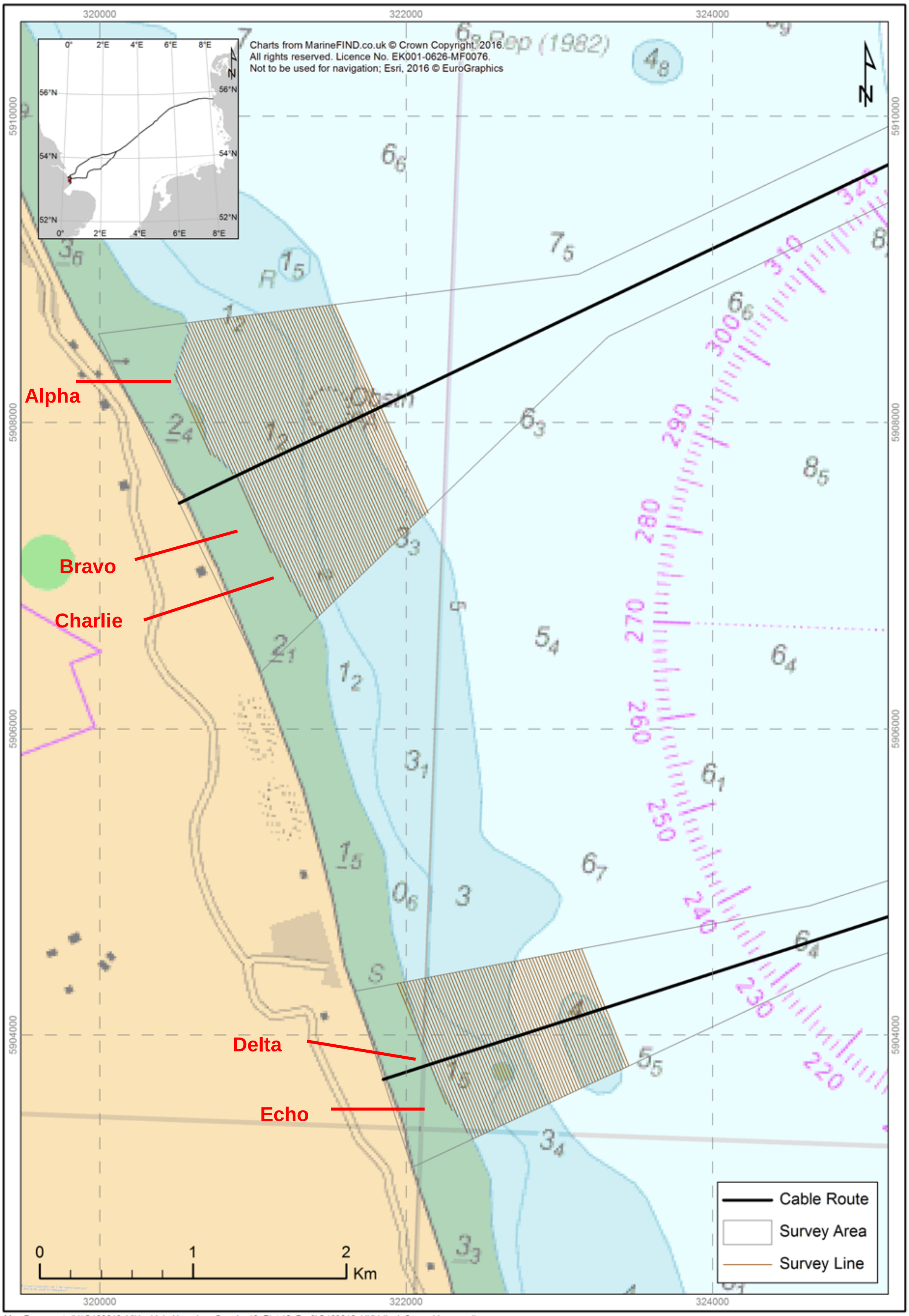
The UK landing consist of two options, landfall 1 (LF1) and landfall 2 (LF2). Within both landfalls, the cable will be installed through horizontal drilling. There are three proposed drilling lines (named “Alpha”, “Bravo” and “Charlie”) at LF1 and two (named “Delta” and “Echo”) at LF2 route which are under evaluation (Figure E.1).

Table E.1 lists the reference points for the UK landing.

As part of the topographic survey, the landward exit point of each drilling line (BMH) plus two further points to indicate the direction of the drilling lines were marked by permanent (B), point marker (V) or wooden pegs (W). Permanent markers were set mainly where lines crossing a tarmac road, whereas point markers (0.5 m long steel pipe with marker plate on top, approx. 0.3 m below ground level) or wooden pegs are set in a field or at the beach. Due to farming activities or other uses of the areas it is not guaranteed that the markers will remain in place permanently.

