Chapter 18: Electric and Magnetic Fields & Sediment Heating

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18 Electric and Magnetic Fields & Sediment Heating

18.1 Introduction

This Chapter introduces Electric and Magnetic Fields (EMF), and calculates the levels of magnetic fields expected to arise from the HVDC cables during the Operations phase of the NorthConnect project. The HVDC cables can also give rise to localised temperature increases, hence sediment heating calculations are also presented within this Chapter. Magnetic fields and sediment heating effects on various receptors are discussed further within the following topic-specific Chapters; Chapters 14 to16 (Benthic Ecology; Fish and Shellfish; and Marine Mammals); and Chapter 19 (Navigation and Shipping).

18.1.1 Electric Fields

Electric field strength is an expression of the intensity of an electric field at a particular location. The standard unit is the volt per meter (V/m). A field strength of 1 V/m represents a potential difference of one volt between points separated by one meter. Electric fields are produced by voltage. DC voltages produce static electric fields, and AC voltages produce alternating (fluctuating) electric fields.

For insulated cables, the electric fields are contained inside the cable, hence, there will be no external electric field caused by the NorthConnect HVDC cables and, as such, electric fields will not be considered further.

18.1.2 Magnetic Fields

Magnetic Fields are produced by electric current flow and are measured in Tesla (symbolised as T), being the standard unit for magnetic flux density. Magnetic Fields are not easily screened and can pass through buildings and cable screens. The Earth's core produces a magnetic field, which is oriented in a north-south alignment, and gives rise to varying magnetic field strengths across the globe. The Earth's magnetic field is strongest towards the poles and weakest at the equator, as represented in Figure 18.1.

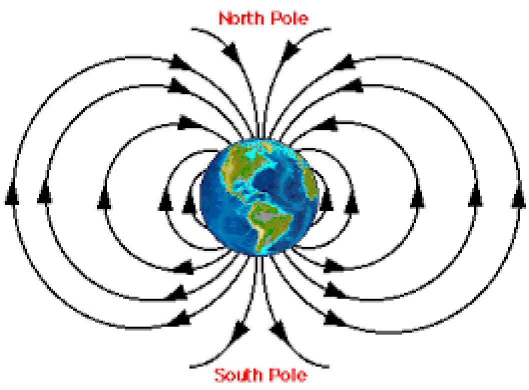

Figure 18.1 Representation of the Earth's Magnetic Field (The University of North Carolina, 2004)

DC cables produce static magnetic fields, which decrease with distance from the cable. The static magnetic fields generated is added or subtracted locally to the earth's natural static magnetic field. Where the outgoing and return paths of a DC circuit (2 cables) are in close proximity, their magnetic fields cancel within relatively short distances from the cables.

High levels of EMF can cause interference with electronic equipment, magnetic equipment and communications such as radio's and compasses. A number of marine species can detect electric and/or magnetic fields and utilise them during feeding, predator detection and navigation. These are considered further in the subject-specific Chapters 14-16.

Magnetic fields can also give rise to compass deviation which are considered with Chapter 19: Shipping and Navigation.

18.2 Sources of Information

18.2.1 Legislative Framework

The Control of Electromagnetic Fields at Work Regulations 2016 implement the European Commission's Directive 213/35/EU on the minimum health and safety requirements regarding the exposure of workers to risk arising from physical agents (electromagnetic fields). The legislation is not directly practicable to the Environmental Impact Assessment (EIA) process; however, it does include action levels which may assist in the interpretation of the numbers provided in this chapter. It should be noted that NorthConnect will ensure compliance with all health and safety legislation to minimise impacts on its workforce.

18.2.2 Guidance

Sources of relevant advice regarding exposure to EMF, although these primarily relate to AC cables, are outlined below:

- Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz) (National Radiological Protection Board, 2004);
- Guidelines for limiting exposure to static magnetic fields (International Commission on Non-Ionizing Radiation Protection, 2009);
- Power Lines: Demonstrating compliance with EMF public exposure guidelines. A Voluntary Code of Practice(Department of Energy & Climate Change, 2012); and
- Electromagnetic Fields at Work, A guide to the Control of Electromagnetic Fields at Work Regulations 2016 (Health and Safety Executive, 2016).

18.3 Methodology

18.3.1 Magnetic Field Assessment

As there will be two cables laid in close proximity to each other, there will be some degree of cancelling out of the magnetic fields generated by each cable. Magnetic fields strengths have been calculated based on a number of scenarios covering both the onshore and offshore cable configurations. It is assumed that the current will always be in the opposite direction, as this will only cease to be the case as the flow of power on the interconnector is reversed and will last for only an instant.

Magnetic flux density (B) is a measure of magnetic interaction, calculated using the Biot-Savart Law, where I is the current, μ is the magnetic permeability of the medium, and R is the radial distance from the current axis. The equation is expressed as follows:

$$B = \frac{\mu I}{2\pi R}$$

All relevant media have relative permeability constants very close to 1. Only ferromagnetic materials have deviating permeabilities. Hence, a permeability of 1 is assumed for all media.

There are local variations and variations over time of the natural magnetic field. These variations are rather small, but still significantly larger than the impact of different permeabilities of different media.

18.3.1.1 Onshore

For the onshore cables, the magnetic flux associated with the cables has been calculated taking account of the Earth's magnetic field and assuming the worst-case scenario that the cables run in a west-east direction, which is only true for part of the route. The resultant numbers have been compared to the levels identified within the Control of Electromagnetic Fields at Work Regulations 2016 and International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, to allow their strength to be put into context. Static electric field have a frequency of zero and, as such, the frequency range category of up to 1Hz applies to DC Cables. Table 18.1 details the levels relevant to the DC cables.

