BERWICK BANK WIND FARM
OFFSHORE ENVIRONMENTAL IMPACT ASSESSMENT

APPENDIX 10.5: CONVERSION FACTORS – MARINE MAMMALS SUPPORTING INFORMATION

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1. INTRODUCTION

1.1. OVERVIEW

1. This supporting information report presents the quantitative outcomes (impact ranges and number of marine mammals potentially affected) of subsea noise modelling using a range of conversion factors selected for the sensitivity analysis undertaken in volume 3, appendix 10.1, annex B for the Berwick Bank Wind Farm (hereafter referred to as "the Proposed Development"). Results are presented for both instantaneous injury based on peak sound pressure level (SPL_{pk}) and Permanent Threshold Shift (PTS) due to cumulative sound exposure level (SEL_{cum}) as an animal flees. The following conversion factors are presented herein:

- 1% constant conversion factor (SEL_{cum} and SPL_{pk});
- 4% reducing to 0.5% conversion factor (SEL_{cum} and SPL_{pk});
- 10% reducing to 1% conversion factor (SEL_{cum} and SPL_{pk});
- 4% constant conversion factor (SPL_{pk} only); and
- 10% constant conversion factor (SPL_{pk} only).

1.2. BACKGROUND

2. The assessment of potential injury and disturbance to marine mammals due to underwater noise during piling for the Proposed Development was initially based on modelling using 1% constant conversion factor as this represents a typical approach adopted by subsea noise assessments. Concerns were raised by consultees during the Road Map process that this 1% constant conversion factor may not, however, be sufficiently representative to allow a robust assessment. Two additional conversion factors were therefore discussed with consultees and subsequently recommended for inclusion in the subsea noise assessment (see Scoping Opinion; volume 3, appendix 6.2). These included a conversion factor of 10% based on a study by Thompson *et al.,* (2020) using data from the Beatrice offshore wind farm in the Moray Firth and a conversion factor of 4% based on recommendations for Moray West and subsequently for Neart na Gaoithe offshore wind farms. Due to concerns that modelling of 10% constant and 4% constant conversion factors may lead to over-precautionary predictions, particularly with respect to SEL_{cum}, at a Road Map Meeting on 16 November 2021, NatureScot, in agreement with MSS, suggested that the modelling could consider a reducing conversion factor scale in line with pile penetration depth (see volume 3, appendix 10.3). The Applicant thereby also modelled a 4% reducing to 0.5% conversion factor and a 10% reducing to 1% conversion factor.

3. Following Road Map Meeting 4, the stakeholders also requested that results should be presented for potential ranges at which marine mammals could experience instantaneous injury in the form of PTS at the maximum hammer energy and the maximum conversion factors for SPL_{pk}. Therefore, supplementary information has been provided to show the ranges of effect and for a constant 4% and constant 10% conversion factor at 4,000 kJ.

4. As to the most appropriate conversion factor to apply to the assessment of underwater noise, the Scoping Opinion directed that the Applicant should provide justification for which of the results are relied on within the assessment to inform appropriate mitigation. A detailed literature review was therefore undertaken by the Applicant which provided a robust evidence base and recommendations as to the most appropriate and precautionary conversion factor to take forward to the assessment (see Technical Note on Choice of Noise Modelling Methodology and Energy Conversion Factor for Pile Source sound exposure level (SEL); volume 3, appendix 10.1, annex A). The study and recommendations were peer-reviewed by an external acoustician with more than 35 years of experience in the field (see volume 3, appendix 10.1, annex H).

5. To demonstrate the sensitivity of the subsea noise modelling to different conversion factors and provide the Statutory Nature Conservation Bodies (SNCBs) more detail on the requested range of conversion factors, a sensitivity analysis was also carried out. The sensitivity analysis investigated all three conversion factors (considered a representative range) for review. The outcomes of the sensitivity analysis are presented in: Sensitivity Analysis for Different Pile source SEL Energy Conversion Factors (volume 3, appendix 10.1, annex B).

6. While the sensitivity analysis (volume 3, appendix 10.1, annex B) provides a useful comparative analysis, it does not apply the modelling outcomes to the environment or describe the numbers of animals potentially affected. This report seeks to provide this context and applies the modelling outputs from the three conversion factors considered in the sensitivity analysis to describe quantitative outcomes. Specifically, the predicted impact ranges for injury and disturbance and the number of animals potentially affected. These outcomes are described in this report for each marine mammal Important Ecological Feature (IEF) assessed in volume 2, chapter 10 and for each of the subject conversion factors.

7. Based on the technical note on energy conversion factor and the results of the sensitivity assessment (volume 3, appendix 10.1, Annex A and Annex B), two conversion factors (4% reducing to 0.5% conversion factor or 1% constant conversion factor) were brought forward for assessment in the Marine Mammal Offshore EIA Report chapter (volume 2, chapter 10). The assessment focused on the ranges predicted to result in injury and/or behavioural effects based on whichever of the two conversion factors represented the most conservative outcome. On the rationale set out in volume 3, appendix 10.1, annex A, use of a 10% reducing to 1% conversion factor is considered likely to result in overly precautionary and unrealistic impacts. Outcomes (numbers of animals affected) generated by the application of this conversion factor are not therefore referenced in the Environmental Impact Assessment (EIA) of marine mammals (volume 2, chapter 10); however, for completeness the results of the quantitative assessment are presented here.

2. APPROACH

8. Zones of injury (auditory) and disturbance (i.e. responsiveness) were the focus of the assessment of potential impacts on marine mammals. A detailed underwater noise modelling assessment has been carried out to investigate the potential for injurious and behavioural effects on IEFs as a result of piling (impulsive sounds), using the latest auditory marine mammal hearing criteria (volume 3, appendix 10.1). The dual criteria (peak sound pressure level (SPL_{pk}) and cumulative sound exposure level (SEL_{cum})) approach was employed in the underwater noise assessment to assess the potential for auditory injury. Ranges for both SPL_{pk} and SEL_{cum} were predicted using the 1% constant or the 4% or 10% reducing conversion factors. For instantaneous injury based on SPL_{pk} the ranges presented are the maximum that could occur at any point over the piling sequence from hammer initiation to full power piling. This was considered to be highly precautionary since it assumes an animal will not move away as piling progresses. Furthermore, predictions of instantaneous injury using a constant conversion factor at the maximum hammer energy using the SPL_{pk} metric were not considered to be representative since such predictions do not account for: a) a fleeing animal (as discussed) and b) a reduction in conversion factor with increasing pile penetration. These results are presented as 'Supplementary Information' (section 3.1.1).

9. Ranges of effect and numbers of individuals potentially within the impacted area presented in this document do not account for designed in mitigation (i.e. monitoring of the potential injury zone) or additional mitigation (i.e. use of an Acoustic Deterrent Device (ADD)) proposed for the Proposed Development.

10. A dose response curve using the unweighted sound exposure level single strike (SEL_{ss}) metric was applied to this assessment to determine the number of animals that may potentially respond behaviourally to received noise levels during piling. The relevant thresholds for onset of these effects along with the evidence base used to derive them are presented in more detail in section 10.11.1 of volume 2, chapter 10.

11. For purposes of this document, Table 2.1 presents density estimates and reference populations (Management Units (MUs)) for marine mammals in the Proposed Development marine mammal study area for use in quantifying the scale of effects. Small Cetacean Abundance in the North Sea (SCANS) III Block R abundance estimates are provided for reference and used in the assessment for harbour porpoise *Phocoena phocoena*, white-beaked dolphin *Lagenorhynchus albirostris* and minke whale *Balaenoptera acutorostrata* (for more details see volume 3, appendix 10.2).

Table 2.1: Density Estimates and Reference Populations for Marine Mammals in the Proposed Development Marine Mammal Study Area

Species	Density (Animals per km^2)	Management Unit	Population in MU	SCANS-III Block R (Hammond *et al*., 2021)
Harbour porpoise	0.299 to 0.826[1]	North Sea	346,601 (IAMMWG, 2021)	38,646
Bottlenose dolphin	Coastal: 0.197 to 0.294[2] Offshore: 0.0298[3]	Coastal East Scotland	224 (Arso Civil *et al.,* 2019)	1,924
White-beaked dolphin	0.243[3]	Celtic and Greater North Sea	43,951 (IAMMWG, 2021)	15,694
Minke whale	0.0387[3]	Celtic and Greater North Sea	20,118 (IAMMWG, 2021)	2,498
Harbour seal	0.0001 to 0.002[4]	East Scotland plus Northeast England	476 + 110 = 586 (Sinclair, 2021; SCOS, 2020)	N/A
Grey seal	0.276 to 1.2[5]	East Scotland and Northeast England	15,400 + 27,200 = 42,600 (Sinclair, 2021; SCOS, 2020)	N/A

[1] Site-specific densities (mean and seasonal peak) estimated from Proposed Development aerial digital survey data (2019 to 2021)
[2] Average coastal density derived from 5-year average from Arso Civil *et al.* (2021) with proportion at the outer Firth of Tay assigned using habitat preference modelling data from Arso Civil *et al.* (2019)
[3] SCANS III (Hammond *et al.*, 2021)
[4] Mean and maximum across the Proposed Development marine mammal study area based on at-sea mean density maps (Carter *et al*., 2020)
[5] Mean monthly density based on site-specific Proposed Development aerial digital survey data (2019 to 2021) and density based on at-sea mean usage maps (Carter *et al*., 2020) across the Proposed Development marine mammal study area

12. The marine mammal assessment presented in section 10.11.2 of volume 2, chapter 10 was based on the maximum design scenario, with both concurrent or single piling at wind turbine or offshore substation platform (OSP)/Offshore convertor station platform foundations using a maximum energy of 4,000 kJ. Since piling is unlikely to reach and maintain the absolute maximum hammer energy of 4,000 kJ at all locations, results for realistic average maximum hammer energy of 3,000 kJ have also been provided for the concurrent piling of wind turbines (as the spatial maximum design) to provide context when discussing behavioural disturbance.

