US Wind, Inc.

Final cable burial risk assessment Export cable corridor

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CONTENTS

ABBREVIATIONS

Abbreviation	Description
AIS	Automatic information system
ALARP	As low as reasonably practicable
ASL	Average seabed level
CBRA	Cable burial risk assessment
CPT	Cone penetration test
DNV	Det Norske Veritas
DOC	Depth of cover
DoL	Depth of lowering
DNREC	Delaware Division of Natural Resources and Environmental Control
DWT	Dead weight tonnage
EC	Export cable
ECC	Export cable corridor
ECR	Export cable route
ENC	Electronic Navigation Chart
IRB	Indian River Bay
KP	Kilometre point
LAT	Lowest astronomical tide
MAG	Magnetometer
MBES	Multibeam echosounder
MDOL	Minimum depth of lowering
MLLW	Mean lower low water
NASCA	North American Submarine Cable Association
nT	Nanotesla
pUXO	potential UXOs
RPL	Route position list
SBP	Sub-bottom profiles
SSB	Stable seabed
SSS	Side scan sonar
TOC	Thickness of cover
TOP	Top of product
t_{soft}	Thickness of soft soil
TSS	Traffic separation scheme
USACE	US Army Corps of Engineers
UXO	Unexploded ordnance
VC	Vibracore
WT	Wood Thilsted
WDA	Wind development Area
WEA	Wind Energy Area
WTG	Wind turbine generator

1. INTRODUCTION

1.1. Project description

US Wind, Inc. (US Wind) is developing the Maryland Offshore Wind Project (MOWP), an offshore wind energy project of up to approximately 2 gigawatts of nameplate capacity within OCS-A 0490 (the Lease), a Lease area of approximately 80,000 acres located approximately 18.5 km (11.5 miles) off the coast of Maryland on the Outer Continental Shelf. Under a Project Design Envelope (PDE) approach, the MOWP could include as many as 121 wind turbine generators (WTG), up to four offshore substations (OSS), and one meteorological tower (Met Tower) in the Lease area. The MOWP will be interconnected to the onshore electric grid by up to four new 230-275 kV export cables to new US Wind substations, with an anticipated connection to the existing Indian River Substation near Millsboro, Delaware.

Figure 1.1 shows the location of the MOWP area on the Maryland Outer Continental Shelf (OCS) as well as the offshore export cable corridors (ECCs). The trapezoidal-shaped Lease area includes nine full OCS Lease Blocks and portions of 11 other OCS Lease Blocks. Export cables will extend from each OSS to a common offshore ECC that extends along the Lease boundary (or several boundaries) to near the northwest corner of the Lease area. The energy generated from the Project will make landfall through a common offshore ECC from the Lease area to one of two optional landfall locations on the Delaware shoreline. The two offshore ECCs are designated as: a) ECC 1, a southern option that makes landfall at 3R's Beach; and b) ECC 2, a northern option that makes landfall at Tower Road. Both offshore ECCs would require that the Project's onshore ECC, crosses the Delaware State Tidelands, inshore of the State/Federal jurisdictional boundary, located 3 statute miles offshore of the coastline. After making landfall, the onshore export cables may be submarine via onshore ECC 1 through Indian River Bay (IRB), or land-based if a terrestrial route is pursued to the point of interconnection. An overview of the onshore ECCs are shown in Figure 1.2.

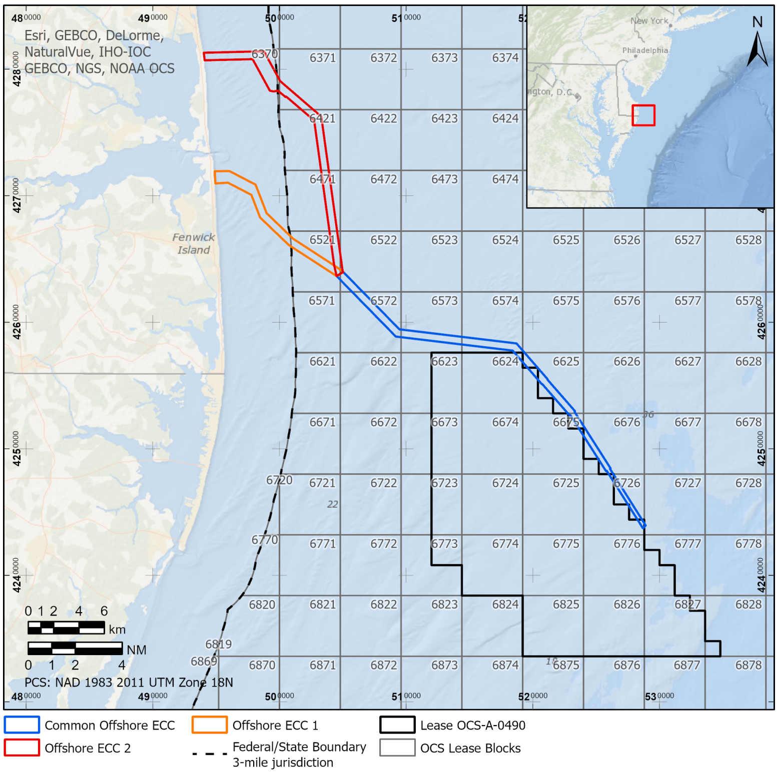


Figure 1.1: US Wind Lease area OCS-A-0490 location with OSS Lease Blocks and Offshore Export Cable Corridors (ECCs).

The onshore extension of ECC1 within IRB has two routes: IRB North and IRB South, which are shown in Figure 1.2.

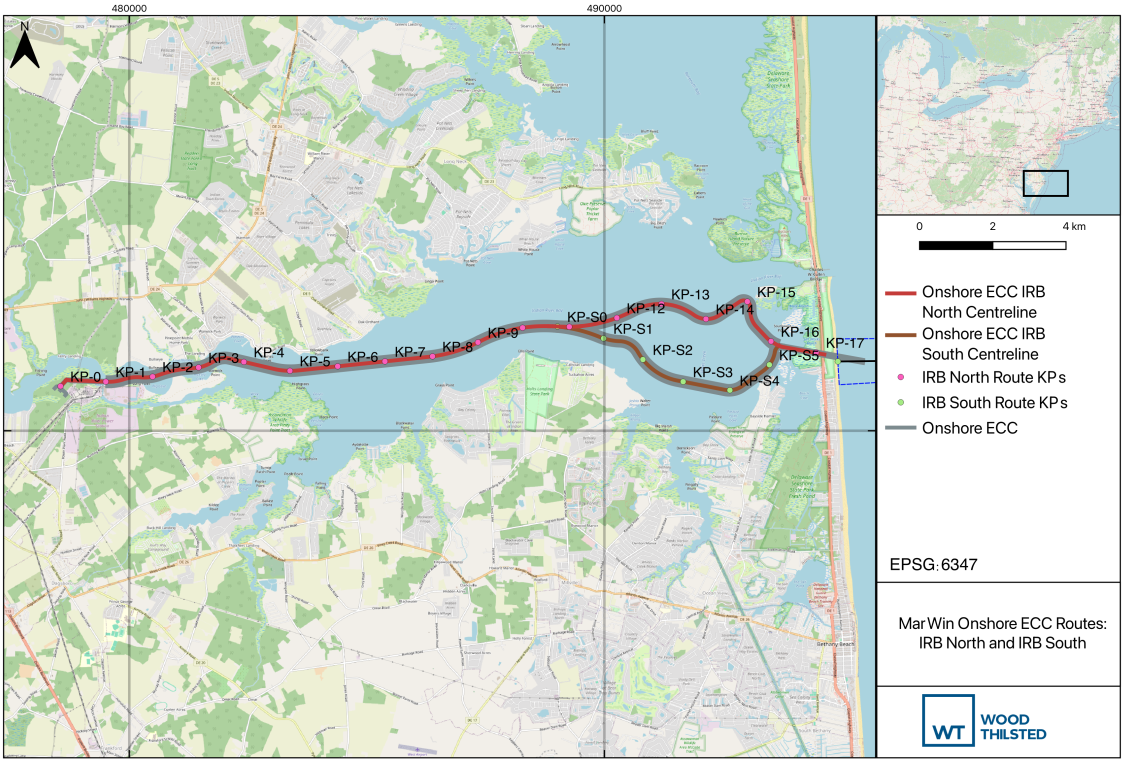


Figure 1.2: Planned routes of onshore ECCs: IRB North and IRB South.

Wood Thilsted (WT) is commissioned to conduct a cable burial risk assessment (CBRA) for the two offshore ECCs as well as the onshore ECC1 through Indian River Bay.

The CBRA comprises (but is not limited to):

- Qualitative risk assessment considering seabed conditions, bathymetry, shipping and fishing activities.
- Quantitative risk assessment determination of burial depths for a range of risk-return periods.

1.2. Data used

Table 1.1 summarizes all the data that has been used in the analysis of this report.

Table 1.1: Data used in this assessment.

Data	Description	Source
Route Boundary	Cable corridor boundaries for both ECCs and Indian River Bay	Client provided shape files
AIS data	AIS tracking data for a period of two years: from 1 January 2019 to 31 December 2019, and from 1 January 2022 to 31 December 2022	AccessAIS [1]
Geotechnical and geophysical survey	Boreholes (BH) and cone penetration tests (CPT) at exploratory locations. Multibeam echosounder (MBES) bathymetry, SSS imagery, medium penetration sub-bottom profiles (SBP), shallow penetration sub-bottom profiles and Magnetometer (MAG) data both offshore ECCs and onshore ECCs in IRB	Alpine [3], [4] and Gardline [13] [14] [15]
Geotechnical and geophysical survey	BH and CPT at MarWin WTG locations. MBES bathymetry, side scan sonar, sub-bottom profiler, transverse gradiometer-configured magnetometer, single-channel ultra-high-resolution seismic, multi-channel ultra-high-resolution seismic and grab samples in the Lease Area and Offshore ECCs	TDI 2021 [30] [29], Fugro 2022 [12]
Geotechnical survey	BH, Vibracores (VC) and CPT along onshore ECCs in IRB and nearshore region of offshore ECCs.	OSI 2022 [21], Sealaska 2023 [26], Alpine 2022 [2]
Geophysical survey	MBES, SSS, SBP, and TVG within the boundary of Onshore ECC within IRB	S.T. Hudson [24]
Fisheries assessment report	-	Sea Risk Solutions LLC [25]
Shallow Geohazards Interpretive Report	Details the high-resolution geophysical data and grab sample acquisition (TDI and Fugro), and assesses the seafloor and shallow geologic hazards and constraints that may affect the MOWP	GEMS [16]

1.3. Burial definition

The following definitions relevant for the understanding of the cable burial recommendations provided in this report are illustrated on Figure 1.3 and Figure 1.4. Where a definition is noted as a level this should be understood as being referenced to MLLW (or another agreed reference depth). Definitions given as a depth or distance are referenced between two levels and not to a particular datum.

- Sea level, MLLW; Mean lower low water.
- Stable seabed (SSB); The reference level at which the seabed is considered static i.e. not mobile.
- As-measured seabed; The seabed level to the noted datum at the moment of survey. This is commonly quoted prior to installation.
- As-installed seabed level; The as-measured seabed level at time of installation.
- Engineered seabed level; The seabed level resulting from seabed preparation, e.g. dredging, prior to cable installation.
- Top of product (TOP); The shallowest level of the cable within the given measured range i.e. every metre or every 5 metres.
- Depth of lowering (DoL); The distance from average seabed to TOP.
- Minimum depth of lowering (MDOL); The minimum DoL calculated by the CBRA to consider the cable safe referenced as depth below SSB.
- Depth of cover (DOC); The distance between the disturbed seabed (directly over the cable) and the TOP.

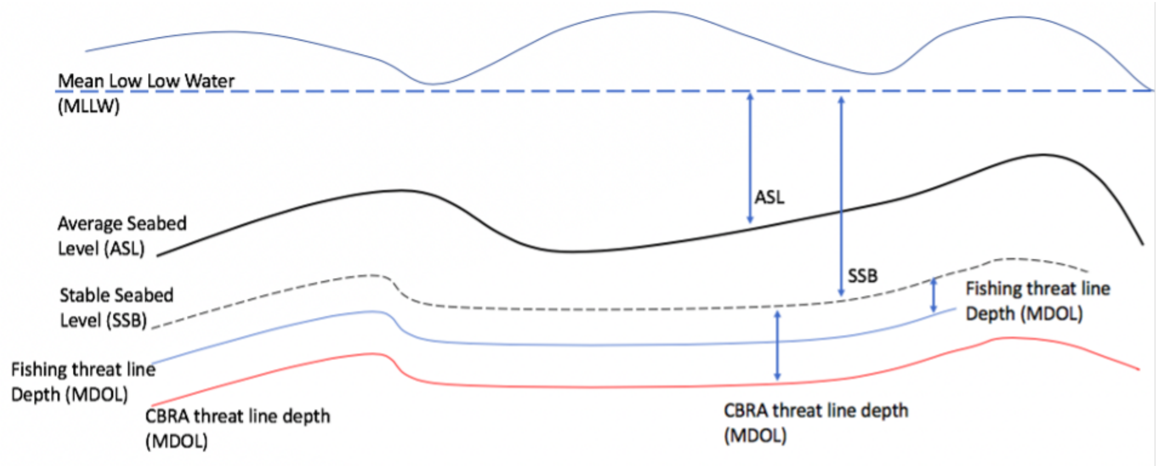


Figure 1.3: Global depth of lowering definitions.

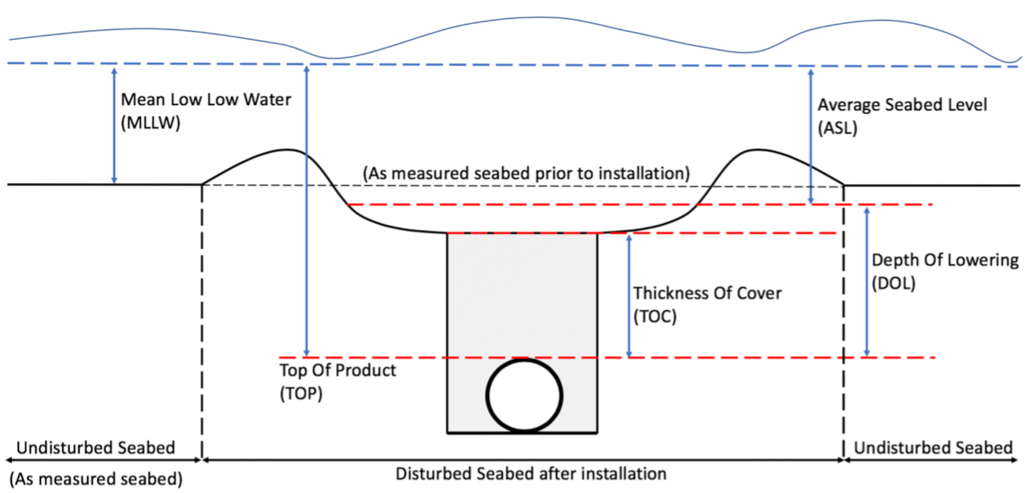


Figure 1.4: Detailed depth of lowering definitions.

1.4. Constraints and limitations

This desk study is prepared considering the particular instruction and requirements of US Wind. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

The results presented are suitable for planning and engineering in representing a depth of lowering (DoL) to mitigate anchor strike risk and risk of typical fishing practices.

2. ROUTE SEGMENTS

The routes analysed in this study are taken as the:

- Centrelines through ECC1 and ECC2 cable corridors
- Centrelines of onshore ECC1 routes in IRB as defined by the zone shown on Figure 1.2: IRB North and IRB South

A route position list (RPL) is extracted using a GIS platform. Four segments are adopted for quantitative analysis as shown in Figure 1.1:

- North landfall (ECC2)
- South landfall (ECC1) - from shore to the junction of ECC1 and ECC2
- Common corridor (ECC1 and ECC2) - from the junction of ECC1 and ECC2 to the Lease Area
- IRB (onshore ECC1) routes, including IRB North route and IRB South route

Segmentation of the routes is predominantly based on soil conditions 3.3. RPL details are presented for each segment in Section 3.3. A graphical representation of the vessel traffic for each segment is presented as part of the probabilistic analysis results in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2.

3. SITE CONDITIONS

The site conditions are assessed along the ECC routes based on geophysical and geotechnical survey data, see Table 1.1.

3.1. Geophysical survey results

Geophysical survey results are used for qualitative risk assessment. Further discussion is presented in Section 4.

3.2. Geotechnical investigations

Geotechnical survey locations along ECC1, ECC2 and onshore ECC1 (IRB North route and IRB South route) are shown on Figure 3.1 [3] [28]. Grab samples are not considered due to the limited depth of investigation. There is typically a vibracore (VC) or cone penetration test (CPT) available for each $1\,\mathrm{km}$ of cable.

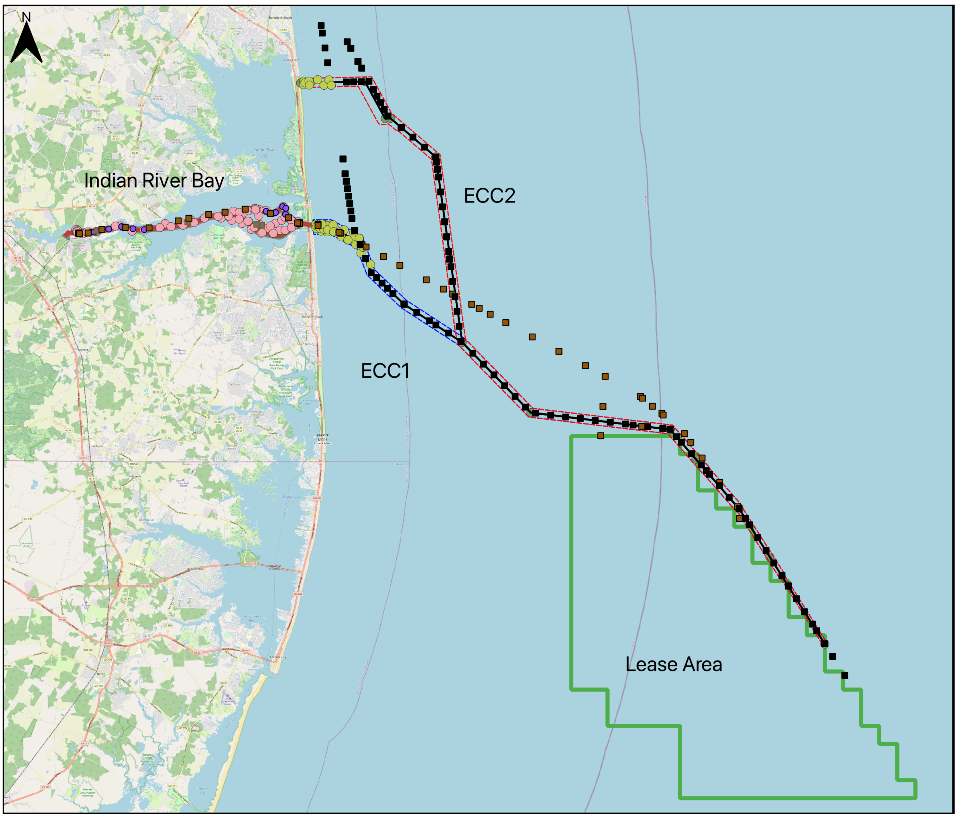


Figure 3.1: Geotechnical survey locations - WEA. Brown (2016-2017 Alpine [3]). Black (TDI-Brooks [28]). Purple (OSI 2022 [21]). Green (Alpine neashore 2022 [2]). Pink (Sealaska 2023 [26]).

3.3. Classification of soils for quantitative assessment

Understanding the geotechnical conditions is an important factor in determining the required burial depth and to identify any obstacles/challenges to the installation process. The soil stratigraphy along the ECCs are categorised as either; soft soil or hard soil with the thickness of soft soil (t_{soft}) accounted for by applying a two-layer soil model. This classification is undertaken to align with Carbon Trust guidance for cable burial risk assessments. The Carbon Trust guidance [7] classifies soft soil as soft silt or clay (with the non-soft category being sands and firm to stiff clays). WT adopt this guidance as general basis for identification of soft and hard soil for the US Wind ECCs.

t_{soft} is interpreted from BH logs [2] [26], VC logs [20] [21] [2] [26] and CPT results [28] [2] [26] and supplemented by engineering judgement. For example, if a clay layer is observed within 1.5 m of the seafloor the profile is considered soft because it is assumed the upper 1.5 m of material will be disturbed during installation exposing the underlying clay material. The largest value of t_{soft} is conservatively adopted for cable sections where multiple observations are available. A full list of test locations and the interpreted t_{soft} is presented in Appendix A.

3.3.1. South landfall

The south landfall section is part of ECC1. Figure 3.2 presents the south landfall route alignment and t_{soft} from geotechnical interpretation. Table 3.1 presents the RPL and t_{soft} adopted for quantitative CBRA.

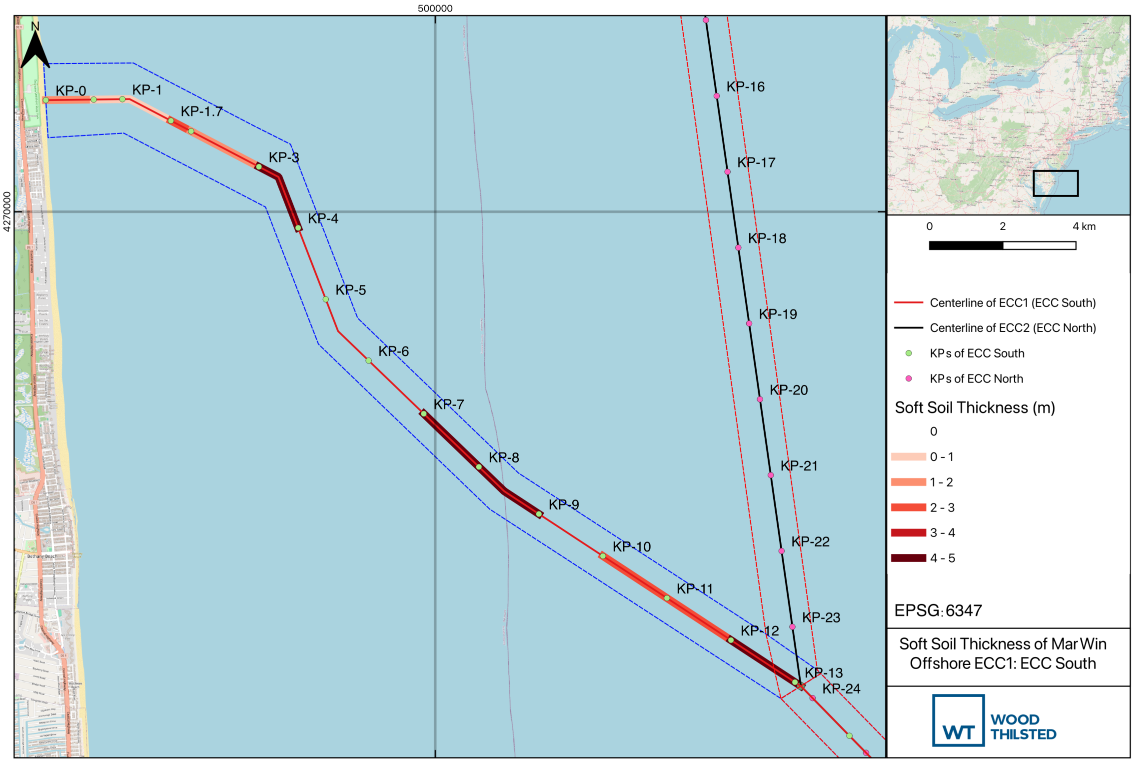


Figure 3.2: Results of soft soil interpretation for south landfall segment. Green dots are KP markers.

Table 3.1: Geotechnical classification of south landfall segment (ECC1).

ID	KP	t_{soft} (m)
1	0 - 0.6	1.4
2	0.6 - 1	0.4
3	1 - 1.7	0.2
4	1.7 - 2	2.8
5	2 - 3	2
6	3 - 4	4.5
7	4 - 7	0
8	7 - 9	4.6
9	9 - 10	0
10	10 - 12	2.6
11	12 - end	4.8

3.3.2. Main corridor

The main corridor section is part of ECC1. It extends from the junction of north and south landfall sections to the Lease area. Figure 3.3 presents the main corridor route alignment and t_{soft} from geotechnical interpretation. Table 3.2 presents the RPL and t_{soft} adopted for quantitative CBRA.

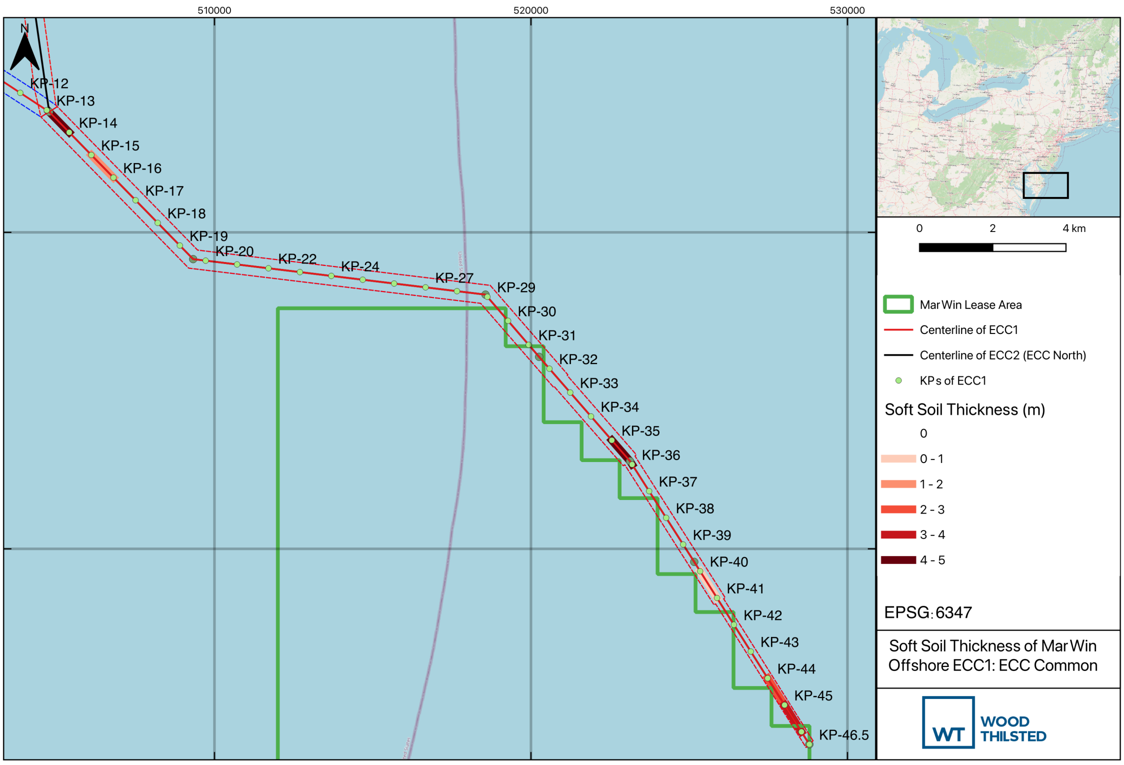


Figure 3.3: Results of soft soil interpretation for main corridor segment. Green dots are KP markers.

Table 3.2: Geotechnical classification of main corridor segment (ECC1).

ID	KP	t_{soft} (m)
1	13 - 14	4.8
2	14 - 15	0
3	15 - 16	2
4	16 - 35	0
5	35 - 36	5
6	36 - 40	0
7	40 - 41	1
8	41 - 44	0
9	44 - 45	2.8
10	45 - 46	3.2
11	46 - end	0

3.3.3. North landfall

The north landfall section is part of ECC2. Figure 3.4 presents the north landfall route alignment and t_{soft} from geotechnical interpretation. Table 3.3 presents the RPL and t_{soft} adopted for quantitative CBRA.

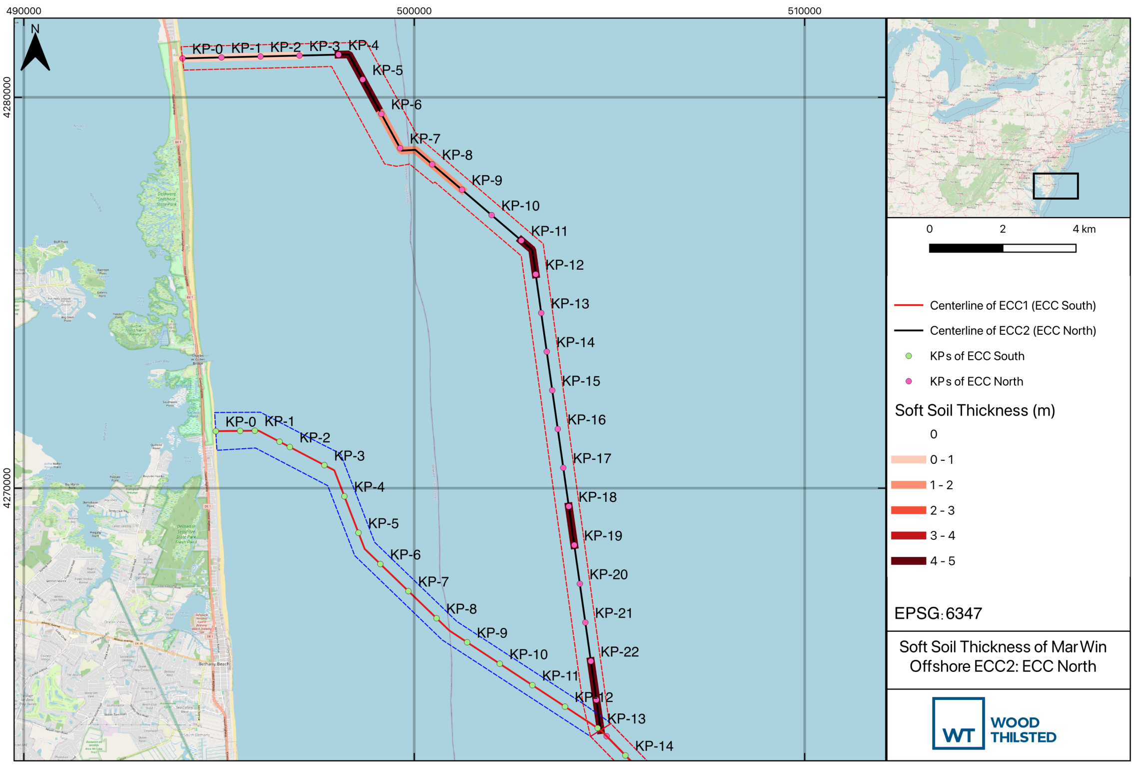


Figure 3.4: Results of soft soil interpretation for north landfall segment. Green dots are KP markers.

Table 3.3: Geotechnical classification of north landfall segment (ECC2).

ID	KP	t_{soft} (m)
1	0 - 1	0.6
2	1 - 3	0.2
3	3 - 4	0
4	4 - 6	5
5	6 - 9	1.1
6	9 - 11	0
7	11 - 12	4.9
8	12 - 18	0
9	18 - 19	4.9
10	19 - 22	0
11	22 - end	4.8

3.3.4. Indian River Bay

Figure 3.5 presents the Onshore ECC1 and t_{soft} from geotechnical interpretation. The Onshore ECC1 include two routes: IRB North route and IRB South route. Furthermore, analysis of the geotechnical survey results suggest that the majority of the seafloor is expected to comprise soft sediments, i.e. the interpreted soft soil thicknesses of SI positions mapped onto IRB North route are within the range of 0 and 14.5 m, so a 14.5 m soft soil thickness has been adopted for CBRA for conservative recommendations due to deep soft sediments in the Indian River Bay. While the maximum interpreted soft soil thickness, 12.1 m, is adopted for the IRB South route.

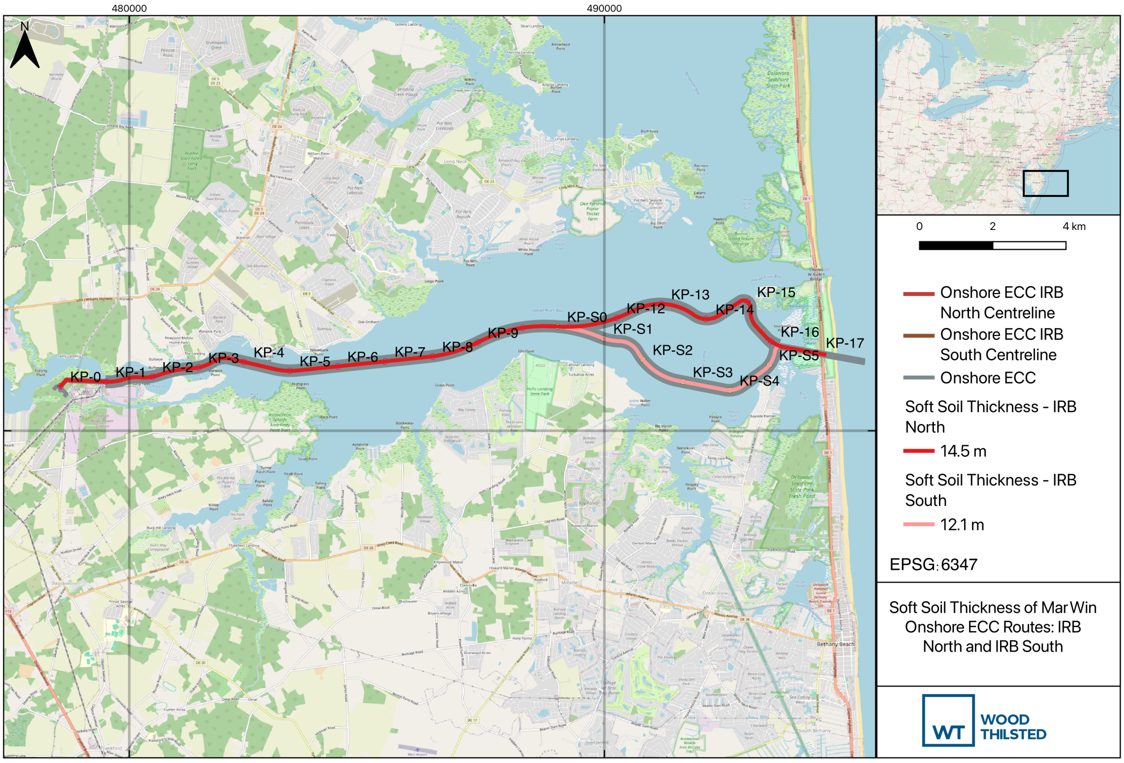


Figure 3.5: Results of soft soil interpretation for the Onshore ECC1 - IRB north and IRB south.

Table 3.4: Geotechnical classification of IRB North route.

ID	KP	t_{soft} (m)
1	0 - 17	14.5

Table 3.5: Geotechnical classification of IRB South route.

ID	KP	t_{soft} (m)
1	S0 - S5.5	12.1

4. Qualitative risk assessment

4.1. Anthropogenic risks

4.1.1. Shipping activity

The Lease area is located just south of the Delaware Bay Southeastern Approach Traffic Separation Scheme (TSS). Traffic separation schemes are usually created in areas with heavy traffic in different directions. It is an area where the navigation of vessels is highly regulated with lanes of vessels travelling the same direction.

The eastern half of the main ECC runs along this TSS. Shipping traffic is identified from AIS data. Figure 4.1 shows the AIS tracks crossing the main ECC. Cargo vessel traffic is shown in blue. It is expected that cargo vessels are less likely to navigate through the Lease area, hence fewer vessels may be expected to cross the export the cable once the windfarm is operational.

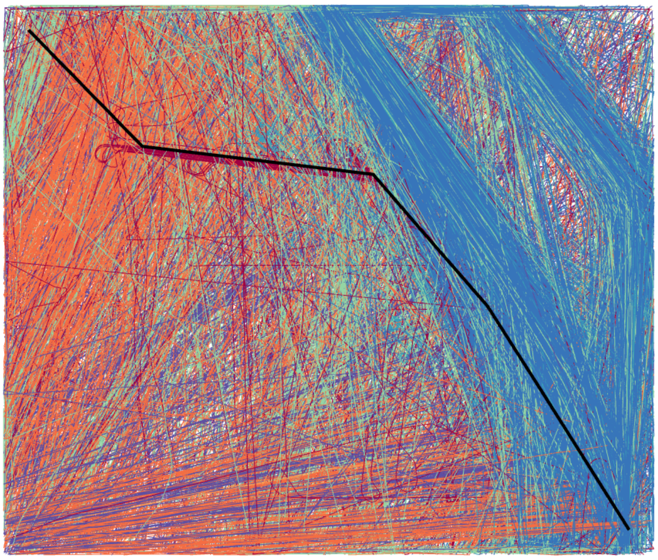
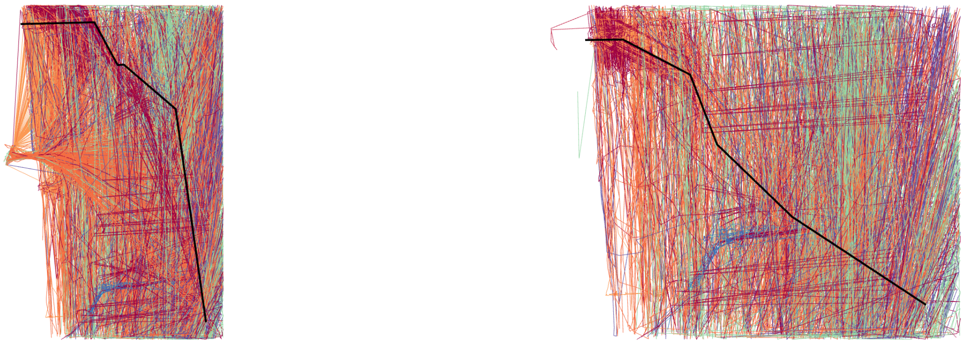


Figure 4.1: AIS Tracks for vessels crossing the main ECC.

Figure 4.2 shows the AIS tracks for vessels crossing the northern and southern ECC landfall sections. Cargo traffic is shown in blue. The data shows very little shipping traffic crossing either of the ECCs in these sections relative to the main corridor section.



(a) ECC Northern landfall **(b)** ECC Southern landfall

Figure 4.2: AIS Tracks for vessels crossing the landfall ECC alternatives.

Figure 4.3 and Figure 4.4 show the AIS tracks for vessels crossing the Onshore ECC1: IRB North route and IRB South route. Cargo traffic is shown in blue. The data shows no shipping traffic in the Onshore ECC1.

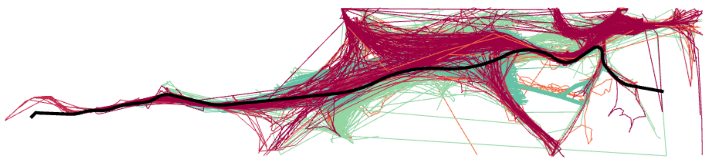


Figure 4.3: AIS Tracks for vessels crossing the Onshore ECC1: IRB North route.

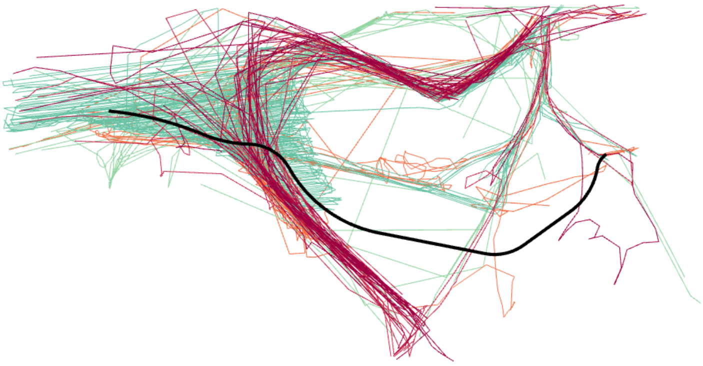


Figure 4.4: AIS Tracks for vessels crossing the Onshore ECC1: IRB South route.

The largest vessels identified crossing the Main ECC has an estimated dead weight tonnage (DWT) of 170,000 tonnes and are identified as cargo vessels. The largest vessel identified for the north and south landfall has an estimated DWT of 24,000 tonnes and only one or two crossings from this size vessel was identified from AIS data. The second and third largest vessels crossing the north and south landfall have an estimated DWT between 13,000 and 11,000 tonnes. These massive vessels can cause severe damage in case of an anchor strike under accidental/emergency circumstances. The largest vessels identified in the Onshore ECC1 has an estimated DWT of 4000 tonnes and are mainly identified as pleasure crafts from AIS data.

4.1.2. Fishing activity

A fisheries assessment report in and around the MOWP area was conducted by Sea Risk Solutions LLC [25]. The findings from this assessment are summarised below.

Bottom otter trawl fishing activity exists to a limited extent between KP-8 and KP-13 of ECC2.

Fishing with pots and traps occurs diffusely throughout both ECCs. It is most intensive towards the shoreline from KP-0 to KP-3 of both ECCs and at the end of the main corridor by the Lease area from KP-31 to KP-46. This type of fishing can cause challenges for the survey and installation operations because caution must be taken in order not to snag either the vertical buoy lines or the lines connecting the traps. Black seabass traps are most often set in strings of about 12 to 36 traps connected by a ground line. This gear may need to be removed where cables are planned to cross. This is to install the cable without damaging the gear as well as protect the cable. It is expected that fishing using pots will contribute to the traffic intensity. Additionally pots and traps occurs in the outer part of the Onshore ECC1.

Bottom gillnet fishing occurs to some extent along the main ECC at KP-29 to KP-44, however this type of fishing has low penetration of the seabed (10 cm for anchors) and is not of high concern to the cable. This type of fishing gear should be removed before installation if the cable alignment crosses gillnet locations.

Although very little, if any, commercial clam dredge activity exists along the ECCs nearshore of the Lease area the external aggression risk from this type of fishery should be considered when planning cable burial. According to the North American Submarine Cable Association, NASCA, surf clam dredging operations with hydraulic dredges penetrate the seabed more than other mobile fishing and harvest gear. Historically submarine telecom cables in the Northeast US seaboard have suffered several cases of damage from hydraulic clam dredges and incident of penetration up to 1 m has been reported.

Targeted commercial sea scallop fishery has not been observed within the ECCs and the scallop fishing activity found is most likely to be transit to and from port.

Hiddink et al. [17] conducted a systematic literature review of both North American and European studies that provide measurements of fishing gear penetration depth, including any study for which penetration depth of a fishing gear or a gear component (e.g., doors, sweeps,and bridles of an otter trawl) was measured or inferred. The three primary fishing practices of concern identified were; trawling, towed dredging and hydraulic dredging. These fishing methods are illustrated in Figure 4.5. The penetration depths into the seafloor were modelled by Hiddink et al. [18] and are shown in Table 4.1.

Carbon Trust recommendations [7] states that the maximum penetration depth of towed fishing techniques is 0.3 m. It is, however, common practice to apply a safety factor of 2 to the calculated penetration of fishing gear.

Based on the available data the recommended minimum depth of lowering to protect against fishing is 1 m. This value is the conservative choice for this analysis to account for the incident reports from hydraulic dredges. The DoL may be increased locally if extensive hydraulic dredging is expected.

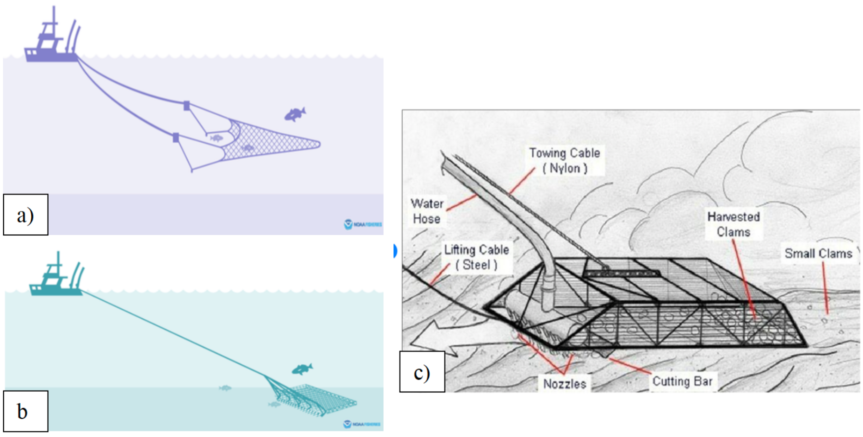


Figure 4.5: Fishing gear: a) Otter trawl. b) Towed dredge. c) Hydraulic dredge.

Table 4.1: Predicted fishing gear penetration [18].

Gear	Penetration Mean $\pm$ standard deviation
Hydraulic Dredge	0.161 $\pm$ 0.058
Towed Dredge	0.055 $\pm$ 0.022
Otter trawl	0.024 $\pm$ 0.011

As has been the case with the Block Island Wind Farm and the Coastal Virginia Offshore Wind Pilot Project, it is likely that the presence of turbines will attract additional recreational activity. It should be expected that recreational fishing activity, and sightseeing, will increase in the offshore area once the wind farm is in operation.

4.1.3. Potential unexploded ordnance

The presence of unexploded ordnances (UXO) is possible due to present and past military use in Warning Area 386 (W-386) [4]. W-386 is special-use airspace over VACAPES OPAREA-Areas 1-12 off the coast of Maryland in which missile, gunnery, and rocket exercises using conventional ordnance are authorized [33]. Many minor magnetic anomalies were identified with potential to be related to shallow buried UXO [4].

A high number of magnetic anomalies are identified in the ECCs and IRB indicating risk of potential UXOs (pUXO).

4.1.4. Existing infrastructure

Two fish havens or existing recreational fishing hotspots are identified near the northern part of ECC2 according to National Oceanic and Atmospheric Administration (NOAA). The exact coordinates of these areas are not known to WT at this point in time. These areas are usually simulating natural reefs and used for recreational purposes and should be avoided in cable routing.

Pot/trap fishing is known in the ECCs. This method of fishing can complicate installation operations. Therefore, these areas should be avoided if possible.

No wreck contacts were interpreted by TDI or Fugro within the current ECC boundaries, although two possible wreck contacts were interpreted just to the south of the common ECC boundary by Fenwick Shoal and one additional possible wreck contact was interpreted just to the north of the northern most ECC2 boundary. These possible wrecks are marked on Figure 4.7 and 4.8. While no wreck locations have been interpreted by TDI and Fugro within the ECC boundaries, one potential cultural resource has been interpreted within the ECC Area of Potential Effect in [23].

No cables or pipelines are identified according to NASCA maps.

4.1.5. Dredging and dumping sites

According to WT's Integrated Geophysical & Geotechnical Site Characterization Report [34], the dredged navigation channel is documented to have been generally 200 ft (61.0 m) wide and 15 ft (4.6 m) deep from the inner ends of the jetties to a point in the Bay substantially 7000 ft (2.1 km) from the ocean shoreline, dredging a channel 9 ft (2.7 m) deep, 100 ft (30.5 m) wide in the Bay and 80 ft (24.4 m) wide in the River, from that depth in the existing channel in Indian River Bay to and including a turning basin 9 ft (2.7 m) deep, 175 ft (53.3 m) wide and 300 ft (91.4 m) long at Old Landing; then about 8200 ft (2.5 km) to the highway bridge at Millsboro, 60 ft (18.3 m) wide, 4 ft (1.2 m) deep [32]. The notional route of the channel is shown in Figure 4.6, although US Army Corps of Engineers (USACE) and Delaware Division of Natural Resources and Environmental Control (DNREC) have indicated to US Wind that the location of the channel shifts to the deepest portions along the route as frequently as on an annual basis.

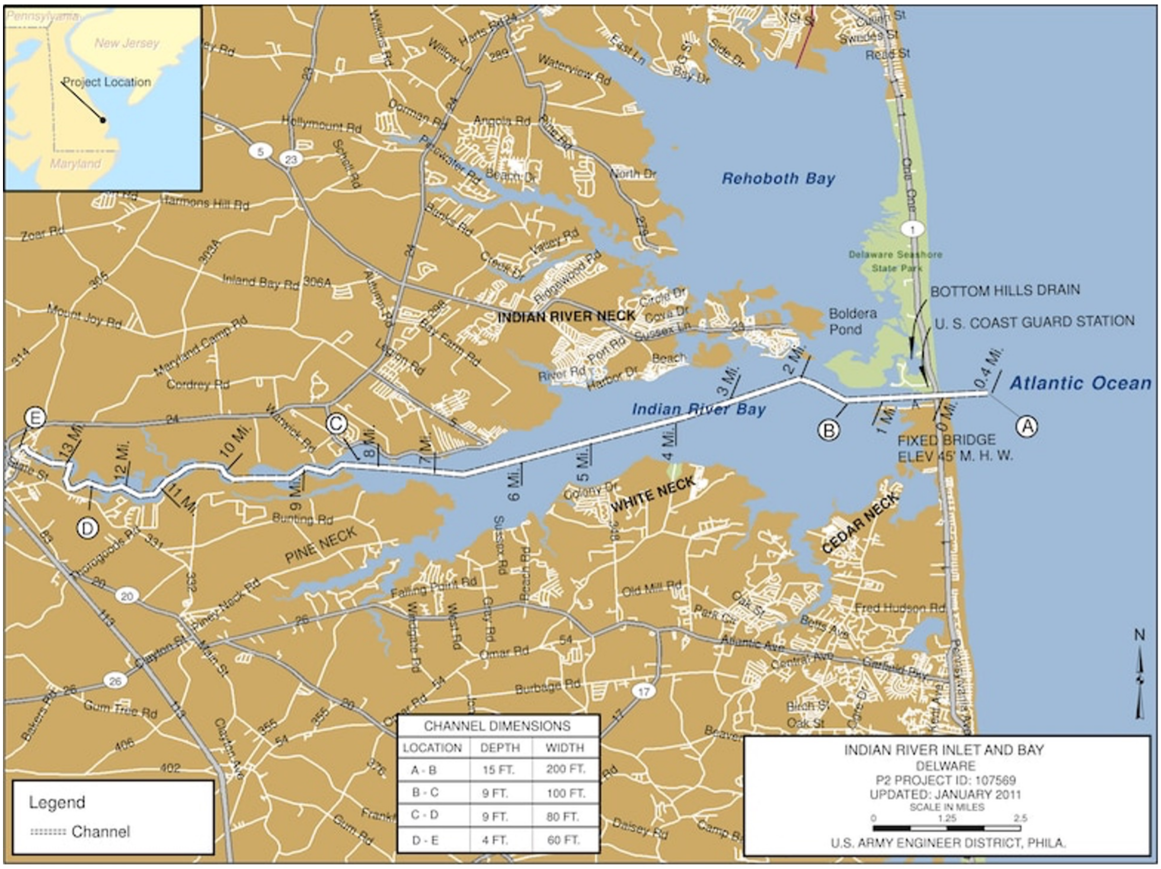


Figure 4.6: Indian River Bay navigation channel route and dimensions [32].

While the full length of the channel is shown in Figure 4.6, Electronic Navigation Chart (ENC) mapping[1] shows that the federally-maintained portion of the channel comprises the stretch from point E eastwards to 7 Mi along the mapped channel alignment in Figure 3 9. USACE has communicated to US Wind that federal maintenance of the navigation channel is not active in this area with the exception of the Indian River Inlet, approximately between points A and B. DNREC occasionally maintains (dredges) along portions of the channel, primarily in Indian River (point C to E) and in other areas of Indian River Bay as needed.

4.1.6. Designated anchorages

No designated anchorages are identified from nautical charts for either ECC.

4.2. Natural risk

The natural risk assessment is based on geophysical site characterization data. Geophysical surveying has been completed in 2021-22 for both the Offshore ECCs and ECC1 within IRB (Table 1.1), and separate shallow hazard and Marine Site Characterization reports have been completed that cover the offshore ECCs, which have been used to inform this assessment [16] [35]. The 2022 geophysical survey results for IRB (Table 1.1) have been used to inform the assessment within ECC1 [24].

[1] https://encdirect.noaa.gov/

4.2.1. Seabed contacts

Seafloor features have been reported by GEMS [16] from MBES, SSS, and MAG based on data acquired by TDI and Fugro in 2021-22. A total of 3,951 sonar point contacts have been identified within the combined Offshore ECCs.

The SSS point contacts generally represent modern debris associated with shipping, storms, fishing, or exploration activities, or are geologic in nature [16]. By far most contacts, 2,531, are unspecified debris or unknown items. Debris of anthropogenic or unknown classification is scattered throughout the Offshore ECCs.

Contacts interpreted to be anthropogenic or of unknown origin are presented in Figure 4.7 and 4.8 [35] following reclassification by WT to align the combined SSS contact database (using TDI's primary contact classification and Fugro's secondary contact classification) [35]. Interpretation of contacts with regard to cultural resources is provided in [23]. Larger scale maps are presented in Appendix D.

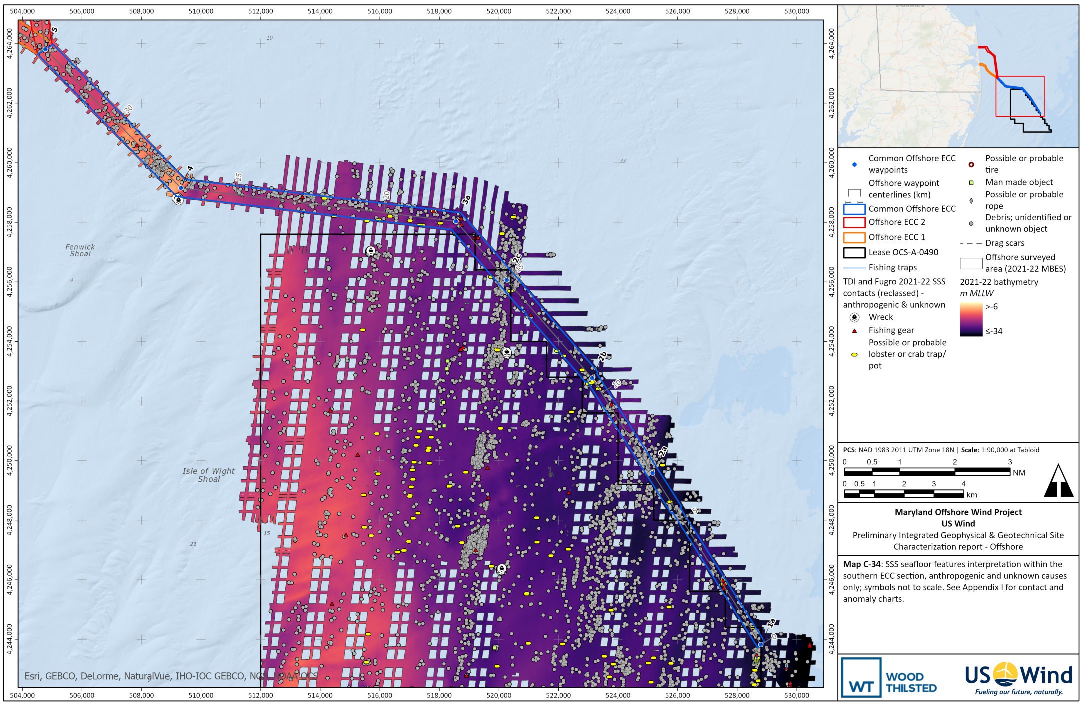


Figure 4.7: Overview map of SSS contacts in the southern ECC from the TDI and Fugro surveys in 2021-22 [35].

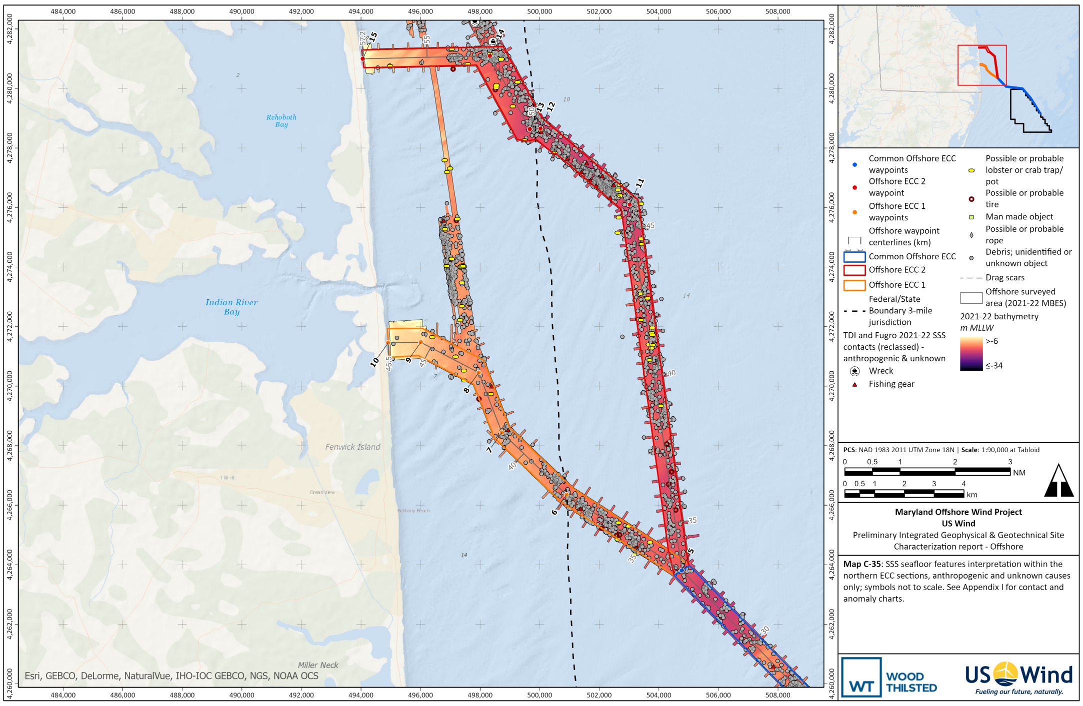


Figure 4.8: Overview map of SSS contacts in the northern ECC sections from the TDI and Fugro surveys in 2021-22 [35].

A total of 473 side scan sonar contacts were identified within the Onshore ECC1 project area from the Hudson 2022 geophysical survey of IRB. A total of 54 of the observed contacts exhibited relief greater than 0.5 m and 9 were observed with relief greater than 1 m. All contacts were classified as possible debris and were designated as either round, linear, rectangular, or irregular [24]. All identified sonar contacts in the Onshore ECC1 are mapped on Figure 4.9. We note that the coverage of the SSS data from which the contacts were interpreted is limited to areas of deeper water, so unmapped contacts may exist in shallower waters. There is a higher density of contacts in the westernmost part of the Onshore ECC1 coming into the grid connection point. These could pose complications to the cable routing as this is the narrowest part of the corridor.

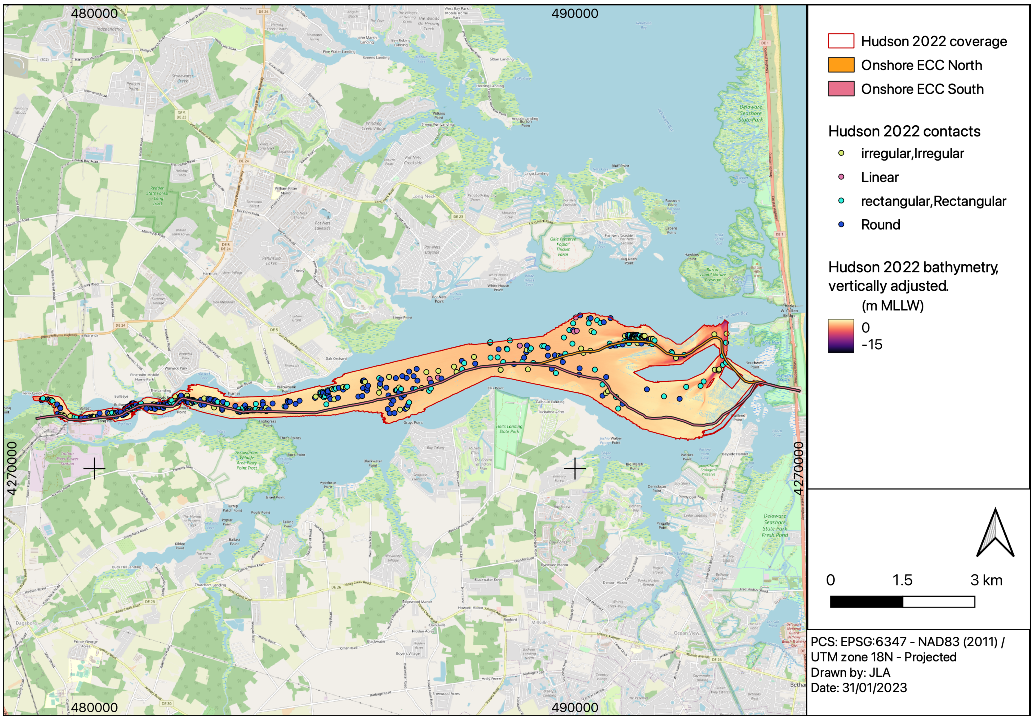


Figure 4.9: Overview map of SSS contacts in the Onshore ECC1 from the Hudson 2022 geophysical survey [24].

4.2.2. Magnetic anomalies

A total of 2,336 magnetic anomalies have been identified within the Offshore ECCs. Most of the interpreted targets are of a relatively low amplitude, with a median anomaly amplitude of only $7.7\,\mathrm{nT}$ (where, nT is short for Nanotesla). Only 143 targets (6%) have an amplitude equal to or exceeding $30\,\mathrm{nT}$.

TDI targets are classified as 'Possible geology', 'Possible small object' or 'Possible medium sized object'. Fugro targets are classified as 'Discrete' or 'Non-discrete' [35]. The distribution of interpreted targets is shown in Figure 4.10 and 4.11 and a summary is given in Table 4.2. Larger scale maps are presented in Appendix D.

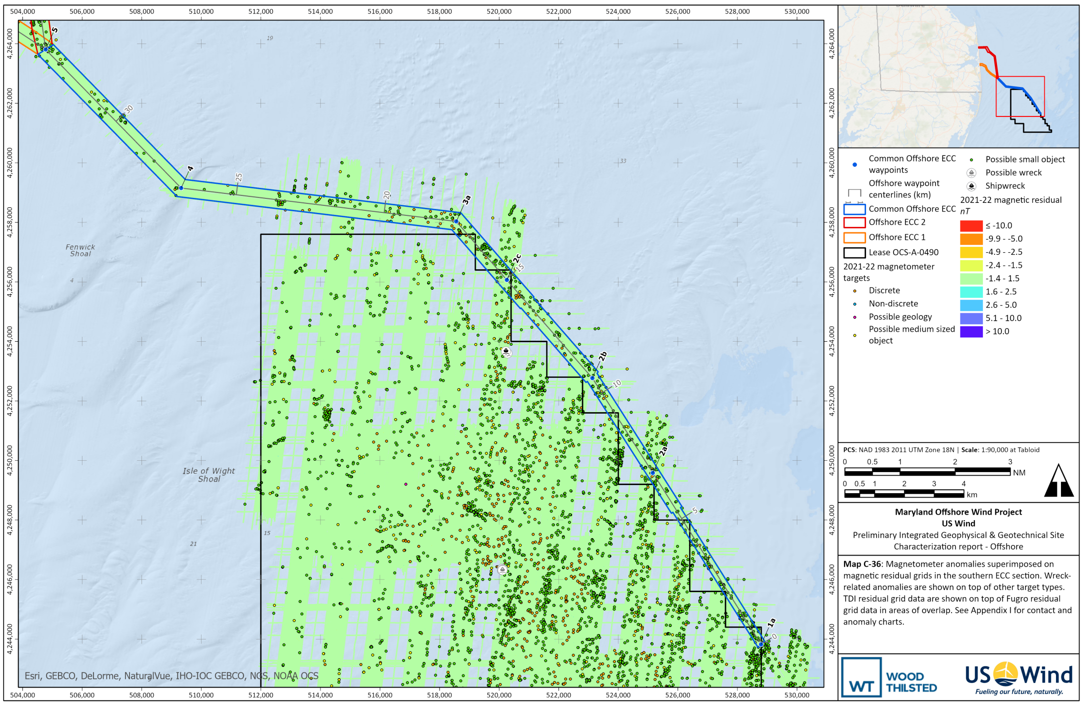


Figure 4.10: Magnetometer anomalies superimposed on magnetic residual grids in the southern ECC section from the TDI and Fugro surveys 2021-22 [35].

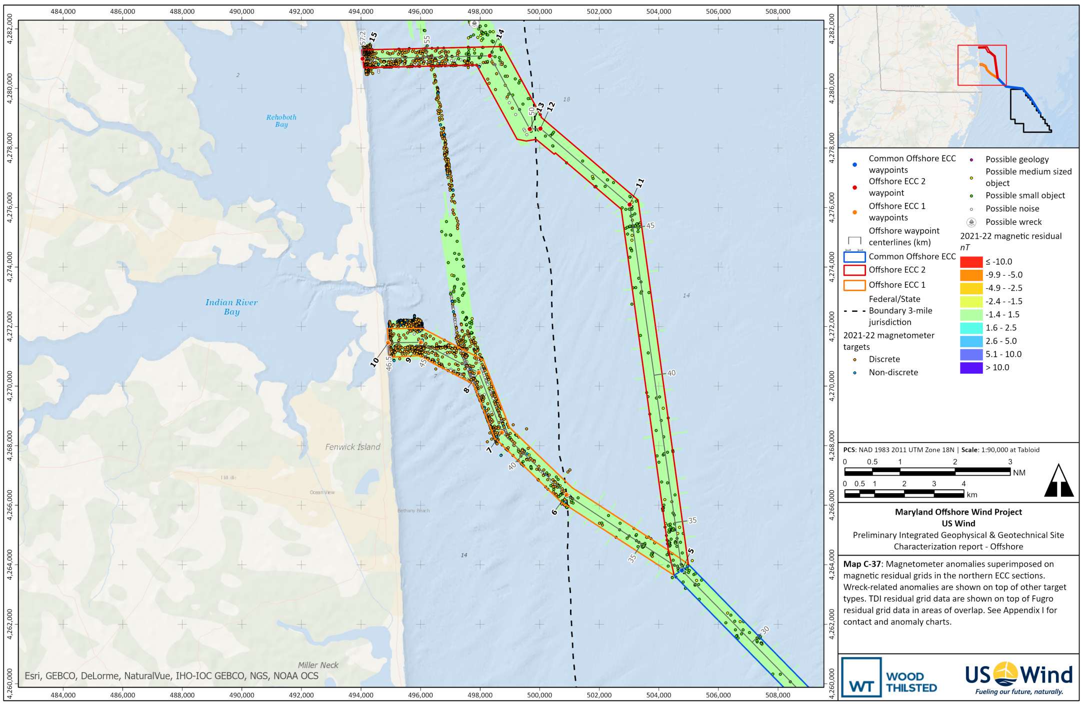


Figure 4.11: Magnetometer anomalies superimposed on magnetic residual grids in the northern ECC sections from the TDI and Fugro surveys 2021-22 [35].

Table 4.2: Summary of magnetometer contacts within the Lease area boundary [35].

Target class	$< 30\,\mathrm{nT}$	$\geq 30\,\mathrm{nT}$	Total
Discrete	902	27	929
Non-discrete	195	9	204
Possible geology	0	2	2
Possible medium sized object	0	105	105
Possible small object	698	0	698
Possible noise	398	0	398
Total	2,193	143	2,336

Given the dynamic seabed and conditions within the ECCs there is the potential for objects to become covered and uncovered due to bedform and sediment migration and due to self-burial, and potentially also for objects to move over time. It should also be noted that the coastal and OCS regional magnetic environment offshore Maryland is characterized by a strong geologic influence [4].

The Hudson geophysical survey identified a total of 462 magnetometer anomalies in the residual grid within the IRB that had an amplitude over 3nT and a wavelength of 14m or less. The target anomalies provided by the Hudson 2022 survey were picked from the analytic signal, and not from the magnetic residual. Many of the residual targets were attributed to natural background, but these could not be distinguished from hazards strictly through magnetic filtering or grid manipulation [24]. The magnetic anomalies identified by the Hudson geophysical survey within the Onshore ECC1 are mapped in Figure 4.12. We note that the coverage of the SSS data from which the contacts were interpreted is limited to areas of deeper water, so unmapped contacts may exist in shallower waters.

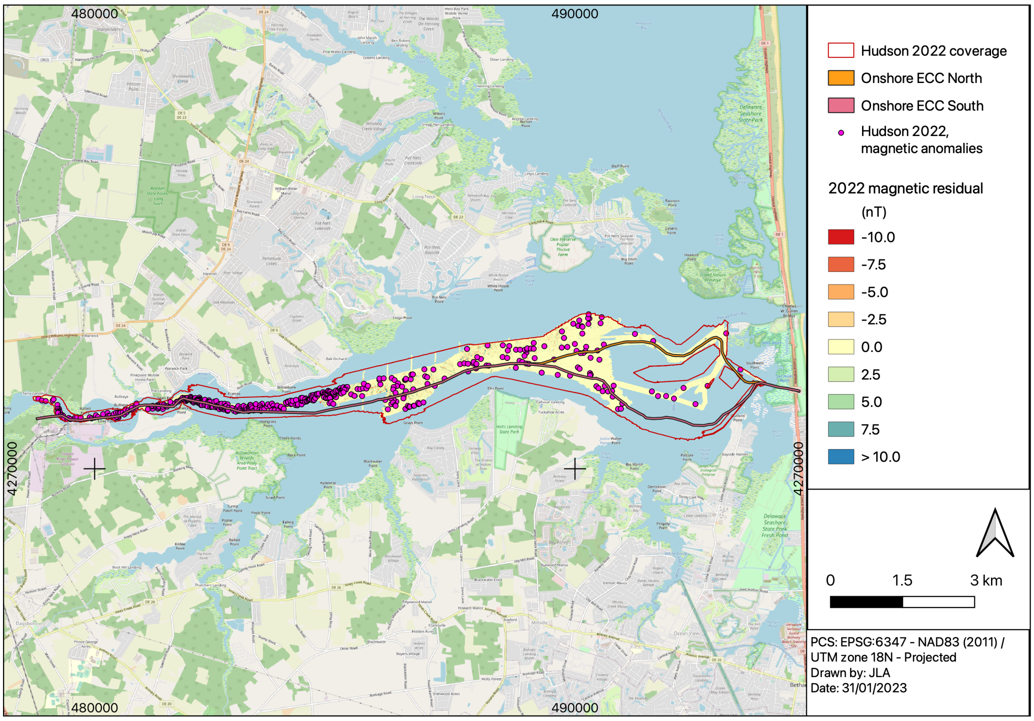


Figure 4.12: Overview map of magnetic geological anomalies in the Onshore ECC1 from the Hudson 2022 geophysical survey [24].

