PREFACE TO SECTION C – NATURAL ENVIRONMENT

To assess the potential impacts of the proposed development on the natural environment, the following impact assessments have been undertaken:

1. Terrestrial Ecology (see Chapter 12)
    a. Terrestrial Habitats
    b. Flora & Fauna
    c. Birds (aquatic and terrestrial)
2. Freshwater Ecology (see Chapter 13)
    a. Freshwater Habitats (including water quality)
    b. Freshwater Flora & Fauna
    c. Migratory Fish (including salmonids)
3. Marine Environment (see Chapter 14)
    a. Marine Habitats
    b. Benthic Environment
    c. Marine Fisheries & Mammals
    d. Hydrodynamics of Sruwaddacon Bay
4. Soils & Geology (see Chapter 15)
    a. Geology
    b. Geotechnical environment
    c. Hydrogeology
    d. Hydrology
    e. Peatland Hydrology

The marine environment, which relates to areas that fall below the high water mark and are influenced by the tidal flows is discussed in Chapter 14. The terrestrial environment above the high water mark (habitats and constituent species of fauna and flora) is described in Chapter 12. Salt marsh is included in the terrestrial habitat descriptions in Chapter 12, as are intertidal habitats as they relate to birds. Fish that use the marine environment are described in Chapter 14 but further details, in particular on migratory fish, are outlined in Chapter 13 along with details on the ecology of freshwater streams traversed by the proposed route. Chapter 15 provides details on hydrogeology and the flow of water in peatlands.

As the terrestrial, marine and freshwater environments are not mutually exclusive, but interact with each other to a greater or lesser extent they cannot be considered alone.

The proposed route traverses terrestrial habitats at Gleann an Ghad (Glengad), tunnels under the intertidal and marine habitats of Sruwaddacon Bay, and traverses a short section of intertidal habitat at the Leenamore River inlet; all of which lie within the Glenamoy Bog Complex cSAC[1].

Otters, which occur in terrestrial, marine and freshwater habitats are considered in Chapter 12, while salmon is considered in the freshwater ecology impact assessment (Chapter 13). Both are Annex II species, but salmon is listed on the Natura site Standard Data Form as a qualifying species for the Glenamoy Bog Complex cSAC. In addition Sruwaddacon Bay lies within the Blacksod Bay/Broadhaven pSPA[2] and Blacksod Bay and Broadhaven Ramsar site. Furthermore, the mouth of Sruwaddacon Bay borders the Broadhaven Bay cSAC. As a result, due regard has been given to the provisions of Article 6 of the Habitats Directive in undertaking the above assessments. A Natura Impact Statement for the Corrib Onshore pipeline is provided in Appendix P.

The following sections provide details on the impacts addressed in the aforementioned assessments and discuss the designated conservation sites traversed by/adjacent to the proposed development. Those designated conservation sites located along and adjacent to the proposed route are shown on Figures C.1 – C.3, while the NPWS site synopses for these sites are provided in Appendix J. Relevant National and European wildlife legislation pertaining to these sites and protected species known to occur along the proposed route are also discussed.

IMPACT ASSESSMENT

Specialists undertaking the above impact assessment studies for this EIS have had the benefit of early involvement in this study. This has allowed specialists to predict how the natural environment will interact with the proposed development so that, where possible, potential significant adverse impacts have been avoided through the consideration of alternatives (see Chapter 3) including alternative routes to avoid areas of environmental sensitivity and alternative construction methods. These specialists have worked with the designers on the development of construction methods in order to avoid and reduce potential impacts that may arise.

The impact assessments contained in section C, in general, refer to both potential impacts and residual impacts. Potential impacts refer to those likely impacts, predicted by the specialists, which may occur as a result of the construction (including commissioning) and operation of the proposed development. The residual impacts are those impacts that occur after the recommended mitigation measures have been implemented. In addition each specialist has assessed the 'do nothing' impact. As there is potential to impact on designated conservation sites, 'worst case' scenario impacts have also been examined.

The potential and residual impacts on the natural environment have been assessed using various definitions of impact significance e.g. slight, moderate, major.

- The Terrestrial Ecology Assessment uses a combination of the NRA criteria, specifically adapted ecological criteria for Ecological Impact Assessment (EcIA), and the impact magnitude and duration as set out in the EPA Guidelines for Environmental Impact Statements.
- The Freshwater Ecology and the Soils & Geology Assessment (including hydrogeology & hydrology and peatland hydrology) generally refer to the criteria used by the NRA in their assessment of impacts, while
- The Marine Ecology Assessment uses the glossary of impacts outlined in the EPA Guidelines for Environmental Impact Statements.

[1] At the time of writing this EIS, the Glenamoy Bog Complex is a candidate Special Area of Conservation.

[2] At the time of writing this EIS, the Blacksod Bay/Broadhaven is a proposed Special Protection Area.

Each chapter assesses the potential impacts broadly as follows:

- Chapter 12 considers impacts on habitats and species, including certain intertidal elements (areas of salt marsh), birds feeding in intertidal areas and marine areas, and otters.

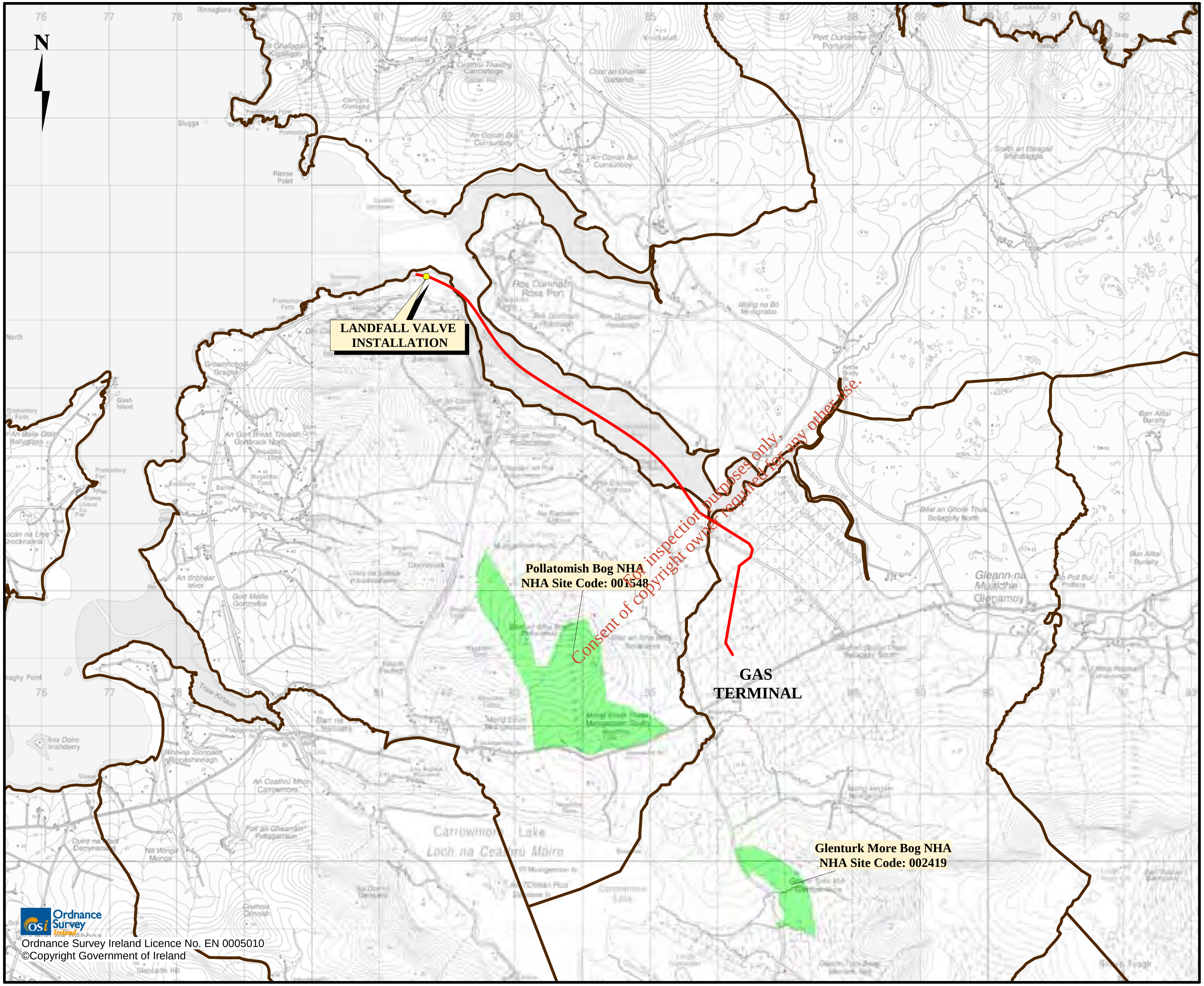
- Chapter 13 considers the impact on Sruwaddacon Bay in terms of impact on the migratory fish, and the freshwater ecology in the streams traversed by the proposed route.

- Chapter 14 considers the marine environment including fish, food sources for birds feeding in intertidal areas and the impact on the habitats and hydrodynamics of the bay.

- Chapter 15 considers the impact of the proposed development on drainage and stability.

Consequently a range of potential impacts have been considered for each of the aforementioned aspects. Therefore, in order to fully identify the range of key potential impacts on the natural environment these have been summarised in Table 18.1 (see Chapter 18).

As discussed above, the impact assessments have considered potential impacts arising from the construction (including commissioning) and operational phases of the proposed development. Potential impacts arising from the decommissioning of the proposed development (see Section 4.7) have been considered in this EIS. Depending on the required decommissioning plans at the time of project completion these are expected to be negligible if services remain in situ or in line with those impacts outlined for the construction phase. Either way, a decommissioning plan will be prepared to ensure that the operations will comply with all international and national legislation relevant to decommissioning at that time. This would include a review of best practice for decommissioning, and will include an environmental appraisal of the proposed decommissioning methods. Decommissioning plans will be subject to regulatory approval at the relevant time.



LEGEND:

- Proposed Route
- Townland
- National Heritage Area (NHA)

Natural Heritage Areas (NHAs) (Indicative only) within 5 km of the Proposed Pipeline

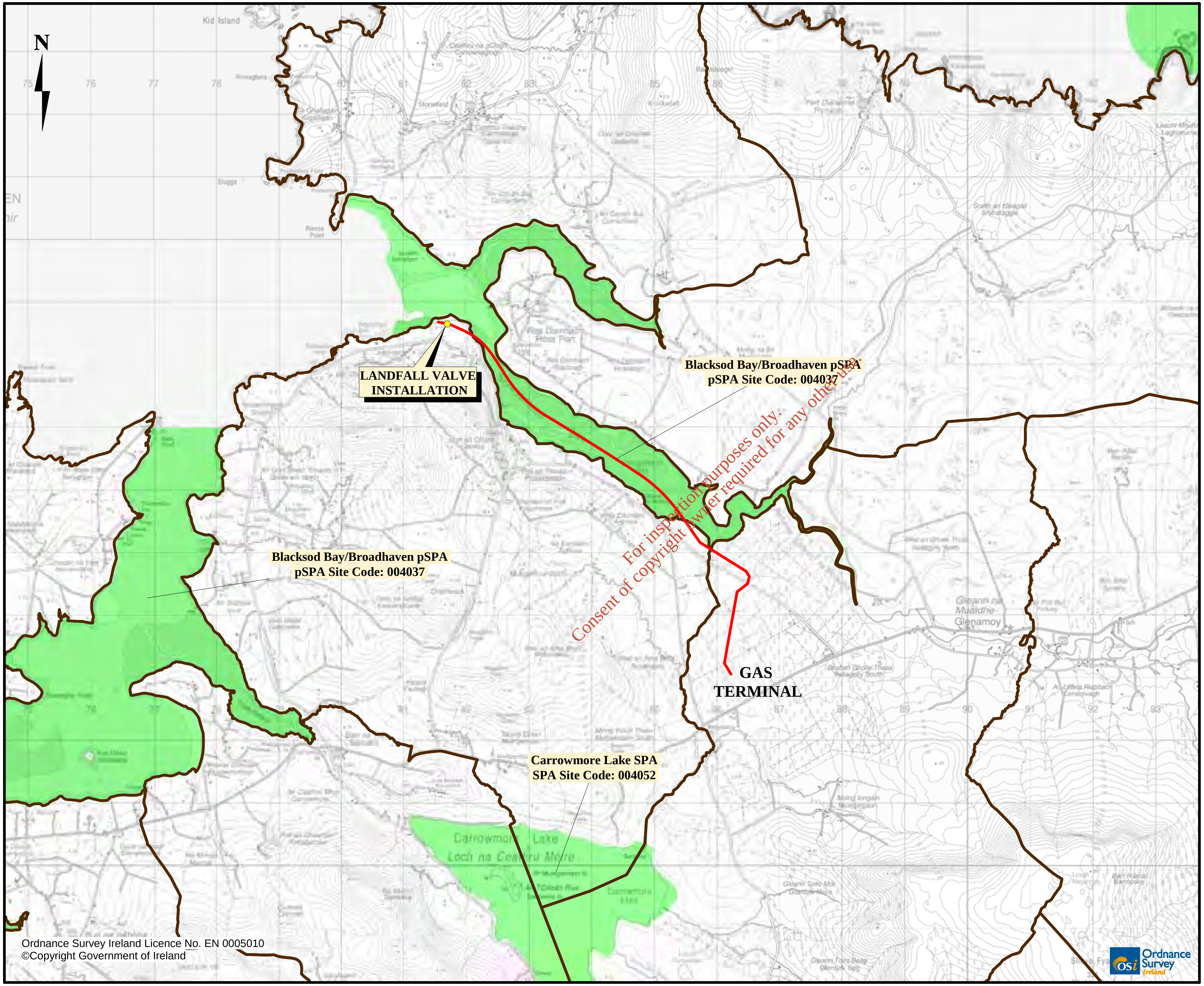
Figure C1

File Ref: COR25MDR0470Mi2152A03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS



LEGEND:

- Proposed Route
- Townland
- Special Protection Area (SPA)

Special Protection Area (SPA) (Indicative only)

Figure C2

File Ref: COR25MDR0470Mi2153A03
Date: May 2010

CORRIB ONSHORE PIPELINE

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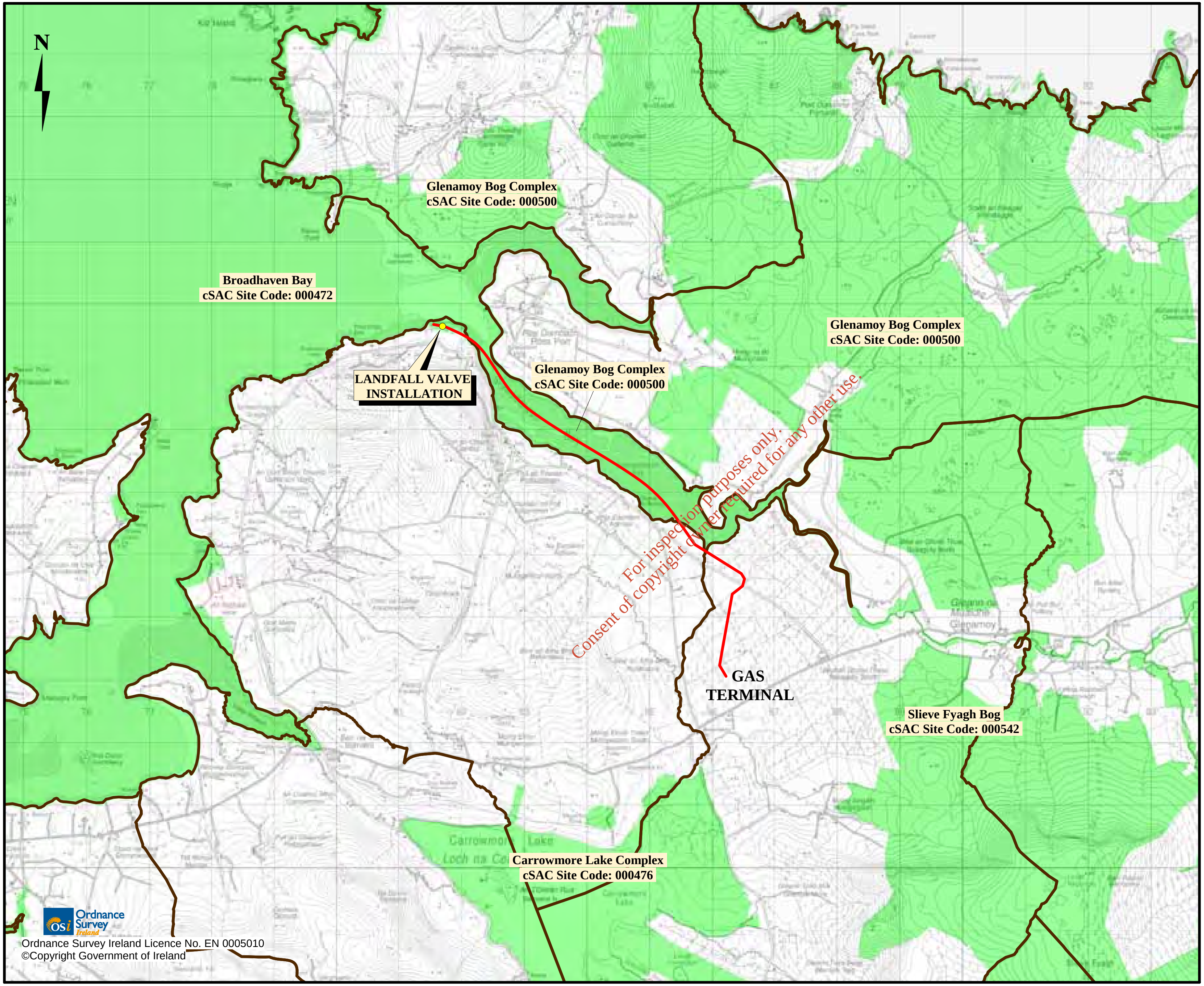


LEGEND:

- Proposed Route
- Townland
- Candidate Special Areas of Conservation (cSAC)

Candidate Special Areas of Conservation (cSAC) (Indicative only)

Figure C3

File Ref: COR25MDR0470Mi2151A03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

LEGISLATIVE BACKGROUND

The following Irish and international legislation was considered in the assessment on the natural environment:

- European Communities (Natural Habitats) Regulations, 1997 (S.I. No. 94 of 1997);
- European Communities (Natural Habitats) (Amendment) Regulations, 1998 (SI 233 of 1998) and 2005 (S.I. 378 of 2005);
- Wildlife Act, 1976;
- Wildlife (Amendment) Act, 2000; and
- Flora Protection Order 1999 (SI No. 94 of 1999).

The Wildlife and Amendment Acts, 1976 and 2000, their associated statutory instruments (including the Flora Protection Order) and Natural Habitat Regulations (for SACs) are implemented and controlled by the National Parks and Wildlife Services (NPWS) of the Department of the Environment, Heritage and Local Government (DoEHLG). NPWS is also responsible for the designation of conservation sites.

EU Directive 92/43/EEC, on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive), was transposed into Irish law by means of the Natural Habitat Regulations, 1997 and (Amendment) Regulations, 1998 and 2005. This enabled the designation of candidate Special Areas of Conservation (cSAC) under Article 3 of the directive as part of the Natura 2000 network. This network comprises Annex I habitats – 'natural habitat types of community interest whose conservation requires the designation of Special Areas of Conservation' and the habitats of Annex II species – 'animal and plant species of community interest whose conservation requires the designation of Special Areas of Conservation'. In addition, the Directive states that: 'The Natura 2000 network shall include the special protection areas classified by the Member States pursuant to Directive 79/409/EEC'.

Article 6.3 of the Habitats Directive states that 'any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives'. The proposed development is not directly connected with the management of any designated conservation sites. Consequently an assessment in accordance with Article 6 has been undertaken (see Appendix P – Natura Impact Statement).

Special Protection Areas (SPAs) are designated under Directive 79/409/EEC on the Conservation of Wild Birds (the Birds Directive). Under the Directive, Ireland is obliged to protect the habitats of birds, which are vulnerable to habitat change or to low population numbers. Aspects of habitat protection are in the context of pollution, deterioration of habitat and disturbance. This Directive is implemented in Ireland under Statutory Instrument (1985) and is encompassed by the Wildlife and Amendment Acts (1976 and 2000).

'Ramsar' refers to an international convention, which was ratified by Ireland in 1985, in relation to wetland sites. The Convention has its roots in the protection of wetland wildfowl and for many sites it is species-associated. More recently Ramsar has taken on the more all-encompassing wetland habitat approach, which in the context of the EU falls in line with site protection under the Habitats Directive. International conventions such as Ramsar are effectively recommendations to countries to implement certain protection measures.

The Ramsar convention has no statutory basis itself, but it is operated through either EU or national legislation. In this case the EU Birds Directive and EU Habitats Directive through the Wildlife and Amendments Acts (1976 and 2000). There is a reporting requirement by the statutory agency, in this case NPWS.

Ramsar requires that 'wise-use' be carried out throughout. Part of this is the EIA process. If at the end of that process it was considered that there would be significant damage then NPWS has to report same to the Ramsar Convention Bureau. Essentially Ramsar is in line with the concept of sustainable development rather than absolute protection.

GLENAMOY BOG COMPLEX – CANDIDATE SPECIAL AREA OF CONSERVATION (SITE CODE 000500)

This is a very large, extensive and complex site, comprising a wide range of habitats including blanket bog and hard and soft coastal habitats. Lowland atlantic blanket bog dominates the site. It is internationally important in terms of its vegetation composition and is a listed Annex I habitat under the EU Habitats Directive; intact, active growing blanket bog is a priority Annex I habitat. Some areas of cSAC blanket bog are of lesser quality in habitat terms, as a result of afforestation, turf cutting - manual and mechanical and their associated management practices, which often result in drainage and "edge" effects. The more floristically important and intact areas occur in the north east of the cSAC, in some of the less accessible area of the complex where *Drepanocladus vernicosus* (a moss) and *Saxifraga hirculus* (Marsh saxifrage) occur. *Petalophyllum ralfsii (*Petalwort*)* is present at Garter Hill. These three species are listed in Annex II of the EU Habitats Directive and are also on the Flora Protection Order (SI 94 of 1999). The nationally rare moss *Homalothecium nitens* also occurs in this site. The *c*SAC also supports Annex species of birds (EU Birds Directive) and mammals as well as nationally important populations of other sea birds.

The NPWS site synopsis concludes: 'This site is of immense ecological importance because of the presence of a number of EU Annex I habitats, including two priority habitats - blanket bog and machair. It supports populations of an Annex II species, Annex II plant species and six Annex I Birds Directive species. It also has nationally important populations of other seabirds. Despite serious damage to parts of the site in recent years, large areas remain in good condition'. This site also includes Sruwaddacon Bay and the small bay north of Ros Dumhach (Rossport); both are included within the Blacksod Bay/Broadhaven pSPA. It is a shallow tidal inlet off Broadhaven Bay Marine cSAC and is of special importance for its wintering wildfowl populations, which feed on the intertidal sand/mud flats. It forms an integral part of the Glenamoy River salmonid fishery. The cSAC has recently been extended to include the Glenamoy and Muingnabo Rivers and many of their tributary streams.

Qualifying EU habitats and species, as listed on the Natura 2000 Standard Data Form for the Glenamoy Bog Complex cSAC, are outlined in Table C.1. The pipeline does not traverse any qualifying habitat. The listed fish species, *Salmo salar* (atlantic salmon), migrate through Sruwaddacon Bay (March-May period and July/August period). None of the three qualifying species of flora occur in any of the habitats crossed by the proposed route. Of the bird species, *Pluvialis apricaria* (Golden Plover) very occasionally feeds on the intertidal areas. *Falco columbarius* (Merlin) and *Pyrrhocorax pyrrhocarax (*Chough) are known to occur in the wider locality.

Table C.1: Qualifying EU habitats and species for the Glenamoy Bog Complex cSAC.

Annex I Habitat types:	**Species:**
7130 Blanket bog (* active only) 4010 Northern Atlantic wet heaths with *Erica tetralix* 1230 Vegetated sea cliffs of the Atlantic and Baltic Coasts 5130 Juniper communis formations on heaths or calcareous grasslands 7150 Depressions on peat substrates of the Rhynchosporion 7140 Transition mires and quaking bogs 3160 Natural dystrophic lakes and ponds 21A0 Machair (* in Ireland)	**Fish listed on Annex II of the Habitats Directive:** *Salmo salar* - Salmon **Plants listed on Annex II of the Habitats Directive** *Petalophylum ralfsii* – a liverwort *Drepanoclados vernicosus* – a moss *Saxifraga hirculus* – Marsh Saxifrage **Birds listed on Annex I of the Birds Directive** *Branta leucopsis* – Barnacle Goose *Hydrobates pelagicus* – Storm Petrel *Falco columbarius* – Merlin *Falco peregrinus* – Peregrine Falcon *Pluvialis apricaria* – Golden Plover *Pyrrhocorax pyrrhocarax* – Chough

BROADHAVEN BAY CANDIDATE SAC (SITE CODE 000472)

The site was known as the Blacksod/Broadhaven pSPA prior to the site review during the 1990s and subsequent cSAC designation. Sections of these sites are now incorporated into three cSACs, namely Mullet/Blacksod Complex, Broadhaven Bay cSAC and the Glenamoy Bog Complex cSAC.

This site is of high conservation importance owing to the presence of several habitats that are listed on Annex I of the EU Habitats Directive: large shallow bays, intertidal sand flats, reefs, marine caves and salt marshes. In addition it has ornithological importance for breeding and wintering birds.

This site, although not traversed by the proposed onshore pipeline route, lies adjacent to Sruwaddacon Bay.

BLACKSOD BAY / BROADHAVEN PROPOSED SPA (SITE CODE 004037)

This site is of high ornithological importance for its excellent diversity of wintering waterfowl and for the nationally important populations of five species that it supports. Of particular note is the usage of the site by over 3% of the national Ringed Plover population. It is also of importance as a breeding site for terns and gulls, especially the localised Sandwich Tern. It is of note that seven of the species that occur regularly are listed on Annex I of the EU Birds Directive, ie. Great Northern Diver, Red-throated Diver, Golden Plover, Bar-tailed Godwit, Sandwich Tern, Common Tern and Arctic Tern.

Suwaddacon Bay is part of this large pSPA and the proposed pipeline will be tunnelled underneath it for approximately 4.8km.

It is understood that the Blacksod Bay / Broadhaven pSPA boundaries are currently under review (information received from NPWS, 2008 onwards). Unlike more recently designated SPAs there is no formal site citation, i.e. the 'Intention to designate' notice which lists the species for which the site was designated. However, the site synopsis lists species for the site as a whole and includes numbers of birds of international and national importance. From the information received from NPWS, it is understood that the currently proposed interests for the re-designated SPA are as follows:

- The site qualifies for designation as an SPA for: Ringed Plover, Bar-tailed Godwit and Sandwich Tern;

- Great Northern Diver, Common Scoter, Dunlin and Light-bellied Brent Goose are all to be listed as species of special conservation interest for the site.

From recent consultations with NPWS (2010), it is understood that, as part of the redesignation process, pSPA boundaries are being re-defined. Whereas formerly the Mean High Water Mark was taken to be the boundary, the proposed new mapping will be to the nearest definable land feature and will include any wetland habitat, (eg. salt marsh). It is further understood that non-wetland areas will only be included if there is a site specific reason to do so.

RAMSAR BLACKSOD BAY / BROADHAVEN (RAMSAR SITE CODE 844)

Designated in 1996 the site covers 683 ha. and is described in the annotated list of Ramsar sites as follows: "composite of diverse marine and coastal habitats that includes vast dune systems and extensive areas of dune grassland with saltmarshes occurring in sheltered bays and inlets. The grasslands are of considerable botanical importance. The site also includes several brackish lakes important to various species of breeding waders, large numbers of wintering waterbirds of various species, and internationally important numbers of Brent geese". Sruwaddacon Bay is part of this site.

DESIGNATED CONSERVATION SITES IN THE WIDER LOCALITY

Designated conservation sites within approximately 5km of the proposed route, and including those traversed, are listed in Table C.2 below along with approximate distances from the nearest point on the proposed route. Those sites not traversed by the proposed route are described in Appendix J where their site synopses (from NPWS) are also given.

Table C.2: Designated Conservation Sites located within approximately 5km of the Proposed Pipeline Route.

Designation	Site Name	Site code	Approximate distance (km) from the nearest point on the proposed route
Special Area of Conservation (cSAC)	Glenamoy Bog Complex	500	0
	Carrowmore Lake Complex	476	1.7
	Slieve Fyagh Bog	542	2.7
	Broadhaven Bay	472	200m west of the landfall
Special Protection Areas (pSPA)	Blacksod Bay/Broadhaven	4037	0
	Carrowmore Lake	4052	3.0
Natural Heritage Area (NHA)	Glenturk More Bog	2419	3.5
	Pollatomish Bog	1548	1.8
	Ederglen Bog	2446	>5
Ramsar site	Blacksod Bay and Broadhaven	844	0

12 TERRESTRIAL ECOLOGY

12.1 INTRODUCTION

This chapter summarises the findings of the assessment relating to the potential impacts of the proposed development on ecology in terms of the terrestrial habitats present and their constituent plant and vertebrate faunal species. It should be read in conjunction with the Ecological Impact Assessment technical report (Appendix J(1)).

An ecological impact assessment (EcIA) was undertaken by Ecological Advisory and Consultancy Services (EACS) and specialist associates. The habitats present are described along with their current status and an evaluation of their scientific interest and conservation value. Potential impacts, including those on adjoining areas, are evaluated. The findings have been used to identify mitigating measures to reduce the impacts and appropriate mitigation or remedial measures are recommended. The Ecological Impact Assessment Report including a full bibliography is provided in Appendix J(1).

In view of the nature of the proposed development and that the pipeline is buried throughout its length, the majority of potential impacts on terrestrial ecology are associated with the construction of the proposed development.

Details on designated conservation sites including the legislative context are provided in the Preface to Section C. Designated sites in the wider locality are described in Appendix J(1).

12.2 METHODOLOGY

The approach and methodology to the Ecological Impact Assessment has been undertaken with due regard to the EPA Advice Notes on Current Practice (2003); EPA 'Guidelines on the Information to be contained in Environmental Impact Statements' (2002); and the Institute of Ecology and Environmental Management's Guidelines for Ecological Impact Assessment (IEEM, 2006) and with reference to the National Roads Authority Guidelines (NRA) for ecological impact assessment (Revision 2, 2009). Due regard is also paid to the provisions of Article 6.3 of the EU Habitats Directive (see Preface to Section C; and Appendix P, Natura Impact Statement (NIS)).

The methodology for this assessment included the following:

- vegetation and faunal surveys (avian and non-avian);
- mapping of habitats, faunal signs and observations;
- collection of data on presence of, and/or potential for, protected plant species; particular attention was paid to the likely occurrence of habitats listed in Annex 1 of the EU Habitats Directive (EU 1992); also to the possible occurrence of plant species and habitats which are considered to be rare or scarce in both a national and local context;
- collection of data on the presence of, and/or habitat potential for, protected species of non-avian fauna; and
- collection of data on the presence of birds, including breeding and migratory species.

A large body of data has been accumulated during previous, and ongoing, studies in connection with the Corrib Gas project. In addition, information was sought and collated from statutory and non-statutory consultees from 2000 to date. This included assimilating information on nearby designated conservation sites, and protected species of flora and fauna. Full details of the data sets considered as part of this assessment are provided in Appendix J.

This information helped define the development and ensure that the design and construction of the proposed development avoids or minimises adverse impacts.

12.2.1 Survey Limitations

Dense vegetation cover, such as found within areas of coniferous plantation and gorse scrub, places a constraint on surveying for badger setts, holts, etc. at any season. In addition to pre-construction surveys these areas will require monitoring during vegetation clearance.

12.2.2 Habitats and Vegetation - Field Surveys

Walk over field surveys were undertaken from July to September 2007 and in 2008. Habitat and vegetation features were noted, as were the plant species present. Areas which had previously been subject to walkover and/or baseline surveys were verified in 2007 and 2008 where access was available. Walkover surveys were also undertaken at na hEachú (Aghoos) in 2010, including a small area which had not been accessible in 2008. In addition, parts of the route at Gleann an Ghad (Glengad) have been subject to frequent monitoring inspections and annual botanical surveys from 2001 to, and including, 2007.

The methodology to be used for baseline vegetation survey was discussed and agreed with National Parks and Wildlife Service (NPWS) personnel early in the consultation process, and follows the standard approach for ecological evaluation and impact assessment. The 'Domin' method of species' frequency assessment was used in baseline surveys in 2001. This method was also used to describe quadrats[1] at the Leenamore River inlet and na hEachú (Aghoos) during the 2008 vegetation surveys (Appendix J(1), Appendix 16. Further details of the Domin method for vegetation survey may be found in Appendix J(1).

Habitat and vegetation type mapping is based on field surveys undertaken in 2007, 2008, 2010; and from 2001 to 2006. Habitat mapping is provided in Appendix J(1).

12.2.3 Non-Avian Vertebrate Fauna Surveys

Various faunal studies have been undertaken in the area since 2002, including surveys of the proposed route, and a survey to re-assess otter activity in the Sruwaddacon Bay area in February and March 2010. Details are given in Appendix J(1). Surveys included a thorough search along the entire shoreline of Sruwaddacon Bay within the intertidal zone along the proposed route and, where possible, a width of approximately 100m was surveyed along the proposed route, depending upon the nature of habitats present. The presence of mammals is indicated principally by their signs, such as dwellings, feeding signs, or droppings - though direct observations are also occasionally made. Surveys also included search for habitats suitable for amphibians and reptiles. Observations made during other surveys are included in the results.

A specialist bat survey was conducted on 6th and 7th September 2007. Accessible structures adjacent to the route which showed potential as roosting sites were surveyed during daylight hours. A survey for potential bat roosts in trees along or adjacent to the proposed route was also undertaken during daylight hours. The presence of bats is indicated principally by their signs, such as staining, feeding signs, or droppings - though direct observations are also occasionally made. An additional bat survey was conducted at locations on the north side of the Bay in August 2008.

Other fauna surveys and monitoring have been conducted in the vicinity of the pipeline route at the Bellanaboy Bridge Gas Terminal site, including bat surveys. Further details of these are provided in Appendix J(1).

12.2.4 Bird Surveys

Bird surveys have been undertaken in the area of Sruwaddacon Bay since 2002 to investigate bird activity in the wider locality. This assessment is based on the large body of data resulting from the studies to date, which include field surveys conducted between 2007 and 2010; and previous bird surveys of the area (2002 to 2007). The surveys include a series of aquatic surveys, including a post breeding season survey (2007), several winter season surveys between 2007 and 2010; as well as post breeding terrestrial bird surveys of the wider area, and dedicated Sand Martin monitoring surveys at Gleann an Ghad (Glengad) from 2008 to 2009.

[1] A quadrat is a defined sample area, usually square, and in this case generally 2m x 2m.

Standard bird census techniques and survey protocol were used (Institute of Environmental Assessment 1995, Sutherland 1996, Bibby *et al.* 2000). Appropriate optics were used throughout the survey. Field surveys were undertaken when weather conditions were suitable for such work (*i.e.* no rain, light winds (< Beaufort Force 4) and good visibility). Further details on these surveys and the methodology used are provided in Appendix J(1).

The reports of the many bird surveys undertaken within the general area since 2002 were also examined as part of this assessment. These included breeding surveys along the original approved pipeline route and at the Bellanaboy Bridge Gas Terminal site; general overwintering surveys; and targeted Brent goose surveys (2003 to 2007), Corncrake surveys and monitoring at the Sand Martin colony at Gleann an Ghad (Glengad) (see Figure 12.1 below). Further details of these reports are provided in Appendix J(1).

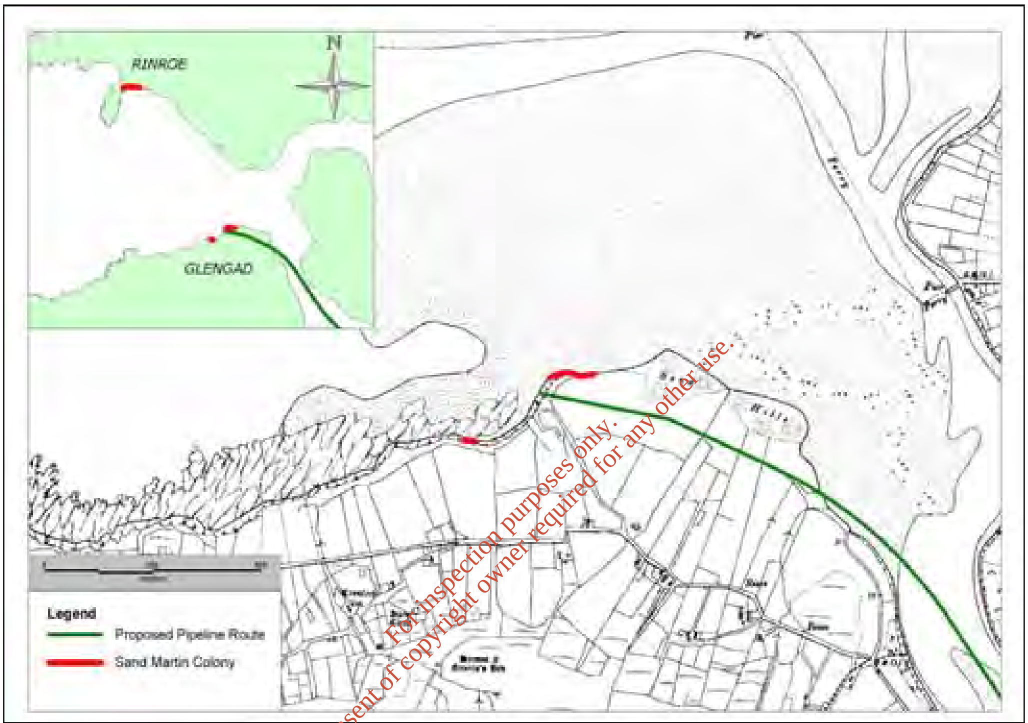


Figure 12.1: Location of Sand Martin Colonies at Gleann an Ghad (Glengad) and Rinroe

12.3 EXISTING ENVIRONMENT

The following sections provide a summary description of the habitats and vegetation, flora and fauna and birds along the proposed route (and where relevant adjoining habitats). More detailed descriptions are provided in Appendix J(1).

12.3.1 Habitats and Vegetation

Approximate chainages are given in the following route description, and in Table 12.2, as an indication of location rather than an exact line of definition between habitat types. This is because the interface between most habitat types is generally a gradual one, with one vegetation type merging into another.

12.3.1.1 Route Description

The following is a description of the habitats along and adjacent to the proposed route and includes those under which the proposed tunnel will pass.

Gleann an Ghad (Glengad) (83.400 to 84.050)

The landfall is on the westerly shore at Gleann an Ghad (Glengad) where the low cliff is of glacial till. Part of the cliff comprises the section which has been cut several times and finally reinstated once the offshore pipeline had been installed in 2009.

A sand martin colony is located in the soft cliffs to the north and north east of the landfall at Gleann an Ghad (Glengad).

This area has been subject to topsoil stripping several times between 2002 and 2009, and was fully reinstated following the completion of offshore pipeline works in autumn 2009. Currently this area comprises mostly bare soil, but the vegetation is starting to regenerate. The LVI and LVI site compound (SC1) will be located in this area.

Continuing eastwards, the pipeline route lies in improved agricultural grassland, which is regularly grazed by sheep. Some of this area now also comprises bare soil with regenerating vegetation following the offshore pipeline works in 2008 and 2009.

The improved and semi-improved grassland through which the route passes is located at the south-western boundary of Glenamoy Bog Complex SAC 500, within the SAC buffer zone, but the route avoids the highly mobile dune system and associated fixed dune grasslands to the north. The area to the south of the dunes has been in the past, and is still, subject to intensive grazing by cattle and sheep. Gaynor (2001) noted that this has led to the development of ‘dry’ grassland which, although it maintains floristic elements of its ‘dune’ origins, it is essentially an enriched (improved) grassland community.

To the north of the route there is evidence of rubbish having been dumped in the dune grasslands in the past: the remains of a car were noted in 2001 to 2003, and currently an old (apparently domestic) rubbish dump is being exposed by erosion.

The agricultural lands become wetter towards the eastern half of the Gleann an Ghad (Glengad) section. The vegetation here is a mosaic of wet, rushy improved grassland, dominated by *Juncus effusus* (soft rush) and *Juncus articulatus* (Jointed rush); and some marshy areas associated with a small stream which flows in a north easterly direction. The vegetation varies considerably depending on the moisture content of the substrate.

The site compound (SC2) for the tunnel reception pit will be located in an area dominated by wet rushy, grassland, part of which is within the SAC. Most field boundaries along this part of the route comprise post and wire fences, with earthen (sod) banks in places.

The marshy area was described in 2001 as being dominated by rushes, common sedge and star sedge. A high proportion of wetland herbs are present and include water horsetail (*Equisetum fluviatile*), yellow flag (*Iris pseudacorus*), marsh ragwort (*Senecio aquaticus*), marsh marigold (*Caltha palustris*), marsh willowherb (*Epilobium palustre*) and bog pimpernel *(Anagallis tenella*).

Progressive degradation of the wet grassland and marshy area has been noted from observations since 2002. This may be a result of grazing and trampling by cattle, or tracking by farm vehicles. Rushes, particularly *Juncus effusus* (Soft rush)*,* are far more abundant now than in 2001.

The *Juncus* and *Iris* dominated areas merge into the small area of salt marsh at the Gleann an Ghad (Glengad) side of the lower estuary crossing. Since 2005 this area of salt marsh has become degraded from run off from above and in places deeply rutted from tracking vehicles. This has led to the encroachment by soft rush. There is no longer a defined boundary to the landward side of the salt marsh which is species poor and dominated at the estuarine edge by *Glaux maritima* (Sea milkwort) and *Puccinellia maritima* (Common saltmarsh-grass).

Sruwaddacon Bay (84.050 to 88.640)

The intertidal sand and mud flats within the route at the Gleann an Ghad (Glengad) side of the estuary have little vegetation, though to the north of the route is an area of accretion upon which salt marsh vegetation is becoming established. The estuarine and intertidal habitats of Sruwaddacon Bay are described in Chapter 14, Marine Environment.

South of Sruwaddacon Bay (88.640 to 91.720)

Continuing under the southern shore of Sruwaddacon Bay the proposed tunnel passes beneath a narrow fringe of saltmarsh (Ch. 88.640 to 88.645), and a short section of undesignated blanket bog which is recovering from apparently past overgrazing. From chainage 88.690 the pipeline route is under, and from chainage 88.770 through an area of undesignated heavily eroding blanket bog with old cutover areas in parts. The Aghoos tunnelling compound (SC3) will be in this location.

The peat erosion is particularly severe between chainages 88.850 to 89.110, with 50 to 70% bare peat surface evident in places. The surface here is very fragmented and uneven, with deep peat hags (erosion channels) and exposed pine stumps. The surface vegetation is dominated by grass species such as *Nardus stricta* (Matt grass), a species which is characteristic of heavily overgrazed areas on acid substrates. Pockets of dense Gorse (*Ulex europeaus*) scrub are present here. The pipeline stringing area will be located in this area. Near the road, are sections of old cutover which have been almost completely cutaway in the past, resulting in shallow peat and modified vegetation. The pipeline stringing area will extend into wet, agricultural grassland - dominated by rushes - which slopes down towards the Leenamore River.

The route then crosses the Leenamore River, a small tidal inlet with an intact fringe salt marsh, mainly on its eastern shore. The salt marsh comprises small areas of two types of salt-marsh vegetation namely tall vegetation, dominated by the rush *Juncus maritimus* and tightly grazed vegetation dominated by the saltmarsh grass *Puccinellia maritima.* The adjacent bed of Sruwaddacon bay is quite stony and is dominated by a variety of brown seaweeds (*Fucus* sp.). The salt marsh vegetation at this location is described in more detail in Appendix J(1).

Wet rushy grassland habitat dominates the small sloping fields on the eastern side of the Leenamore inlet. These small fields have been grazed tightly by livestock in the past. Gorse scrub is present in places and along some field boundaries.

Between chainages 89.350 to 89.540 there is a short section of approximately 190 metres of undesignated more or less intact blanket bog (PB5/PB3). Erosion is continuing in places, especially towards the shore of the Bay, north of the route. The blanket bog vegetation at this location is described in more detail in Appendix J(1). The pipeline route then enters a coniferous plantation, crosses the L1202, and skirts a small area of non-designated blanket bog which occupies a triangle between the south side of the road and the forest edge.

The route then passes along a section of bog mat and stone road through the clear-felled conifer plantation to the Bellanaboy Bridge Gas Terminal.

The main habitats, which occur along and adjacent to the proposed route are summarised in Table 12.1, including those under which the tunnel will pass. They are classified in accordance with the scheme outlined in the 'Guide to Habitats in Ireland' (Fossitt, 2000) and the Joint Nature Conservancy Council Phase 1 habitat survey methodology (JNCC, 1993). Their affinity to EU Annex habitats is also shown. Approximate chainages are given in Table 12.2 as an indication of location rather than an exact line of definition between habitat types. This is because the interface between most habitat types is generally a gradual one, with one vegetation type merging into another.

Descriptions of the habitat and vegetation types encountered along the route are provided in Appendix J(1). Plant nomenclature follows: Stace (1995 and 2010) for most vascular plants; Cope and Gray (2009) for grasses; common names are also after Scannell and Synnott (1987) and Webb (1996); Smith (2004) for mosses, Smith (1991) and Paton (1999) for liverworts and Dahl (1968) for lichens.

12.3.2 Evaluation of Scientific Interest

Habitat evaluation is in accordance with the IEEM (2006) and broadly follows the NRA 'Guidelines for Assessment of Ecological Impacts' (2004), but taking habitat quality into consideration also. It is based on the level of designation, presence of Annex habitats and the following criteria: extent, diversity, naturalness, rarity, fragility, typicalness, recorded history, position, potential value and intrinsic appeal. An evaluation of the habitat types encountered on the route is summarised in general terms in Table 12.3. Habitat frequency of occurrence is indicated by percentage with the exception of earthen (sod) banks, streams, drainage channels and man made surfaces such as roads etc. Further details on habitat evaluation are given in Appendix J(1).

EU Annex Habitats

When an Annex I habitat is present within a designated area it is given a value of international ecological importance under the NRA Guidelines method of evaluation of habitats. However, under other methods of evaluation, habitat quality is also taken into consideration. Where a habitat has been degraded or modified, resulting in vegetation change, the evaluation reflects this. Thus, in the case of the salt marsh at the eastern side of Gleann an Ghad (Glengad) where physical changes have resulted in vegetation change to an extent where the habitat classification is marginal, it is evaluated as being of national/International rather than simply 'international'.

Where an EU Annex I non-priority habitat type occurs outside a designated site it is ranked as being of national importance, e.g. the 190 metres of recovering eroded blanket bog at na hEachú Aghoos which is classified as PB5/PB3. It is proposed that these habitats will be treated as though they are designated and legally protected. See Table 12.3.

12.3.2.1 Plant Species and the Flora Protection Order (FPO)

Desk study and consultations confirmed that no rare species of plant, including those on the current Flora Protection Order 1999 (SI No. 94 of 1999) are known to occur along the route of the proposed development at present. Neither were any FPO species found during the surveys carried out from 2001 to 2010.

Furthermore, it is considered that the habitats present on the proposed route are not suitable for any of the protected plant species listed as occurring within the Glenamoy Bog Complex cSAC.

