River Dee Crossing HDD Underwater Noise and Vibration Assessment

Dŵr Cymru Welsh Water

P00005198

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Cover image shows Horizontal Directional Drill Jetting Assembly; taken from O'Connor Utilities Ltd. 2021.

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1. Introduction

1.1 Project Background

Dŵr Cymru Welsh Water (DCWW) commissioned APEM to produce an Underwater Noise and Vibration Assessment for the proposed River Dee Crossing project (herein referred to as the Proposed Development).

DCWW are proposing to install a new twin water main to increase resilience of supply between Connahs Quay and the development areas to the north of the River Dee. The route of the proposed pipeline requires a directional drill beneath the tidal River Dee (Figure 1).

Figure 1. Location of the Proposed Development Site.

1.2 Summary of works for the Proposed Development

The proposed crossing route commences south of the River Dee within an open field (c. NGR SJ 3006 6953) where it is to be connected to the existing water main. The route follows a north-easterly direction beneath Dock Road, a short section of green open space, an access road, a salt marsh, the River Dee, a further section of salt marsh, a flood bund and TATA Steel's infilled pond/lagoon. It will reconnect to the existing water main in TATA Steel's green open space (brownfield site) (c. NGR SJ3050 7020) (Figure 2).

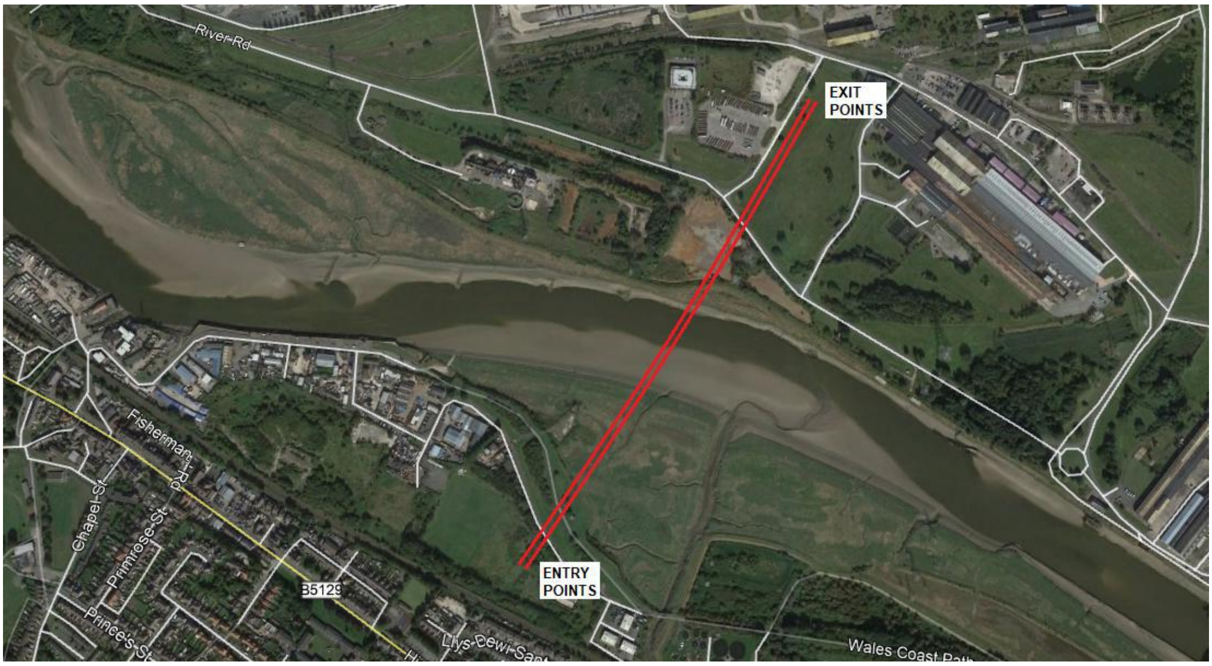

Figure 2: Overview figure showing route of the proposed HDD (taken from O'Connor Utilities Ltd 2021).

To install the new twin water main, two parallel (10m separation) Horizontal Directional Drills (HDD) will be conducted under the River Dee to receive 2x c.900 m 500 mm O/D (SDR-9 PE100) Barrier Pipe, with new connections to connect to existing pipework on either side.