13. The maximum spatial scenario is for up to two vessels piling concurrently. Prediction of injury ranges for this scenario considered two adjacent piles, since cumulative exposure from two piling operations in proximity to one another lead to larger injury ranges and therefore the duration of piling is important in this context. The duration of piling at the maximum hammer energy at wind turbines is slightly longer compared to OSPs/Offshore convertor station platforms. In converse, the assessment of disturbance considered the maximum separation distance between concurrent piling operations and since the metric used was SEL_{ss} the duration to install a pile is not relevant in the subsea noise model. Note that for the assessment of disturbance, whilst subsea noise modelling assumed concurrent piling at two wind turbine foundations, this does not preclude concurrent piling at a wind turbine and OSP/Offshore convertor station platform foundation since the distances between wind turbines at opposite ends of the site is greater than the maximum distance between wind turbines and OSPs/Offshore convertor station platforms. Injury ranges are presented in Table 3.1 to Table 3.4 For disturbance, the impact ranges are the same for wind turbines and OSPs/Offshore convertor station platforms because the underwater noise modelling was based on maximum SEL_{ss} over the piling sequence which is the same for both due to the same maximum hammer energies (Table 3.6 to Table 3.23).

3. RESULTS

14. This section presents results of noise modelling in terms of injury and disturbance ranges and the number of animals potentially affected. Results are presented for each marine mammal IEF assessed in volume 2, chapter 10 (i.e. harbour porpoise, bottlenose dolphin *Tursiops truncatus*, white-beaked dolphin, minke whale, harbour seal *Phoca vitulilna* and grey seal *Halichoerus grypus*). Results for the range of conversion factors selected for the sensitivity analysis (volume 3, appendix 10.1, annex B*)* are presented for each species under the relevant impact headers. However, given that the assessment of significance is provided for selected conversion factors in volume 2, chapter 10, this section provides only information about the magnitude of effect.

3.1. INJURY

Harbour porpoise

15. Based on the dual threshold criteria (SPL_{pk} and SEL_{cum}), the injury ranges for various conversion factors modelled for harbour porpoise are presented in Table 3.1.

16. Using 10% reducing to 1% conversion factor, the most conservative number of individuals that could be potentially injured within the maximum range of 1,415 m (based on maximum hammer energy and concurrent piling at wind turbines, Table 3.1) was estimated as five harbour porpoises. In the case of a 4% reducing to 0.5% conversion factor, also considering the most conservative scenario, there will be less than one animal that could be potentially injured within the maximum range of 439 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, there would be less than one animal that could be potentially injured within the maximum range of 449 m.

Table 3.1: Summary of SPL_{pk} and SEL_{cum} Injury Ranges and Areas of Effect for Harbour Porpoise due to Impact Piling for Wind Turbine and OSP/Offshore Convertor Station Platform Jacket Foundations (Maximum and Realistic Scenarios) Using Three Scenarios: 10% Reducing to 1% Conversion Factor, 4% reducing to 0.5% Conversion Factor and 1% Constant Conversion Factor. Ranges Taken Forward to the Assessment in the EIA Chapter are Shown in Bold.

Threshold	Spatial Scale					
	10% - 1% Conversion Factor		4% - 0.5% Conversion Factor		1% Constant Conversion Factor	
	Range (m)	Area (m^2)	Range (m)	Area (m^2)	Range (m)	Area (m^2)
Concurrent Piling – 4,000 kJ - Wind Turbine						
SPL_{pk} 202 dB re 1 µPa	554	0.964	346	0.376	**449**	0.633
SEL_{cum} 155 dB re 1 µPa²s	1,415	6.3	439	0.605	201	0.127
Concurrent Piling – 3,000 kJ - Wind Turbine						
SPL_{pk} 202 dB re 1 µPa	478	0.7174	298	0.279	**338**	0.473
SEL_{cum} 155 dB re 1 µPa²s	984	3	307	0.296	150	0.071
Single Piling – 4,000 kJ – Wind Turbine*/OSP-Offshore Convertor Station Platform**						
SPL_{pk} 202 dB re 1 µPa	554	0.964	346	0.376	**449**	0.633
SEL_{cum} 155 dB re 1 µPa²s	702*/699**	1.5	286*/285**	0.255	104*/103**	0.033

Bottlenose dolphin and white-beaked dolphin

17. Based on the dual threshold criteria (SPL_{pk} and SEL_{cum}), the injury ranges for various conversion factors modelled for bottlenose dolphin and white-beaked dolphin are presented in Table 3.2.

18. Using 10% reducing to 1% conversion factor, the most conservative number of bottlenose dolphins that could be potentially injured within the maximum range of 53 m (based on maximum hammer energy and concurrent piling at wind turbines, Table 3.2), was estimated as less than one animal. In the case of 4% reducing to 0.5% conversion factor, again considering the most conservative scenario, less than one animal could be potentially injured within the maximum range of 33 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, it was estimated less than one animal could be potentially injured within the maximum range of 43 m.

19. Using 10% reducing to 1% conversion factor, the most conservative number of white-beaked dolphins that could be potentially injured within the maximum range of 53 m (based on maximum hammer energy and concurrent piling in Table 3.2) was estimated as less than one animal. In the case of 4% reducing to 0.5% conversion factor, again considering the most conservative scenario, less than one animal that could be potentially injured within the maximum range of 33 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, it was estimated less than one animal that could be potentially injured within the maximum range of 43 m.

Table 3.2: Summary of SPL_{pk} and SEL_{cum} Injury Ranges and Areas of Effect for Bottlenose Dolphin and White-Beaked Dolphin due to Impact Piling for Wind Turbine and OSP/Offshore Convertor Station Platform Jackets (Maximum and Realistic Scenarios) Using Three Scenarios: 10% reducing to 1% Conversion Factor, 4% reducing to 0.5% Conversion Factor and 1% Constant Conversion Factor. Ranges Taken Forward to the Assessment in the EIA Chapter are Shown in Bold.

Threshold	Spatial Scale					
	10% - 1% Conversion Factor		4% - 0.5% Conversion Factor		1% Constant Conversion Factor	
	Range (m)	Area (m^2)	Range (m)	Area (m^2)	Range (m)	Area (m^2)
Concurrent Piling – 4,000 kJ - Wind Turbine						
SPL_{pk} 202 dB re 1 µPa	53	0.0088	33	0.003	**43**	0.006
SEL_{cum} 185 dB re 1 µPa²s	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]
Concurrent Piling – 3,000 kJ - Wind Turbine						
SPL_{pk} 202 dB re 1 µPa	46	0.0066	29	0.003	**37**	0.004
SEL_{cum} 185 dB re 1 µPa²s	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore Convertor Station Platform						
SPL_{pk} 202 dB re 1 µPa	53	0.0088	33	0.003	**43**	0.006
SEL_{cum} 185 dB re 1 µPa²s	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]	N/E[1]

[1] N/E = Threshold not exceeded

Minke whale

20. Based on the dual threshold criteria (SPL_{pk} and SEL_{cum}), the injury ranges for the conversion factors modelled for minke whale and selected for discussion in this report are presented in Table 3.3.

21. Using 10% reducing to 1% conversion factor, the most conservative number of individuals that could be potentially injured within the maximum range of 5,830 m (based on maximum hammer energy and concurrent piling at wind turbines, Table 3.3) was estimated as four minke whales. In case of 4% reducing to 0.5% conversion factor, again considering the most conservative scenario, less than one animal could be potentially injured within the maximum range of 2,319 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, it was estimated less than one animal could be potentially injured within the maximum range of 1,300 m.

Table 3.3: **Summary of SPL_{pk} and SEL_{cum} Injury Ranges and Areas of Effect for Minke Whale due to Impact Piling for Wind Turbine and OSP/Offshore Convertor Station Platform Jackets (Maximum and Realistic Scenarios) Using Three Scenarios: 10% Reducing to 1% Conversion Factor, 4% Reducing to 0.5% Conversion Factor and 1% Constant Conversion Factor. Ranges Taken Forward to the Assessment in the EIA Chapter are Shown in Bold.**

Threshold	Spatial Scale: 10% - 1% Conversion Factor		4% - 0.5% Conversion Factor		1% Constant Conversion Factor	
	Range (m)	Area (m^2)	Range (m)	Area (m^2)	Range (m)	Area (m^2)
Concurrent Piling – 4,000 kJ - Wind Turbine						
SPL_{pk} 219 dB re 1 µPa	134	0.056	83	0.022	109	0.037
SEL_{cum} 183 dB re 1 µPa^{2}s	5830	106.7	**2,319**	16.886	1,300	5.3
Concurrent Piling – 3,000 kJ - Wind Turbine						
SPL_{pk} 219 dB re 1 µPa	116	0.042	72	0.016	94	0.028
SEL_{cum} 183 dB re 1 µPa^{2}s	4.439	61.9	**1,556**	7.602	675	1.43
Single Piling – 4,000 kJ – Wind Turbine*/OSP-Offshore Convertor Station Platform**						
SPL_{pk} 219 dB re 1 µPa	134	0.056	83	0.022	109	0.037
SEL_{cum} 183 dB re 1 µPa^{2}s	3,015*/2,977**	27.2	**1,030*/1,023****	3.286	332*/325**	0.332

Harbour seal and grey seal

22. Based on the dual threshold criteria (SPL_{pk} and SEL_{cum}), the injury ranges for the conversion factors modelled for harbour seal and grey seal and selected for discussion in this report are presented in Table 3.4.