Table 18.1: Magnetic Flux Reference Levels

Level Description	Magnetic Flux Density (B) [µT]	Source
Worker Exposure Level Values Sensory Effect – Limb	8,000,000 µT	The Control of Electromagnetic Fields at Work Regulations 2016, and ICNRIP Guidelines on Limits of Exposure to Static Magnetic Fields (International Commission on Non-Ionizing Radiation Protection, 2009)
Worker Exposure Level Values Sensory Effect – Head and Trunk	8,000,000 µT	
Worker Exposure Level Values Health Effect - Any part of the Body	2,000,000 µT	
Interference with active implanted medical devices.	500µT	
General public Exposure of any part of the body.	400,000µT	ICNRIP Guidelines on Limits of Exposure to Static Magnetic Fields (International Commission on Non-Ionizing Radiation Protection, 2009)

18.3.1.2 Offshore

The magnetic fields associated with the offshore cables have been calculated taking account of the local natural magnetic field on the cable route off the coast of Scotland, within the model. The magnetic field from the cables is added (vectorially) to the natural magnetic field. The results have been utilised in the marine ecology Chapters 14-16 and, hence, are not assessed here.

18.3.2 Compass Deviation

Compass deviations have been calculated assuming the compass is 1m above sea level. The effect of the magnetic field on compass deviation have also been calculated for consideration in Chapter 19.

18.3.3 Sediment Heating

Sediment heating modelling has been completed to identify the potential increase in seabed temperature, the effects of which are considered in the relevant ecological Chapters.

18.4 Baseline Information

18.4.1 Onshore Electric and Magnetic Fields

The Earth provides a background static magnetic field ranging between 25 and 65 microtesla (µT) and the intensity tends to decrease from the poles to the equator. In the Peterhead area it is approximately 42µT.

Existing potential onshore sources of Electric fields in the Fourfields and HVDC cable route area include the Peterhead substation and overhead electricity cables, and these will be AC, producing alternating electric fields. The electric fields associated with the substation are likely to be screened by the building structure as metal clad building structures act as a Faraday cage, an earthed metal box, which will effectively screen electric fields within the building.

18.4.2 Offshore Electric and Magnetic Fields

The Earth's background static field is also present offshore. At the landfall it will be in the region of 42µT, but the level will increase across the North Sea as the cable moves into more northern latitudes. The Hywind Export Cable will be the only operational power cable within the NorthConnect cable corridor, and it is an AC cable. There will be a crossing with the Hywind and North Connect cables, which is addressed in Section 18.8: Cumulative Assessment.

18.5 Impact Assessment

18.5.1 Operation

18.5.1.1 Onshore Magnetic Field

The onshore HVDC cables' radii will be approximately 0.1m. The two cables will be laid in a single trench as shown in Drawing NCGEN-NCT-Z-XE-0003-01, approximately 1m apart and, 1m below ground and, from the exit of the Road Crossing HDD to Joint Pit 2, a distance of 610m. A similar arrangement will be used for the parts of the route from Joint Pit 2 to Fourfields which aren't ducted. The current in the cable, I = 1400 Amps and the magnetic permeability, µ is assumed to be 1.

Figure 18.2 shows the magnetic flux values in µT for distances perpendicular to the onshore HVDC cables in a single trench, with 0 being the mid-point between the two cables, where the magnetic fields cancel out.

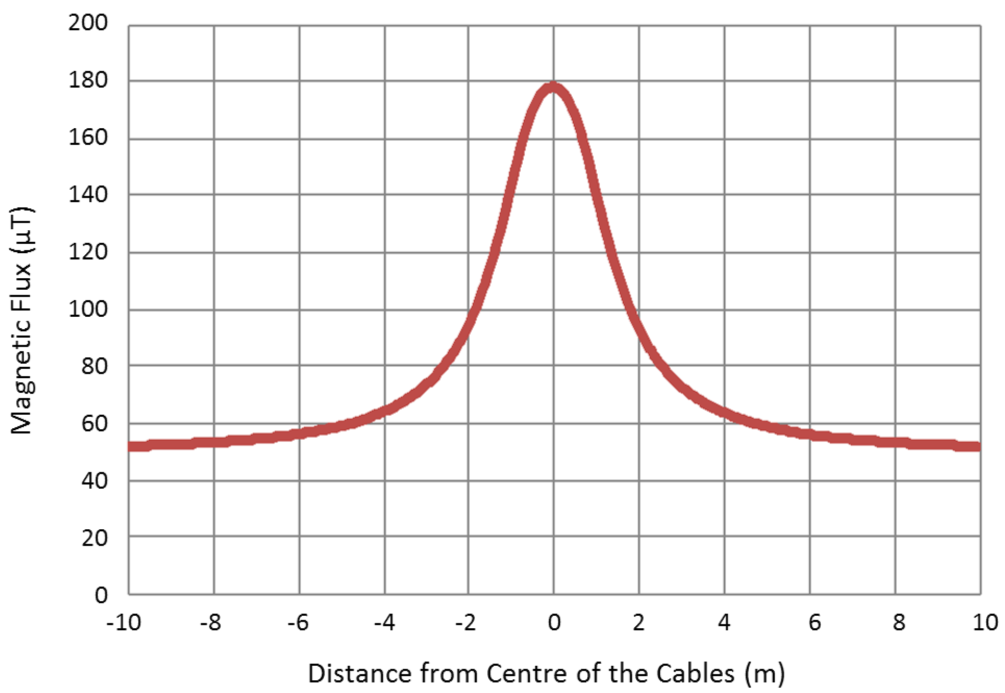

Figure 18.2: Magnetic Field when Crossing Perpendicular to the Onshore HVDC Cables in a Single Trench

The marine HVDC cables will be in separate trenches from the Landfall HDD to Joint Pit 1 and, as indicated in Figure 2.7 of Chapter 2, the cables will be 7m apart, and the cables radii is are assumed to be 0.13m. Figure 18.3 shows the magnetic flux values in µT for distances perpendicular to the marine HVDC cables in two trenches, with 0 being the mid-point between the two cables, where the magnetic fields cancel out.

