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Glossary

Acoustic energy conversion efficiency (or conversion factor)	Describes how much of the hammer energy is converted into acoustic energy i.e. noise

Abbreviations and Acronyms

ADD	Acoustic Deterrent Device
Cefas	The Centre for Environment, Fisheries and Aquaculture Science
CF	Conversion Factor
ES	Environmental Statement
ICOL	Inch Cape Offshore Limited
iPCoD	Interim Population Consequences of Disturbance
km	kilometres
m	metres
MS-LOT	Marine Scotland Licensing Operations Team
MSS	Marine Scotland Science
n	Number of individuals
NOAA	National Oceanic and Atmospheric Administration
PTS	Permanent Threshold Shift
SNH	Scottish Natural Heritage

10B Underwater Noise Modelling Using a 1 % Conversion Factor

10B.1 Introduction

1 One of the parameters used in the underwater noise modelling, the acoustic energy conversion efficiency, or conversion factor (CF), describes how much of the hammer energy is converted into acoustic energy i.e. noise (see *Section 9B.3.1* of *Appendix 9B: Underwater Noise Modelling*).

2 All of the underwater noise modelling described in *Appendix 9B*, *Chapter 9: Natural Fish and Shellfish* and *Chapter 10: Marine Mammals* was undertaken using a CF of 0.5 % in keeping with The Centre for Environment, Fisheries and Aquaculture Science (Cefas), who carried out the noise modelling, current understanding of how much hammer energy is converted to noise (see *Section 10B.2*).

3 During the Gatecheck process, Scottish Natural Heritage (SNH) expressed concerns regarding the value of the CF used in the source model calculation, "*Our view is that the use of a 0.5% conversion factor returns estimated source levels that are lower than expected. We therefore advise that a conversion factor of 1% is used in the noise model instead of the 0.5% which has been used in the information provided at Gatecheck. If the conversion factor of 0.5% is preferred, we would need to see full justification as to the reasons why the 0.5% conversion factor is appropriate for Inch Cape Offshore Limited (ICOL). Our recommendation of 1% follows our advice for the BOWL Piling Strategy and will improve our ability to compare the differences in estimated impacts between developments*".

4 Marine Scotland Licensing Operations Team (MS-LOT) and Marine Scotland Science (MSS) agreed with SNH's concerns.

5 Further information explaining the choice of CF was provided by Cefas (Farcas and Merchant, 2018). This information (justification for using a CF of 0.5 %) has been summarised in Section 10B.2.

6 A conference call between ICOL, Cefas, SNH, MS-LOT, MSS and Natural Power was held on the 10/07/2018 to discuss the issue. However, no resolution was able to be reached without additional information/ further discussion.

7 Therefore, following the conference call, whilst Cefas still maintain their position that the 0.5 % CF is in line with best available science (see Section 10B.2), additional noise modelling using a CF of 1 % was carried out in order that the effect of any potential differences on the assessment for marine mammals (which was conducted using a CF of 0.5 %) could be assessed. The outcomes of this re-modelling, and the implications for the marine mammal impact assessment, are described in this Appendix.

10B.2 Justification for using a CF of 0.5 %

8 To derive an appropriate CF, Cefas conducted a detailed review of the literature (Farcas and Merchant, 2018), which supported the use of 0.5 % as the energy CF. This was based on a

recent review paper (Dahl, de Jong and Popper, 2015) and related observational and numerical studies (e.g. Robinson et al., 2007; Dahl and Reinhall, 2013; Zampolli et al., 2013). While the studies show a range of CF values, Cefas concurs with the conclusion of Dahl, de Jong and Popper (2015), that the weight of evidence suggests that "about half a percent of the hammer impact energy goes into waterborne acoustic energy" (Dahl, de Jong and Popper 2015). This position of a lower CF is supported in a more recent publication from Dahl and Dall'Osto (2017) which indicates a CF of the hammer strike energy into water acoustic energy of approximately 0.1 % - 0.15 %, which represents about one order of magnitude less than a previous reported value (Dahl and Reinhall, 2013) of approximately 1.3 %. Although the ranges at which the energy values are reported are different in these two studies, adjusting for this difference (an energy decay of approximately 30 % between 0 – 80 metres (m)) would still indicate a CF of < 0.2 %. Taken together, this evidence suggests that 0.5 % is a realistic value to use for the CF, and that this may be a conservative estimate based on the most recent literature.

10B.3 Use of a CF of 1 %

9 To assess the difference resulting from using a 1 % rather than 0.5 % CF, the following worst case (Scenario 4; see Table 10B.1) scenarios for both pin piles and monopiles were re-run using a CF of 1 %:

- Permanent Threshold Shift (PTS):
    - Low frequency cetaceans (National Oceanic and Atmospheric Administration (NOAA) (2016) criteria);
    - High frequency cetaceans (NOAA (2016) criteria);
    - Phocid seals in water (Southall *et al*. (2007) criteria); and
- Displacement (minke whale, bottlenose dolphin, white-beaked dolphin, harbour porpoise, grey seal and harbour seal).

10 Use of an Acoustic Deterrent Device (ADD) was incorporated in the re-modelling in addition to the pile driving soft start in line with the modelling undertaken and described in *Appendix 9B* and *Chapter 10*.