4.2.3. Water depth

The water depth in state waters is generally shallower than -18 m MLLW for ECC 2 (northern) and -14 m MLLW for ECC 1 (southern). In federal waters the water depth ranges from -11.1 to -31.8 m MLLW. The water depth typically increases from northwest to southeast, with variations due to bedforms superimposed on this trend. The bathymetric data is acquired by TDI in 2021 [30] and Fugro in 2022 [12] and merged by WT [35]. Shallower water depths are generally limited to the locations of the taller sand ridges and near shore areas. An overview is shown in Figure 4.13 and 4.14. Larger scale maps are presented in Appendix D.

The nearshore part of the ECCs has a relatively shallow water with depths of less than 15 m. Shallow water access and navigational risk must be considered as part of the cable installation strategy for the nearshore area. It is expected that most installation vessels should be able to operate for the part of the ECC with water depths deeper than 15 m.

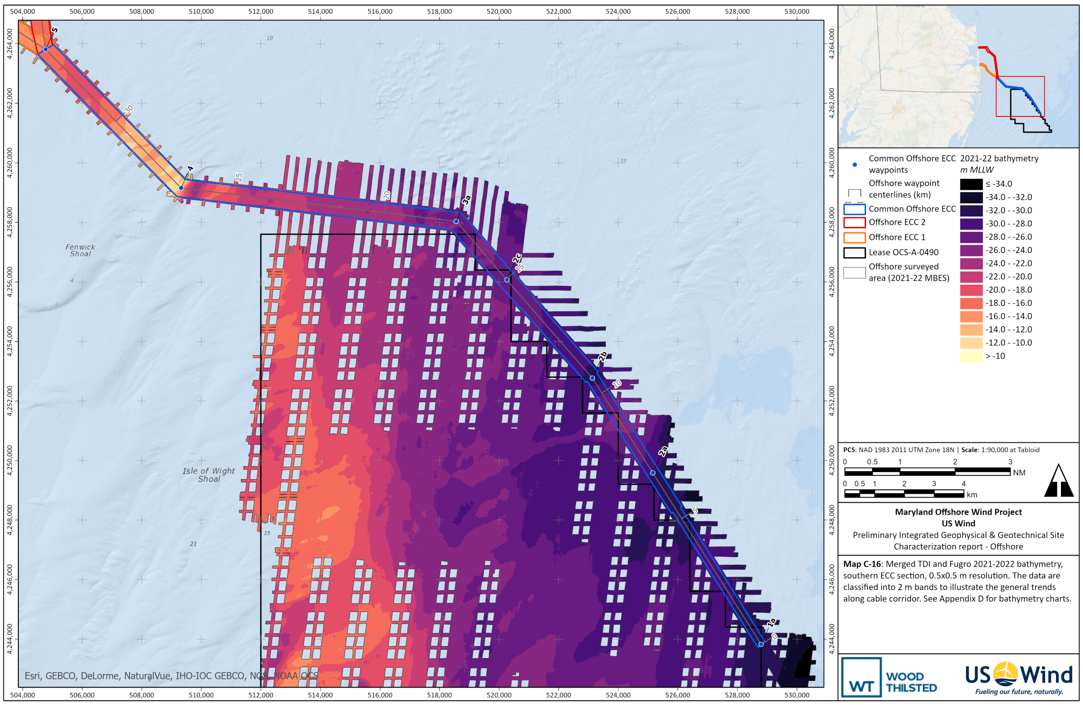


Figure 4.13: Merged TDI and Fugro 2021-2022 bathymetry, Southern ECC section, 0.5x0.5 m resolution [35].

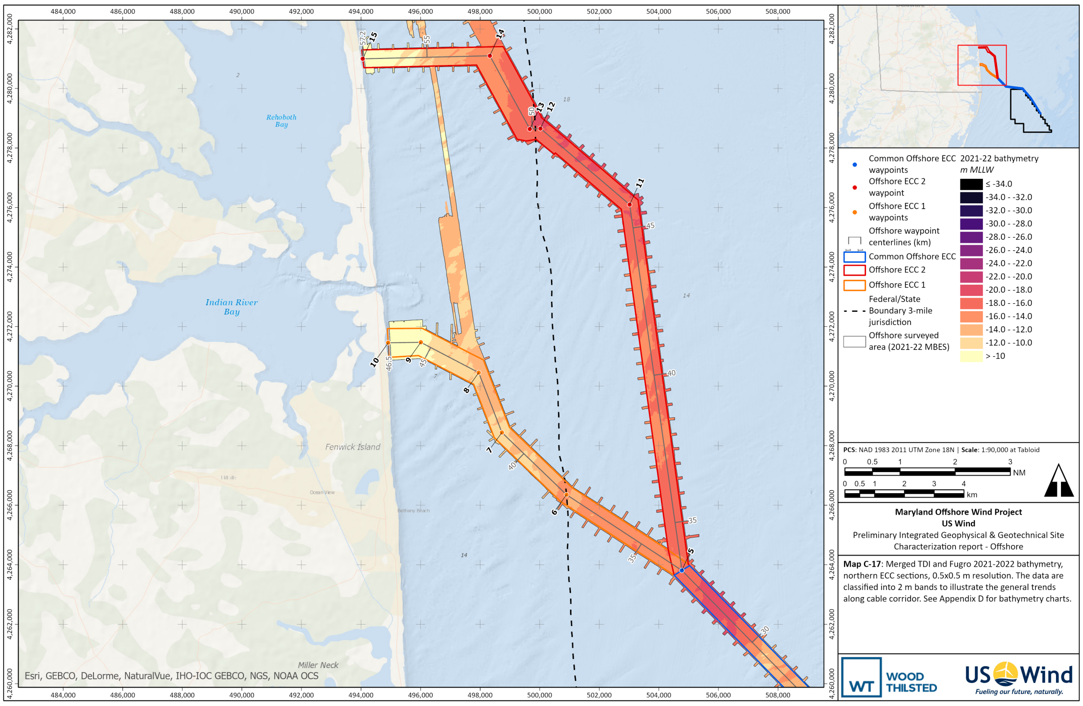


Figure 4.14: Merged TDI and Fugro 2021-2022 bathymetry, Northern ECC sections, 0.5x0.5 m resolution [35].

The Onshore ECC1 has water depths generally ranging bethween -1 to $-4\,\mathrm{mMLLW}$, with deeper channel like features in the westernmost and northeasternmost end of the area according to the Hudson 2022 bathymetry data [24]. The Hudson 2022 bathymetry data have been vertically adjusted from NAVD88 to MLLW by 0.66 m. The adjustment of 66 cm is based on comparison of the Hudson data with Fugro LiDAR and Alpine bathymetry data, which were both processed to MLLW. An overview of the IRB bathymetry is shown in Figure 4.15.

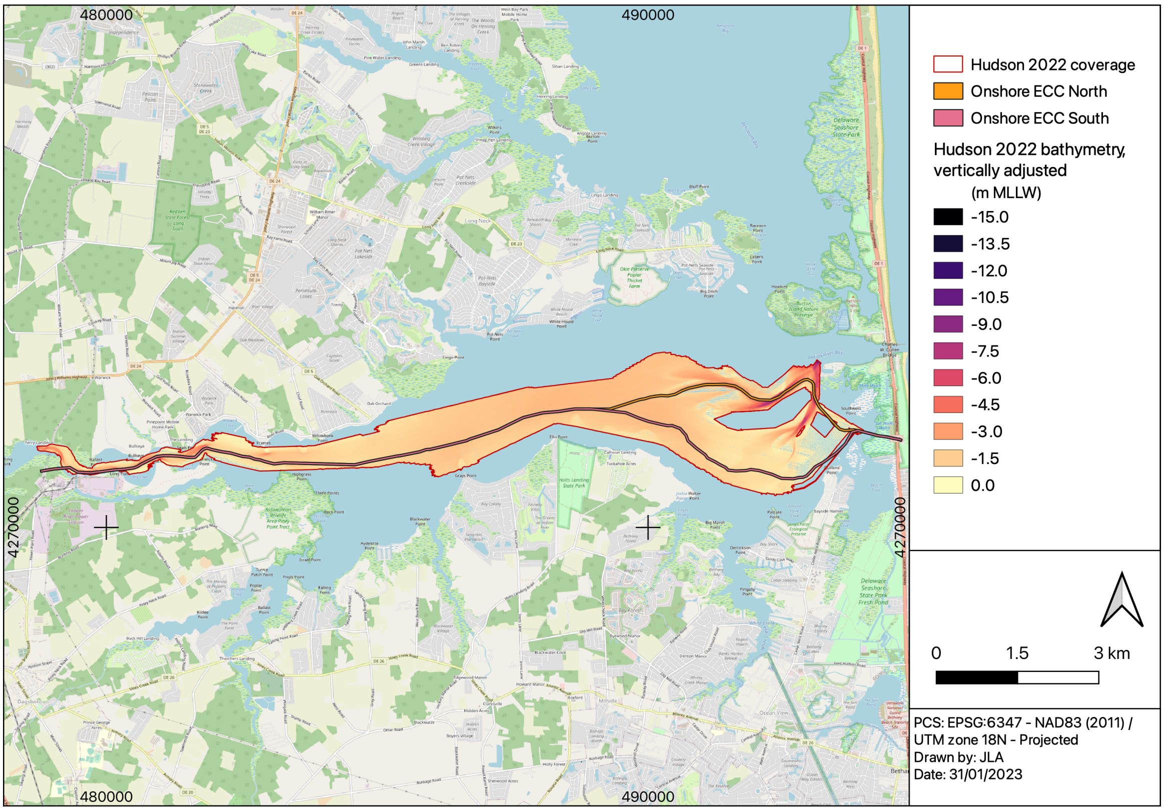


Figure 4.15: Hudson 2022 bathymetry, vertically adjusted from NAVD88 to MLLW by 0.66 m by WT [24].

4.2.4. Slopes

The seafloor across both ECCs slopes regionally from west to east at a gentle gradient of less than 1 percent. However, topographic variations are encountered along both ECCs [35].

The average slope in the ECCs is 0.5°. In general, slopes do not exceed 1° over 91% of the ECCs: in addition, slopes exceed 2° for only 1% of the ECCs. The distribution of slopes within the ECCs are shown in Table 4.3.

Table 4.3: Seafloor slopes within the interpretation area coverage of the ECCs [35].

Classification	Gradient	ECCs interpretation area coverage
(-)	(°)	(%)
Very gentle	< 1	91.2%
Gentle	1-4.9	8.8%
Moderate	5-9.9	0.0%
Steep	10-14.9	0.0%
Very steep	> 15	0.0%

The maximum sampled slope of the common ECC is 5.0° where the ECC passes through a dune field, hence slopes within the interpretation area coverage of the common ECC are not likely to cause cable installation complications as they are less than 10°. The steepest slope within the boundaries of both ECCs is 14.8°, and is encountered on the seaward slope of the IRB delta north of waypoint 9 (Figure 4.16) however as this slope is local re-routing around it can be considered to avoid possible complications to cable installation. The variations in slope along both ECCs are illustrated in Figure 4.16 and 4.17. Larger scale maps are presented in Appendix D.

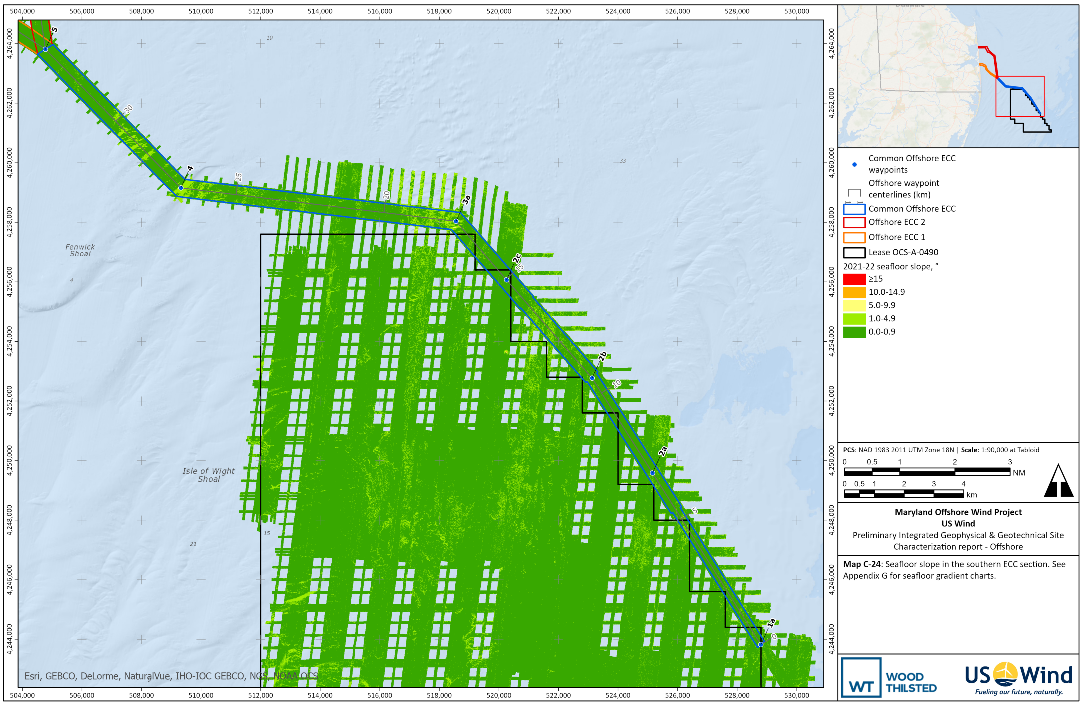


Figure 4.16: Seafloor slope in the southern ECC section [35].

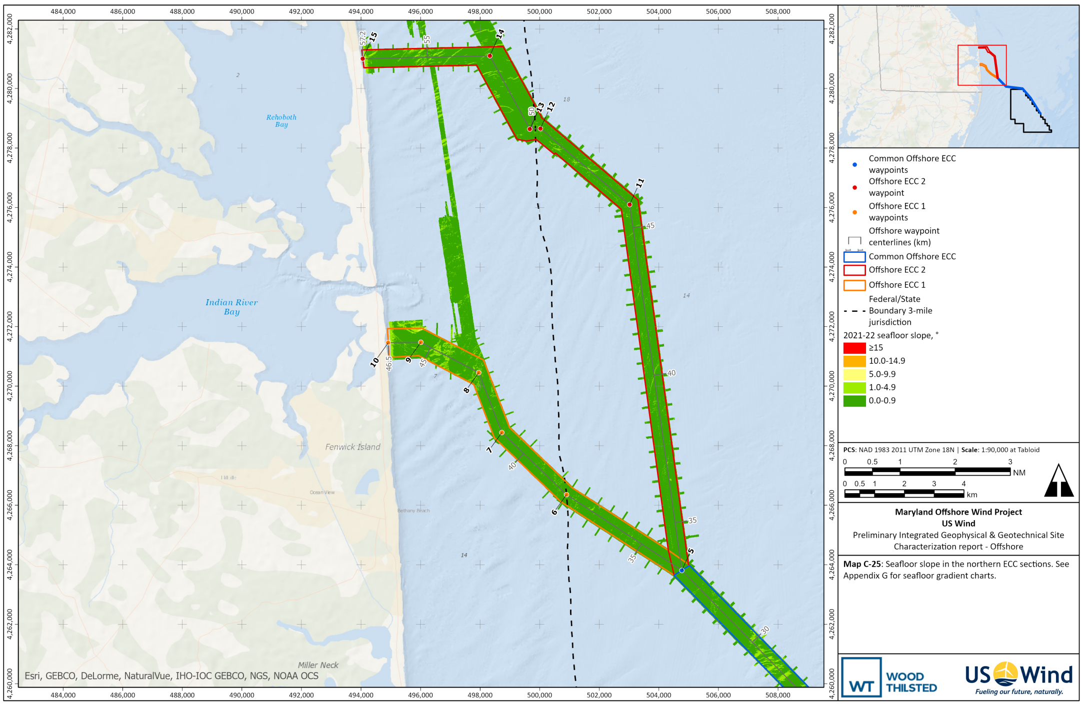


Figure 4.17: Seafloor slope in the northern ECC sections [35].

For the Onshore ECC1 the seafloor is relatively flat and no significant slopes are identified, however local slopes might be pressent near the channel like features identified from the bathymetry data.

4.2.5. Seabed mobility

Evidence of seabed mobility is demonstrated throughout the ECCs [35]. Minor bedforms (minor sand ridges, sand waves/dunes, bedforms in irregular seafloor areas) are migrating at a significant rate relative to the project lifetime. A high-level classification of different seabed mobility zones based on vertical differences between successive bathymetric surveys within the ECCs is shown in Figure 4.18 and 4.19 [35]. Larger scale maps are presented in Appendix D.

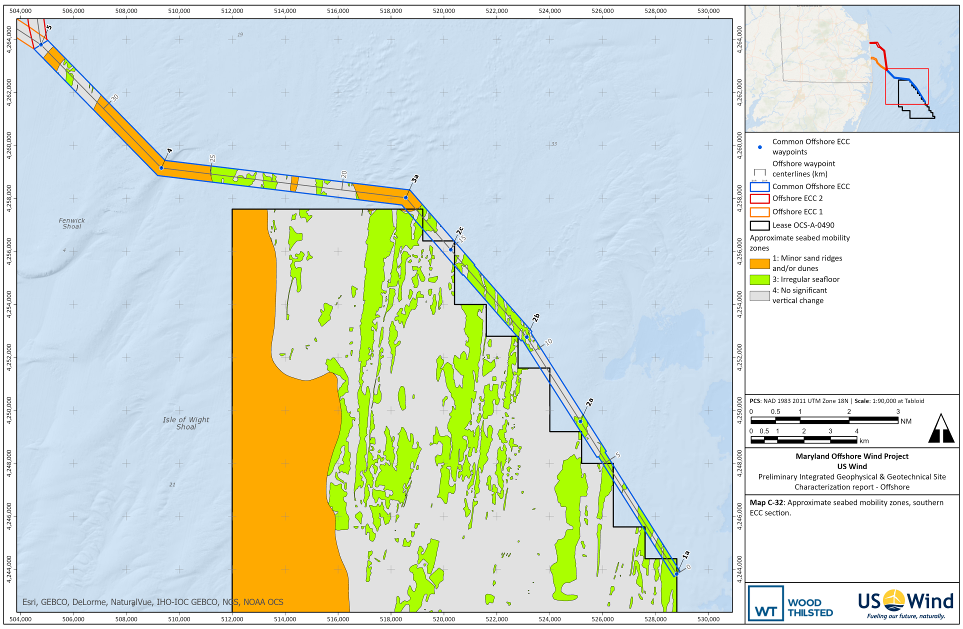


Figure 4.18: Seabed mobility zones in the southern ECC section [35].

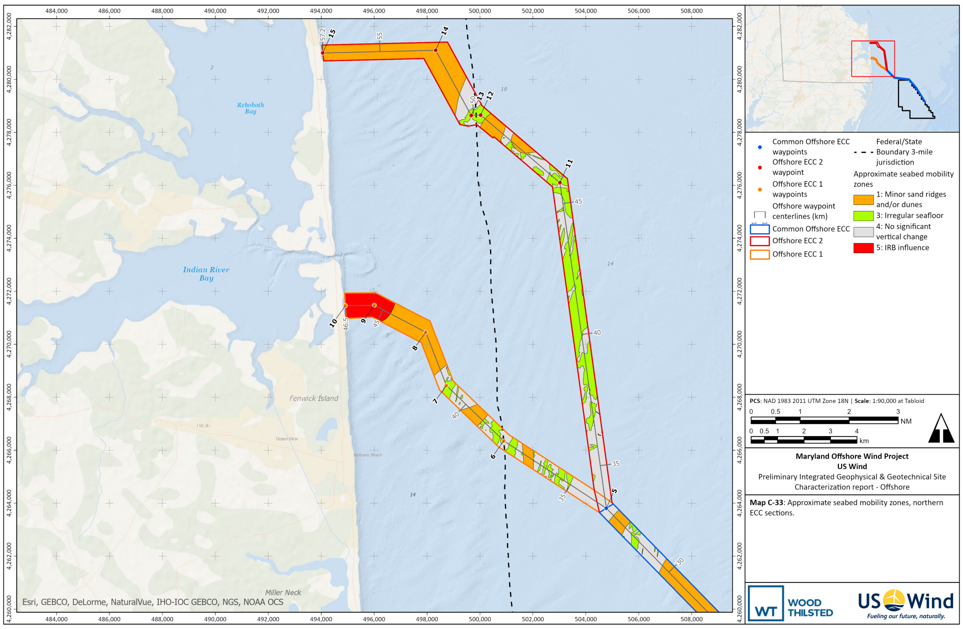


Figure 4.19: Seabed mobility zones in the northern ECC sections [35].

The ECC within State Waters is an area prone to bottom currents that are capable of transporting sediments and causing scour around future export cables. The presence of mobile bedforms supports that inference. Based on the project location, a relatively high potential for sediment transport and scour is anticipated. Within Federal Waters, areas of potential hazard include on mobile bedforms in shallower water depths and around Fenwick Shoal where the largest bedforms identified in the ECCs are mobile [35].

In addition to the identification of mobile bedforms, significant seafloor variability associated with the Indian River delta (zone 5) has been identified within the nearshore portion of ECC 1. The seasonal variability in sediment accumulation associated with the Indian River Bay outflow represents a hazard for the nearshore termination of ECC 1.

Tidal shoals are identified in the Onshore ECC1 by Fugro [11]. Higher mobility rates of the tidal shoals are located closer to the Indian River Inlet. Interpreted migration rates are on the order of 30 to 40 m/yr near the tidal inlet and 10 to 20 m/yr south of the inlet in the vicinity of the potential cable corridor. The assessment further identified areas of sand ripples of minor height.

The Hudson 2022 bathymetry data revealed scour depressions in the western most end of the Onshore ECC 1, in the Indian River, indicating the path of highest velocity water flow out to the bay [24]. Comparison with historic data confirms that there is lateral variation over time in the locations of channels and associated bedforms, particularity in the easternmost part of IRB.

WT have carried out bedform mapping based on the Hudson 2022 bathymetry and backscatter data and the Fugro 2022 LiDAR data. Figure 4.20 shows the distribution of major bedforms and seabed features within Onshore ECC 1 (IRB north and south routes) [34]. Seafloor and seabed features charts at 1: 10,000 are located in Appendix D.

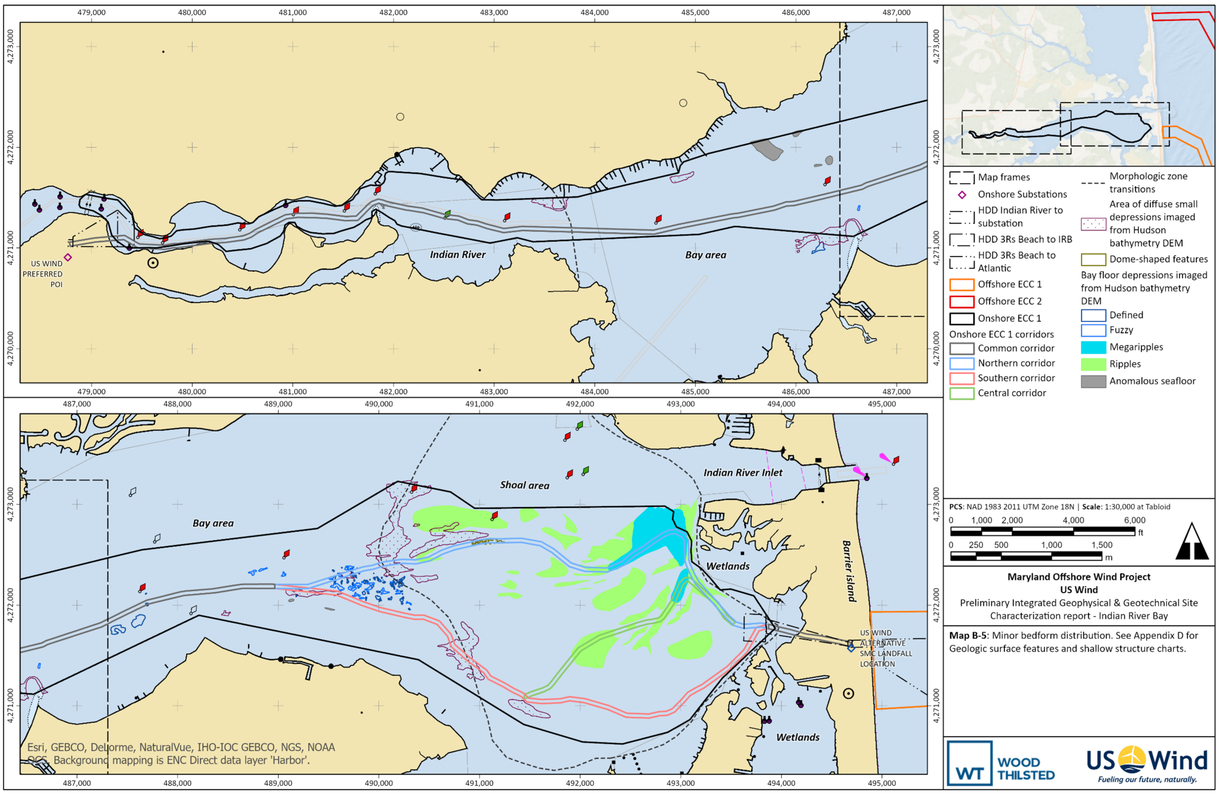


Figure 4.20: Seabed mobility zones within Indian River Bay [34].

Figure 4.21 demonstrates that shoals have been moving, with the direction and rate of movement dependent on the position and orientation of the shoal [34]. An enlarged chart can be found in Appendix D.

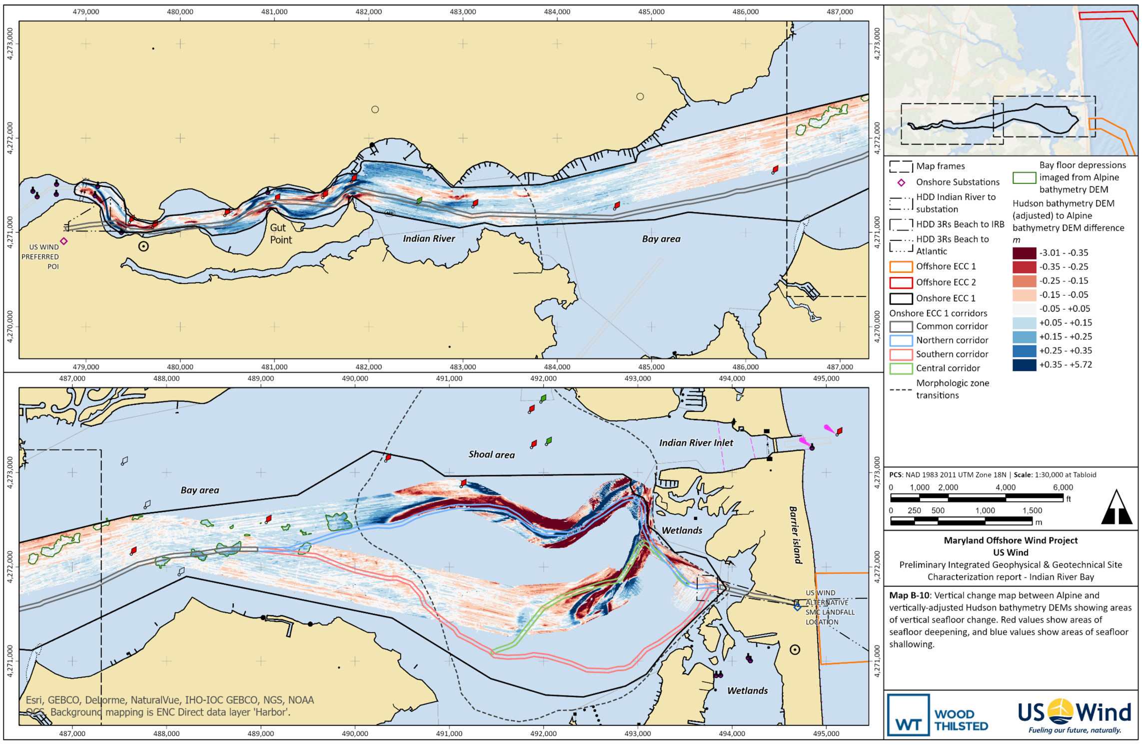


Figure 4.21: Seabed mobility zones within Indian River Bay [34].

Large seabed mobility activity, whether it is sand waves or scour, should be considered due to the risk of exposing or over-heating the cable where there are high volumes of sediment transport.

5. Quantitative risk assessment

Quantitative assessment of the cable burial risk is performed according to the methodology by Carbon Trust [6] and [7]. The thickness of soft soil is accounted for by adopting a two-layer anchor penetration model. Calculation methodology and results are presented in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2.

5.1. AIS data

Vessel traffic is assessed from available automatic identification system (AIS) tracking in the area. The AIS data for this assessment is obtained from [1] for a period of 2 years. The AIS data set is processed to establish unique vessel timestamps and AIS type codes. Approximately 16% of the total data set for the offshore ECCs and 30% for the Onshore ECC1 are ignored because of missing vessel length information that is used to estimate vessel dead weight tonnage (DWT). Changes to the vessel traffic pattern due to construction of the wind farm is not considered in this assessment. Further refinement of the AIS data and anticipated vessel traffic patterns following construction can be completed in subsequent design stages.

5.2. Input parameters

The burial depths are defined based on the fluke penetration of standard anchors and the type of sediment encountered. The route is divided into segments of varying lengths representing sections of similar ground conditions in order to perform the evaluation (c.f. Section 3.3). The cable burial risk assessment (CBRA) method only considers anchorages in emergency cases (e.g. due to a mechanical failure or to prevent a collision). The probability of strike (p_{strike}) is based on vessel size, vessel speed when emergency anchoring, probability of emergency anchoring and ground conditions/cable burial depth. Details on anchor models and calculation of p_{strike} and depth of lowering (DoL) are provided in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2. Table 5.1 summarises the main inputs adopted for the quantitative CBRA for the ECCs.

Table 5.1: Main input parameters for the quantitative CBRA for the cable corridors.

Parameter	Value	Description
$P_{traffic}$	1	Modifier for traffic within each route section
P_{wd}	0.9	Modifier for water depth
V_{ship}	4 kts	Based on assumption of peak tidal current speed
$P_{incident}$	0.01	Conservative value from findings by SAFECO [19]

5.2.1. Water depth modifier

The water depth profile and adjacent obstacles govern a vessel's need for performing emergency anchorage if it loses control (e.g. due to engine failure). The value for P_{wd} should represent the degree of constraints that the vessel master faces in assuring the safety of vessel and crew in case of an incident. A P_{wd} value of 0.9 is conservatively adopted for this analysis. Further optimisation may be possible in subsequent design stages to adopt lower values in areas characterised by deeper water and fewer restrictions/obstacles that would reduce the likelihood of needing to deploy an anchor.

5.2.2. Vessel speed when anchoring

The vessel speed at which a safe emergency anchorage would normally occur is 1-2 knots dependent on vessel size [7]. The larger the vessel the lower the acceptable speed for anchorage. The speed of vessel drift is assumed to be governed by local current speeds, particularly tidal currents. A value of $4\,\mathrm{kts}$ is conservatively adopted for V_{ship}. The value may be refined for final design based on analysis of the maximum tidal current speeds for the US Wind ECC.

5.2.3. Incident rate

Literature provides a large range for the incident rate ($P_{incident}$). DNV [9] reports incident rates as low as 0.0002 for loss of control when on collision course and up to 0.1752 based on engine failure of single-engined tankers in the North Sea. A $P_{incident}$ value of 0.01 is adopted for analysis based on WT experience and engineering judgement.

5.3. Results of quantitative analysis

DoL is derived for a range of return periods, presented in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2. Results for DoL are reported for risk level 1 in 100,00 yrs in Section 6, which is considered neglible risk [10]. Results are summarised in terms of burial depth for defined risk levels and vice versa in Section 6. The detailed results of the CBRA are included in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2.

6. DEPTH OF LOWERING

The DoL is to be measured from the stable seabed level, see Figure 1.3. The stable seabed level is influenced by e.g. seabed mobility, maximum depth of maintained channels, and is not treated further in this cable burial risk assessment. The DoL is selected to reflect the acceptable risk level to the project and considers:

- Results of the qualitative risk assessment (i.e. threat of damage from anthropogenic and natural risks).
- Results of the quantitative CBRA (i.e. the risk of anchor strike to the cable).

Fishing activity is seen to be the main qualitative risk directly affecting the depth of lowering. Vessel traffic intensity and vessel size coupled with geotechnical conditions govern the quantitative risk level.

6.1. DoL by acceptable risk level

Table 6.1 present the minimum depth of lowering (MDOL) for protection against:

- Snagging and/or impact of fishing gear, e.g. hydraulic scallop dredging
- Best estimate of an anchor strike occurrence of 1 in 100,000 years (10^{-5}yrs) based on t_{soft} for ECC1 and ECC2 and considering soft soils only for the Onshore ECC1

The recommended DoL is the deeper of the two burial depths. Quantitative assessment of vessel traffic indicates that burial is not required and a cable laid at the stable seabed elevation will satisfy the frequency of anchor strike being less than 1 in 100,000 years. Therefore, a minimum DoL of 1.0 m is specified based on mitigation of threat of damage from fishing activity as currently identified. The recommended DoL reported below constitutes the target TOP level from an engineering perspective for a 1 in 100,000 year return period of anchor strike. The target DoL for installation must be decided based on the project acceptable risk level and account for local permitting requirements for minimum burial depth.

Table 6.1: Recommended DoL below stable seabed for the ECCs.

Segment	Section	t_{soft} (m)	Fishing DoL	Vessel interaction DoL	Recommended DoL
South landfall	KP00 to KP0.6	1.4	1.0	0.0	1.0
South landfall	KP0.6 to KP01	0.4	1.0	0.0	1.0
South landfall	KP01 to KP1.7	0.2	1.0	0.0	1.0
South landfall	KP1.7 to KP02	2.8	1.0	0.0	1.0
South landfall	KP02 to KP03	2	1.0	0.0	1.0
South landfall	KP03 to KP04	4.5	1.0	0.0	1.0
South landfall	KP04 to KP07	0	1.0	0.0	1.0
South landfall	KP07 to KP09	4.6	1.0	0.0	1.0
South landfall	KP09 to KP10	0	1.0	0.0	1.0
South landfall	KP10 to KP12	2.6	1.0	0.0	1.0
South landfall	KP12 to End	4.8	1.0	0.0	1.0
Main corridor	KP13 to KP14	4.8	1.0	0.0	1.0
Main corridor	KP14 to KP15	0	1.0	0.0	1.0
Main corridor	KP15 to KP16	2	1.0	0.0	1.0
Main corridor	KP16to KP35	0	1.0	0.0	1.0
Main corridor	KP35 to KP36	5	1.0	0.0	1.0
Main corridor	KP36 to KP40	0	1.0	0.0	1.0
Main corridor	KP40 to KP41	1	1.0	0.0	1.0
Main corridor	KP41 to KP44	0	1.0	0.0	1.0
Main corridor	KP44 to KP45	2.8	1.0	0.0	1.0
Main corridor	KP45 to KP46	3.2	1.0	0.0	1.0
Main corridor	KP46 to End	0	1.0	0.0	1.0
North landfall	KP00 to KP01	0.6	1.0	0.0	1.0
North landfall	KP01 to KP03	0.2	1.0	0.0	1.0
North landfall	KP03 to KP04	0	1.0	0.0	1.0
North landfall	KP04 to KP06	5	1.0	0.0	1.0
North landfall	KP06 to KP09	1.1	1.0	0.0	1.0
North landfall	KP09 to KP11	0	1.0	0.0	1.0
North landfall	KP11 to KP12	4.9	1.0	0.0	1.0
North landfall	KP12 to KP18	0	1.0	0.0	1.0
North landfall	KP18 to KP19	4.9	1.0	0.0	1.0
North landfall	KP19 to KP22	0	1.0	0.0	1.0
North landfall	KP22 to End	4.8	1.0	0.0	1.0
Onshore ECC1	IRB North	14.5	1.0	0.0	1.0
Onshore ECC1	IRB South	12.1	1.0	0.0	1.0

6.2. Risk level by depth

The risk of anchor strike for a specific DoL is derived for all cable sections. Results are provided as figures and tables in Appendix B and C. These charts may be helpful in assessing the balance between burial depth, risk appetite and cable installation tool constraints. Figure 6.1 presents an example diagram for the cable section KP40 to KP41 of the main corridor segment. A specific risk level (horizontal axis) can be read for a given burial depth (vertical axis).

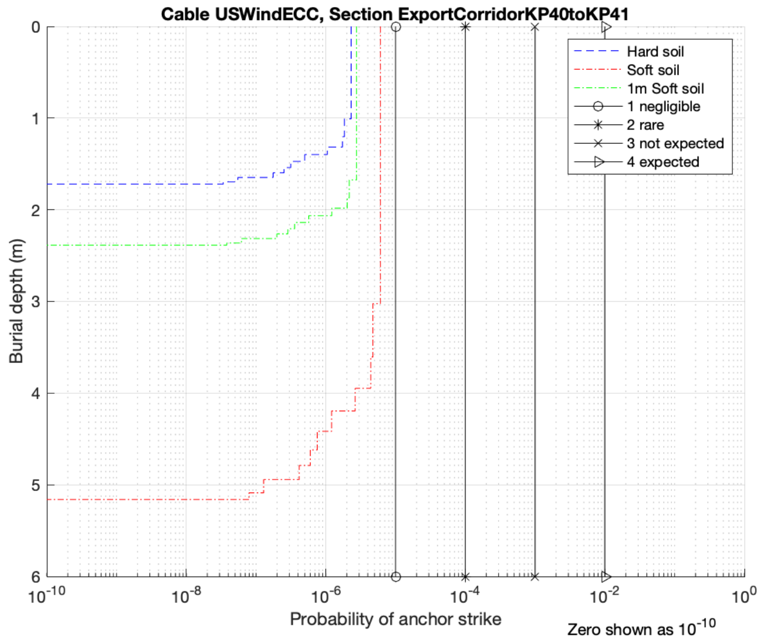


Figure 6.1: Example of risk level by DoL (KP40 to KP41 - Main corridor segment).

7. Recommendations for future assessment

7.1. AIS data quality

AIS data quality is identified as a key issue given that over 14% of data points from the original data set for the ECC and 30% from the Onshore ECC1 were missing vessel lengths in the available data set. There is a risk that a statistically significant amount or size of vessels are lack of dimension information such that vessel lengths have to be extrapolated from the existing data in this assessment and that the overall risk is underestimated and recommended burial depths are too shallow. Figures 7.1 and 7.2 show the distribution of vessel types for data points with missing length information for each area. Figure 7.3 presents the distribution of available vessel length for pleasure craft in each area as well as tankers for the main corridor as these vessel types form the majority of the missing dimension data.

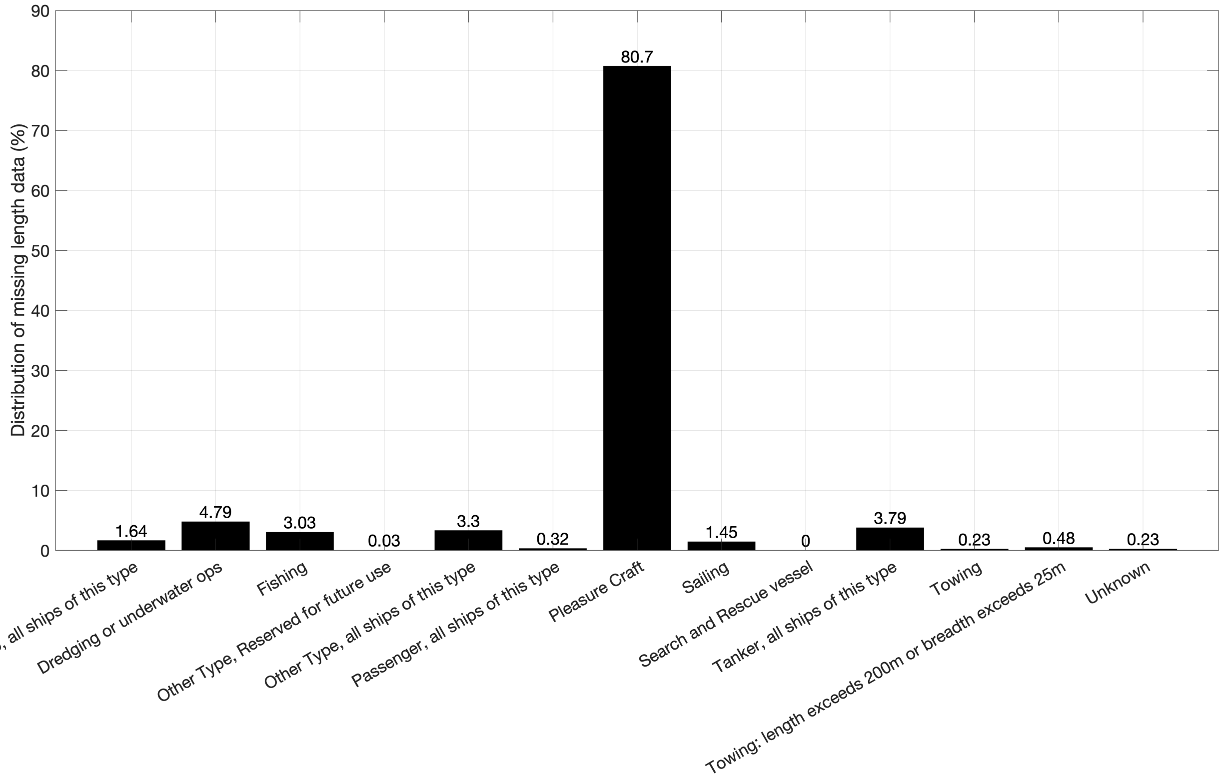
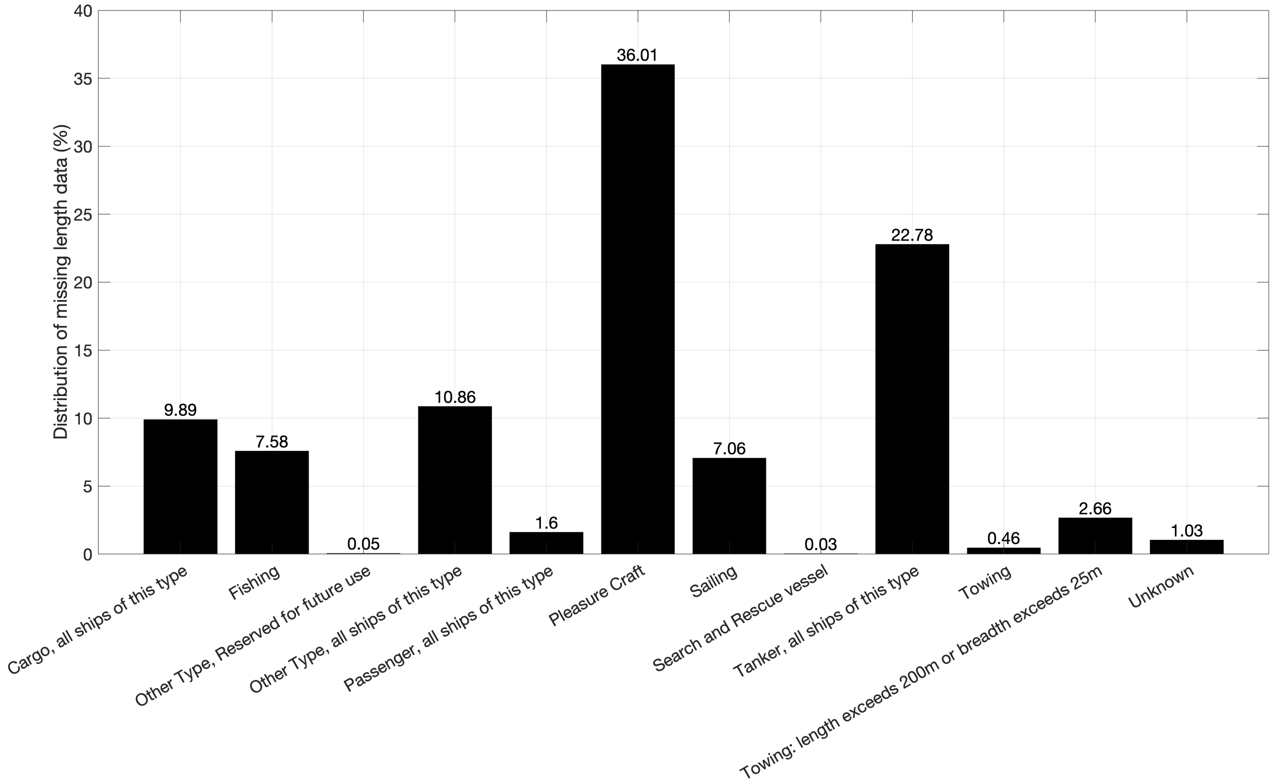
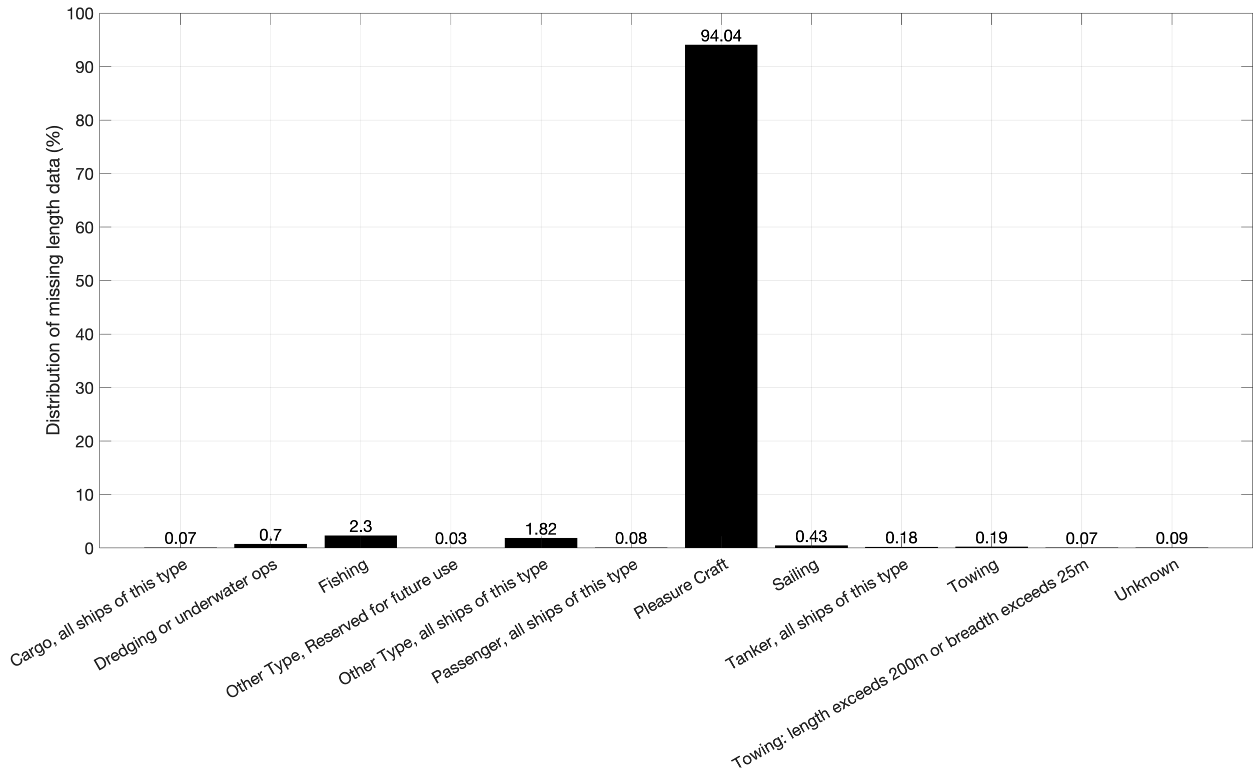


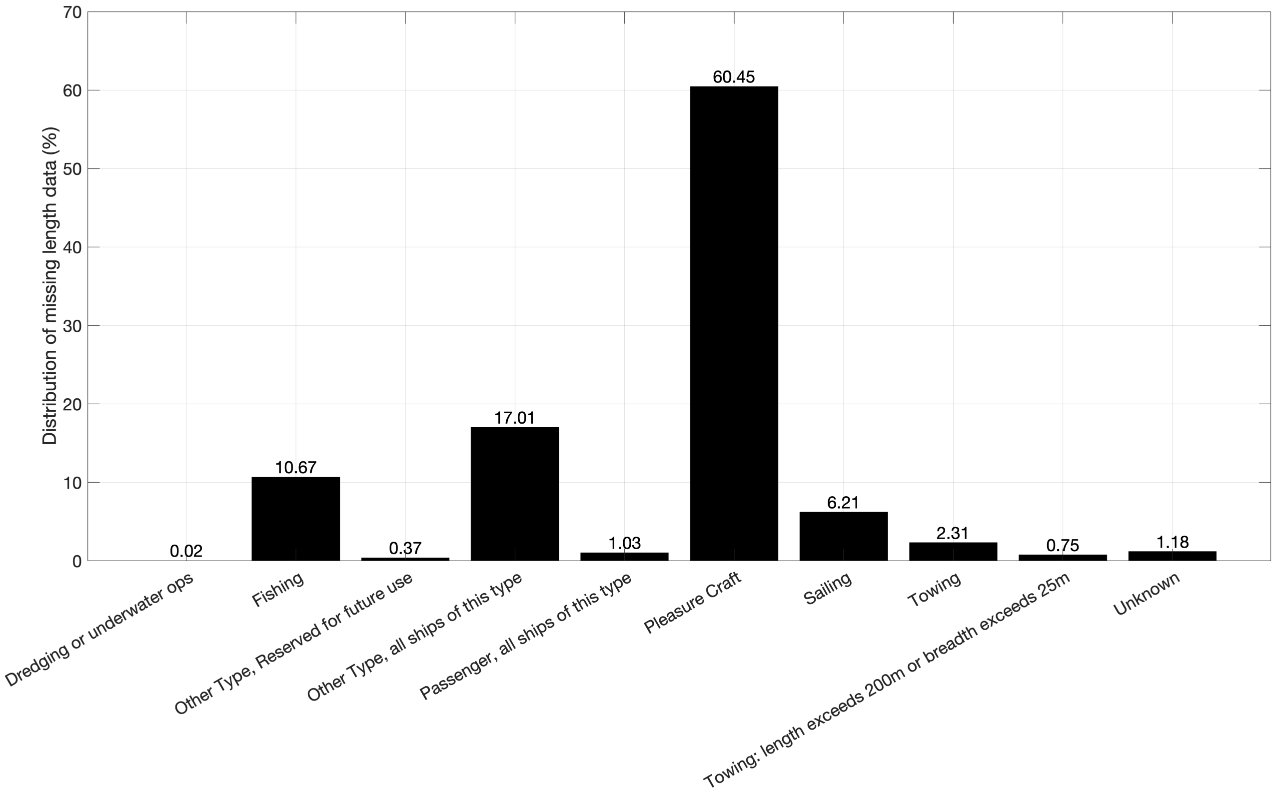
Figure 7.1: Distribution of vessel type for AIS data points missing length information for ECC and IRB.



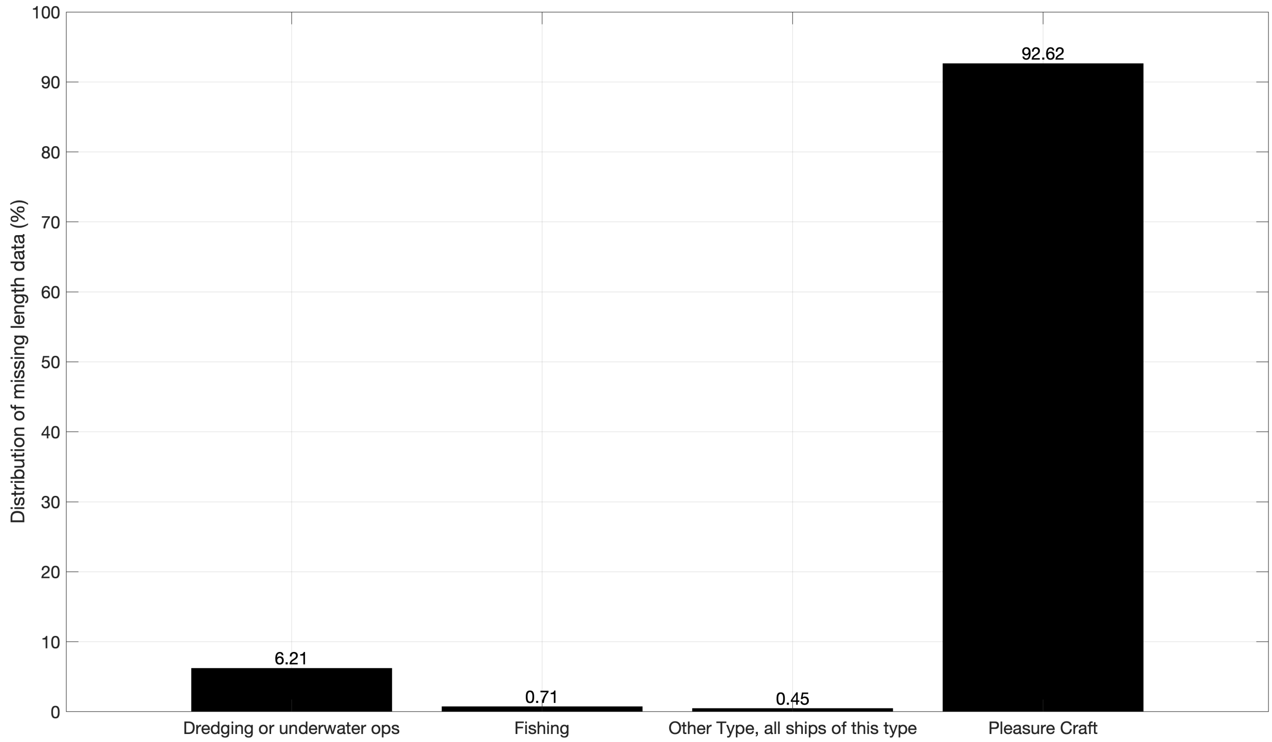
(a) ECC main corridor



(b) ECC north landfall

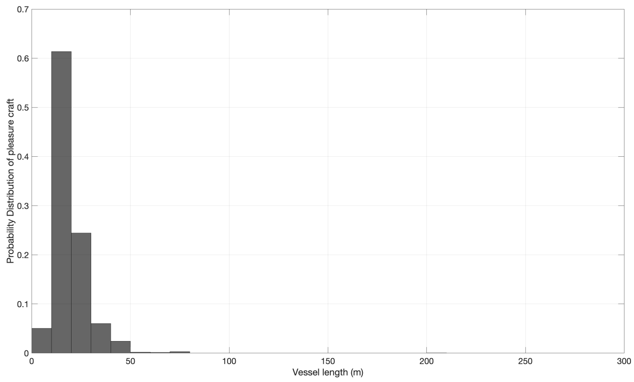


(c) ECC south landfall

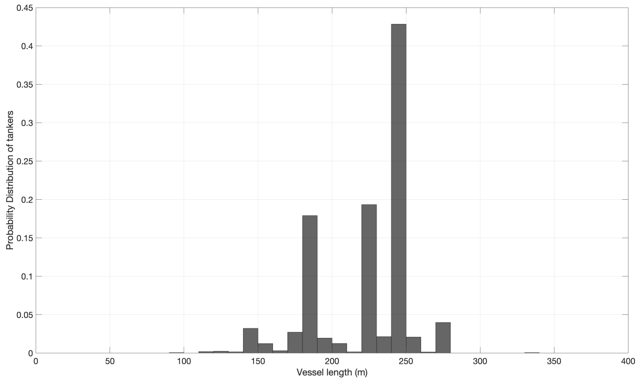


(d) IRB

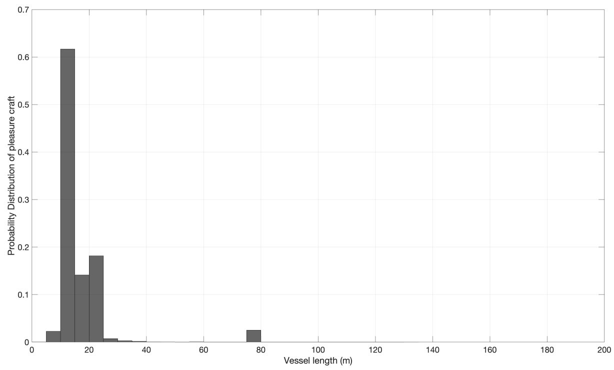
Figure 7.2: Distribution of vessel type for AIS data points missing length information within corresponding area.



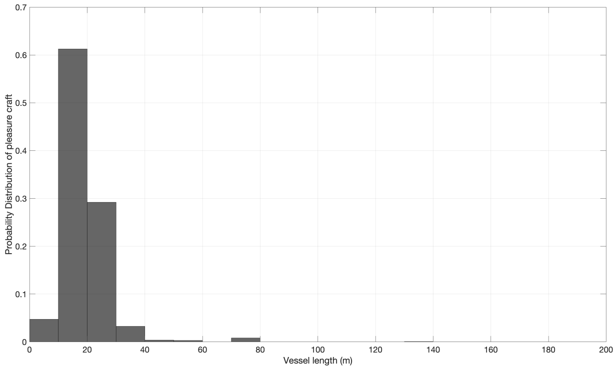
(a) Main corridor - pleasure craft



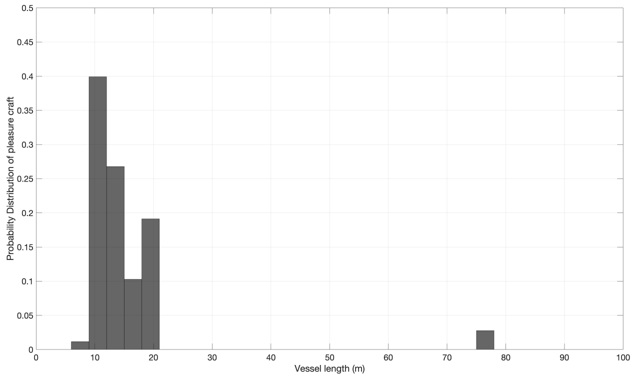
(b) Main corridor - tankers



(c) Northern landfall - pleasure craft



(d) Southern landfall - pleasure craft



(e) Onshore ECC1 (IRB) - pleasure craft

Figure 7.3: Distribution of vessel length information from available AIS data within corresponding area.

Notwithstanding the results of sensitivity analysis, WT recommends that the AIS data is refined or appropriate assumptions made to provide better quality estimates of vessel type, traffic patterns, dimensions and DWT. A data set for a limited area may be procured from a commercial vendor for comparison of data quality.

7.2. AIS data processing

To address the missing dimensions of the AIS dataset, the following review and pre-processing of the AIS data has been conducted prior to use for the CBRA:

1. A check of the AIS vessel meta data completeness, i.e. removing rows when both vessel AIS type and vessel dimension data (including vessel length and width) are missing. For this dataset, 35,293 rows (approximately 2.8

% of raw AIS data) are missing both vessel AIS type number and dimension information. These rows have been left out of the vessel crossing analysis. For the case that only AIS type data is missing, which includes 9 different specific vessels (9 different MMSI numbers) for this dataset, the AIS type has been manually added with online data resource: VesselFinder.

2. After removing rows that missing both AIS type number of vessel dimension data, there are still about 2.5 % rows missing dimension data, of which the AIS type number are known. For example, other type-reserved for future use (AIS number 97), about 92 % of vessels of AIS number 97 do not have associated vessel dimension data. This deficiency applies to a few other vessel types as well (ranging from less than 0.3 % to 5 %), although these vessel types (that are missing vessel dimension data) generally do not show great concerns as they typically have smaller tonnages or dimensions.
3. To deal with missing dimension data, for any specific type of vessel, a 75th percentile (based on the existing data of that AIS category) is applied to fill in the missing information to maintain a conservative (high) estimate of the DWT and in turn the associated DoL for this CBRA. The estimated vessel DWT is based on vessel dimensions (vessel length, width and draught, or length only, depending on available information). Model and calculations for DWT estimates are be found in Appendix B.1, Appendix B.2, Appendix B.3, Appendix C.1, and Appendix C.2.

Figure 7.4 shows the fishing vessel and cargo vessel traffic during 2019 and 2022 across the main ECC and two landfall approaches. It is observed that shipping traffic density and fishing traffic density are relatively low close to the shore of Delaware seashore. This observation is also consistent with 2019 and 2022 cargo vessel traffic map obtained from Northeast Ocean Portal [8] as shown in Figure 7.5.

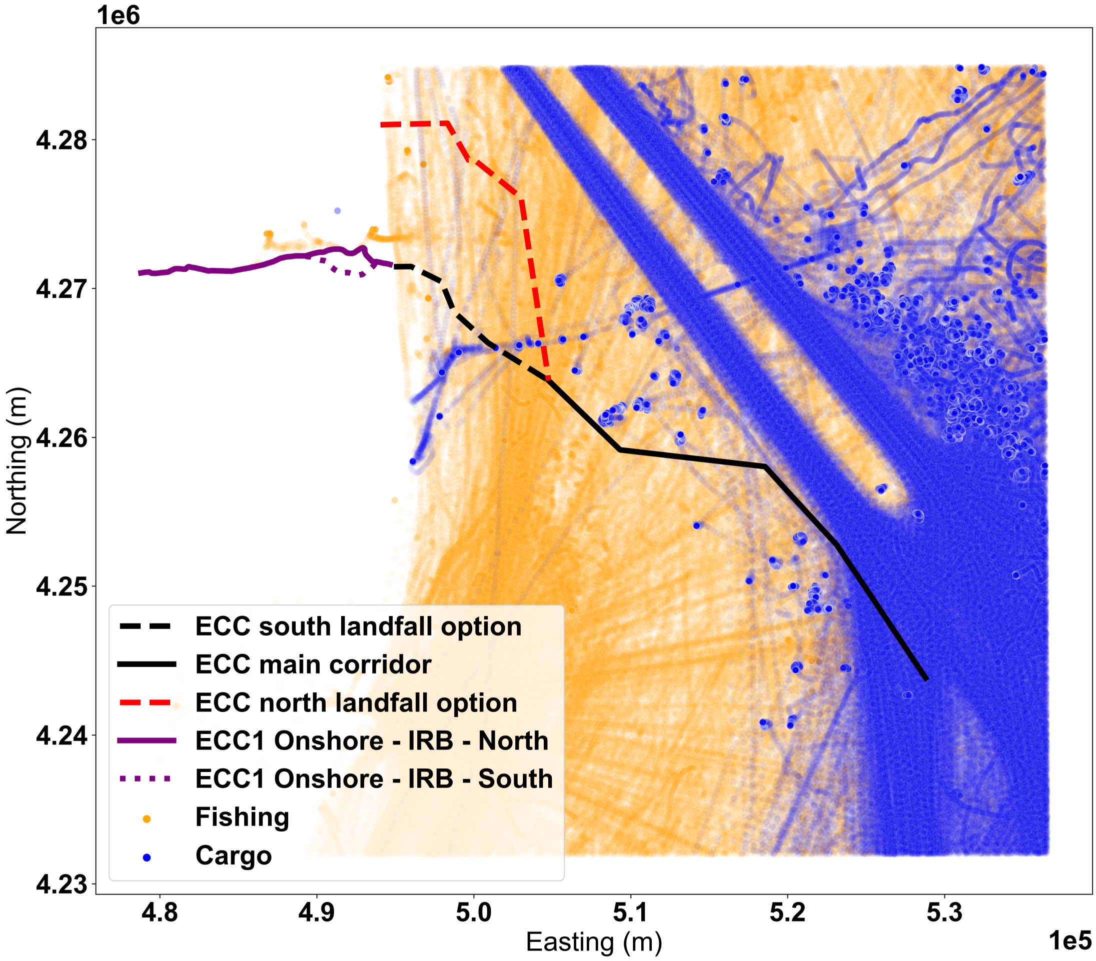


Figure 7.4: Fishing and cargo vessel traffic across US Wind ECC cable route and landfall approaches (AIS data during 2019 and 2022).

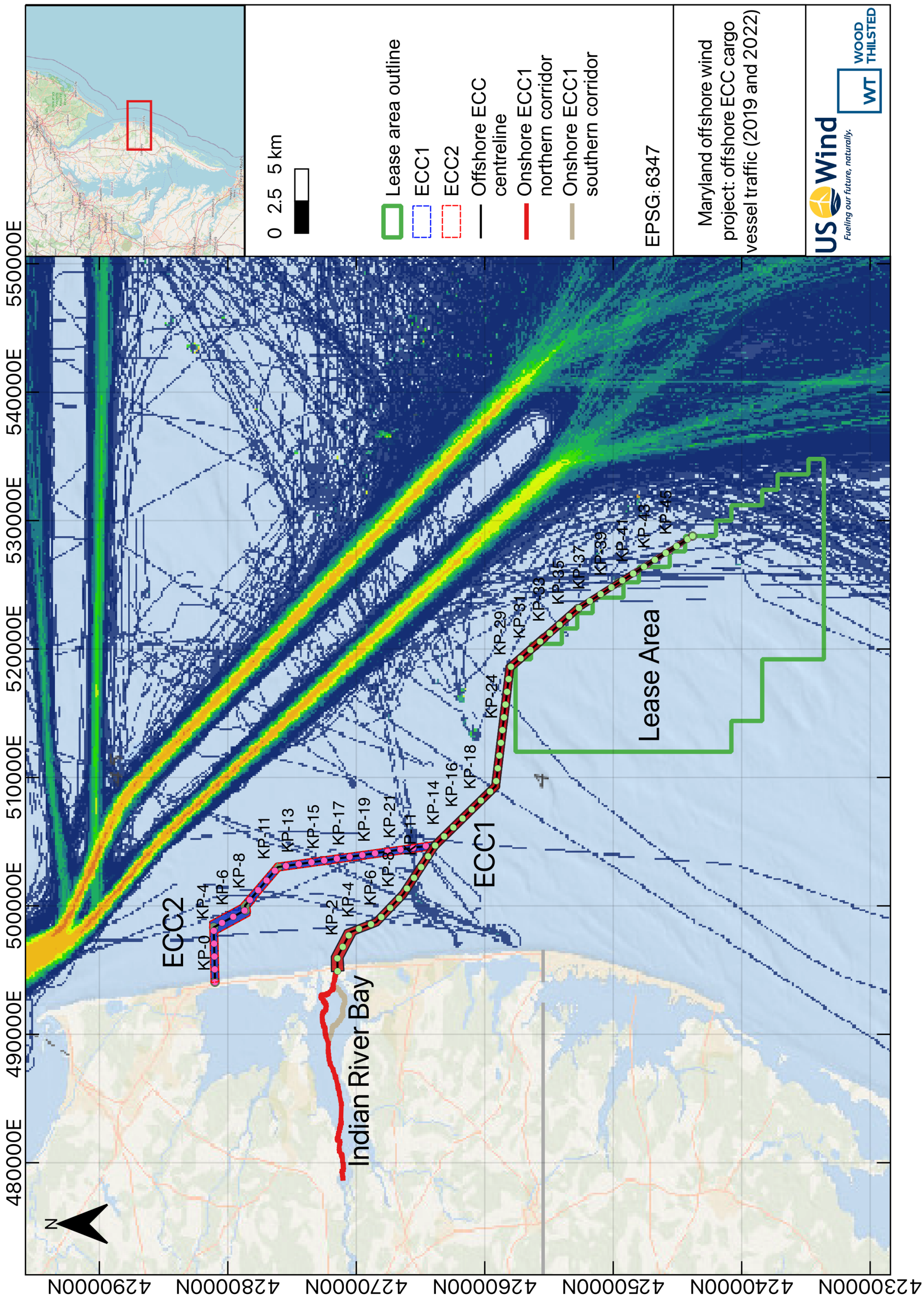


Figure 7.5: Data for 2019 and 2022 cargo vessel transit counts. Source: Northeast Ocean Data [22].

8. CONCLUSION

A cable burial risk assessment is undertaken for the US Wind ECCs. A qualitative risk assessment is completed to identify anthropogenic and natural threats to the cables along the planned cable route. A quantitative risk assessment is evaluated to determine the required DoL for a range of risk return-periods.

Quantitative assessment is completed following the methodology outlined in the Carbon Trust guidelines. Several cable segments are considered based on interpretation of geotechnical conditions. The thickness of soft soil is accounted for by adopting a two-layer anchor penetration model.

A minimum depth of lowering of 1.0m as measured from the stable seabed elevation is recommended for all ECC sections to account for fishing activity and risk of anchor strike. The DoL may be increased locally where knowledge of planned hydraulic dredging operations become available prior to cable installation.

WT has identified issues with the quality of AIS data used for the quantitative assessment. It is recommend the AIS data is refined or appropriate assumptions made in subsequent design stages to better capture the vessel details and traffic patterns.

