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Underwater noise modelling at the Creyke Beck offshore wind farms, Dogger Bank

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1 Introduction

Underwater noise propagation modelling was carried out by the National Physical Laboratory (NPL) (Theobald *et al*. 2012, hereafter the "NPL Report") to assess the effects of noise from the construction of the Creyke Beck offshore wind farms, part of the Dogger Bank development area.

Since the NPL modelling was completed, new noise thresholds and criteria have been developed by the US National Marine Fisheries Service (NMFS, 2016) for impacts on marine mammals and Popper *et al*. (2014) for impact on fish. To obtain impact ranges using these criteria at Creyke Beck, additional modelling has been carried out by Subacoustech Environmental.

The modelling undertaken by Subacoustech Environmental has sought to replicate the results of modelling by NPL as closely as possible, for equivalent inputs and scenarios. Initially Subacoustech's modelling was run to verify that results closely matched the NPL predicted ranges under the original scenarios. The results were then re-analysed to produce new ranges based on the up-to-date criteria.

In addition to these new criteria, additional modelling was carried out by Subacoustech Environmental to estimate noise levels produced by larger hammers using greater blow energies than those previously modelled.

A map of the Creyke Beck sites including the modelling locations, is shown in Figure 1-1.

This report assumes familiarity with basic underwater acoustical concepts and metrics.

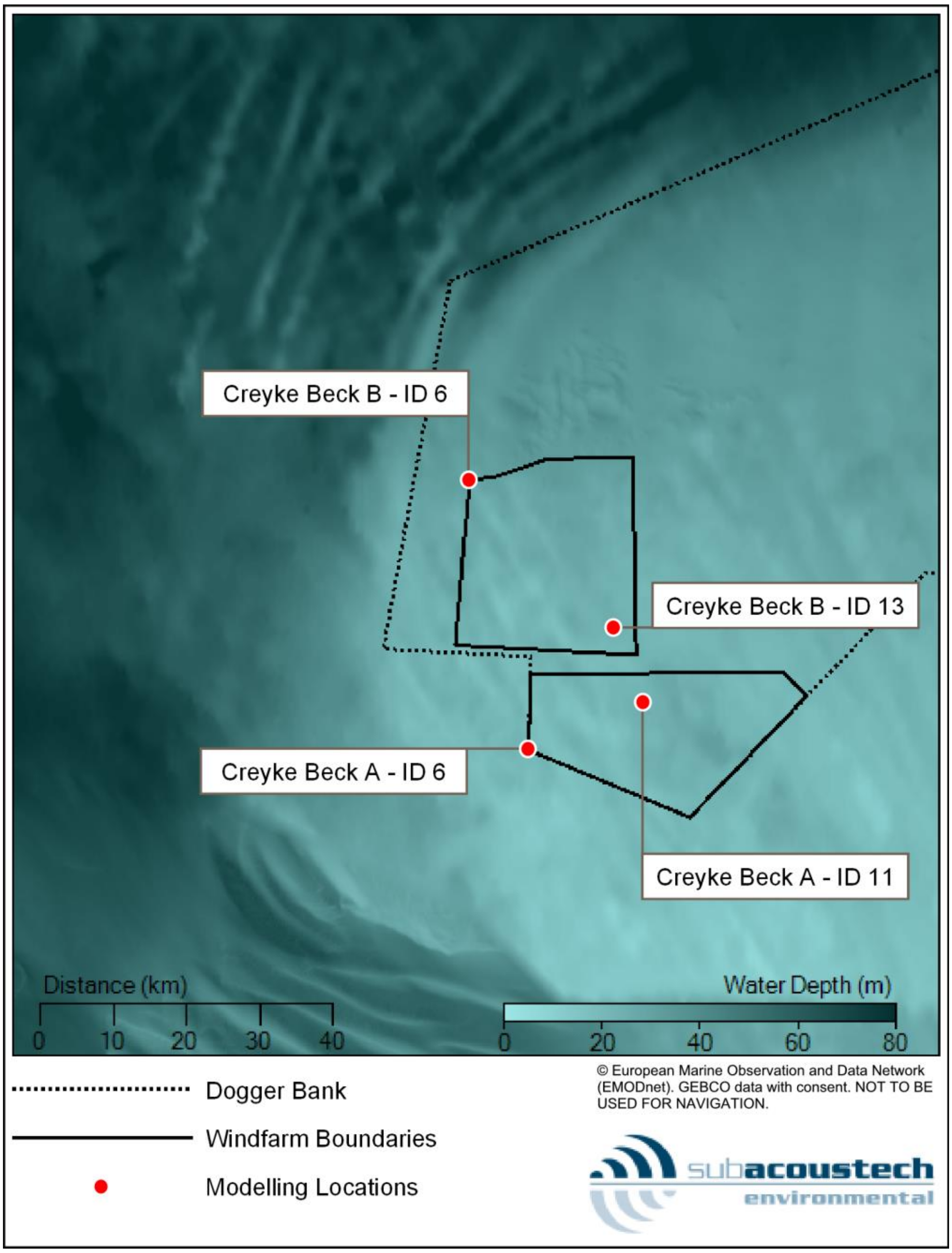

Figure 1-1 Overview map showing the windfarm boundaries and the approximate locations used for the modelling

2 Assessment criteria

2.1 Background

Over the past 20 years it has become increasingly evident that noise from human activities in and around underwater environments have the potential to cause adverse impacts on marine species in the area. The extent to which intense underwater sound might cause an adverse impact to a species is dependent upon the incident sound level, sound frequency, duration of exposure and/or repetition rate of an impulsive sound (Hastings and Popper, 2005), as well as the sensitivity of the species. As a result, scientific interest in the hearing abilities of aquatic animal species has increased. Studies are primarily based on evidence from high intensity sources of underwater noise such as blasting or impact piling, as these sources are likely to have the greatest environmental impact and the clearest observable effects, although there has been more interest in chronic noise exposure over the last ten years.

For this study, various criteria have been used, covering the values used in the NPL Report and the more up to date studies from NMFS (2016) for marine mammals and Popper *et al*. (2014) for fish.

2.2 Criteria from the NPL Report

The following criteria were used in the NPL Report and have been used to give a direct comparison between the NPL modelling and the INSPIRE modelling carried out for this study.

- Southall *et al.* (2007) for species of cetaceans and pinnipeds;
- Lucke *et al.* (2009) for harbour porpoises;
- Popper *et al*. (2006) and Carlson *et al*. (2007) using peak SPLs for injury in fish;
- Halvorsen *et al*. (2011) for SEL_{cum} for injury in fish; and
- McCauley *et al*. (2000) and Pearson *et al*. (1992) for behavioural response in fish.

These criteria are summarised in Table 2-1 to Table 2-5 as they appear in the NPL Report. It should be noted that the Southall and Lucke criteria presented in the NPL Report, and here as a comparison, for marine mammals are only for single strike SEL.

Effect	Criteria
Instantaneous injury / PTS	SPL_{peak} 200 dB re 1 µPa
	SEL_{ss} 179 dB re 1 µPa^{2}s
TTS / fleeing response	SPL_{peak} 194 dB re 1 µPa
	SEL_{ss} 164 dB re 1 µPa^{2}s
Possible avoidance from area	SPL_{peak} 168 dB re 1 µPa
	SEL_{ss} 145 dB re 1 µPa^{2}s

Table 2-1 Criteria for assessing harbour porpoise impacts as presented in the NPL report. These have been derived from Lucke et al. (2009)

Effect	Criteria
Instantaneous injury / PTS	SPL_{peak} 230 dB re 1 µPa
	M_{mf} weighted SEL_{ss} 198 dB re 1 µPa^{2}s
TTS / fleeing response	SPL_{peak} 224 dB re 1 µPa
	M_{mf} weighted SEL_{ss} 183 dB re 1 µPa^{2}s
Likely avoidance from area	SEL_{ss} 170 dB re 1 µPa^{2}s
Possible avoidance from area	SEL_{ss} 160 dB re 1 µPa^{2}s

Table 2-2 Criteria for assessing mid-frequency (MF) cetaceans impacts as presented in the NPL report. These have been derived from Southall et al. (2007)

Effect	Criteria
Instantaneous injury / PTS	SPL_{peak} 230 dB re 1 µPa
	M_{lf} weighted SEL_{ss} 198 dB re 1 µPa²s
TTS / fleeing response	SPL_{peak} 224 dB re 1 µPa
	M_{lf} weighted SEL_{ss} 183 dB re 1 µPa²s
Likely avoidance from area	SEL_{ss} 152 dB re 1 µPa²s
Possible avoidance from area	SEL_{ss} 142 dB re 1 µPa²s

Table 2-3 Criteria for assessing low-frequency (LF) cetaceans impacts as presented in the NPL report. These have been derived from Southall et al. (2007)

Effect	Criteria
Instantaneous injury / PTS	SPL_{peak} 218 dB re 1 µPa
	M_{pw} weighted SEL_{ss} 186 dB re 1 µPa²s
TTS / fleeing response	SPL_{peak} 212 dB re 1 µPa
	M_{pw} weighted SEL_{ss} 171 dB re 1 µPa²s

Table 2-4 Criteria for assessing pinnipeds (in water) impacts as presented in the NPL report. These are from Southall et al. (2007)

Effect	Criteria
Instantaneous injury / PTS	SPL_{peak} 206 dB re 1 µPa
	SEL_{cum} 211 dB re 1 µPa²s
Possible moderate to strong avoidance	SPL_{peak} 168 – 173 dB re 1 µPa
Startle response or C-turn reaction	SPL_{peak} 200 dB re 1 µPa

Table 2-5 Criteria for assessing fish impacts as presented in the NPL report. These are from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al. (2011), McCauley et al. (2000) and Pearson et al. (1992)

2.3 Impacts on marine mammals (NMFS, 2016)

2.3.1 Available literature

Since it was published, Southall *et al.* (2007) has been the source of the most widely used criteria to assess the effects of underwater noise on marine mammals and was the main criteria, along with Lucke *et al.* (2009), used in the NPL Report for marine mammals. NMFS (2016) was co-authored by many of the same authors from the Southall *et al.* (2007) paper and effectively updates its criteria for assessing the risk of auditory injury.

Similarly to the Southall *et al.* (2007) criteria, the NMFS (2016) guidance groups marine mammals into hearing groups and applies weighting filters to the noise to approximate the hearing sensitivity of the receptor. It should be noted that the filters used in Southall *et al.* (2007) differ from those used in NMFS (2016).

The hearing groups given in the NMFS (2016) guidance are summarised in Table 2-6 and Figure 2-1. A further hearing groups for Otariid Pinnipeds is also given for sea lions and fur seals, however this has not been used in this study as those species are not commonly found in the areas surrounding Dogger Bank.

Hearing group	Example species	Generalised hearing range
Low Frequency (LF) cetaceans	Baleen whales	7 Hz to 35 kHz
Mid Frequency (MF) cetaceans	Dolphins, Toothed Whales, Beaked Whales, Bottlenose Whales (including Bottlenose Dolphin)	150 Hz to 160 kHz
High Frequency (HF) cetaceans	True Porpoises (including Harbour Porpoise)	275 Hz to 160 kHz
Phocid Pinnipeds (PW) (underwater)	True Seals (including Harbour Seal)	50 Hz to 86 kHz

Table 2-6 Marine mammal hearing groups (from NMFS, 2016)

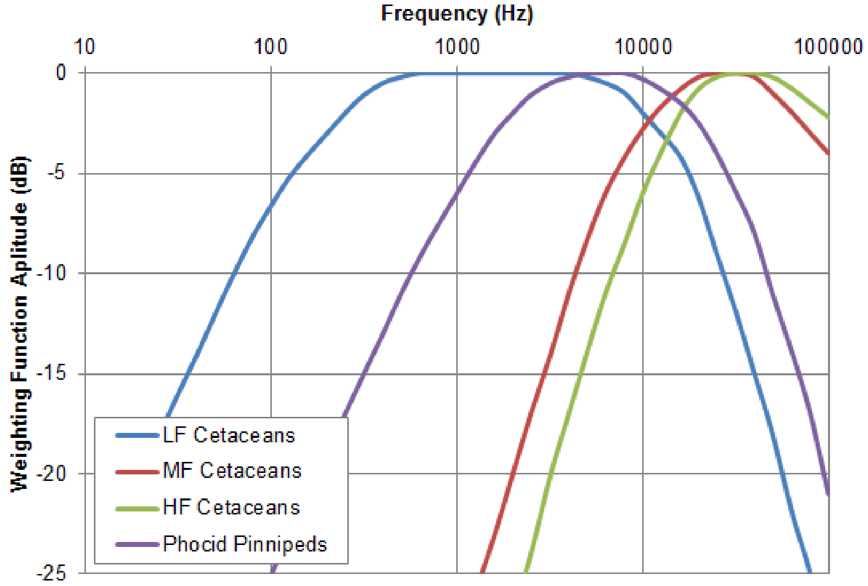

Figure 2-1 Auditory weighting functions for low frequency (LF) cetaceans, mid frequency (MF) cetaceans, high frequency (HF) cetaceans, and phocid pinnipeds (PW) (underwater) (from NMFS, 2016)

NFMS (2016) presents single strike, unweighted peak criteria (SPL_{peak}) and cumulative (i.e. more than a single impulsive sound), weighted sound exposure criteria (SEL_{cum}) for both permanent threshold shift (PTS) where unrecoverable hearing damage may occur and temporary threshold shift (TTS) where a temporary reduction in hearing sensitivity may occur in individual receptors. It should be noted that these cannot be compared like-for-like with criteria in the original ES as cumulative SELs were not considered for marine mammals.

Table 2-7 presents the NMFS (2016) criteria used in this study for each of the key marine mammal hearing groups.

Impulsive noise	**PTS criteria**		**TTS criteria**	
Functional Group	**SEL_{cum} (weighted) dB re 1 µPa²s**	**SPL_{peak} (unweighted) dB re 1 µPa**	**SEL_{cum} (weighted) dB re 1 µPa²s**	**SPL_{peak} (unweighted) dB re 1 µPa**
LF Cetaceans	183	219	168	213
MF Cetaceans	185	230	170	224
HF Cetaceans	155	202	140	196
PW Pinnipeds	185	218	170	212

Table 2-7 Assessment criteria for marine mammals from NMFS (2016) for impulsive noise

2.3.2 Weighted source levels

To undertake the modelling for the NMFS (2016) criteria with regards to the weighted SEL_{cum} criteria, the source levels were first adjusted using the auditory weighting functions shown in Figure 2-1. This significantly alters the source level for each functional group as shown in Figure 2-2 and Figure 2-3.

Noise from impact piling is predominantly low frequency in nature and reduces significantly at frequencies above 1 kHz. The impact piling source levels for monopiles using a 3000 kJ hammer blow energy given as 1/3 octave spectra in Figure 2-2 and Figure 2-3 show that the weighting only makes a modest difference to source levels for LF cetaceans when weightings are applied and a significant reduction for other hearing groups.

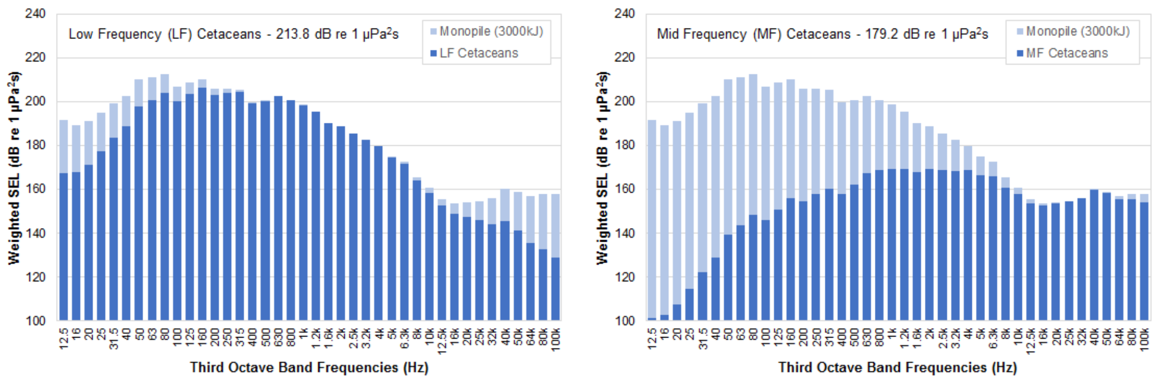

Figure 2-2 Unweighted and NMFS (2016) weighted SEL monopile impact piling source level third octave values for LF and MF cetaceans for a 3000 kJ hammer

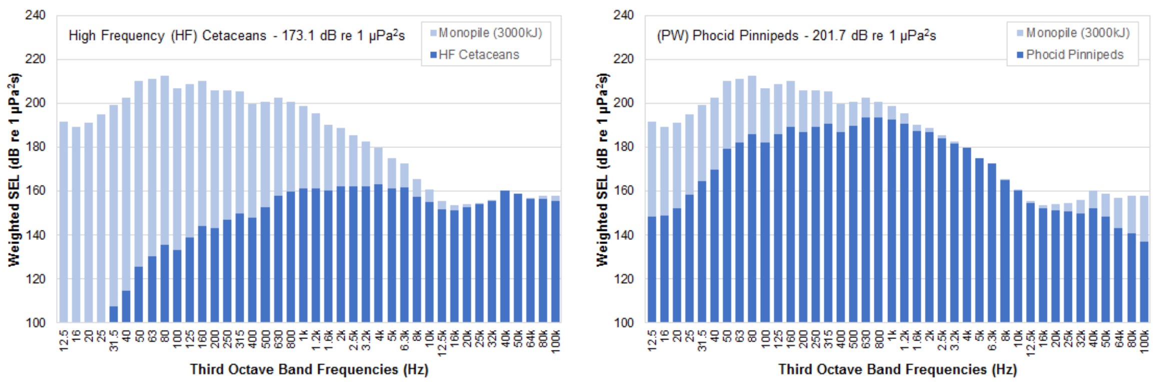

Figure 2-3 Unweighted and NMFS (2016) weighted SEL monopile impact piling source level third octave values for HF cetaceans and phocid pinnipeds for a 3000 kJ hammer

2.4 Impacts on fish (Popper *et al*. 2014)

The effects of noise on fish have been assessed using criteria from Popper *et al*. (2014), which gives specific criteria for mortality and potential mortal injury, recoverable injury and TTS, masking and behaviour from various stimuli, including impact piling. Species of fish are grouped by whether they have a swim bladder and whether that swim bladder is involved in its hearing. The criteria are given as unweighted SPL_{peak}, and SEL_{cum} values and are summarised in Table 2-8.

Type of animal	Mortality & potential mortal injury	Recoverable injury	TTS
Fish: no swim bladder	> 219 dB SEL_{cum} > 213 dB SPL_{peak}	> 216 dB SEL_{cum} > 213 dB SPL_{peak}	>> 186 dB SEL_{cum}
Fish: swim bladder not involved in hearing	210 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	> 186 dB SEL_{cum}
Fish: swim bladder involved in hearing	207 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	186 dB SEL_{cum}

Table 2-8 Assessment criteria for species of fish from Popper et al (2014) for impact piling noise

Where insufficient data is available (which is the case for masking and behavioural effects from impact piling), qualitative criteria have been given, summarising the effect of the noise as having either a high, moderate or low effect on an individual in either the near-field (tens of metres), intermediate-field (hundreds of metres) or far-field (thousands of metres). This also includes information for masking and behavioural effect. These qualitative effects are reproduced in Table 2-9.

Type of animal	Masking	Behaviour
Fish: no swim bladder	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate

Table 2-9 Summary of the qualitative effects on fish from impact piling noise from Popper et al. (2014) (N=Near field, I=Intermediate field, F=Far field)

3 Modelling methodology

3.1 NPL modelling

The original modelling for Creyke Beck was undertaken by NPL. The modelling utilised an energy flux solution by Weston (1976), capable of calculation of underwater noise propagation over large distances while accounting for range-dependent bathymetry and frequency-dependent absorption.

26 locations were modelled by NPL, covering the extents of the two Creyke Beck sites, and for each location pile driving noise was modelled for a hammer operating at up to 2300 kJ for pin pile installation and a hammer of up to 3000 kJ for monopiles.

Results were produced for a variety of available metrics and criteria, including:

- Southall *et al*. (2007) for species of cetaceans and pinnipeds;
- Lucke *et al.* (2009) for harbour porpoises;
- Popper *et al*. (2006) and Carlson *et al*. (2007) using peak SPLs for injury in fish;
- Halvorsen *et al*. (2011) for SEL_{cum} for injury in fish; and
- McCauley *et al*. (2000) and Pearson *et al*. (1992) for behavioural response in fish.

The model used by NPL is not openly available. As such, Subacoustech Environmental have used a different but comparable modelling method.

3.2 Subacoustech Environmental modelling

The primary goal in respect to the first stage of underwater noise propagation modelling presented in this report was to replicate the results from the NPL modelling as closely as possible, to ensure that the new modelling was consistent with that undertaken previously. Results using the NMFS (2016) and Popper *et al*. (2014) criteria could then be calculated with confidence.

For the modelling in this study, Subacoustech Environmental have used the INSPIRE modelling software to predict noise levels and impact ranges from piling at Creyke Beck.

The INSPIRE model (currently version 3.5) is a semi-empirical, depth-dependent, underwater noise propagation model based around a combination of numerical modelling and actual measured data from over 50 datasets of noise propagation, mostly surrounding the UK. It is designed to calculate the propagation of noise in shallow, mixed, coastal waters, typical of the conditions around the UK, and is well suited to the Dogger Bank and Creyke Beck region.

The model can provide estimates of unweighted SPL_{peak} (peak sound pressure level), SEL_{ss} (single strike sound exposure level) and SEL_{cum} (cumulative sound exposure level) noise levels as well as various other weighted noise metrics. Calculations made along 180 equally spaced radial transects, i.e. one every 2°. For each modelling run, a criterion level is specified, allowing a noise contour to be drawn, within which a given effect may occur. These results are then plotted over digital bathymetry data so that impact ranges can be clearly visualised and assessed as necessary.

The methods used within this report meet the requirements set by the NPL Good Practice Guide 133 for underwater noise measurement (Robinson *et al.* 2014).

The approach used considers a wide range of input parameters to ensure as detailed results as possible. The resulting transmission losses have then been compared to (and in some cases extrapolated from) the numbers given in the NPL report to ensure compatibility. This is discussed further in section 3.3.

3.2.1 Modelling location

Modelling has been undertaken at four locations over the two Creyke Beck sites identified in the NPL Report (locations ID6 and ID11 in Creyke Beck A, and locations ID6 and ID13 in Creyke Beck B – Table 4.1 and Table 4.2). These locations have been chosen as they are used for detailed analysis within the NPL Report. The locations cover a wide area of the Creyke Beck sites including both deep and shallow water areas.

The approximate location is given in Figure 1-1 and the coordinates are summarised in Table 3-1.

	Creyke Beck A ID6	Creyke Beck A ID11	Creyke Beck B ID6	Creyke Beck B ID13
Latitude	54.7417°N	54.8003°N	55.07332°N	54.8902°N
Longitude	1.8283°E	1.8796°E	1.5056°E	1.8157°E
Depth (m)	23	32	30	22

Table 3-1 Summary of the modelling locations used for this study

3.2.2 Modelling input parameters

The following environmental and noise source parameters have been assumed in the modelling.

Impact piling

The original modelling by NPL considered two primary scenarios: monopile foundations installed using a hammer with a maximum blow energy of 3000 kJ and pin pile foundations installed using a maximum blow energy of 2300 kJ. In addition to these, several lower blow energies were also modelled to show the ‘soft start’ and ramp up of the impact piling from the start to the maximum (300 kJ and 1900 kJ).

The above initial (comparative) scenarios have been modelled using the Subacoustech Environmental approach described above. In addition, two higher maximum blow energies for monopiles, 3600 kJ and 4000 kJ, could potentially be used for installation and the effects of these have been modelled.

Source levels

Underwater noise modelling requires knowledge of the source level, which is the noise level at 1 m from the noise source. The source levels used by NPL for their modelling were not presented in their report. For this study, the source level has been derived by taking the modelled transmission loss of the noise over distance and fitting it to the impact ranges presented previously in the NPL Report. The resulting source levels have been used for calculating the impact ranges for the NMFS (2016) and Popper *et al*. (2014) criteria. A description for the process of fitting of the data and comparisons to NPL modelling are presented in section 3.3.

The unweighted source levels used for the modelling are provided in Table 3-2 for the maximum blow energies, which are in line with those seen at other, similar scale projects.

	SPL_{peak} source level	SEL_{ss} source level
Pin Pile 2300 kJ (maximum)	243.5 dB re 1 µPa @ 1 m	216.5 dB re 1 µPa²s @ 1 m
Monopile 3000 kJ (maximum)	245.2 dB re 1 µPa @ 1 m	219.2 dB re 1 µPa²s @ 1 m
Monopile 3600 kJ (maximum)	246.7 dB re 1 µPa @ 1 m	219.9 dB re 1 µPa²s @ 1 m
Monopile 4000 kJ (maximum)	247.5 dB re 1 µPa @ 1 m	220.4 dB re 1 µPa²s @ 1 m

Table 3-2 Summary of the unweighted, single strike, source levels used for modelling in this study

It is important to note that the source level value is theoretical and does not necessarily, nor is intended to, represent the actual noise level at 1 m from the piling operation, which is highly complex close to a large distributed source. Its purpose is for the accurate calculation of noise levels at greater distances from the source, to correspond with relevant thresholds, and crucially in this case, to agree with the original NPL modelling.

Frequency content

The size of the pile being installed has been applied to the modelling to estimate the frequency content of the noise. Frequency data was not given in the NPL report. As such, frequency data has been derived using Subacoustech Environmental's noise measurement database. Representative third-octave noise levels dependent on the size of the monopiles and pin piles have been used for this modelling. The SEL third-octave frequency spectrum levels used for modelling are illustrated in Figure 3-1. The shape of each spectrum is the same for all blow energies at source, with the overall source levels adjusted to account for the changing blow energy.

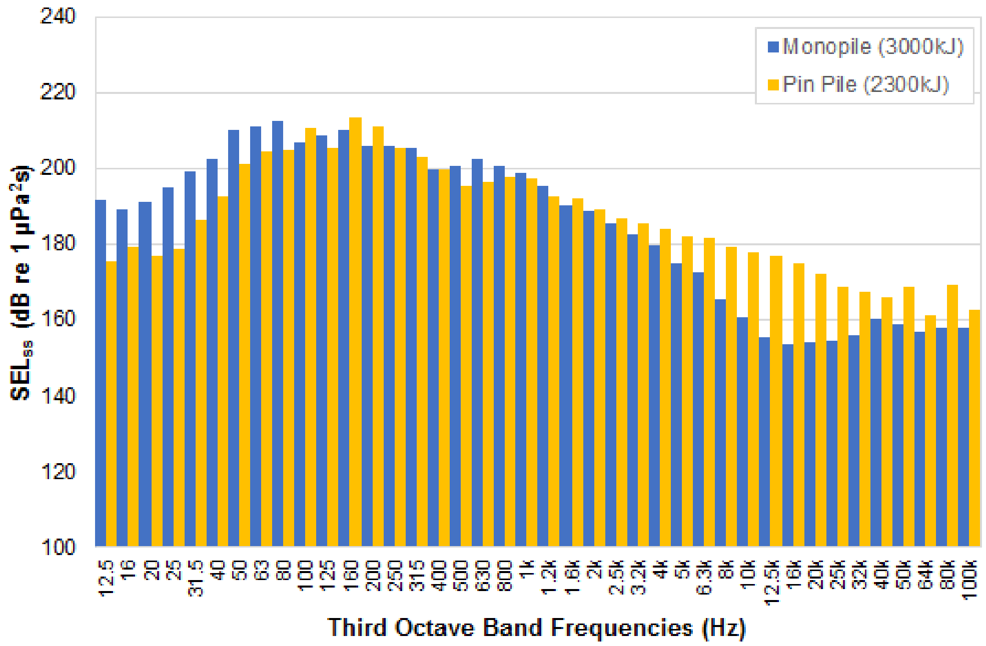

Figure 3-1 SEL_{ss} third-octave source level frequency spectra used for modelling

The noise from monopiles contains more low frequency content and the pin piles contain more high frequency content, due to the dimensions and acoustics of the pile.

Soft start, strike rate, and piling duration

For cumulative SEL, which takes into account the total exposure of a receptor to the noise of the complete piling period, the soft start, strike rate and duration of the piling events have also been considered. Table 4.4 in the NPL Report gives a summary of the parameters used for cumulative strike modelling; all three of these sequences have been considered for this modelling. The parameters used for this modelling, based on those given in the NPL report, are summarised in Table 3-3 below. Sequence 1 assumes 2000 strikes over 65 minutes, sequence 2 assumes 5000 strikes over 140 minutes, and sequence 3 assumes 12600 strikes over 330 minutes.

The soft start, or the use of lower hammer energy for an initial period, takes place over the first half-hour of piling, with a blow energy of 10% of maximum, then for the remaining number of strikes the blow energy is 100%. This is a worst-case scenario, as it is likely that the blow energy will ramp up gradually from 10% to 100% after the soft start and for engineering reasons piling would not be at 100% for this extended period. However information on a ramp-up was unavailable in the NPL report, and thus these worst-case assumptions have been made.

Maximum hammer blow energy	Percent of maximum blow energy	
	10% (soft start)	**100%**
2300 kJ (pin pile)	230 kJ	2300 kJ
3000 kJ (monopile)	300 kJ	3000 kJ
3600 kJ (monopile)	360 kJ	3600 kJ
4000 kJ (monopile)	400 kJ	4000 kJ
Strike rate	1 strike every 3 seconds	1 strike every 1.5 seconds
Duration	30 minutes	35 minutes (sequence 1) 110 minutes (sequence 2) 300 minutes (sequence 3)
Number of strikes	600 strikes	1,400 strikes (sequence 1) 4,400 strikes (sequence 2) 12,000 strikes (sequence 3)

Table 3-3 Summary of the multiple pulse scenarios used for cumulative SEL modelling

Fleeing receptors

Where the SEL_{cum} results are required, a fleeing animal model has been used. This assumes that the animal exposed to the noise levels will swim away from the source as it occurs. For this, a constant speed of 3.25 ms^{-1} has been assumed for the low frequency (LF) cetaceans group (Blix and Folkow, 1995) based on data for Minke whale. All other receptors are assumed to swim at a constant speed of 1.5 ms^{-1} (Otani *et al*. 2000; Hirata, 1999). These are considered worst-case (i.e. relatively slow, leading to greater calculated exposures) as marine mammals are expected to swim much faster under stress conditions.

Environmental conditions

By inclusion of measured data from similar offshore impact piling events, the INSPIRE model intrinsically accounts for various environmental conditions. Data from the British Geological Survey (BGS) presented as part of the Marine Environmental Mapping Programme (MAREMAP) show that the areas around Creyke Beck and the Dogger Bank region generally are made up of sand or gravelly sand.

Bathymetry from the European Marine Observation and Data Network (EMODnet) was used for this modelling. Mean tidal depth was used throughout for the bathymetry to match conditions used in the NPL report.

3.3 Results of original and revised modelling comparison

3.3.1 *Model comparison*

In order to obtain modelling results representative of those produced for the NPL Report, modelling was carried out using the INSPIRE model using the parameters detailed in the previous section to get a general transmission loss over multiple transects. These transmission losses were then compared against the results given in the NPL Report. Location ID6 at Creyke Beck B was chosen as a representative modelling location due to its location in the deeper water to the north and west of the site.

There was good correlation between the two resultant data sets. Figure 3-2 and Figure 3-3 compare the unweighted noise level plots from the NPL Report and the new Subacoustech modelling at the same scale. It should be noted that although the noise levels do not line up perfectly, the figures do show many of the same features, such as a largely uniform distribution in all directions for the highest noise levels, with larger ranges into the deeper water to the north and northwest and some effects of shallower areas and sandbanks to the south, which reduce noise transmission.

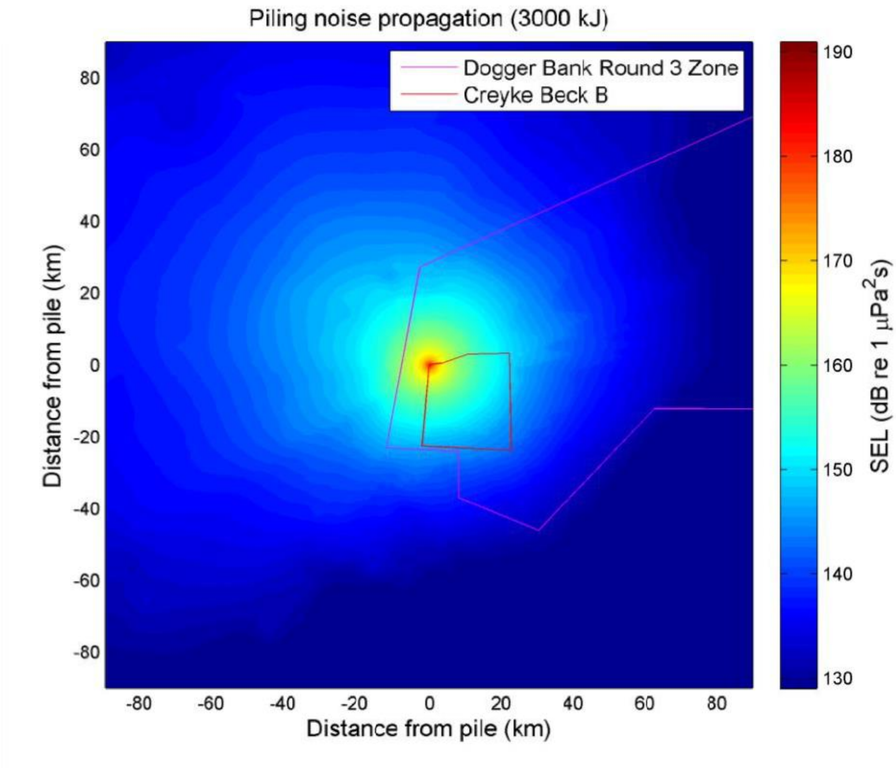

Figure 3-2 SEL_{ss} impact piling noise propagation map for Creyke Beck B location ID6 for a 3000 kJ hammer from the NPL Report, Figure 4.4

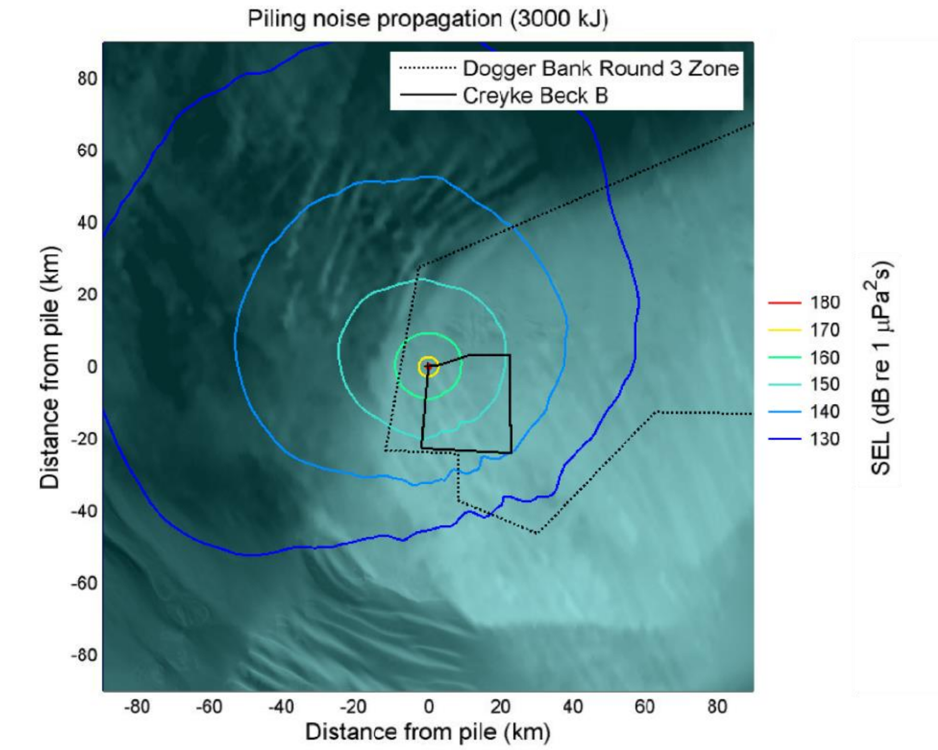

Figure 3-3 SEL_{ss} impact piling noise propagation map for Creyke Beck B location ID6 for a 3000 kJ hammer showing the transmission losses predicted for the INSPIRE modelling

The source level was ascertained by fitting the modelled transmission loss to the impact ranges given in the NPL Report. Figure 3-4 and Figure 3-5 show how the worst-case transect lines up with the higher SPL_{peak} and SEL_{ss} impact ranges given in the NPL Report, resulting in the source levels to be used for modelling in this study, summarised in Table 3-2. A conservative fit to the data has been used so that levels predicted along the worst-case transect intersect with the highest levels reported by NPL; this data is summarised in Table 3-4 and Table 3-5.

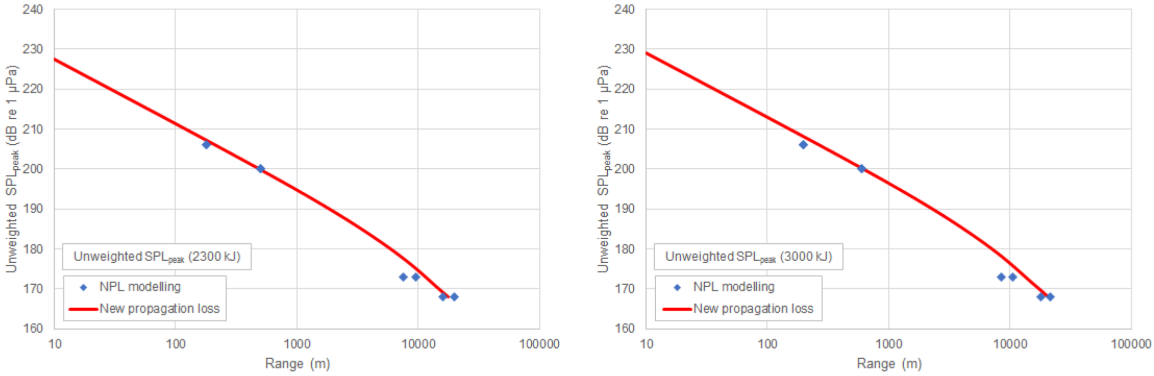

Figure 3-4 Level versus range plots showing a comparison between the reported NPL impact ranges and the new modelling fitted to the data (unweighted SPL_{peak})

SPL_{peak}	Criteria	NPL modelling	INSPIRE worst case
2300 kJ	206 dB re 1 µPa	< 180 m	230 m
	200 dB re 1 µPa	< 500 m	500 m
	173 dB re 1 µPa	7.5 to 9.5 km	11.5 km
	168 dB re 1 µPa	16.0 to 20.0 km	17.7 km
3000kJ	206 dB re 1 µPa	< 200 m	280 m
	200 dB re 1 µPa	< 600 m	490 m
	173 dB re 1 µPa	8.5 to 10.5 km	13.4 km
	168 dB re 1 µPa	18.0 to 21.5 km	20.5 km

Table 3-4 Summary of the maximum modelled SPL_{peak} values compared in Figure 3-4

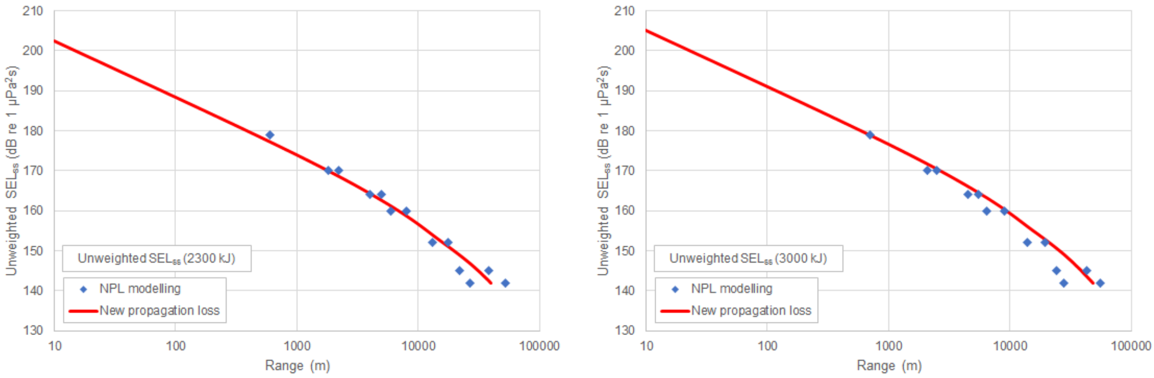

Figure 3-5 Level versus range plots showing a comparison between the reported NPL impact ranges and the new modelling parameters fitted to the data (unweighted SEL_{ss})

SEL_{ss}	Criteria	NPL modelling	INSPIRE worst case
2300 kJ	179 dB re 1 µPa²s	< 600 m	470 m
	164 dB re 1 µPa²s	4.0 to 5.0 km	4.3 km
	145 dB re 1 µPa²s	22.0 to 38.0 km	31.5 km
	170 dB re 1 µPa²s	1.8 to 2.2 km	1.9 km
	160 dB re 1 µPa²s	6.0 to 8.0 km	6.9 km
	152 dB re 1 µPa²s	13.0 to 17.5 km	16.2 km
	142 dB re 1 µPa²s	26.5 to 52.0 km	40.0 km
3000kJ	179 dB re 1 µPa²s	< 700 m	720 m
	164 dB re 1 µPa²s	4.5 to 5.5 km	5.9 km
	145 dB re 1 µPa²s	24.0 to 43.0 km	39.0 km
	170 dB re 1 µPa²s	2.1 to 2.5 km	2.7 km
	160 dB re 1 µPa²s	6.5 to 9.0 km	9.4 km
	152 dB re 1 µPa²s	14.0 to 19.5 km	21.3 km
	142 dB re 1 µPa²s	28.0 to 56.0 km	48.4 km

Table 3-5 Summary of the maximum modelled SEL_{ss} values compared in Figure 3-5

3.3.2 Modelling confidence

Expanding on the data from the previous section, Table 3-6 and Table 3-7 give summaries of direct comparisons between the modelled impact ranges for all blow energies presented by NPL, and the modelling undertaken by Subacoustech Environmental for this report. All the values are either unweighted SPL_{peak} values or unweighted single strike SEL_{ss} values. As stated earlier, where a range of distances are given in the NPL report, the greatest distances have been used to ensure a conservative fit to the data.

It should be noted that the ranges given in the NPL report, and presented below in Table 3-6 and Table 3-7, consider all modelling locations at Creyke Beck B, whereas the Subacoustech Environmental modelling has only considered the a single location (ID6).

Overall, there is a good level of correlation between the two datasets and the results from the INSPIRE model, with the INSPIRE model having a slightly smaller spread of ranges. The chosen approach provides a good substitute for the NPL modelling in calculating the NMFS (2016) and Popper *et al*. (2014) criteria. The full modelling results produced by Subacoustech Environmental ("Sub-E") for the criteria given in the NPL Report are presented in section 4.1.