Table 12.1: Summary of habitat types occurring on and near the proposed route, showing their affinities to EU Annex habitats and the JNCC Phase 1 classification

Guide to Habitats in Ireland (Fossitt, 2000) Habitat (code)	Equivalent EU Annex 1 Habitat and (code no.)	Equivalent JNCC Habitat and (code)
Improved agricultural grassland(GA1)	None	Improved grassland (B4)
Wet grassland (GS4)	None for wet grassland dominated by *Juncus effusus*	Marsh/marshy grassland (B5)
Marsh (GM1)	None	Marsh/marshy grassland (B5)
Lowland blanket bog (PB3)§	Blanket bog* (7130) and Depressions on peat surfaces of the Rhynchosporion (7150)	Blanket bog (E1.6.1)
Cutover bog (PB4)	Depressions on peat surfaces of the Rhynchosporion (7150)	Wet modified bog (E1.7)
Eroding blanket bog (PB5)	None	Wet modified bog (E1.7)
Scrub (WS1)	None for *Ulex europaeus* scrub	Scrub (A2)
Conifer plantation (WD4)	None	Coniferous plantation (A1.2.2)
Recently felled woodland (WS5)	None	Recently-felled coniferous woodland (A4.2)
Earth banks (BL2)	None	Earth bank (J2.8)
Eroding/upland rivers (FW1)	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation (3260)	Oligotrophic running water (G2.3)
Drainage ditches (FW4)	None	Mesotrophic running water (G2.2)
Estuaries (MW4)	Estuaries (1130)	Brackish running water (G2.6)
Muddy sand shores (LS3)	Mudflats and sand flats not covered by sea water at low tide (1140)	Mud/sand (H1.1)
Tidal rivers (CW2)	Estuaries (1130)	Brackish running water (G2.6)
Lower salt marsh (CM1)	Atlantic salt meadows (Glauco-Puccinellietalia maritimae) (1330)	Saltmarsh (H2)
Upper salt marsh (CM2)	Atlantic salt meadows (Glauco-Puccinellietalia maritimae) (1330)	Saltmarsh (H2)
Sedimentary sea cliffs (CS3)	None	Soft cliff (H8,2)
Sedimentary sea cliffs (CS3) – (north-facing to the north of the landfall †)	† Corresponds "loosely" to Vegetated sea cliffs of the Atlantic and Baltic Coasts (1230)	Soft cliff (H8,2)
Embryonic dunes (CD1)	Embryonic shifting dunes (2110)	Open dune (H6.8)
Fixed dunes (CD3)	Fixed coastal dunes with herbaceous vegetation ("grey dunes") (2130)*	Dune grassland (H6.5)
Buildings and artificial surfaces (BL3)‡	None	Built up areas (J3.6)

* indicates EU Annex 1 priority habitat;
§ in this case, formerly heavily grazed lowland blanket bog which shows signs of good recovery (PB5/PB3);
† Refer to habitat evaluation in Appendix J section 4;
‡ this includes man made surfaces including the bog mat and stone roads at the Béal an Átha Buí (Bellanaboy) end of the route.

Table 12.2: Habitats present along the proposed route showing approximate chainages

Route Sections	Chainage		Main habitat(s)	Comment
	From	To		
Landfall and Onshore habitats at Gleann an Ghad (Glengad)	83.38	83.40	Upper shore line and reinstated sedimentary cliff	The landfall.
	83.400	83.825	Improved agricultural grassland (prior to the offshore pipeline landfall works in 2008 and 2009)	Immediately to the east of the landfall soft cliff lies an area of formerly relatively species poor improved grassland. Lies within the SAC. Reinstated in September 2009, this area comprises mostly bare soil and the vegetation is starting to regenerate. The LVI and LVI site compound (SC1) will be located in this area.
	83.825	83.900	Improved agricultural grassland and wet, rushy grassland.	A mosaic dominated by wet, rushy grassland. Boundaries of these vegetation types merge and so are not well-defined. Some of this section of the route lies within the SAC. Site compound SC3 will be located in an area of wet, rushy / improved grassland.
Tunnel	83.900	88.770	The tunnel will pass underneath the following habitats	
	83.900	84.025	Improved agricultural grassland; wet, rushy grassland and marsh	A mosaic of improved grassland, wet, rushy grassland and marshy areas dominated by *Iris pseudacorus* (Yellow Flag). Boundaries of these vegetation types merge and so are not well-defined. Some of this section of the route lies within the SAC.
	84.025	84.050	Lower salt marsh	The boundary between the marshy areas and the salt marsh is not clearly defined. Part of the SAC, the salt marsh is very species poor, with increased growth of rushes in recent years.
	84.050	88.640	Estuary and intertidal	Sruwaddacon Bay (SAC/SPA)
	88.640	88.645	Saltmarsh	Narrow fringe on southern shoreline
	88.645	88.690	Recovering lowland blanket bog (undesignated)	Formerly eroding blanket bog.
	88.690	88.770	Heavily Eroded blanket bog (undesignated)	Aghoos tunnelling compound (SC3) in this location
Onshore habitats from na hEachú (Aghoos) to Béal an Átha Buí (Bellanaboy)	88.770	91.720		
	88.770	88. 850	Heavily Eroded blanket bog (undesignated)	Aghoos tunnelling compound (SC3) in this location
	88.850	89.110	Severely eroded blanket bog with some old cutover (undesignated)	Heavily grazed in the past, the surface is broken by deep erosion channels Some old cutover present at the extreme SE of the pipe stringing area in this location. Occasional small patches of Gorse scrub and along sides of drains in places.
	89.110	89.200	Wet grassland	
			Scrub	Gorse scrub along lower field boundary
	89.200	89.260	Inlet and Salt marsh	Saltmarsh occurs as a narrow fringe along the shore of the inlet. Leenamore River crossing
			Scrub	Small patches of Gorse scrub
	89.260	89.350	Wet grassland	
	89.350	89.540	Recovering eroded blanket bog (undesignated)	Formerly eroding blanket bog with a cover of bare peat generally between 10 and 20%
	89.540	91.720	Coniferous forestry (of varying age class, including clear felled; and also includes artificial surfaces (public road, bog mat and stone roads etc.)	This includes the route section through the clear-felled conifer plantation to the north of the terminal. Ends at Bellanaboy Gas terminal

Table 12.3: Summary of Habitats showing their Ecological Significance and Frequency of Occurrence

Habitat	Approximate Percentage occurrence	Ecological value
Low cliff at landfall	0.1	Low, locally important
Improved grassland	5.1	Low, locally important
Mosaic of improved grassland and wet, rushy grassland	3.1	Low, locally important
Mosaic of: improved; wet, rushy grassland and marsh (tunnel)	1.5	Low to Moderate Locally important
Salt marsh (includes Leenamore inlet and that tunnelled underneath at Gleann an Ghad (Glengad))	0.5	Nationally/Internationally important
Estuary and intertidal (tunnel)	55.5	Internationally important
Scrub	<0.1	Low, locally important
Heavily Eroded blanket bog (undesignated)	1.9	Moderate to High, Locally Important
Severely eroded blanket bog and old cutover (undesignated)	3.1	Low to Moderate Locally important
Recovering eroded blanket bog (undesignated)	2.8	Nationally important
Conifer plantation (including recently felled areas, and artificial surfaces)	26.2	Low, locally important
Sod bank boundaries	-	Low, locally important
Freshwater streams	-	Low, locally important

12.3.3 Fauna (Non-Avian)

The coastal and estuarine portions of the area provide the principal faunal habitats of interest present on site. The proposed route also includes areas of blanket bog habitat, coniferous plantation, improved grassland; wet, rushy grassland, and also small pockets of scrub habitat. The vertebrate fauna of the area may be summarised as being typical of the various habitats, with a good representation of common and ubiquitous species.

A list of Irish mammalian, amphibian and reptilian species is provided in Appendix J(1), along with their adjudged status in the area. Signs of faunal species of interest observed during surveys from 2002 to 2008 have been mapped and are discussed in detail in Appendix J(1).

12.3.3.1 Otter

Otter surveys from 2002 have revealed otter signs along all coastal and estuarine portions of Sruwaddacon Bay and also along the adjacent freshwater reaches of the Glenamoy and Muingnabo Rivers to the east. The 2010 survey also revealed use of all the Bay area by otters, much as had been identified in previous surveys. Survey of the Bay area west of Rossport Pier in 2010 identified considerable otter activity in that area. Otters undoubtedly use many of the small streams and rivers that enter the Bay for washing also.

In surveys prior to 2010 many shoreline caves used by otters were identified as resting places or as potential holts and these are included on the fauna mapping in Appendix J(1). Otter use of many such shoreline caves was confirmed in 2010 survey during which 52 shoreline caves were noted, many of which served as occasional otter resting places (with bedding and/or spraints present within or just outside the entrances). These small caves situated along the coastline have been formed by coastal erosion. Only 3 holts were identified, two of which were considered to be active (of these two, the one at Gleann an Ghad (Glengad) was considered to be an occasional holt, with some evidence of use of this burrow by foxes also). None of the three holts identified could be confirmed as active breeding holts at time of survey in early 2010.

Despite intensive searches close to the shore, with some searches into the adjoining hinterland, no certain principal, or natal, otter holts have been found. The holt at Gleann an Ghad (Glengad) is in use by otters on occasion; it has some potential as a breeding holt, though it is in an unusually exposed location for a breeding holt. The holt will be monitored for activity prior to, and during, construction.

The mapping for the 2010 survey distinguishes between shoreline caves and otter holts. Signs of otters were also noted on the western side of Broadhaven Bay, opposite Sruwaddacon Bay, near Ballyglass Pier, indicating their presence in the greater area. The survey area (in 2007 to 2008 surveys) included a significant stretch of the Aghoos River where a potential otter holt and a number of otter sprainting sites, including fresh spraints and an otter smear were identified.

Further details on otter activity in the area from all surveys are given in Appendix J(1) along with details of holts, resting places, spraints and the otter diet. Holts identified and other signs of otter activity (spraints, feeding signs, footprints and paths) have been mapped (see Appendix J(1)).

12.3.3.2 Badger

Badgers are known to be present in the wider Bay area generally.

Badger footprints and foraging signs were observed in earlier surveys. Foraging signs were found at the edge of the coniferous plantation (east of na hEachú (Aghoos)). In December 2008, badger rooting was identified at na hEachú (Aghoos) just west of the Leenamore River, with badgers foraging on the improved pasture field there. No signs of badger feeding were found within the modified blanket bog habitats present along the proposed route. A badger sett had previously been found closer to na hEachú (Aghoos) village. In February 2010, badger foraging signs were found next to the shore between na hEachú (Aghoos) and Poll an tSómais (Pollatomish). The strong mammal paths observed along many parts of the shore have been created by otters and foxes in the main, but badgers are probably using these paths also.

Several badger setts have been identified in the area, though no main breeding sett has been found in the wider area. Previously, a main sett was present at the north-west of the Terminal site, but this has been inactive in recent years. An active badger sett is known on the north side of the Bay, though signs of badgers foraging along the coast on the north side of the Bay were few.

From surveys conducted in relation to the Gas Terminal it is known that a main badger sett and several smaller setts are present within or close to that location. Badgers are known to range over much of the area of the Gas Terminal site and their activity also extends to the south of the R314, Béal an Mhuirthead (Belmullet) to Gleann na Muaidhe (Glenamoy) road. Post construction faunal surveys in connection with the Mayo to Galway Gas Pipeline (BGE, in 2010) to the south of the R314 between Béal an Átha Buí (Bellanaboy) and Glenturk, have shown that there is continuing badger activity in that area.

Setts identified, and other signs of badger activity (feeding signs, latrines, and paths) have been mapped. Further details of badger activity are provided in Appendix J(1).

12.3.3.3 Bats

During the bat detector survey in September 2007, three bat species were recorded. However, only a few individual bats were encountered during the study. No potential bat roosts were identified and the lack of mature trees in the area means that there are few opportunities for tree roost sites.

A soprano pipistrelle was detected foraging along hedgerows near na hEachú (Aghoos) Church and at Béal an Átha Buí (Bellanaboy). A common pipistrelle was recorded in the area of Béal an Átha Buí (Bellanaboy) during a previous study at the Gas Terminal site. Whilst no detections were made during the 2007 survey, two individuals were detected on the north side of the Bay in August 2008. Leisler's bat, which forages over agricultural landscapes, scrub and woodland was detected foraging over the bay from various locations. It was also recorded south of Béal an Átha Buí (Bellanaboy) along the main R314 road. A single *Myotis* sp. bat was heard briefly between na hEachú (Aghoos) and Poll an tSómais (Pollatomish) – probably a distant Daubenton's bat.

Although not encountered during the 2007 survey, a single brown long-eared bat *Plecotus auritus* was recorded on the north side of the Bay in August 2008.

A list of bat species along with their adjudged status in the area; further information on bat ecology and species descriptions is provided in Appendix J(1). Bat detector "sightings" are mapped (see Appendix J(1) Fauna figures.

12.3.3.4 Other Mammalian Species

A list of other mammalian species is given in Appendix J(1), and indicates their status in the study area. Species known to occur in the area are: brown rat, long-tailed fieldmouse, pygmy shrew, fox, rabbit, Irish hare, pine marten, American mink and red deer.

Fox *Vulpes vulpes* signs are present and frequent in the Bay area. Active rabbit *Oryctolagus cuniculus* burrows are present (and frequent) within and adjacent to the sand dune system to the north of the route at Gleann an Ghad (Glengad), but signs were infrequent or absent elsewhere. The Irish hare *Lepus timidus hibernicus* is present in the area and signs of this species were observed both within the Sruwaddacon Bay area and north of the Bellanaboy Bridge Gas Terminal site. The pine marten *Martes martes* has increased its range across Ireland and is now known to be present in north Co. Mayo (O'Mahony *et al.*, 2005). Presence of this species has been confirmed (sightings and droppings) in various surveys at the Terminal site and they are expected to be present within the coniferous plantation along the route.

No signs of either the grey squirrel *Sciurus carolinensis* or the red squirrel *Sciurus vulgaris* were observed in any of the studies in the area.

No signs of hedgehog were noted but this species is wide-ranging and is certain to be present. The Irish stoat *Mustela erminea hibernica* is wide-ranging and may occur in the area, but no evidence was noted in surveys carried out for this assessment.

American mink *Mustela vison* are known to have spread to Co. Mayo in recent years. No signs were found during earlier surveys, but two mink scats were identified in the Bay area in 2010; one scat was found midway along the northern shore, and another on the north shore at the eastern end of the estuary.

The Common (Harbour) seal *Phoca vitulina was* recorded during the marine mammal surveys in 2005 (CMRC, 2005); and during monitoring in 2007 (Collins, C. 2007) in the estuarine approaches, on sandbanks and shorelines at estuary mouth, in the estuarine channel and on shore line opposite Rossport Pier. The nearest noted location in the same report for Grey seal *Halochoerus grypus* was near Rinroe, while in 2007 this species was observed in the estuarine channel to the west of Rossport Pier. During the 2009/2010 winter bird surveys Common seal were noted hauled out on the shore and on sand banks at the western end, and towards the mouth, of Sruwaddacon Bay.

12.3.3.5 Amphibians and Reptiles

The common frog *Rana temporaria* was observed at several locations. There are no large ponds or pools along the proposed route but several drains were confirmed frog breeding sites; a number of other drains in this area are considered to be potential breeding grounds. These are mapped (see Appendix J(1)). The species is a common prey of otters, foxes, possibly badgers also, as well as other predators.

The common newt *Triturus vulgaris* is not expected in the area and no suitable ponds or pools were found.

The common lizard *Lacerta vivipara* is a common species, but difficult to observe. It is reported locally in the area, especially on the drier, heather dominated sections of cutover bog although no observations were made.

12.3.3.6 Overall Assessment of the Area in Terms of Non-avian Fauna

The potential of the habitats to support species of fauna may be summarised as follows:

Sruwaddacon Bay is utilised by otters, an EU Annex II and IV (Habitats Directive) species. The river supports salmonid populations which are listed on Annex II of the EU Habitats Directive (see also Chapter 13).

A number of small streams flow in to Sruwaddacon Bay or into the Glenamoy River. These provide corridors for otter movements and may also serve an important role as washing places for otters. Almost all streams and larger watercourses were found to be marked by otters where they entered the bay. The Aghoos River is a small river that feeds directly into the Carrowmore Lake cSAC and is used by otters on a regular basis. The various watercourses contribute to the fauna of the area and may be considered as varying in value from Low Local Importance to High Local Importance.

Habitats that are considered to be of Low Local Importance in terms of non-avian fauna: improved grasslands provide forage for common species, such as fox, small mammals are: wet grasslands; blanket bog habitats; coniferous plantation (offers cover but provides very poor foraging habitat for faunal species and do not offer roosting opportunities for bats); field boundaries (scrub and earthen banks) and pockets of scrub provide minor wildlife corridors, cover and foraging grounds in the area for common faunal species and breeding and nesting habitat for some mammalian species.

12.3.3.7 Faunal Species of Conservation Interest

A number of mammalian species are protected under the Wildlife Act and Amendment Acts (1976 and 2000), some of which are known to be present or may be expected to occur occasionally. These include: otter, badger, pine marten, Irish stoat pygmy shrew, hedgehog, and Irish hare. Most of these species may be considered as common species and ubiquitous through much of the Irish countryside. Once relatively scarce, the pine marten has become widespread over much of Ireland. Red deer are occasional in the area.

The following are considered as species of conservation interest (Red Data Book; Whilde, 1993): otter, badger, pine marten, Irish hare, pipistrelle bats, Daubenton's bat, Leisler's bat, and brown long-eared bat. Threatened species include the whiskered bat and Natterer's bat (not expected on site).

All bat species are protected under the Wildlife Act (1976) and Wildlife Amendment Act (2000) and are listed under Annex IV (EU Habitats Directive). Bats are also protected under the Bern Convention (1982) and the Bonn Convention (1979). Bats are not numerous in the Sruwaddacon Bay area - due to the relatively poor foraging habitats in the area and lack of shelter and vegetation cover in the locality.

Badgers are common in Ireland, with an average density nationwide of approximately 0.5 social groups per km^2 (Smal, 1995). Badgers would have far lower densities in upland and blanket bog dominated areas such as in the vicinity of the proposed route.

Otter is a high priority species. The Wildlife (Amendment) Act (2000) protects all types of otter holts and also their resting places. It is listed under Annex II and IV of the EU Habitats Directive. It is also listed as requiring strict protection in Appendix II of the Bern Convention. A species action plan for the otter in Ireland was recently published by NPWS (2008). Otters are widespread in Ireland and their presence can be confirmed on most watercourses in the country (Smal, pers. obs.) but little is known of their densities either on freshwater systems or coastal habitats.

Common and Grey Seal are also protected under the Wildlife Acts and both are listed on Annex II of the EU Habitats Directive.

The common lizard, common frog, and the smooth newt are all protected species under the Wildlife Acts. The common frog is a *Red Data Book* species, but it is common in most Irish habitats. Further details with regard to individual species are given Appendix J(1).

12.3.4 Birds

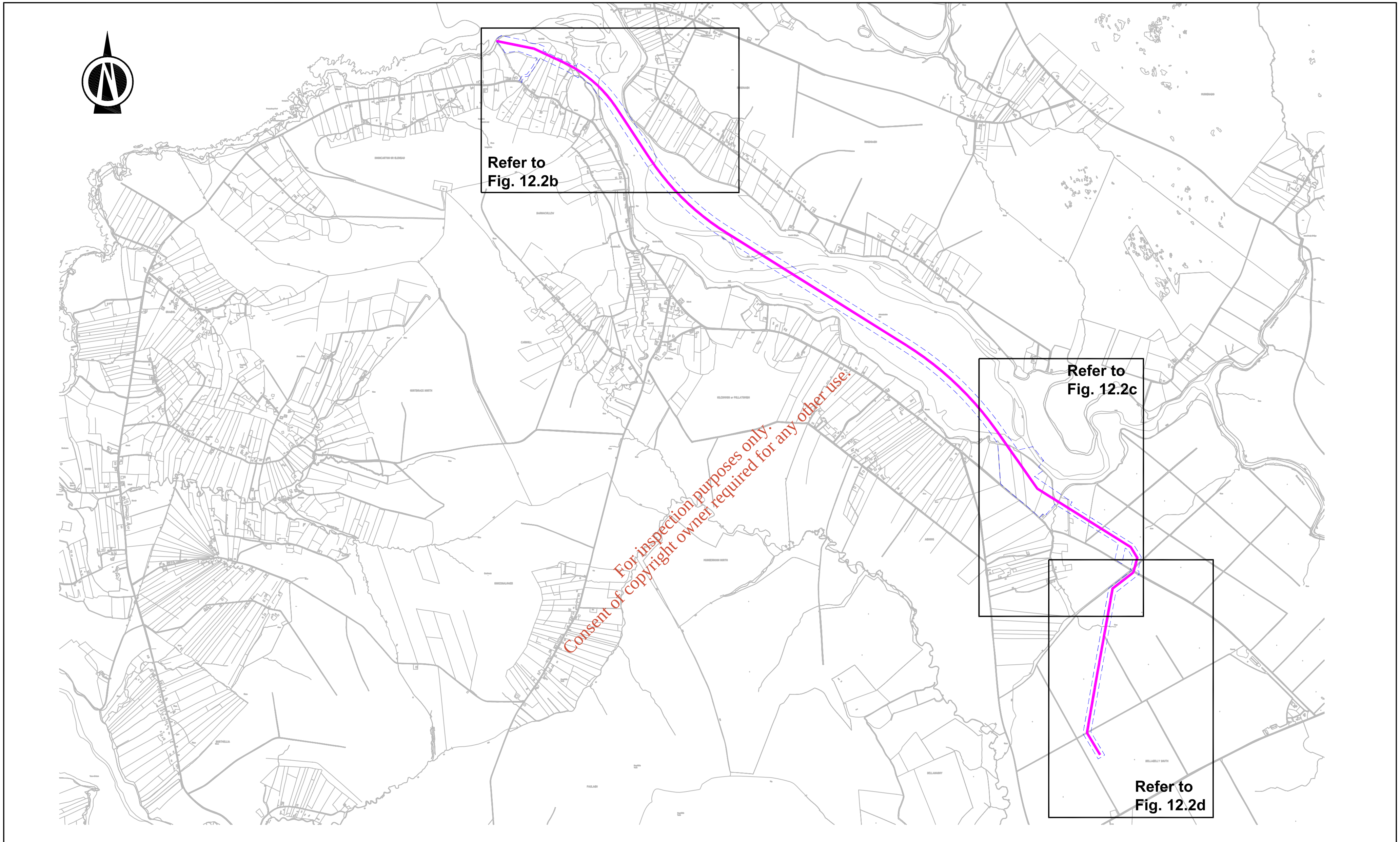
The following sub-sections provide a summary of the results of bird surveys undertaken in 2008/2009 and, previous years. Count areas and observation points used during the surveys are provided in Appendix J(1) and Figures 12.4 and 12.5.

Details of the survey results and desk study are provided in Appendix J(1) along with the scientific and common names of all bird species recorded, bird survey count data, summary tables, schedules and peak counts.

12.3.4.1 Aquatic Bird Studies

A total of 66 bird species have been recorded by aquatic studies in the vicinity of the proposed route. Only one species, Light-bellied Brent Goose, exceeded the threshold of nationally important numbers (i.e. 1% of the estimated National Population). In recent winters peak counts of over-wintering Light-bellied Brent Geese have on occasion exceeded internationally important numbers (>200 individuals).

Further details of the aquatic bird survey results are given in Appendix J(1), including preliminary count results from the Winter Bird and Brent Goose monitoring surveys from October 2009 to March 2010.



Legend:

- Proposed Pipeline Route
- Temporary Working Area

Habitat Mapping

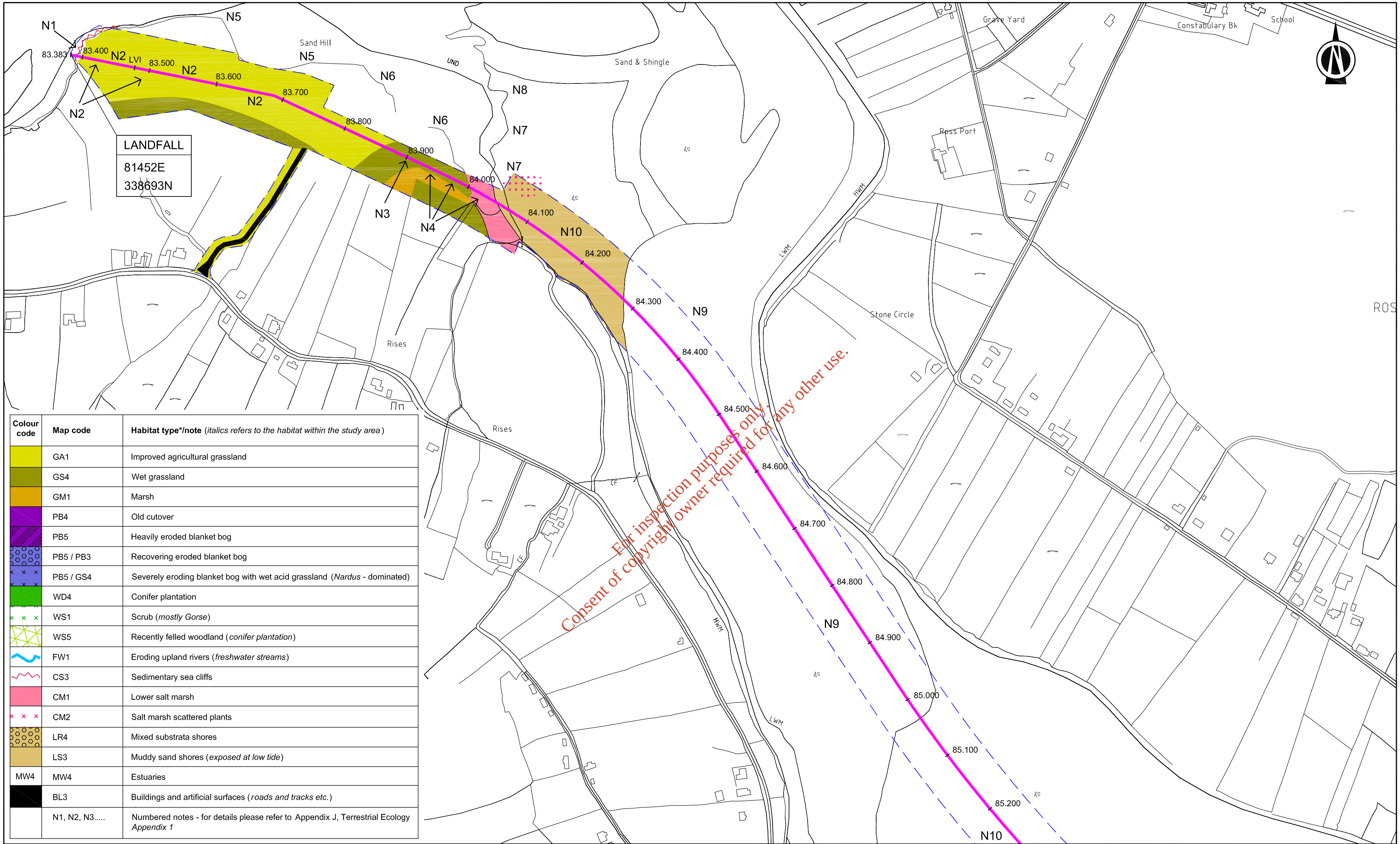
Figure 12.2a - Overview of Habitats

CORRIB ONSHORE PIPELINE

File Ref: COR25MDR0470FG12.2_Habitats Sheet 1 RevA03
Date: May 2010

Corrib natural gas

RPS



Colour code	Map code	Habitat type*/note (*italics refers to the habitat within the study area*)
	GA1	Improved agricultural grassland
	GS4	Wet grassland
	GM1	Marsh
	PB4	Old cutover
	PB5	Heavily eroded blanket bog
	PB5 / PB3	Recovering eroded blanket bog
	PB5 / GS4	Severely eroding blanket bog with wet acid grassland (*Nardus* - dominated)
	WD4	Conifer plantation
	WS1	Scrub (*mostly Gorse*)
	WS5	Recently felled woodland (*conifer plantation*)
	FW1	Eroding upland rivers (*freshwater streams*)
	CS3	Sedimentary sea cliffs
	CM1	Lower salt marsh
	CM2	Salt marsh scattered plants
	LR4	Mixed substrata shores
	LS3	Muddy sand shores (*exposed at low tide*)
MW4	MW4	Estuaries
	BL3	Buildings and artificial surfaces (*roads and tracks etc.*)
	N1, N2, N3.....	Numbered notes - for details please refer to Appendix J, Terrestrial Ecology *Appendix 1*

Legend:

- Proposed Pipeline Route
- Temporary Working Area

Habitat Mapping

Figure 12.2b - Sheet 1 of 3

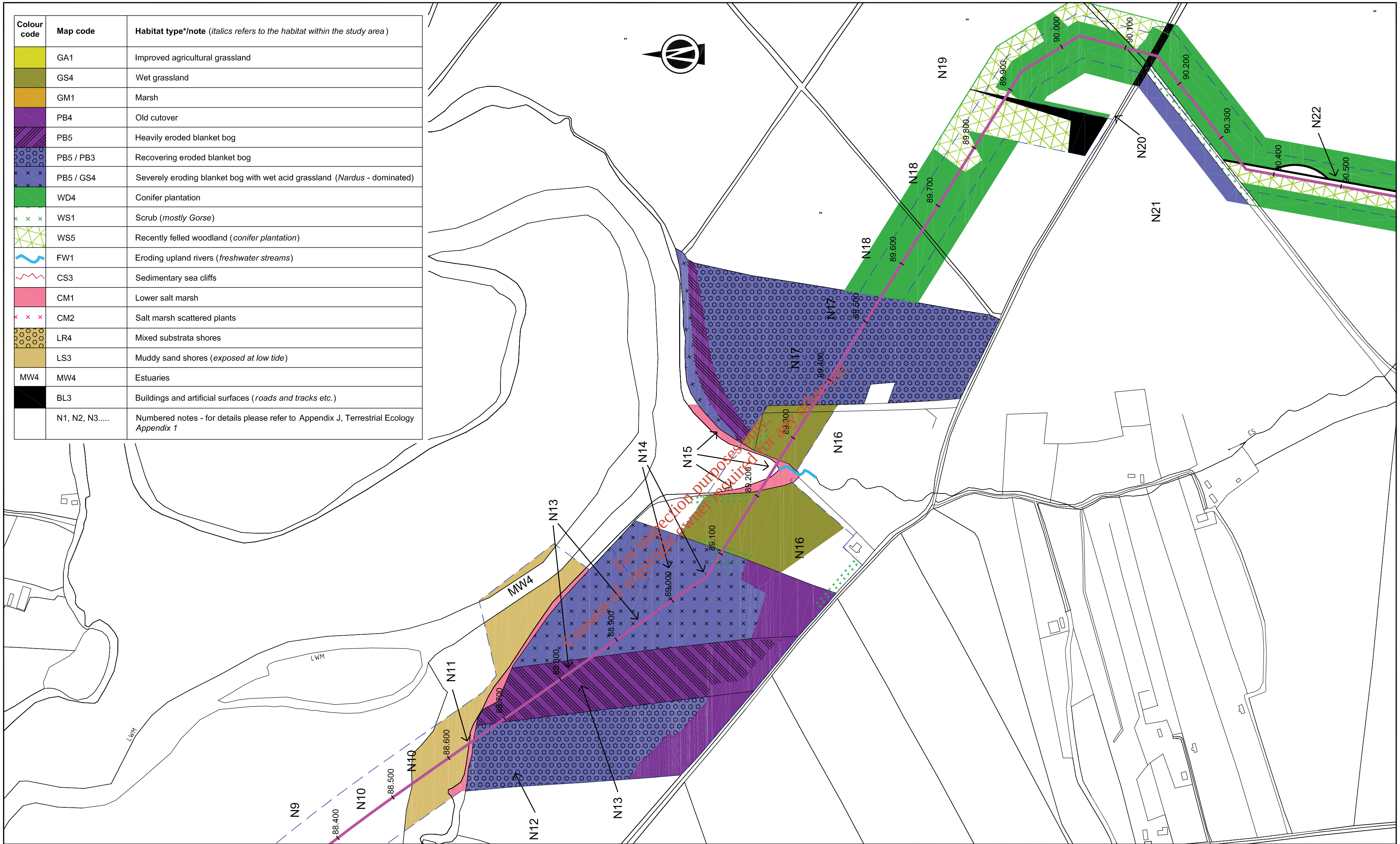
CORRIB ONSHORE PIPELINE

File Ref: COR25MDR0470FG12.2_Habitats Sheets 2-4 RevA03
Date: May 2010

Corrib natural gas

RPS

Colour code	Map code	Habitat type*/note (*italics refers to the habitat within the study area*)
	GA1	Improved agricultural grassland
	GS4	Wet grassland
	GM1	Marsh
	PB4	Old cutover
	PB5	Heavily eroded blanket bog
	PB5 / PB3	Recovering eroded blanket bog
	PB5 / GS4	Severely eroding blanket bog with wet acid grassland (*Nardus* - dominated)
	WD4	Conifer plantation
	WS1	Scrub (*mostly Gorse*)
	WS5	Recently felled woodland (*conifer plantation*)
	FW1	Eroding upland rivers (*freshwater streams*)
	CS3	Sedimentary sea cliffs
	CM1	Lower salt marsh
	CM2	Salt marsh scattered plants
	LR4	Mixed substrata shores
	LS3	Muddy sand shores (*exposed at low tide*)
MW4	MW4	Estuaries
	BL3	Buildings and artificial surfaces (*roads and tracks etc.*)
	N1, N2, N3.....	Numbered notes - for details please refer to Appendix J, Terrestrial Ecology *Appendix 1*



Legend:

- Proposed Pipeline Route
- Temporary Working Area

Habitat Mapping

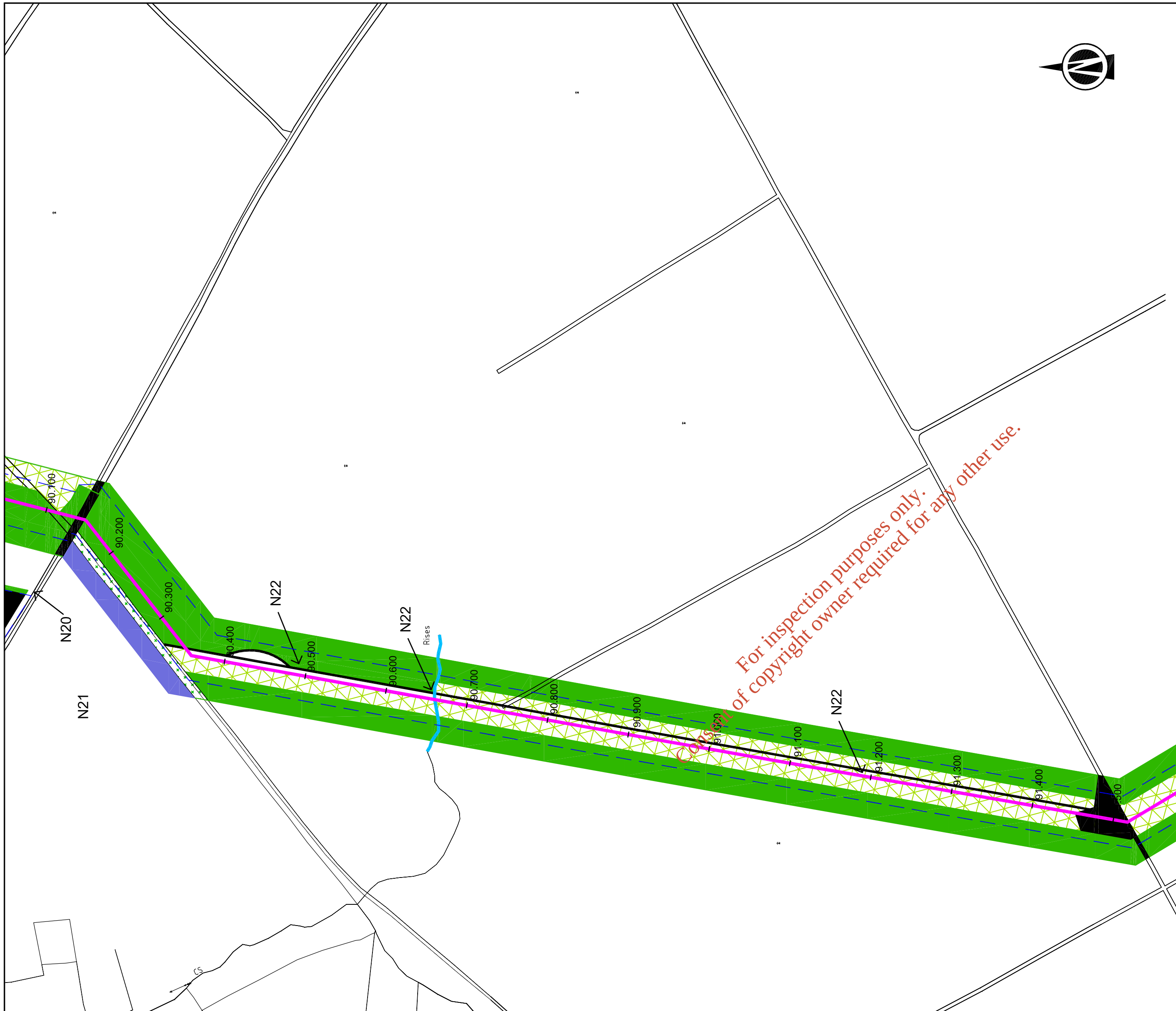
Figure 12.2c - Sheet 2 of 3

CORRIB ONSHORE PIPELINE

File Ref: COR25MDR0470FG12.2_Habitats Sheets 2-4 RevA03
Date: May 2010

Corrib natural gas

RPS



Colour code	Map code	Habitat type*/note (*italics refers to the habitat within the study area*)
	GA1	Improved agricultural grassland
	GS4	Wet grassland
	GM1	Marsh
	PB4	Old cutover
	PB5	Heavily eroded blanket bog
	PB5 / PB3	Recovering eroded blanket bog
	PB5 / GS4	Severely eroding blanket bog with wet acid grassland (*Nardus* - dominated)
	WD4	Conifer plantation
	WS1	Scrub (*mostly Gorse*)
	WS5	Recently felled woodland (*conifer plantation*)
	FW1	Eroding upland rivers (*freshwater streams*)
	CS3	Sedimentary sea cliffs
	CM1	Lower salt marsh
	CM2	Salt marsh scattered plants
	LR4	Mixed substrata shores
	LS3	Muddy sand shores (*exposed at low tide*)
MW4	MW4	Estuaries
	BL3	Buildings and artificial surfaces (*roads and tracks etc.*)
	N1, N2, N3.....	Numbered notes - for details please refer to Appendix J, Terrestrial Ecology *Appendix 1*

Legend:

- Proposed Pipeline Route
- Temporary Working Area

Habitat Mapping

Figure 12.2d - Sheet 3 of 3

CORRIB ONSHORE PIPELINE

File Ref: COR25MDR0470FG12.2_Habitats Sheets 2-4 RevA03
Date: May 2010

Corrib natural gas

RPS

Figure 12.3: **Main feeding areas for Brent Geese**

Plate 12.1: Brent Goose feeding area to the north of the landfall at Gleann an Ghad (Glengad).

Plate 12.2: Brent geese in the Gleann an Ghad (Glengad) feeding area to the north of the landfall.

12.3.4.2 Terrestrial Bird Studies

A number of terrestrial bird studies have been carried out since 2002.

A total of 47 species have been recorded during terrestrial based studies in the area of the proposed route.

Chough were recorded on several occasions during winter surveys of Sruwaddacon Bay in 2002 and 2003 (Arnold 2005d). These sightings took place in the outer bay and along the southern shores of the middle and inner bay.

No Corncrakes were recorded during dedicated surveys, although suitable habitat was noted in parts of the study area. Historical records of breeding Corncrakes in the general area are given in Appendix J(1). Data received from BirdWatch Ireland shows no recent Corncrake records for the study area.

A breeding colony of Sand Martins, a summer visitor, is located in the soft cliff at Gleann an Ghad (Glengad) to the north of the landfall and was first studied in 2002. Two discrete 'sub-colonies' were identified during the 2008 monitoring survey visits. Colony A (the "original colony") is located 30 m north of the proposed pipeline landfall see Figure 12.1 above) while Colony B is located some two hundred metres to the south west of the landfall. In total 48 active Sand Martin burrows were recorded at Gleann an Ghad (Glengad) in the 2008 breeding season. Activity was sporadic in many of these burrows, with some evidence of a proportion of the population producing multiple broods judging from the activity observed at individual burrows over an extended series of site visits. It was judged that at least 30-50% of the active burrows may have had more than one nesting attempt during the 2008 breeding season. Colony A was active from early May to mid-August, while Colony B was active from early June to mid/late August.

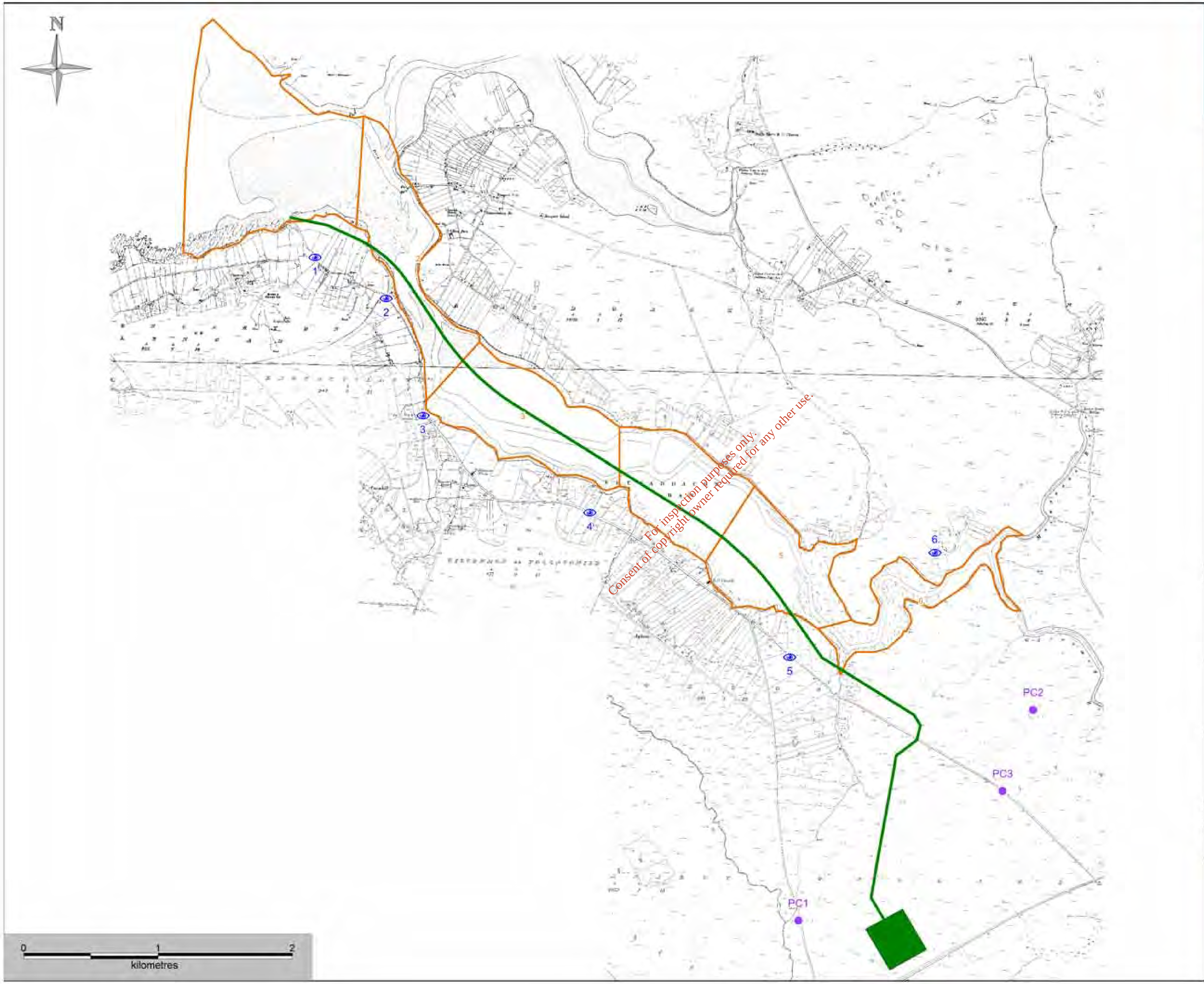
In the 2009 breeding season, a total of three Sand Martin Colonies were identified. Colony A and Colony B were existing colonies located at Gleann an Ghad (Glengad), while Colony C was located at Rinroe Strand and was substantially larger in size than had been observed in this area in 2008.

A total of 67 *viable* Sand Martin burrows were recorded during the 2009 breeding season surveys at Gleann an Ghad (Glengad). Colony monitoring showed that 35 of these burrows were active on at least one of the survey visits. That indicates an overall burrow occupancy rate of 52% of available burrows. A total of 51 viable burrows were recorded in Colony A, 16 viable burrows were available in Colony B and 56 viable burrows were available in Colony C in the 2009 breeding season. Burrow occupancy (i.e. percentage of viable burrows that were occupied) at Colony A was 65% and burrow occupancy in Colony B was 25%.

There is no evidence to suggest that the local Sand Martin breeding population in this area has declined. Conversely, it would appear that this Sand Martin population has expanded, taking advantage of larger expanses of suitable nesting habitat for colony development. At the end of the 2009 breeding season a total of 118 viable burrows were available to Sand Martins in the outer Sruwaddacon Bay area, compared to 80 (68 at Gleann an Ghad (Glengad) and 12 at Rinroe) in the 2008 season (FTC, 2009). Furthermore, breeding success appeared to be relatively high at Gleann an Ghad (Glengad) – at least in the latter half of the breeding season – with chicks/fledglings recorded at many of the burrows in both Colony A and Colony B, and high activity levels (indicating chick provisioning) at many other burrows. This would indicate that the Sand Martins which chose to nest at these locations were successful, and did not appear to be affected by the landfall construction activities in 2009.

Previous Sand Martin surveys carried out in the 2005 breeding season had recorded 37 apparently occupied nests (3 more than was recorded in 2004). These active burrows were located in the area now referred to as Colony A, i.e. the original colony.

R:\Map Production\2008\CE08\548\03\Workspace\Revised EIS\Chapter 12\
CE08-548-03_Figure 12.4_Aquatic Survey Areas & Terrestrial Bird Point Counts_Rev B



Legend

- Survey Area
- Vantage Point
- Proposed Pipeline Route
- Point Count
- Terminal

Date	21/04/10
Name of Client	Ecological Advisory and Consultancy Services (EACS), for Shell E&P Ireland Ltd.
Name of Job	Corrib Onshore Pipeline EIS
Title of Figure	Aquatic Survey Areas & Terrestrial Bird Point Counts
Scales Used	1 : 30,000 @ A3
Figure No.	12.4
Rev	B

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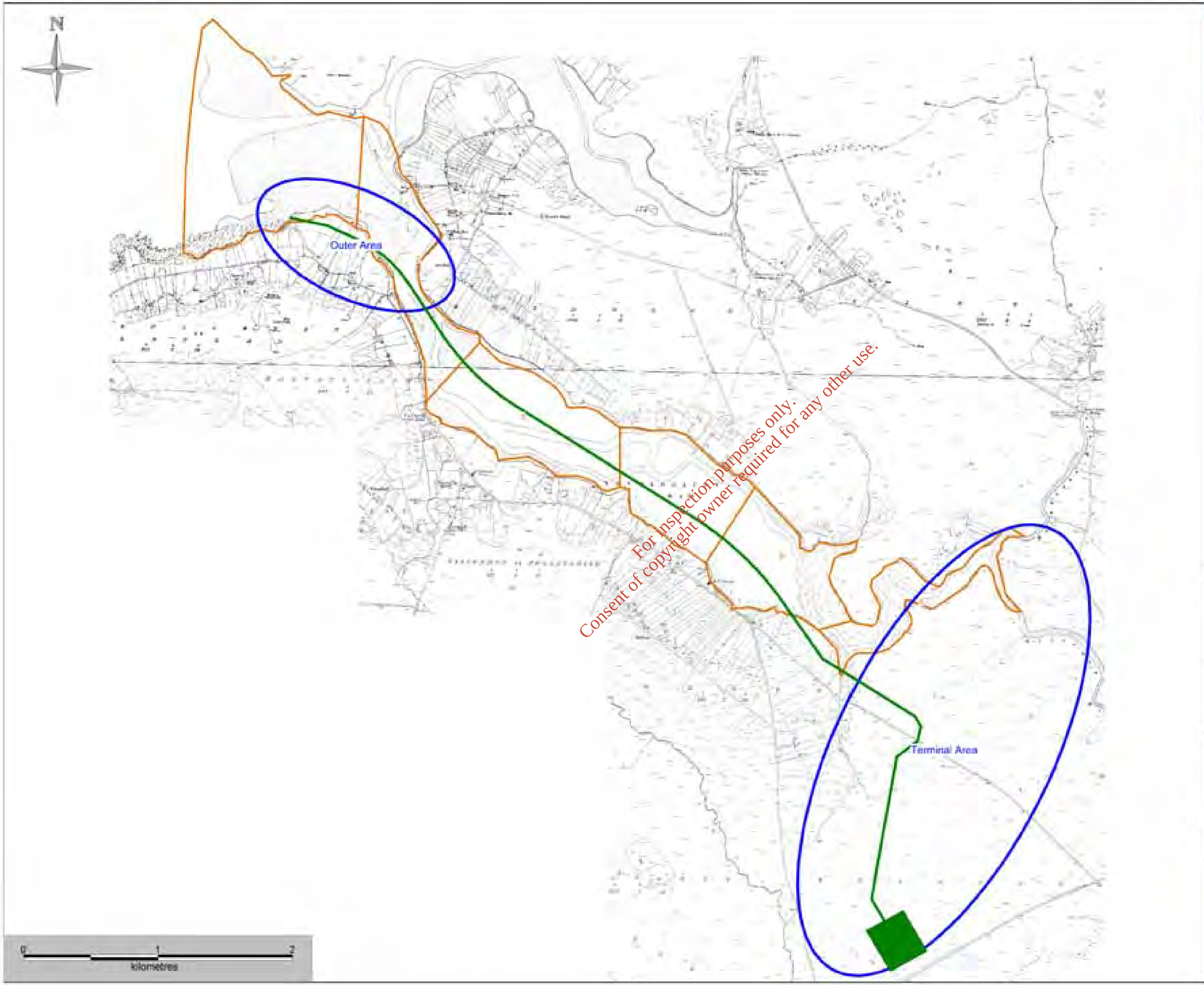

Legend

- Proposed Pipeline Route
- Count Section
- Terminal

Date	27/04/10
Name of Client	Ecological Advisory and Consultancy Services (EACS), for Shell E&P Ireland Ltd
Name of Job	Corrib Onshore Pipeline EIS
Title of Figure	Count Sections Used for Desktop Terrestrial Review
Scales Used	1 : 30 000 @ A3
Figure No.	12.5
Rev	C

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12.3.4.3 Overall Assessment of the Area in Terms of Birds

The overall bird community is typical of the habitats described above.