23. Using 10% reducing to 1% conversion factor, the most conservative number of harbour seals that could be potentially injured within the maximum range of 150 m (based on maximum hammer energy and concurrent piling at wind turbines, Table 3.4) was estimated as less than one animal. In case of 4% reducing to 0.5% conversion factor, again considering the most conservative scenario, less than one animal could be potentially injured within the maximum range of 91 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, it was estimated less than one animal could be potentially injured within the maximum range of 118 m.

24. Using 10% reducing to 1% conversion factor, the most conservative number of grey seals that could be potentially injured within the maximum range of 150 m (based on maximum hammer energy and concurrent piling at wind turbines, Table 3.4) was estimated as less than one animal. In case of 4% reducing to 0.5% conversion factor, again considering the most conservative scenario, less than one animal could be potentially injured within the maximum range of 91 m. Using 1% constant conversion factor and likewise taking into account the most conservative scenario, it was estimated less than one animal could be potentially injured within the maximum range of 118 m.

Table 3.4: **Summary of SPL_{pk} and SEL_{cum} Injury Ranges and Areas of Effect for Harbour Seal and Grey Seal due to Impact Piling for Wind Turbine and OSP/Offshore Convertor Station Platform Jackets (Maximum and Realistic Scenarios) Using 10% Reducing to 1% Conversion Factor. Using Three Scenarios: 10% Reducing to 1% Conversion Factor, 4% Reducing to 0.5% Conversion Factor and 1% Constant Conversion Factor. Ranges Taken Forward to the Assessment in the EIA Chapter are Shown in Bold.**

Threshold	Spatial Scale: 10% - 1% Conversion Factor		4% - 0.5% Conversion Factor		1% Constant Conversion Factor	
	Range (m)	Area (m^2)	Range (m)	Area (m^2)	Range (m)	Area (m^2)
Concurrent Piling – 4,000 kJ - Wind Turbine						
SPL_{pk} 218 dB re 1 µPa	146	0.067	91	0.026	118	0.044
SEL_{cum} 185 dB re 1 µPa^{2}s	150	0.071	53	0.009	25	0.002
Concurrent Piling – 3,000 kJ - Wind Turbine						
SPL_{pk} 218 dB re 1 µPa	126	0.05	78	0.019	102	0.473
SEL_{cum} 185 dB re 1 µPa^{2}s	106	0.035	38	0.005	18	0.001
Single Piling – 4,000 kJ – Wind Turbine*/OSP Offshore Convertor Station Platform **						
SPL_{pk} 218 dB re 1 µPa	146	0.067	91	0.026	118	0.044
SEL_{cum} 185 dB re 1 µPa^{2}s	116*/116**	0.042	47*/47**	0.007	N/E[1]	N/E[1]

[1] N/E = Threshold not exceeded

3.1.1. SUPPLEMENTARY INFORMATION

25. At the request of stakeholders, additional modelling was undertaken to determine the maximum injury ranges based on constant conversion factors at the maximum hammer energy for the SPL_{pk} metric only. These are presented in Table 3.5 along with reducing scenarios showed for comparison.

Table 3.5: **Summary of Injury Ranges due to the Maximum Peak Pressure over the Piling Sequence for Marine Mammals due to Impact Piling for Wind Turbine Foundations ("Maximum" Scenario) and OSP/Offshore Convertor Station Platform Foundations Using Range of Conversion Factors**

Species	Threshold (Unweighted Peak)	Range (m): 1% Constant	4% Constant	10% Constant	4% - 0.5% Reducing	10% - 1% Reducing
Harbour porpoise	PTS - 202 dB re 1 µPa (pk)	449	928	1,519	346	554
Bottlenose dolphin, white-beaked dolphin	PTS - 230 dB re 1 µPa (pk)	43	89	143	33	53
Minke whale	PTS - 219 dB re 1 µPa (pk)	109	223	359	83	134

Species	Threshold (Unweighted Peak)	Range (m)				
		1% Constant	4% Constant	10% Constant	4% - 0.5% Reducing	10% - 1% Reducing
Harbour seal, grey seal	PTS - 218 dB re 1 µPa (pk)	118	243	390	91	146

26. Results for 1% constant conversion factor, 4% reducing to 0.5% conversion factor and 10% reducing to 1% conversion factor in terms of numbers of animals potentially affected were presented in section 3.1 above. Therefore, only results for 4% constant conversion factor and 10% constant conversion factor were presented in this section.

27. Using 4% constant conversion factor, the most conservative number of harbour porpoises that could be potentially injured within the maximum range of 928 m was estimated as less than three animals. In case of 10% constant conversion factor, a maximum number of six animals could be potentially injured within the maximum range of 1,519 m.

28. For bottlenose dolphin and white-beaked dolphin, using 4% constant conversion factor, the most conservative number of individuals that could be potentially injured within the maximum range of 89 m was estimated as less than one animal of each species. In case of 10% constant conversion factor, also less than one animal of each species could be potentially injured within the maximum range of 143 m.

29. Using 4% constant conversion factor, the most conservative number of minke whales that could be potentially injured within the maximum range of 223 m was estimated as less than one animal. In case of 10% constant conversion factor, also less than one animal could be potentially injured within the maximum range of 359 m.

30. For grey seal and harbour seal, using 4% constant conversion factor, the most conservative number of individuals that could be potentially injured within the maximum range of 243 m was estimated as less than one animal of each species. In case of 10% constant conversion factor, also less than one animal of each species could be potentially injured within the maximum range of 390 m.

31. The ranges of effect (instantaneous injury) predicted using a constant conversion factor of either 4% or 10% for the SPL_{pk} metric are less than the range predicted for cumulative exposure for minke whale (2,319 m) using 4% reducing to 0.5%. Therefore, the potential to mitigate for injury was considered with respect to the largest potential injury zone across all species of 2,319 m.

3.2. BEHAVIOURAL DISTURBANCE

32. The estimated number of animals potentially disturbed are based on the maximum adverse piling scenario. Given that species and/or populations have different spatial distribution patterns, these maximum adverse scenarios (i.e. piling locations) vary across the species. For some species the most precautionary estimates were based on the single/concurrent piling location(s) that resulted in the largest areas of effect (i.e. harbour porpoise, white-beaked dolphin, minke whale, harbour seal, grey seal). For bottlenose dolphins, where distributional data showed hotspots in abundance, the more precautionary estimates were derived where predicted noise contours overlapped regions of highest abundance/density (e.g. Firth of Tay).

Harbour porpoise

33. Based on the unweighted SEL_{ss} criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for various piling scenarios and conversion factors modelled for harbour porpoise (and selected for inclusion in this report) are presented in Figure 3.1 to Figure 3.3 with full results given in Table 3.6 to Table 3.8.

34. Using 10% reducing to 1% conversion factor and seasonal peak densities from site-specific survey data (Table 2.1), up to 3,575 animals were predicted to experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ (Figure 3.1, Table 3.6). This reduces to 2,822 using the 1% conversion factor (Table 3.7) and further to 2,090 using the 4% to 0.5% conversion factor (Table 3.8).

35. Similarly, for the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for concurrent piling at wind turbines at a realistic average maximum hammer energy of 3,000 kJ has been assessed as up to 3,033 animals (Figure 3.2 and Table 3.6) reducing to 2,378 at 1% conversion factor (Table 3.7) and 1,757 at 4% to 0.5% conversion factor (Table 3.8).

36. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for single piling at wind turbine/OSP-Offshore convertor station platform driving at a maximum hammer energy of 4,000 kJ has been assessed as up to 2,298 animals (Figure 3.3, Table 3.6) reducing to 1,432 at 1% conversion factor (Table 3.7) and 1,224 at 4% to 0.5% conversion factor (Table 3.8).

