Appendix K

Fresh Water Ecology Assessment

CORRIB ONSHORE PIPELINE

Freshwater Ecology

May 2010

Aquatic Services Unit

1 - INTRODUCTION

1.1 - Overview

Aquatic Services Unit (ASU) was commissioned by RPS to undertake a freshwater ecological impact assessment for the proposed Corrib Onshore Pipeline. In fulfilment of this work ASU undertook (i) a desk study examining existing data and reports on the freshwater ecology along the proposed route, (ii) consulted with fisheries and conservation bodies and (iii) undertook focused fieldwork along the route of the proposed development. The scope of the ASU study included an assessment of the freshwater habitats and freshwater and migratory freshwater species such as Atlantic salmon and lamprey species.

The key areas of potential impact of the proposed development on the freshwater habitats and associated migratory fish and protected species (lamprey) relate to the construction phase and the commissioning phase of the proposed development. Once in operation, there will be no impacts on freshwater resources.

This report describes the existing environment from a freshwater ecological perspective, outlines the methodology used to assess the existing environment, lists the potential impacts (including residual impacts) associated with the proposed development and recommends mitigation measures to avoid/minimise these impacts.

2. Methodology

The methodology employed for this freshwater ecological assessment comprised the following elements:

- A desk study examining existing data and reports of the freshwater ecology along the proposed route;
- Consultation with fisheries and conservation bodies; and
- Fieldwork along the route of the proposed development.

2.1 - Desk Study

The following reports and information sources were examined as part of the freshwater desk study:

- Aquens Ltd. (2003) *Electrofishing operations in the northern region of the Ballina fishery area, Co. Mayo (Year 3)* - Report to Enterprise Energy Ireland Ltd;

- Aquens Ltd. (2002) *Electrofishing operations in the northern region of the Ballina fishery area, Co. Mayo*. (Authors: R. Lyons, M. Kelly Quinn and J. Bracken). Report to Enterprise Energy Ireland Ltd;

- North West Regional Fisheries Board, (2005) *An examination of the causes and factors related to the recent eutrophication of Carrowmore Lake.* Internal Report, North Western Regional Fisheries Board, Ballina;

- Russell Poole, Elvira deEyto, Bryan Kennedy & Mary Dillane (2005) *Results of a survey of the freshwater salmonid habitat of sub-reaches within the Owenmore River System*

2005 A report prepared for Shell E&P Ireland Limited. The Marine Institute and the North Western Regional Fisheries Board;

- EPA's On-line publications on river water quality: http://www.epa.ie/;

- Central Fisheries Board on-line publications into its fisheries investigations in Irish Estuaries (METRIC programme) including Sruwaddacon Bay http://www.cfb.ie/fisheries_research/estuaries/sruwaddaconbay.htm;

- National Parks and Wildlife Services (NPWS) publications on lamprey biology and distribution and FW Pearl mussel (*Margaritifera margaritifera)* biology and distributions in Ireland;

- Discovery Series Ordinance Survey Maps of the region and digitized aerial photographs of the study area upon which the proposed development had been superimposed; and

- NPWS website showing the boundaries of protected sites and detailed aerial imagery of the study area.

- North Western Regional Fisheries Board (NWRFB) on smolt movements in the Glenamoy in spring 2009 and spring 2010.

2.2 - Consultation

In preparation of the impact assessment report, ASU consulted the following agencies as part of the fisheries and Annex II species aspects of the Study Area:

- North Western Regional Fisheries Board (NWRFB): Ballina & Bangor Erris Offices, County Mayo;
- Marine Institute: Newport Office, County Mayo;
- Central Fisheries Board: Dublin; and
- National Parks and Wildlife Service (Ballycroy, Co. Mayo).

2.3 Fieldwork

2.3.1 Aims

The aims of the fieldwork were:

(i) To assess the extent and the quality of the habitats at each of the stream crossing points in terms of their bankside and in-channel structure and substrates, their aquatic plant communities and their [1]macroinvertebrate assemblages, which in turn would determine their uniqueness and sensitivity.

(ii) To determine the presence of Annex II and other fish species using electrofishing means where appropriate.

[1] Macroinvertebrates is the collective name given to the small animals which live in the bed of streams and rivers they include the immature stages and some adult stages of aquatic insects, and the mature stages of aquatic snails, segmented worms, leeches, water mites etc.; they form an important part of the diet of fish.

(iii) To determine water quality based on the EPA's biotic index Q-rating method, which uses collections of aquatic macroinvertebrates to determine the water quality of rivers and streams.

2.3.2 Approach

Using maps and aerial imagery four freshwater rivers and streams were identified along the route of the proposed pipeline. Field surveys of these rivers and streams were carried out in early September 2007 and again in January, September and November 2008 to assess the nature and quality of the habitats present and to assess their water quality. Figure 1 shows the locations of the stream crossing points assessed.

3 EXISTING ENVIRONMENT

3.1 Desk Study

The results of the desk study are presented in the following sections.

3.1.1 General Catchment of the Study Area

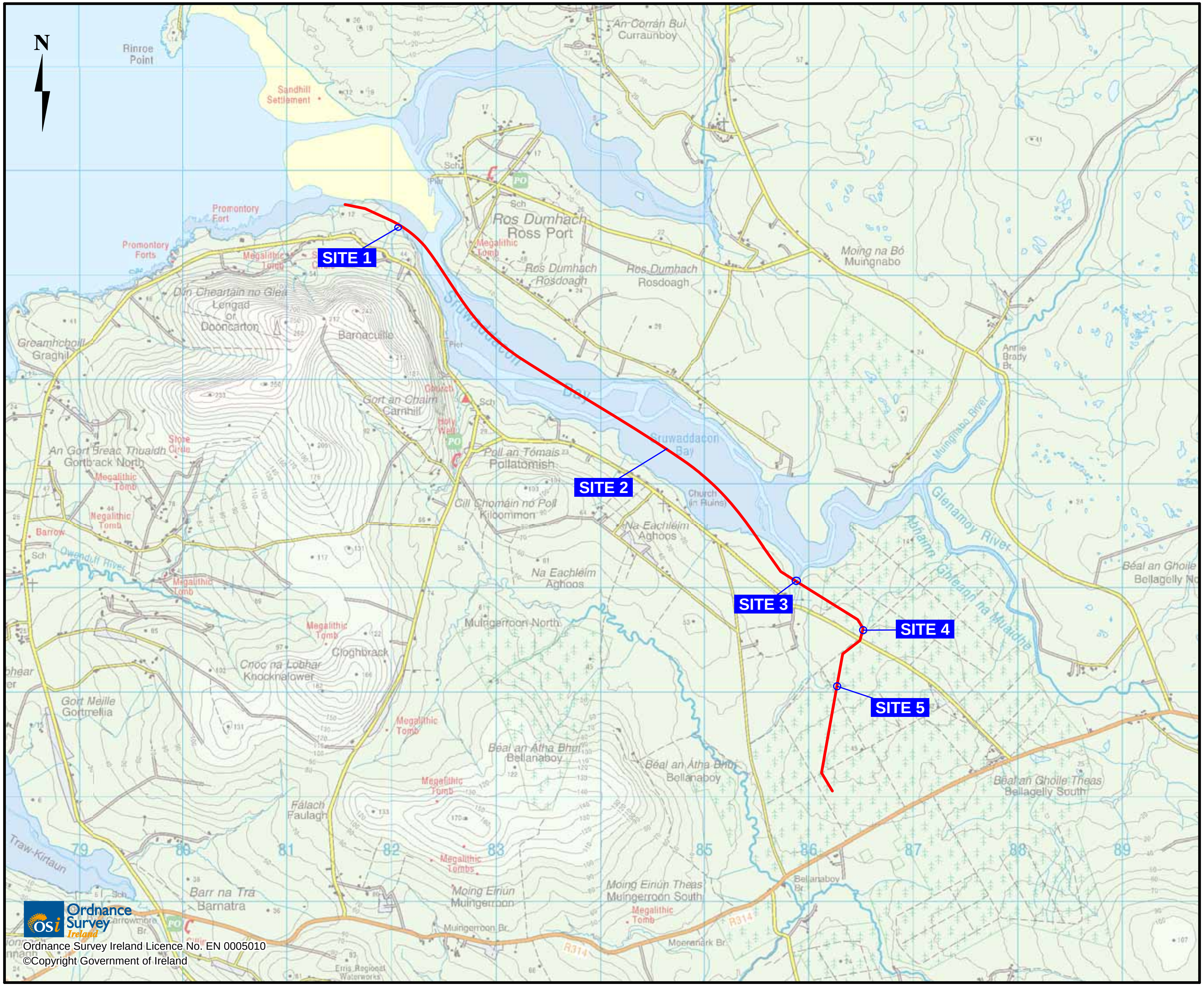
From a freshwater ecological perspective, the immediate study area for the proposed route is confined to Sruwaddacon Bay and the rivers and streams draining to it. The most prominent of these watercourses are the Glenamoy and Muingnabo Rivers both of which enter the head of the bay. In addition, there are a few smaller streams, which also drain to the bay. The locations of these watercourses are illustrated on Figure 1.

The proposed route will cross the following watercourses:

(i) A small[2] 1st order stream just east of the landfall at Glengad (Sampling Site 1); This stream will not be crossed by the proposed route and although, it lies within the temporary working area, it is not anticipated that any works will occur in this area. However, because of its location it has been considered as part of this assessment
(ii) Sruwaddacon Bay (Site 2);
(iii) A small [3]second-order stream draining to the southeast corner of Sruwaddacon Bay, known locally as the Leenamore River in the townland of Aghoos. (Sampling Site 3);
(iv) A 1st order stream close to the roadside about 0.5km south east of Site 3 (in the townland of Ballygelly South (Sampling Site 4); and
(v) A small 1st order stream / drain approximately 0.7km north of the Gas Terminal site in the townland of Ballygelly South (Site 5)

These small rivers and streams listed above (Sites 1, 3, 4 and 5) are all of minor ecological and fisheries importance within the wider study area. Sites 4 & 5 lie outside the Glenamoy Bog Complex SAC, however Site 1 and Site 3 lie within the SAC. However, the temporary working area lies within the boundaries of the SAC. Sruwaddacon Bay is important as a migratory route for Annex II species, Atlantic salmon in particular.