The main works activities are summarised in the following bullets:

- Mobilisation, which will include:
  - Construction of an area for parking of the rig and support vehicles at the drill Entry Point (approximately 50 m x 50 m), and a working area at the Exit Point for pipe handling and drilling fluid transfer (approximately 20 m x 20 m). NB these areas need not be square but can be flexible to avoid e.g. tree root zones.
  - Excavation of a 'launch pit' and a 'reception trench', both 2.0 m x 2.0 m x 1.2 m deep.
- Construction, which will include:

  - Drilling of the pipeline pilot hole – a 12-1/4" diameter HDD.
    - Drill depth will be in excess of 24 m below the river bed at all points and along most of the tunnel route it will be at a depth of 32 m below the river.
    - With the exception of the entry descent and exit climbs, the drill is wholly contained within clay geology. The HDD bores will penetrate the top of the clay before drilling under the historic landfill site to the north of the Dock Road, and remain within the clay while drilling under the River Dee and the leachate lagoon on the north bank of the river.
    - Made ground at the entry site (between 2.90 m and 3.60 m thick) will contain landfill waste – old council general refuse site. Ground investigations and a waste strategy have been completed.
    - Below the Made Ground is a ~12.5 m thick sequence of silty fine to medium Sand before the top of the Clay is encountered at between 15.70 m and 15.90 m bgl.
    - At exit the bore will drill back up through the silty gravelly Sand before encountering Made Ground including cobbles and boulders of concrete and brick from a depth of ~2.4 m bgl (construction rubble).
  - Hole opening passes – progressively larger reamers (e.g. 18", 24" and 28") are pulled through to open the pilot hole to the required finished diameter.
  - Abstraction of water (to facilitate drilling) from the Wepre Gutter, a tidal creek located adjacent to the south working area, at around 8 m^3 per day. (NB this abstraction rate falls below the abstraction licensing threshold of 20 m^3/day).
  - Use of drilling fluid (under pressure) as a drill lubricant, coolant, hole wall sealant and finished barrier pipe grout surround. Drill fluid is continuously recycled and is deployed during both pilot holes and reamer passes.
  - Removal of cuttings via the drilling fluids to the mud pit. The mud pit is a pit that is excavated close to the HDD entry point. The sidewalls of the mud pit are built up to form a bund around the mud pit.
  - Disposal of waste drilling fluid (at the end of the operation) to landfill (non-hazardous waste classification). Cuttings will remain on site for use in reinstatement or landscaping (non-hazardous waste classification).
  - Laydown, jointing, inspection and testing of the barrier pipe in the north, prior to pulling in.
  - Pulling in and testing of the barrier pipe.
  - Connection works – shallow excavations will facilitate connections to the existing water mains in proximity to the HDD entry and exit points.
- Demobilisation including reinstatement of the site.
- Enhancement works

- Works to improve the habitat of an area on the parcel of land to the north of Dock Road, with intention of biodiversity net gain. Works will replace old concrete, hardstanding and scrub with a new species rich grassland habitat.

Further details of the methods are provided in the Method Statement and supporting appendices (O'Connor Utilities Ltd. 2021).

1.3 Timing of works

The works (mobilisation – demobilisation) are planned between May 2022 and April 2023, with the drill period scheduled 25th July 2022 to 11th November 2022.

1.4 Assessment scope

The scope of this assessment is to assess the potential effects of underwater noise and vibration from the Proposed Development on marine ecology receptors.

2. Relevant Law, Policy and Guidance

2.1 Legislation

There are a number of different legislative instruments that are relevant to the assessment of potential effects of underwater noise and vibration due to the Proposed Development. Some key relevant international legislation is indicated in Table 1. At the time of preparing this assessment (May 2021) it is assumed that legal provisions for the UK's exit from the EU include retained relevant EU environmental legislation in relation to marine ecology.

Table 1. Summary of international and national legislation of relevance to the proposed construction.