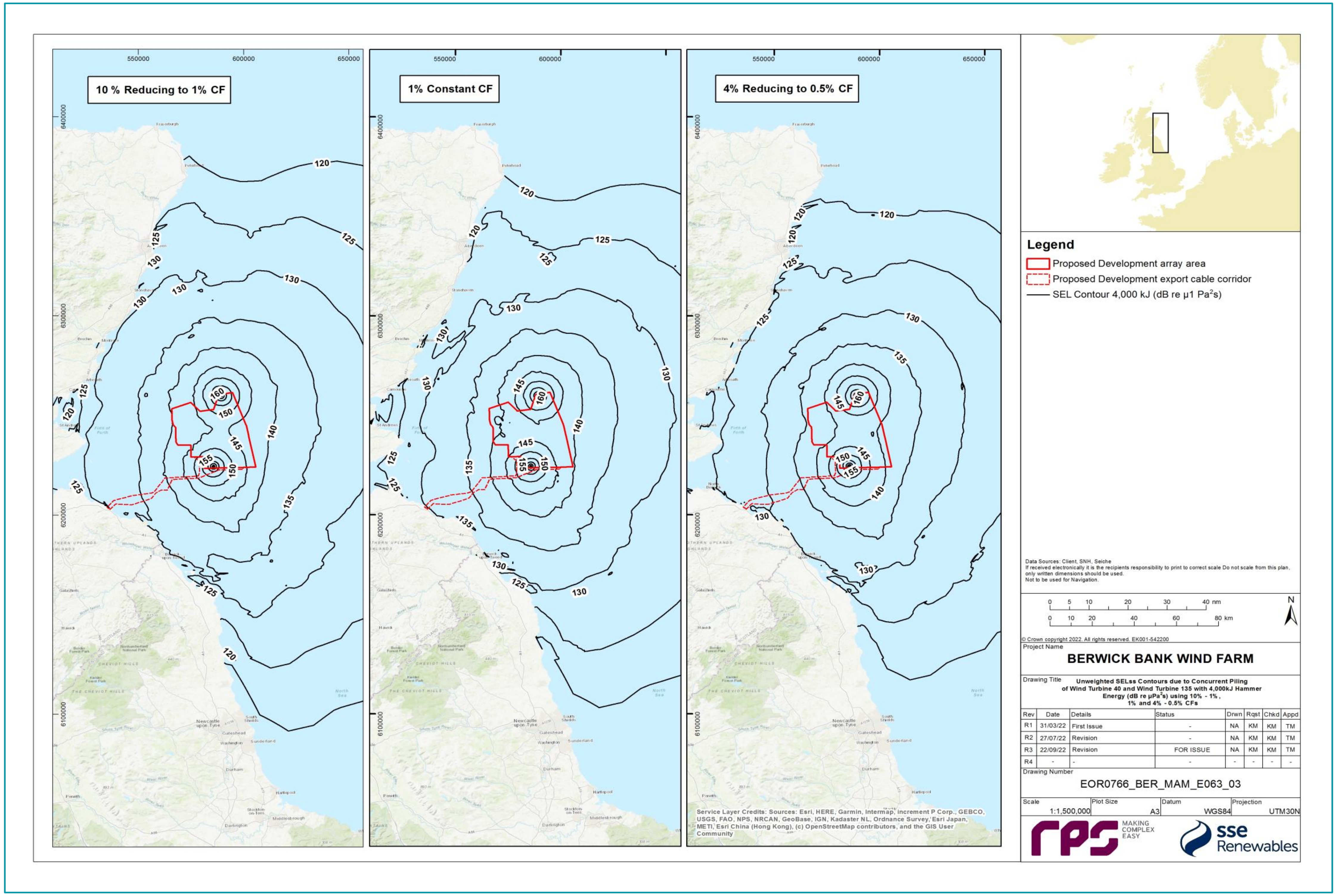

Figure 3.1: Unweighted SEL_{ss} Contours due to Concurrent Piling of Piles Wind Turbine Location 40 and Wind Turbine Location 135 with a 4,000 kJ Hammer Energy (dB re µPa²s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors

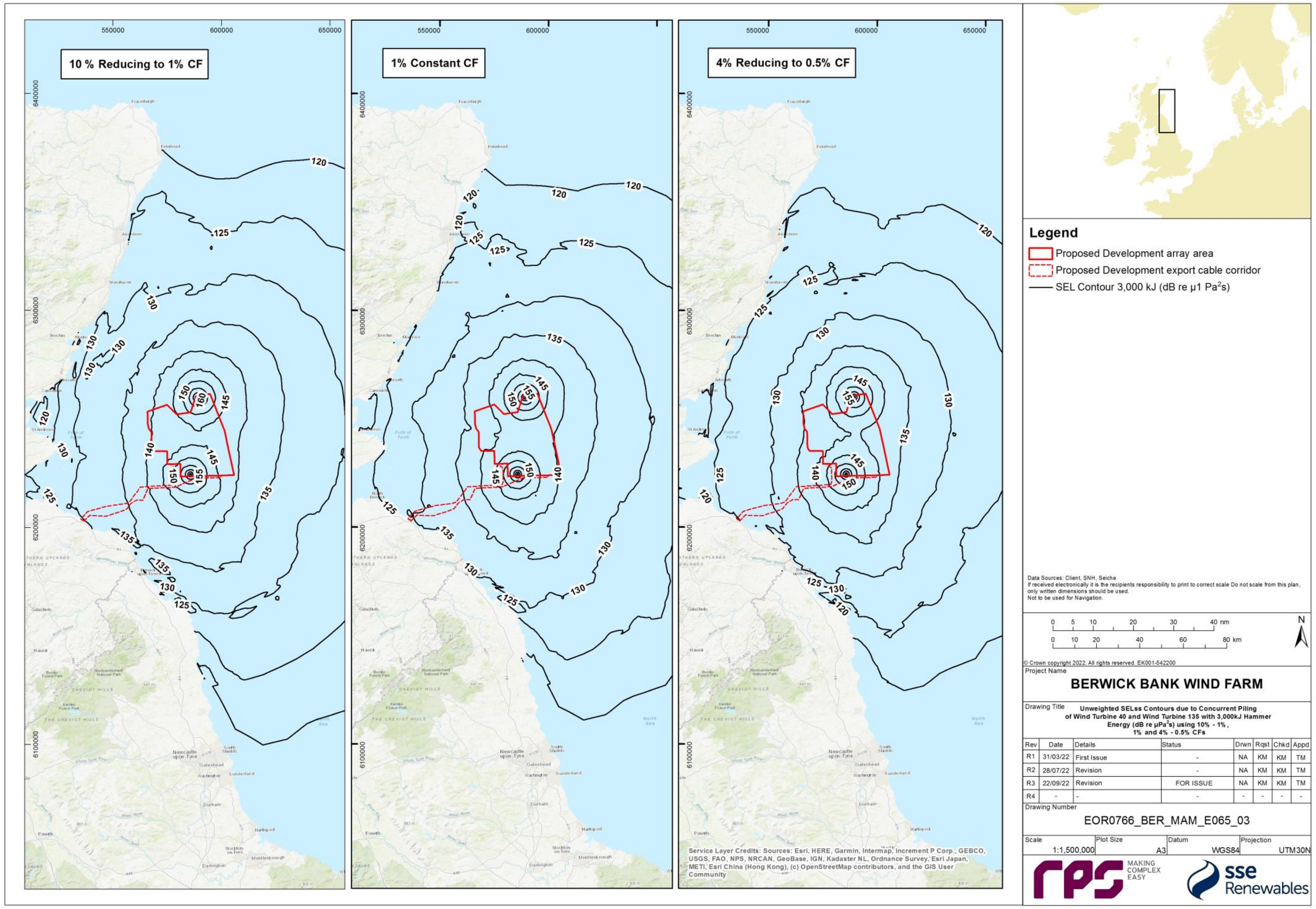

Figure 3.2: **Unweighted SEL$_{ss}$ Contours due to Concurrent Piling of Piles Wind Turbine Location 40 and Wind Turbine Location 135 with 3,000 kJ Hammer Energy (dB re µPa^{2}s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors**