[2] A first order stream is one at or close to the head of a catchment or sub-catchment which has not yet been joined by other tributaries. They tend to be very small.
[3] A second-order stream is formed by the joining of two first-order streams



LEGEND:

Proposed Route

Watercourse crossings/ Freshwater ecology sampling sites

Figure 1

File Ref: COR25MDR0470Mi2123A03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

3.1.2 - Land-use

Aerial photography for the area in the vicinity of the proposed route show that to the north of Sruwaddacon Bay and the Glenamoy River, the bulk of the land area comprises blanket bog and upland areas with just pockets of agricultural land (mainly pasture) especially near the coast, near settlements and at the downstream sections of rivers, for example around the upper tidal reaches of the Muingnabo, where there is a large block of plantation forestry to the south of Sruwaddacon Bay. To the south of the Glenamoy River much more of the area is under forestry and pasture, although there are large upland areas west of Pollatomish and north of Carrowmore Lake where cultivation of any sort is also sparse.

3.1.3 Conservation Designated Sites

Sruwaddacon Bay, the Glenamoy River and Muingnabo Rivers are all part of the Glemamoy Bog Complex Special Area of Conservation (Site Code: 00500). Sruwaddacon Bay is also part of the Blacksod Bay/Broadhaven SPA.

3.1.4 Protected Species

Under the EU Habitats Directive several freshwater aquatic species are legally protected. These are referred to as Annex II species and include among others: Atlantic salmon (*Salmo salar*), the Freshwater Pearl Mussel (*Margaritifera margaritifera*), White-clawed Crayfish (*Austropotamobius pallipes*) and lampreys (3 species). Of these species, only one is definitely reported by Fisheries Board and Marine Institute sources from the general study area, namely Atlantic salmon (from the Glenamoy and Muingnabo Rivers). Of the remaining species, the Brook Lamprey (*Lampetra planeri*), which is non-migratory, is the only lamprey species to have been recorded with certainty in the wider study area i.e. in the Bellanboy River (Poole *et al.*, 2005). However, there have been reports of unidentified lampreys in one of the small streams crossed by the route, namely the Leenamore River (at the Site 4 crossing point) (Aquens, 2003). This species is likely to be Brook lamprey also but could possibly be river lamprey (*L. fluviatilis*) as they are very difficult to tell apart when immature. River lampreys usually enter rivers in early spring to spawn and have also been recorded in the Boyne entering in October-November (pers. comm., CFB). The Central Fisheries Board did not record any lamprey from their phyke net surveys undertaken in October 2006 near the confluence of the Muingnabo and Glenamoy rivers in upper Sruwaddacon Bay.

The others species listed above have not been reported and are unlikely to occur on site. Pearl mussels cannot be entirely ruled out, however, as a small remnant population could possibly exist. Nevertheless, were they to be present, it would tend to be confined to larger rivers and streams in deeper, silt-free waters, indicating that within the study area they would only be possible in the freshwater reaches of the Glenamoy and Muingnabo rivers, i.e. they would not occur in the small streams crossed by the proposed route. So far they are not recorded as occurring in either the Muingnabo or Glenamoy on the national database for the species (pers. comm., Dr. Evelyn Moorkens); furthermore they do not occur in estuarine waters and so would not be present in Sruwaddacon Bay.

White-clawed crayfish only occur in medium to hard water rivers (i.e. with significant levels of calcium carbonate). The essentially soft-water non-alkaline conditions within the study area would indicate that this species is almost certainly absent. Furthermore, it was not encountered during current or previous fieldwork in the study area.

Sea lamprey (*Petromyzon marinus*) is a large species, which would only occur, were it present, in the Muingnabo and Glenamoy Rivers, where it would most likely spawn in the lower or middle reaches. It is a large species and unlikely to go undetected by anglers, which suggests that it does not in fact occur within the study area, from where it has not been reported either by the NPWS or the NWRFB.

3.1.5 Water Quality

The most recent survey published by the EPA in their national monitoring scheme for rivers, which included the rivers in the study area (Hydrometric Area 33), refers to surveys undertaken in 2002 (Clabby, Lucey & McGarrigle, 2002) and prior to that date. These data are published on the EPA web site. The report includes data for the Muingnabo and Glenamoy Rivers, but not for the minor streams that will be crossed by the proposed route.

3.1.5.1 Water Quality Assessment Methods

Water quality is assessed in Ireland using the Biotic Index of Water Quality (BIWQ), developed in Ireland by An Foras Forbartha in the early 1970's and continued by the Environmental Research Unit and in recent years by the Environmental Protection Agency (EPA). Q-values and water quality classes are assigned using a combination of habitat characteristics and structure of the macroinvertebrate community within the waterbody. Individual macroinvertebrate species are ranked for their sensitivity to organic pollution and the Q-value determination is made based primarily on their relative abundance within a biological sample. Table 1 shows the EPA biotic indices and water quality status interpretations (Lucey *et al*., 1999). Samples of macroinvertebrates are obtained using a timed kick-sample method where the streambed is disturbed by the heel of a wader boot and the animals thus disturbed are carried into the pond-net used by the current. The sampling is carried out for two minutes moving from downstream to upstream through shallow riffle habitats. The samples are supplemented by washings of the larger substrate elements (cobbles and boulders) to dislodge animals, which are attached and not easily dislodged by kick-sampling alone.

Table 1 EPA Biotic Index and water quality status interpretations

Biotic Index	Quality Status	Quality Class
Q5, 4-5, 4	Unpolluted	Class A
Q3-4	Slightly Polluted	Class B
Q3, 2-3	Moderately Polluted	Class C
Q2, 1-2, 1	Seriously Polluted	Class D

3.1.5.2. Muingnabo Water Quality

The lower reaches of the Muingnabo river have been surveyed by the EPA in the stretch upstream of Annie Brady's Bridge, (which is named on the Discovery Series O.S. map no. about 3km north west of Glenamoy Village) on six occasions since 1994 and on two of those, 1997 and 2002, the river has been classed as Q3-4 i.e. slightly polluted at one site. On other occasions, including in 2005 and 2008, it was classed as unpolluted (Q4), although not pristine. The Muingnabo catchment is dominated by blanket bog but with some pasture and forestry also present.

3.1.5.3 Glenamoy Water Quality

The lower and middle reaches of the Glenamoy River have been surveyed by the EPA on seven occasions since 1990 and only on one of those occasions was it classed as slightly polluted (Q3-4 in 1994). In 2002 the most downstream site sampled (Glenamoy Bridge) was assigned Q4-5, the second highest value, indicating close to pristine quality conditions, while the same Site in 2005 and 2008 had deteriorated slightly to Q4, still unpolluted. The middle reaches, the Bridge S.E. of Bunalty, and toward the upper reaches (Bridge north of Glencarly) the most recent survey (2008) found good quality condition (Q4-5) at these sites.

It is clear from the EPA data that both these rivers are eminently suitable for salmonid fish.

Table 2: Biological Water Quality Information reported by the EPA for the Muingnabo and Glenamoy Rivers.

MUINGNABO RIVER - EPA River Code	Location	1990	1994	1997	1999	2002	2005	2008
0100	S.W of Sraith an tSeagail (Srahataggle)	4-5	-	-	-	-	-	4
0140	0.6km u/s Annie Brady's Bridge	-	-	-	-	3-4	-	-
0150	0.3km u/s Annie Brady's Bridge	-	4	3-4	4	-	4	-

Note: Q5, 4-5, 4: Unpolluted Q3-4: Slightly polluted

GLENAMOY RIVER - EPA River Code	Location	1990	1994	1997	1999	2002	2005	2008
0020	Br. N Gleann Chalraí (Glencalry)	-	-	-	-	4-5	4	4-5
0050	Br. S.E. of Bun Alltaí (Bunalty)	4-5	3-4	4-5	4-5	4	4-5	4-5
0100	Gleann na Muaidhe (Glenamoy) Bridge	4-5	3-4	4-5	4-5	4-5	4	4

3.1.5.3 Minor Streams

In general, in the absence of point sources of pollution and intensive agriculture over most of the study area, it would be expected that most of the small watercourses within the study area would have satisfactory water quality, i.e. at worst slightly polluted (Q3-4), but generally better than this. The water quality of the watercourses of the Study Area was assessed and results are presented in Section 3.2.1.

3.1.6 Fisheries Information

3.1.6.1 Fisheries at Glenamoy River

The Glenamoy River (Plate 1) is the most important river within the study area for both salmon and seatrout production and it is the only river, consistently fished with rod and line (pers. comm. NWRFB). In the Glenamoy River, spawning takes place outside of the study area from about 200m downstream of the Post Office at Glenamoy Village all the way upstream, where there are extensive stretches of suitable habitat throughout the system, none of which will be impacted by the proposed development. Below Glenamoy village, the river mainly comprises holding and nursery areas for salmon and trout. Some important holding pools exist between Glenamoy Bridge and the estuary. The most important holding area however, is at the mouth of Sruwaddacon Bay in a deep bend in the river situated upstream of Rossport Pier and seaward of Pollathomaish Pier; elsewhere within Sruwaddacon Bay the channel is considered too shallow to hold many fish (pers. comm. NWRFB). Unlike nearby Carrowmore Lake the Glenamoy is a late river, with adult salmon concentrated here between the 2nd week of June into September but more recently salmon are not appearing until mid-July. Now that drift netting has been banned at sea (since January 1st 2007) there were signs of more fish returning into the system in 2007 (pers comm., NWRFB). Two draft net licences, which operate at the mouth of Sruwaddacon Bay, have been suspended until further notice. This fishery normally didn't catch salmon until the 2nd week in June even though the licence covered the period May 12th to July 31st.