Unwtd SPL_{peak}	300 kJ hammer energy		1900 kJ hammer energy		2300 kJ hammer energy		3000 kJ hammer energy	
	NPL	Sub-E	NPL	Sub-E	NPL	Sub-E	NPL	Sub-E
206 dB	< 50 m	70 to 80 m	< 150 m	190 to 200 m	< 180 m	220 to 230 m	< 200 m	270 to 280 m
200 dB	< 100 m	120 to 130 m	< 450 m	430 to 450 m	< 500 m	490 to 500 m	< 600 m	620 to 630 m
173 dB	3.0 to 4.0 km	4.0 to 4.2 km	7.0 to 9.0 km	9.1 to 10.7 km	7.5 to 9.5 km	9.8 to 11.5 km	8.5 to 10.5 km	11.1 to 13.4 km
168 dB	7.0 to 9.0 km	6.4 to 7.1 km	15.0 to 19.0 km	13.0 to 16.3 km	16.0 to 20.0 km	13.8 to 17.7 km	18.0 to 21.5 km	15.2 to 20.5 km

Table 3-6 Comparison between ranges to unweighted SPL_{peak} values given in the NPL Report and the comparative modelling undertaken by Subacoustech Environmental (Sub-E) for location ID6 at Creyke Beck B

Unwtd SEL_{ss}	**300 kJ hammer energy**		**1900 kJ hammer energy**		**2300 kJ hammer energy**		**3000 kJ hammer energy**	
	NPL	Sub-E	NPL	Sub-E	NPL	Sub-E	NPL	Sub-E
179 dB	< 100 m	140 to 150 m	< 550 m	420 to 430 m	< 600 m	460 to 470 m	< 700 m	700 to 720 m
164 dB	1.2 to 1.5 km	1.4 km	3.2 to 4.4 km	3.7 to 3.9 km	4.0 to 5.0 km	4.0 to 4.3 km	4.5 to 5.5 km	5.5 to 5.9 km
145 dB	10.5 to 14.5 km	12.4 to 15.1 km	20.5 to 34.5 km	19.7 to 30.1 km	22.0 to 38.0 km	20.3 to 31.5 km	24.0 to 43.0 km	23.2 to 39.1 km
170 dB	< 600 m	570 to 580 m	1.6 to 2.0 km	1.7 km	1.8 to 2.2 km	1.8 to 1.9 km	2.1 to 2.5 km	2.7 km
160 dB	2.1 to 2.5 km	2.5 to 2.6 km	5.5 to 7.5 km	6.0 to 6.5 km	6.0 to 8.0 km	6.3 to 6.9 km	6.5 to 9.0 km	8.3 to 9.4 km
152 dB	5.5 to 7.5 km	6.5 to 7.2 km	11.5 to 16.0 km	12.6 to 15.3 km	13.0 to 17.5 km	13.1 to 16.2 km	14.0 to 19.5 km	15.8 to 21.3 km
142 dB	14.0 to 19.5 km	15.4 to 20.4 km	25.5 to 49.0 km	22.9 to 38.3 km	26.5 to 52.0 km	23.5 to 40.0 km	28.0 to 56.0 km	26.4 to 48.4 km

Table 3-7 Comparison between ranges to unweighted SEL_{ss} values given in the NPL Report and the comparable modelling undertaken by Subacoustech Environmental (Sub-E) for location ID6 at Creyke Beck B

4 Modelling results

The following sections present the modelling impact ranges for the criteria discussed in section 2 at the Creyke Beck sites and a comparison with the results presented in the NPL Report. Only the results from location ID6 at Creyke Beck B are presented in this section. The complete modelling results for all modelled locations are presented in Appendix A.

4.1 Previously considered criteria

Table 4-1 to Table 4-5 present the impact ranges from the INSPIRE modelling considering the single pulse noise criteria used in the NPL Report, covering the metrics and criteria described in section 2. Also included are the results for the 3600 and 4000 kJ hammer energies.

Predicted ranges smaller than 50 m, and area less than 0.1 km^2 for single strike criteria, and smaller than 100 m for cumulative criteria, have not been presented as the modelling processes are unable to specify that level of accuracy with confidence due to acoustic effects near the source and other noise processes at close ranges.

The results that are large enough to be shown clearly are also presented in Appendix B as contour plots.

Harbour porpoise - impact criterion		**300 kJ hammer energy**	**1900 kJ hammer energy**	**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Instantaneous injury/PTS (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	450 m	500 m	630 m	770 m	860 m
	Min	120 m	430 m	490 m	620 m	760 m	840 m
	Mean	130 m	440 m	500 m	630 m	770 m	850 m
	Area	0.1 km^2	0.6 km^2	0.8 km^2	1.2 km^2	1.8 km^2	2.3 km^2
Instantaneous injury/PTS (SEL_{ss} 179 dB re 1 µPa^{2}s)	Max	150 m	430 m	470 m	720 m	800 m	860 m
	Min	140 m	420 m	460 m	700 m	780 m	850 m
	Mean	150 m	430 m	470 m	710 m	790 m	860 m
	Area	0.1 km^2	0.6 km^2	0.7 km^2	1.6 km^2	2.0 km^2	2.3 km^2
TTS/fleeing response (SPL_{peak} 194 dB re 1 µPa)	Max	280 m	990 m	1.1 km	1.4 km	1.7 km	1.9 km
	Min	270 m	970 m	1.1 km	1.4 km	1.7 km	1.8 km
	Mean	280 m	980 m	1.1 km	1.4 km	1.7 km	1.9 km
	Area	0.2 km^2	3.0 km^2	3.8 km^2	6.0 km^2	8.8 km^2	11 km^2
TTS/fleeing response (SEL_{ss} 164 dB re 1 µPa^{2}s)	Max	1.4 km	4.0 km	4.3 km	5.9 km	6.5 km	6.9 km
	Min	1.4 km	3.8 km	4.0 km	5.5 km	6.0 km	6.3 km
	Mean	1.4 km	3.9 km	4.2 km	5.8 km	6.3 km	6.7 km
	Area	6.4 km^2	47 km^2	54 km^2	110 km^2	130 km^2	140 km^2
Possible avoidance of area (SPL_{peak} 168 re 1 µPa^{2}s)	Max	7.1 km	16.3 km	17.7 km	20.5 km	23.2 km	24.6 km
	Min	6.4 km	13.0 km	13.8 km	15.2 km	16.4 km	17.0 km
	Mean	6.9 km	15.0 km	16.0 km	18.1 km	20.0 km	21.1 km
	Area	150 km^2	710 km^2	810 km^2	1000 km^2	1300 km^2	1400 km^2
Possible avoidance of area (SEL_{ss} 145 re 1 µPa^{2}s)	Max	15.1 km	30.1 km	31.5 km	39.1 km	41.1 km	42.6 km
	Min	12.4 km	19.7 km	20.3 km	23.2 km	23.9 km	24.4 km
	Mean	14.1 km	25.1 km	26.1 km	31.4 km	32.8 km	33.9 km
	Area	620 km^2	2000 km^2	2200 km^2	3100 km^2	3500 km^2	3700 km^2

Table 4-1 Predicted harbour porpoise impact ranges using criteria derived from Lucke et al. (2009) at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		**300 kJ hammer energy**	**1900 kJ hammer energy**	**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Max	< 50 m	90 m	120 m	140 m	150 m	170 m
	Min	< 50 m	80 m	110 m	130 m	140 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	150 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Likely avoidance of area (SEL_{ss} 170 re 1 µPa^{2}s)	Max	580 m	1.7 km	1.9 km	2.7 km	3.0 km	3.2 km
	Min	570 m	1.7 km	1.8 km	2.7 km	2.9 km	3.1 km
	Mean	580 m	1.7 km	1.8 km	2.7 km	3.0 km	3.2 km
	Area	1.0 km^2	8.9 km^2	10 km^2	23 km^2	27 km^2	31 km^2
Possible avoidance of area (SEL_{ss} 160 re 1 µPa^{2}s)	Max	2.6 km	6.5 km	6.9 km	9.4 km	10.2 km	10.7 km
	Min	2.5 km	6.0 km	6.3 km	8.3 km	8.9 km	9.3 km
	Mean	2.5 km	6.4 km	6.8 km	9.1 km	9.7 km	10.2 km
	Area	20 km^2	130 km^2	140 km^2	260 km^2	300 km^2	330 km^2

Table 4-2 Predicted mid-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID6

Low-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^2s)	Max	< 50 m	< 50 m	< 50 m	50 m	50 m	50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^2s)	Max	80 m	240 m	260 m	390 m	430 m	470 m
	Min	70 m	230 m	250 m	380 m	420 m	450 m
	Mean	80 m	240 m	260 m	390 m	430 m	460 m
	Area	< 0.1 km^2	0.2 km^2	0.2 km^2	0.5 km^2	0.6 km^2	0.7 km^2
Likely avoidance of area (SEL_{ss} 152 re 1 µPa^2s)	Max	7.2 km	15.3 km	16.2 km	21.3 km	22.8 km	23.9 km
	Min	6.5 km	12.6 km	13.1 km	15.8 km	16.5 km	17.0 km
	Mean	7.0 km	14.3 km	15.0 km	18.8 km	19.9 km	20.7 km
	Area	150 km^2	640 km^2	700 km^2	1100 km^2	1200 km^2	1300 km^2
Possible avoidance of area (SEL_{ss} 142 re 1 µPa^2s)	Max	20.4 km	38.3 km	40.0 km	48.4 km	50.8 km	52.5 km
	Min	15.4 km	22.9 km	23.5 km	26.4 km	27.2 km	27.8 km
	Mean	18.2 km	30.9 km	32.0 km	37.9 km	39.5 km	40.7 km
	Area	1000 km^2	3000 km^2	3300 km^2	4600 km^2	5100 km^2	5400 km^2

Table 4-3 Predicted low-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID6

Pinnipeds (in water) - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 218 dB re 1 µPa)	Max	50 m	50 m	60 m	70 m	80 m	80 m
	Min	< 50 m	< 50 m	50 m	60 m	70 m	70 m
	Mean	< 50 m	< 50 m	60 m	70 m	80 m	80 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa^2s)	Max	< 50 m	90 m	120 m	150 m	160 m	170 m
	Min	< 50 m	80 m	110 m	140 m	150 m	160 m
	Mean	< 50 m	90 m	120 m	150 m	160 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (SPL_{peak} 212 dB re 1 µPa)	Max	70 m	90 m	110 m	130 m	160 m	170 m
	Min	60 m	80 m	100 m	120 m	150 m	160 m
	Mean	70 m	90 m	110 m	130 m	160 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa^2s)	Max	290 m	870 m	1.2 km	1.4 km	1.6 km	1.7 km
	Min	280 m	850 m	1.2 km	1.4 km	1.6 km	1.7 km
	Mean	290 m	860 m	1.2 km	1.4 km	1.6 km	1.7 km
	Area	0.3 km^2	2.3 km^2	4.2 km^2	6.2 km^2	7.6 km^2	8.8 km^2

Table 4-4 Predicted pinniped (in water) impact ranges using criteria from Southall et al. (2007) at Creyke Beck B, location ID6

Fish - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 206 dB re 1 µPa)	Max	80 m	200 m	230 m	280 m	350 m	380 m
	Min	70 m	190 m	220 m	270 m	340 m	370 m
	Mean	80 m	200 m	230 m	280 m	350 m	380 m
	Area	< 0.1 km²	0.1 km²	0.2 km²	0.2 km²	0.4 km²	0.4 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 1	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 2	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 3	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Possible moderate to strong avoidance (upper bound SPL_{peak} 173 dB re 1 µPa)	Max	4.2 km	10.7 km	11.5 km	13.4 km	15.1 km	16.2 km
	Min	4.0 km	9.1 km	9.8 km	11.1 km	12.3 km	12.9 km
	Mean	4.1 km	10.2 km	11.0 km	12.6 km	14.1 km	14.9 km
	Area	53 km²	320 km²	380 km²	490 km²	620 km²	700 km²
Possible moderate to strong avoidance (lower bound SPL_{peak} 168 dB re 1 µPa)	Max	7.1 km	16.3 km	17.7 km	20.5 km	23.2 km	24.6 km
	Min	6.4 km	13.0 km	13.8 km	15.2 km	16.4 km	17.0 km
	Mean	6.9 km	15.0 km	16.0 km	18.1 km	20.0 km	21.1 km
	Area	150 km²	710 km²	810 km²	1000 km²	1300 km²	1400 km²
Startle response or C-turn reaction (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	450 m	500 m	630 m	770 m	860 m
	Min	120 m	430 m	490 m	620 m	760 m	840 m
	Mean	130 m	440 m	500 m	630 m	770 m	850 m
	Area	0.1 km²	0.6 km²	0.8 km²	1.2 km²	1.8 km²	2.3 km²

Table 4-5 Predicted fish impact ranges using criteria from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al (2011), McCauley et al. (2000) and Pearson et al. (1992) at Creyke Beck B, location ID6

Cells marked with a hyphen (300 kJ and 1900 kJ) are only used for single strike hammer energies within the soft start period. As such cumulative SELs are not intended to be calculated for them.

4.2 NMFS (2016) impact ranges

Table 4-6 to Table 4-13 present the impact ranges for the NMFS (2016) criteria for marine mammals. As before, ranges smaller than 50 m or 100 m have not been presented for single strike criteria for cumulative criteria respectively.

The results show that, using the NMFS (2016) SPL_{peak} criteria, ranges are largely within a few hundred metres, with only the TTS ranges for high-frequency cetaceans extending over 1 km. For the SEL_{cum} criteria, larger ranges are predicted, with PTS for LF cetaceans exceeding 8.1 km and TTS for LF cetaceans exceeding 50 km for the largest hammer blow energies and worst-case ramp-up sequence 3.

The ranges for all species groups are greater with the increase in maximum monopile blow energy. Comparing the PTS and TTS criteria used previously (Lucke *et al.* 2009; Southall *et al.* 2007) to the SPL_{peak} NMFS (2016) criteria, reductions in impact ranges are shown for every hearing group.

As with the previous section, relevant contour plots are presented in Appendix B.

Low-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (219 re 1 µPa)	Maximum	50 m	60 m	70 m	70 m
	Minimum	< 50 m	50 m	60 m	60 m
	Mean	< 50 m	60 m	70 m	70 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	110 m	130 m	140 m
	Mean	90 m	120 m	140 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2

Table 4-6 Predicted unweighted SPL_{peak} impact ranges for low-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

Low-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	1.4 km	2.7 km	3.5 km	4.1 km
	Minimum	690 m	1.6 km	2.1 km	2.5 km
	Mean	1.1 km	2.4 km	3.0 km	3.5 km
	Area	4.2 km^2	17 km^2	29 km^2	39 km^2
Sequence 1 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	30.3 km	34.7 km	36.9 km	38.5 km
	Minimum	14.7 km	16.3 km	17.1 km	17.6 km
	Mean	22.7 km	25.8 km	27.4 km	28.5 km
	Area	1700 km^2	2200 km^2	2500 km^2	2700 km^2
Sequence 2 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	3.0 km	5.0 km	6.1 km	6.9 km
	Minimum	1.1 km	2.2 km	2.8 km	3.3 km
	Mean	2.2 km	3.8 km	4.7 km	5.3 km
	Area	16 km^2	47 km^2	70 km^2	91 km^2
Sequence 2 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	40.2 km	45.3 km	47.9 km	49.8 km
	Minimum	16.0 km	17.7 km	18.6 km	19.2 km
	Mean	28.4 km	32.0 km	33.8 km	35.1 km
	Area	2700 km^2	3500 km^2	3900 km^2	4200 km^2
Sequence 3 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	3.6 km	5.9 km	7.2 km	8.1 km
	Minimum	1.1 km	2.3 km	2.9 km	3.3 km
	Mean	2.5 km	4.2 km	5.1 km	5.8 km
	Area	21 km^2	58 km^2	86 km^2	110 km^2
Sequence 3 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	45.0 km	50.8 km	53.8 km	55.9 km
	Minimum	16.1 km	17.9 km	18.7 km	19.3 km
	Mean	30.8 km	34.6 km	36.6 km	38.0 km
	Area	3300 km^2	4100 km^2	4600 km^2	5000 km^2

Table 4-7 Predicted low-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 3.25 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (230 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (224 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table 4-8 Predicted unweighted SPL_{peak} impact ranges for mid-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table 4-9 Predicted mid-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	390 m	490 m	590 m	660 m
	Minimum	370 m	470 m	580 m	640 m
	Mean	380 m	480 m	590 m	650 m
	Area	0.5 km^2	0.7 km^2	1.1 km^2	1.3 km^2
TTS unweighted SPL_{peak} (196 re 1 µPa)	Maximum	860 m	1.1 km	1.3 km	1.5 km
	Minimum	840 m	1.1 km	1.3 km	1.4 km
	Mean	850 m	1.1 km	1.3 km	1.4 km
	Area	2.3 km^2	3.6 km^2	5.3 km^2	6.4 km^2

Table 4-10 Predicted unweighted SPL_{peak} impact ranges for high-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (155 dB re 1 µPa^{2}s)	Maximum	1.9 km	< 100 m	< 100 m	< 100 m
	Minimum	1.5 km	< 100 m	< 100 m	< 100 m
	Mean	1.7 km	< 100 m	< 100 m	< 100 m
	Area	9.2 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (140 dB re 1 µPa^{2}s)	Maximum	23.1 km	9.7 km	10.7 km	11.5 km
	Minimum	14.4 km	7.6 km	8.3 km	8.7 km
	Mean	19.0 km	9.0 km	9.8 km	10.4 km
	Area	1100 km^2	250 km^2	300 km^2	340 km^2
Sequence 2 – PTS weighted SEL_{cum} (155 dB re 1 µPa^{2}s)	Maximum	3.5 km	< 100 m	< 100 m	< 100 m
	Minimum	2.6 km	< 100 m	< 100 m	< 100 m
	Mean	3.3 km	< 100 m	< 100 m	< 100 m
	Area	33 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (140 dB re 1 µPa^{2}s)	Maximum	33.4 km	15.6 km	17.1 km	18.3 km
	Minimum	17.1 km	9.9 km	10.6 km	11.1 km
	Mean	25.5 km	13.0 km	14.1 km	14.9 km
	Area	2100 km^2	530 km^2	630 km^2	700 km^2
Sequence 3 – PTS weighted SEL_{cum} (155 dB re 1 µPa^{2}s)	Maximum	4.7 km	< 100 m	< 100 m	< 100 m
	Minimum	2.9 km	< 100 m	< 100 m	< 100 m
	Mean	4.0 km	< 100 m	< 100 m	< 100 m
	Area	50 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (140 dB re 1 µPa^{2}s)	Maximum	40.8 km	20.0 km	21.8 km	23.2 km
	Minimum	17.9 km	10.4 km	11.2 km	11.7 km
	Mean	29.6 km	15.3 km	16.6 km	17.5 km
	Area	2900 km^2	750 km^2	890 km^2	990 km^2

Table 4-11 Predicted high-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

Many weighted SEL result ranges for high-frequency cetaceans are greater for the 2300 kJ pin pile installation than the higher energy 3000 to 4000 kJ monopile installation. This is discussed in section 4.2.1.

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (218 re 1 µPa)	Maximum	60 m	70 m	80 m	80 m
	Minimum	50 m	60 m	70 m	70 m
	Mean	60 m	70 m	80 m	80 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (212 re 1 µPa)	Maximum	110 m	130 m	160 m	170 m
	Minimum	100 m	120 m	150 m	160 m
	Mean	110 m	130 m	160 m	170 m
	Area	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2

Table 4-12 Predicted unweighted SPL_{peak} impact ranges for phocid pinnipeds using criteria from NMFS (2016) at Creyke Beck B, location ID6

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	5.3 km	7.9 km	8.8 km	9.5 km
	Minimum	4.3 km	6.3 km	6.9 km	7.4 km
	Mean	5.0 km	7.4 km	8.2 km	8.7 km
	Area	79 km^2	170 km^2	210 km^2	240 km^2
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	8.7 km	12.7 km	14.1 km	15.2 km
	Minimum	6.2 km	8.5 km	9.2 km	9.7 km
	Mean	7.7 km	10.9 km	11.9 km	12.7 km
	Area	190 km^2	370 km^2	450 km^2	510 km^2
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	11.3 km	16.5 km	18.3 km	19.5 km
	Minimum	6.6 km	9.0 km	9.7 km	10.2 km
	Mean	9.2 km	12.9 km	14.1 km	14.9 km
	Area	270 km^2	530 km^2	640 km^2	720 km^2

Table 4-13 Predicted phocid pinnipeds weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

4.2.1 Discussion

Some of the weighted SEL_{cum} results in the previous section appear to give paradoxical results, as a larger hammer hitting a monopile (3000 kJ, 3600 kJ, 4000 kJ) results in lower impact ranges than a smaller hammer hitting a pin pile (2300 kJ). This is most apparent for HF cetaceans and can be explained by examining the difference in sensitivity between the marine mammal hearing groups and the sound frequencies produced by different piles. The effect also exists with mid-frequency cetaceans, however due to the low impact ranges predicted (Table 4-9), this is not apparent in the results.

To illustrate this, Figure 4-1 and Figure 4-2 show the sound frequency spectra for monopiles and pin piles, weighted to account for the sensitivities of each of the NMFS (2016) weightings. These can be compared with the original unweighted frequency spectra in Figure 3-1 (shown faintly in Figure 4-1 and Figure 4-2). Table 4-14 summarises the equivalent source levels that account for the effect of the weightings, explaining the differences in results between pin piles and monopiles in the previous section.

The overall unweighted noise level is higher for the monopile due to the low frequency components of piling noise (i.e. most of the pile strike energy is in the lower frequencies). The NMFS (2016) filters remove most of the low frequency components of the noise, especially when considering MF and HF cetaceans. This leaves the higher frequency noise, which, in the case of the pin piles, is greater than that for monopiles.

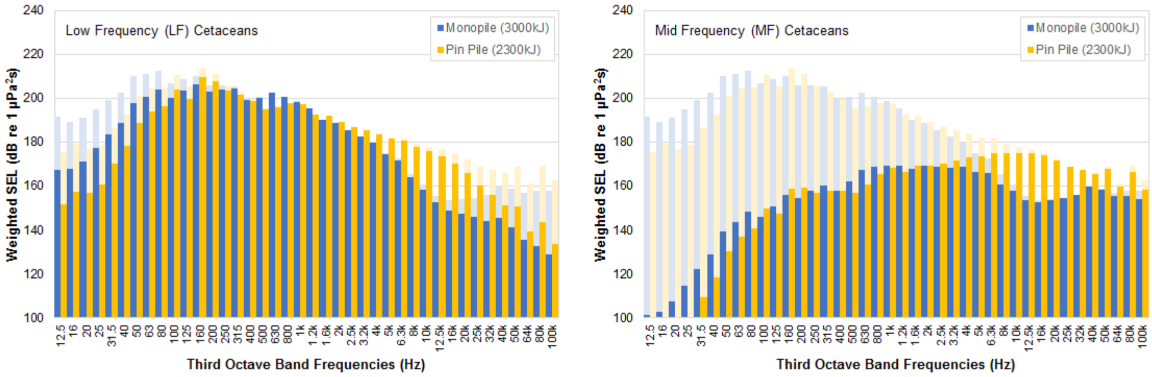

Figure 4-1 Filtered noise inputs for monopiles and pin piles using the LF and MF cetacean weightings from NMFS (2016). The lighter coloured bars show the unweighted third-octave levels

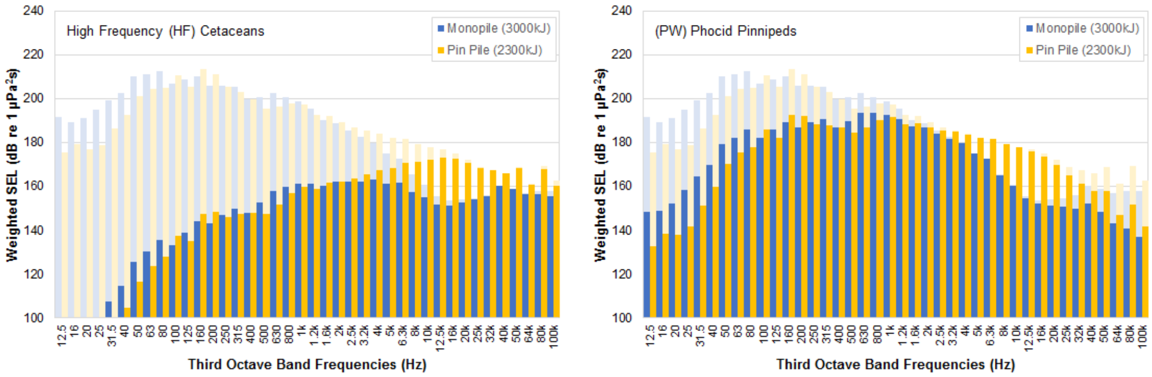

Figure 4-2 Filtered noise inputs for monopiles and pin piles using the HF cetacean and phocid pinniped weightings from NMFS (2016). The pale coloured bars show the unweighted third-octave levels

	Monopile source level (3000kJ)	**Pin pile source level (2300kJ)**
Unweighted SEL_{ss}	219.2 dB re 1 µPa²s @ 1 m	216.5 dB re 1 µPa²s @ 1 m
LF Cetaceans (NMFS) SEL_{ss}	213.9 dB re 1 µPa²s @ 1 m	212.5 dB re 1 µPa²s @ 1 m
MF Cetaceans (NMFS) SEL_{ss}	179.2 dB re 1 µPa²s @ 1 m	183.1 dB re 1 µPa²s @ 1 m
HF Cetaceans (NMFS) SEL_{ss}	173.1 dB re 1 µPa²s @ 1 m	180.0 dB re 1 µPa²s @ 1 m
Phocid Pinnipeds (NMFS) SEL_{ss}	201.7 dB re 1 µPa²s @ 1 m	199.3 dB re 1 µPa²s @ 1 m

Table 4-14 Summary of the NMFS (2016) weighted source levels used for modelling pin piles and monopiles

4.3 Popper *et al*. (2014) impact ranges

Table 4-15 to Table 4-18 present the impact ranges for fish for the Popper *et al*. (2014) criteria, covering unweighted SPL_{peak} and SEL_{cum} metrics for all three piling sequences (Table 3-3). All fleeing calculations have assumed a receptor fleeing at a constant rate of 1.5 ms^{-1}. The results for the 2300 kJ hammer assume installation of pin piles, whereas the other blow energies assume installation of a monopile. Ranges smaller than 100 m have not been presented for the SEL_{cum} results and relevant contour plots are presented in Appendix B.

Fish - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Injury (fish: no swim bladder) unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	110 m	130 m	140 m
	Mean	90 m	120 m	140 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2
Injury (fish: with swim bladder) unweighted SPL_{peak} (207 re 1 µPa)	Maximum	200 m	250 m	300 m	340 m
	Minimum	190 m	240 m	290 m	330 m
	Mean	200 m	250 m	300 m	340 m
	Area	0.1 km^2	0.2 km^2	0.3 km^2	0.4 km^2

Table 4-15 Predicted unweighted SPL_{peak} impact ranges for fish using criteria from Popper et al. (2014) at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 1)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	6.5 km	9.8 km	10.8 km	11.6 km
	Minimum	5.1 km	7.5 km	8.2 km	8.7 km
	Mean	6.1 km	9.0 km	9.8 km	10.5 km
	Area	110 km^2	250 km^2	300 km^2	340 km^2

Table 4-16 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 1 at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 2)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	10.5 km	15.7 km	17.3 km	18.4 km
	Minimum	7.2 km	9.9 km	10.6 km	11.1 km
	Mean	9.2 km	13.0 km	14.1 km	14.9 km
	Area	260 km^2	540 km^2	630 km^2	710 km^2

Table 4-17 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 2 at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 3)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	13.7 km	20.2 km	22.0 km	23.4 km
	Minimum	7.7 km	10.4 km	11.1 km	11.7 km
	Mean	10.9 km	15.4 km	16.6 km	17.6 km
	Area	380 km^2	760 km^2	900 km^2	1000 km^2

Table 4-18 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 3 at Creyke Beck B, location ID6

5 Summary and conclusions

Underwater noise modelling was carried out by NPL in 2012 to assess the effects of impact piling noise on fish and marine mammals from the construction of the Creyke Beck offshore wind farms, in the Dogger Bank development area. In the time since the original modelling was completed, new noise thresholds and criteria have been developed by NMFS (2016) for marine mammals and Popper *et al*. (2014) for fish. To obtain impact ranges for these new criteria, additional modelling has been carried out by Subacoustech Environmental.

The modelling undertaken by NPL utilised an energy flux solution, and the model used is not openly available. Subacoustech have used a different but comparable method using the semi-empirical INSPIRE model. This additional modelling has sought to be compatible with and provide equivalent results to the original modelling. A conservative fit to the data was used so that levels predicted along the worst-case transect match with the highest levels reported originally, especially at the greatest distances. Overall, there was a good level of correlation between the two modelling result datasets.

In addition to modelling to the new criteria, the effects of two piling hammer blow energies greater than that considered originally have been assessed (3600 kJ and 4000 kJ).

The modelling results using the new metrics showed that, using the NMFS (2016) SPL_{peak} criteria, ranges are largely within a few hundred metres, with only the TTS ranges for high-frequency cetaceans extending over 1 km. When considering the SEL_{cum} values for fleeing animals, the PTS and TTS ranges are much larger with TTS ranges for low-frequency cetaceans of 38.5 to 55.9 km depending on the piling sequence. Also, predicted impact ranges for ramp-up sequence 3 (with 12,600 pile strikes) resulted in larger ranges than those predicted for ramp-up sequence 1 (with 2,000 pile strikes).

When considering the Popper *et al*. (2014) criteria, the ranges calculated are no greater than 340 m, with many, especially the SEL_{cum} criteria, being less than 100 m. The exceptions were ranges modelled for TTS, where the largest values predicted were when considering the largest blow energy, with impact ranges of between 11.6 and 23.4 km depending on the piling ramp up scenario.

All modelled scenarios using the increased maximum blow energies for monopiles result in larger impact ranges than with the largest monopile blow energy used in the original report.

References

1. Blix A S and Folkow L P (1995). *Daily energy expenditure in free living minke whales.* Acta Physiol. Scand., 153:61-66.
2. Carlson T, Hastings M, Popper A N (2007). *Memorandum – Update on recommendations for revised interim sound exposure criteria for fish during pile driving activities.* Sent to California Dept. of Trans. And Washingron Dept. of Trans.
3. Halvorsen M B, Casper B M, Woodley C M, Carlson T J, Popper A N (2011). *Predicting and mitigating hydroacoustic impacts on fish from pile installations.* NCHRP Research Results Digest 363, Project 25-28, National cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences, Washington D.C.
4. Hastings M C, Popper A N (2005). *Effects of sound on fish.* Report to the California Department of Transport, under Contract No. 43A01392005, January 2005.
5. Hirata K (1999). *Swimming speeds of some common fish*. National Maritime Research Institute (Japan). Data sourced from Iwai T, Hisada M (1998). *Fishes – Illustrated Book of Gakken* (in Japanese). Accessed on 8th March 2017 at http://www.nmri.go.jp/eng/khirata/fish/general/speed/speede/htm
6. Lucke K, Lepper P A, Blanchet M (2009). *Temporary shift in masked hearing thresholds in a harbour porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli*. J. Acoust. Soc. Am. 125(6), 4060-4070.
7. McCauley R D, Fewtrell K, Duncan A J, Jenner C, Jenner M-N, Penrose J D, Prince R I T, Adhitya A, Murdoch J, McCabe K (2000). *Marine seismic surveys – A study of environmental implications.* Appea Journal, pp 692-708.
8. National Marine Fisheries Service (NMFS) (2016). *Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts*. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.
9. Otani S, Naito T, Kato A, Kawamura A (2000). *Diving behaviour and swimming speed of a free-ranging harbour porpoise (Phocoena phocoena).* Marine mammal science, Volume 16, Issue 4, pp 811-814, October 2000.
10. Pearson W H, Skalski J R, Malme C I (1992). *Effects of sounds from a geophysical survey device on behaviour of captive rockfish (Sebastes spp.)*. Can. J. Fish. Aquat. Sci., 49, pp. 1343-1355.
11. Popper A N, Carlson T J, Hawkins A D, Southall B D, Gentry R L (2006). *Interim criteria for injury in fish exposed to a pile driving operation.* A white paper, available from http://www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6-750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf 2005.
12. Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles*. Springer Briefs in Oceanography, DOI 10. 1007/978-3-319-06659-2.
13. Robinson S P, Lepper P A, Hazelwood R A (2014). *Good practice guide for underwater noise measurement*. National Measurement Office, Marine Scotland, The Crown Estate. NPL Good Practice Guide No. 133, ISSN: 1368-6550.

14. Southall B L, Bowles A E, Ellison W T, Finneran J J, Gentry R L, Green Jr. C R, Kastak D, Ketten D R, Miller J H, Nachtigall P E, Richardson W J, Thomas J A, Tyack P L (2007). *Marine mammal noise exposure criteria: Initial scientific recommendations.* Aquatic Mammals, 33 (4), pp. 411-509.

15. Theobald P, Pangerc T, Wang L, Lepper P (2012). *Underwater noise modelling to support the Dogger Bank Wind Farm Environmental Impact Assessment for Creyke Beck A and Creyke Beck B.* NPL Report AIR (RES) 059, 18th October 2012. In 'Dogger Bank Creyke Beck Environmental Statement Chapter 5 Appendix A: Underwater Noise Technical Report' Appendix Reference 6.5.1, August 2013.

16. Weston D (1976). *Propagation in water with uniform sound velocity by variable-depth lossy bottom.* Journal of Sound and Vibration, 49, pp. 473-483.

Appendix A Complete modelling results

This appendix presents all the results from modelling at the four locations at Creyke Beck A and B.

Predicted ranges smaller than 50 m, and area less than 0.1 km^2 for single strike criteria and 100 m for cumulative criteria, have not been presented as the modelling processes are unable to specify that level of accuracy with confidence due to acoustic effects near the source and other noise processes at close ranges. The results that are large enough to be shown clearly are also presented in Appendix B as contour plots.

A.1 Creyke Beck A, location ID6

Previously considered criteria

Harbour porpoise - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	420 m	480 m	600 m	730 m	800 m
	Min	120 m	410 m	460 m	580 m	710 m	780 m
	Mean	130 m	420 m	470 m	590 m	720 m	790 m
	Area	< 0.1 km^2	0.5 km^2	0.7 km^2	1.1 km^2	1.6 km^2	2.0 km^2
Instantaneous injury/PTS (SEL_{ss} 179 dB re 1 µPa^{2}s)	Max	150 m	430 m	460 m	690 m	770 m	830 m
	Min	140 m	410 m	450 m	680 m	760 m	810 m
	Mean	150 m	420 m	460 m	690 m	770 m	820 m
	Area	0.1 km^2	0.6 km^2	0.7 km^2	1.5 km^2	1.8 km^2	2.1 km^2
TTS/fleeing response (SPL_{peak} 194 dB re 1 µPa)	Max	270 m	920 m	1.0 km	1.3 km	1.6 km	1.7 km
	Min	260 m	900 m	1.0 km	1.3 km	1.5 km	1.7 km
	Mean	270 m	910 m	1.0 km	1.3 km	1.5 km	1.7 km
	Area	0.2 km^2	2.6 km^2	3.3 km^2	5.1 km^2	7.3 km^2	8.8 km^2
TTS/fleeing response (SEL_{ss} 164 dB re 1 µPa^{2}s)	Max	1.4 km	3.6 km	3.8 km	5.2 km	5.6 km	5.9 km
	Min	1.3 km	3.4 km	3.6 km	4.9 km	5.3 km	5.6 km
	Mean	1.4 km	3.5 km	3.7 km	5.1 km	5.5 km	5.8 km
	Area	5.7 km^2	38 km^2	44 km^2	80 km^2	94 km^2	100 km^2
Possible avoidance of area (SPL_{peak} 168 re 1 µPa^{2}s)	Max	5.8 km	12.1 km	12.8 km	14.3 km	15.7 km	16.4 km
	Min	5.5 km	10.4 km	10.9 km	11.9 km	12.8 km	13.3 km
	Mean	5.7 km	11.3 km	11.9 km	13.3 km	14.4 km	15.1 km
	Area	100 km^2	400 km^2	450 km^2	550 km^2	650 km^2	710 km^2
Possible avoidance of area (SEL_{ss} 145 re 1 µPa^{2}s)	Max	11.7 km	20.3 km	21.1 km	25.2 km	26.3 km	27.1 km
	Min	10.2 km	15.5 km	16.0 km	18.4 km	19.1 km	19.5 km
	Mean	11.0 km	18.1 km	18.7 km	21.9 km	23.8 km	23.5 km
	Area	380 km^2	1000 km^2	1100 km^2	1500 km^2	1600 km^2	1700 km^2

Table A 1 Predicted harbour porpoise impact ranges using criteria derived from Lucke et al. (2009) at Creyke Beck A, location ID6

Mid-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa²s)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa²s)	Max	< 50 m	90 m	110 m	140 m	150 m	160 m
	Min	< 50 m	80 m	100 m	130 m	140 m	150 m
	Mean	< 50 m	90 m	110 m	140 m	140 m	160 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²
Likely avoidance of area (SEL_{ss} 170 re 1 µPa²s)	Max	560 m	1.6 km	1.8 km	2.5 km	2.8 km	3.0 km
	Min	550 m	1.6 km	1.7 km	2.4 km	2.7 km	2.8 km
	Mean	560 m	1.6 km	1.7 km	2.5 km	2.7 km	2.9 km
	Area	1.0 km²	8.0 km²	9.2 km²	19 km²	23 km²	26 km²
Possible avoidance of area (SEL_{ss} 160 re 1 µPa²s)	Max	2.4 km	5.6 km	5.9 km	7.8 km	8.3 km	8.7 km
	Min	2.3 km	5.3 km	5.6 km	7.3 km	7.8 km	8.1 km
	Mean	2.4 km	5.5 km	5.8 km	7.5 km	8.0 km	8.4 km
	Area	17 km²	95 km²	110 km²	180 km²	200 km²	220 km²

Table A 2 Predicted mid-frequeny cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck A, location ID6

Low-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa²s)	Max	< 50 m	< 50 m	< 50 m	50 m	50 m	50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa²s)	Max	80 m	230 m	250 m	380 m	420 m	450 m
	Min	70 m	220 m	240 m	370 m	410 m	440 m
	Mean	80 m	230 m	250 m	380 m	420 m	450 m
	Area	< 0.1 km²	0.2 km²	0.2 km²	0.4 km²	0.5 km²	0.6 km²
Likely avoidance of area (SEL_{ss} 152 re 1 µPa²s)	Max	6.1 km	11.9 km	12.4 km	15.3 km	16.1 km	16.6 km
	Min	5.8 km	10.3 km	10.7 km	12.6 km	13.1 km	13.5 km
	Mean	6.0 km	11.2 km	11.6 km	14.1 km	14.8 km	15.3 km
	Area	110 km²	390 km²	420 km²	620 km²	690 km²	730 km²
Possible avoidance of area (SEL_{ss} 142 re 1 µPa²s)	Max	14.8 km	24.9 km	25.7 km	30.1 km	31.1 km	32.0 km
	Min	12.3 km	18.2 km	18.7 km	21.1 km	21.7 km	22.1 km
	Mean	13.7 km	21.6 km	22.3 km	25.9 km	26.9 km	27.6 km
	Area	590 km²	1500 km²	1600 km²	2100 km²	2300 km²	2400 km²

Table A 3 Predicted low-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck A, location ID6

Pinnipeds (in water) - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 218 dB re 1 µPa)	Max	< 50 m	50 m	60 m	70 m	80 m	80 m
	Min	< 50 m	< 50 m	50 m	60 m	70 m	70 m
	Mean	< 50 m	< 50 m	60 m	70 m	80 m	80 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa^{2}s)	Max	< 50 m	90 m	120 m	140 m	160 m	170 m
	Min	< 50 m	80 m	110 m	130 m	150 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	160 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (SPL_{peak} 212 dB re 1 µPa)	Max	70 m	90 m	100 m	130 m	150 m	170 m
	Min	60 m	80 m	90 m	120 m	140 m	160 m
	Mean	70 m	90 m	100 m	130 m	150 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa^{2}s)	Max	280 m	840 m	1.1 km	1.4 km	1.5 km	1.6 km
	Min	270 m	820 m	1.1 km	1.3 km	1.5 km	1.6 km
	Mean	280 m	830 m	1.1 km	1.3 km	1.5 km	1.6 km
	Area	0.2 km^2	2.2 km^2	3.8 km^2	5.6 km^2	6.8 km^2	7.8 km^2

Table A 4 Predicted pinniped (in water) impact ranges using criteria from Southall et al. (2007) at Creyke Beck A, location ID6

Fish - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 206 dB re 1 µPa)	Max	< 50 m	190 m	220 m	270 m	330 m	370 m
	Min	< 50 m	180 m	210 m	260 m	320 m	350 m
	Mean	< 50 m	190 m	220 m	270 m	330 m	360 m
	Area	< 0.1 km^2	0.1 km^2	0.1 km^2	0.2 km^2	0.3 km^2	0.4 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 1	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 2	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 3	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Possible moderate to strong avoidance (upper bound SPL_{peak} 173 dB re 1 µPa)	Max	3.7 km	8.4 km	9.0 km	10.2 km	11.4 km	12.0 km
	Min	3.5 km	7.8 km	8.3 km	9.2 km	9.9 km	10.3 km
	Mean	3.6 km	8.1 km	8.6 km	9.7 km	10.7 km	11.2 km
	Area	39 km^2	200 km^2	230 km^2	290 km^2	360 km^2	390 km^2
Possible moderate to strong avoidance (lower bound SPL_{peak} 168 dB re 1 µPa)	Max	5.9 km	12.1 km	12.8 km	14.3 km	15.7 km	16.4 km
	Min	5.5 km	10.4 km	10.9 km	11.9 km	12.8 km	13.3 km
	Mean	5.7 km	11.3 km	11.9 km	13.3 km	14.4 km	15.1 km
	Area	100 km^2	400 km^2	450 km^2	550 km^2	650 km^2	710 km^2
Startle response or C-turn reaction (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	420 m	480 m	600 m	730 m	800 m
	Min	120 m	410 m	460 m	580 m	710 m	780 m
	Mean	130 m	420 m	470 m	590 m	720 m	790 m
	Area	< 0.1 km^2	0.5 km^2	0.7 km^2	1.1 km^2	1.6 km^2	2.0 km^2

Table A 5 Predicted fish impact ranges using criteria from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al (2011), McCauley et al. (2000) and Pearson et al. (1992) at Creyke Beck A, location ID6

Cells marked with a hyphen are for single strike hammer energies and as such cumulative SELs cannot be calculated for them.

