FIVE ESTUARIES
OFFSHORE WIND FARM

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ENVIRONMENTAL STATEMENT

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Five Estuaries: Landfall impact piling modelling

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1 Introduction

Five Estuaries (VE) is a proposed offshore wind farm situated in the southern North Sea, an extension to the existing Galloper Offshore Wind Farm. As part of the Environmental Impact Assessment (EIA) process, Subacoustech Environmental Ltd. have undertaken detailed underwater noise modelling and analysis in relation to marine mammals and fish at the VE site.

This report presents additional modelling of impact piling for the construction of a sheet piled enclosure at the landfall location on the Essex coast between Holland-on-Sea and Frinton-on-Sea. Although it is expected that vibro-piling will be used for these activities, impact piling has been presented here to represent a worst case with regards to noise as this has not been ruled out.

Figure 1-1 shows the landfall area as well as the representative modelling location used for this study.

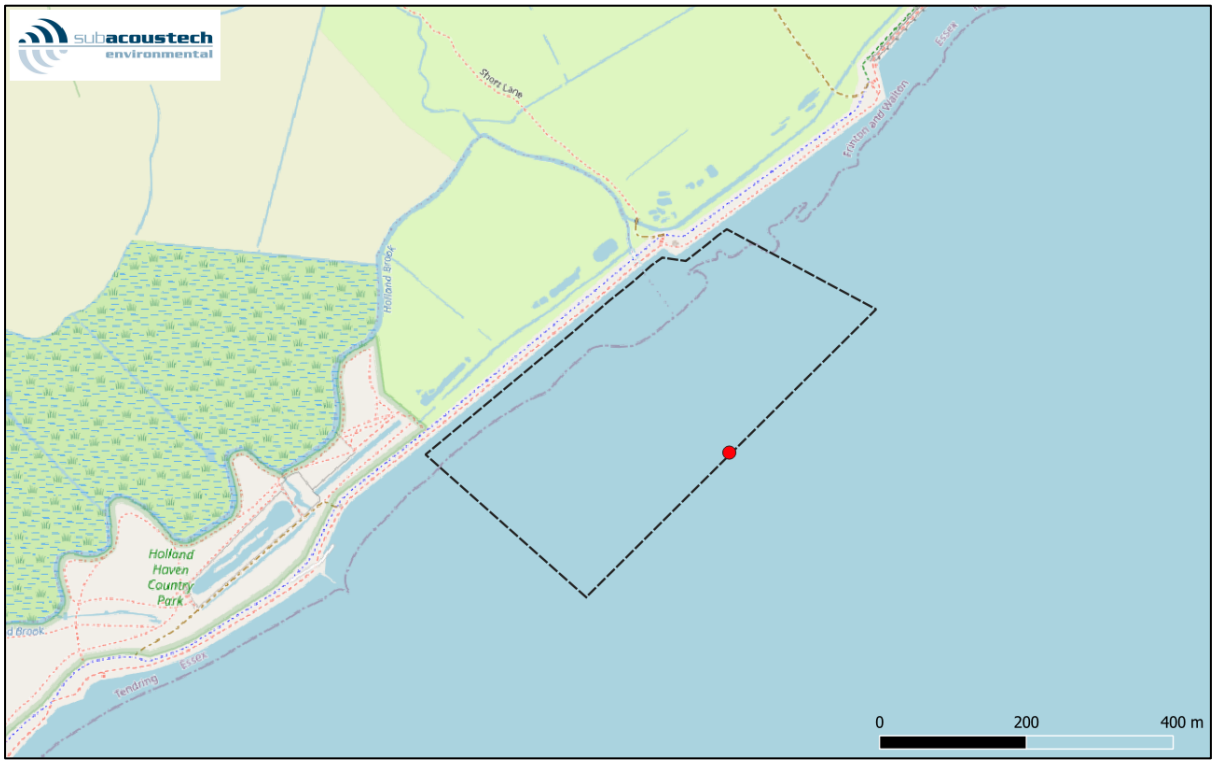

Figure 1-1 Overview map showing the VE landfall area on the Essex coast and the modelling location used in this study (shown as a red point).

This report presents an assessment of the potential underwater noise during impact piling activity during construction activities at landfall. Detailed background information on underwater noise metrics, criteria and the modelling approach are presented in Subacoustech Environmental's previous VE report (4.6.2_VE_PEIR_Volume4_Annex6.2_UWN_V0.5.

