Eastern Green Link 2 - Marine Scheme

Environmental Appraisal Report

Volume 3

Appendix 2.1 - EMF and Compass Deviation Assessment

nationalgrid

Scottish & Southern Electricity Networks
TRANSMISSION

National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc

June 2022

Eastern Link EMF and compass deviation Assessment

Document Control			
Document Properties			
Organisation	National Grid		
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Approved by			
Title	EEN/450/NOTE2021- Eastern Link EMF and compass deviation assessment		
Document Reference	V1		
Version History			
Date	**Version**	**Status**	**Description/Changes**
08/12/21	Draft 1	Draft	

1. Project Overview

Two high voltage direct current (HVDC) submarine cable links are proposed, EL1 connecting Torness to Seaham (Hawthorn Pit) and EL2 connecting Peterhead to Bridlington (Drax). Both EL1 and EL2 have an assumed 2GW capacity. A number of design and installation options are possible. The Marine and Maritime Organisation (MMO) have provided some guidance on the effects to compasses they expect the project to complay with, which are as following guidance:

> *"In relation to Electromagnetic deviation on ships' compasses, the MMO would be willing to accept a three-degree deviation for 95% of the cable route. For the remaining 5% of the cable route no more than five degrees will be attained. The MMO would however expect a deviation survey post the cable being laid; this will confirm conformity with the consent condition. This data must be provided to the UKHO via a hydrographic note (H102), as they may want a precautionary notation on the appropriate Admiralty Charts."*

The preferred installation technique for the cable is a 30m separation between each bipole pair. The operating conditions used throughout the report were as follows:

Cable Configuration	No. of cables	Power per cable	Current per cable	Voltage
Two cable design	2	1 GW	2000A	550kV

In a bipole arrangement, the magnetic field produced by the cable will depend on the current flowing in the cables, the separation of the cables and the distance from the cables. A bipole system will result in a cancellation of the magnetic fields when the cables are in close proximity. As the cables move apart, as is the case with the separated designs, they will act more like single cables which is the worst-case condition for magnetic fields.

An assessment of the cables operation on compass deviations was performed using worst-case conditions. The preferred installation techniques were assessed initially. Where these didn't meet the MMO requirements, dynamic adjustments to the cable separations were made along the route to achieve the requirements.

2. Compass deviations along EL1 and EL2 for preferred design

The magnetic field from the cables, if large enough, will combine with the earth's magnetic field causing a compass to indicate north in a different direction to the magnetic north pole. MMO have advised that 95% of the route should not cause greater than 3-degrees deviations, with the remaining 5% of each route causing no more than 5-degrees deviation.

The magnetic fields and compass deviation from the HVDC cables were calculated along the proposed route of EL1 and EL2 at the sea's surface:

- Two cables each with 30m separation operating at 2000A per cable.

The assessments were performed using Bathymetry data to confirm the cable orientation and sea depth. The orientation of the cables to north, design and depth will all impact extent a compass is deviated from the earth's magnetic north.

The maximum compass deviation for each route has been calculated along its entire length for the maximum current in the cable. The results for routes EL1 and EL2 are shown in Figures A1 and A2 in Appendix A. For smaller currents the compass deviation is proportionately smaller. The proportion of the EL1 and EL2 routes which result in compass deviations of less than 3 and 5 degrees are shown in Table 1.

Table 1: Percentage of EL1 and EL2 route resulting in compass deviations of less than 3- and 5-degree variations.

	Proportion of route below compass deviation threshold
	Two cable design (30m bipole separation)
EL1 Route	
Less than 3 Degrees deviation	31.1%
Less than 5 Degrees deviation	69.3%
EL2 Route	
Less than 3 Degrees deviation	15.7%
Less than 5 Degrees deviation	52.1%

The calculations show that the proposed cable designs would exceed a 3-degree compass deviation requirement over a significant proportion of the EL1 and EL2 routes.

3. Compass deviations with dynamic cable separation along EL1 and EL2

Adjustments to the cable separation long both the EL1 and EL2 routes were made to assess what was needed to achieve the MMO requirements. The cable separation required varied depending on the orientation and depth of the cable. Different separations could be deployed along the length of the route to achieve the requirements.

The cable spacing required to achieved less than a 3-degree deviation over 95% of the route, with the remaining 5% causing no more than 5-degrees deviation were applied to calculations. The results of the dynamic cable separation for both routes are shown in Figures A5 and A6.

The proportion of each route which result in compass deviations of less than 3 and 5 degrees are shown in Tables 2 and 4 for each route and cable design, including the total route values and excluding sections of the route in extremely shallow water (<2m depth). Tables 3 and 5 give the proportion of each route that has specific cables separation distances. For smaller currents the compass deviation is proportionately smaller for each of the results.

3.1 EL1 Route

Table 2: Percentage of EL1 route resulting in compass deviations of less than 3- and 5-degree variations with varying cable separation for a two-cable design.