NMFS (2016) impact ranges

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (219 re 1 µPa)	Maximum	50 m	60 m	70 m	70 m
	Minimum	< 50 m	50 m	60 m	60 m
	Mean	< 50 m	60 m	70 m	70 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	110 m	130 m	150 m
	Minimum	80 m	100 m	120 m	140 m
	Mean	90 m	110 m	130 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2

Table A 6 Predicted unweighted SPL_{peak} impact ranges for low-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID6

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	600 m	1.1 km	1.6 km	1.9 km
	Minimum	400 m	800 m	1.1 km	1.4 km
	Mean	500 m	1.0 km	1.3 km	1.6 km
	Area	0.7 km^2	2.9 km^2	5.6 km^2	8.4 km^2
Sequence 1 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	16.8 km	19.0 km	20.1 km	20.9 km
	Minimum	10.2 km	11.4 km	12.0 km	12.5 km
	Mean	13.5 km	15.3 km	16.3 km	16.9 km
	Area	580 km^2	750 km^2	840 km^2	910 km^2
Sequence 2 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	800 m	1.7 km	2.2 km	2.7 km
	Minimum	500 m	1.0 km	1.3 km	1.6 km
	Mean	600 m	1.3 km	1.8 km	2.2 km
	Area	1.4 km^2	5.8 km^2	10 km^2	15 km^2
Sequence 2 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	20.1 km	22.8 km	24.3 km	25.4 km
	Minimum	10.9 km	12.2 km	12.8 km	13.3 km
	Mean	15.7 km	17.7 km	18.8 km	19.6 km
	Area	790 km^2	1000 km^2	1100 km^2	1200 km^2
Sequence 3 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	900 m	1.8 km	2.4 km	2.8 km
	Minimum	500 m	1.0 km	1.3 km	1.6 km
	Mean	700 m	1.4 km	1.9 km	2.2 km
	Area	1.5 km^2	6.2 km^2	11 km^2	16 km^2
Sequence 3 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	21.4 km	24.4 km	26.1 km	27.4 km
	Minimum	11.0 km	12.3 km	12.9 km	13.3 km
	Mean	16.3 km	18.5 km	19.6 km	20.5 km
	Area	850 km^2	1100 km^2	1200 km^2	1400 km^2

Table A 7 Predicted low-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 3.25 ms^{-1} for the three piling sequences at Creyke Beck A, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (230 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (224 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table A 8 Predicted unweighted SPL_{peak} impact ranges for mid-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²

Table A 9 Predicted mid-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck A, location ID6

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	370 m	460 m	560 m	620 m
	Minimum	360 m	450 m	540 m	600 m
	Mean	370 m	460 m	560 m	610 m
	Area	0.4 km²	0.7 km²	1.0 km²	1.2 km²
TTS unweighted SPL_{peak} (196 re 1 µPa)	Maximum	810 m	1.0 km	1.2 km	1.3 km
	Minimum	780 m	980 m	1.2 km	1.3 km
	Mean	800 m	990 m	1.2 km	1.3 km
	Area	2.0 km²	3.1 km²	4.5 km²	5.4 km²

Table A 10 Predicted unweighted SPL_{peak} impact ranges for high-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID6

High-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	1.2 km	< 100 m	< 100 m	< 100 m
	Minimum	900 m	< 100 m	< 100 m	< 100 m
	Mean	1.1 km	< 100 m	< 100 m	< 100 m
	Area	3.8 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	14.6 km	6.8 km	7.5 km	8.0 km
	Minimum	10.7 km	5.8 km	6.2 km	6.5 km
	Mean	12.8 km	6.3 km	6.9 km	7.3 km
	Area	510 km²	130 km²	150 km²	170 km²
Sequence 2 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	2.1 km	< 100 m	< 100 m	< 100 m
	Minimum	1.7 km	< 100 m	< 100 m	< 100 m
	Mean	1.9 km	< 100 m	< 100 m	< 100 m
	Area	12 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	19.2 km	9.3 km	10.2 km	10.8 km
	Minimum	12.4 km	6.9 km	7.5 km	7.8 km
	Mean	15.9 km	8.3 km	9.0 km	9.5 km
	Area	800 km²	220 km²	250 km²	280 km²
Sequence 3 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	2.4 km	< 100 m	< 100 m	< 100 m
	Minimum	1.9 km	< 100 m	< 100 m	< 100 m
	Mean	2.1 km	< 100 m	< 100 m	< 100 m
	Area	14 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	21.5 km	10.6 km	11.5 km	12.3 km
	Minimum	12.9 km²	7.2 km	7.7 km	8.1 km
	Mean	17.2 km²	8.9 km	9.7 km	10.2 km
	Area	940 km²	250 km²	300 km²	330 km²

Table A 11 Predicted high-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms⁻¹ for the three piling sequences at Creyke Beck A, location ID6

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (218 re 1 µPa)	Maximum	60 m	70 m	80 m	80 m
	Minimum	50 m	60 m	70 m	70 m
	Mean	60 m	70 m	80 m	80 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS unweighted SPL_{peak} (212 re 1 µPa)	Maximum	100 m	130 m	150 m	170 m
	Minimum	90 m	120 m	140 m	160 m
	Mean	100 m	130 m	150 m	170 m
	Area	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²

Table A 12 Predicted unweighted SPL_{peak} impact ranges for phocid pinnipeds using criteria from NMFS (2016) at Creyke Beck A, location ID6

Phocid pinnipeds - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	3.7 km	5.6 km	6.2 km	6.7 km
	Minimum	3.3 km	4.9 km	5.3 km	5.6 km
	Mean	3.6 km	5.2 km	5.8 km	6.2 km
	Area	40 km^2	86 km^2	100 km^2	120 km^2
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	5.5 km	7.8 km	8.5 km	9.1 km
	Minimum	4.4 km	6.0 km	6.5 km	6.8 km
	Mean	5.0 km	7.0 km	7.6 km	8.1 km
	Area	77 km^2	150 km^2	180 km^2	210 km^2
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa^2s)	Maximum	6.0 km	8.7 km	9.6 km	10.3 km
	Minimum	4.6 km	6.2 km	6.7 km	7.0 km
	Mean	5.4 km	7.5 km	8.2 km	8.7 km
	Area	91 km^2	180 km^2	210 km^2	240 km^2

Table A 13 Predicted phocid pinnipeds weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck A, location ID6

Popper et al (2014) impact ranges

Fish - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Injury (fish: no swim bladder) unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	110 m	130 m	150 m
	Minimum	80 m	100 m	120 m	140 m
	Mean	90 m	110 m	130 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2
Injury (fish: with swim bladder) unweighted SPL_{peak} (207 re 1 µPa)	Maximum	190 m	240 m	290 m	320 m
	Minimum	180 m	230 m	280 m	310 m
	Mean	190 m	240 m	290 m	320 m
	Area	0.1 km^2	0.2 km^2	0.3 km^2	0.3 km^2

Table A 14 Predicted unweighted SPL_{peak} impact ranges for fish using criteria from Popper et al. (2014) at Creyke Beck A, location ID6

Fish - impact criterion **(Sequence 1)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS (all fish) SEL_{cum} (186 re 1 µPa²s)	Maximum	4.6 km	6.9 km	7.6 km	8.1 km
	Minimum	4.1 km	5.8 km	6.3 km	6.6 km
	Mean	4.4 km	6.4 km	7.0 km	7.4 km
	Area	60 km²	130 km²	150 km²	170 km²

Table A 15 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 1 at Creyke Beck A, location ID6

Fish - impact criterion **(Sequence 2)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS (all fish) SEL_{cum} (186 re 1 µPa²s)	Maximum	6.6 km	9.4 km	10.3 km	11.0 km
	Minimum	5.2 km	7.0 km	7.5 km	7.9 km
	Mean	5.9 km	8.4 km	9.1 km	9.6 km
	Area	110 km²	220 km²	260 km²	290 km²

Table A 16 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 2 at Creyke Beck A, location ID6

Fish - impact criterion **(Sequence 3)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^{2}s)	Maximum	7.3 km	10.7 km	11.7 km	12.4 km
	Minimum	5.3 km	7.2 km	7.8 km	8.1 km
	Mean	6.4 km	9.0 km	9.8 km	10.3 km
	Area	130 km^2	260 km^2	300 km^2	340 km^2

Table A 17 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 3 at Creyke Beck A, location ID6

A.2 Creyke Beck A, location ID11

Previously considered criteria

Harbour porpoise - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	440 m	500 m	630 m	760 m	840 m
	Min	120 m	430 m	490 m	620 m	750 m	830 m
	Mean	130 m	440 m	500 m	630 m	760 m	840 m
	Area	0.1 km^2	0.6 km^2	0.8 km^2	1.2 km^2	1.8 km^2	2.2 km^2
Instantaneous injury/PTS (SEL_{ss} 179 dB re 1 µPa^{2}s)	Max	150 m	430 m	470 m	710 m	790 m	850 m
	Min	140 m	420 m	460 m	700 m	780 m	840 m
	Mean	150 m	430 m	470 m	710 m	790 m	850 m
	Area	0.1 km^2	0.6 km^2	0.7 km^2	1.6 km^2	1.9 km^2	2.2 km^2
TTS/fleeing response (SPL_{peak} 194 dB re 1 µPa)	Max	280 m	970 m	1.1 km	1.4 km	1.7 km	1.8 km
	Min	270 m	960 m	1.1 km	1.4 km	1.6 km	1.8 km
	Mean	280 m	970 m	1.1 km	1.4 km	1.6 km	1.8 km
	Area	0.2 km^2	2.9 km^2	3.7 km^2	5.7 km^2	8.4 km^2	10 km^2
TTS/fleeing response (SEL_{ss} 164 dB re 1 µPa^{2}s)	Max	1.4 km	3.8 km	4.0 km	5.6 km	6.1 km	6.4 km
	Min	1.4 km	3.7 km	3.9 km	5.3 km	5.7 km	6.0 km
	Mean	1.4 km	3.7 km	4.0 km	5.5 km	5.9 km	6.2 km
	Area	6.2 km^2	43 km^2	49 km^2	93 km^2	110 km^2	120 km^2
Possible avoidance of area (SPL_{peak} 168 re 1 µPa^{2}s)	Max	6.5 km	14.2 km	15.1 km	16.7 km	18.1 km	18.8 km
	Min	6.0 km	11.8 km	12.5 km	13.7 km	14.8 km	15.3 km
	Mean	6.3 km	12.7 km	13.4 km	14.8 km	16.1 km	16.8 km
	Area	120 km^2	500 km^2	560 km^2	690 km^2	810 km^2	880 km^2
Possible avoidance of area (SEL_{ss} 145 re 1 µPa^{2}s)	Max	13.5 km	21.9 km	22.6 km	26.0 km	26.9 km	27.5 km
	Min	11.3 km	17.7 km	18.1 km	20.3 km	20.9 km	21.3 km
	Mean	12.2 km	19.5 km	20.1 km	23.3 km	24.1 km	24.7 km
	Area	460 km^2	1200 km^2	1300 km^2	1700 km^2	1800 km^2	1900 km^2

Table A 18 Predicted harbour porpoise impact ranges using criteria derived from Lucke et al. (2009) at Creyke Beck A, location ID11

Mid-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Max	< 50 m	90 m	120 m	140 m	150 m	170 m
	Min	< 50 m	80 m	110 m	130 m	140 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	150 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Likely avoidance of area (SEL_{ss} 170 re 1 µPa^{2}s)	Max	570 m	1.7 km	1.8 km	2.6 km	2.9 km	3.1 km
	Min	560 m	1.7 km	1.8 km	2.6 km	2.8 km	3.0 km
	Mean	570 m	1.7 km	1.8 km	2.6 km	2.9 km	3.1 km
	Area	1.0 km^2	8.6 km^2	10 km^2	21 km^2	26 km^2	29 km^2
Possible avoidance of area (SEL_{ss} 160 re 1 µPa^{2}s)	Max	2.5 km	6.1 km	6.5 km	8.7 km	9.3 km	9.8 km
	Min	2.5 km	5.7 km	6.0 km	7.7 km	8.2 km	8.5 km
	Mean	2.5 km	5.9 km	6.3 km	8.2 km	8.8 km	9.2 km
	Area	19 km^2	110 km^2	120 km^2	210 km^2	240 km^2	260 km^2

Table A 19 Predicted mid-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck A, location ID11

Low-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Max	< 50 m	< 50 m	< 50 m	50 m	50 m	50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Max	80 m	240 m	260 m	390 m	430 m	460 m
	Min	70 m	230 m	250 m	380 m	420 m	450 m
	Mean	80 m	240 m	260 m	390 m	430 m	460 m
	Area	< 0.1 km^2	0.2 km^2	0.2 km^2	0.5 km^2	0.6 km^2	0.7 km^2
Likely avoidance of area (SEL_{ss} 152 re 1 µPa^{2}s)	Max	6.7 km	13.7 km	14.3 km	17.4 km	18.2 km	18.7 km
	Min	6.2 km	11.5 km	12.0 km	14.3 km	14.9 km	15.4 km
	Mean	6.5 km	12.3 km	12.8 km	15.5 km	16.2 km	16.7 km
	Area	130 km^2	470 km^2	510 km^2	750 km^2	820 km^2	880 km^2
Possible avoidance of area (SEL_{ss} 142 re 1 µPa^{2}s)	Max	16.9 km	25.7 km	26.4 km	29.9 km	30.9 km	31.6 km
	Min	14.0 km	20.1 km	20.6 km	22.9 km	23.5 km	23.9 km
	Mean	15.1 km	23.0 km	23.6 km	27.0 km	27.9 km	28.5 km
	Area	710 km^2	1700 km^2	1700 km^2	2300 km^2	2400 km^2	2500 km^2

Table A 20 Predicted low-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck A, location ID11

Pinnipeds (in water) - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 218 dB re 1 µPa)	Max	50 m	50 m	60 m	70 m	80 m	80 m
	Min	< 50 m	< 50 m	50 m	60 m	70 m	70 m
	Mean	< 50 m	< 50 m	60 m	70 m	80 m	80 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa²s)	Max	< 50 m	90 m	120 m	140 m	160 m	170 m
	Min	< 50 m	80 m	110 m	130 m	150 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	160 m	170 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS/fleeing response (SPL_{peak} 212 dB re 1 µPa)	Max	70 m	90 m	110 m	130 m	160 m	170 m
	Min	60 m	80 m	100 m	120 m	150 m	160 m
	Mean	70 m	90 m	110 m	130 m	160 m	170 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa²s)	Max	290 m	860 m	1.2 km	1.4 km	1.5 km	1.7 km
	Min	280 m	850 m	1.1 km	1.4 km	1.5 km	1.6 km
	Mean	290 m	860 m	1.1 km	1.4 km	1.5 km	1.6 km
	Area	0.3 km²	2.3 km²	4.1 km²	6.0 km²	7.4 km²	8.5 km²

Table A 21 Predicted pinniped (in water) impact ranges using criteria from Southall et al. (2007) at Creyke Beck A, location ID11

Fish - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 206 dB re 1 µPa)	Max	100 m	200 m	230 m	280 m	340 m	380 m
	Min	90 m	190 m	220 m	270 m	330 m	370 m
	Mean	100 m	200 m	230 m	280 m	340 m	380 m
	Area	< 0.1 km²	0.1 km²	0.2 km²	0.2 km²	0.4 km²	0.4 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 1	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 2	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 3	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Possible moderate to strong avoidance (upper bound SPL_{peak} 173 dB re 1 µPa)	Max	4.0 km	9.7 km	10.4 km	12.0 km	13.4 km	14.1 km
	Min	3.8 km	8.3 km	8.9 km	10.0 km	11.1 km	11.7 km
	Mean	3.9 km	9.0 km	9.6 km	10.9 km	12.0 km	12.6 km
	Area	47 km²	250 km²	290 km²	370 km²	450 km²	500 km²
Possible moderate to strong avoidance (lower bound SPL_{peak} 168 dB re 1 µPa)	Max	6.5 km	14.2 km	15.1 km	16.7 km	18.1 km	18.8 km
	Min	6.0 km	11.8 km	12.5 km	13.7 km	14.8 km	15.3 km
	Mean	6.3 km	12.7 km	13.4 km	14.8 km	16.1 km	16.8 km
	Area	120 km²	500 km²	560 km²	690 km²	810 km²	880 km²
Startle response or C-turn reaction (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	440 m	500 m	630 m	760 m	840 m
	Min	120 m	430 m	490 m	620 m	750 m	830 m
	Mean	130 m	440 m	500 m	630 m	760 m	840 m
	Area	0.1 km²	0.6 km²	0.8 km²	1.2 km²	1.8 km²	2.2 km²

Table A 22 Predicted fish impact ranges using criteria from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al (2011), McCauley et al. (2000) and Pearson et al. (1992) at Creyke Beck A, location ID11

Cells marked with a hyphen are for single strike hammer energies and as such cumulative SELs cannot be calculated for them.

NMFS (2016) impact ranges

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (219 re 1 µPa)	Maximum	50 m	60 m	70 m	70 m
	Minimum	< 50 m	50 m	60 m	60 m
	Mean	< 50 m	60 m	70 m	70 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	110 m	140 m	150 m
	Minimum	80 m	100 m	130 m	140 m
	Mean	90 m	110 m	140 m	150 m
	Area	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²

Table A 23 Predicted unweighted SPL_{peak} impact ranges for low-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID11

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	1.0 km	2.0 km	2.7 km	3.1 km
	Minimum	600 m	1.1 km	1.5 km	1.8 km
	Mean	740 m	1.5 km	2.0 km	2.3 km
	Area	1.7 km²	7.0 km²	12 km²	17 km²
Sequence 1 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	17.6 km	19.4 km	20.3 km	20.9 km
	Minimum	12.1 km	13.3 km	13.9 km	14.3 km
	Mean	14.9 km	16.5 km	17.4 km	18.0 km
	Area	690 km²	860 km²	950 km²	1000 km²
Sequence 2 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	1.7 km	3.0 km	3.7 km	4.3 km
	Minimum	800 m	1.5 km	1.9 km	2.3 km
	Mean	1.1 km	2.1 km	2.6 km	3.1 km
	Area	4.0 km²	14 km²	22 km²	30 km²
Sequence 2 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	19.3 km	21.5 km	22.8 km	23.7 km
	Minimum	12.8 km	14. km	14.6 km	15.1 km
	Mean	16.6 km	18.4 km	19.3 km	20.0 km
	Area	860 km²	1100 km²	1200 km²	1300 km²
Sequence 3 – PTS weighted SEL_{cum} (183 dB re 1 µPa²s)	Maximum	1.8 km	3.1 km	3.8 km	4.3 km
	Minimum	800 m	1.5 km	2.0 km	2.3 km
	Mean	1.1 km	2.1 km	2.7 km	3.1 km
	Area	4.2 km²	14 km²	23 km²	31 km²
Sequence 3 – TTS weighted SEL_{cum} (168 dB re 1 µPa²s)	Maximum	19.9 km	22.4 km	23.8 km	24.7 km
	Minimum	12.9 km	14.1 km	14.8 km	15.2 km
	Mean	16.8 km	18.7 km	19.7 km	20.3 km
	Area	890 km²	1100 km²	1200 km²	1300 km²

Table A 24 Predicted low-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 3.25 ms^{-1} for the three piling sequences at Creyke Beck A, location ID11

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (230 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS unweighted SPL_{peak} (224 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²

Table A 25 Predicted unweighted SPL_{peak} impact ranges for mid-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID11

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²

Table A 26 Predicted mid-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck A, location ID11

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	380 m	480 m	590 m	650 m
	Minimum	370 m	470 m	580 m	640 m
	Mean	380 m	480 m	590 m	650 m
	Area	0.4 km²	0.7 km²	1.1 km²	1.3 km²
TTS unweighted SPL_{peak} (196 re 1 µPa)	Maximum	850 m	1.1 km	1.3 km	1.4 km
	Minimum	830 m	1.0 km	1.3 km	1.4 km
	Mean	840 m	1.1 km	1.3 km	1.4 km
	Area	2.2 km²	3.5 km²	5.1 km²	6.2 km²

Table A 27 Predicted unweighted SPL_{peak} impact ranges for high-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck A, location ID11

High-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (155 dB re 1 $\mu Pa^2 s$)	Maximum	1.6 km	< 100 m	< 100 m	< 100 m
	Minimum	1.3 km	< 100 m	< 100 m	< 100 m
	Mean	1.4 km	< 100 m	< 100 m	< 100 m
	Area	6.3 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (140 dB re 1 $\mu Pa^2 s$)	Maximum	16.4 km	8.5 km	9.3 km	9.8 km
	Minimum	12.7 km	6.6 km	7.2 km	7.7 km
	Mean	14.2 km	7.3 km	8.0 km	8.4 km
	Area	630 km^2	170 km^2	200 km^2	220 km^2
Sequence 2 – PTS weighted SEL_{cum} (155 dB re 1 $\mu Pa^2 s$)	Maximum	2.9 km	< 100 m	< 100 m	< 100 m
	Minimum	2.2 km	< 100 m	< 100 m	< 100 m
	Mean	2.5 km	< 100 m	< 100 m	< 100 m
	Area	20 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (140 dB re 1 $\mu Pa^2 s$)	Maximum	19.9 km	11.4 km	12.3 km	12.8 km
	Minimum	14.4 km	8.4 km	9.1 km	9.5 km
	Mean	17.2 km	9.6 km	10.3 km	10.8 km
	Area	930 km^2	290 km^2	330 km^2	370 km^2
Sequence 3 – PTS weighted SEL_{cum} (155 dB re 1 $\mu Pa^2 s$)	Maximum	3.4 km	< 100 m	< 100 m	< 100 m
	Minimum	2.3 km	< 100 m	< 100 m	< 100 m
	Mean	2.8 km	< 100 m	< 100 m	< 100 m
	Area	24 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (140 dB re 1 $\mu Pa^2 s$)	Maximum	20.9 km	12.2 km	13.1 km	13.7 km
	Minimum	14.7 km	8.7 km	9.4 km	9.8 km
	Mean	18.2 km	10.2 km	11.0 km	11.5 km
	Area	1000 km^2	330 km^2	380 km^2	420 km^2

Table A 28 Predicted high-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck A, location ID11

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (218 re 1 µPa)	Maximum	60 m	70 m	80 m	80 m
	Minimum	50 m	60 m	70 m	70 m
	Mean	60 m	70 m	80 m	80 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (212 re 1 µPa)	Maximum	110 m	130 m	160 m	170 m
	Minimum	100 m	120 m	150 m	160 m
	Mean	110 m	130 m	160 m	170 m
	Area	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2

Table A 29 Predicted unweighted SPL_{peak} impact ranges for phocid pinnipeds using criteria from NMFS (2016) at Creyke Beck A, location ID11

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	4.7 km	7.0 km	7.7 km	8.3 km
	Minimum	3.7 km	5.5 km	6.0 km	6.4 km
	Mean	4.2 km	6.1 km	6.7 km	7.2 km
	Area	55 km²	120 km²	140 km²	160 km²
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	7.1 km	9.8 km	10.6 km	11.2 km
	Minimum	5.2 km	7.2 km	7.8 km	8.3 km
	Mean	5.9 km	8.2 km	8.9 km	9.4 km
	Area	110 km²	210 km²	250 km²	280 km²
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	7.8 km	10.6 km	11.4 km	12.0 km
	Minimum	5.5 km	7.5 km	8.1 km	8.6 km
	Mean	6.4 km	8.8 km	9.5 km	10.0 km
	Area	130 km²	240 km²	280 km²	320 km²

Table A 30 Predicted phocid pinnipeds weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck A, location ID11

<u>Popper et al (2014) impact ranges</u>

Fish - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Injury (fish: no swim bladder) unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	110 m	140 m	150 m
	Minimum	80 m	100 m	130 m	140 m
	Mean	90 m	110 m	140 m	150 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²
Injury (fish: with swim bladder) unweighted SPL_{peak} (207 re 1 µPa)	Maximum	200 m	250 m	300 m	330 m
	Minimum	190 m	240 m	290 m	320 m
	Mean	200 m	250 m	300 m	330 m
	Area	0.1 km²	0.2 km²	0.3 km²	0.3 km²

Table A 31 Predicted unweighted SPL_{peak} impact ranges for fish using criteria from Popper et al. (2014) at Creyke Beck A, location ID11

Fish - impact criterion **(Sequence 1)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS (all fish) SEL_{cum} (186 re 1 µPa²s)	Maximum	5.8 km	8.6 km	9.4 km	9.9 km
	Minimum	4.6 km	6.7 km	7.3 km	7.7 km
	Mean	5.1 km	7.4 km	8.1 km	8.5 km
	Area	82 km²	170 km²	200 km²	230 km²

Table A 32 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 1 at Creyke Beck A, location ID11

Fish - impact criterion **(Sequence 2)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS (all fish) SEL_{cum} (186 re 1 µPa²s)	Maximum	8.4 km	11.5 km	12.4 km	13.0 km
	Minimum	6.2 km	8.5 km	9.2 km	9.6 km
	Mean	7.0 km	9.7 km	10.4 km	10.9 km
	Area	160 km²	290 km²	340 km²	370 km²

Table A 33 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 2 at Creyke Beck A, location ID11

Fish - impact criterion **(Sequence 3)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^{2}s)	Maximum	9.2 km	12.3 km	13.2 km	13.8 km
	Minimum	6.5 km	8.8 km	9.4 km	9.9 km
	Mean	7.6 km	10.3 km	11.1 km	11.6 km
	Area	180 km^2	340 km^2	390 km^2	420 km^2

Table A 34 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 3 at Creyke Beck A, location ID11

A.3 Creyke Beck B, location ID6

Previously considered criteria

Harbour porpoise - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	450 m	500 m	630 m	770 m	860 m
	Min	120 m	430 m	490 m	620 m	760 m	840 m
	Mean	130 m	440 m	500 m	630 m	770 m	850 m
	Area	0.1 km^2	0.6 km^2	0.8 km^2	1.2 km^2	1.8 km^2	2.3 km^2
Instantaneous injury/PTS (SEL_{ss} 179 dB re 1 $µPa^2s$)	Max	150 m	430 m	470 m	720 m	800 m	860 m
	Min	140 m	420 m	460 m	700 m	780 m	850 m
	Mean	150 m	430 m	470 m	710 m	790 m	860 m
	Area	0.1 km^2	0.6 km^2	0.7 km^2	1.6 km^2	2.0 km^2	2.3 km^2
TTS/fleeing response (SPL_{peak} 194 dB re 1 µPa)	Max	280 m	990 m	1.1 km	1.4 km	1.7 km	1.9 km
	Min	270 m	970 m	1.1 km	1.4 km	1.7 km	1.8 km
	Mean	280 m	980 m	1.1 km	1.4 km	1.7 km	1.9 km
	Area	0.2 km^2	3.0 km^2	3.8 km^2	6.0 km^2	8.8 km^2	11 km^2
TTS/fleeing response (SEL_{ss} 164 dB re 1 $µPa^2s$)	Max	1.4 km	4.0 km	4.3 km	5.9 km	6.5 km	6.9 km
	Min	1.4 km	3.8 km	4.0 km	5.5 km	6.0 km	6.3 km
	Mean	1.4 km	3.9 km	4.2 km	5.8 km	6.3 km	6.7 km
	Area	6.4 km^2	47 km^2	54 km^2	110 km^2	130 km^2	140 km^2
Possible avoidance of area (SPL_{peak} 168 re 1 $µPa^2s$)	Max	7.1 km	16.3 km	17.7 km	20.5 km	23.2 km	24.6 km
	Min	6.4 km	13.0 km	13.8 km	15.2 km	16.4 km	17.0 km
	Mean	6.9 km	15.0 km	16.0 km	18.1 km	20.0 km	21.1 km
	Area	150 km^2	710 km^2	810 km^2	1000 km^2	1300 km^2	1400 km^2
Possible avoidance of area (SEL_{ss} 145 re 1 $µPa^2s$)	Max	15.1 km	30.1 km	31.5 km	39.1 km	41.1 km	42.6 km
	Min	12.4 km	19.7 km	20.3 km	23.2 km	23.9 km	24.4 km
	Mean	14.1 km	25.1 km	26.1 km	31.4 km	32.8 km	33.9 km
	Area	620 km^2	2000 km^2	2200 km^2	3100 km^2	3500 km^2	3700 km^2

Table A 35 Predicted harbour porpoise impact ranges using criteria derived from Lucke et al. (2009) at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Max	< 50 m	90 m	120 m	140 m	150 m	170 m
	Min	< 50 m	80 m	110 m	130 m	140 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	150 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Likely avoidance of area (SEL_{ss} 170 re 1 µPa^{2}s)	Max	580 m	1.7 km	1.9 km	2.7 km	3.0 km	3.2 km
	Min	570 m	1.7 km	1.8 km	2.7 km	2.9 km	3.1 km
	Mean	580 m	1.7 km	1.8 km	2.7 km	3.0 km	3.2 km
	Area	1.0 km^2	8.9 km^2	10 km^2	23 km^2	27 km^2	31 km^2
Possible avoidance of area (SEL_{ss} 160 re 1 µPa^{2}s)	Max	2.6 km	6.5 km	6.9 km	9.4 km	10.2 km	10.7 km
	Min	2.5 km	6.0 km	6.3 km	8.3 km	8.9 km	9.3 km
	Mean	2.5 km	6.4 km	6.8 km	9.1 km	9.7 km	10.2 km
	Area	20 km^2	130 km^2	140 km^2	260 km^2	300 km^2	330 km^2

Table A 36 Predicted mid-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID6

Low-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^{2}s)	Max	< 50 m	< 50 m	< 50 m	50 m	50 m	50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^{2}s)	Max	80 m	240 m	260 m	390 m	430 m	470 m
	Min	70 m	230 m	250 m	380 m	420 m	450 m
	Mean	80 m	240 m	260 m	390 m	430 m	460 m
	Area	< 0.1 km^2	0.2 km^2	0.2 km^2	0.5 km^2	0.6 km^2	0.7 km^2
Likely avoidance of area (SEL_{ss} 152 re 1 µPa^{2}s)	Max	7.2 km	15.3 km	16.2 km	21.3 km	22.8 km	23.9 km
	Min	6.5 km	12.6 km	13.1 km	15.8 km	16.5 km	17.0 km
	Mean	7.0 km	14.3 km	15.0 km	18.8 km	19.9 km	20.7 km
	Area	150 km^2	640 km^2	700 km^2	1100 km^2	1200 km^2	1300 km^2
Possible avoidance of area (SEL_{ss} 142 re 1 µPa^{2}s)	Max	20.4 km	38.3 km	40.0 km	48.4 km	50.8 km	52.5 km
	Min	15.4 km	22.9 km	23.5 km	26.4 km	27.2 km	27.8 km
	Mean	18.2 km	30.9 km	32.0 km	37.9 km	39.5 km	40.7 km
	Area	1000 km^2	3000 km^2	3300 km^2	4600 km^2	5100 km^2	5400 km^2

Table A 37 Predicted low-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID6

Pinnipeds (in water) - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 218 dB re 1 µPa)	Max	50 m	50 m	60 m	70 m	80 m	80 m
	Min	< 50 m	< 50 m	50 m	60 m	70 m	70 m
	Mean	< 50 m	< 50 m	60 m	70 m	80 m	80 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa^{2}s)	Max	< 50 m	90 m	120 m	150 m	160 m	170 m
	Min	< 50 m	80 m	110 m	140 m	150 m	160 m
	Mean	< 50 m	90 m	120 m	150 m	160 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (SPL_{peak} 212 dB re 1 µPa)	Max	70 m	90 m	110 m	130 m	160 m	170 m
	Min	60 m	80 m	100 m	120 m	150 m	160 m
	Mean	70 m	90 m	110 m	130 m	160 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa^{2}s)	Max	290 m	870 m	1.2 km	1.4 km	1.6 km	1.7 km
	Min	280 m	850 m	1.2 km	1.4 km	1.6 km	1.7 km
	Mean	290 m	860 m	1.2 km	1.4 km	1.6 km	1.7 km
	Area	0.3 km^2	2.3 km^2	4.2 km^2	6.2 km^2	7.6 km^2	8.8 km^2

Table A 38 Predicted pinniped (in water) impact ranges using criteria from Southall et al. (2007) at Creyke Beck B, location ID6

Fish - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 206 dB re 1 µPa)	Max	80 m	200 m	230 m	280 m	350 m	380 m
	Min	70 m	190 m	220 m	270 m	340 m	370 m
	Mean	80 m	200 m	230 m	280 m	350 m	380 m
	Area	< 0.1 km^2	0.1 km^2	0.2 km^2	0.2 km^2	0.4 km^2	0.4 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 1	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 2	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
PTS (SEL_{cum} 211 dB re 1 µPa^{2}s) – Sequence 3	Max	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Min	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	-	-	< 50 m	< 50 m	< 50 m	< 50 m
	Area	-	-	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Possible moderate to strong avoidance (upper bound SPL_{peak} 173 dB re 1 µPa)	Max	4.2 km	10.7 km	11.5 km	13.4 km	15.1 km	16.2 km
	Min	4.0 km	9.1 km	9.8 km	11.1 km	12.3 km	12.9 km
	Mean	4.1 km	10.2 km	11.0 km	12.6 km	14.1 km	14.9 km
	Area	53 km^2	320 km^2	380 km^2	490 km^2	620 km^2	700 km^2
Possible moderate to strong avoidance (lower bound SPL_{peak} 168 dB re 1 µPa)	Max	7.1 km	16.3 km	17.7 km	20.5 km	23.2 km	24.6 km
	Min	6.4 km	13.0 km	13.8 km	15.2 km	16.4 km	17.0 km
	Mean	6.9 km	15.0 km	16.0 km	18.1 km	20.0 km	21.1 km
	Area	150 km^2	710 km^2	810 km^2	1000 km^2	1300 km^2	1400 km^2
Startle response or C-turn reaction (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	450 m	500 m	630 m	770 m	860 m
	Min	120 m	430 m	490 m	620 m	760 m	840 m
	Mean	130 m	440 m	500 m	630 m	770 m	850 m
	Area	0.1 km^2	0.6 km^2	0.8 km^2	1.2 km^2	1.8 km^2	2.3 km^2

Table A 39 Predicted fish impact ranges using criteria from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al (2011), McCauley et al. (2000) and Pearson et al. (1992) at Creyke Beck B, location ID6

Cells marked with a hyphen are for single strike hammer energies and as such cumulative SELs cannot be calculated for them.

NMFS (2016) impact ranges

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (219 re 1 µPa)	Maximum	50 m	60 m	70 m	70 m
	Minimum	< 50 m	50 m	60 m	60 m
	Mean	< 50 m	60 m	70 m	70 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	110 m	130 m	140 m
	Mean	90 m	120 m	140 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2

Table A 40 Predicted unweighted SPL_{peak} impact ranges for low-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	1.4 km	2.7 km	3.5 km	4.1 km
	Minimum	690 m	1.6 km	2.1 km	2.5 km
	Mean	1.1 km	2.4 km	3.0 km	3.5 km
	Area	4.2 km^2	17 km^2	29 km^2	39 km^2
Sequence 1 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	30.3 km	34.7 km	36.9 km	38.5 km
	Minimum	14.7 km	16.3 km	17.1 km	17.6 km
	Mean	22.7 km	25.8 km	27.4 km	28.5 km
	Area	1700 km^2	2200 km^2	2500 km^2	2700 km^2
Sequence 2 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	3.0 km	5.0 km	6.1 km	6.9 km
	Minimum	1.1 km	2.2 km	2.8 km	3.3 km
	Mean	2.2 km	3.8 km	4.7 km	5.3 km
	Area	16 km^2	47 km^2	70 km^2	91 km^2
Sequence 2 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	40.2 km	45.3 km	47.9 km	49.8 km
	Minimum	16.0 km	17.7 km	18.6 km	19.2 km
	Mean	28.4 km	32.0 km	33.8 km	35.1 km
	Area	2700 km^2	3500 km^2	3900 km^2	4200 km^2
Sequence 3 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	3.6 km	5.9 km	7.2 km	8.1 km
	Minimum	1.1 km	2.3 km	2.9 km	3.3 km
	Mean	2.5 km	4.2 km	5.1 km	5.8 km
	Area	21 km^2	58 km^2	86 km^2	110 km^2
Sequence 3 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	45.0 km	50.8 km	53.8 km	55.9 km
	Minimum	16.1 km	17.9 km	18.7 km	19.3 km
	Mean	30.8 km	34.6 km	36.6 km	38.0 km
	Area	3300 km^2	4100 km^2	4600 km^2	5000 km^2

Table A 41 Predicted low-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 3.25 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (230 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (224 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table A 42 Predicted unweighted SPL_{peak} impact ranges for mid-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table A 43 Predicted mid-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	390 m	490 m	590 m	660 m
	Minimum	370 m	470 m	580 m	640 m
	Mean	380 m	480 m	590 m	650 m
	Area	0.5 km^2	0.7 km^2	1.1 km^2	1.3 km^2
TTS unweighted SPL_{peak} (196 re 1 µPa)	Maximum	860 m	1.1 km	1.3 km	1.5 km
	Minimum	840 m	1.1 km	1.3 km	1.4 km
	Mean	850 m	1.1 km	1.3 km	1.4 km
	Area	2.3 km^2	3.6 km^2	5.3 km^2	6.4 km^2

Table A 44 Predicted unweighted SPL_{peak} impact ranges for high-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID6

High-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	1.9 km	< 100 m	< 100 m	< 100 m
	Minimum	1.5 km	< 100 m	< 100 m	< 100 m
	Mean	1.7 km	< 100 m	< 100 m	< 100 m
	Area	9.2 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	23.1 km	9.7 km	10.7 km	11.5 km
	Minimum	14.4 km	7.6 km	8.3 km	8.7 km
	Mean	19.0 km	9.0 km	9.8 km	10.4 km
	Area	1100 km²	250 km²	300 km²	340 km²
Sequence 2 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	3.5 km	< 100 m	< 100 m	< 100 m
	Minimum	2.6 km	< 100 m	< 100 m	< 100 m
	Mean	3.3 km	< 100 m	< 100 m	< 100 m
	Area	33 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	33.4 km	15.6 km	17.1 km	18.3 km
	Minimum	17.1 km	9.9 km	10.6 km	11.1 km
	Mean	25.5 km	13.0 km	14.1 km	14.9 km
	Area	2100 km²	530 km²	630 km²	700 km²
Sequence 3 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	4.7 km	< 100 m	< 100 m	< 100 m
	Minimum	2.9 km	< 100 m	< 100 m	< 100 m
	Mean	4.0 km	< 100 m	< 100 m	< 100 m
	Area	50 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	40.8 km	20.0 km	21.8 km	23.2 km
	Minimum	17.9 km	10.4 km	11.2 km	11.7 km
	Mean	29.6 km	15.3 km	16.6 km	17.5 km
	Area	2900 km²	750 km²	890 km²	990 km²

Table A 45 Predicted high-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

Phocid pinnipeds - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (218 re 1 µPa)	Maximum	60 m	70 m	80 m	80 m
	Minimum	50 m	60 m	70 m	70 m
	Mean	60 m	70 m	80 m	80 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS unweighted SPL_{peak} (212 re 1 µPa)	Maximum	110 m	130 m	160 m	170 m
	Minimum	100 m	120 m	150 m	160 m
	Mean	110 m	130 m	160 m	170 m
	Area	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²

Table A 46 Predicted unweighted SPL_{peak} impact ranges for phocid pinnipeds using criteria from NMFS (2016) at Creyke Beck B, location ID6

Phocid pinnipeds - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 μPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 μPa^2s)	Maximum	5.3 km	7.9 km	8.8 km	9.5 km
	Minimum	4.3 km	6.3 km	6.9 km	7.4 km
	Mean	5.0 km	7.4 km	8.2 km	8.7 km
	Area	79 km^2	170 km^2	210 km^2	240 km^2
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 μPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 μPa^2s)	Maximum	8.7 km	12.7 km	14.1 km	15.2 km
	Minimum	6.2 km	8.5 km	9.2 km	9.7 km
	Mean	7.7 km	10.9 km	11.9 km	12.7 km
	Area	190 km^2	370 km^2	450 km^2	510 km^2
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 μPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 μPa^2s)	Maximum	11.3 km	16.5 km	18.3 km	19.5 km
	Minimum	6.6 km	9.0 km	9.7 km	10.2 km
	Mean	9.2 km	12.9 km	14.1 km	14.9 km
	Area	270 km^2	530 km^2	640 km^2	720 km^2

Table A 47 Predicted phocid pinnipeds weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID6

<u>*Popper et al (2014) impact ranges*</u>

Fish - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Injury (fish: no swim bladder) unweighted SPL_{peak} (213 re 1 μPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	110 m	130 m	140 m
	Mean	90 m	120 m	140 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2
Injury (fish: with swim bladder) unweighted SPL_{peak} (207 re 1 μPa)	Maximum	200 m	250 m	300 m	340 m
	Minimum	190 m	240 m	290 m	330 m
	Mean	200 m	250 m	300 m	340 m
	Area	0.1 km^2	0.2 km^2	0.3 km^2	0.4 km^2

Table A 48 Predicted unweighted SPL_{peak} impact ranges for fish using criteria from Popper et al. (2014) at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 1)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^{2}s)	Maximum	6.5 km	9.8 km	10.8 km	11.6 km
	Minimum	5.1 km	7.5 km	8.2 km	8.7 km
	Mean	6.1 km	9.0 km	9.8 km	10.5 km
	Area	110 km^2	250 km^2	300 km^2	340 km^2

Table A 49 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 1 at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 2)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^{2}s)	Maximum	10.5 km	15.7 km	17.3 km	18.4 km
	Minimum	7.2 km	9.9 km	10.6 km	11.1 km
	Mean	9.2 km	13.0 km	14.1 km	14.9 km
	Area	260 km^2	540 km^2	630 km^2	710 km^2

Table A 50 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 2 at Creyke Beck B, location ID6

Fish - impact criterion **(Sequence 3)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	13.7 km	20.2 km	22.0 km	23.4 km
	Minimum	7.7 km	10.4 km	11.1 km	11.7 km
	Mean	10.9 km	15.4 km	16.6 km	17.6 km
	Area	380 km^2	760 km^2	900 km^2	1000 km^2

Table A 51 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 3 at Creyke Beck B, location ID6

A.4 Creyke Beck B, location ID13

Previously considered criteria

Harbour porpoise - impact criterion		**300 kJ hammer energy**	**1900 kJ hammer energy**	**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Instantaneous injury/PTS (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	440 m	500 m	630 m	770 m	850 m
	Min	120 m	430 m	490 m	620 m	750 m	840 m
	Mean	130 m	440 m	500 m	630 m	760 m	840 m
	Area	0.1 km^2	0.6 km^2	0.8 km^2	1.2 km^2	1.8 km^2	2.2 km^2
Instantaneous injury/PTS (SEL_{ss} 179 dB re 1 µPa^{2}s)	Max	150 m	430 m	470 m	710 m	790 m	850 m
	Min	140 m	420 m	460 m	700 m	780 m	840 m
	Mean	150 m	430 m	470 m	710 m	790 m	850 m
	Area	0.1 km^2	0.6 km^2	0.7 km^2	1.6 km^2	1.9 km^2	2.2 km^2
TTS/fleeing response (SPL_{peak} 194 dB re 1 µPa)	Max	280 m	980 m	1.1 km	1.4 km	1.7 km	18.2 km
	Min	270 m	960 m	1.1 km	1.4 km	1.6 km	11.9 km
	Mean	280 m	970 m	1.1 km	1.4 km	1.6 km	12.7 km
	Area	0.2 km^2	2.9 km^2	3.7 km^2	5.8 km^2	8.4 km^2	500 km^2
TTS/fleeing response (SEL_{ss} 164 dB re 1 µPa^{2}s)	Max	1.4 km	3.8 km	4.0 km	5.6 km	6.1 km	6.4 km
	Min	1.4 km	3.7 km	3.9 km	5.2 km	5.7 km	5.9 km
	Mean	1.4 km	3.7 km	4.0 km	5.4 km	5.8 km	6.1 km
	Area	6.2 km^2	43 km^2	49 km^2	91 km^2	110 km^2	120 km^2
Possible avoidance of area (SPL_{peak} 168 re 1 µPa^{2}s)	Max	6.5 km	13.9 km	14.8 km	16.6 km	18.2 km	19.0 km
	Min	6.0 km	11.9 km	12.6 km	13.8 km	14.8 km	15.4 km
	Mean	6.2 km	12.7 km	13.5 km	15.0 km	16.3 km	17.0 km
	Area	120 km^2	510 km^2	570 km^2	700 km^2	830 km^2	910 km^2
Possible avoidance of area (SEL_{ss} 145 re 1 µPa^{2}s)	Max	13.2 km	22.5 km	23.4 km	27.9 km	29.2 km	30.1 km
	Min	11.5 km	18.1 km	18.6 km	21.4 km	22.2 km	22.8 km
	Mean	12.2 km	20.0 km	20.7 km	24.2 km	25.1 km	25.8 km
	Area	460 km^2	1300 km^2	1300 km^2	1800 km^2	2000 km^2	2100 km^2

Table A 52 Predicted harbour porpoise impact ranges using criteria derived from Lucke et al. (2009) at Creyke Beck B, location ID13

Mid-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{mf} SEL_{ss} 198 dB re 1 µPa^2s)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{mf} SEL_{ss} 183 dB re 1 µPa^2s)	Max	< 50 m	90 m	120 m	140 m	150 m	170 m
	Min	< 50 m	80 m	110 m	130 m	140 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	150 m	170 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2	0.1 km^2
Likely avoidance of area (SEL_{ss} 170 re 1 µPa^2s)	Max	570 m	1.7 km	1.8 km	2.6 km	2.9 km	3.1 km
	Min	560 m	1.7 km	1.8 km	2.6 km	2.8 km	3.0 km
	Mean	570 m	1.7 km	1.8 km	2.6 km	2.9 km	3.0 km
	Area	1.0 km^2	8.6 km^2	10 km^2	21 km^2	25 km^2	29 km^2
Possible avoidance of area (SEL_{ss} 160 re 1 µPa^2s)	Max	2.5 km	6.1 km	6.4 km	8.6 km	9.2 km	9.7 km
	Min	2.5 km	5.7 km	6.0 km	7.8 km	8.3 km	8.7 km
	Mean	2.5 km	5.9 km	6.2 km	8.1 km	8.7 km	9.1 km
	Area	19 km^2	110 km^2	120 km^2	210 km^2	240 km^2	260 km^2

Table A 53 Predicted mid-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID13

Low-frequency cetaceans - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 230 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Instantaneous injury/PTS (M_{lf} SEL_{ss} 198 dB re 1 µPa^2s)	Max	< 50 m	< 50 m	< 50 m	50 m	50 m	50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (SPL_{peak} 224 dB re 1 µPa)	Max	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Min	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS/fleeing response (M_{lf} SEL_{ss} 183 dB re 1 µPa^2s)	Max	80 m	240 m	260 m	390 m	430 m	460 m
	Min	70 m	230 m	250 m	380 m	420 m	450 m
	Mean	80 m	240 m	260 m	390 m	430 m	460 m
	Area	< 0.1 km^2	0.2 km^2	0.2 km^2	0.5 km^2	0.6 km^2	0.7 km^2
Likely avoidance of area (SEL_{ss} 152 re 1 µPa^2s)	Max	6.7 km	13.3 km	14.0 km	17.3 km	18.2 km	18.9 km
	Min	6.2 km	11.6 km	12.1 km	14.4 km	15.0 km	15.5 km
	Mean	6.4 km	12.3 km	12.8 km	15.6 km	16.4 km	17.0 km
	Area	130 km^2	470 km^2	520 km^2	770 km^2	840 km^2	900 km^2
Possible avoidance of area (SEL_{ss} 142 re 1 µPa^2s)	Max	16.8 km	27.5 km	28.4 km	33.8 km	35.3 km	36.3 km
	Min	14.0 km	21.2 km	21.8 km	24.5 km	25.0 km	25.5 km
	Mean	15.2 km	23.9 km	24.6 km	28.3 km	29.4 km	30.1 km
	Area	720 km^2	1800 km^2	1900 km^2	2500 km^2	2700 km^2	2800 km^2

Table A 54 Predicted low-frequency cetacean impact ranges using criteria derived from Southall et al. (2007) at Creyke Beck B, location ID13

Pinnipeds (in water) - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 218 dB re 1 µPa)	Max	50 m	50 m	60 m	70 m	80 m	80 m
	Min	< 50 m	< 50 m	50 m	60 m	70 m	70 m
	Mean	< 50 m	< 50 m	60 m	70 m	80 m	80 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Instantaneous injury/PTS (M_{pw} SEL_{ss} 186 dB re 1 µPa²s)	Max	< 50 m	90 m	120 m	140 m	160 m	170 m
	Min	< 50 m	80 m	110 m	130 m	150 m	160 m
	Mean	< 50 m	90 m	120 m	140 m	160 m	170 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS/fleeing response (SPL_{peak} 212 dB re 1 µPa)	Max	70 m	90 m	110 m	130 m	160 m	170 m
	Min	60 m	80 m	100 m	120 m	150 m	160 m
	Mean	70 m	90 m	110 m	130 m	160 m	170 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²
TTS/fleeing response (M_{pw} SEL_{ss} 171 dB re 1 µPa²s)	Max	290 m	860 m	1.2 km	1.4 km	1.6 km	1.7 km
	Min	280 m	850 m	1.1 km	1.4 km	1.5 km	1.6 km
	Mean	290 m	860 m	1.1 km	1.4 km	1.5 km	1.7 km
	Area	0.3 km²	2.3 km²	4.1 km²	6.0 km²	7.4 km²	8.5 km²

Table A 55 Predicted pinniped (in water) impact ranges using criteria from Southall et al. (2007) at Creyke Beck B, location ID13

Fish - impact criterion		300 kJ hammer energy	1900 kJ hammer energy	2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Instantaneous injury/PTS (SPL_{peak} 206 dB re 1 µPa)	Max	80 m	200 m	230 m	280 m	350 m	380 m
	Min	70 m	190 m	220 m	270 m	330 m	370 m
	Mean	80 m	200 m	230 m	280 m	340 m	380 m
	Area	< 0.1 km²	0.1 km²	0.2 km²	0.2 km²	0.4 km²	0.4 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 1	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 2	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
PTS (SEL_{cum} 211 dB re 1 µPa²s) – Sequence 3	Max	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Min	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	-	-	< 100 m	< 100 m	< 100 m	< 100 m
	Area	-	-	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Possible moderate to strong avoidance (upper bound SPL_{peak} 173 dB re 1 µPa)	Max	4.0 km	9.5 km	10.3 km	11.7 km	13.1 km	13.8 km
	Min	3.8 km	8.5 km	9.1 km	10.3 km	11.3 km	11.9 km
	Mean	3.9 km	8.9 km	9.6 km	10.8 km	12.0 km	12.7 km
	Area	47 km²	250 km²	290 km²	370 km²	450 km²	500 km²
Possible moderate to strong avoidance (lower bound SPL_{peak} 168 dB re 1 µPa)	Max	6.5 km	13.9 km	14.8 km	16.6 km	18.2 km	19.0 km
	Min	6.0 km	11.9 km	12.6 km	13.8 km	14.8 km	15.4 km
	Mean	6.2 km	12.7 km	13.5 km	15.0 km	16.3 km	17.0 km
	Area	120 km²	510 km²	570 km²	700 km²	830 km²	910 km²
Startle response or C-turn reaction (SPL_{peak} 200 dB re 1 µPa)	Max	130 m	440 m	500 m	630 m	770 m	850 m
	Min	120 m	430 m	490 m	620 m	750 m	840 m
	Mean	130 m	440 m	500 m	630 m	760 m	840 m
	Area	0.1 km²	0.6 km²	0.8 km²	1.2 km²	1.8 km²	2.2 km²

Table A 56 Predicted fish impact ranges using criteria from Popper et al. (2006), Carlson et al. (2007), Halvorsen et al. (2011), McCauley et al. (2000) and Pearson et al. (1992) at Creyke Beck B, location ID13

Cells marked with a hyphen are for single strike hammer energies and as such cumulative SELs cannot be calculated for them.