11 Because no mid frequency cetaceans had the potential to be exposed to noise levels sufficient to induce the onset of PTS when using a CF of 0.5 %, and no bottlenose dolphins were predicted to be within 10 kilometres (km) of the piling locations (see Figure 10.2 Bottlenose dolphin density in *Chapter 10*), this was not considered to be a worst case scenario and was therefore not re-run. However, because the number of bottlenose dolphins with the potential to be displaced is used in the population level modelling (using Interim Population Consequences of Disturbance (iPCoD)), the effect of using a 1 % CF on displacement was assessed. Because this modelling (displacement) also applied to the other species, the effect of using a 1 % CF on displacement was also assessed for minke whale, white-beaked dolphin, harbour porpoise, grey seal and harbour seal.

Table 10B.1: Details of Scenario 4

Scenario	Description	Location	Species modelled	Blow energy[1]	Number of pin piles per 24 h period	Number of monopiles per 24 h period
4	Piling at 2 locations (2 vessels)	F3+F4	All	Highest Expected	12	2

10B.3.1 PTS

12 Figure 10B.1, Figure 10B.2 and Figure 10B.3 show the modelled received noise levels (dB re 1 $\mu Pa^2 s$) for a CF of 0.5 % (Figures 10.14, 10.15 and 10.18 in *Chapter 10*) compared to the re-modelled received noise levels for a CF of 1 % for the worst case scenarios/ species groups described above (paragraph 9). The corresponding 2013 Inch Cape Environmental Statement (ES) contours (ICOL, 2013) have also been mapped so that they can be easily compared. A 25 km radius from the two noise modelling locations (i.e. the distance to which animals have been modelled to flee) is also depicted.

13 The difference between the 0.5 % CF and 1 % CF PTS contours is most apparent for low frequency cetaceans (which had the greatest flee speed of the species groups modelled; 2.1 $m.s^{-1}$ (see section 10.7.1 of *Chapter 10*)) and phocid seals in water (which had the next greatest flee speed; 1.8 $m.s^{-1}$).

14 The 1 % CF low frequency cetacean pin pile and monopile contours are both larger than that used to inform the 2014 Inch Cape Consent (ICOL, 2013). The size of these (1 % CF) contours is a function of the distance to which animals have been modelled to flee (25 km; see Figure 10B.1). In the model, once animals reach a distance of 25 km from the noise modelling location/ sound source they remain stationary (and therefore continue to be exposed). This assumption may not be realistic since, if animals continue to be exposed to noise levels sufficient to induce PTS, they may continue to find this noise level ‘disturbing’ and thus continue to flee.

15 The 1 % CF phocid seals in water and high frequency cetacean pin pile and monopile contours are both smaller than those used to inform the 2014 Inch Cape Consent (ICOL, 2013).

[1] See Tables 10.4 (pin piles) and 10.5 (monopiles) of the chapter for details.

Figure 10B.1: Modelled received noise levels (dB re 1 μPa^{2}s) for PTS from pile driving under Scenario 4 for low frequency cetaceans

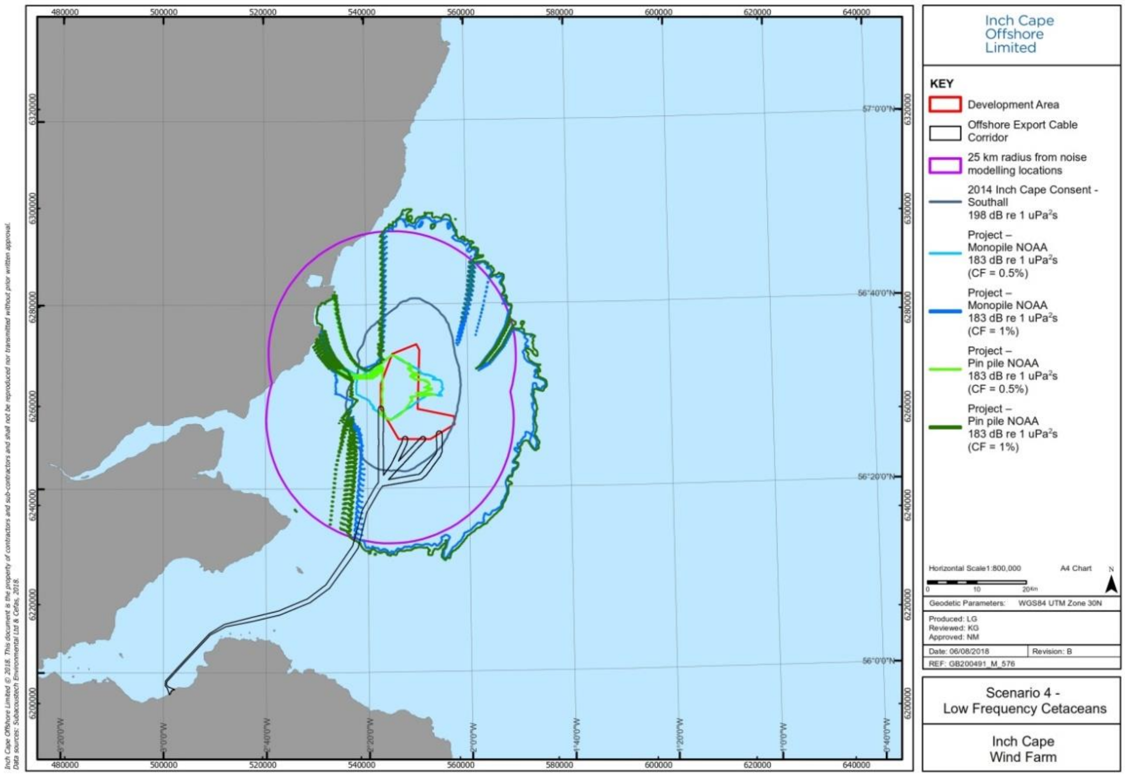


Figure 10B.2: Modelled received noise levels (dB re 1 μPa^{2}s) for PTS from pile driving under Scenario 4 for high frequency cetaceans

