Appendix 5.13. Underwater Noise Impact Assessment

WAVE DYNAMICS
ACOUSTIC CONSULTANTS

Mortarstown WWTP

Underwater Noise Impact Assessment

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Executive Summary

Wave Dynamics was commissioned by Uisce Eireann as acoustic consultants for the Mortarstown Upper project located at 6-10 Maple Ct, Mortarstown Upper, Co. Carlow, Ireland.

Upgrades to the Mortarstown Wastewater Treatment Plant are intended to ensure effluent meets Wastewater Discharge Licence. Works include a new 900mm outfall pipeline and headwall, requiring a temporary cofferdam in the River Barrow.

This report evaluates underwater noise risks from sheet pile installation, focusing on sensitive species within the River Barrow and Nore Special Area of Conservation. The most sensitive identified receptors include lampreys, salmon, shad and otters.

Piling for the cofferdam, lasting around a week within a three-month works programme (post-2028), is the primary potential source of underwater noise. Other construction activities are not expected to generate significant underwater sound levels. The pilling methodology is unknown at this time, therefore a conservative assessment of sheet piles installed by vibratory and/or impact hammers has been undertaken. A logarithmic spreading model estimates propagation to aquatic receptors. The noise impact assessment uses established guidelines for anthropogenic activity on sensitive fish and marine mammals.

Noise impacts were assessed for key fish identified. Results indicate an overall low risk of impact: the sound level falls below all threshold values for all receptors beyond 12m from source, even under worst-case assumptions. Within 12m, temporary threshold shifts may occur, while injury risks are limited to under 2m. Given species' mobility and limited spawning suitability at the site, prolonged exposure is unlikely.

As the river is only 30–40m wide, migrating fauna may occasionally pass within 12m during piling activity. Timing works to avoid peak migration periods is recommended.

Table of Contents

1 Introduction

1.1 Scope

Wave Dynamics were engaged by Uisce Eireann as the acoustic consultants on Mortarstown WWTP, Mortarstown Upper, Co. Carlow, Ireland.

Upgrade works have been proposed to Mortarstown Wastewater Treatment Plant (WWTP). The principal objective of the works is to ensure that the treatment process can produce a treated effluent which satisfies the conditions of the Wastewater Discharge Licence (D0028-01).

As part of the proposed upgrade works a single, temporary cofferdam in the River Barrow will be required to install a new headwall and outfall pipe. This report assesses likely levels of underwater noise transmission into the River Barrow from the installation of sheet piles required for the cofferdam, and the impact of this noise on sensitive species within the river. Species that could be occupying the river around the piling location have been reviewed for potential sensitivity to this noise source.

1.2 Underwater Noise Impact

Over the past 25 years, it has become clear that human-made underwater noise can affect marine life. The level of harm depends on how loud the sound is, its frequency, how long it lasts, and how often it occurs. Loud activities like blasting or piling are studied most, but interest in long-term noise effects is growing. The main impacts on marine species include:

- Physical injury or death
- Temporary or permanent hearing damage
- Behavioural disturbance

1.3 Terminology used in this assessment

Sound can be defined as the periodic disturbance in pressure from some equilibrium value. The unit of pressure is given in Pascals, Pa, or Newtons per square metre N/m^2. Sound levels are expressed in decibels, dB, and for underwater measurements are often relative to a fixed reference pressure of 1 μPa.

Peak Sound Level (SPL_{peak})

For instantaneous pressure pulses such as a drop hammer impact or explosion, the peak sound level is the maximum absolute value of the instantaneous sound pressure recorded. SPL_{peak} is calculated using the variation in pressure from peak to equilibrium (zero) within the wave.

RMS Sound Pressure Level (SPL_{rms})

The Root-Mean-Square Sound Pressure Level is often used to quantify noise of a continuous nature and is the standard way to express average sound levels over a specified time period. The SPL_{rms} is calculated by squaring, averaging, and then taking the square root of the values measured over a given time interval.

Sound Exposure Level (SEL)

The problems associated with the time-period over which the Sound Pressure Levels are averaged, as highlighted above, can be overcome by describing a transient pressure wave in terms of the Sound Exposure Level. The Sound Exposure Level is the sum of the acoustic energy over a measurement period and effectively considers both the level of the sound, and the duration over which the sound is present in the acoustic environment. When a sound time-period is less than 1 second, the SPL_{rms} will be greater than the SEL, and for signals of greater than 1 second, the SEL will be greater than the SPL_{rms}.

Cumulative Sound Exposure Level (SEL_{cum})

Where multiple transient pressure wave events occur, the total or cumulative Sound Exposure Level from multiple events can be calculated by summing the SEL from a number of individual events. The individual events can be separated in time and/or space. For instance, the events could be consecutive from drop hammer impacts or continuous from vibration piling over a given period.

Temporary Threshold Shift (TTS)

A short-term reduction in hearing sensitivity following exposure to high sound levels. Hearing sensitivity is recoverable within minutes, hours or weeks depending on the exposure type and may or may not reduce fitness. If repeated it may lead to permanent threshold shift.

Permanent Threshold Shift (PTS)

A long-term reduction in hearing sensitivity following exposure to high sound levels. PTS is categorised as TTS that persists after a period of recovery, typically a month. This causes irreversible hearing loss, by long term exposure to sound above safe limits or a single sound event.