NMFS (2016) impact ranges

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (219 re 1 µPa)	Maximum	50 m	60 m	70 m	70 m
	Minimum	< 50 m	50 m	60 m	60 m
	Mean	< 50 m	60 m	70 m	70 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	100 m	130 m	140 m
	Mean	90 m	110 m	140 m	150 m
	Area	< 0.1 km^2	< 0.1 km^2	0.1 km^2	0.1 km^2

Table A 57 Predicted unweighted SPL_{peak} impact ranges for low-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID13

Low-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	900 m	1.8 km	2.4 km	2.9 km
	Minimum	600 m	1.2 km	1.6 km	2.0 km
	Mean	700 m	1.4 km	1.9 km	2.3 km
	Area	1.6 km^2	6.6 km^2	12 km^2	17 km^2
Sequence 1 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	19.4 km	21.9 km	23.3 km	24.3 km
	Minimum	13.1 km	14.6 km	15.2 km	15.7 km
	Mean	15.7 km	17.6 km	23.3 km	19.3 km
	Area	780 km^2	980 km^2	1100 km^2	1200 km^2
Sequence 2 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	1.6 km	2.8 km	3.6 km	4.1 km
	Minimum	800 m	1.6 km	2.1 km	2.5 km
	Mean	1.1 km	2.1 km	2.7 km	3.1 km
	Area	3.9 km^2	14 km^2	23 km^2	31 km^2
Sequence 2 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	23.6 km	26.6 km	28.2 km	29.3 km
	Minimum	14.0 km	15.3 km	16.0 km	16.5 km
	Mean	18.0 km	20.0 km	21.1 km	21.9 km
	Area	1000 km^2	1300 km^2	1400 km^2	1500 km^2
Sequence 3 – PTS weighted SEL_{cum} (183 dB re 1 µPa^{2}s)	Maximum	1.7 km	3.0 km	3.8 km	4.3 km
	Minimum	800 m	1.6 km	2.1 km	2.5 km
	Mean	1.1 km	2.2 km	2.8 km	3.2 km
	Area	4.3 km^2	15 km^2	24 km^2	33 km^2
Sequence 3 – TTS weighted SEL_{cum} (168 dB re 1 µPa^{2}s)	Maximum	25.2 km	28.5 km	30.2 km	31.4 km
	Minimum	14.1 km	15.4 km	16.1 km	16.6 km
	Mean	18.5 km	20.7 km	21.8 km	22.6 km
	Area	1.1 km^2	1400 km^2	1500 km^2	1600 km^2

Table A 58 Predicted low-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 3.25 ms^{-1} for the three piling sequences at Creyke Beck B, location ID13

Mid-frequency cetaceans - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
PTS unweighted SPL_{peak} (230 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS unweighted SPL_{peak} (224 re 1 µPa)	Maximum	< 50 m	< 50 m	< 50 m	< 50 m
	Minimum	< 50 m	< 50 m	< 50 m	< 50 m
	Mean	< 50 m	< 50 m	< 50 m	< 50 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2

Table A 59 Predicted unweighted SPL_{peak} impact ranges for mid-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID13

Mid-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²

Table A 60 Predicted mid-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID13

High-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (202 re 1 µPa)	Maximum	380 m	480 m	590 m	650 m
	Minimum	370 m	470 m	580 m	640 m
	Mean	380 m	480 m	590 m	650 m
	Area	0.4 km²	0.7 km²	1.1 km²	1.3 km²
TTS unweighted SPL_{peak} (196 re 1 µPa)	Maximum	850 m	1.1 km	1.3 km	1.4 km
	Minimum	840 m	1.1 km	1.3 km	1.4 km
	Mean	850 m	1.1 km	1.3 km	1.4 km
	Area	2.2 km²	3.5 km²	5.1 km²	6.2 km²

Table A 61 Predicted unweighted SPL_{peak} impact ranges for high-frequency cetaceans using criteria from NMFS (2016) at Creyke Beck B, location ID13

High-frequency cetaceans - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Sequence 1 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	1.5 km	< 100 m	< 100 m	< 100 m
	Minimum	1.3 km	< 100 m	< 100 m	< 100 m
	Mean	1.4 km	< 100 m	< 100 m	< 100 m
	Area	5.9 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	16.7 km	8.1 km	8.9 km	9.4 km
	Minimum	13.0 km	6.8 km	7.4 km	7.8 km
	Mean	14.6 km	7.3 km	8.0 km	8.5 km
	Area	670 km²	170 km²	200 km²	220 km²
Sequence 2 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	2.8 km	< 100 m	< 100 m	< 100 m
	Minimum	2.2 km	< 100 m	< 100 m	< 100 m
	Mean	2.4 km	< 100 m	< 100 m	< 100 m
	Area	19 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	21.9 km	11.3 km	12.2 km	12.9 km
	Minimum	15.5 km	8.6 km	9.3 km	9.7 km
	Mean	18.1 km	9.8 km	10.5 km	11.1 km
	Area	1000 km²	300 km²	350 km²	390 km²
Sequence 3 – PTS weighted SEL_{cum} (155 dB re 1 µPa²s)	Maximum	3.3 km	< 100 m	< 100 m	< 100 m
	Minimum	2.4 km	< 100 m	< 100 m	< 100 m
	Mean	2.8 km	< 100 m	< 100 m	< 100 m
	Area	24 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
14.6Sequence 3 – TTS weighted SEL_{cum} (140 dB re 1 µPa²s)	Maximum	24.8 km	12.8 km	13.9 km	14.6 km
	Minimum	15.9 km	9.1 km	9.7 km	10.2 km
	Mean	19.5 km	10.6 km	11.4 km	12.0 km
	Area	1200 km²	350 km²	410 km²	450 km²

Table A 62 Predicted high-frequency cetacean weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID13

Phocid pinnipeds - impact criterion		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
PTS unweighted SPL_{peak} (218 re 1 µPa)	Maximum	60 m	70 m	80 m	80 m
	Minimum	50 m	60 m	70 m	70 m
	Mean	60 m	70 m	80 m	80 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
TTS unweighted SPL_{peak} (212 re 1 µPa)	Maximum	110 m	130 m	160 m	170 m
	Minimum	100 m	120 m	150 m	160 m
	Mean	110 m	130 m	160 m	170 m
	Area	< 0.1 km²	0.1 km²	0.1 km²	0.1 km²

Table A 63 Predicted unweighted SPL_{peak} impact ranges for phocid pinnipeds using criteria from NMFS (2016) at Creyke Beck B, location ID13

Phocid pinnipeds - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Sequence 1 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 1 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	4.5 km	6.7 km	7.4 km	7.9 km
	Minimum	3.9 km	5.7 km	6.2 km	6.6 km
	Mean	4.1 km	6.1 km	6.7 km	7.1 km
	Area	53 km²	110 km²	140 km²	160 km²
Sequence 2 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 2 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	6.8 km	9.6 km	10.4 km	11.1 km
	Minimum	5.4 km	7.4 km	8.0 km	8.5 km
	Mean	5.9 km	8.3 km	9.0 km	9.5 km
	Area	110 km²	220 km²	250 km²	290 km²
Sequence 3 – PTS weighted SEL_{cum} (185 dB re 1 µPa²s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km²	< 0.1 km²	< 0.1 km²	< 0.1 km²
Sequence 3 – TTS weighted SEL_{cum} (170 dB re 1 µPa²s)	Maximum	7.7 km	10.8 km	11.8 km	12.5 km
	Minimum	5.7 km	7.8 km	8.4 km	8.9 km
	Mean	6.5 km	9.0 km	9.8 km	10.4 km
	Area	130 km²	260 km²	300 km²	340 km²

Table A 64 Predicted phocid pinnipeds weighted SEL_{cum} impact ranges using criteria from NMFS (2016) assuming a fleeing speed of 1.5 ms^{-1} for the three piling sequences at Creyke Beck B, location ID13

<u>Popper et al (2014) impact ranges</u>

Fish - impact criterion		2300 kJ hammer energy	3000 kJ hammer energy	3600 kJ hammer energy	4000 kJ hammer energy
Injury (fish: no swim bladder) unweighted SPL_{peak} (213 re 1 µPa)	Maximum	90 m	120 m	140 m	150 m
	Minimum	80 m	110 m	130 m	140 m
	Mean	90 m	120 m	140 m	150 m
	Area	< 0.1 km²	< 0.1 km²	0.1 km²	0.1 km²
Injury (fish: with swim bladder) unweighted SPL_{peak} (207 re 1 µPa)	Maximum	200 m	250 m	300 m	340 m
	Minimum	190 m	240 m	290 m	320 m
	Mean	200 m	250 m	300 m	330 m
	Area	0.1 km²	0.2 km²	0.3 km²	0.3 km²

Table A 65 Predicted unweighted SPL_{peak} impact ranges for fish using criteria from Popper et al. (2014) at Creyke Beck B, location ID13

Fish - impact criterion **(Sequence 1)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	5.5 km	8.2 km	9.0 km	9.6 km
	Minimum	4.7 km	6.9 km	7.5 km	7.9 km
	Mean	5.1 km	7.4 km	8.1 km	8.6 km
	Area	80 km^2	170 km^2	200 km^2	230 km^2

Table A 66 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 1 at Creyke Beck B, location ID13

Fish - impact criterion **(Sequence 2)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^2s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^2s)	Maximum	8.1 km	11.4 km	12.4 km	13.0 km
	Minimum	6.4 km	8.7 km	9.4 km	9.8 km
	Mean	7.1 km	9.9 km	10.6 km	11.1 km
	Area	160 km^2	310 km^2	360 km^2	390 km^2

Table A 67 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 2 at Creyke Beck B, location ID13

Fish - impact criterion **(Sequence 3)**		**2300 kJ hammer energy**	**3000 kJ hammer energy**	**3600 kJ hammer energy**	**4000 kJ hammer energy**
Mortality (fish: no swim bladder) SEL_{cum} (> 219 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: no swim bladder) SEL_{cum} (> 216 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder not involved in hearing) SEL_{cum} (210 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Mortality (fish: swim bladder involved in hearing) SEL_{cum} (207 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
Recoverable injury (fish: with swim bladder) SEL_{cum} (203 dB re 1 µPa^{2}s)	Maximum	< 100 m	< 100 m	< 100 m	< 100 m
	Minimum	< 100 m	< 100 m	< 100 m	< 100 m
	Mean	< 100 m	< 100 m	< 100 m	< 100 m
	Area	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2	< 0.1 km^2
TTS (all fish) SEL_{cum} (186 re 1 µPa^{2}s)	Maximum	9.2 km	13.0 km	14.0 km	14.8 km
	Minimum	6.7 km	9.2 km	9.8 km	10.3 km
	Mean	7.7 km	10.7 km	11.5 km	12.1 km
	Area	190 km^2	360 km^2	420 km^2	460 km^2

Table A 68 Predicted unweighted SEL_{cum} impact ranges for fish using criteria from Popper et al. (2014) assuming a fleeing speed of 1.5 ms^{-1} for piling sequence 3 at Creyke Beck B, location ID13

Appendix B Modelling figures

This appendix presents the modelled impact ranges from section 4 and Appendix A as contour plots. Only the impact ranges large enough to be shown clearly for the map scale have been included here.