Figures E.2 to E.6 show the beach landfalls in plan view with dot markers indicating reference points along the line.

After the onshore survey had been completed, the “Bravo” option was discounted by the Project as a viable option.



Map Document: (V:\G160616_VikingLink_NearshoreGeophys\3_Plots\2_Draft\Q160616_UKValkyrieSurveyLines.mxd)
30/09/2016 - 10:42:28

Figure E.1: UK drilling line options

Table E.1: List of Reference Points - UK Landfalls

Point no.	Type	Geographic coordinates		UTM31N		Ellip. Height [m]	LAT [m]	ODN [m]
		Latitude	Longitude	Easting [m]	Northing [m]			
Alpha1	B	53.293113°N	0.299353°W	320 007.4	5 908 279.7	49.8	8.6	4.5
Alpha2BMH	W	53.293011°N	0.298036°W	319 919.2	5 908 271.7	47.3	6.0	2.0
Alpha3	W	53.293232°N	0.300902°W	320 111.1	5 908 289.0	53.4	12.1	8.0
Bravo1	B	53.282750°N	0.304912°W	320 334.3	5 907 113.2	49.9	8.7	4.6
Bravo2BMH	V	53.282526°N	0.303952°W	320 269.4	5 907 090.6	47.0	5.8	1.7
Bravo3	W	53.283794°N	0.309386°W	320 636.9	5 907 218.0	53.9	12.6	8.6
Charlie1	B	53.279595°N	0.305659°W	320 370.9	5 906 760.4	49.6	8.4	4.3
Charlie2BMH	V	53.279334°N	0.304669°W	320 303.8	5 906 733.8	47.0	5.8	1.7
Charlie3	W	53.281105°N	0.311371°W	320 757.9	5 906 914.0	54.9	13.6	9.6
Delta1	B	53.254932°N	0.323018°W	321 425.1	5 903 974.1	48.6	7.3	3.2
Delta2BMH	V	53.254939°N	0.322176°W	321 369.0	5 903 977.0	46.6	5.3	1.2
Delta3	W	53.254891°N	0.327961°W	321 754.6	5 903 957.2	53.5	12.2	8.2
Echo1	B	53.251606°N	0.325875°W	321 601.9	5 903 597.1	49.4	8.1	4.0
Echo2BMH	V	53.251598°N	0.324692°W	321 522.9	5 903 599.1	47.1	5.8	1.7
Echo3	W	53.251634°N	0.329872°W	321 868.6	5 903 590.2	53.2	11.9	7.9