2 Receptors

2.1 Identified Potential Receptors

The River Barrow and River Nore SAC conservation objectives[1] (site code 002162) identify the following fauna as listed species under Habitats Directive:

[1016] Desmoulin's Whorl Snail (Vertigo moulinsiana)
[1029] Freshwater Pearl Mussel (Margaritifera margaritifera)
[1092] White-clawed Crayfish (Austropotamobius pallipes)
[1095] Sea Lamprey (Petromyzon marinus)
[1096] Brook Lamprey (Lampetra planeri)
[1099] River Lamprey (Lampetra fluviatilis)
[1103] Twaite Shad (Alosa fallax)
[1106] Atlantic Salmon (Salmo salar)
[1355] Otter (Lutra lutra)

Molluscs

The molluscs have no dedicated hearing apparatus but can detect tactile vibration to some extent; and the Crayfish have limited sensory apparatus, providing some awareness of the underwater sound environment.

Fish

The hearing sensitivity of the fish fauna listed varies and has been summarised below:

- Sea, Brook & River Lamprey are jawless fish that lack swim bladders[2].
- The Twaite Shad is a clupeid and has specialist hearing abilities. It has a swim bladder with direct mechanical coupling that link it to the inner ear[3].
- The Atlantic Salmon has a swim bladder but lacks secondary hearing modifications linking the swim bladder to the ear[4].

Marine Mammals

Although not a true marine mammal, the Eurasian river otter (Lutra Lutra) is semi-aquatic with traditional mammalian hearing (like sea otters). Eurasian river otters in the River Barrow have the ability to leave the water if underwater piling noise is high. Sea otters are believed to have a lower sensitivity to underwater sounds compared with other amphibious marine mammals (seals and sea lions), especially at low frequencies[5]; this is likely to be similar for Eurasian river otters.

[1] NPWS. (2025). *Conservation Objectives: River Barrow and River Nore SAC 002162*. Version 2. National Parks and Wildlife Service, Department of Housing, Local Government and Heritage.
[2] Borowiec, B.G., Docker, M.F., Johnson, N.S., Moser, M.L., Zielinski, B. and Wilkie, M.P. (2021). Exploiting the physiology of lampreys to refine methods of control and conservation. *Journal of Great Lakes Research*. [online] doi:https://doi.org/10.1016/j.jglr.2021.10.015.
[3] Lovell, J. (2009). *The Inner Ear Morphology and Hearing Abilities of Twaite Shad and a Selection of Marine and Freshwater Fish*. [online] *Institute of Acoustics*. Available at: https://www.ioa.org.uk/system/files/proceedings/j_lovell_the_inner_ear_morphology_hearing_abilities_of_twaite_shad_a_selection_of_marine_freshwater_fish.pdf [Accessed 28 Aug. 2025].
[4] Harding, H., Bruintjes, R., Radford, A.N. and Simpson, S.D. (2016). *Measurement of Hearing in the Atlantic Salmon (Salmo Salar) Using Auditory Evoked Potentials, and Effects of Pile Driving Playback on Salmon Behaviour and Physiology*. The Scottish Government.
[5] Ghoul, A. and Reichmuth, C. (2014). Hearing in the sea otter (Enhydra lutris): auditory profiles for an amphibious marine carnivore. *Journal of Comparative Physiology A*, 200(11), pp.967–981. doi:https://doi.org/10.1007/s00359-014-0943-x.

2.2 Electro Fishing

Electro fishing for Lampreys at the proposed site was conducted on 3rd July 2025 by Triturus Environmental. No Lampreys were recorded during the survey, and survey of the river conditions at site suggested it is low value to Lampreys for both spawning and as a nursery habitat. The central channel was not considered to be of high value for salmonids due to slow flow rates and a more homogenous profile.

3 Assessment Criteria

Contemporary underwater noise assessments use assessment criteria derived by Popper et al., 2014[6], and Southall et al., 2019[7], to estimate the potential noise impact for fish and marine mammals respectively. They indicate cumulative sound levels and/or peak sound levels that can cause adverse effects on hearing and injury.

Assessment of more sensitive fish and marine mammals provides a robust position in relation to the impact on molluscs.

Criteria Adopted for Fish

Popper et al, 2014[6], have proposed exposure criteria for noise sources of different character. Vibratory pile driving is classified as a continuous noise source and although a table is presented by Popper et al. it contains minimal numerical thresholds for use within this assessment. Due to greater amounts of historical research for impulsive plie driving, bespoke numerical criteria have been developed, and a summary has been shown below in Table 1.

Table 1 – Impact pile driving criteria for fish as defined by Popper et al (2014).