The fish counters installed by the NWRFB on the outfall from Carrowmore Lake indicate that the [4]smolt run (for salmon and seatrout) is finished by the second week in May. A recent study conducted on the Glenamoy by the NWRFB, indicates that the main peak in smolt out-migration is in April (pers. comm. Mr. Michael Hughes, Fisheries Inspector, NWRFB). A repeat survey in spring 2010 had still not seen a significant migration of smolts by early May and this has been attributed to the freezing weather for the first two months of the year and the very dry weather in April.

The timing of seatrout returns is less well defined than that of the salmon but the peak of the seatrout run into Sruwaddacon Bay is roughly mid June to mid July and during this period Pollathomais Pier is a popular angling location, although they are fished from the shore in many places throughout the bay, where the channel is accessible (pers. comm. NWRFB).

[4] Smolts are juvenile salmon or seatrout, usually around 2 years old, which have altered physiologically while still in freshwater to allow them to migrate into saline waters.

The Glenamoy Community Angling Association, which has around 40 active members, controls angling for salmon and seatrout on the Glenamoy River; it also issues permits to visiting anglers. The bulk of the club's angling is conducted from mid-July to October in the freshwater reaches of the river. In 2007 a programme of catch-and-release was in operation and again in 2008. This conservation measure means that all fish taken on rod-and-line have to be returned to the river. The Glenamoy is a spate river, fishing best after floods, especially later in a series of floods as the water clarity improves. Most salmon taken by anglers are [5]grilse of 6-7lbs although larger fish are occasionally taken later in the season. Seatrout range from 1.5-4lbs, mainly 2-2.5lbs.

Plate 1 Glenamoy River looking downstream from Glenamoy Bridge 5km upstream of Sruwaddacon Bay.

3.1.6.2 Fisheries at Muingnabo River

There is very limited electrofishing data available for the Muingnabo river, and what is available indicates trout to be present (pers. comm., Salmon Research Agency). The hydromorphology of the system as revealed by aerial photos and maps would indicate that the middle and upper reaches are likely to contain spawning areas suitable for both salmon and trout. However, in discussions with NWRFB, it is clear that the river is more important for trout and seatrout than salmon. Some limited angling is believed to occasionally take place in the lower reaches (pers comm. NWRFB), just upstream and downstream of Annie Brady's Bridge (Plate 2) and up until a few years ago nets for poaching were regularly taken from this part of the river. This is usually a sign that a watercourse is reasonably productive for fish.

[5] grilse are salmon which have spent one winter at sea before returning to freshwater

Plate 2 Muingnabo River looking downstream from Annie Brady's Bridge and 3km upstream of Sruwaddacon Bay.

3.2 Field Study Results

3.2.1 Site Descriptions of Proposed Route Crossing/Sampling Points

Crossing Points /Sampling Sites	Grid Ref.	Chainage	Q-Rating	Description	Fishery Value	Ecological Value
Site 1	F82063 38465	84.05	Q3-4	Very little wetted channel, so that both diversity and numbers of fish likely to occur would be low. For this reason, and the fact that the stream was immediately upstream of the seashore, it was decided not to electro-fish it.	**low**	**low**
Site 2		84.05-88.65	This is a marine site and assessed in the Marine Ecology Assessment for the EIS		**high**	**high**
Site 3	F85880 35062	89.25	Estuarine influence at the crossing point thus unsuitable for Q-rating: Q4-5 10m upstream	Moderate to slow flow glide, coarse (angular cobble substrate)	**moderate**	**moderate**
Site 4	F86477 34520	90.15	Q4	Very slow-flow, canal-like stream with typical macroinvertebrate types present (water beetles, damselfly larvae, water boatmen, etc.).	**low**	**low**
Site 5	F86258 34069	90.7	n/a	Very small flow over soft organic (peat) substrate; overgrown with bankside vegetation so that the channel was not visible. Too small and unsuitable habitat for electrofishing.	**low**	**low**

Site 1 ([6]ING: 82063 38465),

This is a very small first-order stream which has little [7]cover for fish and very little wetted channel, so that both diversity and numbers of fish likely to occur would be low. For this reason, and the fact that the stream was immediately upstream of the seashore, it was decided not to electro-fish it.

Kick-samples indicated that the water quality at Site 1 was slightly polluted (Q3-4), see Table 2 for macroinvertebrates encountered. It can be concluded that this stream has a low ecological value. It drains into Sruwadaccon Bay (Glenamoy Bog Complex SAC).

Plate 3 Site 1 stream showing close-up of channel (full wetted width) and substrate with *Montia fontana* (Blinks) present at the margin (6-9-07).

[6] ING = Irish National Grid
[7] Cover here refers to overhanging banks, heavy instream vegetation, bouders, pools etc.

Taxa	EPA Quality Category	Abundance Rating
Ephemeroptera		
Heptageniidae	A	N
Baetidae	C	D
Plecoptera		
Amphinemoura	B	C
Trichoptera		
Polycentropus sp.	C	F
Philopotomus sp.	C	F
Hemiptera		
Hemiptera indet.	C	F
Diptera		
Chironomidae	D	D
Simuliidae	C	F
Crustacea		
Gammarus sp.	C	C
Annelida		
Oligochaetae	E	C
Q- value		**Q 3-4**

- Few (F) = 1 - 5 individuals
- Common (C) = 6 - 20 individuals
- Numerous (N) = 21 – 50 individuals
- Dominant (D) = 51 – 75 individuals
- Excessive (E) = >75% of total abundance

Table 2 Macroinvertebrates taken in a kick-sample at Site 1

Site 2

This is Sruwaddacon Bay under which the pipeline will be laid in a tunnel. It is a fully marine site and details of its habitats are presented in a separate report (Appendix L), which deals with the marine environment. The main channel here is a holding area for salmon and seatrout on their upriver migrations to the Glenamoy and Muingnabo rivers (pers. comm. NWRFB) and these species can be expected to occur here during the mid June to September period. Smolts would pass this area in the late March - early May period on their seaward migrations. It is a very sensitive site whose main importance is as a migratory route at certain times of the year. Species, namely salmon and seatrout feeding may also occur in this area. Other Annex II species such as (lamprey) may travel through this channel if they occur within the system; they would be expected to have a spring and possibly also a late autumn-winter migration, although no records exist (see earlier Section 3.2.1).

Site 3 (ING: F85880 35062)

The proposed crossing point (Site 3) is situated at the lower freshwater - upper estuarine limits of the small Leenamore River, which drains to a small tidal embayment at the south east corner of Sruwaddacon Bay. It is in the very lowest riverine reaches extending onto the top of the shore (Plate 4) and the macroinvertebrate community present in the stony substrate is notable for a mixture of freshwater and estuarine elements (Table 3).

Plate 4 View of the shoreline with brown seaweed (*Fucus* sp.), where the Leenamore River flows on to it just downstream from the Site 3 crossing point (view to the SSE, 28-1-2008).

Plate 5 Site 3 Crossing point in the right foreground and Sruwaddacon Bay in the background – view to the NNW (17-11-2008)

Upstream, between the proposed crossing point and the road, the channel is a series of meanders with riffles and pools, typical of eroding salmonid waters. This section is noticeable for its luxuriant cover of the aquatic moss *Fontinalis antipyretica* on boulders and large cobbles (Plate 6). The substrate is similarly coarse to the crossing point but with more gravel and coarse sand patches. A site chosen here (ING: F 85875 34947) was 1.7m wide and 15-20cm deep with a moderate-flow glide with boulder substrate (with heavy cover of *Fontinalis*) interspersed with gravel patches. The bank was 0.7-0.8m high, open and grassed with stands of rushes abundant and frequent Marsh Thistle and Lesser celandine, occasional Yellow Flag and patches of *Sphagnum* and other mosses. Marginally, in-stream there were small, restricted patches of Watercress, Fool's Watercress and Water Starwort. The invertebrates at this site were without estuarine influence and diverse (Table 3) and they indicate fair to good water quality conditions (Q4-5).

Further downstream shortly above the crossing at a site which is influenced by spring tides (pers comm. local landowner) (ING: F 85885 35039), the stream divides into two channels with one forming a shallow run or riffle-glide with a coarse cobble, boulder and gravel substrate in moderate shallow turbulent flow. The channel width here was 1.5-2.2m with depth ranging from 5-15cm. The banks were open, low (0.8m LHS, 0.45m RHS) and grassed with brown seaweed (*Fucus* sp.) clothing the vertical under-cut of the bank. In-stream, the boulders were covered with algal scum and a very occasional stunted *Fucus* stipe. Kick-samples revealed the presence of 5 gobies, attesting to the stronger estuarine nature of the site at this point.

Kick-samples taken on the shoreline in the shallow eastern low-tide stream at the crossing point revealed a fully estuarine low diversity fauna of brown shrimp (*Crangon crangon*), gobies (*Pomatoschistus* sp.) and gammarids.

Below the crossing the east and west margins of the intertidal area were dominated by small boulders and cobbles covered in brown seaweed (mainly *Fucus* sp.). A central area comprised silty sand with an infauna dominated by polychaete worms (nereids), oligochaet worms and small numbers of the crustacean (*Corophium sp.*) sp. These are very typical low-salinity estuarine macroinvertebrates.

The river at the crossing was not electrofished at the time of assessment. However the stretch immediately upstream has been electrofished by Aquens on three occasions in the recent past i.e. in 2001, 2002 and 2003 at a point about 200m upstream of the proposed crossing at ING: F 85864 34889. Only 3 trout were taken in the 2002 survey and 3 in 2003 (3 x 0+ trout in 2002 and 3 x 1+ trout in 2003); there were no trout taken at the site in 2001. Other fish taken there were 1 lamprey (unidentified *Lampetra* sp.?), 1 stickleback and 3 young eels in 2003, 1 stickleback, 2 minnow and 1 eel in 2002 and 7 stickleback and 5 eels in 2001 (Aquens, 2003). Aquens (2002) indicated that this site was poor from a fisheries perspective and perhaps too close to the sea. These returns for electrofishing indicate that the site is of low fisheries value. This proposed crossing lies within the Glenamoy Bog Complex SAC.

Table 3 Macroinvertebrates taken in a kick-sample at Site -3.