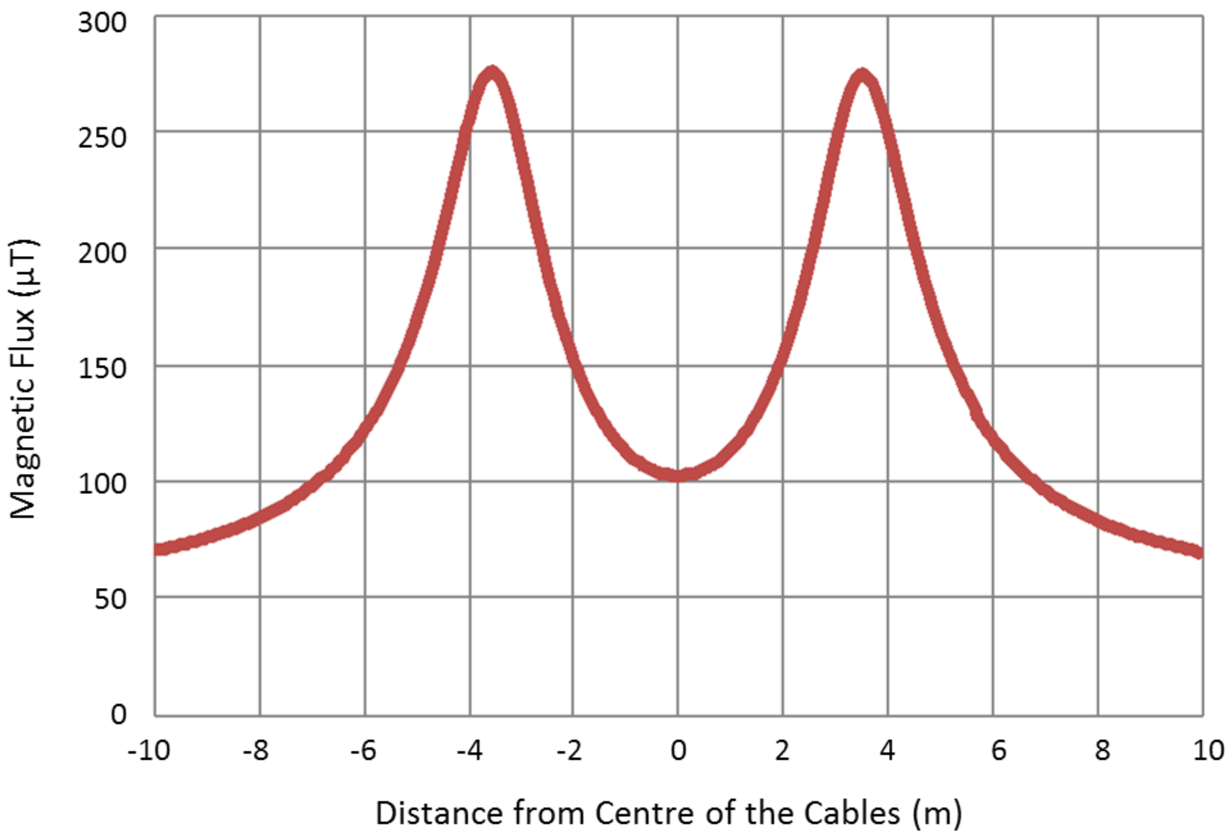

Figure 18.3: Magnetic Flux when Crossing Perpendicular to the Marine HVDC Cables in Two Trenches

The Road Crossing HDD and ducted cables will be deeper and afforded insulation by the ducts and, as such, the associated magnetic flux levels will be lower than those shown in Figures 18.2 and 18.3.

The maximum magnetic flux values are experienced at ground level directly above one of the cables in the two-trench design (270µT) as shown in Figure 18.3, and between the two cables in the single trench design (180µT). The peak magnetic flux for the two-trench design is 270µT including the Earth's magnetic field. This is 230µT below the level that causes interference with active implanted medical devices and 1000 times lower than general public exposure levels (see Table 18.1). The peak levels dissipate rapidly with distance, halving in both scenarios within 2 meters.

It should however be noted that implanted medical devices are likely to be in the torso not the feet, so for people standing above the cables, magnetic field at the torso >1m above ground level will be less than 150µT for the two trench design and 100µT for the single trench.

Considering the cables are located in grazing fields, then there are unlikely to be human receptors in the immediate vicinity of the cables for more than a few moments at a time. The cables will be ducted under the core paths and planned Fourfields paths and, as such, will be deeper and hence give rise to even lower magnetic flux levels. The effect of onshore cable magnetic fields on human receptors are considered to be **negligible** and **non-significant** due to their low levels.

18.5.1.2 Offshore Magnetic Fields

As discussed in Chapter 2, there is a possibility that the offshore cables could be bundled together, installed in close proximity to one another. If this is the case, then the fields between the two cables will cancel each other out and, therefore, the external magnetic field will be negligible as shown in Figure 18.4. However, for the purposes of the EIA we are considering the worst-case scenario that the cables will be laid in separate trenches.