Type of Animal	Mortality and potential mortal injury	Recoverable injury	TTS
Fish: no swim bladder	>219 dB SEL_{cum} or >213 dB SPL_{peak}	>216 dB SEL_{cum} or >213 dB SPL_{peak}	>>186 dB SEL_{cum}
Fish: swim bladder not involved in hearing	210 dB SEL_{cum} or >207 dB SPL_{peak}	203 dB SEL_{cum} or >207 dB SPL_{peak}	>186 dB SEL_{cum}
Fish: swim bladder involved in hearing	207 dB SEL_{cum} or >207 dB SPL_{peak}	203 dB SEL_{cum} or >207 dB SPL_{peak}	186 dB SEL_{cum}
Eggs and larvae	210 dB SEL_{cum} or >207 dB SPL_{peak}	(Near) Moderate (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low

Note: Mortality and mortal injury - immediate or delayed death.
Recoverable injury - injuries, including hair cell damage, minor internal or external hematoma.
TTS, for these Guidelines, is defined as any change in hearing of 6 dB or greater that persists. This level is selected since levels less than 6 dB are generally difficult to differentiate. It is also the view of the WG that anything less than 6 dB will not be a significant effect from the standpoint of hearing.

Criteria Adopted for Marine Mammals

Southhall et al., 2019[7], have proposed noise exposure criteria for different categories of marine mammal, a common method used for evaluating underwater noise impact on aquatic mammals. The *Mustelidae* family, are semi-aquatic mammals that spend most of their time in water and are categorised by Southall et al. as Other Marine Carnivores in Water (OCW). Eurasian river otters, although not officially classifying as marine carnivores, are part of the *Mustelidae* family and therefore the criteria for OCW have been used within this assessment. These criteria are expected to be robust upon comparing to the heightened sensitivity of other mammals within this category (e.g. seals and sea lions)[5].

[6] 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., Svein Løkkeborg, Rogers, P.H., Southall, B.L., Zeddies, D.G. and Tavolga, W.N. (2014). Sound Exposure Guidelines for Fishes and Sea Turtles. *SpringerBriefs in oceanography*, pp.33–51. doi:https://doi.org/10.1007/978-3-319-06659-2_7.
[7] Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. and Tyack, P.L. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals*, 45(2), pp.125–232. doi:https://doi.org/10.1578/am.45.2.2019.125.

An adapted table of relevant criteria has been shown in below:

Table 2. Summary of criteria relevant to Other Marine Carnivores in Water (OCW).

Weighted SEL_{cum} or Unweighted Single Strike SPL_{peak}	**Impulsive**		**Non-Impulsive**	
	PTS	**TTS**	**PTS**	**TTS**
OCW (unweighted)	232 dB SPL_{peak}	226 dB SPL_{peak}	-	-
OCW (weighted)	203 dB SEL_{cum}	188 dB SEL_{cum}	219 dB SEL_{cum}	199 dB SEL_{cum}

Note: SEL_{cum} has been weighted to approximate the specific hearing sensitivity of the receptor

Explosives and impact piling are considered impulsive noise sources, whereas vibratory piling and drilling are considered are considered non-impulsive.

As piling works are understood to potentially use impact piling and vibratory piling, both have been considered within this assessment.

4 Noise Climate

4.1 Baseline Noise Level

Commercial trade on the river Barrow is understood to have ended in 1959 with current boating traffic primarily consisting of small recreational river boats which are regulated by Waterways Ireland. A baseline noise survey was not undertaken at the site however, underwater noise climates in similar rural sections of river indicate the baseline noise levels will be low relative to any proposed piling activity.

4.2 Bathymetric Survey

A bathymetric survey was conducted on the river Barrow during July 2021 by Triturus Environmental for the location of proposed works.

A SONAR survey confirmed an average mean depth of the River Barrow of around 2.4m in vicinity of the proposed site works. The River Barrow follows a typical trapezoidal profile, with shallow margins steeply grading into a deeper centre channel of >3m as shown in Figure 4 (Appendix A).

A bottom substrate hardness survey indicated the riverbed, at the location where the piles will be driven, is a mixture of both soft and harder substrata e.g. gravels, cobbles, occasional boulders.

4.3 Proposed Site Works

Upgrade works have been proposed to the Mortarstown Wastewater Treatment Plant. The project includes construction of a new 900mm diameter outfall pipeline and a new headwall at the discharge point to the River Barrow classified as part of the River Barrow and River Nore Special Area of Conservation.

Site works in close proximity to the river (around the headwall area) are anticipated to commence post 2028 in the season deemed most appropriate to minimise impact on the surrounding environment. Construction works are estimated to last three months with initial piling estimated to occur for about a week.

The most significant potential impact on aquatic life will be the temporary works, more specifically the installation of temporary sheet piles to form a cofferdam at the termination of the outfall pipe. Piling works are proposed within the water as well as on the river's edge, depending on tidal depth. It is understood that extent of other works such as trenching, construction of a temporary working platform, installing the pipeline / headwall and removing the sheet piling, is not expected to cause underwater noise levels above the noise exposure criteria adopted.

The proposed boundary of site works, location of temporary sheet pile installation and SAC designation have been shown below in Figure 1, Figure 2 and Figure 3 (Appendix A) respectively.

Sheet piles will be driven into the embankment utilising different pile driving methods depending on the properties of the soil. Impact and vibratory hammers are the most common pile driving options, followed by push hammers. Vibratory and push hammers are quieter solutions, but they have limited pile driving capabilities and can only be used where soil condition allow therefore impact hammer piling may still be required. The use of push hammers is less common and there is minimal noise data available for this activity. For robust assessment, both noise from impact hammer piling as well as vibratory piling have been used to predict worst case source noise levels.