Taxa	**EPA Quality Category**	**Abundance Rating**	**Abundance Rating**	**Abundance Rating**	**Abundance Rating**
Ephemeroptera		Crossing Point	10m upstream of Crossing Point	50m upstream of Crossing Point	60m upstream of Crossing Point
Heptagenia	A				F
Baetidae	C			F	F
Plecoptera					
Isoperla	A				F
Leuctra	B				F
Trichoptera					
Hydropsyche sp.	C				F
Polycentropidae	C		F		
Rhyacophila sp.	C				F
Tinodes	C			F	F
Limnephilidae	C		F	F	
Silo	B				F
Sericostoma	B				F
Colepotera					
Elmis	C			F	F
Limnius	C				F
Diptera					
Dicranota	C			F	F
Tipula sp.	C	F			
Chironomidae	D	F			F
Diptera sp.	~	F			
Crustacea					
Gammaridae sp.	C	E	D	D	C
Crangon	~	C			
Jaera sp.	~	C	E	D	
Mollusca					
Sphaeridae	D				
Potamopyrgus jenkinsi	D		F	F	F
Hirudinae					
Glossiohonia	D				F
Annelida					
Oligochaetae	E	D			C
Q- value		**N/A**	**N/A**	**N/A**	**Q 4-5**

- Few (F) = 1 - 5 individuals
- Common (C) = 6 - 20 individuals
- Numerous (N) = 21 – 50 individuals
- Dominant (D) = 51 – 75 individuals
- Excessive (E) = >75% of total abundance

Plate 6 Channel upstream of the Site 3 crossing point showing *Fontinalis* moss-covered boulders and gravel on the streambed. (28-1-2008).

Site 4 (ING: F86477 34520)

This crossing point is on a small stream situated immediately adjacent to the road (northern side) at a point where the flow is very restricted and no more than a grass-choked flush. Immediately below this (ING: F86493 34533) the stream opens out (1.0-1.2m wide) and deepens (0.6m water over 0.5m organic detritus/mud) into a canal-like channel with floating macrophytes (Water starwort *Callitriche stagnalis*, and Pondweed *Potamogeton sp.* - Plate 7). Macroinvertebrate fauna taken in netsweeps through the vegetation and loose upper detritus revealed a typical pond-type fauna (Table 4). The banks are backed by open-planted conifer and broadleaf (Alder) trees with an understorey of ferns, rushes and bramble. Although the site was not electro-fished because of seasonal considerations, it is unsuitable for salmonids and lamprey by virtue of its bottom substrate and extremely sluggish flows; it would be suitable for 3-spined sticklebacks. Further downstream the watercourse may contain habitat suitable for eel and small trout but its small size means that it is of low fisheries importance.

Upstream of the road this small stream, which is very close to its source (based on map and aerial photo observations) at this point, lies under a dense canopy of Rhododendron beside coniferous plantation and bog. It eventually joins the lower tidal reaches of the Glenamoy River about 1km upstream of its confluence with the lower tidal reaches of the Muingnabo River. Almost the entire catchment of the stream is within coniferous plantation.

The stream macroinvertebrates ranged across several families and classes including some sensitive groups and indicate that the water quality is unpolluted, although not pristine, i.e. Q4 rather than a Q5 quality rating (Table 4).

Plate 7 Channel immediately downstream of the Site 4 crossing point showing floating Starwort and bank-side rushes moss-covered boulders (28-1-2008).

Table 4 Macroinvertebrates taken in netsweeps through the vegetation and superficial sediments at Site 4

Taxa	EPA Quality Category	Abundance Rating
Plecoptera		
Nemoura sp	B	N
Trichoptera		
Limnephilidae	C	C
Hemiptera		
Hespercorixa sahlbergi	C	F
Corixid sp.		
Odonata		
Coenagrion	C	C
Phyrenasoma	B	F
Coleoptera		
Ilibyius spp.	C	F
Larva indet	C	C
Diptera		
Chironomidae	D	N
Dixidae	-	F
Crustacea		
Asellus	D	F
Mollusca		
Lymnea peregra	D	C
Sphaeridae	D	F
Annelida		
Oligochaetae	E	N
Q- value		**Q 4**

- Few (F) = 1 - 5 individuals
- Common (C) = 6 - 20 individuals
- Numerous (N) = 21 – 50 individuals
- Dominant (D) = 51 – 75 individuals
- Excessive (E) = >75% of total abundance

Site 5 (ING: F86258 34069)

This is the final watercourse crossing of the proposed route before it joins the Bellanaboy Bridge Gas Terminal site. The watercourse in question is a first order stream, which was surveyed on September 6th, 2007. It is a [8]headwater tributary of a small stream, which flows to the southeastern corner of Sruwaddacon Bay. At the crossing it is surrounded by coniferous plantation forestry with immediate land-use associated with a bog mat road (since removed). It is culverted under the latter temporary road immediately upstream of the proposed crossing point in a steel pipe. The stream in question is considered to be a trickle, in places broadening into a stagnant wetland seepage or flush (Plate 8) and reverting back to a trickle. The wetland/flush areas are dominated by Flote grass (*Glyceria* sp.) and Water starwort (*Callitriche stagnalis)*, while the trickle area is overgrown with bankside grasses and other vegetation so that the channel, less than 0.5m across, is totally hidden from view. Bankside vegetation includes Marsh cinquefoil, Soft rush, Wild Angelica,

[8] Headwater refers to the top of the catchment i.e. close to the source of a watercourse

Creeping buttercup, Bent (*Agrostis spp.)* and Bramble, with some Greater Tussock sedge. The bed comprises peaty detritus-filled soft sediment. The site is clearly unsuitable for salmonids and probably contains no fish or lampreys. Bottom invertebrates including *Asellus*, corixid nymhs (immature waterboatmen insects) and pea mussels (Sphaeridae) were noted in net sweeps. The site did not lend itself to a water quality rating using the Q-value system because of the nature of the substrate, which comprised soft organic sediment, with very low and sluggish flows. The ecological and fisheries value of the site is very low because of its small size, the very sluggish flows and very organic deep sediment.

Plate 8 Site 4: Crossing point of a small first order stream about 0.7km north of the Gas Terminal (6/09/2007).

2.7 – POTENTIAL IMPACTS

2.7.1 - Overview

The key areas of potential impact of the proposed development on the freshwater habitats and associated migratory fish and lamprey species relate to the construction and commissioning of the pipeline. Once it is in operation, there will be no impacts on freshwater resources. The following sections therefore deal in particular with the potential impacts associated with the construction and the commissioning / testing phases of the project. A review of the proposed construction methods was undertaken in order to examine the potential impact of the proposed development. The following section deals with key potential impacts.

It is proposed to traverse beneath Sruwaddacon Bay in a tunnel to minimise impacts on the Bay. The possibility of surface intervention being required is very small (as outlined in Chapter 5). However, in the very unlikely event that an intervention pit is required during the construction phase, then there is potential to impact on migratory Annex II species if such works occur during the migratory season. It is proposed to cross Sites 3, 4 and 5 using open cut methods where a trench is excavated to install the pipeline, services, etc. (see Chapter 5 of the EIS for further details).

2.7.2 - Construction Phase

2.7.2.1 - Crossings of Small Streams/ Rivers (Site 1, Site 3, Site 4, Site 5)
The proposed development includes the crossing of three small streams / rivers and works within close proximity to one small stream. Sites 1, 4 and 5 are approximately 1m or less in width, while Site 3 is approximately 40m in width. All have minor or negligible fishing resources. None of these streams /rivers hold significant populations of aquatic species, animal or plant although Aquens (2003) recorded a lamprey (*Lampetra* sp.) about 200m upstream of the proposed crossing point, within the freshwater reaches of the Leenamore River. Sites 4 & 5 are outside the Glenamoy Bog Complex SAC at the proposed crossing points, while Site 3 lies within the SAC. There are three principal types of potential impact associated with the proposed open cut construction.

<u>Suspended Sediment and Habitat Loss/Damage</u>

The potential impacts associated with the crossings will be those related with the disturbance of the habitat of the streams in question, associated with the open-cut crossings. These will account for a short length of stream channel coinciding with the footprint of the crossing and amounting to a maximum of 20m of channel length, resulting in the potential disruption of about 20m^2 of streambed habitat. This marks a maximum, however, and in reality the actual crossing point will be much narrower than the temporary working area width, every effort being made to confine it to just a few metres. There is also the potential for siltation to occur downstream of each crossing if basic mitigation measures are not carried out. In this case the streambed downstream of each crossing could become blanketed with silt dislodged during trenching. This in turn would decrease the quality of the habitat (which in all cases besides Sites 4 and 5 - comprises gravels, cobbles and coarse sand), by smothering it with finer sediment thus adversely impacting the macroinvertebrates and any fish species present, which would likely emigrate out of the affected area until the substrate reverted to pre-construction conditions. Siltation of bottom substrates could also damage spawning beds were these present. It is unlikely that any of these small streams hold significant spawning beds for any species given their small size. However, pockets of spawning gravel for trout probably occur throughout the channel in each case and given the upstream locations of Sites 4 and 5 on their respective watercourses, and therefore the potential for a greater length of downstream channel to be impacted, in these cases special care will need to be taken during construction.

The streams at Sites 4 and 5 could potentially be adversely impacted depending on the degree of sediment escapement and deposition during the construction of these crossings. The streams in question, however, by virtue of their size and habitats, are of minor ecological importance, which reduces the significance of the impacts, which could occur. The crossing of the Leenamore River (Site 3) is located on the foreshore where the river is subject to full tidal inundation when the tide is in. The crossing at this point will be at least 40m in length. The adjoining habitats comprise low-diversity, soft sediment and boulder shore with brown seaweeds in variable salinity. These habitats can sustain a degree of sedimentation without significant adverse impact. Thus, provided efforts are made to reduce the quantity of solids escaping during the construction phase, there should be negligible impact from the crossing at this point. Ideally the coarse surface material (30c-50cm) should be removed along the line of the crossing in advance of trench excavation so that they can be replaced as the surface material on the back-filled trench by way of reinstatement. Likely impacts to the streams as a result of open-cut crossings, before mitigation measures are taken, would be considered to be minor localised, temporary, negative impacts would occur in the case of Site 3, while the unmitigated impacts at Site 4 and 5 could be termed minor to moderate, local impacts.