Note:
Type: B – Permanent Marker, V – Point Marker, W – Wooden Peg

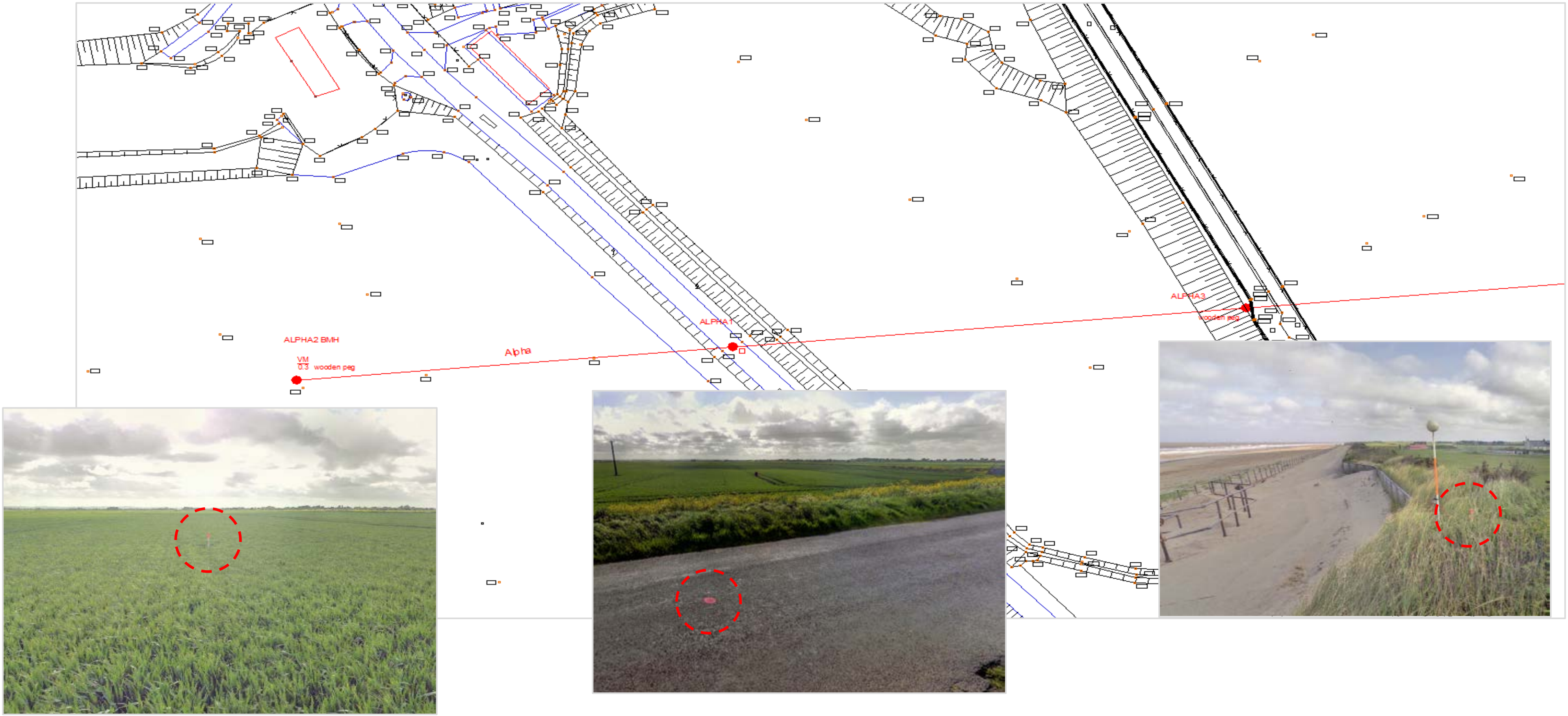


Figure E.2: Plan view of proposed landfall “Alpha” (BMH and reference points marked in red)