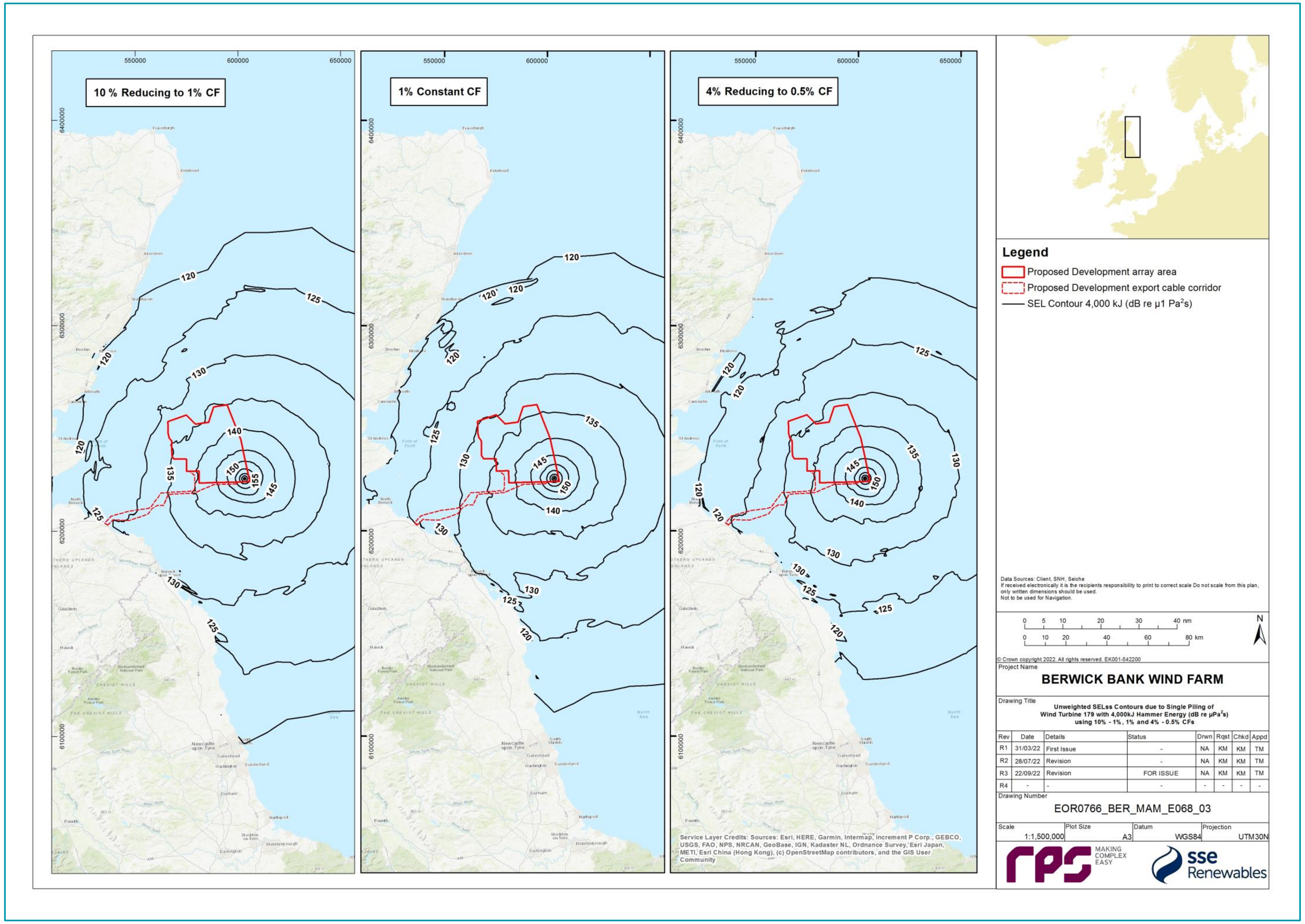

Figure 3.3: Unweighted SEL_{ss} Contours due to Single Piling of Pile Wind Turbine Location 179 with a 4,000 kJ Hammer Energy (dB re µPa²s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors

Table 3.6: Number of Harbour Porpoises Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios. Average Number is Based on the Monthly Average Density whilst Maximum is Based on the Seasonal Peak Density Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals		% Reference Population (MU)		% SCANS III Block R	
	Average	Maximum	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	1,294	3,575	0.37	1.03	3.35	9.25
Concurrent Piling - 3,000 kJ - Wind Turbine	1,098	3,033	0.32	0.88	2.84	7.85
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	831	2,298	0.24	0.66	2.15	5.95

Table 3.7: Number of Harbour Porpoises Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios. Average Number is Based on the Monthly Average Density whilst Maximum is Based on the Seasonal Peak Density Using 1% Constant Conversion Factor

Scenario	Number of Animals		% Reference Population (MU)		% SCANS III Block R	
	Average	Maximum	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	1,021	2,822	0.29	0.81	2.64	7.30
Concurrent Piling - 3,000 kJ - Wind Turbine	860	2,378	0.25	0.69	2.23	6.55
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	518	1,432	0.15	0.41	1.34	3.71

Table 3.8: Number of Harbour Porpoises Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios. Average Number is Based on the Monthly Average Density whilst Maximum is Based on the Seasonal Peak Density Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals		% Reference Population (MU)		% SCANS III Block R	
	Average	Maximum	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	756	2,090	0.22	0.60	1.96	5.41
Concurrent Piling - 3,000 kJ - Wind Turbine	636	1,757	0.18	0.51	1.65	4.55
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	443	1,224	0.13	0.35	1.15	3.17

Bottlenose dolphin

37. Based on the unweighted SELss criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for various piling scenarios and conversion factors modelled for bottlenose dolphin offshore populations are the same as for harbour porpoise and are presented in for harbour porpoise and are presented Figure 3.1 to Figure 3.3. The piling scenarios for the coastal bottlenose dolphin population are different to those presented for offshore communities, because the maximum adverse scenario has been assessed for piling locations closest to the Firth of Tay, where the density of bottlenose dolphins within 2 to 2 m depth contour is highest. These are presented in Figure 3.4 to Figure 3.6.

38. Based on 10% reducing to 1% conversion factor and bottlenose dolphin population distributed within 2 m to 20 m depth contour (Table 2.1) (for more details see volume 3, appendix 10.2), up to seven animals were predicted to experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ (Figure 3.4; Table 3.9). This number reduces to five and three animals for the 1% constant conversion factor and the 4% reducing to 0.5% conversion factor respectively (Table 3.10 and Table 3.11).

39. When referring to offshore populations and the same piling scenario, up to 129 animals could be affected if using the 10% reducing to 1% conversion factor (Figure 3.1, Table 3.9). For the 1% constant conversion factor and the 4% reducing to 0.5% conversion factor 101 and 75 animals could be affected respectively (Table 3.10 and Table 3.11).

40. The number of animals potentially disturbed within 2 m to 20 m depth contour based on estimates for concurrent piling at wind turbines at realistic average maximum hammer energy of 3,000 kJ and using the 10% reducing to 1% conversion factor has been assessed as up to six animals (Figure 3.5; Table 3.9). This number reduces to four and two animals for the 1% constant conversion factor and the 4% reducing to 0.5% conversion factor respectively (Table 3.10 and Table 3.11).

41. Based on the same piling scenario and offshore populations, up to 109 animals could be affected if using the 10% reducing to 1% conversion factor (Figure 3.2; Table 3.9). For the 1% constant conversion factor and the 4% reducing to 0.5% conversion factor 85 and 63 animals could be affected respectively (Table 3.10 and Table 3.11).

42. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed distributed within 2 m to 20 m depth contour based on estimates for OSP/Offshore convertor station platform single piling at wind turbine/OSP-Offshore convertor station platform at a maximum hammer energy of 4,000 kJ has been assessed as up to five animals (Figure 3.6, Table 3.9) reducing to three at 1% constant conversion factor (Table 3.10) and two at 4% reducing to 0.5% conversion factor (Table 3.11).

43. Based on the same piling scenario and offshore populations, up to 82 animals could be affected if using the 10% reducing to 1% conversion factor (Figure 3.3; Table 3.9). For the 1% constant conversion factor and the 4% reducing to 0.5% conversion factor 63 and 44 animals could be affected respectively (Table 3.10 and Table 3.11).

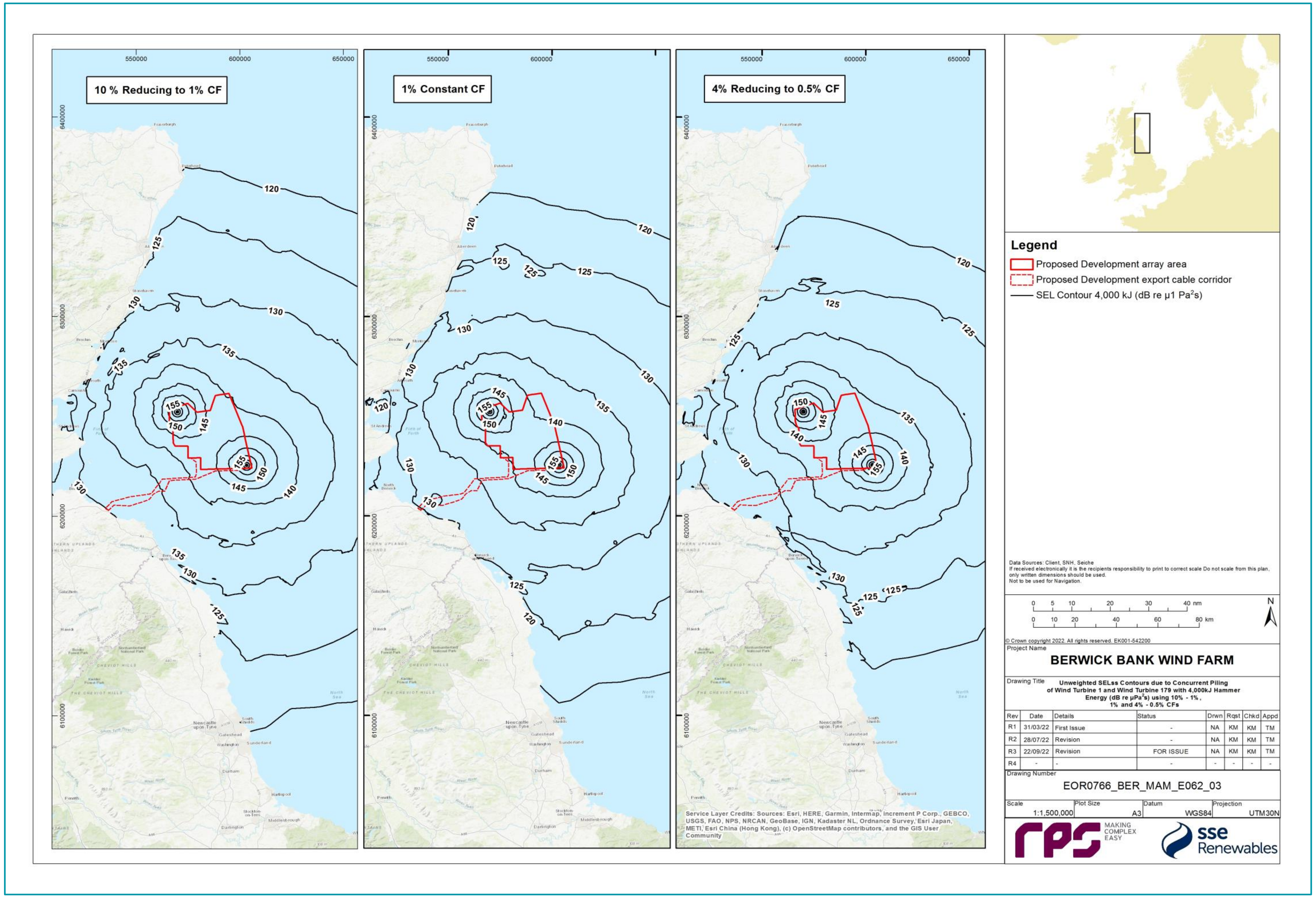

Figure 3.4: **Unweighted SEL_{ss} Contours due to Concurrent Piling of Piles at Wind Turbine Location 1 and Wind Turbine Location 179 with 4,000 kJ Hammer Energy (dB re µPa^{2}s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors**