	Proportion of route below compass deviation threshold	
	Total route	**Route greater than 2m depth**
% of route below 3 degrees deviation	98.7%	99.4%
% of route below 5 degrees deviation	99.2%	99.9%

Table 3: Percentage of EL1 with each specific cable separation for a two-cable design

Cable separation	% of route
0.2m	5.0
5m	6.8
10m	58.3
20m	0
30m	29.9

3.2 EL2 Route

Table 4: Percentage of EL2 route resulting in compass deviations of less than 3- and 5-degree variations with varying cable separation for a two-cable design.

	Proportion of route below compass deviation threshold	
	Total route	**Route greater than 2m depth**
% of route below 3 degrees deviation	95.4	95.6
% of route below 5 degrees deviation	99.4	99.5

Table 5: Percentage of EL2 with each specific cable separation for a two-cable design

Cable separation	% of route
0.2m	3.3
5m	2.5
10m	79.0
20m	0.0
30m	15.3

4. Magnetic field assessment

The maximum magnetic field for the proposed 30m cable design and a bundled bipole configuration were calculated. The maximum magnetic field was calculated at vertical distances of 0 to 20 meters from the seabed, and horizontal drop off along the seabed. A worst-case burial depth of 1m was used for all calculations.

The calculation results can be found in Appendix B: Table B1 and B2, demonstrating the maximum magnetic field from the cable, and the maximum magnetic field and geomagnetic field combined. Figure B1 and B3 also shows the horizontal magnetic field drop off along the seabed from the bundled and separated cable designs. Figures B2 and B4 show the cross sectional calculated magnetic field demonstrating both the vertical and horizontal reduction with distance from the cables.

The maximum calculated magnetic fields for all cable designs are compliant with ICNIRP 1994 and 2009 public static magnetic field exposure limits at the seabed surface. The highest magnetic field observed was 399.8 μT for the 30m separated cable design at the seabed, which reduce with vertical and horizontal distance. For these separated designs the magnetic field resulted in a combined field slightly above the background at 20m from the cable. The bundled cable design had significantly lower magnetic fields due to cancellation, with a maximum calculated field of 79.2 μT. These designs typically reduced to a background geomagnetic field around 8m from the cable, having only a very localised effect.

5. Induced electric field assessment

The HVDC cable will produce a magnetic field which decreases with distance from the cables. The movement of the sea through the magnetic field will result in a small localised electric field being produced. A background electric field will be present in the Sea due to the geo-magnetic field and localised magnetic anomalies. The strength of this field varies continuously due to the strength, speed and directions of the tide.

The convention for calculating induced electric fields for the Basslink, BritNed HVDC and Western Link connections is:

$$\text{Induced electric field } (\mu V/m) = \text{Velocity } (m/s) \times \text{Magnetic field } (\mu T)$$

The induced electric field was calculated for a variety of velocities representative of tidal velocities in the Irish Sea, which may or may not be appropriate here.

The background geomagnetic field in the area is around 49 µT. Given this the background induced electric field could range between 4.9 and 61 µV/m in tidal velocities ranging between 0.1 m/s and 1.25 m/s. This does not take account of localised magnetic anomalies, which could result in higher localised electric fields, or of greater tidal velocities.

Table B3 in appendix B gives the calculated induced electric field at various tidal velocities for each of the design options. The separated cable designs produced greater magnetic fields and therefore induced electric fields.

Calculations indicate the electric field is highly dependent on the tidal velocity and that the effects around the cables are localised. In the worst-case design, separated two cable operation, the induced electric field is of a similar magnitude to that already present around 20 m from the seabed. For the bundled cable designs, the induced electric field is a similar magnitude to the that occurring naturally at 8m from the seabed.

6. Summary

- The preferred cable installation technique with 30m bipole separation will not meet the compass deviation requirements, set out by the MMO along either EL1 or EL2 routes.
- Changing the cable separation dynamically along the route will allow the compass deviation requirements to be achieved.
- This report demonstrates that the compass deviation requirements can be met in all situations with varying cable separations along the route lengths.
- HVDC cables will produce magnetic fields which inherently comply with ICNIRP occupational and public static exposure limits. A distance of 0.8m from the cable centre from separated cable designs and 0.39m from bundled cable designs should be maintained in areas where indirect effects of the cables could be observed onshore, such as pacemaker interference.
- The induced electric fields from all cable designs are localised, with the bundled cables increasing above background to around 8m from the seabed and around 20m for the separated designs.

Appendix A: Calculated compass deviations from Eastern Link 1 and 2

Figure A1: Calculated compass deviations for EL1 route with two cable design. Compass deviations at sea level were calculated along the entire route using the depth to seabed and cable angle to vertical for each station mark. Spot calculation were along performed to test validity of automated approach.