A number of magnetic anomalies are identified in the ECCs with data and known military activity in the area indicating risk of potential UXO's (pUXO). A review of the survey data is to be conducted prior to installation to identify any pUXO to be avoided or removed for cable installation operations. Large numbers of magnetic anomalies in the Onshore ECC1 are expected to be due to fishing gear.

Avoidance of shipwrecks and potential cultural resources will be required and therefore are not expected to pose additional risk.

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A. Geotechnical interpretation of vibracores and cone penetration tests

A.1. ECC1 KP0-KP13

Table A.1: Interpretation of soft soil thickness for MarWin ECC1 between KP0 and KP13. Coordinates refer to survey locations.

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
0.2	22sb_3R_01	4271631.59	495060.75	0 to 3.8 sand; 3.8 to 4.3 silty clay; 4.1 to 4.3 clayey silt with trace sand and organic matter (peat), moist, medium stiff; 4.3 to 28.6 sand; 28.6 to 29 stiff silt; 29 to 30.2 hard sandy clay; 30.2 to 31.9 sand with trace gravel, wet, medium dense.	BH Data	0
0.2	22sb_3R_02	4271378.42	495080.26	0 to 3.7 silty sand; 3.7 to 3.8 sandy clay; 3.8 to 4.3 very soft fat clay; 4.3 to 34.4 sand.	BH Data	0
0.2	22cb_3R_05	4271519.49	495149.28	0 to 0.2 silty sand and sandy silt; 0.2 to 0.5 soft clay; 0.5 to 2.2 sand with silt layers; 2.2 to 4.6 clay, silty clay, silty sand, sandy silt; 4.6 to 5.8 sand; 5.8 to 6.8 clay, silty clay and silty sand sandy silt; 6.8 to 7.3 sand; 11.6 to 20 sand; 24.8 to 29.4 interbedded sand, silty sand and sandy silt; 29.4 to 30.	CPT Data	0
0.3	A01_hysical	4271628.20	495228.20	0 to 0.2 light brown fine Sand; 0.2 to 0.9 dark brown to light gray Silt; 0.9 to 1.4 dark to light brown Silt with some fine Sand; 1.4 to 2.1 light brown to dark gray fine Sand with Clay lens at 6'4"; 2.1 to 3.4 dark to light gray fine Sand with black laminations and little coarse Sand.	VC Data	1.4
0.3	A02_hysical	4271591.00	495220.10	0 to 0.6 light brown finemedium Sand; 0.6 to 1.4 graygreen fine Sand with little Silt, lens of brown Silt at 4'; 1.4 to 2.4 light gray finemedium Sand; 2.4 to 3.1 graybrown Silty fine Sand.	VC Data	0
0.3	A03_hysical	4271557.30	495219.30	0 to 0.4 light brown finemedium Sand with trace gravel and shell fragments; 0.4 to 0.8 gray fine Sand with some Silt, slightly sticky; 0.8 to 2.8 light brown with gray finemedium Sand; 2.8 to 3.1 gray fine Sand with some Silt.	VC Data	0

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Table A.1 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
0.5	22cb_3R_07	4271348.98	495361.19	0 to 4.7 interbeded silty sand, sandy silt, clay , silty clay; 4.7 to 17 sand, silty sand; 18.8 to 19.5 sand.	CPT Data	0
0.5	22cb_3R_07a	4271350.45	495361.89	From 20.7 to 21.8 sand; 25.6 to 30.2 clay, silty clay, silty sand, sandy silt; 30.2 to 30.6 sand.	CPT Data	0
0.5	22sb_3R_03	4271509.2	495370.85	0 to 3.1 loose sand; 3.1 to 4.9 soft fat clay; 4.9 to 5.5 medium dense sand; 5.5 to 6.7 fat clay; 6.7 to 30.7 sand.	BH Data	0
0.5	22vc_3R_12	4271187.35	495426.56	0 to 6 fine to medium sand.	VC Data	0
0.5	22vc_3R_11	4271650.67	495469.33	0 to 2.4 fine sand; 2.4 to 3 soft clay; 3 to 4.2 fien sand; 4.2 to 4.8 soft clay; 4.8 to 5.7 firm clay.	VC Data	0
0.7	22cb_3R_08	4271637.05	495591.37	0 to 0.2 hard clay; 0.2 to 3.4 interbedded silty sand, sandy silt, sand; 3.4 to 4.5 sand; 4.5 to 9 interbedded clay, silty clay silty sand, sandy silt; 9 to 9.4 sand; 14.6 to 19 sand; 20.4 to 21.2 sand, silty sand.	CPT Data	0
0.7	22cb_3R_09	4271307.30	495599.93	0 to 2 clay with silt layers; 2 to 2.8 sand; 4.2 to 7.9 sand with thin silt layers; 7.9 to 10 interbedded clay, silty sand, sandy silt, silty clay layers; 13.6 to 18.7 sand.	CPT Data	0
0.7	22sb_3R_04	4271488.86	495600.34	from 0.6 to 4.4 sand; 4.4 to 8.8 fat clay; 8.8 to 25 sand.	BH Data	0
0.9	22vc_3R_13	4271574.52	495819.50	0 to 3 fine sand; 3 to 4.8 soft clay; 4.8 to 6 firm to hard clay.	VC Data	0
0.9	22vc_3R_14	4271291.66	495863.06	0 to 1.2 medium to fine sand; 1.2 to 1.8 silt; 1.8 to 3 fine to very fine sand; 3 to 3.6 soft clay; 3.6 to 6 firm clay.	VC Data	0
0.9	22vc_3R_15	4271131.40	495820.96	0 to 4.8 fien sand; 4.8 to 5.8 fin gravel.	VC Data	0
0.9	22cs_3R_13	4271550.55	495779.83	0 to 0.4 soft clay; 0.4 to 0.9 clay, silty sand, sandy silt; 0.9 to 3 sand, silty sand; 3 to 7.2 clay, and silty clay; 7.2 to 8.6 sand; 11 to 18 sand.	CPT Data	0.4
0.9	22cs_3R_14	4271271.36	495847.34	0 to 0.4 soft clay; 0.4 to 2.4 interbedded clay, silty clay, silty sand, sandy silt; 2.4 to 2.8 sand; 2.8 to 6.8 interbedded clay, silty sand, sandy silt; 6.8 to 8 sand; 9.2 to 14.2 snad;	CPT Data	0.4

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Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
1.2	22vc_3R_16	4271589.92	496198.17	0 to 3.6 fine sand; 3.6 to 5.7 clay.	VC Data	0
1.2	22cs_3R_16	4271603.71	496221.47	0 to 0.2 soft clay; 0.2 to 3.6 interbedded silty sand, sandy silt, clay; 3.6 to 8.2 clay with thin silt layers; 8.2 to 9.4 sand; 11.2 to 12.6 sand; 13.2 to 14.4 sand.	CPT Data	0.2
1.5	22vc_3R_18	4271126.45	496267.40	0 to 6 fine to very fine sand.	VC Data	0
1.5	22cs_3R_18	4271142.35	496252.99	0 to 2 interbedded silty sand, sandy silt, clay; 2 to 2.5 clay; 2.5 to 6.9 sand; 7 to 11.4 sand;	CPT Data	0
1.5	22vc_3R_19	4271263.54	496429.91	0 to 1.2 fine sand; 1.2 to 1.8 firm clay; 1.8 to 2.4 soft clay; 2.4 to 3 firm clay; 3 to 5.5 fine sand.	VC Data	0
1.8	22cs_3R_29	4271119.92	496660.18	0 to 2.8 soft clay; 2.8 to 3.8 nsad; 3.8 to 5.2 interbedded clay, silty clay, sandy silt, silty sand; 5.2 to 7 sand.	CPT Data	2.8
1.9	A04_hysical	4271047.20	496730.50	0 to 0.2 brown to gray finemedium Sand with trace silt; 0.2 to 0.6 dark brown Silt with Peat; significant organic content; 0.6 to 1.1 Section sent to lab unopened; 1.1 to 1.4 dark gray silty Clay; highly plastic; 1.4 to 1.8 dark gray silty fine Sand with few thin plastic laminations; 1.8 to 2.3 Section sent to lab unopened; 2.3 to 2.4dark gray silty Sand; 2.4 to 2.7 gray finemedium Sand; 2.7 to 3.1 Section sent to lab unopened.	VC Data	1.4
2	22vc_3R_20	4271262.39	496957.46	0 to 1.2 fine sand; 1.2 to 1.8 soft clay; 1.8 to 3 fine sand; 3 to 3.6 soft clay; 3.6 to 5 fien sand.	VC Data	0
2.1	22vc_3R_22	4270798.70	496766.61	0 to 1.8 fien sand; 1.8 to 2.4 silt; 2.4 to 3 firm clay; 3 to 3.6 very fine sand; 3.6 to 4.2 soft clay; 4.2 to 6 fine to very fine sand.	VC Data	0
2.5	21CS_007	4271237.48	497651.34	0.0 to 0.4 is soft clay; 0.4 to 4.6 is medium to dense sand; 4.6 to 5 firm to hard clay.	CPT Data	0.4
2.5	21VC_007	4271237.48	497651.34	0 to 1.1 fincoarse sand with shell fragments; 1.1 to 2.1 Light grey Silty fine SAND with shell fragments; 2.1 to 2.7 Grey fine medium SAND; 2.7 to 3.4 Grey Sandy CLAY; 3.4 to 3.7 Grey fine medium Sand with fine sand seams.	VC Data	0

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Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
2.5	22cs_3R_32	4270604.95	497210.50	0 to 2 soft clay; 2 to 3.4 sand; 3.4 to 4.4 clay, sand, silty sand; 4.4 to 6.2 snad; 6.2 to 6.6 silty sand, sandy silt; 6.6 to 8.2 sand.	CPT Data	2
2.6	22vc_3R_24	4270591.18	497197.23	0 to 2.4 fien to very fien sand; 2.4 to 3 silt; 3 to 5.5 fien sand.	VC Data	0
2.6	22vc_3R_25	4271079.49	497580.83	0 to 5.8 fien sand.	VC Data	0
2.8	22vc_3R_26	4270689.02	497510.85	0 to 5.6 fine sand.	VC Data	0
3.1	22vc_3R_27	4270721.93	497958.58	0 to 1.2 fien sand; 1.2 to 1.8 hard clay; 1.8 to 3 fien sand; 3 to 5.4 very soft clay; 5.4 to 5.9 fien sand.	VC Data	0
3.1	22cs_3R_27	4270708.27	497944.70	0 to 1.1 silty sand, sandy silt; 1.1 to 4.4 clay; 4.4 to 5.8 sand.	CPT Data	2
3.4	22vc_3R_28	4270293.26	497727.35	0 to 3.6 fine sand; 3.6 to 6 firm clay.	VC Data	0
3.4	21CS_005	4270307.69	498009.19	0.0 to 4.5 is soft clay; 4.5 to 5.0 is medium to dense sand.	CPT Data	4.5
3.5	A05_hysical	4270284.30	498135.70	0 to 0.5 gray finecourse Sand with trace fine Gravel; 0.5 to 0.6 finemedium Sand with trace 1/2" thick lenses of sticky Silt; 0.6 to 1.2 gray finecoarse Sand with trace 1/2" layers of dark gray sticky Silt; 1.2 to 1.5 gray fine Sand with trace pieces of wood; 1.5 to 1.8 Section sent to lab unopened; 1.8 to 1.9 brown sticky Clay with some Silt and fine Sand; 1.9 to 3.1 light gray-brown fine Sand with trace light gray Silt.	VC Data	0
3.7	22cs_3R_24	4270107.84	498209.55	0 to 3 interbedded silty sand, sandy silt clay and silty clay; 3 to 4 clay; 4 to 7.2 snad.	CPT Data	0
4	22vc_3R_30	4269717.44	498067.57	0 to 5.6 fine sand.	VC Data	0
4.4	21VC_003	4269378.80	498368.30	0 to 1.5 Fine medium SAND with shell fragments; 1.5 to 1.6 Grey Sandy GRAVEL with pebbles; 1.6 to 2.6 Grey fine medium SAND with shell fragments; 2.6 to 4.3 Tan fine coarse SAND with gravel; 4.3 to 4.4 Tan Gravely medium coarse SAND.	VC Data	0
4.4	21CS_003	4269377.37	498377.00	0 to 2.1 is medium to dense sand; 2.1 to 3 firm to hard clay; 3 to 4 medium to dense sand.	CPT Data	0

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Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
4.9	22vc_3R_31A	4268988.13	498705.96	0 to 0.6 coarse sand; 0.6 to 1.2 silt; 1.2 to 5.8 fien to medium dense sand.	VC Data	0
5.5	21CS_174	4268433.38	498738.50	0.0 to 1.6 is medium to dense sand; 1.6 to 2.4 firm to hard clay; 2.4 to 3.7 medium to dense sand.	CPT Data	0
5.5	21CS_174_R	4268421.91	498746.48	0.0 to 1.8is medium to dense sand; 1.8 to 2.8 firm to hard clay; 2.8 to 4.5 medium to dense sand.	CPT Data	0
6	21VC_173	4268095.80	499105.63	0 to 1.1 Light brown to grey fine coarse SAND with occasional gravel and shell fragments; 1.1 to 4.1 Fine medium SAND with shell fragments.	VC Data	0
6.5	21CS_172	4267738.30	499465.47	0.0 to 2.9 is medium to dense sand; 2.9 to 4.9 firm to hard clay.	CPT Data	0
7	21VC_171	4267394.91	499822.47	0 to 1.1 Fine medium SAND with shell fragments; 1.1 to 4.2 Dark grey CLAY.	VC Data	0
7.5	21CS_170	4267045.88	500179.50	0.0 to 4.3is medium to dense sand.	CPT Data	0
8.5	21VC_168	4266358.51	500901.22	0 to 0.15 Tan fine medium SAND w/ shell fragments; 0.15 to 0.85 Dark grey CLAY; 0.85 to 1.8 Grey fine medium SAND.	VC Data	0.9
8.5	21VC_167_R	4266348.52	500930.45	0 to 0.35 Light brown to grey, fine medium SAND with occasional gravel and shell fragments; 0.35 to 1.62 Dark grey CLAY; 1.62 to 2. Grey fine medium SAND.	VC Data	1.6
8.5	21CS_167	4266333.18	500941.15	0.0 to 4.6 soft clay and silt.	CPT Data	4.6
9.5	21CS_165	4265789.24	501765.35	0.0 to 4.8 is medium to dense sand.	CPT Data	0
10.5	21CS_163	4265239.09	502603.17	0.0 to 1.5 soft clay; 1.5 to 4.1 medium to dense sand.	CPT Data	1.5
11	21CS_162	4264975.52	503026.99	0.0 to 2.6 soft clay; 2.6 to 3.6 medium to dense sand.	CPT Data	2.6
11	21CS_162_R	4264964.24	503031.21	0.0 to 2.4 soft clay; 2.4 to 3.5 medium to dense sand.	CPT Data	2.4
12	21CS_160	4264431.24	503860.63	0.0 to 3.4 medium to dense sand; 3.4 to 4.8 firm to stiff clay.	CPT Data	0
13	21CS_175	4263877.80	504699.76	0.0 to 1is medium to dense sand; 1 to 4.8 soft clay.	CPT Data	4.8

A.2. ECC1 KP13-KP46

Table A.2: Interpretation of soft soil thickness for MarWin ECC1 between KP13 and KP46. Coordinates refer to survey locations.

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
13	21CS_175	4263877.80	504699.76	0.0 to -1.2 is medium to dense sand; -1.2 to -4.8 silt or soft clay.	CPT Data	4.8
14.1	21CS_156	4263088.25	505476.84	0.0 to -4.8 is medium to dense sand.	CPT Data	0
15.1	21CS_154_R	4262366.58	506178.45	0.0 to -2 soft clay; -2 to -4.8 medium to dense sand.	CPT Data	2
16.1	21CS_152_R2	4261656.81	506877.57	0.0 to -4.8 stiff to hard clay.	CPT Data	0
17.1	21CS_150	4260938.04	507581.76	0.0 to -3.8 is medium to dense sand.	CPT Data	0
18.1	21CS_148	4260227.84	508278.07	0.0 to -4.9 is medium to dense sand.	CPT Data	0
19.1	21CS_146	4259516.20	508967.10	0.0 to -5 is medium to dense sand.	CPT Data	0
19.9	21CS_144	4259122.50	509630.57	0.0 to -3.8 is medium to dense sand; -3.8 to -5 stiff to hard clay.	CPT Data	0
20.9	21CS_142	4258985.80	510630.89	0.0 to -5 is medium to dense sand.	CPT Data	0
21.9	21CS_140	4258864.75	511624.25	0.0 to -3.6 is medium to dense sand; -3.6 to -5 silt.	CPT Data	0
22.9	21CS_138_R	4258767.28	512601.31	0.0 to -3 is medium to dense sand.	CPT Data	0
22.9	21CS_138	4258757.49	512604.09	0.0 to -3 is medium to dense sand.	CPT Data	0
23.9	21CS_136_R	4258629.27	513587.49	0.0 to -2 is medium to dense sand.	CPT Data	0
23.9	21CS_136	4258635.03	513603.76	0.0 to -2.4 is medium to dense sand.	CPT Data	0
24.9	21CS_134_R	4258522.24	514567.97	0.0 to -2 is medium to dense sand; -2 to -3.2 soft clay; -3.2 to -5 silt.	CPT Data	0
24.9	21CS_134	4258518.94	514585.13	0.0 to-1.6 is medium to dense sand; -1.6 to -4.2 silt; -4.2 to -4.8 medium to dense sand.	CPT Data	0
25.9	21CS_132	4258399.13	515585.73	0.0 to -5 is medium to dense sand.	CPT Data	0
26.4	21CS_131	4258333.93	516094.85	0.0 to -1.8 is medium to dense sand; -1.8 to -2.4 firm to stiff clay; -2.4 to -4.9 medium to dense sand.	CPT Data	0
27.4	21CS_129	4258227.01	517067.12	0.0 to -5 is medium to dense sand.	CPT Data	0
28.4	21CS_127_R	4258099.34	518054.00	0.0 to -5 is medium to dense sand.	CPT Data	0
28.4	21CS_127	4258091.64	518082.51	0.0 to -4.9 is medium to dense sand.	CPT Data	0
28.9	21CS_126	4258035.58	518558.64	0.0 to -4.9 is medium to dense sand.	CPT Data	0

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Table A.2 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
29.5	21CS_124	4257562.73	518968.74	0.0 to -4.9 is medium to dense sand.	CPT Data	0
30	21CS_123	4257186.62	519299.70	0.0 to -1.8 is medium to dense sand.	CPT Data	0
31	21CS_121	4256437.57	519957.34	0.0 to -3.6 is medium to dense sand; -3.6 to -4.9 firm to stiff clay.	CPT Data	0
32	21CS_119	4255685.43	520615.55	0.0 to -3 is medium to dense sand; -3 to -5 firm to stiff clay.	CPT Data	0
32.5	21CS_118_R	4255306.97	520942.01	0.0 to -2.8 is medium to dense sand.	CPT Data	0
32.8	21CS_106_R	4255069.68	521148.14	0.0 to -3.6 is medium to dense sand; -3.6 to -4.9 firm to stiff clay.	CPT Data	0
33.8	21CS_104	4254309.52	521810.81	0.0 to -3.4 is medium to dense sand; -3.4 to -4.9 firm to stiff clay.	CPT Data	0
34.9	21CS_102	4253546.45	522472.60	0.0 to -1.8 is medium to dense sand.	CPT Data	0
34.9	21CS_102_R	4253535.52	522466.66	0.0 to -2.6 is medium to dense sand; -2.6 to -4.9 firm to stiff clay.	CPT Data	0
35.9	21CS_100	4252794.67	523118.91	0.0 to -1.5 is medium to dense sand; -1.5 to -4.9 soft clay.	CPT Data	5
36.6	21CS_116_R	4252143.30	523544.80	0.0 to -2.4 is medium to dense sand; -2.4 to -3 silt.	CPT Data	0
36.6	21CS_116	4252131.04	523538.54	0.0 to -2.4 is medium to dense sand; -2.4 to -3.1 silt.	CPT Data	0
37.1	21CS_115	4251721.47	523811.54	0.0 to -4.8 is medium to dense sand.	CPT Data	0
38.1	21CS_113	4250874.97	524349.99	0.0 to -3.6 is medium to dense sand; -3.6 to -4.9 silt.	CPT Data	0
39.1	21CS_111	4250022.81	524901.97	0.0 to -3.6 is medium to dense sand; -3.6 to -4 frim clay; -4 to -4.2 medium to dense sand.	CPT Data	0
40.1	21CS_109_R	4249192.76	525416.00	0.0 to -1.4 is medium to dense sand.	CPT Data	0
40.1	21CS_109	4249183.72	525422.73	0.0 to -1 silt; -1 to -2 medium to dense sand.	CPT Data	1
41.1	21CS_107_R	4248361.01	525963.92	0.0 to -2 is medium to dense sand; -2 to -4.7 firm to hard clay.	CPT Data	0
41.1	21CS_107	4248346.56	525956.25	0.0 to -2.4 is medium to dense sand; -2.4 to -5 firm to hard clay.	CPT Data	0
41.9	21CS_098_R	4247679.05	526386.84	0.0 to -3.4 is medium to dense sand; -3.4 to -4.9 firm to hard clay.	CPT Data	0

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Table A.2 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
41.9	21CS_098	4247656.45	526374.68	0.0 to -3.2 is medium to dense sand; -3.2 to -4.9 firm clay.	CPT Data	0
42.9	21CS_096	4246824.93	526918.72	0.0 to -4.7 is medium to dense sand.	CPT Data	0
43.9	21CS_094	4245975.49	527456.38	0.0 to -3.8 is medium to dense sand.	CPT Data	0
43.9	21CS_094_R	4245966.03	527447.39	0.0 to -3.3 is medium to dense sand.	CPT Data	0
44.9	21CS_092_R	4245139.74	527983.91	0.0 to -2.8 soft clay; -2.8 to -4.9 firm to hard clay.	CPT Data	2.8
44.9	21CS_092	4245125.49	527982.94	0.0 to -3.4 loose sand; -3.4 to -4.9 medium to dense sand.	CPT Data	0
45.4	21CS_091	4244696.23	528238.85	0.0 to -2.1 silt.	CPT Data	2.1
45.4	21CS_091_R	4244702.21	528257.33	0.0 to -3.2 silt; -3.2 to -5 medium to dense sand.	CPT Data	3.2
46.4	21CS_089_R	4243848.58	528788.88	0.0 to -1.8 is medium to dense sand.	CPT Data	0
46.4	21CS_089	4243840.04	528777.40	0.0 to -3.3 is medium to dense sand.	CPT Data	0
47.4	21CS_087	4243001.26	529314.25	0.0 to -4.8 is medium to dense sand.	CPT Data	0

A.3. ECC2 KP0-KP23

Table A.3: Interpretation of soft soil thickness for MarWin ECC2 between KP0 and KP23. Coordinates refer to survey locations.

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
0.2	22sb_TR_01	4281118.81	494280.37	0 to -1.83 silty sand; -1.83 to -8.53 fat clay; -8.53 to -9.14 lean clay; -9.14 to -11.58 clayey sand with silt; -11.58 to -14.63 lean clay with silt; -14.63 to -18.29 sand with gravel and clay; -18.29 to -33.66 silty sand.	BH Data	0
0.2	22sb_TR_02	4280888.28	494257.43	0 to -1.22 medium silty sand; -1.22 to -8.53 fat clay; -8.53 to -9.14 sandy lean clay; -9.14 to -11.13 clayey sand; -11.13 to -12.8 sandy lean clay; -12.8 to -14.02 fine clayey sand; -14.02 to -17.22 sandy lean clay; -17.22 to -17.37 well graded gravel; -17.37 to -33.99 medium silty sand with gravel.	BH Data	0

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Table A.3 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
0.3	22cb_TR_05	4281008.85	494360.34	0 to -0.6 silty sand and sandy silt; -0.6 to -1.2 clay or silty clay; -1.2 to -14.8 clay and silty clay, with occasional thin sand layer; -17.8 to -24.2 sand; -27.2 to -34.4 sand.	CPT Data	0
0.5	22sb_TR_03	4281011.73	494523.21	0 to -1.37 silty sand; -1.37 to -7.92 fat clay; -7.92 to -10.36 medium silty sand; -10.36 to -14.33 sandy fat clay; -14.33 to -15.24 sand; -15.24 to -17.07 lean clay; -17.07 -26.82 silty sand; -26.82 to -27.22 lean clay; -27.22 to -27.43fine silty sand; -27.43 to -28.96, lean clay ; -28.96 to -29.87 silty sand; -29.87 to -31.24 lean clay ; -31.24 to -32 medium silty sand.	CPT Data	0
0.5	22cb_TR_03	4281008.52	494521.18	0 to -0.6 soft clay; -0.6 to -1.4 sand; -1.4 to -6.2 firm to hard clay; -6.2 to -9.4 silt; -9.4 to -10.4 sand; -10.4 to -18 interbedded clay, sand and silt; -18 to -26.4 sand; -26.4 to -32.4 interbeded sand, clay, and silt.	BH Data	0.6
0.6	22cb_TR_07	4281119.05	494630.37	0 to -0.3 soft clay; -0.3 to -1.1 silty sand and sandy silt; -1.1 to -2.5 sand; -2.5 to -13 interbedded clay, silty clay, silty sand, sandy silt; -13 to -15.2 dense sand; -15.2 to -20.2 clay, silty clay, silty sand, sandy silt; -20.2 to -23.2 sand.	CPT Data	0.3
0.6	22cb_TR_08	4280860.05	494650.13	0 to -0.1 soft clay; -0.1 to -3.1 sand; -3.1 to -6.8 clay; -6.8 to -8.3 clay, silty clay; -8.3 to -9.4 sand; -9.4 to -14 interbeded clay, silty clay, silty sand, sandy silt; -15.9 to -16.4 sand; -16.4 to -18.8 clay, silty clay, silt; -18.8 to -22.8 sand.	CPT Data	0.1
0.7	22cb_TR_06	4280995.96	494732.12	0 to -0.5 silt; -0.5 to -3.4 sand; -3.4 to -13.4 firtm to hard clay.	CPT Data	0.5
1.1	22cs_TR_15	4281218.08	495199.06	0 to -0.1 soft clay; -0.1 to -4.2 interbedded sandy silt and silty sand; -4.2 to -5.8 sand; -5.8 to -10.2 interbedded clay, silty clay, sandy silt, silty sand; -10.2 to -10.5 sand; -10.5 to -13 clay, silty clay, silty sand, sandy silt.	CPT Data	0.1

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Table A.3 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
1.5	22cs_TR_18	4280846.30	495614.74	0 to -0.2 soft clay; -0.2 to -0.6 silty sand and sandy silt; -0.6 to -5, sand; -5 to -7.9 silty sand and sandy silt.	CPT Data	0.2
1.9	22cs_TR_19	4281201.85	495938.44	0 to -0.1 soft clay; -0.1 to -0.7 silty sand sandy silt; -0.7 to -1.9 sand; -1.9 to -2.3 silty sand, sand, sandy silt; -2.3 to -6.8 sand.	CPT Data	0.1
2	22cs_TR_20	4280849.22	496097.47	0 to -0.2 soft clay; -0.2 to -1.2 silty sand and sandy silt, clay, silty clay; -1.2 to -1.8 clay; -2.2 to -3.8 sand.	CPT Data	0.2
2	22cs_TR_21a	4280849.76	496097.02	0 to -0.2 soft clay; -0.2 to -4.1 sand; -4.1 to -7.1 interbedded silty sand, sandy silt, clay, silty clay.	CPT Data	0.2
3	21CS_030_CPT	4281060.02	497096.95	0.0 to -2 is medium to dense sand; -2 to -2.9 is soft clay; -2.9 to -4.9 is medium to dense sand.	CPT Data	0
3	21VC_030_VC	4281068.80	497098.20	0 to -1.1 dark grey fine sand; -1.1 to -2 is dark grey clay; -2 to -2.5 dark grey, fine-medium sand with gravel; -2.5 to -2.9, light grey silty fine sand; -2.9 to -3.1 orange to brown fine-medium sand; -3 to -3.6 interbedded sand and clay layers.	VC Data	0
3.5	21CS_029_R_CPT	4281078.54	497580.87	0.0 to -1.2 is loose sand; -1.2 to -1.7 silt; -1.7 to -2.7 is medium to dense sand.	CPT Data	0
4.1	21CS_217_R2_CPT	4281985.72	498109.80	0.0 to -0.2 is soft clay; -0.2 to -2.6 is loose sand; -2.6 to -4.1 is clay.	CPT Data	0.2
4.5	21CS_215_R_CPT	4281104.55	498599.30	0.0 to -1.2 loose sand; -1.2 to -3.5 silt.	CPT Data	0
5	21VC_213_R_VC	4280560.10	498896.60	0 to -1 dark grey fine sand and sandy silt; -1 to 3.6 is dark grey clay with shell fragments.	VC Data	3.6
5	21CS_213_R_CPT	4280570.95	498895.69	0.0 to -2.1 silt; -2.1 to 5 soft clay.	CPT Data	5
5.5	21VC_212_VC	4280120.50	499129.7	0 to -0.25 dark grey silty fine sand; -0.25 to -0.4 balck silty clay; -0.4 to -1.75 dark grey fine sand-clayey silt; -1.75 to -3.9 dark grey clay.	VC Data	4
6	21CS_211_CPT	4279695.39	499364.92	0.0 to -5 is loose sand.	CPT Data	0
6	21CS_211_R_CPT	4279685.40	499371.73	0.0 to -5 is loose sand.	CPT Data	0

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Table A.3 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
6.5	21VC_210_R_VC	4279243.60	499606.00	0 to -0.6 sandy to cayey silt; -0.6 to -0.75 silty fine sand; -0.75 to -1.05 silty clay; -1.05 to -1.45 fine to medium sand; -1.45 to -2.6 fien medium sand.	VC Data	1.1
7.2	21CS_209_R_CPT	4278813.56	499845.13	0.0 to -0.3 is loose sand; -0.3 to -1.9 is medium to dense sand.	CPT Data	0
7.2	21CS_209_CPT	4278818.56	499871.95	0.0 to -0.3 is loose sand; -0.3 to -1.9 is medium to dense sand.	CPT Data	0
7.2	21VC_209_R_VC	4278802.00	499852.40	0 to -0.25 fine coarse sand; -0.25 to -0.45 silyty clay; -0.45 to -0.75 fine medium sand; -0.75 to -0.95 medium coarse sand; -0.95 to -1.2 gravely sand; -1.2 to -1.35 fine sand; -1.35 to -2.45 fine medium sand with gravel; -2.45 to -2.55 sandy clay.	VC Data	0
8.4	21CS_206_R_CPT	4278046.46	500717.88	0.0 to -0.4 is loose sand; -0.4 below is medium to dense sand.	CPT Data	0
8.4	21CS_206_CPT	4278056.63	500737.46	0.0 to -0.4 is loose sand; -0.4 to -3.1 is medium to dense sand.	CPT Data	0
8.4	21CS_206_R3_CPT	4278030.00	500731.22	0.0 to -0.4 is loose sand; -0.4 below is medium to dense sand.	CPT Data	0
8.4	21CS_206_R2_CPT	4278039.81	500745.14	0.0 to -0.4 is loose sand; -0.4 below is medium to dense sand.	CPT Data	0
9.4	21CS_204_CPT	4277397.42	501482.29	0.0 to -3.1 is medium to dense sand.	CPT Data	0
9.4	21CS_204_R_CPT	4277410.01	501510.71	0.0 to -3.8 is medium to dense sand.	CPT Data	0
10.4	21CS_202_CPT	4276738.67	502268.72	0.0 to -3.6 is medium to dense sand.	CPT Data	0
10.4	21CS_202_R_CPT	4276746.62	502275.97	0.0 to -4.9 is medium to dense sand.	CPT Data	0
11.4	21CS_200_R_CPT	4276088.11	503009.88	0.0 to -4.5 is soft clay; -4.5 to -4.9 is medium to dense sand.	CPT Data	4.5
11.4	21CS_200_CPT	4276095.32	503021.63	0.0 to -4.5 is soft clay; -4.5 to -4.9 is medium to dense sand.	CPT Data	4.5
11.7	21CS_199_R_CPT	4275777.80	503058.74	0.0 to -4.3 soft clay.	CPT Data	4.3
11.7	21CS_199_R2_CPT	4275766.33	503049.32	0.0 to -3.5 is soft clay; -3.5 to -4.9 is firm to hard clay.	CPT Data	3.5
11.7	21CS_199_CPT	4275752.10	503077.75	0.0 to -4.9 is soft clay.	CPT Data	4.9
12.2	21CS_198_CPT	4275269.24	503135.54	0.0 to -4.9 is medium to dense sand.	CPT Data	0
12.7	21CS_197_CPT	4274768.63	503202.91	0.0 to -4.5 is medium to dense sand.	CPT Data	0

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Table A.3 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
13.7	21CS_195_CPT	4273776.30	503340.72	0.0 to -4.9 is medium to dense sand.	CPT Data	0
14.7	21CS_193_CPT	4272790.26	503473.63	0.0 to -4 is medium to dense sand.	CPT Data	0
15.7	21CS_191_CPT	4271800.35	503612.37	0.0 to -4.9 is medium to dense sand.	CPT Data	0
16.7	21CS_189_R_CPT	4270818.93	503739.10	0.0 to -4.9 is medium to dense sand.	CPT Data	0
16.7	21CS_189_CPT	4270812.28	503748.69	0.0 to -1.6 is medium to dense sand.	CPT Data	0
16.7	21CS_189_R2_CPT	4270794.16	503744.63	0.0 to -4.9 is medium to dense sand.	CPT Data	0
17.7	21CS_187_CPT	4269835.50	503880.38	0.0 to -4.6 is medium to dense sand.	CPT Data	0
17.7	21CS_187_R_CPT	4269811.64	503887.07	0 to -2.9 is medium to dense sand, -2.9 to -4.6 is soft clay.	CPT Data	0
18.2	21CS_186_CPT	4269345.08	503950.45	0.0 to -4.7 is soft clay.	CPT Data	4.7
18.2	21CS_186_R_CPT	4269319.36	503934.50	0.0 to -4.9 soft clay.	CPT Data	4.9
18.7	21CS_185_CPT	4268824.88	504028.39	0.0 to -4.8 is medium to dense sand.	CPT Data	0
19.7	21CS_183_R_CPT	4267844.22	504141.86	0.0 to -4.8 is medium to dense sand.	CPT Data	0
19.7	21CS_183_CPT	4267841.63	504157.69	0.0 to -3.5 is medium to dense sand.	CPT Data	0
20.2	A09_Physical_VC	4267007.90	504145.10	0 to -1 fine to coarse sand with some gravel; -1 to -1.65 sandy gravel; -1.65 to -4.66 fine-medium sand.	VC Data	0
20.7	21CS_181_CPT	4266848.78	504297.77	0.0 to -2.8 is medium to dense sand; -2.8 to -4.9 is firm to hard clay.	CPT Data	0
21.7	21CS_179_CPT	4265863.13	504431.34	0.0 to -3.9 is medium to dense sand.	CPT Data	0
22.7	21CS_177_CPT	4264869.91	504567.71	0.0 to -4.8 is soft clay.	CPT Data	4.8
23	21CS_160_CPT	4264431.24	503860.63	0.0 to -3.4 is medium to dense sand; -3.4 to -4.8 firm to hard clay.	CPT Data	0
23.7	21CS_175_CPT	4263877.80	504699.76	0.0 to -1.4 is medium to dense sand; -1.4 to -4.8 is soft clay.	CPT Data	0

A.4. IRB North KP0-KP17

Table A.4: Interpretation of soft soil thickness for MarWin IRB North Route between KP0 and KP17. Coordinates refer to survey locations.

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
0.7	23vc_01	4271275.47	479172.74	0 to -3silt; -3 to -3.7 silty sand; -3.7 to -4.5 clay with silt soft; -4.5 to -4.7 sand with gravel.	VC Data	4.5
0.7	23sb_01	4271209.26	479209.84	0 to -3.7 very soft clay; -3.7 to -4.7 sand; -4.7 to -26 sand, with gravel.	BH Data	3.7
0.7	23cs_11rev_CPT	4271192.52	479182.39	0.0 to -5.8 is soft clay; -5.8 to -21.1 is medium to dense sand.	CPT Data	5.8
0.8	23cs_16_CPT	4271269.66	479270.39	0.0 to -5.0 is soft clay; -5.0 to -8.4 is medium to dense sand.	CPT Data	5
0.8	23vc_02	4271176.26	479229.39	0 to -4.9 soft clay; -4.9 to -5.2 sand.	VC Data	4.9
0.8	23cs_12rev_CPT	4271127.70	479245.73	0.0 to -4.9 is soft clay; -4.9 to -21.2 is medium to dense sand.	CPT Data	4.9
0.8	23vc_04	4271130.30	479270.19	0 to -3.8 soft silt; -3.8 to -4.5 sand.	VC Data	3.8
0.8	23vc_04A	4271129.55	479271.40	0 to -3.5 soft clay; -3.5 to -4.9 sand and sand with gravel.	VC Data	3.5
0.9	23vc_03	4271199.90	479319.74	0 to -5 soft silt; -5 to -5.3 sand.	VC Data	5
0.9	23cs_13_CPT	4271160.74	479320.35	0.0 to -5.0 is soft clay; -5.0 to -16.7 is medium to dense sand; -16.7 to -18.0 is soft clay; -18.0 to -24.1 is medium to dense sand.	CPT Data	5
0.9	23sb_02	4271090.75	479300.59	0 to -4.1 soft clay; -4.1 to -28.1 sand with gravel; -28.1 to -29.4 medium stiff clay; -29.4 to -30 silty sand.	BH Data	4.1
0.9	23cs_14rev_CPT	4271070.62	479309.41	0.0 to -3.8 is soft clay; -3.8 to -16.7 is medium to dense sand; -16.7 to -16.8 is firm to hard clay; -16.8 to -24.2 is medium to dense sand.	CPT Data	3.8
1	VC-IRB-02	4271033.20	479364.00	0 to -2.6 soft clay with peat.	VC Data	2.6
1	VC-IRB-01	4271065.10	479360.00	0 to -1.6 soft clay; -1.6 to -1.8 sand.	VC Data	1.6
1	23cs_17_CPT	4271139.50	479397.87	0.0 to -5.7 is soft clay; -5.7 to -7.9 is medium to dense sand.	CPT Data	5.7
1	VC-IRB-03	4271004.00	479426.70	0 to -2.2 soft clay.	VC Data	2.2
1	23sb_03	4271059.70	479430.37	0 to -3.4 soft clay with silt; -3.4 to -12.8 sand; -12.8 to -13.3 clay; -13.3 to -15.2 sand; -15.2 to -16.5 clay; -16.5 to – 26.2 sand.	BH Data	3.4
1.1	23cs_18_CPT	4271069.32	479549.80	0.0 to -5.4 is soft clay; -5.4 to -7.7 is medium to dense sand.	CPT Data	5.4
1.2	23vc_05A	4271011.10	479630.87	0 to -1.6 soft silt; -1.6 to -3.1 sand.	VC Data	1.6

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Table A.4 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
1.35	23cs_19_CPT	4271079.43	479800.26	0.0 to -5.7 is soft clay; -5.7 to -8.3 is medium to dense sand.	CPT Data	5.7
1.5	VC-IRB-17	4271056.50	479990.60	0 to -2 soft clay; -2 to -2.8 sand.	VC Data	2
1.7	22vc_07	4271099.60	480159.70	0 to -3 silt; -3 to -4.6 medium to fine sand; -4.6 to -15 coarse to fine sand.	VC Data	0.9
1.95	22vc_08	4271119.70	480399.80	0 to -17.7 silty clay; -17.7 to -17.9 sand; -17.9 to -18.9 silty clay; -18.9 to -19.8 fine sand.	VC Data	5.8
2.15	23cs_20_CPT	4271159.85	480571.35	0.0 to -2.9 is soft clay; -2.9 to -7.1 is medium to dense sand.	CPT Data	2.9
2.2	22vc_09	4271188.10	480618.70	0 to -9 silt; -9 to -16 fine sand.	VC Data	2.7
2.5	VC-IRB-04	4271289.20	480905.70	0 to -2.8 soft clay.	VC Data	2.8
3	22vc_10	4271319.20	481353.10	0 to -14.2 silty clay; -14.2 to -16.2 silt; -16.2 to -20.2 fine sand.	VC Data	4.9
	23vc_11	4271519.13	481799.98	0 to -5.6 very soft silt; -5.6 to -5.9 sand.	VC Data	5.6
3.9	23cs_21_CPT	4271520.01	482160.04	0.0 to -8.0 is soft clay; -8.0 to -11.0 is medium to dense sand.	CPT Data	8
4	22vc_12	4271479.80	482209.50	0 to -19.6 silty clay.	VC Data	6
4.25	VC-IRB-05	4271418.90	482447.40	0 to -2.1 soft clay.	VC Data	2.1
4.75	23vc_13	4271180.22	482901.12	0 to -5.5 soft clay.	VC Data	5.5
4.75	22vc_14	4271341.00	482960.50	0 to -1.3 silt; -1.3 to -20 silty clay.	VC Data	6.1
5.5	23cs_22_CPT	4271260.69	483700.13	0.0 to -11.8 is soft clay; -11.8 to -11.9 is firm to hard clay; -11.9 to -12.3 is medium to dense sand.	CPT Data	11.8
4.5	22vc_15	4271280.60	483710.30	0 to -9.1 silty clay; -9.1 to -12.1 silt; -12.1 to -16.1 fine sand and silt.	VC Data	4.9
4.8	VC-IRB-06	4271394.10	484030.70	0 to -2.8 soft clay.	VC Data	2.8
5.5	23vc_16	4271420.23	484740.61	0 to -5.4 soft clay.	VC Data	5.4
5.5	23cs_23_CPT	4271419.82	484769.92	0.0 to -12.9 is soft clay; -12.9 to -14.2 is medium to dense sand.	CPT Data	12.9
5.9	23cs_44_CPT	4271679.62	485100.07	0.0 to -12.0 is soft clay.	CPT Data	12
6.25	23vc_17	4271484.96	485484.96	0 to -5.4 soft clay.	VC Data	5.4
6.75	VC-IRB-07-ALT	4271859.40	485960.40	0 to -1.2 soft clay; -1.2 to -1.8 sand; -1.8 to -2 sandy clay; -2 to -2.2 fine sand.	VC Data	1.2
6.9	23cs_45_CPT	4271750.64	486099.59	0.0 to -12.3 is soft clay.	CPT Data	12.3
7	23vc_18	4271569.42	486280.07	0 to -5.5 soft clay.	VC Data	5.5
7.05	23cs_24_CPT	4271608.83	486329.21	0.0 to -14.3 is soft clay.	CPT Data	14.3
7.55	VC-IRB-08-ALT	4272031.90	486667.40	0 to -1.6 very soft clay; -1.6 to -1.9 sand.	VC Data	1.6
7.65	23cs_46_CPT	4271920.56	486799.83	0.0 to -12.9 is soft clay.	CPT Data	12.9

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Table A.4 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
7.8	23vc_19	4271750.11	487000.15	0 to -5.7 soft clay.	VC Data	5.7
8.55	23cs_25_CPT	4272049.60	487679.30	0.0 to -14.5 is soft clay.	CPT Data	14.5
8.55	23vc_20	4272050.22	487699.47	0 to -5.5 soft clay.	VC Data	5.5
8.8	VC-IRB-24	4272285.20	487980.50	0 to -3 soft clay with trace peat.	VC Data	3
9.35	23vc_21	4272160.15	488600.38	0 to -5.8 soft clay.	VC Data	5.8
9.55	23cs_47_CPT	4272049.48	488799.68	0.0 to -1 soft clay; -1to -12.7 is medium to dense sand.	CPT Data	1
9.55	23cs_48	4272049.99	488799.73	0 to -1.5 soft clay; -1.5 to -5.4 interbedded clay, silty sand, and sandy silt; -5.4 to -12.1 sand.	CPT Data	1.5
9.8	VC-IRB-09-ALT	4272436.50	489062.80	0 to -3 very soft clay with peat layer.	VC Data	3
10	23cs_26_CPT	4272159.85	489270.10	0.0 to -2.4 is soft clay; -2.4 to -7.8 is medium to dense sand.	CPT Data	2.4
10	23vc_22A	4272179.90	489300.65	0 to -2.4 soft clay; -2.4 to -3.6 sand.	VC Data	2.4
10	23vc_22	4272179.08	489299.40	0 to -3 soft clay; -3 to -3.7 sand.	VC Data	3
10.4	23cs_53_CPT	4272500.31	489600.42	0.0 to -4.3 is soft clay; -4.3 to -8.4 is medium to dense sand; -8.4 to -8.5 is soft clay; -8.5 to -12.0 is medium to dense sand.	CPT Data	4.3
10.8	23vc_23	4272420	490000	0 to -4.1 soft clay; -4.1 to -5.4 sand.	VC Data	4.1
11.1	23cs_54_CPT	4272399.77	490299.87	0.0 to -4.5 is soft clay; -4.5 to -12.6 is medium to dense sand.	CPT Data	4.5
11.3	VC-IRB-10-ALT	4272635.30	490397.20	0 to -3 very soft clay with peat.	VC Data	3
11.5	23vc_24	4272539.65	490639.79	0 to -5 soft clay; -5 to -5.7 sand.	VC Data	5
11.5	23cs_27_CPT	4272560.50	490660.75	0.0 to -5 is soft clay; -5to -7.0 is medium to dense sand.	CPT Data	5
11.85	23vc_40rev	4272628.14	490995.18	0 to -0.9 silt ynsad; -0.9 to -5.4 soft clay.	VC Data	5.4
11.9	23cs_55_CPT	4272699.93	491050.17	0.0 to -6.4 is soft clay; -6.4 to -12.7 is medium to dense sand.	CPT Data	6.4
11.9	23vc_48	4272675.30	491069.91	0 to -0.2 silty sand; -0.2 to -5.9 soft clay.	VC Data	5.9
11.9	23_vc49	4272595.06	491075.49	0 to -0.35 silt ysand; -0.35 to -5.8 soft clay silt.	VC Data	5.8
12	23vc_47	4272636.92	491154.15	0 to -5.7 soft clay.	VC Data	5.7
12.1	23_vc25rev	4272620.22	491300.29	0 to -3.9 soft clay; -3.9 to -5.4 sand.	VC Data	3.9
12.6	23cs_28_CPT	4272549.63	491790.96	0.0 to -6.1 is soft clay; -6.1 to -7.8 is medium to dense sand.	CPT Data	6.1
12.6	22vc_27	4272495.20	491786.50	0 to -3.2 silty clay; -3.2 to -4.2 clay; -4.2 to -9.9 silty clay; -9.9 to -17.2 fine sand.	VC Data	9.9
12.9	VC-IRB-11-ALT	4272359.80	492078.70	0 to -0.9 nsad; -0.9 to -2.8 soft clay.	VC Data	2.8

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Table A.4 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
13.2	22vc_28	4272419.20	492400.00	0 to -13.2 fine sand; -13.2 to -14.2 fine gravel and fine sand.	VC Data	0
13.8	22vc_29	4272800.30	492880.90	0 to -4.2 fine sand; -4.2 to -5 silt and fine sand; -5 to -20 silty clay.	VC Data	0
13.8	23cs_29_CPT	4272799.80	492908.65	0.0 to -10.1 is soft clay.	CPT Data	10.1
13.9	23vc_42rev	4272749.99	492949.73	0 to -2.8 sandy silt; -2.8 to -5.5 soft silt clay.	VC Data	5.5
14	22vc_30	4272699.50	493089.70	0 to -5 fine snad; -5 to -20 silty clay.	VC Data	0
14.4	22vc_31	4272300.60	493070.30	0 to -19.4 silty clay.	VC Data	5.9
14.4	23cs_30_CPT	4272279.91	493101.23	0.0 to -10.8 is soft clay.	CPT Data	10.8
14.5	23vc_44rev	4272099.83	493039.73	0 to -0.3 silt ysand; -0.3 to -5.4 soft clay.	VC Data	5.4
14.65	VC-IRB-12	4272066.40	493269.50	0 to -0.5 fine sand; -0.5 to -1.2 clayey silt; -1.2 to -2.7 soft silty clay.	VC Data	2.7
14.75	23cs_36_CPT	4271999.49	493349.47	0.0 to -2.5 is medium to dense sand; -2.5 to -6.8 is soft clay; -6.8 to -7.5 is medium to dense sand.	CPT Data	0
14.75	23vc_43	4271945.02	493419.88	0 to -1 sandy silt; -1 to -4 soft clay.	VC Data	4
14.85	23vc_45rev	4271839.82	493495.68	0 to -1 sandy silt; -1 to -5 soft clay.	VC Data	5
14.85	23cs_41_CPT	4271841.06	493500.41	0.0 to -0.4 is soft clay; -0.4 to -1.7 is medium to dense sand; -1.7 to -6.3 is soft clay; -6.3 to -24.2 is medium to dense sand.	CPT Data	6.3
14.95	23sb_06	4271820.13	493609.82	0 to -2.8 fine sand; -2.8 to -7 possible clay; -7 to -24 sand.	BH Data	0
15.1	23cs_42	4271730.33	493700.10	0 to -1.5 soft clay; -1.5 to -3.1 sand; -3.1 to -6.5 soft clay; -6.5 to -24.7 sand.	CPT Data	1.5
15.25	VC-IRB-16	4271722.80	493860.40	0 to -0.5 fine sand.	VC Data	0
15.25	23sb_04rev	4271791.96	493884.33	0 to -3.5 soft clay; -3.5 to -4.3 sand; -4.3 to -7.3 soft clay; -7.3 to -9.8 sand; -9.8 to -28 sand.	BH Data	7.3
15.25	23cs_38_CPT	4271800.21	493900.19	0.0 to -2.8 is soft clay; -2.8 to -4.2 is medium to dense sand; -4.2 to -7.1 is soft clay; -7.1 to -13.9 is medium to dense sand.	CPT Data	2.8
15.35	23sb_05	4271629.25	493915.67	0 to -5.5 soft clay; -5.5 to -17.6 sand; -17.6 to -18.3 clat silt; -18.3 to -27.8 sand; -27.8 to -29.1 clay; -29.1 to -32 nsad;	BH Data	5.5
14.4	23cs_43_CPT	4271700.62	493950.53	0.0 to -6.9 is soft clay; -6.9 to -23.4 is medium to dense sand.	CPT Data	6.9

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Table A.4 – *Continued from previous page*

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
15.4	VC-IRB-15-ALT	4271676.30	493994.60	0 to -1.2 fine sand; -1.2 to -2.4 silty clay.	VC Data	0
15.4	VC-IRB-14-ALT	4271708.20	493997.70	0 to -1.6 sand; -1.6 to -1.8 silt; -1.8 to -2.3 silty clay.	VC Data	0
15.4	VC-IRB-13-ALT	4271737.10	494002.00	0 to -1.1 sand; -1.1 to -1.5 soft silty clay; -1.6 to -2.73 soft silt yclay.	VC Data	0

A.5. IRB South KPS0-KPS5.5

Table A.5: Interpretation of soft soil thickness for MarWin IRB South Route between KPS0 and KPS5.5. Coordinates refer to survey locations.

Approx. KP	VC / CPT ID	Northing (m)	Easting (m)	Layering from log	SI Type	Soft soil thickness [m]
S0.3	23cs_26_CPT	4272159.85	489270.1	0.0 to -2.5 is soft clay; -2.5 to -8 silty sand, sandy silt, sand.	CPT Data	2.5
S0.6	23cs_49_CPT	4271899.90	489500.12	0.0 to -0.8 is soft clay; -0.8 to -5 silty sand, sandy silt; -5 to -12 sand, and silty sand.	CPT Data	0.8
S1.2	23cs_50_CPT	4271700.35	490200.34	0.0 to -1.5 is soft clay; -1.5 to -4 silty sand and sandy silt; -4 to -12 is medium to dense sand.	CPT Data	1.5
S2	23cs_31_CPT	4271840.64	490620.90	0.0 to -4.8 soft clay; -4.8 to -7.5 sand and silty sand.	CPT Data	4.8
S2.5	23cs_51_CPT	4271300.33	490800.18	0.0 to -0.8 soft clay; -0.8 to -3 silty sand and sandy silt; -3 to -12.5 sand.	CPT Data	0.8
S3.2	23cs_32_CPT	4271050.00	491461.37	0.0 to -4.6 is soft clay; -4.6 to -7.3 silty sand, sandy silt.	CPT Data	4.6
S3.6	23cs_52_CPT	4271400.45	491900.53	0.0 to -12.1 soft clay.	CPT Data	12.1
S4.8	23cs_34rev_CPT	4271239.59	492700.32	0 to -4.8 soft clay; -4.8 to -8 sand and silty sand.	CPT Data	4.8
S5.5	23cs_39_CPT	4271549.07	493600.37	0.0 to -0.4 soft clay; -0.4 to -1.8 medium to dense sand; -1.8 to -3.8 soft clay; -3.8 to -13.5 medium to dense sand.	CPT Data	0.4
S5.6	23sb_07rev	4271622.25	493631.20	0 to -2 fine sand; -2 to -4.3 possible clay; -4.3 to -10.4 sand; -10.4 to -24 interbedded sand, silt and clay.	BH Data	0
S5.7	23cs_42_CPT	4271730.33	493700.10	0 to -1.5 soft clay; -1.5 to -3 sand; -3 to -6.5 soft clay; -6.5 to -24.5 sand.	CPT Data	1.5
S5.7	23sb_06	4271820.13	493609.82	0 to -2.8 fine sand; -2.8 to -8.5 possib le clay; -8.5 to -24 sand;	BH Data	0

B. CBRA PROBABILITY REPORTS - OFFSHORE ECC ROUTES

B.1. CBRA probability reports - Cable ECC2 KP0 to KP24

B.1.1. Cable layout overview

An overview of the cable layout and sections analysed is shown in figure B.1.

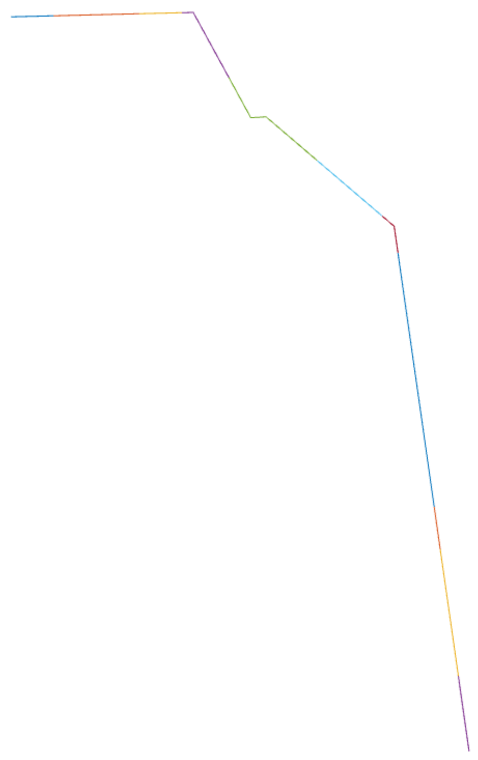


Figure B.1: Overview of cable layout and sections analysed.

B.1.2. Vessel movement

Vessel movement has been assessed using [1].

An overview of cable layout with vessel movements is shown on Figure B.2.

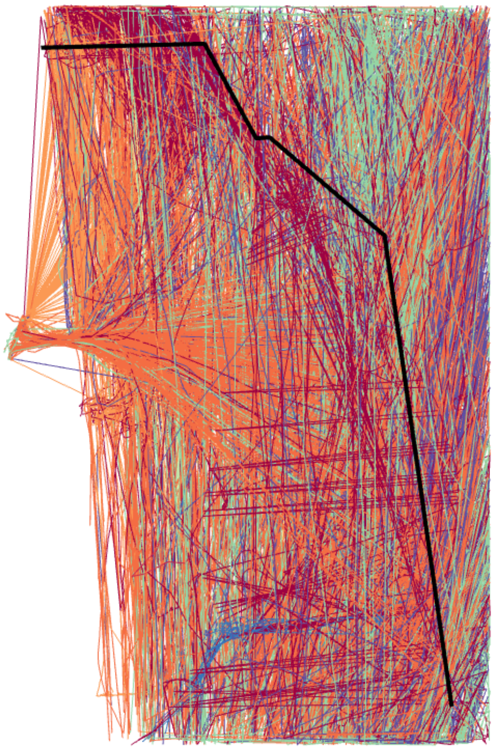


Figure B.2: Overview of cable layout with vessel movements.

AIS data date range is 01 Jan 2019 to 31 Dec 2019, and 01 Jan 2022 to 31 Dec 2022, covering a period of 2.0 years.

Table B.1 provides a summary of the vessels crossing all cables. Sections B.1.8 and B.1.9 details the number of vessels crossing each individual cable for each vessel size over the data set period.

Table B.1: Vessel classifications. Number of vessels and crossings are based on the full period of the AIS data set.

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, No additional information	79	1	11	699
Cargo, all ships of this type	70	1	2	23856
Diving ops	34	2	3	16
Dredging or underwater ops	33	2	3	4144
Fishing	30	111	378	1043
High speed craft (HSC), all ships of this type	40	1	1	248
Law Enforcement	55	3	8	467

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Other Type, Reserved for future use	95	1	1	138
Other Type, all ships of this type	90	57	556	3707
Passenger, all ships of this type	60	26	151	995
Pleasure Craft	37	635	1091	9818
Reserved	38	1	1	44
Sailing	36	133	152	133
Spare - Local Vessel	56	2	3	13030
Tanker, all ships of this type	80	1	1	19
Towing	31	127	469	1835
Towing: length exceeds 200m or breadth exceeds 25m	32	2	8	494
Tug	52	5	17	1132
Unknown	0	5	9	7515

The most common vessels were:

- PADRE ISLAND, Other Type, all ships of this type class, 2852 tonnes, 164 crossings
- DODGE ISLAND, Other Type, all ships of this type class, 2906 tonnes, 150 crossings
- ST JOHNS RIVER, Passenger, all ships of this type class, 32 tonnes, 46 crossings
- TIKI XIV, Pleasure Craft class, 65 tonnes, 44 crossings
- NS INTERCEPTOR, Passenger, all ships of this type class, 16 tonnes, 43 crossings

The largest vessels were:

- EVANGELIA L, Cargo, all ships of this type class, 23856 tonnes, 2 crossings
- CHINCOTEAGUE, Spare - Local Vessel class, 13030 tonnes, 1 crossings
- CHARLESTON, Spare - Local Vessel class, 10898 tonnes, 2 crossings
- PHOENIX, Pleasure Craft class, 9818 tonnes, 1 crossings

B.1.3. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely “soft” or “hard”. This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material [17].

The two-layered approach adopted in this section considers the case where a layer of soft soil has been deposited over stiffer material. This model does not consider the case where hard soil is overlying soft soil. Soft soil is defined as cohesive soil with an undrained shear strength less than 40kPa.

Table B.2 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely thick hard and soft soil.

Table B.2: Anchor model.

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-2	4	1084.4	1.0	0.72	2.16	128.8	38.1
2	2-5	8	1741.0	1.2	0.85	2.54	194.4	61.6
3	5-8	13	2296.6	1.3	0.93	2.80	247.4	81.6
4	8-10	17	2795.2	1.4	1.00	2.99	293.5	99.6
5	10-12	21	3255.4	1.5	1.05	3.16	335.1	116.3
6	12-15	26	3687.1	1.6	1.10	3.29	373.4	132.0
7	15-18	30	4096.5	1.6	1.14	3.41	409.2	146.9
8	18-20	34	4487.6	1.7	1.17	3.52	443.0	161.1
9	20-22	38	4863.6	1.7	1.21	3.62	475.1	174.9
10	22-25	42	5226.4	1.8	1.24	3.71	505.8	188.1

DWT is estimated from (dimensions in metres, DWT in tonnes):

$$DWT = max \begin{cases} (length/5.32)^{(1/0.351)} & \text{ref [5], fig 1.3} \\ length \times width \times draught \times 0.7 \times 1.025/1.7 & \text{ref [5], fig 1.2} \end{cases} \tag{B.1}$$

Displacement is taken as $1.7 \times DWT$ (ref [5]), adopting container ship parameters.

Anchor mass is estimated from ref [7], fig 9.2.

Fluke length is estimated from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \tag{B.2}$$

Anchor penetration is based on soil type (ref [27]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \tag{B.3}$$

Anchor penetration for the two-layered soil model is calculated using Equation B.4 and the schematic outlined in Figure B.3 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \tag{B.4}$$

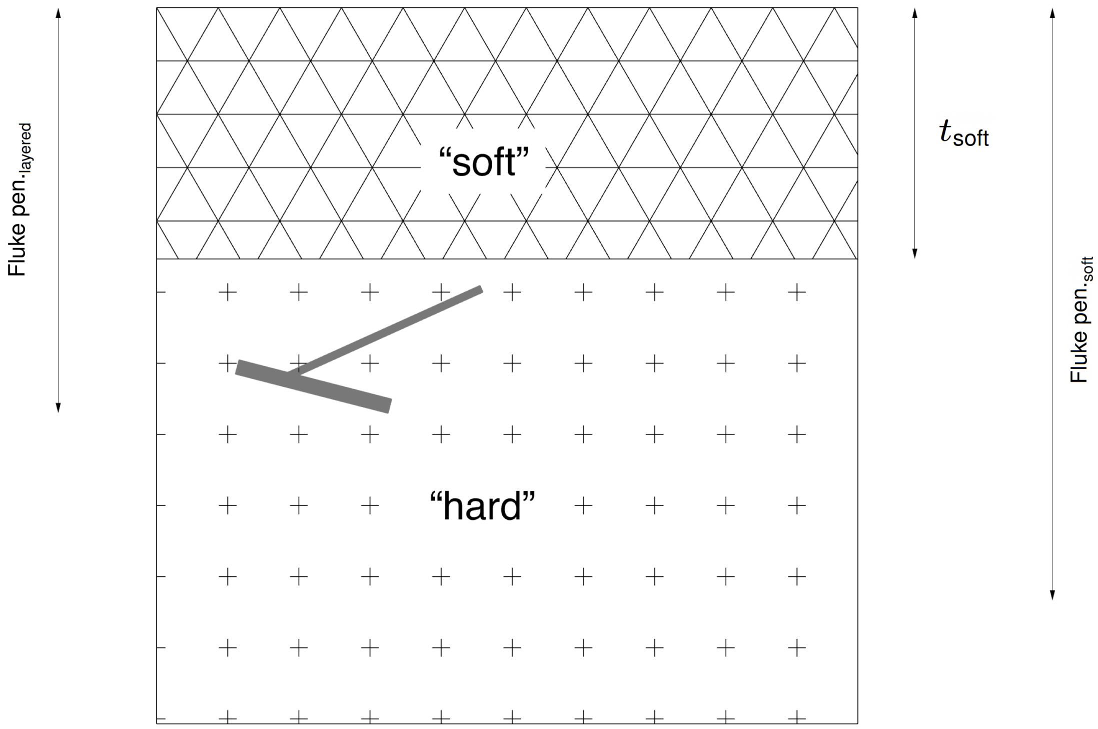


Figure B.3: Two-layered soil anchor penetration calculation schematic.

Ultimate holding capacity (UHC) is based on soil type, (UHC in kN and penetration in metres) and calculated using Equation B.5.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{B.5}$$

Figures B.4 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on figure B.5.

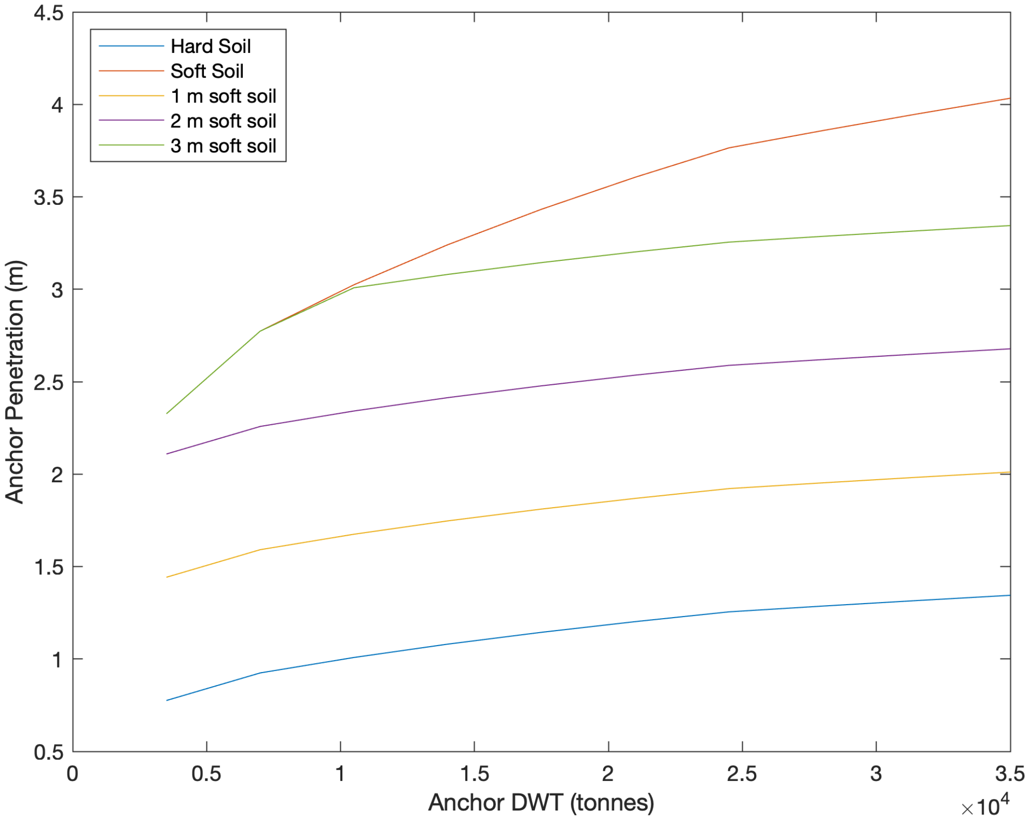


Figure B.4: Anchor penetration for various thicknesses of soft soil.

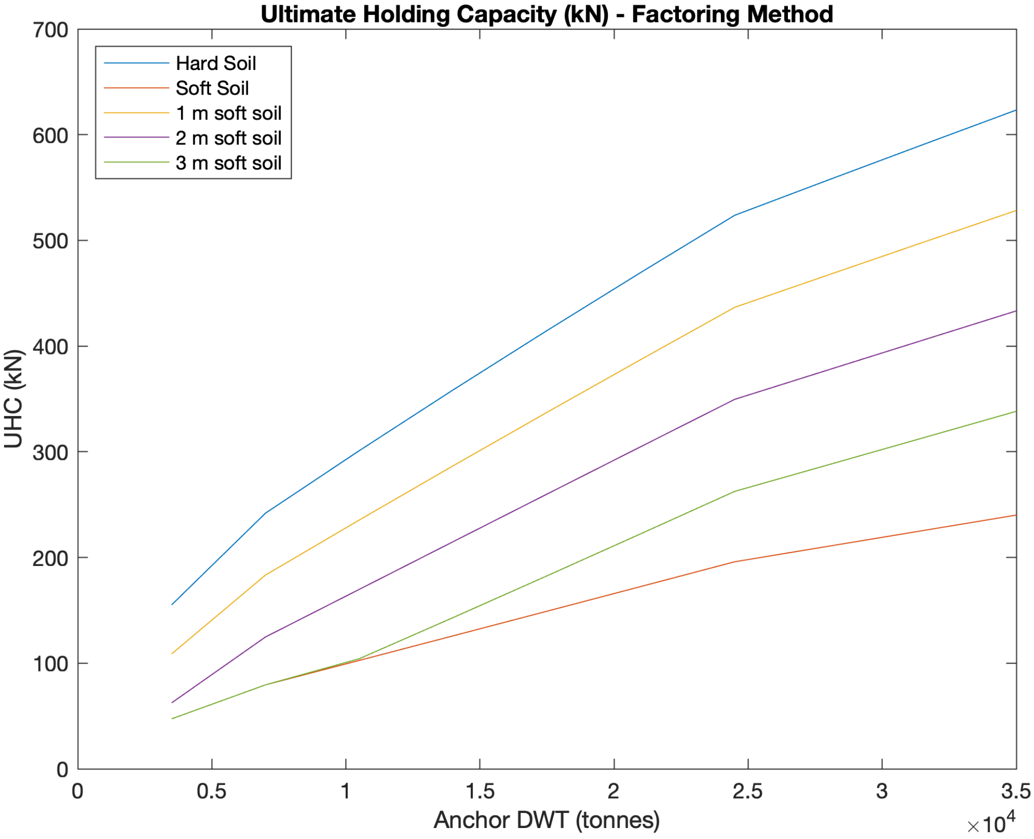


Figure B.5: UHC for various thicknesses of soft soil.

Table B.3 shows the ship model used.

D_{ship}, the estimate of distance an anchor is dragged, is calculated using Equation B.6 (ref [31]), D_{ship} in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{Disp \times 0.51444(v_{ship})^2}{4UHC} \tag{B.6}$$

Table B.3: Ship model.