Title	Summary and Relevance
Convention on the Conservation of European Wildlife and Natural Habitats (the 'Bern Convention') 1982	Annex III of the Bern Convention concerns the conservation of European wildlife and natural habitats. It includes a list of protected faunal species. Some fish species on this list could be present within the vicinity of the Proposed Development.
The Conservation of Habitats and Species Regulations 2017 (as amended)	The Conservation of Habitats and Species Regulations 2017 (as amended) (the 'Habitats Regulations') provide for the designation and protection of Special Protection Areas (SPAs) and Special Area of Conservation (SACs) now that the UK has completed its transition period and has left the European Union. The principal amendments made to the Habitats Regulations to make them compatible with the post-Brexit legal position were made by The Conservation of Habitats and Species and Planning (Various Amendments) (England and Wales) Regulations 2018 and The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019. SACs are identified based on the presence of natural habitat types listed in Annex I and populations of the species listed in Annex II of the EC Habitat Directive. Some marine mammal and fish species potentially present in the vicinity of the Proposed Development are Annex II species and are mentioned in designations for nearby protected sites.
Wildlife and Countryside Act (1981 as amended)	The Act provides for the designation of Sites of Special Scientific Interest (SSSIs), which are selected as the best national examples of habitat types, sites with notable species and sites of geological importance. Various species of marine animals (including all species of porpoise, dolphin and whale) are also protected from being killed, injured or disturbed under provisions in Schedule 5 of the WCA 1981.
Conservation of Seals Act (1970)	Provide for the protection and conservation of seals in England and Wales and Scotland and in the adjacent territorial waters. Grey seals could potentially be present in the vicinity of the Proposed Development.
Marine Strategy Framework Directive (MSFD) (2008/56/EC) / Marine Strategy Regulations, 2010.	The Marine Strategy Regulations transpose the MSFD into UK law. The principal aim of the MSFD is for marine waters to achieve 'good environmental status' by meeting 11 environmental descriptors. One of these descriptors concerns the introduction of energy, including underwater noise and requires that pressures, such as the input of anthropogenic noise from both impulsive sources (e.g. piling) and continuous sources (e.g. shipping and dredging), are 'at levels that do

Title	Summary and Relevance
	not adversely affect the marine environment'. Post Brexit, the requirements of the Directive are assumed to continue to apply.
National Environment and Rural Communities (NERC) Act 2006	Section 41 of the NERC Act 2006 requires the publication of a list species and habitats that are of principal importance for the purpose of conserving biodiversity. This list is based on the priority species which were identified under the UK Biodiversity Action Plan (BAP). Some fish species on this list are potentially present in the vicinity of the Proposed Development,
Salmon and Freshwater Fisheries Act 1975 (as amended by the Environment Act 1995)	This Act aims to protect all migratory and freshwater fish stocks (particularly salmon and trout) from activities that could result in direct mortality, barriers to migration and degradation of habitats. Some of the migratory and freshwater species protected under this Act are potentially present in the vicinity of the Proposed Development at different times of the year.
The Eels (England and Wales) Regulations 2009	These Regulations establish measures for the recovery of the stock of European eel. European eel could potentially be present in the River Dee in the vicinity of the Proposed Development.

3. Methodology

3.1 Data Collation and Acquisition

To enable an assessment of potential effects of underwater noise and vibration on marine ecology receptors it was necessary to first establish the baseline (or existing) environment by conducting a high level desk-based review of available data.

3.1.1 Scoping of Marine Ecology species for consideration

To determine which species should be screened into the assessment, a review was conducted of the following data sources:

- The Dee Estuary Ramsar designated site listing;
- Dee Estuary Special Area of Conservation (SAC) designated site listing;
- Dee Estuary Special Protection Area (SPA) designated site listing;
- Dee Estuary Site of Special Scientific Interest (SSSI) designated site listing;
- Afon Dyfrdwy (River Dee) SSSI designated site listing;
- River Dee (England) SSSI designated site listing; and
- River Dee and Bala Lake Special Area of Conservation (SAC) designated site listing

Key information obtained from the data reviews is summarised in Section 4: Existing Baseline Conditions below.

Otter are known to be present throughout the Dee catchment and are mentioned in designations for the Dee Estuary SAC, Afon Dyfrdwy (River Dee) SSSI and River Dee (England) SSSI and River Dee and Bala Lake Special Area of Conservation (SAC). It is considered, however, that any effects on otter would be indirect via effects on their food source (invertebrates and fish) and consequently they have been scoped out of assessment.

The receptors scoped into the assessment were:

- benthic invertebrates;
- fish; and
- marine mammals.

A desk-based review of available data was considered sufficient to effectively inform the assessment of potential ecological effects.

3.2 Assessment Methodology and Significance Criteria

3.2.1 Introduction

The identification and assessment of the potential noise and vibration effects on ecological receptors was conducted in accordance with the Chartered Institute of Ecology and Environmental Management (CIEEM) guidelines for Environmental Impact Assessment (EIA) (CIEEM 2018).

The assessment approach was based on the conceptual ‘source-pathway-receptor’ model. This model identified likely environmental effects resulting from the proposed construction of the Development. This process provided an easy to follow assessment route between effect sources and potentially sensitive receptors ensuring a transparent impact assessment. The parameters of this model are defined as follows:

- **Source**: the origin of a potential effect (noting that one source may have several pathways and receptors) i.e. an activity such as jetty foundation installation which has a resultant impact e.g. generation of underwater noise and vibration.
- **Pathway**: the means by which the impact could influence a receptor e.g. for the example above, underwater noise could dissipate through water and through the seabed.
- **Receptor**: the element of the receiving environment that is affected e.g. for the above example, one receptor could be fish within the water column subjected to noise and vibration.