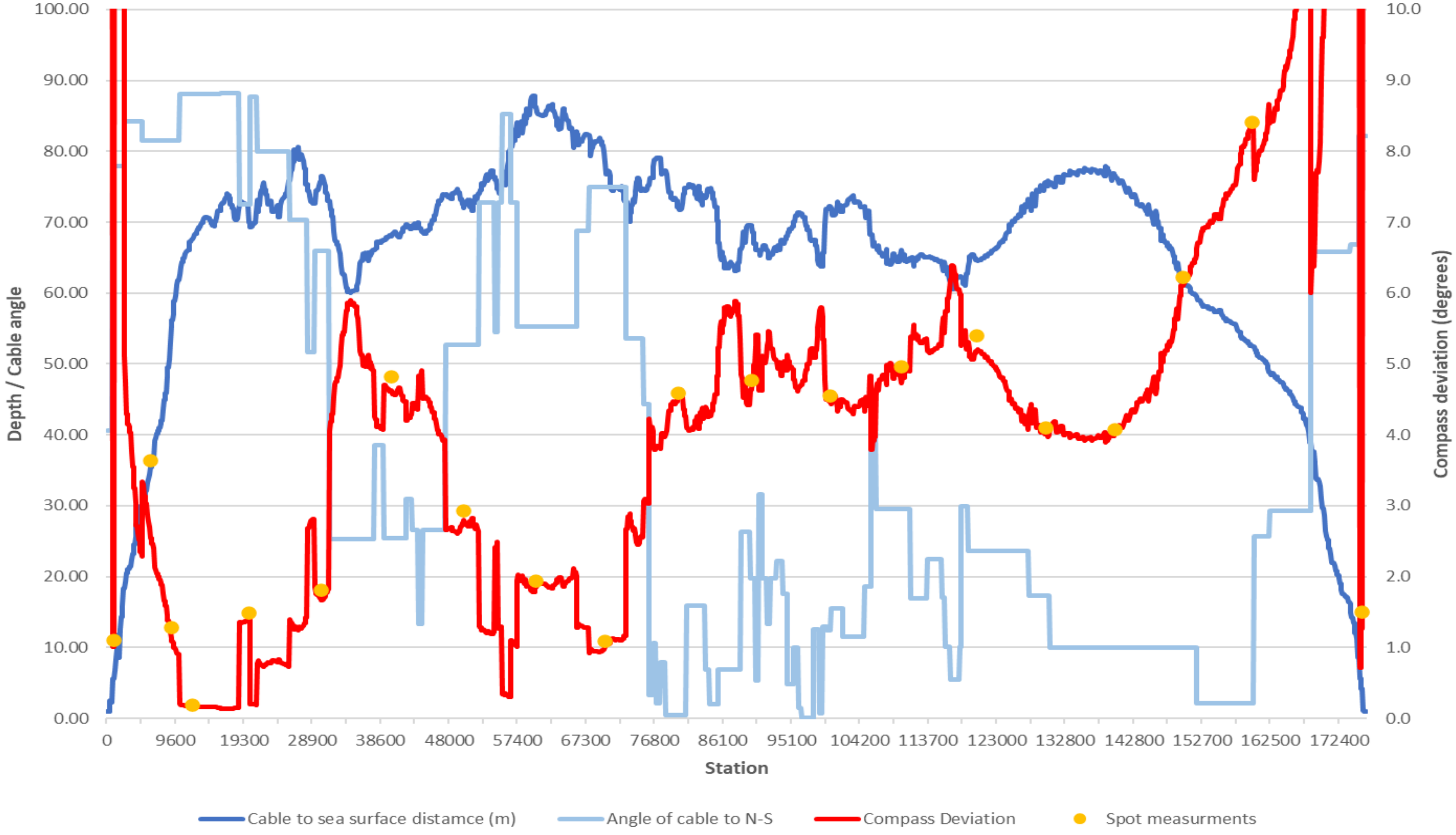


Figure A2: Calculated compass deviations for EL2 route with two cable design. Compass deviations at sea level were calculated along the entire route using the depth to seabed and cable angle to vertical for each station mark. Spot calculation were along performed to test validity of automated approach.