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-2	4.0	1.0	0.9	0.0100	34.93	118.19
2	2-5	4.0	1.0	0.9	0.0100	46.28	146.13
3	5-8	4.0	1.0	0.9	0.0100	54.56	165.44
4	8-10	4.0	1.0	0.9	0.0100	61.32	180.67
5	10-12	4.0	1.0	0.9	0.0100	67.13	193.44
6	12-15	4.0	1.0	0.9	0.0100	72.29	204.54

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
7	15-18	4.0	1.0	0.9	0.0100	76.96	214.43
8	18-20	4.0	1.0	0.9	0.0100	81.24	223.37
9	20-22	4.0	1.0	0.9	0.0100	85.22	231.57
10	22-25	4.0	1.0	0.9	0.0100	88.95	239.16

B.1.4. Probabilistic anchor strike assessment for surface lay

Table B.4 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in section B.1.9. The highest risk (per km) cables are:

- ECCNorthLandfall, NorthKP12toKP18, RPhard 183946 yr/km, RPsoft 54442 yr/km
- ECCNorthLandfall, NorthKP01toKP03, RPhard 851983 yr/km, RPsoft 261620 yr/km
- ECCNorthLandfall, NorthKP19toKP22, RPhard 994379 yr/km, RPsoft 293852 yr/km
- ECCNorthLandfall, NorthKP06toKP09, RPhard 1144687 yr/km, RPsoft 339744 yr/km
- ECCNorthLandfall, NorthKP09toKP11, RPhard 1433620 yr/km, RPsoft 424685 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [7]), D$_{ship}$ in m, v$_{ship}$ in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \tag{B.7}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is (P$_{s.n}$ is the P$_{strike}$ of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \tag{B.8}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table B.4: Surface lay probabilistic assessment.

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCNorthLandfall	NorthKP00toKP01	6629196 yr, 6629196 yr/km	1961803 yr, 1961803 yr/km	10
ECCNorthLandfall	NorthKP01toKP03	1703967 yr, 851983 yr/km	523240 yr, 261620 yr/km	2
ECCNorthLandfall	NorthKP03toKP04	3434565 yr, 3434565 yr/km	1054102 yr, 1054102 yr/km	8
ECCNorthLandfall	NorthKP04toKP06	6108520 yr, 3054259 yr/km	1813463 yr, 906731 yr/km	7
ECCNorthLandfall	NorthKP06toKP09	3434060 yr, 1144687 yr/km	1019232 yr, 339744 yr/km	4
ECCNorthLandfall	NorthKP09toKP11	2867241 yr, 1433620 yr/km	849371 yr, 424685 yr/km	5
ECCNorthLandfall	NorthKP11toKP12	6280433 yr, 6280433 yr/km	1862498 yr, 1862498 yr/km	9

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCNorthLandfall	NorthKP12toKP18	1103674 yr, 183946 yr/km	326654 yr, 54442 yr/km	1
ECCNorthLandfall	NorthKP18toKP19	8885257 yr, 8885255 yr/km	2625710 yr, 2625709 yr/km	11
ECCNorthLandfall	NorthKP19toKP22	2983137 yr, 994379 yr/km	881556 yr, 293852 yr/km	3
ECCNorthLandfall	NorthKP22toEnd	3861350 yr, 2168016 yr/km	1141079 yr, 640677 yr/km	6

B.1.5. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table B.2 is less than the depth considered. Table **??** shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section B.1.10 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

B.1.6. Results for one-layered soil

Table **??** shows the recommended burial depths for target return period.

Table B.5: Burial depths to achieve target frequencies

Cable	Section	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCNorthLandfall	NorthKP00toKP01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP01toKP03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP03toKP04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP04toKP06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP06toKP09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP09toKP11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP11toKP12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP12toKP18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP18toKP19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP19toKP22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP22toEnd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.6 shows the total anchor strike risk over the total length of the surface laid cable.

Table B.6: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Soft soil return period	Rank
ECCNorthLandfall	277426 yr	82855 yr	1

Table B.7 shows the required burial depths to achieve certain target frequencies

Table B.7: Burial depths to achieve target frequencies, total cable.

Cable	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCNorthLandfall	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2

Section B.1.12 shows the anchor strike frequency for buried cables assessed over the total length, with zero frequency taken as 10^{-10} for plotting purposes.

B.1.7. Results for two-layered soil

Table B.8 shows calculated return periods for each cable for the two-layered soil approach.

Table B.8: Two-layered soil model summary.

Cable	Section	Soft soil thickness (m)	Return period	Return period per km
ECCNorthLandfall	NorthKP00toKP01	0.6	5337462 yr	5337462 yr/km
ECCNorthLandfall	NorthKP01toKP03	0.2	1603829 yr	801914 yr/km
ECCNorthLandfall	NorthKP03toKP04	0	3434565 yr	3434565 yr/km
ECCNorthLandfall	NorthKP04toKP06	5	1813463 yr	906731 yr/km
ECCNorthLandfall	NorthKP06toKP09	1.1	2214894 yr	738298 yr/km
ECCNorthLandfall	NorthKP09toKP11	0	2867241 yr	1433620 yr/km
ECCNorthLandfall	NorthKP11toKP12	4.9	1862498 yr	1862498 yr/km
ECCNorthLandfall	NorthKP12toKP18	0	1103674 yr	183946 yr/km
ECCNorthLandfall	NorthKP18toKP19	4.9	2625710 yr	2625709 yr/km
ECCNorthLandfall	NorthKP19toKP22	0	2983137 yr	994379 yr/km
ECCNorthLandfall	NorthKP22toEnd	4.8	1141079 yr	640677 yr/km

Table B.9 shows the required burial depth to achieve the target return frequency using the two-layered soil model. Target frequencies are the same as defined in section C.2.5.

Table B.9: Burial depths to achieve target frequencies.

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
ECCNorthLandfall	NorthKP00toKP01	0.6	0.0	0.0	0.0	0.0

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
ECCNorthLandfall	NorthKP01toKP03	0.2	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP03toKP04	0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP04toKP06	5	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP06toKP09	1.1	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP09toKP11	0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP11toKP12	4.9	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP12toKP18	0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP18toKP19	4.9	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP19toKP22	0	0.0	0.0	0.0	0.0
ECCNorthLandfall	NorthKP22toEnd	4.8	0.0	0.0	0.0	0.0

Table B.10 shows the total anchor strike risk over the total length of the surface laid cable for the two-layered soil approach.

Table B.10: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Two-Layered soil return period	Soft soil return period	Rank
ECCNorthLandfall	277426 yr	182179 yr	82855 yr	1

Table B.11 shows the required burial depths to achieve certain target frequencies for the total cable length using the two-layered soil approach for each soft soil thickness.

Table B.11: Burial depths to achieve target frequencies, total cable.

Cable	Soft Soil Thickness	Cable length (km)	Two-Layered Soil, 1.0e-02	Two-Layered Soil, 1.0e-03	Two-Layered Soil, 1.0e-04	Two-Layered Soil, 1.0e-05
ECCNorthLandfall	0.0	12.00	0.0	0.0	0.0	0.0
ECCNorthLandfall	0.2	2.00	0.0	0.0	0.0	0.0
ECCNorthLandfall	0.6	1.00	0.0	0.0	0.0	0.0
ECCNorthLandfall	1.1	3.00	0.0	0.0	0.0	0.0
ECCNorthLandfall	4.8	1.78	0.0	0.0	0.0	0.0
ECCNorthLandfall	4.9	2.00	0.0	0.0	0.0	0.0
ECCNorthLandfall	5.0	2.00	0.0	0.0	0.0	0.0

B.1.8. Vessel movement maps

Figure B.6: Vessel movement,Cable ECCNorthLandfall, NorthKP00toKP01.

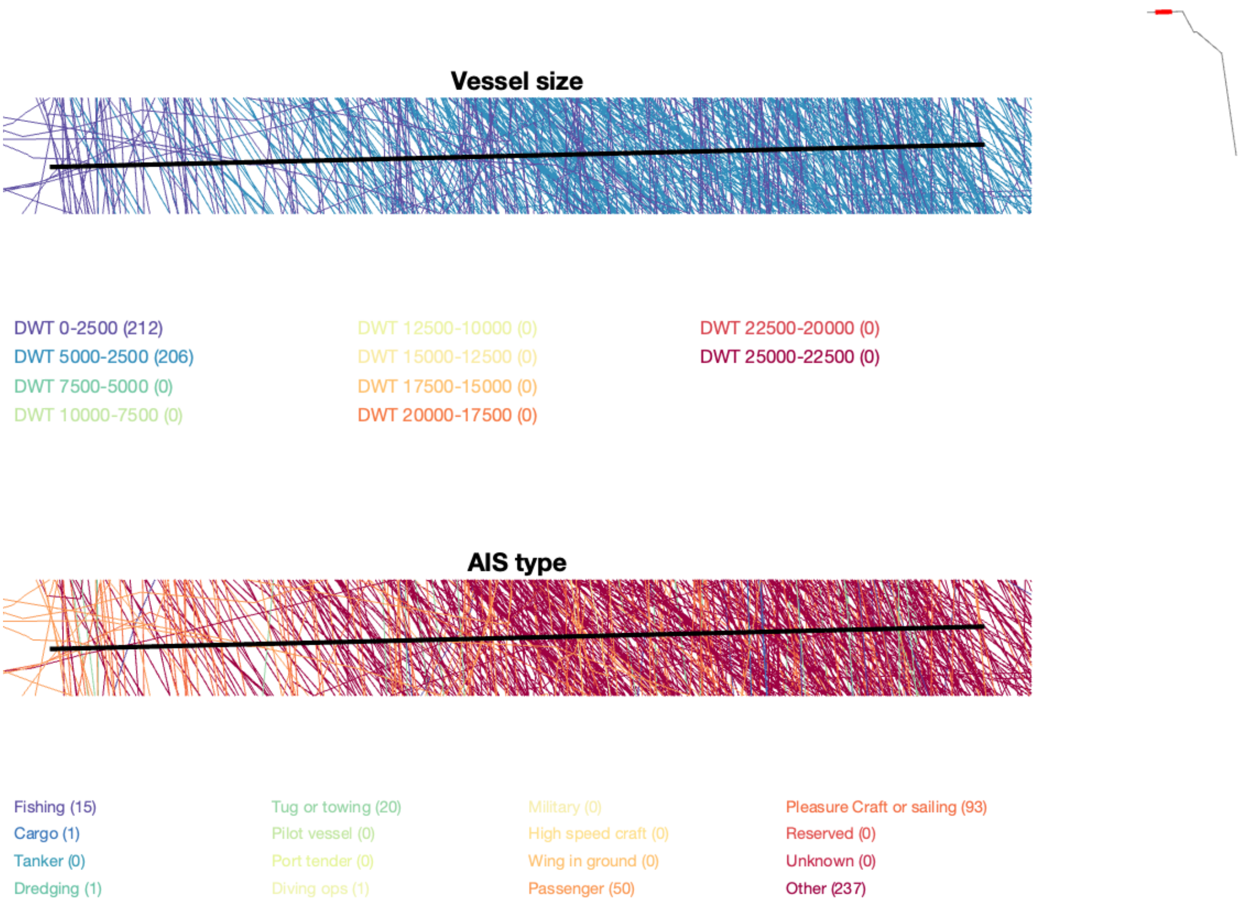


Figure B.7: Vessel movement,Cable ECCNorthLandfall, NorthKP01toKP03.

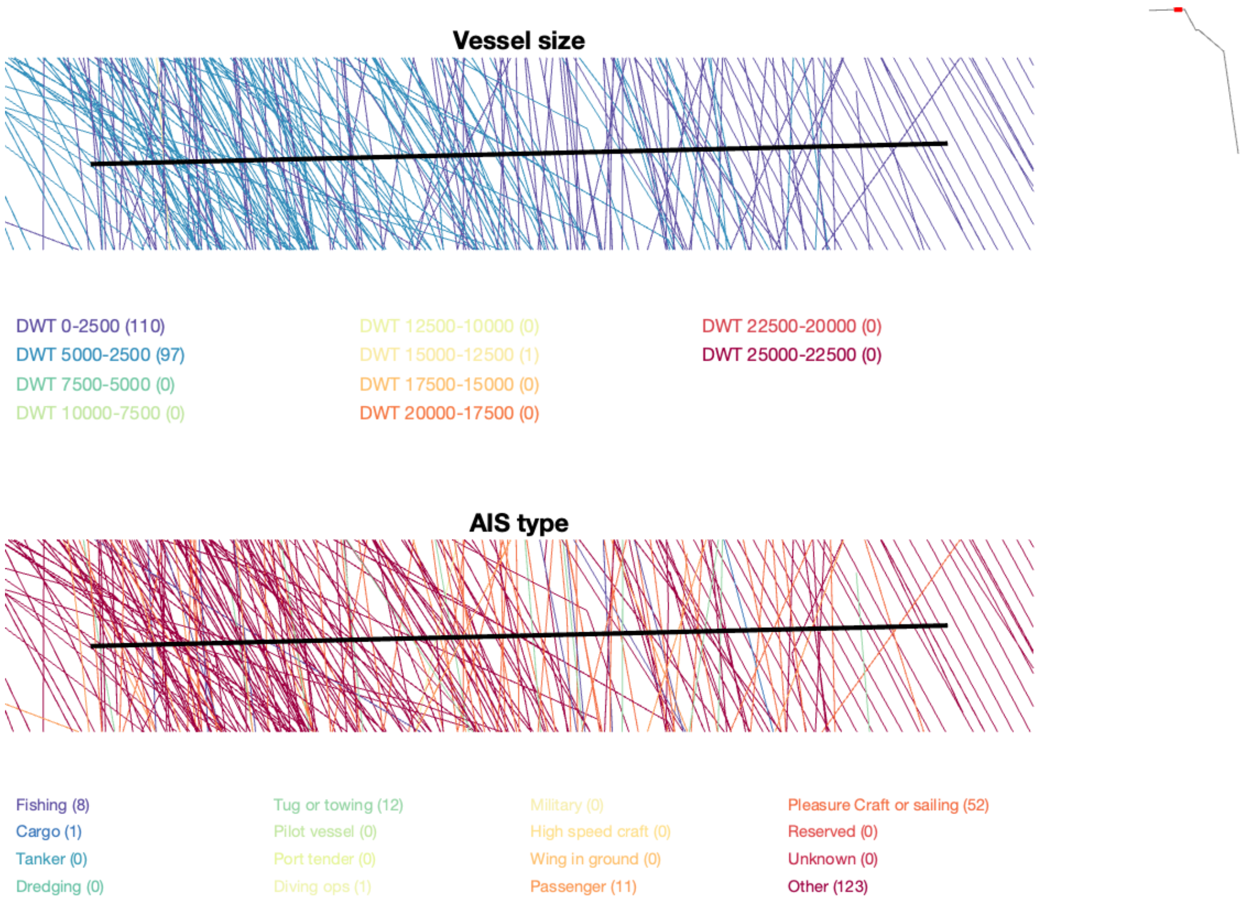


Figure B.8: Vessel movement,Cable ECCNorthLandfall, NorthKP03toKP04.

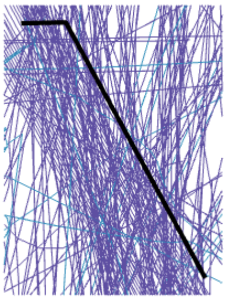
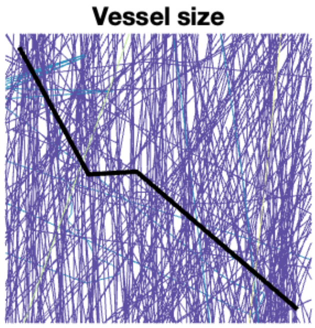


Figure B.9: Vessel movement,Cable ECCNorthLandfall, NorthKP04toKP06.



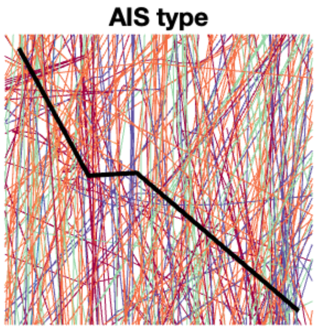
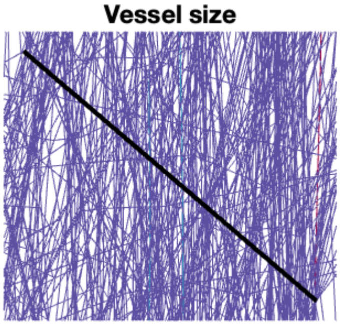


Figure B.10: Vessel movement,Cable ECCNorthLandfall, NorthKP06toKP09.



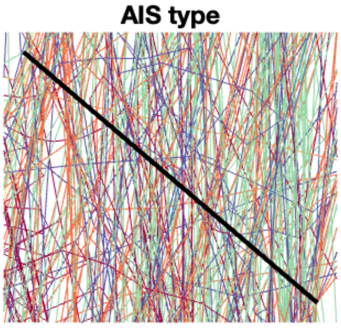
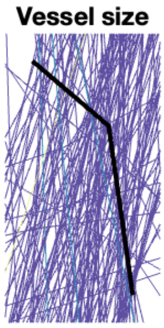


Figure B.11: Vessel movement,Cable ECCNorthLandfall, NorthKP09toKP11.



DWT 0-2500 (127)
DWT 5000-2500 (2)
DWT 7500-5000 (0)
DWT 10000-7500 (0)
DWT 12500-10000 (1)
DWT 15000-12500 (0)
DWT 17500-15000 (0)
DWT 20000-17500 (0)
DWT 22500-20000 (0)
DWT 25000-22500 (0)

Fishing (17)
Cargo (0)
Tanker (0)
Dredging (0)
Tug or towing (37)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (4)
Pleasure Craft or sailing (59)
Reserved (0)
Unknown (1)
Other (12)

Figure B.12: Vessel movement,Cable ECCNorthLandfall, NorthKP11toKP12.

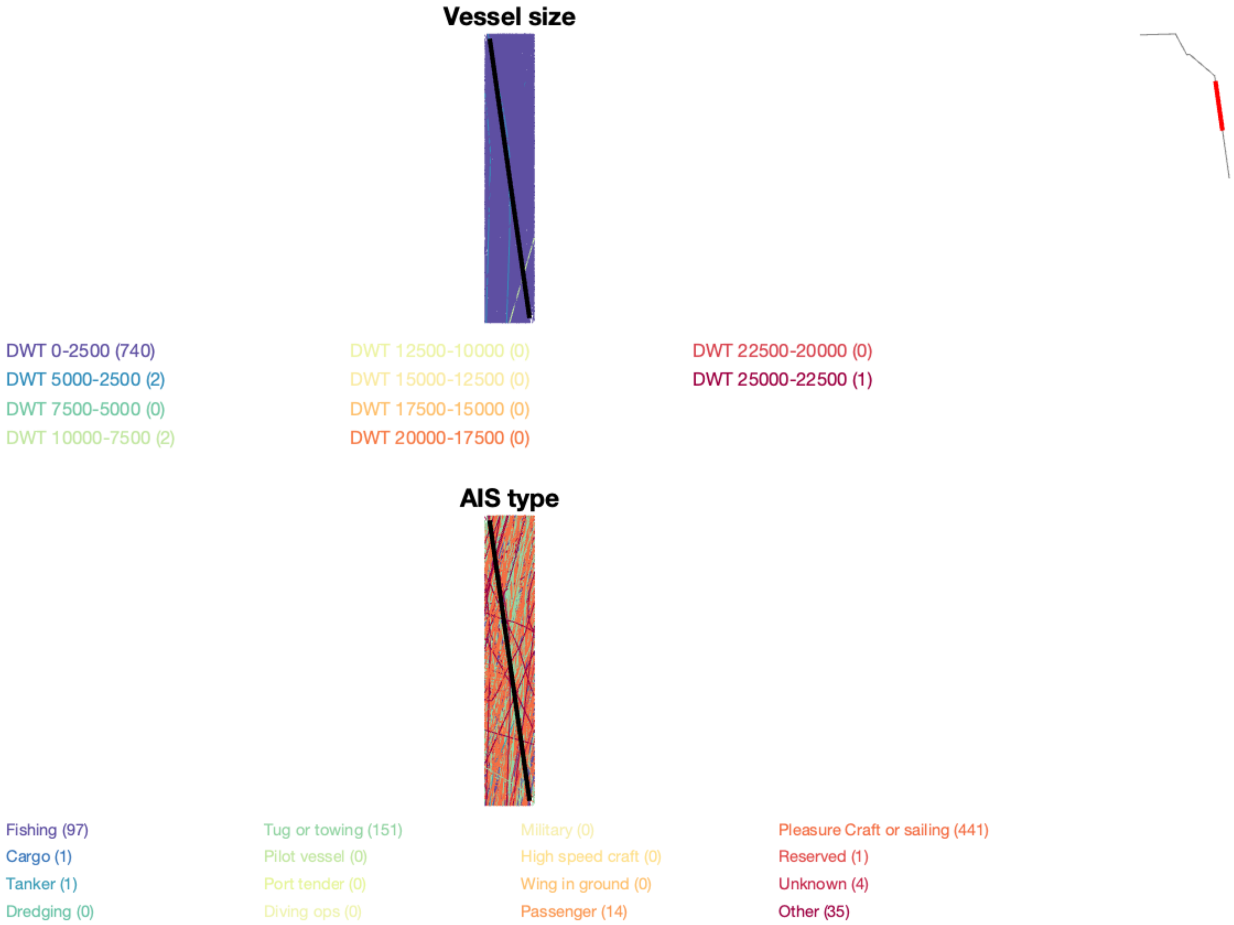


Figure B.13: Vessel movement,Cable ECCNorthLandfall, NorthKP12toKP18.

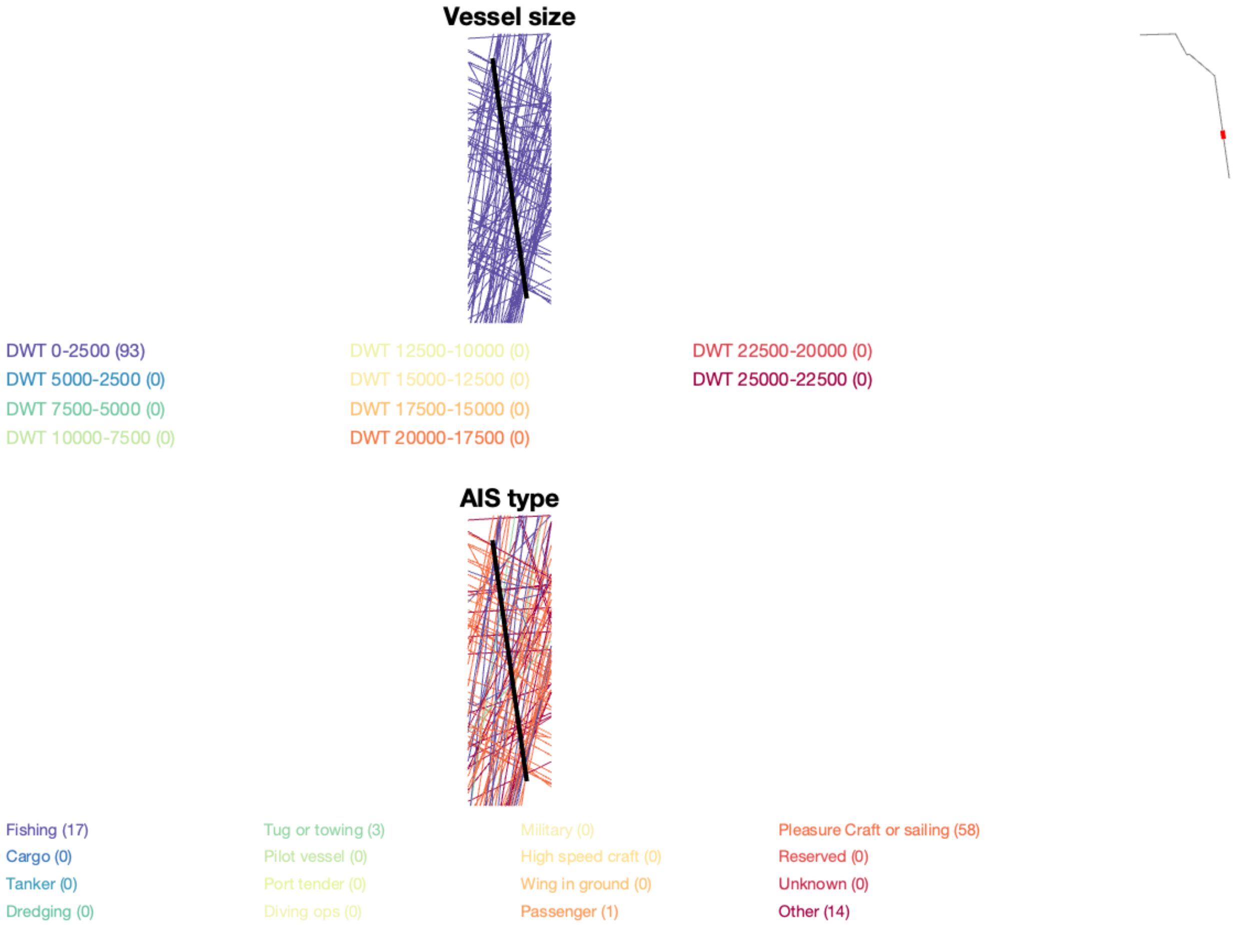


Figure B.14: Vessel movement,Cable ECCNorthLandfall, NorthKP18toKP19.

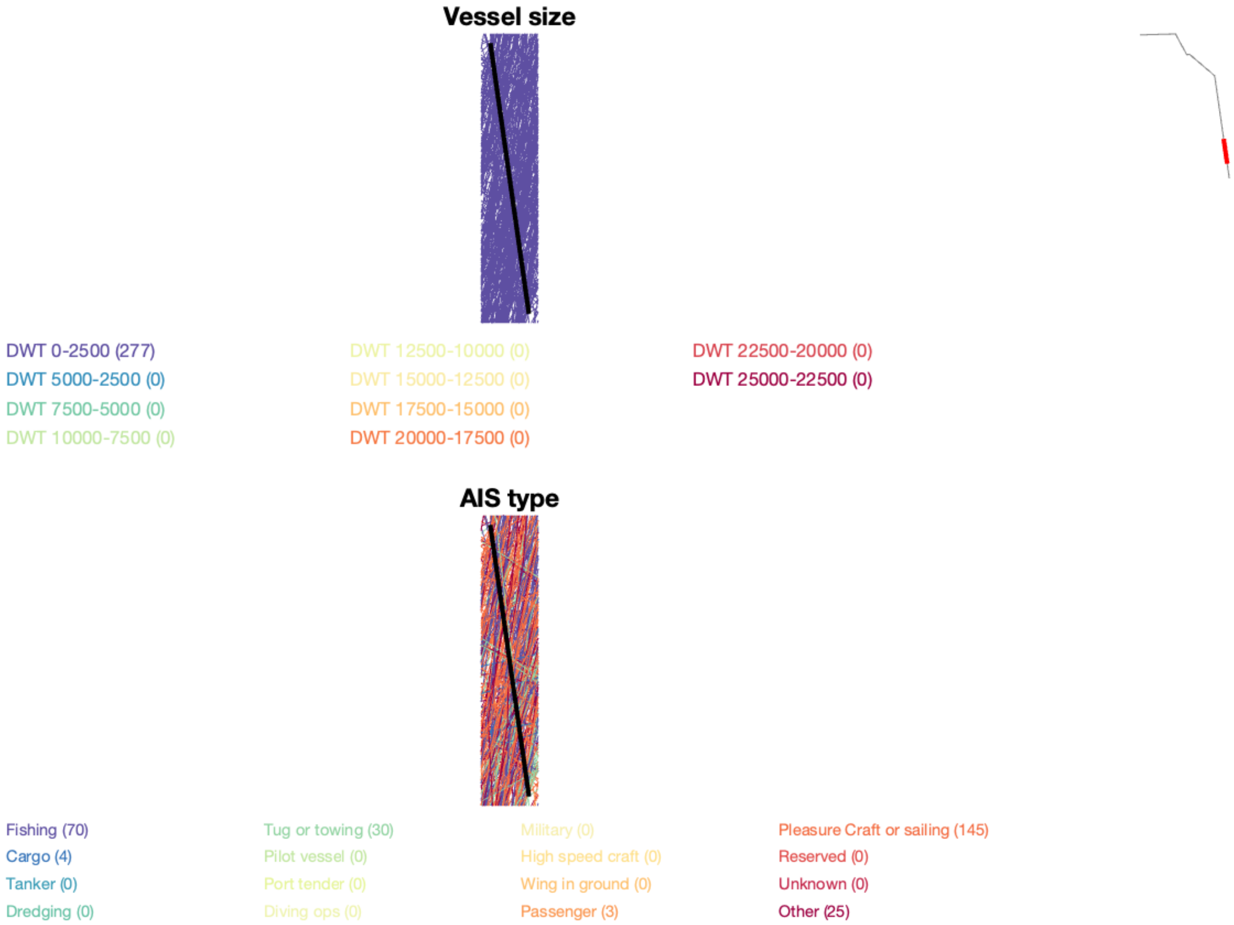


Figure B.15: Vessel movement,Cable ECCNorthLandfall, NorthKP19toKP22.

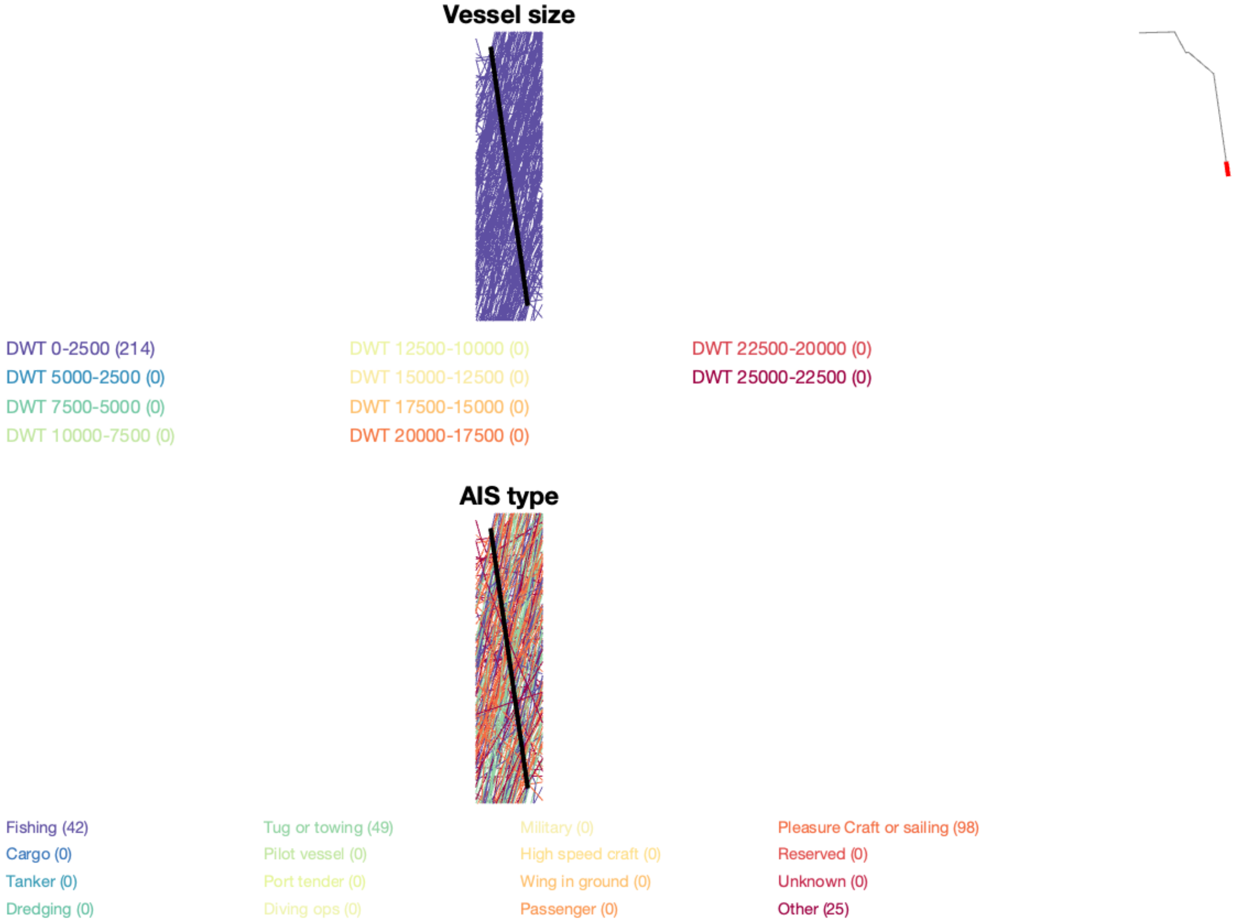


Figure B.16: Vessel movement,Cable ECCNorthLandfall, NorthKP22toEnd.

B.1.9. Full anchor strike assessment for surface lay

Table B.12 shows the results if cable is surface-laid.

Table B.12: Surface lay probabilistic assessment (full results)

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCNorthLandfall	NorthKP00toKP01	1 2 3 4 5 6 7 8 9 10	122 2 0 0 0 0 0 0 0 0	1.48e-07 3.21e-09 0 0 0 0 0 0 0 0	5.00e-07 1.01e-08 0 0 0 0 0 0 0 0	1.51e-07 6629196 yr 6629196 yr/km	5.10e-07 1961803 yr 1961803 yr/km
ECCNorthLandfall	NorthKP01toKP03	1 2 3 4 5 6 7 8 9 10	212 206 0 0 0 0 0 0 0 0	2.57e-07 3.30e-07 0 0 0 0 0 0 0 0	8.68e-07 1.04e-06 0 0 0 0 0 0 0 0	5.87e-07 1703967 yr 851983 yr/km	1.91e-06 523240 yr 261620 yr/km
ECCNorthLandfall	NorthKP03toKP04	1 2 3 4 5 6 7 8 9 10	110 97 0 0 0 1 0 0 0 0	1.33e-07 1.56e-07 0 0 0 2.50e-09 0 0 0 0	4.50e-07 4.91e-07 0 0 0 7.09e-09 0 0 0 0	2.91e-07 3434565 yr 3434565 yr/km	9.49e-07 1054102 yr 1054102 yr/km
ECCNorthLandfall	NorthKP04toKP06	1 2 3 4 5 6 7 8 9 10	126 7 0 0 0 0 0 0 0 0	1.52e-07 1.12e-08 0 0 0 0 0 0 0 0	5.16e-07 3.54e-08 0 0 0 0 0 0 0 0	1.64e-07 6108520 yr 3054259 yr/km	5.51e-07 1813463 yr 906731 yr/km

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	<u>Hard soil</u> Total Pstrike (-) Return period (yr) Return period (yr/km)	<u>Soft soil</u> Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCNorthLandfall	NorthKP06toKP09	1 2 3 4 5 6 7 8 9 10	229 6 0 1 1 0 0 0 0 0	2.77e-07 9.62e-09 0 2.12e-09 2.33e-09 0 0 0 0 0	9.38e-07 3.04e-08 0 6.26e-09 6.70e-09 0 0 0 0 0	2.91e-07 3434060 yr 1144687 yr/km	9.81e-07 1019232 yr 339744 yr/km
ECCNorthLandfall	NorthKP09toKP11	1 2 3 4 5 6 7 8 9 10	283 2 0 0 0 0 0 0 0 1	3.42e-07 3.21e-09 0 0 0 0 0 0 0 3.08e-09	1.16e-06 1.01e-08 0 0 0 0 0 0 0 8.29e-09	3.49e-07 2867241 yr 1433620 yr/km	1.18e-06 849371 yr 424685 yr/km
ECCNorthLandfall	NorthKP11toKP12	1 2 3 4 5 6 7 8 9 10	127 2 0 0 1 0 0 0 0 0	1.54e-07 3.21e-09 0 0 2.33e-09 0 0 0 0 0	5.20e-07 1.01e-08 0 0 6.70e-09 0 0 0 0 0	1.59e-07 6280433 yr 6280433 yr/km	5.37e-07 1862498 yr 1862498 yr/km
ECCNorthLandfall	NorthKP12toKP18	1 2 3 4 5 6 7 8 9 10	740 2 0 2 0 0 0 0 0 1	8.96e-07 3.21e-09 0 4.25e-09 0 0 0 0 0 3.08e-09	3.03e-06 1.01e-08 0 1.25e-08 0 0 0 0 0 8.29e-09	9.06e-07 1103674 yr 183946 yr/km	3.06e-06 326654 yr 54442 yr/km
ECCNorthLandfall	NorthKP18toKP19	1 2 3 4 5 6 7 8 9 10	93 0 0 0 0 0 0 0 0 0	1.13e-07 0 0 0 0 0 0 0 0 0	3.81e-07 0 0 0 0 0 0 0 0 0	1.13e-07 8885257 yr 8885255 yr/km	3.81e-07 2625710 yr 2625709 yr/km

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCNorthLandfall	NorthKP19toKP22	1 2 3 4 5 6 7 8 9 10	277 0 0 0 0 0 0 0 0 0	3.35e-07 0 0 0 0 0 0 0 0 0	1.13e-06 0 0 0 0 0 0 0 0 0	3.35e-07 2983137 yr 994379 yr/km	1.13e-06 881556 yr 293852 yr/km
ECCNorthLandfall	NorthKP22toEnd	1 2 3 4 5 6 7 8 9 10	214 0 0 0 0 0 0 0 0 0	2.59e-07 0 0 0 0 0 0 0 0 0	8.76e-07 0 0 0 0 0 0 0 0 0	2.59e-07 3861350 yr 2168016 yr/km	8.76e-07 1141079 yr 640677 yr/km

B.1.10. Anchor strike probability graphs for buried cables

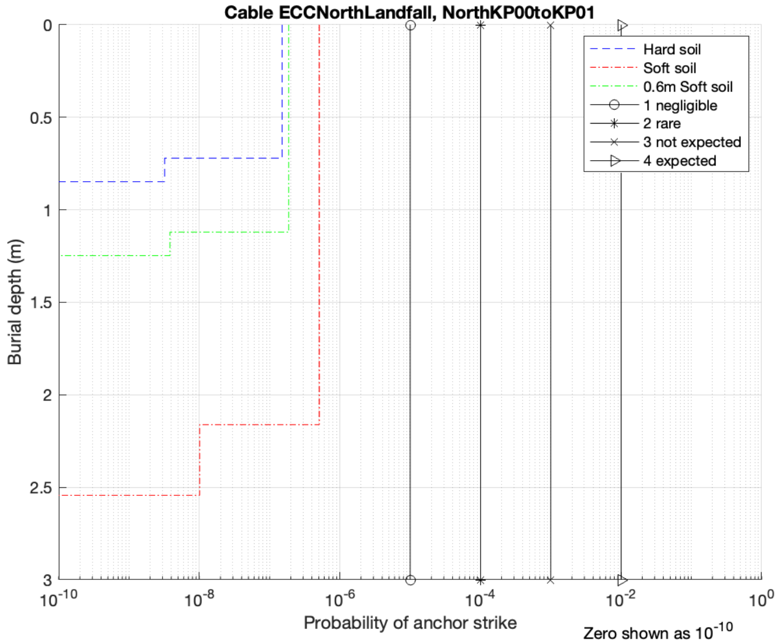


Figure B.17: Anchor strike risk vs burial depth, NorthKP00toKP01.

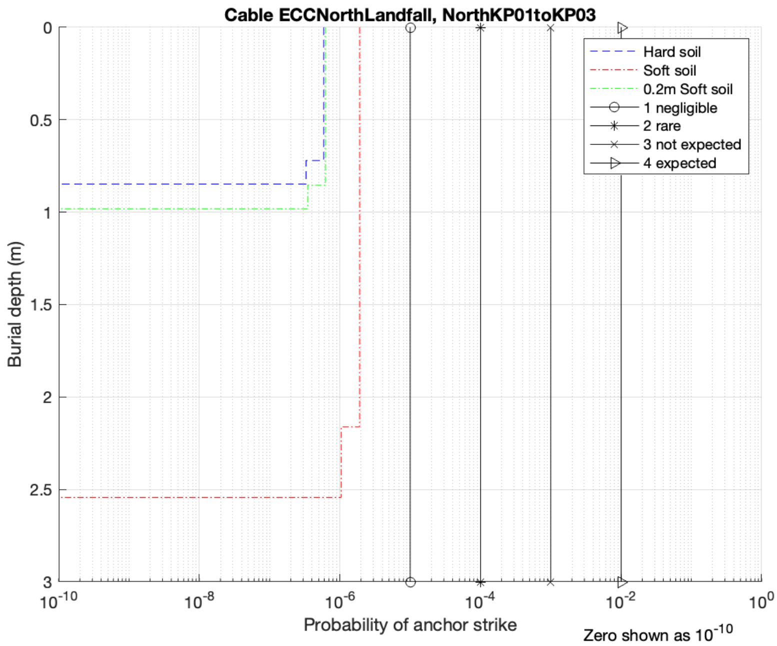


Figure B.18: Anchor strike risk vs burial depth, NorthKP01toKP03.

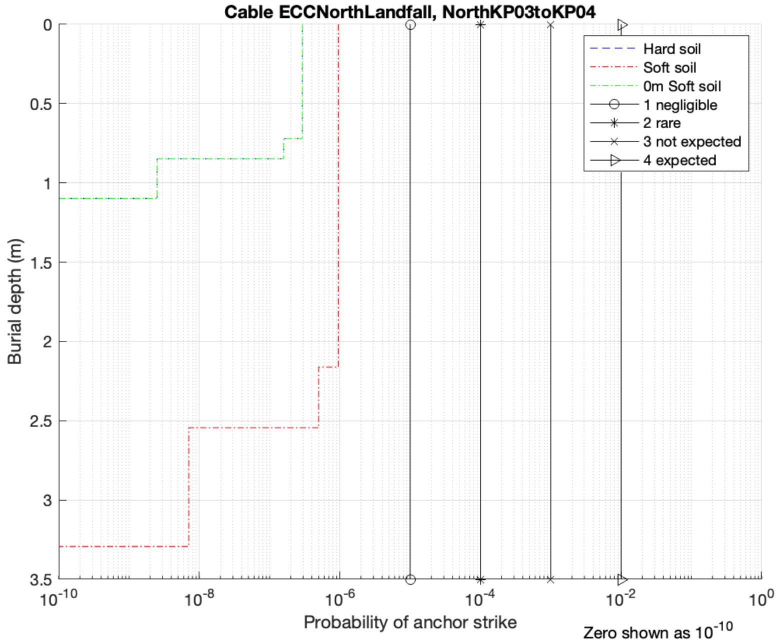


Figure B.19: Anchor strike risk vs burial depth, NorthKP03toKP04.

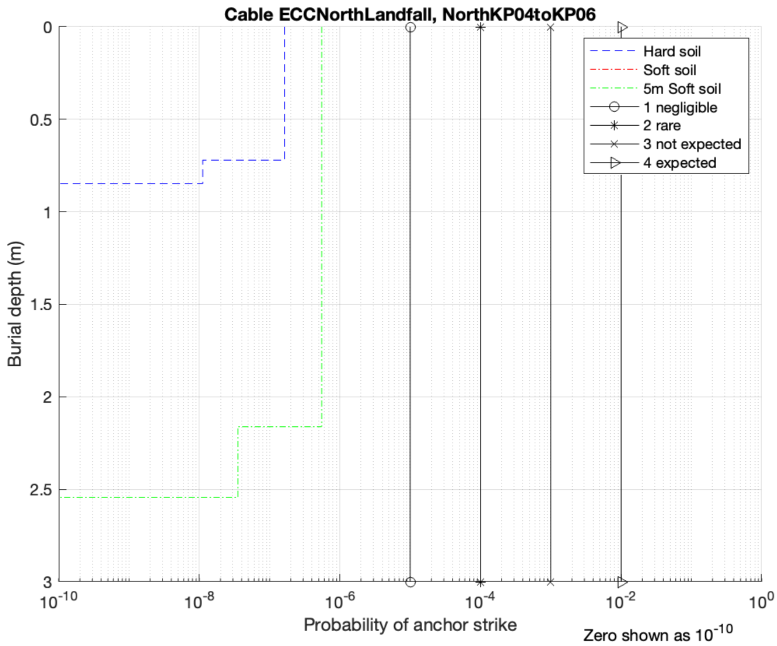


Figure B.20: Anchor strike risk vs burial depth, NorthKP04toKP06.

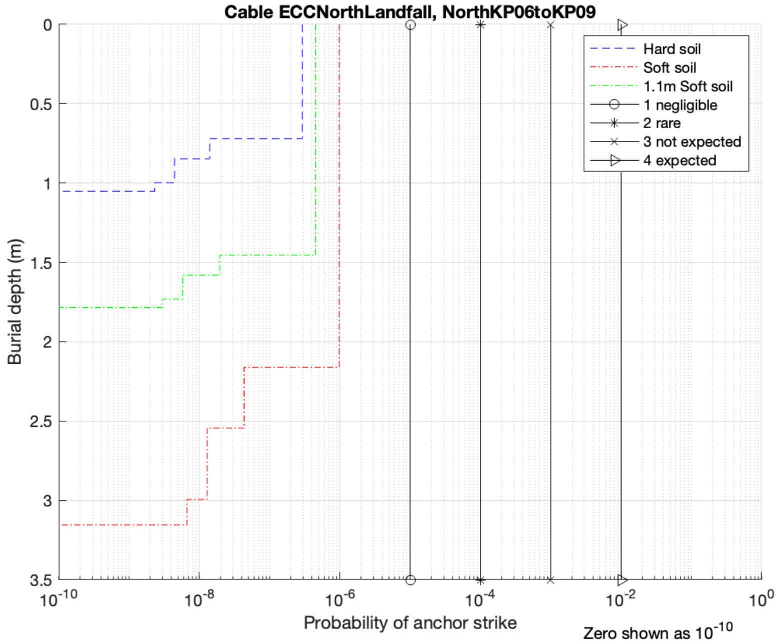


Figure B.21: Anchor strike risk vs burial depth, NorthKP06toKP09.

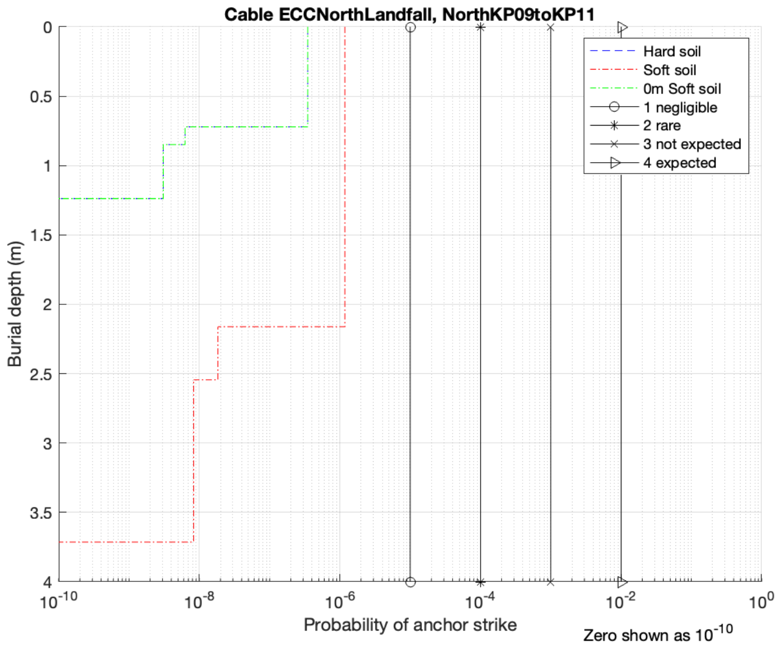


Figure B.22: Anchor strike risk vs burial depth, NorthKP09toKP11.

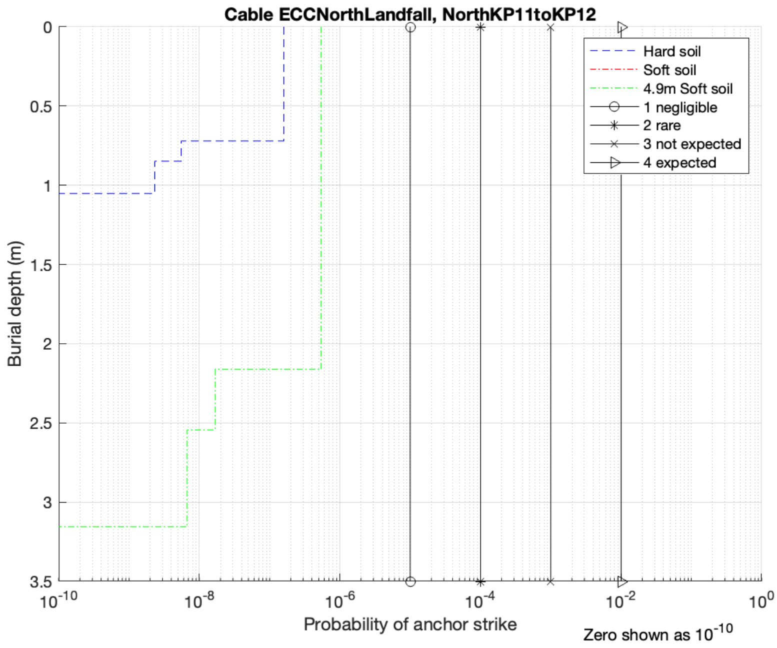


Figure B.23: Anchor strike risk vs burial depth, NorthKP11toKP12.

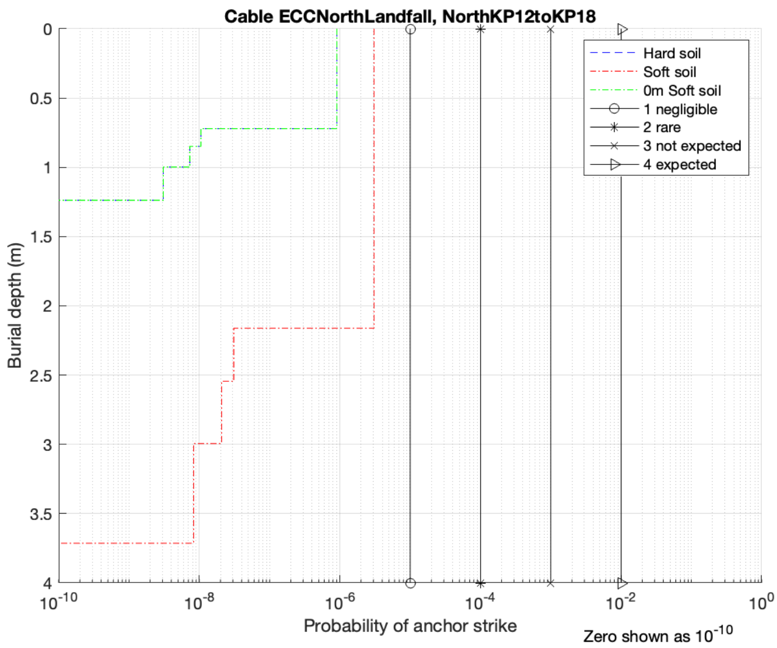


Figure B.24: Anchor strike risk vs burial depth, NorthKP12toKP18.

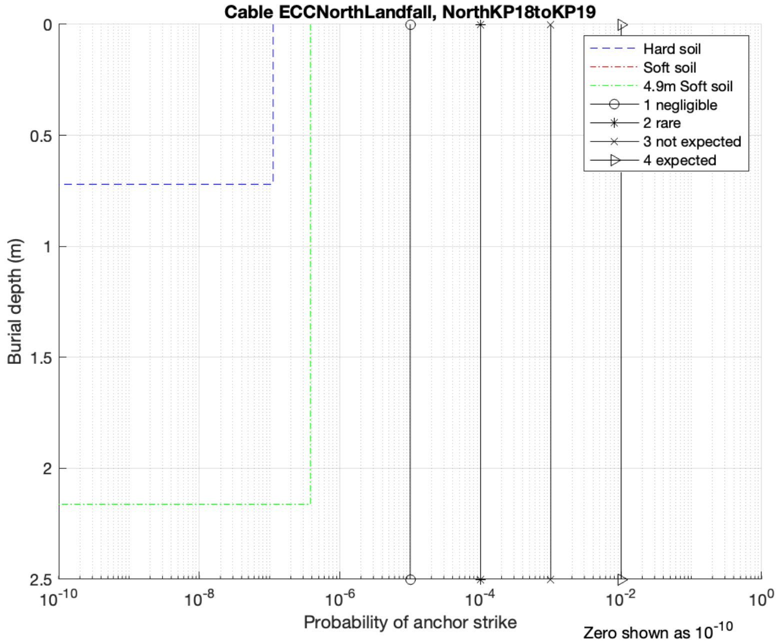


Figure B.25: Anchor strike risk vs burial depth, NorthKP18toKP19.

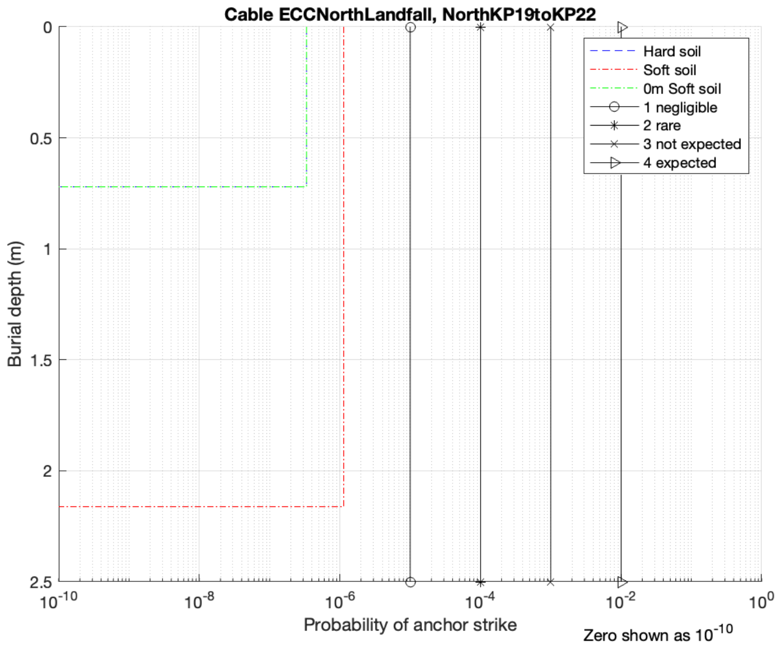


Figure B.26: Anchor strike risk vs burial depth, NorthKP19toKP22.

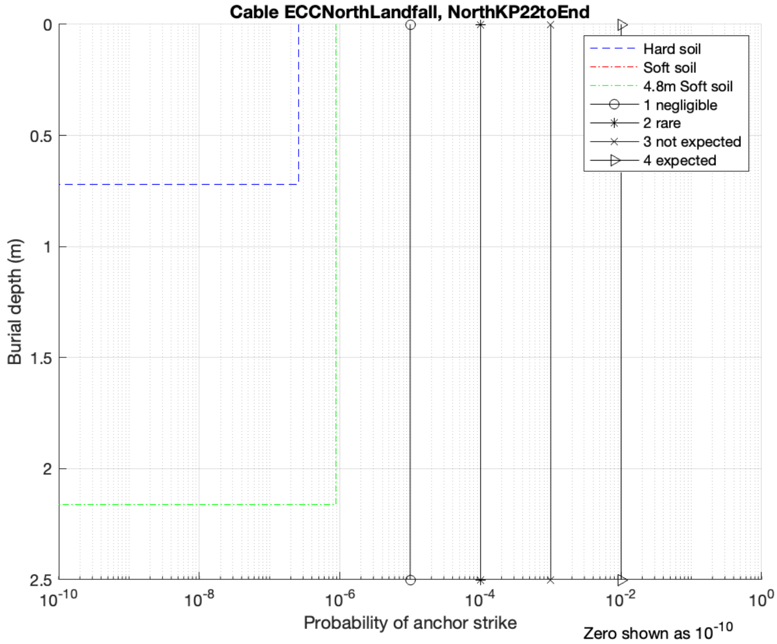


Figure B.27: Anchor strike risk vs burial depth, NorthKP22toEnd.

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B.1.11. Anchor strike probability tables for buried cables, by section

Table B.13: RP for burial depths, layered soil, table 1 of 3.

Depth (m)	NorthKP00toKP01	NorthKP01toKP03	NorthKP03toKP04	NorthKP04toKP06	NorthKP06toKP09
0.00	5337462	1603829	3434565	1813463	2214894
0.25	5337462	1603829	3434565	1813463	2214894
0.50	5337462	1603829	3434565	1813463	2214894
0.75	5337462	1603829	6327560	1813463	2214894
1.00	5337462	Inf	399257038	1813463	2214894
1.25	Inf	Inf	Inf	1813463	2214894
1.50	Inf	Inf	Inf	1813463	51354864
1.75	Inf	Inf	Inf	1813463	332058116
2.00	Inf	Inf	Inf	1813463	Inf
2.25	Inf	Inf	Inf	28215358	Inf
2.50	Inf	Inf	Inf	28215358	Inf
2.75	Inf	Inf	Inf	Inf	Inf
3.00	Inf	Inf	Inf	Inf	Inf
3.25	Inf	Inf	Inf	Inf	Inf
3.50	Inf	Inf	Inf	Inf	Inf
3.75	Inf	Inf	Inf	Inf	Inf

Table B.14: RP for burial depths, layered soil, table 2 of 3.

Depth (m)	NorthKP09toKP11	NorthKP11toKP12	NorthKP12toKP18	NorthKP18toKP19	NorthKP19toKP22
0.00	2867241	1862498	1103674	2625710	2983137
0.25	2867241	1862498	1103674	2625710	2983137
0.50	2867241	1862498	1103674	2625710	2983137
0.75	159014692	1862498	94896754	2625710	Inf
1.00	324481735	1862498	324481735	2625710	Inf
1.25	Inf	1862498	Inf	2625710	Inf
1.50	Inf	1862498	Inf	2625710	Inf
1.75	Inf	1862498	Inf	2625710	Inf
2.00	Inf	1862498	Inf	2625710	Inf
2.25	Inf	59422850	Inf	Inf	Inf
2.50	Inf	59422850	Inf	Inf	Inf
2.75	Inf	149201486	Inf	Inf	Inf
3.00	Inf	149201486	Inf	Inf	Inf
3.25	Inf	Inf	Inf	Inf	Inf
3.50	Inf	Inf	Inf	Inf	Inf

Depth (m)	NorthKP09toKP11	NorthKP11toKP12	NorthKP12toKP18	NorthKP18toKP19	NorthKP19toKP22
3.75	Inf	Inf	Inf	Inf	Inf

Table B.15: RP for burial depths, layered soil, table 3 of 3.

Depth (m)	NorthKP22toEnd
0.00	1141079
0.25	1141079
0.50	1141079
0.75	1141079
1.00	1141079
1.25	1141079
1.50	1141079
1.75	1141079
2.00	1141079
2.25	Inf
2.50	Inf
2.75	Inf
3.00	Inf
3.25	Inf
3.50	Inf
3.75	Inf

B.1.12. Anchor strike probability graphs for buried cables, total cable length

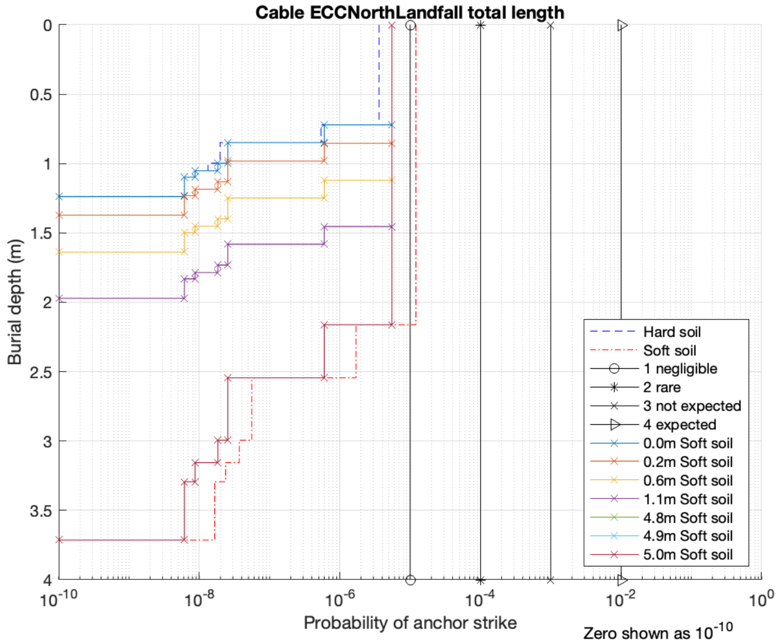


Figure B.28: Anchor strike risk vs burial depth, Cable ECCNorthLandfall

B.1.13. Anchor strike probability tables for buried cables, entire length

Table B.16: RP for burial depths, total cable length, ECCNorthLandfall

Depth (m)	Layered soil
0.00	182179
0.25	182179
0.50	182179
0.75	182179
1.00	182179
1.25	182179
1.50	182179
1.75	182179
2.00	182179
2.25	1668078
2.50	1668078
2.75	39313326
3.00	54400469
3.25	115362511
3.50	162240868
3.75	Inf

B.2. CBRA probability reports - Cable ECC1 KP0 to KP13

B.2.1. Cable layout overview

An overview of the cable layout and sections analysed is shown in figure B.29.

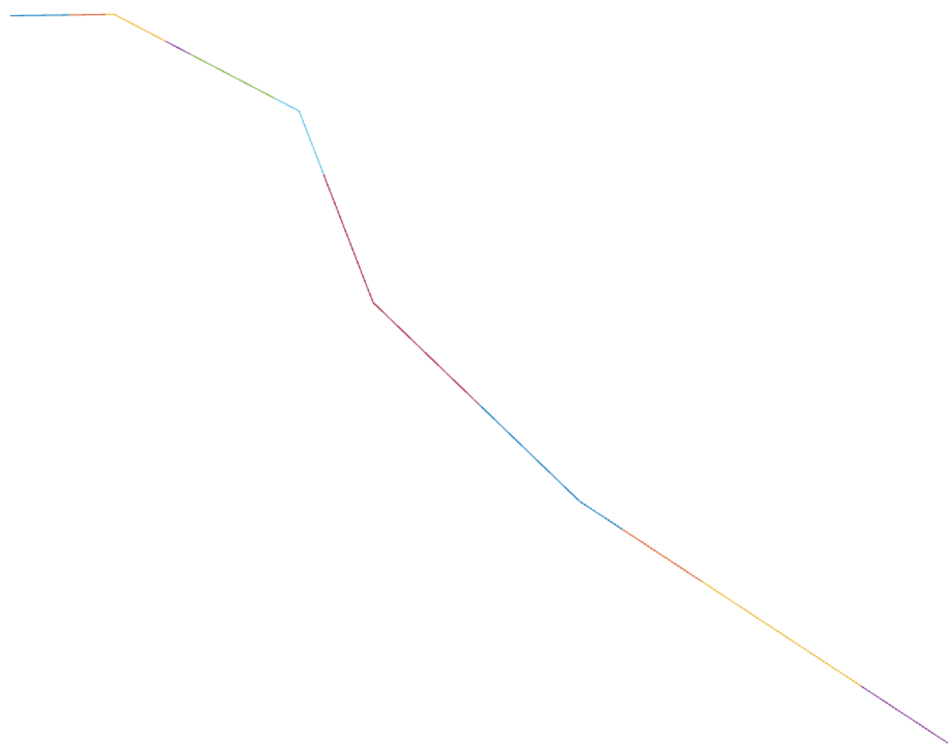


Figure B.29: Overview of cable layout and sections analysed.

B.2.2. Vessel movement

Vessel movement has been assessed using [1].

An overview of cable layout with vessel movements is shown on Figure B.30.

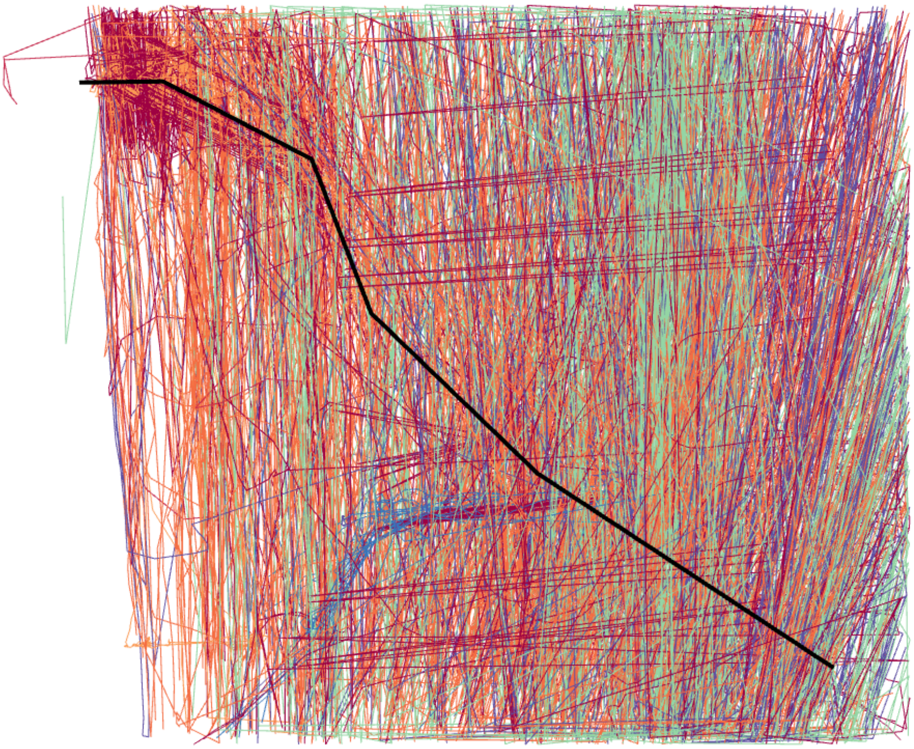


Figure B.30: Overview of cable layout with vessel movements.

AIS data date range is 01 Jan 2019 to 31 Dec 2019, and 01 Jan 2022 to 31 Dec 2022, covering a period of 2.0 years.

Table B.17 provides a summary of the vessels crossing all cables. Sections B.2.8 and B.2.9 details the number of vessels crossing each individual cable for each vessel size over the data set period.

Table B.17: Vessel classifications. Number of vessels and crossings are based on the full period of the AIS data set.

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, No additional information	79	1	14	699
Cargo, all ships of this type	70	1	1	23856
Diving ops	34	2	2	16
Fishing	30	102	321	1043
High speed craft (HSC), all ships of this type	40	1	1	248
Law Enforcement	55	2	4	446
Other Type, Reserved for future use	95	1	1	138

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Other Type, all ships of this type	90	49	237	3707
Passenger, all ships of this type	60	23	115	995
Pleasure Craft	37	549	786	9818
Reserved	38	1	1	44
Sailing	36	123	132	133
Search and Rescue vessel	51	1	2	6
Spare - Local Vessel	56	2	2	13030
Tanker, all ships of this type	80	1	1	19
Towing	31	121	411	1340
Towing: length exceeds 200m or breadth exceeds 25m	32	1	1	494
Tug	52	6	19	1132
Unknown	0	5	10	7515

The most common vessels were:

- NS INTERCEPTOR, Passenger, all ships of this type class, 16 tonnes, 65 crossings
- WESTERLY, Other Type, all ships of this type class, 8 tonnes, 62 crossings
- TIKI XIV, Pleasure Craft class, 65 tonnes, 43 crossings
- DORIS MORAN, Towing class, 690 tonnes, 24 crossings
- ALLISON, Pleasure Craft class, 8 tonnes, 22 crossings

The largest vessels were:

- EVANGELIA L, Cargo, all ships of this type class, 23856 tonnes, 1 crossings
- CHINCOTEAGUE, Spare - Local Vessel class, 13030 tonnes, 1 crossings
- CHARLESTON, Spare - Local Vessel class, 10898 tonnes, 1 crossings
- PHOENIX, Pleasure Craft class, 9818 tonnes, 1 crossings

B.2.3. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely “soft” or “hard”. This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material [17].

The two-layered approach adopted in this section considers the case where a layer of soft soil has been deposited over stiffer material. This model does not consider the case where hard soil is overlying soft soil. Soft soil is defined as cohesive soil with an undrained shear strength less than 40kPa.

Table B.18 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely thick hard and soft soil.

Table B.18: Anchor model

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-2	4	1084.4	1.0	0.72	2.16	128.8	38.1
2	2-5	8	1741.0	1.2	0.85	2.54	194.4	61.6
3	5-8	13	2296.6	1.3	0.93	2.80	247.4	81.6
4	8-10	17	2795.2	1.4	1.00	2.99	293.5	99.6
5	10-12	21	3255.4	1.5	1.05	3.16	335.1	116.3
6	12-15	26	3687.1	1.6	1.10	3.29	373.4	132.0
7	15-18	30	4096.5	1.6	1.14	3.41	409.2	146.9
8	18-20	34	4487.6	1.7	1.17	3.52	443.0	161.1
9	20-22	38	4863.6	1.7	1.21	3.62	475.1	174.9
10	22-25	42	5226.4	1.8	1.24	3.71	505.8	188.1

DWT is estimated from (dimensions in metres, DWT in tonnes):

$$DWT = max \begin{cases} (length/5.32)^{(1/0.351)} & \text{ref [5], fig 1.3} \\ length \times width \times draught \times 0.7 \times 1.025/1.7 & \text{ref [5], fig 1.2} \end{cases} \quad \text{(B.9)}$$

Displacement is taken as $1.7 \times DWT$ (ref [5]), adopting container ship parameters.

Anchor mass is estimated from ref [7], fig 9.2.