These will not persist for longer than 2 to 3 years (possibly only 1) after construction, when any deposited silts would have had time to wash away in floods. All these impacts can be easily reduced by good construction site management and simple mitigation measures as described below.

Release of Contaminants - Cement and Oil

Only cured, precast concrete elements will be used at open-cut stream crossings and so the possibility of cement spills into the streams in question will not arise.

Oil accidentally discharged to streams can give rise to fish kills and the death of streambed macroinvertebrates (Lytle and Peckarsky, 2001). Again this can be readily avoided by careful construction site management and appropriate mitigation measures.

Leenamore Crossing (estuarine)

The proposed development includes the crossing of Leenamore River, which is estuarine. This crossing is within the Glenamoy Bog Complex SAC. It is proposed to construct the Leenamore crossing using open-cut methods.

Sruwaddacon Bay

The pipeline will traverse the Bay in a tunnel constructed underneath the Bay. In the very unlikely event of an intervention pit, this has the greatest potential to give rise to significant adverse impacts because of the importance of the crossing route as a migratory route for Atlantic salmon and seatrout in particular, but also potentially for lamprey.

The greatest potential threat during construction of these crossings comes from suspended solids, generated either by the disturbance of the in situ marine sediments if a temporary intervention pit is required or through the escape of bentonite, a clay used in construction projects. It is mixed with water to form slurry, the consistency of which depends on the application. For trenchless construction, bentonite is used to lubricate and cool drilling heads and as a liquid medium for removing excavated spoil by pumping. Bentonite is injected only into the drilling head. The volume and pressure of the bentonite used is monitored on a continuous basis throughout the tunnelling process in case of an unexpected drop in pressure which would signal a leak in the system.

<u>Suspended solids can have the following impacts on fish:</u>

Behavioural:
(altered swimming behaviour, breakdown in schooling, altered foraging rates and success, avoidance – lateral and or vertical).

Sublethal:
(physiological changes including increased blood sugar, increased blood cortisol, increased coughing response and reduced feeding success all of which are considered signs of stress or alarm. Repeated stress can lead to reduced growth rates).

Lethal: (direct mortality due to severe gill damage).

The affects of suspends solids depends principally on a combination of concentration and duration of exposure. The nature of the solids involved is also a factor with larger angular silt and sand particles considered more damaging than smaller particles.

Essentially, the higher the concentration of solids is and the longer the exposure period, the higher the risk is of adverse impacts occurring to fish. Thus while a fish may be exposed to relatively high levels of suspended solids for a short time period with no adverse impacts, a much lower concentration over an extended period of exposure can have chronic or lethal impacts.

Direct mortalities from high suspended solids in nature is likely to be rare because in experiments these affects are not normally observed until concentration of tens or hundreds of thousands of milligrams per litre of suspended solids are in question and these levels rarely occur in nature (Alabaster and Lloyd 1980, McDonald & Jensen 1996). In the case of the Sruwaddacon Bay sediment, most of the material known to occur in the surficial layers, based on geotechnical surveys undertaken, is sand or gravel, with some silt and clay. The bulk of this sediment will fall out of suspension very rapidly so that any plumes arising are unlikely to contain high suspended solids concentrations except within relatively close proximity to the site of the works (50-100m).

In laboratory experiments the onset of avoidance can be demonstrated in coho salmon (*Oncorhynchus kisutch*) at concentrations at around 300mg/l when 1% of the test animals surfaced in test vessels. This effect didn't become pronounced (i.e. affected individuals went above 5% of the test population) until concentrations reached >2500mg/l of suspended solids (Servizi & Martens 1992). However the authors indicate that there is a greater tendency for lateral avoidance than vertical avoidance movements at lower solids concentrations. This can be explained by the fact that fish which surface have a greater risk of predation by avian predators e.g. gulls and terns.

There is uncertainty as to the concentrations of suspended solids and duration of exposure in the event of an intervention pit being required in Sruwaddacon Bay during the course of tunnelling. However due to the low probability of it being required, the associated risk of any adverse impacts on migratory fish is considered to be negligible.

If sheet-piling, coffer-dam, or other open-cut type techniques are used to construct an intervention pit there is the possibility of elevated suspended sediment concentrations arising. These would result from disturbance of the native sediments while the structures were being installed. Open-cut work in the main low tide channel(s) is likely to give rise to greatest exposure risk to fish during migratory periods as they would be expected to be concentrated in these areas, especially as the tide ebbs, whereas, works in intertidal areas exposed during low tide are less likely to give rise to suspended solids problems as (i) these may be accessed and resolved during low water periods or (ii) if they have to be enclosed in sheet pile enclosures, the latter will be off the channels and in areas of lower currents. Dewatering of sheet-pile trenches and cofferdams could also give rise to intermittent or sustained suspended solids pulses in the receiving waters. This situation may occur where smolts on their seaward migrations in the March – May period or adults salmon and seatrout returning to the Muingnabo (but especially the Glenamoy River) would have to pass through or around plumes of increased turbidity. However, the exact concentrations or durations of such occurrences are uncertain and they would be over a short duration, namely when the structures are being constructed.

In their review of suspended sediment impacts on fish, Wilber and Clarke (2001) indicate that for juvenile and adult salmon the 'most probable' suspended solids dosage range (i.e. concentration x duration of exposure) for outward migrating smolts and inward migrating adults in the context of estuarine dredging would be concentrations of up to 1000mg/l for periods of up to 24hrs. They base these figures on average smolt emigration rates and adult immigration rates. Quoting from an extensive previous review of sediment impacts on fish (MacDonald and Jensen 1996), they indicate that for concentrations and exposures within this range, most studies indicated behavioural and sub-lethal rather than lethal responses by salmonids. In a worst case scenario, i.e. if cofferdams need to be installed in or close to permanent low-tide channels, the works in Sruwaddacon Bay may produce similar suspended solids concentrations for short periods, at least close to the works and especially in areas where tidal currents are strong (e.g. by the main tidal channels and in the outer bay) giving rise to scour around temporary structures. In situations where this occurs, smolts may alter their swimming behaviour or slow their emigration rates, possibly exposing them to greater risk of predation by birds or to increased stress and poorer growth or greater risk of gill damage. Returning adults would be less at risk from predation if their advance up the bay were slowed. It is worth noting however, salmon still make their upriver spawning migrations annually under natural conditions in some estuaries where high turbidity levels are recorded (e.g. the river Suir with suspended solids levels of up to several hundred milligrams per litre - pers. obs.) and the Severn estuaries, where solids levels of more than a thousand have been noted (Alabaster & Lloyd 1980). It seems unlikely therefore that returning adults would be prevented from passing the works in Sruwaddacon, although slowing their rate of immigration during periods of increased solids washout from the works is possible.

Without fish counters on the Glenamoy River, in particular, there isn't a clear understanding of the timing of juvenile salmon or seatrout movements in Sruwaddacon Bay. However, recent investigations (spring 2009) using a smolt trap, indicate that peak smolt out-migration occurs in April and in 2010 this had not happened by May 11th. Moreover, it is believed that during the summer adult salmon may enter the bay from the sea on high tide and drop back down again during the ebb and that this may persist over an extended period until a rise in river flow will prompt fish to ascend the rivers. In this potential situation their exposure to suspended sediment plumes could be greater than the averages suggested in Wilber and Clarke (2001). However, even in these situations, salmon may still be able to avoid any plumes generated or those plumes may have suspended solids below levels likely to have significant adverse impacts. The risk however, would be increased. In the latter case, significant adverse impacts would be those that would prevent the salmon spawning successfully, as these would affect the species at a population level, rather than at the level of individuals. Such impacts are considered to be very unlikely to occur.

Impact of Bentonite

Bentonite is used in trenchless construction. When used successfully, there is very little risk to the environment, as the bentonite remains sealed within the drill shaft. However, there is a very low risk of bentonite seeping out through soil or rock fissures into the overlying watercourses. If the concentrations are high enough, i.e. tens or hundreds of thousands of milligrams, then direct fish mortality could occur in a relatively short period, i.e. less than a day. Lower concentration of several thousands of milligrams could produce the same impacts over more extended periods (a week or more). Much lower concentrations i.e. several hundreds of milligrams per litre are likely to cause very turbid conditions because of the slow settlement rate of bentonite. This could reduce feeding rates in fish but clearly the more important impact would be associated with catastrophic release amounts. A large outbreak in the low tide channel, especially in the middle of the bay, where the channel is narrowest, during low tide, and during a smolt migration event would expose smolts to possible gill damage and possibly slowed migration until the plume had dispersed during flooding tide, if they didn't just swim around it. Exposure long enough to cause mortalities in this open situation would be very unlikely. The combination of criteria both spatial and temporal which would have to be met to give rise to either of these impacts occurring is considered very remote. The risks associated with these

events are considered to be low because the bentonite will be used at low pressures and low quantities relative to other trenchless methods. Nevertheless, mitigation measures will be required and will be utilised.
There is also a risk from bentonite at the Aghoos tunnelling compound, where it is being batched in preparation for use during the tunnelling process and where it is being recycled from spoil for reuse also in tunnelling. If these areas are not properly secured then spills and leakages could introduce the slurry into the marine surface waters with potential for serious adverse impacts. This eventuality is considered low but will need to be mitigated against also.

Cement Grouting

The segment lined tunnel will be surrounded in a layer of cement grout to form an outer concrete lining for the segments. This will be manually pumped from a container within the tunnel in stages as it advances. The grout is more viscous than bentonite and considered very unlikely to travel up through the overburden and reach the bay. Cement is a strong alkali and can give rise to very serious fish kills if it escapes into surface waters. In this case such an eventually is considered remote. There is also a risk associated with the batching of cement grout at the Aghoos tunnelling compound, if run-off from the compound became contaminated with cement. Normal best practice in construction site management will be sufficient to prevent this eventuality.