The post breeding and winter season bird studies show that bird diversity and numbers in the vicinity of the proposed route are low. The relatively low bird diversity and numbers are also reflected in previous bird studies of the general area. Species that were recorded in highest numbers in these studies and previous studies were flocking species such as Light-bellied Brent Goose, Black-headed Gull, Great-black-backed Gull, Common Gull and Oystercatcher. Curlew were also consistently recorded in moderate numbers (typically 50-80 birds).

It is interesting to note that all the studies show a general trend of the 'outer section' of Sruwaddacon Bay holding the highest number of bird species in comparison to the middle and inner sections.

A comparison of the terrestrial bird species carried out in the vicinity of the pipeline less straightforward owing to the restriction of land access available in the 2007 field study, however the results of surveys conducted in 2008 were in line with earlier assessments. The point count locations used in the 2007 field study are largely representative of the area in the vicinity of the Gas Terminal (i.e. conifer plantation and blanket bog habitats. It is worth noting that previous terrestrial bird studies recorded the vast majority of terrestrial bird species in the vicinity of the Bellanaboy Gas Terminal.

Breeding Sand Martins at Gleann an Ghad (Glengad) appear to have expanded their range during the 2008 and 2009 breeding seasons, with two sub-colonies now located at Gleann an Ghad (Glengad) and one colony located at Rinroe Strand. At least 35 Sand Martin burrows were recorded as active in the 2009 breeding season.

12.3.4.4 Evaluation of Scientific Interest of Birds

Most bird species are protected under the Wildlife Acts, barring those regarded as pest species, and for those considered as game species (where they may be hunted under conditions). Under the Wildlife (Amendment) Act, 2000 it is an offence to disturb their breeding or resting places.

Only one species, Light-bellied Brent Goose, exceeded the threshold of nationally important numbers (i.e. 1% of the estimated National Population). It should be noted that recent apparent increases in Light-bellied Brent Goose numbers in Ireland (40,000 from 20,000 - per. com. K. Colhoun) indicate that the threshold for internationally important numbers may increase from 200 to 400 (1% of the International Population). However, recent consultations with BirdWatch Ireland indicate that the next revision is likely to be in 2012, with a mean peak of 350.

None of the other waterbird species recorded by the post breeding study exceeded the threshold of nationally important numbers (i.e. 1% of the estimated National Population). Overall, bird diversity and abundance is relatively poor.

A total of 47 species have been found by terrestrial based studies in the area of the proposed route. Overall, bird diversity and abundance is considered relatively low. The lack of mature 'woody' vegetation outside of the coniferous plantation characterises the coastal nature of the terrestrial parts of the study area. It also explains the lack or scarcity of many nationally common terrestrial bird species.

A total of 66 bird species have been recorded during aquatic studies in the vicinity of the proposed route.

Several species of high conservation concern (i.e. Annex I and/or Red listed species) were recorded by the field studies in the vicinity of the route; Bar-tailed Godwit, Chough, Curlew, Common / Arctic Tern, Golden Plover, Great-northern Diver, Hen Harrier, Little Tern, Lapwing, Shoveler, Red-throated Diver, Sandwich Tern, Little Egret, Black-headed Gull, Herring Gull, Redshank, Whooper Swan and Peregrine Falcon. Most of these species normally occurred in very low numbers (i.e. <10) and only from time to time. Common /Arctic Tern and Sandwich Tern have occurred occasionally in small numbers, with the former observed in 2002 and the latter in 2002 and 2007. Of all the high priority species, only Curlew and Black-headed Gull are present in any numbers throughout the year. Both species can be found widely both in the aquatic and adjoining terrestrial habitats throughout the year with peak numbers typically occurring in the winter.

Light-bellied Brent Goose is an Internationally important migratory species, listed under Annex II of the Birds Directive, the Bern Convention and the Bonn Convention. It is an Amber listed species (BoCCI, Lynas, 2007), and it is a species of special interest for the Blacksod Bay/Broadhaven SPA.

Other bird species recorded by all studies are either of medium conservation concern or of no conservation concern in Ireland. A list of all species together with their conservation status is given in Appendix J(1).

12.4 POTENTIAL IMPACTS

The following sections address the potential impacts during the construction, commissioning, and the operational phases of the proposed development. In addition the 'do nothing' scenario and 'worst case' scenario are also addressed. For the purposes of the ecology impact assessment, potential impacts associated with the LVI are addressed separately (see Section 12.4.2.4 and 12.4.3.2).

Potential impacts on habitats and species are summarised in sections 12.4.2 and 12.4.3 while the predicted level of post construction impacts are outlined for the short term and long term in Section 12.7. Further discussion on these impacts is provided in Appendix J(1).

Criteria for assessing impact level have been derived from those set out in Appendix 4 of the NRA discipline - specific EcIA Guidelines criteria, and expanded in order to be able to address issues such as habitat quality. Terminology for impact significance and duration follows that set out by the EPA (2003) in its generic guidelines. These criteria are outlined in Appendix J(1). The impact magnitude described in the following sections is negative unless otherwise stated as being positive or neutral. Where the impact is stated as being localised, it refers to the immediate area of impact.

12.4.1 'Do Nothing' Scenario

The proposed development is situated in a relatively remote area of north-west Co. Mayo where landuse is mainly forestry and agricultural.

If the development were not to proceed, the habitats crossed by the proposed route would remain as they are, with current landuse practices continuing.

There is little pressure on land for development in the area apart from some pressure for one-off housing in the countryside. There are no expected large-scale changes in the area. Thus, it would be expected that the area would undergo only minor changes in a 'do-nothing' scenario.

In a 'do nothing' scenario, the local fauna and bird communities will continue to be subject to disturbance, displacement and habitat loss impacts through land use activities including agriculture, commercial forestry, turf cutting and natural sediment movements within the dynamic intertidal and marine environment.

12.4.2 'Worst Case' Scenario

Worst case impacts arise in the event of failure of mitigation measures. In the event that mitigation measures fail it is possible that a pollution incident could have significant negative impacts on terrestrial habitats. However, such impacts would be localised spatially. In the event that reinstatement of habitats is unsuccessful, this would lead to vegetation change and likely indirect affects on dependent faunal species, however, such impacts would be localised to the temporary working area and, at worst, immediately adjacent habitats.

An exceptional pollution event as a result of sediment run off or chemical pollutants into aquatic or wetland (peatland) habitats could result in significant impacts on wildlife therein, or downstream.

The implementation of the mitigation measures outlined in Section 12.5 will ensure that such worst case impacts are avoided.

12.4.3 Construction Phase

In order to be able to assess the potential impacts of the proposed development, the construction plan, which shows the extent of the development including proposed key construction areas, has been examined along with construction methodologies outlined in Chapter 5. As discussed above, construction methodologies have been developed in consultation with ecological experts to avoid and/or minimise potential impacts (see Chapter 5). Therefore the description of potential impacts in the following sub-sections relate to those potential impacts resulting from the proposed construction methods. Construction phase impacts are those associated with all stages of construction, including: fencing, construction activities – including associated construction compounds, pipe stringing areas etc; and reinstatement activities.

The method of construction onshore will vary according to the ground conditions and habitat type. The principal construction method for terrestrial habitats will be conventional spread techniques, though treatment of the surface vegetation will vary. In the unlikely event of problems being encountered during tunnelling underneath Sruwaddacon Bay, or in the case of an emergency, an intervention pit may be required. Other crossings such as those for streams and the Leenamore river (inlet on the southern shore of Sruwaddacon Bay) will be by open cut construction methods.

Potential impacts on habitats and species are considered below. Further details are given in Appendix J(1). Table 9 in Appendix J(1) summarises the potential and predicted impact levels for habitat types and species which occur along the proposed route.

Recommendations for mitigation, including habitat reinstatement for the various habitat types, are outlined in Section 12.5 below.

12.4.3.1 Habitats

In addition to the information provided in the following sections on individual habitats, Table 12.4 below outlines the extent of habitat loss or disturbance, both temporary and permanent resulting from the proposed development. The extent of habitat loss has been estimated on the basis of the information provided by the Habitat Mapping and the area to be disturbed within the temporary working areas, pipeline stringing areas, site compounds and temporary access roads.

In most cases part of the temporary site compounds lie within the temporary working area so therefore only that part of the compound that lies outside the temporary working area has been quantified in Table 12.4

Landfall and Gleann an Ghad (Glengad) Terrestrial Section

Improved grassland and wet, rushy, improved grassland will be subject to standard spread techniques i.e. excavation, backfilling, etc within temporary working area. The larger, *Iris* - dominated marshy area to the east and salt marsh will not be subject to impact because the pipeline tunnel will pass beneath them. Consequently, impacts will be confined to improved grassland, and wet, rushy improved grassland. Impacts will include temporary loss of habitat, and habitat disruption during construction. Impacts associated with site compound, SC1 and SC2 are expected to be temporary /short term.

Impacts are expected to be direct, localised and moderate during construction. See below for impacts associated with the LVI itself.

Plate 12.3 Improved agricultural grassland at Gleann an Ghad (Glengad) prior to landfall construction activities in 2008 (facing west towards Broadhaven Bay).

Recovering Eroded Blanket bog - undesignated (Ch. 89.350 to 89.540)

Recovering eroded blanket bog is considered to be an EU Annex I habitat (PB5/PB3). It is nevertheless modified to some degree and is valued as being of National importance. The main impacts on blanket bog are associated with compaction and hydrology (see also Chapter 15 of EIS).

The most critical effect of compaction is on the roots of the vegetation. Compaction can cause an oxygen deficit around the roots which in turn leads to die back and surface vegetation change. Compaction is also associated with surface water-logging which also results in species change, often resulting in dominance by rush species and a loss of typical blanket bog species.

The potential impact of hydrological change is a concern, especially in the context of a linear feature such as a pipeline. Without mitigation, a buried pipeline might effectively function as a field drain, resulting in water egress from the bog, drying and long term permanent change in habitat. For this reason precaution against sub-bog drainage will be put in place (see 6 Mitigation below. (See also Chapter 15).

Another potential impact is interference with chemical balance, for example as a result of the importation of non-chemically compatible materials such as stone. This could result in permanent vegetation change.

Specialised construction methods have been developed with ecological input for construction in blanket bog habitats in order to minimise any potential impact, but at the same time to ensure the effective construction and safety of personnel during construction. The proposed methodology includes the installation of a stone road and the need for turving in the 190 metre section of recovering blanket bog at na hEachú (Aghoos) (ch. 89.350 to 89.540). Turving involves removal of the upper active vegetation layer in the form of large turves, approximately 2m x 1m x 0.5m deep, which are then stored within the temporary working area. At the end of construction the bog surface will be carefully reinstated with these turves. Full details of the proposed methodology are provided in Chapter 5.

Potential impacts resulting from the proposed construction methodologies on recovering blanket bog traversed by the proposed route are expected to be temporary, direct, localised and moderate.

Plate 12.4: Removing turves in intact blanket bog habitat traversed by the Bord Gáis Mayo to Galway Gas Pipeline in the Glenturk More Bog NHA.

Eroding Blanket bog (undesignated)

Construction methodology in these areas will be standard spread techniques, i.e. without the removal of the vegetation layer as turves. The surface layer, including the scraw, will be removed and stored pending reinstatement. An outline of the proposed methodology to enable vegetation regeneration and restoration is set out in Section 6 of Appendix J(1).

Construction phase impact levels are expected to be short term, direct, localised and moderate.

Cutover Blanket bog (Undesignated)

Cutover is present on a small part of the pipeline stringing area. Other areas of cutover will be used as storage areas for surface layer peat removed from the construction compound, where construction methodology in these areas will be standard spread techniques without the removal of the vegetation layer as turves.

Construction phase impact levels are expected to be short term, direct, localised and moderate.

Salt Marsh

Construction of the Leenamore River crossing will disturb some salt marsh. At this location a turving technique similar to that described for blanket bog will be employed. This type of habitat is vulnerable particularly because of the friable nature of the substrate and relatively low coherence of the vegetative layer. Salt marsh is an EU Annex 1 habitat and it has to be valued according to its Annex status, with impact level assessed accordingly. The salt marsh at Gleann an Ghad (Glengad) will not be subject to impact because the pipeline tunnel will pass underneath it.

The potential impact level on salt marsh affected during construction is expected to be direct, temporary, localised and moderate.

Plate 12.5: Typical fringe salt marsh, dominated by *Puccinelia* spp. and *Glaux maritima*

Intertidal Habitats

The use of the tunnel between Gleann an Ghad (Glengad) and na hEachú (Aghoos) will avoid impacts to intertidal habitats. The potential impacts on intertidal habitats of an intervention pit, if required in a worst case scenario, are described in Chapter 14 of this revised EIS. Potential impacts on species of fauna using the intertidal habitats are discussed below.

In the unlikely event that an intervention pit were required at the western end of the Bay in the intertidal zone, any access to the foreshore will avoid the developing salt marsh (see Note 7 Habitat map sheet 1), and the occasional bird feeding and loafing area near that location.

Earthen (Sod) Bank Boundaries

Some earthen (sod) bank field boundaries may need to be dismantled during construction. Such impacts are expected to be temporary, localised Slight Negative

Scrub (Gorse)

During construction the removal of scrub will result in short term loss of habitat. In habitat terms the potential impact is considered to be temporary, localised and slight. The potential impact of this is mainly associated with faunal species and is considered in Section 12.4.2.2.

Conifer Plantations

The loss of habitat as a result of tree felling within the temporary working area of the proposed pipeline will result in localised, slight impact in habitat terms. The main impact is that associated with habitat loss for fauna and is considered in Section 12.4.2.2.

EU Annex habitats - General

The area of Glenamoy Bog Complex cSAC EU Annex habitats to be disturbed during construction of the pipeline will be confined to a 40m working area for the approximately 50m crossing of the Leenamore River inlet and is extremely localised in the context of the area of the designated site as a whole and the Annex habitat types present therein.

Disturbance to the undesignated recovering Annex I blanket bog habitat (PB5/PB3) at na hEachú (Aghoos) will also be confined to a 40m working width for the 190m stretch of pipeline through this area.

No impact on annexed habitats outside the immediate area of construction activities is anticipated.

Soft Coastal Habitats – Sediment Movements

As shown on Pipeline Alignment Sheet 1 of 6 (See Appendix A), the LVI site compound (SC1) and the tunnel reception compound (SC2) do not impact directly upon either the salt marsh or the dune system at Gleann an Ghad (Glengad). The proposed development will have no impact upon sediment movement in and around the existing or developing dune and salt marsh habitats.

In the unlikely event of an intervention pit being required, any access required to the foreshore will avoid the developing salt marsh and the dune system. Therefore, the proposed development will have no impact on the rates of sedimentation and erosion.

It should be noted as outlined in Chapter 14, that Sruwaddacon Bay is a dynamic system providing a transitional zone between the freshwater riverine flow and the fully marine environment of Broadhaven Bay. The entire estuary is continuously swept by semi-diurnal tides. Given the natural variability and dynamic nature of the estuary, constantly changing patterns of sedimentation and erosion are expected – as have been observed in recent years for example, with sand accretion leading to the developing foredunes on the northern side of the main dune system; and the developing salt marsh to the north of the wayleave (Habitat sheet 1, Note 7).

Table 12.4: Quantification of temporary and permanent habitat disturbance resulting from the Corrib Onshore Pipeline development

Habitat description	Area (m2)	Description of works	Comment
Reinstated sedimentary cliff and foreshore	400	LVI drainage	Temporary disturbance (is within the cSAC)
Improved agricultural grassland	440	LVI footprint	Permanent change (is within the cSAC)
	894	LVI side slopes	Temporary disturbance (is within the cSAC)
	629	LVI hard standing	Temporary disturbance (is within the cSAC)
	4,500	TWA/SC1	Temporary /short term disturbance (is within the cSAC)
	2,190	Access road to LVI	Permanent change ($1,177m^2$ is within the cSAC)
	11,400	TWA between SC1 and SC2	Temporary disturbance (9,995 m^2 is within the cSAC)
Mosaic of improved agricultural grassland and wet ,rushy, grassland	3500	TWA/SC2	Temporary / short term disturbance ($626m^2$ is within the cSAC)
Wet grassland, marsh, salt marsh and estuarine habitats	n/a	Tunnel	Temporary disturbance only if an emergency intervention pit is required
Lower salt marsh and intertidal estuarine at Leenamore River	2,026.87	TWA	Temporary disturbance
Scrub (mostly Gorse)	400	TWA	Some permanent loss of Gorse scrub within 14m permanent wayleave
Wet, rushy, grassland at na hEachú Aghoos/Leenamore	7, 200	TWA	Temporary disturbance
Heavily eroded blanket bog	23,964	TWA/SC3	Short term disturbance
Old cutover	27,012	Peat storage areas	Short term disturbance
Severely eroding blanket bog with wet acid grassland (*Nardus* – dominated)	20,643	TWA/Pipeline stringing area	Temporary /short term disturbance (PSA includes some wet, rushy grassland)
Eroding upland rivers (freshwater streams)	-	TWA	Temporary disturbance
Recovering eroded blanket bog	7,600	TWA	Temporary disturbance
Conifer plantation	30,091.93	TWA	Permanent change of habitat
Recently felled woodland (conifer plantation) including artificial surfaces	53,860.57	TWA	Temporary disturbance
	4,000	SC4	Temporary disturbance
Buildings and artificial surface	10,000	SC5	Short term disturbance

12.4.3.2 Fauna (Non-Avian)

Wildlife along the proposed pipeline route is expected to be affected by disturbance during the construction of the proposed development across the existing open countryside and within Sruwaddacon Bay. Temporary loss of foraging areas and breeding habitat may temporarily displace certain species. Mitigation measures are recommended to ameliorate these impacts. Potential impact levels are summarised below.

Habitat Loss, Fragmentation and Disturbance

Along the proposed route, the affected habitats may be considered within the context of the principal habitat types referred to earlier.

- Intertidal sands, mudflats and salt marsh provide foraging habitat for otters, foxes, and avian species. Foraging of some species will be affected in the vicinity of construction. Salt marsh also serves as a wildlife corridor for the movement of mammals along the shore. Construction impacts are expected to be localised, temporary, slight to moderate depending upon the species.

- No significant impacts are expected on the fauna of the dune system and associated habitats at Gleann an Ghad (Glengad). Foraging of some species will be affected in the immediate vicinity of construction works. This will result in potentially temporary, localised, slight impacts during construction.

- Loss of habitats and associated disturbance within the agricultural grassland areas are expected to have a temporary / short term, localised imperceptible or slight impact. There will be impacts on common and ubiquitous species. There will also be loss of foraging habitat for species such as badgers, and other common species. These agricultural habitats are common in the area, and there are expected to be Imperceptible to Slight Negative impacts on fauna.

- Loss of scrub and earthen bank boundaries will affect both birds and mammals as a result of some loss of foraging habitat and also through loss of commuting routes. During construction these are expected to be localised, temporary and slight.

- The coniferous plantations provide limited foraging and breeding habitat for a number of mammalian and avian species. Foraging of some species will be affected in the vicinity of pipeline construction. During construction these are expected to be localised, temporary and slight.

- Blanket bog habitats provide breeding habitat for amphibian species and foraging habitat for some mammalian and avian species. During construction impacts would be expected to be localised, temporary and slight.

Specific potential impacts on fauna include:

Common Species

There may be some mortality of small common species during construction. Protected species such as pygmy shrew and hedgehog may be directly impacted. There are limited ways to protect such species and they are common in Ireland. Potential impacts may be considered as imperceptible or neutral.

Many species will move away from the areas of disturbance, returning after habitat re-instatement to use the affected areas much as before. These species would include red deer, Irish hare, Pine marten, Irish stoat etc., as well as non-protected species such as fox.

Seals

See Chapter 14 for potential impacts on seals.

Badgers

Badgers are active on both sides of Sruwaddacon Bay, in particular the portion of the route between the Terminal site and the southern side of the bay.

The proposed development will entail minor loss of foraging habitat for this species for a short period only. Badgers may attempt to cross open pipeline trenches, especially in the area to the north of the Terminal. There are not however, expected to be any long-term significant impacts on badgers present in the general locality. Badgers are expected to persist in the locality in numbers as at present.

However, badgers are at some risk of falling into open trenches during construction.

Potential impacts on badgers during construction are therefore expected to be temporary and slight. Pre-construction surveys will be completed to check for any further badger setts that may be impacted on by the proposed development.

Otters

Short-term impacts on otters are to be expected. Otters use all of the Bay area as foraging habitat and there are numerous resting places along the shores of the Bay. One occasional holt is present in the Gleann an Ghad (Glengad) area - to the south west of the landfall.

The foraging range of individual otters will undoubtedly be affected to some extent during construction works. Machinery and disturbance could reduce otter access to some portions of their range, which may have implications for food availability for otters during this period – which may be more critical for female otters with young. Such impacts are expected to be Slight to Moderate.

Otters can be relatively tolerant of disturbance, but will undoubtedly be affected by the construction of the pipeline in the short term – mainly through localised disturbance. Otters occur on watercourses in urban areas and become tolerant of human activity. Given the nature of the development, it is considered that otter populations and their use of the Bay area will not be significantly affected in the long-term, provided that any holts with otters present are not directly impacted.

As with badgers, otters may attempt to cross open pipeline trenches. The Bay area is expected to return to its existing condition after works are completed and habitat reinstatement has restored the small area of affected shorelines and habitats to much as before. The food supply of otters is likely to return to existing conditions over a relatively short period of time.

Impacts on otters are expected to be temporary slight negative, to potentially moderate negative during construction.

Plate 12.6: One of many small caves used by otters as resting places (otter spraint at entrance)

Bats

Few bats were recorded in the study area.

Bat species within the survey area are not expected to be affected by either the construction phase or subsequent existence of the proposed pipeline across the existing landscape. Loss of vegetation and temporary loss of habitat during construction will not affect bat populations to any measurable extent. Construction works would have little or no impact on bat movements in the Bay area and will not affect foraging habitats for bats in the area to any measurable extent.

Potential impacts on bats during construction are expected to be temporary Neutral or Imperceptible Negative.

Amphibians and Reptiles

Frogs are present and common in some localities in the study area, notably in bog habitats at the south-east of the pipeline route. There are several, confirmed frog breeding sites as well as additional potential frog breeding sites. Some of these will be directly impacted by the development. Mitigation measures will be required in these areas to ameliorate impacts on amphibians. Potential impact levels on amphibians will be temporary and slight negative during construction.

Impacts on the common lizard may be temporary and slight and some mortality may occur during construction works.

Potential Impacts on Wildlife in Surrounding Areas

The proposed development is expected to have an imperceptible impact on the wildlife in surrounding areas. The pipeline temporary working area is narrow and impacts will be limited to those addressed above. There is no indication that impacts on fauna will extend beyond the vicinity of the pipeline and the Bay area. Impacts would not be expected to be of any higher magnitude than those discussed above.

12.4.3.3 Birds

It should be noted that, when assessing impact levels on qualifying bird species and species of special conservation interest for the cSAC and pSPA, the impact magnitude on a designated site of international importance and the species of importance to that site cannot be given a value lower than Moderate when following discipline-specific guidelines (i.e. EcIA guidance, NRA and IEEM), even though the likelihood for disturbance may be extremely low, and the potential impact of a highly localised and temporary - even transient nature. (See Appendix J 1, Table 7). Under the EPA generic impact assessment guidelines however, such an impact would be classified as imperceptible or slight.

Potential impacts on birds include habitat loss or degradation; and disturbance as result of the presence, movement and noise generated by personnel and machinery associated with the construction works.

It must be noted that, with the exception of site compounds, the temporary working area in terrestrial habitats is narrow and the nature of pipeline construction, with habitat reinstatement, ensures that the impacts will be highly localised both spatially and temporally.

The proposed segment-lined tunnelling method of construction under the Bay will avoid disruption to the important estuarine habitats for birds.

Potential impacts on birds fall into several categories; they are discussed in more detail in Appendix J(1), and include:

- **Habitat loss and degradation**
    - Terrestrial bird habitats

There is the potential for the construction of the pipeline onshore to disturb and degrade habitats for birds, either temporarily or in the longer term. On land the pipe-laying will involve earthworks and this involves a risk of habitat damage and wider impacts such as those caused by run-off, hydrological changes and pollution of surface or ground water. Any habitat changes leading to a loss or deterioration of nesting and/or feeding habitat will result in a temporary (short term in the case of SC3), slight negative impact.

- Estuarine and intertidal habitats

  The habitats of greatest importance traversed by the pipeline route are within the Natura 2000 designated intertidal areas of Sruwaddacon Bay. The potential impacts on intertidal habitats of an emergency intervention pit, if required in a worst case scenario, are described in Chapter 14.

  The construction, operation and decommissioning of such a pit would, depending upon its location, have the potential to cause loss of / disturbance to food sources for aquatic birds; contamination of estuarine waters / sediments (see Chapter 14); disturbance to sedimentation patterns; and potential for disturbance and/or displacement, habitat degradation; and local disturbance to feeding or roosting birds in the immediate vicinity of the pit. In a worst case scenario, if an intervention pit were to be required, the potential impacts on birds, might be expected to be temporary, slight/moderate (depending upon location) and localised.

- **Disturbance** – lighting, construction noise and vibration

  - Light – the impact of artificial light during the construction process has the potential to impact upon the movement, distribution, and activity of birds. The potential impacts are anticipated as being temporary to short term (in the case of SC3), localised slight to moderate negative impact.

  - Noise – the construction noise associated with the various compounds along the onshore pipeline route also has the potential to negatively impact upon the bird community locally. The potential impacts are anticipated as being temporary to short term (e.g. in the case of SC3), localised, moderate negative.

  - Noise and vibration from the tunnelling operation: this is described in more detail in Appendix J1. In summary, given the low level of the worst case scenario for vibration caused by the TBM, the potential for disturbance of birds or their benthic prey would appear to be highly localised (spatially and temporally) in extent, and moderate negative at most. If there were to be perceptible impacts associated with the passage of the TBM under any area of the Bay the chances of the potential impacts on birds or their prey are unlikely to be anything other than highly localised and temporary. Impacts on benthic fauna are discussed in Chapter 14.

- **Indirect sources of disturbance** – There are potential interactions between the disturbance factors above and there are a number of additional potential impacts which may also impact upon the birds in the area. These include the movement of people and vehicles – traffic and construction activities. Increased collision risk from light arrays, fences, cranes etc. Such impacts would be expected to be temporary, slight to moderate and highly localised.

Potential impacts on the qualifying species and species of special conservation interest for the pSPA and cSAC considered in further detail in Appendix J(1).

Landfall Valve Installation (LVI)

During construction, there will be temporary loss of habitat in areas adjacent to the landfall valve installation, including the side slopes and site compound SC1. In addition, there will be permanent loss of habitat at the small footprint of the landfall valve installation (approximately 20m x 22m), and along the access road (2190m^2).

These works will all be located in areas of improved agricultural grassland of low ecological value, though much of this area is currently bare soil - having been reinstated in 2009.

An excavation will be necessary in the reinstated cliff to enable construction of the drainage outfall. Construction impacts are expected to be localised, direct, moderate, and temporary in all but the footprint area of the LVI and the access road where it will be permanent.

The landfall valve installation is located immediately to the south of an active Sand Martin colony (Colony A) at Gleann an Ghad (Glengad) and within 200m of another, smaller Sand Martin colony (Colony B). Studies since 2002 have shown that the birds return each year and use the same burrows for breeding. They usually arrive in late April/early May and depart in September. The LVI is not expected to impact on Sand Martin feeding behaviour as they forage over a wide area in the locality.

It should be noted that construction activities on the cliff and causeway in 2002, 2008, and 2009 did not appear to interfere with the Sand Martins and they appeared to feed (on the wing) normally and undisturbed, and bred successfully. At that time a foreshore exclusion zone was also set up such that no personnel or vehicles were allowed on the foreshore below the colony. (See Mitigation measures).

Potential impacts associated with disturbance by human presence might be expected, however Sand Martins are a species which is extremely tolerant of noisy activities and is known to nest in noisy sand quarries. Impacts on the Sand Martin colony are therefore expected to be temporary Imperceptible to Slight Negative and Neutral in the long term.

12.4.3.4 Other Potential Impacts

No impact on habitats within designated conservation sites outside the immediate area of construction activities is anticipated.

No impacts are anticipated as a result of local road maintenance.
Potential impacts resulting from the spread of invasive species are discussed in Appendix J(1).

Plate 12.7: Young Sand Martins in burrow at Gleann an Ghad (Glengad) from (Arnold, 2005)

12.4.4 Operational Phase

12.4.4.1 Pipeline Wayleave

No impacts are anticipated during the operational phase in connection with the onshore pipeline.

After construction and reinstatement the level of 'traffic' at the wayleave will be restricted to occasional routine walkover inspections. These would not be expected to have any significant impacts on habitats present or local wildlife.

12.4.4.2 Landfall Valve Installation (LVI)

There will be a small permanent loss of habitat at the footprint of the landfall valve installation (approximately 20m x 22m) and along the access road. This will be located in an area of improved agricultural grassland of low ecological value. Impacts are expected to be long term, localised, direct, and moderate.

Normal operation of the LVI will not have any impact upon wildlife using the area, including the occasional otter holt and the Sand Martin colony close by. The facility will not require illumination during night-time.

Regular monitoring checks at the LVI will involve one or two individuals with a small vehicle or jeep and are not expected to impact on species using the site any more than current agricultural activities impact on the area.

If works or servicing is required at the LVI at any stage, then this may temporarily disturb faunal species for the duration of the work, but no lasting impact is expected.

12.5 MITIGATION MEASURES

The following sections provide summary details on the mitigation measures proposed to ameliorate against those potential impacts outlined in Section 12.4. A full description of the proposed mitigation measures are provided in Appendix J(1).

12.5.1 Habitats and Vegetation

12.5.1.1 Habitat Protection and Reinstatement

Improved agricultural grassland and wet, rushy improved grassland (including cSAC Habitats at Gleann an Ghad (Glengad))

Fencing will be put in place to protect the Annex 1 dune grassland located north of the proposed pipeline route (see Section 12.3). The topsoil removed will be carefully stored (separately from the sub-soil).

Whilst the fields have been agriculturally improved some are nevertheless within the SAC and in order to prevent the pollution of the native gene pool by alien genotypes no imported seeds will be used. There is a sufficient seed bank within the top soil and it will be allowed to re-vegetate naturally as previously. Surface drainage will be put in place at the time of reinstatement to prevent water logging where appropriate.

Blanket Bog Habitats (Undesignated)

Recovering Eroded Blanket Bog (undesignated)

The 190m section of undesignated recovering eroded blanket bog (PB5/PB3) at na hEachú (Aghoos) will be treated as though it were designated. (See Chapter 5 for full details of proposed construction methodologies and Chapter 15 Peatland Hydrology and Appendix M). The following measures will apply:

- The top vegetated sod (i.e. living layer of the bog) will be excavated to a depth of at least 50 cm, thus allowing for full protection of the roots. This layer should be kept viable by irrigation if necessary because blanket peat is prone to shrinkage and drying. The longer the period of storage (i.e. time between excavation and reinstatement), the higher the likelihood of damage and less successful reinstatement.

- The turves (vegetated sod-peat) will be stored separately from the amorphous humified peat and in a single layer.
- There will be provision for the continual monitoring of turve storage during construction.
- There will be minimal delay between construction and reinstatement of this route section and every effort will be made to minimise the length of time.
- The replacement of turves (vegetated sod-peat) is the final stage of construction. They will be packed firmly over a regulation layer of peat. Any gaps will be as small as possible and hand packed with peat scraw as the process is being done.
- Peat plugs will be placed at intervals within the stone road and in the trench to prevent the pipeline acting as a large field drain and having adverse effects on the hydrology of the bog (see Chapter 15)
- Where the stone road is installed, enough peat will be left in place over the mineral layer into which the stone can be pressed thus reducing the potential for lateral and lengthways water flow (a measure requested by NPWS for the Bord Gáis Mayo to Galway gas pipeline construction in blanket peat at Upper Glencullin in 2006.
- Measures to avoid compaction:
  - Reduce vehicle movement to a minimum
  - Low ground pressure vehicles will be used when setting out the site prior to the haul road (floating or stone) being put in place.
  - Fencing will be put in place to prevent encroachment and damage to the bog outside the working width.
- To avoid chemical change, any imported stone will be sourced locally.
- Following reinstatement, a fence will be maintained to protect the reinstated section until there is strong vegetation growth and the turves have "knitted" together properly.
- A "no grazing" régime will be in place over the initial post-reinstatement period and for a minimum period of three years thereafter.
- Post construction monitoring will be carried under the post construction monitoring programme for as long as deemed necessary by the project ecologist, in consultation with other peatland experts. The duration of monitoring will ultimately depend upon the speed of reinstatement.

As a result of experience on the Bord Gáis Mayo to Galway gas pipeline at Upper Glencullin, the following are known to be key to successful reinstatement:

- Utmost care will be taken to ensure that turving is done slowly in order to maintain the integrity of the turves, as far as is practically possible. If due care is exercised at the turving stage, then there is greater potential for a good reinstatement.
- Storage, care and meticulous reinstatement of turves is key to the success or otherwise of habitat recovery.
- Measures to restore natural drainage and surface water flows will be implemented. (See Chapter 15 and Appendix M).

Anderson (2003[2]) notes that sand mixed with peat is sometimes packed between turves in order to promote plant growth between the turves. However, from experience at Upper Glencullin it would appear that where mineral "soil" from broken rock exists, then *Juncus effusus* will take hold (increasingly so in 2008 at the eastern upper end of Glencullin where there were no turves for reinstatement). The introduction of sand into any gaps is not therefore recommended.

Depth of Turves

The depth of turves lifted at Upper Glencullin, and proposed for this section of the Corrib onshore pipeline, is in line with practice elsewhere (Anderson, 2003) where depths vary from 4-5cms (i.e. seed bank layer only on poor heath) to 100cm. on rich organic soils. Anderson reports on turves in peat habitats (heaths and moors) being generally in the order of 15 to 25 cm. and she notes that in a wetland situation (sedges and rushes) the turf depth was between 50 and 80cms, depending upon rooting depth. The deeper the turves, the greater likelihood of vegetation recovery, especially in a blanket bog situation where water retention is vital.

Eroded and Cutover Blanket Bog (undesignated)

There is no requirement to lift turves in the heavily and severely eroded, or cutover areas; nor would it be feasible because of the extremely uneven surface. However, in the interest of local biodiversity, the aim in reinstatement is to maintain an undulating profile to provide varying micro-habitats for colonising plant species.

Outline details for habitat reinstatement and vegetation restoration are given in Appendix J(1).

Salt Marsh

The following measures will be implemented at the crossing of the Leenamore River inlet.

Turves will be taken and stored carefully in a single layer either on bog mats or at the edge of the shoreline. They will be protected and, if stored on bog mats, will be watered regularly with sea water. The salt marsh will be reinstated by carefully replacing the turves evenly.

At the eastern end of the bay where the peat bank/salt marsh interface is steep, it will be re-profiled.

Intertidal Habitats (refer to Figure 12.2)

Protection of the algal, shingle and gravel beds

In the unlikely event that an intervention pit is required in the intertidal zone at the western end of the Bay, measures will be implemented to protect the intertidal areas to the north of the route at the western side of the estuary - i.e. south - east of the dune system at Gleann an Ghad (Glengad). This area is an occasional feeding ground for waders and is used as an occasional roost by over-wintering Light-bellied Brent Geese, particularly in strong westerly gales. These measures include: a commitment to avoid this area as far as possible; but if it has to be disturbed then it will be reinstated and re-profiled using the stored shingle/gravel. All works will be agreed with the environmental officer and Project Ecologist in consultation with NPWS.

Protection of the developing new salt marsh (approximately north of chainage 84.00)

Sediment accretion is resulting in the development of a new salt marsh and embryonic sand dunes (Habitat mapping, Notes 7 and 8), both Annex habitats under the EU habitats Directive, at the eastern side of the Gleann an Ghad (Glengad) dune system north of the proposed route. In the unlikely event that an intervention pit is required at the western end of the Bay no vehicular movements in the intertidal zones outside the working width will be permitted.

[2] Anderson, P. 2003 *Habitat translocation – a best practice guide*. CIRIA for the Highways Agency London; and Anderson, P. 2003 *A review of habitat translocation* CIRIA

Please see Chapter 14 for intertidal habitats at the Leenamore River inlet crossing.

Sod (Earthen Bank) Boundaries

Earthen (sod) banks, will be carefully dismantled with the surface sods being stored separately and fully reinstated manually post construction. Those earthen (sod) banks which do not require to be dismantled within the temporary working area will be fenced off to protect them from construction traffic.

Post construction monitoring will be undertaken as part of the ecological monitoring programme to monitor the recovery of the reinstated sod banks. The duration of monitoring will depend upon the speed of their recovery.

Scrub

As a biodiversity enhancement measure it is proposed to plant native scrub species at na hEachú (Aghoos) in order to increase habitat and species diversity. In due course such planting will provide faunal refuge and food (insects) for bird and non-avian faunal species. Species which would be appropriate, and have been recorded in the wider area on peaty substrates include: *Salix aurita* (Eared willow); *Salix caprea* (Goat Willow) and *Salix cinerea subsp.* oleifolia (Grey willow).

The native gorse species on site is *Ulex europeaus* (European Gorse) and is recommended for planting in places, for example at road margins. This species had been present on road margins in the areas prior to recent road widening.

Further details are given in Chapter 10, Landscape and Visual Assessment.

Conifer Plantations

Where feasible native willow species will be planted at the edges of the wayleave through areas of coniferous plantation. It is noted that no tree or scrub planting is possible in the 14m wide wayleave over the pipeline itself.

Construction Areas and Protection of Habitats

No works will be undertaken outside of the temporary working area shown on Figure 5.2 without prior consultation with the Project Ecologist.

Road Maintenance Works

Should any road maintenance works be required, road margins will be inspected prior to maintenance works commencing in order to target appropriate mitigation measures if necessary.

Invasive Plant Species

In the event that invasive plant species (e.g. *Rhododendron ponticum)* are found to be present within the reinstated area then necessary measures will be taken to remove them, in accordance with accepted best practice appropriate to the habitat on which they are present. If such species are found to occur within the working area prior to construction, they will be removed and destroyed in accordance with accepted best practice for the particular species involved.

12.5.2 Non-Avian Fauna

Standard mitigation measures (as set out below), as would apply to any large-scale development, will be adopted in the construction of the proposed development. These include limiting season of disturbance to trees and vegetation (see also under birds below) and in order to reduce impacts on breeding species, to provide for habitat replacement, and measures to reduce pollution and sedimentation into water bodies and watercourses during the construction phase.

Best practice will be adhered to throughout. Specific measures are required, principally to protect otters, badgers and frogs on site. They also include provision for pre-construction surveys and monitoring, during and post-construction. A full description of proposed mitigation is set out in Appendix J(1), including Tables 10a and 10b.

Badger and Otter

Some mitigation measures are common to both badger and otter so are considered jointly below. Species-specific measures are shown accordingly:

- A pre-construction survey within the temporary working area and including an area, to approximately: 50 - 100m either side of the centre line for otters; and 30m either side of the centre line for badger, will be undertaken within 1-3 months prior to construction. (The optimal survey period is from December to April).

- Areas of dense vegetation affected by the development which could not be thoroughly searched will require monitoring by appropriate experts during vegetation clearance. These include the route sections in coniferous plantations south of the Bay, and dense gorse scrub near the Leenamore River inlet

- The appropriate season for checks on holts for breeding activity would be from April through to September/October. Any holts/setts identified in the pre-construction survey to be directly impacted will require evacuation/removal by zoological experts under licence from NPWS prior to construction taking place - for humanitarian consideration.

- Construction works in close proximity of active setts/holts or principal otter foraging areas will be limited to daylight hours where feasible.

- During construction, open trenches will provide ramps for otters and badgers and other wildlife to escape.

- At known otter or badger crossing points, gaps will be left at the base of any fencing to allow access for wildlife species across the pipeline route.

- The tunnelling site works compounds (S2 and S3) should be fenced with fully wildlife proofed fencing so as to prevent larger mammals from entering these compounds and then not able to exit.

- Fencing along the access road at Gleann an Ghad (Glengad), and around the LVI works compound should be provided with mammal gates at intervals.

- Visual screening of works close to holts or principal areas of otter activity may be considered appropriate during the works.

Bats

Pre-construction surveys will include inspection of the route for potential bat roosts such as any mature trees along or close to the route.

Frogs

Amphibians present within all of the affected portions of the route will be removed prior to construction proceeding and placed into alternative suitable habitats in the locality (under appropriate licence from NPWS). Where practical in the context of construction, water levels will be maintained in the drains (used by frogs). Habitat reinstatement will re-create the former channel and drain systems so that frogs may use these post-construction. Where feasible, artificial breeding pools will be created within unaffected portions of wetland habitats adjacent to the route where practical

Other Species

There are no specific mitigation measures recommended for other faunal species.

12.5.3 Birds

Potential impacts of the pipeline project on the local birds can be minimised by implementing the following mitigation measures.

- Acoustic screening barriers will be installed on the boundary of the site compounds at na hEachú (Aghoos) and Gleann an Ghad (Glengad). Noise monitoring will be carried out throughout the construction process and take into account the bird usage areas as sensitive noise receptors. Noise contours are shown in Appendix 17, Figures 17.1 and 17.2.

- Lighting in site compounds will be directed downwards and be designed to minimise light leakage outside the working area. Lighting will be designed in such a manner that only areas crucial for works and security purposes will be lit. At SC3 the light level reaching the foreshore will be no more than the light intensity of the order of a full moon (0.3lux). The finish of all structures and materials will be designed to minimise reflected glare. Large structures and uprights will have green lighting designed to minimise impact on birds while reducing collision risk with these structures. See Appendix 17.3 for light contours and Chapter 10 for details of the lighting design proposals for SC3.

- The acoustic screening barriers at na hEachú (Aghoos) and Gleann an Ghad (Glengad) will also provide additional mitigation against light spillage outside the compound.

- Intensive bird monitoring will be continued throughout the construction period and regular reports will be submitted to NPWS detailing the bird community present and contrasting findings with recent pre-construction survey results. In addition, the feasibility of monitoring nocturnal bird distribution and abundance during the period of tunnelling operations, and while the Aghoos compound (SC3) is in place, will be investigated.

- Good working practices will prevail throughout construction and post construction monitoring of the route. For example, machinery, equipment, fuel and other materials associated with the development will be stored appropriately (e.g. bunded fuel tanks).

- Litter and other waste material will also be stored and disposed of appropriately. This will minimise the potential risk of damage or pollution to birds and their habitats.

- Any environmentally hazardous material used during construction works will be carefully stored. An environmental management plan will be fully implemented that applies best practice on minimising the risk of pollution of soils, surface or ground-waters.

- The tunnel arisings will only be spread or stored in areas where there will be no degradation of existing habitats for birds. In the event of surplus excavate, the feasibility of constructing a suitable sand-bank for nesting Sand Martin at a suitable location in the locality will be explored.

- The greatest numbers and diversity of species of elevated conservation importance occur in the vicinity of the development from October to April. Therefore in the unlikely event that an intervention pit is required within the Bay during this time, detailed method statements will be prepared, which will outline measures to avoid and minimise the potential impact on birds. Pre -construction monitoring will be undertaken immediately prior to works to inform these method statements. Such works will only be undertaken with prior agreement with NPWS.

- Where feasible, vegetation clearance will be undertaken outside the breeding bird season which extends approximately from March to August inclusive.

- Measures for the protection of the Sand Martin colony are described below in connection with construction of the landfall valve installation.

- Where feasible, the construction activity and movement of vehicles in the vicinity of the compounds will be minimised during night-time hours. Construction of the compounds, until the acoustic screening is in place will take place during daylight hours only.

- The settlement ponds at na hEachú (Aghoos) will be covered by wire or plastic mesh of small enough mesh size to prevent access to birds.

- A walkover of the on-land portions of the route will be undertaken prior to construction in order to survey the birds. This will ensure that any site specific issues in relation to avifauna will be highlighted before construction. It will also allow tailored mitigation measures to be undertaken in light of any new issues which may have arisen in the interim. This walkover will be undertaken by a suitably qualified expert. Following the field visit, and prior to construction, the grassland areas in the temporary working area will be mown, if deemed appropriate, in order to discourage ground nesting birds from attempting to breed on the temporary working area.

- In order to minimise the impact of habitat loss and deterioration on the local birds, appropriate habitat reinstatement (re-vegetation and planting of native scrub species) will be undertaken as part of the development. The need and design of such a programme will be assessed by a suitably qualified expert in consultation with the project ecologist.

During and post construction monitoring will be conducted in accordance with the monitoring programme to be drawn up by the project ecologist in consultation with NPWS and will include a biennial survey of the temporary working area and surrounding habitats to assess the bird population.

12.5.4 Landfall Valve Installation

12.5.4.1 Protection of the Sand Martin Colony

The following mitigation measures will be implemented:

- An exclusion zone will be defined above and behind the colony such that no construction activities affect the existing burrows or threaten the stability of the cliff in which the burrow are situated.

- No personnel, traffic and construction activities will be permitted between the LVI footprint boundary and the cliff-top directly above the colony.

- Protection fencing will be in place before any work commences.

- A wide foreshore exclusion zone will be set out to prevent any activity on the foreshore below and in front of the burrows which may deter normal behaviour and could result in lowered breeding success.

- Any stock-piled soil will be netted to prevent birds from making nest burrows therein.

- The width of exclusion zones will be decided in consultation with NPWS.

12.5.4.2 Landscaping and Re-vegetation

The following measures are proposed and will be incorporated into the method statements for reinstatement (see Chapter 5):

- The topsoil removed from the footprint will be carefully stored (separately from the sub-soil). These soil heaps will be covered with netting to prevent sand martins from making burrows in them.

- Following construction this topsoil will then be used on the slopes of the facility, which will then be left to revegetate naturally. It is proposed therefore that no seed or topsoil will be imported into the cSAC in order to prevent the introduction of non-native genotypes which could result in the genetic pollution of the local plant populations, also to protect against the introduction of pest species.

- To aid topsoil stability and grass growth, a geotextile membrane will be laid on the slopes of the facility.

12.5.5 Monitoring

A monitoring programme will be devised by the project ecologist in consultation with NPWS to address all issues associated with habitats and species. This will include pre-construction, during construction and post construction monitoring. The contractor will be made aware of the programme and schedule for mitigation.

Where sensitive and / or designated habitats have been reinstated, monitoring will be necessary. The intervals and duration of monitoring will be agreed in consultation with NPWS. Route sections which require habitat monitoring post construction include:

- The landfall, LVI and tunnelling compound areas at Gleann an Ghad (Glengad).