Fluke length is estimated from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \quad \text{(B.10)}$$

Anchor penetration is based on soil type (ref [27]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \quad \text{(B.11)}$$

Anchor penetration for the two-layered soil model is calculated using Equation B.12 and the schematic outlined in Figure B.31 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \quad \text{(B.12)}$$

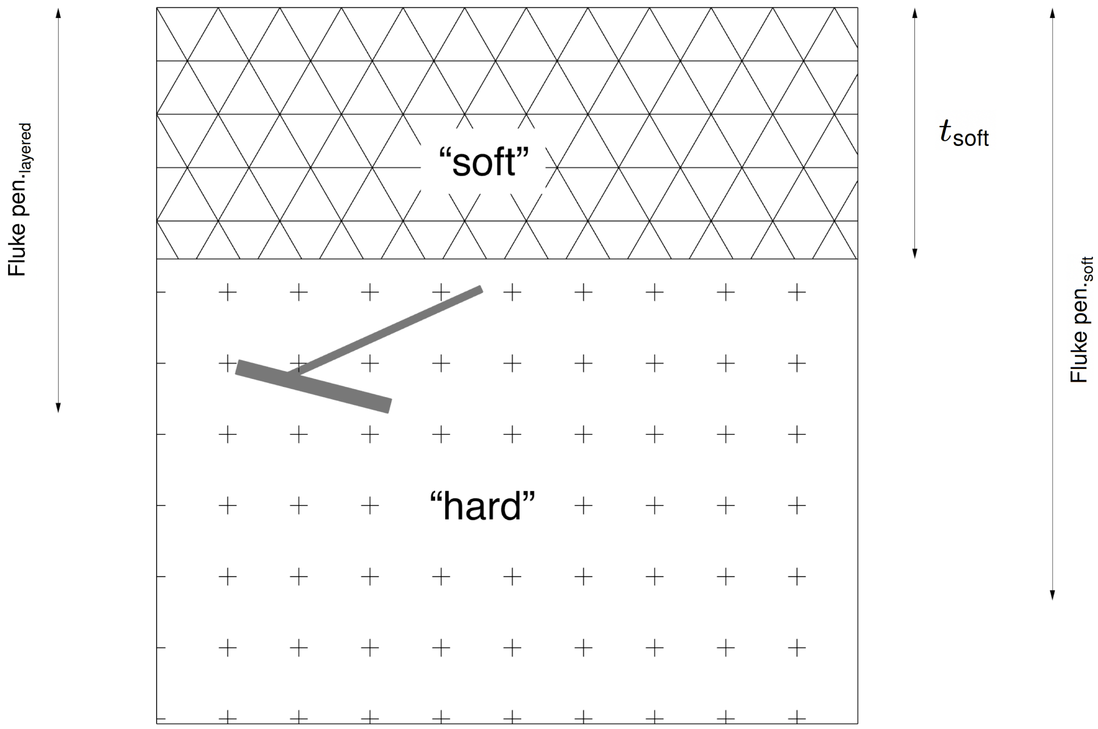


Figure B.31: Two-layered soil anchor penetration calculation schematic.

Ultimate holding capacity (UHC) is based on soil type, (UHC in kN and penetration in metres) and calculated using Equation B.13.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{B.13}$$

Figures B.32 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on Figure B.33.

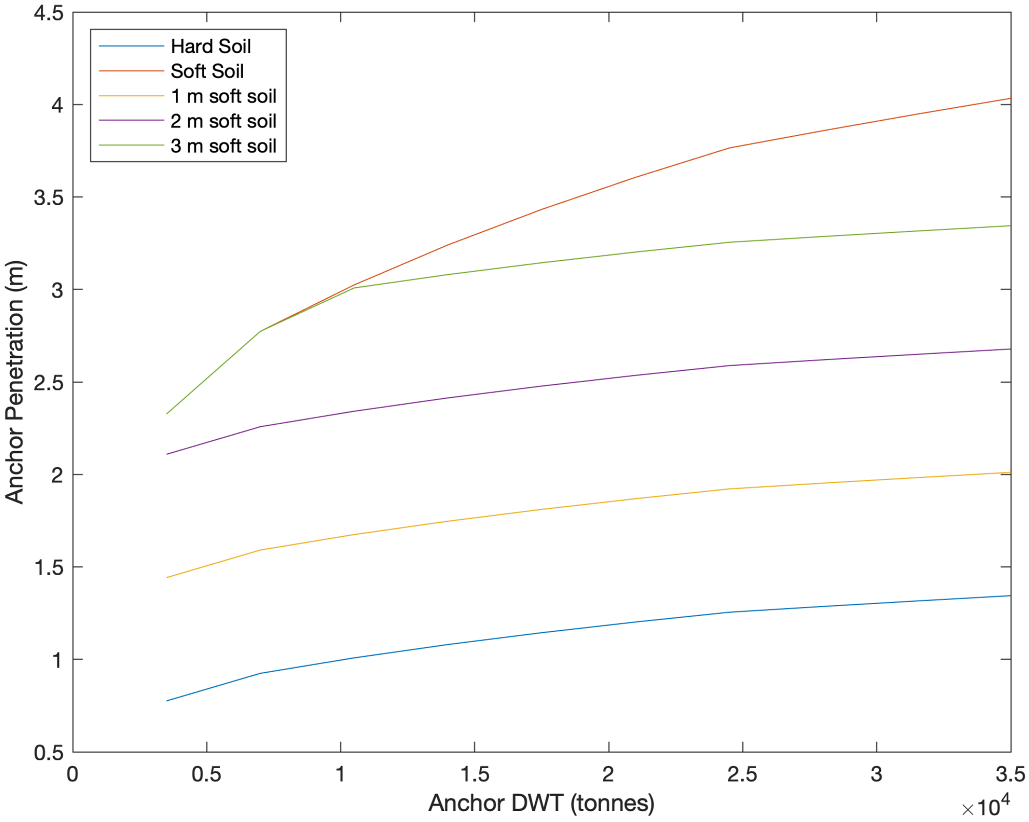


Figure B.32: Anchor penetration for various thicknesses of soft soil.

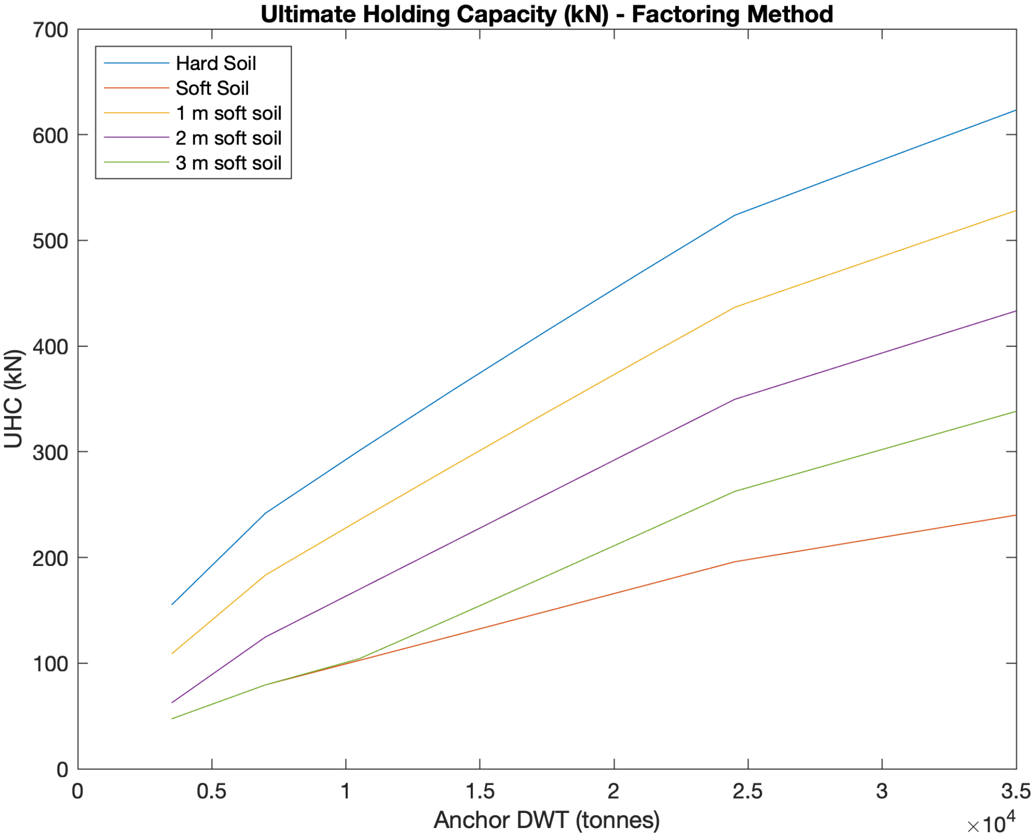


Figure B.33: UHC for various thicknesses of soft soil.

Table B.19 shows the ship model used.

D$_{ship}$, the estimate of distance an anchor is dragged, is calculated using Equation B.14 (ref [31]), D$_{ship}$ in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{Disp \times 0.51444(v_{ship})^2}{4UHC} \tag{B.14}$$

Table B.19: Ship model.

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-2	4.0	1.0	0.9	0.0100	34.93	118.19
2	2-5	4.0	1.0	0.9	0.0100	46.28	146.13
3	5-8	4.0	1.0	0.9	0.0100	54.56	165.44
4	8-10	4.0	1.0	0.9	0.0100	61.32	180.67
5	10-12	4.0	1.0	0.9	0.0100	67.13	193.44
6	12-15	4.0	1.0	0.9	0.0100	72.29	204.54

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
7	15-18	4.0	1.0	0.9	0.0100	76.96	214.43
8	18-20	4.0	1.0	0.9	0.0100	81.24	223.37
9	20-22	4.0	1.0	0.9	0.0100	85.22	231.57
10	22-25	4.0	1.0	0.9	0.0100	88.95	239.16

B.2.4. Probabilistic anchor strike assessment for surface lay

Table B.20 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in section B.2.9. The highest risk (per km) cables are:

- ECCSouthLandfall, SouthKP10toKP12, RPhard 798730 yr/km, RPsoft 236500 yr/km
- ECCSouthLandfall, SouthKP07toKP09, RPhard 1177368 yr/km, RPsoft 348211 yr/km
- ECCSouthLandfall, SouthKP04toKP07, RPhard 1255406 yr/km, RPsoft 371674 yr/km
- ECCSouthLandfall, SouthKP12toEnd, RPhard 2920897 yr/km, RPsoft 863163 yr/km
- ECCSouthLandfall, SouthKP09toKP10, RPhard 3226831 yr/km, RPsoft 954747 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [7]), D_{ship} in m, v_{ship} in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \tag{B.15}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is ($P_{s.n}$ is the P_{strike} of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \tag{B.16}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table B.20: Surface lay probabilistic assessment.

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCSouthLandfall	SouthKP00toKP0_6	15302387 yr, 24480404 yr/km	4522056 yr, 7234280 yr/km	9
ECCSouthLandfall	SouthKP0_6toKP01	15890941 yr, 42385660 yr/km	4695981 yr, 12525517 yr/km	10
ECCSouthLandfall	SouthKP01toKP1_7	9498034 yr, 13501061 yr/km	2806793 yr, 3989740 yr/km	8
ECCSouthLandfall	SouthKP1_7toKP02	19674498 yr, 66356377 yr/km	5814072 yr, 19609177 yr/km	11
ECCSouthLandfall	SouthKP02toKP03	6166634 yr, 6166634 yr/km	1822321 yr, 1822321 yr/km	6

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCSouthLandfall	SouthKP03toKP04	8484337 yr, 8484337 yr/km	2518291 yr, 2518291 yr/km	7
ECCSouthLandfall	SouthKP04toKP07	3766218 yr, 1255406 yr/km	1115021 yr, 371674 yr/km	3
ECCSouthLandfall	SouthKP07toKP09	2354737 yr, 1177368 yr/km	696422 yr, 348211 yr/km	2
ECCSouthLandfall	SouthKP09toKP10	3226832 yr, 3226831 yr/km	954748 yr, 954747 yr/km	5
ECCSouthLandfall	SouthKP10toKP12	1597459 yr, 798730 yr/km	472999 yr, 236500 yr/km	1
ECCSouthLandfall	SouthKP12toEnd	3190459 yr, 2920897 yr/km	942822 yr, 863163 yr/km	4

B.2.5. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table B.18 is less than the depth considered. Table B.21 shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section B.2.10 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

B.2.6. Results for one-layered soil

Table B.21: Burial depths to achieve target frequencies.

Cable	Section	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCSouthLandfall	SouthKP00toKP0_6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP0_6toKP01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP01toKP1_7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP1_7toKP02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP02toKP03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP03toKP04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP04toKP07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP07toKP09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP09toKP10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP10toKP12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP12toEnd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.22 shows the total anchor strike risk over the total length of the surface laid cable.

Table B.22: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Soft soil return period	Rank
ECCSouthLandfall	399371 yr	118159 yr	1

Table B.23 shows the required burial depths to achieve certain target frequencies

Table B.23: Burial depths to achieve target frequencies, total cable.

Cable	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCSouthLandfall	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Section B.2.12 shows the anchor strike frequency for buried cables assessed over the total length, with zero frequency taken as 10^{-10} for plotting purposes.

B.2.7. Results for two-layered soil

Table B.24 shows calculated return periods for each cable for the two-layered soil approach.

Table B.24: Two-layered soil model summary.

Cable	Section	Soft soil thickness (m)	Return period	Return period per km
ECCSouthLandfall	SouthKP00toKP0.6	1.4	8319911 yr	13310000 yr/km
ECCSouthLandfall	SouthKP0.6toKP01	0.4	13819217 yr	36859783 yr/km
ECCSouthLandfall	SouthKP01toKP1.7	0.2	8878898 yr	12620985 yr/km
ECCSouthLandfall	SouthKP1.7toKP02	2.8	5814072 yr	19609177 yr/km
ECCSouthLandfall	SouthKP02toKP03	2	2146871 yr	2146871 yr/km
ECCSouthLandfall	SouthKP03toKP04	4.5	2518291 yr	2518291 yr/km
ECCSouthLandfall	SouthKP04toKP07	0	3766218 yr	1255406 yr/km
ECCSouthLandfall	SouthKP07toKP09	4.6	696422 yr	348211 yr/km
ECCSouthLandfall	SouthKP09toKP10	0	3226832 yr	3226831 yr/km
ECCSouthLandfall	SouthKP10toKP12	2.6	473909 yr	236955 yr/km
ECCSouthLandfall	SouthKP12toEnd	4.8	942822 yr	863163 yr/km

Table B.25 shows the required burial depth to achieve the target return frequency using the two-layered soil model. Target frequencies are the same as defined in section C.2.5.

Table B.25: Burial depths to achieve target frequencies.

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
ECCSouthLandfall	SouthKP00toKP0_6	1.4	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP0_6toKP01	0.4	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP01toKP1_7	0.2	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP1_7toKP02	2.8	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP02toKP03	2	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP03toKP04	4.5	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP04toKP07	0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP07toKP09	4.6	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP09toKP10	0	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP10toKP12	2.6	0.0	0.0	0.0	0.0
ECCSouthLandfall	SouthKP12toEnd	4.8	0.0	0.0	0.0	0.0

Table B.26 shows the total anchor strike risk over the total length of the surface laid cable for the two-layered soil approach.

Table B.26: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Two-Layered soil return period	Soft soil return period	Rank
ECCSouthLandfall	399371 yr	153324 yr	118159 yr	1

Table B.27 shows the required burial depths to achieve certain target frequencies for the total cable length using the two-layered soil approach for each soft soil thickness.

Table B.27: Burial depths to achieve target frequencies, total cable.

Cable	Soft Soil Thickness	Cable length (km)	Two-Layered Soil, 1.0e-02	Two-Layered Soil, 1.0e-03	Two-Layered Soil, 1.0e-04	Two-Layered Soil, 1.0e-05
ECCSouthLandfall	0.0	4.00	0.0	0.0	0.0	0.0
ECCSouthLandfall	0.2	0.70	0.0	0.0	0.0	0.0
ECCSouthLandfall	0.4	0.37	0.0	0.0	0.0	0.0
ECCSouthLandfall	1.4	0.63	0.0	0.0	0.0	0.0
ECCSouthLandfall	2.0	1.00	0.0	0.0	0.0	0.0
ECCSouthLandfall	2.6	2.00	0.0	0.0	0.0	0.0
ECCSouthLandfall	2.8	0.30	0.0	0.0	0.0	0.0
ECCSouthLandfall	4.5	1.00	0.0	0.0	0.0	0.0
ECCSouthLandfall	4.6	2.00	0.0	0.0	0.0	0.0
ECCSouthLandfall	4.8	1.09	0.0	0.0	0.0	0.0

B.2.8. Vessel movement maps

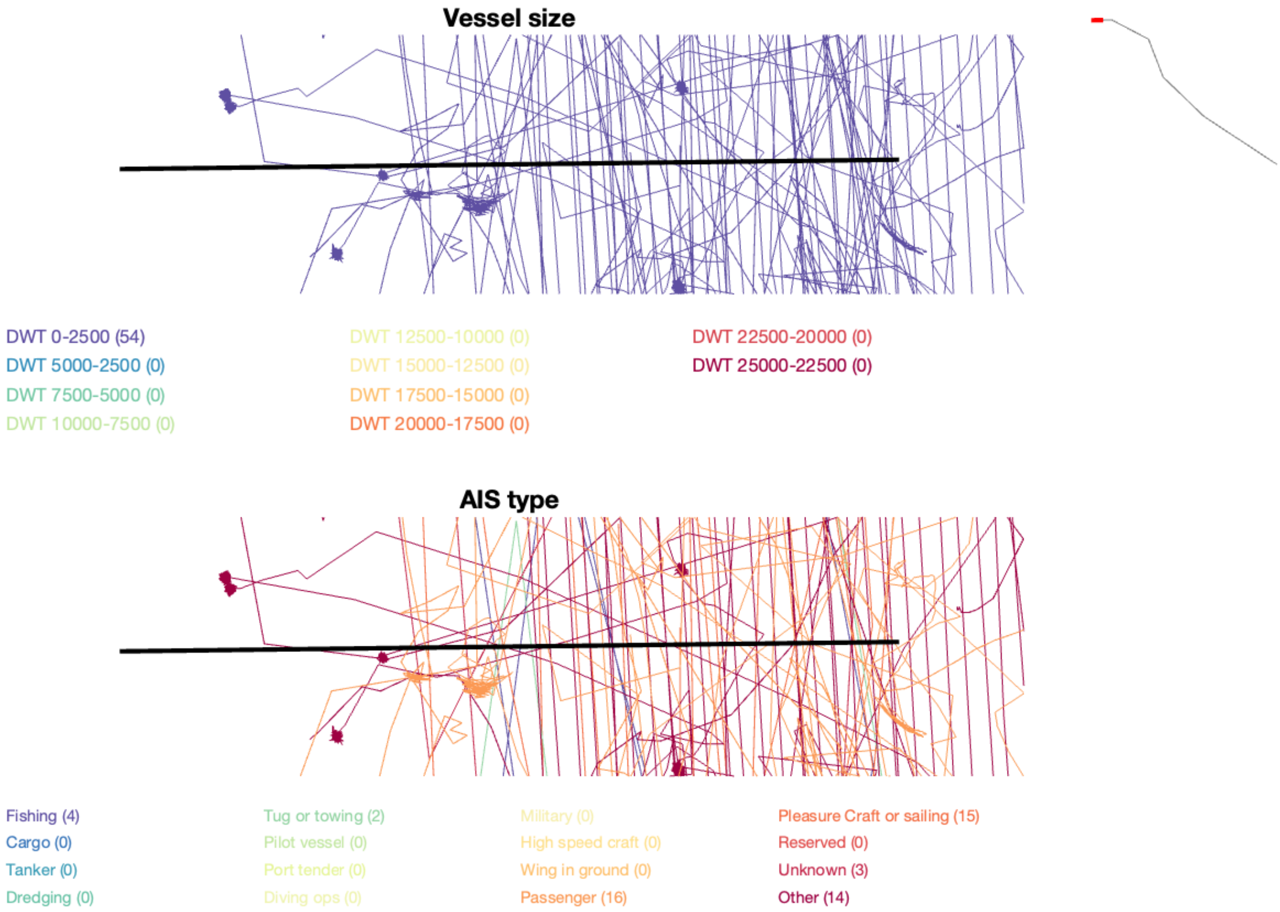


Figure B.34: Vessel movement,Cable ECCSouthLandfall, SouthKP0toKP0.6.

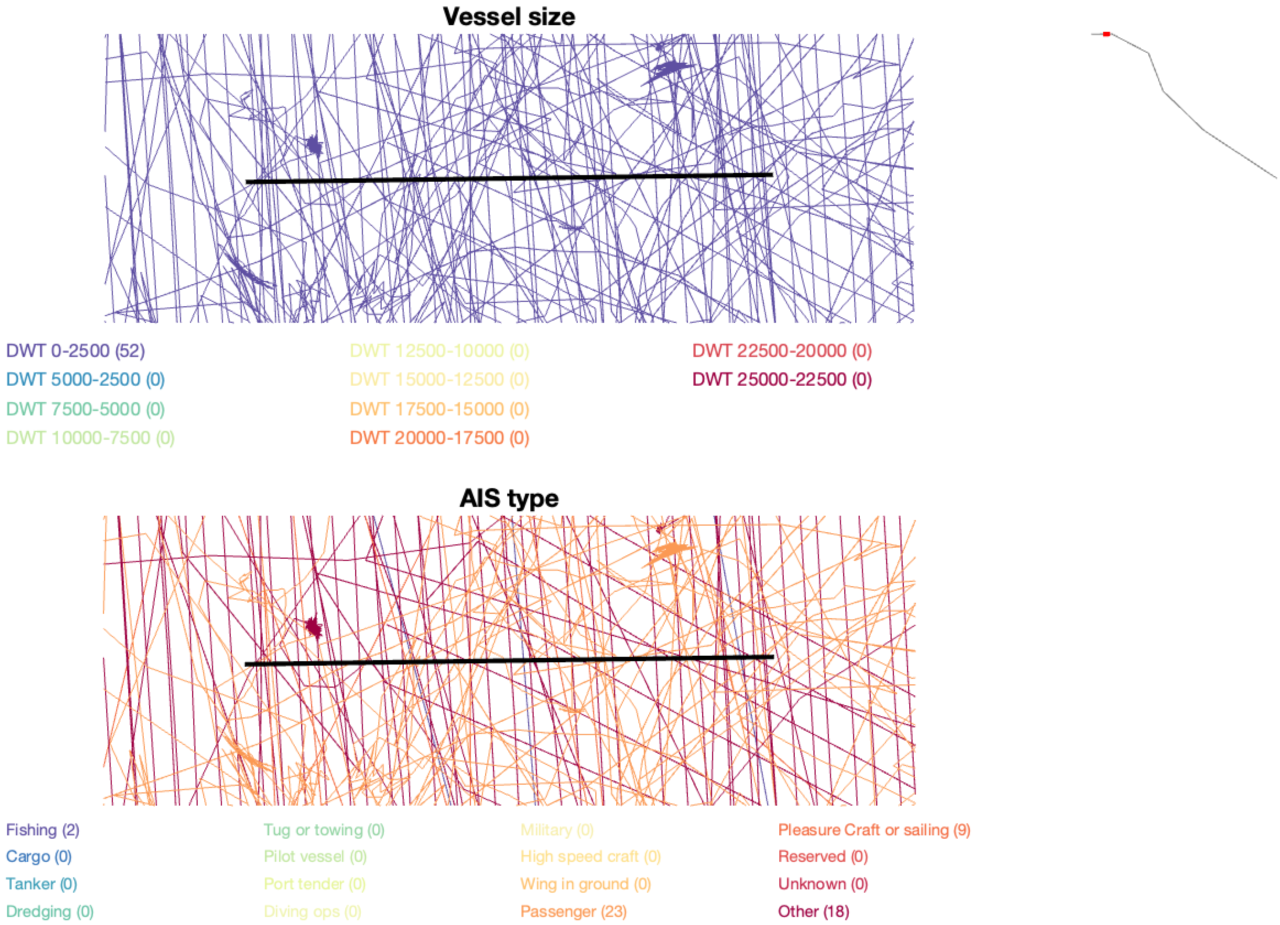


Figure B.35: Vessel movement,Cable ECCSouthLandfall, SouthKP0.6toKP01.

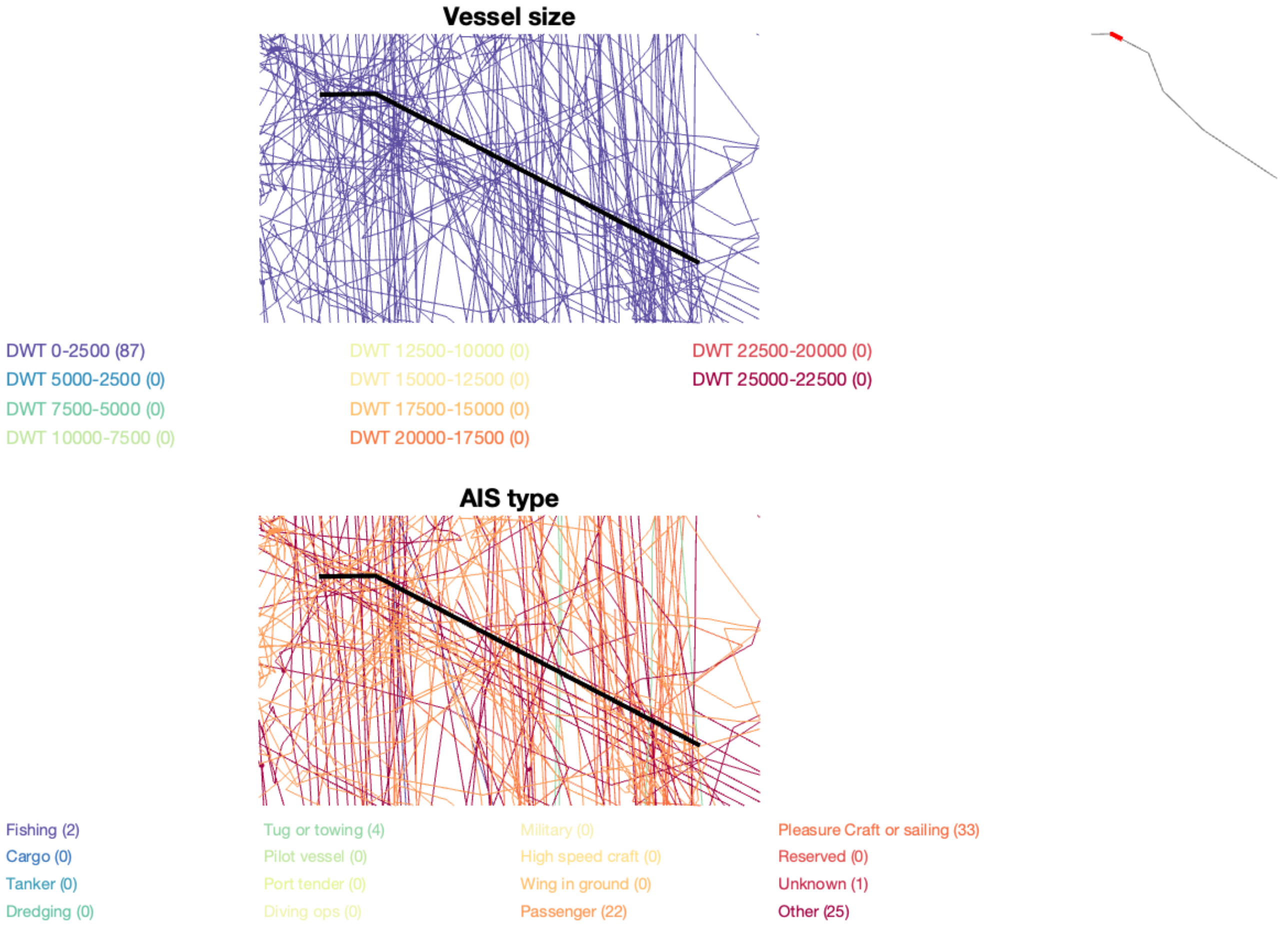


Figure B.36: Vessel movement,Cable ECCSouthLandfall, SouthKP01toKP1.7.

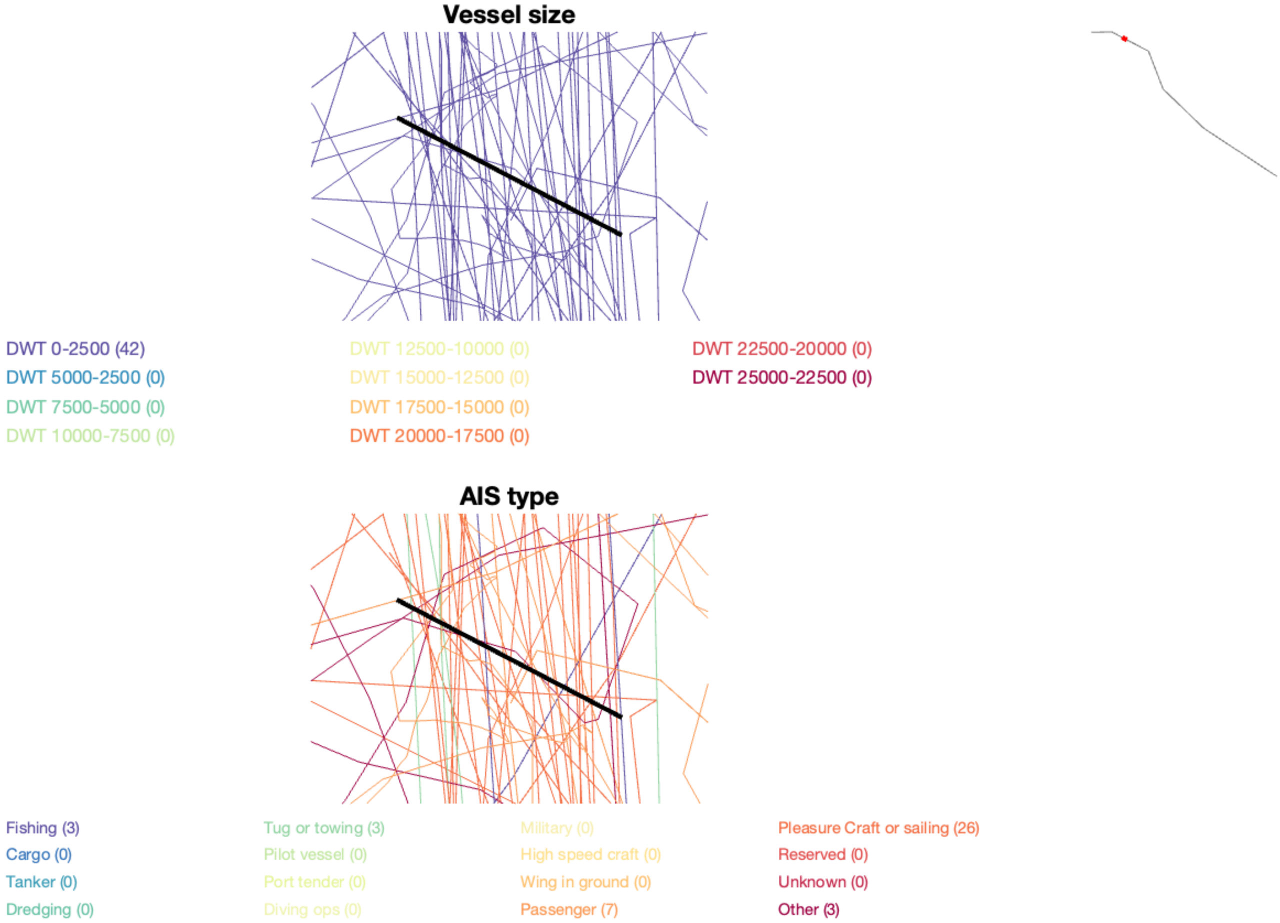


Figure B.37: Vessel movement,Cable ECCSouthLandfall, SouthKP1.7toKP02.

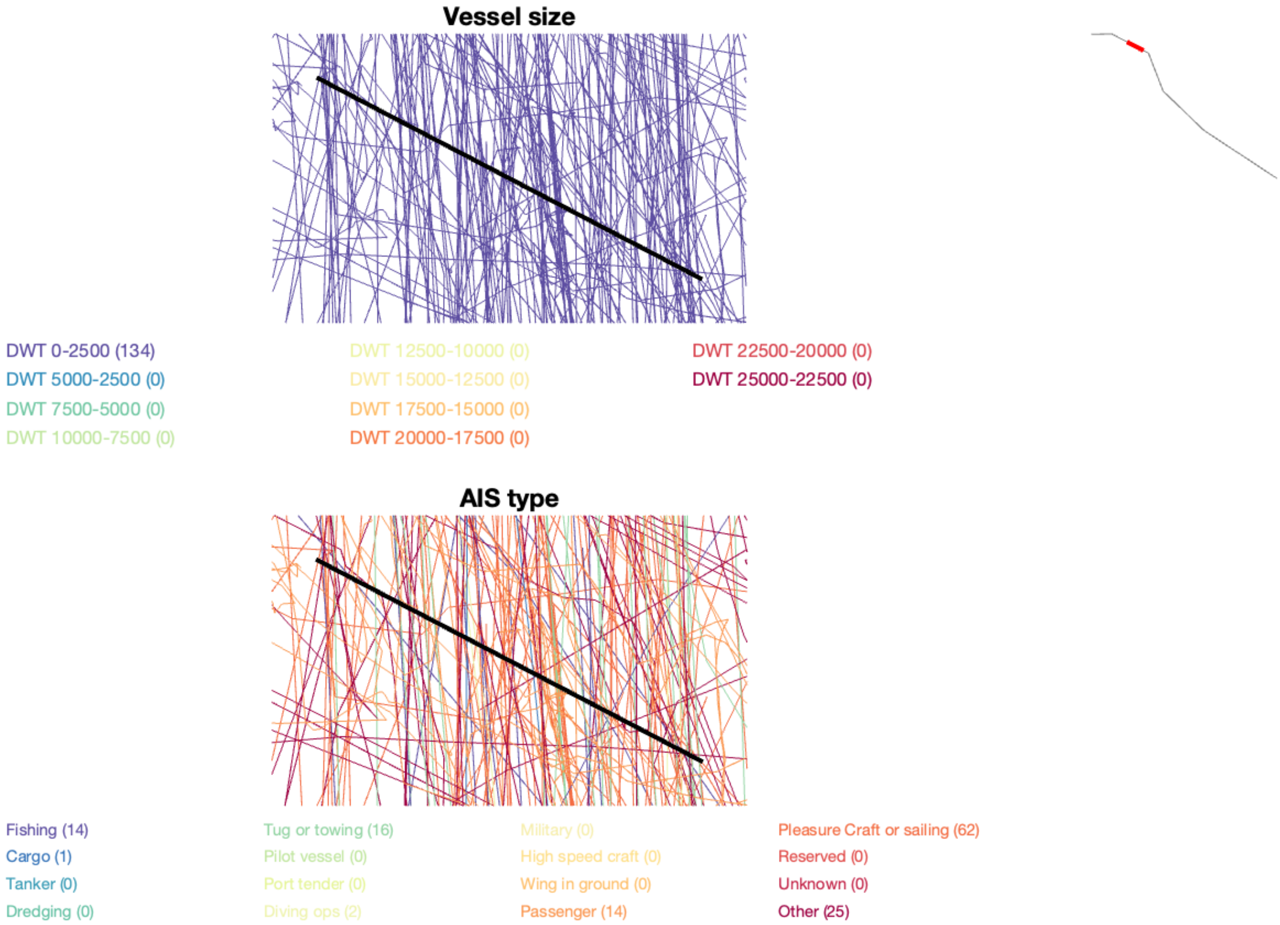


Figure B.38: Vessel movement,Cable ECCSouthLandfall, SouthKP02toKP03.

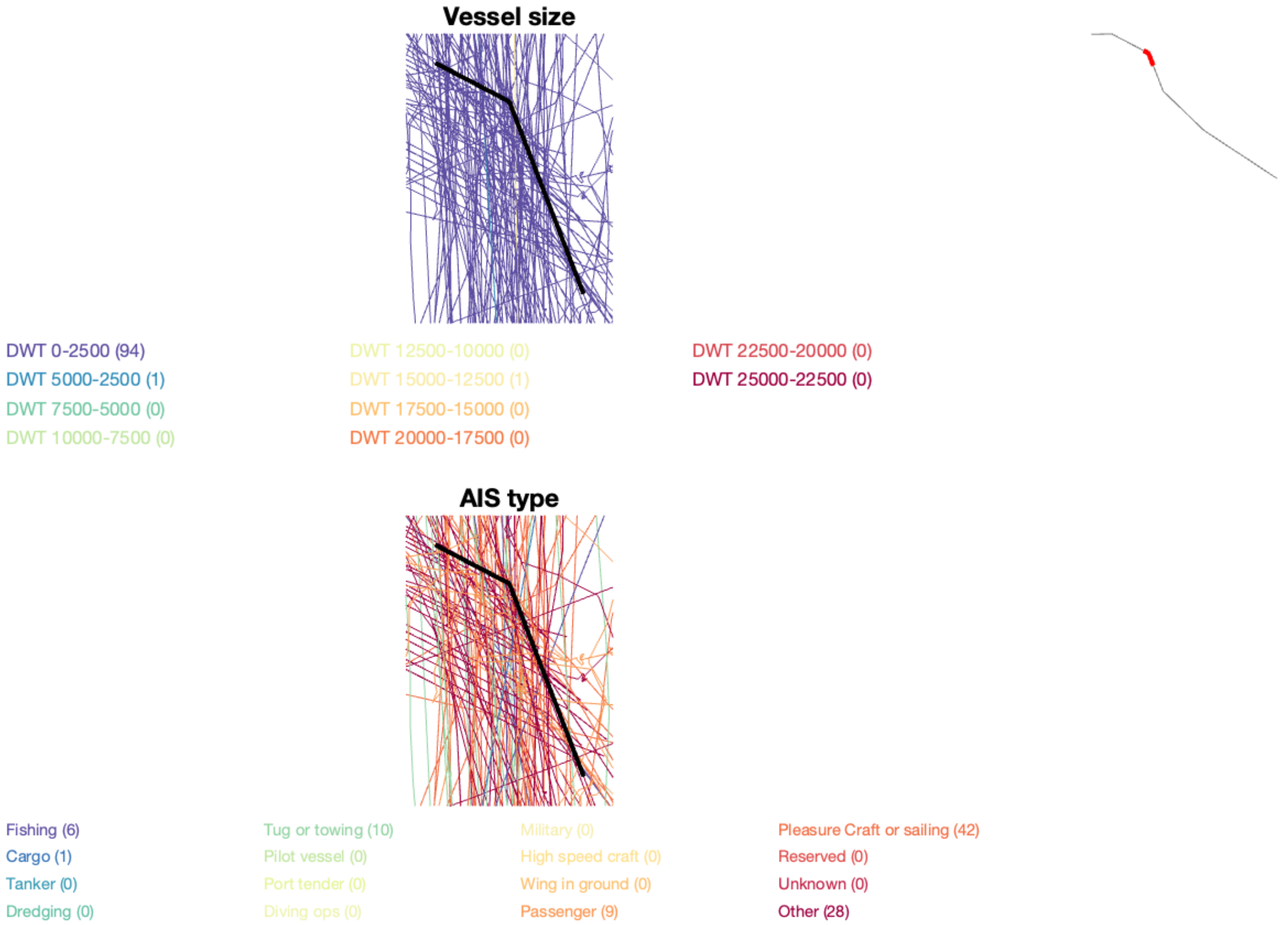


Figure B.39: Vessel movement,Cable ECCSouthLandfall, SouthKP03toKP04.

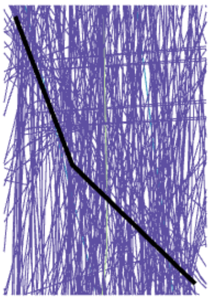
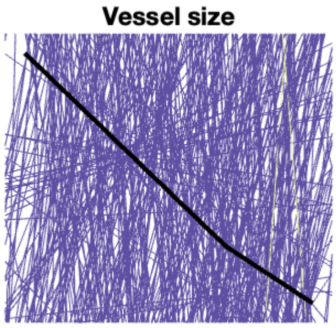
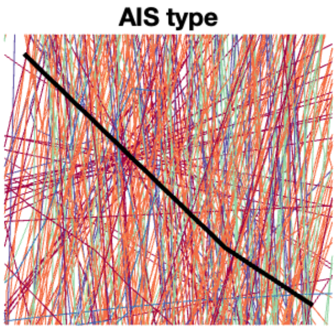


Figure B.40: Vessel movement,Cable ECCSouthLandfall, SouthKP04toKP07.



DWT 0-2500 (349)
DWT 5000-2500 (0)
DWT 7500-5000 (0)
DWT 10000-7500 (0)
DWT 12500-10000 (1)
DWT 15000-12500 (0)
DWT 17500-15000 (0)
DWT 20000-17500 (0)
DWT 22500-20000 (0)
DWT 25000-22500 (0)



Fishing (47)
Cargo (3)
Tanker (0)
Dredging (0)
Tug or towing (64)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (1)
Wing in ground (0)
Passenger (7)
Pleasure Craft or sailing (190)
Reserved (0)
Unknown (1)
Other (37)

Figure B.41: Vessel movement,Cable ECCSouthLandfall, SouthKP07toKP09.

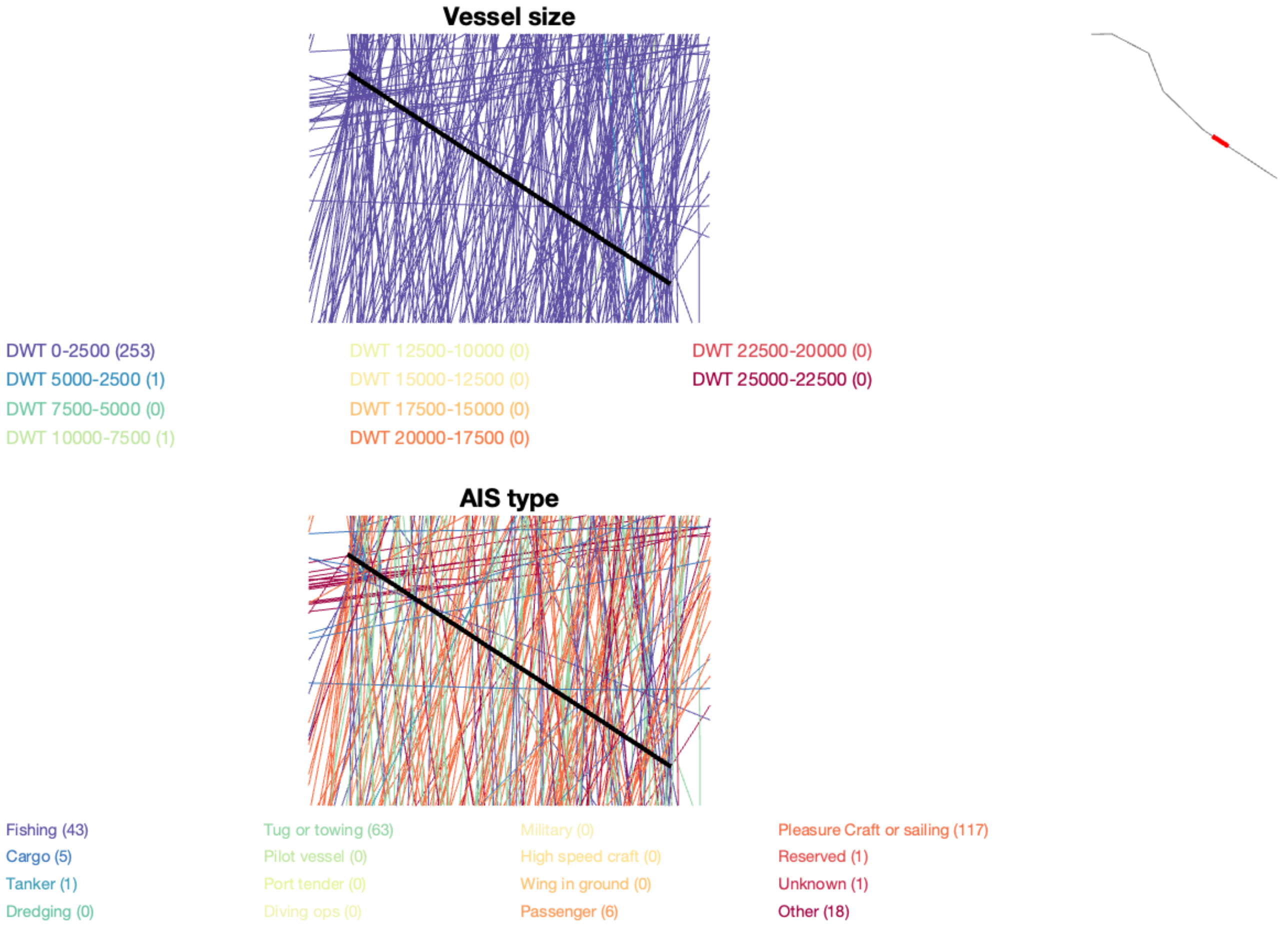


Figure B.42: Vessel movement,Cable ECCSouthLandfall, SouthKP09toKP10.

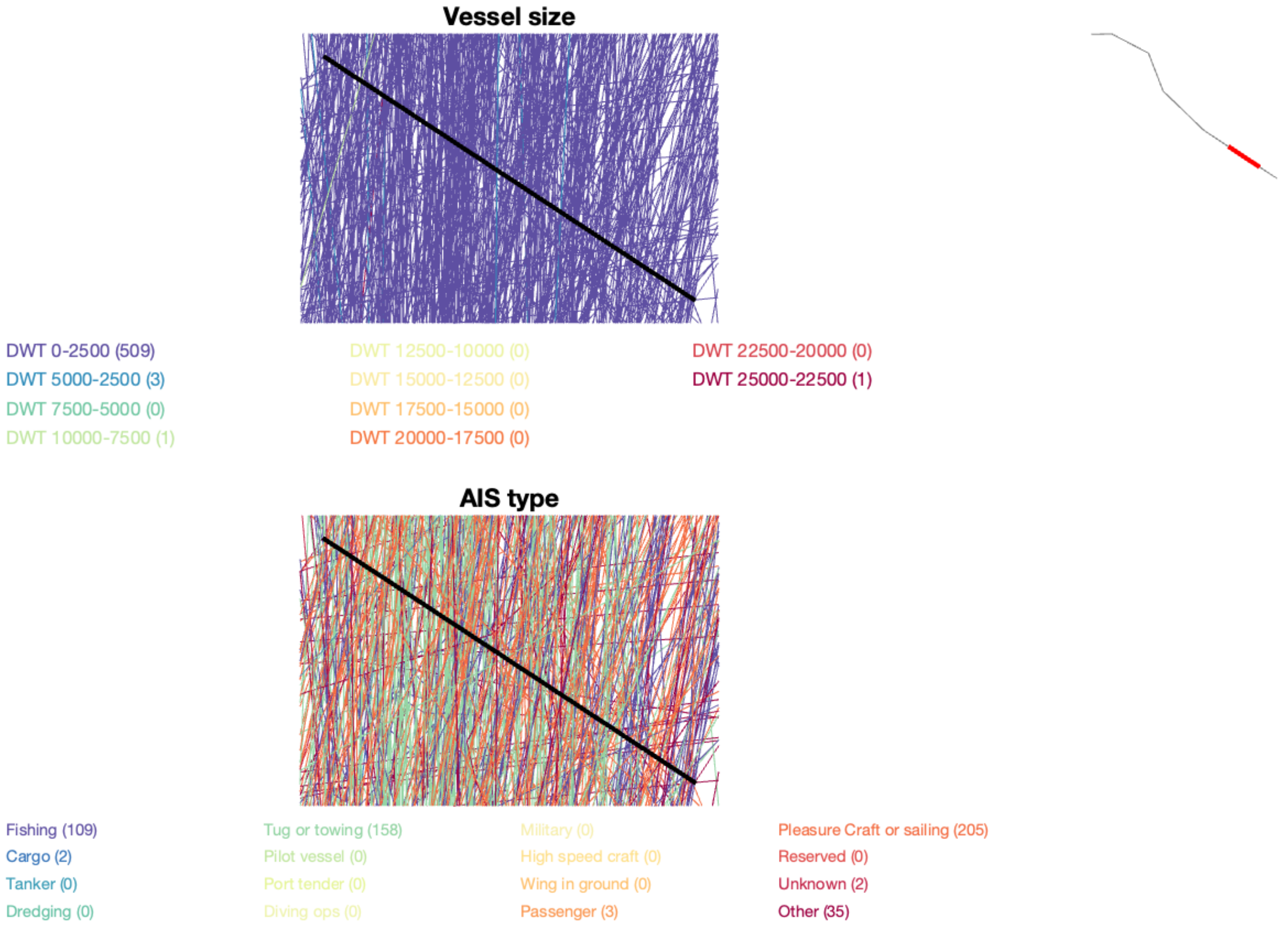


Figure B.43: Vessel movement,Cable ECCSouthLandfall, SouthKP10toKP12.

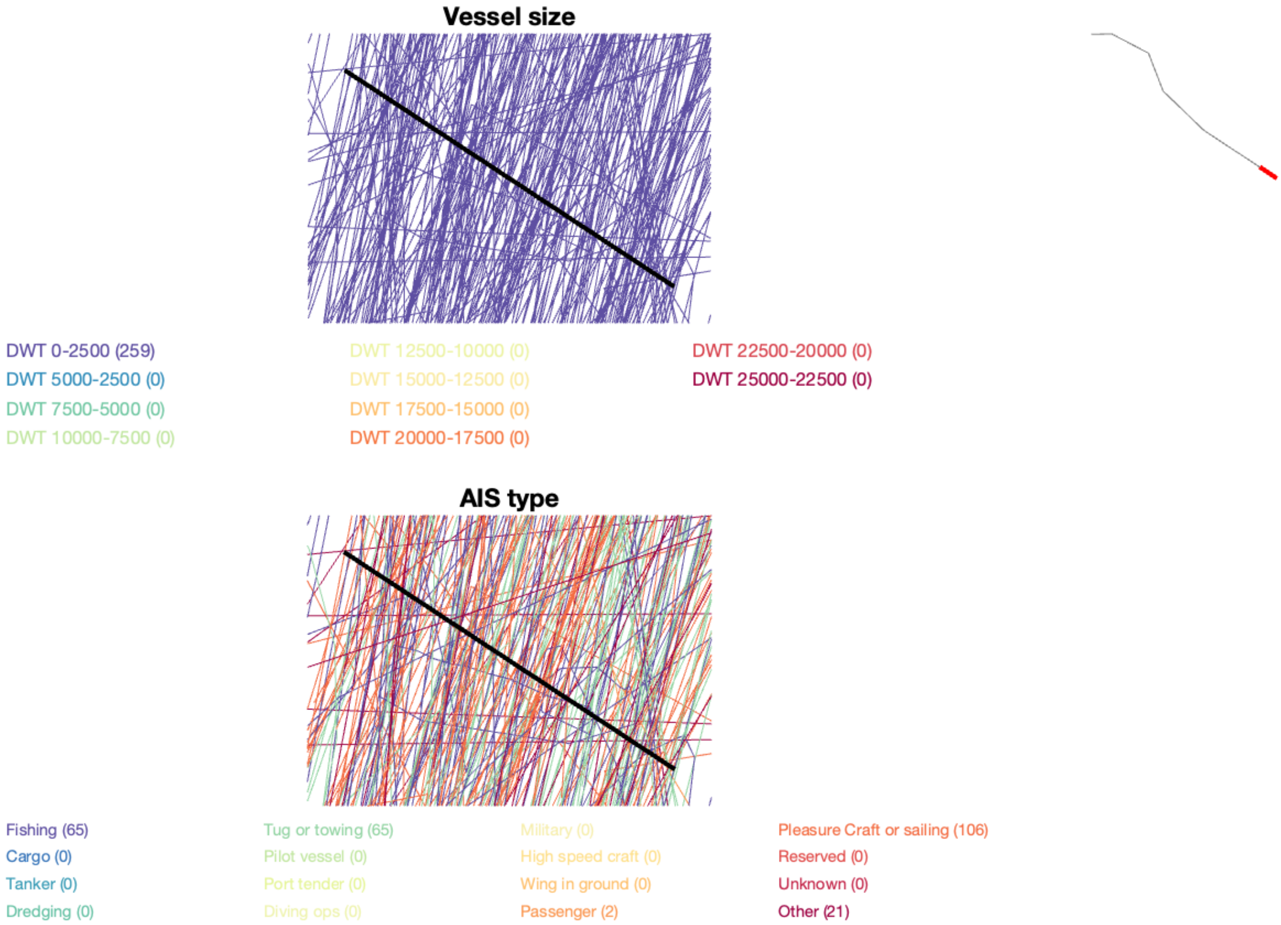


Figure B.44: Vessel movement,Cable ECCSouthLandfall, SouthKP12toEnd.

B.2.9. Full anchor strike assessment for surface lay

Table B.28: Surface lay probabilistic assessment (full results).

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	<u>Hard soil</u> Total Pstrike (-) Return period (yr) Return period (yr/km)	<u>Soft soil</u> Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCSouthLandfall	SouthKP00toKP0_6	1 2 3 4 5 6 7 8 9 10	54 0 0 0 0 0 0 0 0 0	6.53e-08 0 0 0 0 0 0 0 0 0	2.21e-07 0 0 0 0 0 0 0 0 0	6.53e-08 15302387 yr 24480404 yr/km	2.21e-07 4522056 yr 7234280 yr/km
ECCSouthLandfall	SouthKP0_6toKP01	1 2 3 4 5 6 7 8 9 10	52 0 0 0 0 0 0 0 0 0	6.29e-08 0 0 0 0 0 0 0 0 0	2.13e-07 0 0 0 0 0 0 0 0 0	6.29e-08 15890941 yr 42385660 yr/km	2.13e-07 4695981 yr 12525517 yr/km
ECCSouthLandfall	SouthKP01toKP1_7	1 2 3 4 5 6 7 8 9 10	87 0 0 0 0 0 0 0 0 0	1.05e-07 0 0 0 0 0 0 0 0 0	3.56e-07 0 0 0 0 0 0 0 0 0	1.05e-07 9498034 yr 13501061 yr/km	3.56e-07 2806793 yr 3989740 yr/km
ECCSouthLandfall	SouthKP1_7toKP02	1 2 3 4 5 6 7 8 9 10	42 0 0 0 0 0 0 0 0 0	5.08e-08 0 0 0 0 0 0 0 0 0	1.72e-07 0 0 0 0 0 0 0 0 0	5.08e-08 19674498 yr 66356377 yr/km	1.72e-07 5814072 yr 19609177 yr/km

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCSouthLandfall	SouthKP02toKP03	1 2 3 4 5 6 7 8 9 10	134 0 0 0 0 0 0 0 0 0	1.62e-07 0 0 0 0 0 0 0 0 0	5.49e-07 0 0 0 0 0 0 0 0 0	1.62e-07 6166634 yr 6166634 yr/km	5.49e-07 1822321 yr 1822321 yr/km
ECCSouthLandfall	SouthKP03toKP04	1 2 3 4 5 6 7 8 9 10	94 1 0 0 0 1 0 0 0 0	1.14e-07 1.60e-09 0 0 0 2.50e-09 0 0 0 0	3.85e-07 5.06e-09 0 0 0 7.09e-09 0 0 0 0	1.18e-07 8484337 yr 8484337 yr/km	3.97e-07 2518291 yr 2518291 yr/km
ECCSouthLandfall	SouthKP04toKP07	1 2 3 4 5 6 7 8 9 10	215 2 0 1 0 0 0 0 0 0	2.60e-07 3.21e-09 0 2.12e-09 0 0 0 0 0 0	8.80e-07 1.01e-08 0 6.26e-09 0 0 0 0 0 0	2.66e-07 3766218 yr 1255406 yr/km	8.97e-07 1115021 yr 371674 yr/km
ECCSouthLandfall	SouthKP07toKP09	1 2 3 4 5 6 7 8 9 10	349 0 0 0 1 0 0 0 0 0	4.22e-07 0 0 0 2.33e-09 0 0 0 0 0	1.43e-06 0 0 0 6.70e-09 0 0 0 0 0	4.25e-07 2354737 yr 1177368 yr/km	1.44e-06 696422 yr 348211 yr/km
ECCSouthLandfall	SouthKP09toKP10	1 2 3 4 5 6 7 8 9 10	253 1 0 1 0 0 0 0 0 0	3.06e-07 1.60e-09 0 2.12e-09 0 0 0 0 0 0	1.04e-06 5.06e-09 0 6.26e-09 0 0 0 0 0 0	3.10e-07 3226832 yr 3226831 yr/km	1.05e-06 954748 yr 954747 yr/km

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCSouthLandfall	SouthKP10toKP12	1 2 3 4 5 6 7 8 9 10	509 3 0 1 0 0 0 0 0 1	6.16e-07 4.81e-09 0 2.12e-09 0 0 0 0 0 3.08e-09	2.08e-06 1.52e-08 0 6.26e-09 0 0 0 0 0 8.29e-09	6.26e-07 1597459 yr 798730 yr/km	2.11e-06 472999 yr 236500 yr/km
ECCSouthLandfall	SouthKP12toEnd	1 2 3 4 5 6 7 8 9 10	259 0 0 0 0 0 0 0 0 0	3.13e-07 0 0 0 0 0 0 0 0 0	1.06e-06 0 0 0 0 0 0 0 0 0	3.13e-07 3190459 yr 2920897 yr/km	1.06e-06 942822 yr 863163 yr/km

B.2.10. Anchor strike probability graphs for buried cables

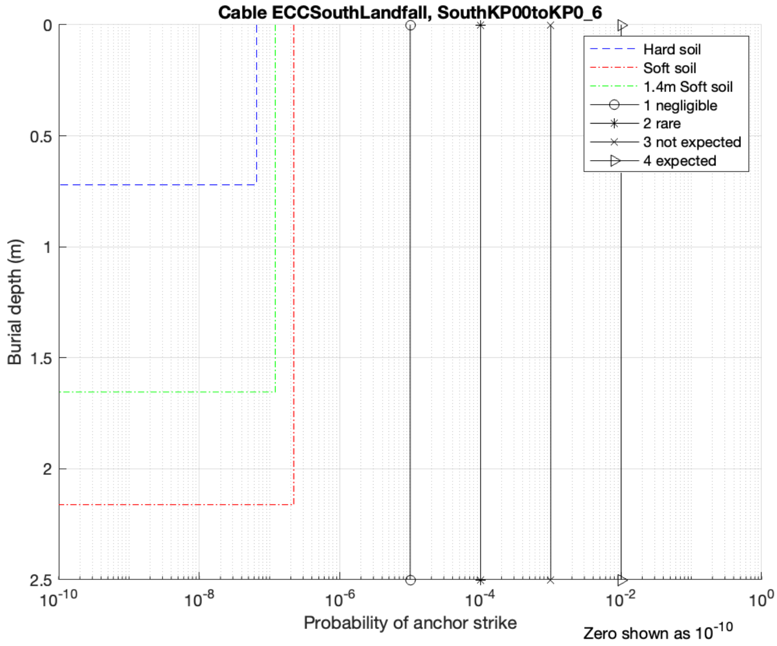


Figure B.45: Anchor strike risk vs burial depth, SouthKP00toKP0.6.

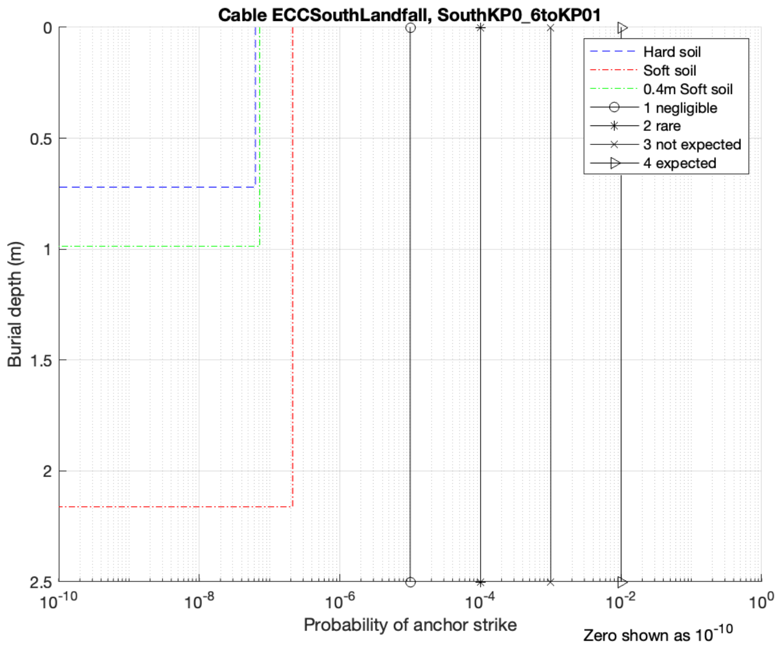


Figure B.46: Anchor strike risk vs burial depth, SouthKP0.6toKP01.

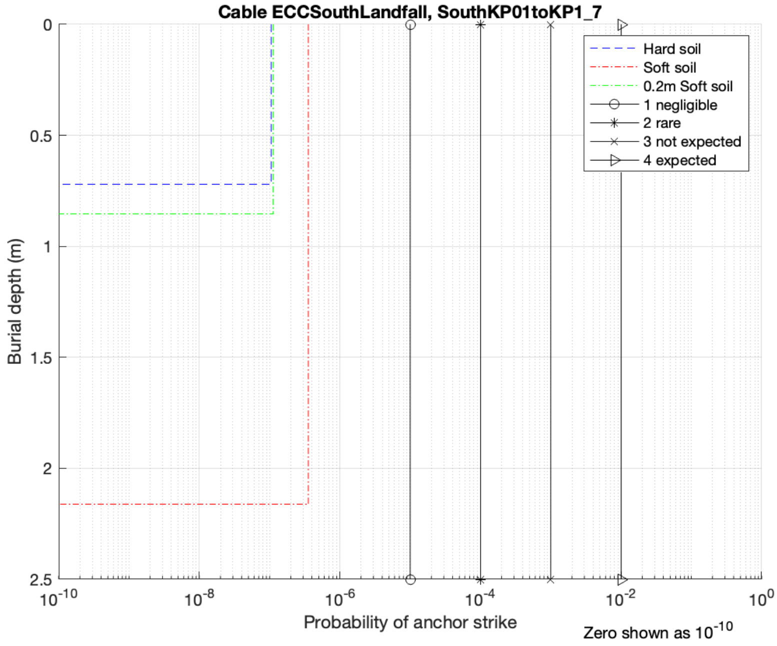


Figure B.47: Anchor strike risk vs burial depth, SouthKP01toKP1.7.

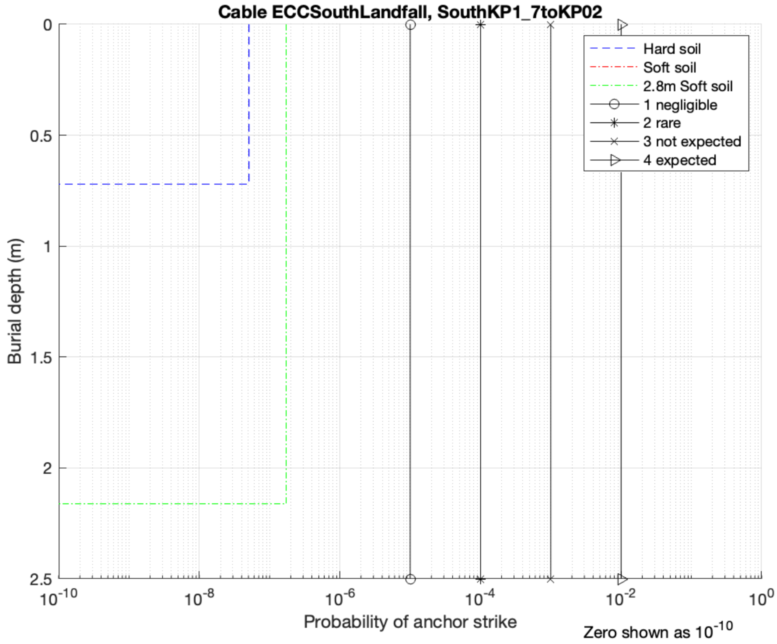


Figure B.48: Anchor strike risk vs burial depth, SouthKP1.7toKP02.

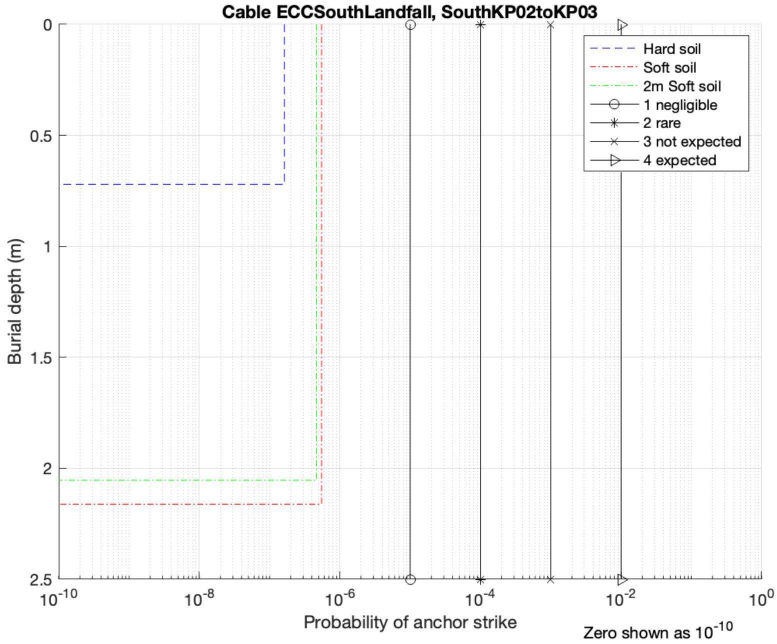


Figure B.49: Anchor strike risk vs burial depth, SouthKP02toKP03.

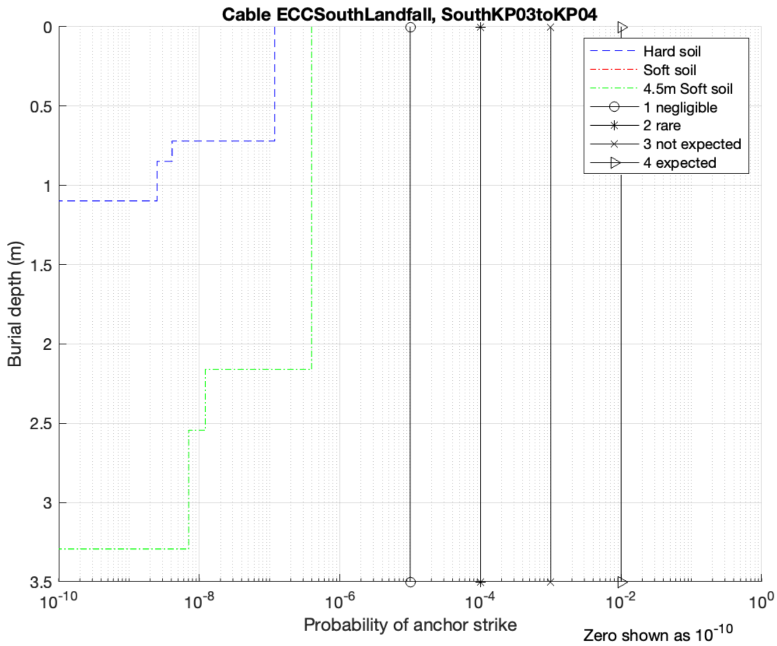


Figure B.50: Anchor strike risk vs burial depth, SouthKP03toKP04.

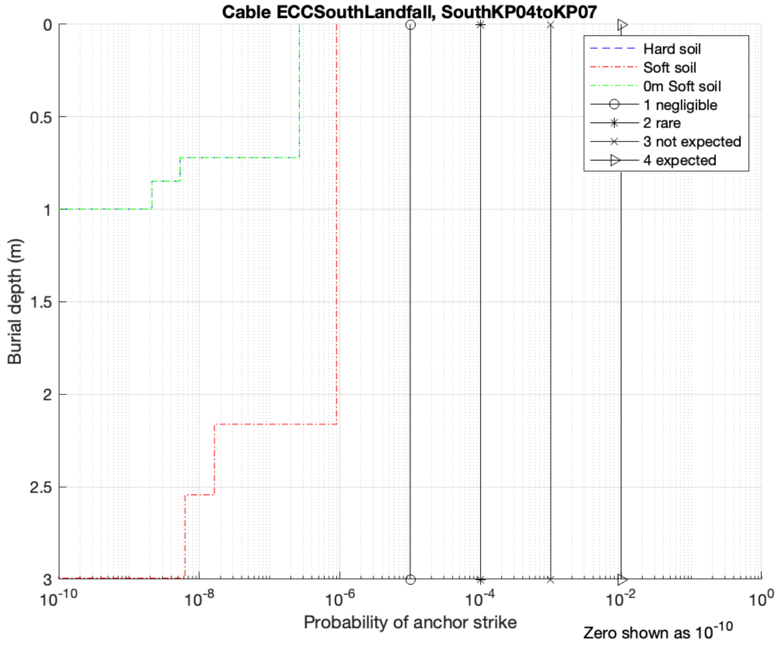


Figure B.51: Anchor strike risk vs burial depth, SouthKP04toKP07.

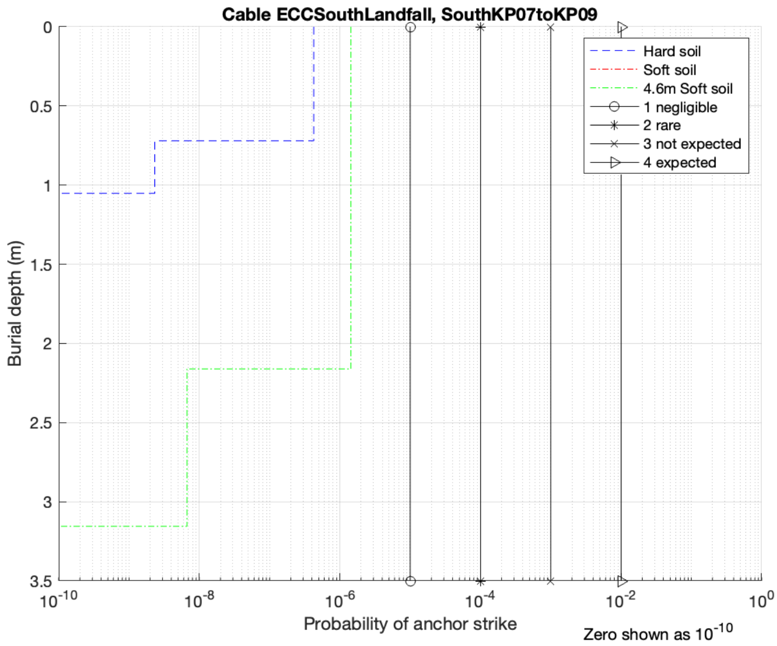


Figure B.52: Anchor strike risk vs burial depth, SouthKP07toKP09.