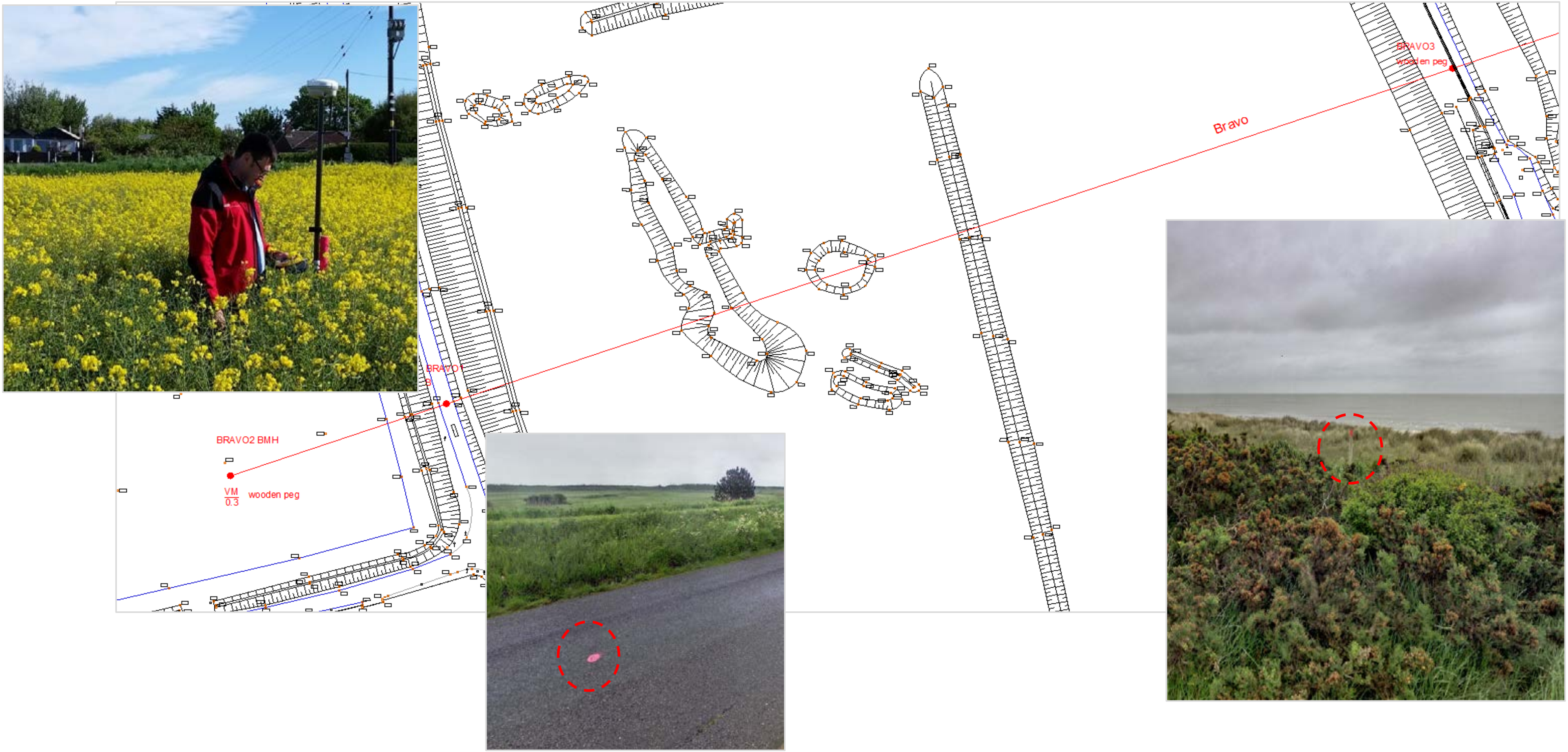


Figure E.3: Plan view of proposed landfall "Beta" (BMH and reference points marked in red)

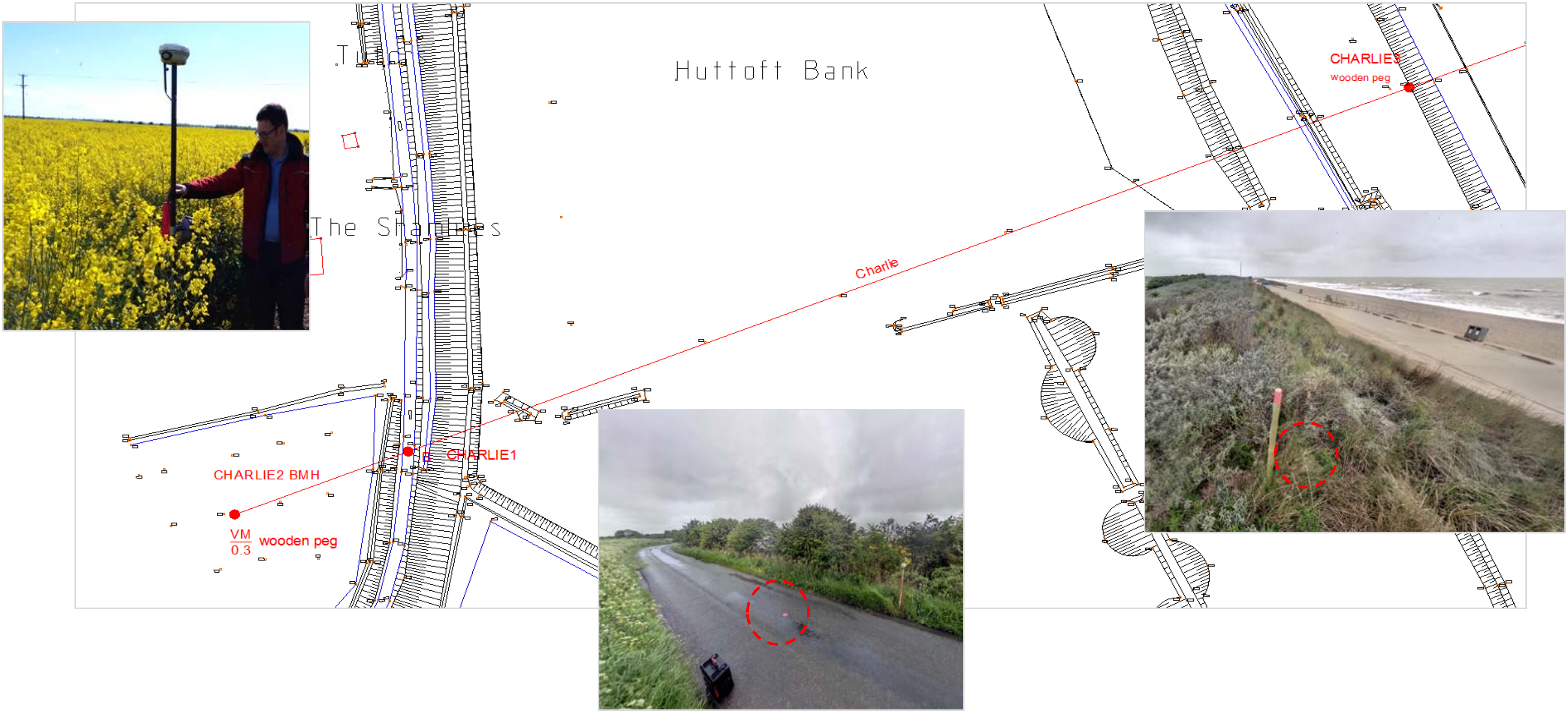


Figure E.4: Plan view of proposed landfall "Charlie" (BMH and reference points marked in red)