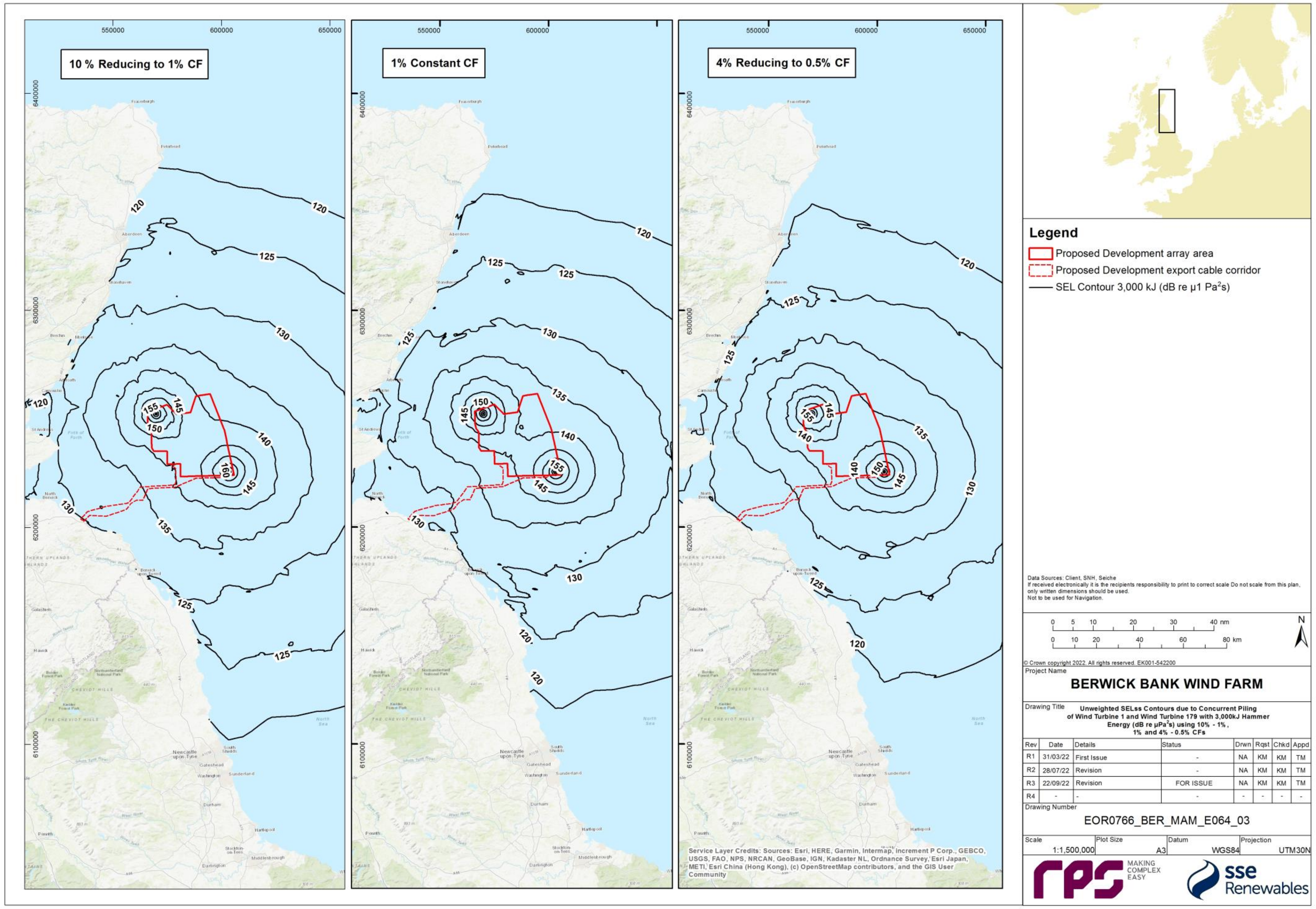

Figure 3.5 Unweighted SEL_{ss} Contours due to Concurrent Piling of Piles at Wind Turbine Location 1 and Wind Turbine Location 179 with 3,000 kJ Hammer Energy (dB re µPa²s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors

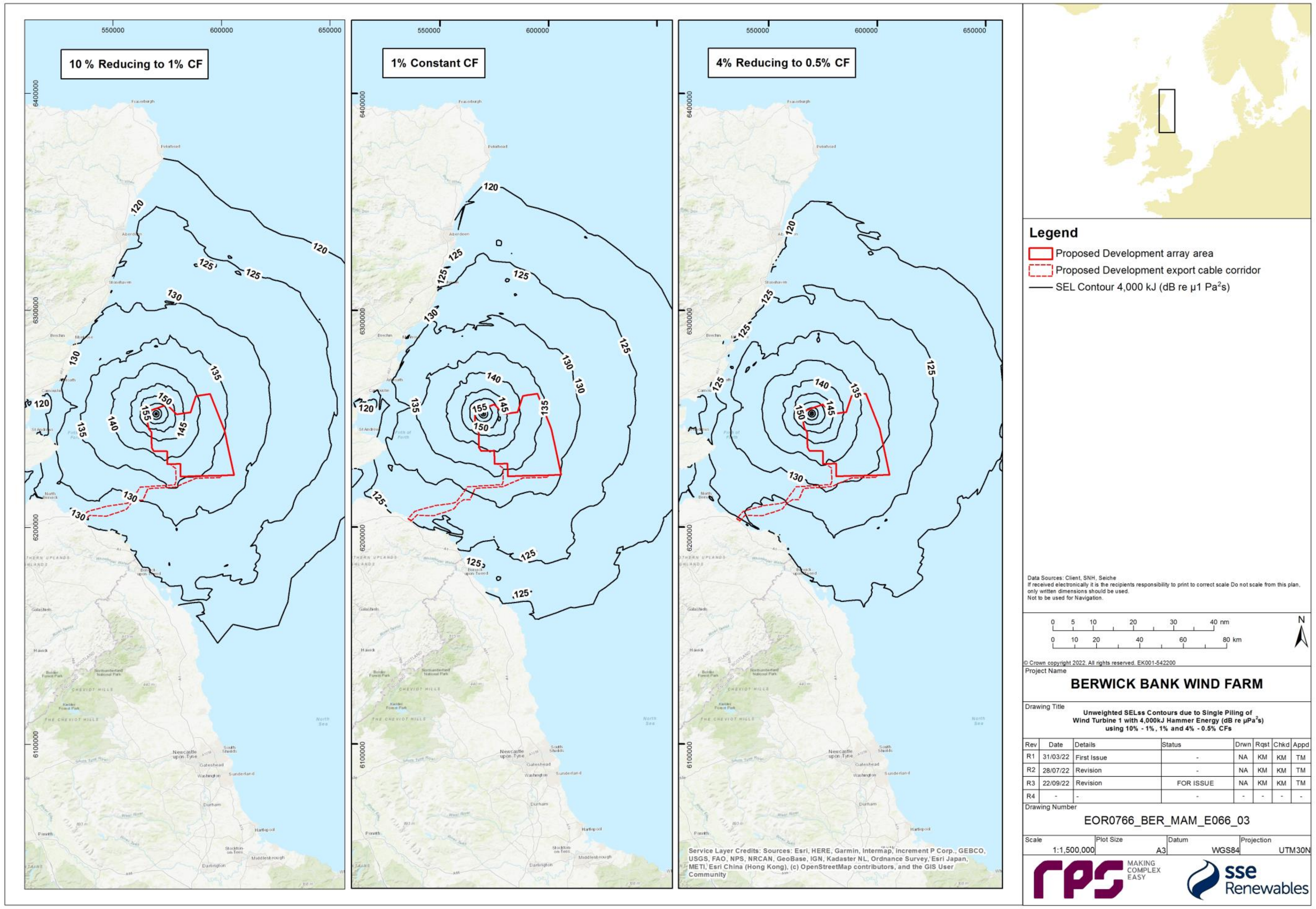

Figure 3.6: **Unweighted SEL_{ss} Contours due to Single Piling of Pile at Wind Turbine Location 1 with 4,000 kJ Hammer Energy (dB re µPa^{2}s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factors**

Table 3.9: Number of Bottlenose Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Coastal	Offshore	Coastal [2]	Offshore [3]
Concurrent Piling - 4,000 kJ - Wind Turbine	7	129	3.07	6.70
Concurrent Piling - 3,000 kJ - Wind Turbine	6	109	2.48	5.69
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	5	82	2.12	4.31

[1] Number of animals is rounded to nearest whole number.
[2] CES MU population was used as a reference population for individuals disturbed in coastal areas.
[3] SCANS III bottlenose dolphin estimated abundance was used as a reference population for individuals disturbed offshore.