- Other cSAC sections of the route at Gleann an Ghad (Glengad); and the nearby sand dune system Annex I habitats which lie outside the working area; including the developing salt marsh and embryonic dunes.

- The shore lines, salt marsh and intertidal zones at, and in the vicinity of, the Leenamore inlet.

- Non-designated blanket bog habitats at na hEachú (Aghoos).

- Areas of biodiversity enhancement at na hEachú (Aghoos).

The purpose of monitoring is to assess the recovery of the habitat after reinstatement. It is particularly important in the early stages post reinstatement so that, in the event that habitat recovery is not progressing as expected, early indicators can be picked up and remedial action taken.

The extent and details of the faunal (avian and non-avian) monitoring will be included in the monitoring programme to be drawn up by the project ecologist in consultation with NPWS.

Monitoring recommendations in relation to non - avian fauna are summarised in Tables 11a and 11b of Appendix J(1). Requirements for bird monitoring are summarised in Section 12.5.3 above.

The purpose of the post-construction monitoring for fauna is to assess the activity of vertebrates of conservation interest in relation to the base-line (and pre-construction) surveys, to report on possible negative or positive impacts, and to recommend additional mitigation or ameliorative measures that would restore or enhance the habitat quality for these species within the area of the development site.

The Project Ecologist will be advised of any changes in construction schedule or methodology that might affect proposed mitigation and the monitoring programme.

12.5.6 Fencing

Method statements will be set out for fencing in sensitive habitats and where species mitigation measures are required. Fencing will be carried out in accordance with mitigation set out for habitats and species. Fencing will not proceed until pre-construction mitigation measures are in place where required.

12.5.7 Method Statements

Method statements for construction will include details of mitigation and reinstatement in relation to sensitive habitats and protected species. They will be drawn up in consultation with NPWS through the Project Ecologist.

12.6 RESIDUAL IMPACTS

Residual impacts are summarised in sections 12.7.1 – 12.7.4 and in Table 9 in Appendix J(1). The terminology for impact duration is in accordance with the EPA Guidelines (2003). Long term significant impacts are not expected because of the nature of pipeline construction and the fact that, with the exception of the landfall valve installation footprint, habitats can be reinstated.

12.6.1 Habitats

Landfall and Gleann an Ghad (Glengad) (Improved agricultural grassland and wet, rushy improved grassland).

Predicted impacts are expected to be slight in the short term and neutral in the long term. The landfall valve installation (LVI) is considered separately below at 12.7.4 below.

Blanket Bog Habitats at na hEachú (Aghoos) (Undesignated)

Blanket bog habitats are expected to take longer than others to recover, so a short to medium term, moderate impact magnitude is expected. However, from experience with intact cSAC blanket bog reinstatement using turves and subsequent post construction monitoring on the Bord Gáis Mayo to Galway Gas Pipeline, given careful reinstatement and the application of best practice throughout the construction phase, it is considered that blanket bog vegetation should recover after a few years; possibly in the short term rather than medium term.

With successful reinstatement the impacts are predicted to be slight to moderate in the medium term, reducing to neutral or imperceptible in the long term.

In the eroded and cutover areas, where the vegetation layer will not be removed as turves, restoration of vegetation cover might be expected to take longer than in the turved areas. With successful management of vegetation restoration, the impacts are predicted to be moderate in the short term, reducing to imperceptible in the long term.

Salt Marsh

With successful reinstatement the impact level is expected to be slight to moderate in the short term, and becoming neutral or imperceptible in the long term.

Intertidal Habitats

Residual impacts on intertidal habitats, other than salt marsh, at the Leenamore River inlet are described in Chapter 14.

Residual impacts resulting from the requirement for a temporary intervention pit are described in Chapter 14.

Sod (Earthen) Bank Boundaries

Careful dismantling and reinstatement should result in the impact on sod banks being slight in the short term and neutral in the long term.

Scrub (Gorse)

With some habitat restoration the impact on scrub is expected to be moderate in the short term and neutral to slight in the long term. The planting of native scrub, including gorse will result in an overall neutral, or slight positive, impact in the long term.

Conifer Plantations

The duration of this impact will be permanent where trees are required to be felled and no re-planting permitted over the centreline of the pipeline. However this must be put in the context of local forest management which has seen extensive clear-felling of large areas of mature conifer plantation in recent years. By its nature it is a transient man-made habitat. The clearance of trees for the pipeline development is viewed as an extension of the forest management in the area, as the mature trees would be due for felling in rotation.

The planting of native scrub species such as willow, and gorse as referred to above, will compensate for the loss of tree cover to some extent, and should offset the loss of habitat by increasing local biodiversity, resulting in a neutral, possibly slight positive, impact in the long term.

12.6.2 Non- avian Fauna

The proposed development will incur short-term impacts on various faunal species. Most of these can be considered as neutral, imperceptible or slight negative. Impacts on otters in the bay area in the short term are likely to be localised, moderate. The overall impacts of the proposed pipeline scheme on the fauna in the locality may be considered as neutral in the medium to long-term. There are not expected to be any long-term significant impacts on species of conservation interest present on site such as otters, badgers, bats, frogs etc. provided that mitigation measures are implemented as recommended.

Given best practice design and operation of the proposed development, without pollution incidents, with recommendations included within this EIS incorporated, and with accompanying mitigation and remedial measures included, the residual impact of the development on fauna are expected to be neutral or imperceptible.

If habitat enhancement, such as artificial ponds, can be provided at na hEachú (Aghoos) as part of the reinstatement programme to create suitable habitat for frogs and smooth newts (which might be present in the general locality), this would result in neutral, or potentially slight positive in the long term.

12.6.3 Birds

For birds, post construction, with the successful implementation of mitigating measures, the residual impacts are expected to be generally neutral.

Habitat reinstatement and enhancement would potentially lead to an increase in the quality of certain terrestrial habitats as a resource for nesting and feeding birds in the medium term, resulting in a possible slight, positive residual impact.

Overall, given the narrow width of the working area, the proposed mitigation measures and the availability of similar habitats to those that will be directly affected, it is unlikely that there will be any significant effects on the wider local avian community.

Overall the potential residual impacts on birds would be slight or imperceptible in the short term, neutral in the long term. There would be no long terms impacts on the wider local avian community.

12.6.4 Landfall Valve Installation (LVI)

The construction of the LVI will result in loss of habitat on the footprint of the facility and the access road for the duration of the operational phase. Prior to landfall construction works, the habitat present was improved agricultural grassland of low ecological value - a commonly occurring habitat both adjacent to the working area and in the wider locality. Although there will be slight loss of foraging habitat for birds and small mammals, it is expected that in the long term - with likely further agricultural improvement in the locality - the residual impact will be slight.

In addition, the provision for naturally regenerated grassland areas on the slopes of the facility and on level areas will compensate to some extent, for the loss of the pre-existing grassland. The residual impact in vegetation and faunal terms and also in the context of the present function of this area as a buffer zone within the cSAC, is expected to be slight.

In the short term impact level is expected to be moderate for the footprint of the LVI, but imperceptible to slight for other areas associated with the LVI. Long term impacts are expected to be slight to moderate (LVI footprint) and imperceptible to slight for reinstated areas.

13 FRESHWATER ECOLOGY

13.1 INTRODUCTION

This chapter summarises the freshwater ecological impact assessment carried out for the proposed development by Aquatic Services Unit (ASU). The scope of the study included a desk and field based assessment of the freshwater habitats and associated species, both freshwater and migratory, such as Atlantic salmon and lamprey species.

The key areas of potential impact of the proposed development on freshwater resources relate to the construction and commissioning phases, as no impacts will arise once in operation. Consultation was also undertaken with relevant bodies/individuals.

This assessment describes the existing freshwater environment, the methodology used for assessment, potential and residual impacts identified and makes recommendations for mitigation measures to avoid/minimise these impacts.

The full report (including bibliography) on the Freshwater Ecology Assessment is presented in Appendix K. Details on designated conservation sites and the legislative context are provided in the Preface to Section C of the EIS.

13.2 METHODOLOGY

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

- A desk study which examined all available data and reports on freshwater resources along the proposed route of the pipeline, including examination of the occurrence of legally protected Habitats Directive, Annex II freshwater species[1].
- Consultation with the following:
  - The North Western Regional Fisheries Board (NWRFB);
  - The Marine Institute;
  - The Central Fisheries Board (CFB);
  - National Parks and Wildlife Service (NPWS);
  - Salmon Research Agency; and
  - Local Angling/Fisheries organisations.
- A field study of rivers and streams along the proposed route in early September 2007 and in January 2008, September 2008 and November 2008.

13.2.1 Field Study

Points at which the proposed pipeline would have the potential to cause impacts on rivers and streams were identified using the 1:50,000 Discovery Series Ordnance Survey Maps No. 22 and 23 and using aerial photography of the Study Area (2008).

[1] Protected under the EU Habitats Directive and include Atlantic Salmon (*Salmo salar*); Freshwater Pearl Mussel (*Margaratifera margaratifera*); White-clawed crayfish (*Austropotamobius pallipes*) and Lampreys (3 species).

The proposed pipeline crosses a total of three streams / rivers (Sites 3, 4 and 5) and is tunnelled for 4.6km underneath Sruwaddacon Bay (Site 2) as outlined in Table 13.1 and illustrated on Figure 13.1. In addition, a stream (Site 1) located east of the landfall at Gleann an Ghad (Glengad) was sampled and assessed, as it lies within the temporary working area, although it is not anticipated that any works will occur in this area. These crossing points were chosen as the assessment/sampling locations for the field study.

Table 13.1 Location and description of watercourses traversed by crossings along the proposed route.

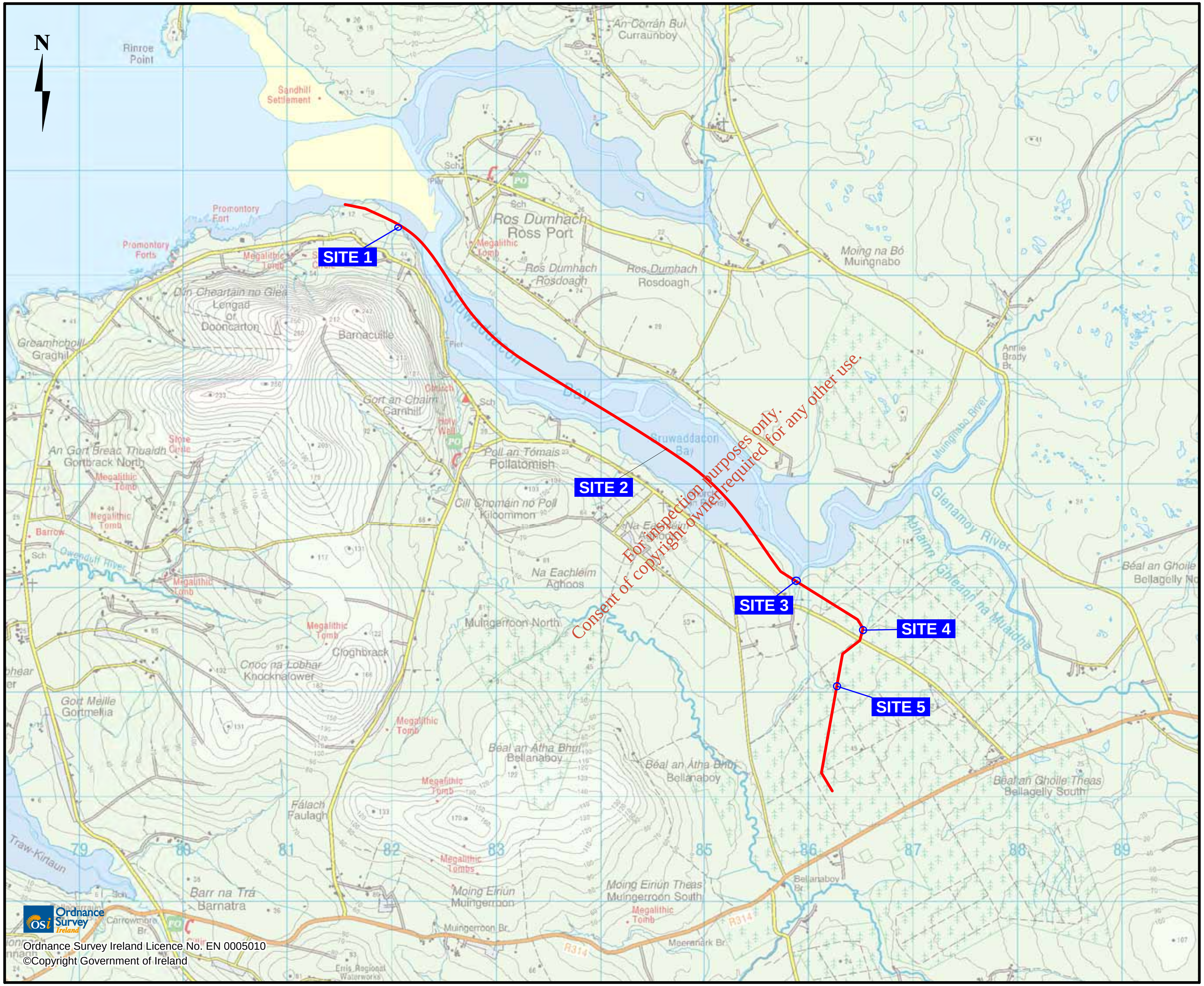
Crossing Point/ Sampling Site No.	Approximate Chainage	Location/Townland	Brief Description
1	84.05	Just east of the landfall at Barr na Coilleadh (Barnacuille)	A small first order[2] stream close to outer Sruwaddacon Bay. This stream will not be crossed by the pipeline.
2*	84.05.-88.65	Sruwaddacon Bay	Sruwaddacon Bay is the migratory route for salmon and seatrout in and out of the Glenamoy and Muingnabo Rivers.
3	89.25	Leenamore River	A small second order[3] stream draining to the southeast corner of Sruwaddacon Bay, known locally as the Leenamore.
4	90.15	Na hEachú (Aghoos)	A first order stream close to the roadside about 0.5km east of the most downstream crossing of the Leenamore River.
5	90.7	Na hEachú (Aghoos)	A small first order stream/drain ~0.7km north of the Bellanaboy Bridge Gas Terminal site.

* This Site is a marine site and is also addressed in Chapter 14.

The following assessments were carried out as part of the fieldwork for this assessment:

- **Habitat assessment:** The quality of the habitat was assessed with regard to its suitability as habitat for invertebrate and plant communities as well as for supporting fish population.
- **Water Quality Assessment:** Biological sampling was carried out to determine the water quality of the site and was classified in accordance with the EPA Biological River Classification System (Q-values).
- **Aquatic flora assessment:** Assessment of in-stream vegetation.
- **Assessment of fish stocks:** Fish stocks were not directly assessed (by electrofishing) on the small watercourses because they were too small to warrant it (i.e. Site 1, 4 and 5) and Site 3 is estuarine. In the latter case, an assessment relied on historical electrofishing data (Aquens 2002, 2003) and an assessment of habitats was used to determine the fisheries value of the sites.

[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.
[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 13.1

File Ref: COR25MDR0470Mi2123A03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

13.3 EXISTING ENVIRONMENT

The study area for the proposed route is confined to Sruwaddacon Bay and the rivers and streams, which drain to the bay. The most prominent of these watercourses are the Glenamoy and Muingnabo Rivers, both of which enter the head of the bay. Sruwaddacon Bay and the lower sections of the Glenamoy and Muingnabo Rivers are all part of the Glenamoy Bog Complex Special Area of Conservation (see Preface to Section C of this EIS). Sites 1, 3, 4 and 5 are all of minor ecological importance within the wider study area, however, Sites 1 and 3 lie within the SAC. Site 2, which also lies within the SAC, is an important migratory route for Annex II species, Atlantic salmon in particular (see Preamble to Section C). The existing environment is described in more detail in the following sections in terms of the information retrieved from the desktop (including consultation) and field study.

13.3.1 Desktop Study

13.3.1.1 Protected Species

Just one Annex II species has been reported by the Central Fisheries Board (CFB) and Marine Institute from the general study area, namely Atlantic salmon (from the Glenamoy and Muingnabo Rivers). Of the other aquatic Annex II 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 Bellanaboy 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 (Site 3) (Aquens, 2003) at a point about 200m upstream of the proposed crossing. 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. The CFB did not record any lamprey from their surveys undertaken in October 2006 near the confluence of the Muingnabo and Glenamoy Rivers in upper Sruwaddacon Bay.

The freshwater pearl mussel has not been recorded in the area (according to the national database for the species (pers. comm. Dr. Evelyn Moorkens) and were it 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 any of the small streams traversed by the proposed route. Furthermore they do not occur in estuarine waters and so would not be present in Sruwaddacon Bay.

The white-clawed crayfish was not encountered during current or previous fieldwork in the study area and is almost certainly absent given the unsuitable soft-water, non-alkaline conditions. No sea lamprey (*Petromyzon marinus*) were found and none have been reported by the NPWS or the NWRFB or local anglers.

13.3.1.2 Water Quality

Biological water quality is monitored by the Environmental Protection Agency (EPA) and includes survey data for the Muingnabo and Glenamoy Rivers within the Study Area (Hydrometric Area 33) but not for minor streams, which will be crossed by the proposed route. Results available are summarised in Table 13.2. It is clear from the EPA data that despite some water quality impairment, these two rivers are eminently suitable for salmonids.

Table 13.2: Biological Water Quality Information reported by the EPA for the Muingnabo and Glenamoy Rivers.

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	Glenamoy Bridge	4-5	3-4	4-5	4-5	4-5	4	4
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

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.

13.3.1.3 Fisheries Information

Glenamoy River

The Glenamoy River (Plate 13.1) is the most important river within the study area for both salmon and seatrout production and 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 Gleann na Muaidhe (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 Gleann na Muaidhe (Glenamoy) Village, the river mainly comprises holding and nursery areas for salmon and trout, the most important of which is located at the mouth of Sruwaddacon Bay in a deep bend in the river situated upstream of Rossport Pier and seaward of Pollatomish Pier. Elsewhere within Sruwaddacon Bay the channel is considered too shallow to hold many fish (pers. comm. NWRFB). In contrast to nearby Carrowmore Lake the Glenamoy River is a late river, with adult salmon concentrated here between the second week of June into September. This fishery normally didn't catch salmon until the second week in June even though the licence covered the period May 12th to July 31st. Since a ban was imposed on driftnetting on 1st January 2007, there are signs of more fish returning into the system in 2007 (pers comm., NWRFB). Two drift net licences, which operate at the mouth of Sruwaddacon Bay, have been suspended until further notice.

The fish counters installed by the NWRFB on the outfall from Carrowmore Lake indicate that the smolt[4] run (salmon and seatrout) is finished by the second week in May. Investigations undertaken in the Glenamoy River in spring 2009 showed that the peak smolt run occurred in mid to late April, while in 2010 no smolts had been recorded by the middle of the first week in May (pers comm. NWRFB). The later run in 2010 is thought to relate to the very cold weather in the first 2 months of 2010, which would have slowed the development of the smolts in combination with low water levels in the Glenamoy 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 Pollatomish 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 on the Glenamoy River and the association also issues permits to visiting anglers.

Plate 13.1: Glenamoy River looking downstream from Glenamoy Bridge about 5km upstream Sruwaddacon Bay.

Muingnabo River

Limited electrofishing data is available for the Muingnabo River, but what is available indicates the presence of trout (pers. comm. Salmon Research Agency). Despite the likelihood of suitable spawning areas for salmon and trout based on the rivers hydromorphology, it is clear from discussions with the NWRFB that this river is more important for trout and seatrout than salmon. Some limited angling is believed to take place in the lower reaches (pers comm. NWRFB), just upstream and downstream of Annie Brady's Bridge (Plate 13.2). Up until a few years ago, poaching nets were regularly taken from the river indicating its reasonable productivity.

Plate 13.2: Muingnabo River looking downstream from Annie Brady's Bridge and about 3km upstream of Sruwaddacon Bay.

13.3.2 Field Study

A summary of the results of the field assessment is presented in Table 13.3. The results are presented in full in Appendix K.

Table 13.3: Summary of the results yielded from the field study of watercourses traversed by the proposed route.

Crossing / Sampling Site (Irish National Grid Reference)	Q-Value Rating	Aquatic Flora	Habitat Description	Importance / Classification (Based on field assessment of sites)
1 (F82063 38465)	Q3-4	*Montia fontana* (Blinks) present marginally	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 ecological value. This stream runs into the Glenamoy Bog complex SAC.
2	N/a	N/a	Marine Habitat (See Chapter 14).	High Ecological Value as Migratory Route for Salmon and Seatrout. Lies within the Glenamoy Bog Complex SAC
3 (F85880 35062)	Q 4-5, 10m up-stream*	Devoid of in-channel flora at crossing point, *Fontinalis* (moss) upstream, *Fucus* (brown seaweed) downstream	Moderate to slow flow glide, coarse (angular cobble substrate).	Low to moderate ecological value. Probably used by eel, and intermittently by trout; gobies immediately downstream. This stream runs into the Glenamoy Bog Complex SAC and the crossing point for the pipeline is within the SAC.
4 (F86477 34520)	Q4	*Potamogeton sp*. and *Callitriche stagnalis* present at water surface	Very slow-flow, canal-like stream with typical macroinvertebrate types present (water beetles, damselfly larvae, water boatmen etc.).	Moderate to low ecological value; unsuitable at the crossing site for salmonid fish or lamprey, although these could be present further downstream. Lies outside the Glenamoy Bog Complex SAC.
5 (F86258 34069)	N/a	In-stream vegetation at crossing point, some Flote grass (*Glyceria* sp.) and Water starwort (*Callitriche stagnalis*) immediately upstream.	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 ecological and fisheries value at the site; trout, eel and lamprey known from further down in the catchment (Leenamore River). Lies outside the Glenamoy Bog Complex SAC.

*Estuarine influence at the proposed route crossing point thus unsuitable for Q-rating. Instead Q-value rating was undertaken 10m upstream of the proposed crossing point.

13.4 POTENTIAL IMPACTS

The methodologies used to determine the magnitude of the impacts outlined in the following section take into account the guidelines given by the EPA and the NRA in their publications:

- *Guidelines on the information to be contained in Environmental Impact Statements (EPA 2002);*
- *Advice Notes on Current Practice in the Preparation of Environmental Impact Statements (EPA 2003);*
- *Environmental Assessment and Construction Guidelines (NRA 2004-2010); and*

The assessment of potential impacts have been broadly based on the criteria for assessment of impacts in aquatic systems as outlined in Tables 13.4 and 13.5.

Table 13.4: Qualifying criteria used for rating water courses.

Rating	Qualifying Criteria	Qualifying Criteria
A	Internationally Important	Sites designated or qualifying for designation as SAC or SPA under the EU Habitat or Birds Directive. Major Salmon River Fishery.
B	Nationally Important	Sites or waters designated or proposed as an NHA or Statutory Nature Reserves. Major Trout River fishery. Water bodies with major amenity fishery value. Commercially important coarse fishery.
C	High Value, locally important	Small waterbodies with known salmonid populations or with good potential salmonid habitat. Sites containing any resident or regularly occurring population of Annex II species.
D	Moderate value, locally important	Small water bodies with some coarse fisheries or some potential salmonid habitat. Any water body with unpolluted water (Q-value rating 4-5).
E	Low value, locally important	Artificial or highly modified habitats with low species diversity and low wildlife value. Water bodies with no current fisheries value and no significant potential fisheries value.

Table 13.5: Criteria used for assessing impact level on water courses.

A Sites				
	Temporary	**Short-term**	**Medium-term**	**Long-term**
Extensive	Major	Severe	Severe	Severe
Localised	Major	Major	Severe	Severe
B Sites				
	Temporary	**Short-term**	**Medium-term**	**Long-term**
Extensive	Major	Major	Severe	Severe
Localised	Moderate	Moderate	Major	Major
C Sites				
	Temporary	**Short-term**	**Medium-term**	**Long-term**
Extensive	Moderate	Moderate	Major	Major
Localised	Minor	Moderate	Moderate	Moderate
D Sites				
	Temporary	**Short-term**	**Medium-term**	**Long-term**
Extensive	Minor	Minor	Moderate	Moderate
Localised	Not significant	Minor	Minor	Minor

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 phases of the pipeline. Once in operation, there will be no impacts on freshwater resources. The following sections therefore deal with the potential impacts associated with the construction phase and the commissioning/testing phase of the proposed development. A review of the proposed construction methods was undertaken in order to examine the potential impact of the proposed development.

As outlined in Chapter 5, it is proposed to construct underneath Sruwaddacon Bay using a segment lined tunnel which will minimise disturbance of the Bay. However, in the very unlikely event that a temporary intervention pit is required during the construction phase, then there is potential to cause impact to migratory fish (salmon and lamprey). The other sites (Site 1, 3, 4 and 5) will be crossed using an open-cut method where a trench is excavated to install the pipeline, services, etc.

A summary of the potential impacts identified for the construction and commissioning phases of the proposed development is presented in Table 13.10.

There are five principal types of potential impact associated with the proposed construction although only one (the release of suspended solids) is considered the most likely source of impact. These include:

1. Release of suspended solids;
2. Release of contaminants (e.g. cement, oil);
3. Temporary disruption to habitats;
4. Noise from the TBM; and
5. Phosphate mobilisation.

In addition the 'worst case' scenario (Section 13.4.2) and the 'no development' scenario (Section 13.4.3) are addressed. Furthermore, details on the assessment of the risk of phosphate mobilisation are provided below.

13.4.1 Releases of Suspended Solids

Without mitigation, the excavation of open-cut crossings can generate considerable amounts of suspended sediment. At Site 3 which is located on the foreshore, where the river is subject to full tidal inundation when the tide is in, potential impacts on freshwater life are extremely low and impacts on intertidal or estuarine life are also likely to be low because of the very large dilutions available from the tidal waters. Nevertheless, simple mitigation measures can reduce such siltation very considerably. In the case of Site 4 and 5, because they are located toward the head of their respective small catchments, suspended solids from these sites are potentially more damaging to freshwater life downstream. However, simple mitigation measures can reduce these potential impacts to acceptable levels.

In the very unlikely event that a temporary intervention pit is required within Sruwaddacon Bay, excavation and de-watering of cofferdams can have the potential to give rise to elevated suspended solids, a feature which can also be mitigated. During tunnelling there is a potential risk (albeit very low) of bentonite clay leaking into Sruwaddacon Bay. This would cause an increase in suspended solids in the vicinity of the leaks.

Construction of the tunnel will require a large tunnelling compound at Na hEachú (Aghoos) and a small compound at Gleann an Ghad (Glengad) from which suspended solids could escape into the bay. The Aghoos tunnelling compound will contain the bentonite handling plant which includes separation and recycling facilities, a storage area for tunnelling arisings as well as associated contaminated runoff storage and treatment facilities. Leaks from the surface water drainage system in the compound and/or failure or malfunction of the treatment system has the potential to result in the discharge of suspended solids into the bay with the possibility of adversely impacting migrating salmon if it occurred during the migratory season.

The main potential impacts of excessive suspended solids are (i) smothering of fish spawning beds in rivers and streams, some of which, occur downstream of Sites 4 and 5, (ii) damage to fish gills which if severe enough could result in gill disease and increased levels of mortality and (iii) damage to aquatic macroinvertebrates, which form a food source for fish. Within Sruwaddacon Bay, elevated suspended solids occurring during the passage of smolts could cause them to alter their swimming patterns, which may expose them to greater risk of predation by fish-eating birds. Impacts on adult migratory salmon would be expected to be less likely although in a worst case these might be slowed in their progress up the bay. As indicated above, the risk of all these potential impacts can be considerably reduced by mitigation (see Section 13.5).

13.4.2 Release of Contaminants

13.4.2.1 Cement and Oil

Concrete will be used in the construction of the tunnelling compounds (see Chapter 5) and although unlikely there is a very remote possibility that a spill might reach the shoreline, where the high pH of the cement could cause fish kills. This potential impact is easily mitigated by good engineering practice. Cement grout will be used in the lining of the tunnel and within the tunnel. Given that it is a viscous material and because it will be pumped at low pressure, it is considered a very remote possibility that any will escape up through the sediment overburden to reach the waters of the bay. It will be batched in the Aghoos tunnelling compound within a separate drainage area, the run-off from which will be treated. Therefore, the possibility of adverse impacts from the use of cement grout is expected to be very low. Oil spills from construction vehicles and plant can cause damage to fisheries and the environment. However, such impacts can be easily prevented by suitable mitigation.

13.4.2.2 Commissioning – Hydrostatic Testing

When the pipeline is in place it will have to be filled with water and pressurised to its test pressure. The water will then be discharged at the end of the water outfall pipe offshore. Although, it is considered unlikely, the water may become contaminated during testing e.g. with suspended solids, heavy 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, appropriate treatment can be carried out to mitigate this.

13.4.3 Temporary Disruption to Habitats

The quality of the habitats in terms of spawning, feeding or nursery for fish at Sites 1, 3, 4 and 5 is considered low to moderate. For this reason, the temporary damage to the habitat associated with open-cut crossings can be described as minor. Nevertheless, simple mitigation measures can serve to virtually eliminate this impact.

13.4.4 Noise from the TBM

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.

13.4.4.1 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*.

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. 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. 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.

13.4.4.2 Noise Output from the TBM

Appendix H3 presents the noise output model for the TBM during its passage beneath the 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 measurements 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 about 10m of the TBM, to about 140-120dB re 1µPa at 90m distance. These sound levels are the highest modelled.

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 to 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.

Table 13.6 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 13.6: Approximate sound pressure levels (SPL) at 0-10m and 90m from the TBM at five frequencies

Frequency	Approximate SPL at 0-10m	Approximate SPL at 90m	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 13.6 also shows 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 13.7). These show that for the TBM the highest levels of exceedence of the thresholds are in the higher frequencies.

Table 13.7: Approximate noise levels in units of particle acceleration at 0-10m and 90m from the TBM at five frequencies

Frequency	**Approximate particle acceleration sound level at 0-10m**	**Approximate particle acceleration sound level at 90m**	**Salmon hearing Threshold[5]**	**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 13.7 also shows 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.

13.4.4.3 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 13.6 above, suggests that the degree of exceedence of the hearing threshold by the salmon in terms of pressure (Table 13.6) 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 13.8).

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

Table 13.8: 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	Strong reaction by the majority of individuals, but habituation may limit effect
90dB and above	Stronger avoidance reaction by virtually all individuals

Using this scale, and comparing it with the figures in the two last columns in Table 13.6 suggests that there exists the possibility of avoidance reactions by some salmon of the TBM noise, particularly in the near field (0-10m). In terms of sound as particle motion (the form to which salmon are considered most sensitive), Table 13.9 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 13.9 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 13.9: Approximate noise levels in units of particle acceleration at 0-10m and 90m from the TBM at five frequencies

Frequency	Exceedence of salmon hearing threshold (at 0-10m)	Exceedence of salmon hearing threshold (at 90m)	Salmon hearing Threshold[6]	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 13.9 also shows 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)

Thus, using the Nedwell *et al.,* (2007) assessment scale (Table 13.8), and the data in Table 13.6, 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 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 13.7), as these do not exceed reaction thresholds at the frequencies in question (Table 13.9).

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

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 reported in the literature (LaBar *et al.*, 1978; Moore *et al.*, 1998). 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.

13.4.4.4 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. No data could be found 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.

13.4.4.5 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.

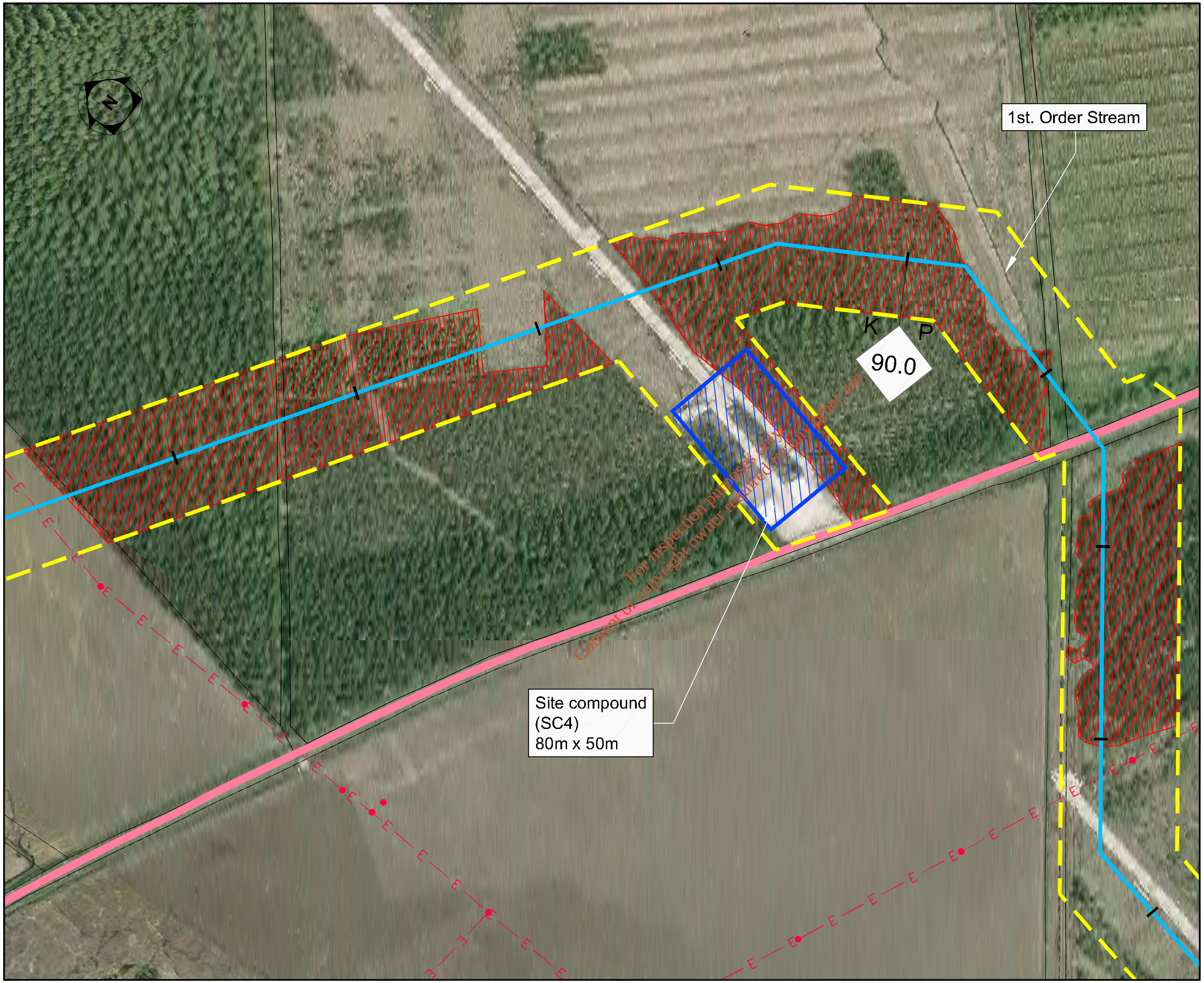
13.4.5 Phosphate Mobilisation

Tree felling is associated with phosphate mobilisation, which can impact on water quality. It is proposed to fell approximately 3ha of trees (in peatlands) as part of the construction of the proposed development (See Figure 13.2). The area to be felled represents 1% of approximately 374ha commercial coniferous forest (in Béal an Ghoile (Ballygelly) South) of non native lodgepole pine, owned and managed by Coillte. When mature, these conifers would be due for felling in rotation. Coillte own approximately 40,350 ha of land in Co. Mayo for forestry.

The main migration pathway whereby phosphate enters surface watercourses is via surface water run-off but it can also be leached from sediment released into watercourse. It is anticipated that the principal source of any phosphate in the area is rock phosphate, which was used as a forestry fertiliser in the area in the past.

In order to ensure that runoff waters from the exposed peat, after felling of the trees, do not result in phosphate contamination of nearby surface water courses, mitigation measures will be put in place. These will include the implementation of sedimentation control, avoidance of works in periods of high rainfall, and the use of the fresh brash mats on machine routes, to avoid soil damage, erosion and sedimentation. Appropriate settlement and filtration methods will be used to reduce sediment emissions from excavated spoil to the watercourse. The Environmental Management Plan (see Chapter 18 of the EIS) will also establish monitoring protocols for sediment control. Furthermore, the topography of the area is relatively flat and therefore it will be easier to control drainage from the site.

No significant water courses exist in the area where tree felling is required. A short section (1m -1.2m wide) of a first order stream exists at chainage 90.15 (see outline of stream in Figure 13.2), the area of which will be felled. This minor stream does not lead to any sensitive fisheries or drinking water sources. This stream and the drainage from the area to be felled discharges directly to the upper tidal reaches of Sruwaddacon Bay via small streams and drainage channels (see Catchment Map in Chapter 15). It should also be noted that these are transitional waters, where phosphate is already naturally present.



Tree Areas to be Felled

Areas of Trees to be felled for Construction of Corrib Onshore Pipeline

Figure 13.2

File Ref: COR25MDR0470Fg 13.2A03
Date: May 2010
Scale: NTS

CORRIB ONSHORE PIPELINE

It is anticipated that the risk of phosphate mobilisation and the impact on water quality will be low because of the relatively small size of the area required to be felled, the temporary nature of the works, the implementation of mitigation measures as outlined above and the low sensitivity of the receiving environment.

Conifer felling should be seen in the context of local forest management which has seen extensive (ongoing) clear-felling of large areas of conifer plantation in recent years.

13.4.6 Impact Assessment Summary

A summary of potential impacts is provided in Table 13.10 below.

Table 13.10: Summary of the potential impacts (including likelihood of the occurrence and significance) for both open cut (Sites 3, 4 and 5) and tunnelling (Site 2), in the absence of mitigation.

Crossing /Sampling Site	Nature of the Impact	Importance of the Habitats (according to Table 13.4)	Significance of Impact (according to Table 13.5)	Duration	Likelihood of Occurrence
1*	Damage to habitat and invertebrates	Moderate value, locally important	Not significant	**Temporary	Low
2	Increased risk to smolts from suspended solids between late March and early May	Internationally Important	Major	Temporary	Low
3	Damage to habitat and invertebrates	High value- locally important	Minor	Temporary	Moderate
4	Damage to habitat and invertebrates, damage to spawning beds	High value-, locally important	Minor	Temporary	Moderate
5	Damage to habitat and invertebrates, damage to spawning beds	High value-, locally important	Minor	Temporary	Moderate

* This site is not crossed by the proposed route but lies within the temporary working area. ** Temporary = impact lasting for 1 year or less.

A summary of the mitigation measures recommended for each stream/river crossing of the proposed development are provided in Table 13.11. In addition to these measures detailed method statements will be drawn up and agreed with NWRFB and NPWS prior to undertaking the crossings. Furthermore, works within the above crossings are likely to be supervised by staff from NWRFB. Moreover, a programme of monitoring of suspended solids will be undertaken during the works.

13.4.7 'Worst Case' Scenario

In the event that mitigation measures fail it is possible that certain aspects of the construction activities could have an adverse affect on the habitats and invertebrates.

There is potential for siltation to occur downstream of each crossing if 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 the case of Site 3 only - 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 migrate 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 as Sites 4 and 5 are crossed upstream of their respective watercourses, there is potential for a greater length of downstream channel to be impacted. In these cases special care will need to be taken during construction. In the case of Site 3, because it is both very close to its discharge to the seashore, only 5-10m of channel would be impacted by siltation.

In a worst case scenario, i.e. if a temporary intervention pit is required in or close to permanent low-tide channels, the associated works in Sruwaddacon Bay may produce high suspended solids concentrations for short periods, at least close to the works and especially if works are undertaken in areas where tidal currents are strong (e.g. by the main tidal channels and in the outer bay). If this occurred during times of migration, smolts may alter their swimming behaviour or slow their migration 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, that 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 and Lloyd 1980)). It seems unlikely therefore that returning adults would be prevented from passing the works in Sruwaddacon, although slowing their rate of migration during periods of increased solids washout from the works is possible. 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, however, are considered to be very unlikely to occur. Similar risks would be associated with a bentonite breakout, in the unlikely event of one occurring.

13.4.8 'No Development' Scenario

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.

13.5 MITIGATION MEASURES

13.5.1 Aghoos Tunnelling Compound

The tunnelling compound at Na hEachú (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 compound 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 the compound has the potential to give rise to solids discharge during peat excavations. However careful construction management, in particular the channelling of all run-off to settlement and filtration, will reduce this risk very considerably.

The above mitigation measures should reduce to negligible the possibility of any impacts occurring from this compound. The most sensitive receptors would be migrating salmon or salmon smolts during their migratory periods.

13.5.2 Tunnelling

Bentonite pressure and rate of usage will be constantly monitored at the tunnelling control area within the Aghoos tunnelling compound in order to detect any change in pressure that might indicate a breakout. If the latter is detected, pumping will immediately cease.

13.5.3 Stream Crossings

Flumes will be used to divert the stream over the stream crossing points in order to facilitate construction of crossings in the dry. This will considerably reduce the amount of silt likely to escape during construction of the crossings.

13.5.4 Intervention Pit

In the unlikely event that an intervention pit will be required this will be enclosed by an inner and outer rectangle of sheet piles to isolate the pit. Spoil excavated from the pit will be placed between the inner and outer sheet-pile walls and any excess brought ashore. If water needs to be pumped from the pit this will be treated by settlement in a settlement tank on board a floatable pontoon alongside the pit.

13.5.5 Timing of Works

As outlined in Chapter 5, it is expected that the construction phase of the Corrib Onshore Pipeline will be carried out over approximately 26 months. Tunnelling underneath the bay may coincide with migrating salmonids in the April-May (smolts) and July - September period (adults). In the very unlikely event of an intervention pit being required within the bay the NWRFB will be notified and consulted in advance. In the event that such works might be required within the sensitive periods, additional mitigation measures such as the monitoring of smolt upstream of the works to allow breaks in the works for the passage of smolt and appropriate filtration of works will be undertaken.

The quality of the habitats in terms of spawning, feeding or nursery for fish at Sites 1, 4 and 5 is of low ecological value, while at Site 3, the Leenamore River (due to its higher flow and larger dimensions) is slightly higher. For this reason, the temporary damage to the habitat associated with open-cut crossings at all streams except the Leenamore River can be described as minor to negligible, with the latter described as minor. Nevertheless, simple mitigation measures will serve to virtually eliminate this impact. These include diversion of stream flow through flume pipes, while excavating the crossings, settlement and filtration of water from the de-watering of trenches, retaining streambed substrate and replacing this after the trench has been back-filled. In any case all works will be undertaken only with the prior agreement of NWRFB.

It is therefore not considered necessary that works in river/stream crossings are undertaken outside of the sensitive seasons. However, it is acknowledged that the implementation of the aforementioned mitigation measures will be of the utmost importance during the works.

Table 13.11: Summary of mitigation measures at each stream/river crossing and at tunnelling compounds.

Crossings	Construction Phase						Commissioning Phase
Stream / River crossings	Divert stream flow through flume pipe, while excavating crossing. (Sites (1*), 3, 4, 5)	Pump-over with in-stream filter material-straw bales or similar. (Site 4).	Settlement and filtration of water from the de-watering of trenches. (Sites (1*), 3, 4, 5)	Retain streambed substrate at crossing and replace after the trench has been back-filled. (Site 3)	Temporary bridging structures for access across the watercourses. (Sites (1*), 3, 4 and 5).	Construction during dry weather. (Sites 3, 4 and 5)	Analyse and if necessary treat hydrostatic test water before discharge to marine waters.
Sruwaddacon Bay Site 2	Use of segment lining tunnelling method.	If a temporary intervention pit is required within the bay all works will be agreed with NWRFB prior to undertaking.	Monitor for smolt upstream of works. Allow breaks in the works for the passage of smolt if necessary.	If a temporary intervention pit is required appropriate filtration systems will be provided for all de-waterings before release to the bay.	Monitoring of suspended solids.	Continuous monitoring of bentonite use in order to detect leaks or breakout.	
Tunnelling Compounds Site 2	Discharge no contaminated water or drilling fluids from the tunnelling works into Sruwaddacon Bay.	Route all run-off from the construction and operation of the compounds through suitable settlement and filtration processes before discharge and monitor the pH and suspended solids / turbidity levels of the discharge.	Install a hydrocarbon interceptor on the run-off from the compound.	Bund all bentonite processing, treatment, storage or batching areas. Use a filter press as part of the treatment system.	Bund all cement handling, or storage areas. Use a filter press as part of the treatment system.	Bund and secure all oil storage and re-fuelling facilities.	

*It is not anticipated that any works will occur at Site 1 however, mitigation measures have been recommended in the event that works are required.

13.6 RESIDUAL IMPACTS

There will be no residual impacts on Freshwater Ecology.

Once the recommended mitigation measures are implemented only minor to negligible impacts on the streams (Sites 1, 3, 4 and 5) can be expected. This will be in the form of minor silt deposition on the streambeds below the crossings. These impacts will be temporary, lasting no more than one year or less in most cases.

Once all necessary mitigation measures are taken in the case of the tunnelling beneath Sruwaddacon Bay and the associated compounds, 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.

14 MARINE ENVIRONMENT

14.1 INTRODUCTION

This chapter describes the potential impacts of the construction and operation of the proposed Corrib Onshore Pipeline on the estuarine and marine environment. Sruwaddacon Bay shown on Figure 14.1 is considered in this impact assessment.

No impacts on the marine environment will occur as a result of the operation of the proposed development. The construction phase however has the potential to impact on the marine environment and therefore a review of the proposed construction methodologies (see Chapter 5) has been undertaken to assess the potential impacts and outline mitigation measures to prevent or minimise these potential impacts.

Sruwaddacon Bay is a dynamic ecosystem providing a transitional zone between the freshwater riverine flow and the fully marine environment of Broadhaven Bay. The entire estuary is continuously swept by semi-diurnal tides. Consequently, a general understanding of the oceanographic and geomorphological conditions within the estuary is required to gain a full understanding of the marine environment along the proposed route, including the route of the tunnel from Gleann an Ghad (Glengad) to Na hEachú (Aghoos).

Sections 14.2 to 14.6 below provide details on the proposed methodology, existing environment, potential impacts and mitigation measures. Oceanography and Hydrography are discussed separately in Section 14.7.

This impact assessment was undertaken by RPS. Further details on survey results, hydrodynamic modelling and bibliography are provided in Appendix L.

Details on designated conservation sites including the legislative context are provided in the Preface to Section C.

14.2 METHODOLOGY

The purpose of the assessment was to gain an understanding of the marine environment along the route of the proposed development through a literature review and consultation (Section 14.2.1) and marine and field surveys (Section 14.2.2). The key objectives of the assessment were to:

- identify habitats or species on, or close to, the proposed route, which are likely to be of commercial, scientific or conservation value;
- investigate the presence of protected species of flora or fauna;
- evaluate the estuary's importance to more mobile marine species including fisheries (resident and migratory) and for marine mammals; and
- evaluate and model the hydrodynamics of the bay in order to understand oceanographic changes caused by different construction methodologies.

14.2.1 Literature Review and Consultation

Information was obtained from the following sources:

- Most existing literature is already represented in the EIS for the Corrib Field Development (2001). This covers both existing published literature relating to the local fisheries, cetaceans and sea mammals and benthic communities within the region, but also site specific survey data carried out as part of the study at that time.

- Marine fish species: Central Fisheries Board METRIC Estuary Investigation of Sruwaddacon Bay 2006 (CFB, 2006).
- Consultation with National Parks and Wildlife Services and North Western Regional Fisheries Board.
- Dedicated survey effort, validated records of incidental sightings and standings from the database maintained by the Irish Whale and Dolphin Group (www.iwdg.ie) performed for the period since the submission of the original EIS (October 2001).
- Marine mammal observation surveys from the coast of Broadhaven Bay in 2001-2002 (O Cadhla *et al*., 2003), 2005 (CMRC, 2006), and during acoustic survey operations in 2008 (OSC, 2008 & Coppock, 2008) along with further observations from within Sruwaddacon Bay and Curraunboy Bay during all geophysical survey operations (Conner, 2007) and the ongoing monitoring programme in Broadhaven Bay (CMRC, 2010).

14.2.2 Marine and Field Surveys

The following marine surveys were undertaken between 2007 and 2010 for the purposes of this impact assessment:

- Marine habitat mapping and benthic ecology of Sruwaddacon Bay area (RSK and Ecoserve, 2007, Wilson, 2007_2 and Wilson 2010_1).