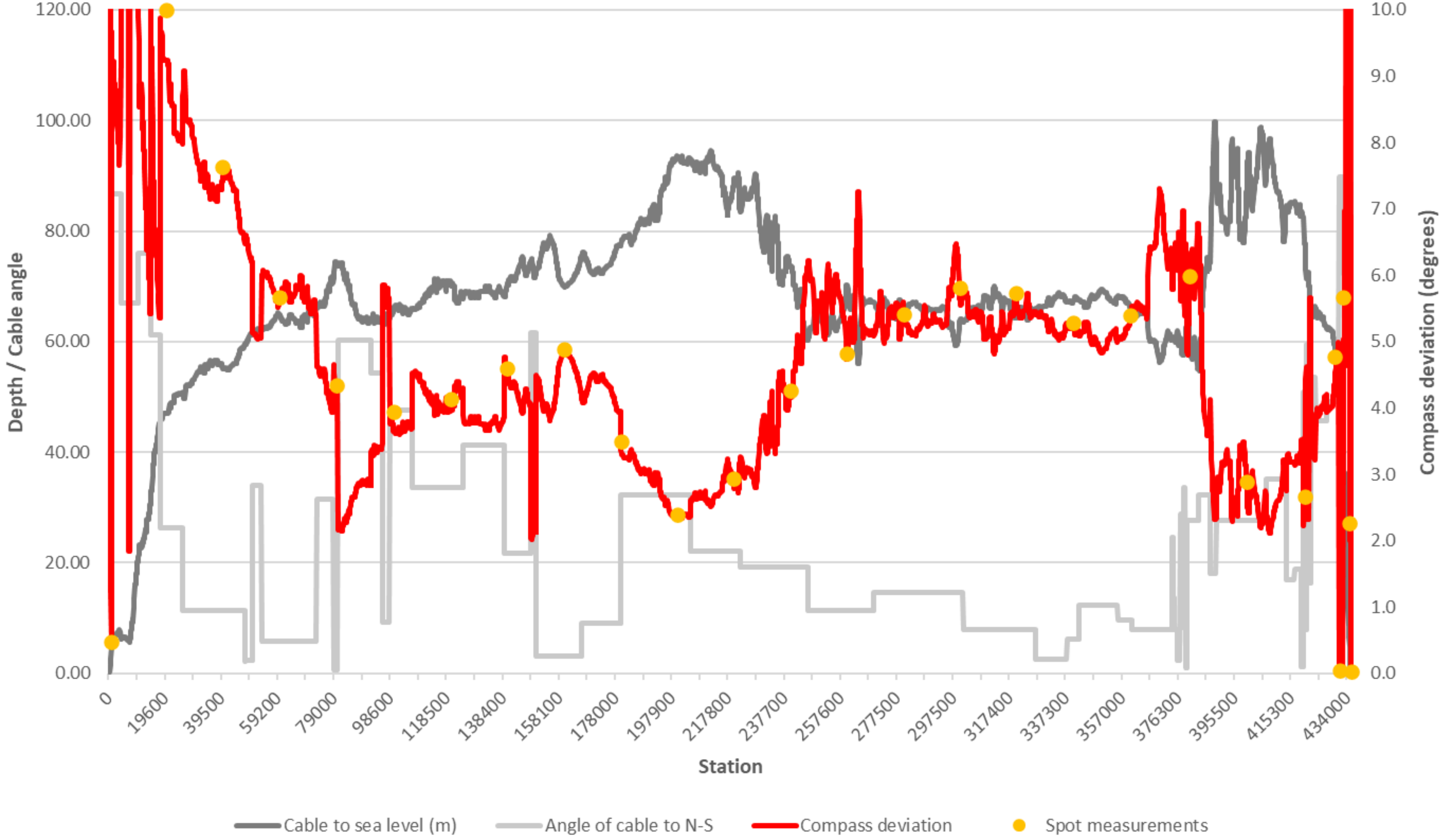


Figure A5: Calculated compass deviations for EL1 route with a two-cable design and dynamic cable separation along the route. Compass deviations at sea level were calculated along the entire route using the depth to seabed and cable angle to vertical for each station mark. The changes in cable separation are given by the green solid line.