Iterative steps involved in the assessment approach included:

- Determination of potential interactions between the Development and ecological receptors;
- Definition of baseline environment within the influence of the Development;
- Assessment of the value and sensitivity of ecological receptors;
- Consideration of embedded mitigation (i.e. measures that are already included in the project design/methods to mitigate effects) as part of the initial assessment;
- Assessment of the magnitude of effects;
- Assessment of the significance of impacts; and
- Proposal of additional mitigation measures to reduce, prevent or where possible offset any adverse significant effects identified after consideration of embedded mitigation design (if required).

3.2.2 Identification of Effects Pathways

An initial stage of the assessment was to identify potential interactions between the Development proposals and marine ecology receptors. As outlined previously there are expected interactions between underwater noise and benthic invertebrates, fish and marine mammals.

3.3 Assessment Criteria

This assessment was based on consideration of activities with associated impacts. It was then assessed whether these impacts could have potential effects on species. A number of aspects were considered when assessing potential impacts/effects including:

- Nature of effect i.e. beneficial or adverse; direct or indirect;
- Extent of the effect (geographical area e.g. site-wide, local, district, regional, and the size of the population affected);
- Value of the receptor (Table 2);
- Sensitivity of the receptor (Table 3);
- Magnitude of the impact (Table 4),
- Duration:
    - Temporary or permanent effect. If the effect occurs on all of, or a proportion of, a community/population on a continual basis it can be considered to be permanent. If it is not on a continual basis when considering the community/assemblage/population or habitat level it can be described as temporary (e.g. intermittent piling);
    - Persistence of the effect e.g. short term (1 year), medium term (2-10 years), long term (>10 years) or permanent; and
- Reversibility:
    - An irreversible effect is one from which recovery is not possible within a reasonable timescale or there is no reasonable chance of action being taken to reverse it. A reversible effect is one from which spontaneous recovery is possible or which may be counteracted by mitigation (CIEEM 2018).
- Timing and frequency of effects in relation to key potential periods of increased sensitivity e.g. migration periods for diadromous fish species; food resources during coastal bird breeding periods etc.

The value and sensitivity of each receptor was determined based on consideration of factors outlined in Table 2 and Table 3 and the magnitude of the potential effect was based on the criteria set out in Table 4. Based on the value/sensitivity of the receptor and the predicted magnitude of the potential effect, the significance of effect was then determined as indicated in Table 5.

3.3.1 Value and Sensitivity

Guidelines used to assign the value and sensitivity of the receptor are provided in Table 2 and Table 3. It should be noted that high value and high sensitivity are not necessarily linked within a particular effect. A receptor could be of high value (e.g. an interest feature of a Special Area of Conservation (SAC) or Special Protection Area (SPA)) but have a low or negligible physical/ecological sensitivity to an effect such as underwater noise and vibration and vice versa. Information relating to value and sensitivity of receptors to impacts has been clearly indicated in the assessment narrative where appropriate.

Table 2. Value Criteria for Marine Ecology Assessment

Value	Definition
Very High	• A feature of an internationally designated site or candidate site (SPA, pSPA, SAC, cSAC, pSAC, Ramsar site etc.) or an area which the country agency has determined meets the published selection criteria for such designation, irrespective of whether or not it has yet been notified. • Internationally significant species listed in Annex II of the Habitats Directive. • Globally threatened species (i.e. critically endangered or endangered on IUCN Red list) or species listed on Annex 1 of the Berne Convention. • Regularly occurring populations of internationally important species that are rare or threatened in the UK or of uncertain conservation status. • A regularly occurring, nationally significant population/number of any internationally important species. • Species are highly regarded for their important biodiversity, social/community value and / or economic value.
High	• A feature of a nationally designated site (SSSI, NNR, MNR, MCZ) or a discrete area, which the country conservation agency has determined meets the published selection criteria for national designation (e.g. SSSI selection guidelines) irrespective of whether or not it has yet been notified. • Regularly occurring, globally threatened species (i.e. Vulnerable or lower on IUCN Red list) or species listed on Annex 1 of the Berne Convention. • Previously UKBAP species; S41 species of NERC Act • Species possess important biodiversity, social/community value and / or economic value.
Medium	• Features of viable areas of key habitat identified in the Regional/County BAP or smaller areas of such habitat which are essential to maintain the viability of a larger whole. • Water Framework Directive biological element. • Any regularly occurring significant population that is listed in a Local Red Data Book. • Significant populations of a regionally/county important species. • Species possess moderate biodiversity, social / community value and / or economic value.
Low	• Features of areas of habitat identified in a sub-County (District/Borough) BAP or in the relevant Natural Area profile. • Features of District sites that the designating authority has determined meet the published ecological selection criteria for designation, including Local Nature Reserves selected on District/Borough ecological criteria (District sites, where they exist, will often have been identified in local plans). • Features that are scarce within the District/Borough or which appreciably enrich the District/Borough habitat resource. • Species are abundant, common or widely distributed. • Species possess low biodiversity, social/community value and / or economic value.