Hydrostatic Testing

Hydrostatic testing requires large amounts of water to be abstracted from a surface or groundwater sources to fill the pipeline. The water pressure is then increased to the test pressure of the pipe to ensure its structural integrity. The water in the pipe is then treated and discharged. Although high pressure can in extreme circumstances give rise to supersaturation of the water (and subsequently lead to gas bubble disease in fish) with nitrogen gas from any air trapped in the pipe during testing, there will be no measurable quantities within the test water. The water may also become contaminated with suspended solids, metals and hydrocarbons from the inside of the pipe all of which might have a detrimental impact on fish, depending on the concentrations involved, if discharged untreated into a receiving water body. However, the test water will be analysed for a range of parameters (temperature, pH, dissolved oxygen, total gas pressure, suspended solids, iron, chromium, cadmium, nickel, copper, lead, zinc and total petroleum hydrocarbons), details of which will be agreed with the NWRFB prior to undertaking. The hydrostatic test water will be disposed of offshore via the water outfall pipe in consultation and agreement with relevant statutory bodies.

<u>Noise</u>

The tunnel boring machine (TBM) will generate noise as it traverses beneath Sruwadaccon Bay. This noise will be at a level that maybe audible to fish within the bay and therefore has the potential to affect their behaviour. The following section addresses the likelihood of impact to migratory species, in particular the Annex II species Atlantic salmon (*Salmo salar*) and trout (*Salmo trutta*), both of which pass through the bay on their seaward migration as smolts and on their return migrations as adults.

Hearing in Fish

Fish are known to have complex and diverse inner ear structures with a broad range of hearing sensitivities, generally weighted toward lower frequencies. Some species, such as goldfish (*Carassius auratus*), freshwater catfish (*Ictalurus punctatus*), and some members of the herring family can hear across a wider range of frequencies and quieter sounds, these species are sometimes referred to as *hearing specialists*. Others, particularly flatfish, e.g. dab and plaice, hear over a narrower range of frequencies and have much lower sensitivities to sound (they have no swim bladders); salmon and trout fall into this latter group also, which are sometimes referred to as *hearing generalists*.

Assessing the Sensitivity of Fish to Sound

The sensitivity of fish to sound has been measured experimentally by exposing groups or individuals of a particular species to pure tone sound across a range of frequencies in hertz (Hz) and increasing strengths in decibels (dB) and then assessing their response by the use of specialist behavioural or neuro-physiological testing methods. The output from these experiments are plots of the lowest sound in dB that a fish is sensitive to at each frequency in Hz tested, i.e. its *hearing threshold*. These plots or graphs of hearing threshold in decibels (usually of sound pressure level - SPL) against frequency are known as *audiograms*. Note that a fish's hearing threshold may be different at every frequency, within the frequency range over which it can hear.

Audiograms of fish are the most widely used tool to assess whether a fish is likely to be able to hear a sound produced anthropogenically in the aquatic environment, for example from boat or ship passage, dredging, pile-driving, underwater blasting or in this case tunnelling. Audiograms are also used to assess whether fish are likely to be able to hear natural background noise e.g. from fast flowing rivers or rough seas. By comparing the fish audiogram with the measured or modelled sound output from a given anthropogenic activity across an appropriate range of frequencies, we can judge whether a fish species will be likely to hear these sounds or not. Thus if a sound is at a frequency higher or lower than one to which fish species is sensitive, it will not hear the sound. If the sound is within the detectable frequency range of the species, the fish will likely hear the sound if the dB pressure level is above the hearing threshold at that frequency. However, there are other complicating factors, in particular the affect of natural background noise which, depending on its frequency range and level may mask anthropogenic sound to a greater or lesser degree.

Impact of Anthropogenic Sound on Fish

Although much research has been done on the ability of fish to detect various sounds, the significance of anthropogenic noise on fish is not well understood and is only beginning to be researched in some detail. Some research for example has been done on the impact of noise on fish in aquaculture settings because of the economic implications if for example continuous noise e.g. from pumps and aeration systems in tank farms were to result in sub-optimal growth in the cultured species. Research on fish in the wild has assessed startle or avoidance reactions to anthropogenic sound (Kastelein *et al.*, 2008; Knudsen *et al.*, 1997; Maes *et al.,* 2002) and also, whether noise can impair hearing either temporarily or permanently in fish (Scholik and Yan, 2001) and the physiological basis of these affects. Various researchers have also assessed avoidance reactions of fish to vessel noise and whether fish show biochemical signs of stress following exposure to vessel noise (Wysocki *et al.*, 2006). More acute impacts of noise on fish e.g. injury or death are generally only associated with high energy sound impulses e.g. associated with underwater explosions (Yelverton *et al.*, 1975).

Noise Output from the TBM

Appendix H3 presents the noise output model for the TBM during its passage beneath Sruwaddacon Bay. Figure 25 from Appendix H3 presents the modelled output at its most conservative, i.e. the highest noise output modelled at high water along the axis of the tunnel. The measurement are of Sound Pressure Level expressed as dB re 1μPa.

This shows that the highest noise output is at the 31.5 Hz frequency with a pressure level in dB re 1 μPa of around 160 within a few metres of the TBM and approximately 145 dB at a distance of 90m. At higher and lower frequencies the dB level is generally lower and declining with distance from the TBM. On average the sound output within the frequency range modelled (i.e. 1-100Hz) ranges from 160dB to 120dB re 1μPa within 10m of the TBM to about 140-120dB re 1μPa at 90m distance. These sound levels are the highest modelled. They represent the situation at the cutting face and propagating along the axis of the tunnel during high water; they show a clear decline with distance. A slightly faster decline in noise levels with distance from the source will occur at right angles to the path of the tunnel.

If we compare these noise pressure levels with the audiogram of the Atlantic salmon (Hawkins and Johnstone, 1978) we can judge if these sound levels are likely be audible to that species. The salmon is most sensitive to sound pressure level at 160Hz when it can detect 95 dB re 1μPa. Outside these frequencies its threshold rises so that for example at 100Hz the threshold is about 98 dB re 1μPa, at 50 Hz about 105 dB re 1μPa, at 30 Hz about 107.5 dB re 1μPa, while at the higher end of the spectrum e.g. 300 Hz, the threshold is about 112 dB re 1μPa. Under conditions of low ambient noise, therefore, salmon can be expected to hear the noise from the TBM as this will exceed the salmon’s hearing thresholds at all the relevant frequencies. It is also likely that salmon will be able to detect the noise of the TBM down to at least 5Hz and probably lower as they have been shown to be sensitive to lower frequencies than those tested by Hawkins and Johnstone (1978) (Knudsen, 1992).

The data presented above indicates that within the first 90m at least of the TBM, sound output will be audible to salmon (adults and smolts) passing through the area. Table 5 below presents the approximate noise output from the TBM at various frequencies including 31.5Hz, which is the frequency at which the highest noise levels are predicted. Also included are the hearing thresholds for the salmon (*Salmo salar*) derived from Hawkins and Johnstone (1978) at those same frequencies and in the final two columns the amount by which the TBM noise exceeds the thresholds both close to the TBM and at 90m.

Table 5. Approximate noise pressure levels (SPL) in dB re 1µPa at 0-10m and 90m from the TBM at five frequencies (in Hz)

Frequency	Approximate SPL at 0-10m	Approximate SPL at 90m	[9]Salmon hearing threshold	Exceedence of salmon hearing threshold (at 0-10m)	Exceedence of salmon hearing threshold (at 90m)
(Hz)	(dB re 1µPa)	(dB re 1µPa)	(dB re 1µPa)	(dB re 1µPa)	(dB re 1µPa)
5	143	133	107.5*	35.5	25.5
10	130	125	107.5*	22.5	17.5
31.5	160	145	107.5**	52.5	37.5
50	140	125	105	35	20
100	142	125	99	43	26

* extrapolated from the threshold at 30Hz ** value for 30Hz

Table 5 also shows and the corresponding hearing thresholds for Atlantic salmon at the same or near frequencies based on the audiogram from Hawkins and Johnstone (1978) as well as the exceedance level of these thresholds by TBM noise at 0-10m and at 90m from the tunnelling face.

While sound in water as it affects animals is generally measured in sound pressure level units (SPL), i.e. dB re 1µPa, it is now known that salmon are more sensitive to particle motion, than pressure, especially at lower frequencies (Knudsen *et al.,* 1992). Furthermore, Knudsen *et al.,* (1992) appear to have been the first authors to measure the avoidance reaction of Atlantic salmon smolts to sound levels expressed in terms of particle motion, in this case particle acceleration, which is expressed as dB re $10^{-5}ms^{-2}$. To facilitate a comparison with the findings of Knudsen *et al.,* (1992), the sound output from the TBM has also been presented as particle acceleration (Appendix H3, Figure 26). These data have been compared with the salmon hearing thresholds (also expressed in units of particle acceleration) at a range of relevant frequencies (Table 6). These show that for the TBM the highest levels of exceedence of the thresholds are in the higher frequencies.

9 From Hawkins and Johnstone (1978)

Table 6. Approximate noise levels in units of particle acceleration (dB re $10^{-5}ms^{-2}$) at 0-10m and 90m from the TBM at five frequencies (in Hz)

Frequency	Approximate particle acceleration sound level at 0-10m	Approximate particle acceleration sound level at 90m	[10]Salmon hearing threshold	Exceedence of salmon hearing threshold (at 0-10m)	Exceedence of salmon hearing threshold (at 90m)
(Hz)	(dB re $10^{-5}ms^{-2}$)	(dB re $10^{-5}ms^{-2}$)	(dB re $10^{-5}ms^{-2}$)	(dB re $10^{-5}ms^{-2}$)	(dB re $10^{-5}ms^{-2}$)
5	27.5	20	22*	7.5	-2
10	25	15	22*	3	-7
31.5	63	45	22**	41	25
50	45	35	21	34	14
100	55	35	14	44	21

* extrapolated from the threshold at 30Hz ** value for 30Hz

Table 6 also shows and the corresponding hearing thresholds for Atlantic salmon at the same or near frequencies based on the audiogram from Knudsen et al., (1992) as well as the difference between these thresholds by TBM noise at 0-10m and at 90m from the tunnelling face.