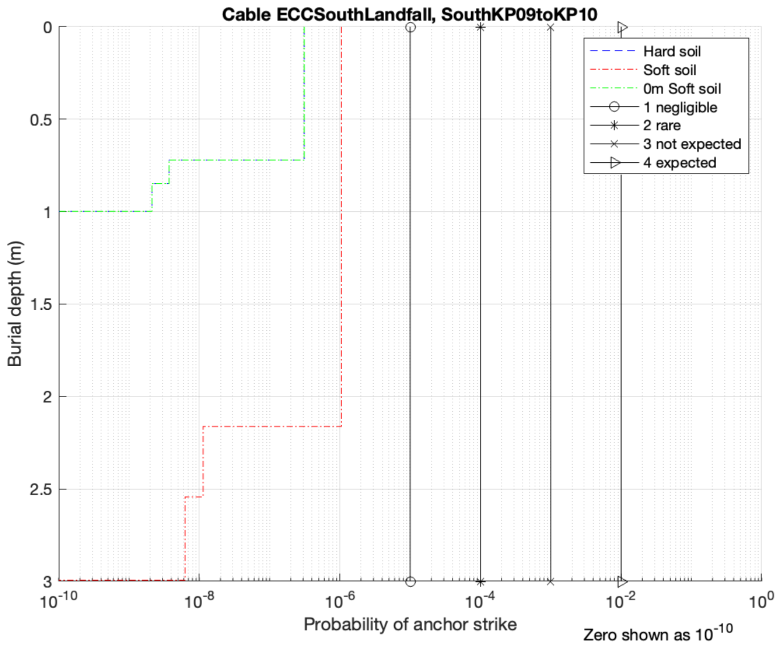


Figure B.53: Anchor strike risk vs burial depth, SouthKP09toKP10.

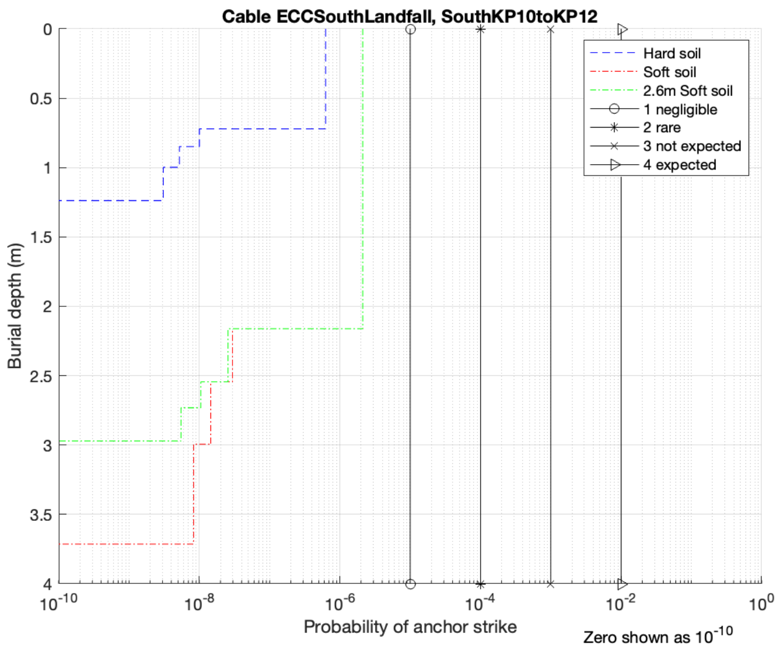


Figure B.54: Anchor strike risk vs burial depth, SouthKP10toKP12.

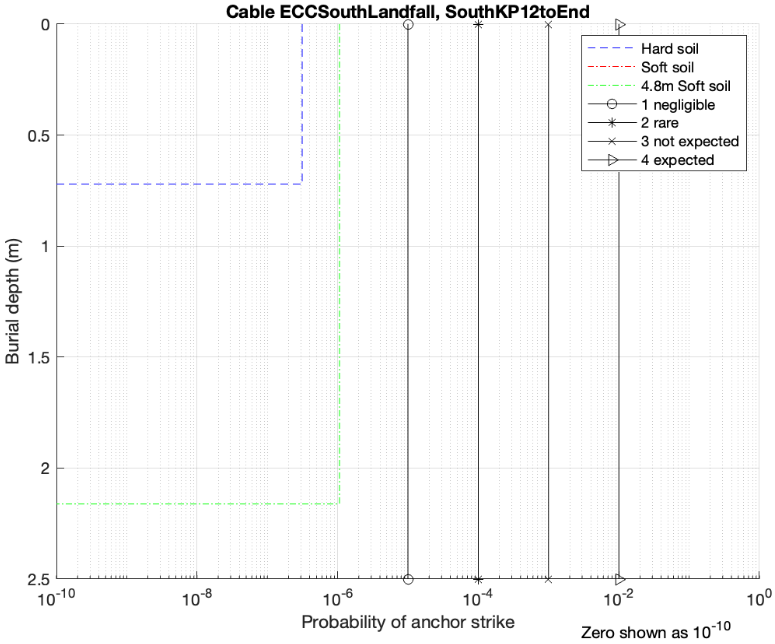


Figure B.55: Anchor strike risk vs burial depth, SouthKP12toEnd.

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B.2.11. Anchor strike probability tables for buried cables, by section

Table B.29: RP for burial depths, layered soil, table 1 of 3.

Depth (m)	SouthKP00toKP0_-6	SouthKP0_-6toKP01	SouthKP01toKP1_-7	SouthKP1_-7toKP02	SouthKP02toKP03
0.00	8319911	13819217	8878898	5814072	2146871
0.25	8319911	13819217	8878898	5814072	2146871
0.50	8319911	13819217	8878898	5814072	2146871
0.75	8319911	13819217	8878898	5814072	2146871
1.00	8319911	Inf	Inf	5814072	2146871
1.25	8319911	Inf	Inf	5814072	2146871
1.50	8319911	Inf	Inf	5814072	2146871
1.75	Inf	Inf	Inf	5814072	2146871
2.00	Inf	Inf	Inf	5814072	2146871
2.25	Inf	Inf	Inf	Inf	Inf
2.50	Inf	Inf	Inf	Inf	Inf
2.75	Inf	Inf	Inf	Inf	Inf
3.00	Inf	Inf	Inf	Inf	Inf
3.25	Inf	Inf	Inf	Inf	Inf
3.50	Inf	Inf	Inf	Inf	Inf
3.75	Inf	Inf	Inf	Inf	Inf

Table B.30: RP for burial depths, layered soil, table 2 of 3.

Depth (m)	SouthKP03toKP04	SouthKP04toKP07	SouthKP07toKP09	SouthKP09toKP10	SouthKP10toKP12
0.00	2518291	3766218	696422	3226832	473909
0.25	2518291	3766218	696422	3226832	473909
0.50	2518291	3766218	696422	3226832	473909
0.75	2518291	187567638	696422	268242842	473909
1.00	2518291	Inf	696422	Inf	473909
1.25	2518291	Inf	696422	Inf	473909
1.50	2518291	Inf	696422	Inf	473909
1.75	2518291	Inf	696422	Inf	473909
2.00	2518291	Inf	696422	Inf	473909
2.25	82303637	Inf	149201486	Inf	38950311
2.50	82303637	Inf	149201486	Inf	38950311
2.75	141102779	Inf	149201486	Inf	181784650
3.00	141102779	Inf	149201486	Inf	Inf
3.25	141102779	Inf	Inf	Inf	Inf

Depth (m)	SouthKP03toKP04	SouthKP04toKP07	SouthKP07toKP09	SouthKP09toKP10	SouthKP10toKP12
3.50	Inf	Inf	Inf	Inf	Inf
3.75	Inf	Inf	Inf	Inf	Inf

Table B.31: RP for burial depths, layered soil, table 3 of 3.

Depth (m)	SouthKP12toEnd
0.00	942822
0.25	942822
0.50	942822
0.75	942822
1.00	942822
1.25	942822
1.50	942822
1.75	942822
2.00	942822
2.25	Inf
2.50	Inf
2.75	Inf
3.00	Inf
3.25	Inf
3.50	Inf
3.75	Inf

B.2.12. Anchor strike probability graphs for buried cables, total cable length

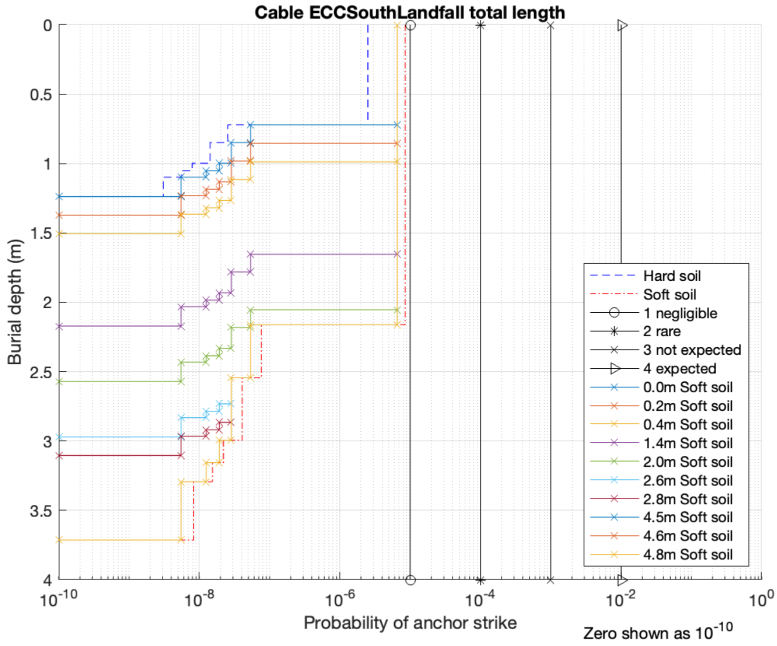


Figure B.56: Anchor strike risk vs burial depth, Cable ECCSouthLandfall.

B.2.13. Anchor strike probability tables for buried cables, entire length

Table B.32: RP for burial depths, total cable length, ECCSouthLandfall.

Depth (m)	**Layered soil**
0.00	153324
0.25	153324
0.50	153324
0.75	153324
1.00	153324
1.25	153324
1.50	153324
1.75	153324
2.00	153324
2.25	18661734
2.50	18661734
2.75	35059598
3.00	51839275
3.25	79440440
3.50	181784650
3.75	Inf

B.3. CBRA probability reports - Cable ECC1 KP13 to KP46

B.3.1. Cable layout overview

An overview of the cable layout and sections analysed is shown in figure B.57.

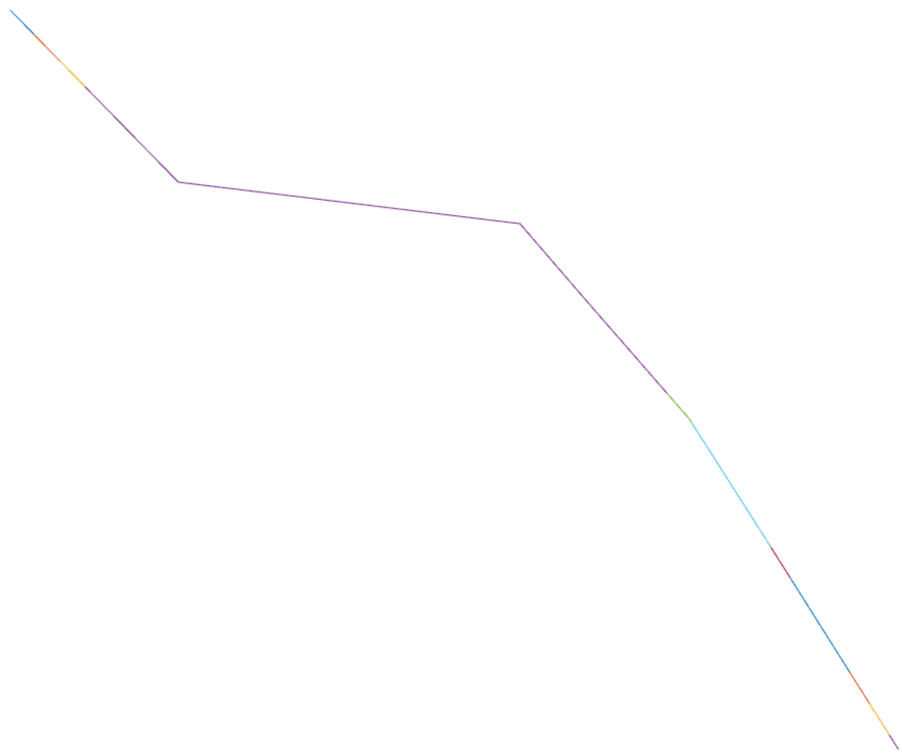


Figure B.57: Overview of cable layout and sections analysed.

B.3.2. Vessel movement

Vessel movement has been assessed using [1].

An overview of cable layout with vessel movements is shown on Figure B.58.

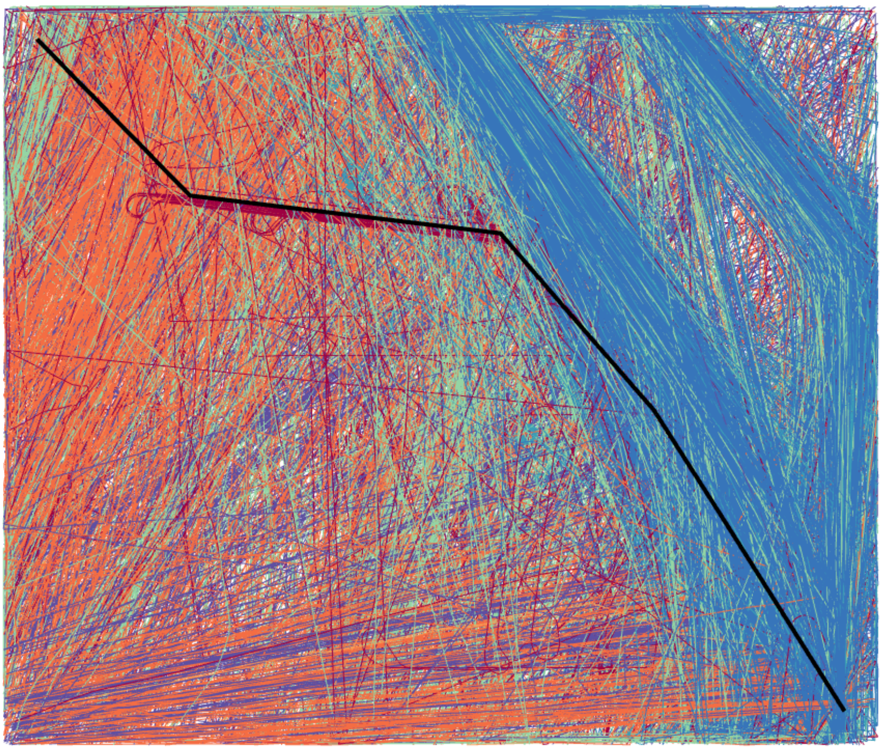


Figure B.58: Overview of cable layout with vessel movements.

AIS data date range is 01 Jan 2019 to 31 Dec 2019, and 01 Jan 2022 to 31 Dec 2022, covering a period of 2.0 years.

Table B.33 provides a summary of the vessels crossing all cables. Sections B.3.8 and B.3.9 details the number of vessels crossing each individual cable for each vessel size over the data set period.

Table B.33: Vessel classifications. Number of vessels and crossings are based on the full period of the AIS data set.

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, Hazardous category A	71	12	58	97544
Cargo, Hazardous category B	72	2	7	103206
Cargo, Hazardous category C	73	1	1	170551
Cargo, Hazardous category D	74	5	12	120393
Cargo, No additional information	79	16	42	98473
Cargo, all ships of this type	70	359	1297	138173
Dredging or underwater ops	33	3	5	1544
Fishing	30	207	846	9005

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
High speed craft (HSC), all ships of this type	40	1	1	248
Other Type, all ships of this type	90	66	233	4308
Passenger, No additional information	69	1	3	313
Passenger, all ships of this type	60	34	57	102248
Pleasure Craft	37	878	1243	32058
Port Tender	53	1	1	2
Reserved	38	1	1	168
Sailing	36	251	275	559
Spare - Local Vessel	56	6	22	40313
Tanker, Hazardous category B	82	3	4	18119
Tanker, Hazardous category D	84	1	2	45756
Tanker, all ships of this type	80	84	253	94366
Towing	31	172	876	1893
Towing: length exceeds 200m or breadth exceeds 25m	32	2	9	494
Tug	52	7	26	1132
Unknown	0	9	24	40313

The most common vessels were:

- FUGRO BRASILIS, Other Type, all ships of this type class, 1652 tonnes, 74 crossings
- EXPLORER, Towing class, 971 tonnes, 65 crossings
- DOLE COLOMBIA, Cargo, all ships of this type class, 32510 tonnes, 56 crossings
- CAPT JEFF, Fishing class, 44 tonnes, 52 crossings
- CHIQUITA PASSION, Cargo, all ships of this type class, 42436 tonnes, 51 crossings

The largest vessels were:

- MEISHAN BRIDGE, Cargo, Hazardous category C class, 170551 tonnes, 1 crossings
- HYUNDAI MERCURY, Cargo, all ships of this type class, 138173 tonnes, 1 crossings
- MSC ESTHI, Cargo, all ships of this type class, 134717 tonnes, 2 crossings
- CSCL AMERICA, Cargo, all ships of this type class, 132445 tonnes, 2 crossings
- MSC RACHELE, Cargo, all ships of this type class, 132445 tonnes, 1 crossings

B.3.3. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely “soft” or “hard”. This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material [17].

The two-layered approach adopted in this section considers the case where a layer of soft soil has been deposited over stiffer material. This model does not consider the case where hard soil is overlying soft soil. Soft soil is defined as cohesive soil with an undrained shear strength less than 40kPa.

Table B.34 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely thick hard and soft soil.

Table B.34: Anchor model.

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-18	30	4096.5	1.6	1.14	3.41	409.2	146.9
2	18-35	60	6576.8	1.9	1.34	4.02	617.7	237.6
3	35-52	89	8675.3	2.1	1.47	4.42	786.0	314.8
4	52-70	119	10558.8	2.2	1.58	4.73	932.4	384.3
5	70-88	149	12297.2	2.3	1.66	4.98	1064.6	448.7
6	88-105	178	13927.9	2.5	1.73	5.20	1186.4	509.2
7	105-122	208	15474.3	2.5	1.80	5.39	1300.1	566.7
8	122-140	238	16951.9	2.6	1.86	5.57	1407.5	621.7
9	140-158	268	18372.0	2.7	1.91	5.72	1509.5	674.7
10	158-175	298	19742.8	2.8	1.96	5.87	1607.0	725.8

DWT is estimated from (dimensions in metres, DWT in tonnes):

$$DWT = max \begin{cases} (length/5.32)^{(1/0.351)} & \text{ref [5], fig 1.3} \\ length \times width \times draught \times 0.7 \times 1.025/1.7 & \text{ref [5], fig 1.2} \end{cases} \quad \text{(B.17)}$$

Displacement is taken as $1.7 \times DWT$ (ref [5]), adopting container ship parameters.

Anchor mass is estimated from ref [7], fig 9.2.

Fluke length is estimated from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \quad \text{(B.18)}$$

Anchor penetration is based on soil type (ref [27]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \quad \text{(B.19)}$$

Anchor penetration for the two-layered soil model is calculated using Equation B.20 and the schematic outlined in Figure B.59 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \tag{B.20}$$

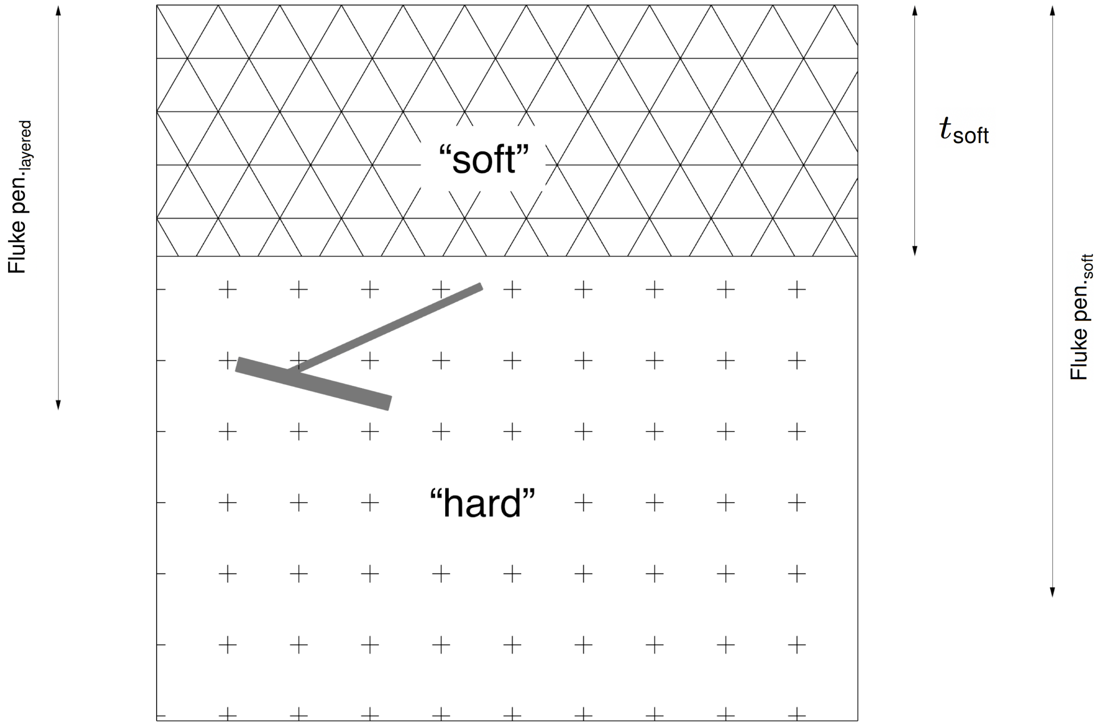


Figure B.59: Two-layered soil anchor penetration calculation schematic.

Ultimate holding capacity (UHC) is based on soil type, (UHC in kN and penetration in metres) and calculated using Equation B.21.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{B.21}$$

Figures B.60 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on Figure B.61.

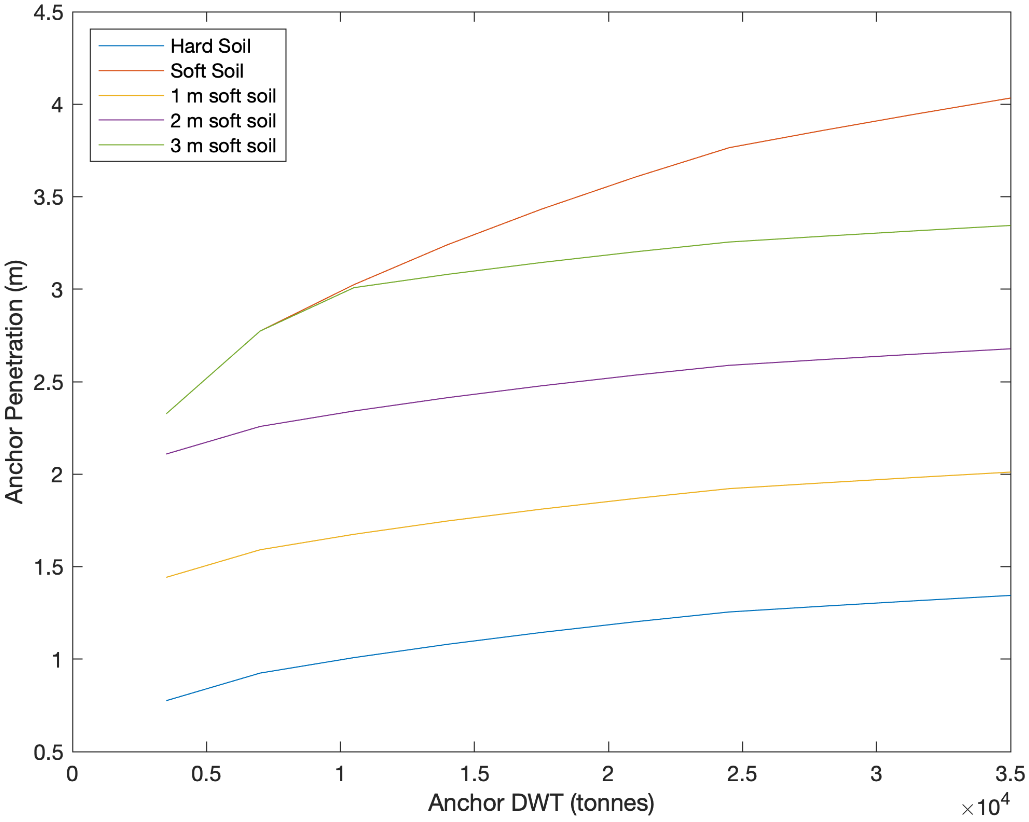


Figure B.60: Anchor penetration for various thicknesses of soft soil.

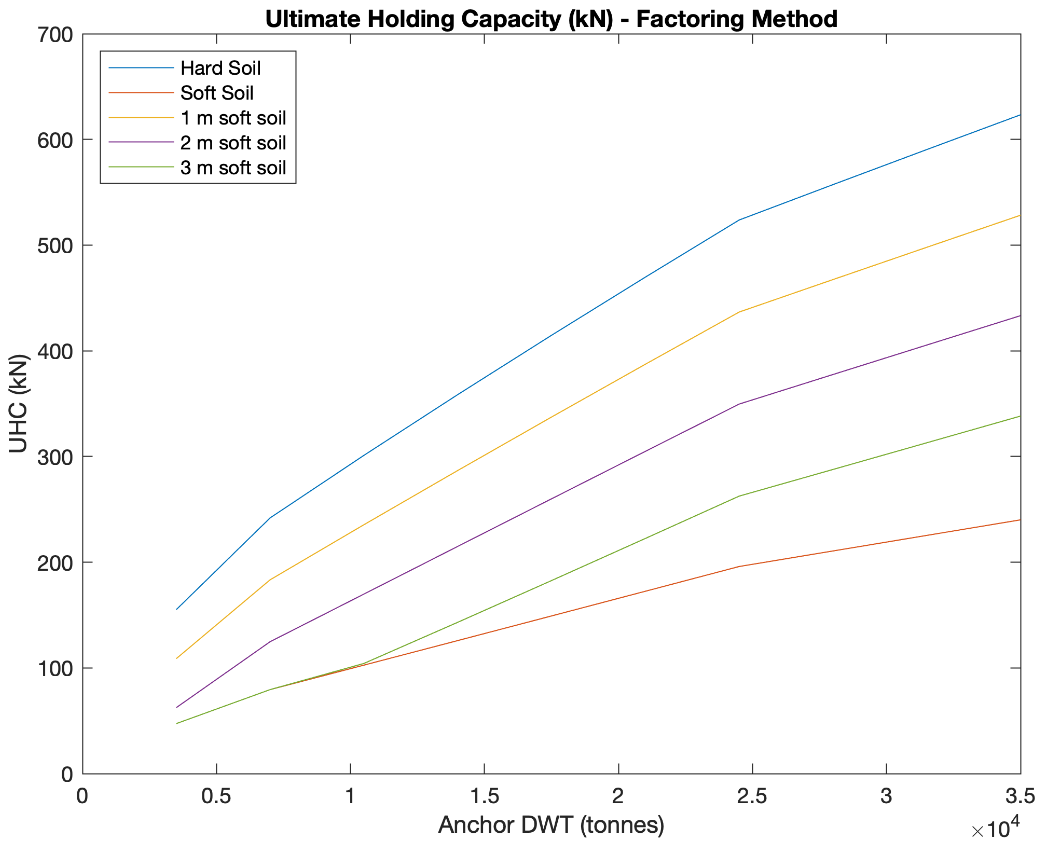


Figure B.61: UHC for various thicknesses of soft soil.

Table B.35 shows the ship model used.

D_{ship}, the estimate of distance an anchor is dragged, is calculated using Equation B.22 (ref [31]), D_{ship} in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{Disp \times 0.51444(v_{ship})^2}{4UHC} \tag{B.22}$$

Table B.35: Ship model.

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-18	4.0	1.0	0.9	0.0100	76.96	214.43
2	18-35	4.0	1.0	0.9	0.0100	101.97	265.11
3	35-52	4.0	1.0	0.9	0.0100	120.21	300.14
4	52-70	4.0	1.0	0.9	0.0100	135.10	327.77
5	70-88	4.0	1.0	0.9	0.0100	147.91	350.94
6	88-105	4.0	1.0	0.9	0.0100	159.27	371.08

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
7	105-122	4.0	1.0	0.9	0.0100	169.56	389.01
8	122-140	4.0	1.0	0.9	0.0100	179.01	405.24
9	140-158	4.0	1.0	0.9	0.0100	187.77	420.12
10	158-175	4.0	1.0	0.9	0.0100	195.98	433.89

B.3.4. Probabilistic anchor strike assessment for surface lay

Table B.36 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in section B.3.9. The highest risk (per km) cables are:

- ECCMain, MainKP16toKP35, RPhard 8924 yr/km, RPsoft 3240 yr/km
- ECCMain, MainKP36toKP40, RPhard 86110 yr/km, RPsoft 33008 yr/km
- ECCMain, MainKP41toKP44, RPhard 142885 yr/km, RPsoft 54333 yr/km
- ECCMain, MainKP40toKP41, RPhard 923538 yr/km, RPsoft 355461 yr/km
- ECCMain, MainKP44toKP45, RPhard 1206013 yr/km, RPsoft 455632 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [7]), D_{ship} in m, v_{ship} in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \tag{B.23}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is ($P_{s.n}$ is the P_{strike} of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \tag{B.24}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table B.36: Surface lay probabilistic assessment.

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCMain	MainKP13toKP14	1666833 yr, 1836301 yr/km	598219 yr, 659041 yr/km	7
ECCMain	MainKP14toKP15	2027230 yr, 2027229 yr/km	727564 yr, 727564 yr/km	8
ECCMain	MainKP15toKP16	2193202 yr, 2193202 yr/km	787131 yr, 787131 yr/km	9
ECCMain	MainKP16toKP35	169556 yr, 8924 yr/km	61560 yr, 3240 yr/km	1
ECCMain	MainKP35toKP36	2723609 yr, 2723609 yr/km	1022926 yr, 1022926 yr/km	10
ECCMain	MainKP36toKP40	344438 yr, 86110 yr/km	132031 yr, 33008 yr/km	2
ECCMain	MainKP40toKP41	923538 yr, 923538 yr/km	355461 yr, 355461 yr/km	4

Cable	Section	Hard soil return period	Soft soil return period	Rank
ECCMain	MainKP41toKP44	428656 yr, 142885 yr/km	162999 yr, 54333 yr/km	3
ECCMain	MainKP44toKP45	1206013 yr, 1206013 yr/km	455632 yr, 455632 yr/km	5
ECCMain	MainKP45toKP46	1240237 yr, 1240237 yr/km	469541 yr, 469541 yr/km	6
ECCMain	MainKP46toEnd	3007479 yr, 6425639 yr/km	1132441 yr, 2419520 yr/km	11

B.3.5. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table B.34 is less than the depth considered. Table B.37 shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section B.3.10 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

B.3.6. Results for one-layered soil

Table B.37: Burial depths to achieve target frequencies.

Cable	Section	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCMain	MainKP13toKP14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP14toKP15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP15toKP16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP16toKP35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4
ECCMain	MainKP35toKP36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP36toKP40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP40toKP41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP41toKP44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP44toKP45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP45toKP46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ECCMain	MainKP46toEnd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table B.38 shows the total anchor strike risk over the total length of the surface laid cable.

Table B.38: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Soft soil return period	Rank
ECCMain	62108 yr	23112 yr	1

Table B.39 shows the required burial depths to achieve certain target frequencies

Table B.39: Burial depths to achieve target frequencies, total cable.

Cable	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
ECCMain	0.0	0.0	0.0	0.0	0.0	0.0	1.1	4.0

Section B.3.12 shows the anchor strike frequency for buried cables assessed over the total length, with zero frequency taken as 10^{-10} for plotting purposes.

B.3.7. Results for two-layered soil

Table B.40 shows calculated return periods for each cable for the two-layered soil approach.

Table B.40: Two-layered soil model summary.

Cable	Section	Soft soil thickness (m)	Return period	Return period per km
ECCMain	MainKP13toKP14	4.8	598219 yr	659041 yr/km
ECCMain	MainKP14toKP15	0	2027230 yr	2027229 yr/km
ECCMain	MainKP15toKP16	2	1369687 yr	1369687 yr/km
ECCMain	MainKP16toKP35	0	169556 yr	8924 yr/km
ECCMain	MainKP35toKP36	5	1026498 yr	1026498 yr/km
ECCMain	MainKP36toKP40	0	344438 yr	86110 yr/km
ECCMain	MainKP40toKP41	1	780808 yr	780808 yr/km
ECCMain	MainKP41toKP44	0	428656 yr	142885 yr/km
ECCMain	MainKP44toKP45	2.8	645964 yr	645964 yr/km
ECCMain	MainKP45toKP46	3.2	585695 yr	585695 yr/km
ECCMain	MainKP46toEnd	0	3007479 yr	6425639 yr/km

Table B.41 shows the required burial depth to achieve the target return frequency using the two-layered soil model. Target frequencies are the same as defined in section C.2.5.

Table B.41: Burial depths to achieve target frequencies.

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
ECCMain	MainKP13toKP14	4.8	0.0	0.0	0.0	0.0

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
ECCMain	MainKP14toKP15	0	0.0	0.0	0.0	0.0
ECCMain	MainKP15toKP16	2	0.0	0.0	0.0	0.0
ECCMain	MainKP16toKP35	0	0.0	0.0	0.0	0.0
ECCMain	MainKP35toKP36	5	0.0	0.0	0.0	0.0
ECCMain	MainKP36toKP40	0	0.0	0.0	0.0	0.0
ECCMain	MainKP40toKP41	1	0.0	0.0	0.0	0.0
ECCMain	MainKP41toKP44	0	0.0	0.0	0.0	0.0
ECCMain	MainKP44toKP45	2.8	0.0	0.0	0.0	0.0
ECCMain	MainKP45toKP46	3.2	0.0	0.0	0.0	0.0
ECCMain	MainKP46toEnd	0	0.0	0.0	0.0	0.0

Table B.42 shows the total anchor strike risk over the total length of the surface laid cable for the two-layered soil approach.

Table B.42: Total cable surface lay probabilistic assessment.

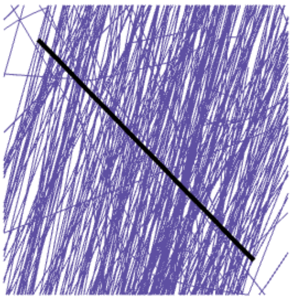
Cable	Hard soil return period	Two-Layered soil return period	Soft soil return period	Rank
ECCMain	62108 yr	50323 yr	23112 yr	1

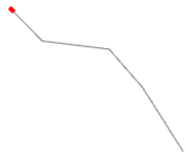
Table B.43 shows the required burial depths to achieve certain target frequencies for the total cable length using the two-layered soil approach for each soft soil thickness.

Table B.43: Burial depths to achieve target frequencies, total cable.

Cable	Soft Soil Thickness	Cable length (km)	Two-Layered Soil, 1.0e-02	Two-Layered Soil, 1.0e-03	Two-Layered Soil, 1.0e-04	Two-Layered Soil, 1.0e-05
ECCMain	0.0	27.47	0.0	0.0	0.0	1.1
ECCMain	1.0	1.00	0.0	0.0	0.0	1.8
ECCMain	2.0	1.00	0.0	0.0	0.0	2.5
ECCMain	2.8	1.00	0.0	0.0	0.0	3.0
ECCMain	3.2	1.00	0.0	0.0	0.0	3.3
ECCMain	4.8	0.91	0.0	0.0	0.0	3.4
ECCMain	5.0	1.00	0.0	0.0	0.0	3.4

B.3.8. Vessel movement maps





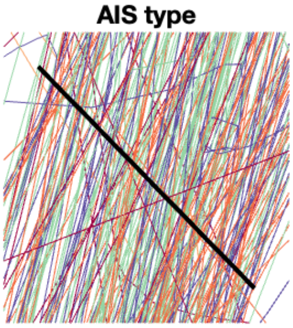


Figure B.62: Vessel movement,Cable ECCMain, MainKP13toKP14.

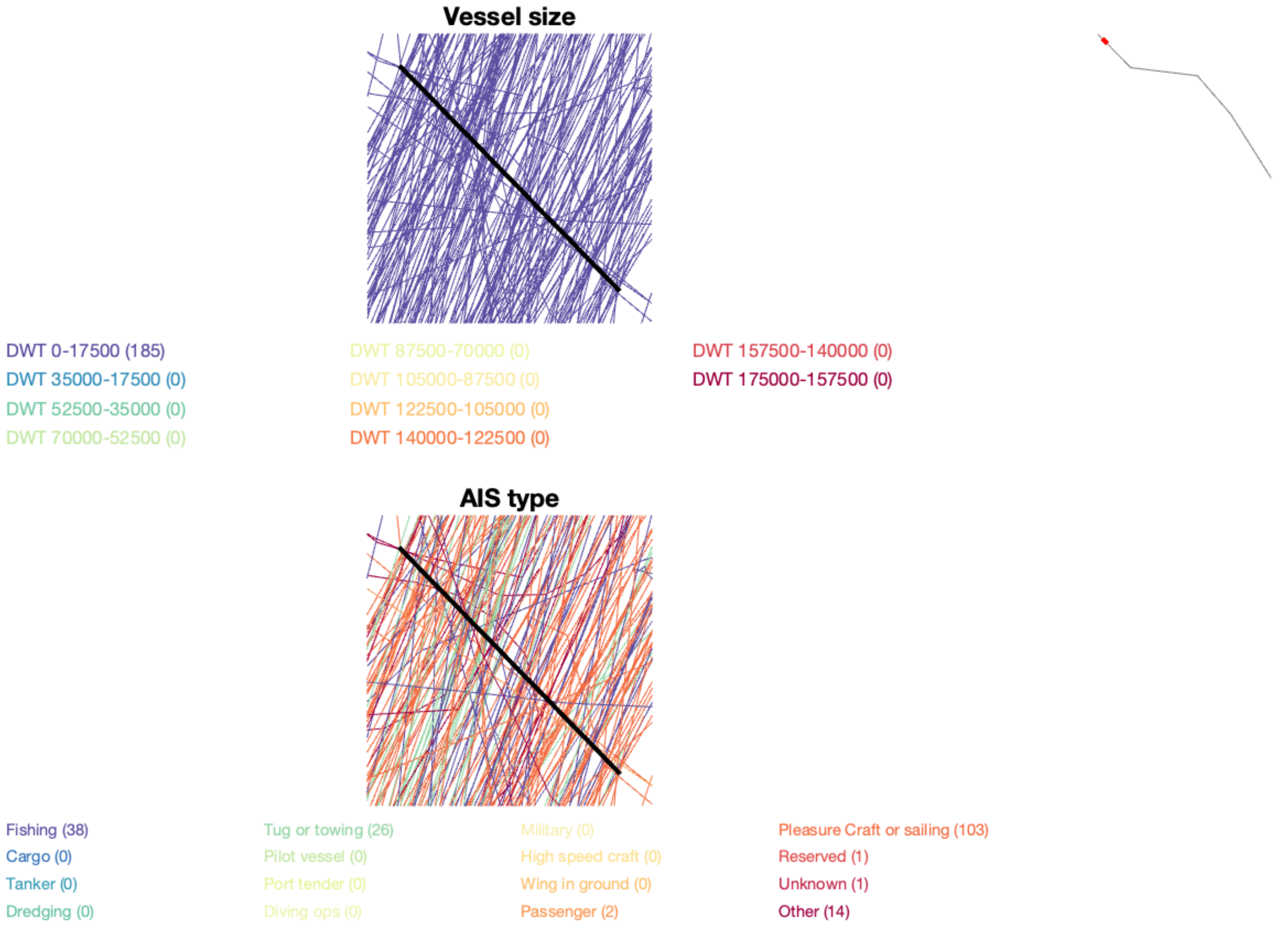
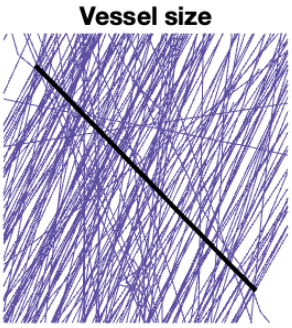
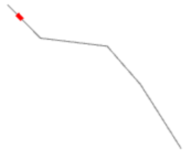
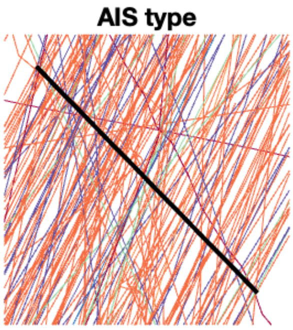


Figure B.63: Vessel movement,Cable ECCMain, MainKP14toKP15.





DWT 0-17500 (171)
DWT 35000-17500 (0)
DWT 52500-35000 (0)
DWT 70000-52500 (0)
DWT 87500-70000 (0)
DWT 105000-87500 (0)
DWT 122500-105000 (0)
DWT 140000-122500 (0)
DWT 157500-140000 (0)
DWT 175000-157500 (0)



Fishing (32)
Cargo (1)
Tanker (0)
Dredging (0)
Tug or towing (9)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (2)
Pleasure Craft or sailing (122)
Reserved (0)
Unknown (1)
Other (4)

Figure B.64: Vessel movement,Cable ECCMain, MainKP15toKP16.

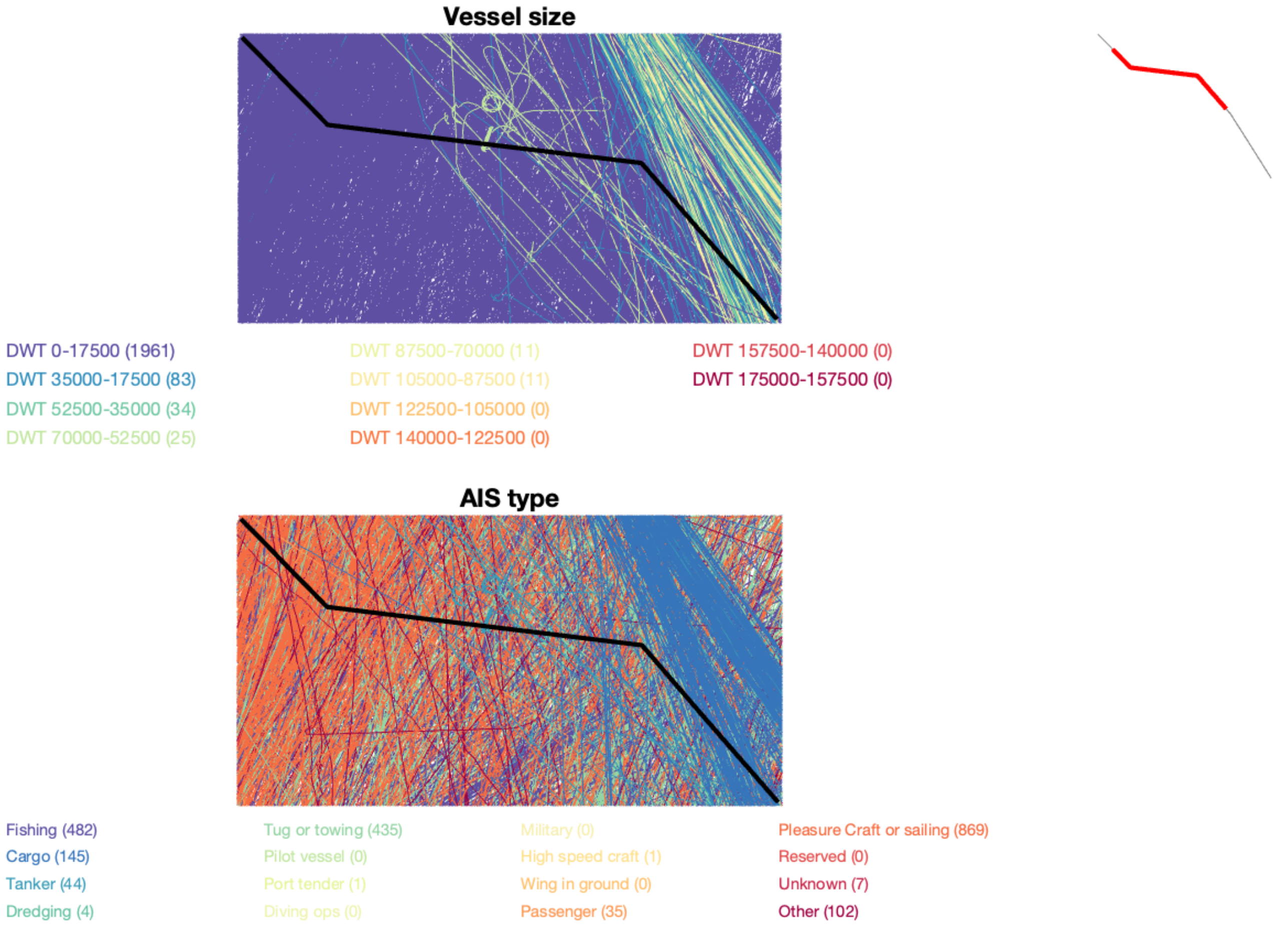
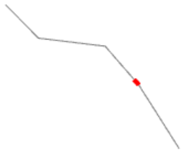


Figure B.65: Vessel movement,Cable ECCMain, MainKP16toKP35.

Vessel size



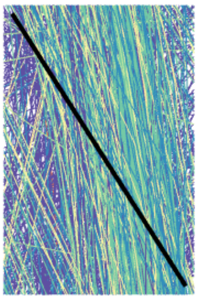
DWT 0-17500 (80)
DWT 35000-17500 (17)
DWT 52500-35000 (10)
DWT 70000-52500 (3)
DWT 87500-70000 (4)
DWT 105000-87500 (1)
DWT 122500-105000 (1)
DWT 140000-122500 (1)
DWT 157500-140000 (0)
DWT 175000-157500 (0)

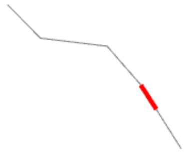
AIS type

Fishing (24)
Cargo (31)
Tanker (8)
Dredging (0)
Tug or towing (26)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (0)
Pleasure Craft or sailing (14)
Reserved (0)
Unknown (1)
Other (13)

Figure B.66: Vessel movement,Cable ECCMain, MainKP35toKP36.

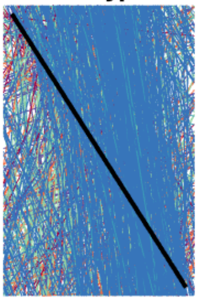
Vessel size





DWT 0-17500 (376)
DWT 35000-17500 (246)
DWT 52500-35000 (143)
DWT 70000-52500 (27)
DWT 87500-70000 (30)
DWT 105000-87500 (26)
DWT 122500-105000 (0)
DWT 140000-122500 (2)
DWT 157500-140000 (0)
DWT 175000-157500 (0)

AIS type



Fishing (74)
Cargo (448)
Tanker (80)
Dredging (0)
Tug or towing (123)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (2)
Pleasure Craft or sailing (84)
Reserved (0)
Unknown (9)
Other (30)

Figure B.67: Vessel movement,Cable ECCMain, MainKP36toKP40.

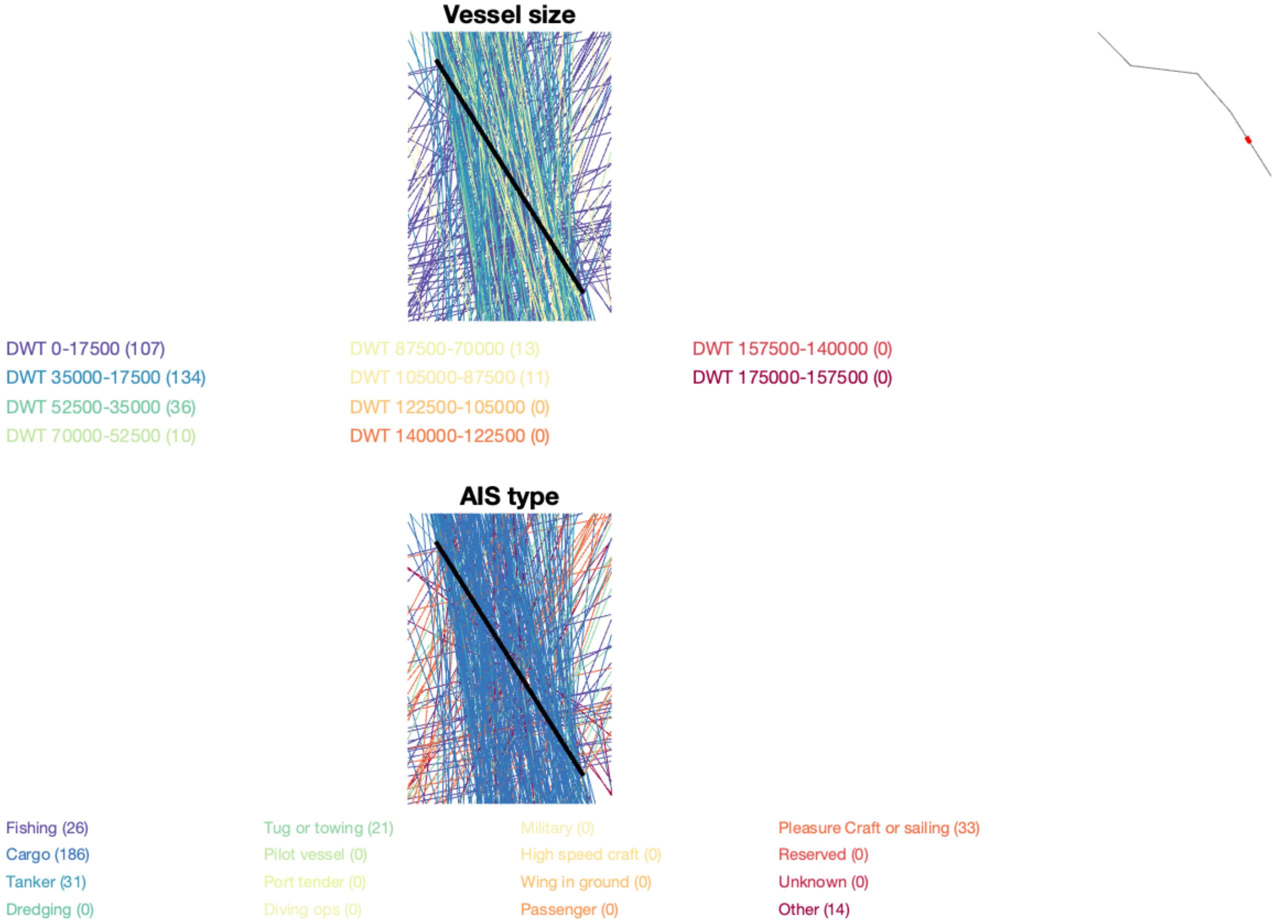


Figure B.68: Vessel movement,Cable ECCMain, MainKP40toKP41.

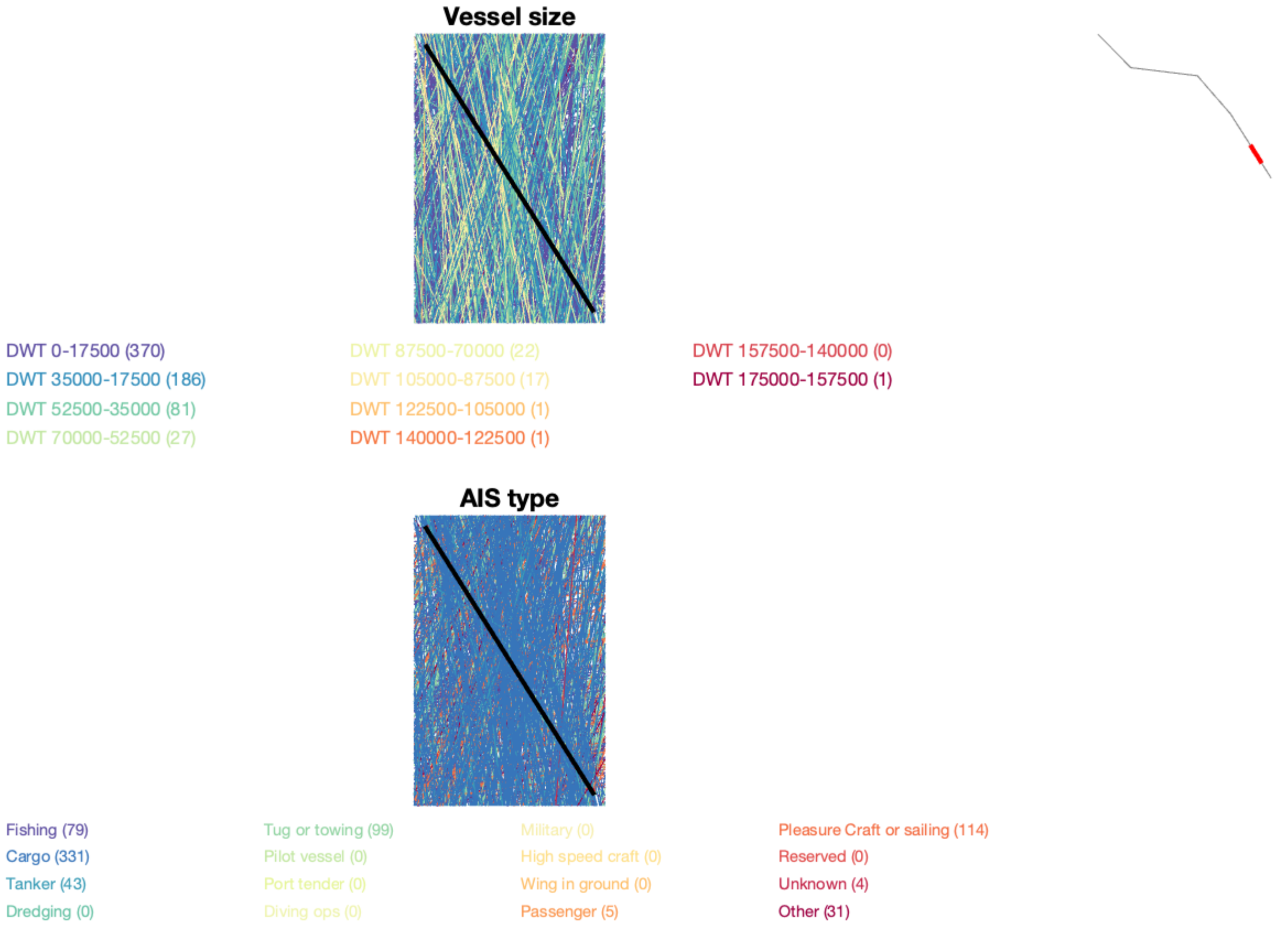


Figure B.69: Vessel movement,Cable ECCMain, MainKP41toKP44.

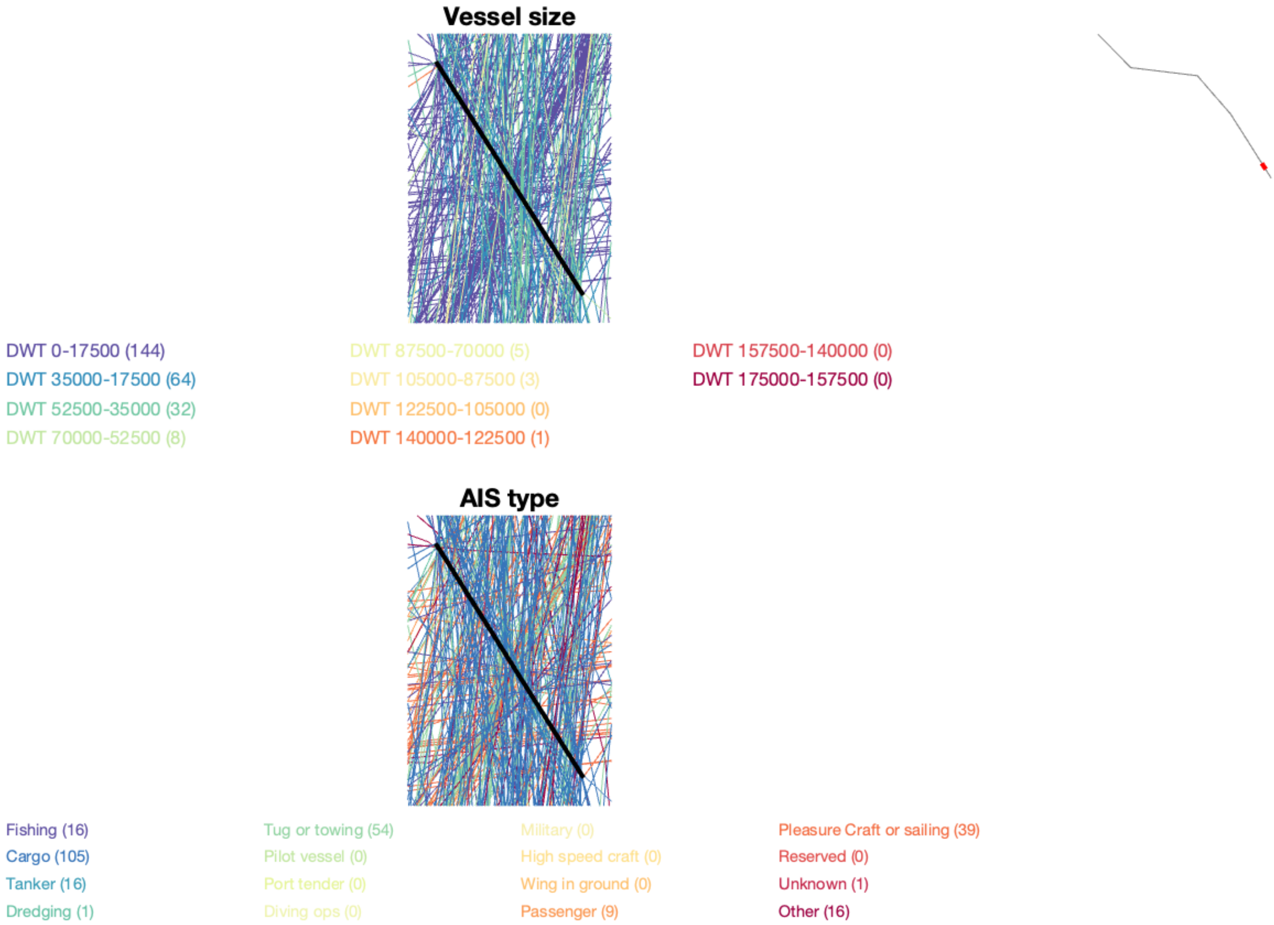
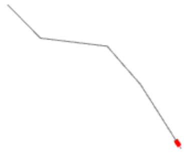


Figure B.70: Vessel movement,Cable ECCMain, MainKP44toKP45.



Vessel size

AIS type

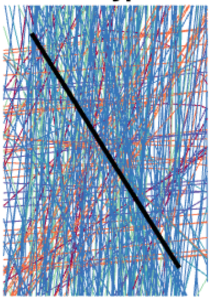


Figure B.71: Vessel movement,Cable ECCMain, MainKP45toKP46.

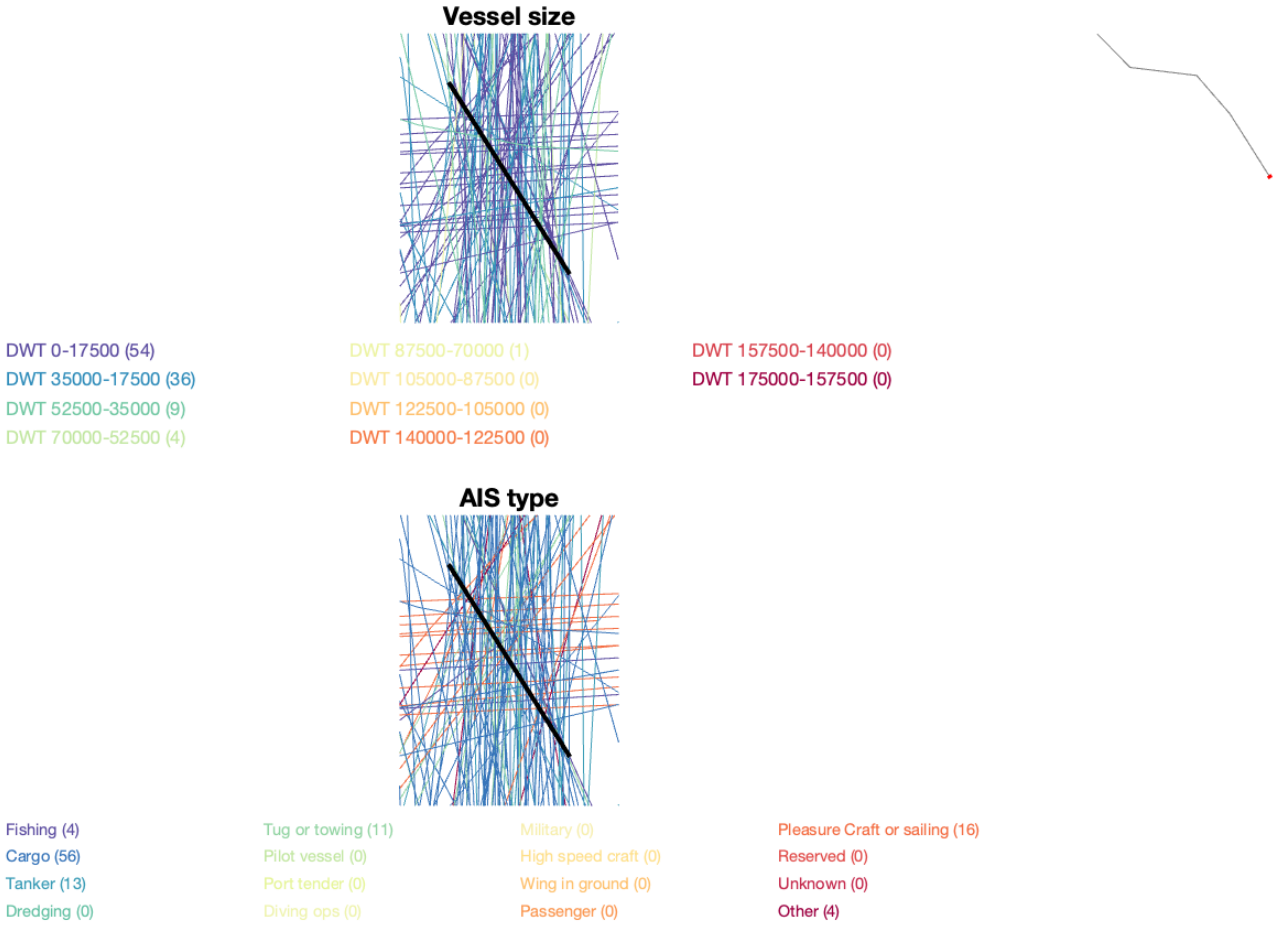


Figure B.72: Vessel movement,Cable ECCMain, MainKP46toEnd.

B.3.9. Full anchor strike assessment for surface lay

Table B.44: Surface lay probabilistic assessment (full results).

Cable	**Section**	**Vessel cat.**	**Vessel count**	**Pstrike hard soil (-)**	**Pstrike soft soil (-)**	**Hard soil** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**	**Soft soil** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**
ECCMain	MainKP13toKP14	1 2 3 4 5 6 7 8 9 10	225 0 0 0 0 0 0 0 0 0	6.00e-07 0 0 0 0 0 0 0 0 0	1.67e-06 0 0 0 0 0 0 0 0 0	6.00e-07 1666833 yr 1836301 yr/km	1.67e-06 598219 yr 659041 yr/km
ECCMain	MainKP14toKP15	1 2 3 4 5 6 7 8 9 10	185 0 0 0 0 0 0 0 0 0	4.93e-07 0 0 0 0 0 0 0 0 0	1.37e-06 0 0 0 0 0 0 0 0 0	4.93e-07 2027230 yr 2027229 yr/km	1.37e-06 727564 yr 727564 yr/km
ECCMain	MainKP15toKP16	1 2 3 4 5 6 7 8 9 10	171 0 0 0 0 0 0 0 0 0	4.56e-07 0 0 0 0 0 0 0 0 0	1.27e-06 0 0 0 0 0 0 0 0 0	4.56e-07 2193202 yr 2193202 yr/km	1.27e-06 787131 yr 787131 yr/km
ECCMain	MainKP16toKP35	1 2 3 4 5 6 7 8 9 10	1961 83 34 25 11 11 0 0 0 0	5.23e-06 2.93e-07 1.42e-07 1.17e-07 5.64e-08 6.07e-08 0 0 0 0	1.46e-05 7.62e-07 3.54e-07 2.84e-07 1.34e-07 1.41e-07 0 0 0 0	5.90e-06 169556 yr 8924 yr/km	1.62e-05 61560 yr 3240 yr/km

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
ECCMain	MainKP35toKP36	1 2 3 4 5 6 7 8 9 10	80 17 10 3 4 1 1 1 0 0	2.13e-07 6.01e-08 4.17e-08 1.40e-08 2.05e-08 5.52e-09 5.87e-09 6.20e-09 0 0	5.94e-07 1.56e-07 1.04e-07 3.41e-08 4.86e-08 1.29e-08 1.35e-08 1.40e-08 0 0	3.67e-07 2723609 yr 2723609 yr/km	9.78e-07 1022926 yr 1022926 yr/km
ECCMain	MainKP36toKP40	1 2 3 4 5 6 7 8 9 10	376 246 143 27 30 26 0 2 0 0	1.00e-06 8.69e-07 5.96e-07 1.26e-07 1.54e-07 1.43e-07 0 1.24e-08 0 0	2.79e-06 2.26e-06 1.49e-06 3.07e-07 3.65e-07 3.34e-07 0 2.81e-08 0 0	2.90e-06 344438 yr 86110 yr/km	7.57e-06 132031 yr 33008 yr/km
ECCMain	MainKP40toKP41	1 2 3 4 5 6 7 8 9 10	107 134 36 10 13 11 0 0 0 0	2.85e-07 4.73e-07 1.50e-07 4.68e-08 6.66e-08 6.07e-08 0 0 0 0	7.95e-07 1.23e-06 3.74e-07 1.14e-07 1.58e-07 1.41e-07 0 0 0 0	1.08e-06 923538 yr 923538 yr/km	2.81e-06 355461 yr 355461 yr/km
ECCMain	MainKP41toKP44	1 2 3 4 5 6 7 8 9 10	370 186 81 27 22 17 1 1 0 1	9.87e-07 6.57e-07 3.37e-07 1.26e-07 1.13e-07 9.38e-08 5.87e-09 6.20e-09 0 6.79e-09	2.75e-06 1.71e-06 8.42e-07 3.07e-07 2.68e-07 2.19e-07 1.35e-08 1.40e-08 0 1.50e-08	2.33e-06 428656 yr 142885 yr/km	6.13e-06 162999 yr 54333 yr/km
ECCMain	MainKP44toKP45	1 2 3 4 5 6 7 8 9 10	144 64 32 8 5 3 0 1 0 0	3.84e-07 2.26e-07 1.33e-07 3.74e-08 2.56e-08 1.66e-08 0 6.20e-09 0 0	1.07e-06 5.88e-07 3.33e-07 9.09e-08 6.08e-08 3.86e-08 0 1.40e-08 0 0	8.29e-07 1206013 yr 1206013 yr/km	2.19e-06 455632 yr 455632 yr/km

Cable	**Section**	**Vessel cat.**	**Vessel count**	**Pstrike hard soil (-)**	**Pstrike soft soil (-)**	**<u>Hard soil</u>** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**	**<u>Soft soil</u>** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**
ECCMain	MainKP45toKP46	1 2 3 4 5 6 7 8 9 10	117 91 26 8 3 1 0 1 0 0	3.12e-07 3.21e-07 1.08e-07 3.74e-08 1.54e-08 5.52e-09 0 6.20e-09 0 0	8.69e-07 8.36e-07 2.70e-07 9.09e-08 3.65e-08 1.29e-08 0 1.40e-08 0 0	8.06e-07 1240237 yr 1240237 yr/km	2.13e-06 469541 yr 469541 yr/km
ECCMain	MainKP46toEnd	1 2 3 4 5 6 7 8 9 10	54 36 9 4 1 0 0 0 0 0	1.44e-07 1.27e-07 3.75e-08 1.87e-08 5.12e-09 0 0 0 0 0	4.01e-07 3.31e-07 9.36e-08 4.54e-08 1.22e-08 0 0 0 0 0	3.33e-07 3007479 yr 6425639 yr/km	8.83e-07 1132441 yr 2419520 yr/km

B.3.10. Anchor strike probability graphs for buried cables

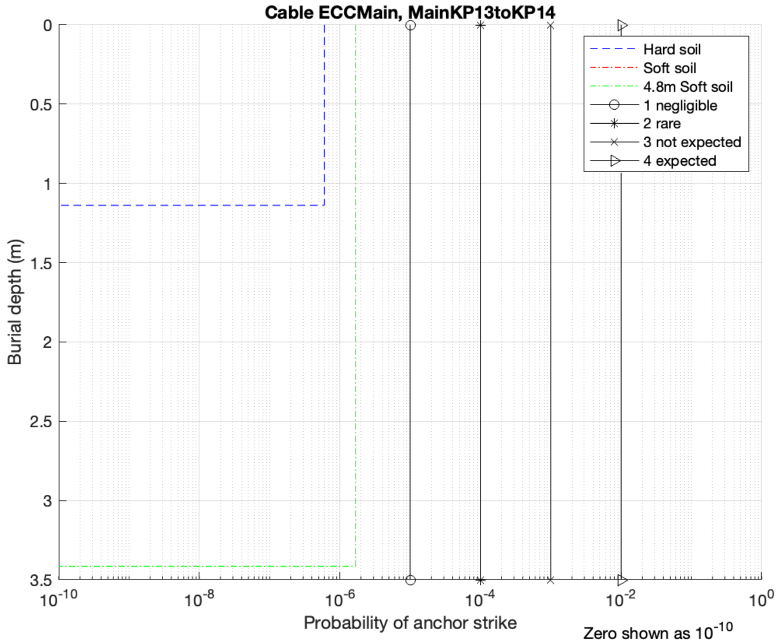


Figure B.73: Anchor strike risk vs burial depth, MainKP13toKP14.