B.1 Creyke Beck A, location ID6

Previously considered criteria contour plots

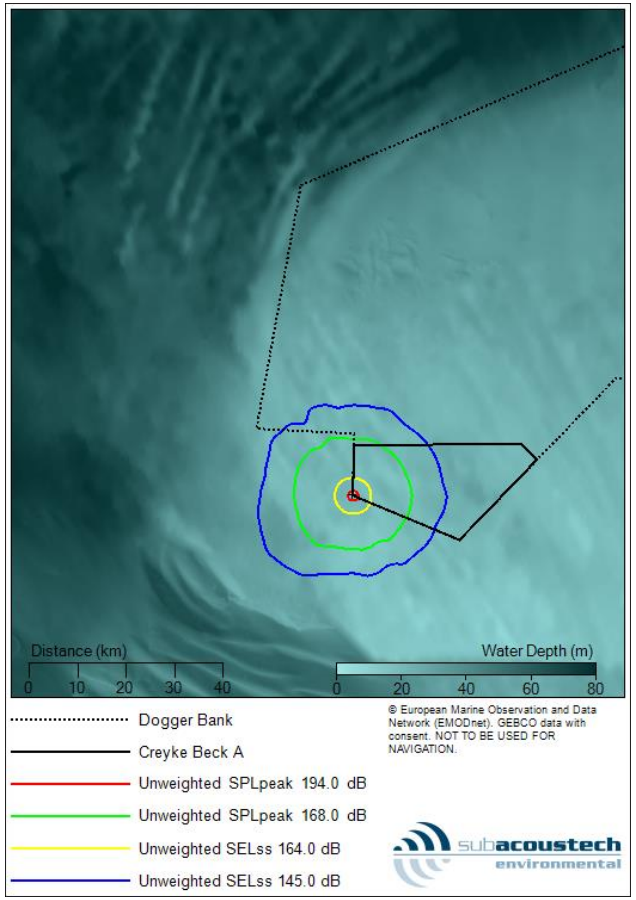

Figure B 1 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

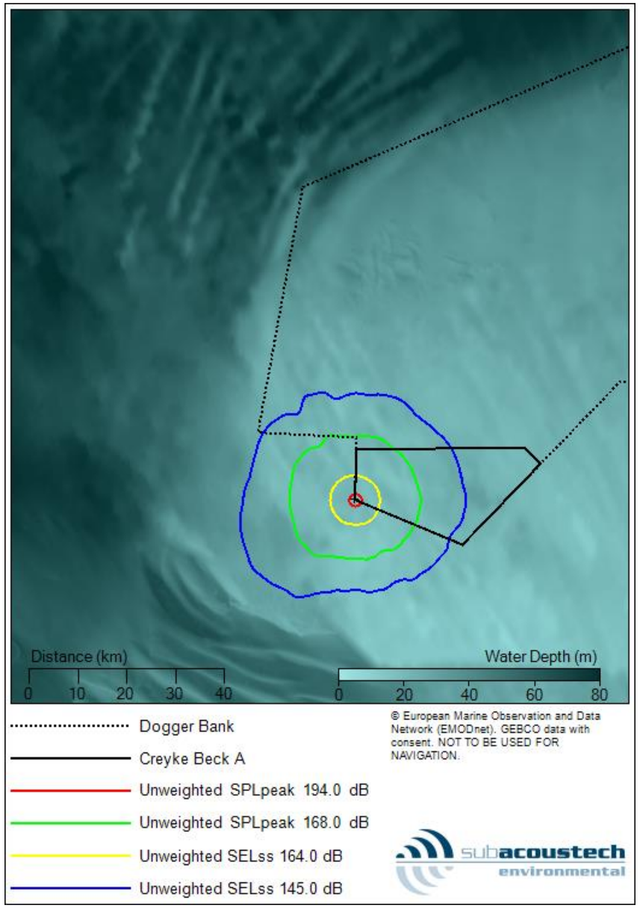

Figure B 2 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

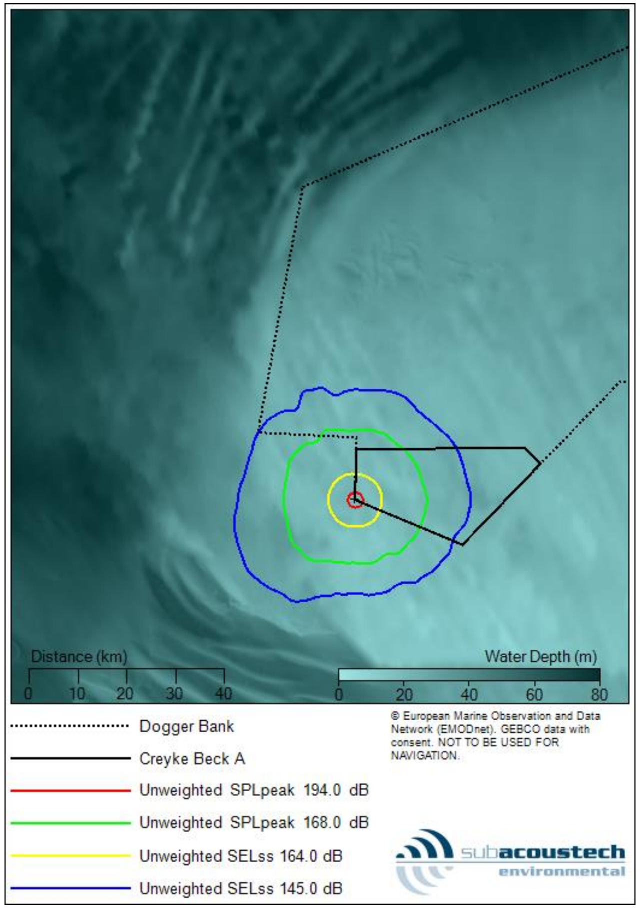

Figure B 3 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

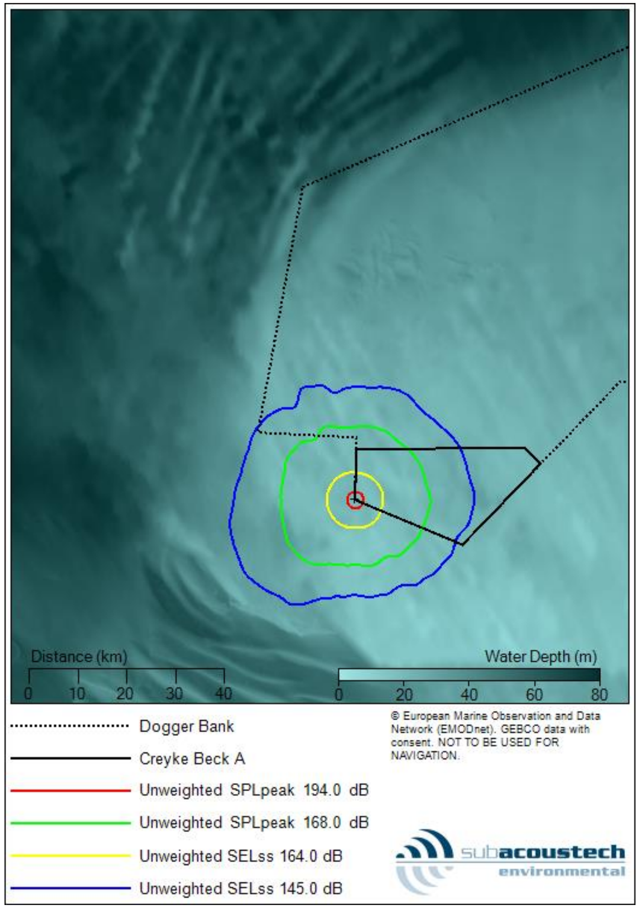

Figure B 4 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

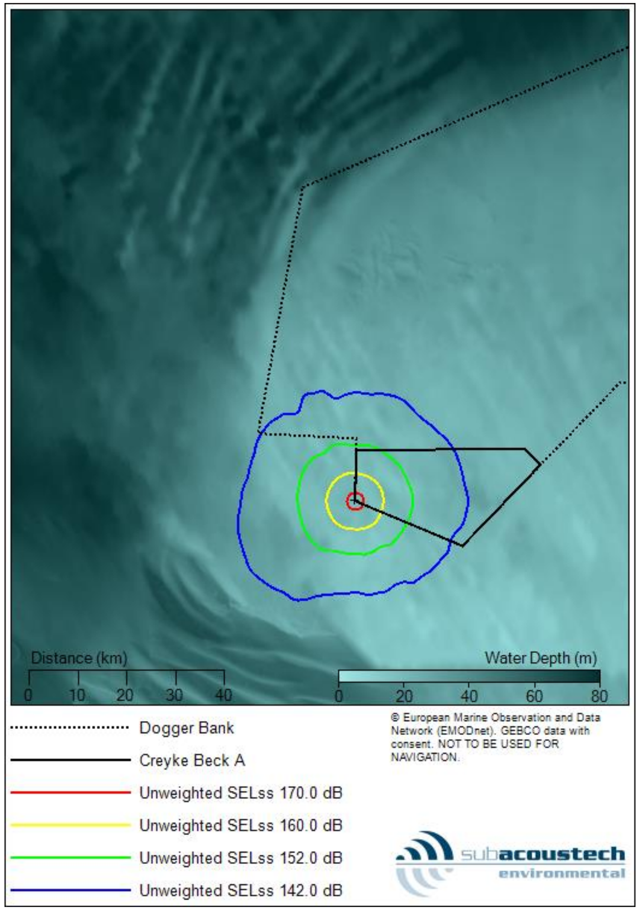

Figure B 5 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

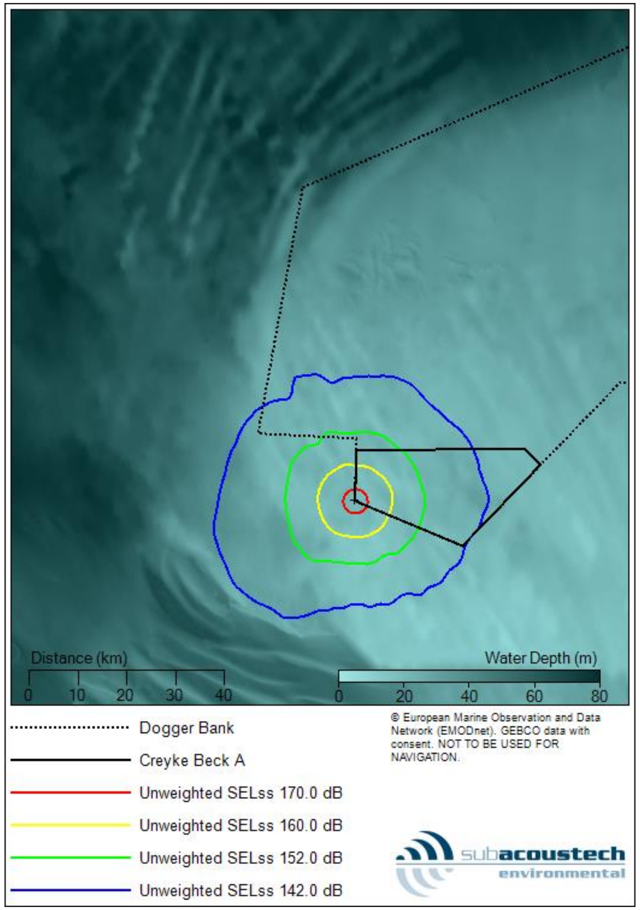

Figure B 6 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

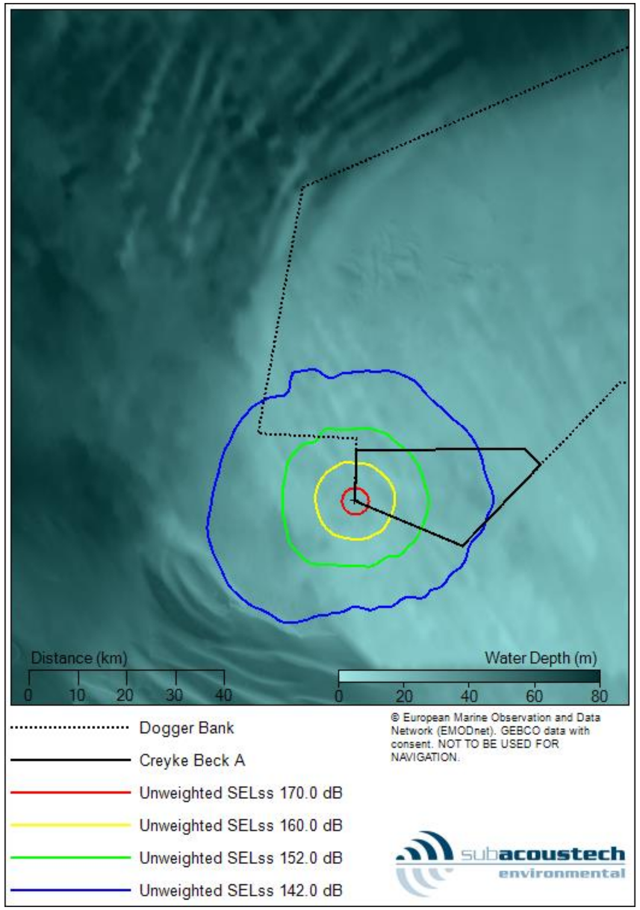

Figure B 7 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

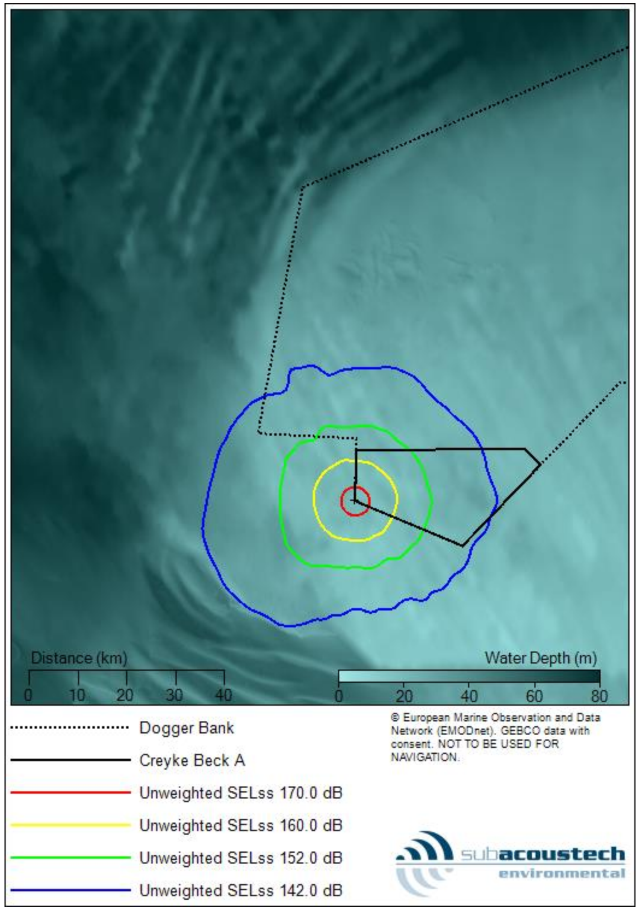

Figure B 8 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

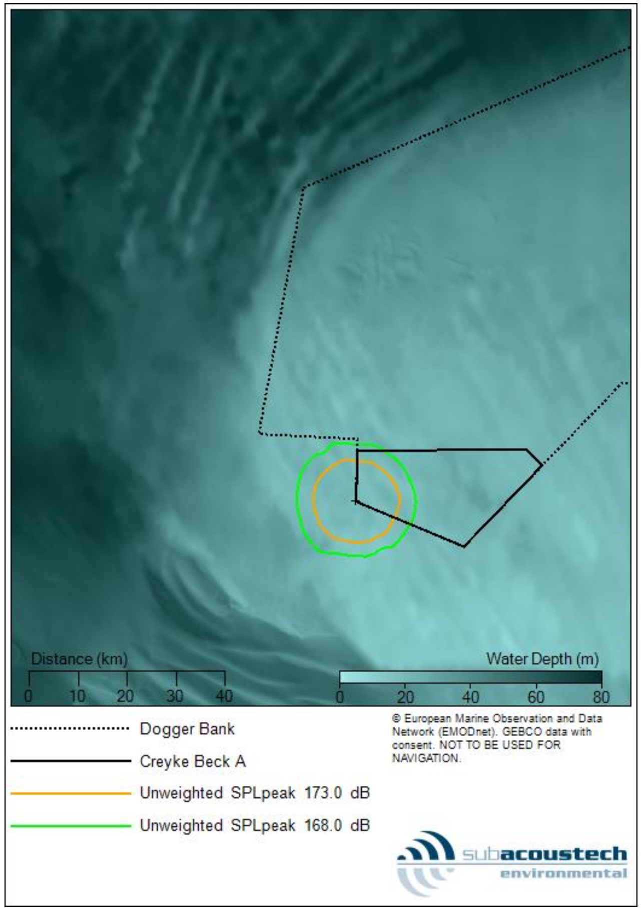

Figure B 9 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

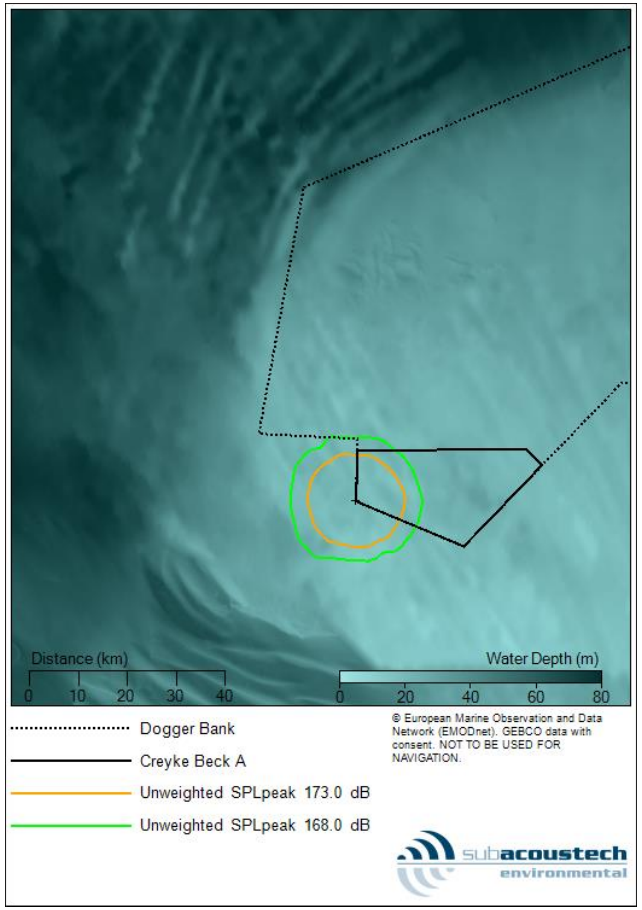

Figure B 10 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

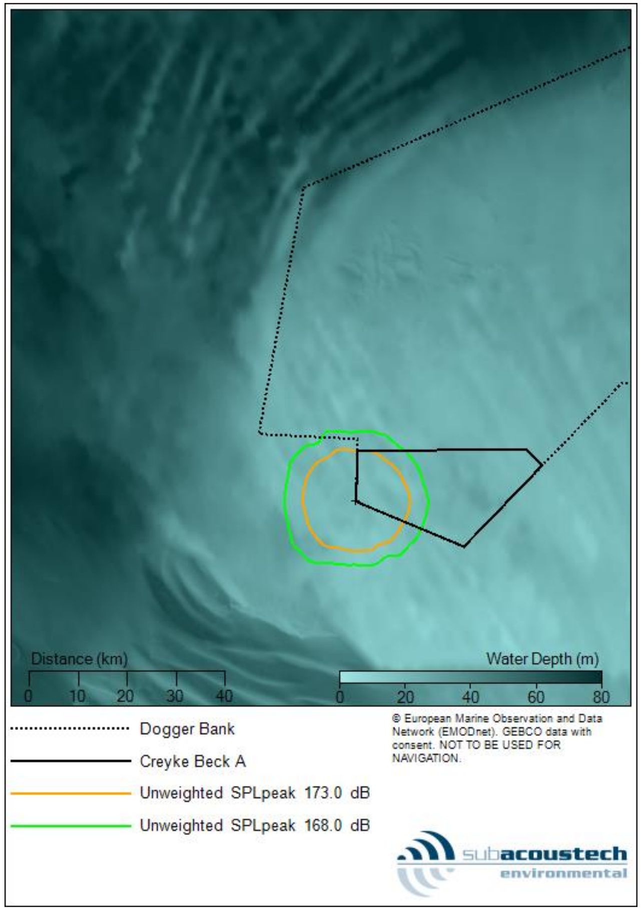

Figure B 11 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

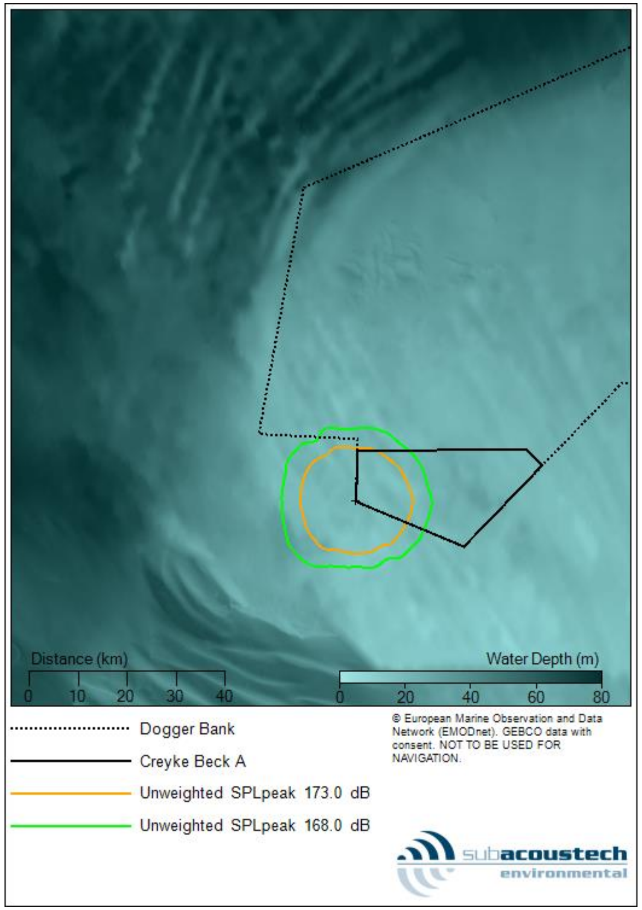

Figure B 12 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

NMFS (2016) contour plots

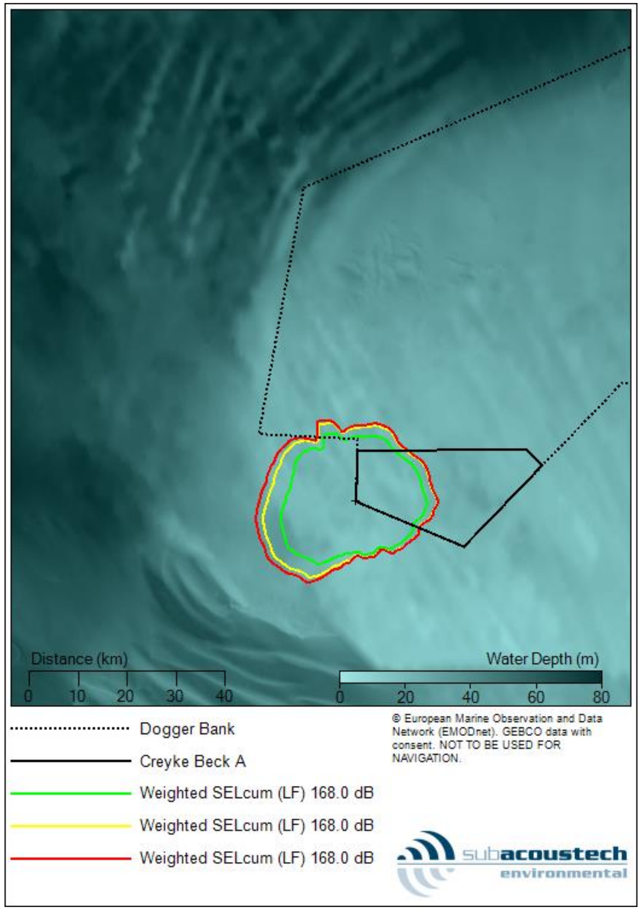

Figure B 13 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

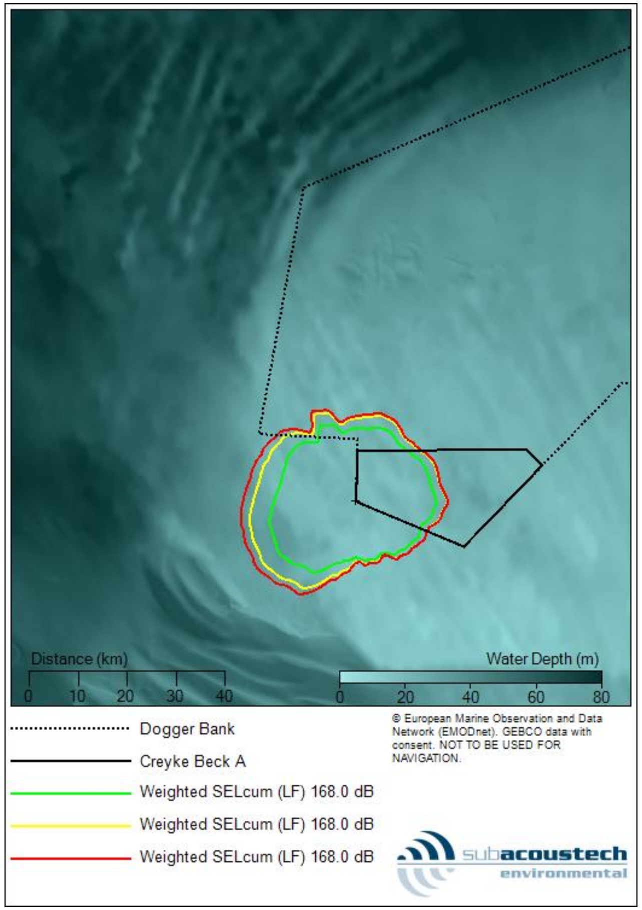

Figure B 14 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

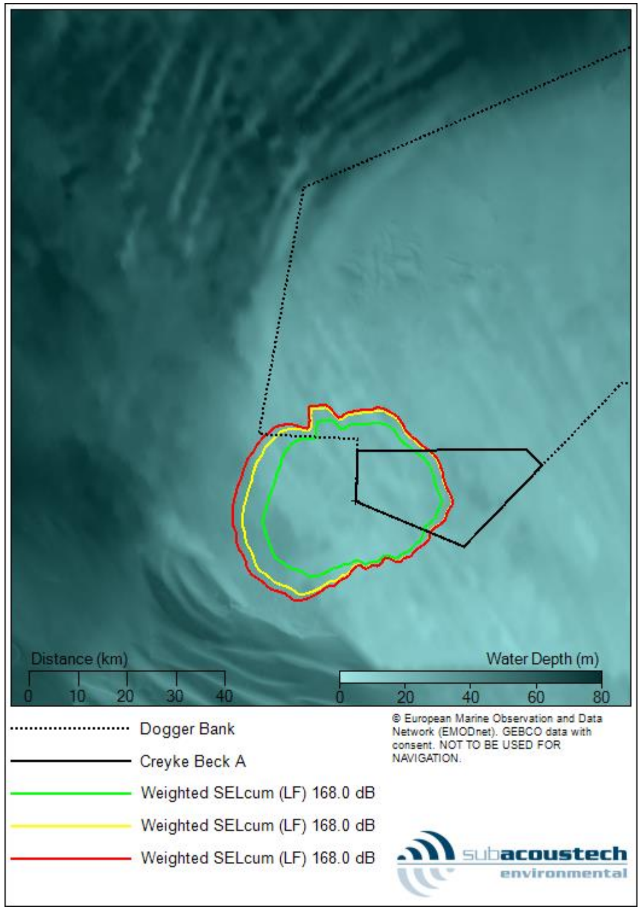

Figure B 15 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

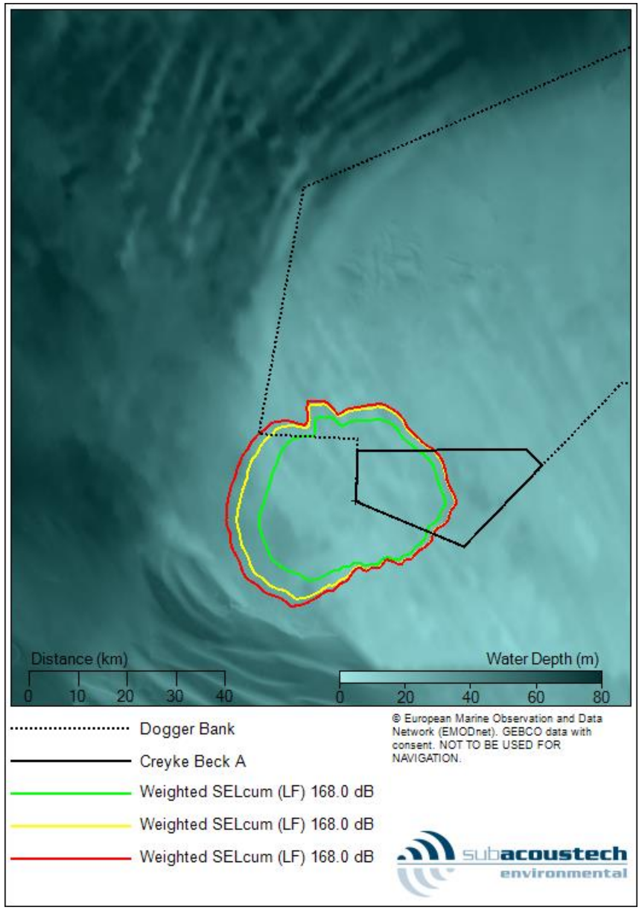

Figure B 16 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

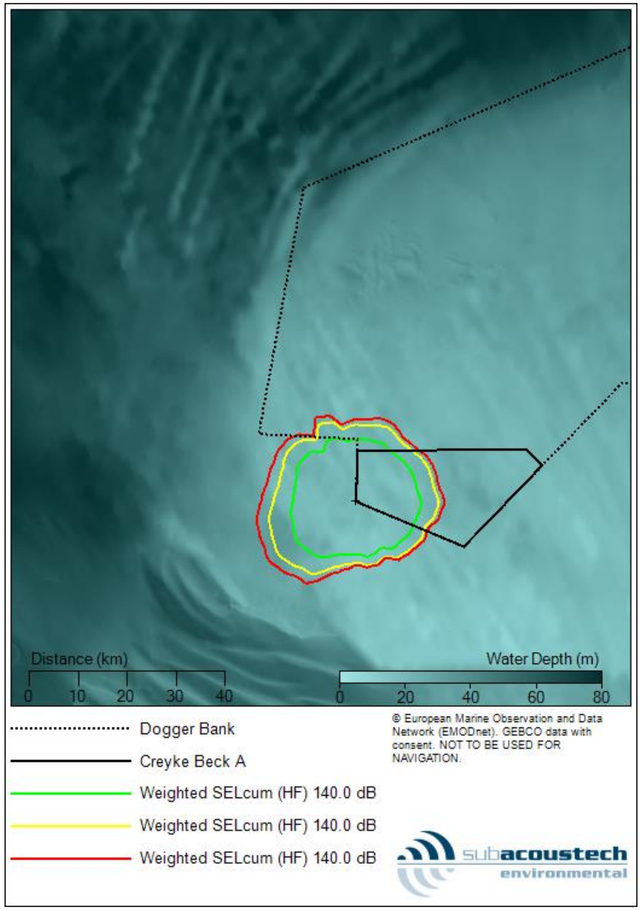

Figure B 17 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

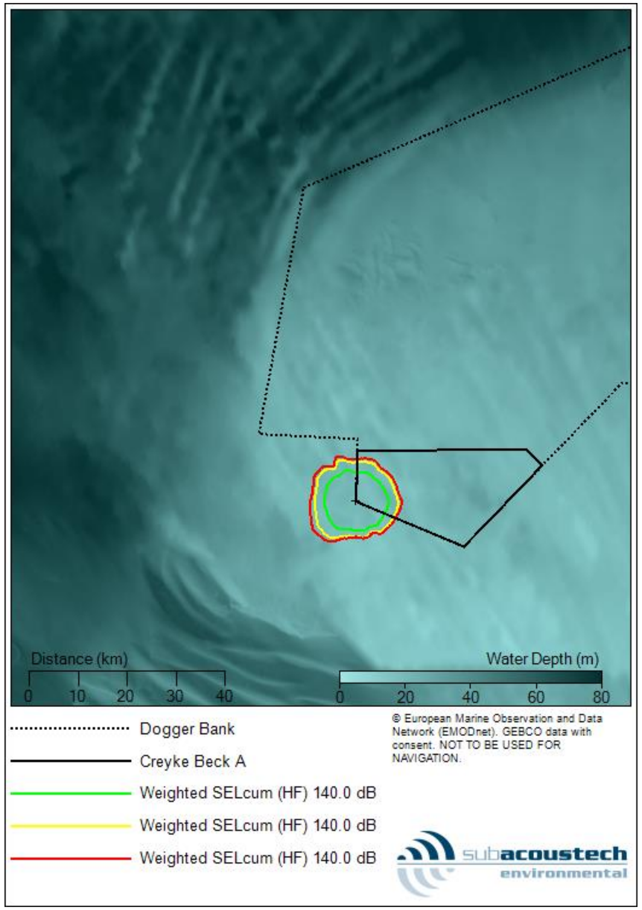

Figure B 18 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

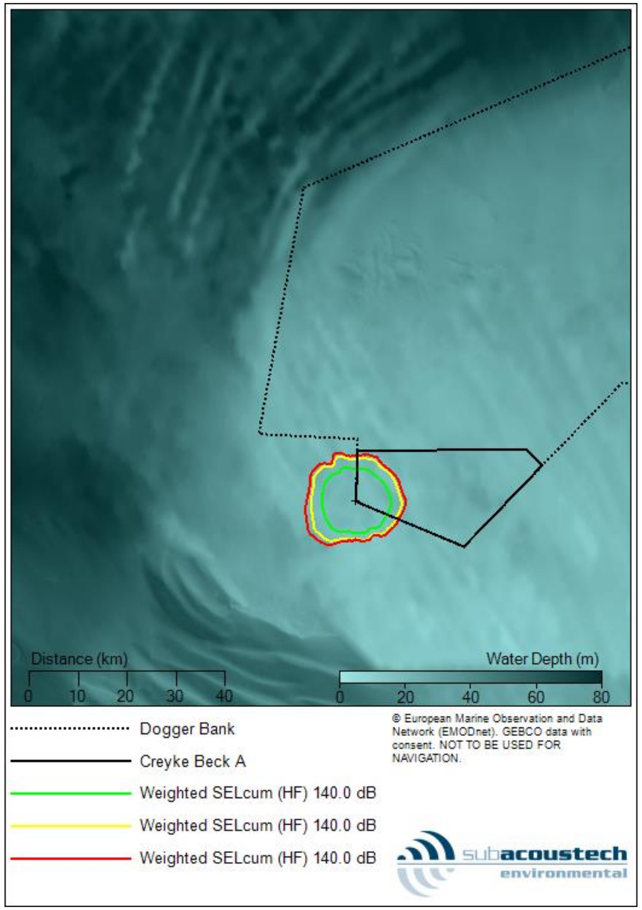

Figure B 19 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

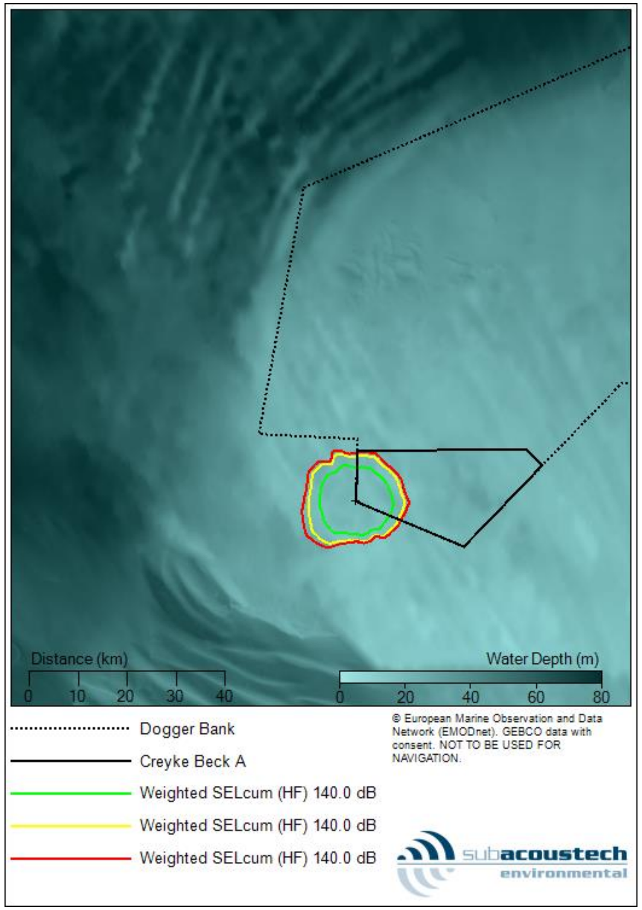

Figure B 20 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

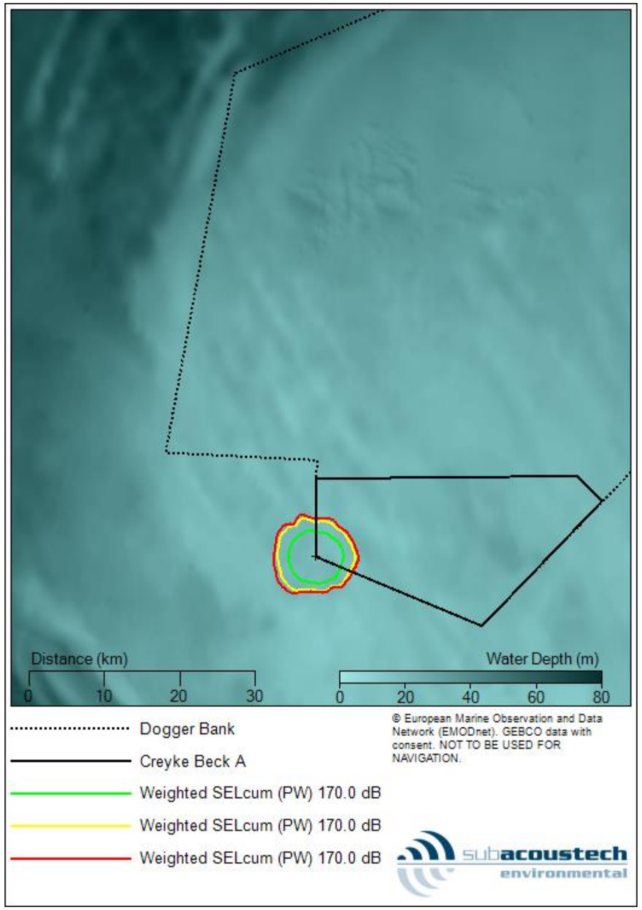

Figure B 21 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

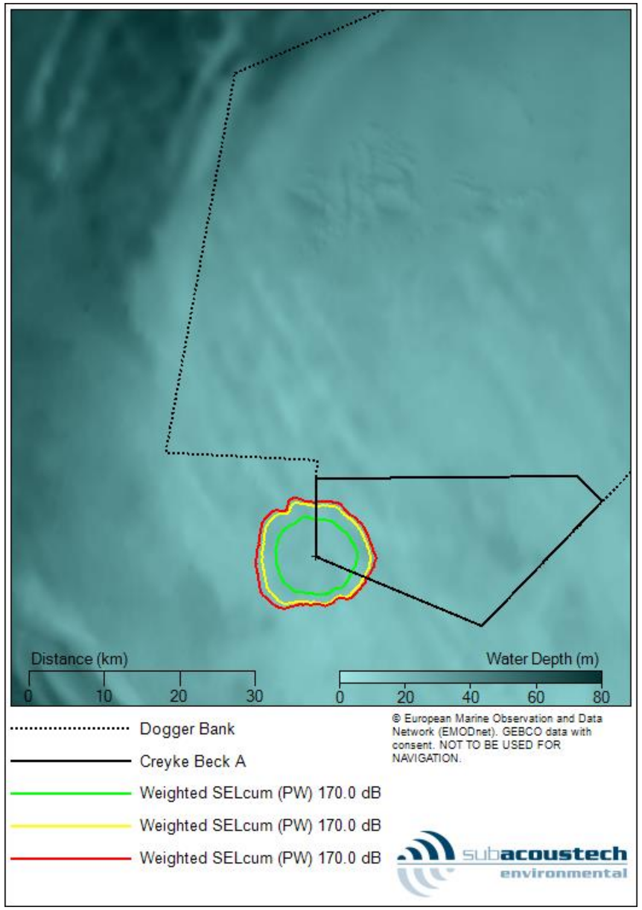

Figure B 22 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

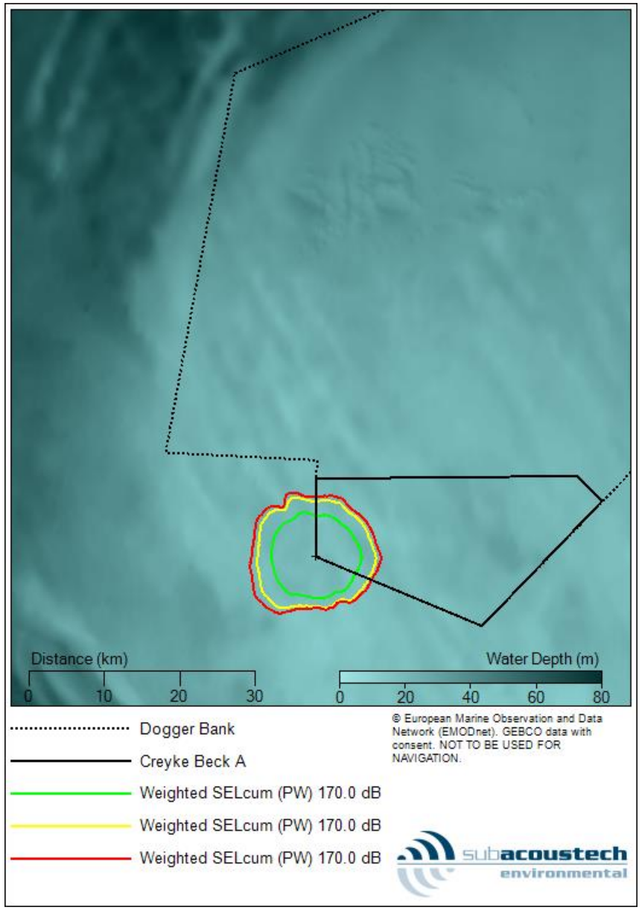

Figure B 23 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

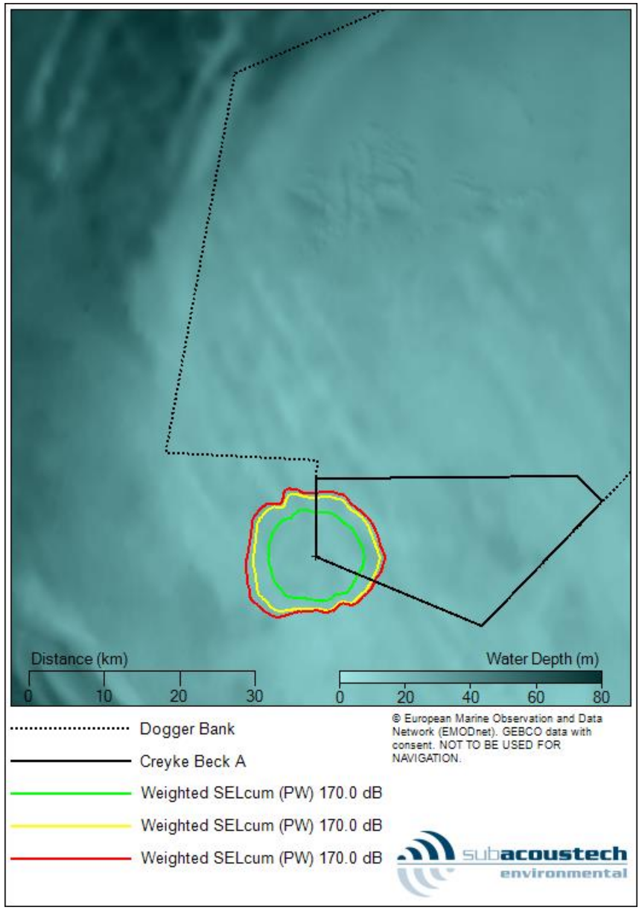

Figure B 24 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

Popper et al. (2014) contour plots

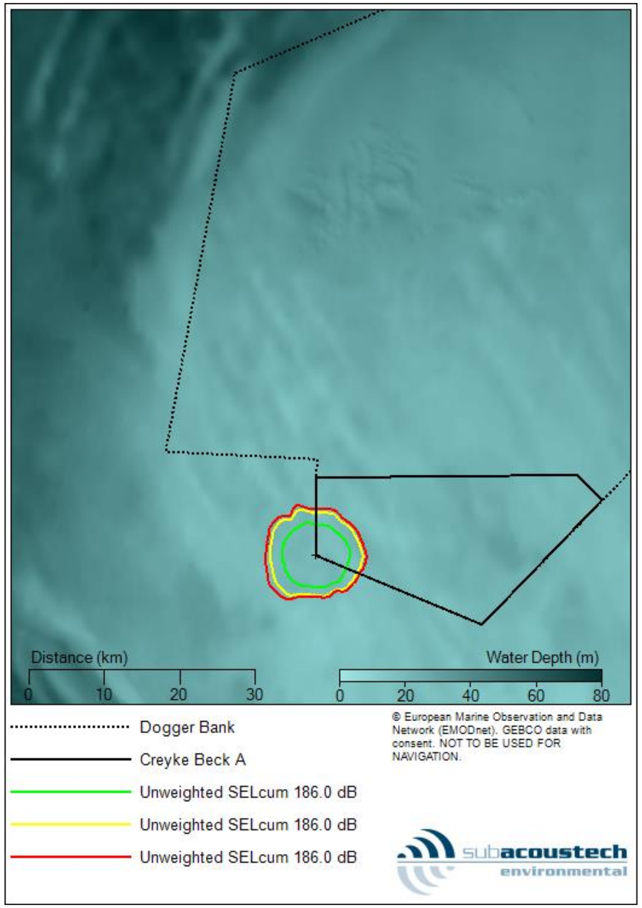

Figure B 25 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

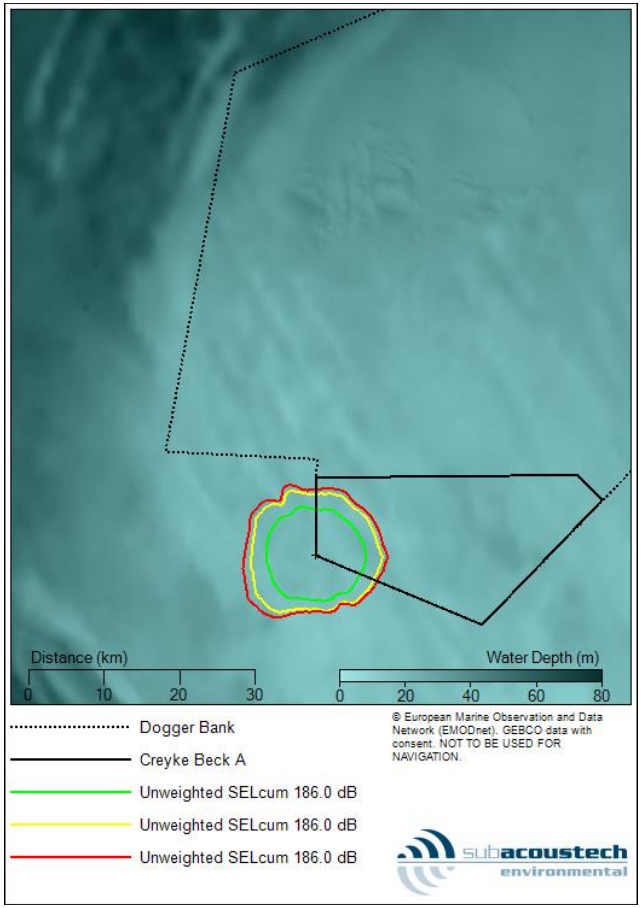

Figure B 26 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

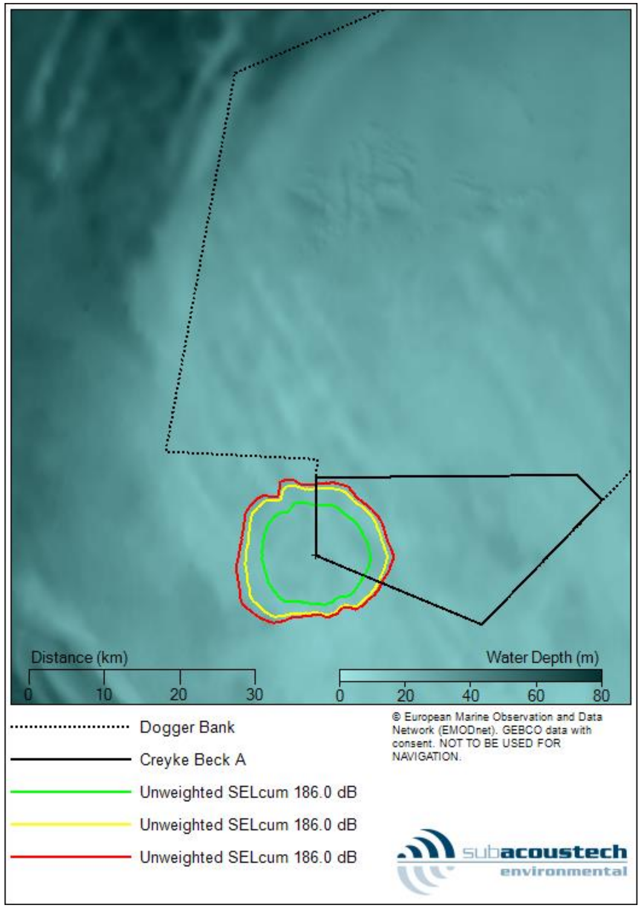

Figure B 27 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

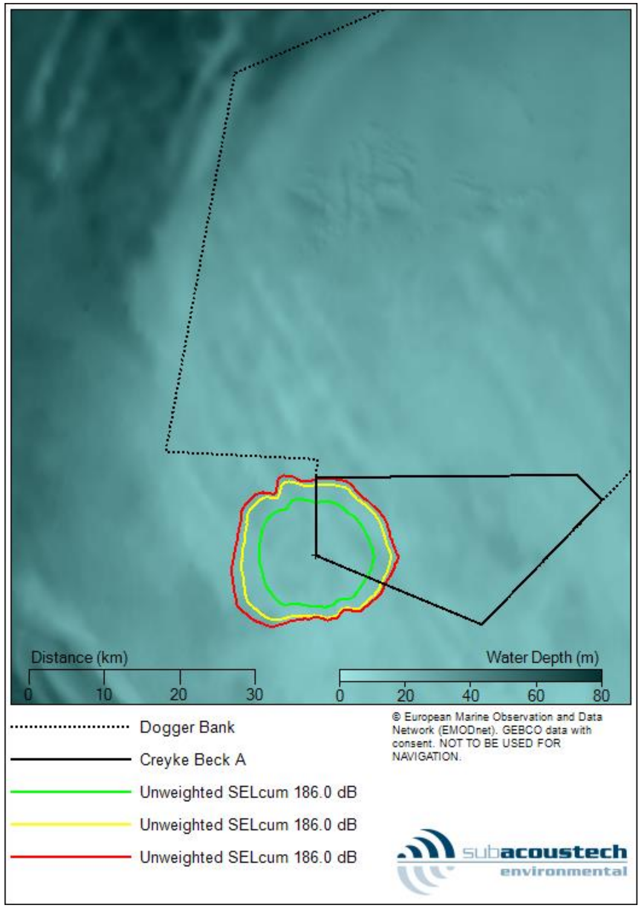

Figure B 28 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

B.2 Creyke Beck A, location ID11

Previously considered criteria contour plots

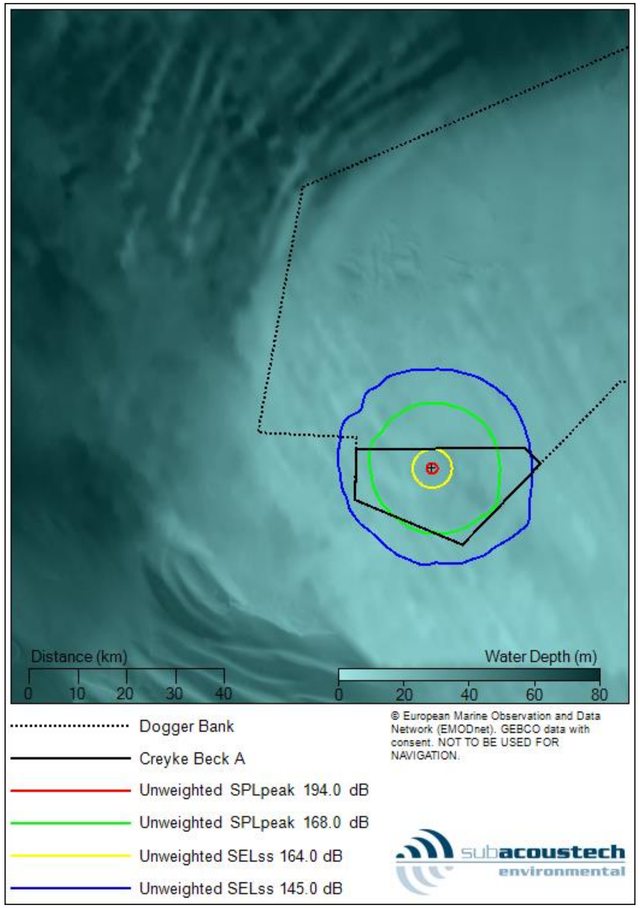