Value	Definition
Negligible	• Species present are common and widespread. • Species are not considered particularly important for their biodiversity, social/community or economic value.

Table 3. Sensitivity Criteria for Underwater Noise and Vibration Assessment

Sensitivity	Definition
Very High	• Species are under significant pressure and/or are highly sensitive to changing environments. • Species are intolerant of the effect with little or only slow recovery.
High	• Species may be under significant pressure and/or highly sensitive to changing environments. • Species may have a very low capacity to tolerate the effect with little or only slow recovery.
Medium	• Species may be currently under pressure or are slow to adapt to changing environments. • Species may have a low capacity to tolerate or recover from the effect.
Low	• Species are generally adaptable to changing environments. • Species may show some tolerance of the effect or recover quickly from the effect.
Negligible	• Species are highly tolerant of the effect.

3.3.2 Magnitude

Magnitude of effect was assessed taking into account the application of any embedded mitigation design measures to be incorporated at the construction phase. Where embedded mitigation design has been considered this has been clearly indicated in the likely effects below (where relevant). Guidelines used to assign magnitude of the effect are provided in Table 4.

Table 4. Magnitude Criteria for Underwater Noise and Vibration Assessment

Magnitude	Definition
Major	• Effect causes a change to all or a significant proportion of the population resulting in a decline in the abundance of the population, or other trophic levels, that will not be reversed through natural recruitment for several generations.
Moderate	• Effect causes a substantial change in abundance, affecting a portion of a population that may last for more than two years but does not result in long term impacts to the population itself or other trophic levels.
Minor	• Effect causes a change to a small group of localised individuals of a population for a short period of time (up to two years) but does not affect the viability of the population or other trophic levels.
Negligible	• Effects on the population are undetectable or within the range of natural variation.
No Change	• The activity will have no interaction with the receptor.

3.3.3 Impact Significance

Following the identification of the receptor value and sensitivity and the determination of the magnitude of the effect, the significance of the impact was determined guided by the matrix presented in Table 5. In line with CIEEM guidance, only impacts that were of moderate or major significance were considered to represent those with the potential to be 'significant' which is consistent with EIA terminology.

Table 5. Matrix to Guide Determination of Impact Significance.

Sensitivity/ Value	Magnitude of Impact				
	Major	**Moderate**	**Minor**	**Negligible**	**No Change**
Very High	Major	Major	Minor or Moderate	Negligible or Minor	Neutral
High	Major	Moderate or Major	Minor or Moderate	Negligible or Minor	Neutral
Medium	Moderate or Major	Minor or Moderate	Minor	Negligible or Minor	Neutral
Low	Minor or Moderate	Minor	Negligible or Minor	Negligible	Neutral
Negligible	Minor	Negligible or Minor	Negligible	Negligible	Neutral

It is important that the matrix (and indeed the definitions of value/sensitivity and magnitude) is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each effect assessment and it is not a prescriptive formulaic method. Professional judgement has been applied to the assessment of likelihood and ecological significance of a predicted effect and where required modifications have been made to the outputs of Table 5 with reasoning clearly indicated. For the purpose of this assessment CIEEM guidance (2018) has been followed which states that an ecologically significant impact is:

"an impact that either supports or undermines biodiversity conservation objectives for 'important ecological features".

3.3.4 Mitigation Measures

The impact assessment considered the likely significance of impacts after consideration of any embedded mitigation design. Whilst this report does not form part of an EIA, standard EIA practice has been followed in relation to mitigation measures and for any impacts considered to be of moderate or higher significance after the implementation of embedded mitigation design, further mitigation/enhancement measures would be proposed to reduce the significance of impact to minor or lower.

3.4 Limitations and Assumptions

A full baseline review of the existing conditions at the site has not been conducted as part of this assessment. The main focus of the review provided within Section 5 was to provide information to determine the receptors potentially in the vicinity of the Development, their sensitivity to noise and vibration and to determine which species should be assessed within the full assessment. The assessment has primarily been based on the potential presence of receptors as opposed to their abundance.