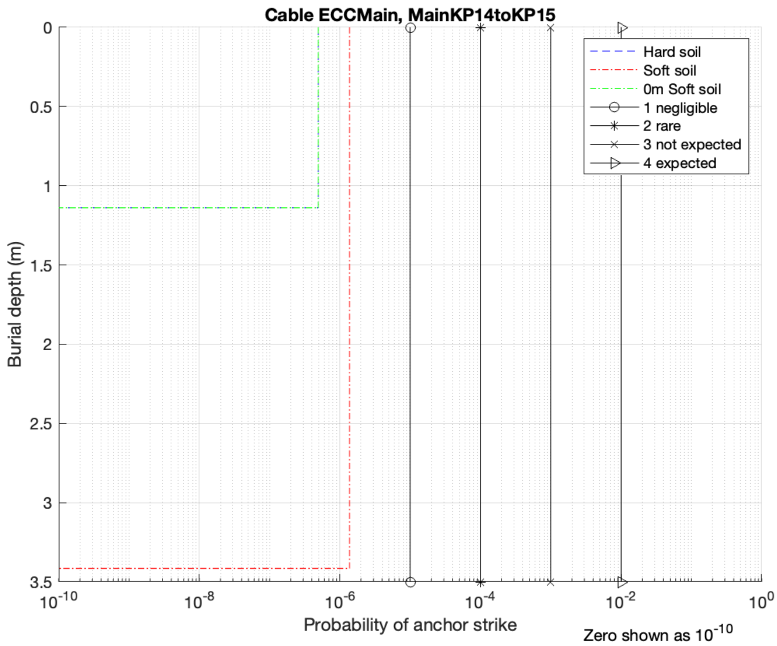


Figure B.74: Anchor strike risk vs burial depth, MainKP14toKP15.

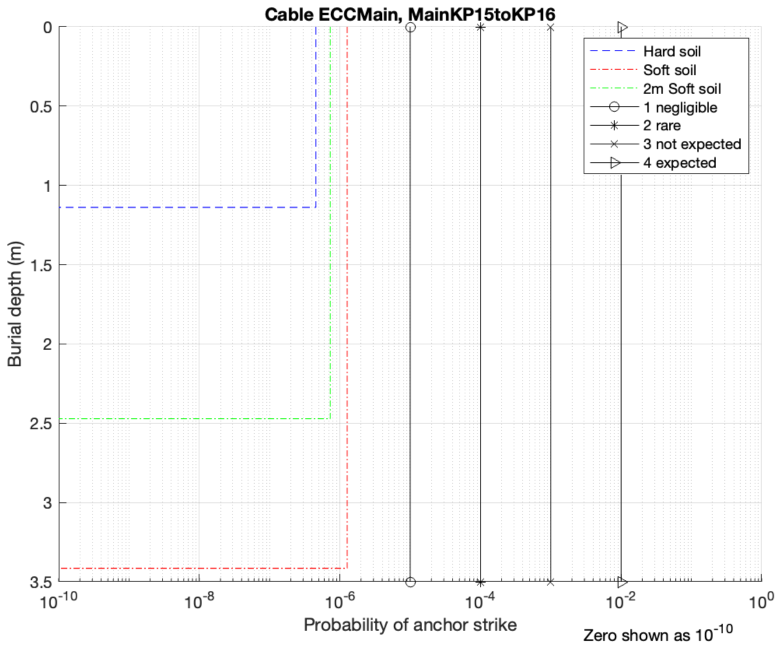


Figure B.75: Anchor strike risk vs burial depth, MainKP15toKP16.

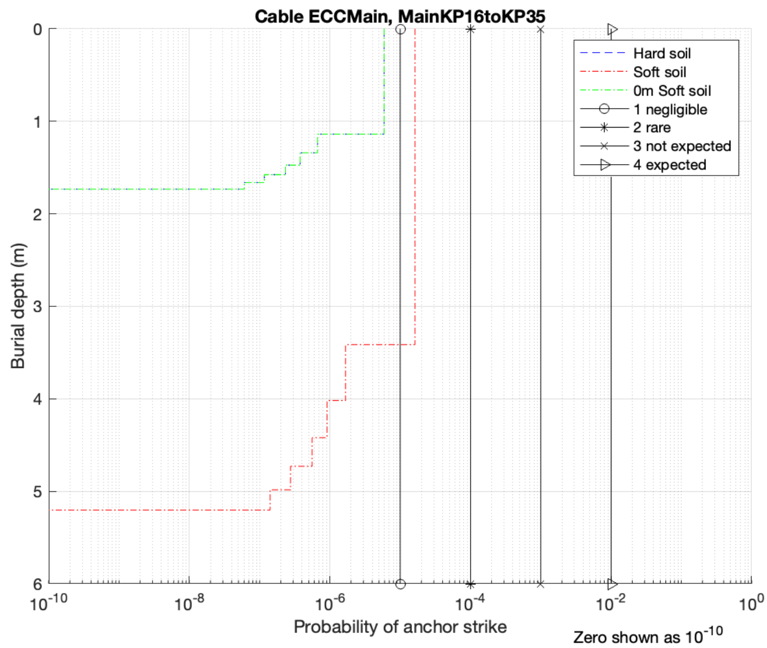


Figure B.76: Anchor strike risk vs burial depth, MainKP16toKP35.

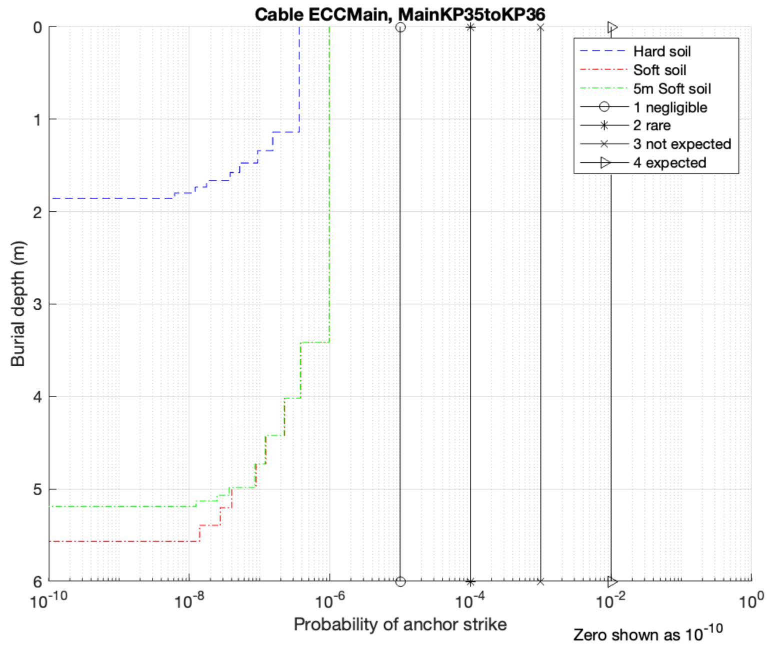


Figure B.77: Anchor strike risk vs burial depth, MainKP35toKP36.

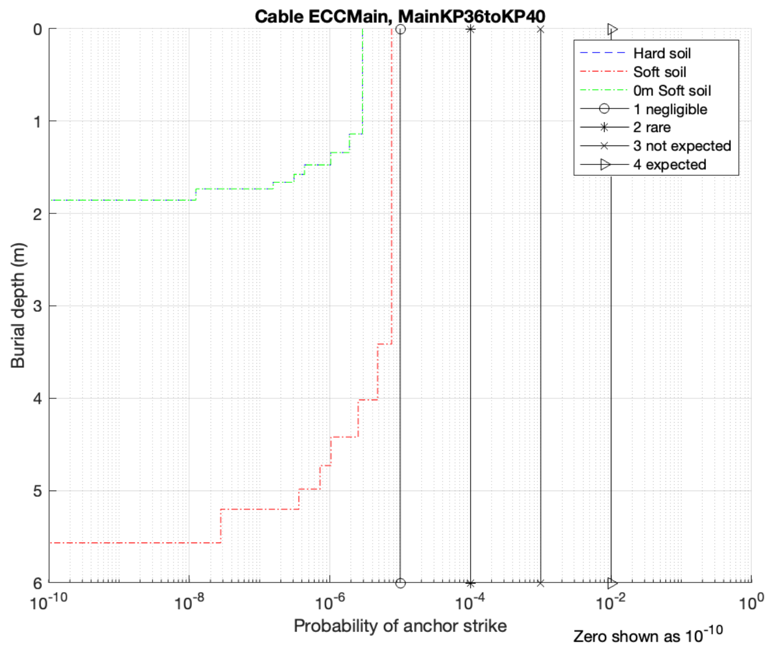


Figure B.78: Anchor strike risk vs burial depth, MainKP36toKP40.

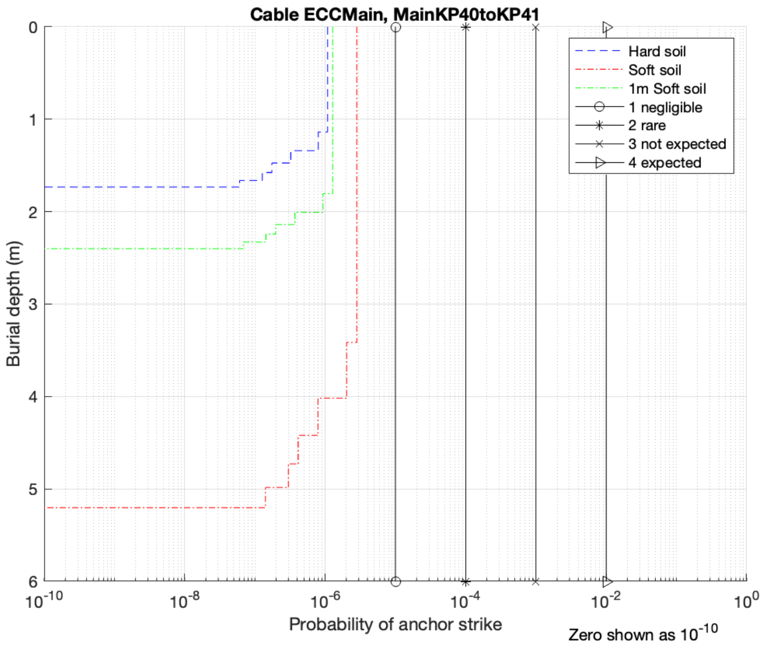


Figure B.79: Anchor strike risk vs burial depth, MainKP40toKP41.

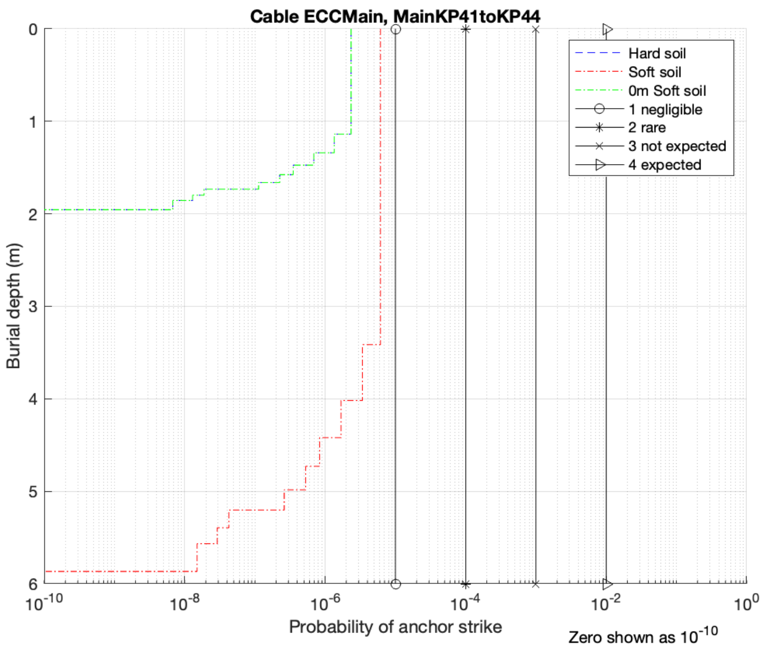


Figure B.80: Anchor strike risk vs burial depth, MainKP41toKP44.

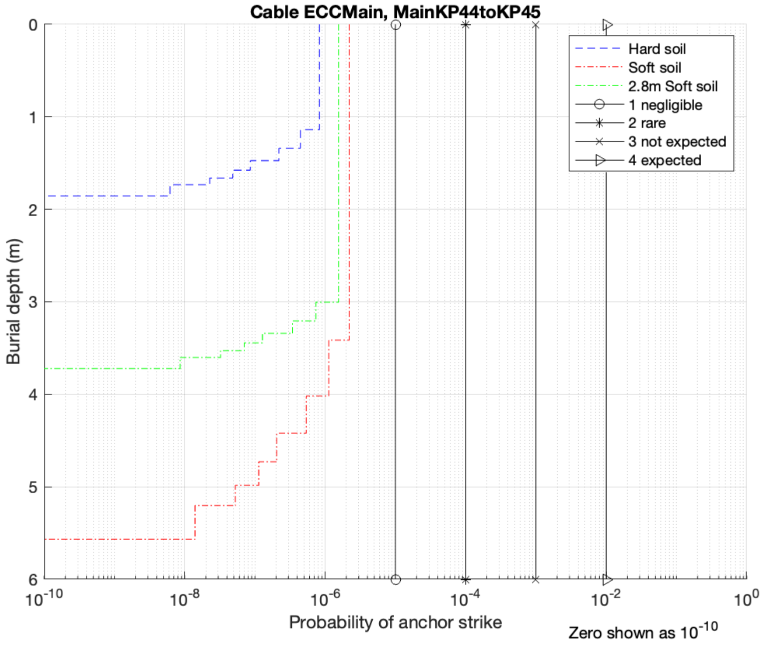


Figure B.81: Anchor strike risk vs burial depth, MainKP44toKP45.

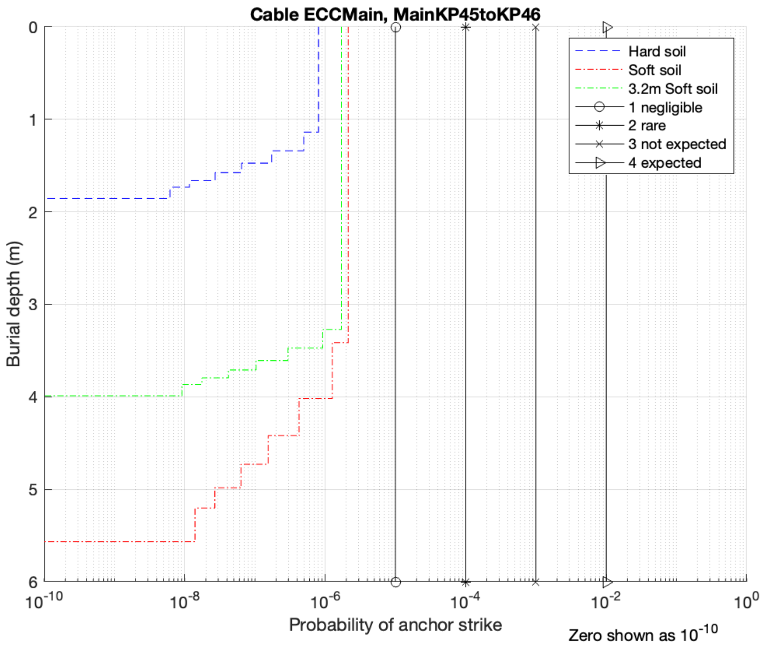


Figure B.82: Anchor strike risk vs burial depth, MainKP45toKP46.

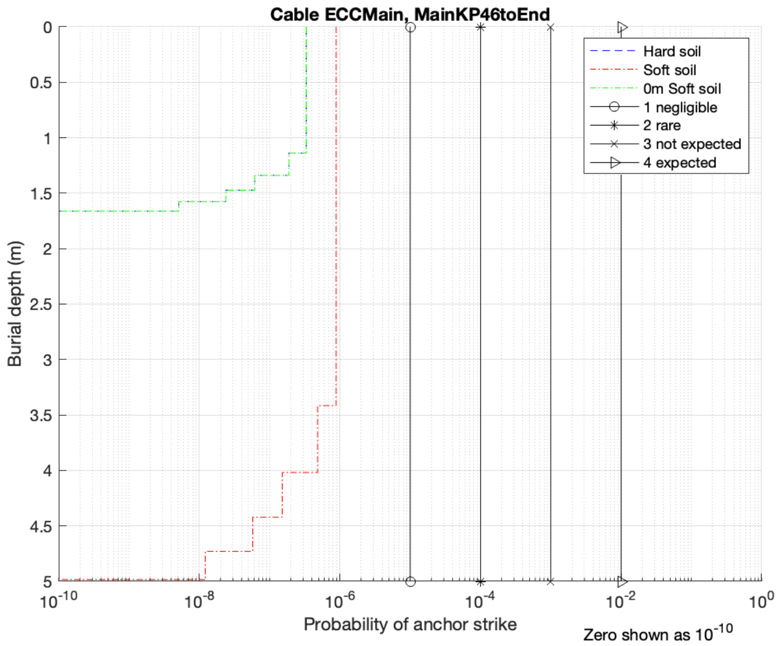


Figure B.83: Anchor strike risk vs burial depth, MainKP46toEnd.

B.3.11. Anchor strike probability tables for buried cables, by section

Table B.45: RP for burial depths, layered soil, table 1 of 3.

Depth (m)	MainKP13toKP14	MainKP14toKP15	MainKP15toKP16	MainKP16toKP35	MainKP35toKP36
0.00	598219	2027230	1369687	169556	1026498
0.25	598219	2027230	1369687	169556	1026498
0.50	598219	2027230	1369687	169556	1026498
0.75	598219	2027230	1369687	169556	1026498
1.00	598219	2027230	1369687	169556	1026498
1.25	598219	Inf	1369687	1494891	1026498
1.50	598219	Inf	1369687	4271631	1026498
1.75	598219	Inf	1369687	Inf	1026498
2.00	598219	Inf	1369687	Inf	1026498
2.25	598219	Inf	1369687	Inf	1026498
2.50	598219	Inf	Inf	Inf	1026498
2.75	598219	Inf	Inf	Inf	1026498
3.00	598219	Inf	Inf	Inf	1026498
3.25	598219	Inf	Inf	Inf	1026498
3.50	Inf	Inf	Inf	Inf	2632757
3.75	Inf	Inf	Inf	Inf	2632757
4.00	Inf	Inf	Inf	Inf	2632757
4.25	Inf	Inf	Inf	Inf	4470745
4.50	Inf	Inf	Inf	Inf	8355396
4.75	Inf	Inf	Inf	Inf	11680431
5.00	Inf	Inf	Inf	Inf	27044914
5.25	Inf	Inf	Inf	Inf	Inf
5.50	Inf	Inf	Inf	Inf	Inf

Table B.46: RP for burial depths, layered soil, table 2 of 3.

Depth (m)	MainKP36toKP40	MainKP40toKP41	MainKP41toKP44	MainKP44toKP45	MainKP45toKP46
0.00	344438	780808	428656	645964	585695
0.25	344438	780808	428656	645964	585695
0.50	344438	780808	428656	645964	585695
0.75	344438	780808	428656	645964	585695
1.00	344438	780808	428656	645964	585695
1.25	526118	780808	742774	645964	585695
1.50	2293475	780808	2842389	645964	585695
1.75	80616481	780808	53001381	645964	585695

Depth (m)	MainKP36toKP40	MainKP40toKP41	MainKP41toKP44	MainKP44toKP45	MainKP45toKP46
2.00	Inf	1075875	Inf	645964	585695
2.25	Inf	6965974	Inf	645964	585695
2.50	Inf	Inf	Inf	645964	585695
2.75	Inf	Inf	Inf	645964	585695
3.00	Inf	Inf	Inf	645964	585695
3.25	Inf	Inf	Inf	2917338	585695
3.50	Inf	Inf	Inf	14188455	3383232
3.75	Inf	Inf	Inf	Inf	23755621
4.00	Inf	Inf	Inf	Inf	Inf
4.25	Inf	Inf	Inf	Inf	Inf
4.50	Inf	Inf	Inf	Inf	Inf
4.75	Inf	Inf	Inf	Inf	Inf
5.00	Inf	Inf	Inf	Inf	Inf
5.25	Inf	Inf	Inf	Inf	Inf
5.50	Inf	Inf	Inf	Inf	Inf

Table B.47: RP for burial depths, layered soil, table 3 of 3.

Depth (m)	MainKP46toEnd
0.00	3007479
0.25	3007479
0.50	3007479
0.75	3007479
1.00	3007479
1.25	5304509
1.50	41930701
1.75	Inf
2.00	Inf
2.25	Inf
2.50	Inf
2.75	Inf
3.00	Inf
3.25	Inf
3.50	Inf
3.75	Inf
4.00	Inf
4.25	Inf

Depth (m)	MainKP46toEnd
4.50	Inf
4.75	Inf
5.00	Inf
5.25	Inf
5.50	Inf

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B.3.12. Anchor strike probability graphs for buried cables, total cable length

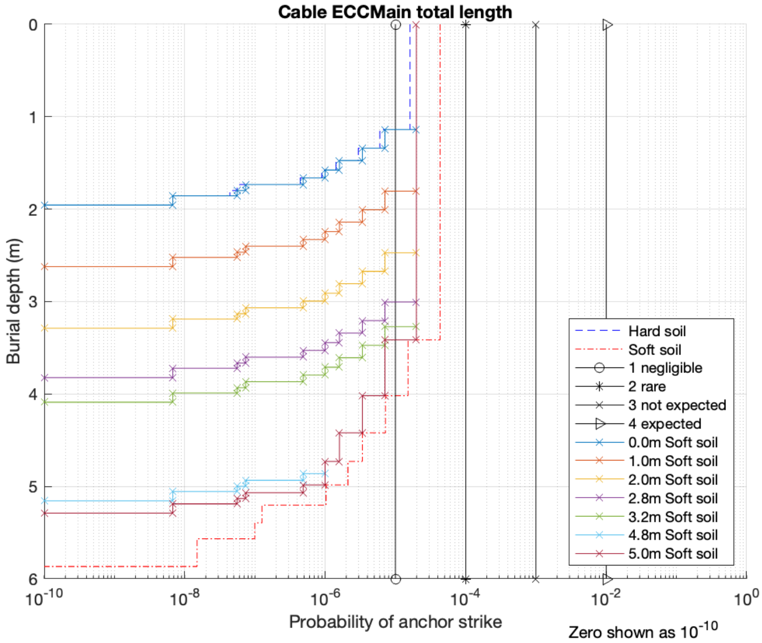


Figure B.84: Anchor strike risk vs burial depth, Cable ECCMain.

B.3.13. Anchor strike probability tables for buried cables, entire length

Table B.48: RP for burial depths, total cable length, ECCMain.

Depth (m)	**Layered soil**
0.00	50323
0.25	50323
0.50	50323
0.75	50323
1.00	50323
1.25	50323
1.50	50323
1.75	50323
2.00	50323
2.25	50323
2.50	50323
2.75	50323
3.00	50323
3.25	50323
3.50	141277
3.75	141277
4.00	141277
4.25	294955
4.50	627094
4.75	1000994
5.00	2063598
5.25	147269221
5.50	Inf

C. CBRA probability reports - Onshore ECC (IRB) routes

C.1. CBRA probability reports - Cable IRB North

C.1.1. Cable layout overview

An overview of the cable layout and sections analysed is shown in figure C.1.

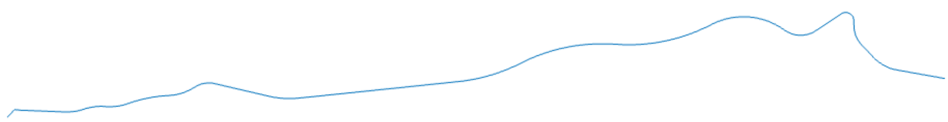


Figure C.1: Overview of cable layout and sections analysed

C.1.2. Vessel movement

Vessel movement has been assessed using [1].

An overview of cable layout with vessel movements is shown on Figure C.2.

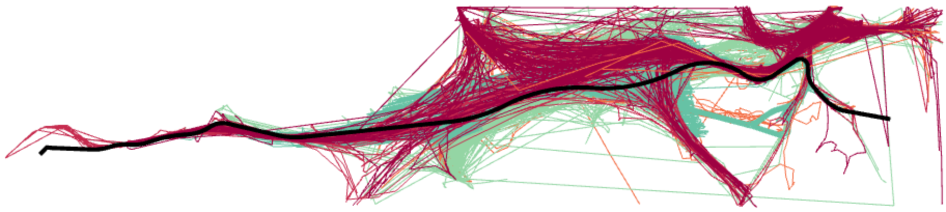


Figure C.2: Overview of cable layout with vessel movements

AIS data date range is 01 Jan 2019 to 31 Dec 2019, and 01 Jan 2022 to 31 Dec 2022, covering a period of 2.0 years.

Table C.1 provides a summary of the vessels crossing all cables. Sections C.1.8 and C.1.9 details the number of vessels crossing each individual cable for each vessel size over the data set period.

Table C.1: Vessel classifications. Number of vessels and crossings are based on the full period of the AIS data set.

Vessel classification	Vessel AIS number	Number of vessels	Number of crossings	Maximum DWT (t)
Dredging or underwater ops	33	1	49	4144
Law Enforcement	55	2	21	4
Other Type, all ships of this type	90	4	95	1879
Pleasure Craft	37	14	98	44
Towing	31	3	322	1092
Unknown	0	1	44	6

The most common vessels were:

- TOW BOAT 'PATRIOT', Towing class, 1 tonnes, 158 crossings
- REVOLUTION, Towing class, 3 tonnes, 127 crossings
- MP MIKE, Other Type, all ships of this type class, 2 tonnes, 72 crossings
- YETI, Dredging or underwater ops class, 4144 tonnes, 49 crossings
- MP ALPHA, Unknown class, 6 tonnes, 44 crossings

The largest vessels were:

- YETI, Dredging or underwater ops class, 4144 tonnes, 49 crossings
- CAN DU, Other Type, all ships of this type class, 1879 tonnes, 8 crossings
- TOW BOAT 'FREEDOM', Towing class, 1092 tonnes, 37 crossings

C.1.3. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely "soft" or "hard". This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material [17].

The two-layered approach adopted in this section considers the case where a layer of soft soil has been deposited over stiffer material. This model does not consider the case where hard soil is overlying soft soil. Soft soil is defined as cohesive soil with an undrained shear strength less than 40kPa.

Table C.2 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely thick hard and soft soil.

Table C.2: Anchor model

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-0.50	0.85	361.3	0.7	0.49	1.48	49.5	12.5
2	0.50-1	2	580.0	0.8	0.58	1.74	74.7	20.2
3	1-2	3	765.0	0.9	0.64	1.92	95.1	26.7
4	2-2	3	931.1	1.0	0.68	2.05	112.8	32.6
5	2-2	4	1084.4	1.0	0.72	2.16	128.8	38.1
6	2-3	5	1228.3	1.1	0.75	2.26	143.5	43.2
7	3-4	6	1364.6	1.1	0.78	2.34	157.3	48.1
8	4-4	7	1494.9	1.1	0.80	2.41	170.3	52.7
9	4-4	8	1620.2	1.2	0.83	2.48	182.6	57.2
10	4-5	8	1741.0	1.2	0.85	2.54	194.4	61.6

DWT is estimated from (dimensions in metres, DWT in tonnes):

$$DWT = max \begin{cases} (length/5.32)^{(1/0.351)} & \text{ref [5], fig 1.3} \\ length \times width \times draught \times 0.7 \times 1.025/1.7 & \text{ref [5], fig 1.2} \end{cases} \quad \text{(C.1)}$$

Displacement is taken as $1.7 \times DWT$ (ref [5]), adopting container ship parameters.

Anchor mass is estimated from ref [7], fig 9.2.

Fluke length is estimated from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \tag{C.2}$$

Anchor penetration is based on soil type (ref [27]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \tag{C.3}$$

Anchor penetration for the two-layered soil model is calculated using Equation C.4 and the schematic outlined in Figure C.3 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \tag{C.4}$$

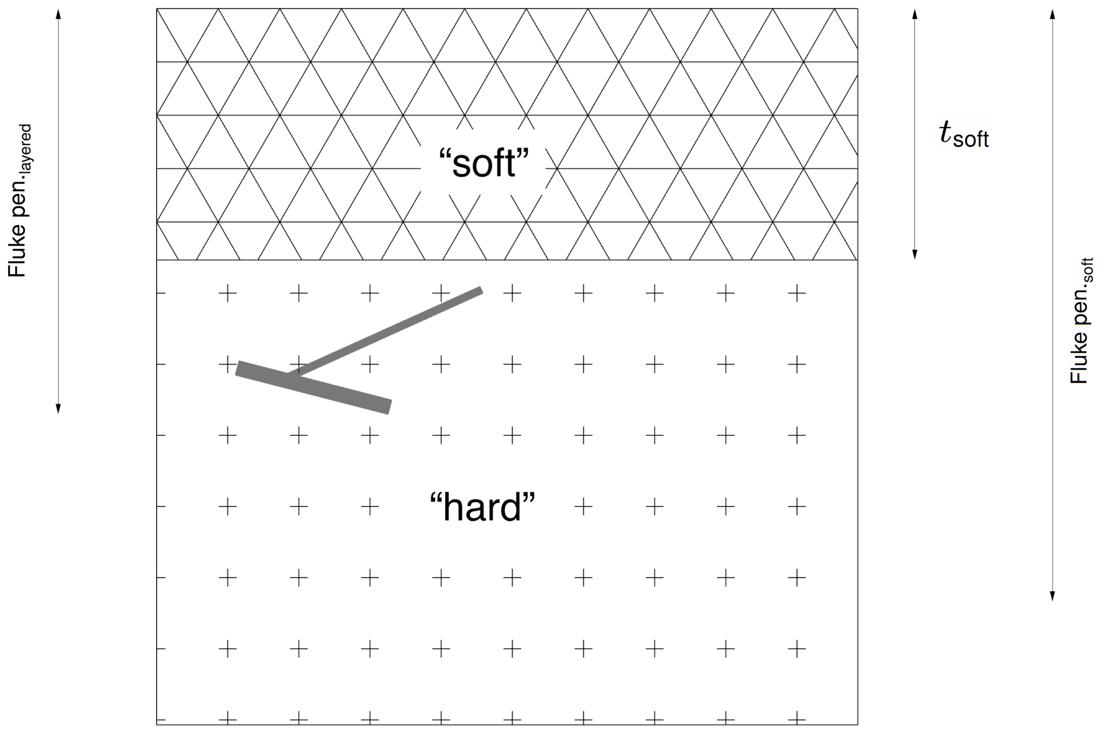


Figure C.3: Two-layered soil anchor penetration calculation schematic.

Ultimate holding capacity (UHC) is based on soil type, (UHC in kN and penetration in metres) and calculated using

Equation C.5.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{C.5}$$

Figures C.4 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on figure C.5.

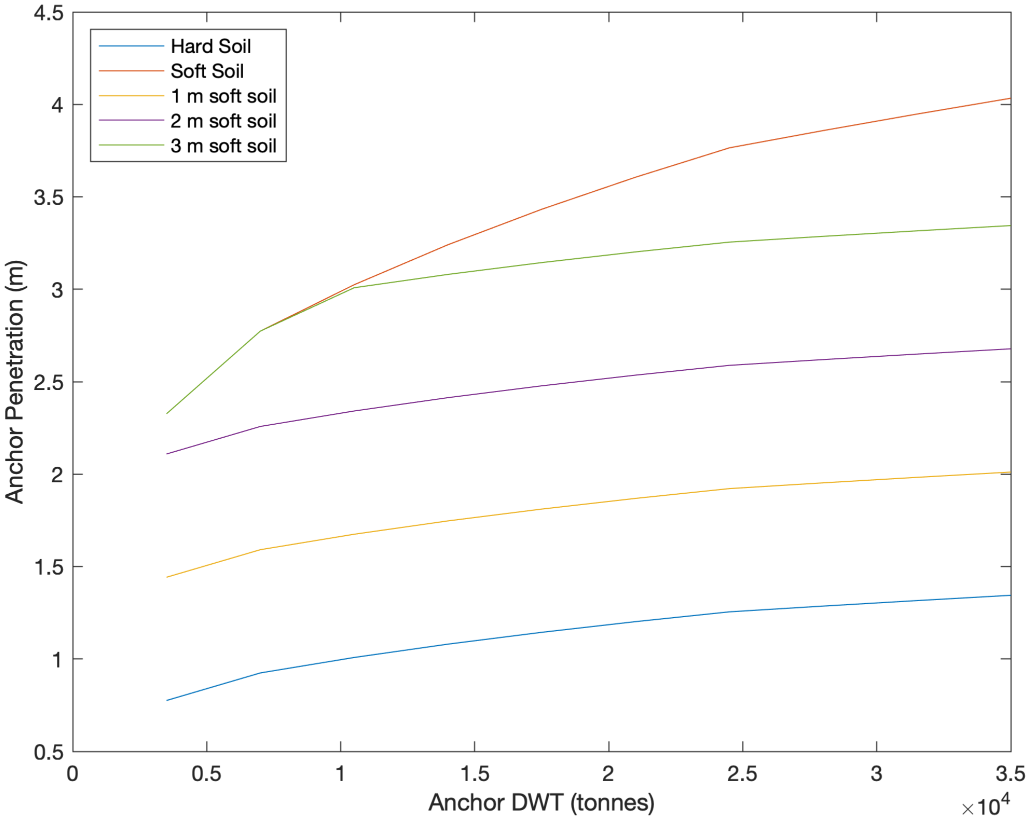


Figure C.4: Anchor penetration for various thicknesses of soft soil

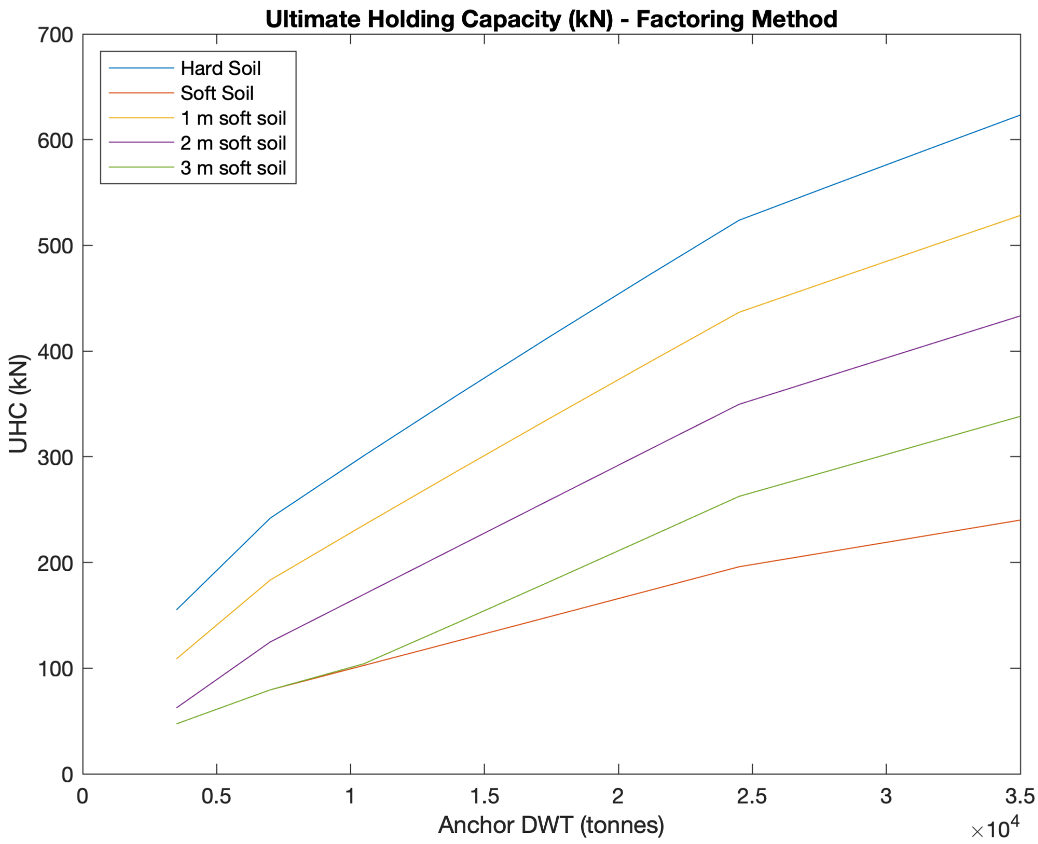


Figure C.5: UHC for various thicknesses of soft soil

Table C.3 shows the ship model used.

D$_{ship}$, the estimate of distance an anchor is dragged, is calculated using Equation C.6 (ref [31]), D$_{ship}$ in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{Disp \times 0.51444(v_{ship})^2}{4UHC} \tag{C.6}$$

Table C.3: Ship model

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-0.50	4.0	1.0	0.9	0.0100	18.17	72.22
2	0.50-1	4.0	1.0	0.9	0.0100	24.08	89.29
3	1-2	4.0	1.0	0.9	0.0100	28.39	101.08
4	2-2	4.0	1.0	0.9	0.0100	31.90	110.39
5	2-2	4.0	1.0	0.9	0.0100	34.93	118.19
6	2-3	4.0	1.0	0.9	0.0100	37.61	124.98

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
7	3-4	4.0	1.0	0.9	0.0100	40.04	131.01
8	4-4	4.0	1.0	0.9	0.0100	42.27	136.48
9	4-4	4.0	1.0	0.9	0.0100	44.34	141.49
10	4-5	4.0	1.0	0.9	0.0100	46.28	146.13

C.1.4. Probabilistic anchor strike assessment for surface lay

Table C.4 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in section C.1.9. The highest risk (per km) cables are:

- IRBNorth, IRBNorthKP0toKP17, RPhard 127276 yr/km, RPsoft 33473 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [7]), D$_{ship}$ in m, v$_{ship}$ in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \tag{C.7}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is (P$_{s.n}$ is the P$_{strike}$ of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \tag{C.8}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table C.4: Surface lay probabilistic assessment

Cable	Section	Hard soil return period	Soft soil return period	Rank
IRBNorth	IRBNorthKP0toKP17	2186419 yr, 127276 yr/km	575025 yr, 33473 yr/km	1

C.1.5. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table C.2 is less than the depth considered. Table C.5 shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section C.1.10 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

C.1.6. Results for one-layered soil

Table C.5: Burial depths to achieve target frequencies

Cable	Section	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
IRBNorth	IRBNorthKP0toKP17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C.6 shows the total anchor strike risk over the total length of the surface laid cable.

Table C.6: Total cable surface lay probabilistic assessment

Cable	Hard soil return period	Soft soil return period	Rank
IRBNorth	2186419 yr	575025 yr	1

Table C.7 shows the required burial depths to achieve certain target frequencies

Table C.7: Burial depths to achieve target frequencies, total cable

Cable	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
IRBNorth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Section C.1.12 shows the anchor strike frequency for buried cables assessed over the total length, with zero frequency taken as 10^{-10} for plotting purposes.

C.1.7. Results for two-layered soil

Table C.8 shows calculated return periods for each cable for the two-layered soil approach.

Table C.8: Two-layered soil model summary

Cable	Section	Soft soil thickness (m)	Return period	Return period per km
IRBNorth	IRBNorthKP0toKP17	14.5	575025 yr	33473 yr/km

Table C.9 shows the required burial depth to achieve the target return frequency using the two-layered soil model. Target frequencies are the same as defined in section C.2.5.

Table C.9: Burial depths to achieve target frequencies

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
IRBNorth	IRBNorthKP0toKP17	14.5	0.0	0.0	0.0	0.0

Table C.10 shows the total anchor strike risk over the total length of the surface laid cable for the two-layered soil approach.

Table C.10: Total cable surface lay probabilistic assessment

Cable	Hard soil return period	Two-Layered soil return period	Soft soil return period	Rank
IRBNorth	2186419 yr	575025 yr	575025 yr	1

Table C.11 shows the required burial depths to achieve certain target frequencies for the total cable length using the two-layered soil approach for each soft soil thickness.

Table C.11: Burial depths to achieve target frequencies, total cable

Cable	Soft Soil Thick-ness	Cable length (km)	Two-Layered Soil, 1.0e-02	Two-Layered Soil, 1.0e-03	Two-Layered Soil, 1.0e-04	Two-Layered Soil, 1.0e-05
IRBNorth	14.5	17.18	0.0	0.0	0.0	0.0

C.1.8. Vessel movement maps

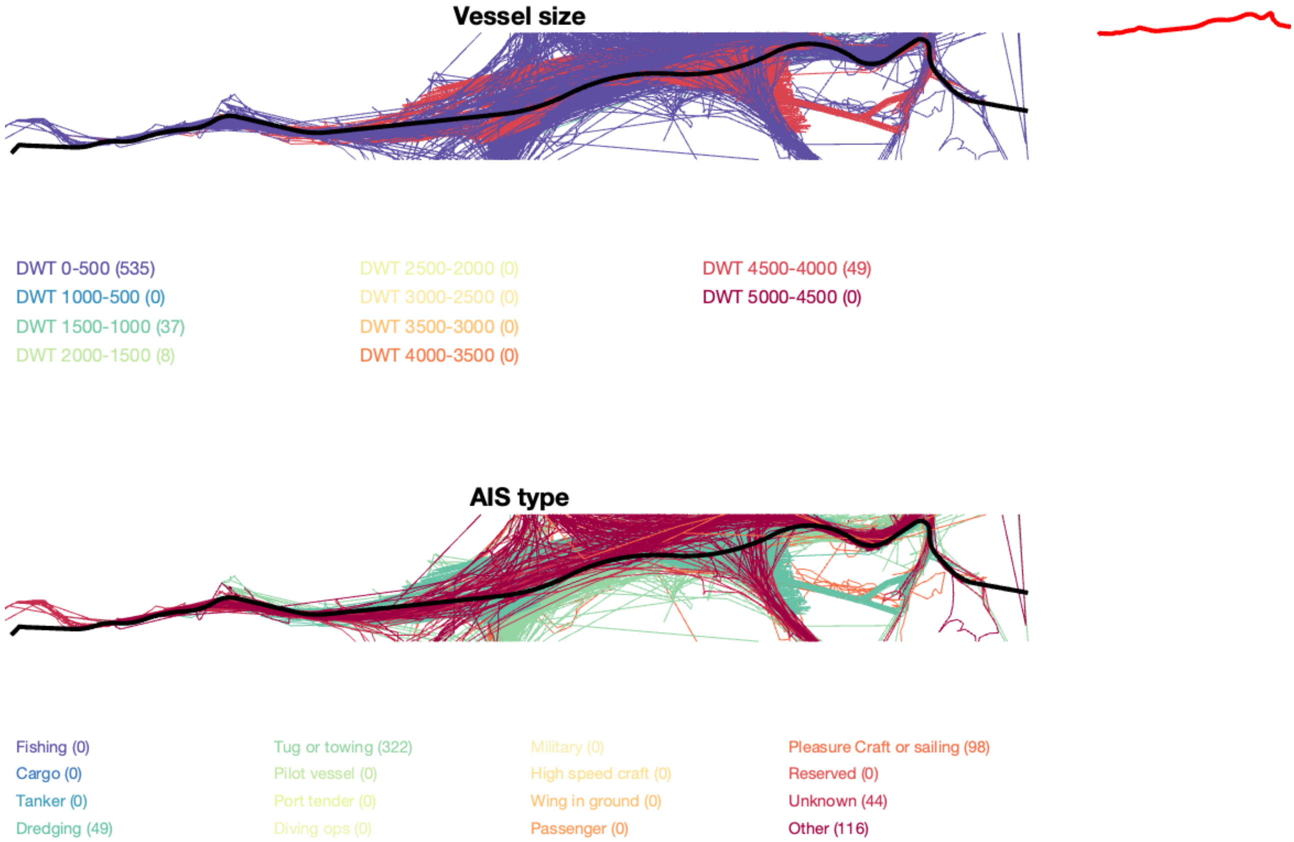


Figure C.6: Vessel movement,Cable IRBNorth, IRBNorthKP0toKP17

C.1.9. Full anchor strike assessment for surface lay

Table C.12: Surface lay probabilistic assessment (full results)

Cable	**Section**	**Vessel cat.**	**Vessel count**	**Pstrike hard soil (-)**	**Pstrike soft soil (-)**	**Hard soil** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**	**Soft soil** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**
IRBNorth	IRBNorthKP0toKP17	1 2 3 4 5 6 7 8 9 10	535 0 37 8 0 0 0 0 49 0	3.37e-07 0 3.64e-08 8.84e-09 0 0 0 0 7.53e-08 0	1.34e-06 0 1.30e-07 3.06e-08 0 0 0 0 2.40e-07 0	4.57e-07 2186419 yr 127276 yr/km	1.74e-06 575025 yr 33473 yr/km

C.1.10. Anchor strike probability graphs for buried cables

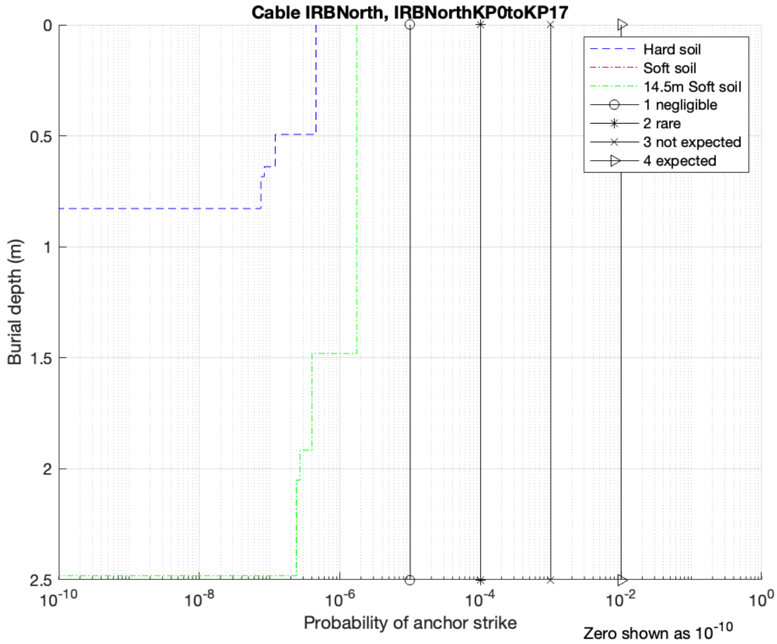


Figure C.7: Anchor strike risk vs burial depth, IRBNorthKP0toKP17

C.1.11. Anchor strike probability tables for buried cables, by section

Table C.13: RP for burial depths, layered soil, table 1 of 1

Depth (m)	IRBNorthKP0toKP17
0.00	575025
0.25	575025
0.50	575025
0.75	575025
1.00	575025
1.25	575025
1.50	2497477
1.75	2497477
2.00	3692538
2.25	4162881
2.50	Inf
2.75	Inf

C.1.12. Anchor strike probability graphs for buried cables, total cable length

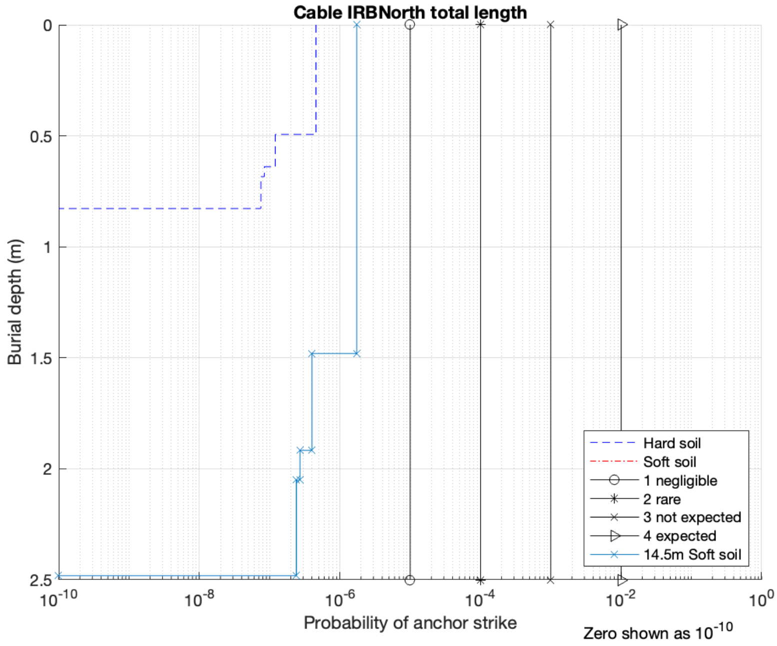


Figure C.8: Anchor strike risk vs burial depth, Cable IRBNorth

C.1.13. Anchor strike probability tables for buried cables, entire length

Table C.14: RP for burial depths, total cable length, IRBNorth

Depth (m)	Layered soil
0.00	575025
0.25	575025
0.50	575025
0.75	575025
1.00	575025
1.25	575025
1.50	2497477
1.75	2497477
2.00	3692538
2.25	4162881
2.50	Inf
2.75	Inf

C.2. CBRA probability reports - Cable IRB South

C.2.1. Cable layout overview

An overview of the cable layout and sections analysed is shown in figure C.9.

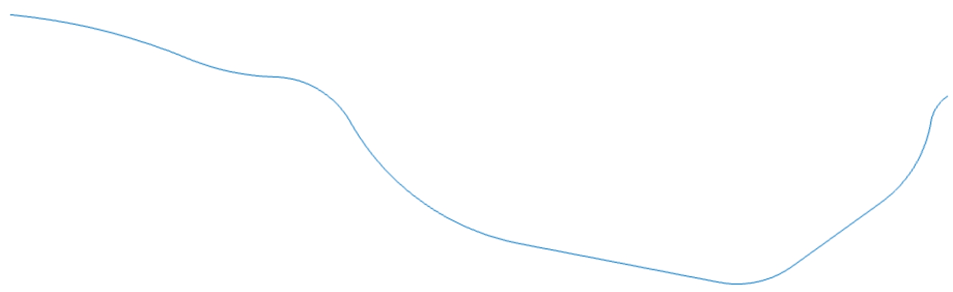


Figure C.9: Overview of cable layout and sections analysed.

C.2.2. Vessel movement

Vessel movement has been assessed using [1].

An overview of cable layout with vessel movements is shown on Figure C.10.

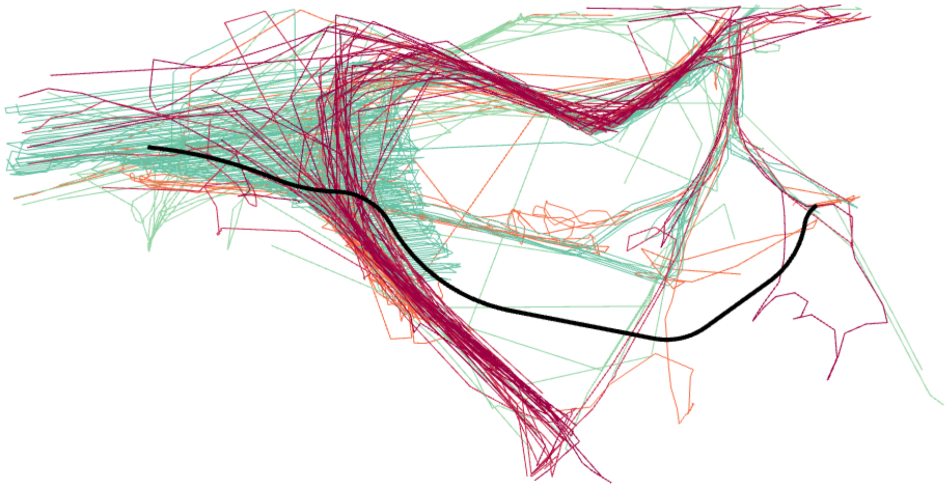


Figure C.10: Overview of cable layout with vessel movements.

AIS data date range is 01 Jan 2019 to 31 Dec 2019, and 01 Jan 2022 to 31 Dec 2022, covering a period of 2.0 years.

Table C.15 provides a summary of the vessels crossing all cables. Sections C.2.8 and C.2.9 details the number of vessels crossing each individual cable for each vessel size over the data set period.

Table C.15: Vessel classifications. Number of vessels and crossings are based on the full period of the AIS data set.

Vessel classification	**Vessel AIS number**	**Number of vessels**	**Number of crossings**	**Maximum DWT (t)**
Dredging or underwater ops	33	1	15	4144
Law Enforcement	55	2	8	4
Other Type, all ships of this type	90	2	14	2
Pleasure Craft	37	6	19	44
Towing	31	3	36	1092
Unknown	0	1	18	6

The most common vessels were:

- TOW BOAT 'PATRIOT', Towing class, 1 tonnes, 24 crossings
- MP ALPHA, Unknown class, 6 tonnes, 18 crossings
- YETI, Dredging or underwater ops class, 4144 tonnes, 15 crossings
- LEGS II, Pleasure Craft class, 4 tonnes, 9 crossings
- MP MIKE, Other Type, all ships of this type class, 2 tonnes, 9 crossings

The largest vessels were:

- YETI, Dredging or underwater ops class, 4144 tonnes, 15 crossings
- TOW BOAT 'FREEDOM', Towing class, 1092 tonnes, 4 crossings
- NEW LITTLE BOAT, Pleasure Craft class, 44 tonnes, 2 crossings
- THE DOG HOUSE, Pleasure Craft class, 44 tonnes, 1 crossings
- NOT YET, Pleasure Craft class, 23 tonnes, 1 crossings

C.2.3. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely "soft" or "hard". This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material [17].

The two-layered approach adopted in this section considers the case where a layer of soft soil has been deposited over stiffer material. This model does not consider the case where hard soil is overlying soft soil. Soft soil is defined as cohesive soil with an undrained shear strength less than 40kPa.

Table C.16 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely thick hard and soft soil.

Table C.16: Anchor model.

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-0.50	0.85	361.3	0.7	0.49	1.48	49.5	12.5
2	0.50-1	2	580.0	0.8	0.58	1.74	74.7	20.2
3	1-2	3	765.0	0.9	0.64	1.92	95.1	26.7
4	2-2	3	931.1	1.0	0.68	2.05	112.8	32.6
5	2-2	4	1084.4	1.0	0.72	2.16	128.8	38.1
6	2-3	5	1228.3	1.1	0.75	2.26	143.5	43.2
7	3-4	6	1364.6	1.1	0.78	2.34	157.3	48.1
8	4-4	7	1494.9	1.1	0.80	2.41	170.3	52.7
9	4-4	8	1620.2	1.2	0.83	2.48	182.6	57.2
10	4-5	8	1741.0	1.2	0.85	2.54	194.4	61.6

DWT is estimated from (dimensions in metres, DWT in tonnes):

$$DWT = max \begin{cases} (length/5.32)^{(1/0.351)} & \text{ref [5], fig 1.3} \\ length \times width \times draught \times 0.7 \times 1.025/1.7 & \text{ref [5], fig 1.2} \end{cases} \tag{C.9}$$

Displacement is taken as $1.7 \times DWT$ (ref [5]), adopting container ship parameters.

Anchor mass is estimated from ref [7], fig 9.2.

Fluke length is estimated from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \tag{C.10}$$

Anchor penetration is based on soil type (ref [27]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \tag{C.11}$$

Anchor penetration for the two-layered soil model is calculated using Equation C.12 and the schematic outlined in Figure C.11 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \tag{C.12}$$

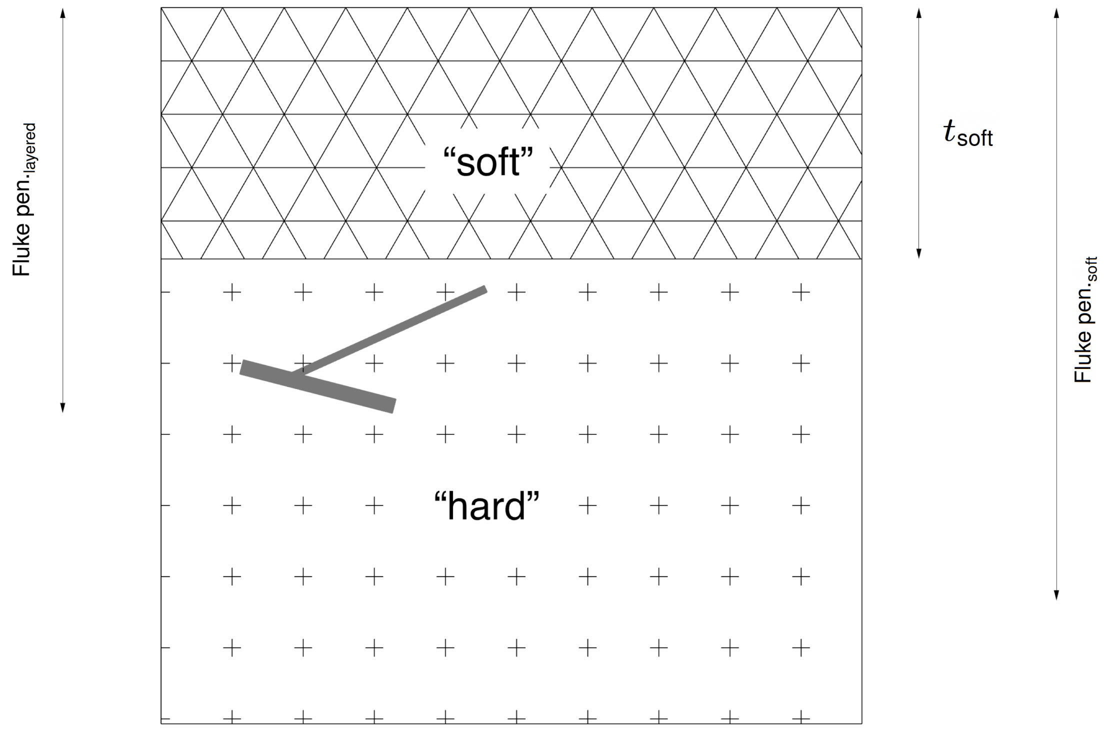


Figure C.11: Two-layered soil anchor penetration calculation schematic.

Ultimate holding capacity (UHC) is based on soil type, (UHC in kN and penetration in metres) and calculated using Equation C.13.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{C.13}$$

Figures C.12 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on figure C.13.

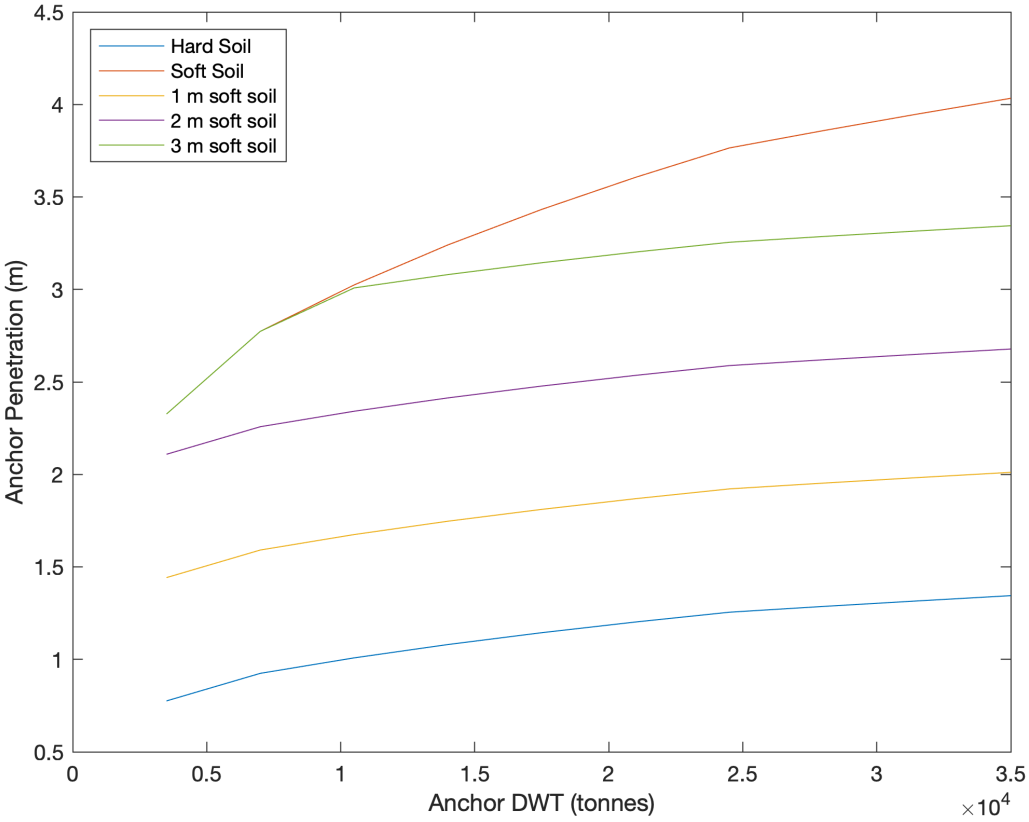


Figure C.12: Anchor penetration for various thicknesses of soft soil.

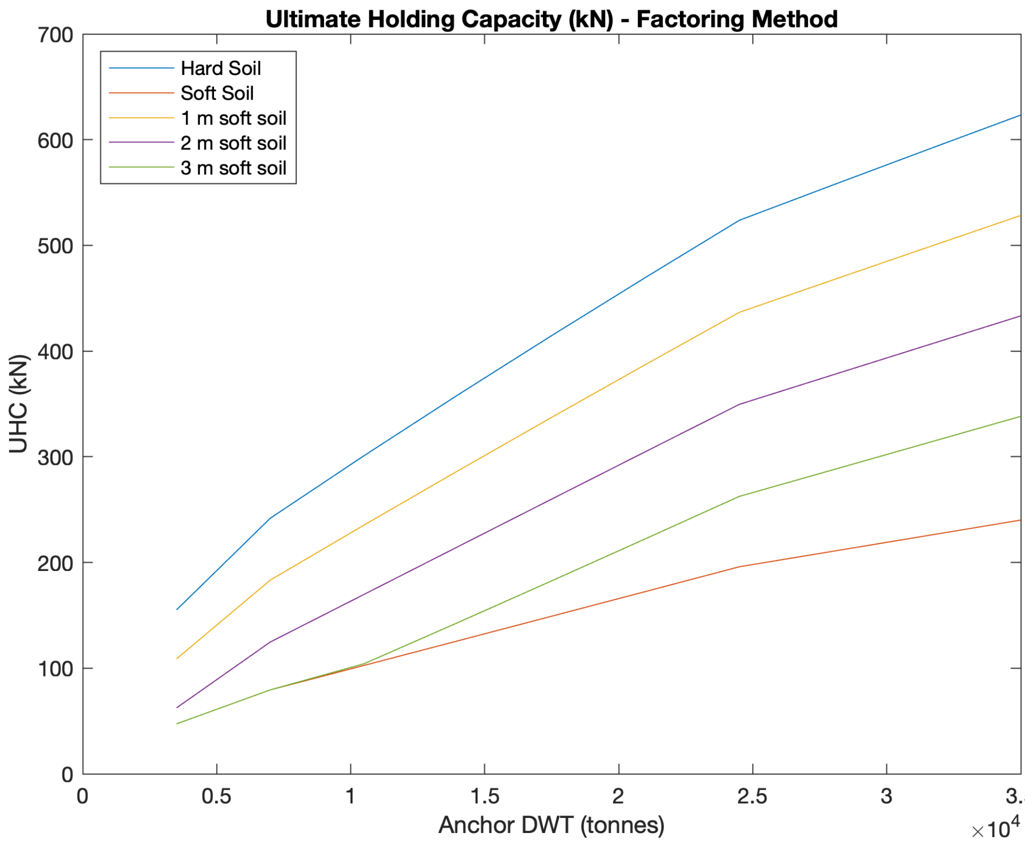


Figure C.13: UHC for various thicknesses of soft soil.

Table C.17 shows the ship model used.

D$_{ship}$, the estimate of distance an anchor is dragged, is calculated using Equation C.14 (ref [31]), D$_{ship}$ in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{Disp \times 0.51444(v_{ship})^2}{4UHC} \tag{C.14}$$

Table C.17: Ship model.

Vessel category	**DWT (1000t)**	**Vship (kts)**	**Ptraffic (-)**	**Pwd (-)**	**Pincident (-)**	**Dship hard soil (m)**	**Dship soft soil (m)**
1	0-0.50	4.0	1.0	0.9	0.0100	18.17	72.22
2	0.50-1	4.0	1.0	0.9	0.0100	24.08	89.29
3	1-2	4.0	1.0	0.9	0.0100	28.39	101.08
4	2-2	4.0	1.0	0.9	0.0100	31.90	110.39
5	2-2	4.0	1.0	0.9	0.0100	34.93	118.19
6	2-3	4.0	1.0	0.9	0.0100	37.61	124.98

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
7	3-4	4.0	1.0	0.9	0.0100	40.04	131.01
8	4-4	4.0	1.0	0.9	0.0100	42.27	136.48
9	4-4	4.0	1.0	0.9	0.0100	44.34	141.49
10	4-5	4.0	1.0	0.9	0.0100	46.28	146.13

C.2.4. Probabilistic anchor strike assessment for surface lay

Table C.18 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in section C.2.9. The highest risk (per km) cables are:

- IRBSouth, IRBSouthKPS0toKPS5_5, RPhard 2170682 yr/km, RPsoft 580304 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [7]), D$_{ship}$ in m, v$_{ship}$ in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \tag{C.15}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is (P$_{s.n}$ is the P$_{strike}$ of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \tag{C.16}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table C.18: Surface lay probabilistic assessment.

Cable	Section	Hard soil return period	Soft soil return period	Rank
IRBSouth	IRBSouthKPS0toKPS5.5	11865801 yr, 2170682 yr/km	3172171 yr, 580304 yr/km	1

C.2.5. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table C.16 is less than the depth considered. Table C.19 shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section C.2.10 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

C.2.6. Results for one-layered soil

Table C.19: Burial depths to achieve target frequencies.

Cable	Section	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
IRBSouth	IRBSouthKPS0toKPS5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C.20 shows the total anchor strike risk over the total length of the surface laid cable.

Table C.20: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Soft soil return period	Rank
IRBSouth	11865801 yr	3172171 yr	1

Table C.21 shows the required burial depths to achieve certain target frequencies

Table C.21: Burial depths to achieve target frequencies, total cable.

Cable	Hard, 1.0e-02	Soft, 1.0e-02	Hard, 1.0e-03	Soft, 1.0e-03	Hard, 1.0e-04	Soft, 1.0e-04	Hard, 1.0e-05	Soft, 1.0e-05
IRBSouth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Section C.2.12 shows the anchor strike frequency for buried cables assessed over the total length, with zero frequency taken as 10^{-10} for plotting purposes.

C.2.7. Results for two-layered soil

Table C.22 shows calculated return periods for each cable for the two-layered soil approach.

Table C.22: Two-layered soil model summary.

Cable	Section	Soft soil thickness (m)	Return period	Return period per km
IRBSouth	IRBSouthKPS0toKPS5.5	12.1	3172171 yr	580304 yr/km

Table C.23 shows the required burial depth to achieve the target return frequency using the two-layered soil model. Target frequencies are the same as defined in section C.2.5.

Table C.23: Burial depths to achieve target frequencies.

Cable	Section	Soft soil thickness (m)	Layered soil, 1.0e-02	Layered soil, 1.0e-03	Layered soil, 1.0e-04	Layered soil, 1.0e-05
IRBSouth	IRBSouthKPS0toKPS5.5	12.1	0.0	0.0	0.0	0.0

Table C.24 shows the total anchor strike risk over the total length of the surface laid cable for the two-layered soil approach.

Table C.24: Total cable surface lay probabilistic assessment.

Cable	Hard soil return period	Two-Layered soil return period	Soft soil return period	Rank
IRBSouth	11865801 yr	3172171 yr	3172171 yr	1

Table C.25 shows the required burial depths to achieve certain target frequencies for the total cable length using the two-layered soil approach for each soft soil thickness.

Table C.25: Burial depths to achieve target frequencies, total cable.