4.4 Piling Noise data

As piling activity is not due to commence on site until at least 2028, underwater sheet piling noise data measured at a similar site has been used for this assessment.

Source sound levels have been derived from measurements conducted by Hart Crowser and Illingworth & Rodkin for the URS Corporation[8] (2009) during piling works on the Kink Arm, Port of Anchorage, Alaska. During the survey sheet piles were installed using both impact and vibratory piling methods. Data was gathered over four days with over 9929 impulse hammer strikes recorded, providing a reliable source of piling data.

For impact piling, both *BSP SL30* and *J&M 115* impact hammers were used during the survey; to form robust assessment the louder *J&M 115* has been used in the calculations. For vibratory piling, an *APE 200-6* vibratory driver was used which is estimated to be similar in form to vibratory drivers that will be used at the Mortarstown Wastewater Treatment Plant.

The worst case recorded Peak SPL and SEL levels have been used and have been shown in Table 3 and Table 4 Impact sheet piling and vibration sheet piling respectively.

Table 3. Predicted Impact piling source levels used within this assessment.

Impact Sheet Piling (*J&M 115*)	**Reference level at ~5m**
Peak SPL (dB re 1 μPa)	195 dB
SEL per single strike (dB re 1 $\mu Pa^2 s$)	165 dB

Table 4. Predicted Vibratory piling source levels used within this assessment.

Vibratory Sheet Piling (*APE 200-6*)	**Reference level at ~7m**
Peak SPL (dB re 1 μPa)	184 dB
SEL per second of operation (dB re 1 $\mu Pa^2 s$)	171 dB

Source Data Limitations

As the Port of Anchorage is located on an estuary, the width and depth of the channel far exceeds the dimensions of the River Barrow. Propagation loss from the source to the receiver during this survey is not likely to be representative of propagation at the study site. Reference levels used are measured close to the source to minimise the impact of this effect.

The results of this survey were recorded during the driving of ~27m long piles. Due to the shallow depth of the River Barrow the sheet piles used will likely be shorter and thinner.

4.5 Propagation Model

Piles driven within the water will have the most direct noise transmission path to the receptors. From bathymetry data a concave river profile is present and therefore there will be direct 'line of sight' between the noise source and the receiver locations. Vibration will be transferred from the impact hammer through the pile and into the riverbed causing the highest underwater reradiated noise where the pile meets the seabed.

In accordance with good practice guidance[9], a simple logarithmic spreading model has been used to predict the propagation of sound levels from the key sources of underwater noise associated with the proposed works. This model is represented by a logarithmic equation and incorporates factors for noise attenuation and absorption losses.

[8] URS Corporation (2009). *Acoustic Monitoring and In-situ Exposures of Juvenile Coho Salmon to Pile Driving Noise at the Port of Anchorage Marine Terminal Redevelopment Project Knik Arm, Anchorage, Alaska.* Report No. 12684-03. A report produced by Hart Crowser and Illingworth & Rodkin for URS Corporation, October 2019.

[9] NPL (2014). *Good Practice Guide for Underwater Noise Measurement*, National Measurement Office, Marine Scotland, The Crown Estate, Robinson, S.P., Lepper, P. A. and Hazelwood, R.A., NPL Good Practice Guide No. 133, ISSN: 1368-6550.

Despite the simple logarithmic spreading model representing a basic model of propagation loss, its use is an established approach in Environmental Impact Assessments that has been accepted for recent developments in shallow water marine environments (e.g. Stantec, 2023[10]; RPS, 2018[11]).

The logarithmic model for sound propagation shown below has been applied to estimate how noise levels from major underwater sources related to the proposed site works will spread. This approach uses a logarithmic relationship that considers reductions due to both spreading and absorption.

$$L_{reciever} = L_{ref} - N \log_{10}(R/R_0) - \alpha(R - R_0)$$

Where:

- $L_{reciever}$ represents the sound level received at a distance R from the source;
- R is the distance in meters between the source and the reciever;
- R_0 is the distance in meters between the source and the reference measurement position;
- L_{ref} is the reference level, or the intensity of sound produced at the reference measurement position;
- N is the coefficient accounting for losses from geometric spreading; and
- α is the coefficient for sound absorption in water and at interfaces (such as sediment or the water surface), measured in dB per meter.

Gathered empirical data on attenuation (N coefficient) and absorption (α coefficient) factors were shared during the UK Institute of Fisheries Management Conference on May 23, 2013. This data stems from monitoring efforts at various construction sites in shallow water settings. These have been listed below:

- Russian River New Bridge in Geyserville, California[12];
- San Rafael Sea Wall in San Francisco Bay, California[12];
- Scroby Sands Offshore Wind Farm located off the coast of Great Yarmouth[13];
- North Hoyle Offshore Wind Farm in Liverpool Bay[13];
- Kentish Flats Offshore Wind Farm located off the coast of Kent[13];
- Burbo Bank Offshore Wind Farm in Liverpool Bay[13];
- Barrow Offshore Wind Farm located south west of Walney Island[13]; and
- Belvedere Energy-from-Waste Plant on Thames Estuary (measurements collected by Subacoustech Ltd on behalf of the Environment Agency and Costain).