4. Existing Baseline Conditions

4.1 Invertebrates

EMODnet data indicates that intertidal habitat in the vicinity of the works is likely to be representative of ‘Polychaete/oligochaete-dominated upper estuarine mud shores’ (EUNIS code: A2.32, JNCC code: LS.LMu.UEst) and saltmarsh (EUNIS code: A2.5, JNCC code: LMU.Sm) (EMODnet 2021). The habitat A2.32 supports few infaunal species and is principally characterised by a restricted range of polychaetes and oligochaetes (EEA 2021).

In the subtidal environment, the habitat is likely to be infralittoral sandy mud (EUNIS code: A5.33, JNCC code: SS.SMu.ISaMu; EMODnet 2021). This habitat generally supports a rich variety of polychaetes, tube building amphipods and deposit feeding bivalves.

Large decapods such as crabs are present within the Dee Estuary and could potentially be present in the vicinity of the Proposed Development (Natural England & the Countryside Council for Wales 2010).

4.2 Fish

At least 46 fish species have been recorded within the Mersey Estuary (data collated from ERL (1992), Hering (1998), and APEM (2007 & 2011) and EA monitoring data) and it is likely that most of these species could also be found in the neighbouring Dee Estuary.

Sea lamprey (*Petromyzon marinus*), river lamprey (*Lampetra fluviatilis*), brook lamprey (*Lampetra planeri*), smelt (*Osmerus eperlanus*), Twaite shad (*Alosa fallax*), grayling (*Thymallus thymallus*), bullhead (*Cottus gobio*), and Atlantic salmon (*Salmo salar*) are all known to be present in the River Dee and are designated Annex II species in several surrounding protected sites (CCW, 2002; Natural England, 2021). In addition, the diadromous species European eel (*Anguilla anguilla*) could be present. This species is protected under European eel management plan legislation (Eel Recovery Plan, Council Regulation No 110/2007) implemented under The Eels (Wales and England) Regulations 2009.

4.3 Marine Mammals

Grey seals (*Halichoerus grypus*) are listed in the Natura 2000 Standard Data Form for the Dee Estuary SAC (JNCC 2015), but not as primary or qualifying features. This species is also an Annex II protected species (JNCC, 2015; CCW, 2002; Natural England, 2021).

A large grey seal ‘haul out’ of 300-500 individuals is found on the eastern side of Salisbury Middle, adjacent to Hilbre Island which forms part of the North Wales grey seal population (Natural England & the Countryside Council for Wales 2010). Seals from this population could potentially transit to the proposed Development site.

Other marine mammals could potential transit to the vicinity of the Proposed Development but they are considered unlikely to be present this far upstream in the estuary.

5. Assessment of Impacts

5.1 Introduction to potential effects

5.1.1 Invertebrates

The effects of noise and vibration on invertebrates is not well understood, however, anthropogenic sources of underwater sound and vibration have been shown to have effects on benthic invertebrates that do not rely on acoustics for communication. Studies of invertebrates have indicated that increased noise and vibration levels can potentially result in increased mortality, injury to tissues, changes in growth and reproductive rates and changes in food uptake in invertebrates (Popper & Hawkins 2018; Hawkins & Popper 2016; Solan *et al*. 2016; Aguilar de Soto *et al*. 2013; Spiga *et al*. 2012; Lagardère 1982).

Invertebrate species are unable to detect sound pressure but are likely to be able to detect particle motion through a variety of organs such as hairs on the body that respond to mechanical stimulation, chordotonal organs associated with joints, or vibrations transmitted through the exoskeleton from the substrate (Popper & Hawkins 2018).

5.1.2 Fish

Underwater noise and vibration may cause the following effects on fish:

- Behavioural effects (e.g. reduced detection of predators/prey, inhibited communication between conspecifics, alteration in swimming behaviour);
- Masking effects (i.e. the reduced detectability of a given sound owing to the simultaneous occurrence of another sound);
- Temporary threshold shift (TTS) in hearing (short or long-term changes in hearing sensitivity that may or may not reduce fitness);
- Recoverable tissue injury (not resulting in mortality e.g. hair cell damage, minor internal or external hematoma etc.); and
- Mortality or potential mortal injury (immediate or delayed death).

5.1.3 Marine mammals

Underwater noise and vibration can have physical and behavioural effects on marine mammals. Physical injury can include Permanent Threshold Shift (PTS), or a TTS in hearing, and behavioural effects can include avoidance of an area subject to noise and vibration disturbance.

One potential effect is masking, which occurs when the ability to detect or recognise a sound of interest is affected by another sound. Masking effects can interfere with communication in marine mammals which can be crucial in social learning (particularly for odontocete cetaceans) and it can disrupt return echoes which are used to locate mobile prey and discern environmental structure (Erbe *et al*. 2016).