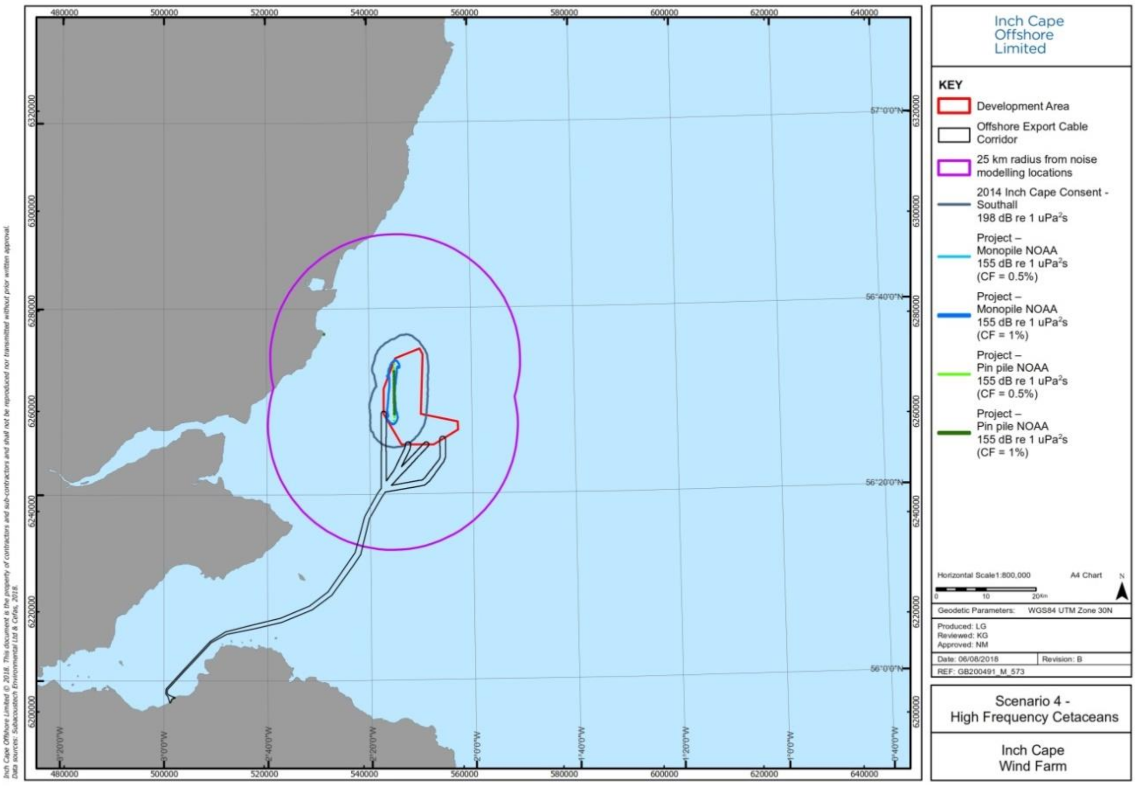
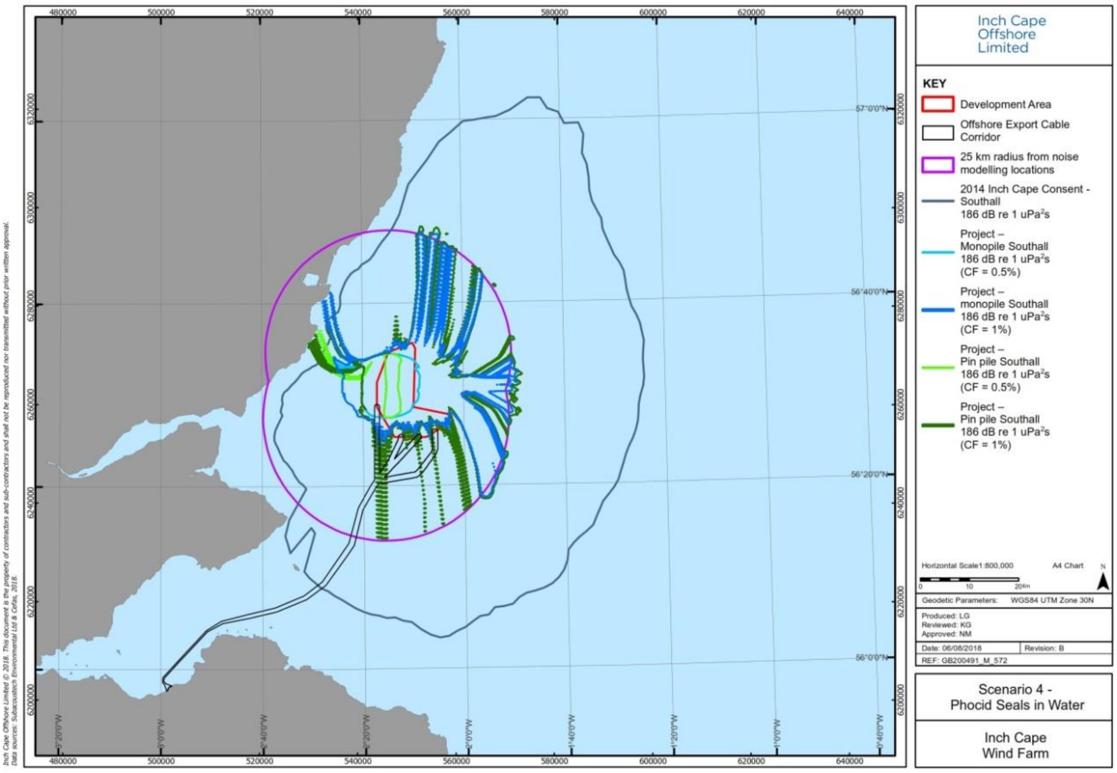