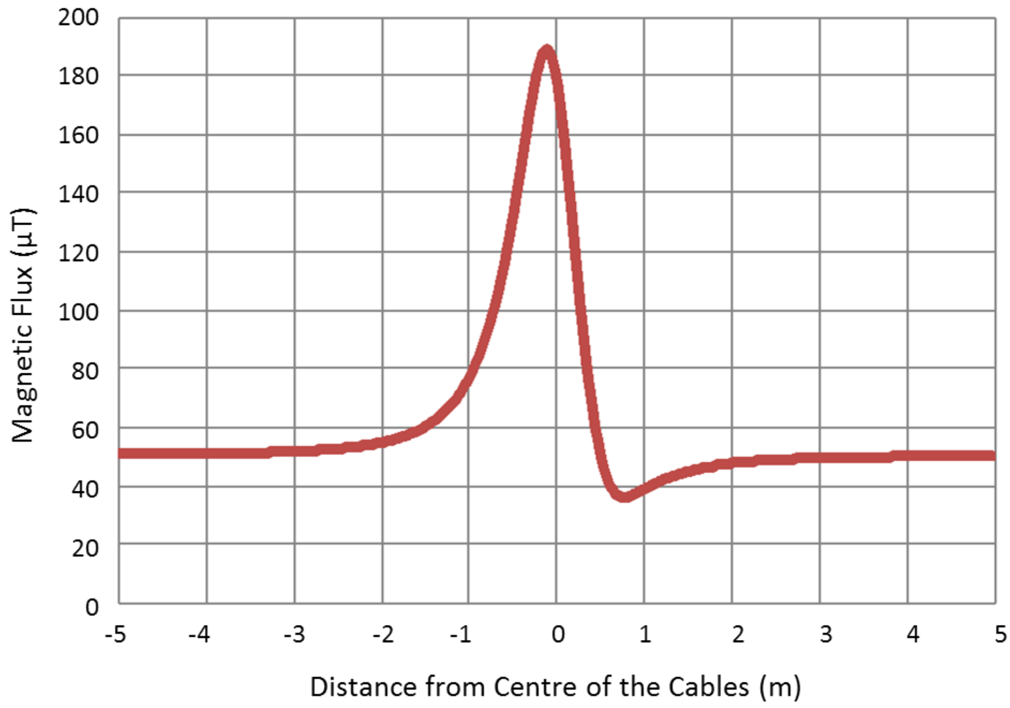

Figure 18.4: Bundled Cable Depth of Burial 0.4m – Magnetic Flux on seabed When Crossing Perpendicular

The worst-case depth of burial (DOB) is 0.4 m in hard substrates and 0.5 m in soft substrates. Cable separation will likely be between 20m and 100m as discussed in Chapter 2 and the Construction Method Statement (NorthConnect, 2018). The current in the cable, I = 1400 Amps and the magnetic permeability µ, is assumed to be 1. Figures 18.5, 18.6 and 18.7 assume a DOB of 0.4m and a cable separation of 20m, 40m and 100m respectively. In all three instances the peak magnetic flux is 640µT, with levels reducing to <300 µT within 2 m of the seabed in all cases.

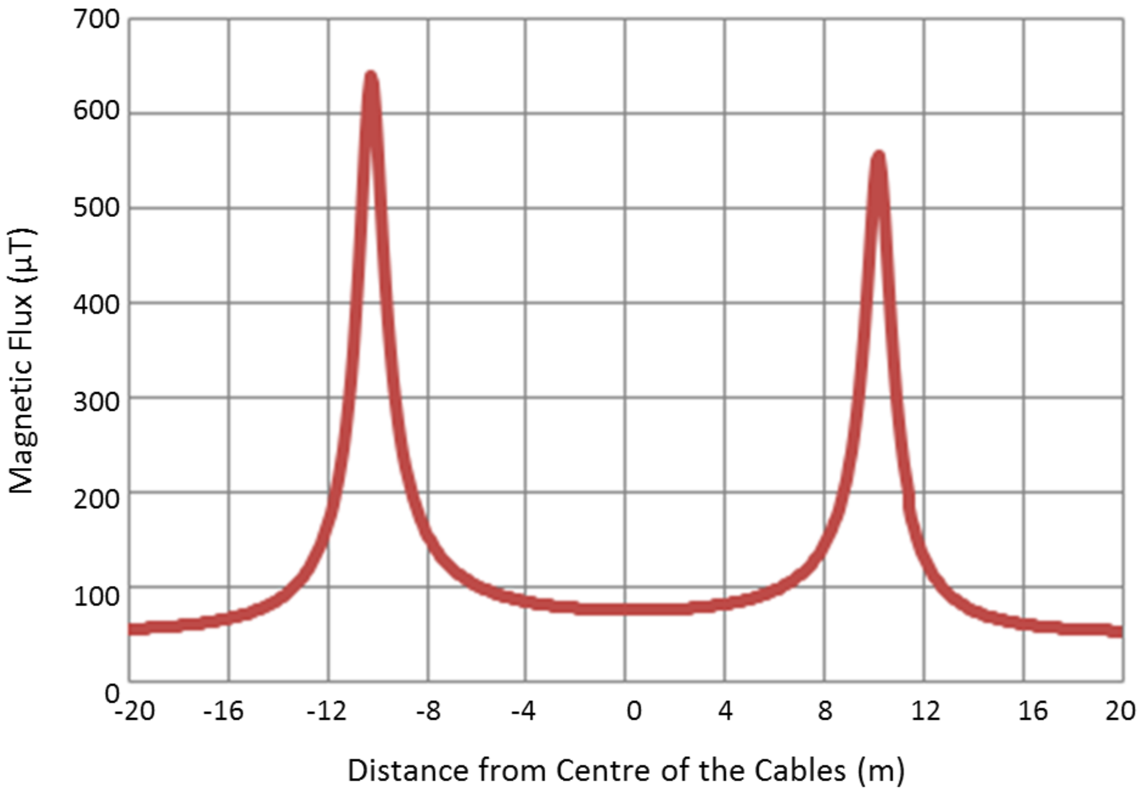

Figure 18.5: Magnetic Flux on seabed When Crossing Perpendicular - 20m Separation, 0.4m DOL