5.2 Sources of underwater noise and vibration

The primary potential source of underwater noise and vibration for the Proposed Development is from HDD for the pipeline.

Section 1.2 provides an overview of the HDD. The drill depth will be in excess of 24 m below the river at all points and a 12-1/4" (311mm) diameter HDD will be used (prior to reaming).

5.2.1 Underwater noise

Sparse data are available for sound levels generated by HDD works, however, for HDD operations within a riverine environment 39 m below the riverbed, Nedwell *et al*. (2012) indicated that an unweighted Sound Pressure Level of 129.5 dB re: 1 µPa was recorded, although no frequency data were available.

Use of the HDD technique for pipe laying will avoid the requirement to use more aggressive (and noisy) methods of cable installation, such as blasting and trenching.

5.2.2 Riverbed vibration

Recent studies of vibration levels have been conducted for a 450 mm diameter HDD operation in south Dublin, Ireland (Reilly *et al*. 2020). The operation was on land and during this project vibration limits of no more than 10 mm/s were imposed during the HDD works. The HDD profile was approximately 150 m long and the drill was 9 m below the ground level. The vibration levels recorded were typically less than 1 mm/s with a maximum of 5 mm/s.

The British Standards Institute has published empirical predictors for groundborne vibration arising from mechanised construction works including tunnelling (BS 5228-2:2009; BSI 2009). This equation is:

$$v_{res} \leq \frac{180}{x^{1.3}}$$

Where v_{res} is the resultant Peak Particle Velocity (PPV) in millimetres per second (mm/s) and x is the distance measured along the ground surface in metres (m).

This assessment has assumed that vibration travels up through the sediment under the River Dee in the same way as along the ground surface. As the drill depth is a minimum of 24 m below the river the v_{res} is calculated to be 2.89 mm/s which is within the range reported by Reilly *et al*. (2020).

5.3 Impact Assessment

5.3.1 Invertebrates

Underwater noise

Invertebrates are generally considered to be more sensitive to particle motion than sound pressure (Hawkins & Popper 2016 and see Section 6.1.1 above). Consequently, the potential effects of noise from HDD on invertebrates is **scoped out** of this assessment.

Riverbed vibration

There are currently no widely recognised noise and vibration criteria for invertebrates but studies have found that shore crabs *Carcinus maenas* have a sensitivity to particle motion and they could sense a frequency of between 90 and 200 Hz, and vibrations of <0.01 m s^{-2} (Hughes *et al*. 2014). The sensitivity of the hermit crab *Pagurus bernhardus* to vibration was found to vary and ranged from 0.06 to 0.55 m s^{-2} (root mean square, RMS, vertical plane; Roberts *et al*. 2017). However, studies of these effects have not been made in PPV (mm/s) and therefore a direct comparison with the expected vibration levels from HDD for the proposed Development cannot be made.

There has been little research into the noise and vibration levels that cause observable effects on invertebrates such as crabs although some research suggests that the susceptibility of crabs to noise and vibration effects could be determined by life stage and size (Wale *et al*. 2013a).

As criteria for invertebrates are not available, this assessment has considered previous studies on the effects of noise and vibration on invertebrates together with professional judgement. The effects of relatively low levels of vibration are expected to be of Negligible magnitude. Value of the receptor is Low and sensitivity is expected to be Low. Overall, the significance of the impact is assessed to be **Negligible**.

5.3.2 Fish

Underwater noise

Hearing abilities of fish will vary in relation to morphological adaptations of the acoustico-lateralis apparatus, in particular the distance of the swim bladder to the inner ear (Bone *et al*. 1995; Hasting & Popper 2005; Mason 2013). Species that do not possess a swim bladder such as flatfish have a lower hearing ability than many other fish species and as such, rely on the detection of particle motion (the oscillatory displacement of fluid particles in a sound field) (Popper *et al*. 2014). Species with swim bladders with no connection to the inner ear (e.g. cod or salmon), have better hearing but can also only detect particle motion. Species with an extension of the swim bladder that terminates within the inner ear (e.g. shad and herring), are able to hear sounds over a far greater range than other species, and can detect both particle motion and sound pressure (a form of stress measured in term of force/unit area) (Higgs *et al*. 2004; Gill *et al*. 2012).

Popper *et al*. (2014) provides exceedance criteria for fish which indicates continuous noise sources of 170 dB re: 1 µPa rms for 48 hrs could result in recoverable injuries and 158 dB re: 1 µPa rms for 12 hours could result in temporary threshold shifts (TTS) in hearing.