1.1 Modelling methodology

Impact piling noise from installation of a sheet piled enclosure has been modelled using Subacoustech Environmental's INSPIRE noise modelling software (v5.1) at the location shown in Figure 1-1 (51.8149°N, 001.2337°E). As the furthest from land and therefore deepest location, this represents the location likely to lead to the largest potential impact ranges. A single scenario has been modelled, considering the installation of 750 mm wide Larssen sheet piles, measuring 20 m in length using the assumed ramp up give in Table 1-1. It is possible that eight piles could be sequentially installed in a 24-hour period, this has been considered in the modelling.

Table 1-1 Summary of the soft start and ramp up scenario used for the impact piling modelling

Sheet pile	**60 kJ**	**Ramp-up**	**300 kJ**
Number of strikes	100	800	1,200
Duration	10 minutes	20 minutes	30 minutes
Blow rate	10 bl/min	40 bl/min	
1 pile: 2,100 strikes, 1 hour duration per pile 8 piles: 16,800 strikes, 8 hours total duration			

Both high and low tides have been considered for this modelling using tidal data from the Walton-on-the-Naze:

- Mean High Water Springs (MHWS): 4.6 m above lowest astronomical tide (LAT); and
- Mean Low Water Springs (MLWS): 0.1 m above LAT.

The unweighted source levels used for modelling are given in Table 1-2.

Table 1-2 Summary of the unweighted source levels used for modelling.

Source levels	**Sheet pile (MHWS)** 750 mm wide, 300 kJ blow energy	**Sheet pile (MLWS)** 750 mm wide, 300 kJ blow energy
Unweighted SPL_{peak}	224.0 dB re 1 µPa @ 1 m	216.7 dB re 1 µPa @ 1 m
Unweighted SEL_{ss}	194.2 dB re 1 μPa^2s @ 1 m	171.0 dB re 1 μPa^2s @ 1 m

Modelling has been undertaken for the Southall *et al*. (2019) noise criteria for marine mammals and the Popper *et al*. (2014) criteria for fish and sea turtles, as per the previous modelling undertaken by Subacoustech Environmental for VE.

2 Modelling results

This section presents the modelled impact ranges for impact piling noise at landfall for installation of a sheet piled enclosure. The modelling shows that greater noise levels and impact ranges are predicted during the high tide (MHWS) scenario.

For the results presented throughout this report, any predicted ranges smaller than 50 m and areas less than 0.01 km^2 for single strike criteria, and predicted ranges smaller than 100 m and areas less than 0.1 km^2 for cumulative criteria, have not been presented. At ranges this close to the noise source, the modelling processes are unable to model to a sufficient level of accuracy due to complex acoustic effects present near the pile. These ranges are given as “less than” this limit (e.g., “<100 m”).

Also, due to the proximity to the coast of the modelling location, the majority of the minimum ranges are identical as this is determined by the distance to the coast.

2.1 Predicted noise levels at 750 m

In addition to the source levels presented in Table 1-2, it is useful to look at the predicted noise levels at a range of 750 m from the noise source as a “standard” distance comparable to other projects or situations. A summary of the modelled, unweighted levels at a range of 750 m are given in Table 2-1, considering the transect with the greatest noise level while piling using the maximum hammer blow energy.

Table 2-1 Summary of the maximum predicted unweighted SPL_{peak} and SEL_{ss} noise levels at a range of 750 m from the impact piling noise sources.

Predicted level at 750 m range	**Sheet pile (MHWS)** 750 mm wide, 300 kJ blow energy	**Sheet pile (MLWS)** 750 mm wide, 300 kJ blow energy
Unweighted SPL_{peak}	171.4 dB re 1 µPa	153.8 dB re 1 µPa
Unweighted SEL_{ss}	142.3 dB re 1 μPa^2s	109.4 dB re 1 μPa^2s

2.2 Marine mammal criteria

Table 2-2 to Table 2-6 present the impact piling modelling results in terms of the Southall *et al*. (2019) and Southall *et al*. (2007) criteria for marine mammals. All PTS and TTS ranges are predicted to be less than 50 m for SPL_{peak} criteria and less than 100 m for SEL_{cum} criteria. This is due to the energy in use for the hammer and the shallow water in which the installation will take place.

Table 2-2 Summary of the unweighted SPL_{peak} impact ranges for marine mammals using the Southall et al. (2019) impulsive criteria.

Southall *et al*. (2019) Unweighted SPL_{peak} (Impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
PTS	LF (219 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	HF (230 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	VHF (202 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	PCW (218 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
TTS	LF (213 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	HF (224 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	VHF (196 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
	PCW (212 dB)	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m

Table 2-3 Summary of the weighted SEL_{cum} impact ranges for marine mammals using the Southall et al. (2019) impulsive criteria assuming a fleeing animal for a single pile installation.