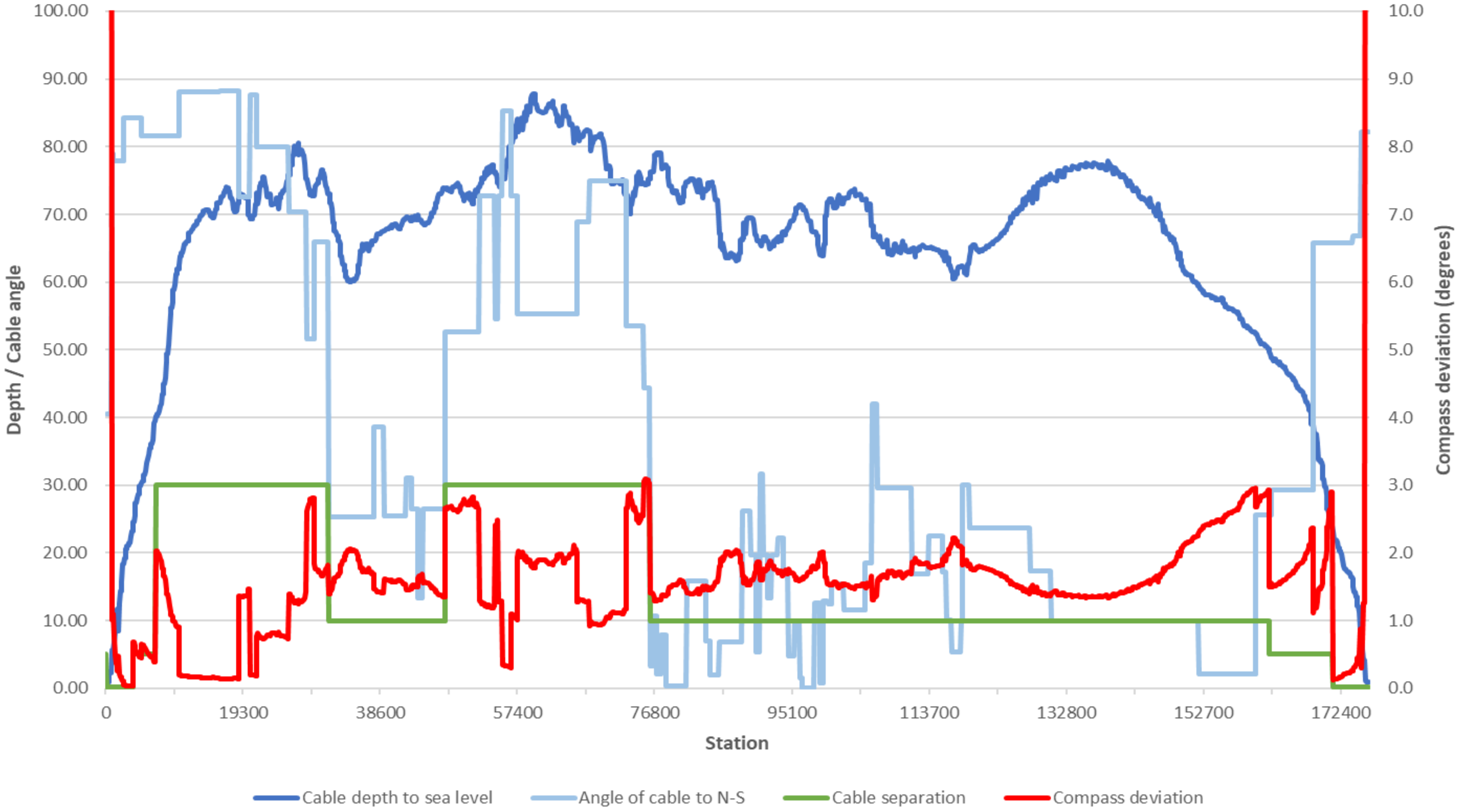
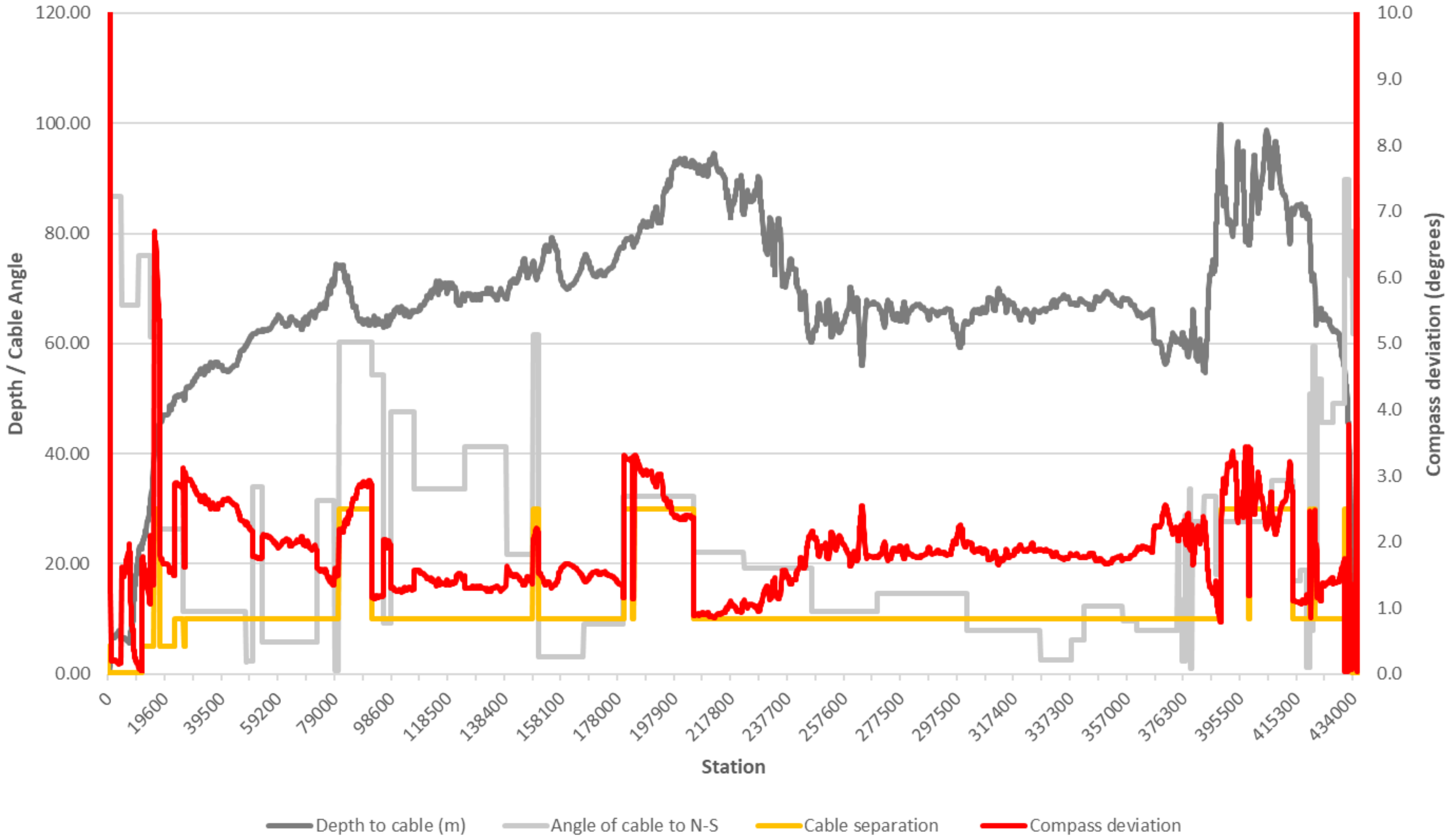