Affect of Noise on Salmon

While there has been a reasonable body of work on establishing the sensitivity to sound of various fish species, the implications for the fish of those sounds is less well understood. The analysis presented in Table 5 above, suggests that the degree of exceedence of the hearing threshold by the salmon in terms of pressure (Table 5) is fairly modest ranging from 22.5 to 52.5 dB re 1µPa in the near field (0-10m) and 17.5-37.5 dB re 1µPa at 90m. In a recent report, Nedwell *et al.* (2007) used data from several sources and a range of species and noise sources to validate a scale with which to assess the likelihood that a given level of noise above the hearing threshold of a fish species would invoke an avoidance reaction (see Table 7).

Table 7 Criteria for assessing the likelihood that a noise will result in avoidance reactions in fish. (after Nedwell *et al.,* 2007)

Sound level above the species hearing threshold	**Effect**
Less than 0 dB	None
0-50dB	Mild reaction in minority of individuals, probably not sustained
50-90dB	Stronger reaction by the majority of individuals, but habituation may limit effect
90dB and above	Strong avoidance reaction by virtually all individuals

Using this scale, and comparing it with the figures in the two last columns in Table 5 suggests that there exists the possibility of avoidance reactions by some salmon of the TBM noise, particularly in the near field (0-10m).

[10] Calculated by Knudsen *et al*., (1992) from the audiograms of Hawkins and Johnstone (1978)

In terms of sound as particle motion (the form to which salmon are considered most sensitive), Table 8 compares the level of exceedence of the salmon hearing threshold with levels measured by Knudsen *et al.,* (1992) at which smolts were observed to exhibit a spontaneous *awareness reaction threshold.* This can broadly be described as a state of alertness which precedes an avoidance reaction but the latter would only follow if sound levels were to increase by about another 10 dB re $10^{-5}ms^{-2}$. The data in Table 8 suggest that smolts (and adults), would probably not react to the sound output from the TBM, including in the near field (0-10m), as it doesn't reach the required thresholds.

Table 8. Approximate noise levels in units of particle acceleration (dB re $10^{-5}ms^{-2}$) at 0-10m and 90m from the TBM at five frequencies (in Hz)

Frequency	Exceedence of salmon hearing threshold (at 0-10m)	Exceedence of salmon hearing threshold (at 90m)	[11]Salmon hearing threshold	Awareness reaction threshold measured as dB above the hearing threshold
(Hz)	(dB re $10^{-5}ms^{2}$)	(dB re $10^{-5}ms^{2}$)	(dB re $10^{-5}ms^{2}$)	(dB re $10^{-5}ms^{-2}$)
5	7.5	-2*	22	25±3.5
10	3	-7	22	33±3.6
31.5	41	25	22	~59
50	34	14	21	~61
100	44	21	14	~74

* Negative signs mean that the hearing threshold was not reached at that frequency.

Table 8 also shows and the corresponding hearing thresholds for Atlantic salmon at the same or near frequencies based on the audiogram from Knudsen et al., (1992), as the levels at the same frequencies which resulted in smolts exhibiting an awareness reaction threshold (Knudsen et al., 1992)

The authors (Knudsen *et al*, 1992) suggest that when dealing with responses to sound in fish 'it is reasonable to operate with three different thresholds'. (i) The *hearing threshold*, which is what the audiogram of a fish represents, i.e. the lowest level of sound detectable by a species at any given frequency in the absence of background noise; this they believe is fairly constant for a species, (ii) a spontaneous, physiological [12]*awareness reaction threshold*, which they say is well above the absolute hearing threshold and (iii) an *avoidance response threshold* which is higher again than the awareness reaction threshold. The latter two are believed to be variable and to depend on for example, time of the year, time of the day and the physiological and behavioural condition of the fish.

Thus, using the Nedwell *et al.,* (2007) assessment scale (Table 7), and the data in Table 5, which is based on sound pressure levels, it would seem that a proportion of smolts within a distance of less than 90m of the TBM (probably much less), might exhibit an avoidance response from the TBM noise source. However, based on the

[11] Calculated by Knudsen *et al*., 1992 from the audiograms of Hawkins and Johnstone (1978)

[12] *spontaneous awareness reaction threshold* was indicated by a sudden reduction in heart rate and an decrease in breathing movements in the affected fish.

data from Knudsen *et al.,* 1992, in which the TBM noise is measured as particle acceleration, neither smolts nor adults would be expected to react to the TBM noise expressed (Table 6), as these do not exceed reaction thresholds at the frequencies in question (Table 8).

On their downstream migration, smolts are likely to generally follow the area of the bay experiencing the fastest flows i.e. close to the low tide channel, as this ensures the most rapid transport toward the sea. This channel is generally well outside the route of the tunnel except at two positions. The first is in the middle of the bay where the tunnel route crosses the channel as the latter switches from the northern to the southern side of the bay, and the second is in the outer bay where the tunnel crosses the low tide channel and then hugs its northern edge until crossing it again as it approaches Glengad. In the middle of the bay the tunnel is only in this region of the low-tide channel for about 2.5weeks, based on an average tunnel advance rate of 11m per day, while in the outer bay, the tunnel will be adjacent to the channel for about 2.5months. Only at these points is it considered possible that noise from the TBM could stimulate avoidance reactions in salmon because outside of these areas the line of the tunnel would be too far from the main channel of the bay.

Three other variables are likely to influence the reaction of salmon to TBM noise and reduce its influence. These are: (i) background noise, (ii) the salmon's migratory impulse and especially, (iii) downtime in the operation of the TBM. It is known that background or ambient noise in rivers and in the sea is sufficiently high under certain conditions that it could mask the influence of anthropogenic noise, in this case from the TBM. This would have the affect of raising the hearing threshold of fish, making it more difficult for them to hear anthropogenic noise. In the case of salmon, Hawkins & Johnstone (1978) indicated that if background noise rose to within 23.75 dB of the fish's auditory threshold, then masking would occur. Background noise levels within coastal waters for wind speeds of 3-8 m/s (~ Beaufort 2-4) are in the range 95 – 115 dB re. 1 µPa in the frequency range 10 Hz to 100 Hz (Kinsler *et al*., 1982). Under these conditions, were they to occur in Sruwaddacon Bay during salmon migration, it would make it more difficult for salmon (adults and smolt) and other fish to hear the TBM noise, particularly at greater distance (i.e. >90m) and therefore be less likely to react to it.

Research undertaken by the Marine Institute in 2004 and 2005 showed that smolts leaving their freshwater sites in inner Clew Bay took less than a day to reach Clare Island in the outer bay i.e. a distance of more than 25km. They calculated the swimming speeds at 0.5m/s or ~1.5km /hr. These emigration rates are broadly in line with those reported by some other authors (LaBar *et al.*, 1978), while a bit higher than reported by others 0.14-0.35m/s (Moore *et al.*, 1998). Smolts move faster seaward during ebb tides than during flood tides, which accounts for the range of speeds reported in Moore *et al.* (1998). It is also reported that smolts tend to leave rivers at night (possibly to give the cover from fish eating birds such as cormorant and heron – Moore *et al.*, 1998). It is likely, therefore, that when smolts leave the Glenamoy River, mainly during elevated flows in that river, the majority will swim rapidly through the bay and not be deterred by TBM noise. Returning adult salmon are also likely to swim through the bay on a flooding tide without being deflected or retarded by noise from the TBM, provided the water levels are sufficiently high in the

Glenamoy River, otherwise, under low flow conditions in the river, they would normally drop back again with the ebbing tide (pers. comm. NWRFB).

If smolts were to exhibit avoidance reactions, it would most likely happen in those areas in the middle bay and outer bay where the TBM will be closest to the main flow channel but only if these times coincided with the migration windows of the smolts and the adults. Where avoidance reactions have been observed in the laboratory (Knudsen *et al.*, 1992), Atlantic salmon smolts moved rapidly to deeper water in response. This same behaviour was exhibited by smolts of North American salmon species under the same circumstances, and they were additionally observed to move horizontally away from the noise source if they couldn't move into deeper water (Mueller *et al.,* 1998). It is suggested therefore that if smolts do exhibit avoidance reactions in Sruwaddacon Bay they will tend to swim to deeper water and or away from the track of the TBM. In the majority of instances, this should mean that they would simply swim around the source but continue toward the sea and within a few minutes be beyond the avoidance reaction threshold of TBM noise. If on the other hand some smolts were to stop their seaward migration, when current conditions would otherwise permit them to advance (something which is considered very unlikely), then it is important to note that the TBM will only be tunnelling for 20 minutes in every hour, leaving 40 minutes when there will be no noise generated from the TBM. In that time, a smolt could have travelled between 300m and 1200m downstream based on the travel times for smolts given above. Thus in the unlikely event that TBM noise were to impede the passage either of smolts or adults during tunnelling, the 66% downtime in each hour should be more than adequate to allow groups of adults or smolts to pass beyond the influence of TBM noise every hour.

Other Fish Species

Trout were observed by Knudsen *et al.,* 1992 to react in a similar way to noise as salmon smolts, such that the scenario outlined above for salmon smolts should be similar for trout. It is notable that their audiogram indicates that they are less sensitive to sound (pressure) than salmon over the same frequencies (Nedwell, *et al.*, 2006).

Neither river lamprey nor sea lamprey have been recorded within the catchment of Sruwaddacon Bay, however, we cannot definitively rule them out as occurring. I am not aware of any data available on the auditory sensitivity of lamprey but the fact that they are very primitive vertebrates, without a swim bladder, would suggest that they have a low sensitivity to sound and therefore are very unlikely to be adversely impacted by TBM noise.

Conclusion

The data analysis undertaken would suggest that there is only a small likelihood that salmon (smolts or adults) will exhibit avoidance reactions to noise from the TBM. However, if this were to happen, it is not expected to prevent either the outward migration of smolts or the inward migration of adults. In the extremely unlikely event that salmon would halt their migration because of the noise, then the 40 minutes downtime in the operation of the TBM in every hour would be sufficient to allow smolts and adults to pass beyond the influence of the TBM. It is considered that

TBM noise will therefore have negligible adverse impact on salmon and that the impact on trout and lamprey (were they to be present in the bay) would be similarly low.