  Information on the marine environment and ecology provided is based on a review of the existing literature and further fieldwork undertaken by Ecoserve and RSK in the summer of 2007 with a further benthic assessment undertaken by Wilson (RPS) at selected sites in the winter of 2007, and more extensively throughout the estuary, in 2010.

  Sub-tidal and inter-tidal field surveys addressed both regional habitat and site-specific benthic communities along the proposed route and were carried out in accordance with habitats assessments by MESH (Mapping European Seabed Habitats) and MNCR (Marine Nature Conservation Review; Connor *et al*., 2004). These results are summarised below (Section 14.3) while details on all survey data are contained in Appendix L.

  The main objectives of the study was to collect information with which to establish an overall description of the inter-tidal (and shallow sub-tidal) environments of the survey sites and from which to detect any potential future changes as a result of construction. The survey was to identify sensitive habitats and species that might be affected by the development or would require special conservation under European legislation (See Preamble to Section C). Furthermore, to assess the size and availability of the flora, macro-invertebrates or fish species that may provide an important food source for over wintering birds within the SPA and larger predatory species (such as otters and seals) that may use the estuary from time to time (see Chapter 12).

  Sites previously surveyed of the upper and lower parts of Sruwaddacon Bay by Aqua-fact in 2000 and Ecoserve in 2001, were revisited by RSK and Ecoserve in 2007 to assess natural variability of these sites during the intervening years. The main body of the bay, however, are covered predominantly by the RSK 2007 study, and the two additional surveys undertaken by Wilson (RPS) in 2007 and 2010.

- Geomorphological survey data (bathymetry and seabed features) from a geophysical survey (Osiris 2007).

  Data acquired by Osiris in 2007 (see Section 14.3 and Chapter 15) as part of the geophysical assessment of Sruwaddacon Bay was further reviewed to provide a geomorphological map of both the inter-tidal and sub-tidal sediments within the bay. Produced from a combination of sidescan sonar reflectivity and bathymetric depth and reflectivity, these techniques can delineate variations in sediment types and physical attributes over the entire site covered by the survey vessel. These data were compared with the ground truthed habitat mapping undertaken on foot and by seabed samples undertaken at the same time by both RSK and Ecoserve in the same year.

- Marine mammal observations within Sruwaddacon Bay during all geophysical survey operations (Osiris and Conner, 2007).

  Data acquired during the Osiris 2007 geophysical assessment of Sruwaddacon Bay estuary was supported by marine mammal observations onsite, and provides important supplementary information as to excursion of marine mammals into Sruwaddacon Bay. The presence of marine mammals were further recorded when observed during other survey operations carried out within the estuary between 2007 and 2010.

- Oceanographic survey undertaken within Sruwaddacon Bay estuary (EGS, 2007) and reworked into an oceanographic overview (Wilson, 2007_1).

  Oceanographic data acquired for the hydrodynamic model validation reviewed and assessed by RPS to provide a broad understanding of tidal flows and levels at various points along the estuary. This provides an idea of operational constraints due to very shallow waters and tidal heights taken into account during other survey works carried out for this assessment and in finding suitable construction methodologies for the proposed pipeline.

- Modelling of the oceanographic data to provide a numerical hydrodynamic model of the Sruwaddacon Bay estuary (HR Wallingford, 2007) and preliminary validation assessment (Wilson 2010_2).

  Hydrodynamic modelling of Sruwaddacon Bay was undertaken by HR Wallingford. The results of this modelling are summarised below (Section 14.7) while the modelling report is provided in Appendix L. A brief validation assessment was carried out using drogue streamlining in the central part of the bay by Wilson in winter of 2010 (Wilson 2010_2).

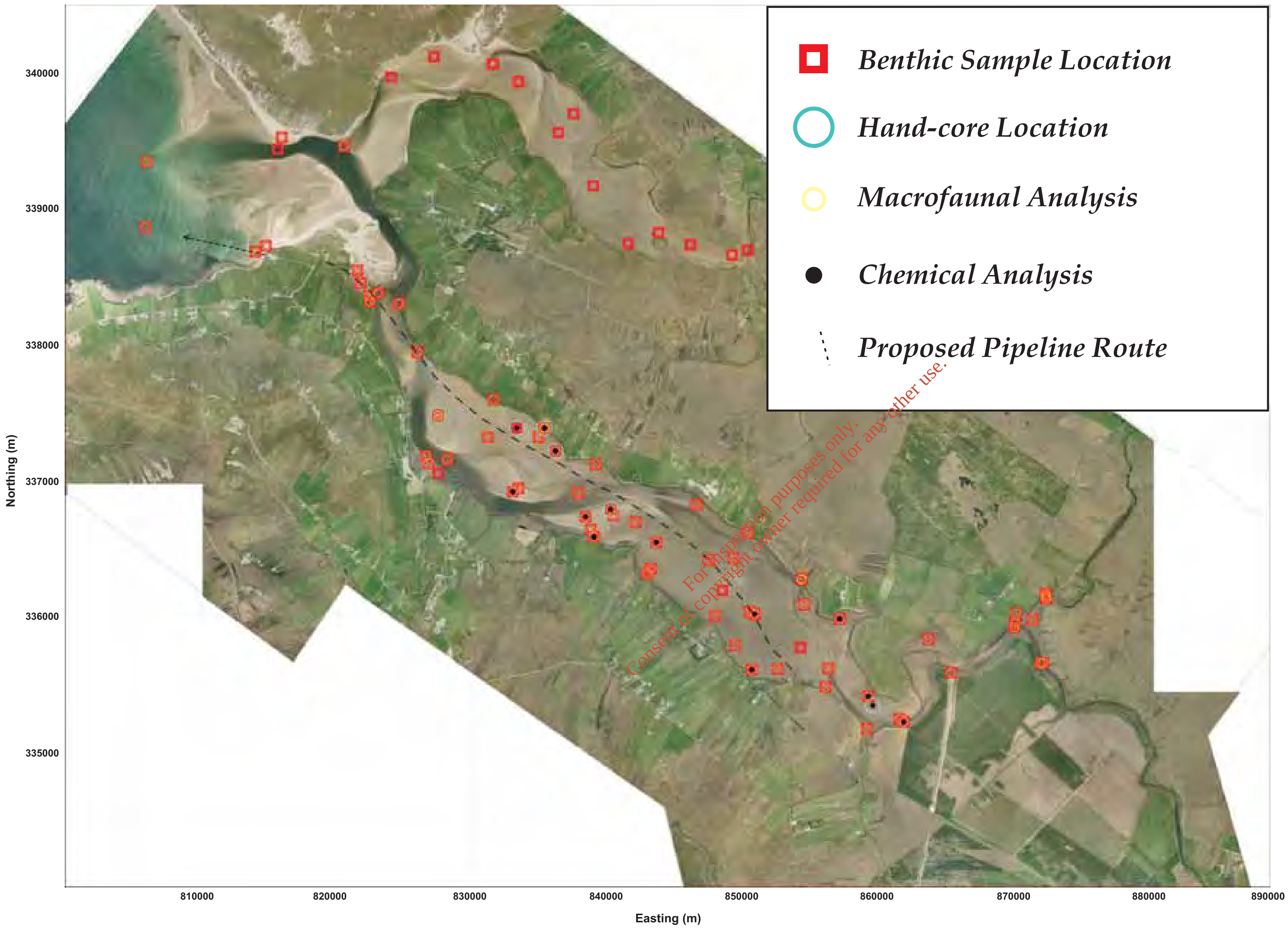
- Baseline Survey of Fish Communities in the Sruwaddacon Estuary 2008 (CFB, 2008).

  A repeated survey of the fish communities of the Sruwaddacon Estuary to assess the springtime use within the estuary, carried out by the Central Fisheries Board. Field operations were completed in May 2008 as per the 2006 METRIC procedures, using the same techniques and equipment as the earlier study.

14.2.2.1 Marine Ecology Surveys

In July 2007, a walkover survey of the inter-tidal areas and the lower Sruwaddacon Bay crossing point, proposed at that time was undertaken by Ecoserve, in line with a previous study at this site by Aqua-fact in 2000 and Ecoserve in 2001. This area represents the initial marine section of the proposed pipeline route as it passes southeast of the Gleann an Ghad (Glengad) landfall. The littoral biotopes were mapped down the shore and quantitative samples taken from each of the principal biotopes. The biotopes were mapped and interpreted using the biotope classification provided by Connor *et al.* (1997). In addition triplicate replicate macro-invertebrate samples were taken at a number of stations using multiple cores (6.5cm diameter) to a depth of 10 cm and a combined survey area of ca.0.09m^2. Samples were passed through a 1 mm mesh sieve and later processed for macro invertebrate identification. These data build on existing samples acquired in the soft sediments taken at both of the previous surveys using similar devices. All samples were sieved using a 1mm aperture mesh with all invertebrates recovered, identified and counted.

Mapping of biotopes along the shore was undertaken using techniques developed by the SensMap project using Emblow *et al*. (1998) and Davies *et al*. (2001). Marine inter-tidal biotope mapping was based on the use of aerial photographs to map the distribution and extent of possible habitat changes and biotopes according to Marine Nature Conservation Review (MNCR; Connor *et al*., 2004). A 'wireframe' map was generated by delineating distinct features from the aerial photograph which were later ground-truthed onsite. Survey operations were generally conducted two hours either side of low water spring tides where possible.



Environmental Sample Positions within the Sruwaddacon Estuary (RSK, 2007 & Ecoserve 2007)

Figure 14.1

File Ref: MDR0470GrEIS007 RevA03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

Also in 2007, RSK completed a regional environmental assessment of the entire Sruwaddacon Bay system (including Curraunboy Bay, which is located to the north of Sruwaddacon Bay). All work in the inter-tidal and sub-tidal areas was performed using a GPS positioned hand-held personal data assistant (PDA) with pre-loaded sample locations and possible habitat changes identified using recent aerial photography.

Seabed sampling was undertaken in both the inter-tidal and sub-tidal zones by taking triplicate samples at all stations using a small Van Veen grab sampler (combined area of 0.09m^2 and a penetration of 10cm). A further sample was acquired and sub-sampled for particle size or chemical analysis. In total, 49 stations were sampled using grabs within the estuary area, as shown in Figure 14.1 (RSK, 2007), along with additional shallow sub-surface core samples at six of the locations. These were acquired using a 1m stainless steel corer with a removable plastic inner sleeve of (inner diameter - 50mm).

Cores were taken on an opportunistic basis to provide a coarse appraisal of homogeneity of near-surface sediments. The densities of the lugworm (*Arenicola marina),* a large macro-invertebrate species which burrows too deep to be effectively sampled using the grab, was also assessed at each location, when surveyed on foot, by carrying out a count of surface casts within a 10m^2 area (Plate 14.1).

Plate 14.1 *Arenicola marina* beds near Pollatomish Pier.

The very shallow nature and extensive inter-tidal area meant that access to the site by both personnel and vessels, was limited. Consequently survey operations were carried out using a relatively small and easily transportable grab type sampler (Van Veen) which has a surface sample area of 0.03m^2. This device generally limits penetration to between 5 and 10cm for many of the sites, missing larger animals, such as the lugworm (polychaete species *Arenicola marina*), which are able to burrow deeper. Consequently additional counts of casts were carried out at each sample point to allow for this factor. The aperture mesh size of 1mm used in the macro-invertebrate sampling was chosen to reflect the granular nature of the sediments recovered over much of the estuary. A greater number of macro-invertebrates would have been recovered if a finer 500µm mesh had been employed.

More comprehensive surveys of the sediment macro-invertebrates were carried out within the Srwuaddacon in subsequent years, with samples based on a larger surface areas (0.25m^2), a deeper surface penetration (15-20cm depth) and a combination of both coarse and fine aperture meshes (1000 and 500µm; Wilson 2007_1 and 2010_1). These indicated that approximately twice the number of individuals and a few more species are recorded if a finer 500µm mesh is used, although the overall biomass of this proportion is generally only a few percent of the total population due to the smaller size of the animals (Wilson, 2007_2). This was further confirmed by a later survey which was undertaken at 16 sites located throughout the bay in areas of exposed sand banks during periods of low water by RPS within the estuary (Wilson 2010_1). These sites were delineated to reflect areas identified by recent ornithological observations as banks routinely used by over-wintering birds. Sampling was undertaken to reflect both a vertical separation of the surface 5cm from the underlying 5-20cm, as well as a size separation of both 500 and 1000μm for each of these depths. Results showed that whilst 63% of the total macrofauna were recorded above 1mm, this proportion constituted over 91% of the biomass. The proportion of this material available to waders in the surface 5cm was equivalent to an average of 46% of the total fauna recorded by both number and biomass, although a high standard deviation of around 28% showed that this value varied from site to site dependant upon the variability of some larger faunal species (typically the cockle *Cerastoderma edule*, Wilson 2010_1).

In addition to macro-invertebrate analysis, biotopes were mapped based on the methodology used in Wyn *et al.* (2006), principally based on identifying the sediment type and algal characteristics, as well as diversity and abundance of the significant fauna present(RSK, 2007). Biotope notes were recorded directly onto a personal data assistant (PDA), using the device to position the key boundaries between sediment changes identified within the aerial photography, and concentrating in key areas where possible routes may cross the estuary. Provisional classifications of habitats were made in accordance to Connor *et al.* (2004) using a combination of field observations grain size analysis and macro-invertebrate assemblages present. Larger megafauna and epifauna were recorded by examining hard surfaces, looking on the undersides of rocks and seaweeds and by digging small holes and obvious burrows in addition to qualitative counts and biomass measurements (Wilson 2007, 1 and 2010_1).

14.2.2.2 Benthic Survey Data Limitations

Sruwaddacon Bay estuary is a dynamic transitional ecosystem which is continuously swept by the semi-diurnal tidal cycle along its entire length. As such, a general understanding of the oceanographic and geomorphological conditions is required for the whole estuary, in addition to site specific habitats recorded along the proposed route. Whilst the survey was undertaken in accordance with MESH and MNCR standard habitat mapping practices, large areas of generally homogenous environments were classified with relatively few samples, with the possibility of small or subtle variations on some sites remaining unrecorded.

The main benthic survey undertaken in 2007 within the bay exhibited some limitations to the data due to small sample area and shallow penetration where vertical migration of some more mobile species during prolonged periods of sand exposure may have occurred. This was only likely in areas where the underlying redox discontinuity layer (a depth in the sediment where the aerobic respiration ceases due to the lack of oxygen) was below the depth of the sampler, observed at only one station recorded in an exposed sandbank towards the downstream part of the bay.

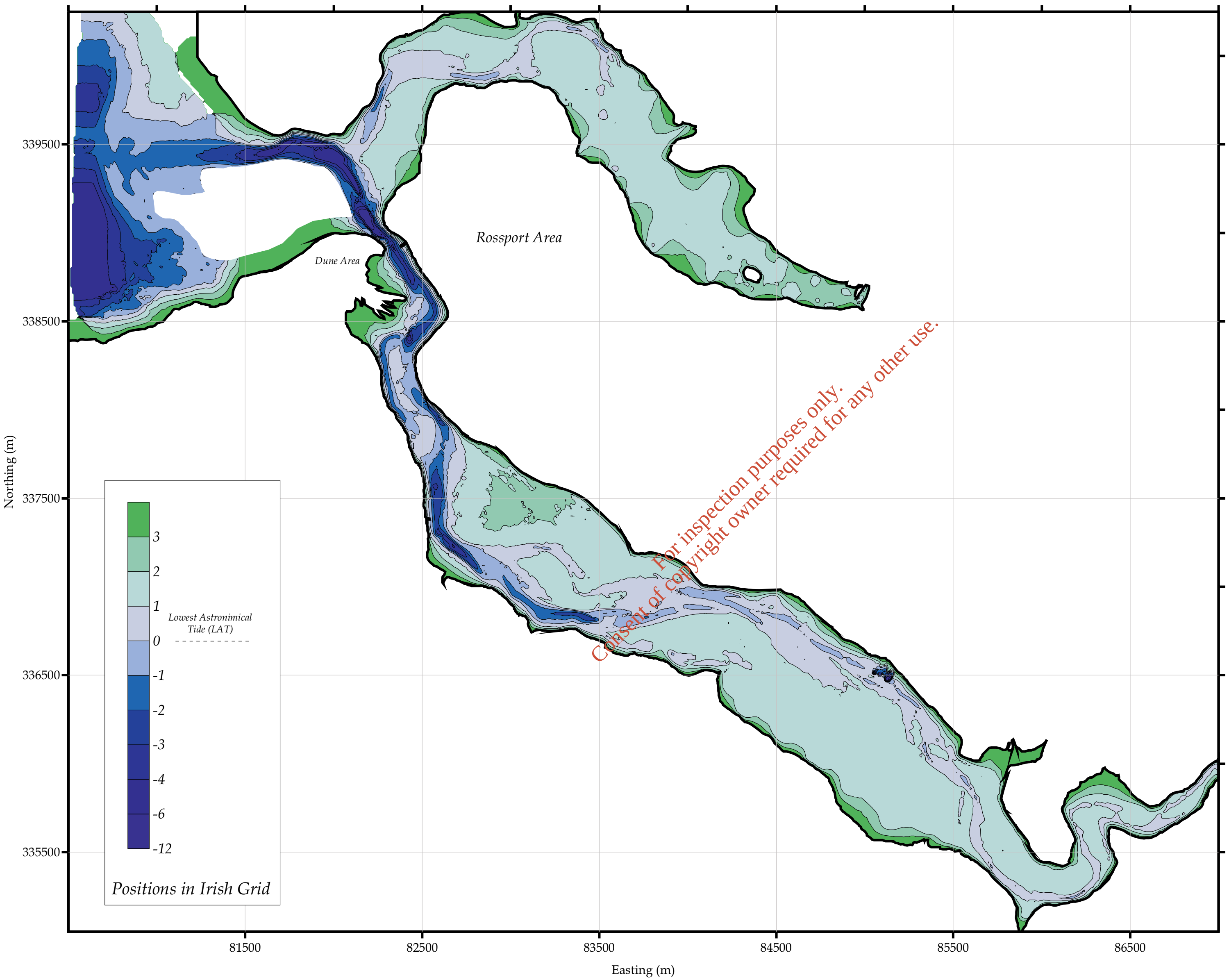
14.3 EXISTING ENVIRONMENT

The following sections describe the existing environment in terms of geomorphology and benthic environment (physico-chemistry and macro-invertebrate community), habitat and biotope in Sruwaddacon Bay, while Sections 14.3.2 and 14.3.3 provide details on the lower and upper estuary. Further details on these aspects are provided in Appendix L.

14.3.1 Sruwaddacon Bay

14.3.1.1 Geomorphology

A geophysical survey of Sruwaddacon Bay (Osiris 2007) was undertaken to provide information on the bathymetry, surface sediments, near surface geology and the presence of metallic contacts within the survey area in order to assist with the selection of a route through or beneath the bay. The results of the survey are discussed for this purpose in Chapter 15 of the EIS. The resulting data were also used to provide geomorphological charts of Sruwaddacon Bay as a whole which forms the physical basis for habitat mapping, as well as showing oceanographic influences on the sediments within the survey area.



Bathymetric Representation of Sruwaddacon and Curraunboy Bays

Figure 14.2

File Ref: MDR0470GrEIS008 RevA03
Date: May 2010

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Corrib natural gas

RPS

Geophysical data showed the majority of the estuary to be dominated by marine sands with a clearly defined channel meandering the length of the estuary around extensive sand flats from the neck of the estuary to the confluence of the Glenamoy and Muingnabo rivers. Bathymetric data, acquired using a combination of both marine and terrestrial survey techniques, along with interpolation from aerial photographs showed that a large proportion of the site consisted of shallow sand flats of very shallow depth at high water (see Figure 14.2). These data show that the majority of the sand flats within the bay are found between the +1m and +2m relative to chart datum (CD or the point of the lowest low water tide), meaning that much of the area is exposed around mid-tide (approximately +1.9mCD). Following the course of the channel from the river confluence in the southeast, the main channel periodically fragments and recombines at a number of points with the channels varying from 30 to 100m in width during periods of low water. Additionally, the depth of water within this channel generally ranges from -0.6mCD in the south, to -4.1mCD in the central part of the bay, although there are a number of areas that technically dry out at extreme low water periods (and would be totally dominated by riverine freshwater flows during extreme low water times).

At the constriction, in the western part of Sruwaddacon Bay, two smaller channels merge back into a larger flow approximately 100m across, which is bordered by a build-up of granular sediments along the western side of the shoreline. Here, channel bed levels fall to -5.0mCD, before the channel veers slightly northwest and becomes very narrow (approximately 60m). Here the bed level drops to its deepest point in the system (-11.0mCD). Once past Ros Dumhach (Rossport) Pier on the east bank, the course alters direction to the west at the convergence with the mouth of the Curraunboy Bay, and a bed level rises back to between 0.0mCD and -6.0mCD (average level of -1.5mCD), which is maintained until it enters the eastern part of Broadhaven Bay.

The geomorphological data (a combination of seabed morphology and reflectivity; (see Figure 14.3)), shows the surface geology is dominated by granular sediments. These are a combination of reworked medium to fine marine sands in the central part of the bay, and mixed gravel deposits derived from glacial tills and weathered bedrock deposited at the margins or in areas of stronger current flow.

This is highlighted in the mouth of Sruwaddacon Bay, where the base of the channel is made up of sandy gravels, bordered by bank deposits (mainly gravels and mixed sediments) or gravely sands. Once into the central part of the estuary, the gravel areas are limited to the bank deposits in a thin perimeter, generally 30m to 50m wide, bordering the margins between the mid and high water marks on the foreshore. No rock outcrops were identified within the bay with the exception of those recorded on the eastern bank of the estuary's northern mouth.

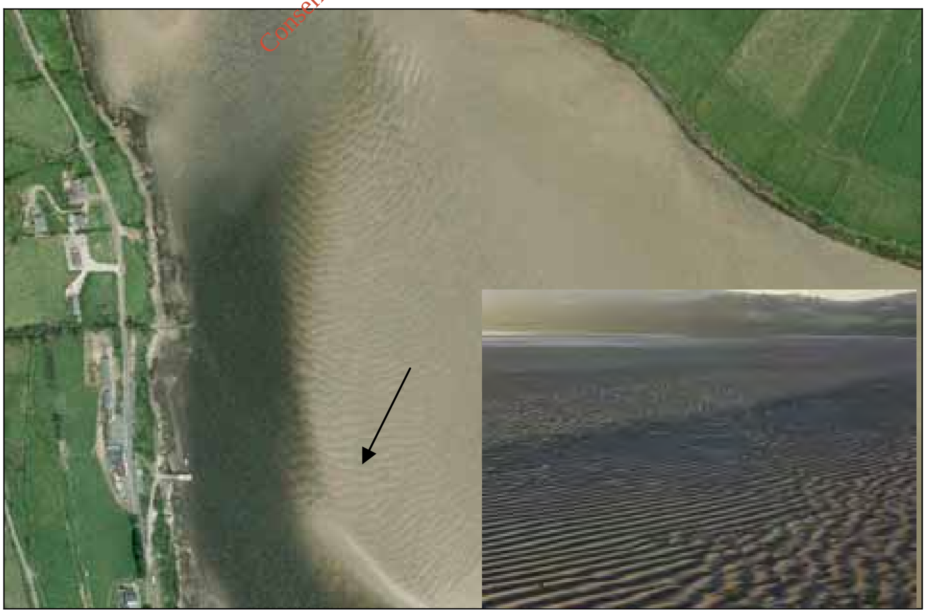


Plate 14.2: Mega-rippled bedforms in lower Sruwaddacon Bay

In addition to sediment variations, a large number of mega-rippled bedforms were recorded over much of the sands (Plate 14.2). These are caused by strong currents or areas of wave action, indicating that the sediments are dynamic and continuously being reworked by the overlying water movement. This produces sediments that are non-depositional environments where silts, clays and very fine sands are continuously winnowed away leaving larger granular sands. The larger, more clearly defined features were recorded close to or within the main channel where current flows are greatest, whilst sandbanks in the southern half of the bay showed generally featureless or very minor rippled bedforms, indicative of lower current speeds. The largest features were recorded on the seaward facing sand bank orientated from E – W (indicative of north –south currents). Here, some of these features had a height of 0.5m and average wavelengths of between 5.0m and 15.0m; easily discernible from aerial photography. A cross-section of these bedforms confirmed a dominant southerly or flooding flow (I.Wilson observations). This is supported by hydrodynamic modelling discussed in Section 14.7.

14.3.1.2 Benthic Environment

Physico-chemistry

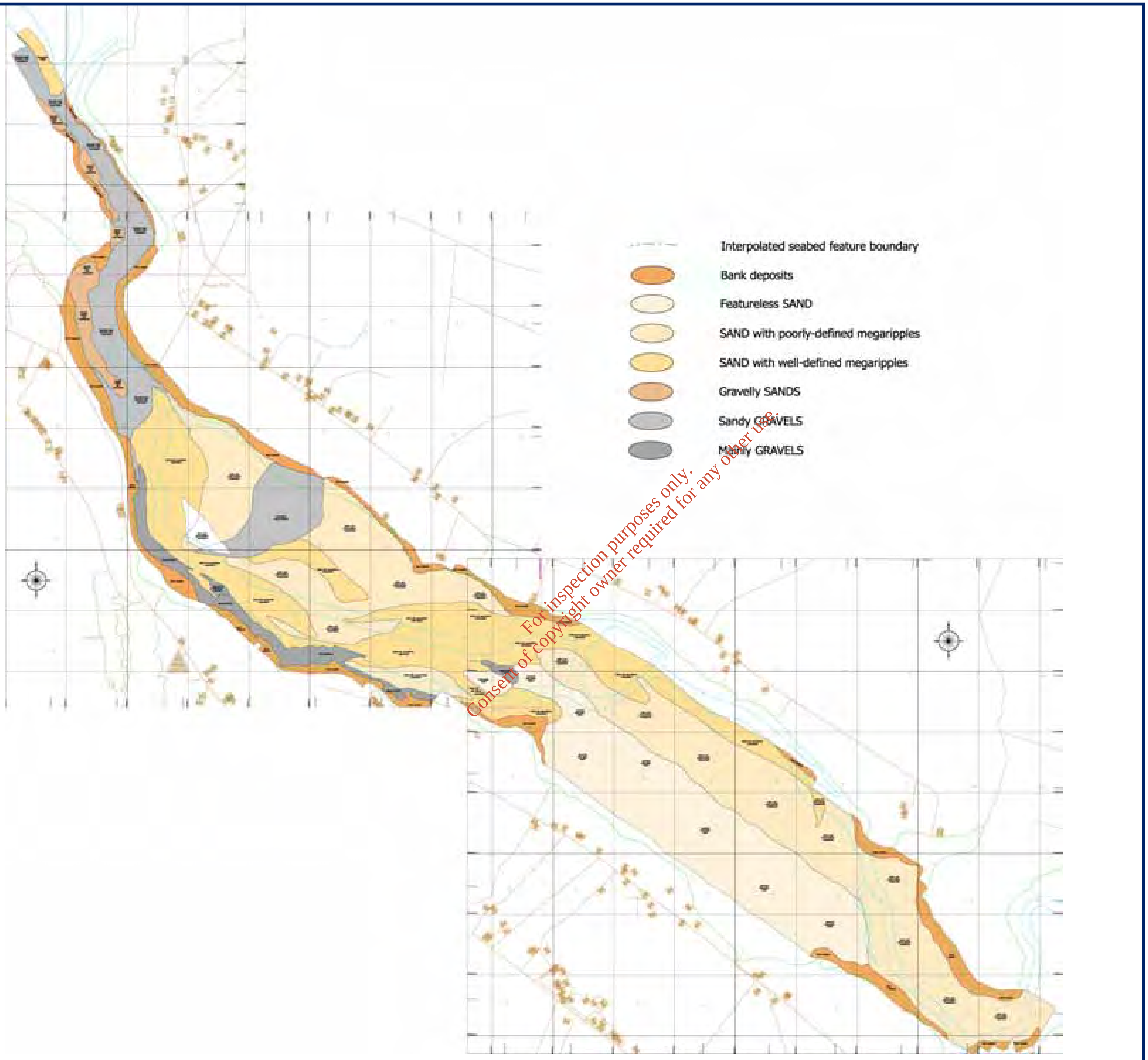
The combined field environmental surveys acquired seabed sediment samples from a total of 62 sample sites within the inter-tidal and sub-tidal areas of Sruwaddacon Bay from the east of Broadhaven Bay to Glenamoy and Muingnabo River confluence (Figure 14.1; RSK 2007, Ecoserve 2007, Wilson 2010_1). Samples acquired were processed for a number of different factors relating to macro-invertebrate, chemical or particle size analysis based on location within the bay or river. Physico-chemical analysis was carried out by the Environment Agency in the UK, accredited to UKAS, whilst the macro-invertebrates were analysed by Hebog Environmental Limited in North Wales, who are members of the NMBAQC quality assurance scheme, and Ecoserve Limited. The survey in 2010 was processed by Benthic Solutions Limited for particle size analysis and macro-invertebrate analysis, both tests accredited within the NMBAQC quality assurance scheme.

Particle Size

Physico-chemical properties of the sediments within Sruwaddacon Bay are discussed in detail within Appendix L. Particle size analysis, carried out on all stations sampled in 2007 and 2010, looked at ten or more size classes and were classified according to Folk (1954) and their relative contents of gravel (>2mm), sand (>63µm to 2mm) and muds (<63µm). Results showed that the vast majority of surface sediments were classified as sand (with grain sizes between 63 and 2000µm) (Figure 14.4). This generally reconciles the seabed features chart (Figure 14.3), which showed a predominance for high energy sands throughout the Bay.

Gravels remained unrecorded in most areas with the exception of sites at the base of the main northern channel or within the bank deposits along the margins of the bay proper, where the bay is bordered by glacial till and/or weathered bedrock deposits at the high water mark. The largest proportion of gravels recorded during the survey was seen at a station within this upper zone (at 71.7% of sediment >2000µm). These larger gravels, support a significant biological community, and further stabilises the upper interstitial material which consequently also shows significant percentages of finer sediments (<63µm).

Throughout the main part of the bay, sediment fines were generally absent or very low, although elevated fines were recorded at a few sites further upstream, within inlets or high up on the shoreline where currents are slow. This pattern of distribution was also reflected in the proportion of total organic carbon (TOC). Often directly associated with the proportions of silts and clays, the TOC levels within the sediments were generally low with the majority of stations recording levels below 1%, falling to below detectable limits (0.01 to 0.1%) at a quarter of sites in the seaward half of the bay. The highest levels of organic carbon (around 2.1%), were recorded high up on the shoreline or within the silty mixed bank deposits, with a moderate level recorded outside of Sruwaddacon Bay in eastern Broadhaven Bay (around 1.5%). The levels of TOC found throughout the survey were lower than might be anticipated for an estuarine environment, where muddy sediments generally carry higher organic loads. Locally, these were lower than levels recorded during a similar survey within the Inner Broadhaven Bay, where most sites recorded levels greater than 2.6% (Aqua-Fact 2004), or in the outer Broadhaven Bay area (RSK 2007_2).



Seabed Features Chart of Sruwaddacon Bay

Figure 14.3

File Ref: MDR0470GrEIS009 RevA03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

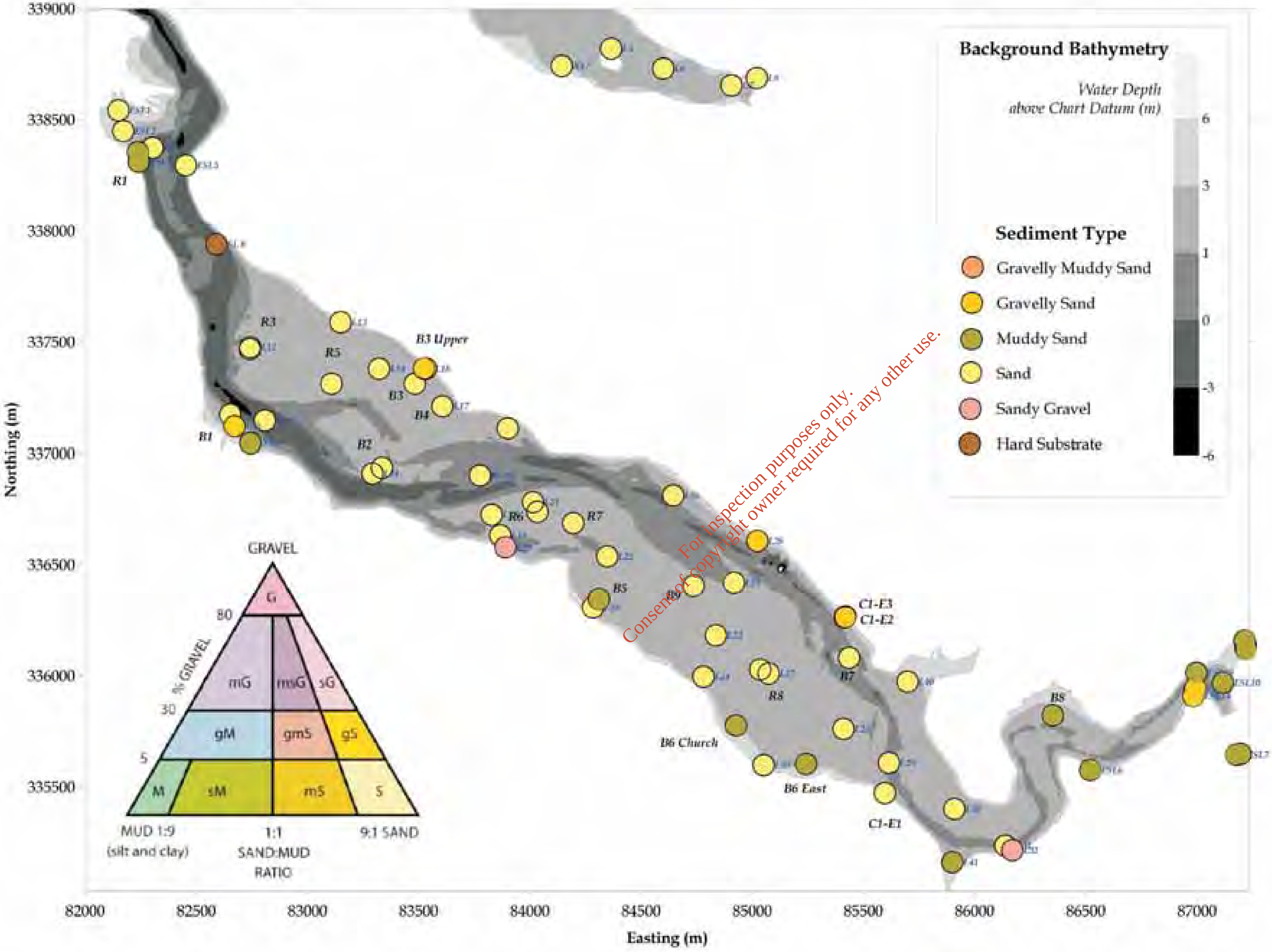
Chemical analysis for sulphides, the product of anaerobic respiration, heavy and trace metals and sediment hydrocarbon were analysed on sixteen surface and three sub-surface samples taken from within Sruwaddacon Bay (RSK 2007). Samples selected for additional chemical analysis were based upon a broad geographical coverage of the main Bay.

Sulphides

The results showed undetectable levels of sulphides at 9 out of the 16 surface stations indicative of well oxygenated surface sediments. Of the remaining 6, the four highest concentrations were recorded high up on the shoreline within mixed sediments, or within the mouth of the Glenamoy River and central part of the estuary.

Heavy and trace metals

For heavy and trace metals, elements of the greater potential for toxicity have been compared with Ecotoxicological Assessment Criteria (EAC) proposed by OSPAR (2000). EACs are defined as concentration levels of a substance above which concern is indicated. Table 14.1 shows a summary of metal results for sites within the bay and a comparison with the EAC limits where relevant. For the most part, all metals recorded within Sruwaddacon Bay recorded relatively low concentration at or below the lower OSPAR EAC limit. This was particularly so for the sediments found within the central sands and at the northern, downstream end of the estuary where currents were strongest. Only stations in the mixed sediments, on the upper foreshore or located within embayments, particularly towards the upper river mouth, regularly indicated elevated levels above those of the rest of the bay, but still within the OSPAR EAC limits.



Surface Sediment Types within the Sruwaddacon and Curraunboy Area (Classified according to Folk (1954), colours as per BGS classification)

Figure 14.4

File Ref: MDR0470GrEIS010 RevA03
Date: May 2010

CORRIB ONSHORE PIPELINE

Table 14.1: Heavy and Trace Metals within Sruwaddacon Bay

Metal	Range (mg/kg)		
	Sruwaddacon Bay	**Lower EAC**	**Upper EAC**
Mercury	<0.05	0.05	0.5
Cadmium	<0.1	0.1	1
Silver	<10	-	-
Copper	<0.1 to 4.03	5	50
Arsenic	1.44 to 11.7	1	10
Lead	1.72 to 13.8	5	50
Chromium	4.11 to 11.7	10	100
Zinc	3.93 to 36.1	50	500
Nickel	0.78 to 6.62	5	50
Tin	<20	-	-
Aluminium	672 to 6,560	-	-
Barium	5.3 to 34.3	-	-
Iron	2,440 to 24,200	-	-
Manganese	<0.05 to 224	-	-
Lithium	1.43 to 15.9mg	-	-

This pattern of distribution reflects the influence of the hydrodynamics and the river on the bay. Areas close to the river show lower current speeds (see Section 14.7) and a greater influence from riverine suspended materials which are deposited high up on the water line and within sheltered inlets and embayments. These mixed and/or finer sediments act as a sink for the low level contaminants that are flushed into the marine system remaining locked within the substrate. Conversely, in the centre of the bay and towards the north, the strong tidal flows rework the sands winnowing away fines and the contaminants that they carry. Statistically, this can be clearly seen with correlations between these chemical parameters (Appendix L), where a clear correlation ($P<0.01$) exists between the matrix metals of aluminium and barium and all of the other physico-chemical properties of the samples with the exception of arsenic and manganese.

The overall concentrations of trace metals recorded in Sruwaddacon Bay were generally of the same order as those recorded within Broadhaven Bay, with the exception of cadmium and copper, which were marginally higher in the open water environment (RSK 2007_2). Concentrations of metals in both Sruwaddacon Bay and Broadhaven Bay are low, reflecting an area which has been subject to relatively little anthropogenic influence.

Total Petroleum Hydrocarbons

Concentrations of Total Petroleum Hydrocarbons (TPH) in the surface sediments were generally quite high ranging from 11.2 to 238 mg/kg. The majority of surface sediments sampled fell below the level of 100ppm, an action level for possible harmful environmental effects, used by regulatory authorities in the UK (i.e. CEFAS). The highest levels of TPH, recorded above this threshold were found in an upper part of the estuary where levels of metals, TOC and sediment fines were also elevated. A significant correlation between TPH and some of the metals and physical sediment parameters indicated that TPH, as a polarised complex organic molecule, had become bound within clays of the depositional environment found at these sites. Nevertheless, the overall TPH recorded during the whole survey were notably higher than compared to previously analysed offshore survey samples (i.e. Broadhaven Bay; which ranged from 5.8 to 13mg/kg, RSK 2007_2). A brief review of the laboratory method (undertaken by the Environmental Agency, UK) revealed that a variation in the way TPH was analysed may have resulted in a broader organic fractions being represented within these results.

A brief assessment of sub-surface sediments within the main part of the bay using shallow cores to a depth 1m, revealed homogenous surface sands at all sites sampled with the exception of one close to the bank deposits, where sub-surface gravels were recorded. This highlights the fact that the coarser substrates recorded along the upper shoreline continue into the bay beneath the surface sand layer.

This is discussed in more detail in Chapter 15. Physico-chemical analysis of the base from these cores equally confirmed a relatively homogeneous environment. Only the metal arsenic recorded marginally higher concentrations than those recorded on the surface with an insignificant maximum of 10.3mg/kg. As with the surface samples, the cores showed a pattern of marginally higher levels within most parameters progressively upstream.

Macrobenthos

The benthic macro-invertebrate community was quantitatively assessed over the whole of Sruwaddacon Bay area using a small grab sampler, small corer or large template in both the inter-tidal and sub-tidal areas. Samples were sieved using either 0.5 or 1mm aperture mesh (RSK 2007, Ecoserve 2007, Wilson 2010_1). Deeper dwelling macro-invertebrates, such as the polychaete lugworm (*Arenicola marina)* were further assessed via additional counts of surface casts within a $10m^2$ (RSK, 2007). The diversity and abundance of the biological communities within estuarine soft sediments provides an important source of food for larger predatory fauna (such as birds, fish and some mammals) throughout the year.

In general, the biological abundance and diversity were low, as expected for a higher energy estuarine environment (Elliot *et al.*, 1998), where a predominance of moderately sorted marine sands and few fines provide a relatively homogenous niche for the infaunal community (Figure 14.5). Of the 62 stations analysed for biology within Sruwaddacon Bay, the total abundance of individuals ranged from 11 – $6,272/m^2$, although the greatest abundance was recorded at three stations located high up in the estuary which recorded considerable numbers of either the polychaete *Tubificoides benedeni* or oligochaete annelids, thought to be a result of freshwater inputs at those sites, or the crustacean *Corophium volutator*. Low abundances were recorded over the majority of the sand flats (ca. $<900/m^2$) with very low abundances ($<250/m^2$) recorded within the sub-littoral channel sites. These reduced populations indicate the high energy sand environment within the channel and increased freshwater influences during low water times. These can be compared to the higher faunal abundances (average number of individuals of $2,850m^2$) recorded in Inner Broadhaven Bay, close to Béal an Mhuirthead (Belmullet) by Aqua-Fact in 2004.

Following identification, the biological species from the RSK survey underwent statistical analysis using a variety of univariate and multivariate techniques in order to establish patterns and correlation both within the faunal population and with other environmental variables recorded at each of the stations (Table 14.2 and Figure 14.5). A full list of species along with the results are included in Appendix L.

Table 14.2 Range (Mean) of Univariate Statistics for Macro-invertebrates in Sruwaddacon Bay

Site	No. of Species	No. of Individuals m^2	Pielou's Evenness Index (J')	Shannon-Weiner Diversity (H)	Simpson's Dominance Index (λ)
Outer Bay	9-11(10)	356-689 (522)	0.47-0.82 (0.65)	1.04-1.96 (1.50)	0.21-0.55 (0.38)
Channel lower estuary	2-9 (5.2)	56-700 (222)	0.68-0.99 (0.87)	0.68-1.67 (1.27)	0.21-0.51 (0.34)
Adjacent to the channel	5-7 (5.5)	89-1,911 (575)	0.21-0.97 (0.70)	0.33-1.88 (1.21)	0.16-0.87 (0.43)
Central sands	1-14(7.2)	11-2,344 (837)	0.34-1.00 (0.61)	0-1.89 (1.05)	0.25-1.00 (0.51)
Inlets and sites of mixed sediments	5-14 (8.9)	167-3,556 (1,468)	0.44-0.80 (0.66)	1.02-2.02 (1.40)	0.19-0.59 (0.35)

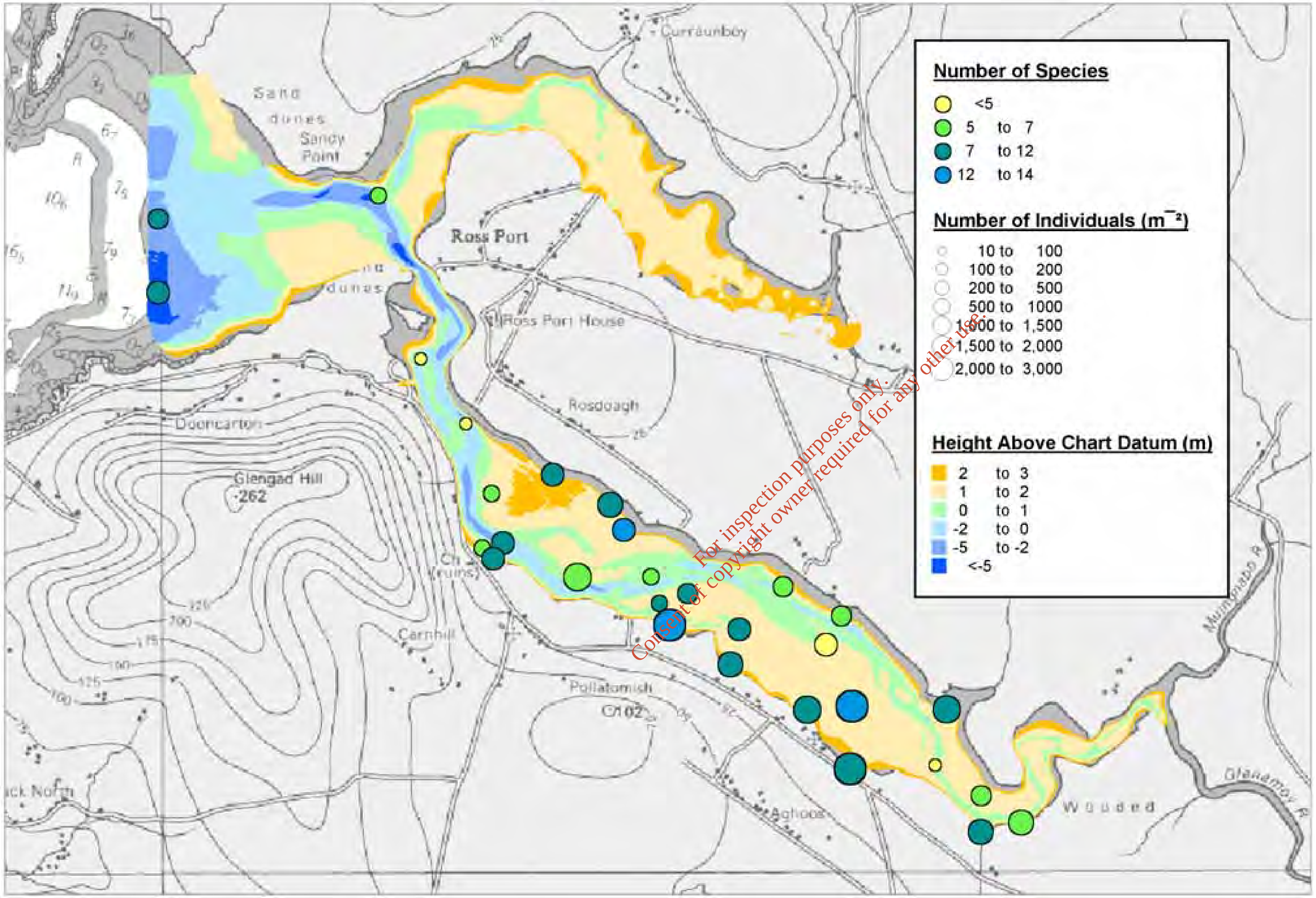
Statistically, the pattern of the macrofaunal community is complicated but generally reflects the sediment type, position relative to the channel and freshwater influences. In general, a pattern of lower diversity and abundance close to the main channel can be seen. In 2007, the species numbers were low (below 12) for the majority of sites with the highest number of species (14) recorded at two stations close to the upper shoreline where the seabed showed mixed sediments. Two stations in the central channel of the upper estuary gave exceptionally low numbers recording only one or two species. These can be compared to the slightly finer sediments recorded within the Inner Broadhaven Bay, which indicated a generally greater richness 4 – 18 species for a sample area a third of the size (Aqua-Fact, 2004). Subsequently, the diversity indices for Sruwaddacon Bay were also very low at the majority of sites. The highest diversity was again found within the mixed sediments high up on the shoreline. A similar pattern was observed in the later detailed study of the main sand banks undertaken by RPS in 2010. This also showed very poor macrofaunal population of <300 individuals/m^2 and a gradient of increased biological numbers in areas where tidal energy is limited, such as the upper parts of the tide and embayments were the proportion with of fines are increased (Wilson 2010_1).

Numerically dominant species were not evenly spread throughout the survey area as they were found to be absent in many of the samples (RSK 2007). Broadly, the biological community reflected the exposed to moderately exposed inter-tidal estuarine sand flats (Elliot *et al*., 1998). The population was dominated by annelid worms, comprising nearly 75% of all animals recorded in 2007 and 61% in 2010. Polychaetes constituted 55% of these with *Ophelia rathkei and* a single spionid, *Pygospio elegans* accounting for 7% and 31% of all individuals, respectively, (although often unevenly distributed). Oligochaete annelids were only recorded in inter-tidal stations, but accounted for fewer than 20% of all individuals, with *Heterochaeta costata* responsible for half. Overall percentages of other faunal groups found included Crustacea at 10% (around 32% of total individuals in 2010) and Mollusca at around 8% (6.5% in 2010). The most abundant crustaceans recorded, were gammaridean amphipods, predominantly of the species *Bathyporeia* and *Urothoe,* or in areas of greater fines, *Corophium* (RSK 2007 and Wilson 2010_1). These are typical characteristics of mobile, fine to medium sands.