Figure A6: Calculated compass deviations for EL2 route with a two-cable design and dynamic cable separation along the route. Compass deviations at sea level were calculated along the entire route using the depth to seabed and cable angle to vertical for each station mark. The changes in cable separation are given by the yellow solid line



Appendix B: Calculated magnetic and induced electric fields from Eastern Link 1 and 2

Table B1: Calculated maximum magnetic field for each of the four design options for EL1 and EL2. Calculations provided for increasing vertical distance from the seabed and maximum current load. All calculations were performed at a minimum burial depth of 1m.

	Maximum cable magnetic field only					
Distance above seabed	**Seabed**	**0.5m**	**1m**	**5m**	**10m**	**20m**
Bundled bipole (0.2m)	79.2	35.4	19.95	2.22	0.66	0.18
Bipole 30m separation	399.8	266.4	199.6	66.6	36.4	18.02

Table B2: Calculated maximum total magnetic field from the cables and geomagnetic field combined for each of the four design options for EL1 and EL2. Calculations provided for increasing vertical distance from the seabed and maximum current load. All calculations were performed at a minimum burial depth of 1m. (Assumed geomagnetic field: magnitude 49.715, dip 68.679°)

	Maximum cable and geomagnetic field					
Distance above seabed	**Seabed**	**0.5m**	**1m**	**5m**	**10m**	**20m**
Bundled bipole (0.2m)	126.8	83.69	68.68	51.79	50.33	49.88
Bipole 30m separation	404.4	273.2	212.7	102.8	82.99	66.82

Table B3: Calculated induced electric field for each cable design using the calculated magnetic fields provided in Table A2. The induced electric field was calculated for a range of tidal velocities at increasing vertical distances from the cables.

		Induced electric field (µV/m)			
	Tidal velocity	**0.1 m/s**	**0.3m/s**	**0.75 m/s**	**1.25 m/s**
Bundled bipole (0.2m)	Seabed	12.68	38.04	95.10	158.50
	0.5m	8.37	25.11	62.77	104.61
	1m	6.87	20.60	51.51	85.85
	5m	5.18	15.54	38.84	64.74
	10m	5.03	15.10	37.75	62.91
	20m	4.99	14.96	37.41	62.35
Bipole 30m separation	Seabed	40.44	121.32	303.30	505.50
	0.5m	27.32	81.96	204.90	341.50
	1m	21.27	63.81	159.53	265.88
	5m	10.28	30.84	77.10	128.50
	10m	8.30	24.90	62.24	103.74
	20m	6.68	20.05	50.12	83.53

Figure B1: Calculated magnetic field with and without geomagnetic field at the seabed for a bundled bipole design- EL1 and EL2. Calculations were performed at maximum current load.