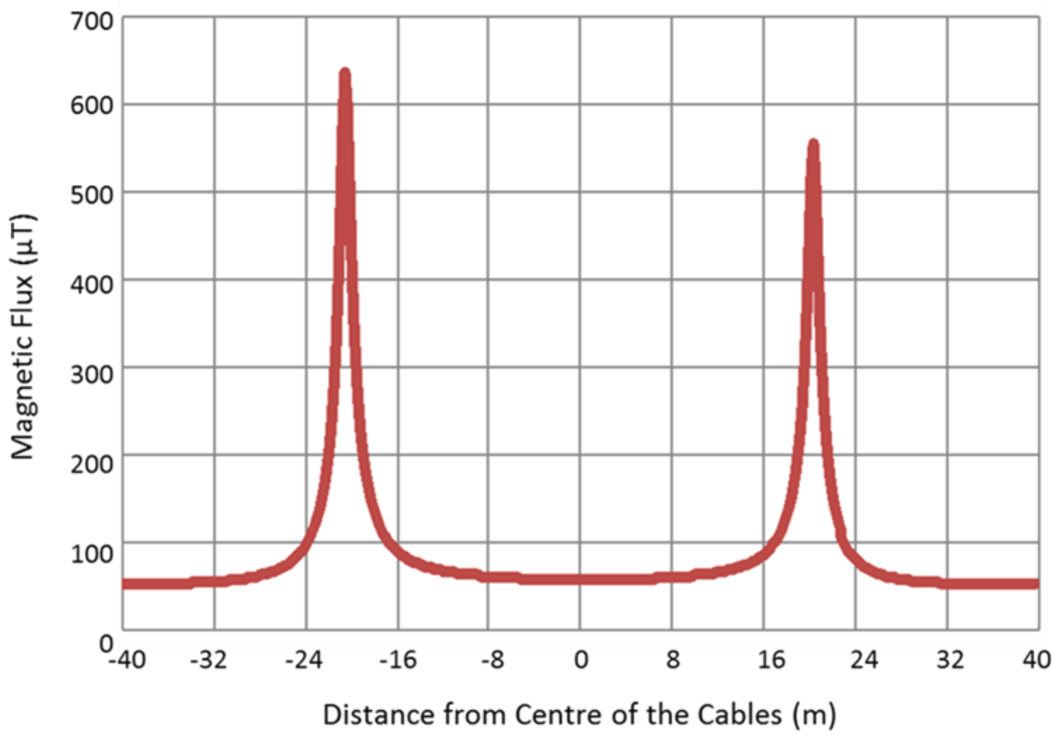

Figure 18.6: Magnetic Flux on seabed When Crossing Perpendicular - 40m Separation, 0.4m DOL

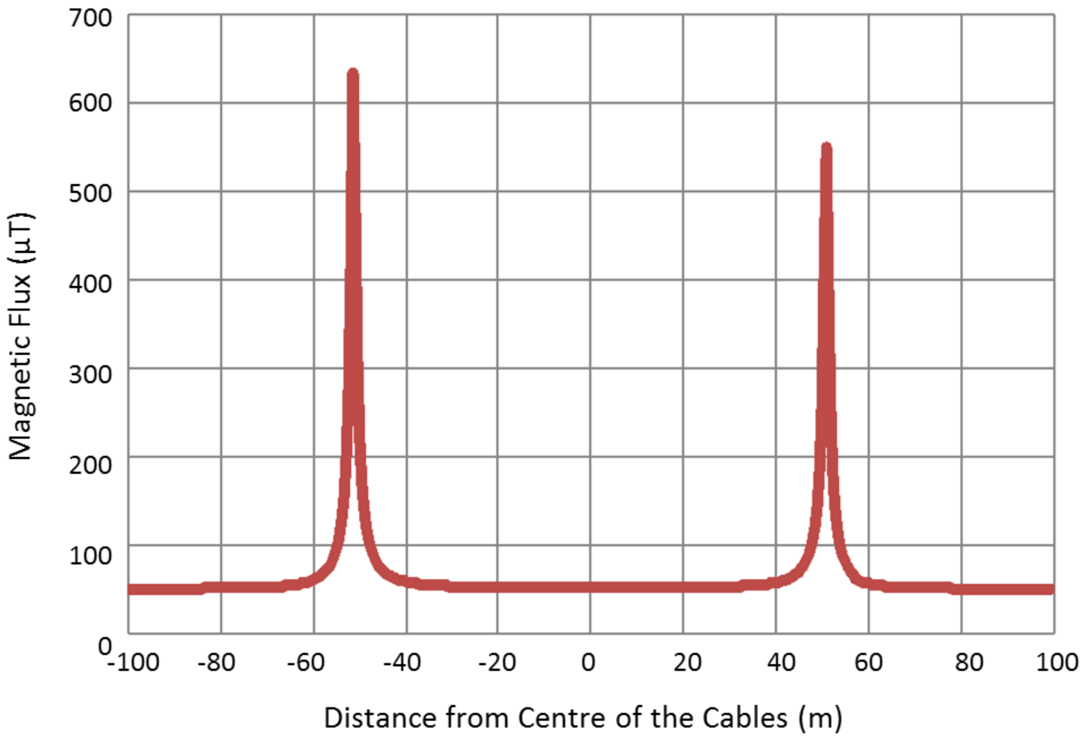

Figure 18.7: Magnetic Flux on seabed When Crossing Perpendicular - 100m Separation, 0.4m DOB

The majority of the cable will, however, have a DOB of over 0.8m and, Figure 18.8 assumes a cable separation of 40m and a DOB of 1m. The peak DOB is 310µT for a cable with a DOB of 1m.

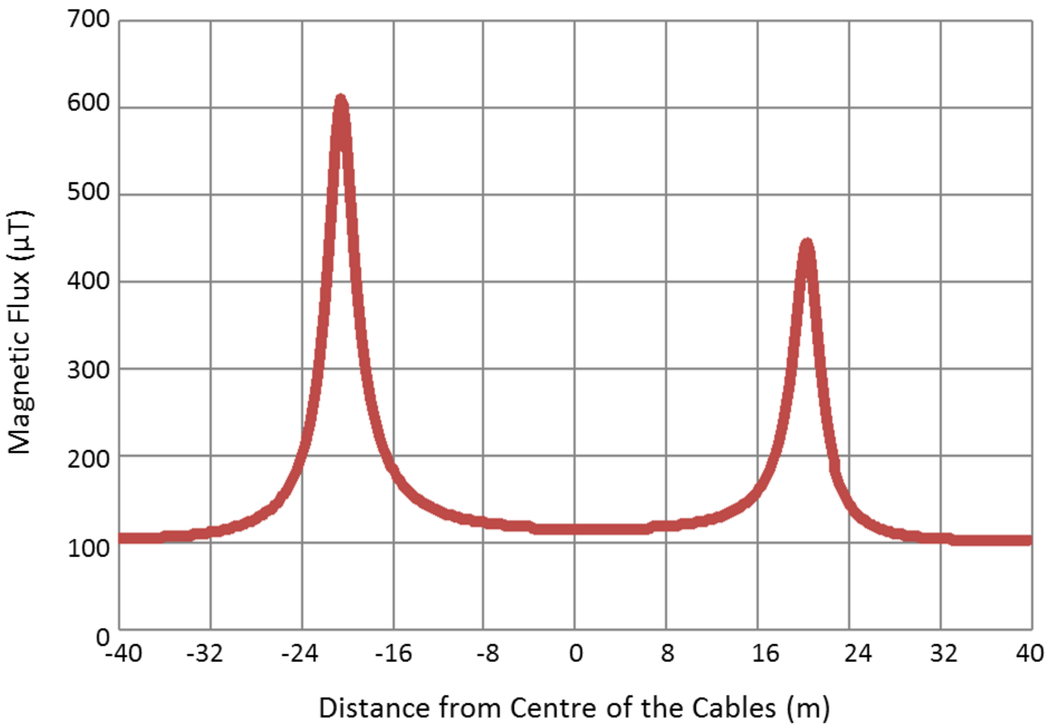

Figure 18.8: Magnetic Flux on seabed When Crossing Perpendicular - 40m Separation, 1m D