The noise generated by HDD is expected to be considerably below the exceedance criteria and magnitude of effect is Minor. The value of some fish species potentially present is Very high and for others it is High to Low and sensitivity to underwater noise can vary from High to Low based on the hearing ability of different fish species as indicated above. However, considering the low potential noise levels generated by the HDD in the water column the impact of noise on fish is assessed to be **Negligible**.

Riverbed vibration

The fish community includes a number of migrating species of conservation importance including river and sea lamprey. However, the larvae of lamprey live within the marginal silt of rivers (freshwater silts upstream of the estuary) and so would not be expected to be affected by vibration from the HDD activities. Insufficient data exists to make a recommendation for guidelines in relation to vibration effects on other species (particle motion through the river bed). As such a qualitative assessment has been conducted using published literature and professional judgement.

Studies undertaken for the Felindre to Tirley gas pipeline project in South Wales found there were likely to be no significant effects of vibration and noise on fish species using the rivers where tunnelling was taking place (Nedwell *et al.* 2008).

Salmonid embryo mortality has been reported from vibrations of 146 mm/s, and the State of Alaska Department of Fish and Game standards limit blast-induced streambed vibrations to 0.5 in/s (13 mm/s) to protect salmonid embryos (Dunlap 2009). As described in Section 5.2.2, vibration levels of 2.89 mm/s are predicted to reach the riverbed and so the magnitude of the effect is assessed to be Negligible. The value of some fish species potentially present is Very high and for others it is High to Low and sensitivity is considered to be Low. Overall, the significance of the impact is assessed to be **Negligible**.

5.3.3 Marine Mammals

Underwater noise

Underwater noise can cause physical injury to marine mammals in the form of Permanent Threshold Shift (PTS) (i.e. permanent hearing damage caused by very intensive noise or by prolonged exposure to noise) or TTS. It can also cause behavioural effects such as avoidance of an area subject to noise disturbance.

Southall *et al*. (2019) criteria has been considered in relation to potential noise levels from HDD. Southall *et al*. (2019) indicated that for a non-pulse (continuous) noise source such as HDD (as opposed to a single pulse e.g. from piling) there is potential for a Permanent Threshold Shift (PTS) in seals in water at Sound Exposure Levels (SEL) of

≥201 dB re: 1 μPa^2s and of TTS at 181 dB re: 1 μPa^2s. Based on available evidence, the noise levels at which injury of marine mammals could occur are considerably higher than those expected to be generated by the proposed HDD works. No values are provided in Southall *et al*. (2019) for the levels at which non-pulses could result in marine mammal behavioural effects. However, given the low levels of noise expected to be generated and their highly mobile nature, behavioural effects are not expected to occur. In addition, although seals have the potential to transit to the Proposed Development site it is likely that numbers of seals swimming that far upstream in the estuary are very low.

The magnitude of the effect is assessed to be Negligible. Seals are a Very high value receptor and sensitivity to the levels of underwater noise generated by HDD is considered to be Low. Overall, the potential impact of noise on marine mammals is assessed to be **Negligible**.

Riverbed vibration

The effects of particle motion on marine mammals are not well understood but it is believed that most marine mammals are likely to be able to detect it. However, as none of the marine mammals that are likely to be present in the area during drilling are known to rest on the riverbed and are highly mobile species the potential impacts of vibration from HDD on marine mammals has been **scoped out**.

6. Summary

The main quantitative data available for assessment of underwater noise were available from Nedwell *et al*. (2012) which indicated an unweighted Sound Pressure Level of 129.5 dB re: 1µPa had been recorded for a riverine HDD project. In addition, using the British Standards Institute empirical predictors for groundborne vibration arising from tunnelling (BS 5228-2:2009; BSI 2009), the predicted vibration levels on the riverbed for the Proposed Development were determined to be less than 2.89 mm/s.

The effects of underwater noise and vibration from HDD under the River Dee have been assessed for benthic invertebrates, fish and marine mammals based on available information and underwater noise effect criteria for fish and marine mammals.

Due to insufficient information on the effects of vibration on marine ecology receptors and an absence of exceedance criteria, the assessment has been based on previous studies on the effects of noise and vibration on marine ecology receptors together with professional judgement.

The conclusions of the assessment are summarised below in

Table 6.

Table 6. Summary of Impacts of Underwater Noise and Vibration from HDD on marine ecology receptors.

Effect	Receptor	Significance of impact
Underwater Noise	Benthic invertebrates	Scoped Out
Riverbed Vibration		Negligible
Underwater Noise	Fish	Negligible
Riverbed Vibration		Negligible
Underwater Noise	Marine mammals	Negligible
Riverbed Vibration		Scoped Out

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