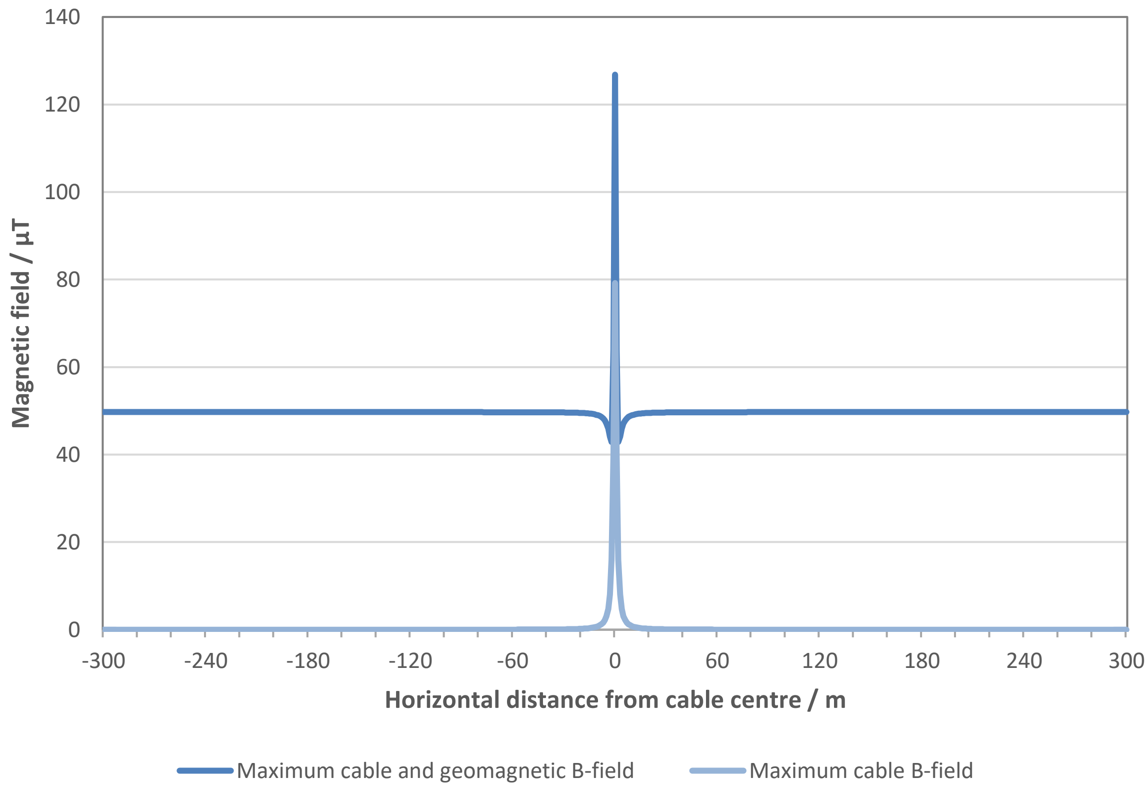
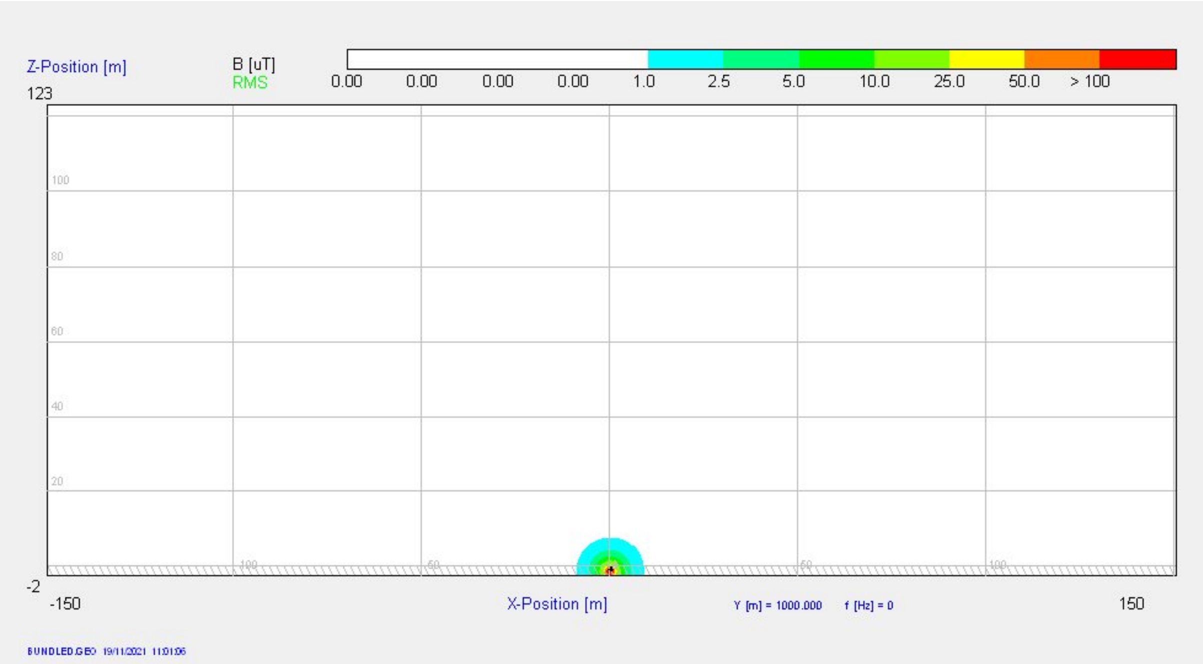


Figure B2: Cross sectional calculated maximum magnetic field without geomagnetic field for a bundled bipole design- EL1 and EL2. Calculations were performed at maximum current load. Hashed line represents seabed, horizontal and vertical scales in metres. (Each figure represents a different axis scale, but are the same calculation)