18.5.1.3 Compass Deviation

The magnetic fields associated with the cables could cause compass deviation. As discussed above magnetic fields reduce with distance, hence, the deeper the water the lower the compass deviation effect. Similarly, the closer cables are to each other, the greater the cancelling effect between the two cables. Hence, compass deviation in shallow waters can be reduced by installing the cables closer together. Figure 18.9 shows the maximum cable separation that can be employed while achieving compass deviations of less than 5 degrees at various water depths.

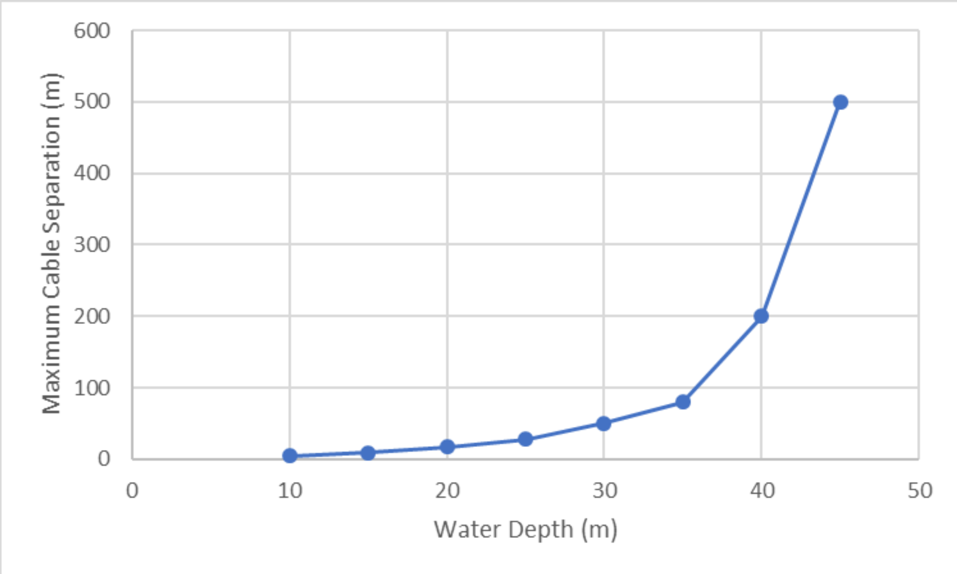

Figure 18.9: Maximum Cable Separation by Water Depth to Achieve <5-degree Compass Deviation

At 25m water depth a cable separation of <28m will give rise to a compass deviation of less than 5 degrees, whereas at 30m water depth a separation of <50m is required. The exit point is in the region of 26.5m water depth, so a separation of <35m would be sufficient to keep compass deviation below 5 degrees. Within Scottish Territorial Waters (STW), cable separation is likely to be between 20 and 40m. Beyond STW, water depths are greater than 45m and, as such, cables anywhere within the consenting corridor will not increase compass deviation by more than 5 degrees.

18.5.1.4 Sediment Heating

The cables will generate heat and in theory could increase the temperature of the surrounding sediments, which could have knock-on ecological impacts primarily to benthic species, as discussed in Chapter 14: Benthic Ecology. The heating associated with the cables has therefore been modelled. Figure 18.10 shows the predicted sediment heating assuming a 20m cable separation, a Depth of Lowering (DOL) of 0.5m and an ambient seabed temperature of 9°C for the North Sea. Figure 18.11 provides a closer view of the temperatures around one of the cables.