Table 3.10: Number of Bottlenose Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 1% Constant Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Coastal	Offshore	Coastal [2]	Offshore [3]
Concurrent Piling - 4,000 kJ - Wind Turbine	5	101	2.25	5.29
Concurrent Piling - 3,000 kJ - Wind Turbine	4	85	1.71	4.46
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	3	63	1.49	3.29

[1] Number of animals is rounded to nearest whole number.
[2] CES MU population was used as a reference population for individuals disturbed in coastal areas.
[3] SCANS III bottlenose dolphin estimated abundance was used as a reference population for individuals disturbed offshore.

Table 3.11: Number of Bottlenose Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Coastal	Offshore	Coastal [2]	Offshore [3]
Concurrent Piling - 4,000 kJ - Wind Turbine	3	75	1.27	3.92
Concurrent Piling - 3,000 kJ - Wind Turbine	2	63	1.07	3.30
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	2	44	0.84	2.30

[1] Number of animals is rounded to nearest whole number.
[2] CES MU population was used as a reference population for individuals disturbed in coastal areas.
[3] SCANS III bottlenose dolphin estimated abundance was used as a reference population for individuals disturbed offshore.

White-beaked dolphin

44. Based on the unweighted SELss criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for various piling scenarios and conversion factors modelled for white-beaked dolphin are the same as for harbour porpoise and are presented in Figure 3.1 to Figure 3.3; full results are given in Table 3.12 to Table 3.14.

45. Using 10% reducing to 1% conversion factor and SCANS III densities (Table 3.12), up to 1,051 animals were predicted to experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ (Figure 3.1, Table 3.12). This reduces to 830 using the 1% constant conversion factor (Table 3.13) and further to 615 using the 4% reducing to 0.5% conversion factor (Table 3.14).

46. Similarly, for the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for concurrent piling at wind turbines at a realistic average maximum hammer energy of 3,000 kJ has been assessed as up to 892 animals (Figure 3.2; Table 3.12) reducing to 699 for the 1% constant conversion factor (Table 3.13) and 517 for the 4% reducing to 0.5% conversion factor (Table 3.14).

47. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for single piling at wind turbine/OSP-Offshore convertor station platform at a maximum hammer energy of 4,000 kJ has been assessed as up to 676 animals (Figure 3.3; Table 3.12) reducing to 516 for the 1% constant conversion factor (Table 3.13) and 360 for the 4% reducing to 0.5% conversion factor (Table 3.14).

Table 3.12: Number of White-Beaked Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	1,051	2.39	6.3
Concurrent Piling - 3,000 kJ - Wind Turbine	892	2.03	5.35
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	676	1.54	4.05

Table 3.13: Number of White-Beaked Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 1% Constant Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	830	1.89	4.97
Concurrent Piling - 3,000 kJ - Wind Turbine	699	1.59	4.19
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	516	1.17	3.09

Table 3.14: Number of White-Beaked Dolphins Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	615	1.40	3.68
Concurrent Piling - 3,000 kJ - Wind Turbine	517	1.18	3.10
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	360	0.82	2.16

Minke whale

48. Based on the unweighted SELss criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for various piling scenarios and conversion factors modelled for minke whale are the same as for harbour porpoise and are presented in Figure 3.1 to Figure 3.3.

49. Using 10% reducing to 1% conversion factor and SCANS III densities (Table 2.1) (for more details see volume 3, appendix 10.2), up to 167 animals were predicted to experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ (Figure 3.1, Table 3.15). This reduces to 142 using the 1% constant conversion factor (Table 3.16) and further to 107 using the 4% reducing to 0.5% conversion factor (Table 3.17).

50. Similarly, for the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for concurrent piling at wind turbines at a realistic average maximum hammer energy of 3,000 kJ has been assessed as up to 142 animals (Figure 3.2, Table 3.15) reducing to 111 for the 1% constant conversion factor (Table 3.16 and Table 3.13) and 82 for the 4% reducing to 0.5% conversion factor (Table 3.17).

51. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for single piling at wind turbine/OSP-Offshore convertor station platform at a maximum hammer energy of 4,000 kJ has been assessed as up to 107 animals (Figure 3.3; Table 3.15) reducing to 82 for the 1% constant conversion factor (Table 3.16) and 57 for the 4% reducing to 0.5% conversion factor (Table 3.17).

Table 3.15: Number of Minke Whales Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	167	0.83	6.71
Concurrent Piling - 3,000 kJ - Wind Turbine	142	0.71	5.69
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	107	0.54	4.31

Table 3.16: Number of Minke Whales Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 1% Constant Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS III Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	132	0.66	5.29
Concurrent Piling - 3,000 kJ - Wind Turbine	111	0.55	4.46
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	82	0.41	3.29

Table 3.17: Number of Minke Whales Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals	% Reference Population	% Abundance in SCANS Block R
	Average	Average	Average
Concurrent Piling - 4,000 kJ - Wind Turbine	97	0.49	3.92
Concurrent Piling - 3,000 kJ - Wind Turbine	82	0.41	3.30
Single Piling – 4,000 kJ – Wind Turbine/OSP -Offshore convertor station platform	57	0.29	2.30

Harbour seal

52. Based on the unweighted SEL_{ss} criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for concurrent piling scenarios and conversion factors modelled for harbour seal are the same as for harbour porpoise and are presented in Figure 3.1 to Figure 3.2. The noise disturbance contours for single piling scenario and conversion factors modelled for harbour and grey seal are presented in Figure 3.7.

53. Using 10% reducing to 1% conversion factor and maximum densities based on mean at-sea usage values from Carter *et al*. (2020) (Table 2.1) (for more details see volume 3, appendix 10.2), three animals were predicted to experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ (Figure 3.1; Table 3.18). Two animals could potentially experience disturbance when using the 1% constant conversion factor (Table 3.19) and the 4% reducing to 0.5% conversion factor (Table 3.20).

54. Similarly, for the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for concurrent piling at wind turbines at a realistic average maximum hammer energy of 3,000 kJ has been assessed as two animals (Figure 3.2; Table 3.18). Two and one animal/s could potentially experience disturbance when using the 1% constant conversion factor (Table 3.19) and the 4% reducing to 0.5% conversion factor, respectively (Table 3.20).

55. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for single piling at wind turbine/OSP-Offshore convertor station platform at a maximum hammer energy of 4,000 kJ has been assessed as two animals (Figure 3.7; Table 3.18). One could potentially experience disturbance when using the 1% constant conversion factor (Table 3.19) and the 4% to 0.5% conversion factor (Table 3.20).

Table 3.18: Number of Harbour Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	<1	3	0.02	0.49
Concurrent Piling - 3,000 kJ - Wind Turbine	<1	3	0.02	0.42
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	<1	2	0.01	0.27

[1] Number of animals is rounded to nearest whole number.

Table 3.19: Number of Harbour Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 1% Constant Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	<1	2	0.02	0.39
Concurrent Piling - 3,000 kJ - Wind Turbine	<1	2	0.02	0.31
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	<1	1	0.01	0.19

[1] Number of animals is rounded to nearest whole number.

Table 3.20: Number of Harbour Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals [1]		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	<1	2	0.01	0.27
Concurrent Piling - 3,000 kJ - Wind Turbine	<1	1	0.01	0.22
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	<1	1	0.01	0.12

[1] Number of animals is rounded to nearest whole number.

Grey seal

56. Based on the unweighted SEL_{ss} criteria and the assumptions of the dose response relationship described in more detail in volume 2, chapter 10, the noise disturbance contours for concurrent piling scenarios and conversion factors modelled for grey seal are the same as for harbour porpoise and are presented in Figure 3.1 and Figure 3.2. The noise disturbance contours for single piling scenario and conversion factors modelled for harbour and grey seal are presented in Figure 3.7.

57. Using 10% reducing to 1% conversion factor and maximum densities based on mean at-sea usage values from Carter *et al*. (2020) (Table 2.1) (for more details see volume 3, appendix 10.2), up to 1867 animals were predicted could experience potential disturbance from concurrent piling at wind turbines at a maximum hammer energy of 4,000 kJ Figure 3.1; Table 3.21). This reduces to 1,358 animals using the 1% constant conversion factor (Table 3.22) and further to 935 using the 4% reducing to 0.5% conversion factor (Table 3.23).

58. Similarly, for the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for concurrent piling at wind turbines at a realistic average maximum hammer energy of 3,000 kJ has been assessed as up to 1,488 animals (Figure 3.2; Table 3.21) reducing to 1,095 for the 1% constant conversion factor (Table 3.22) and 759 for the 4% reducing to 0.5% conversion factor (Table 3.23).