In 2007, molluscs as a group, were generally unimportant (not occurring at any of the sub-tidal samples) with the mud snail *Hydrobia ulvae* comprising the vast majority of all individuals, although the occasional edible cockle (*Cerastoderma edule*) constituted the largest infaunal species found during the survey. This general pattern was repeated in 2010, although greater numbers of juvenile cockles were recorded at a number of locations relating to the base of partially eroded channels outside the main current flow. These were also accompanied by elevated numbers of other bivalves *Angulus tenuis* and *Retusa obtuse (Wilson 2010_1)*. Although seasonal variations cannot be ruled out similarities in the results between summer and winter records in 2007 (RSK, 2007 & Wilson 2007_1) showed little variation, suggesting that longer term variations in the faunal population may be to blame. Echinoderms remained unrecorded in any of the samples from both years, reflecting their preference for fully marine conditions.

Relationships between the biological communities of grouped sites were tested using a statistical Bray-Curtis similarity program (PRIMER, 2005). These showed weak clustering of the sites at approximately 30% or less. Therefore these groupings are made up of sites that were generally more dissimilar than similar to each other. This notwithstanding, a review of grouped similarities within the survey area revealed a clear separation between the Inter-tidal sites (cluster A) from those of the sub-tidal sites (cluster B) which were within or close to the main channel at the northern end of the bay (Figure 14.6). Here, the channel stations exhibited species typical of high energy sandy sediments such as the amphipods *Bathyporeia* and *Urothoe* and the polychaetes *Spiophanes bombyx* and *Ophelia rathkei*. The remaining inter-tidal sites were further separated into three sub-clusters which related to position in the bay, freshwater influences or sediments with mixed or significant greater silt/clay components. These sites were characterised by Nereid polychaetes, *Pygospio elegans*, oligochaetes and the gastropod mollusc *Hydrobia ulvae*.

Statistical analyses comparing the clustered groups of sites and other environmental variables showed poor correlations except with the presence or absence of sediments fines (<63μm). No significant correlations were observed between biology and any chemical parameters (i.e. metals, TPH or sulphide).



Species Richness (per site) and Abundance (per m^2)

Figure 14.5

File Ref: MDR0470GrEIS011 RevA03
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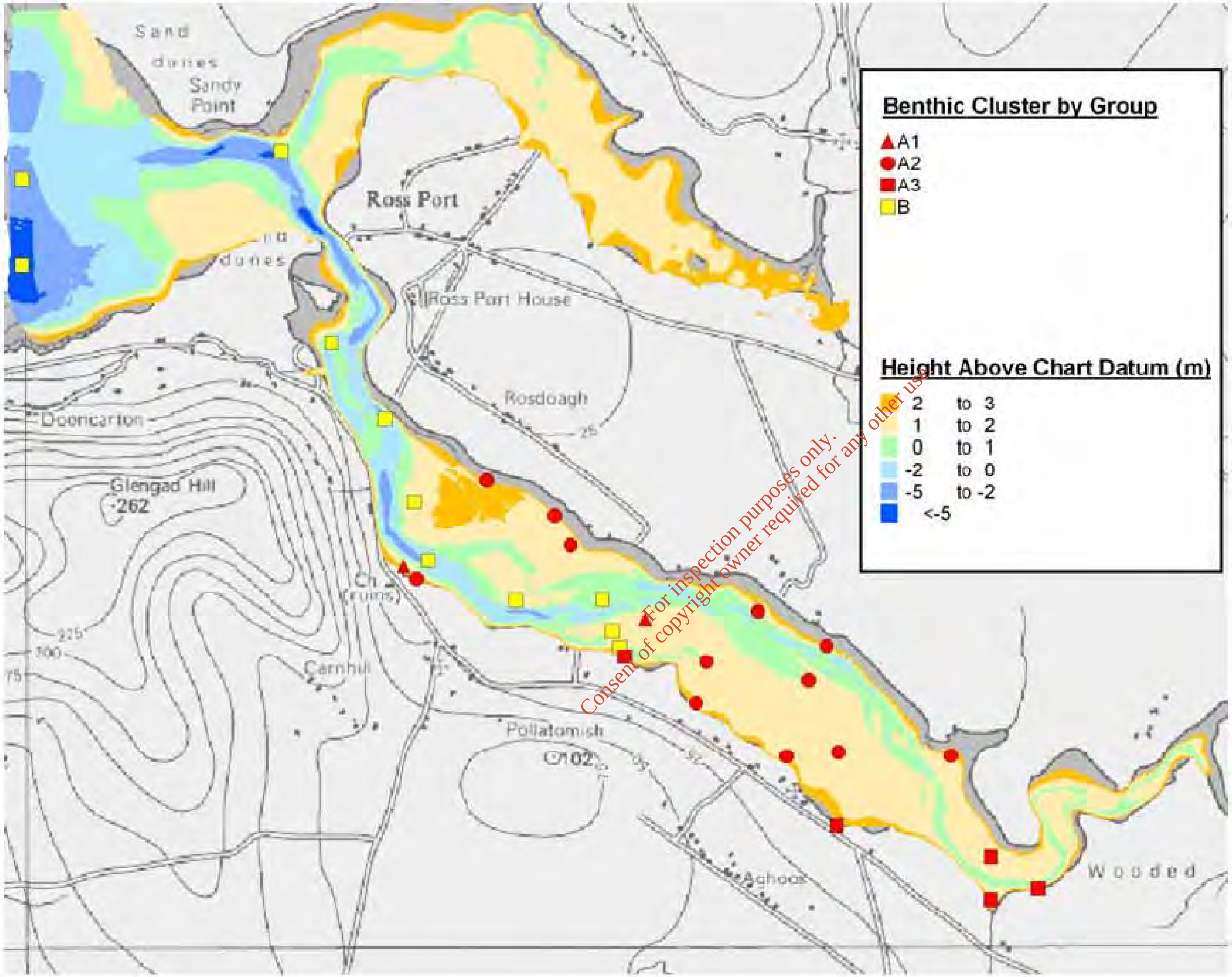
As the macrofauna constitutes an important food source to higher predators, both resident and transient, within Sruwaddacon Bay, an assessment of the macro–invertebrate biomass in the surface sediments over 1mm (considered to be the minimum size to be selected for predation) was measured quantitatively on all analysed samples using an ash-free dry weight conversion (outlined in RSK 2007, Wilson 2007_2 and Wilson 2010_1). For the earlier studies, the total biomass recorded throughout the bay was low at all sites, with values ranging from 0.003g/m^2, within the upstream channel, to 11.86g/m^2 recorded at the top of the bank in a downstream section of the bay. This can be compared to 0.15 to 11.5g/m^2 recorded in 2010 for a similar depth and minimum body size. Unlike abundance, the biomass of the bay was dominated by molluscs, and in particular the edible cockle (*Cerastodema edule*) contributing over 90% of the biomass at selected sites in 2007 and 85% in 2010. Molluscs accounted for around 75% and 48% for all sites combined in 2007 and 2010, respectively. The dominant polychaete taxa, contributed to only 19% of the biomass overall in 2007, with all stations recording less than 0.5g/m^2. This was partially due to the small size of macro-invertebrate recorded during the study and the general absence of the larger polychaete species, such as the burrowing lugworm (*Arenicola marina),* or the mobile ragworm (*Hediste diversicolor),* which can burrow down into deeper sediments and may live beneath the effective level of sampling thereby evading capture. In 2010, the proportion of biomass constituted by polychaetes had increased to 31% (2.13g/m^2), although the majority of this was due to very large numbers of *Tubificoides benedeni* in a few stations where lower tidal energies were encountered (Wilson 2010_1). In 2007, the existence of a very shallow layer of anoxic sediments recorded over most of the estuary would prevent any significant vertical migration by the ragworm (Wilson 2007_2). However, observations in 2010 suggested that the depth of this layer had universally increased slightly from that of the earlier study, also undertaken in the winter period (Wilson 2010_1). This may partially be due to the bioturbation by increased numbers of *Arenicola marina* recorded throughout the sands of the bay.

In 2007, significant populations of *Arenicola marina* were limited to clearly defined patches, in particular towards the upper shores and in areas where standing/surface water remained but generally avoiding gravels and upper-stream areas due to an intolerance to freshwater. The highest density of *Arenicola marina* was recorded at 40-45 individuals/m^2, recorded at a mid-tidal muddy sand and a relatively high organic content. However, by 2010, the number and coverage of *Arenicola* casts had increased significantly to cover most of the sands throughout the bay. The reason for this is uncertain but this fact highlights the natural variability in the macrofaunal population within the bay between survey years and through some seasons.

Epifauna on the Upper Shoreline

In addition to the biomass recorded within the sediments of the main bay and on the upper shore, the thin perimeter of mixed gravels found bordering the entire bay also supports a significant population of epifaunal species living amongst larger stones and within the fucoids (Wilson 2007_2 and Wilson 2010_1). Fauna in the upper sections of the bay were dominated by the gammarid crustaceans *Echinogammarus marinus* and *Gammarus zaddachi* although some molluscs, in particular *Littorina,* were a common genus particularly downstream where freshwater effects were less marked. In 2007, a calculation of the biomass showed a progressive increase from 0.33g/m^2 to 3.445g/m^2 (the south and north sides of the upper estuary) to 7.7g/m^2 recorded in the centre of the estuary (RSK 2007). This latter site recorded 11 species and over twice as many individuals (1360m^2) than found at the upper estuary during that year. Overall, epifaunal biomass was almost an order of magnitude greater than those recorded within the underlying soft sediments at similar locations. In 2010, the total biomass varied by a similar amount (from 0.56 to 7.57g/m^2) between stations, with the 12 species and 1048 individuals per m^2 recorded at the most abundant site, although far fewer molluscs were recorded on this occasion.



Geographical Locations of Clustered Communities

Figure 14.6

File Ref: MDR0470GrEIS012 RevA03
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Regional Habitat and Biotope

In addition to sediment sampling, a regional assessment of both the habitats and associated biotopes were mapped for the whole of Sruwaddacon Bay (RSK, 2007) using the methodology described by Wyn *et al.* (2006) (see Figure 14.7). Provisional classifications of habitats according to Connor *et al.* (2004) were made following field observations and later analysis of both sediment samples and macro-invertebrate communities. Further detail is provided in Appendix L.

The biological communities recorded within the estuary are clearly dominated by the physical processes occurring, principally:

1. the effect of tides; and

2. the input of freshwater from the Glenamoy River and numerous small tributaries dotted around the perimeter of the bay.

Sruwaddacon Bay is interesting in that all stages of the estuary, from small freshwater streams to fully marine conditions, are represented within a relatively small area. The high-energy nature of the large yet shallow bay has resulted in the sediments being dominated by moderately exposed sands with few areas of low-energy muddy communities, typical of most estuaries, confined to the upstream end of the bay and small inlets away from the main channel. No unusual or rare biotopes were recorded within the wet areas of Sruwaddacon Bay.

Habitat denominations within the upper inter-tidal areas around the estuary were relatively consistent, with few exceptions. Grass dominated (*Puccinelia* spp,) saltmarsh (EU Annex 1 habitat) was present around the majority of the upper inter-tidal zone of the estuary, typically as a fringe between terrestrial vegetation and marine habitats (dominated by algae). The saltmarsh is described further in Chapter 12. Tidal influences into this zone were often marked by a strandline of decaying fucoid algae, together with an associated community of talitrid amphipods. An exception to this foreshore, was the seaward end of the northern shore, where steep cliffs of bedrock mark the upper boundary with a zone affected by sea spray and encrusted by lichens (possibly *Caloplaca marina* and *Verrucaria* sp.)

Between the upper saltmarsh or cliff areas and the homogenous sands that make up the majority of the Bay's surface soils, a regular band of mixed sediments supported several discrete but regular communities, with the thickness of the band characterised by the upper tidal range and the gradient of the shore. Traversing down the shore, the upper saltmarsh or bedrock gave way to a succession of varying habitats. These start with the clean coarse gravels, associated crustaceans and upstream, where freshwater influences are greatest, the channel wrack (*Pelvetia canaliculata)*, marking the upper limit of the high water mark.

Below this a zone of often mixed spiral wrack (*Fucus spiralis*), bladder wrack (*F.vesiculosus*) and in areas near freshwater input, horned wrack (*F.ceranoides)* was attached to large cobbles and boulders. Regular downshore strips of the gutweed *Enteromorpha* sp. and occasionally sea lettuce *Ulva lactuca* were also common near freshwater inputs (numerous ditches and small gullies). Further down the shore, egg wrack (*Ascophyllum nodosum)* and the epiphytic *Polysiphonia lanosa* were dominant. Epifaunal species were common within the fucoids, and included winkles (*Littorina* sp.), amphipods, and occasional juvenile shore crab (*Carcinus maenas*). Further seaward (towards fully marine conditions), occasional limpets (*Patella vulgata*), mussels (*Mytilus edulis*), barnacles (*Semibalanus balanoides*) and, less frequently, anemones (*Actinia* sp.) occurred attached to boulders. Below this, sedimentary environments were recorded throughout the remainder of the estuary.

Soft sediments are difficult to delineate as they are prone to very gradual changes. Consequently, the separation of these areas was generally based on aerial photography, assisted by changes in analysed macrobenthos and particle size parameters. Due to an inability to survey all of the study area during extreme low water periods, some inter-tidal areas could only be characterised by aerial photographic records.

Sandy sediments dominate the bay. However, a small variation in habitat is recorded due to subtle changes in exposure from both channel currents and wave action. The most mobile sands were recorded in the seaward third of the bay which had granular, freely-draining medium sands and a relatively deep redox layer (up to 15-20cm). Well-developed bedforms (ripples and meg-ripples) indicated these areas to be subject to strong currents. Obvious fauna in these areas was sparse although higher numbers of lugworms (*Arenicola marina*) were recorded when compared to previous survey years. The majority of the remaining sands within the bay showed varying levels of rippling (some wave induced in the shallower areas), and the sand flats became less well drained south of Poll an tSómais (Pollatomish) Pier. Mixed sediments occurred at the margins of the bay, but showed varying levels of gravel and elevated fines. Some gravels in the channels of small freshwater streams showed reworking with fines winnowed away. These gave rise to fluvial deposits, inhabited by both *Enteromorpha* sp. alongside fucoids, reflecting the brackish conditions.

Large areas of anoxic muddy sediments, more typical of many low-energy estuaries, were limited to small sheltered embayment in the upper estuary. Here, there were shallow basins outside the main current flow and sheltered from wave action, which have become a depositional environment. The resulting sediments were soft and unconsolidated with a relatively shallow redox layer.

General Anthropogenic Influences on Sruwaddacon Bay Marine Habitat

The bay is regularly punctuated by small sources of freshwater inputs. Many of these emanate from small man made ditches to assist in drainage of neighbouring farm lands and cut over peat bog. These will introduce small quantities of farm related runoff from the catchment area into the marine system during periods of wet weather.

Items of debris are littered on the upper shore line predominantly along the northern shoreline of the bay. Although some of this material can be considered as general "flotsam and jetsam" which are blown onto the shoreline via the prevailing south-westerly winds, a large proportion of the debris relates to terrestrial based dumping. Particular items of note are derelict vehicles, domestic waste, collapsed buildings and general building related debris.

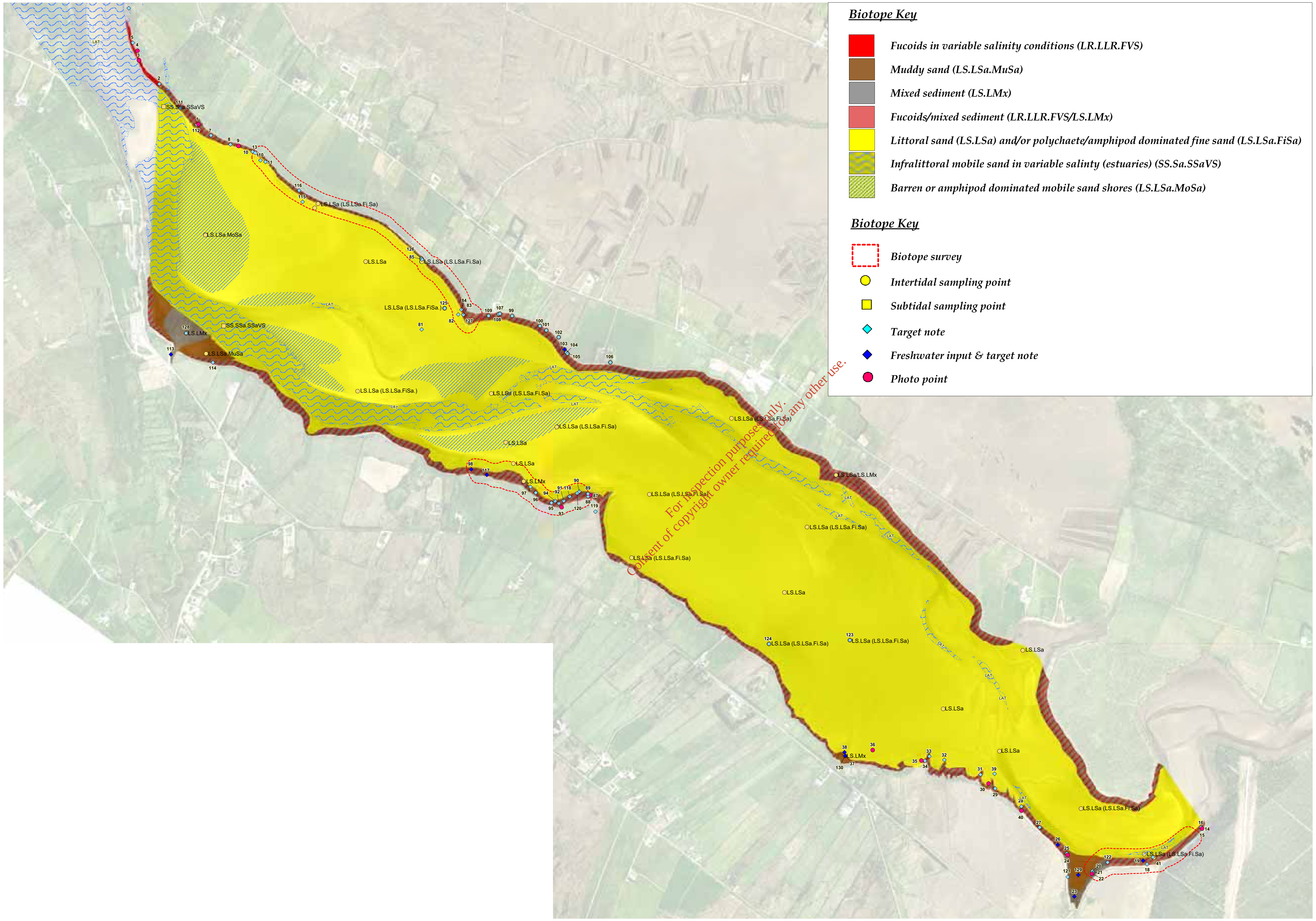
Other indicators of local anthropogenic disturbance are the grazing of livestock, fencing and the presence of vehicle tracks in the saltmarsh habitat (RSK, 2007). No bait collectors or recreational angling activity were observed during any of field studies, although locals were observed and are known to forage for shellfish (in particular for the mussel *Mytilus edulis* and the periwinkle *Littorina*) along the lower estuary, and the cockle *Cerastoderma edulis*) along the north-eastern shoreline of the bay. Several road/track access points lead onto the shoreline.

14.3.2 Proposed Pipeline Route

14.3.2.1 Geomorphology

The proposed pipeline route in Sruwaddacon Bay starts in the marine sector east of the landfall at Gleann an Ghad (Glengad) along the originally consented pipeline route (See Preamble). Consequently, this region of the bay has been subject to numerous survey activities, undertaken initially in 2000 and 2001, and revisited by Ecoserve in 2005, and again in 2007 as part of the current study to assess natural environmental changes at the site within the intervening years.

After the initial landfall, the proposed route passes into the natural narrowing of Sruwaddacon Bay. The western section is a shallow shelving sandy bay flanked to the south by weathered bed rocks and bank deposits and to the north by a reworked bank of both coarse and fine gravels. The bathymetric data (Figure 14.8) was unable to penetrate into the western bay due to its shallow nature. However, the main entrance of Sruwaddacon Bay was a classic channel feature with steep cut sides along the channel in the main flow, and a gently shelving inlet to the northwest. The proposed route starts at the top of the bay and follows the sandy part of the beach into a minor basin, approximately 1.1m above chart datum (CD), before following the alignment of the estuary and heading southeast across two shallow banks (ca. +0.8mCD) and a further channel (ca. -1mCD) at around 500m. Beyond this point, the seabed slowly rises until reaching the highest point on the main bank at +2.1mCD and 1000m. The route then tends to fall away slowly in steps but remaining above chart datum until the reaching the central channel at around -0.5mCD after 2100m. Another small bank at around +1.6mCD is encountered at 2300m, before passing over a relic channel feature at +0.9mCD at 2600m. The remainder of the route follows the main line of the upper estuary bank which remains at a consistent



Habitat and Biotope Map for the Sruwaddacon Estuary (RSK 2007)

Figure 14.7

File Ref: MDR0470GrEIS014 RevA03
Date: May 2010

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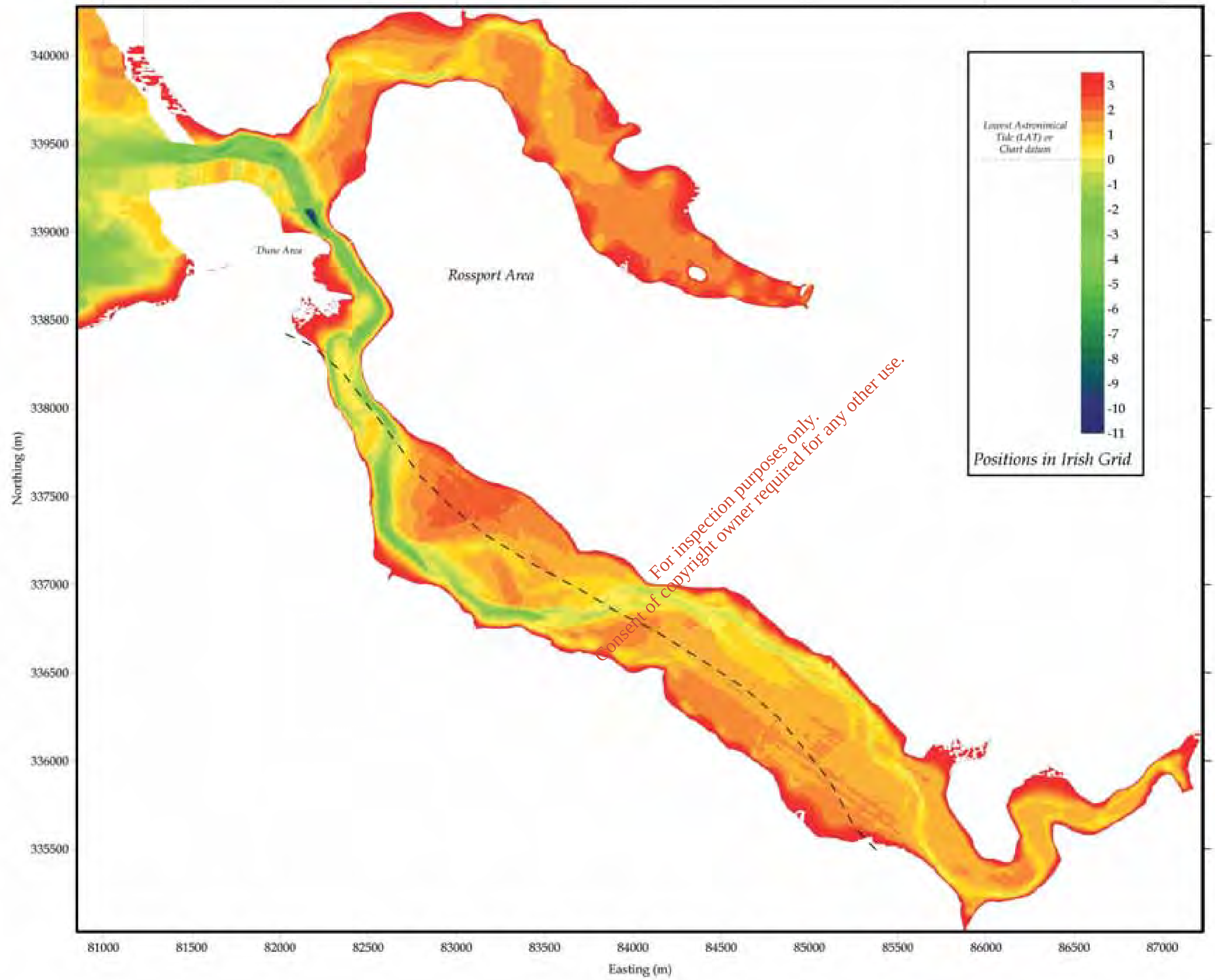
depth of around 1.5m above chart datum before encountering the rise of the bank and the edge of the upstream estuary after around 4200m.

Sonar data of the route indicated a mixed coarse sand and fine gravel passing into the initial channel. This quickly becomes a winnowed coarse rippled, sometime megarippled, sand through to the initial sand bank, before showing a slow transition to a finer sand along the remaining length of the route. No bedrock is expected, although small pockets of coarse gravels are expected along an isolated band on the lower foreshore on the upper estuary where the route leaves the estuary.

14.3.2.2 Benthic Environment

The western shore consisted of a fine muddy sandy bay between a raised cobble area to the north and a rocky shore to the south (Table 14.3), with a small stream running through the site. The extreme upper shore, dominated by grass and sea pinks (*Armeria maritime*) and amphipod burrows, were backed by a 0.5 m high peat 'cliff' to the west and a broad strand. In the north-west, the shore comprised muddy sand showing evidence of peppery furrow shells (*Scrobicularia plana)* and some *Ulva* spp. (*Enteromorpha* spp.). Below this was found the largest biotope in the area, characterised by *Arenicola* casts and the cockle (*Cerastoderma edule)* in muddy sand, becoming anoxic water-saturated muddy sand in the west with very few *Arenicola marina* casts and a small stream with an area of *Ulva* spp. (*Enteromorpha* spp.) covered rocks and muddy sands. In some areas an anoxic layer within millimeters of the surface was recorded down to the lower shore and the waters edge.

The reworked gravel bank to the east supported a green succulent and *Pelvetia canaliculata*, or the occasional area of fine sand with some *Ascophyllum nodosum* and *Fucus vesiculosus* attached to cobbles. A number of horizontal zonations were apparent within the coarser sediments with the fucoids *Pelvetia canaliculata*, *Ascophyllum nodosum*, *Fucus vesiculosus* and *Fucus serratus* dominant within the biotopes, along with a red filamentous algae.



Bathymetry of the Sruwaddacon

Figure 14.8

File Ref: MDR0470GrEIS021 RevA03
Date: May 2010

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Table 14.3: Summary of Habitat Zonation for the Lower Estuary (West Bank)

Shore	Habitat/Biotope	JNCC Code*
Upper	Talitrids on the upper shore and strand-line	LS.LSa.St.Tal
↓	*Hediste diversicolor*, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud	LS.LMu.MEst.HedMacSct
	Macoma balthica and *Arenicola marina* in littoral muddy sand	LS.LSa. MuSa.MacAre
Lower	*Fucus vesiculosus* on mid eulittoral variable salinity boulders and stable mixed substrata	LR.LLR.FVS.FserVS

* The Joint Nature Conservancy Council Phase 1 habitat survey methodology (JNCC, 1993).

The south of the bay was rocky backed by *Armeria maritima* and some peat, or high bank of rocky bedrock below farmland where the shoreline narrowed. Vertical zonation was apparent on the bedrock with lichen zones found below *Armeria maritime. Ascophyllum nodosum* and *Fucus spiralis* with patches of C*ladophora* spp. located on the upper shore, whilst *Fucus vesiculosus* and *Fucus serratus* were on the lower shore. Topshells (*Gibbula* spp.) winkles (*Littorina littorea*), limpets (*Patella vulgata*), barnacles, mussels (*Mytilus edulis*) and shore crabs *Carcinus maenas* were all recorded on rocks and amongst seaweed along this shore.

On the opposite eastern bank, the sheltered shore consisted of mixed cobbles and boulders with some sections of bedrock, backed by a steep rocky bank leading up to farmland (Table 14.4). *Armeria maritima* occurred above the upper shore, which was characterised by boulders and cobbles supporting the lichen *Verrucaria maura*. The cobbles below this supported a band of *Pelvetia canaliculata.* The mid-shore was dominated by *Ascophyllum nodosum* with *Gibbula* spp., *Patella lapillus*, *Littorina littorea*, *Carcinus maenas,* C*ladophora* spp. with barnacles and the anemones *Actinia equina* and *Actinia obtusa* were found on or around boulders. The lower shore was a zone of *Fucus vesiculosus* and attached epiphyte *Ceramium,* with patches of *Ulva* spp. (*Enteromorpha* spp.). Rocks in this zone supported barnacles and large patches of mussels (*Mytilus edulis*). Below this a zone *Fucus serratus,* along with *A. nodosum*, *Mastocarpus stellatus* and *F. vesiculosus* were found on mixed substrata with clumps of the mussel *Mytilus edulis* present on the rocks. Fauna included spirorbids on the fronds of *Fucus*, the limpet *Patella vulgata* and *Gibbula* sp, dog whelks (*Nucella* spp.) and a number of winkles including *Littorina obtusata* and *Littorina littorea*.

Table 14.4: Summary of Habitat Zonation for the Lower Estuary (East Bank)

Shore	Habitat/Biotope	JNCC Code
Upper	*Verrucaria maura* on littoral fringe rock	LR.FLR.Lic.Ver
↓	*Pelvetica canaliculata* on sheltered variable salinity littoral fringe rock	LR.LLR.FVS.PelVS
	Ascophyllum nodosum and *Fucus vesiculosus* on variable salinity mid-eulittoral rock	LR.LLR.FVS.AscVS
Lower	*Fucus vesiculosus* on mid eulittoral variable salinity boulders and stable mixed substrata	LR.LLR.FVS.FvesVS

The shoreline of upper part of Sruwaddacon Bay is backed by peat. The inter-tidal zone is similar in nature to the majority of the north coast areas (Table 14.5), with the marine area separated from the fully terrestrial environment by a low bank of earth and peat. The uppermost shoreline is characterised by a fringe of saltmarsh turf over thin soil and stones. Further down the shore there is a clear transition into a zone of cobbles and boulders. As with other areas along this part of the estuary, the littoral shoreline is marked by growth of the channel wrack *Pelvetia canaliculata* and *Enteromorpha* sp., characteristic of reduced salinity conditions (possibly as a result of freshwater seepage from the cliff and neighbouring farm land.

The boulders and large cobbles are characterised by an overgrowth of black lichen, possibly *Verrucaria maura*. Going seaward, macroalgae coverage becomes total with, firstly, a thin band of bladder wrack (*Fucus vesiculosus*), followed by a thicker band of egg wrack (*Ascophyllum nodosum*), attached to the cobbles and boulders. Fauna recorded within the fucoids comprised occasional epifauna, barnacle (*Semibalanus balanoides*), mussel (*Mytilus edulis*), and, less frequently, anemone (*Actinia equina*); mobile fauna included occasional limpet (*Patella vulgata*), frequent winkles (*Littorina* sp.), and frequent amphipods and shore crab (*Carcinus maenas*) under rocks. Beyond this band of fucoids over mixed sediment (e.g. cobbles, sand), the clear zonation of communities cease, and the soft sandy sediment of the majority of the Bay starts.

Table 14.5: Summary of Habitat Zonation for the Upper Estuary

Shore	Habitat/Biotope	JNCC Code
Upper	Saltmarsh	LS.LMp.Sm
↓	*Pelvetica canaliculata* on sheltered variable salinity littoral fringe rock	LR.LLR.FVS.PelVS
	Verrucaria maura on littoral fringe rock	LR.FLR.Lic.Ver
	Fucus vesiculosus on mid eulittoral variable salinity boulders and stable mixed substrata	LR.LLR.FVS.FvesVS
	Ascophyllum nodosum and *Fucus vesiculosus* on variable salinity mid-eulittoral rock	LR.LLR.FVS.AscVS
	Mixed Sediment	LS.Lmx
Lower	Polychaete/amphipod dominated fine sand shore	LS.LSa.FiSa

The lower shore was characterised by flat, stable sand, indicative of lower-energy conditions with a fine overgrowth of patchy filamentous green algae. Surface evidence of infauna was clear, with the occasional lugworm casts (*Arenicola marina*) and the large Maldanid polychaete (bamboo worm) also recorded.

The distribution of the dominant macrofauna varies with sediment type or proximity to the channels. Whilst samples within the upstream channel recorded very low numbers of individuals of freshwater tolerant crustacean *Bathyporeia elegans* and the rag worm *Hediste diversicolor,* the open sand flats are dominated by the small tube-dwelling polychaete *Pygospio elegans*. This was recorded at most sites with an abundance ranging from 133 to 2,130 individuals/m^2. Other top ranking species along the route are the annelids *Heterochaeta costata* and *Tubificoides sp*., the small mysid *Neomysis integer,* found generally on or close to the bank deposits and the gammarid *Corophium volutator*. Most other species were only represented by a few individuals at each site. A number of the species recorded, in particular the larger polychaetes, the mollusc *Hydrobia ulvae* and the crustaceans *Neomysis, Bathyporeia* and *Corophium* are all important food groups for birds feeding in the inter-tidal zone. However, the cumulative average of <100 individuals/m^2 recorded throughout area is considered low for this type of habitat, where waders are known to feed. For example the JNCC biotope for an estuarine mudflat with high numbers of ragworms (LS.LMu.MEst.HedMac) would typically record populations in excess of 1,000/m^2 for Hediste diversicolor alone (Conner, 2004). An additional study of the epifaunal macro-invertebrates within the coarser bank deposits (Wilson, 2007_2), indicated a small population of gammarid crustaceans living amongst the rocks, which would provide an additional food source for wading and foraging birds along this part of the upper shore equivalent to between 0.33 and 3.45g/m^2, although a significant proportion of these animals would be inaccessible to most birds due to the size of some of the stones.

Extensive surveys of the soft sediments (using cores, and quadrates) and hard substrates (via by quadrat counts) was undertaken in 2005 by Ecoserve, with additional sampling and walk-over surveys in 2007 (Table 14.6) and an additional site in 2010 (Wilson 2010_1).

Table 14.6: Sediment, Chemical and Biological Parameters along the Proposed Pipeline Route in Sruwaddacon Bay

Site	Easting	Northing	%Gravel	% coarse and very coarse sands	% medium to very fine sands	% Fines	Mean Size	TOC
ESL1	82150	338543	0	5.59	94.47	0	0.29	-
ESL2	82172	338450	0	6.53	93.50	0	0.3	-
ESL3	82241	338312	0	1.66	90.57	7.80	0.24	-
ESL5	82454	338296	0	4.60	95.36	0	0.3	-
SL7	82304	338375	0	64.13	35.86	0	0.61	1.70
R1	82238	338354	0	49.38	48.60	2.03	0.25	0.02
R3	82741	337468	0	73.23	26.77	0	0.32	<0.01
R5	83108	337312	0	47.84	48.20	3.96	0.24	0.04
R6	84035	336739	0	40.95	59.05	0	0.23	<0.01
R7	84196	336688	0	39.10	58.77	2.13	0.23	0.05
B9	84737	336406	0	41.78	56.18	2.05	0.23	0.22
R8	85036	336029	0	25.95	70.29	3.77	0.20	0.02
B6 East	85242	335604	0	20.79	55.25	23.96	0.11	0.89

Site	Easting	Northing	Sulphide	Al (mg/g)	Hg	As	Ba	Cd	Cr	Cu
L14	83322	337380	<20.0	1510	<0.0500	4.27	7.99	<0.100	4.79	<0.100
L17	83607	337211	<20.0	1140	<0.0500	4.3	5.34	<0.100	4.53	0.39
L22	84348	336538	41.2	2110	<0.0500	3.58	12	<0.100	5.62	0.51
L27	85074	336010	<20.0	2820	<0.0500	3.58	13.7	<0.100	6.69	0.83

Site	Easting	Northing	Fe	Pb	Li	Mn	Ni	Ag	Sn	Zn	TPH
L14	83322	337380	3900	1.8	4.06	<0.0500	1.73	<10.0	0.4	6.19	29000
L17	83607	337211	3020	2.12	2.09	<0.0500	1.35	<10.0	0.6	5.06	23800
L22	84348	336538	5830	1.84	4.13	<0.0500	2.37	<10.0	0.5	9.64	129000
L27	85074	336010	8810	2.13	4.68	5.45	3.21	<10.0	0.5	14	49900

Site	Easting	Northing	Species	Individuals (m^2)	Diversity	Simpsons
ESL1	82150	338543	11	5,611	1.985	0.68
ESL2	82172	338450	10	856	1.861	0.55
ESL3	82241	338312	16	1,144	2.507	0.70
ESL5	82454	338296	16	900	3.016	0.80
SL7	82304	338375	3	56	0.95	0.44
R1*	82238	338354	14	884	2.23	0.7088
R3*	82741	337468	10	476	1.965	0.6049
R5*	83108	337312	20	1028	3.454	0.8849
R6*	84035	336739	10	124	3.021	0.886
R7*	84196	336688	20	1112	2.759	0.7284
B9*	84737	336406	11	812	1.543	0.4979
R8*	85036	336029	15	800	2.921	0.8162
B6 East*	85242	335604	11	3428	0.7882	0.2072

* based on 0.5mm samples processed down to 20cm (Wilson 2010_1)

Inter-tidal sampling of the soft sediments in 2005, indicated low numbers of macrofauna, with low diversities polychaetes recorded in the upper shore, with the occasional mollusc (*Macoma balthica)* and crustacean (*Corophium volutator)* at mid and lower shores. Further sampling in 2007, and 2010 revealed a slightly different picture, with 27 species of fauna recorded at the western shore included eighteen species of polychaete worms, nine species of crustaceans and two species of molluscs. This fell to between 10 and 20 species recorded along the proposed route with the distribution of species related to the level of reworking and sediment mobility as this reduced slowly along the length of the proposed route towards the upper estuary. Of the dominant taxa, the annelids *Tubificoides benedeni*, *Pygospio elegans* and *Eteone flava/longa* dominated the sands, with large numbers of the crustacean *Bathyporeia pelagica* recorded within the mobile sediments, or *Corophium volutator* where the current energy was slightly lower. The mollusc *Cerastoderma edule* was also recorded at most sites, although for the most part, this species was represented by only one or two large individuals.

For the hard substrate, a quantitative assessment of the epifaunal coverage was carried out by Ecoserve at three levels on the eastern shoreline. This revealed 22 species or higher taxa present, dominated by barnacles (*Semibalanus balanoides),* at all levels, with the periwinkle (*Littorina obtusata)* and the tube polychaete (Spirorbidae indet) found in high densities in the mid shore and further periwinkles (*Littorina saxatilis* and *L.littorea*), mussels (*Mytilus edulis*), limpets (*Patella vulgate*) and the anemone (*Actinia equine)* on the lower shore.

For algaes, the upper shore was dominated by *Fucus spiralis, Pelvetia canaliculata* and *Verrucaria maura* in roughly equal measure, changing to almost completely *Ascophyllum nodosum* in the mid shore and light covering by *A.nososum* and *F. vesiculosus* for the lower shore.

14.3.3 Changes in the Marine Fauna in Sruwaddacon Bay

A number of similar surveys carried out at selected locations between 2001 and 2010 have highlighted natural changes that have occurred over time. On the western shore of the lower estuary a second stream was recorded in 2007 which introduced some new biotopes to the shoreline. The absence of this stream in the earlier survey may have reflected the extremely dry summer of 2005 when the earlier survey was conducted. Sediment analyses at selected locations have revealed some variations in the proportion of fines, whilst general observations of sandbanks and channels during survey operations within the estuary has revealed subtle changes in the depths of some channels and the shape of some banks surrounding the main channel (personal observations by P.Cowman and I.Wilson, 2010). Biological changes include a notable increase in the density and coverage by the polycheate *Arenicola marina* over most of the lower-energy sand banks along the length of the bay.

14.3.4 Inshore Fisheries and Fish Species

No commercial fisheries exist within Sruwaddacon Bay. Consequently, no catch logs can be related to this area. Furthermore the shallow water depth in the estuary means that access by fishing vessels (commercial or recreational) would be very difficult. The closest commercial fish related data was taken from the outer Broadhaven Bay by the Marine Institute, which was trawled many times over an eight year period between 1993 and 2000.

Information on fish species within Sruwaddacon Bay is limited. As part of the METRIC Program, the Central Fisheries Board (CFB) implemented a monitoring program for fish in transitional waters under the requirements of the Water Framework Directive (WFD). In addition to gathering and standardising existing archival datasets, new datasets were collected within thirteen estuaries surveyed in 2006, including Sruwaddacon Bay. The survey was carried out in October 2006, in conjunction with North Western Regional Fisheries Board (NWRFB) and again for Sruwaddacon in May 2008 (CFB, 2008) to review springtime fish use within the bay.

On both surveys, a total of three sampling methods were used (Appendix L). The majority of the survey was carried out using a beach seine net, which encompassed the majority of geographical area and habitat range within the estuary. In addition, fyke nets were placed in the middle and upper sections of the estuary, but were not suitable in the lower estuary due to exposure in 2006, but were obtained in 2008. Beam trawls were used in the lower estuary and mid-estuary during periods of high water.

In the initial 2006 survey, results from the seine nets recorded the lowest abundance of any estuary surveyed by the CFB in the period 2001-2005. The Sand goby (*Pomatoschistus minutes)* was recorded throughout the estuary, encountered at five of the six sites, whilst Sprats (*Sprattus sprattus*) were found associated with the *Fucus* area of the mid estuary. The highest abundances were recorded at the uppermost sites, as was the case with juvenile flounder (*Platichthys flesus;* 8-25cm), also shown in the fyke netting at all sites. This technique also revealed Bearded Rockling (*Ciliata mustela*) in the mid-estuary sites and trout (*Salmo trutta*) in the upper freshwater area. Species composition was similar to that of Tullaghan Bay close by and surveyed in the same week. Eels (*Anguilla anguilla*) were found in low abundance in the estuary.

Trawl sampling in Sruwaddacon Bay was characterised by a low Catch Per Unit Effort (CPUE) and the lowest diversity of any trawl samples taken during the METRIC project. Pipefish (*Entelurus aequoreus* and *Syngnathus rostellatus*) were present in low numbers in five of the six trawls and were associated with the large amount of weed found at these locations.

Hard substrate habitats within the lower and mid estuary revealed a low diversity and abundance within the fish communities, thought to be a natural feature of estuaries in the region (CFB 2006). Whilst many estuaries are generally considered to be a productive environment, this is not the case for Sruwaddacon Bay where relatively strong flowing currents continuously rework sediments maintaining a sparse macro-invertebrate community with a low biomass over the majority of the survey area. Fish assemblages within Sruwaddacon Bay and neighbouring Curraunboy Bay were similar to those recorded in nearby Tulachán (Tullaghan), which exhibited a similar habitat. The fast currents and a lack of depth at low water can provide difficult conditions for small fish to thrive (CFB 2006). Only species like the pipefish may be able to tolerate stronger currents by clinging onto the weed.

When looking at the seasonal changes in the fish usage within the Sruwaddacon, the timing of the autumn (2006) and spring (2008) sampling programmes were based on long-term studies of rivers (i.e. Thames estuary in the UK), which demonstrated the peak periods of use by fish species. The underlying differentiator between these two periods is considered to be related to temperature changes where falling marine temperatures encourage a range of marine-associated species into the estuarine waters (such as young stage gadoids, including cod, pollock and whiting) or the movement of many species into the marine waters following a rise in spring temperatures.

A comparison of fish populations recorded between the 2006 and 2008 surveys showed a greater number of species captured in both beach seine and fyke deployments during the later survey whilst the beam trawl gave similar results. Many of the additional species were represented by only a single individual, with a very low mean number recorded per sample (Table 14.7), with the only exception being the sandeel (*Ammodytes tobianus*). Taking into account a slight increase in sampling effort and the targeting of more varied habitats in the later study, results were shown to broadly mirror the earlier autumn pattern, where the sand goby (*Potamoschistus minutus*) was the only species strongly represented. Mean flounder numbers were lower in the spring survey for both beach seine and fyke nets.

The increase in fish species in the spring survey was probably due to sampling effort being dispersed onto a wider range of different substrata. Fykes were laid in the outer bay (not accessible in 2006 due to the weather) and over rocky areas, whilst beach seines were conducted in weedy areas. These last two environments tend to provide greater protection to small and juvenile fish species.

The total species numbers captured in Sruwaddacon in 2008 were slightly higher than those of east coast waters such as the Boyne, Liffey and Rogerstown at similar seasons, although there was no consistent trend when comparing spring and autumn species totals. However, whilst the Sruwaddacon datasets indicated an estuary with a relatively wide species richness in both spring and autumn samples, in line with other estuaries, it contains these species at generally low abundance levels.

Of the samples collected in the autumn of 2006 and spring of 2008, none of the species recorded were unusual or were listed as Annex II species under the Habitats Directive. This includes the anadromous species such as the lampreys, shad or salmonids. Whilst these data are separated by two years, they represent only a relatively short snap-shot of species using the estuary at these times. However, the data are expected to give a good representation of the fish species using the bay during these key seasons. Salmonids and other anadromous species along with their migrations are discussed in more detail in Chapter 13.

Table 14.7 Catch per unit effort for Non-target Fish Species Recorded in Sruwaddacon Bay and Curraunboy Bay in the Autumn 2006 and Spring 2008 (CFB 2006 & 2008).

Species	Common Name	Beach seine		Fyke nets		Beam trawl	
		08	06	08	06	08	06
Ammodytes tobianus	Lesser sand eel	42.8				0.1	0.17
Pollachius pollachius	Pollock	2.3		0.2	2.67		
Platichthys flesus	Flounder	1.8	4.17	1.2	5	0.3	
Gobiusculus flavescens	Two spotted goby	1.3				0.4	0.17
Pleuronectes platessa	Plaice	1.3	0.5			0.4	0.17
Pomatoschistus minutus	Sand goby	1.2	14			0.8	0.17
Atherina presbyter	Sand smelt	1.0	0.5				
Scophthalmus rhombus	Brill	0.8				0.1	
Unidentified	Gadoid juveniles	0.6				1.3	
Crenilabrus melops	Corkwing wrasse	0.4	0.17	0.45			0.33
Pomatoschistus microps	Common goby	0.2				0.1	
Syngnathus acus	Greater pipefish	0.2				0.6	
Anguilla anguilla	European eel	0.1		0.2	1.67		
Salmo trutta	Sea trout	0.1	0.17		0.33		
Labrus bergylta	Ballan wrasse	0.1		0.5			
Solea solea	Common sole	0.1					
Spinachia spinachia	15 spine stickleback	0.1					1.00
Gaidropsarus vulgaris	Three beard rockling			1			0.17
Ciliata mustela	Five beard rockling			0.7	4.33		
Taurulus bubalis	Long-spined sea scorpion			0.5			
Lipophrys pholis	Shanny			0.2			
Callionymus lyra	Dragonet					0.1	
Entelurus aequoreus	Snake pipefish					0.1	1.33
Raja clavata	Thornback ray					0.1	
Scyliorhinus canicula	Lesser spotted dogfish			0.3			
Psetta maxima	Turbot					0.2	
Myoxocephalus scorpius	Bull rout		0.5				0.17
Sprattus sprattus	Spratt		4.17				
Mugilidae	Mullet spp.		0.17				
Dicentrarchus labrax	Bass				0.33		0.33
Labrus bimaculatus	Cockoo wrasse						
Syngnathus rostellatus	Nilsonns Pipefish						0.33

14.3.5 Aquaculture/Shellfishery Activities

The previous EIS in 2001 (RSK, 2001) and 2009 (RPS, 2009) identified the limited development of aquacultural activities within the vicinity of Sruwaddacon Bay. There is currently only one licensed oyster culturing facility (*Ostrea edulis,* T10/81) within Sruwaddacon Bay (licence T10/81), which exists in the south side of Sruwaddacon Bay, close to Poll an tSómais (Pollatomish) pier. However, it is understood that very little culturing is carried out at the site and the licence is known to have remained unutilised for a number of years, up to October 2007, when operations recommenced. It is understood that the facility is not currently in production (personal observations I. Wilson, February 2010).