Figure B 29 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ

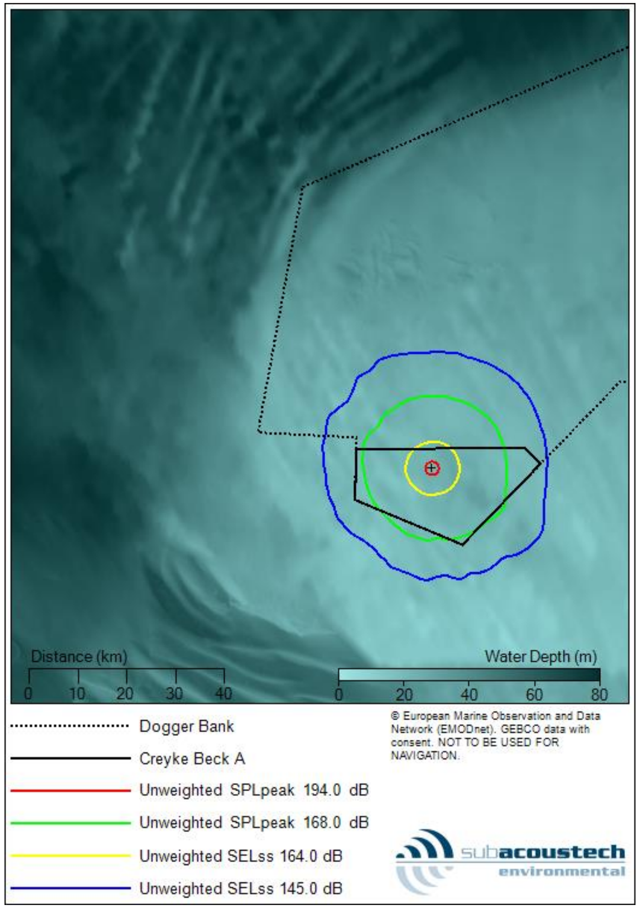

Figure B 30 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ

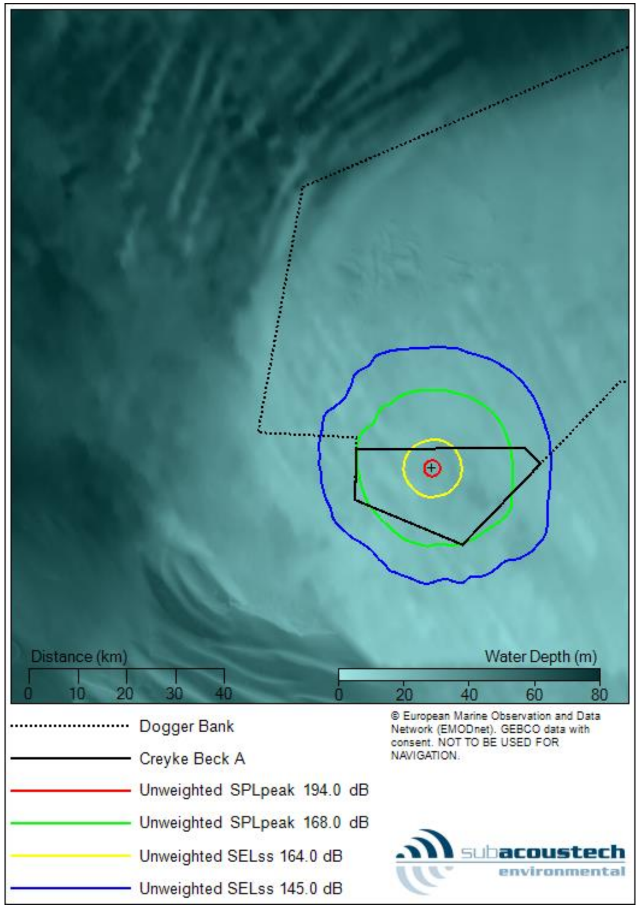

Figure B 31 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ

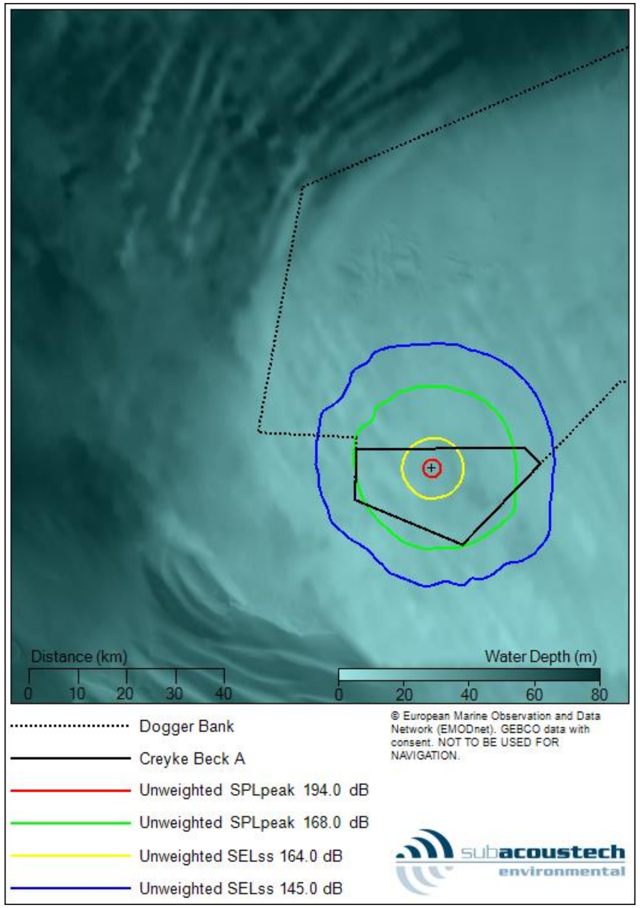

Figure B 32 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ

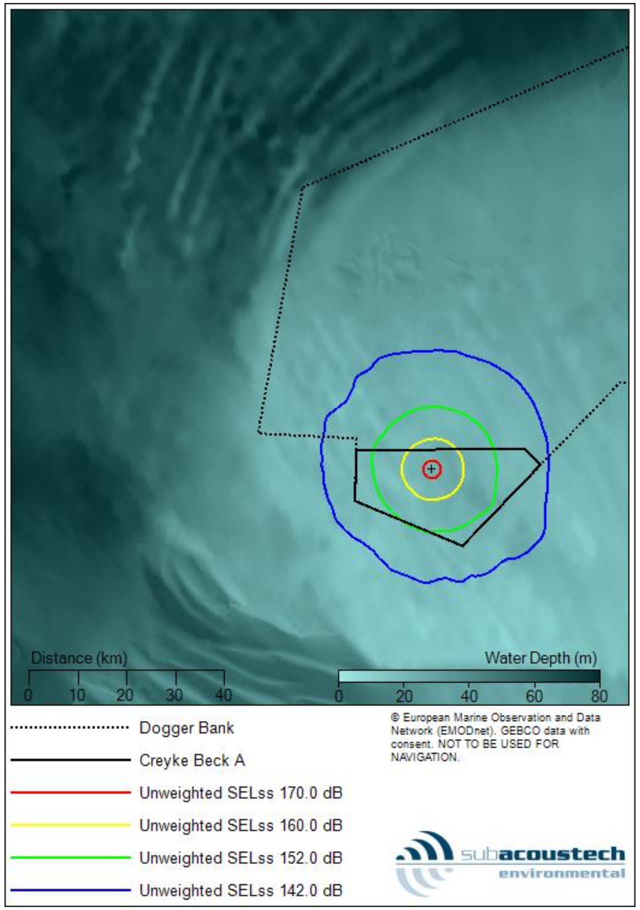

Figure B 33 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ

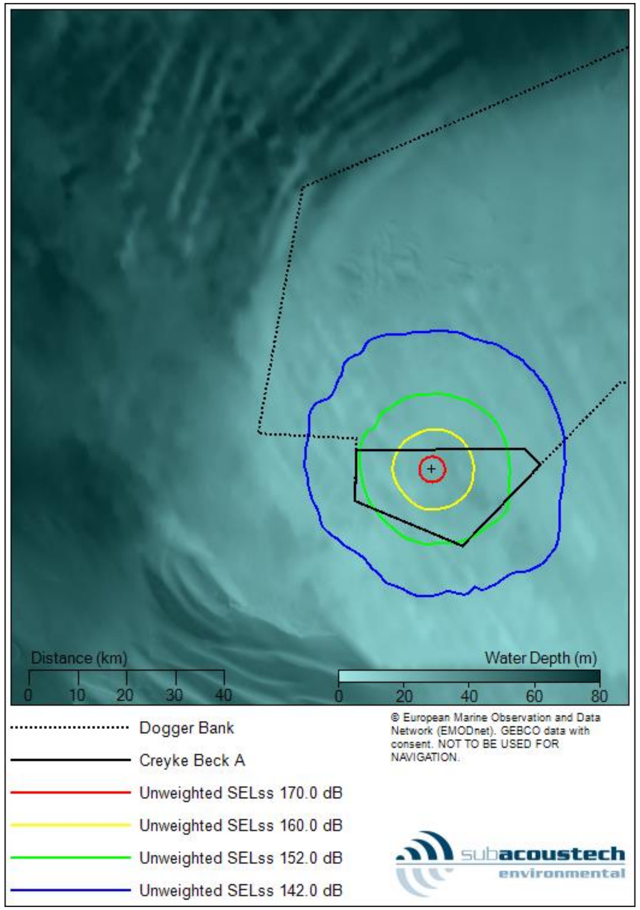

Figure B 34 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ

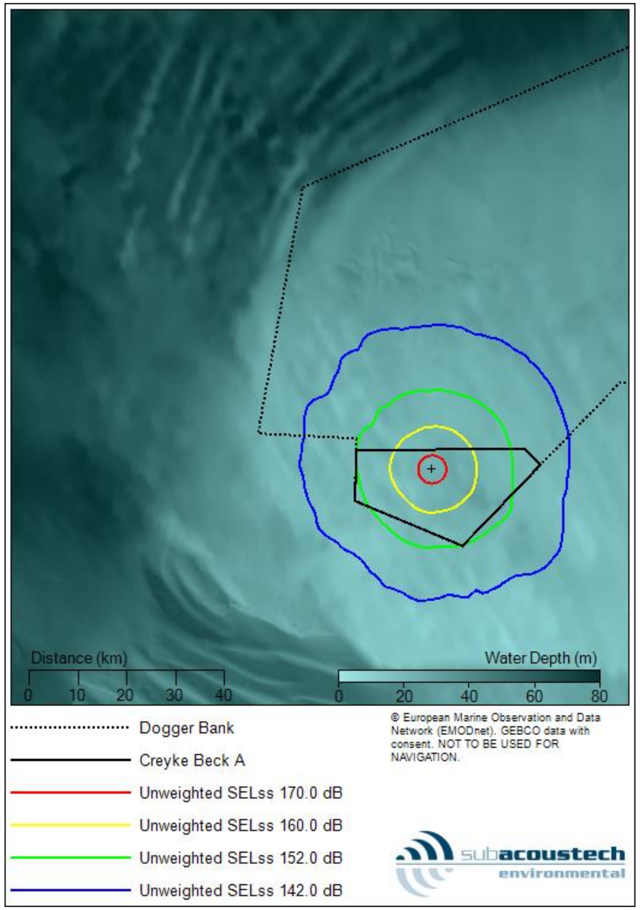

Figure B 35 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ

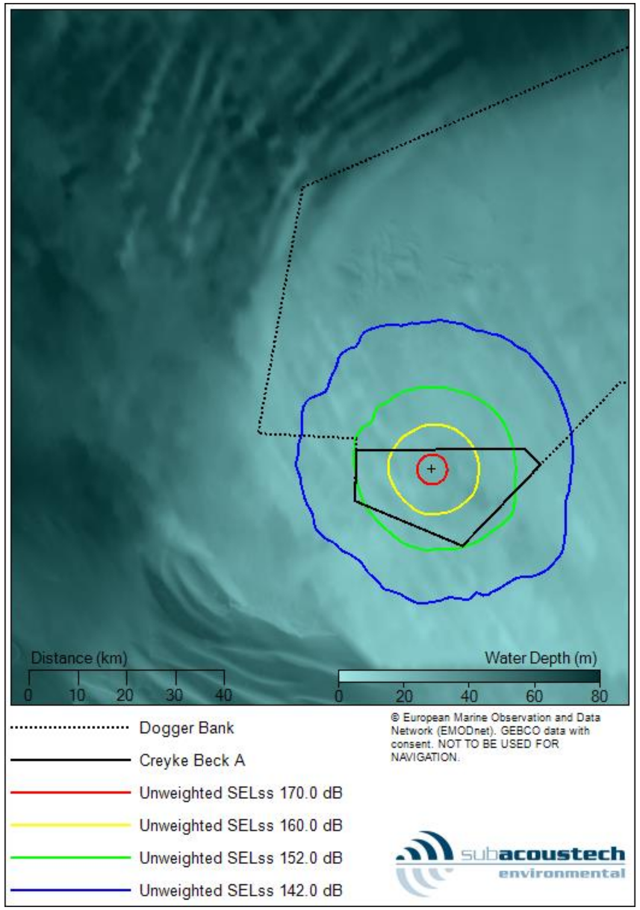

Figure B 36 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ

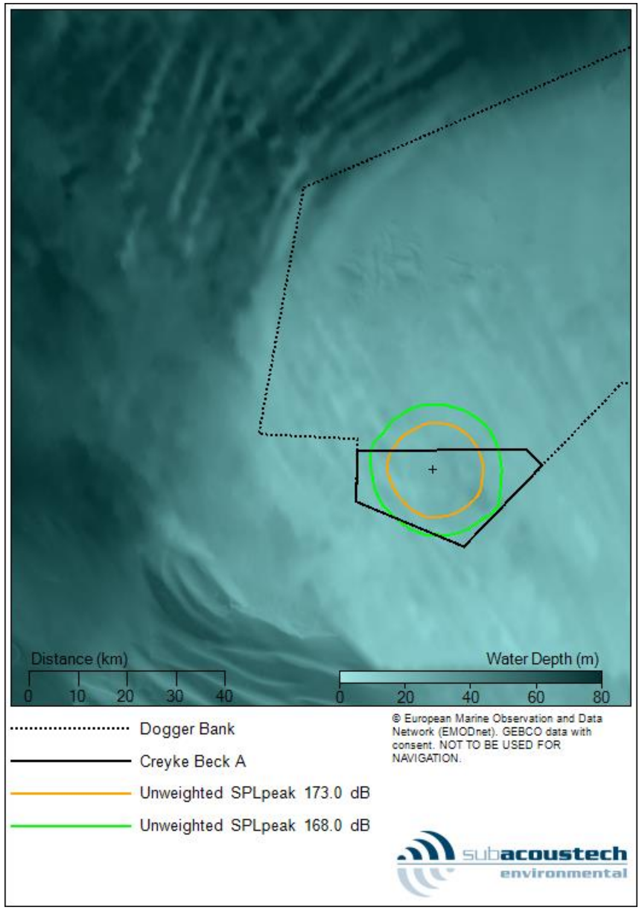

Figure B 37 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ

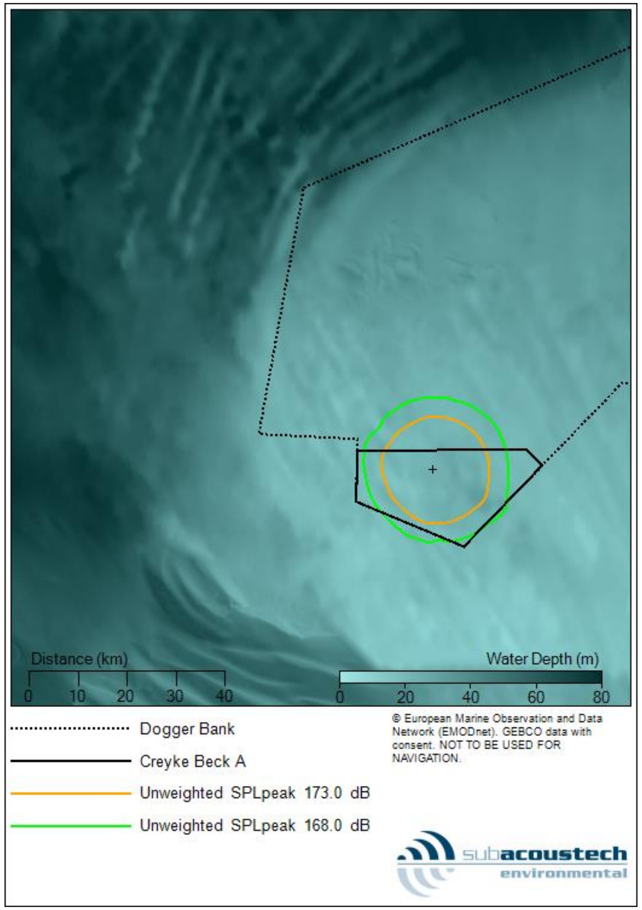

Figure B 38 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ

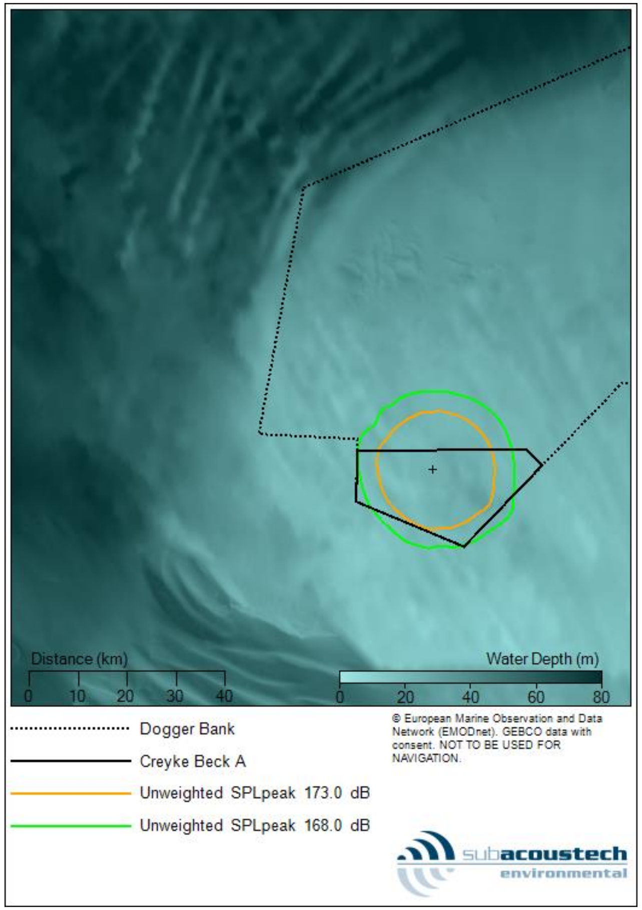

Figure B 39 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ

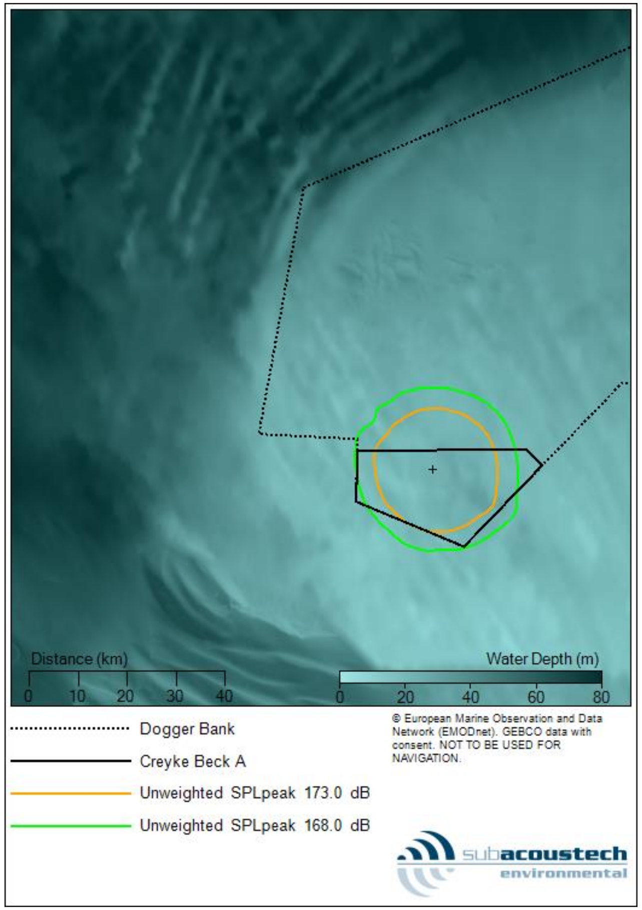

Figure B 40 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ

NMFS (2016) contour plots

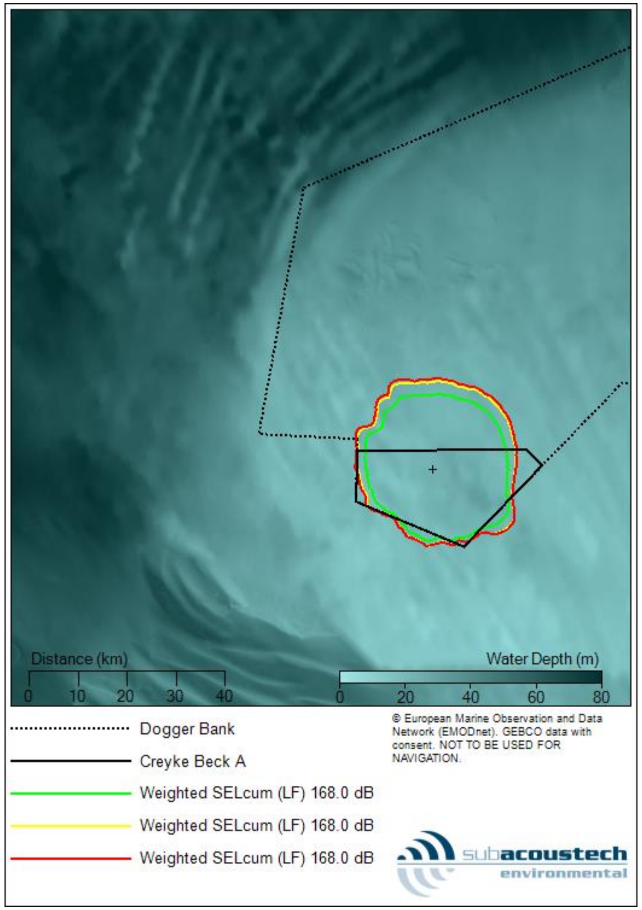

Figure B 41 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

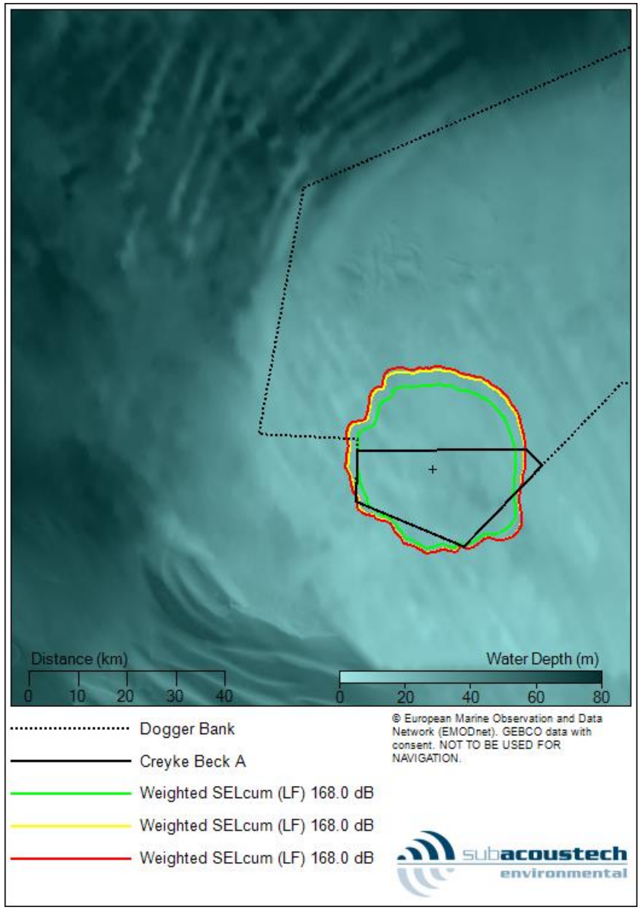

Figure B 42 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

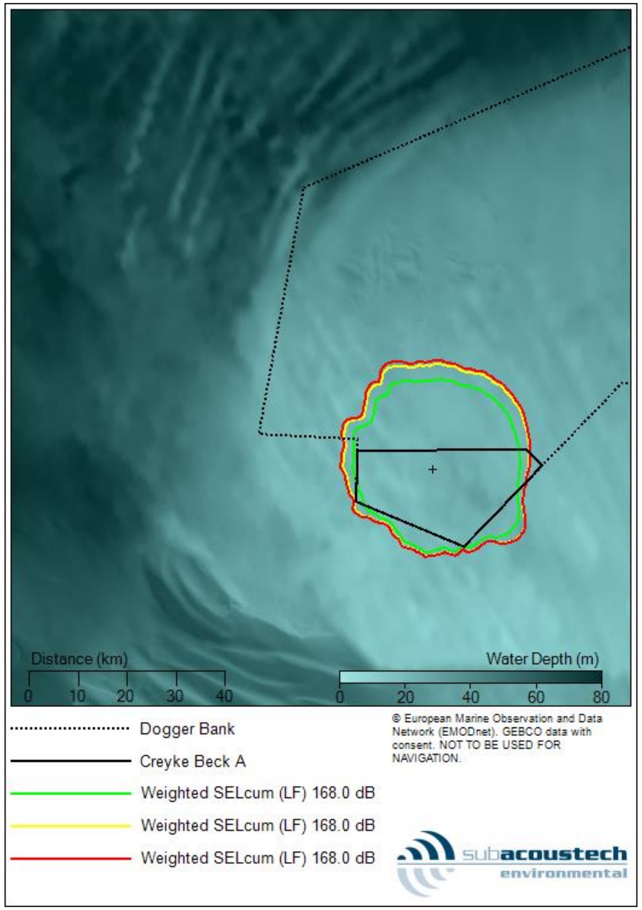

Figure B 43 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

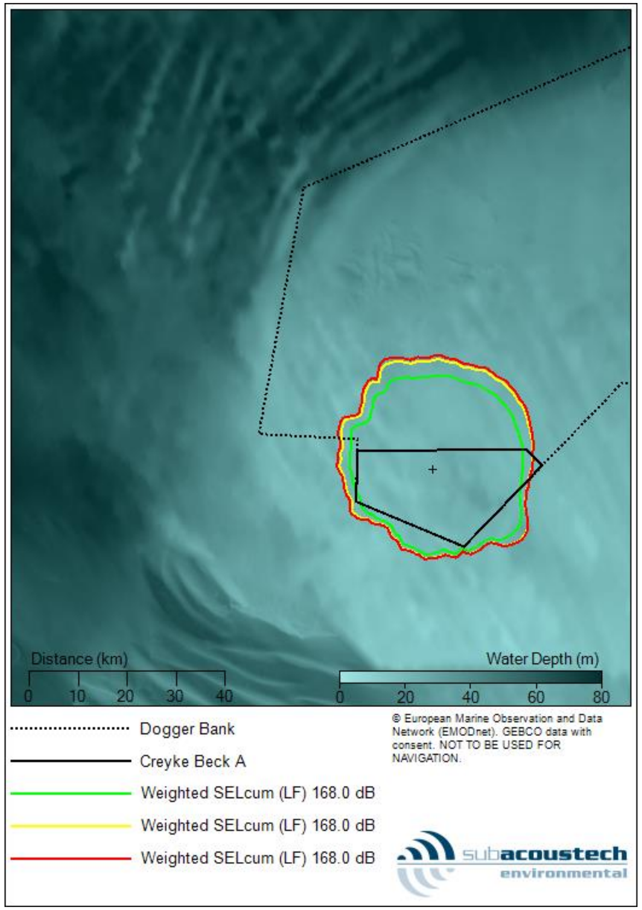

Figure B 44 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

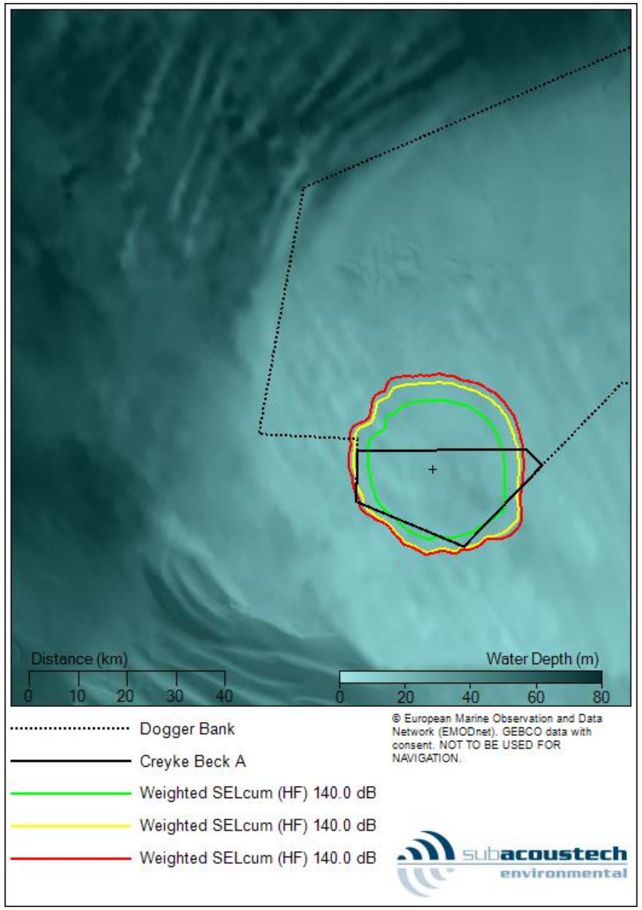

Figure B 45 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

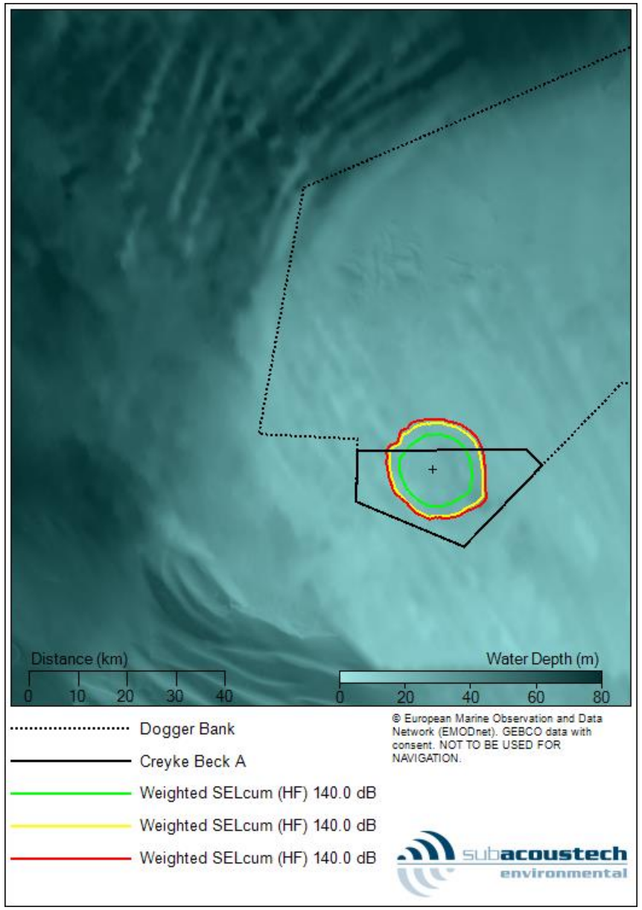

Figure B 46 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

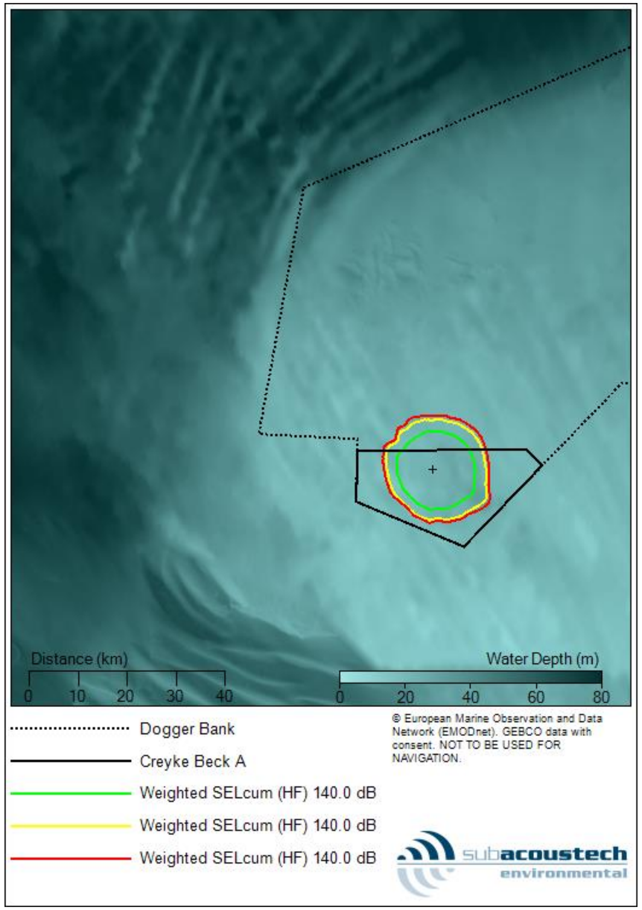

Figure B 47 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

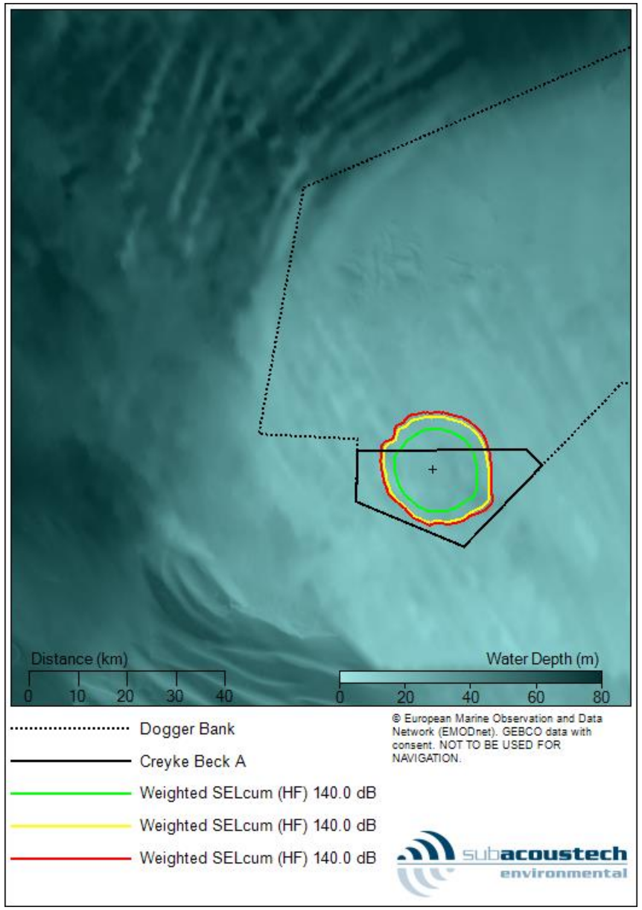

Figure B 48 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

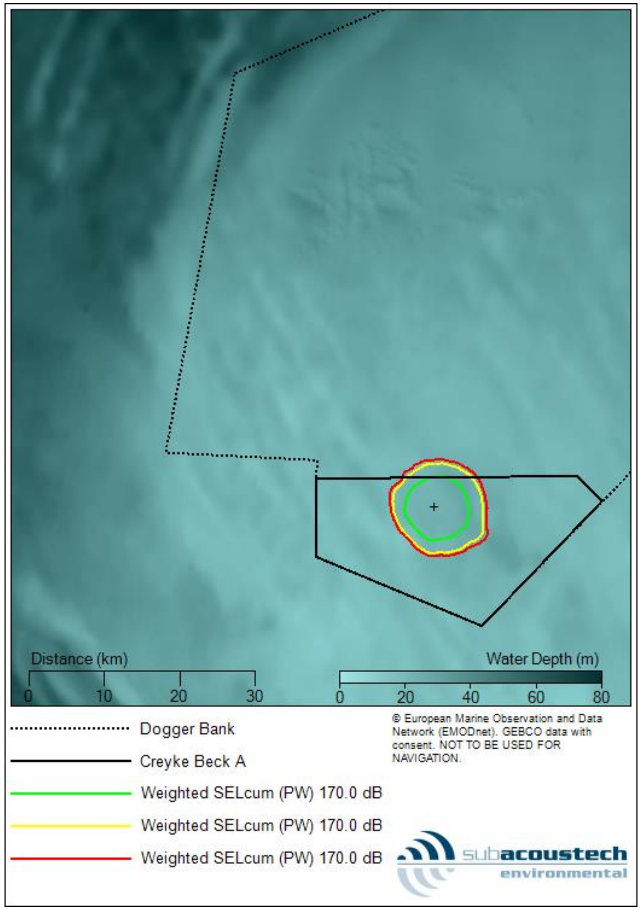

Figure B 49 Contour plot showing the weighted SEL$_{cum}$ impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

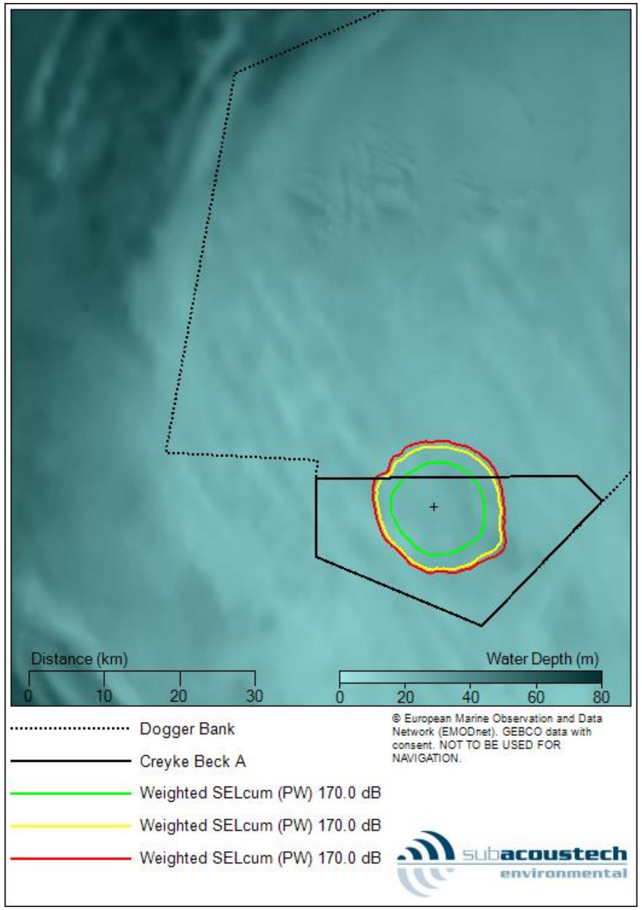

Figure B 50 Contour plot showing the weighted SEL$_{cum}$ impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

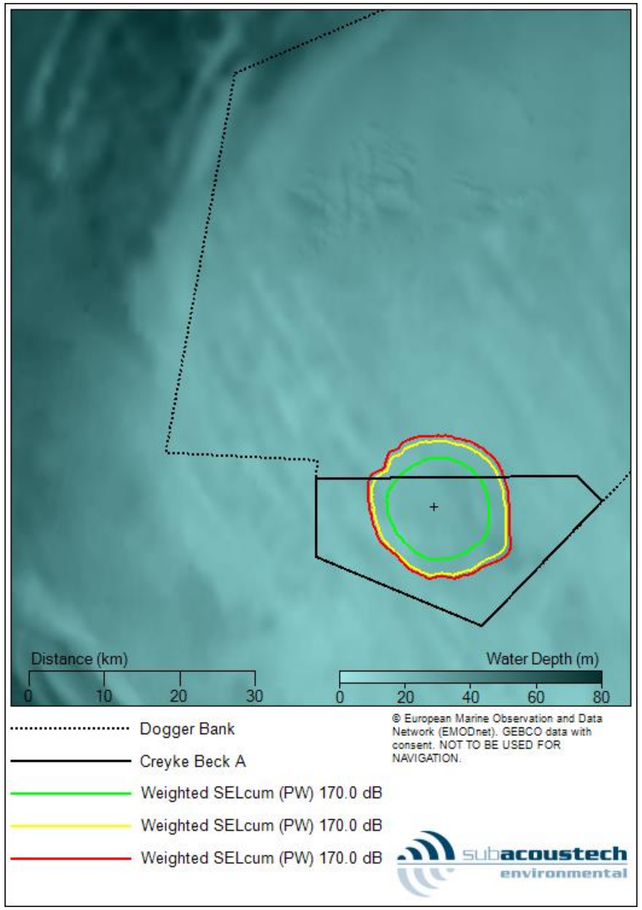

Figure B 51 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

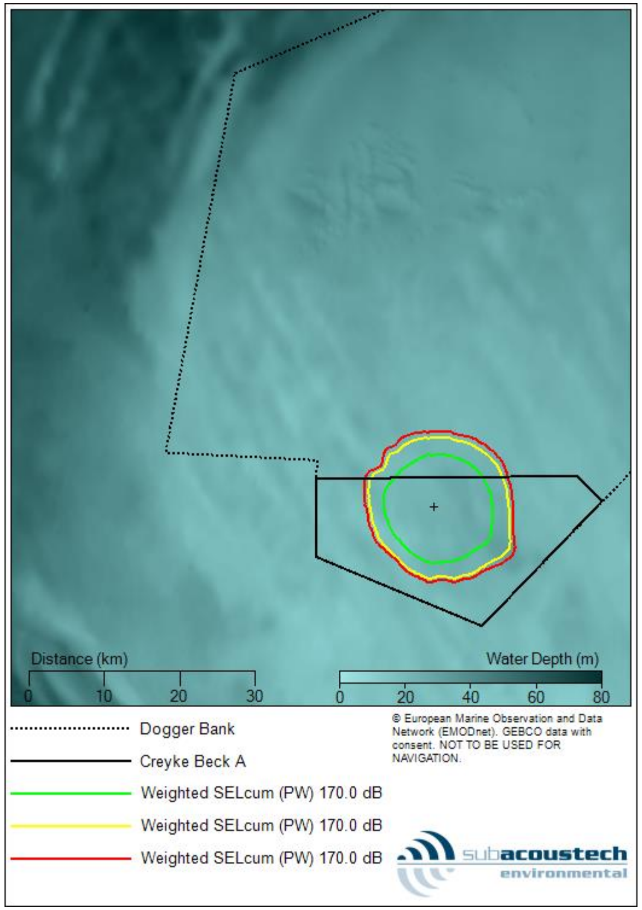

Figure B 52 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

Popper et al. (2014) contour plots

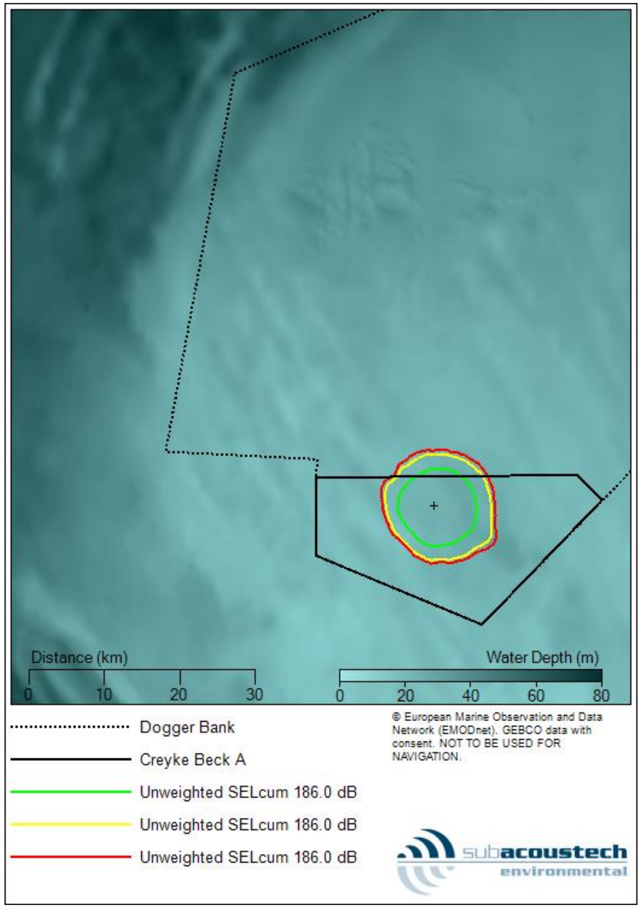

Figure B 53 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID11 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

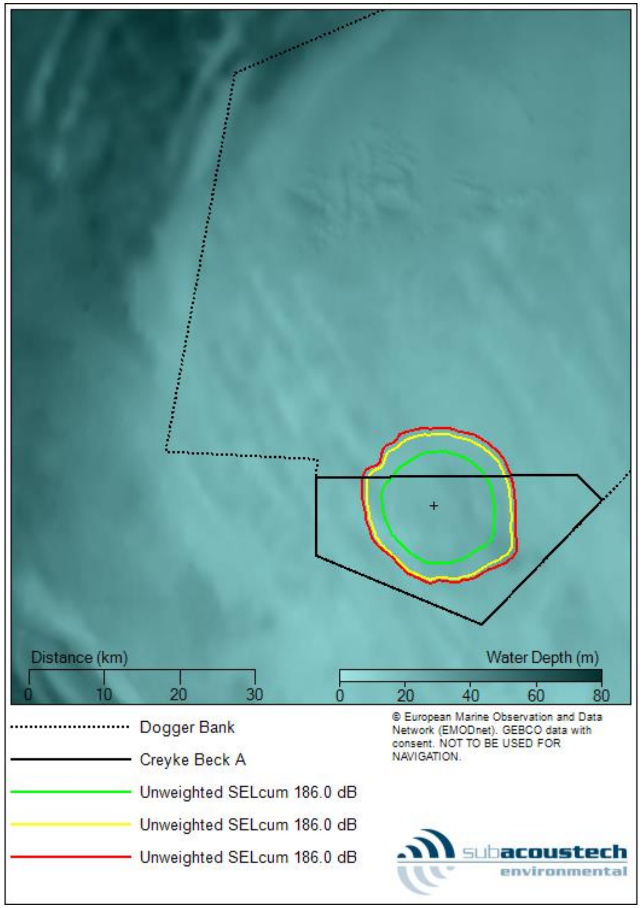

Figure B 54 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

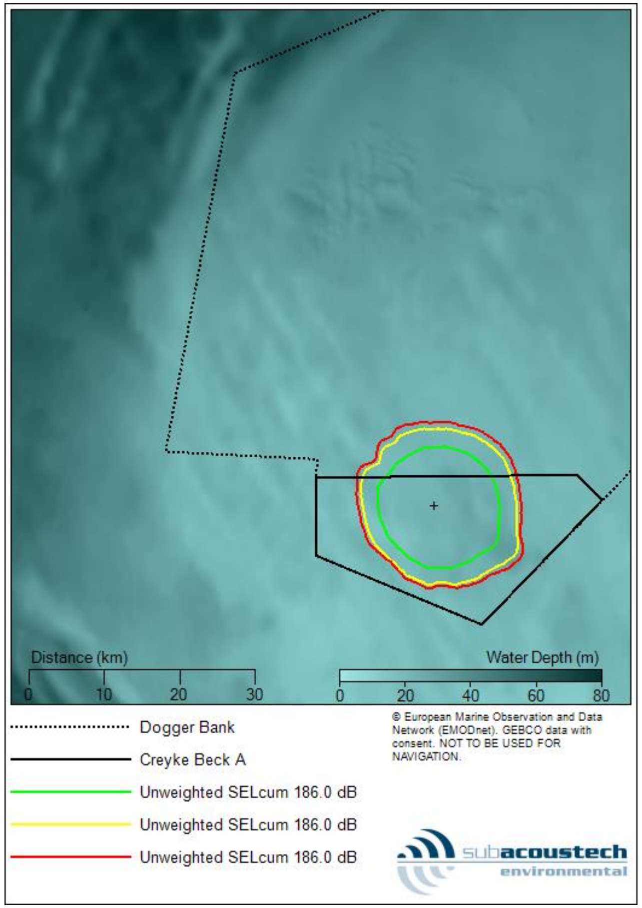

Figure B 55 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

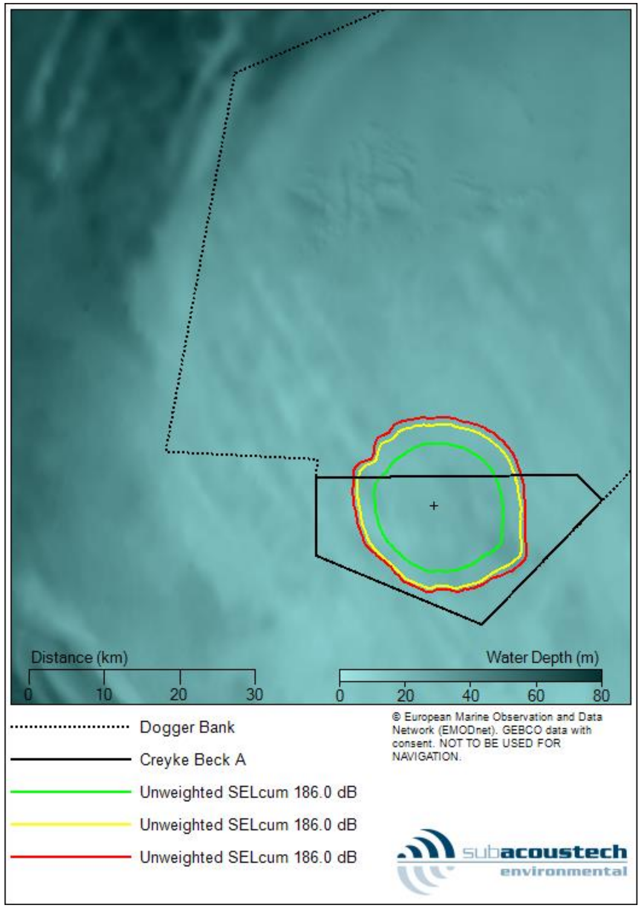

Figure B 56 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck A, location ID11 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