Cable	Soft Soil Thickness	Cable length (km)	Two-Layered Soil, 1.0e-02	Two-Layered Soil, 1.0e-03	Two-Layered Soil, 1.0e-04	Two-Layered Soil, 1.0e-05
IRBSouth	12.1	5.47	0.0	0.0	0.0	0.0

C.2.8. Vessel movement maps

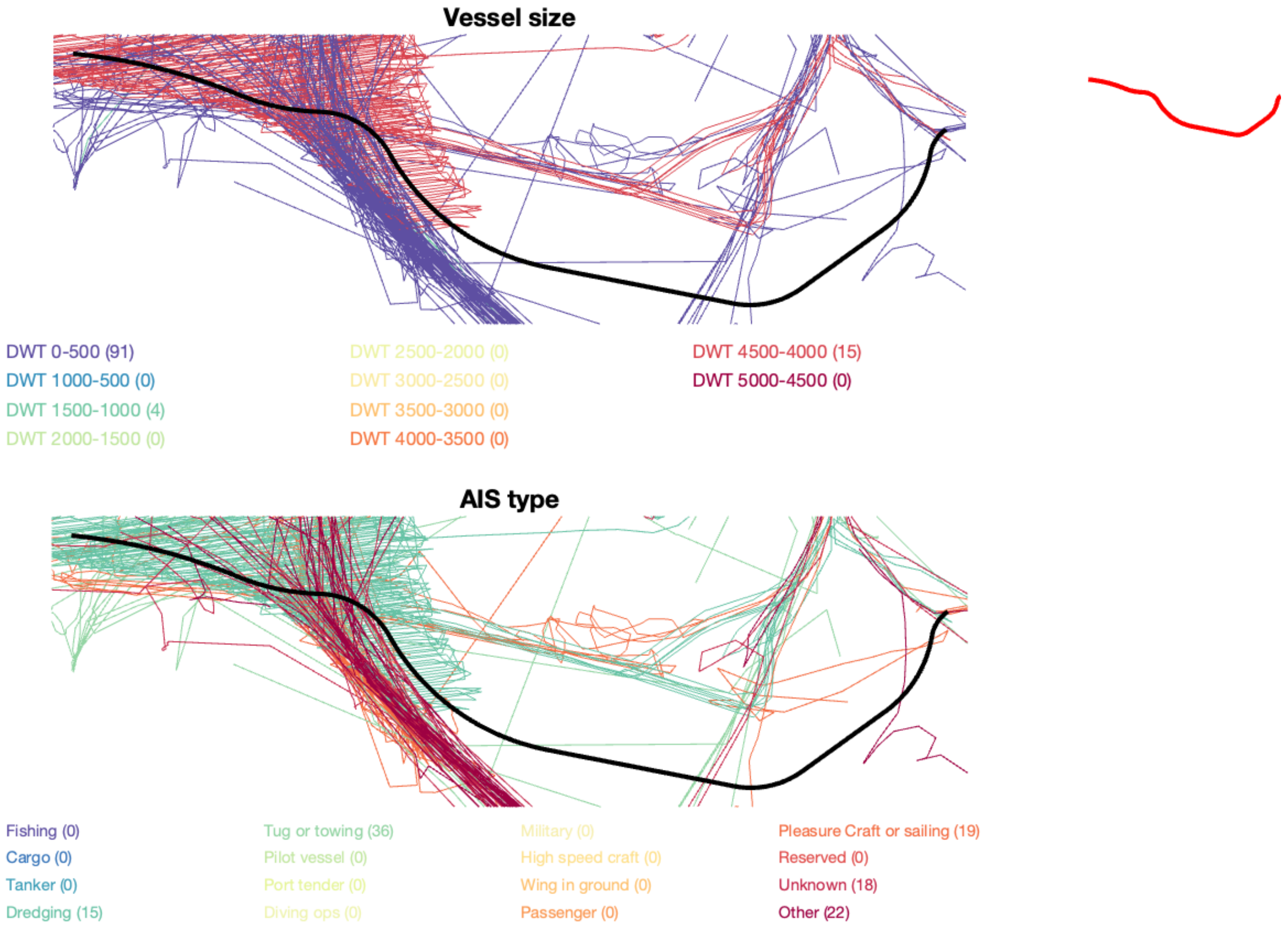


Figure C.14: Vessel movement,Cable IRBSouth, IRBSouthKPS0toKPS5.5.

C.2.9. Full anchor strike assessment for surface lay

Table C.26: Surface lay probabilistic assessment (full results).

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
IRBSouth	IRBSouthKPS0toKPS5.5	1 2 3 4 5 6 7 8 9 10	91 0 4 0 0 0 0 0 15 0	5.73e-08 0 3.93e-09 0 0 0 0 0 2.30e-08 0	2.28e-07 0 1.40e-08 0 0 0 0 0 7.35e-08 0	8.43e-08 11865801 yr 2170682 yr/km	3.15e-07 3172171 yr 580304 yr/km

C.2.10. Anchor strike probability graphs for buried cables

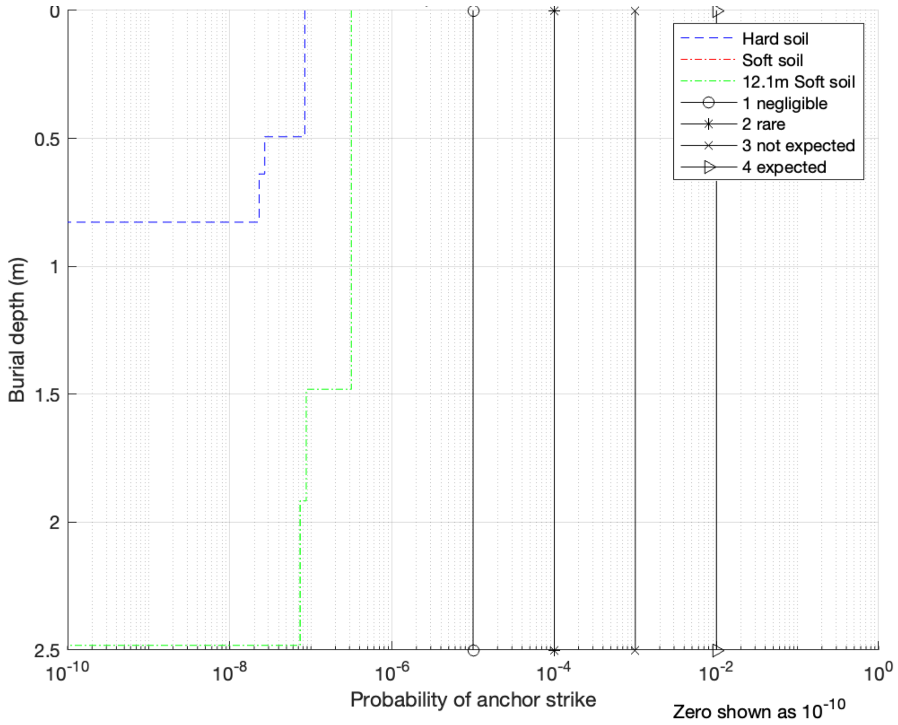


Figure C.15: Anchor strike risk vs burial depth, IRBSouthKPS0toKPS5.5.

C.2.11. Anchor strike probability tables for buried cables, by section

Table C.27: RP for burial depths, layered soil, table 1 of 1.

Depth (m)	IRBSouthKPS0toKPS5.5
0.00	3172171
0.25	3172171
0.50	3172171
0.75	3172171
1.00	3172171
1.25	3172171
1.50	11422609
1.75	11422609
2.00	13598745
2.25	13598745
2.50	Inf
2.75	Inf

C.2.12. Anchor strike probability graphs for buried cables, total cable length

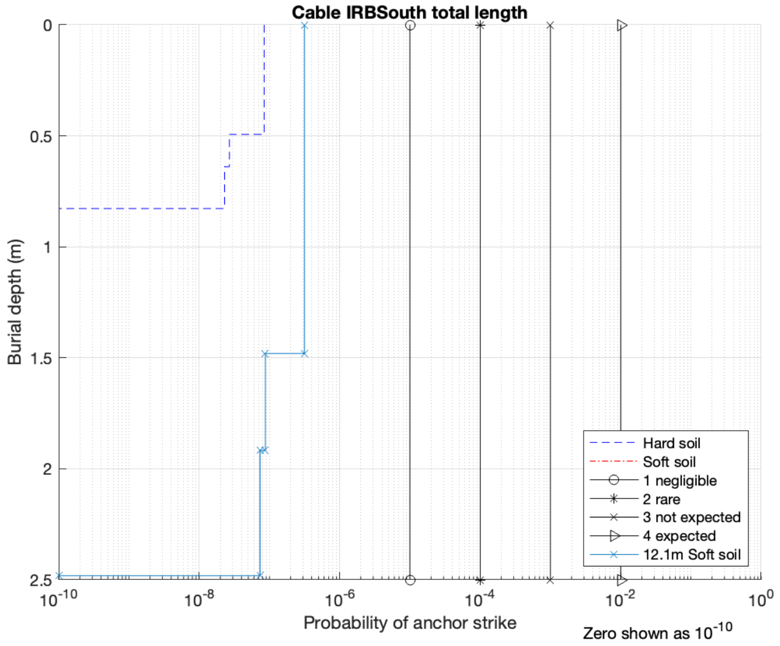


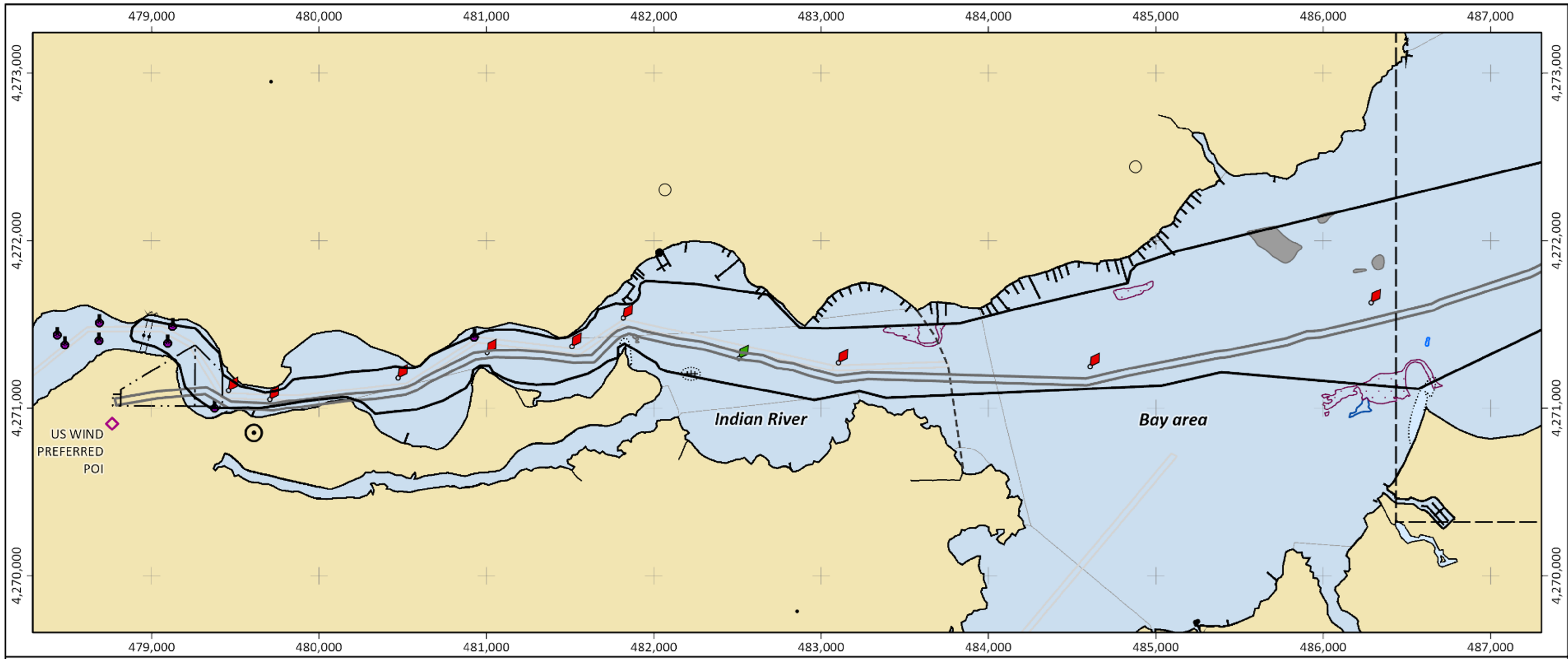
Figure C.16: Anchor strike risk vs burial depth, Cable IRBSouth.

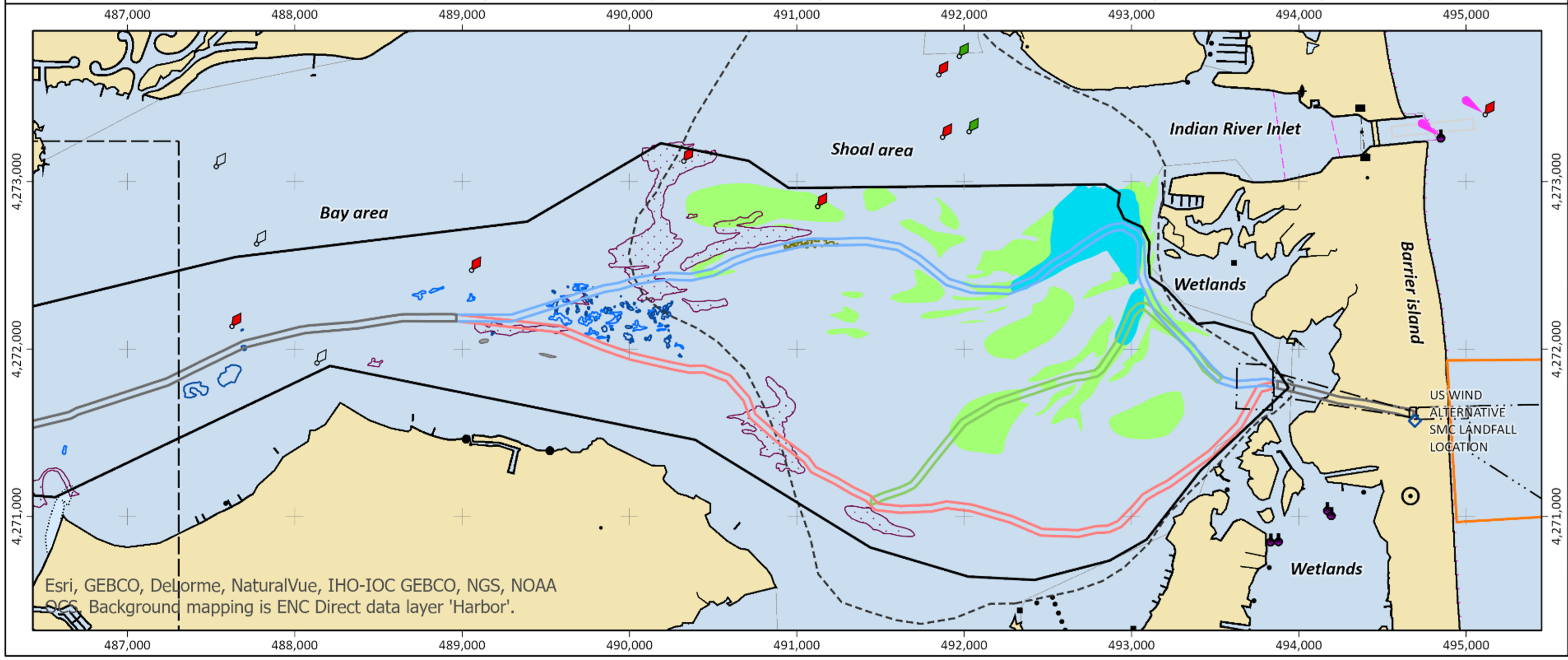
C.2.13. Anchor strike probability tables for buried cables, entire length

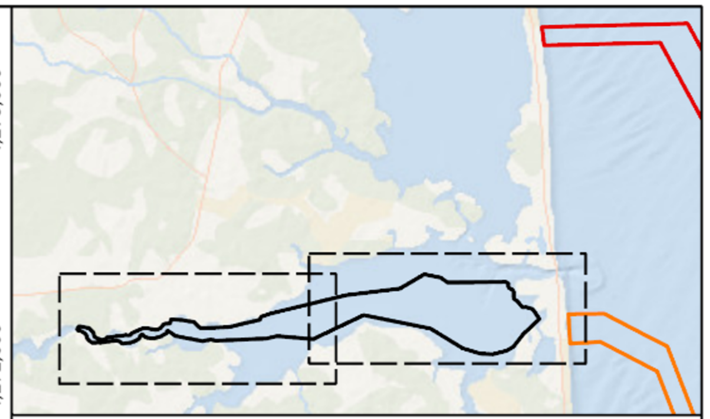
Table C.28: RP for burial depths, total cable length, IRBSouth.

Depth (m)	Layered soil
0.00	3172171
0.25	3172171
0.50	3172171
0.75	3172171
1.00	3172171
1.25	3172171
1.50	11422609
1.75	11422609
2.00	13598745
2.25	13598745
2.50	Inf
2.75	Inf

D. OVERVIEW MAPS







Map frames
Onshore Substations
HDD Indian River to substation
HDD 3Rs Beach to IRB
HDD 3Rs Beach to Atlantic
Offshore ECC 1
Offshore ECC 2
Onshore ECC 1

Onshore ECC 1 corridors
Common corridor
Northern corridor
Southern corridor
Central corridor

Morphologic zone transitions
Area of diffuse small depressions imaged from Hudson bathymetry DEM
Dome-shaped features

Bay floor depressions imaged from Hudson bathymetry DEM
Defined
Fuzzy
Megaripples
Ripples
Anomalous seafloor

PCS: NAD 1983 2011 UTM Zone 18N | **Scale**: 1:30,000 at Tabloid

0 1,000 2,000 4,000 6,000 ft

0 250 500 1,000 1,500 m

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Map B-5: Minor bedform distribution. See Appendix D for Geologic surface features and shallow structure charts.

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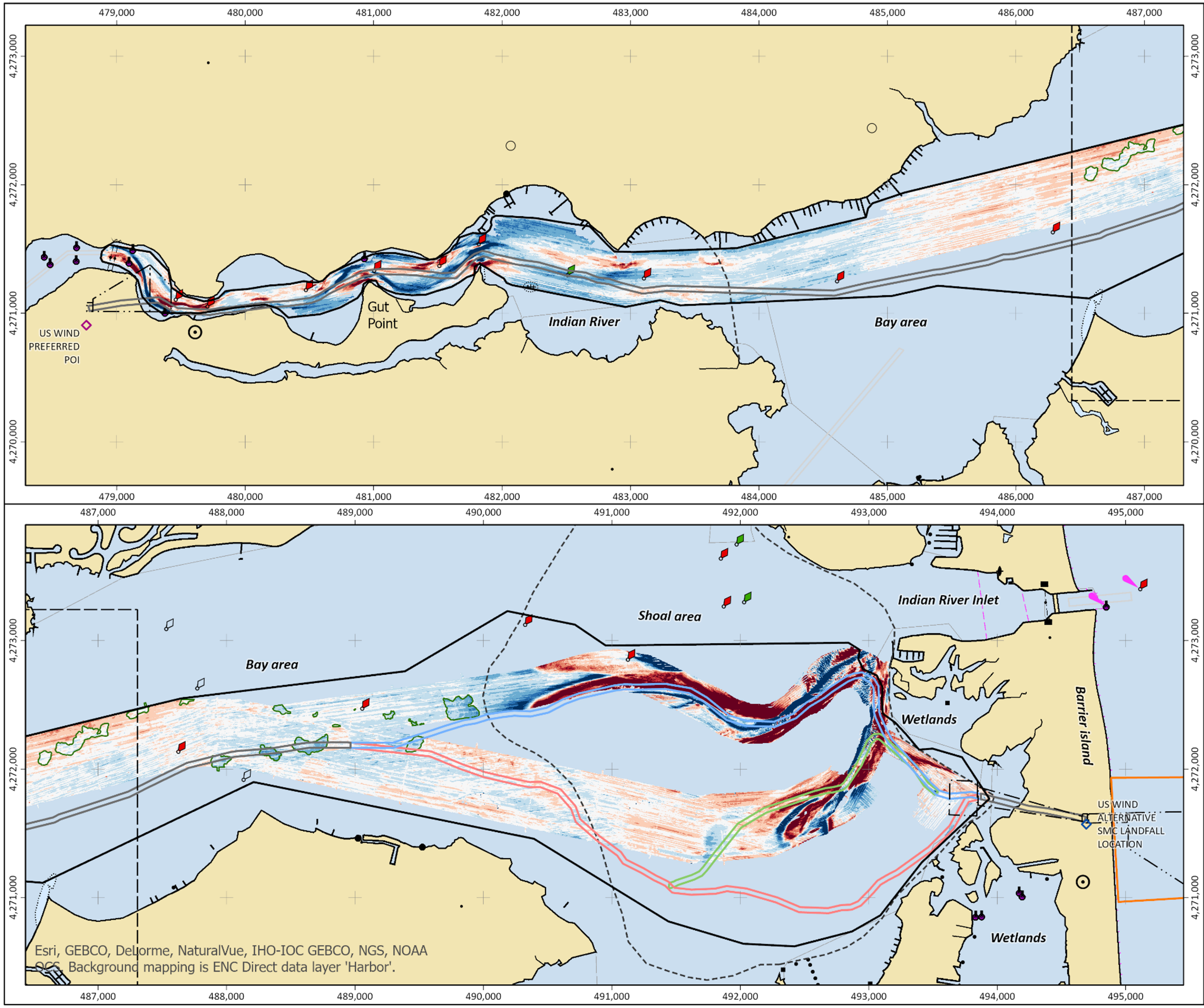

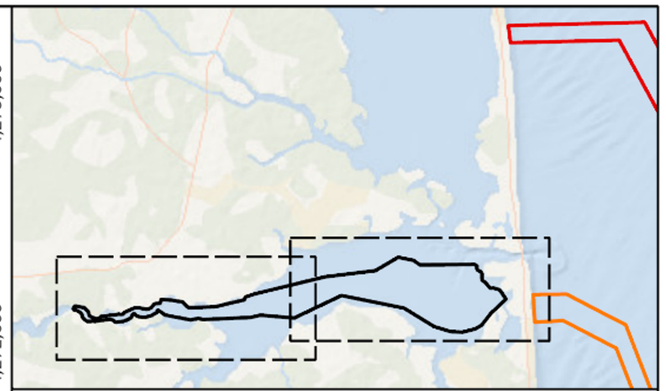

Map frames
Onshore Substations
HDD Indian River to substation
HDD 3Rs Beach to IRB
HDD 3Rs Beach to Atlantic
Offshore ECC 1
Offshore ECC 2
Onshore ECC 1
Onshore ECC 1 corridors
Common corridor
Northern corridor
Southern corridor
Central corridor
Morphologic zone transitions

Bay floor depressions imaged from Alpine bathymetry DEM

Hudson bathymetry DEM (adjusted) to Alpine bathymetry DEM difference
m
-3.01 - -0.35
-0.35 - -0.25
-0.25 - -0.15
-0.15 - -0.05
-0.05 - +0.05
+0.05 - +0.15
+0.15 - +0.25
+0.25 - +0.35
+0.35 - +5.72

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:30,000 at Tabloid

0 1,000 2,000 4,000 6,000 ft
0 250 500 1,000 1,500 m

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Map B-10: Vertical change map between Alpine and vertically-adjusted Hudson bathymetry DEMs showing areas of vertical seafloor change. Red values show areas of seafloor deepening, and blue values show areas of seafloor shallowing.

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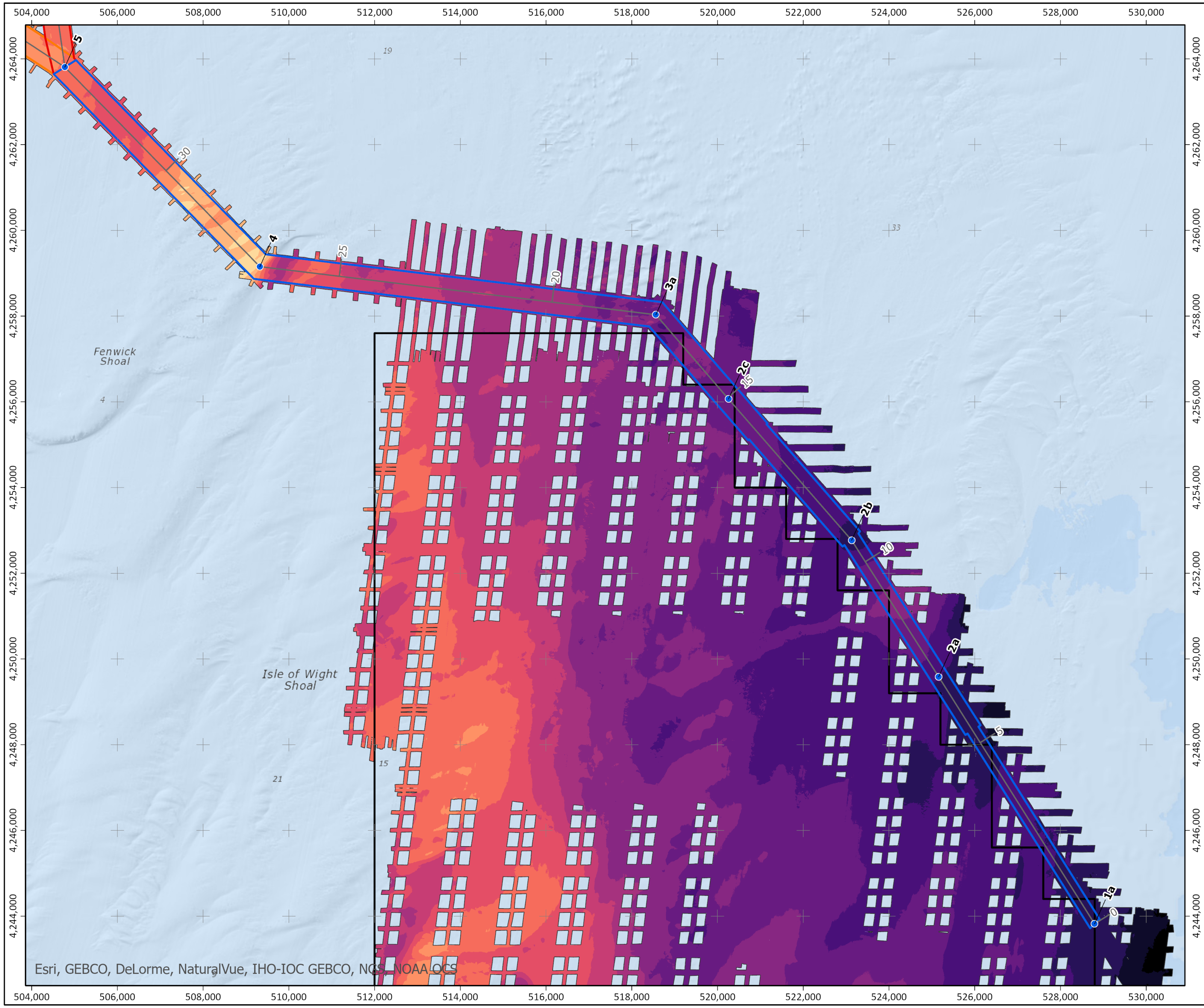

Common Offshore ECC waypoints
Offshore waypoint centerlines (km)
Common Offshore ECC
Offshore ECC 2
Offshore ECC 1
Lease OCS-A-0490
Offshore surveyed area (2021-22 MBES)

2021-22 bathymetry
m MLLW

- ≤ -34.0
- -34.0 - -32.0
- -32.0 - -30.0
- -30.0 - -28.0
- -28.0 - -26.0
- -26.0 - -24.0
- -24.0 - -22.0
- -22.0 - -20.0
- -20.0 - -18.0
- -18.0 - -16.0
- -16.0 - -14.0
- -14.0 - -12.0
- -12.0 - -10.0
- > -10

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

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Map C-16: Merged TDI and Fugro 2021-2022 bathymetry, southern ECC section, 0.5x0.5 m resolution. The data are classified into 2 m bands to illustrate the general trends along cable corridor. See Appendix D for bathymetry charts.

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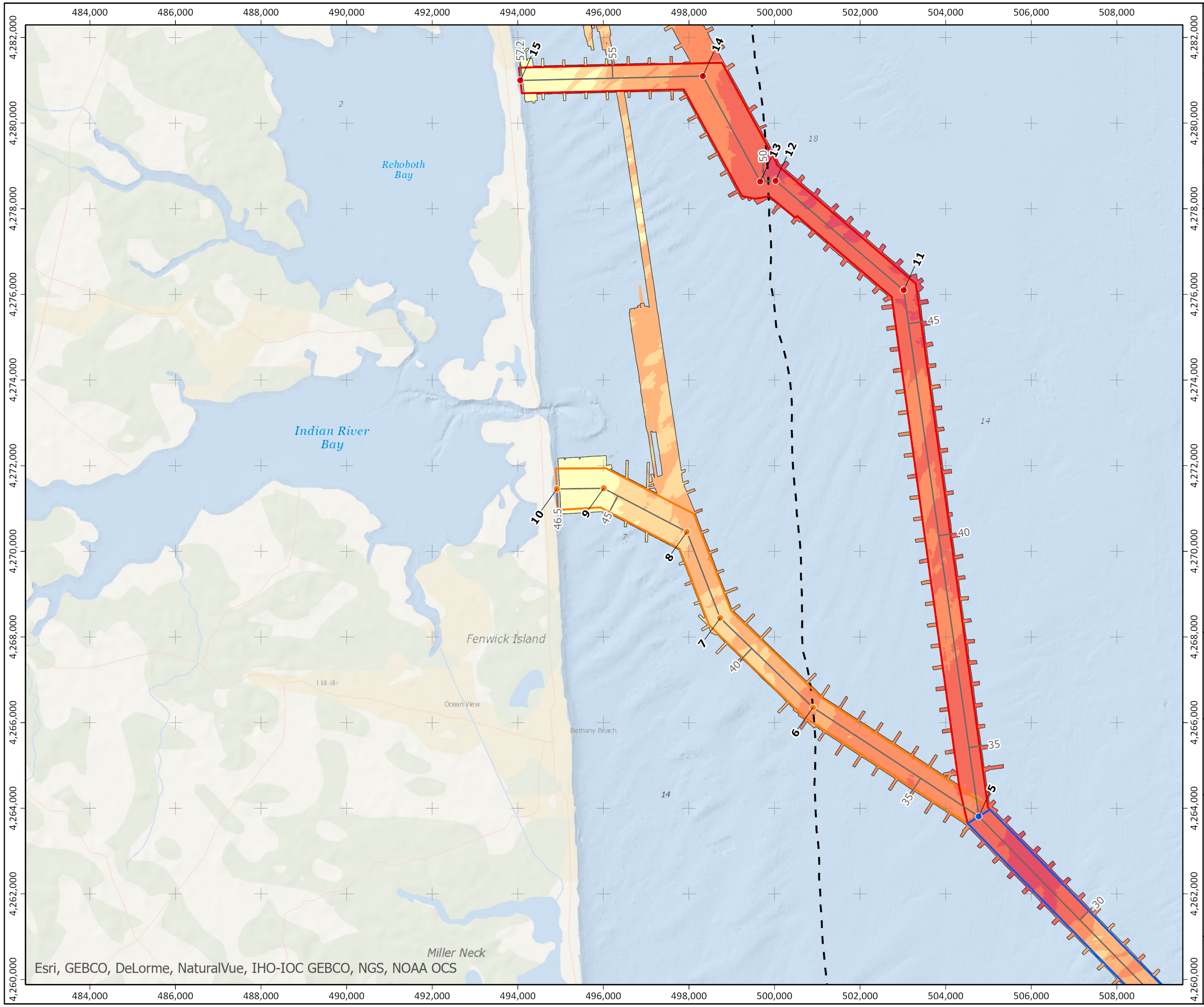

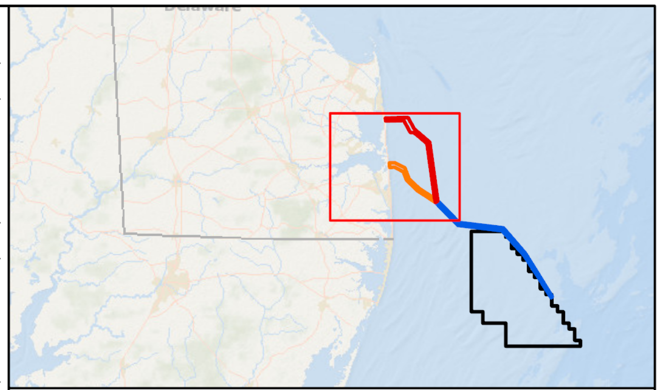

- Common Offshore ECC waypoints
- Offshore ECC 2 waypoint
- Offshore ECC 1 waypoints
- Offshore waypoint centerlines (km)
- Common Offshore ECC
- Offshore ECC 2
- Offshore ECC 1
- Federal/State Boundary 3-mile jurisdiction
- Offshore surveyed area (2021-22 MBES)

2021-22 bathymetry
m MLLW

- ≤ -34.0
- -34.0 - -32.0
- -32.0 - -30.0
- -30.0 - -28.0
- -28.0 - -26.0
- -26.0 - -24.0
- -24.0 - -22.0
- -22.0 - -20.0
- -20.0 - -18.0
- -18.0 - -16.0
- -16.0 - -14.0
- -14.0 - -12.0
- -12.0 - -10.0
- > -10

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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Map C-17: Merged TDI and Fugro 2021-2022 bathymetry, northern ECC sections, 0.5x0.5 m resolution. The data are classified into 2 m bands to illustrate the general trends along cable corridor. See Appendix D for bathymetry charts.

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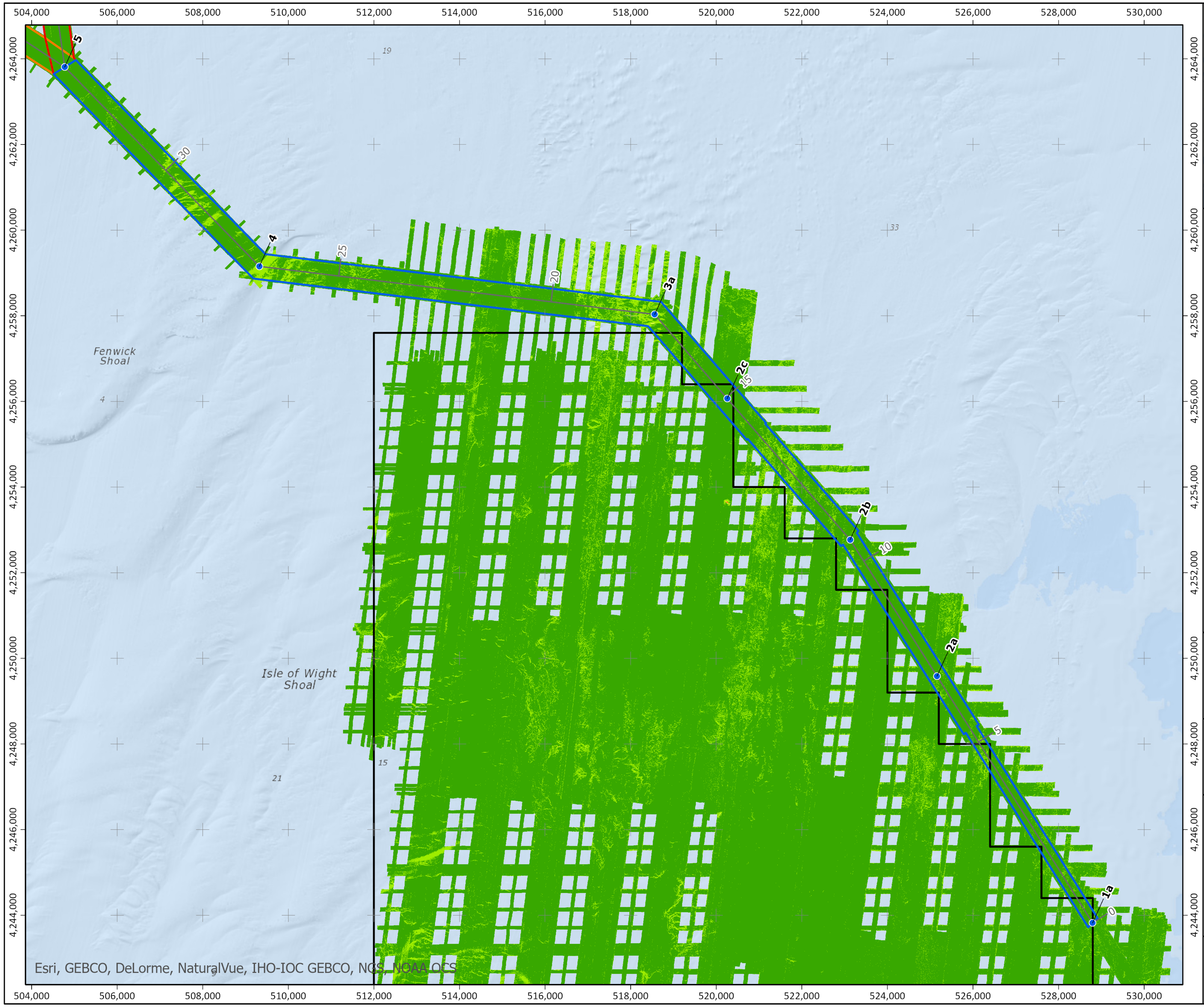

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Map C-24: Seafloor slope in the southern ECC section. See Appendix G for seafloor gradient charts.

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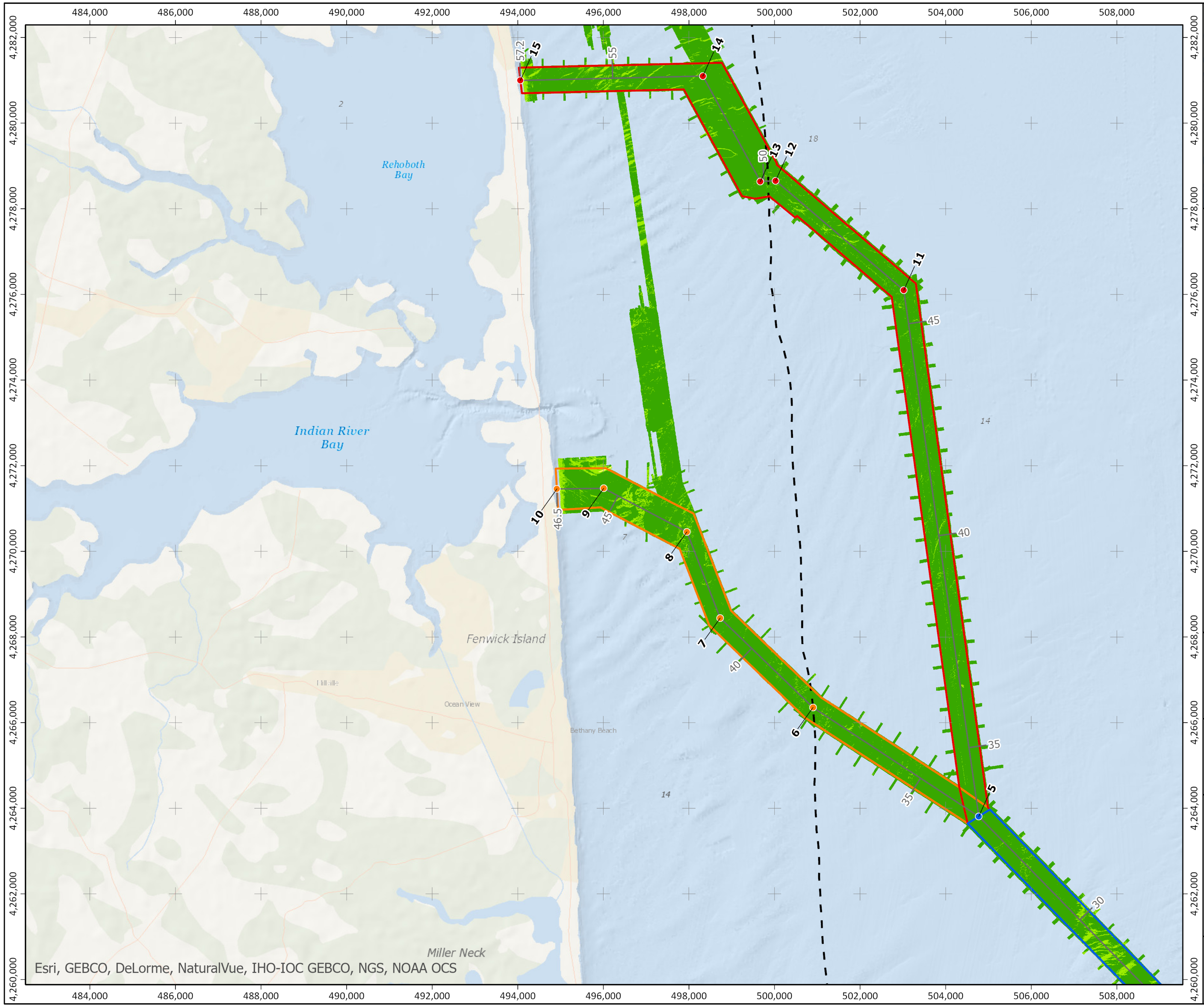

Common Offshore ECC waypoints

Offshore ECC 2 waypoint

Offshore ECC 1 waypoints

Offshore waypoint centerlines (km)

Common Offshore ECC

Offshore ECC 2

Offshore ECC 1

Federal/State Boundary 3-mile jurisdiction

2021-22 seafloor slope, °

≥15

10.0-14.9

5.0-9.9

1.0-4.9

0.0-0.9

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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Map C-25: Seafloor slope in the northern ECC sections. See Appendix G for seafloor gradient charts.

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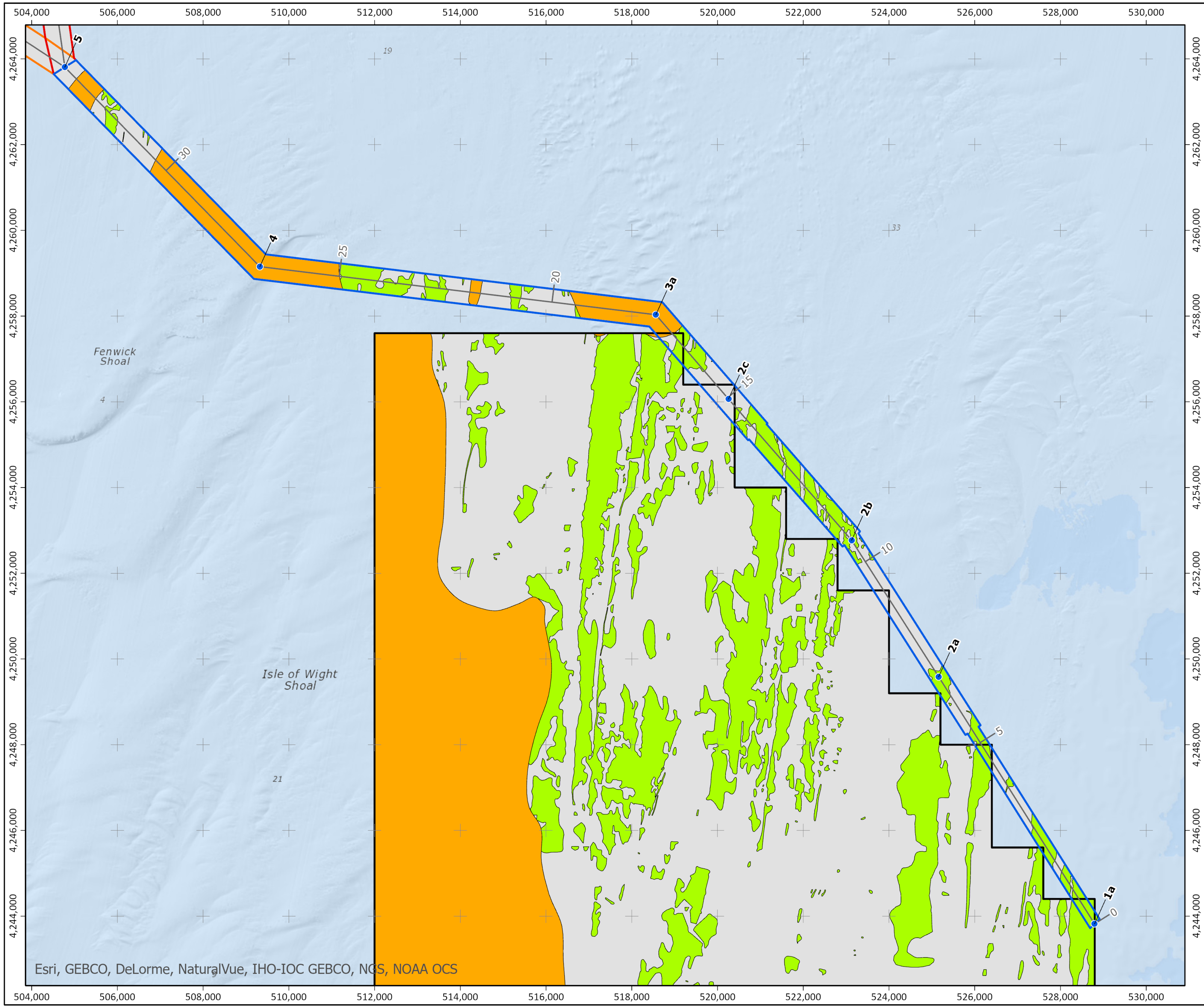

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Map C-32: Approximate seabed mobility zones, southern ECC section.

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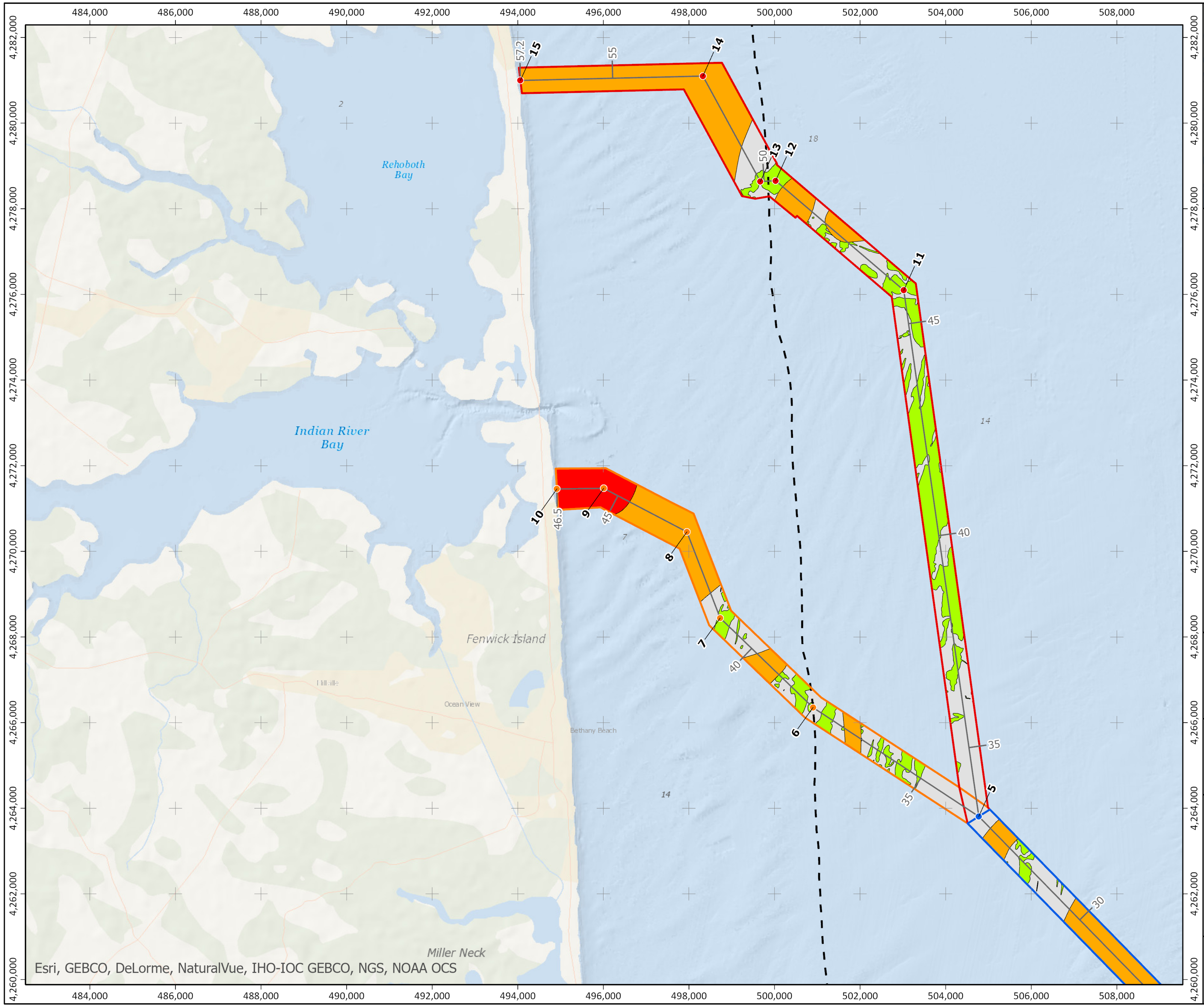

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Map C-33: Approximate seabed mobility zones, northern ECC sections.

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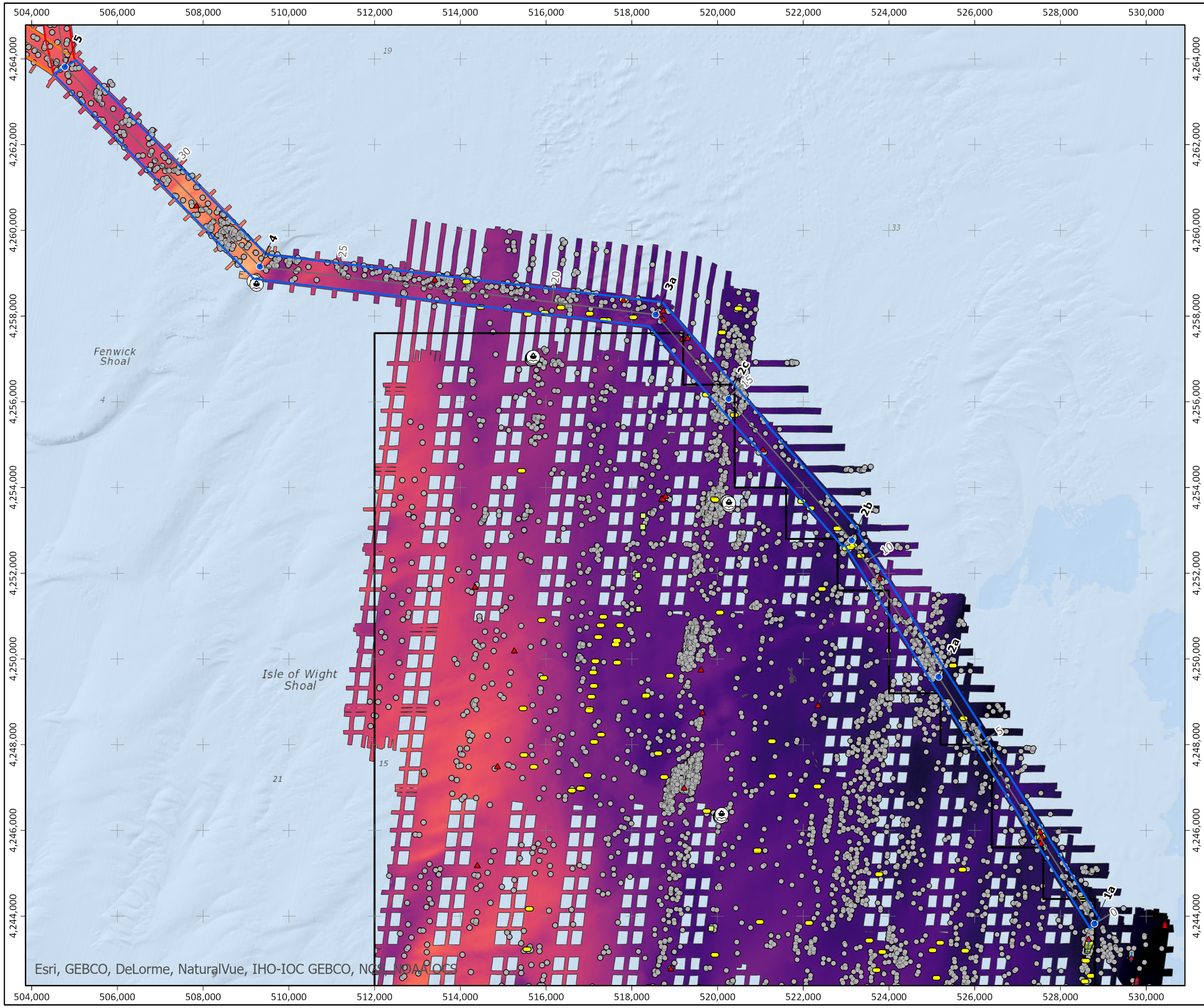

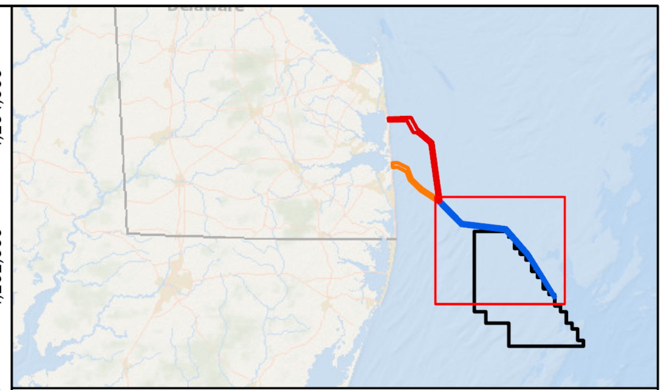

- Common Offshore ECC waypoints
- Offshore waypoint centerlines (km)
- Common Offshore ECC
- Offshore ECC 2
- Offshore ECC 1
- Lease OCS-A-0490
- Fishing traps

TDI and Fugro 2021-22 SSS contacts (reclassed) - anthropogenic & unknown

- Wreck
- Fishing gear
- Possible or probable lobster or crab trap/ pot
- Possible or probable tire
- Man made object
- Possible or probable rope
- Debris; unidentified or unknown object
- Drag scars
- Offshore surveyed area (2021-22 MBES)

2021-22 bathymetry
m MLLW

>-6

≤-34

PCS: NAD 1983 2011 UTM Zone 18N | **Scale**: 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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Map C-34: SSS seafloor features interpretation within the southern ECC section, anthropogenic and unknown causes only; symbols not to scale. See Appendix I for contact and anomaly charts.

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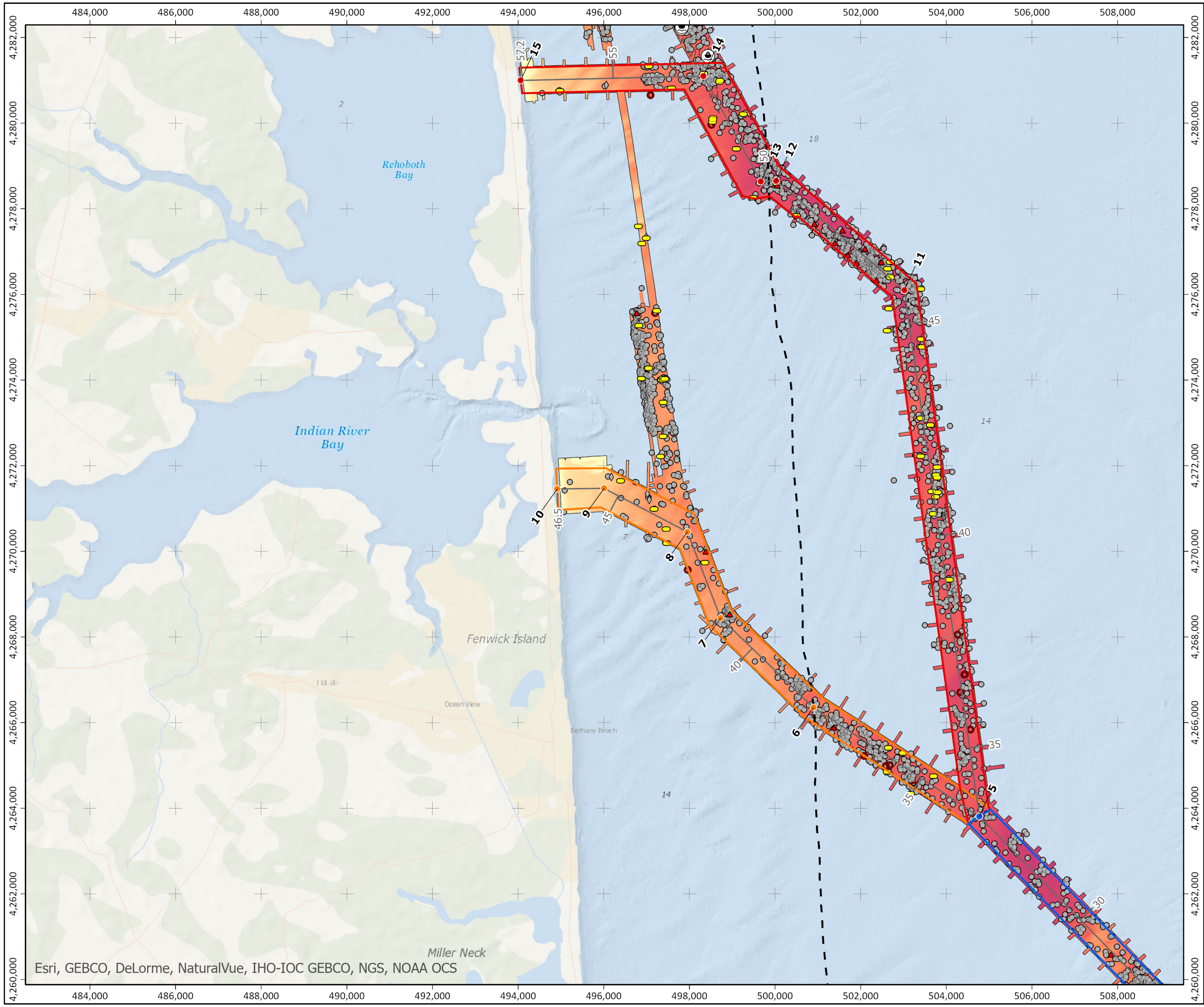

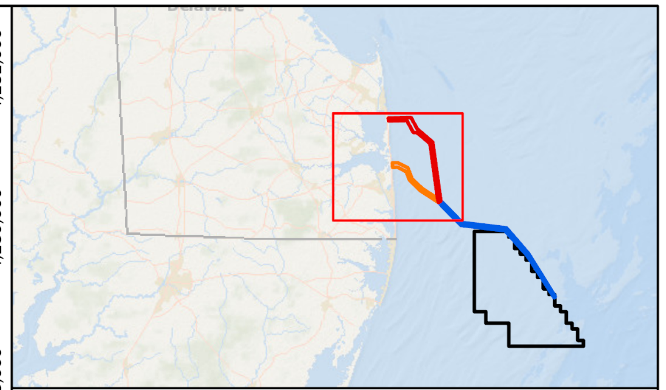

- Common Offshore ECC waypoints
- Offshore ECC 2 waypoint
- Offshore ECC 1 waypoints
- Offshore waypoint centerlines (km)
- Common Offshore ECC
- Offshore ECC 2
- Offshore ECC 1
- Federal/State Boundary 3-mile jurisdiction

TDI and Fugro 2021-22 SSS contacts (reclassed) - anthropogenic & unknown

- Wreck
- Fishing gear
- Possible or probable lobster or crab trap/ pot
- Possible or probable tire
- Man made object
- Possible or probable rope
- Debris; unidentified or unknown object
- Drag scars
- Offshore surveyed area (2021-22 MBES)

2021-22 bathymetry
m MLLW
>-6
≤-34

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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Map C-35: SSS seafloor features interpretation within the northern ECC sections, anthropogenic and unknown causes only; symbols not to scale. See Appendix I for contact and anomaly charts.

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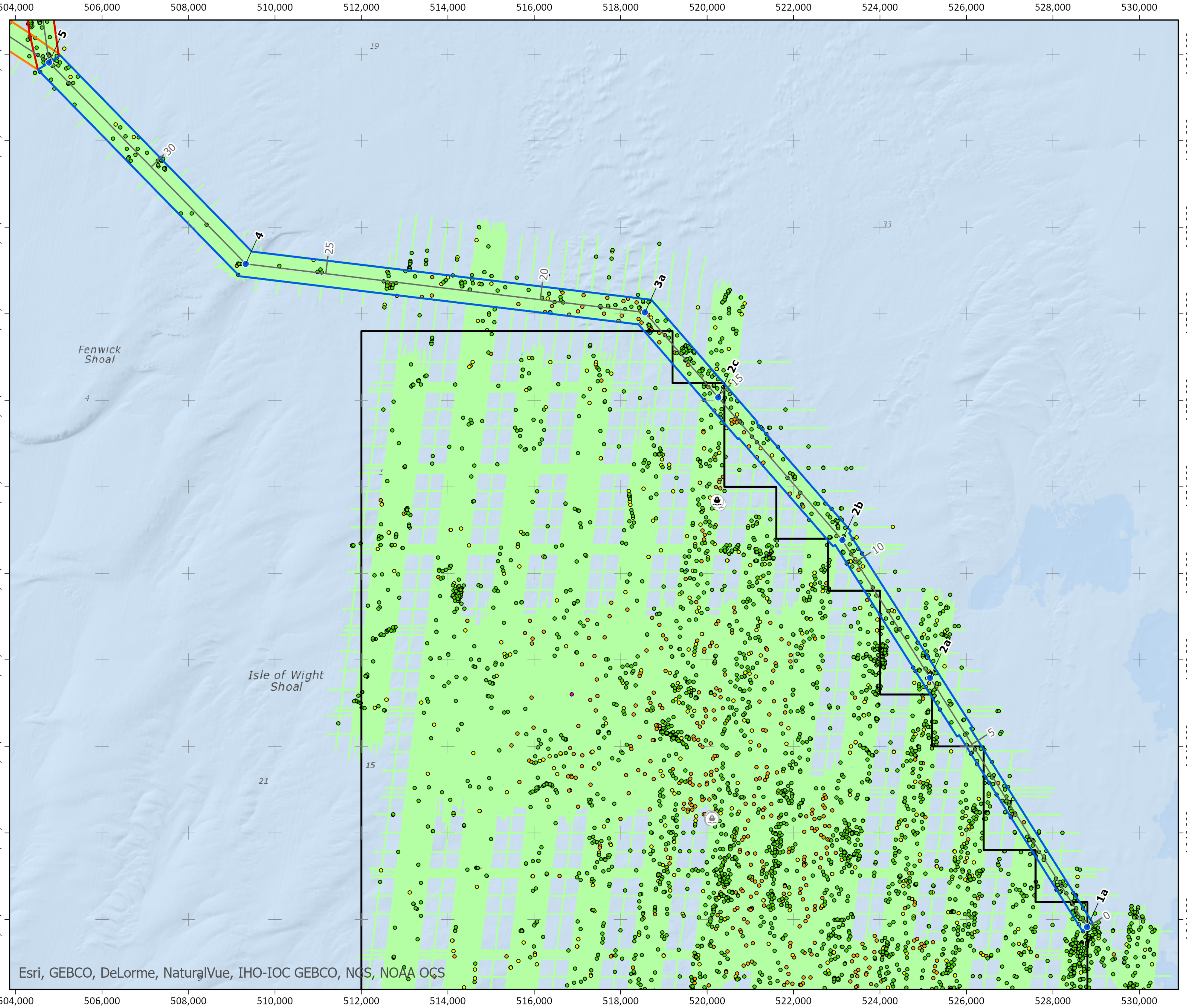

Common Offshore ECC waypoints

Offshore waypoint centerlines (km)

Common Offshore ECC

Offshore ECC 2

Offshore ECC 1

Lease OCS-A-0490

2021-22 magnetometer targets

- Discrete
- Non-discrete
- Possible geology
- Possible medium sized object
- Possible small object
- Possible wreck
- Shipwreck

2021-22 magnetic residual nT

- ≤ -10.0
- -9.9 - -5.0
- -4.9 - -2.5
- -2.4 - -1.5
- -1.4 - 1.5
- 1.6 - 2.5
- 2.6 - 5.0
- 5.1 - 10.0
- > 10.0

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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Map C-36: Magnetometer anomalies superimposed on magnetic residual grids in the southern ECC section. Wreck-related anomalies are shown on top of other target types. TDI residual grid data are shown on top of Fugro residual grid data in areas of overlap. See Appendix I for contact and anomaly charts.

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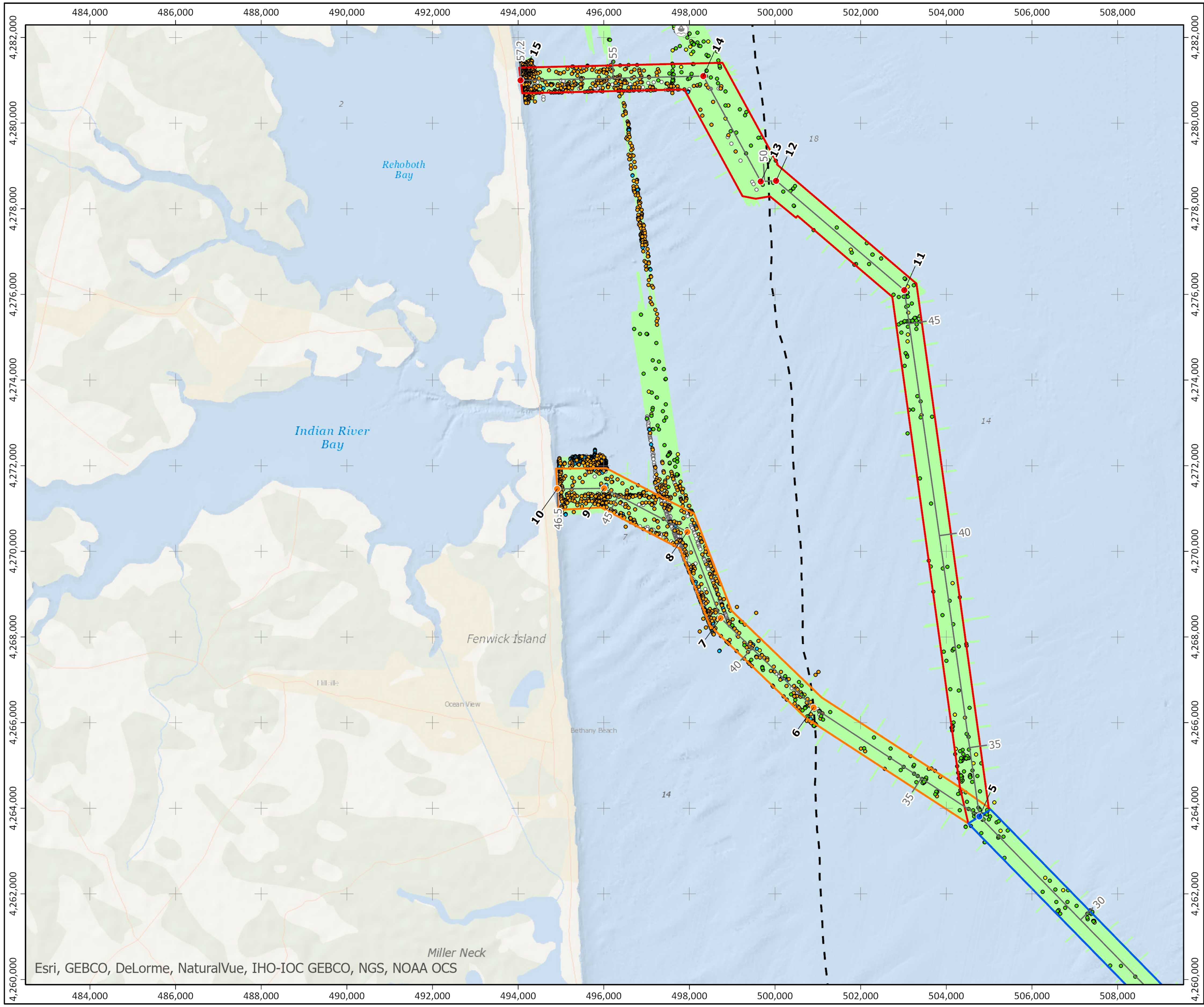

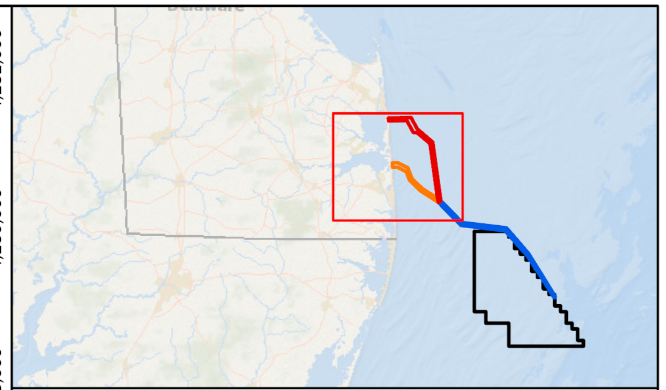

- Common Offshore ECC waypoints
- Offshore ECC 2 waypoint
- Offshore ECC 1 waypoints
- Offshore waypoint centerlines (km)
- Common Offshore ECC
- Offshore ECC 2
- Offshore ECC 1
- Federal/State Boundary 3-mile jurisdiction

2021-22 magnetometer targets
- Discrete
- Non-discrete

- Possible geology
- Possible medium sized object
- Possible small object
- Possible noise
- Possible wreck

2021-22 magnetic residual *nT*
- ≤ -10.0
- -9.9 - -5.0
- -4.9 - -2.5
- -2.4 - -1.5
- -1.4 - 1.5
- 1.6 - 2.5
- 2.6 - 5.0
- 5.1 - 10.0
- > 10.0

PCS: NAD 1983 2011 UTM Zone 18N | **Scale:** 1:90,000 at Tabloid

0 0.5 1 2 3 NM

0 0.5 1 2 3 4 km

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US Wind
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Map C-37: Magnetometer anomalies superimposed on magnetic residual grids in the northern ECC sections. Wreck-related anomalies are shown on top of other target types. TDI residual grid data are shown on top of Fugro residual grid data in areas of overlap. See Appendix I for contact and anomaly charts.

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