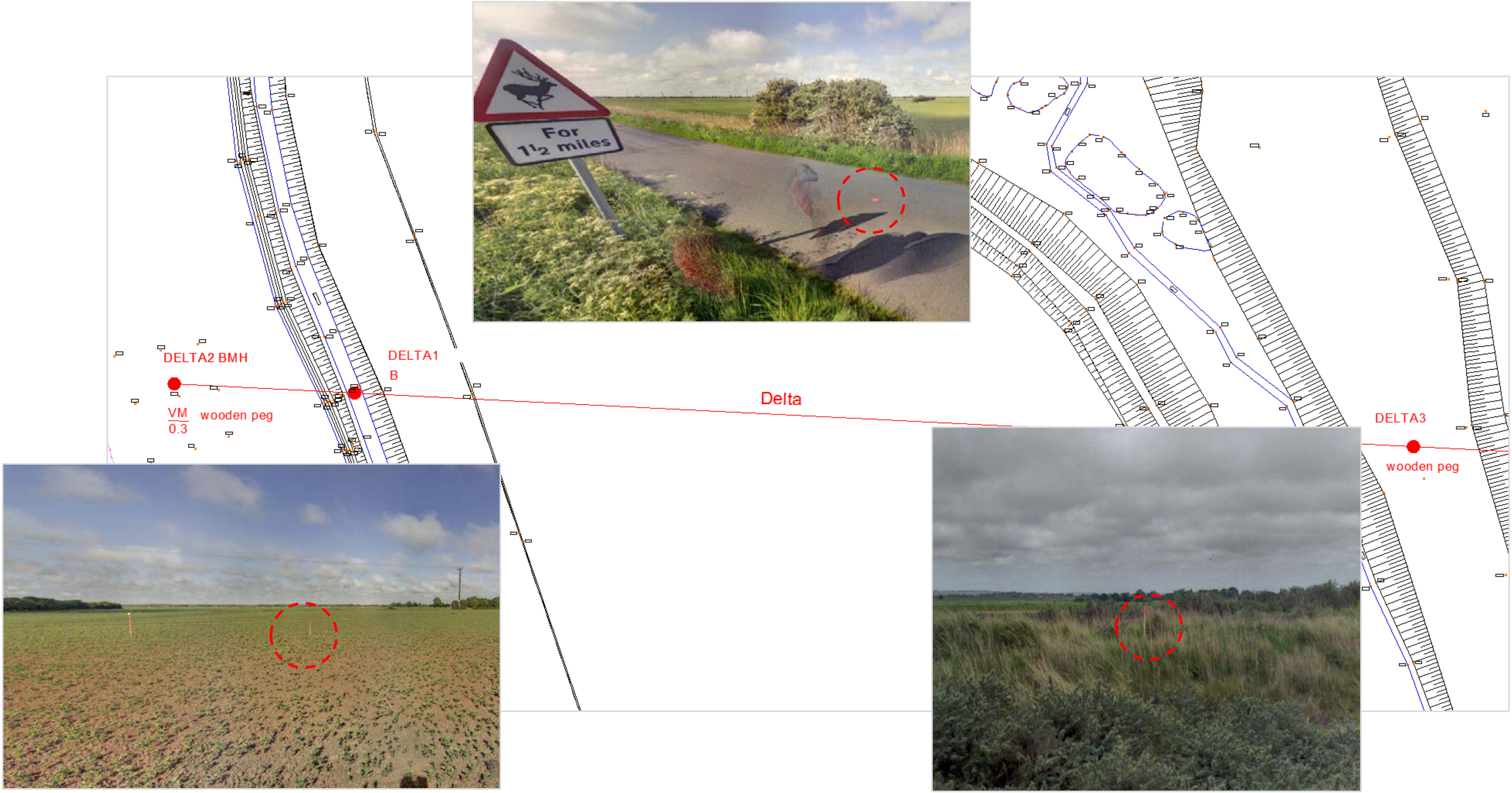


Figure E.5: Plan view of proposed landfall “Delta” (BMH and reference points marked in red)

Figure E.6: Plan view of proposed landfall “Echo” (BMH and reference points marked in red)

E.2 DANISH STATION DESCIPTIONS

E.2.1 Establishment of Reference Points for Denmark Landfall

In the vicinity of the proposed Beach Manhole, three reference point were established in the vicinity of the proposed beach manhole and marked permanently with a point marker (0.50 m long steel pipe with marker plate on top, approximately 0.30 m below ground level).