Figure 10B.3: Modelled received noise levels (dB re 1 µPa²s) for PTS from pile driving under Scenario 4 for phocid seals in water



16 Table 10B.2 shows the estimates of the number of individuals of each species (and per cent of reference population) which have the potential to be exposed to noise levels sufficient to induce the onset of PTS due to underwater noise from pile driving according to Scenario 4 for both pin piles and monopiles using a 0.5 % CF (as per *Chapter 10*) and a 1 % CF.

17 For harbour porpoise and harbour seal there is a negligible difference between the numbers of animals estimated to have the potential to be exposed to noise levels sufficient to induce the onset of PTS using the different (0.5 % CF and 1 % CF) contours.

18 While there is an order of magnitude difference between the number of minke whales and the number of grey seals which have the potential to be exposed to noise levels sufficient to induce the onset of PTS using the different (0.5 % CF and 1 % CF) contours, the per cent of the reference population estimated to have the potential to be exposed remains small in both cases (0.5 % for minke whales and ≤1.4 % for grey seals; see Table 10B.2).

19 It should be noted that although the number of grey seals estimated to have the potential to be exposed using the 1 % CF contours for pin piles and monopiles has increased (compared to the number estimated to have the potential to be exposed using the 0.5 % CF contours), it is still less than the number used to inform the 2014 Inch Cape Consent (ICOL, 2013).

20 Although the number of minke whales estimated (using the 1 % CF contours) to have the potential to be exposed to noise levels sufficient to induce the onset of PTS is greater than the number used to inform the 2014 Inch Cape Consent (ICOL, 2013), the per cent of the reference population with the potential to be affected remains small (0.5 %; see Table 10B.2).

Table 10B.2: The number of individuals (n) and per cent of reference population (%) with the potential to be impacted by PTS onset due to underwater noise from concurrent pile driving at two locations (two vessels) for the 2014 Inch Cape Consent (ICOL, 2013) and the Development – Scenario 4 (Worst Case) – for both pin piles and monopiles using a 0.5 % (as per *Chapter 10*) and a 1 % CF. The numbers in brackets are 95 % confidence intervals

Species	2014 Inch Cape Consent		CF value used in noise modelling	Development (pin piles)				Development (monopiles)			
				Southall *et al.*		NOAA		Southall *et al.*		NOAA	
	n	%		n	%	n	%	n	%	n	%
Minke whale[2]	24	<0.1	0.5 %	0	0	4.3 (1.4 - 11.5)	<0.1	0	0	6.7 (2.3 - 20.1)	<0.1
			1 %	-		119.5 (37.5 - 496.7)	0.5	-		112.1 (35.8 - 462.6)	0.5
Harbour porpoise	30	<0.1	0.5 %	0	0	0.1 (<0.1 - 0.1)	<0.1	0	0	0.1 (0.0 - 0.1)	<0.1
			1 %	-		0.1 (0.1 - 0.2)	<0.1	-		2.8 (1.6 - 4.0)	<0.1
Grey seal	822	11.6	0.5 %	12.1 (3.4 - 20.9)	0.1	0	0	47.0 (13.3 - 80.7)	0.3	0	0
			1 %	225.4 (80.3 - 370.5)	1.4	-		180.0 (61.0 - 299.1)	1.1	-	
Harbour	78	12.2	0.5 %	0.6	0.1	0	0	1.5	0.3	0	0

[2] In contrast to the numbers estimated using a 0.5 % CF, the number of minke whales with the potential to be impacted by PTS onset using a 1 % CF is greater for pin piles than monopiles. This is due to differences in the shapes of the noise impact contours, and the way they relate to the minke whale density surface (Figure 10.1 in *Chapter 10*).

Species	2014 Inch Cape Consent		CF value used in noise modelling	Development (pin piles)				Development (monopiles)			
				Southall *et al.*		NOAA		Southall *et al.*		NOAA	
	n	%		n	%	n	%	n	%	n	%
seal				(0.1 - 0.1)				(0.3 - 1.4)			
			1 %	6.0 (0.80 - 11.2)	1.2	-		8.5 (0.8 - 16.2)	1.7	-	

<u>Magnitude of Impact and Significance of Effect</u>

21 Using the magnitude of impact and significance of effect criteria defined in section 10.7.4 and section 10.7.5 of *Chapter 10*, Table 10B.3 summarises and compares the significance of effect on marine mammals resulting from the change from using a 0.5 % to a 1 % CF.