From this data, the average N coefficient is 17.91 (based on 11 measurements), and the average α coefficient is 0.00523 dB m^{-1} (based on 9 measurements).

The resulting propagation model used within this assessment is:

$$L_{reciever} = L_{ref} - 17.91 \log10(R/R_0) - 0.00523(R - R_0)$$

Model Limitations

There are a number of limitations associated with the use of simple logarithmic spreading models[9]. Such models do not account for changes in bathymetry and, therefore, are not able to predict the changes in sound propagation caused by sand banks and changes in water depths.

[10] Stantec (2023). *Linkspan Replacement*, Fishguard Harbour Environmental Statement: Marine Biodiversity. ABPmer Report No. R.2885. A report produced by ABPmer for RPS, April 2018.
[11] RPS (2018). *Fair Isle Ferry Upgrade, Underwater Nosie Assessment.* ABPmer Report No. R.4174. A report produced by ABPmer for Stantec, March 2023.
[12] Illingworth, R. and Rodkin, R. (2007). *Compendium of Pile Driving Sound Data.* Prepared for: The California Department of Transportation, Sacramento, CA.
[13] Nedwell, J.R., Turnpenny, A.W.H., Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L. and Howell, D. (2007a). *A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise.* Subacoustech Report No. 534R1231.

Another limitation of simple logarithmic spreading models is that they do not explicitly include frequency dependence and so cannot predict the increased transmission loss at high frequencies due to increased sound absorption.

The proposed works at Mortarstown Wastewater Treatment Plant take place in very shallow water <4m therefore, the propagation of noise will be limited. Shallow water has a high cut-off frequency and attenuates any signals with frequencies lower than this cut-off frequency. The cut-off frequency gets higher as the water gets shallower[14]. In this way, the propagation of low frequency underwater noise such as piling will be reduced in very shallow water locations compared to in the deep oceanic waters. At high frequencies, >10 kHz, increasing absorption also prevents sound propagating over large distances in shallow water.

While advanced models exist, they depend on a multitude of assumptions and variables such as hammer energy, pile penetration depth, sediment properties, and acoustic impedance that necessitate precise empirical data for reliable outcomes; however, the source data used for this assessment is derived from generalized studies, lacking the site-specific precision and validation required to meaningfully populate these parameters. They typically need extensive input data e.g. hammer energy or pile depth, which can only be accurately specified after finalizing the project's design and methods.

Overall, a simple logarithmic spreading model based on conservative assumptions is considered proportionate and sufficiently precautionary to use for this underwater noise assessment.

[14] Harland, E.J., Jones, S.A.S. and Clarke, T. (2005). *SEA 6 Technical report: Underwater ambient noise*. QINETIQ/S&E/MAC/CR050575.

5 Impact

5.1 Risk of Impact

For cumulative sound exposure level calculations, a stationary animal model was applied. This approach assumes that the receptor stays in position during exposure to high noise levels, providing a worst-case estimate of the exposure received. It represents a worst-case scenario because the receptors are migratory, anticipated to be highly mobile, and unlikely to stay motionless in the water close to the noise source; instead, they would likely swim away if encountering noise deemed disturbing or hazardous. The model assumes the receptor remains in the middle of the river, nearest to the piling activity, for 10 minutes - a duration viewed as a worst-case estimate for the time needed to drive a single pile.

This assessment assumes an impact hammer strike rate of 1 strike per second. This is robust as the typical operating rate of single acting hammers range between 35 and 60 strikes per minute.

A summary of predicted peak sound pressure levels and cumulative sound exposure levels for both impact and vibratory piling at notable distances from the source is shown below:

Table 5. Summary of predicted sound levels at notable distances from the source.

Distance from source	Impact Sheet Piling		Vibratory Sheet Piling	
	Predicted SPL_{peak}	Predicted SEL_{cum}	Predicted SPL_{peak}	Predicted SEL_{cum}
1 m	208 dB	205 dB	199 dB	214 dB
10 m	190 dB	187 dB	181 dB	196 dB
25 m	182 dB	180 dB	174 dB	189 dB
50 m	177 dB	175 dB	168 dB	183 dB
100 m	171 dB	169 dB	163 dB	178 dB
150 m	168 dB	166 dB	159 dB	174 dB
200 m	165 dB	163 dB	157 dB	172 dB
300 m	162 dB	159 dB	153 dB	168 dB
400 m	159 dB	157 dB	150 dB	165 dB
500 m	157 dB	154 dB	148 dB	163 dB

Impact Piling Risk

Threshold distances from the source at which adverse effects on hearing and injury for marine fauna are likely - using criteria set out by Popper et al. (2014) and Southall et al. (2019) - have been tabulated below for impact piling.

Table 6. Marine animal threshold distances associated with impact piling activity.

Type of Animal	Mortality and potential mortal injury	Recoverable injury	PTS	TTS
Fish: no swim bladder	No Threshold	No Threshold	-	< 12 m
Fish: swim bladder not involved in hearing	< 2 m	< 2 m	-	< 12 m
Fish: swim bladder involved in hearing	< 2 m	< 2 m	-	< 12 m
Eggs and larvae	< 2 m	-	-	-
Other Marine Carnivores in Water (OCW)	-	-	< 2 m	< 10 m

Vibration Piling Risk

Threshold distances from the source at which adverse effects on hearing and injury for marine mammals are likely - using criteria set out by Southall et al. (2019) - have been tabulated below for vibration piling.