The facility is located approximately 500m away from the proposed pipeline route and it is anticipated that there will be no impact on the aquaculture activity if the licence were to be utilised again. Therefore there will be no economic impact on the facility.

Elsewhere, subsistence foraging by local residents occurs for the mussel (*Mytilus edulis*) and the periwinkle (*Littorina littorea*) at and around the coarse substrates at the mid to low-water mark on the eastern bank of Sruwaddacon Bay entrance, and for the cockle (*Cerastoderma edule*) on the main sand bank in the north part of the bay.

Shellfish fishermen, who routinely operate from the pier at An Baile Glas (Ballyglass), do not carry out any fishing for shellfish species within Sruwaddacon Bay due to inappropriate habitats and unsuitable access. The bulk of their catches, that of the lobster (*Homarus gammarus*) and the edible crab (*Cancer pagurus*) occurs in the outer areas of Broadhaven Bay, where the rocky coastlines provide a suitable habitat.

It is understood that Broadhaven Bay will be designated as shellfish waters within the meaning of the Shellfish Waters Directive (79/923/EEC). However at the time of writing it is not known if the designated boundaries will extend into Sruwaddacon Bay.

14.3.6 Marine Mammals and other Large Marine Species

Since the submission of the original EIS in 2001 (RSK 2001), a number of inshore monitoring surveys were commissioned north of the study area. In 2001 and 2002 marine mammal monitoring was carried out in Broadhaven Bay from cliff top and boat-based visual observations and photo-identification, between August, 2001 and October, 2002. This included some acoustic monitoring (O Cadhla *et al*., 2003). Following this, marine mammal monitoring in Broadhaven Bay, was undertaken in 2005 using both visual and acoustic survey methods. Visual monitoring (cliff-based only) was undertaken over 46 days between 12th June and 30th September, 2005, whilst acoustic monitoring took place over ninety-nine days between 24th June to 30th September 2005 (CMRC, 2006). In 2007, a geophysical survey of Sruwaddacon Bay area was undertaken between June 19th June to 1st August, 2007. This was supported by a dedicated and qualified Marine Mammal Observer (MMO), who was vessel based at all times (C. Collins, 2007). Further observations were carried out as part of the ongoing marine mammal monitoring surveys (CMRC, 2010) and during dredging operations along the proposed pipeline route in Broadhaven Bay between 8th July and 5th November, 2008 (OSC and Coppock 2008) . These surveys were to ensure compliance to the guidelines described in the “Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters” during survey and construction operations. In addition to these dedicated field survey observations, validated records of incidental sightings and strandings were acquired from the database maintained by the Irish Whale and Dolphin Group (www.iwdg.ie). Searches were performed for the period since the submission of the original EIS (October 2001). Table 14.8 presents a summary of records of marine mammals species, when identified to species within the Broadhaven Bay and the entrance to Sruwaddacon Bay survey site.

These site-specific surveys have allowed for a much more accurate assessment of the existing populations within the inshore area of Broadhaven Bay. Based on the above observations it can be concluded that Broadhaven Bay and its neighbouring waters are important for marine mammals, both cetaceans and pinnipeds, in terms of diversity and abundance. Photo-identification studies suggest a level of residency of bottlenose dolphins, with records of newborn and young calves of dolphins (common, bottlenose and white-sided) reported. This may reflect the area’s importance as a potential breeding ground or nursery area for some species. The most common species of cetacean recorded in Broadhaven Bay was the small and generally inconspicuous harbour porpoise (*Phocoena phocoena*), constituting over 26% of all cetaceans observed in the bay between August, 2001 and October, 2002 (O.Cadhla, 2003). All but one observation of this species was recorded during a period of high or ebbing tide. Despite numerous sightings within Broadhaven Bay, the relative abundance of this difficult to spot Annex II species may have been underestimated. Consequently, a further acoustic survey was undertaken using remote recording devices situated seaward of Sruwaddacon Bay and Curraunboy confluence. The vocalisation of harbour porpoises were recorded in all months of the study with the highest number of recordings made at the listening station situation closest to the Gleann an Ghad (Glengad) landfall location. Although no cetaceans were recorded within Sruwaddacon Bay or Curraunboy Bay, an occasional foray into these areas by this species cannot be ruled out. This species was not observed at sea in the late 2007 and 2008, but was occasionally sighted in Broadhaven Bay from the shore in 2005, 2008 and 2009. Excursions by larger whales or dolphins in Sruwaddacon Bay remain very unlikely.

Table 14.8 Species list of Marine Mammals recorded within the Broadhaven Bay Area

Common name	Scientific name	*Source: When observed*
Minke whale	*Balaenoptera acutorostrata*	1,2,6
Sei whale	*Balaenoptera borealis*).	6
Killer whale	*Orcinus orca*	2
Pilot whale	*Globicephala melas*	3,
Risso's dolphin	*Grampus griseus*	1,2,3,6
Bottlenose dolphin	*Tursiops truncates*	1,2,5,6
White-sided dolphin	*Lagenorhynchus acutus*	1
White-beaked dolphin	*Lagenorhynchus albirostris*	1
Common dolphin	*Delphinus delphis*	1,2,3,6
Harbour porpoise	*Phocoena phocoena*	1,2,3,6
Unidentified dolphin	*Tursiops truncates?*	5,6
Pinnipeds		
Common seal	*Phoca vitulina*	1,2,4,5,6
Grey seal	*Halichoerus grypus*	1,2,4,5,6
Unidentified seal	*Halichoerus grypus?*	1,5,6

Sources: (1) 2001-2002: O Cadhla et al., 2003; (2) 2005: (CMRC, 2006); (3) Summer 2007: Collins, 2007; (4) IWDC 2001-2007: IWDC database records and OSC and (5) Coppock, summer 2008 and *(6) 2005: (CMRC, 2010).*

Broadhaven Bay has a resident population of both common and grey seals regularly recorded in Boardhaven Bay from 2001 to 2010. Both common and grey seals have been observed in the entrance (O Cadhla *et al*, 2003) and the lower portion of the estuary, particularly during periods of high flows (C Collins, 2007). It is presumed that the seals visit the narrow fast flowing channel at the point of the confluence to feed, as the natural hydrodynamics of the channel would concentrate fish species into a relatively small area. During more recent visits to the estuary, a small family group of grey seals has been recorded within the mouth of the Sruwaddacon, as well at occasional sightings on banks within the bay and swimming within the upper part of the estuary in 2007 and 2010 ((I.Wilson/Ornithologist observations).

In addition to the significant numbers of cetaceans recorded within Broadhaven Bay, the apparent biological importance of the region is also supported by the occasional observation of basking sharks *(Cetorhinus maximus*), sun fish (*Mola mola*), and a single sighting of a sea turtle (species unknown), along with large numbers of seabirds. However, only the otter and seal has been recorded within Sruwaddacon Bay estuary itself (see Chapter 12 for further details on otters).

14.4 POTENTIAL IMPACTS

As outlined in Chapter 5 it is proposed to tunnel beneath Sruwaddacon Bay using a Tunnel Boring Machine (TBM).. This method avoids surface intervention in the sea-bed, unless an exceptional problem is encountered during tunnelling, which is considered to be extremely unlikely (see Chapter 5). Bentonite is used during the process to lubricate the TBM drilling head and to carry arisings back to the compound for processing. Its use is monitored throughout the process to avoid potential releases of bentonite into the marine environment.

Should an exceptional problem be encountered during the works and an intervention pit be required, then there is potential to cause impact to the immediate and adjacent habitats. This can be caused by noise, excavation activities, sediment scour, increased traffic, sediment suspension and potential emissions. These may affect habitat, the hydrodynamic regime, and the sediments or pollute both the sediments and waters. There may also be a requirement for a temporary jetty on the shore should an intervention pit be required.

Flora and fauna, water quality and sediment stability have the potential to be negatively impacted by the construction process. This includes releases into the marine system carried by surface runoff from the compounds or noise and vibration effects in the sediments caused by the tunnelling operation.

Loss/change of Sediment Habitat

The extremely unlikely event of the construction of the pipeline requiring a temporary surface intervention pit will impact the sediments and associated fauna at this location of the bay. Whilst the location of this pit could be anywhere along the length of the pipeline route, its subsequent impact will vary subject to its location and proximity to the main channel. The natural habitat varies slightly along the route from a low energy sand flat in the upper estuary, to a higher energy medium to coarse sand with some fine gravels in the lower estuary and the lower channel. Both ends of the route are bordered by a thin band of mixed sediments high up on the foreshore. In addition to the direct impact to the habitats at the site, secondary habitat change will also occur due to increased sediment scour and deposition caused to sediments surrounding the operations by temporary changes in the hydrodynamics within the vicinity of the operations. The overall impacts are expected to be slight and temporary.

The potential for a bentonite leakage is extremely unlikely, although should this occur it is not expected to cause habitat loss, although there would be an imperceptible impact within a limited geographical range of the escape. This is expected to be only temporary.

Change in Water Quality and Sediment Load

Whilst the pumping of ground/pore waters may take place during the construction phase, no additional water supplies will be used. Therefore the salinity and temperatures are not likely to alter much from the range normally experienced in these areas.

The movement of seabed sediments during the construction of an intervention pit (in the extremely unlikely event that it should be required) will increase the turbidity of the surrounding waters over the short term. Any bentonite leakage would equally have a notable impact on sediment turbidity and suspended load. This increase in turbidity could result in increased siltation and the smothering of sediments and organisms accompanied by a reduction in the light available to the seabed for photosynthesis. High levels of suspended solids settling on the seabed can alter habitats resulting in a potential loss of feeding and spawning grounds. Mobile species (including sensitive species such as salmon and sea trout) may temporarily move away from unfavourable conditions. However sessile, benthic fauna may be smothered and lost. As the area to be developed in the littoral and sub-littoral environments is small, the impact will also be localised and imperceptible.

Impacts of increased turbidity are likely to be minimal in the overall context of the bay as there is already a relatively high degree of suspended solids and peat-staining in this area from riverine influx from the surrounding bog. Furthermore, as the majority of sediments reflect a medium to high energy environment, there are little or no sediment fines naturally present. Consequently, a discharge of coarser sediments (such as sands) will have a limited area of settlement during periods of increased sediments loads.

A release of bentonite may marginally increase the levels of some chemical components within the vicinity of the discharge. These may include some metals, although the components within the bentonite drilling fluid are naturally occurring and generally non-toxic to marine benthic fauna.

A small quantity of this suspended clay can escape into the water course and produce a plume effect within the water column and a smothering effect on benthic communities, in particular suspension feeders. In small quantities and areas of low tidal movement, the viscous high density clay will initially remain localised before becoming suspended and flushed out of the estuary over subsequent tidal cycles. Should a release be coincidental to a period of migrating salmonids where a short-term elevation in turbidity could have a detrimental effect on fish gills, the higher concentrations (>300mg/l) will be avoided by the adults during their passage, or in an extreme case, migration may be delayed for a tidal cycle. Dilution of bentonite to below this level, will occur rapidly from the point source. Marine fauna will be unaffected by the plume as the strong tidal flow will prevent any significant settlement of the clay into the reworked sediments of the bay. Consequently, this impact is expected to be negligible and temporary.

Noise Pollution

Little is known about the effects of noise and vibration on invertebrates; however impacts are likely to be minimal, given the low populations recorded within the vicinity, and the short term for the works. Noise impacts would also be likely on vertebrate fauna for the area. For the most part, this will be the population of fish species which live within close proximity of the proposed route or migrate up and down the estuary during the daily tidal cycles. The most sensitive biological receptors will be the seal population, known to patrol the lower part of the estuary on occasion. However, the proposed route is considered not to be very important for foraging, with the majority located beneath the shallow bank areas where water depths are limited. This very mobile species is expected to simply avoid the immediate area during noisier parts of the construction phase. Consequently, impacts are likely to be imperceptible and temporary.

The tunnel boring machine (TBM) operates by slowly rotating a cutter head that will produce a low level ground vibration through the sediments and water column above the route of the pipeline. Since sound moves differently through water than it does through air, it is also measured differently for the two media. Noise travelling through air is typically measured in decibels (dB) relative to a reference pressure of 20 micro-Pascals (μPa) however, as water is denser than air, sound travels much faster and further, so noise travelling through water is measured in dB relative to a much lower reference pressure of 1 μPa. Since our hearing responds logarithmically to received sound levels, the ratio to the reference is also expressed in logarithmic terms, in dB:

$$SPL\ (dB) = 20\log\frac{P}{P_0}$$

where SPL is the *Sound Pressure Level* and P_0 is the reference, 1μPa. Every 20dB thus represents a ten-fold increase in SPL.

These reference pressures are standards adopted among acoustic engineers. Since the reference pressures that apply to the two mediums are not the same, direct comparisons between measurements taken in air and water cannot be made.

The likely groundborne vibration arising from tunnelling was modelled for the proposed pipeline route, sediment type and expected geological profiles at selected points along the proposed profile (Taylor, 2010, see Appendix H3). The model shows that the main output frequencies occur at 16Hz, 20Hz, 31.5Hz, 40Hz and 63Hz. The vibration outside this frequency range is not of significant amplitude and the responses are generally below 10Pa (140dB re. 1 μPa).

The vibration model shows that the highest underwater noise output is at 31.5 Hz with a pressure level of around 100Pa (160dB re. 1 μPa) within a few metres of the TBM, decreasing to less than *ca.* 30Pa

(149.5dB re. 1 µPa) within a 30m distance from the TBM, and *ca.* 18Pa (145 dB re. 1 µPa) at a distance of 90m. At higher and lower frequencies the pressure level (dB re. 1 µPa) is generally lower and also declines with distance from the TBM.

Frequencies of 4, 25 and 63Hz also show moderate outputs of between 145dB re. µ1Pa and 150dB re. 1µPa (Figure 25, Taylor, 2010). Outside of these frequencies, the responses were generally below 10Pa (140dB re. 1 µPa).

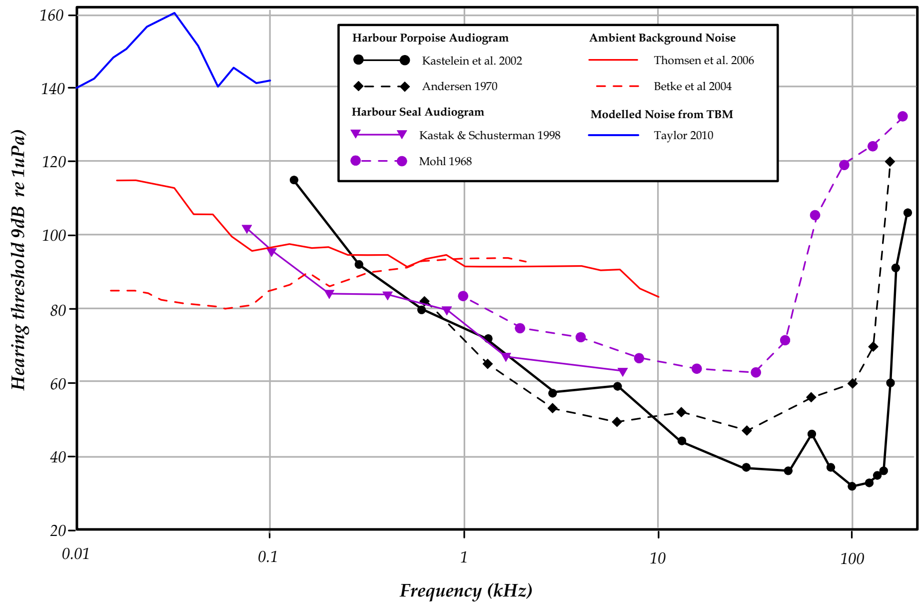
On average the sound output within the frequency range modelled (i.e. 1-100Hz) ranges from 160dB re 1µPa to 120dB re 1µPa within 10m of the TBM to about 140-120dB re 1µPa at 90m distance. These sound levels are the highest modelled. They represent the situation directly above the cutting face and propagating 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.

Owing to the tidal nature of the site, the proposed route of the TBM will pass beneath sediments exposed by the receding tide for significant periods of time. A review of the bathymetric profile in Sruwaddacon Bay (Chapter 14 Figure 14.2) shows that less than 2% of the route lies below lowest astronomical tide (LAT), whilst around 38% remains exposed when the tide is at mean sea level (MSL). Consequently, whilst the propagation of groundborne vibration will be occur through the seabed throughout construction, temporally this will only also impact the overlying waters in respect of underwater noise for a proportion of the time. These areas relate mainly to the channel areas represented by between 2 and 44% of the route during maximum and minimum low water periods, respectively. The excavation of the tunnel by the TBM will neither be static nor continuous with the tunnel expected to advance around 11m on average per day, and to be underway for less than a third of the total operational time per day. (See Chapter 5 of the EIS)

<u>Background Noise levels</u>

Ambient underwater noise levels depend upon a number of factors, including surface interaction between wind and waves, rainfall, marine animals and shipping. Early studies into ambient noise levels (Knudsen *et al*., 1948 and Wenz 1962) determined relationships between descriptors of physical and anthropogenic noise sources (e.g. ships, wind speed) and noise spectrum level in the deep open ocean. In shallow water (which includes the North Sea and the waters around Ireland), there is greater spatial and temporal variability in ambient noise level. Ambient noise levels would be expected to be higher in coastal locations due to the noise from breaking surf; the movement of shingle, sand, gravel and other sea/coast interactions; and from ships (near ports, harbours and shipping lanes) and smaller vessels. Thomsen *et al* (2006) published results on the measurements of ambient noise around wind farms in the North Sea, with results showing a 1/3rd-octave spectrum typically peaking at just below 115dB re 1µPa at around 20 to 30Hz but falling to below 95 dB re 1µPa above 250Hz (Figure 14.9). Other common ambient background noises are quite natural and relate to the clicking of communicating crustacea (1 to 100kHz), or are anthropogenic and relate to marine engines. These can vary from fast running outboard motors (152-156dB re 1µPa @ 630Hz to 6.3KHz) or slower running fishing type vessels (151dB re 1µPa @ 250Hz to 1KHz). Vessel noise is broadband, ranging from 10 Hz to 10 kHz or more, and source levels can vary by vessel type from 157 to 187dB re 1µPa for a variety of vessel types travelling at 10 knots (Kipple and Gabriele, 2004). Other ship borne devices, such as sonars and echo sounders, typically operate at 100 to 500KHz frequency in shallow water environments.

Figure 14.9 Summary of Modelled TBM Sound Pressure Levels compared to expected ambient background noise and the Audiograms of Harbour Porpoises and Harbour Seals



<u>Noise Impacts to Marine Mammals</u>

Based on extensive survey and monitoring programs in 2001-2, 2005, 2008 and 2009 (see Appendices in Offshore Supplementary Update Report, RSK, 2009) the only marine mammals apart from otters, known to use Sruwaddacon Bay are harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) To date there are no records of cetaceans occurring in Sruwaddacon Bay. The occasional presence of harbour porpoise (*Phocoena phocoena*) and larger odontocetes (e.g. dolphins) cannot be ruled out; however, while they are known to occur in Broadhaven Bay, it is unlikely that they would enter the shallower waters of Sruwaddacon Bay, unless pursuing prey species. Despite the unlikelihood of their presence, potential impacts on odontocetes have been assessed.

Impacts to marine mammals will vary with the sensitivity of the receptor species. The baleen whales (mysticetes), whose collective auditory range of 7 Hz to 22 kHz can be classed as low-frequency (Table 4.9; after Southall *et al*., 2007) are not found in the waters of the Sruwaddacon, although they have been recorded further out in Broadhaven Bay (CMRC, 2010). While low-frequency noise propagates further than higher frequency noise in optimal conditions, it may be possible that mysticetes are impacted by the noise from tunnelling; however, the shallow and tidal nature of the site is not conducive to transmission of low frequency sound, and it is expected that this will be rapidly dissipated in the intertidal and nearshore environment. As such, baleen whales are not anticipated to be impacted by the operations. Of the toothed whales and dolphins (odontocetes), only the smaller species could be expected to occur within the estuary on rare occasions, whilst the seals (pinnipeds) are commonly recorded at the entrance of the Bay and can be occasionally seen to venture into the Sruwaddacon to forage or haul out. Table 4.9 summarises the typical auditory range for all of these species, although the sensitivity of these ranges may alter significantly with the frequency. Kastelein et al. (2002) showed that the harbour porpoise exhibited a very wide hearing range with relatively high hearing thresholds, although this was relatively poor (ca. 92-115dB re 1μPa) at the lower frequencies produced by the TBM. Hearing was notably more sensitive (i.e. lower thresholds) in the mid and higher frequency bands (60-80 dB between 1 to 8KHz, falling to only 32 to 46dB re 1μPa from 16 to140kHz, respectively. Consequently noise output from the TBM below 100Hz is unlikely to interfere with the sounds used for routine foraging and communication activity of the odontocetes encountered in the region.

The hearing sensitivity of harbour seals is marginally greater than that of the cetaceans for the lower frequencies with a central hearing range of around 8 to 16kHz, and potentially with some infrasonic perception (,Figure 14.9). The summary figure shows that the higher frequencies produced by the

TBM might just be detectable by the seal on the very limit of its auditory range when within close proximity to the drilling location, but this level is well below any threshold for damage for this species 218dB re.1μPa, Table 4.9). The majority of the TBM frequencies will be imperceptible to this group.

Table 4.9: Summary of Key Hearing Frequencies for Sensitive Receptor Species and Criteria for Injury (after Southall *et al.* 2007)

Species of marine mammal	**Potential for occurrence in Sruwaddacon Bay**	**Approximate distance from nearest sighting to the estuary narrows at Rossport Pier**	**Estimated auditory bandwidth (hearing group*)**	**Criteria for injury***
Sei whale (*Balaenoptera borealis*)	Not expected	11 km	7 Hz to 22 kHz (Low-frequency cetaceans)	Sound Pressure 230 dB_{peak} re.1μPa (flat) Sound exposure 198 dB re.1μPa^2-s(M_{lf})
Minke whale (*Balaenoptera acutorostrata*)	Not expected	5 km		
Killer whale (*Orcinus orca*)	Not expected	8 km	150 Hz to 160 kHz Mid-frequency cetaceans	Sound Pressure 230 dB_{peak} re.1μPa (flat) Sound exposure 198 dB re.1μPa^2-s(M_{mf})
Risso's dolphin (*Grampus griseus*)	Not expected	4 km		
White-beaked dolphin (*Lagenorhynchus albirostris*)	No expected	13 km		
White-sided dolphin (*Lagenorhynchus acutus*)	Not expected	3 km		
Common dolphin (*Delphinus delphis*)	Not expected§	4 km		
Bottlenose dolphin (*Tursiops truncatus*)	Rare§	1.5 km		
Harbour porpoise (*Phocoena phocoena*)	Rare§	2.5 km	200 Hz to 180 kHz (High-frequency cetaceans)	Sound Pressure 230 dB_{peak} re.1μPa (flat) Sound exposure 198 dB re.1μPa^2-s(M_{hf})
Harbour seal (*Phoca vitulina*)	Rare to occasional	0 km	In water: 75 Hz to 75 kHz In air: 75 Hz to 30 kHz	(IN WATER) Sound Pressure 218 dB_{peak} re.1μPa (flat) Sound exposure 186 dB re.1μPa^2-s(M_{pw}) (IN AIR) Sound Pressure 149 dB_{peak} re.20μPa (flat) Sound exposure 144 dB re.20μPa^2-s(M_{pa})
Grey Seal (*Halichoerus grypus*)	Occasional	0 km		

**Data from Southall* et al., *2007, Table 2 and Table 3.*

§ For assessment purposes it is assumed that these species would occur rarely, if at all.

Overall, the majority of noise energy produced from the TBM operation in water is below 100 Hz; any vibration outside this range is unlikely to be of an amplitude high enough to affect marine mammals. The hearing sensitivity of the high and mid frequency cetaceans along with the pinnipeds falls rapidly below 100 Hz. Table 4.9 also lists example criteria contained within Southall *et al.* (2007) which have been adopted by the UK Joint Nature Conservation Committee (JNCC) as a suitable criteria to determine what constitutes an 'injury offence' in accordance with Article 12 of the Habitats Directive. The TBM noise output model shows that the expected maximum outputs fall well below these limits. Consequently, the overall impact of the TBM noise to marine mammals is expected to be imperceptible and temporary. No mitigation procedures are deemed necessary for this the level of impact.

Noise Impacts to Fish

The potential impacts to the migratory Annex II fish species (Salmon and Lamprey) from TBM operations are discussed in Chapter 13 of the EIS, whilst the impacts to the small population of resident marine fish are considered below. As noted above, approximately 2 to 44% of the tunnel route will pass beneath channel areas that will be flooded with water during low water spring and neap tides, respectively. The majority of resident marine fish species will be limited to these channel areas for most of the time, and only periodically move into shallow waters over the main banks to feed with the advancing tide.

The sensitivity of different fish species to noise and vibration is dependant upon whether the fish has a swim bladder or specialised auditory couplings within to the inner ear (e.g. herrings). These make them more sensitive to sound pressure waves. Species without specialised auditory coupling (e.g. cod) or fish with reduced or absent swim bladders (e.g. flounders, mackerels and rays) have lower sensitivities (Fay 1988). Auditory thresholds for all groups vary from below 80dB re 1µPa to over 100dB re 1µPa for these different groups in the frequency range 30Hz to 1kHz. In reality, for shallow field environments the broadband ambient background noise caused by wind induced waves in shallow waters acts to mask any sensitivity threshold to below around 100dB re 1µPa. Fish also have a "lateral line" system that runs lengthwise down each side of the body and over the head. The lateral line consists of pressure-sensitive cells that convert subtle changes in water pressure into neural pulses that allow fish to avoid collisions, participate in schooling behaviour, orient to water currents, elude predators, and detect prey. For most fish, the lateral line is only sensitive to low frequency (10 Hz to 30Hz) (Popper and Fay, 1993) and near-field pressure changes, limited to an area immediately surrounding the fish. It should be noted that the sensitivity, is at a level well below that which would detect the TBM operation.

Noise levels of 140 to 160dB re 1µPa arising from the tunnelling and transmitted to the water column would be perceptible to all fish species, but with a peak frequency of 31.5Hz, this would be at the very lower end of the audible range. The largest impact on marine fish is likely to be that affecting demersal species such as the flounder (*Platichthys flesus)* or the goby (*Pomatoschistus sp)* located on the seabed directly above the drilling location, although these have the lowest sensitivity to noise.

Behavioural response by fish to noise and vibration is related to the perceived loudness of the sound. Nedwell et al, (2003 & 2007), carried out an assessment of fish avoidance from noise and vibration produced during a construction project. He produced criteria for fish behavioural responses and concluded that this is based on the level of noise in dB above the hearing threshold of the fish (i.e. dBht). The range of responses listed in his 2007 report were as follows:

- 90 dBht (species) and above – Strong avoidance reaction by virtually all individuals;
- 50 - 90 dBht (species) - Stronger reaction by the majority of individuals, but habituation may limit effect
- 0 – 50 dBht (species) – Mild reaction in minority of individuals, probably not sustained.

Outputs from the vibration modelling show a worst case scenario for underwater noise occurring at high tide, along the axis of the tunnel and at a frequency of 31.5Hz. At 90m from the TBM, the modelled underwater noise level is 145 dB re 1µPa.

Assuming an average hearing threshold for fish species within Sruwaddacon Bay of 100dB re 1µPa (approximate lower threshold for Atlantic salmon), the Nedwell data above would suggest that, for the less sensitive species such as flounder and plaice, the likely effect of the tunnelling activities at this distance would result in a mild reaction in a minority of individuals (i.e. 45dBht). While for more sensitive species, represented by the Atlantic cod, with lower hearing thresholds, it is likely that the response of fish would be within the category of 'stronger reaction' but that the effect could be limited by habituation. Thus within 90m of the TBM, some marine species may avoid the area, while others are much less likely to be affected, with the possibility that affected species may habituate to the noise in any case.

It is important to note that, the duration of this impact will be small as this is limited by actual drilling time (ca. 1/3rd) and will only occur whilst the seabed is covered by water. Consequently, impacts to the marine fish species caused by noise and vibration are expected to be negligible and short term.

<u>Noise Impacts on Benthos</u>

Unlike noise impacts caused by the TBM to the surrounding air and waters, the impact to the sediment environment is based on the vibration produced by the slow rotation drill head (ca 6 revolutions per minute). Data derived from the model (Taylor 2010), predicted the highest vibration velocity as 0.16 mm/s (RMS) with a broadband frequency range of 1 to 100 Hz. This is equivalent to a peak particle velocity (ppv) of approximately 0.5 mm/s. This can be compared to the 14m Hamburgh Elbe tunnel, which recorded a ppv of 0.5mm/s between 20 and 100Hz at 50m through mixed sediments, or the 4m Boston MWWST tunnel, which recorded a ppv of 0.2mm/s between 20 to 80Hz in limestone. To place the unit into context, a ppv level of 0.5 mm/s may just be perceptible to humans in a residential environment but probably not detectable in water logged sediments where minor settlement may absorb some of the energy. Dissipation of the vibration velocities in the field will typically halve with each doubling of distance from the TBM location (i.e. 0.16 mm/s reduces to approximately 0.07 mm/s 40 m away and to 0.035 mm/s 80m away).

Little or no information is known on the effect of low level vibrations on the benthos. However, given the small vibration values modelled and the short term nature of the localised activity, impacts are expected to be limited to short term behavioural mechanisms. Vibrations may impact on the benthos in the following ways:

- Consolidation of sands. Sands deposited onto the seabed from suspension usually undergo an extended period of consolidation where particles continue to settle into interstitial spaces. The introduction of a short period of low frequency vibration may accelerate this process and cause some sediments to slump slightly leaving an area of water on the surface. This is only likely to effect areas where sediments have previously been disturbed due to other processes, such as continued erosion and deposition at the edges of the channel, and current related bedforms.

- Benthos migration. Unlike the terrestrial earth worm, which migrates to the surface during periods of vibration as a behavioural response to avoid drowning from rainfall, polychaetes and other macro-invertebrate species are likely to retract or migrate into the sediment in predator-avoidance behaviour. Groups such as the molluscs may simply retract surface siphons, whilst surface dwelling amphipods and some polychaetes may migrate vertically downwards. In the case of the latter, the depth to which the species can retreat will be limited by of the redox discontinuity layer (RDL), where free-oxygen remains available to the organism within the interstitial waters. This layer is typically around 2-5cm thick for most of the bay (Wilson 2010_1). The impact of vertical migration may be a minor reduction in avian predation by species with shorter beaks in the immediate area (ca. 50m) of the TBM location. As drilling is not continuous, the more mobile benthos will quickly return to normal behaviour immediately after drilling.

All impacts will be localised and temporary, as the continued movement of the TBM will ensure that any given area will not be impacted by more than 2 or 3 days at a time during periods when exposed by the tide.

Pollution and Waste

During the construction phase of the proposed development, pollutants and chemicals used could contaminate the area. Potential contamination of sediments and marine organisms from the accidental release of hydraulic, pipeline grout, lubricant and fuel oils associated with excavation equipment and machinery onsite, or drilling related leakage may occur. This can arise from accidental spillages to water, through poor operational management, the non-removal of spillages, poor storage, handling and transfer of oil and chemicals or poor handling or accidental release of bentonite fluids during drilling operations. Other sources of contamination are minor metal spoils from the cutting of sheet piling.

Should contamination occur, species and habitats could be seriously impacted. Future colonisation of the area could be inhibited. Bioaccumulation of certain substances could occur in the flora and fauna present. If suitable precautions are taken and best practice for the storage, handling and disposal of hazardous materials are followed, such impacts are largely avoided.

Concrete structures

There are no specific plans to use concrete structures for the proposed marine section of the pipeline route, although concrete structures may be used during the construction phase to provide supports or scour protection. Concrete is regularly used in the construction of piers, sea walls, mooring and slipways around the Irish coast and is typically formulated to seal quickly from the ingress of sea water and to prevent leaching of possible harmful admixtures such as heavy metals, gypsum etc. Where concrete coatings or mattressing are used in the pipeline construction in gravity moorings or for scour protection (usually in the form of a jacket or large flexible mattresses), these are typically supplied preformed and hardened before entering the marine environment. Consequently, they are expected to be benign to the surrounding environment and to have a negligible impact.

Fish Including Salmonids

The numbers and variety of fish recorded within Sruwaddcon Bay are low, with most species limited to a relatively small area of the channel for extended periods of time during low water periods. The installation of an intervention pit if required could adversely impact fish population in the immediate vicinity of the works due to elevated noise or vibration to the surrounding waters. The overall impact of this is expected to be imperceptible and temporary.

There is currently only one licensed oyster culturing facility (*Ostrea edulis,* T10/81) within Sruwaddacon Bay (licence T10/81), which exists in the south side of Sruwaddacon Bay, close to Poll an tSómais (Pollatomish) pier. However, it is understood that very little culturing is carried out at the site and the licence is known to have remained unutilised for a number of years, up to October 2007, when operations recommenced. It is understood that the facility is not currently in production. However, even if this was not the case, the impact of the proposed development will be insignificant or nil.

Impacts on cSAC and cited Species in Sruwaddacon Bay

The construction area falls under two Annex I habitat designations, ie. '"estuaries" (Code 1130) and "sandflats not covered by seawater' (Code 1140; Natura, 2000), neither of which are qualifying habitats for the cSAC. Both of these are generally large scale features defined as a result of local geographical characteristics and the surrounding hydrodynamics. Even in the event that surface intervention pits are required, the construction of the pipeline through this area would have a very limited spatial impact on these qualities. Given the existing dynamic and highly variable nature of the environment, all impacts will be temporary post construction.

As the site is also part of a large pSPA for resident and over-wintering birds, the construction operations within Sruwaddacon Bay estuary, have the potential to disturb the bird population and a small surface area of their potential food source (invertebrates) either directly, through the very unlikely event of an intervention pit, or indirectly through vibration of sediments close to the TBM along the route. Birds are discussed further in Chapter 12.

'Do-Nothing' Scenario

In the absence of the development it is likely that the marine habitats and water quality along the proposed route would remain unchanged, although both environments are subject to short term variability and long term natural changes.

The 'Worst Case' Impact

In the event that mitigation measures fail it is possible that certain aspects of the construction activities associated with the tunnelling could have an adverse affect on the hydrodynamic flow within the estuary and cause the localised flow of the main channel to vary slightly. This will alter the erosional/deposition regimes within certain parts of the bay, along with the habitats they support. The hydrography of the bay may also alter. Given the natural variability and dynamic nature of the estuary, this impact would be short to medium term, with slight to moderate significance of neutral to negative quality.

In the unlikely event of an accidental bentonite release during surface construction (if necessary), the receiving environment would show a slight impact over a short term on sediments around the periphery of the bay. This is likely to have only an imperceptible impact on water quality for a very short term.

14.5 MITIGATION MEASURES

Mitigation measures have been developed to prevent, control and minimise potential impacts from the proposed upper and lower estuary. The key mitigation measures for the pipeline route will be as follows:

- Use of a segment-lined tunnel (i.e. trenchless operation) to further avoid and/or minimise surface interaction on the Bay;
- The area of habitat disturbance will be kept to a minimum during construction, and will be limited to the high water area at the head of the Leenamore inlet in the absence of surface interaction along the route. This area will be reinstated to its original condition by replacing excavated material and preserving the surface sediment type. Epifauna & flora attached to large stones will be preserved by relocating to a similar height on the shore for the duration of the construction works. These will then be reinstated on completion of the construction. Impacts will be slight to moderate, localised and temporary;
- The construction period will be undertaken over as short a time period as possible;
- To minimise the interruption of adult salmonid migration and that of other anadromous fish in the estuary, the flow within the main channel will be maintained to allow the passage of fish during construction;
- The surface sediments of the proposed route through the Sruwaddacon Bay will be reinstated to their original condition if impacted;
- Any significant scour areas will be in-filled by back filling with the surrounding surface sediments to preserve the current hydrodynamic regime of the estuary; and
- All bentonite usage will be monitored though materials balance calculations, pressure monitoring in the lines and above ground visual assessment of the works;
- In the unlikely event that emergency surface intervention should be required, construction methods will be agreed in advance with the NWRFB and the NPWS to minimise disturbance to the migration of salmonids and resident and over-wintering birds. Potential noise impacts during the construction of an intervention pit construction would be monitored and guidelines followed to minimise the impact of construction to sensitive receptors (i.e.pinepeds and cetaceans).

Loss or Alteration of Habitats and Species Composition

During construction, any areas of seashore or seabed to be disturbed (i.e. upper Leenamore inlet) should be kept to a minimum i.e. within the temporary working area. As the upper estuary covers two thin bands of bank deposits, in the event that a temporary intervention pit will be required within one of these areas, the larger stones and associated fauna will be manually removed from the working area and placed on either side of the route at the same point up the shoreline to ensure the correct tidal exposure. The remaining surface sediments, as well as the superficial substrates over the remainder of the sand flats will be mechanically removed and placed to the side of the working area to preserve the invertebrate populations within. By preserving the marine life and sediments types, impacts to the marine habitats will be imperceptible and short term.

Increased Suspended Solids

Disturbance of inter-tidal and sub-tidal habitats will be minimised so as to reduce the creation of suspended solids within the marine and estuarine habitats. The working area will be bordered by sheet piling (or similar) which will surround the main excavation site minimising the escape of suspended sediments from the site. As most sediments within the bay contain very little fines, the retention of excavated spoil at the work locations for backfilling adjacent sections will also minimise the release of sediments within the main flow of the estuary where it will be dispersed.

The potential for an accidental release of bentonite will be minimised by closely monitoring its use during all works.

Noise and Vibration Pollution

The tunnel boring machine (TBM) will produce a low-level noise emissions in the sediments and overlying waters when at high water. Modelled data shows that both the level and frequency of both noise and vibration caused by the TBM will have negligible impact on the benthos, fish and marine mammals in the estuary.

Pollutants and Waste

Best practice for the storage, handling and disposal of hazardous materials will be followed to prevent chemical pollution. All fuels or chemicals kept on the construction site will be stored in protected containers and all refuelling and maintenance will be carried out in bunded containment areas. Refuelling and maintenance in areas draining directly to water habitats will be avoided where possible. Oil interceptors will also be installed in appropriate locations. Equipment will be regularly maintained and leaks repaired immediately. Accidental spillages will be contained and cleaned up immediately. Remediation measures will be carried out in the unlikely event of pollution of the marine environment.

14.6 RESIDUAL IMPACT

There will be no discernible residual impacts on the marine environment once constructed.

There is the potential to cause habitat disturbance due to noise, excavation activities, sediment scour, emissions and elevated sediment loads. However, allowing for the mitigation measures outlined above, the limited operational window envisaged for the construction period of an intervention (in the extremely unlikely event that it is required) and the dynamic nature of the environment, residual impacts within the bay are expected to be localised and imperceptible over a short term.

If surface intervention construction were to be required, a relatively localised area of impact would occur to the soft surface sediments due to scour and temporary changes in hydrodynamics. However, the existing population of surface macro-invertebrate fauna is generally for the majority of the proposed route subject to natural stresses and sediment dynamics. Furthermore, the sediments are expected to physically return to normal within a small number of tidal cycles, closely followed by a re-colonisation by the faunal population within a few months (through natural sediment dynamics) to a year (though spring reproductive cycle and settlement). Therefore, the residual impact will be imperceptible and short term.

There will be no residual impacts on transient or highly mobile species, such as fish (including migrating salmon), seals and possible cetaceans once the development is in operation.

14.6.1 Monitoring

Geomorphological Survey of Route Corridor

Any proposed intervention pit locations will be surveyed using a combination of acoustic (SBES or AGDS), video/sampling techniques to confirm the current geomorphology prior to the survey works, intermittently throughout the construction period and on completion of the works. The purpose of the survey is to identify the sediment and habitat types prior to operations, and to monitor the scale and reinstatement of the natural sediment dynamics following the works. These survey works will also assist in the reinstatement of the pre-operational conditions prior to the demobilisation of the marine equipment.

Cetacean/Marine Mammal Observers

Existing monitoring activities within Broadhaven Bay show that only seals occasionally pass into the proposed working area, although there is an expectation that Harbour porpoises may also enter the estuary on rare occasions. Operational monitoring for marine mammals and cetaceans will be carried out from the channel edge during the deployment of sheet piling for an intervention pit, should it be required. Field observers will record the excursion of any animal into the vicinity of the survey area (500m) during the deployment of the sheet piling prior to excavation activities. The deployment of the sheet piling (using a vibration technique) will be undertaken using a soft-start procedures should marine mammals be located within this observation area. The animal's identification and behaviour will be recorded throughout the period of these operations.

Ecological Habitats and Biota

Should surface intervention be necessary, pre-and post-project monitoring will be carried out at the impacted location to substantiate conclusions relating to the macrofaunal and habitat impacts outlined within this EIS. Benthic sampling will be carried out using variety of video, visual observations and sampling in both littoral and sub-littoral areas of the corridor. Spatially, the survey will be undertaken at a control site in a similar sediment type and hydrodynamic regime. Additional attention will be paid to extensive areas of scour.

Sampling and analysis will include full particle size analysis, benthic macrofauna, biomass and, on selected sites, sediment chemistry (including low level heavy and trace metals and hydrocarbons). Hard substrates will be qualitatively assessed for biological coverage and recolonisation. It is recommended that pre and post construction surveys are carried out with a further repeated monitoring survey undertaken one or two years after completion of the construction, should an intervention pit be required. Further ecological monitoring will be undertaken following an interpretation of the rate of recovery from the initial studies.

Bentonite Release

Environmental survey monitoring will be carried out in the unlikely event of a bentonite release. A water quality and benthic assessment will be carried out along the up and down stream route of the dispersion. Sampling and analysis will include water quality and turbidity, sediment particle size analysis, benthic macrofauna, and sediment chemistry relating to components within the fluid. Tissue sampling of shellfish within the bay may also be undertaken. Monitoring will take place immediately after an accidental release and repeated approximately one year later.

14.7 OCEANOGRAPHY AND HYDROGRAPHY

14.7.1 Introduction

This section describes the hydrography of Sruwaddacon Bay. This includes the neighbouring Curraunboy bay which falls within the hydrodynamic boundary of the estuary and affects the oceanographic regime within Sruwaddacon Bay which is a combination of the daily tidal cycles and riverine flow, through the system. Furthermore, a numerical hydrodynamic model is also described which predicts the changes to the currents likely to occur during potential construction alternatives for the proposed route and suggest mitigation measures to combat any adverse effects. The primary construction proposal is based upon a segment lined method i.e. trenchless method which will not impact the marine system within the bay. However, potential construction requirements dictate that temporary engineering works may be necessary along the proposed route to resolve potential blockages. This would then have the potential to impact on the marine system and be exposed to the ebb and flow of the tidal cycle on a daily basis. Any structures deployed within the bay will alter the current dynamics for the duration of the works.

14.7.2 Bathymetry

The hydrography of Sruwaddacon Bay and Curraunboy Bay was acquired during a geophysical survey (Osiris, 2007). Data was collected using a combination of vessel–mounted and land-based survey techniques. A limited access to the bay by vessel meant that large areas of relatively flat seabed have been interpolated from relatively few data points. However, a combined dataset and interpolation is estimated to be within a 20cm vertical accuracy.

The bathymetric data covered all areas within the bay except a north facing sand bank in the estuary mouth adjacent to the Curraunboy convergence, some shallow inlets within the main estuary and along the upper section of the Glenamoy river east of the proposed landfall and the confluence of the Glenamoy and Muingnabo Rivers. Consequently, the river channel at this location was digitised from detailed aerial photographs, along with the whole of the upper high water estuarine boundary (a height of 3.7m above chart datum was applied).

Figure 14.8 shows a full interpolation of Sruwaddacon Bay and Curraunboy hydrography. This indicates the dominated channel of flow which meanders the length of each bay. Within Sruwaddacon Bay, the channel separates and recombines at a number of points with the depth of the channel remaining shallow (<0.6m) for the majority of its course in the upper estuary during low water periods. The upper third of Sruwaddacon Bay channel dries, in part, above chart datum during extreme low water springs, although flow will remain within these areas due to a persistent riverine component. Areas close to or within the channel (particularly in the downstream area of the bay) indicate stronger currents with clearly defined rippled bedforms. These are particularly well developed on the outer edge of the main sand bank southeast of the mouth, where their form indicates a strong flooding tide influence.

A review of the historical admiralty chart data (which includes bathymetric soundings of Sruwaddacon Bay taken in 1852-3) and a more recent representation of the main channel given by the Ordnance Survey, show significant variability in the route of the main channel over time. This is not unexpected as the whole environment is based upon a dynamic relationship between the prevailing meteorological, tidal and river effects upon scouring, reworking and deposition of materials within the sand banks. Consequently, the natural course of the channel and the dimensions of certain banks are likely to vary continuously. Further anecdotal evidence of this ongoing process has been observed during a number of recent field surveys into the bay which have identified recent changes in the main channel and adjacent banks, particularly in the lower reaches of the estuary surrounding the main channel (P.Cowman/I.Wilson personnel observations 2010).

14.7.3 Oceanography

Oceanographic data was recovered during two surveys within Sruwaddacon Bay using a combination of tide recorders, profiling current meters and temperature sensors. Seabed mounted instruments were deployed at 4 points within the estuary between 24th July, 2007 and 8th August, 2007 (EGS

2007). An additional tide gauge was deployed at An Baile Glas (Ballyglass) Pier between the dates 14th June, 2007 and 8th August, 2007 (Osiris 2007). The flow of currents through the central part of the bay was further verified using drogue streamlining on a mid high water period in February of 2010 (Wilson 2010_2).

14.7.3.1 Tidal Data

An Baile Glas (Ballyglass) Pier (southern Broadhaven Bay) is classed as a secondary port by the United Kingdom Hydrographic Office (UKHO), and was the position for a tide recorder deployed within a seabed frame for a 55 day period. The final dataset was a combination of seven shorter observations deployed for the duration of the geophysical and oceanographic operations in Sruwaddacon Bay. The depth of the instrument deployment was levelled statistically using mean sea level and provided a reference for all other tide recorders within Sruwaddacon Bay, deployed for a simultaneous fourteen day period. These were recorded using four seabed mounted pressure sensors deployed between Sruwaddacon Bay/Curraunboy Bay confluence and the upper neck of the estuary.

A comparison of the five datasets, reduced to mean sea level, showed that there was a notable phase change (time delay) in the tidal cycle with penetration into estuary. The constriction in the channel at the mouth and the friction caused by the shallow seabed over the 9km separation between the ends of the estuary retards the high water over the length of the estuary by over 40 minutes. Conversely, the low water time is delayed by over two hours, as the returning flood is delayed in the constriction of the mouth. Furthermore, the tidal range within the estuary also falls from 3.7m at the bay mouth, to 2.9 m at the upper station, a difference of over 80cm. The tidal times and ranges at the confluence of the two bays, was similar to those recorded at An Baile Glas (Ballyglass) Pier (Appendix L).

14.7.3.2 Tidal Streams Data

Tidal currents were recorded using acoustic doppler current profilers (ADCPs) at 4 seabed mounted moorings deployed the length of Sruwaddacon Bay over a fourteen day period. These instruments were able to record current speed and direction for the whole of the water column. The data was depth-averaged to remove spikes prior to further processing (Note: this may result in the occasional peak event also being averaged out of the dataset if not recorded at other depths within the profile). The depth averaged data is summarised in Table 14.10 and represented into a scatter plot (Figure14.10).

Table 14.10: Summary Depth Averaged Current Meter Data for Sruwaddacon Bay.

Mooring	Depth Averaged Velocities (m/s)		Depth Averaged Directions (degrees)		Duration of Flow (hours)	
	Maximum	Mean	Flood	Ebb	Flood	Ebb
4	1.08†	0.40†	109	294	5.48	6.24
1	1.22	0.56	041	212	5.45	6.36
2	1.00	0.37	084	271	5.65	6.37
3	0.60	0.23	142	309	4.52	5.99

† *only half of the dataset was recovered due to sediment burial midway through the spring tide.*

Overall, mean depth averaged data recorded the strongest flows at Mooring 1 (lower estuary) at 1.22 m/sec (2.37 knots) during the spring tides. This decreased progressively upstream towards the river, falling to 0.6m/sec (1.17 knots) at Mooring 3 (upper estuary). The current speed fell slightly to 1.08m/sec (2.1 knots) downstream at the bay convergence (at Mooring 4) where the channel widens (although it should be noted that not all of the spring tidal current data were recorded here due to the instrument being partially buried midway through the observation period). The mean direction of each of the flood and ebb flows is also presented in Table 14.10, or can be seen in Figure 14.10, and follows the orientation of the main channel at each respective location.