22 Magnitude of impact (PTS from piling) remains low (i.e. unchanged at <10 % of the population), and significance of effect remains minor (i.e. unchanged), for all species (for the Development) when a CF of 1 % is used (see Table 10B.3).

23 Because the significance of effect (PTS from piling) remains minor when a CF of 1 % is used, population level modelling is not required (for either low frequency cetaceans (minke whale), high frequency cetaceans (harbour porpoise), or phocid seals in water (grey seal and harbour seal)).

Table 10B.3: The significance of the potential effects of PTS from piling on marine mammals

Species	2014 Inch Cape Consent	Development	
		CF value of 0.5 %	CF value of 1 %
Minke whale	Minor	Minor	Minor
Harbour porpoise	Minor	Minor	Minor
Grey seal	Minor to moderate	Minor	Minor
Harbour seal	Minor to moderate	Minor	Minor

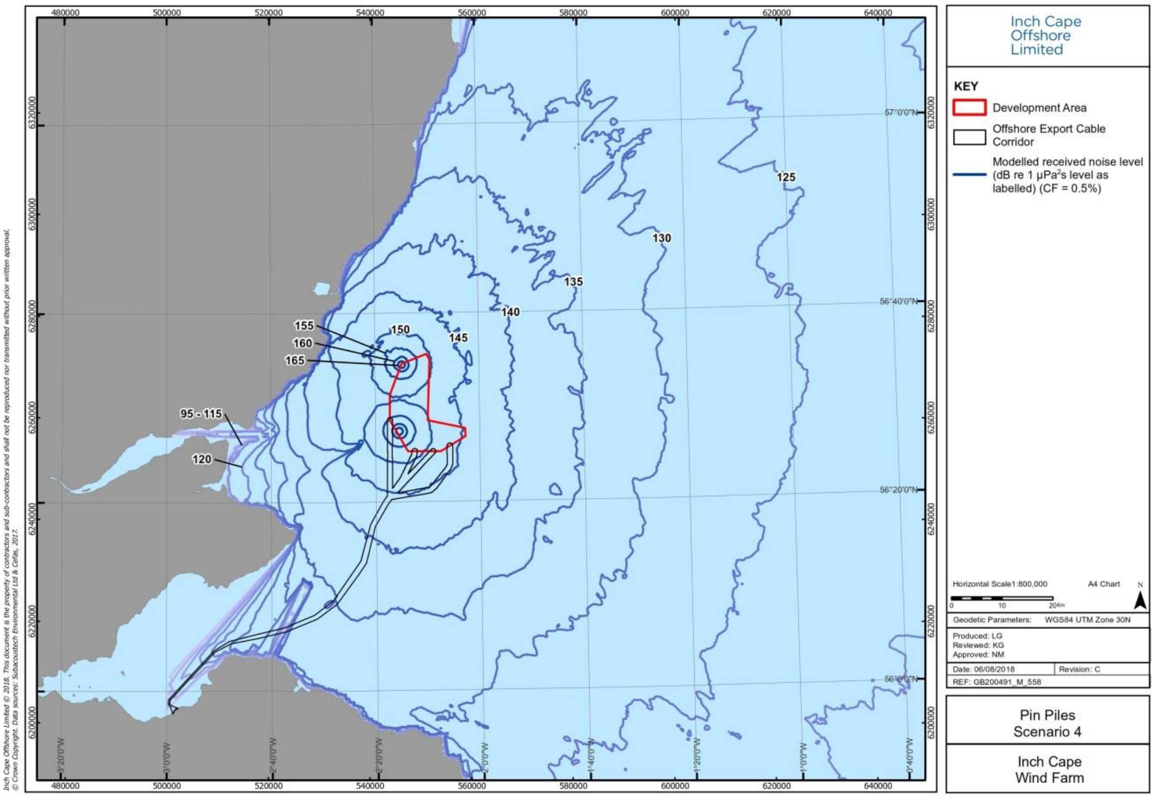
10B.3.2 Displacement

24 Figure 10B.4 shows the modelled received noise levels for a CF of 0.5 % compared to the re-modelled received noise levels for a CF of 1 % for pin piles. Figure 10B.5 shows the equivalent information for monopiles. The 0.5 % and 1 % CF contours have not been displayed on single (pin pile and monopile) figures as these were too confusing to read due to the numbers of contours and amount of labelling required.