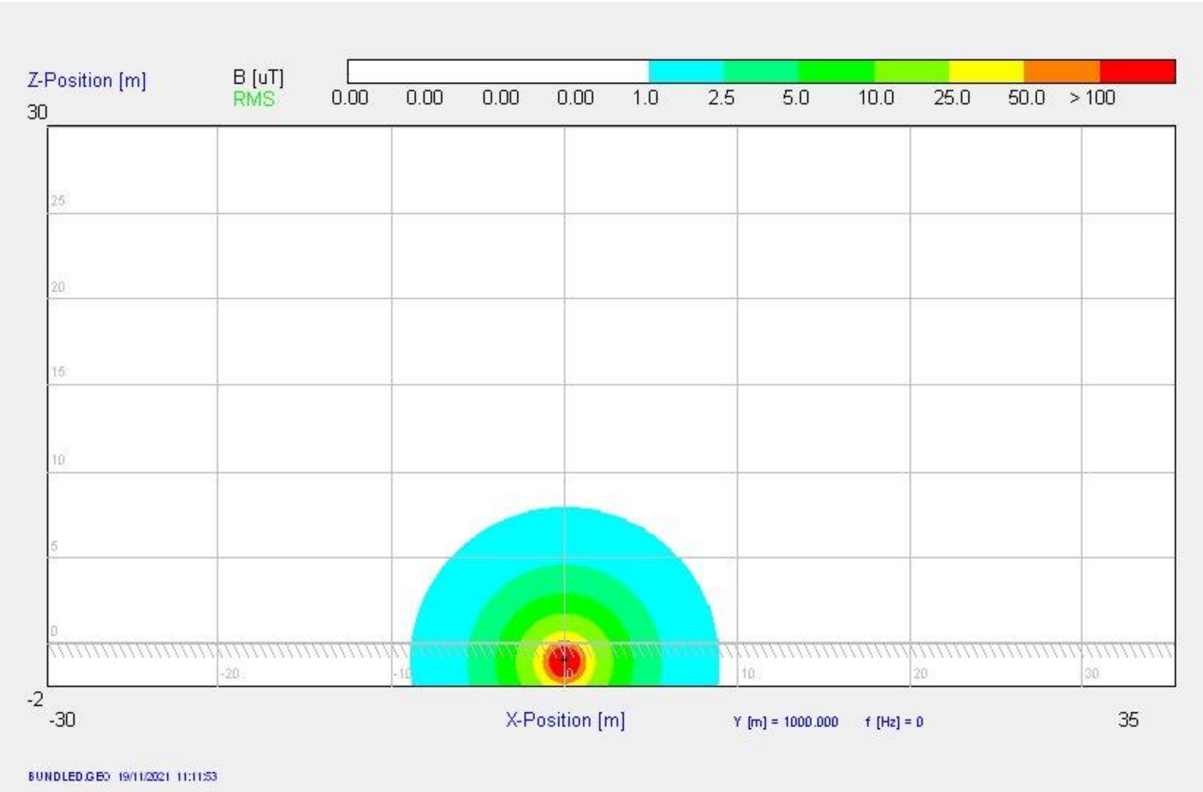


Figure B3: Calculated magnetic field with and without geomagnetic field at the seabed for a 30m separated bipole design- EL1 and EL2. Calculations were performed at maximum current load.

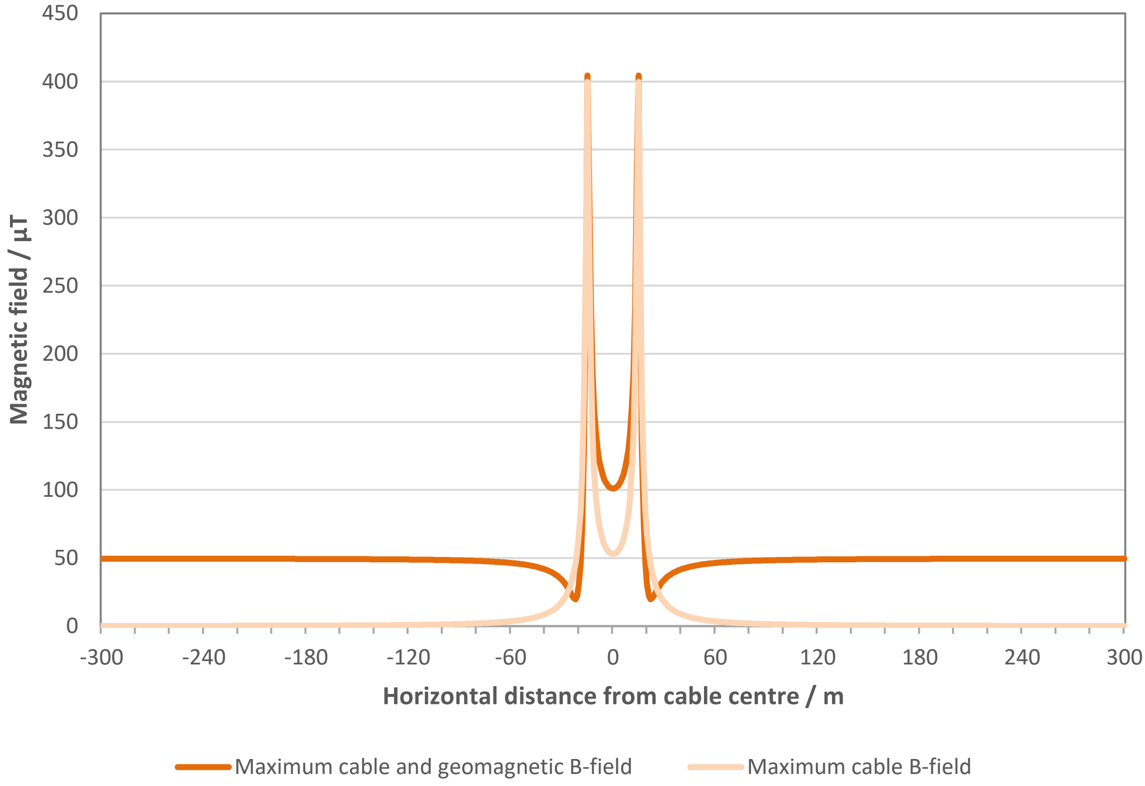


Figure B4: Cross sectional calculated maximum magnetic field without geomagnetic field for a 30m separated bipole design- EL1 and EL2. Calculations were performed at maximum current load. Hashed line represents seabed, horizontal and vertical scales in metres.