Table 7. Marine animal threshold distances associated with vibration piling activity.

Type of Animal	PTS	TTS
Other Marine Carnivores in Water (OCW)	No Threshold	< 7 m

5.2 Behavioural Response

Behavioural reactions to acoustic exposure are less predictable and difficult to quantify than effects of noise exposure on hearing or physiology, as reactions are highly variable and context specific[15].

Agencies such as the U.S. National Marine Fisheries Service, as well as other, currently use SPL_{rms} 150 dB (ref. 1 µPa) as the sound pressure level that may result in onset of behavioural effects[16]. It is indicated that levels above this threshold are expected to cause temporary changes in behaviour which might include startle responses, feeding disruption and area avoidance. However, Popper et al., 2019[17], state concerns with this figure, including its origin and scientific basis is unknown and a single criterion value for behaviour does not consider animal age, season, or motivational state along with very substantial species differences.

In the absence of any alternative numerical criteria for behavioural effects, this SPL criterion has been compared with a conservative estimate of SPL_{rms} by using SPL_{peak} – 3 dB. This has been used to estimate an indicative range that could induce behavioural effects. Behavioural effects of impact piling could be observed up to ~700 m from source and behavioural effects of vibratory piling could be observed up to ~310 m from source.

[15] Southall, Brandon L., Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr, David Kastak, et al. (2007). *Marine Mammal Noise-Exposure Criteria: Initial Scientific Recommendations*. Aquatic Mammals 33 (4): 411–521.
[16] Caltrans (2015). *Technical guidance for assessment and mitigation of the hydroacoustics effects of pile driving on fish*. p. 532. Sacramento, CA.
[17] Popper, A.N. and Hawkins, A.D. (2019). An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *Journal of Fish Biology*, 94(5), pp.692–713. doi:https://doi.org/10.1111/jfb.13948.

6 Conclusion

An evaluation has been conducted on the possible effects of underwater sound generated by impact and vibratory piling for the planned temporary cofferdam at Mortarstown Upper on various fish species (including Lampreys, Atlantic Salmon, and Twaite Shad) as well as otters within the River Barrow.

The worst-case piling operations will occur with the end of the piles submerged in water, a logarithmic spreading model has been used to determine the propagation to receptors within the water.

Drawing from established guidelines on potential harm to fish[6] and other aquatic carnivores like otters[7], the overall likelihood of negatively impact on vulnerable species remains low, even when applying conservative estimates. During piling, sound intensities at a distance greater than 12m from the source are expected to be below levels capable of inducing temporary threshold shift in fish or marine mammals, including in the most adverse scenarios.

At distances less than 12m from the source temporary threshold shift is predicted to occur in marine animals, in addition to injury / permanent threshold shift and potential mortality occurring at distances less than 2m from the source. As the sensitive marine animals within this assessment are mobile, under normal conditions, entering and/or staying within these ranges during piling works is unlikely. Furthermore, electrofishing at the site suggested low value for spawning (eggs and larvae).

As the river is only 30-40 m wide (dependant on rainfall and season) any marine fauna migrating along the river during the piling works may have to swim within 12m of the source to traverse. Piling works should therefore be scheduled with consideration to seasonal migratory patterns to avoid months with peak migration for respective species (often during spring).