B.3 Creyke Beck B, location ID6

Previously considered criteria contour plots

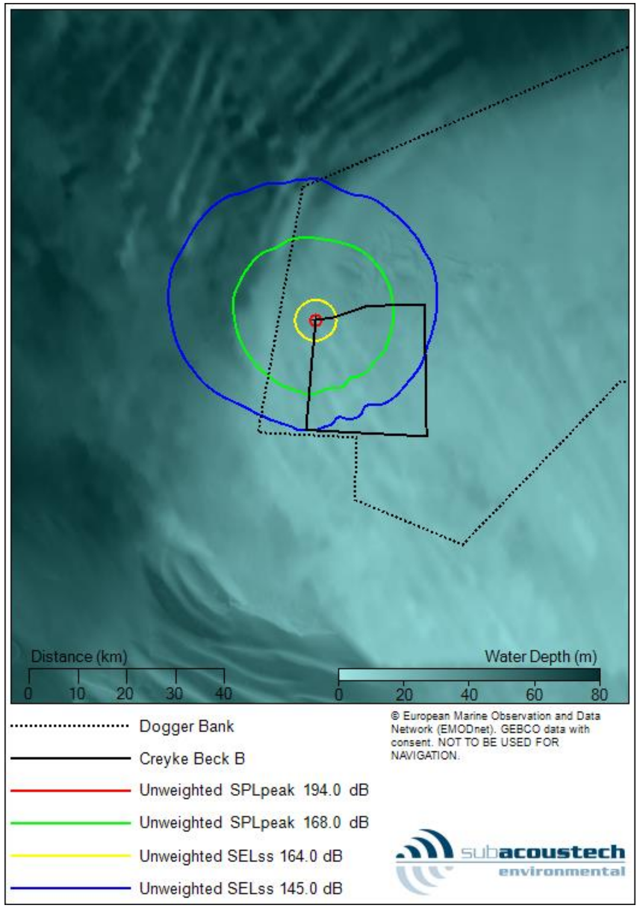

Figure B 57 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

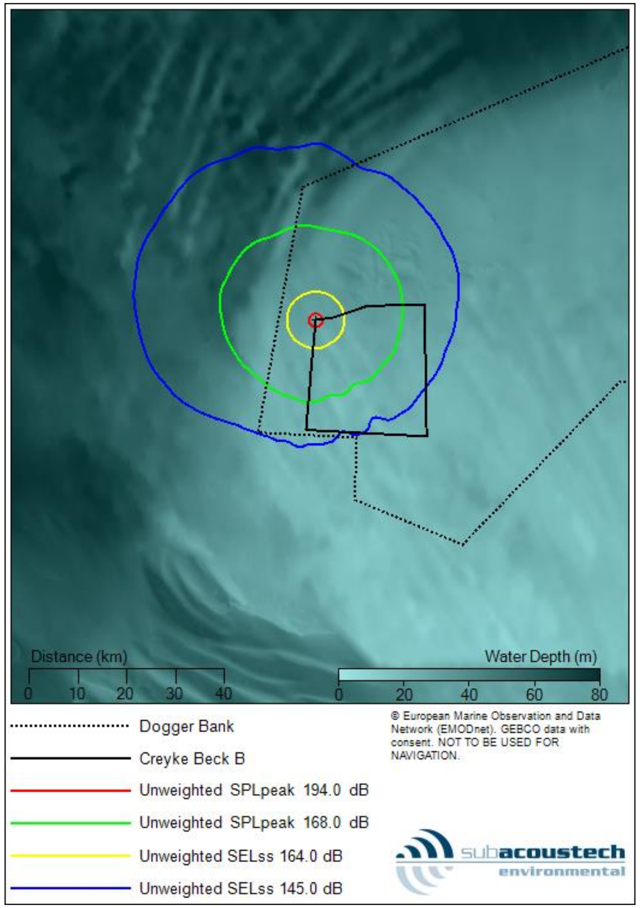

Figure B 58 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

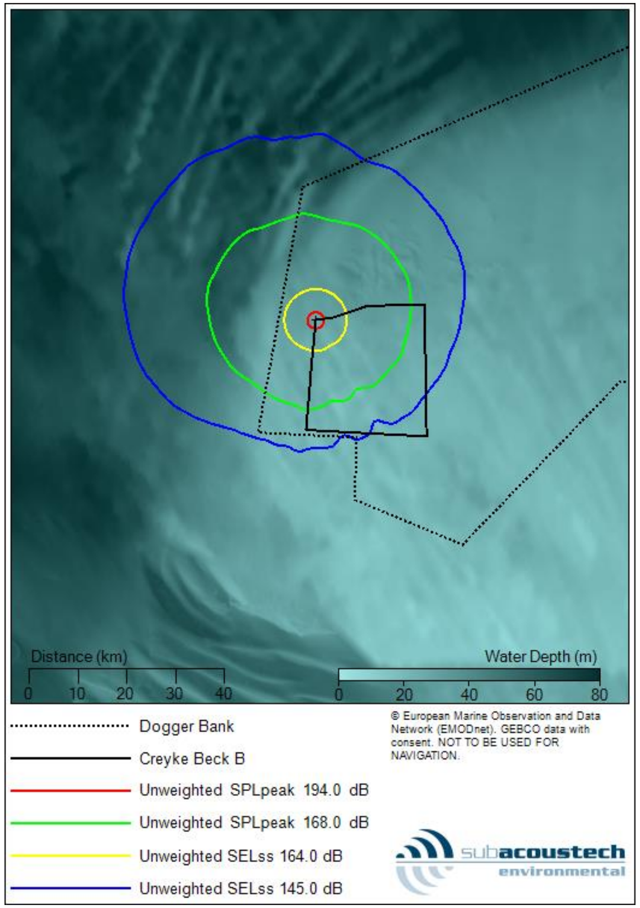

Figure B 59 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

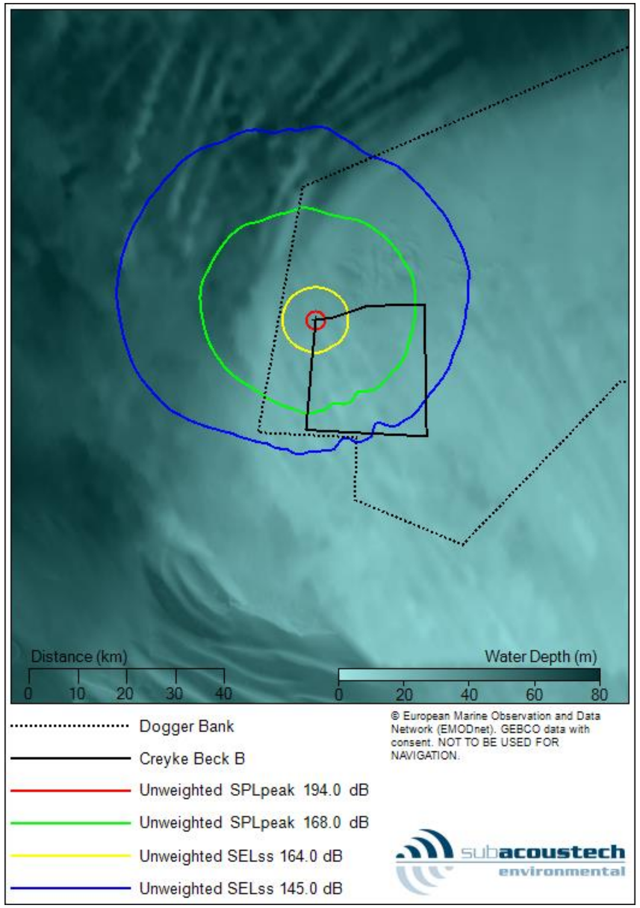

Figure B 60 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

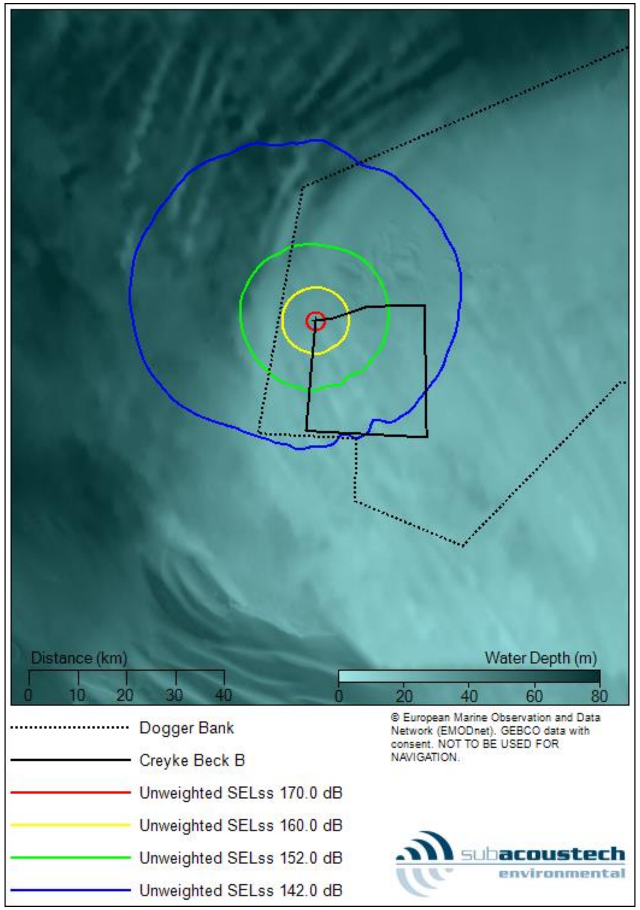

Figure B 61 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

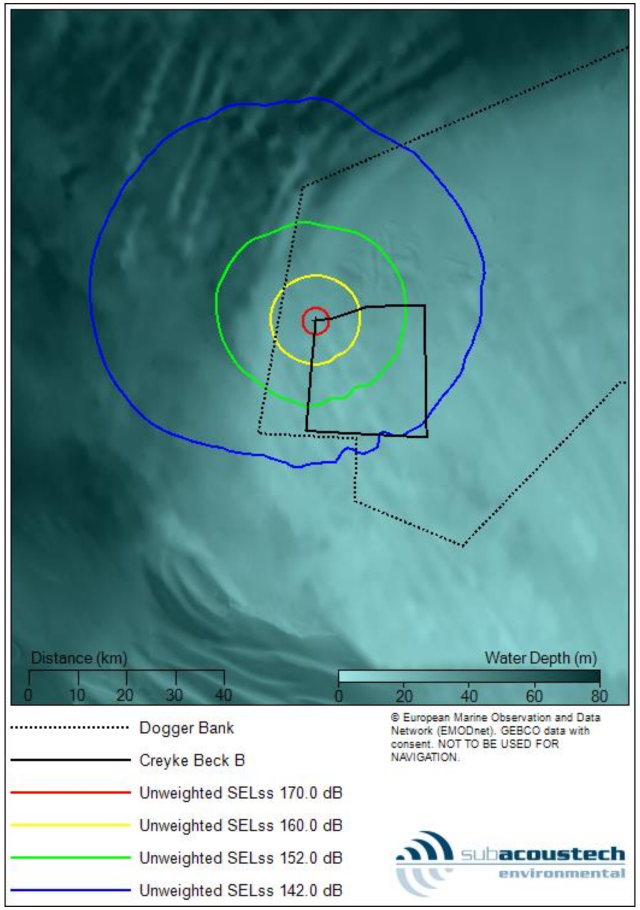

Figure B 62 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

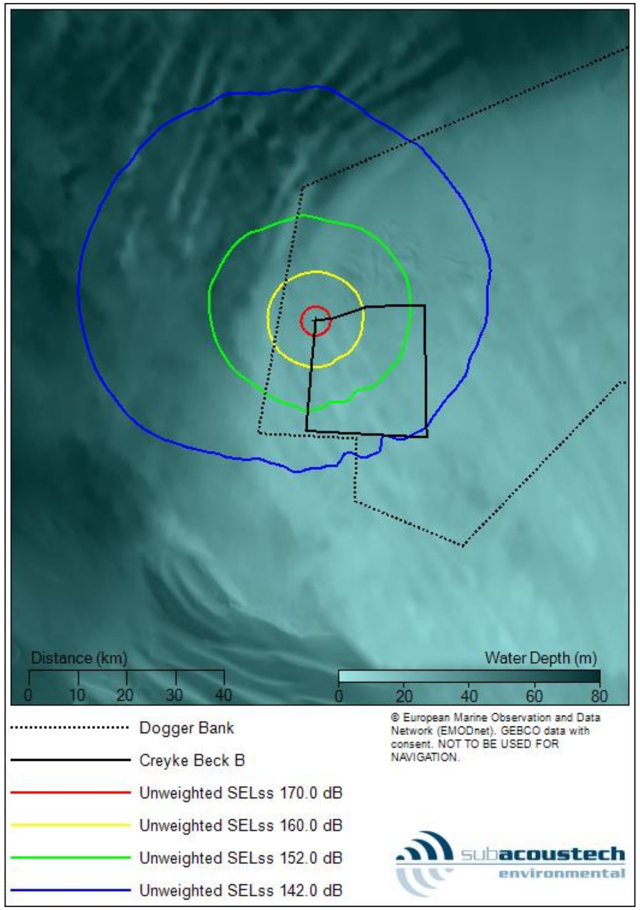

Figure B 63 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

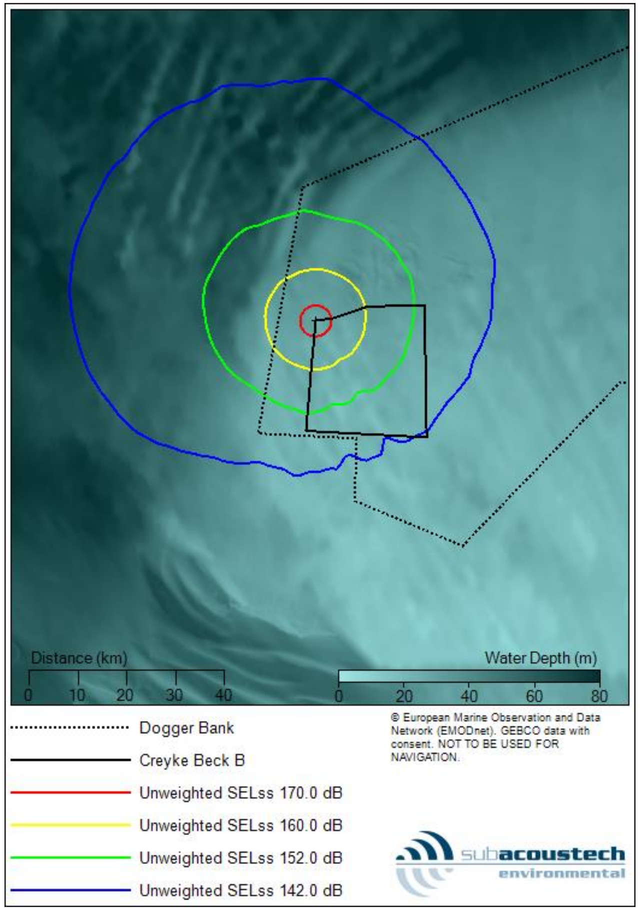

Figure B 64 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

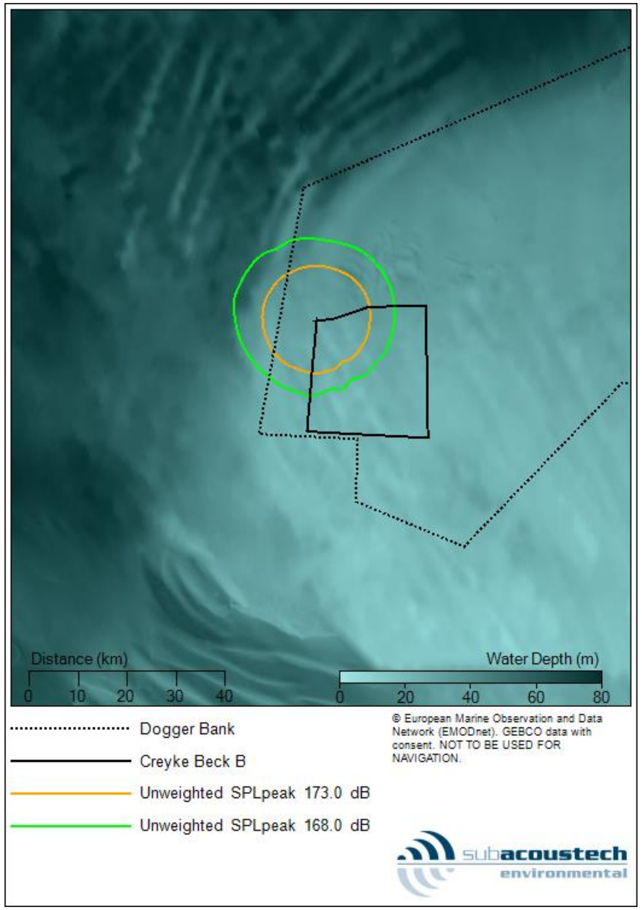

Figure B 65 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ

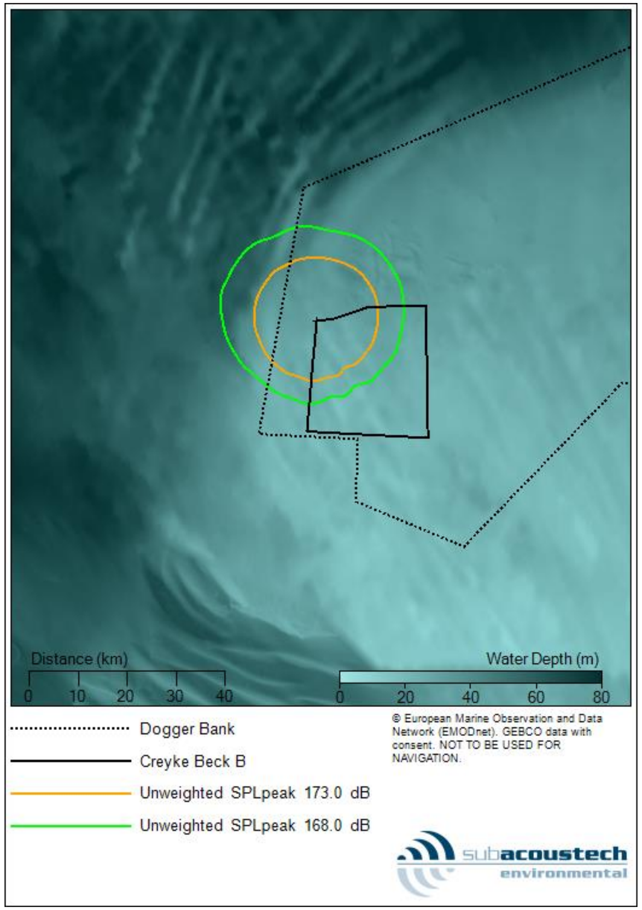

Figure B 66 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ

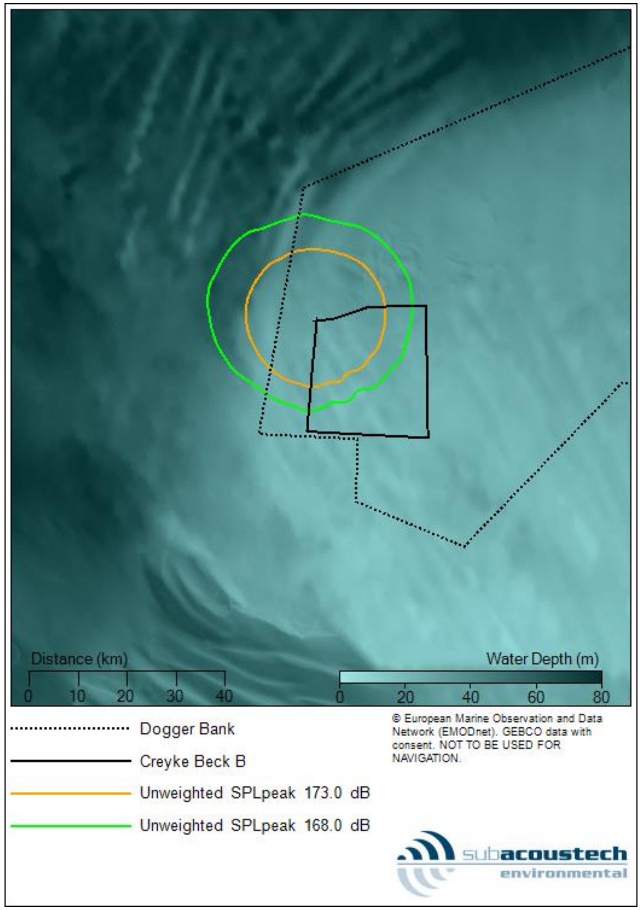

Figure B 67 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ

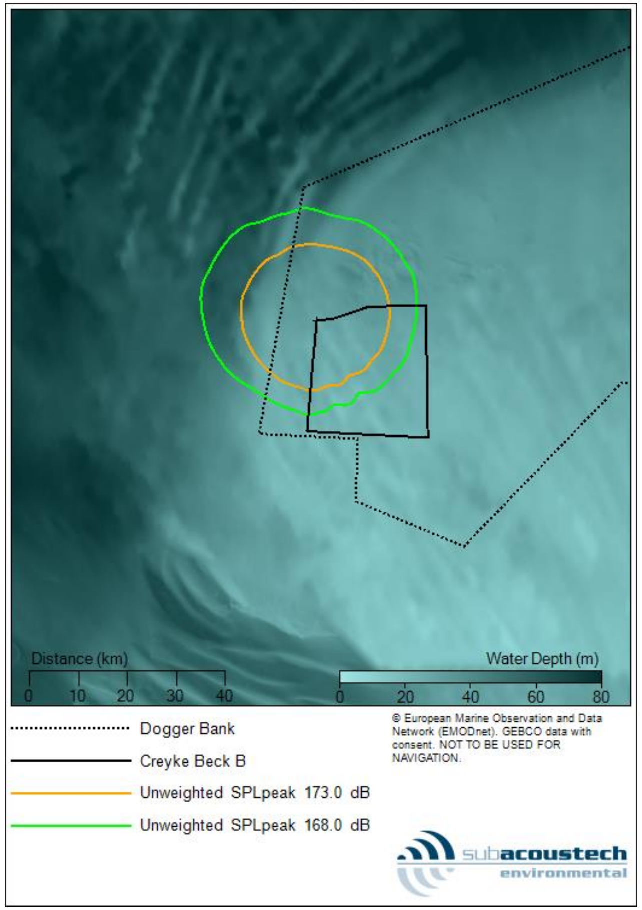

Figure B 68 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ

NMFS (2016) contour plots

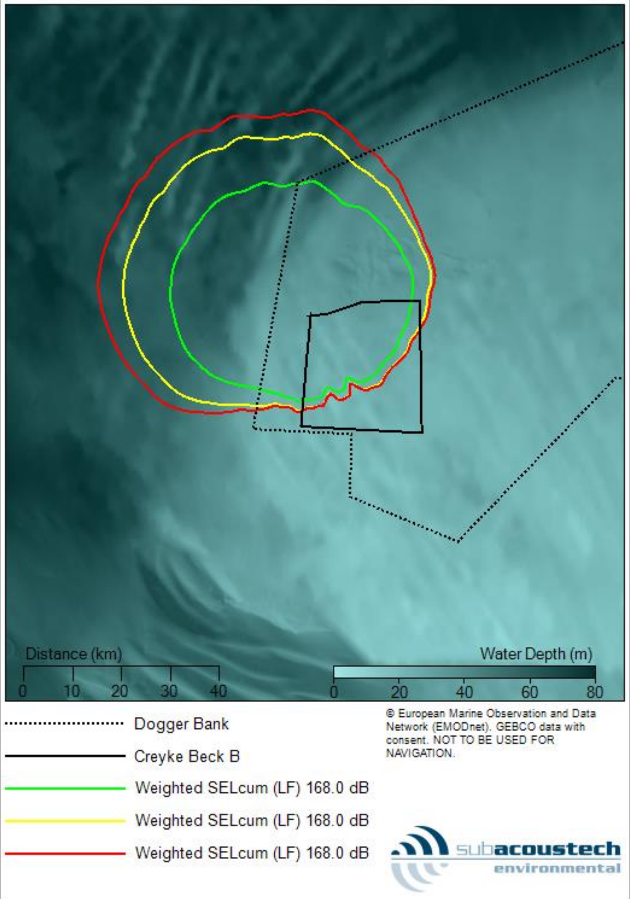

Figure B 69 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

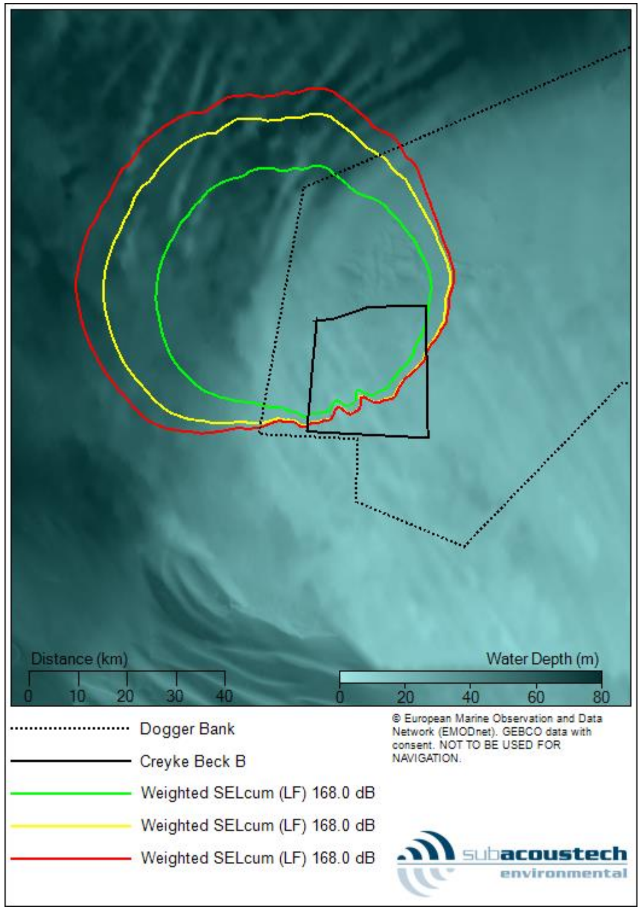

Figure B 70 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

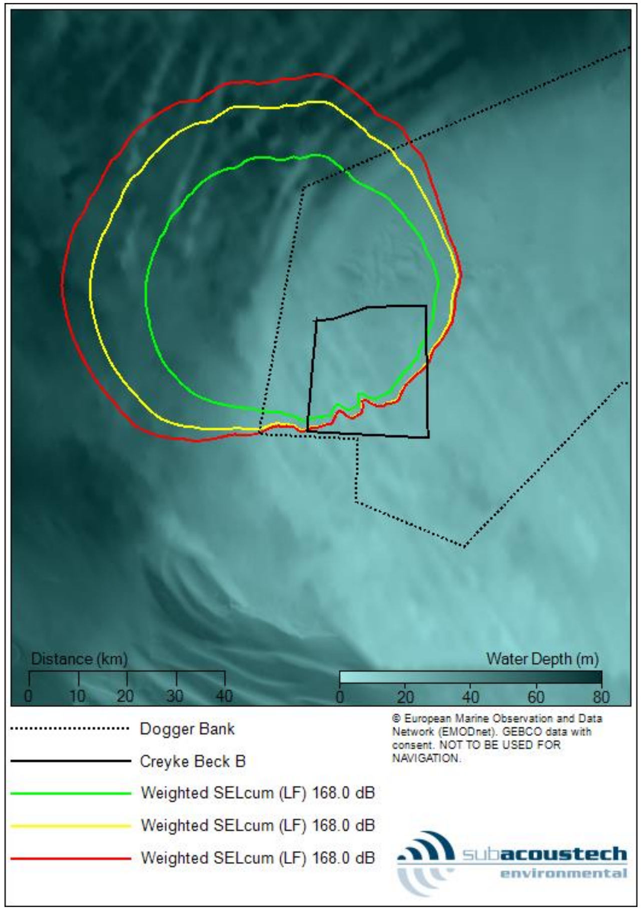

Figure B 71 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

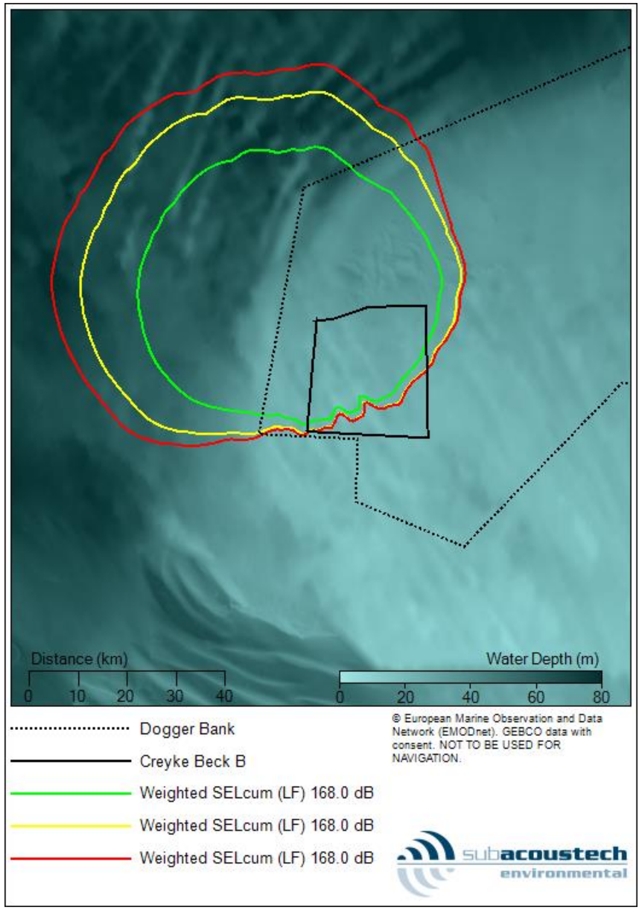

Figure B 72 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

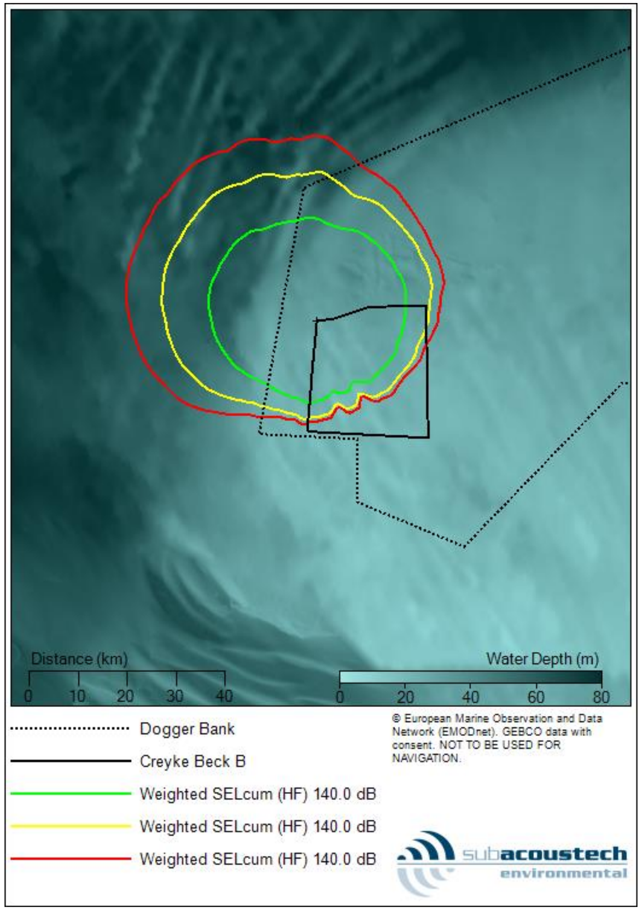

Figure B 73 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

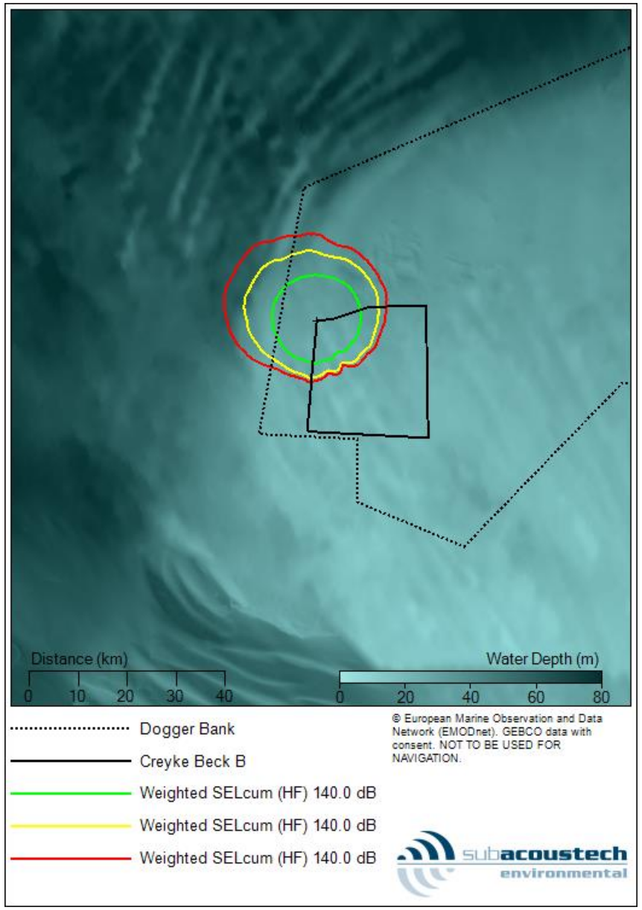

Figure B 74 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

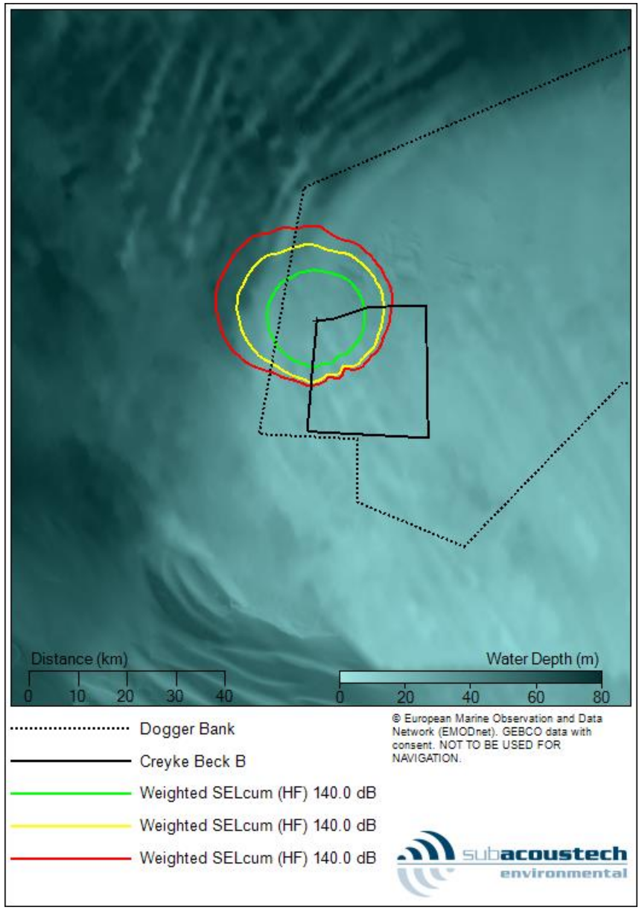

Figure B 75 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

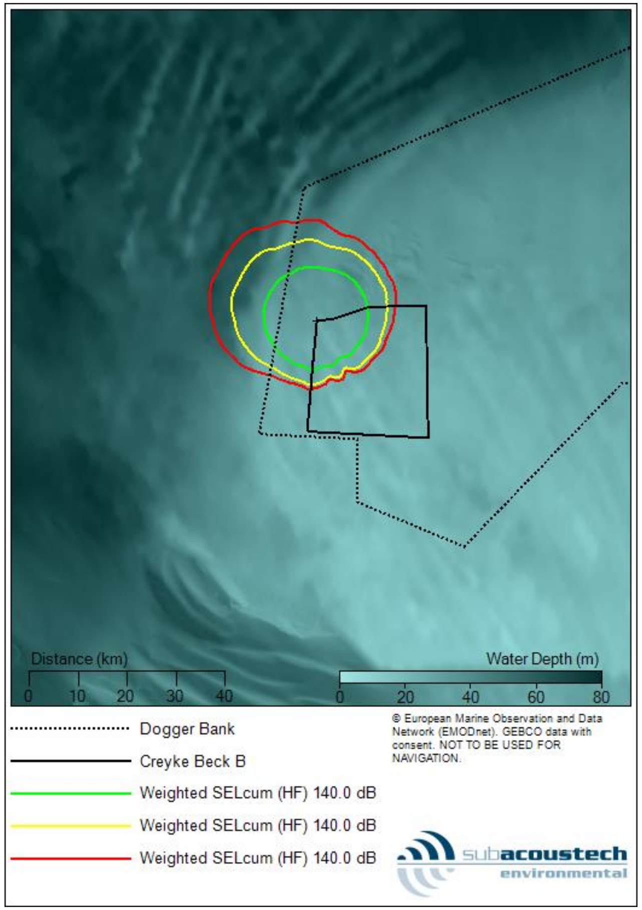

Figure B 76 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

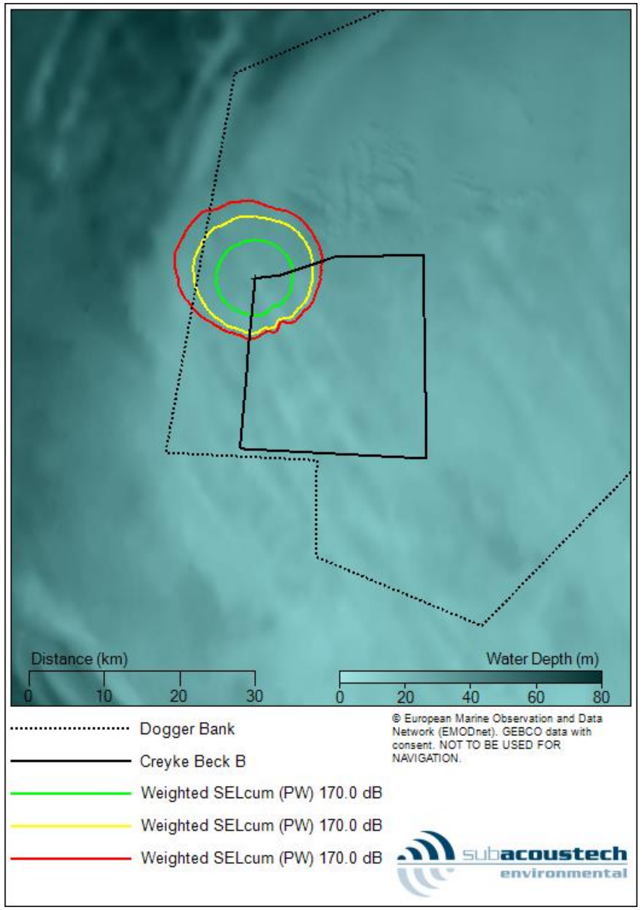

Figure B 77 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

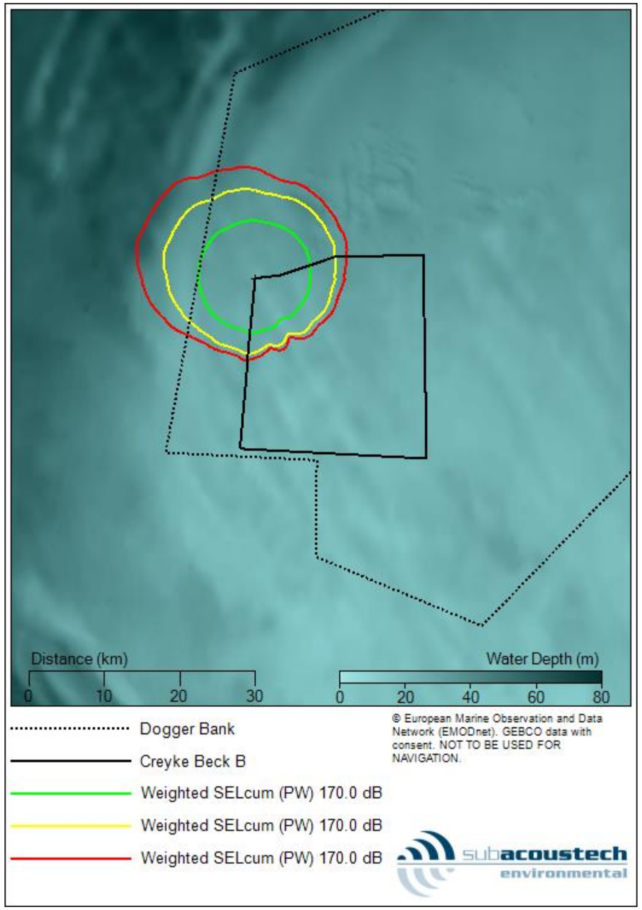

Figure B 78 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

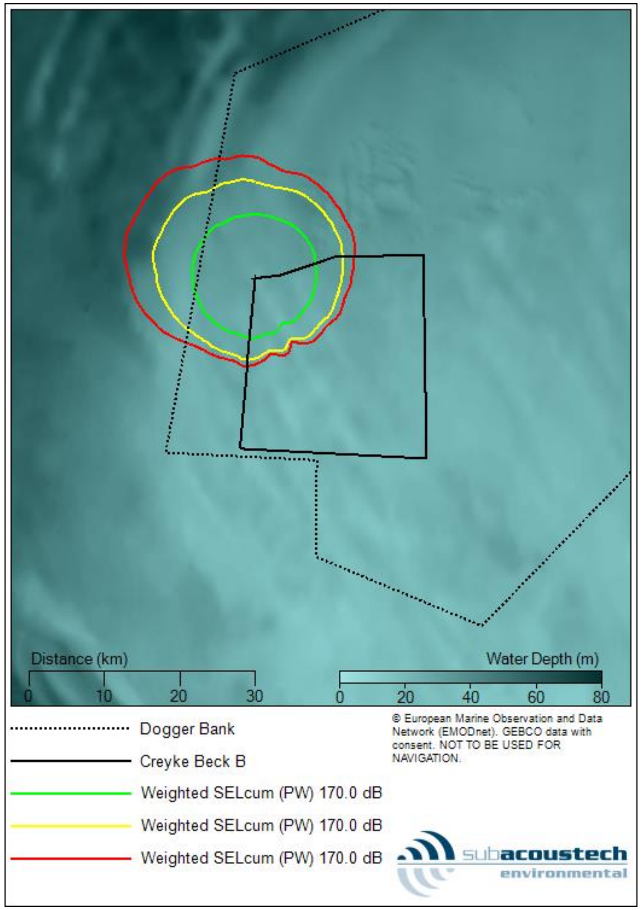

Figure B 79 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

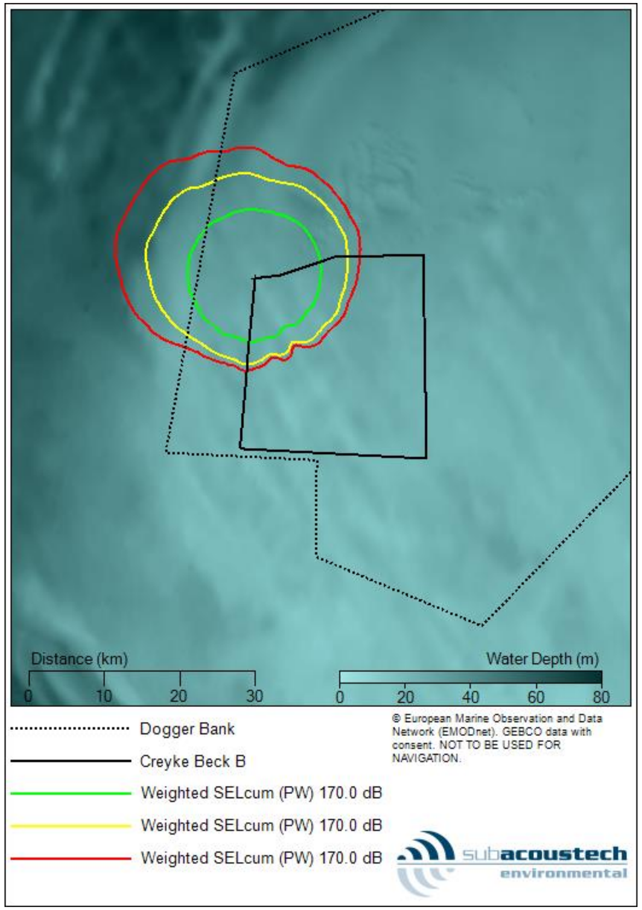

Figure B 80 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

Popper et al. (2014) contour plots

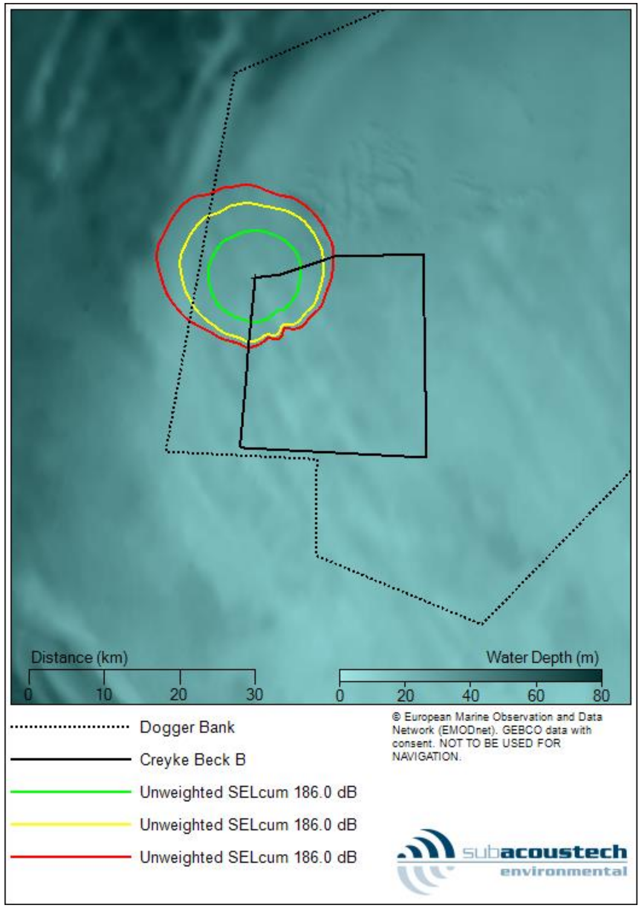

Figure B 81 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID6 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

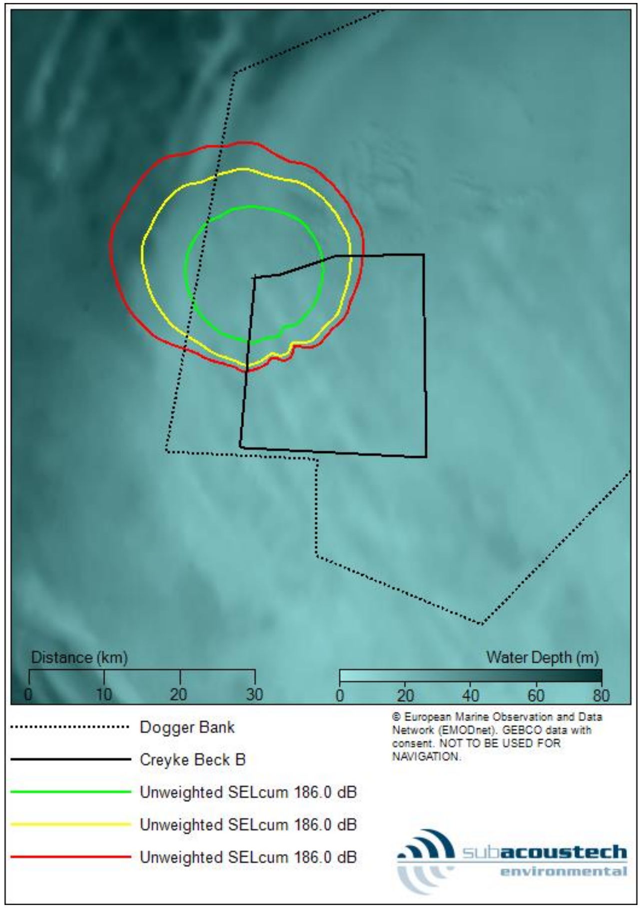

Figure B 82 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

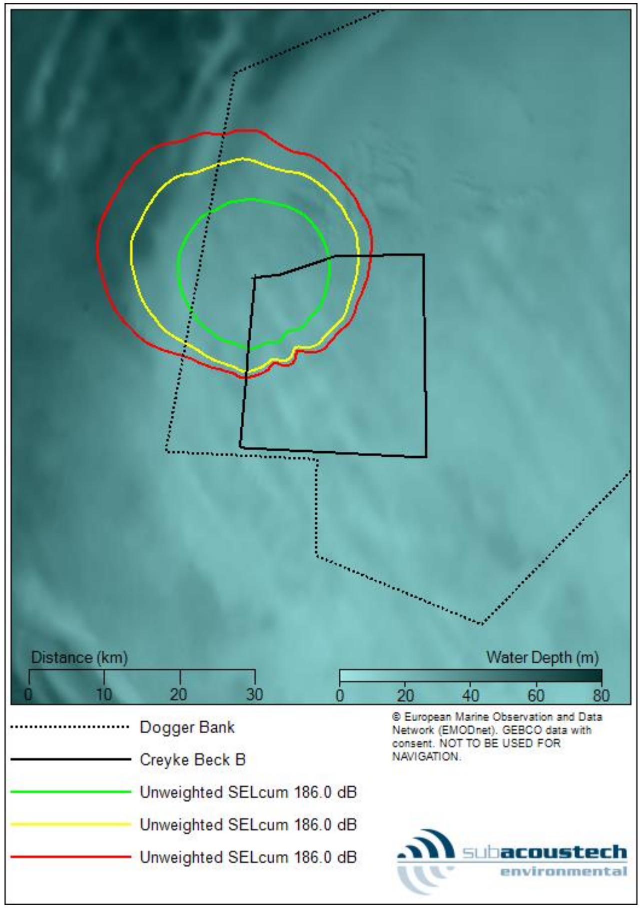

Figure B 83 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

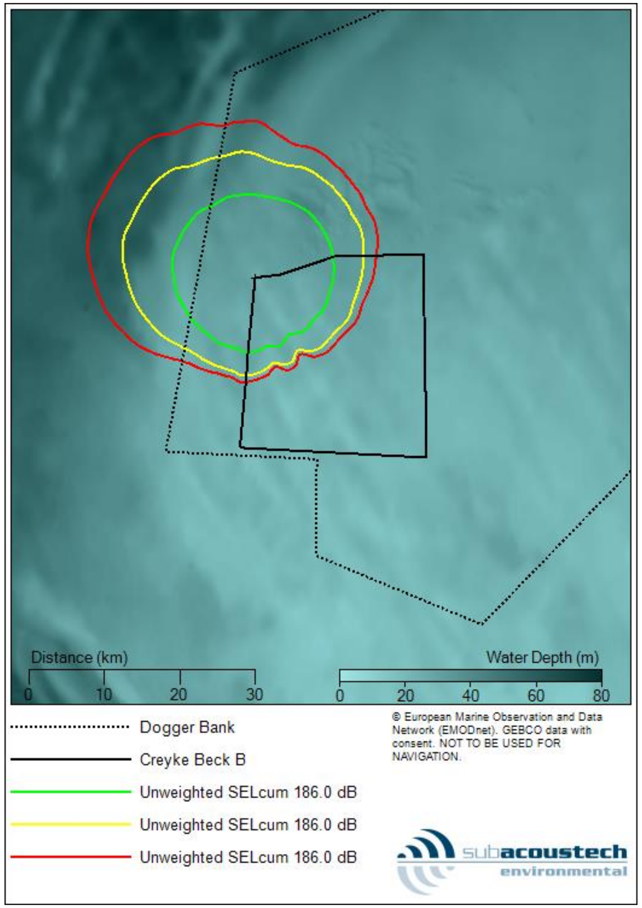

Figure B 84 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID6 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

B.4 Creyke Beck B, location ID13

Previously considered criteria contour plots

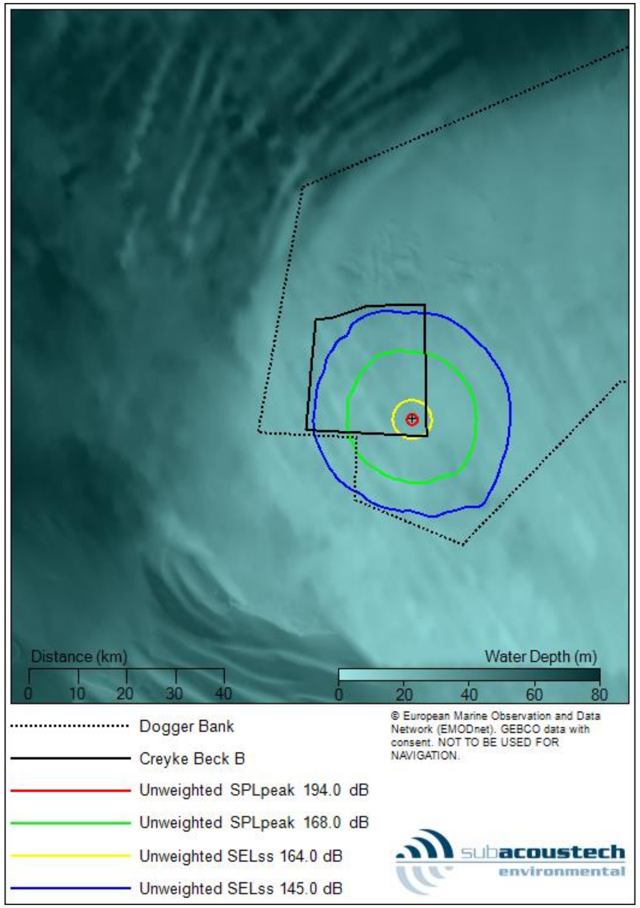

Figure B 85 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ

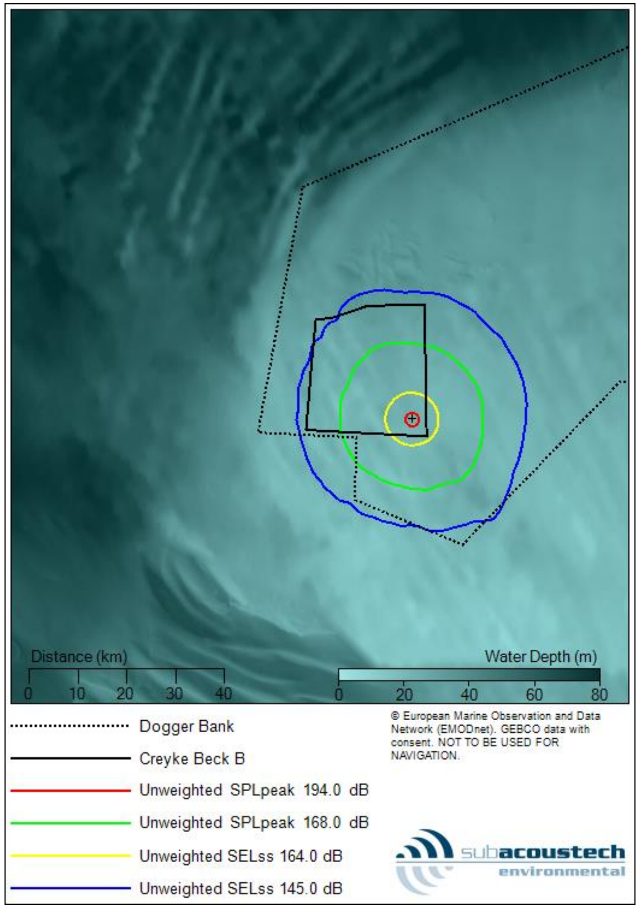

Figure B 86 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ

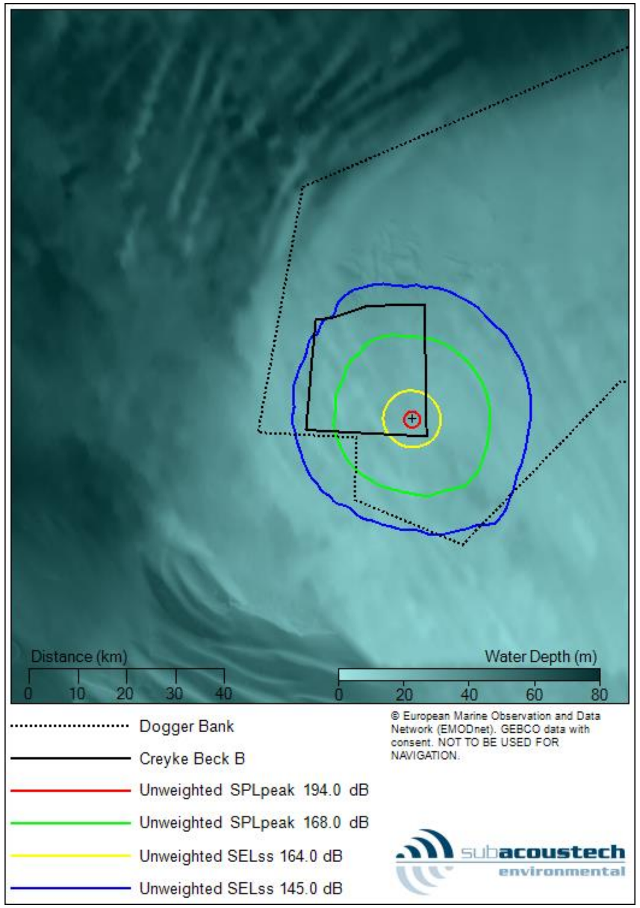

Figure B 87 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ

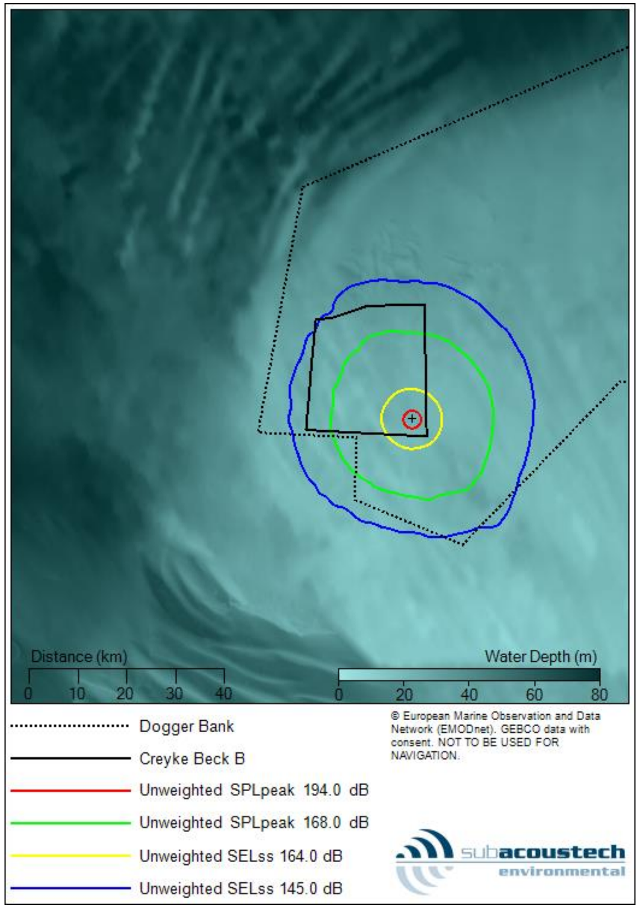

Figure B 88 Contour plot showing the unweighted SPL_{peak} and SEL_{ss} impact ranges for TTS/fleeing response and avoidance in harbour porpoise from Lucke et al. (2009) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ