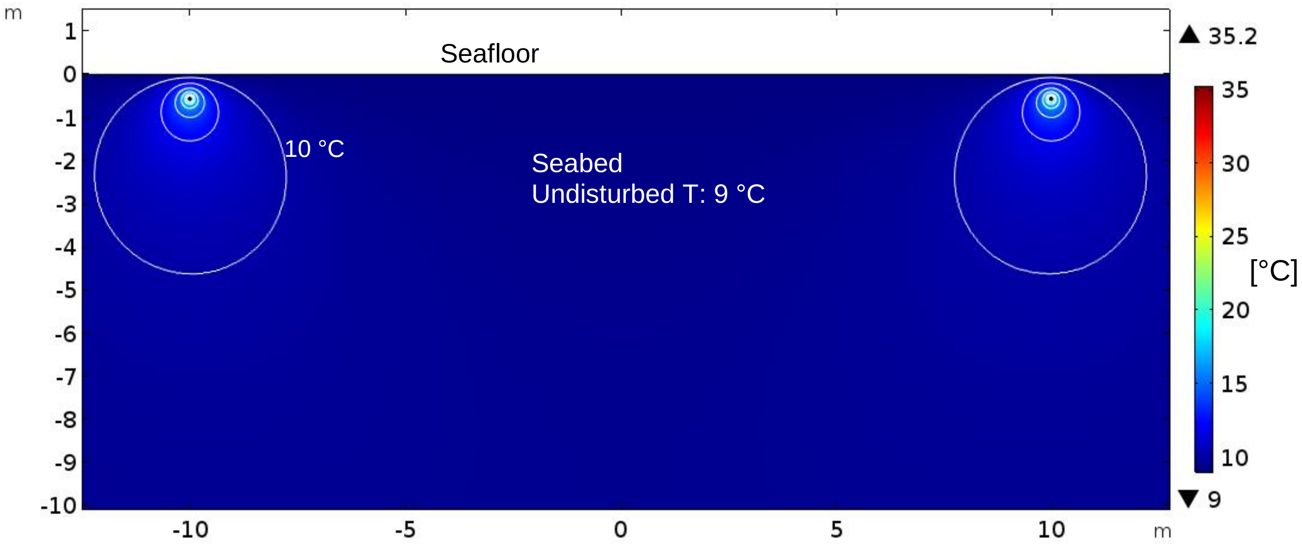

Figure 18.10: Sediment Temperatures for Cables 20m Separation and DOL 0.5m

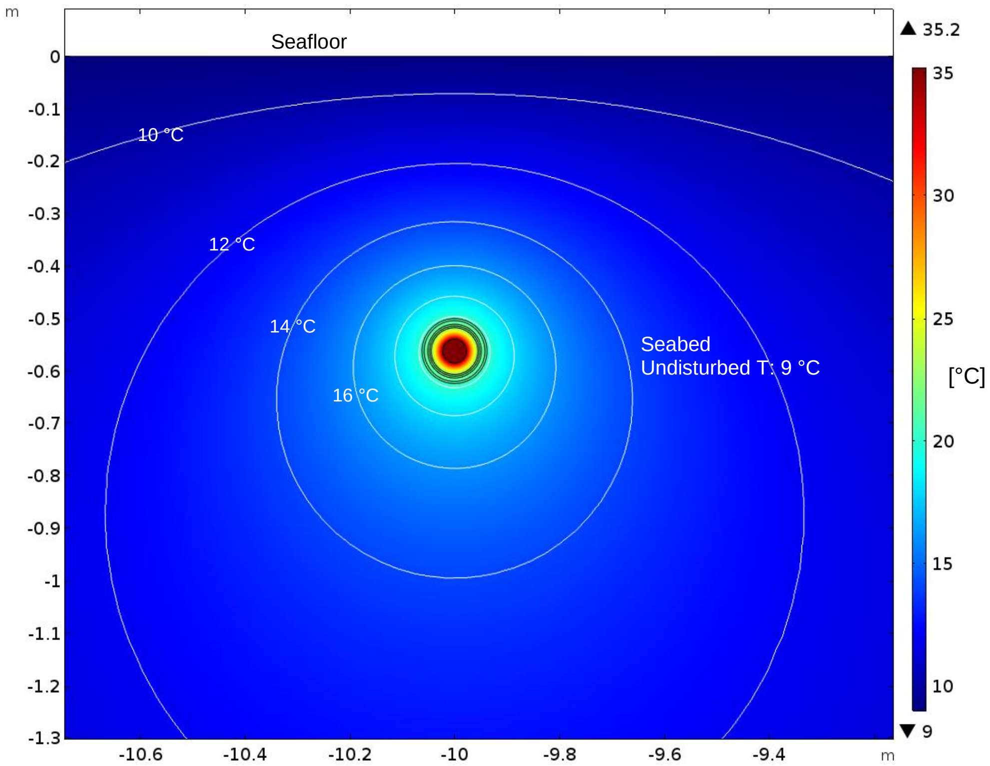

Figure 18.11: Sediment Temperatures for Cables 20m Separation DOL 0.5m (Close Up)

The model output demonstrates that sediment heating effects are extremely localised and, as such, there are no interaction effects between the two cables at a 20m separation. Increases above 1 degree are localised to an area with a radius of less than 2.5m, with the centre point being below the cable. This is due to heat dissipation nearer the top of the seabed, and probably due to the increased heat dissipation facilitate by seawater. Seafloor temperatures are not predicted to increase. Temperature increases of up to 7 degrees occur for an area within a radius of 0.2m, so significant temperature increases are very localised.

Bundled cables give rise to higher temperatures as they interact with each other. Figures 18.12 and 18.13 assume a 0.5m depth of lowering for a bundled cable.