59. For the largest conversion factor of 10% reducing to 1% the number of animals potentially disturbed based on estimates for single piling at wind turbine/OSP-Offshore convertor station platform at a maximum hammer energy of 4,000 kJ has been assessed as up to 988 animals (Figure 3.7**;** Table 3.21) reducing to 705 for the 1% constant conversion factor (Table 3.22) and 463 for the 4% reducing to 0.5% conversion factor (Table 3.23).

Table 3.21: Number of Grey Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 10% Reducing to 1% Conversion Factor

Scenario	Number of Animals		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	429	1,867	1.01	4.38
Concurrent Piling - 3,000 kJ - Wind Turbine	342	1,488	0.80	3.49
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	227	988	0.53	2.32

Table 3.22: Number of Grey Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 1% Constant Conversion Factor

Scenario	Number of Animals		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	312	1,358	0.73	3.19
Concurrent Piling - 3,000 kJ - Wind Turbine	251	1,095	0.59	2.57
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	162	705	0.38	1.66

Table 3.23: Number of Grey Seals Predicted to be Disturbed in the Vicinity of the Proposed Development as a Result of Different Piling Scenarios Using 4% Reducing to 0.5% Conversion Factor

Scenario	Number of Animals		% Reference Population	
	Average	Maximum	Average	Maximum
Concurrent Piling - 4,000 kJ - Wind Turbine	215	935	0.50	2.19
Concurrent Piling - 3,000 kJ - Wind Turbine	174	759	0.41	1.78
Single Piling – 4,000 kJ – Wind Turbine/OSP-Offshore convertor station platform	106	463	0.25	1.09

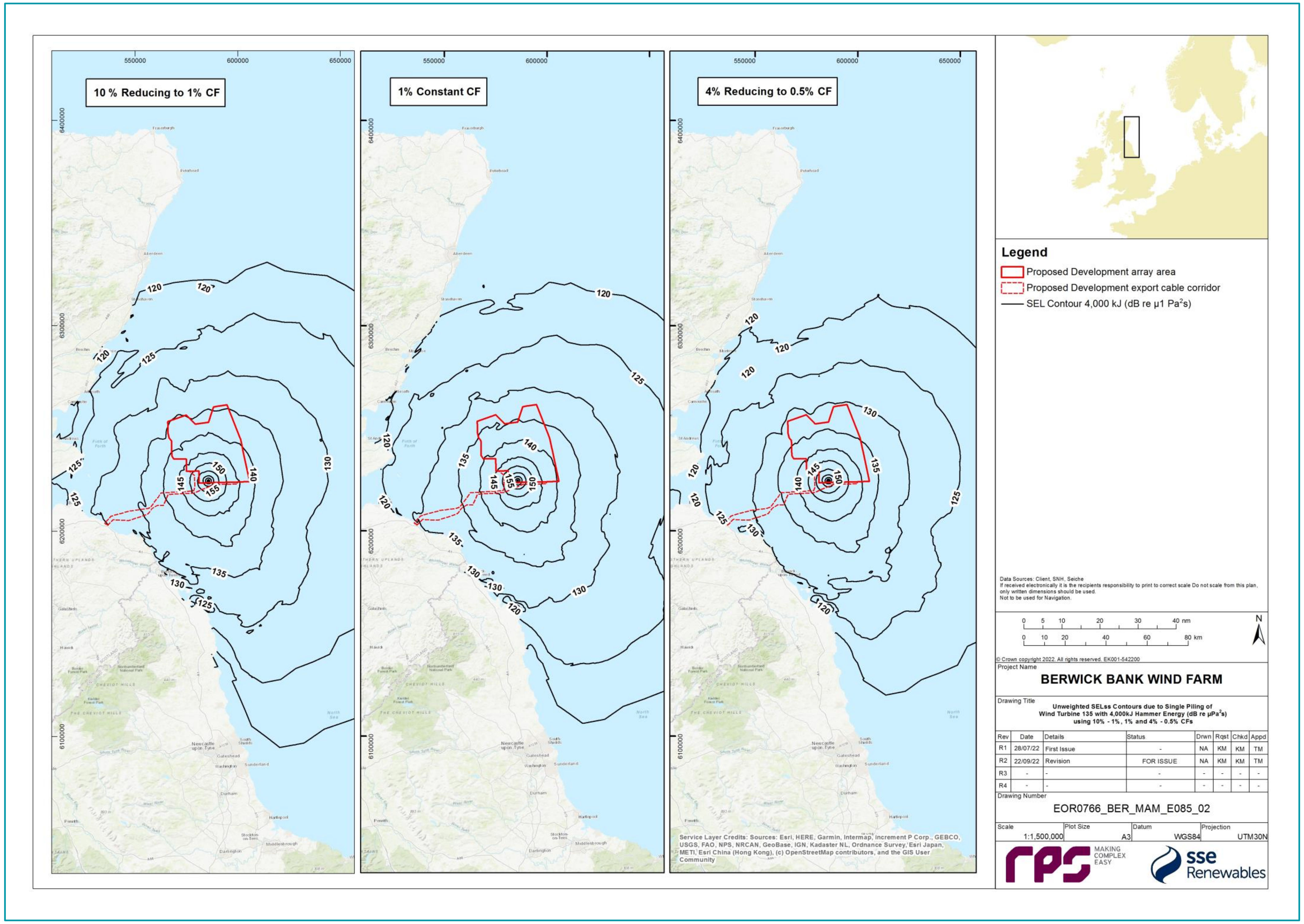

Figure 3.7: **Unweighted SEL$_{ss}$ Contours due to Single Piling of Piles at Wind Turbine Location 135 with 4,000 kJ Hammer Energy (dB re µPa^{2}s) Using 10% Reducing to 1%, 4% Reducing to 0.5% and 1% Constant Conversion Factor**

4. SUMMARY

60. This document provides an overview of the magnitude of injury and disturbance to marine mammals from underwater noise resulting from piling activities. Modelled noise contours from three selected conversion factors were applied: 10% reducing to 1% conversion factor, 4% reducing to 0.5% conversion factor and 1% constant conversion factor (as presented in the subsea noise sensitivity assessment; volume 3, appendix 10.1, annex B). As highlighted in the technical note on conversion factors provided in volume 3, appendix 10.1, annex A, the application of 10% reducing to 1% conversion factor in modelling of injury and noise disturbance contours is considered to result in overestimated impact ranges and subsequently these results have not been taken forward to the impact assessment of marine mammals. Instead, results generated using either a 4% reducing to 0.5% conversion factor (recommended in the technical note on conversion factors; volume 3, appendix 10.1, annex A) or the 1% constant conversion factor (commonly applied to previous offshore wind farm subsea noise assessments) have been taken forward to the assessment of significance in volume 2, chapter 10.

61. Supplementary information on a 4% and 10% constant conversion factor has also been presented for the assessment of instantaneous injury at the request of stakeholders. The ranges of effect (SPL_{pk}) predicted using a constant conversion factor of either 4% or 10% for the SPL_{pk} metric are less than the range predicted for cumulative exposure for minke whale (2,319 m) based on SEL_{cum} and using the 4% reducing to 0.5% conversion factor. Therefore, as a precautionary approach, the potential to mitigate for injury was considered with respect to the largest potential injury zone for all species (2,319 m).

62. The reason for considering two different conversion factors was to adopt the more precautionary approach since the larger predicted ranges switched between the 4% reducing to 0.5% and 1% constant conversion factor across the marine mammal hearing groups and depending on the acoustic metric applied. Thus, maximum injury ranges were predicted for different species using either the 4% reducing to 0.5% conversion factor or the 1% constant conversion factor depending on which of the dual acoustic metrics (SPL_{pk} or SEL_{cum}) resulted in the largest predicted ranges (Table 4.1). For behavioural effect ranges, where the unweighted SEL_{ss} metric was applied, the 1% constant conversion factor resulted in the larger impact ranges compared to the 4% reducing to 0.5% and therefore this conversion factor was used for the marine mammal behavioural assessment for all species.

Table 4.1: Summary of Injury Ranges and Corresponding Acoustic Metric (SPL_{pk} or SEL_{cum}) and Conversion Factor (1% Constant or 4% Reducing to 0.5%) Taken Forward for the Marine Mammal Impact Assessment

Species	Maximum Injury Range (m)	Acoustic Metric	Conversion Factor
Concurrent Piling – 4,000 kJ – Wind Turbine			
Harbour porpoise	449	SPL_{pk}	1%
Bottlenose dolphin/white-beaked dolphin	43	SPL_{pk}	1%
Minke whale	2,319	SEL_{cum}	4% reducing to 0.5%
Grey seal/harbour seal	118	SPL_{pk}	1%
Concurrent Piling – 3,000 kJ – Wind Turbine			
Harbour porpoise	338	SPL_{pk}	1%
Bottlenose dolphin/white-beaked dolphin	37	SPL_{pk}	1%
Minke whale	1,556	SEL_{cum}	4% reducing to 0.5%
Grey seal/harbour seal	102	SPL_{pk}	1%
Single Piling – 4,000 kJ – Wind Turbine*/OSP-Offshore Convertor Station Platform**			
Harbour porpoise	449	SPL_{pk}	1%
Bottlenose dolphin/white-beaked dolphin	43	SPL_{pk}	1%
Minke whale	1,030*/1,023**	SEL_{cum}	4% reducing to 0.5%
Grey seal/harbour seal	118	SPL_{pk}	1%

5. REFERENCES

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