Figure E.7 shows a plan view of the reference points, and Figure E.8 shows the four reference points at ground level.

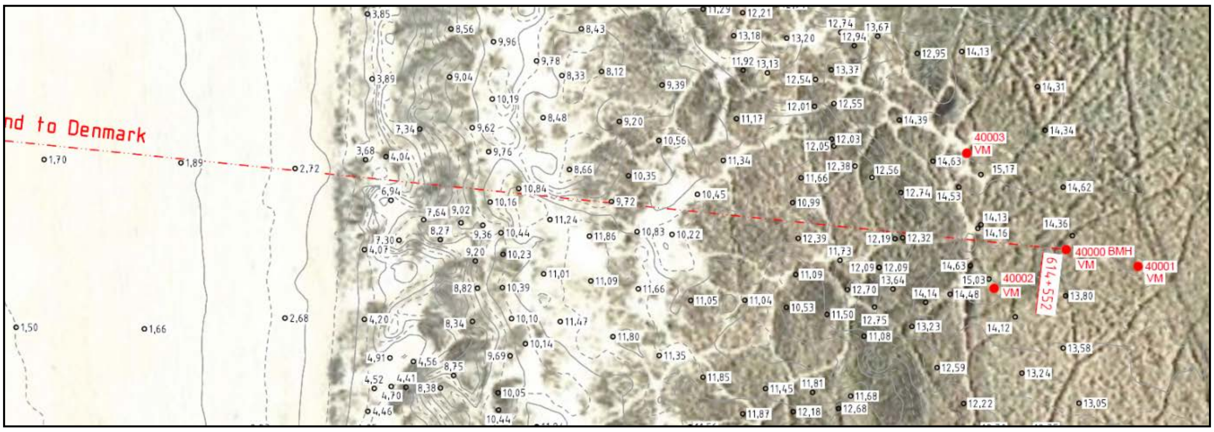


Figure E.7: Plan View of Proposed Cable Route (BMH and reference points marked in red)

Table E.2 lists the reference points for the DK landing.

Table E.2: List of Reference Points - Danish Landfall

Point no.	Type	Geographic coordinates		UTM31N		UTM32N		Ellip. Height [m]	LAT [m]	DRV90 [m]
		Latitude	Longitude	Easting [m]	Northing [m]	Easting [m]	Northing [m]			
40000 BMH	V	55.764230ºN	8.178611ºW	824 779.6	6 191 987.3	448 461.0	6 180 145.0	55.4	14.1	14.5
40001	V	55.764207ºN	8.178742ºW	824 787.9	6 191 985.4	448 469.2	6 180 142.3	55.4	14.1	14.5
40002	V	55.764196ºN	8.178473ºW	824 771.2	6 191 982.8	448 452.3	6 180 141.3	55.2	14.9	14.9
40003	V	55.764338ºN	8.178441ºW	824 768.0	6 191 998.5	448 450.5	6 180 157.1	55.6	13.3	15.3

Notes:
For the Danish landfall, the coordinates of the reference points are given in two geographic reference systems: UTM zone 32N is the standard for Denmark, whereas UTM zone 31N covers most of the cable route and is therefore set as the main reference system for the Viking Link project.
Type V indicates a point marker.