Appendix A – Figures

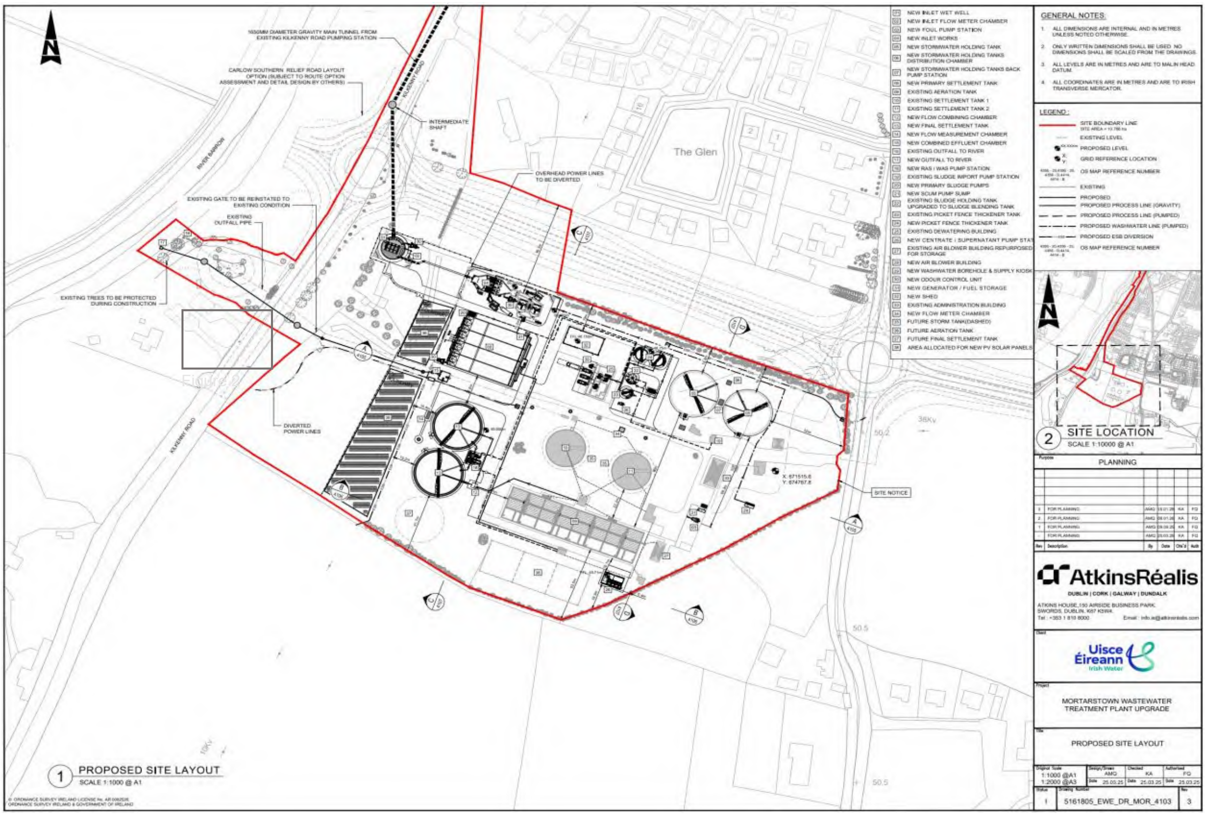

Figure 1 - Proposed Boundary of Site Works.

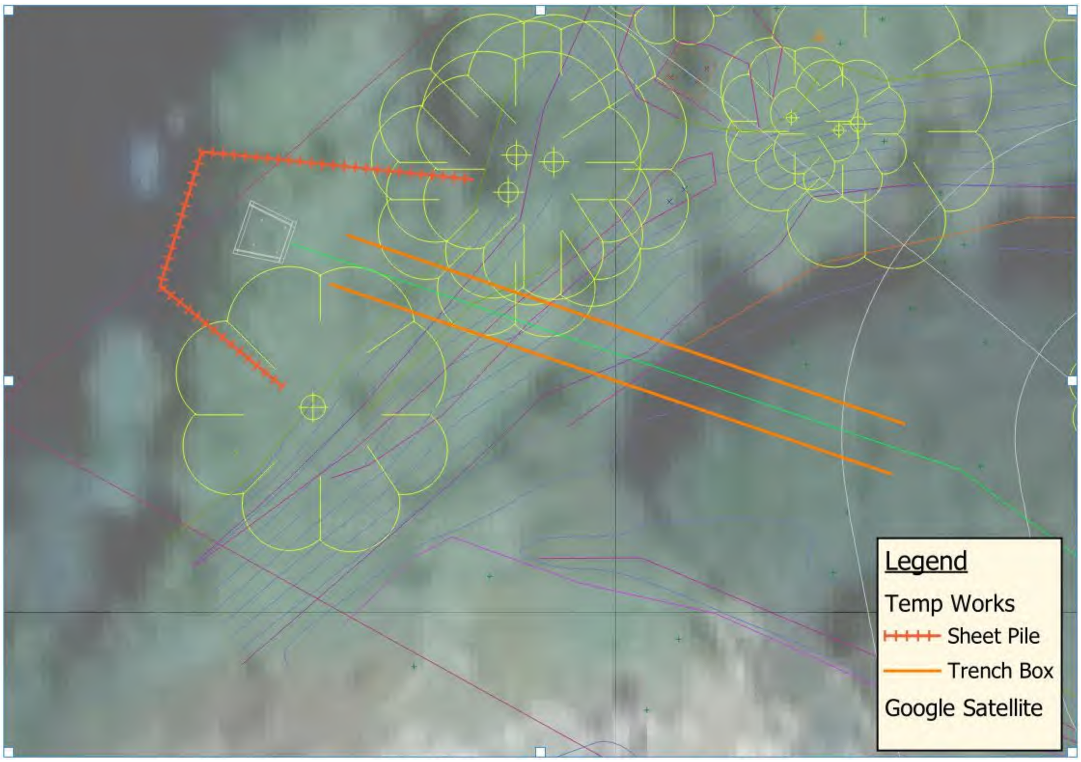

Figure 2 - Proposed location of sheet piles.