Southall *et al*. (2019) Weighted SEL_{cum} (Impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
PTS	LF (183 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (185 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (155 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (185 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
TTS	LF (168 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (170 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (140 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (170 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Table 2-4 Summary of the weighted SEL_{cum} impact ranges for marine mammals using the Southall et al. (2019) impulsive criteria assuming a fleeing animal for eight sequential pile installations.

Southall *et al*. (2019) Weighted SEL_{cum} (Impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
PTS	LF (183 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (185 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (155 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (185 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
TTS	LF (168 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (170 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (140 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (170 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Table 2-5 Summary of the weighted SEL_{cum} impact ranges for marine mammals using the Southall et al. (2019) non-impulsive criteria assuming a fleeing animal for a single pile installation.

Southall *et al*. (2019) Weighted SEL_{cum} (Non-impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
PTS	LF (199 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (198 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (173 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (201 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
TTS	LF (179 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (178 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (153 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (181 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Table 2-6 Summary of the weighted SEL_{cum} impact ranges for marine mammals using the Southall et al. (2019) non-impulsive criteria assuming a fleeing animal for eight sequential pile installations.

Southall *et al*. (2019) Weighted SEL_{cum} (Non-impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
PTS	LF (199 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (198 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (173 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (201 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
TTS	LF (179 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	HF (178 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	VHF (153 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	PCW (181 dB)	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

2.3 Fish criteria

Table 2-7 and Table 2-9 present the impact piling modelling ranges in terms of the Popper *et al*. (2014) criteria for fish and sea turtles.

When considering a single sheet pile installation, the maximum TTS ranges (186 dB SEL_{cum} threshold) are predicted out to 160 m when considering a stationary receptor during the MHWS scenario, reducing to less than 100 m when a fleeing animal is assumed. For eight sequentially installed sheet piles, the maximum ranges increase to a maximum of 460 m for a stationary receptor during the MHWS scenario. However, it is an overly conservative case to consider that the eight sequentially installed piles will all occur at high tide as the tide will change throughout the day.

Table 2-7 Summary of the of the unweighted SPL_{peak} impact ranges for fish using the Popper et al. (2014) pile driving criteria.

Popper *et al*. (2014) Unweighted SPL_{peak} (Pile driving)	**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
	Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
213 dB	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m
207 dB	< 0.01 km^2	< 50 m	< 50 m	< 50 m	< 0.01 km^2	< 50 m	< 50 m	< 50 m

Table 2-8 Summary of the unweighted SEL_{cum} impact ranges for fish using the Popper et al. (2014) pile driving criteria assuming both a fleeing and stationary animal for a single pile installation.

Southall *et al*. (2019) Weighted SEL_{cum} (Impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
Fleeing (1.5 ms^{-1})	219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	186 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
Stationary (0 ms^{-1})	219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	186 dB	< 0.1 km^2	160 m	150 m	160 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Table 2-9 Summary of the unweighted SEL_{cum} impact ranges for fish using the Popper et al. (2014) pile driving criteria assuming both a fleeing and stationary animal for eight sequential pile installations.

Southall *et al*. (2019) Weighted SEL_{cum} (Impulsive)		**Sheet pile (MHWS)**				**Sheet pile (MLWS)**			
		Area	**Max range**	**Min range**	**Mean range**	**Area**	**Max range**	**Min range**	**Mean range**
Fleeing (1.5 ms^{-1})	219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	186 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
Stationary (0 ms^{-1})	219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	186 dB	0.5 km^2	460 m	240 m	390 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

3 Summary and conclusions

Subacoustech Environmental have undertaken a study to assess the potential underwater noise and its effects during impact piling activity at landfall for VE.

The modelling results show that noise levels and ranges for potential impacts will be greater during high tide conditions. All ranges at which PTS and TTS impacts could occur for marine mammals are expected to be less than 100 m. For fish, the maximum TTS range (186 dB SEL_{cum} threshold) is predicted to be 160 m for a single pile, increasing to 460 m when 8 sequentially installed piles are considered. These fish impact ranges consider a stationary receptor at high tide, the predicted ranges reduce to less than 100 m when a fleeing animal, or low tide, is assumed.

The outputs of this modelling, in conjunction with Subacoustech Environmental's previous modelling report for VE, have been used to inform analysis of the impacts of underwater noise on marine mammals and fish in their respective assessments.

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