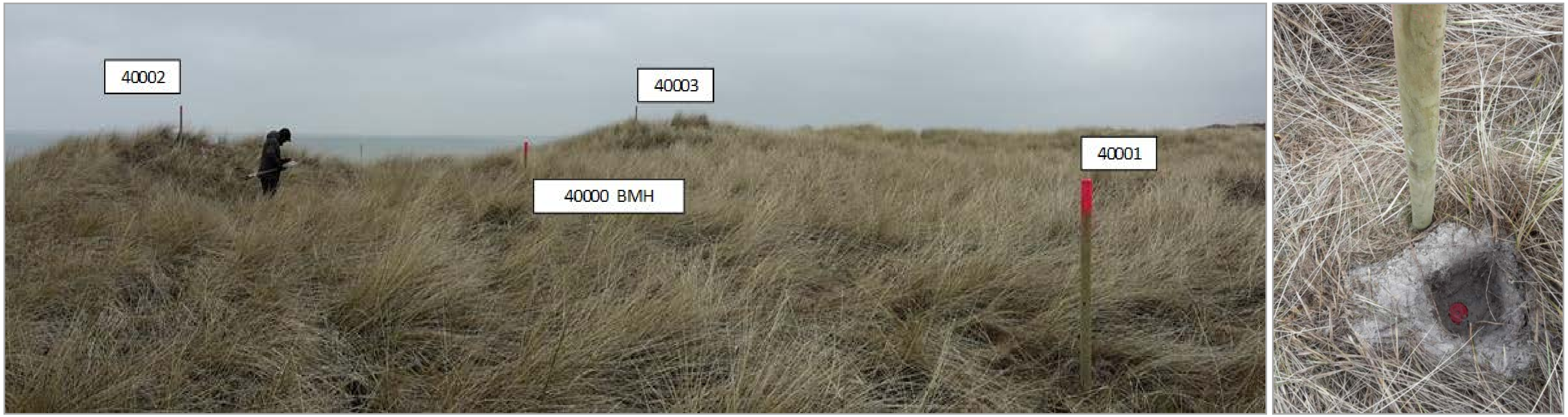


Figure E.8: Overview of reference points Danish landfall (left), example of point marker (right)

F. TOPOGRAPHIC AND BATHYMETRIC REDUCTION

F.1 TOPOGRAPHIC REDUCTION

At the Danish Landfall two locations with known position and height were used to perform crosschecks to verify the performance and settings of the GPS receiver. Across the survey area 3D laser scanner was utilised, complemented by data from a total station, to create a continuous data set. The topographic data at the Danish Landfall were reduced to Dansk Vertikal Reference 1990 (DVR90).

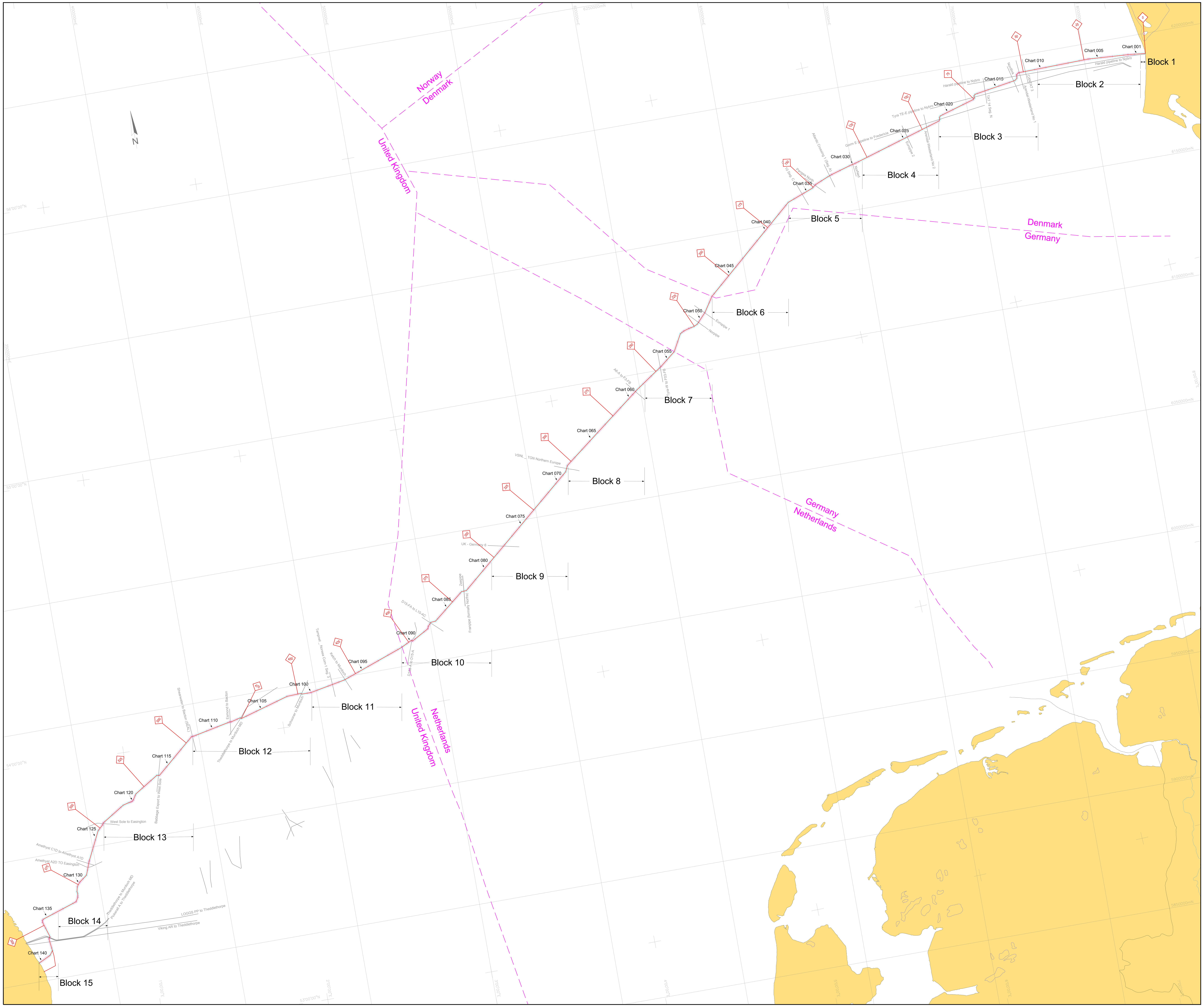
At the UK Landfalls, due to inaccessible terrain the 3D laser scanner topographic survey with total station was performed mainly along accessible infrastructure (road, sea defence wall). To facilitate building a complete coverage DTM, topographic data derived from orthophotos were locally purchased and integrated, referenced to total station data. All topographic data at the UK Landfall were reduced to Ordnance Datum Newlyn (ODN).