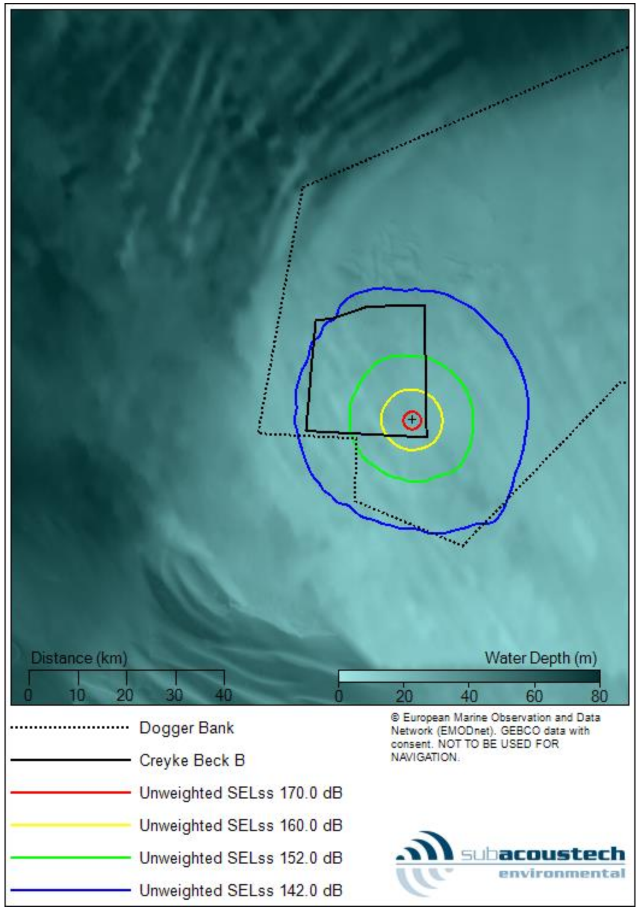

Figure B 89 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ

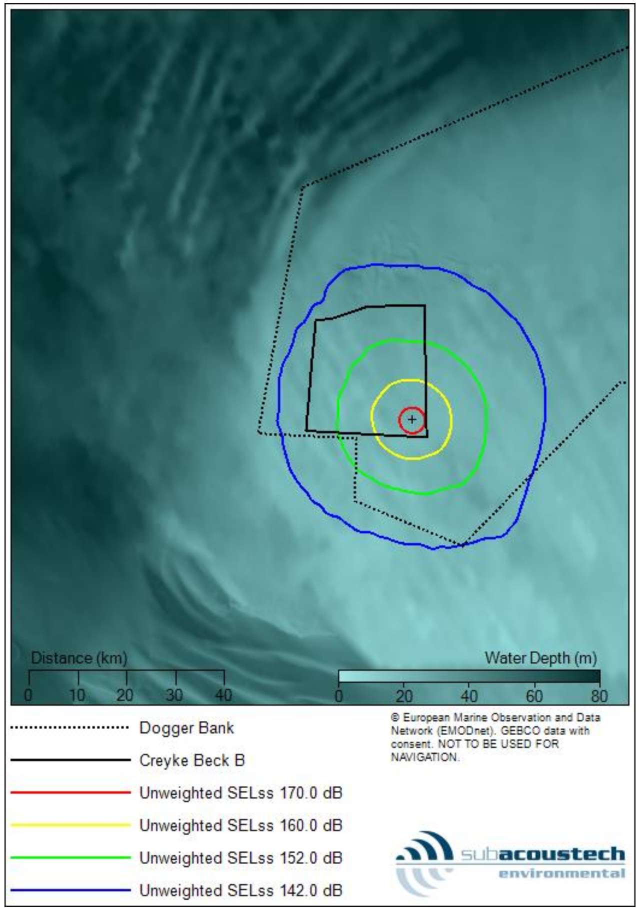

Figure B 90 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ

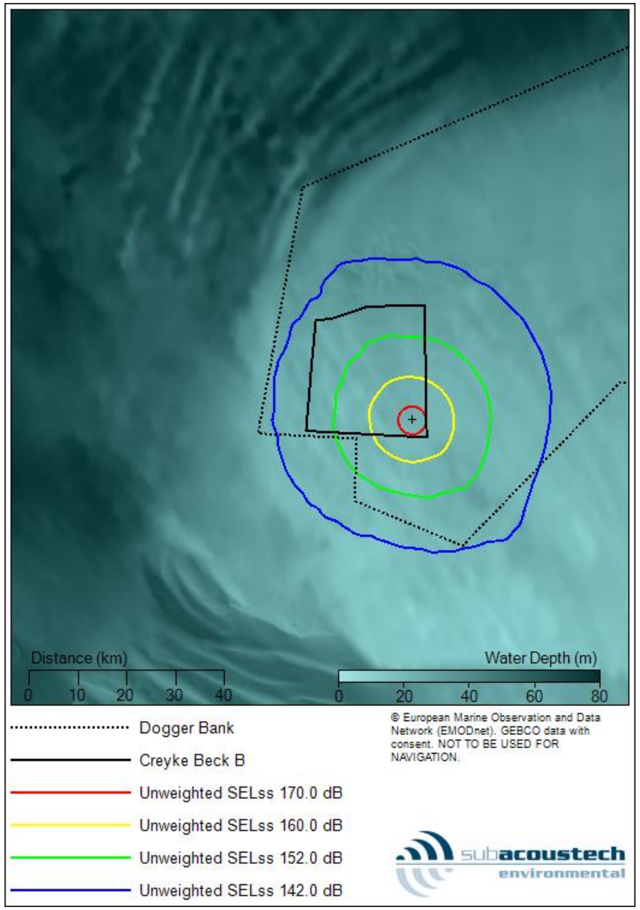

Figure B 91 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ

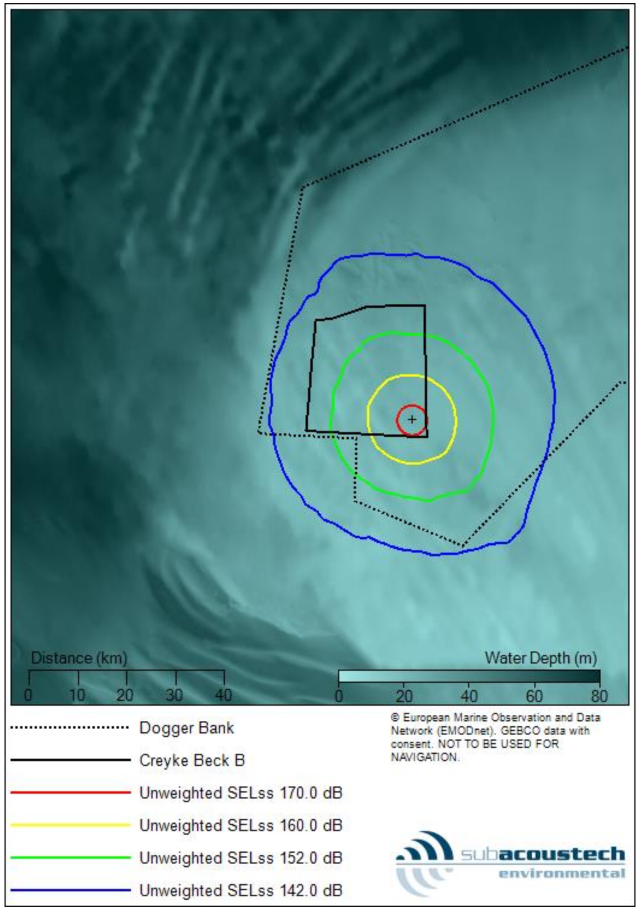

Figure B 92 Contour plot showing the unweighted SEL_{ss} impact ranges for avoidance in LF and MF cetaceans from Southall et al. (2007) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ

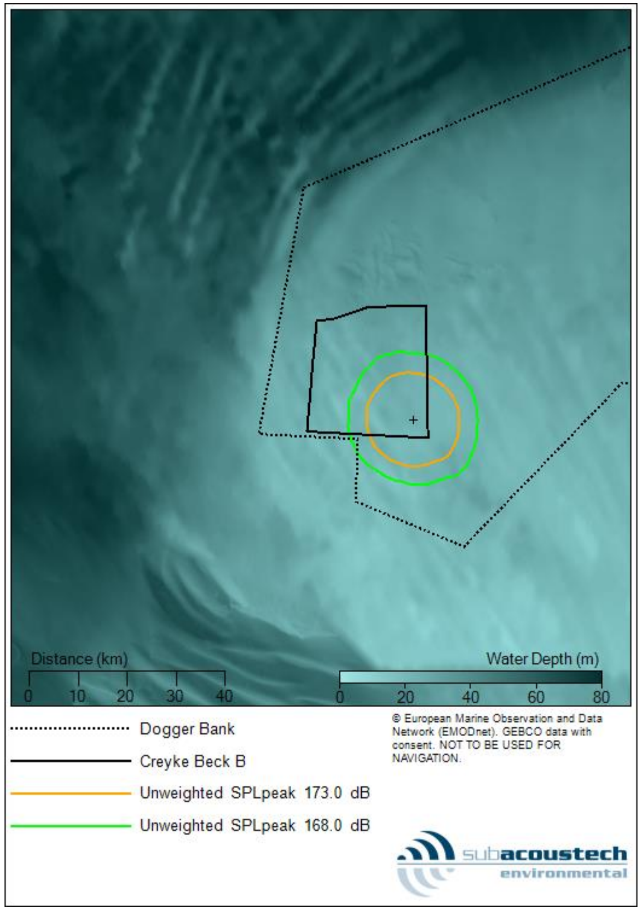

Figure B 93 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ

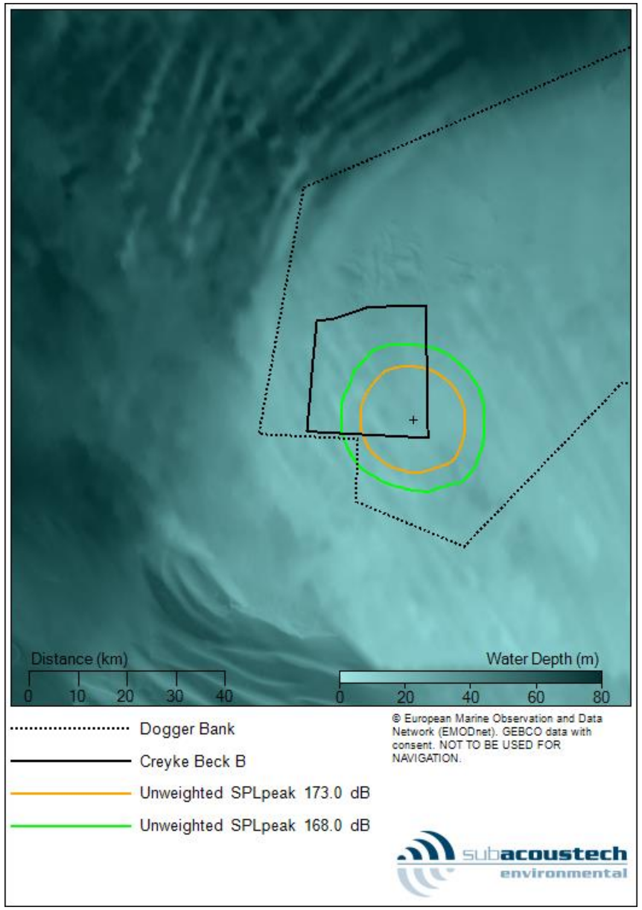

Figure B 94 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ

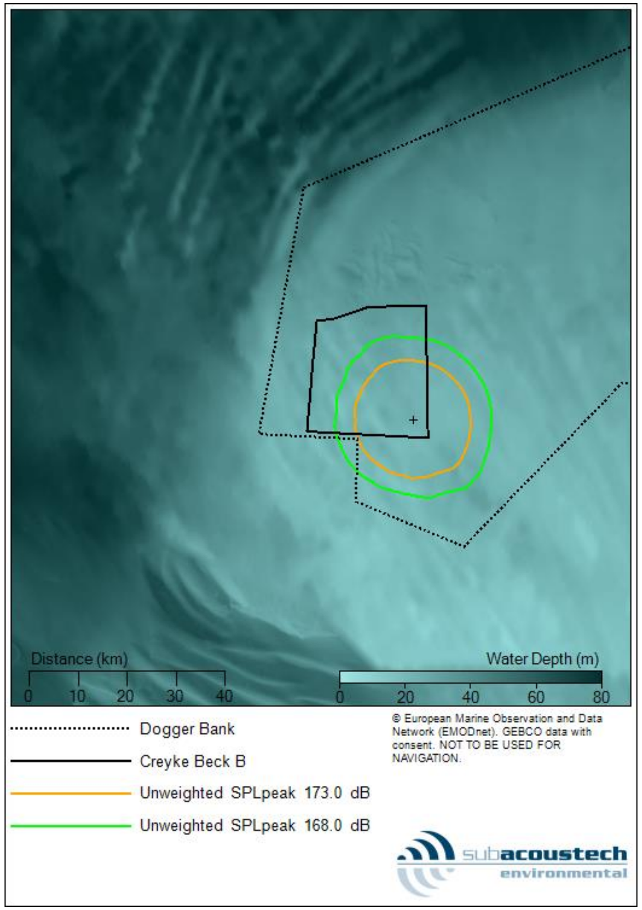

Figure B 95 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ

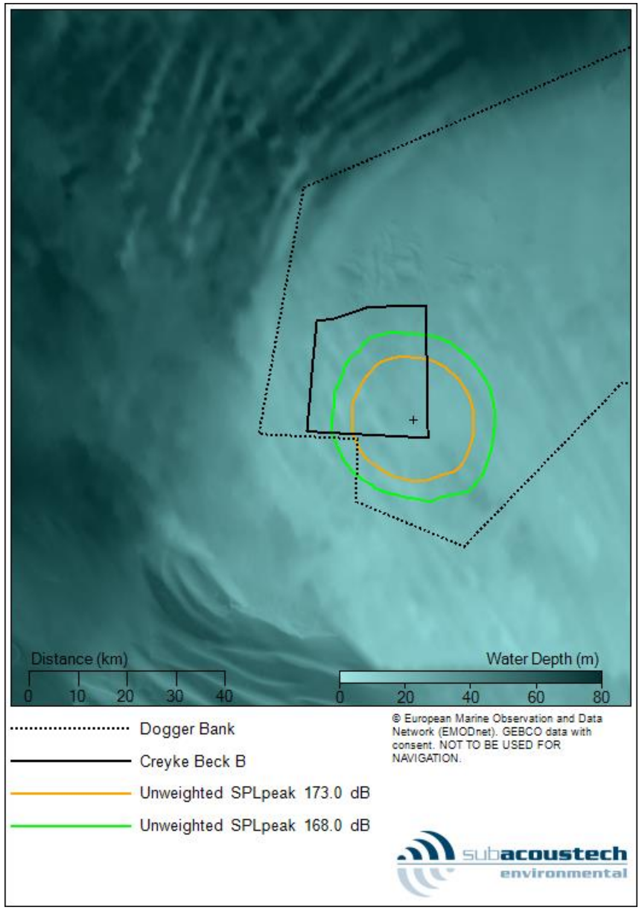

Figure B 96 Contour plot showing the unweighted SPL_{peak} impact ranges for avoidance in species of fish at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ

<u>*NMFS (2016) contour plots*</u>

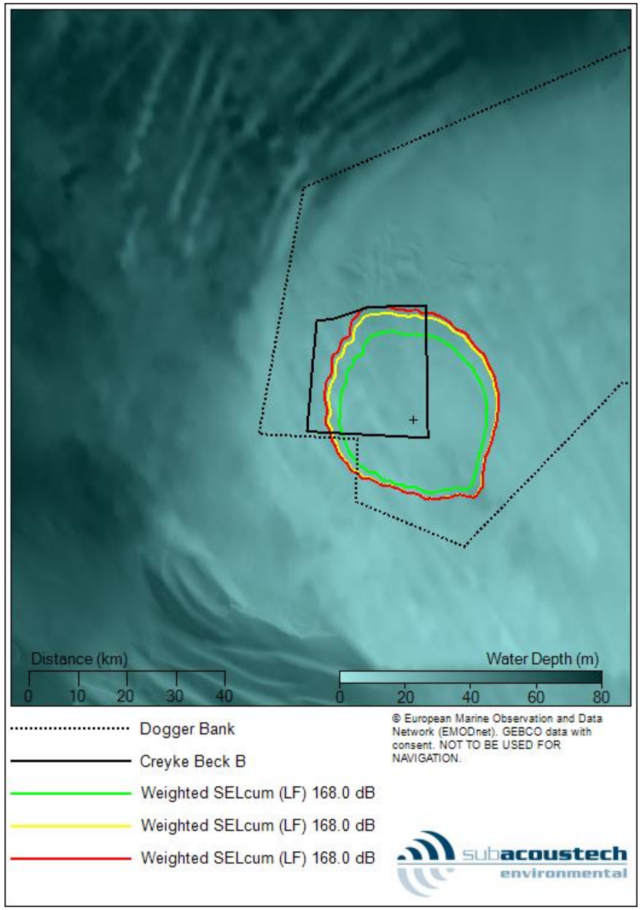

Figure B 97 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

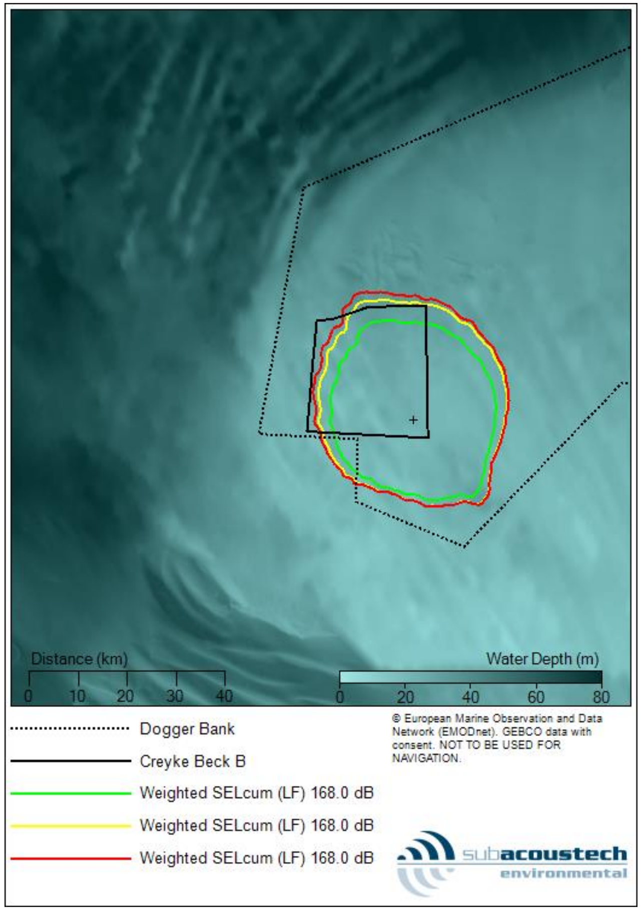

Figure B 98 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

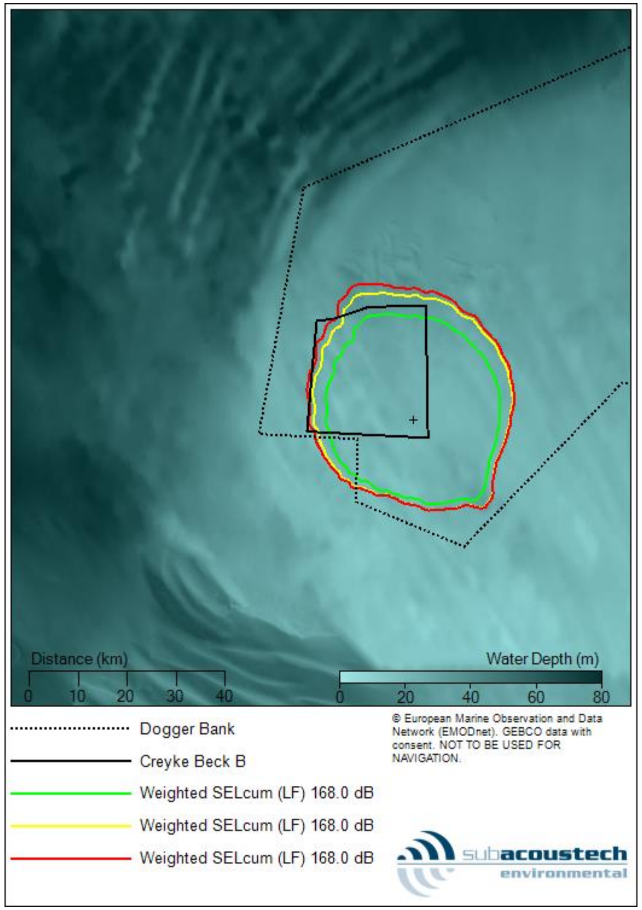

Figure B 99 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

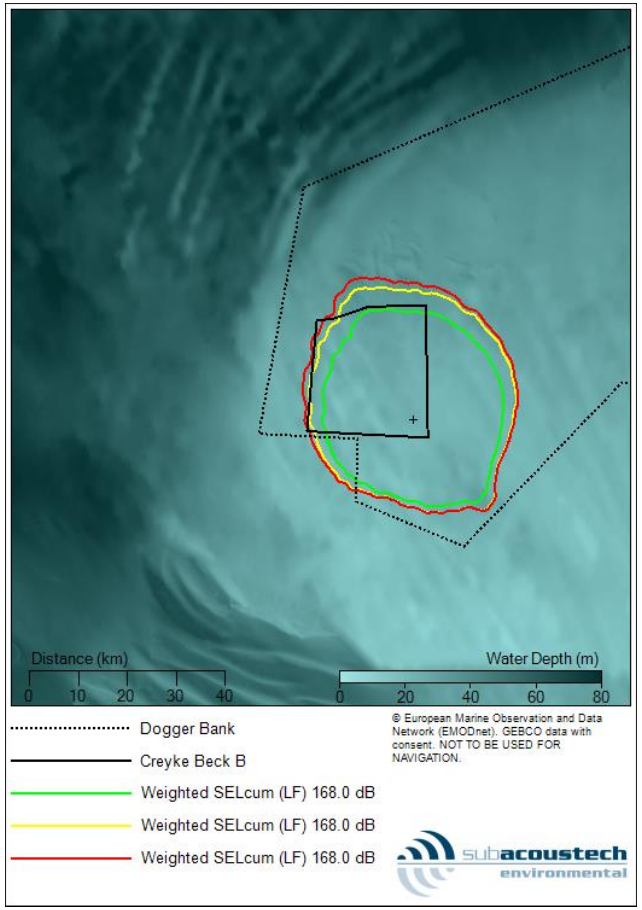

Figure B 100 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in LF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

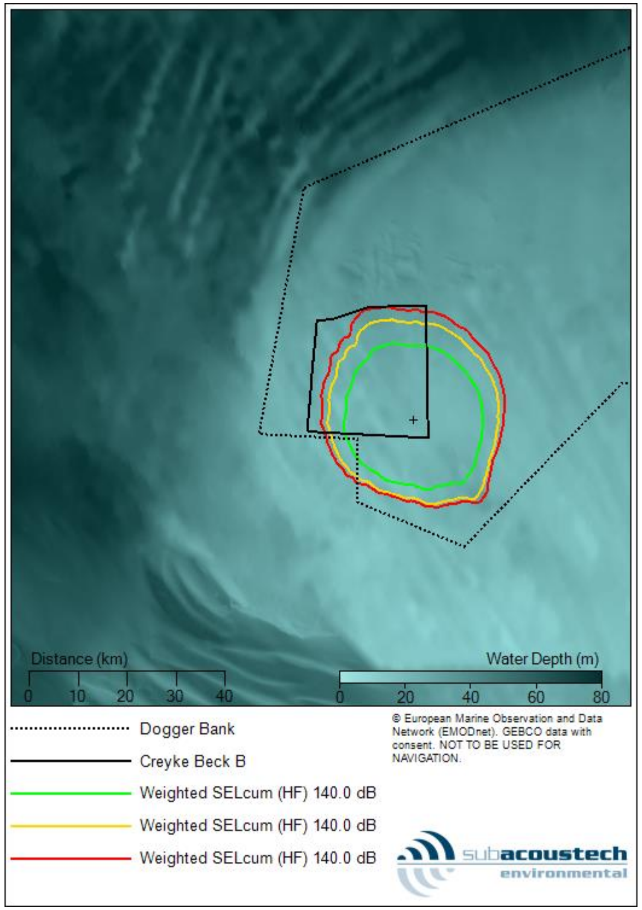

Figure B 101 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

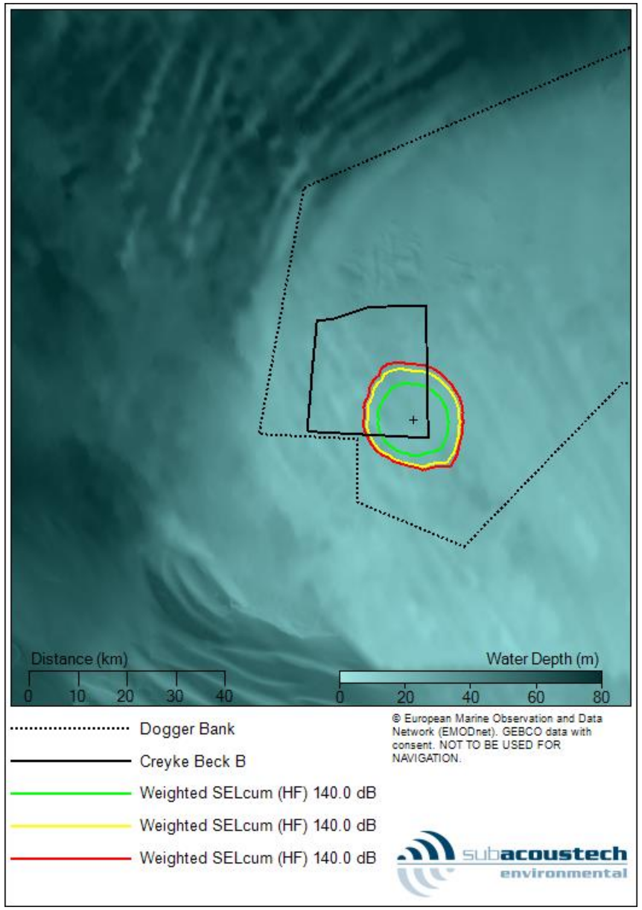

Figure B 102 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

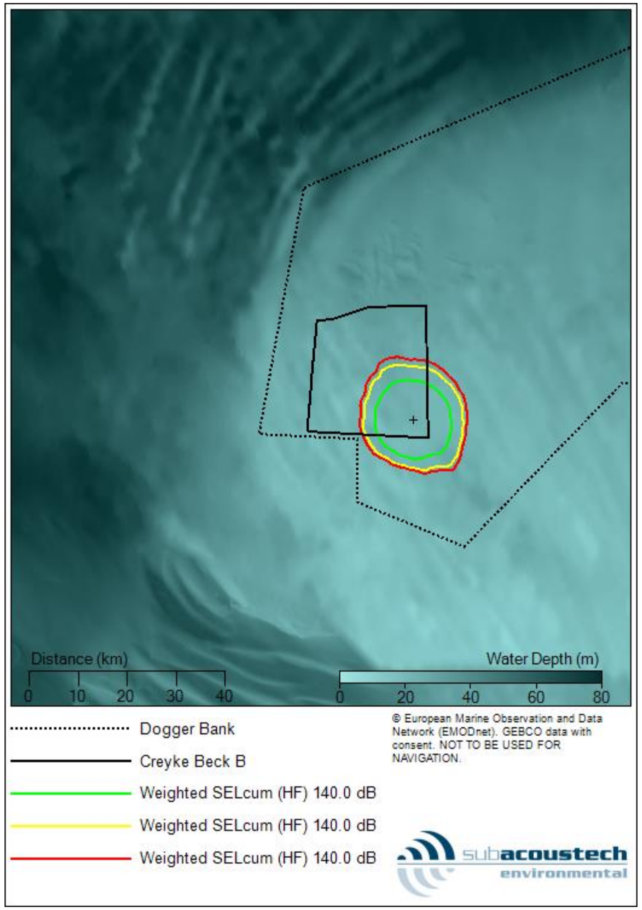

Figure B 103 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

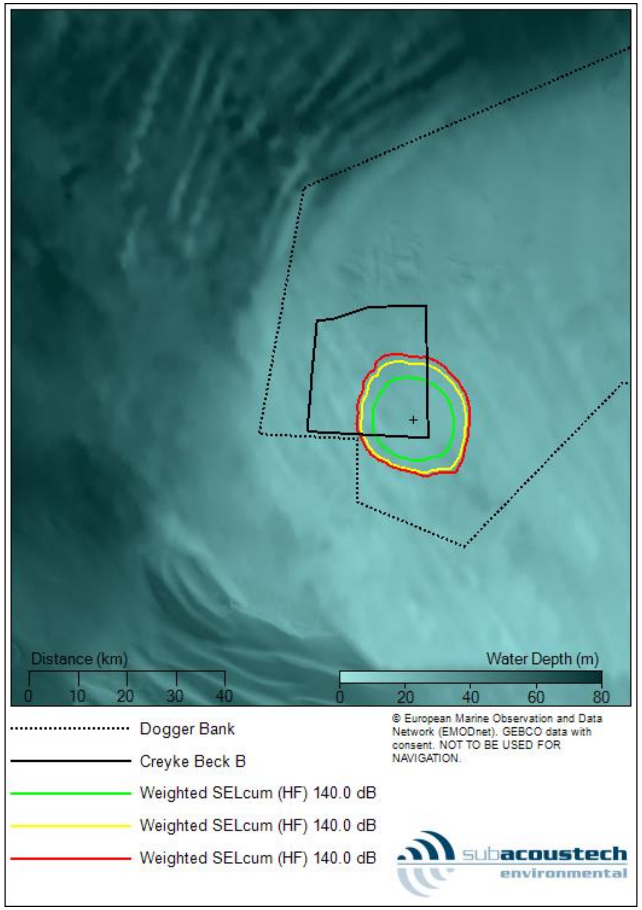

Figure B 104 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in HF cetaceans from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

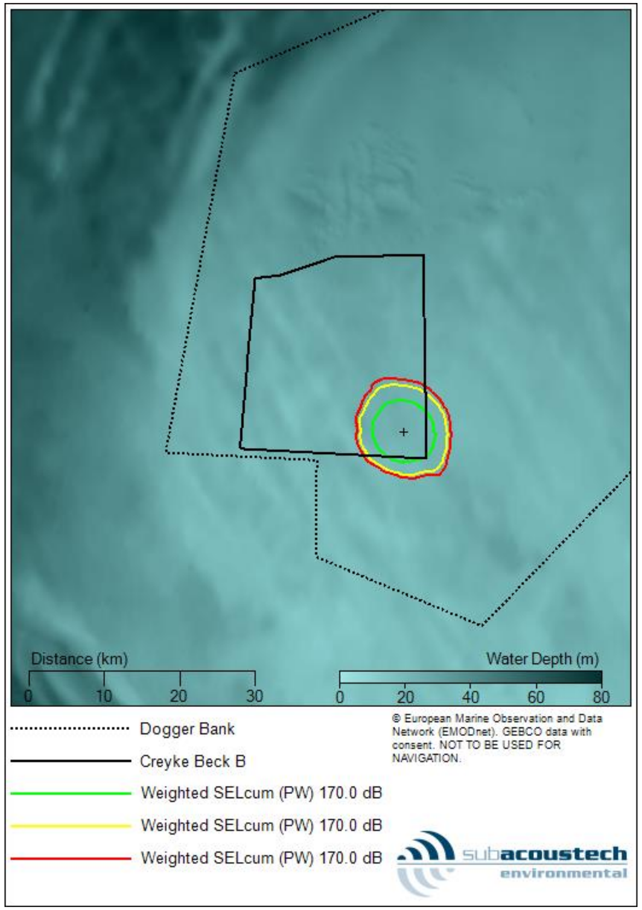

Figure B 105 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

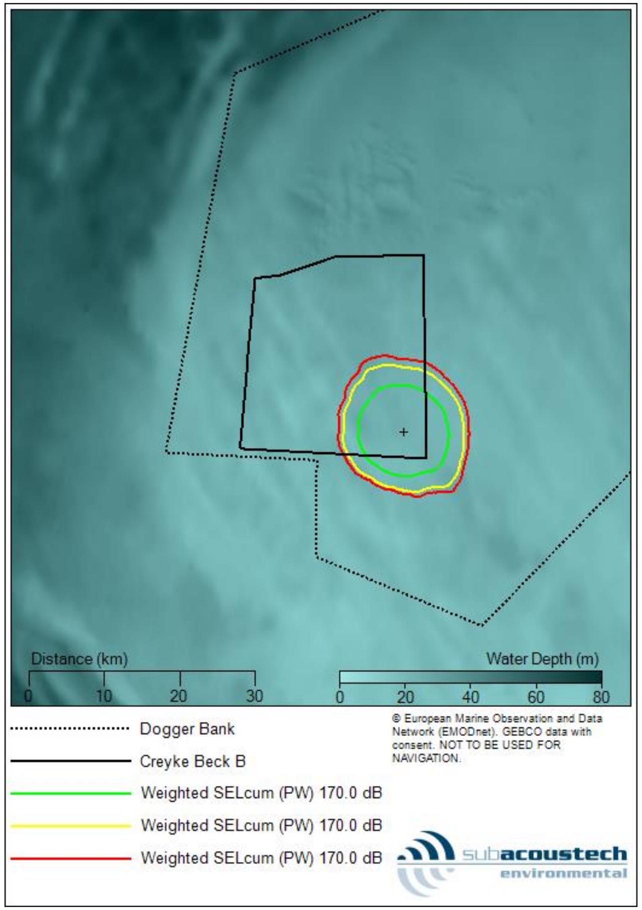

Figure B 106 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

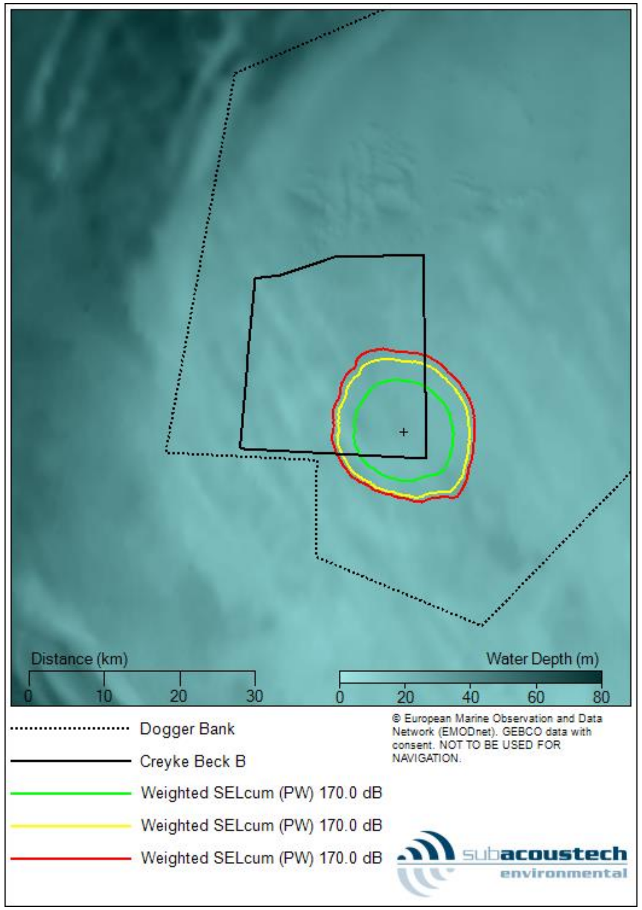

Figure B 107 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

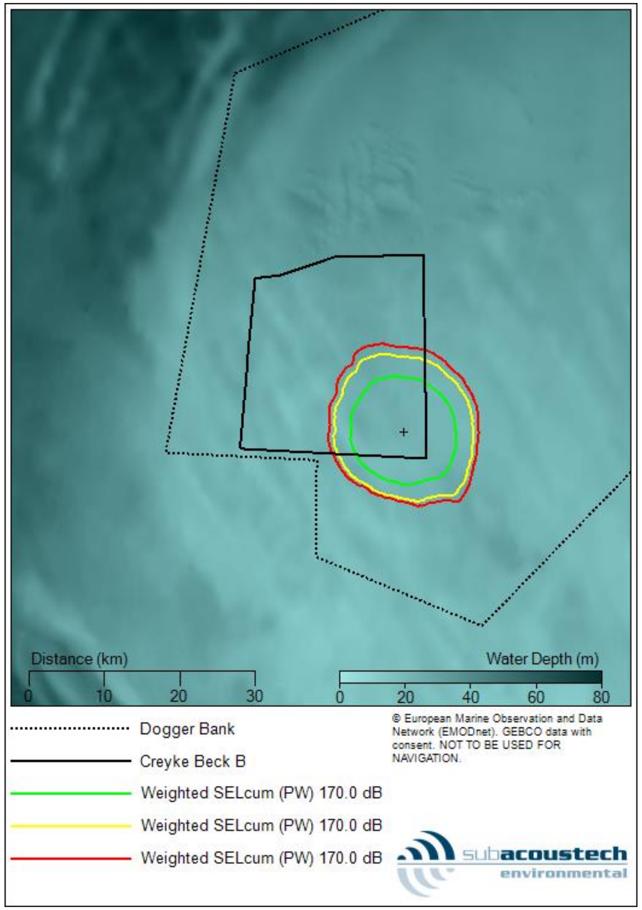

Figure B 108 Contour plot showing the weighted SEL_{cum} impact ranges for TTS in phocid pinnipeds from NMFS (2016) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

Popper et al. (2014) contour plots

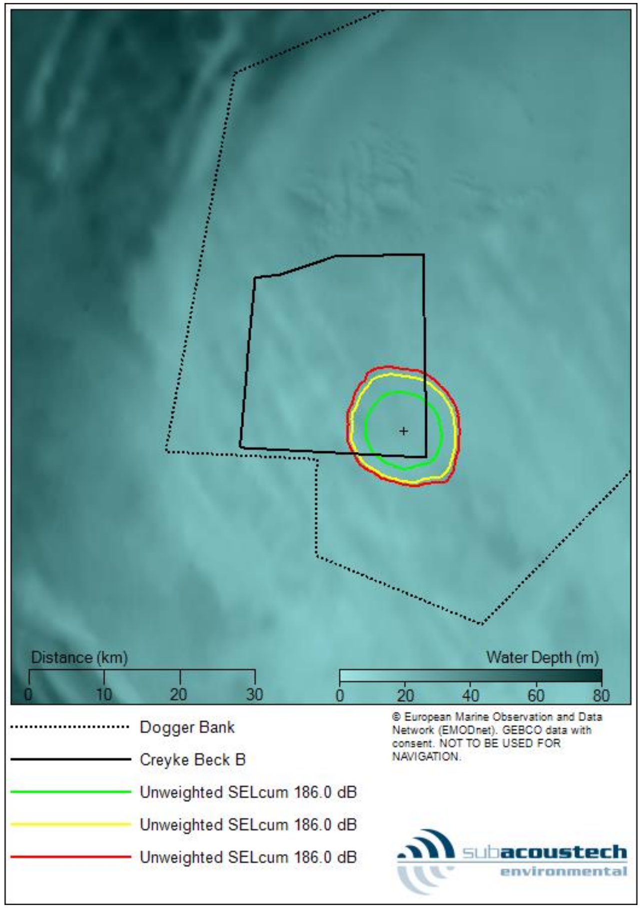

Figure B 109 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID13 for installing a pin pile using a maximum blow energy of 2300 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

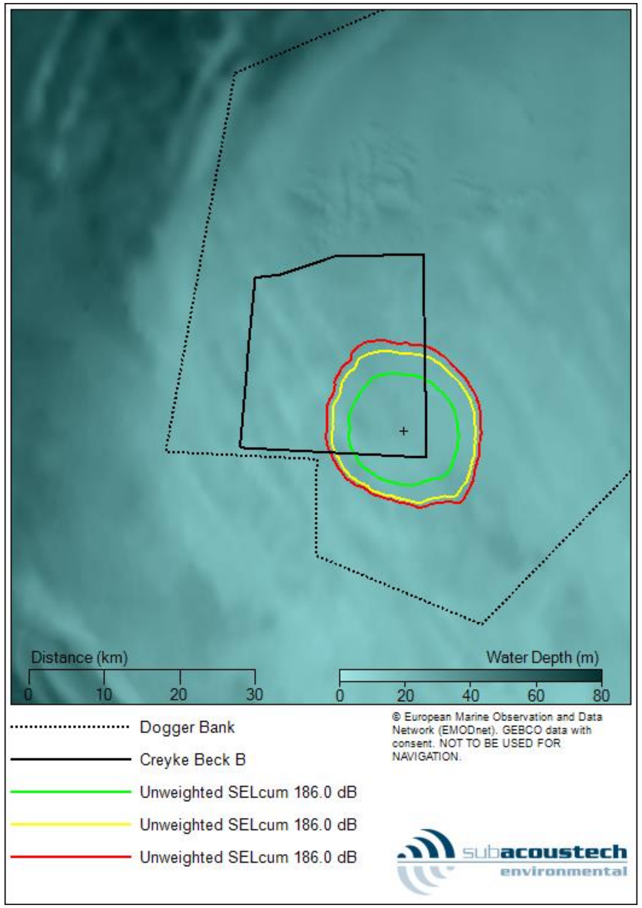

Figure B 110 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

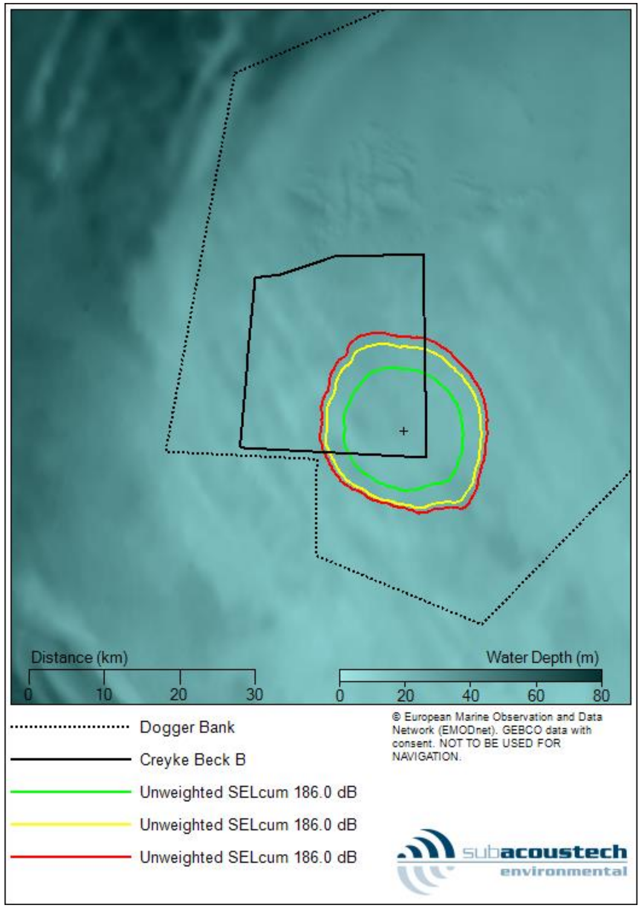

Figure B 111 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 3600 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

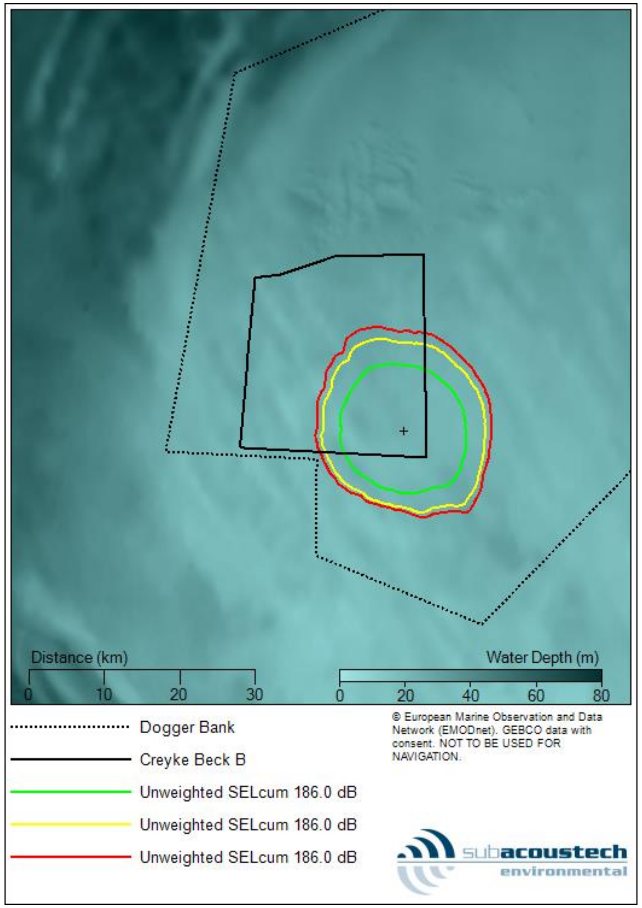

Figure B 112 Contour plot showing the unweighted SEL_{cum} impact ranges for TTS in species of fish from Popper et al. (2014) at Creyke Beck B, location ID13 for installing a monopile using a maximum blow energy of 4000 kJ for the three ramp-up scenarios (scenario 1 = green, scenario 2 = yellow, scenario 3 = red)

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