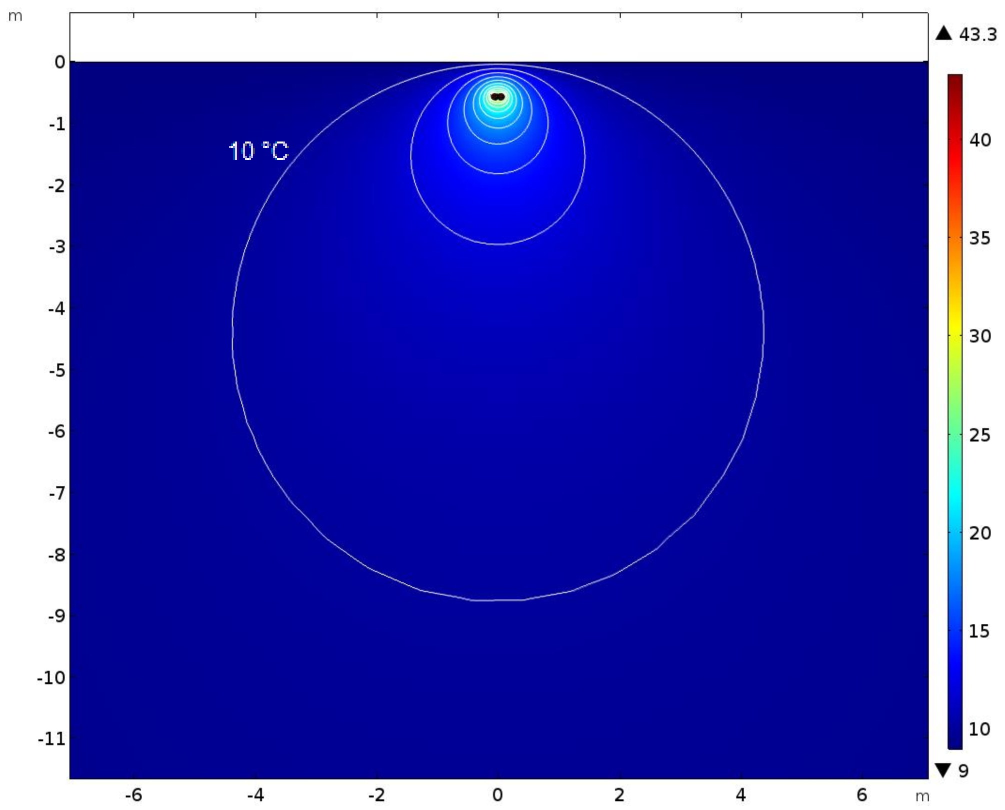

Figure 18.12: Sediment Temperatures for Bundled Cables DOL 0.5m

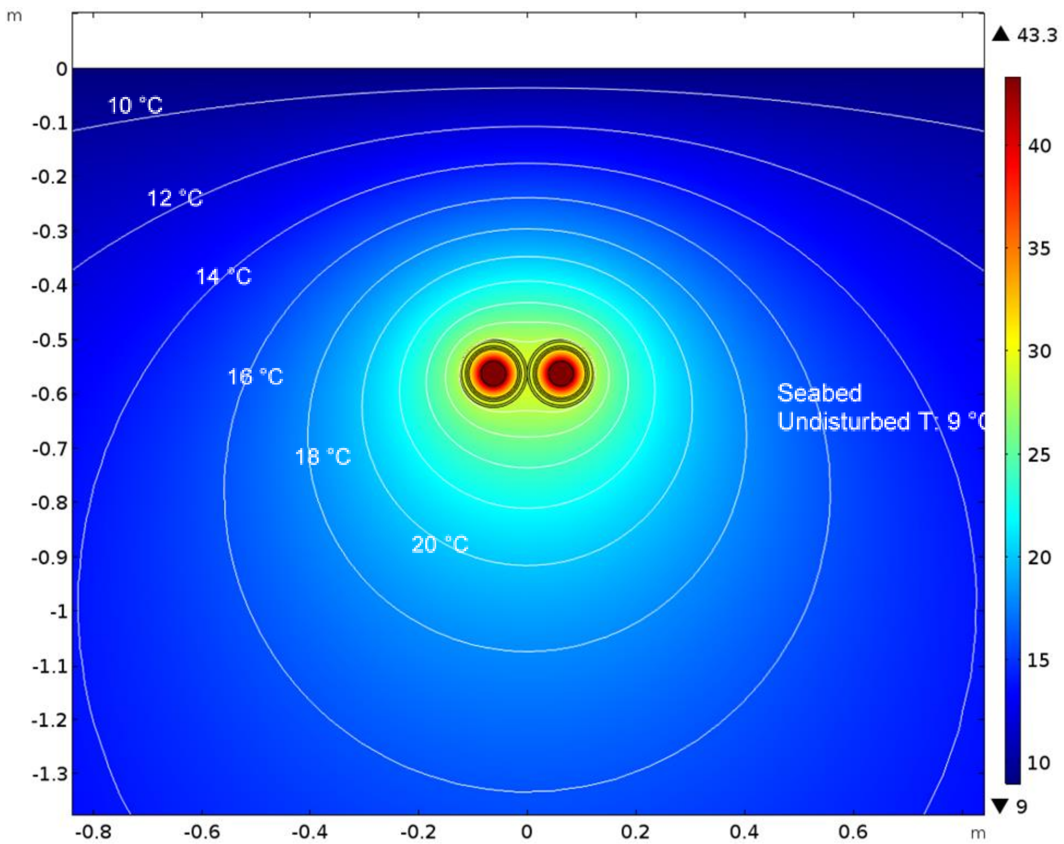

Figure 18.13: Sediment Temperatures for Bundled Cables DOL 0.5m – Close Up

With bundled cables, the 1-degree increase area is also localised to a radius of less than 2.5m, however, the increase of up to 7 degrees covers a wider area with a radius of 0.5m.

18.6 Mitigation Measures

No secondary mitigation is required to minimise impacts, as the need to minimise magnetic field, compass deviation and sediment heating effects has been considered throughout the project design process and is included as primary mitigation.

18.7 Residual Effects

18.8 Cumulative Assessment

18.8.1 Onshore Magnetic Field

An assessment of magnetic fields associated with the NorthConnect Converter Station and HVAC Cable Route, was included within the Environmental Statement (NorthConnect, 2015). The HVAC cables and AC components of the converter station were calculated, to give rise to, a 18μT magnetic fields. For the cable this is at ground level (assuming a 1.5m burial depth), for the converter station it was at the boundary fence. Some of the DC components could give rise to 57μT at 5m, the public will be a minimum of 5m from these components.

Due to the low levels of magnetic fields associated with the HVAC cables, and the fact that they will only be close to the HVDC cables near the converter station; and they will be in ducts at depth; no significant cumulative effects are expected, between the HVAC and HVDC cables.

Similarly, the HVDC cables will be in ducts much deeper than 1m (as used in the calculations in section 18.5.1.1), near the site boundary, and as such, no significant cumulative effects are expected with the DC components of the Converter Station.

NorthConnect have committed to carrying out, pre and post-energisation magnetic field measurements at the Fourfield site, to show that magnetic fields generated will not have a detrimental effect on the public. The HVDC cables need to be energised to allow this to happen, hence, the measurement will be of the cumulative effects.

18.8.2 Offshore

EMF and sediment heating effects are very localised and, as such, the only project with which there could be cumulative effects is the Hywind Scotland Pilot Park Offshore Windfarm. Statoil have calculated that the magnetic field surrounding their cables would be 6μT reducing to 2 μT within 2m and having negligible effects on the environment (Statoil, 2015). At the crossings the magnetic fields could, in theory, interact, however, there will be rock protection between the cables reducing the interaction between the cables. The interactions will be extremely localised to within 2m and the Hywind levels of magnetic flux are so low that the overall effect would be **negligible, non-significant**.

18.9 Summary

The only impact assessed within this Chapter was the effect of onshore magnetic flux on human receptors, this was deemed to be negligible, non-significant. The magnetic flux levels and sediment heating effects on ecological receptors are considered in topic-specific Chapters 14-16 (Benthic Ecology; Fish and Shellfish; and Marine Mammals); and compass deviation is discussed in Chapter 19 (Navigation and Shipping).

The potential for cumulative effects with the Hywind Scotland Pilot Park Offshore Wind Farm has identified that their magnetic flux levels were extremely low and hence cumulative effects are negligible, non-significant.

18.10 References

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