25 The difference between the 0.5 % CF and 1 % CF displacement contours is apparent for both pin piles and monopiles.

Figure 10B.4: Modelled (0.5 % CF; (a)) and re-modelled (1 % CF; (b)) received noise levels (dB re 1 µPa2s) for displacement from pin pile driving under Scenario 4

(a) CF = 0.5 % (same as Figure 10.24 in *Chapter 10*)



(b) CF = 1 %

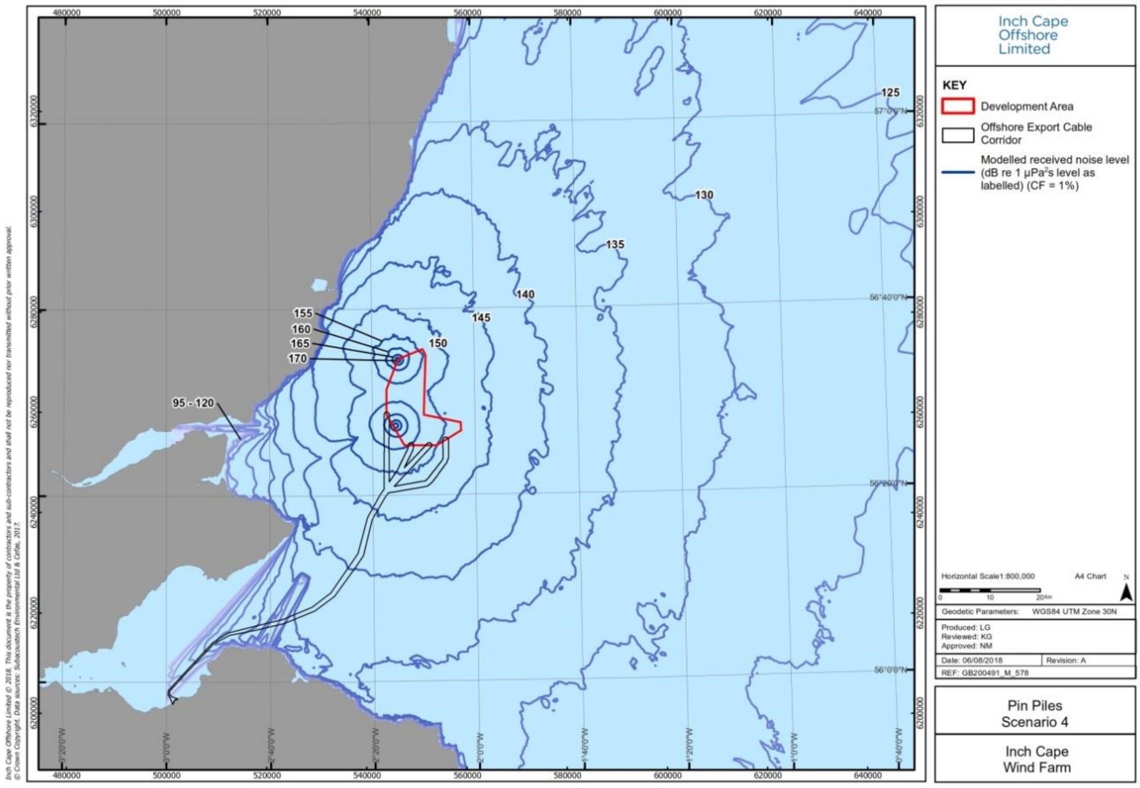
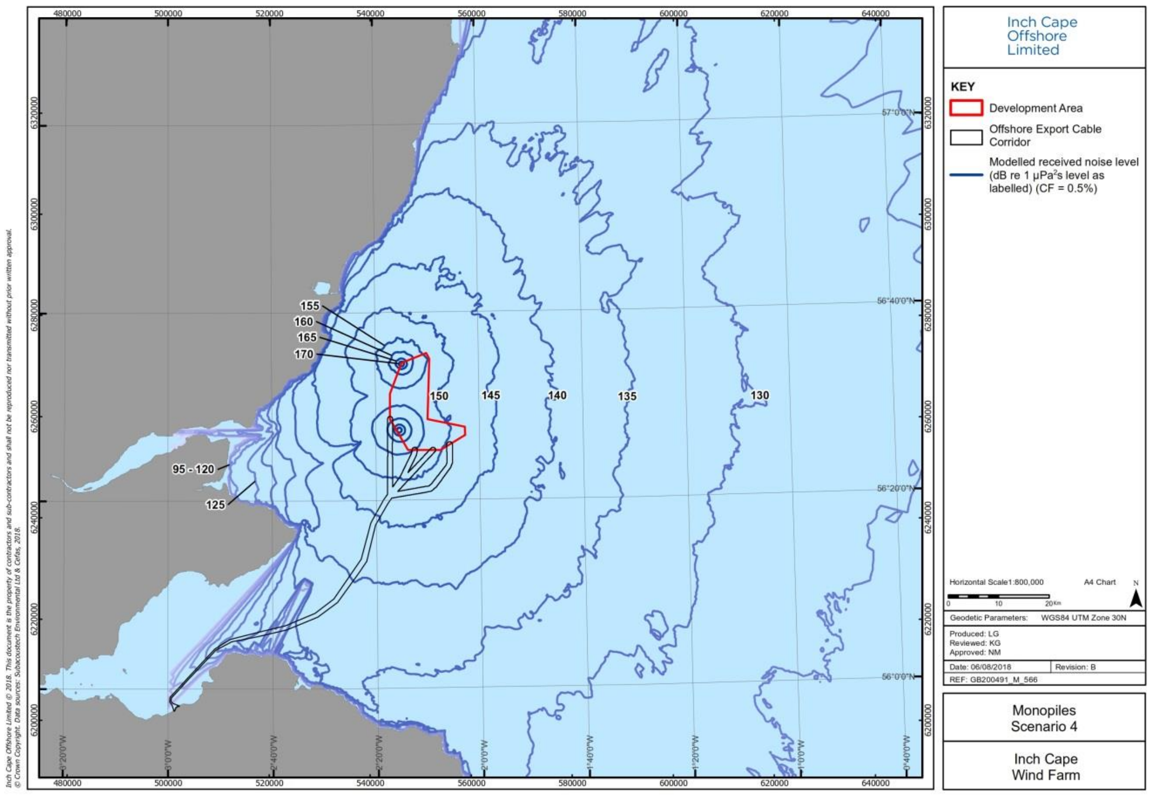
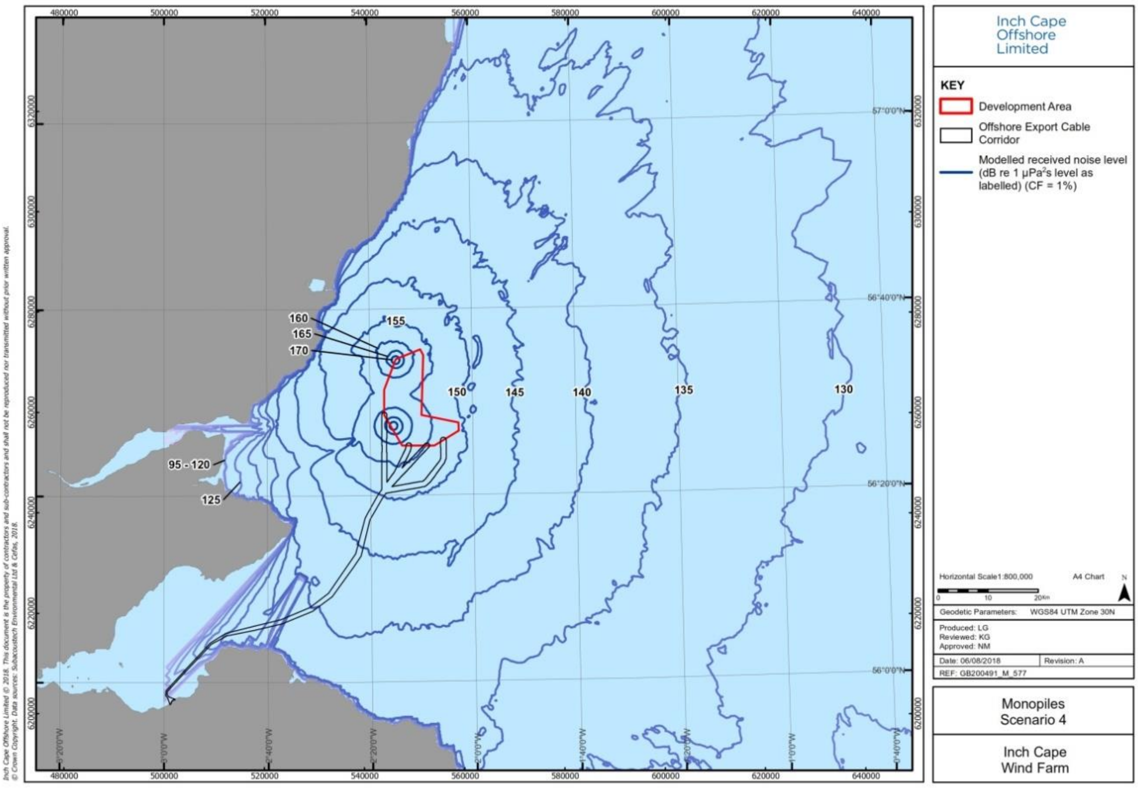