F.2 BATHYMETRIC REDUCTION

Tide calculations were based on GNSS real time observed data. The ellipsoidal height was derived relative to the GRS 1980 ellipsoid, using PosMV data for heave correction and Fugro's Starfix G2+ solutions.

All water depths were referenced to Lowest Astronomical Tide (LAT), reduced using post processed GNSS height data collected in real time on board the Fugro Pioneer. The LAT reduction process is a two stage operation; firstly the GNSS height data is reduced to Mean Sea Level (MSL) using the DTU13 Geoid reference model. Next, the height data is reduced to LAT using a DTU13 to LAT model developed by BLAST (Bringing Land and Sea Together) for the North Sea area covering Denmark, the Netherlands, Germany and the UK with full coverage along the proposed route.

G. OVERVIEW CHART



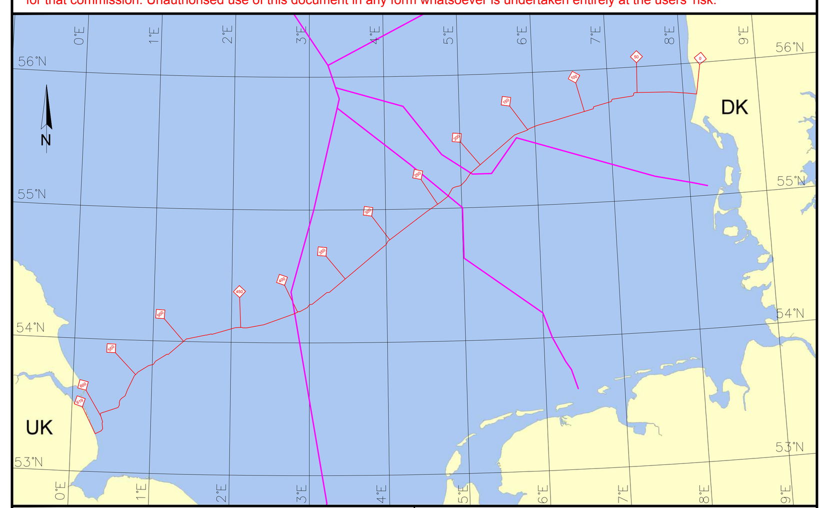
LEGEND:

- Kilometre Post indicating distance from Danish landfall
- Proposed cable route position
- Existing pipeline/cable route with identification
- International maritime boundary

NOTES:

COORDINATE REFERENCE SYSTEM:

Geodetic datum :	ETRS 89	Projection :	Transverse Mercator	False Easting :	500 000 m
Ellipsoid :	GRS 80	UTM Zone :	31 North	False Northing :	0 m
Semi major axis:	6 378 137.000	Central Meridian :	3° East	Scale Factor at CM :	0.9996
Inverse flattening:	298.257222101	Latitude of Origin :	0° North		
Vertical datum :	Lowest Astronomical Tide (LAT)				



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VIKING LINK

DENMARK TO UK - ROUTE 4v10 OVERVIEW CHART

SCALE 1 : 500,000

0 25,000 50,000 metres

0 50,000 100,000 150,000 feet

Route: 4v10		Survey Date: March - July 2016	Project Ref: J35045			
Issue No:	Date:	Description:	Interpr:	Drawn:	Chkd:	Appr:
03	16/12/16	Revised Final	Var.	Var.	Var.	Var.
02	02/12/16	Final	Var.	Var.	Var.	Var.
01	28/10/16	Draft	Var.	Var.	Var.	Var.
Client Ref.:		Drawing No.: J35045-RO-Overview-500k.dwg	Chart: Chart 001 of 001		App.: G	