No Development Option

In the absence of the development it is likely that the habitats and water quality along the proposed route would remain unchanged, although both are subject to natural and other anthropogenic variability.

MITIGATION

Construction Phase

Small stream crossings

In the case of the stream / river crossings along the route, open cut crossings will be used to carry the pipe under the streambed. In order to mitigate against the loss of solids into the streams downstream of the open cuts, the stream water will be diverted through the crossing point in a flume pipe (the preferred option in all cases) or the upstream end will be dammed and water pumped around the crossings to maintain flow downstream. These methods will allow all in-stream works to proceed in the dry.

Where the stream sediment comprises coarse materials e.g. sand gravel and cobble (Site 1 and Site 3) the surface 20-30cm of sediments over the full area of the crossing footprint will be excavated in the dry and set aside on a geotextile mat for later re-instatement.

In order to prevent unnecessary damage to streambeds and to prevent the generation of large amounts of suspended sediment, construction vehicles will only traverse the three identified watercourse crossings using temporary bridging structures, which will remain in place as running-tracks. These may consist for example of flume pipes secured with clean, crushed stone free from fines and topped with bog mat or other rip-proof material to act as a secure surface for vehicular traffic.

Ideally, the works will be carried out in the May-September period when water levels will be at their lowest. However, given the relatively minor ecological and fisheries value of the streams involved, this timing should be flexible in terms of season, although it is recommended that the actual crossings should only be commenced during dry weather. Even in the middle of winter the flow in all of these streams will drop very substantially even after a few days of dry weather because they all have small catchment areas.

No waters that may seep into the pipe trench during construction will be discharged directly to any watercourse or the sea without first being treated by settlement and / or filtration in order to remove suspended solids. Suspended solids should be monitored at the outfalls from treatment works to ensure that they are below 50mg/l.

If there is a requirement for refuelling it should be done in accordance with the Environmental Management Plan, which will ensure spill risk is monitored and containment / recovery measures are available.

All plant such as compressors and pumps will be placed on drip trays with absorbent material to prevent contamination of surface or groundwaters with hydrocarbons. Spill kits should be available in the event of a spillage.

Concrete will be pre-cast before use at any stream crossing. All cement contaminated washings, if they arise, will first be neutralised to pH 6-8.5 and settled to removed solids before being discharge to watercourses.

Sruwaddacon Bay

Mitigation by Avoidance - Timing

In the unlikely event of surface intervention being required in Sruwaddacon Bay the use of certain time windows during the works could considerably reduce the potential for adverse impacts between the works and migrating fish (in particular salmon and sea trout). It is now known that the bulk of smolts out-migrate from the Glenamoy in April (pers. comm. NWRFB) – (late March – early May). Adult salmon on the Glenamoy are late returning from mid June (mainly mid July) to September with peaks in the latter part of that window during 2008.

A smolt trap was also placed on the lower Glenamoy River to assess the timing of the peak smolt runs during the March-May 2010 period. This data will be compared with the same statistics for 2009 and, where available, for other rivers in the region. This data will be available for assessment prior to construction beginning. Smolts will also be monitored in the spring of the year(s) of construction in order to add to this body of data.

Given that smolts would be considered more vulnerable than adults both to predators and suspended solids, it would be more important to halt any surface intervention activities (e.g. sheet-piling) during their passage through Sruwaddacon Bay than that for adult salmon or trout. Segment lined tunnelling will considerably reduce the likelihood of any surface interventions in the bay. However, if intervention should be required during the smolt run (i.e. late March – late May) the bay will be monitored upstream of the works and if smolt are detected the works will be halted temporarily until they pass. If any surface intervention work is required in the bay the NWRFB will be consulted and notified in advance.

Site preparation, including low-risk work such as construction of sheet-pile trenches in upper shore sandy areas at the landward side of the crossing, and other ground preparation works, would be possible at any time of the year after careful risk-assessment and consultation with the NWRFB, as these would be much less likely to produce sediment outwash into the main channel.

<u>Mitigation by Method - Trenchless Construction</u>

Trenchless construction is proposed for Sruwaddacon Bay to minimise potential impacts. Although this method uses bentonite, the latter will be used at low pressure, so that the risk of seepage into the overlying waters of the bay will be very low. Furthermore, during the drilling process, the pressure at the pump will be monitored on a continuous basis and any unusual fluctuation, that would indicate a leak or other eventuality, will result in pumping being stopped immediately. Also, the bay will be under constant observation in case bentonite seeps through the overburden. If this happens, the bentonite pumping will also be stopped and grout pumped into the point of the leak before drilling recommences.

In addition, The tunnelling compound at Aghoos will have a large hard standing area containing a bentonite handling plant which will circulate and recycle bentonite slurry throughout the tunnelling process via dedicated hoses to and from the TBM and includes areas for settlement and filtration. The bentonite handling plant is used to separate tunnel arisings from the drilling fluid. A storage area for tunnel arisings will be located adjacent to the bentonite handling plant. The bentonite handling area will include an area for mixing bentonite with water to form slurry.

The tunnelling compound at Aghoos will also contain a cement grout handling area for storing and mixing cement grout for use in tunnelling operations. This process will be carried out within an area of hard standing.

The bentonite handling area and cement grout handling area will have a separate drainage system from which all run-off will be collected and pumped into a storage tank. Bunding will be used where appropriate. All wastewater from this tank will be directed to a filter press and the solids removed as a cake for licensed disposal. All residual water from this process will be tankered off site for disposal in a waste water treatment plant.

All drainage from areas within the compound, that are not bunded or have their own drainage areas as described, will be directed through a bypass separator for removal of hydrocarbons followed by a settlement lagoon for removal of suspended solids and the installation of a filtration system for removal of finer particles. The settlement lagoon can be used as an additional reserve volume of fresh water for use in the tunnelling process, if required. Any excess water from the settlement lagoon will be treated to an acceptable standard and then discharged to a local drain. In this manner all potentially contaminated drainage will be kept separate from routine, un-contaminated or slightly contaminated run-off.

The construction of this compound has the potential to give rise to solids discharge from peat excavations, however, the construction of the compound has been designed to minimise any run-off from these earth works.

A detailed method statement describing how the trenchless crossing will be achieved at Site 2, including monitoring and mitigation measures which will be employed to prevent bentonite spills into the environment.

<u>Intervention Pit</u>

If during the tunnelling process, the TBM encounters an impenetrable obstruction, which cannot be mitigated via the tunnel bore, an intervention pit may be sunk at the point along the tunnel where the obstruction is encountered. This will consist of rectangular pit with an outer and inner layer of sheet piles. If the intervention pit has to be situated within the permanent low-tide channel (i.e. in permanently wet areas) it could give rise to the escapement of sediment into the water column during its installation, with potential consequences for any migratory fish present. This being the case, the pit would not be installed without prior agreement with NWRFB. In addition, if it is observed that adult salmon or smolts were congregating upstream or downstream of the works within the bay as a result of sediment escape, then the works would be temporarily halted for a few tides to allow fish to pass. The requirement for these downtimes and their duration would be decided in consultation with the NWRFB.

The contractors will draw up a detailed method statement describing how the intervention-pit will be installed and how they will be managed in order to minimise potential pollution emanating from it at Site 2.

If an intervention pit is required a comprehensive pre-construction, construction and post-construction suspended solids monitoring programme will be implemented to ensure that excessive amounts of solids are not escaping from the works. A programme of monitoring will be agreed in advance with NPWS and NWRFB.

NPWS and NWRFB will be kept informed of the progress of all crossing activities within Sruwaddacon Bay including any pollution incidents, should they occur.

Handling of Excavated Spoil and Dewaterings

Spoil excavated from sheetpiled sections will not be stockpiled where it could be exposed to tidal scour. Instead it will be conveyed onshore to temporary stockpiles or alternatively be retained within the sheet-pile structures, separated from tidal scour by the outer sheet-pile ring.

All sheetpile enclosure de-watering will be pumped onto an adjoining pontoon where it will be settled and filtered to an acceptable standard before being discharged into the bay. Suspended solids should be monitored at the outfalls from treatment works to ensure that they are below 100mg/l for marine discharges.

Any bentonite or uncured grout that might seep out from the active tunnel into a sheetpile enclosure will be pumped into containers on board adjoining pontoons and conveyed ashore for treatment.

If it was observed that adult salmon or smolts were congregating upstream or downstream of the works within the bay as a results of sediment escape, then the works would be temporarily halted for a few tides to allow fish to pass. The requirement for these downtimes and their duration will be decided in consultation with the NPWS and NWRFB.

Hydrostatic Testing

Once the pipeline is in place, it must be pressure tested with water. This requires the pipe to be filled with water. Water for testing will be abstracted at a rate that will not endanger the habitats or fisheries of the source. After pressure testing water will be analysed for contaminants and if found to be present at unacceptable levels the water will be subject to appropriate treatment e.g. settlement, advanced hydrocarbon separation, microfiltration, metal ion removal etc. The discharge point for this test water will be at end of the water discharge pipeline, offshore in deep water.

RESIDUAL IMPACTS

Once the pipeline is in operation, there will be no impacts on freshwater resources.

Small Streams

All small streams crossed are of minor ecological importance and once the mitigation measures as outlined are adopted then there will be negligible, temporary impacts on them. The impact occurring will relate to siltation of the streambed for some distance downstream of the crossing point resulting in temporary reduction of macroinvertebrate and fish biomass. Such impacts are unlikely to affect more than 100-200m of stream and will constitute a very minor impact.

Sruwaddacon Bay Crossing

Once all necessary mitigation measures are taken in the case of Sruwaddacon Bay there will be no residual impacts on migratory salmonids or EU Annex II listed species as a result for the construction and commissioning phases of the project.

If in the unlikely event that an intervention pit is required and provided that the in-channel works do not impede the smolt run in any way, then serious adverse impacts at a population scale for salmon, trout and lamprey will be avoided.

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