Figure 10B.5: Modelled (0.5 % CF; (a)) and re-modelled (1 % CF; (b)) received noise levels (dB re 1 µPa2s) for displacement from monopile driving under Scenario 4

(a) CF = 0.5 % (same as Figure 10.30 in *Chapter 10*)



(b) CF = 1 %



26 Table 10B.4 shows the estimates of the number (and per cent of reference population) of individuals of each species which have the potential to be displaced due to underwater noise from pile driving according to Scenario 4 using a 0.5 % CF (as per *Chapter 10*) and a 1 % CF. The 2014 Inch Cape Consent (ICOL, 2013) estimates are also shown.

27 There is very little difference between the number of animals estimated to have the potential to be displaced using the different (0.5 % CF and 1 % CF) contours for bottlenose dolphin, white-beaked dolphin and harbour seal. The differences for minke whale, harbour porpoise and grey seal are more notable. However, with the exception of white-beaked dolphin for monopiles using a 1 % CF (69 animals with the potential to be displaced), the number of animals estimated to have the potential to be displaced is less for the Development than it was for the assessment which was used to inform the 2014 Inch Cape Consent (ICOL, 2013) regardless of whether a 0.5 % or a 1 % CF is used.

Table 10B.4: The number of individuals (n) and per cent of reference population (%) of each species with the potential to be displaced due to underwater noise from concurrent pile driving at two locations (two vessels) for the 2014 Inch Cape Consent (ICOL, 2013) and the Development – Scenario 4 (Worst Case) – for both pin piles and monopiles using a 0.5 % (as per *Chapter 10*) and a 1 % CF. The numbers in brackets are 95 % confidence intervals

Species	2014 Inch Cape Consent		CF value used in noise modelling	Development			
				Pin piles		Monopiles	
	n	%		n	%	n	%
Minke whale	543 (17 - 4846)	0.3	0.5 %	110 (35 - 560)	0.5	158 (56 - 848)	0.7
			1 %	155 (49 - 829)	0.7	219 (70 - 1217)	0.9
Bottlenose dolphin	19 (1 - 27)	9.7	0.5 %	6 (5 - 7)	3.1	8 (7 - 11)	4.1
			1 %	8 (7 – 10)	4.1	11 (9 – 14)	5.6
White-beaked dolphin	51 (2 - 330)	0.2	0.5 %	32 (13 - 130)	0.2	48 (20 - 198)	0.3
			1 %	47 (19 - 194)	0.3	69 (26 - 282)	0.4
Harbour porpoise	556 (29 - 1934)	0.3	0.5 %	207 (109 - 447)	0.1	302 (160 - 665)	0.1
			1 %	296 (156 - 651)	0.1	423 (224 - 942)	0.2
Grey seal	3212 (244 - 4682)	45.2	0.5 %	810 (306 - 1314)	5.1	1236 (471 - 2001)	7.7
			1 %	1208 (460 - 1955)	7.6	1799 (689 - 2908)	11.3
Harbour seal	340 (49 - 435)	53.3	0.5 %	17 (2 - 31)	3.3	20 (3 - 36)	3.9
			1 %	19 (3 – 36)	3.7	22 (3 - 41)	4.3

Magnitude of Impact and Significance of Effect

28 Because the numbers of animals estimated (using the 1 % CF contours) to have the potential to be displaced are only slightly greater than the numbers estimated using the 0.5 % CF contours, the per cent of the reference populations with the potential to be affected remains small (< 1 % for minke whale, white-beaked dolphin and harbour porpoise; ≤ 5.6 % for bottlenose dolphin; and ≤ 4.3 % for harbour seal; see Table 10B.4).

29 It follows, therefore, that the magnitude of impact (displacement from piling) remains low (i.e. unchanged at <10 % of the population), and significance of effect (displacement from piling) remains minor (i.e. unchanged), for these five species (for the Development) when a CF of 1 % is used (see Table 10B.5).

30 Because the cumulative population level modelling (using the iPCoD framework) was re-run to incorporate 16, rather than three, bouts of blasting at the Aberdeen Harbour Expansion Project (see Table 10.1 of *Chapter 10*) with no real change to the potential impact on the size of the bottlenose dolphin population over the 25 year period modelled (see *Chapter 10* and *Appendix 10A: Assessment of Population Level Effects on Bottlenose Dolphins using iPCoD*[3]), it has not been deemed necessary to re-run iPCoD for this Inch Cape only scenario. This is because the number of bottlenose dolphins which have the potential to be displaced using the 1 % CF contours (eight for pin piles and 11 for monopiles) is only slightly greater than the number estimated using the 0.5 % CF contours (six for pin piles and eight for monopiles), and much less than the number predicted to be displaced by the blasting at Aberdeen (53 animals; see Table 10.13 in *Chapter 10*) which was included in the cumulative population level modelling (see section 10.11.1 of *Chapter 10*).

31 Because the number of grey seals estimated to have the potential to be displaced using the 1 % CF contours is greater than the number estimated using the 0.5 % CF contours, the per cent of the reference population with the potential to be affected changes from < 10 % (7.7 %) to 10-20 % (11.3 %) for monopiles when a 1 % CF is used. It follows, therefore, that the magnitude of impact (displacement from piling) increases from low to moderate/ medium, and significance of effect (displacement from piling) increases from minor to moderate, for grey seals (for the Development) for monopiles when a CF of 1 % is used (see Table 10B.5). However, this is still markedly lower than the 45.2 % (of the reference population) estimated to have the potential to be displaced in the assessment to inform the 2014 Inch Cape Consent (ICOL, 2013).

32 The grey seals which have the potential to be displaced due to piling at the Development may not breed in the Firth of Forth. In addition, grey seals travel extensively and use a wide range of habitats including multiple foraging areas and haul out sites (McConnell *et al*., 1999). Displacement is therefore not expected to have the same effect on grey seals as it might have on a species which does not travel so extensively. Given that the number of grey seals counted in the East Scotland Seal Management Unit is increasing (Duck *et al*., 2017), there is likely to be suitable alternative habitat for feeding and hauling out, and it is likely

[3] *Chapter 10* and *Appendix 10A* that were submitted to MS-LOT for Gatecheck have been updated.

that animals will become habituated to the lower levels of piling noise, it is considered unlikely that displacement will have a long-term impact at the population level (and will therefore be minor in the long term for monopiles when using a 1 % CF).

Table 10B.5: The significance of the potential effects of displacement from piling on marine mammals

Species	2014 Inch Cape Consent	Development	
		CF value of 0.5 %	CF value of 1 %
Minke whale	Minor	Minor	Minor
Bottlenose dolphin	Moderate	Minor	Minor
White-beaked dolphin	Minor	Minor	Minor
Harbour porpoise	Minor	Minor	Minor
Grey seal	Major	Minor	Pin piles: Minor Monopiles: Moderate
Harbour seal	Major	Minor	Minor

10B.4 Conclusions

33 Although the noise impact contours modelled using a CF of 1 % differ from those modelled using a CF of 0.5 %, the findings of the assessment described in *Chapter 10* do not materially change.

34 Therefore, the modelling carried out using the 0.5 % CF is considered appropriate to be used for the Marine Mammal assessment when read in conjunction with this Appendix.

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