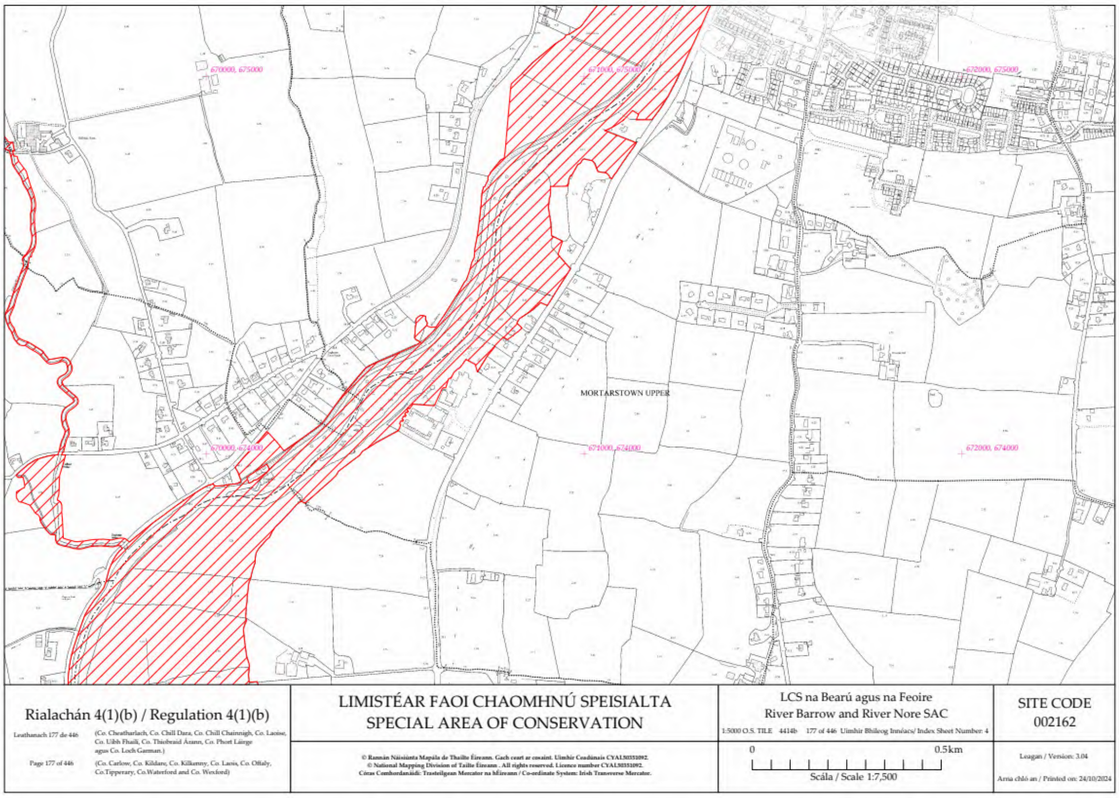

Figure 3 - SAC Designation Map.

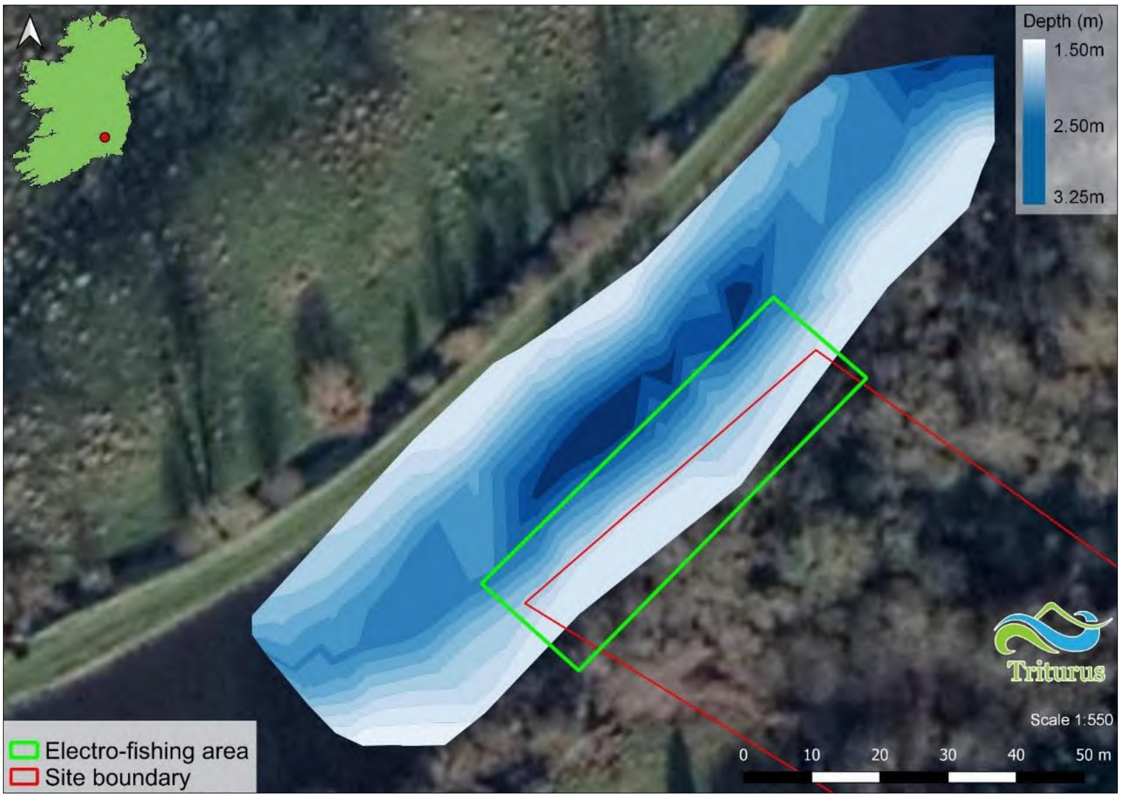

Figure 4 – Electro fishing area and heatmap displaying the river depths around the proposed site.