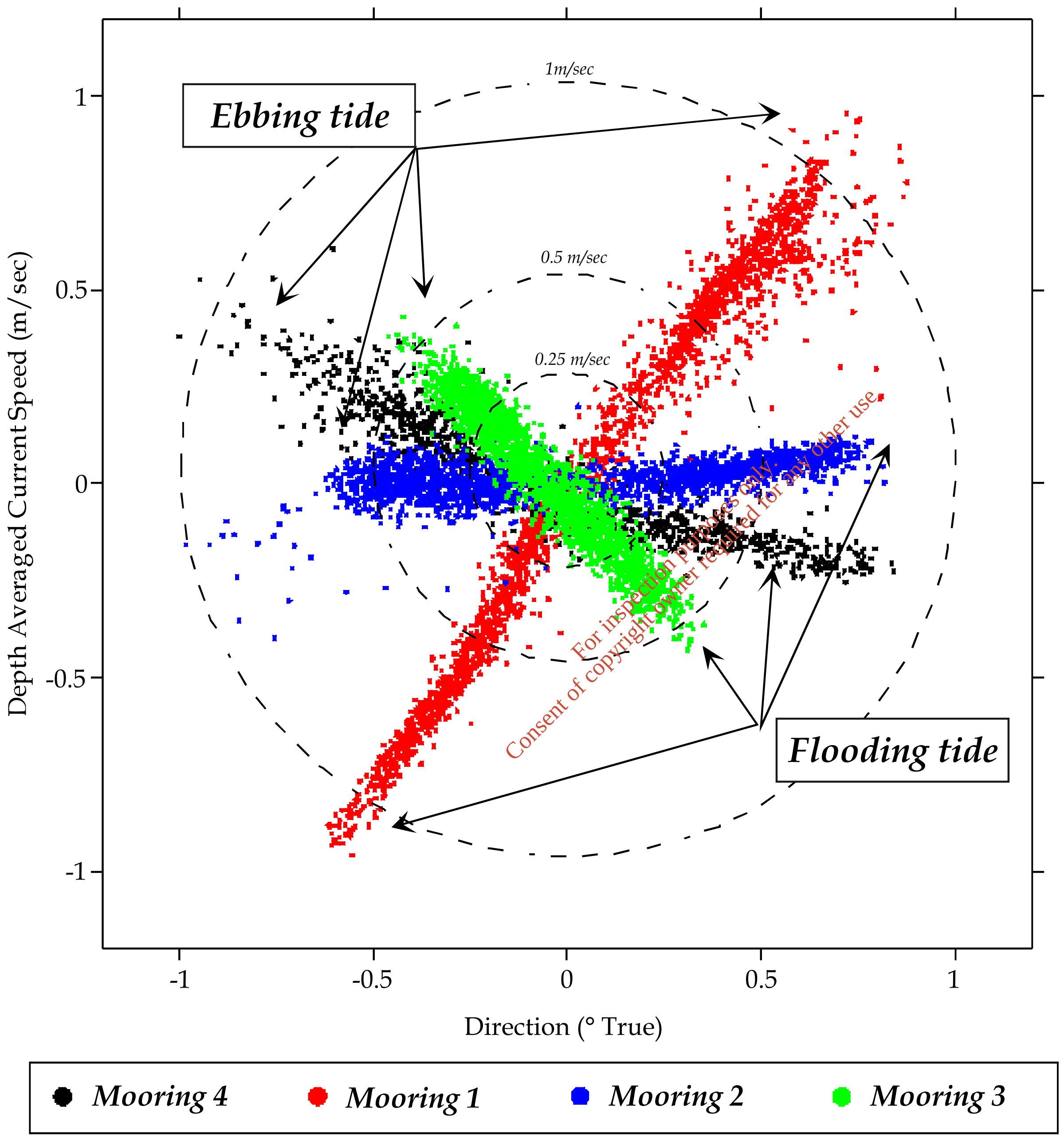
This pattern of current velocities highlights the constriction to the current flow skewing the sinusoidal shape of the tidal curve progressively upstream. This results in an uneven balance in both current velocities and duration. Table 14.10 shows the mean duration (in hours) for both flooding and ebbing tides. In all cases, the ebbing tide is extended showing a prolonged ebb flow of between 43 minutes in the centre of the estuary, to 88 minutes further upstream at the proposed upper estuary.

A review of peak flows from the raw data indicated that slightly stronger flows can occur, predominantly along the surface with the exception of the lower estuary (Mooring 1), where a peak flow of 1.52 m/sec (2.95 knots) was recorded at mid depth (3.1m) at the beginning of the ebbing tide.

14.7.3.3 Hydrodynamic Flow Model

To be able to model the circulation of the tidal flow throughout Sruwaddacon Bay, the hydrographic data was inputted into a finite-element mesh (HR Wallingford, 2007). This consisted of triangular elements with a flexible variation of the resolution throughout the model domain ranging from 20m (within the channels) to 100m (across the open sand flats). Hydrodynamic quantities (e.g. water levels, current magnitude and direction) were computed at each node. This model was then validated using observations recorded at the four moorings deployed within Sruwaddacon Bay, with the results showing a realistic representation of modelled hydrodynamics versus the recorded data for each of the mooring locations.

By running the model over a sequence for a typical spring cycle, the general flow behaviour along with the expected velocities was observed (HW+10 hours, Figure 14.11a and HW+5 hours, Figure 14.11b). Overall, the constriction to flow within Sruwaddacon Bay mouth retards the flooding tide. This results in a shorter, yet stronger flooding flow within the downstream area compared to longer but slower ebbing tide. This results in the productions of current related bedforms at the seaward end of the bay, which can be clearly observed in both hydrographic and aerial photographic data in this area. The hydrodynamic model indicates that the strongest tidal flows within the operational area would occur at the downstream estuary, with a maximum speed of approximately 2m/sec (3.9 knots; Figure 14.11a) during a flooding spring flow. A freshwater flow of 2.5m^3/sec was used in the production of this model, although average data records for the Glenamoy river suggest an average freshwater flow an order of magnitude below this (i.e. ca, 0.25m^3/sec).



Scatter Plot of Depth Averaged Current Speed and Direction

Figure 14.10

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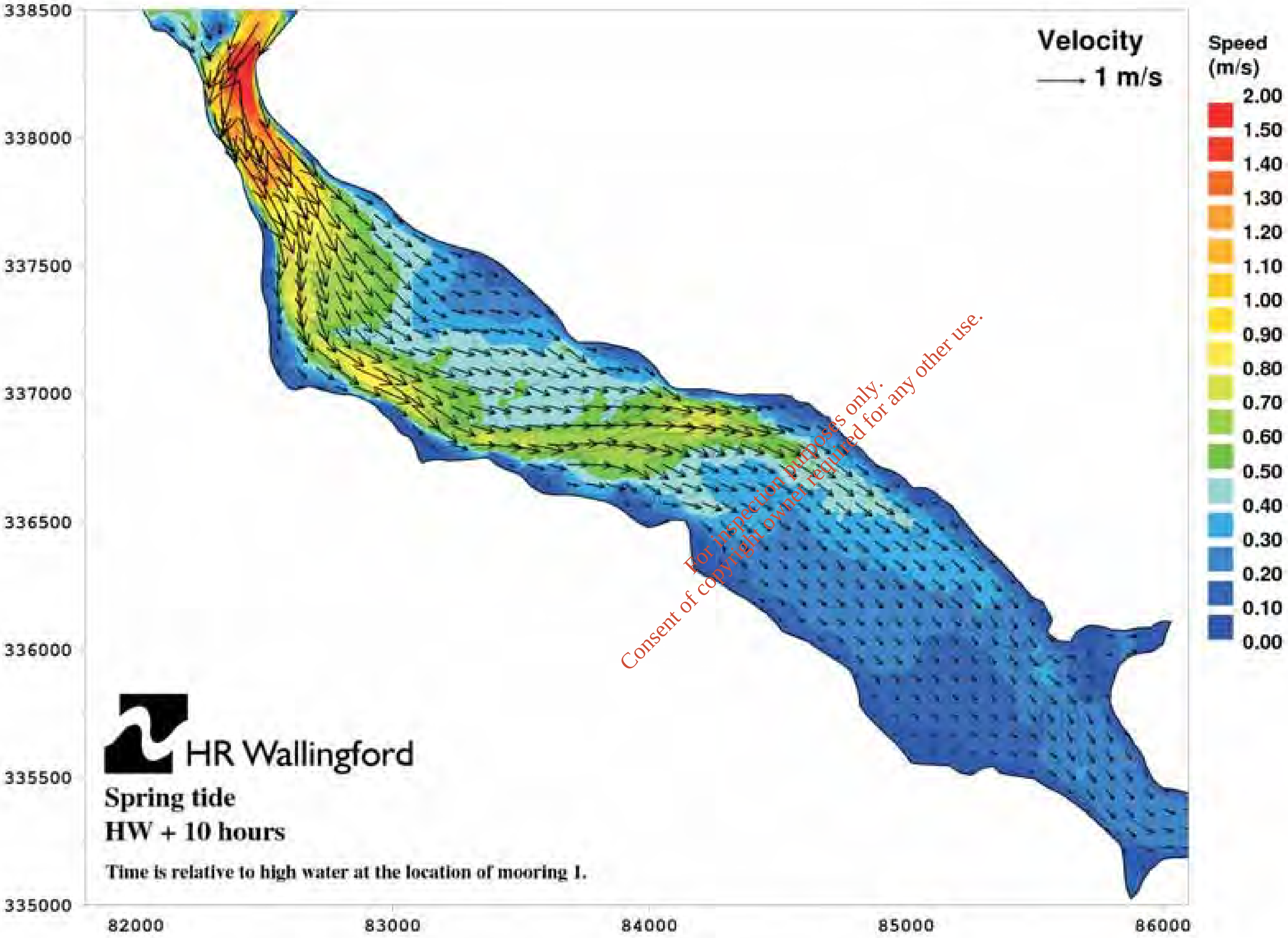

Modelled Peak Flows within Sruwaddacon Bay

Figure 14.11a

File Ref: MDR0470GrEIS023 RevA03
Date: May 2010

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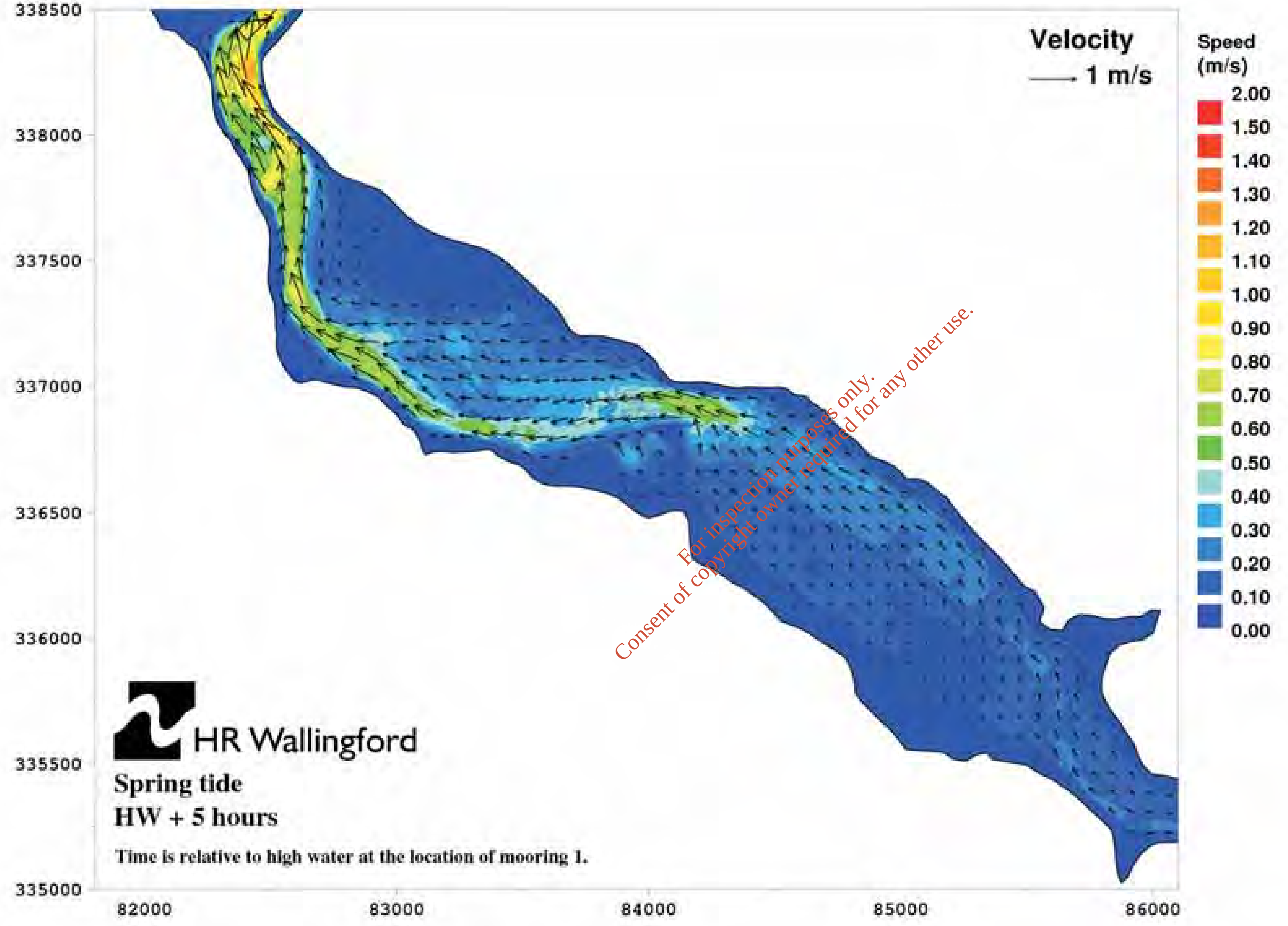

Modelled Peak Flows within Sruwaddacon Bay

Figure 14.11b

File Ref: MDR0470GrEIS023 RevA03
Date: May 2010

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14.7.3.4 Natural Changes in the Channel

Natural variations in the level of the seabed and the flow of the channel are occurring in the Sruwaddacon Estuary on a continuous basis. The sediment transport within a system comprises of both bedload transport and suspended load transport. Bedload transport occurs when the forces exerted by the flow of water on the sediment bed is sufficiently large to cause the sediment to be displaced by suspension into the water column or rolling along the seabed, or conversely, slow to allow suspended sediment to settle. The strength of the forces within the moving water mass depends on the velocity of flow and the roughness of the sea bed (increased by coarser sediments or sediment bed forms such as ripples and mega-ripples). The presence of wind driven waves can also increase these forces.

Sediment movement is controlled by oceanographic factors such as tidal streams, storms surges, waves, river discharges and wind-driven currents, which together act upon sedimentological factors such as particle size, seabed roughness, bedforms and suspended sediment load to determine way that sediment is transported. In the Sruwaddacon the flow of the semi diurnal tidal range over a 1.8 to 3.2m range is highly modified by the prevailing geology and bathymetry of the bay producing considerable friction to the movement of water along its length. This has been hydrodynamically modelled and subsequently verified with field measurements along the length of the bay. The latter showed a slow transformation of the tide from a sinusoidal curve near the open sea to a more triangular curve of reducing amplitude progressively into the bay. The tidal currents show flood tide asymmetry which will tend to transport materials into Sruwaddacon Bay compared with the weaker but longer ebbing tide. The tidal currents are considered to be the primary controlling factor for sediment transport and bed level changes in the estuary.

The semi-diurnal tide drives an exchange of water between Broadhaven Bay and Sruwaddacon Bay. The volume of water exchanged is a function of the bathymetric profile and the tidal range (approx. 6.9M m^3). Whilst the period of tidal exchange remain approximately the same, a higher spring tidal range produces a greater volume, this will generate faster current velocities and increase sediment mobility. The potential oceanographic contributors to channel erosion and bed level changes are as follows:

- Storm surges:
  Storm surges in Broadhaven Bay will lead to a modified water level in the sea which will modify the flow into and out of Sruwaddacon Bay. The influence of storm surge will be limited dependent upon on frequency and event magnitude. Impacts to the Sruwaddacon oceanography will be temporary before returning to the normal tidally dominated equilibrium.

- Waves:
  Sruwaddacon Bay is directly sheltered from Atlantic waves as a result of the narrow entrance. Locally generated wind waves will be small as a result of the size of the estuary and extensive drying tidal flats, reducing the length over which the wind can generate waves. Thus wave action is limited within the bay and not considered to be a primary controlling factor for bed level changes within the bay.

- Wind-driven currents:
  Wind-driven currents are small for reasons outlined above and are not a primary control factor for bed level changes within the bay.

- River discharge:
  The discharge from the Glenamoy River is highly variable but small compared to the volume of tidal flow in Sruwaddacon Bay (i.e. <1m^3/sec to mean 300 m^3/sec, respectively). Nevertheless, the river discharge reinforces the late ebb tidal flow in the shallow channel passing over the upper pipeline crossing and is of local important in maintaining the low tide channel in this area.

- Sea level rise:
  Sea-level is continuing to rise with respect to the land level, a process that is ongoing since the end of the last glacial period many thousands of years ago. Although predicted to rise in the future, the magnitude of this is low (typically predicted between 3.5 to 8mm per year) and not considered significant to the volume of water exchange and impact on bed level changes within the bay.

In conclusion tidal action is considered to be the dominant oceanographic control factor for bed level changes within Sruwaddacon Bay. The potential sedimentological contributors to channel erosion and bed level changes are as follows;

- Seabed sediment size and type
  The sediments in Sruwaddacon Bay are in dynamic equilibrium with the oceanography, established over thousands of years. The continuous transfer of tidal energy into the sediments results in the suspension and subsequent transportation of finer sediments (such as silts, clays and riverine organics) out of the bay. Consequently, the seabed in Sruwaddacon Bay is predominantly made up of granular marine sands with little or no finer sediments recorded in the main flow areas.

- Presence of harder/coarser ground
  The tidal flow is controlled by the constriction at the mouth of the bay, reducing the duration of flow but strengthening the currents, producing granular sediments, coarser than would normally be expected for an enclosed estuary. This constriction is bordered by bedrock and not liable to change.

- Presence of bed forms
  The dominant tidal action (predominantly flooding tide) reworks the seabed sediments and has resulted in the creation of bedforms such as ripples and mega-ripples in the sediment deposits.

- Existing suspended sediment load
  The river flow continuously introduces suspended sediments into the estuary. This is predominantly made up of organic matter, fines and peat staining from the surface runoff from the surrounding bog areas. Water quality sampling undertaken in 2007 showed the concentration of this material to be around (52mg/l). Sediment analysis within the central part of the estuary showed that all of this material remains in suspension until discharged into Broadhaven Bay.

In conclusion, the generally coarse, granular material is in a dynamic equilibrium with the dominant tidal action.

Observed Morphological Changes in Sruwaddacon Bay over Time

Sruwaddacon Bay has infilled with sediment as sea level has risen over thousands of years since the end of the last glacial period. Sruwaddacon Bay is a dynamic system and subject to small natural changes over long periods of time. Consequently, the routing of the main channel and inter-tidal banks may have altered over time. The bay can be subdivided into three segments along its length with respect to morphology. These are:

(1) The short outer segment which has strong tidal flow velocities and a well defined channel constrained by geology;

(2) the wide middle segment which has a well defined channel, moderate tidal flow velocities and large volumes of sediment stored between the banks of the bay; and

(3) the inner segment which has a shallow meandering channel with low tidal flow velocities and large volumes of sediment stored between the banks of the bay.

A change in the pattern of banks and channels is demonstrated through a comparison of historical data over the past 170 years (Figure 14.12). Data obtained by the Admiralty using a lead line in 1852-3, was compared with high resolution multi-beam echo sounder data acquired in 2007. Although the earlier dataset is based in qualitative observations of the flow and very limited spot depth locations, the main alignment of the tidal channel and key depths can be compared. This comparison shows that with the exception of a change in the channel position in the middle segment of the bay, the combination of banks and channels has remained broadly unaltered over this period. However, the recent bathymetric data has identified three areas where the channel pattern has already altered or may naturally alter over time in the future (Figure 14.12). This is supported by a first addition drawing from the Ordnance Survey dated 1839 which showed an earlier route for the channel.

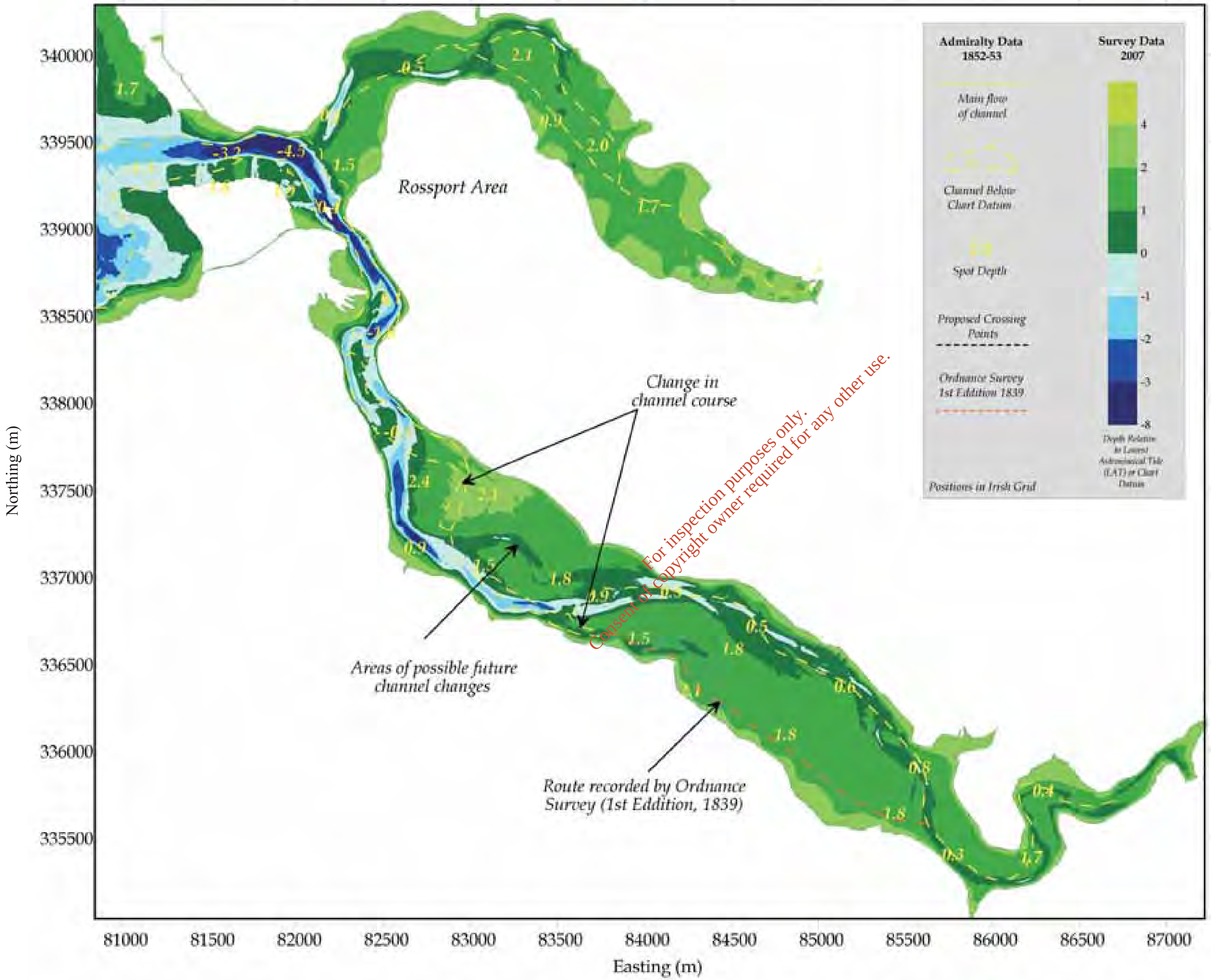
14.7.3.5 Water Quality Parameters

Water quality parameters were measured in Sruwaddacon Bay during both the ecological survey (RSK, 2007) and the oceanographic measurements (EGS, 2007). Data were acquired as a combination of spot readings for turbidity, total suspended solids and temperature, using an electronic data sonde and near seabed (20cm) self-recording measurements of temperature and salinity at the four mooring locations over a 14 day tidal cycle. In addition, meteorological data (including rainfall) were acquired from Met Éireann at Béal an Mhuirthead (Belmullet) to assess the impact this might have on the consistency of the above readings. However, whilst a number of short-period peaks in rainfall were identified, these peaks were below 6mm for July falling to below 3mm in August for the period of the oceanographic observations. Consequently salinity and suspended load readings will not have been adversely affected due to elevated river flows produced by heavy rainfall during the study period.

Temperature records for the Bay over the full tidal cycle showed that overall temperatures vary more during periods when the warmer riverine flows predominate. For the summer observation period, the high water times showed a consistent 14 - 16°C for all sites except the upstream Mooring 3 which was typically 1.5-2°C warmer, whilst low water periods showed considerable variability at 15 - 18.5°C, except mooring 3 which varied by a further 3°C.

Salinity records for the Bay over the full tidal cycle showed that Moorings 1, 2 and 4, within the mouth and lower estuary were dominated by seawater. High water salinities remained consistently around 33 ± 1psu (practical salinity units) during all states of the tide, whilst salinities progressively fell to between 10 and 20psu during neaps, or 20 to 30psu during spring tides between the mid estuary (mooring 2) and the bay confluence (mooring 4). Only the upstream locations (mooring 3) showed a notable fluctuation in salinity at both high and low water times, for both neap and spring cycles. For high water, the salinity varied from 10 to 33 psu (neaps to springs, respectively), whilst the low water becomes completely fresh (psu <0.1) during neaps, but reaches 10psu during the spring tides

Combined turbidity and suspended solid readings recorded during the ecological survey indicated that the two parameters could not be statistically correlated (high turbidity readings did not necessary relate to elevated sediment loads), presumably due to the variability in peat-staining from the river run-off. The highest recorded turbidity (24-27 NTU) was recorded in Sruwaddacon Bay within an hour of low water, indicating that suspended material of freshwater origin contributed significantly to the levels of turbidity at that time. The highest level of total suspended solids was also recorded at the same place and time. Lower turbidity levels (<2 NTU) were recorded during the flooding tide along the main channels or during the high water slacks when the clearer seawater influence is at its greatest. Generally, all total suspended solids records were similar ranging from 14 to 70 mg/l (RSK 2007, Ecoserve 2007). This is approximately 20 times higher than those recorded for the full marine conditions found in the outer Broadhaven Bay (near Iorras (Erris) Head, (Ecoserve, 2005), where the suspended sediment load is dispersed or carried out to deeper waters and slower currents where it is deposited on the seabed.



Changes in Seabed Bathymetry in Sruwaddacon Bay

Figure 14.12

File Ref: MDR0470GrEIS018 RevA03
Date: May 2010

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14.7.4 Potential Impact of Tunnelling beneath Sruwaddacon Bay

The construction along the proposed route may require some operations to be undertaken within the marine sections of the route along the length of the estuary from the narrow, fast flowing lower section to the wider, slower-flowing upper section of the estuary. In all cases, segment lined tunnelling beneath the Bay will not impact on the oceanography within the Bay. However, the potential impact of an emergency surface intervention pit on the Bay's tidal circulation during construction has been assessed, for completeness, as a worst-case scenario. The deployment of an intervention pit within the marine section will be based upon a sheet piling (or similar) operation for a relatively short length of time.

Any construction operations carried out within the bay have the potential to cause a physical impact by altering the flow regime around temporary structures and producing both scour and deposition effects which may lead to a loss or aggregation of surface sediments and an alteration to the existing sediment regime.

Long term observations of the Bay shows slow changes in the shape and route of the channel, which is expected to continue even in the event that the project does not impact within the bay.

14.7.5 Modelling of Oceanographic Impacts During Construction

By using the hydrodynamic model described in section 14.7.3, several temporary construction scenarios have been employed to assess variations in the flow regime for the duration of the construction at various locations. These data, were then used to assess the propensity of the altered flows to induce additional scour, or deposition beyond that normally experienced at any given locations. This assessment is conservative, as it does not take into account any scour mitigation methods.

The potential impact to localised hydrodynamics and sediment scour are highly variable dependant upon the exact location of a proposed intervention pit. As this is not known, the range of possible impacts have been reviewed based on two simulated scenarios placing an intervention pit within the central channel at both the lower and upper ends of the estuary as these constitute the range of conditions expected to be encountered along any part of the proposed route.

For the simulation, the intervention pits were represented as islands in the hydrodynamic model to prevent flow through them. Additionally, the existence of the adjacent pontoon was also represented as a solid in the shallow water depths, thus preventing flow to the seafloor. This assessment therefore treats the effects of the obstruction in a very conservative manner, as part of the flow may pass underneath the pontoon during mid to high water periods. The geometry and location of these contingency access pits are likely to be notably smaller than modelled here, but will be engineered following a technical evaluation of the obstruction if encountered.

The outputs of the hydrodynamic model, producing a hydrodynamic footprint, were combined with the available information on sediment type and distribution to assess the maximum impact on sediment mobility and the potential for scour. The grain size information relates to the sand fraction, whilst other coarser fractions may also be present in the margin for the bay. The lower estuary was assessed based on a combination of sediment parameters and observations taken during recent survey works (RSK, 2007. Ecoserve, 2007, Osiris, 2007 and Wilson 2010_1). Here, the channel was described as coarse sands and gravels, flanked by bank deposits of sands through to cobbles and boulders, particularly to the east. The upper estuary was characterised as a medium to fine sand across both the flats and within the channel, and flanked by bank deposits of sands through to cobbles and boulders.

14.7.5.1 Lower Estuary

Even though the likely necessity for an intervention pit for the tunnel is extremely low, a simulation of a single intervention pit was run in a central location of the lower estuary (area of peak flow close to the route; HR Wallingford, 2007_2) as a worst case scenario. This simulation was run over several spring tidal cycles and peak flows recorded for both flood and ebb tides (Figure 14.13). Control simulations were also used to extract the reference flow for each location to provide a summary hydrodynamic footprint for the full cycle.

The pit has been located in the centre of the main channel to represent a 'worst-case' scenario. The pit will form an obstruction to flow producing a shadow zone on either side of the pit, together with lateral zones of increased current velocity of around 0.3m/s. Location A, positioned on the north western bank of the channel, showed a greater increase in maximum ebb velocity from 1.5 to 1.8m/s with similar variation (ca. 0.3m/s) for the weaker flood flow. Location B showed the opposite, with small increase in the maximum ebb (ca. 0.1m/s), but a greater increase in the larger flood flow, from 1.4 to 1.8 m/s (Table 14.11).

Channel sediments were predominantly mixed coarse sands and gravels, grading to bedrock at the eastern end. Finer surface sediments are expected to be mobile during the peak flows in the tidal cycle and local scour will occur. Assuming a representative diameter of 12m for the access pit and applying the scour estimation methods of May and Willoughby (1990), Escarameia and May (1997) and Breusers *et al.,* (1977), the maximum scour depths ranges from 3.4 to 7.9m at Location A and from 5.1 to 7.6m at Location B. Assuming that the intervention pit is in this location for 4 weeks, the scour may not have time to develop to its full depth during this period but a large amount of the potential scour can be expected. However, as the channel naturally deepens to around 4m seaward of the lower route, scour will further deepen this and extend the channel to the point of the pit (Figure 14.13). Assuming a cone-shaped scour hole with an angle of repose of the sediments under local flow conditions of 10°, the scoured area associated with this depth is around 5,700m^2, near Location A and 4,950m^2 near Location B. All calculation are conservative, based on a homogenous sediment size with depth and the absence of cyclic infill of scour on alternating tides.

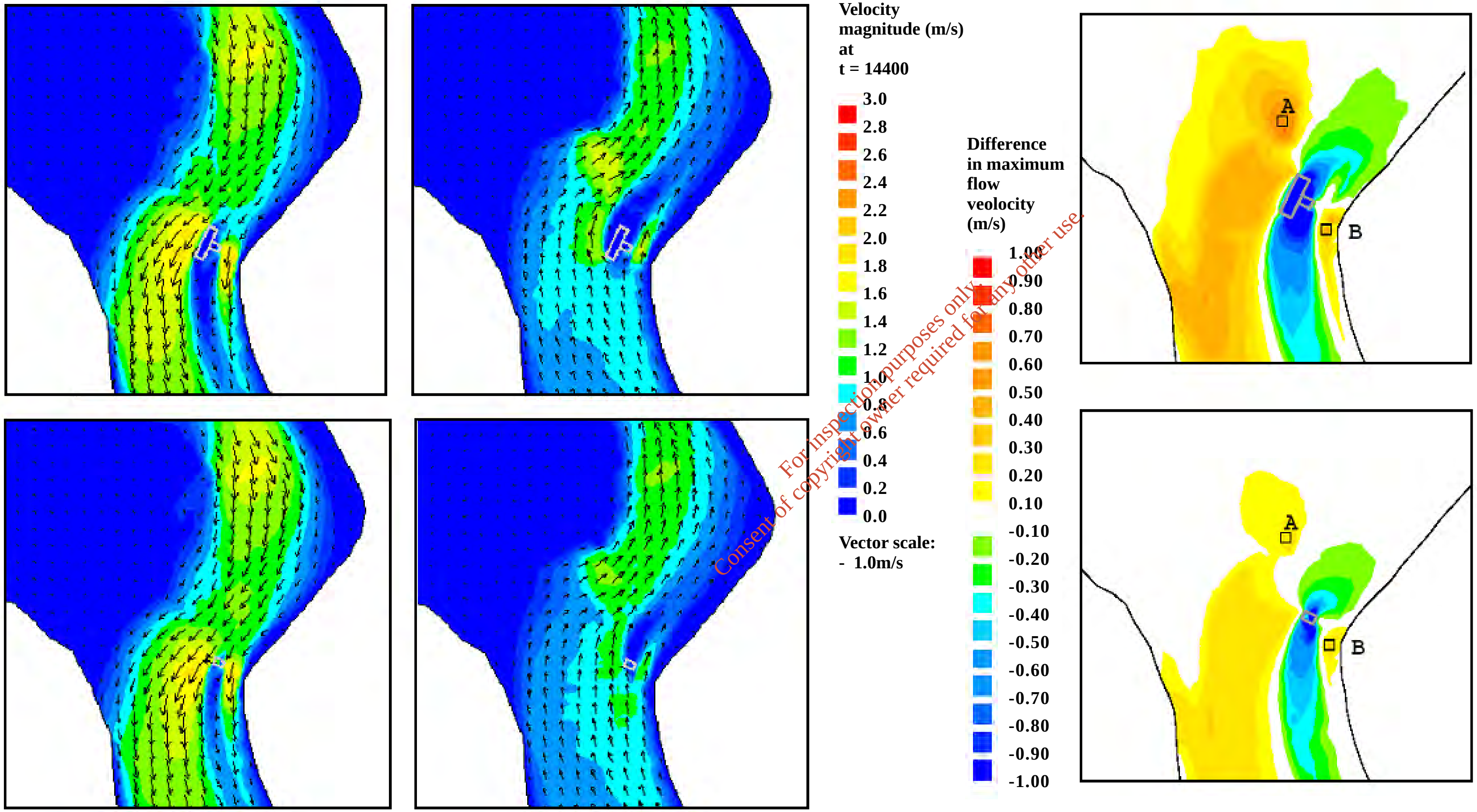
Table 14.11: Summary of Simulated Flows and Predicted Scour at two ends of the Estuary.

Route Location	**Baseline max.ebb velocity**	**Scenario max.ebb velocity**	**Baseline max.flood velocity**	**Scenario max. flood velocity**	**Estimated scour depth**	**Scoured area associated with scour depth**
	m/s	**m/s**	**m/s**	**m/s**	**m**	**m²**
Lower Estuary						
Pit, Location A	1.5	1.8	0.9	1.2	7.5	5,700
Pit, Location B	0.6	0.7	1.4	1.8	7.0	4,950
Upper Estuary						
Pit, Location A	0.2	0.3	0.3	0.6	3.5	900
Pit, Location B	0.2	0.6	0.4	0.7	5.0	1,600

14.7.5.2 Upper Estuary

A simulation of two separate scenarios relating to a smaller intervention pit within the main channel were run for the proposed upper estuary towards the mouth of the Glenamoy River (HR Wallingford, 2007_2). Each simulation was run over several spring tidal cycles and peak flows recorded for both flood and ebb tides (Figure 14.14). Control simulations were also used to extract the reference flow for each location to provide a summary hydrodynamic footprint for the full tidal cycle. A summary of the impacts are as follows:

Flood Tide *Ebb Tide* *Variation in Flow*



Summary of Hydrodynamic Footprint for the Downstream Estuary

Figure 14.13

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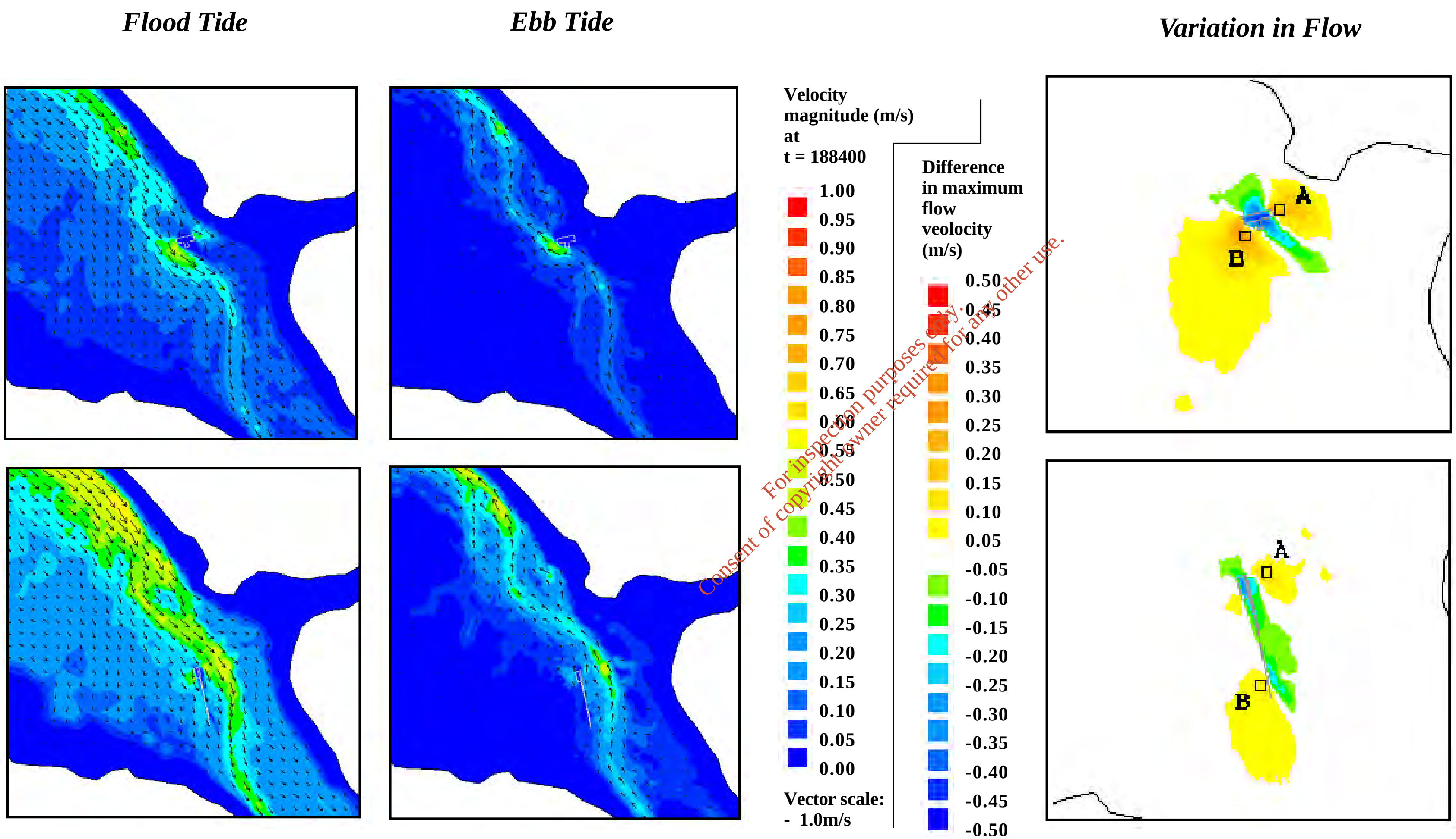

Summary of Hydrodynamic Footprint for the Upstream Estuary

Figure 14.14

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The intervention pit has been located in the centre of the main channel crossed by the upper estuary to represent a worst-case scenario, although in reality the proposed route follows a much shallower bank to the south and west were currents are expected to be more benign. Together with the adjacent pontoon, this pit will form an obstruction to the flow through the channel. A shadow zone can be seen on either side of the pit and pontoon, together with zones of increased maximum flow velocities (Location A and B). Assuming a discharge from the Glenamoy River of $2.5m^3/s$, the maximum increase is approximately 0.35m/s for ebb tides whilst flood velocity changes up to 0.3m/s. The effects on the flow direction are generally less than 10 degrees. The effects of these flow obstructions on the modelled maximum water level excursion are less than 0.1m throughout the bay.

Owing to the medium to fine sandy nature of the sediments within this part of the bay, the finer surface sediments will be mobile during the high water peak of the tidal cycle and local scour, estimated to be around 3m in the areas indicated by yellow and orange based on Breusers et al. (1977), May and Willoughby (1990) and Escarameia and May (1997), assuming that the potential scour of up to 7.4m has insufficient time to develop during the maximum of four weeks required for the structure. Some deposition of fine material will also take place in the areas of green.

14.7.6 Predicted Impacts during Construction

There are no predicted oceanographic impacts to the estuary in the likely situation that an intervention pit will not be required for the construction. However, for a worst-case scenario model for an intervention pit necessary along any part of the route in exceptional circumstances, simulations were run and predictions of the hydrodynamic and resulting impacts to the seabed assessed. These are a central intervention pit at the lower estuary and two scenarios, including a 'worst-case' location for an intervention pit within the channel for the upper estuary. These predictions show that scouring and winnowing of sediments around temporary structures during construction can be significant, particular if located within the main channel flow for either of the upper and lower estuary. Whilst, the hydrodynamics of the region would be expected to revert to their natural course post construction, a significant alteration in the hydrography of the area caused by excessive scour may have a significant impact on the flow patterns within the estuary over a longer term.

Excessive scour of the seabed will remove and smother large areas of habitat within close proximity to the construction site.

'Do-Nothing' Scenario

In the absence of the development it is likely that the marine habitats and hydrodynamics along the proposed construction routes would remain unchanged, although the current regime is subject to short term variability and long tern natural changes.

The 'Worst Case' Impact

In the event that the project or mitigation measures fail it is possible that the surface construction activities could produce significant areas of scour at the point within the estuary where an intervention pit was required. This would result in a seabed hollow on completion of the operations which might fail to infill post construction and subsequently alter the hydrography and oceanography at this location. On the lower estuary, this could result in a lengthening of the existing deeper water channel, possibly altering the routing for the main channel. This in turn could result in erosion and deposition of the larger bank features surrounding the channel over time. Given the natural variability and dynamic nature of the estuary, this impact could be medium to long term, with slight to moderate significance of neutral to negative quality.

14.7.7 Mitigation during Construction

The key mitigation measures for the construction route in the event of an intervention pit will be as follows:

- the size of the pit will be reduced to a minimum to present as small an impact as necessary to the flow of the currents along the route;

- the shape of the pit will be designed to induce minimum impact to the flow of the currents along the route;
- a hydrodynamic simulation will be run prior to operations to assess the potential for impact by the operation;
- partial to full reinstatement of sediments around scour features will be carried out to reduce effects;
- following a further review of the construction designs, the use of scour protection (such as weighted matressing out to 10m) will be considered if necessary; and
- any significant scour areas will be in-filled by back filling with the surrounding surface sediments to preserve the current hydrodynamic regime of the estuary. Natural reinstatement of sediments within the scoured area are expected to occur through normal sediment movement processes during the stronger periods of tidal flow.

14.7.8 Residual Impacts

Assuming segment lined tunnelling is employed successfully without any complications (i.e. no intervention pits), there will be no residual environmental impact within the marine section of Sruwaddacon Bay. In the unlikely event that emergency surface intervention should be required during tunnelling, there remains a potential to cause some disturbance of the seabed predominantly due to altered sediment mobility around temporary structures causing scour and deposition. Allowing for mitigation and coupled with the fact that most of the scour will naturally refill with mobile re-deposited material post construction, the residual impacts are expected to be neutral to negative of imperceptible to slight amplitude and over the short term.

A minor deepening and lengthening of the deeper channel may remain within the lower estuary area if a pit was required in this area. As the seabed in this region is generally coarse and mobile, the impact of this change will be insignificant. Isolated areas of scour remaining will naturally infill with surrounding sediments as previously recorded during geotechnical operations in the bay in 2008 (Wilson, 2008).

14.7.10 Monitoring of Hydrography

Should emergency surface intervention be required, then the immediate hydrography of the seabed around the location of the pit will be surveyed using a small vessel and single beam echo sounder (SBES) both prior to and after the construction works. Aerial photography will be used to continue to monitor the regional flow of the main channel and surrounding banks within the bay twelve months after the completion of the construction works. Further monitoring will be carried out over a longer subsequent period based on these results.

15 SOILS, GEOLOGY, HYDROLOGY & HYDROGEOLOGY

This chapter examines the potential impact of the proposed development on soils, geology, hydrology and hydrogeology. No impacts to these issue areas are anticipated during the operational phase; however, the construction phase has the potential to result in impact. Consequently, impact assessments have been undertaken on the geology (including geotechnical characteristics) (see Section 15.1), hydrology (see Section 15.2) and hydrogeology (see Section 15.3) along the route, while a separate assessment of blanket bog hydrology has been undertaken on the peatlands traversed by the proposed route (see Section 15.4). Details on the potential impacts and associated mitigation measures are provided within each of these sections. Residual Impacts are outlined in Section 15.7.

These assessments were undertaken by:

- RPS (geotechnical, hydrology and hydrogeology aspects);
- Applied Ground Engineering Consultants (AGEC) (geological conditions within the Bay, peat stability, stone road in peat and ground movement risk); and
- Hydro-Environmental Services (peatland hydrology).

15.1 SOILS & GEOLOGY

Two separate assessments were undertaken to gain an understanding of the geological and geotechnical characteristics along the proposed route. RPS undertook an assessment on the geotechnical aspects in non-peat areas traversed by the route, while AGEC undertook an assessment on the peat areas traversed by the route and the geological conditions within the bay.

A desk study of available information including aerial photography, available background information including Geological Survey of Ireland (GSI) information and historical ground investigation data (as set out in Appendix M1-A and M1-B), was undertaken for the proposed route.

Walkover surveys were also carried out to assess the route, including a geomorphological walkover survey by AGEC of the peat areas (see Appendix M3). A number of ground investigations were also undertaken along the route in 2007, 2008, 2009 and 2010 (see Section 15.1.1). Various investigation techniques were used to determine stratification and soil types and gain samples for laboratory testing. These investigations involved both land and marine works and included shell and auger drilling, rotary coring, cone penetrometer testing (CPT) (used to collect information to classify soil type), televiewer surveying, geophysical surveying, peat depth probing and shear vane testing (used to estimate the undrained shear strength of the material).

Details on the ground investigations are summarised in Table 15.1 and Section 15.1.1. A detailed assessment of the geotechnical aspects of the proposed works in non peat areas is contained in Appendix M1. A report by AGEC on the assessment of peat stability along the route including a detailed analysis of the proposed ‘stone road’ method of construction in peat areas (see Chapter 5) is provided in Appendix M2.

15.1.1 Existing Environment

15.1.2 Route Description

The geology and soils of this route can be divided into distinct sections, of which blanket bog forms approximately one third. Each section of the pipeline route is described in Table 15.1 along with the approximate chainages (as shown in the route alignment sheets in Appendix A of this EIS) and the proposed construction methods for each section (as described in Chapter 5). The ground conditions anticipated along the route are summarised in the following sections with detailed assessments in Appendices M1, M2 and M3.

Table 15.1: Description of geology along route (showing approximate chainages) with details of Proposed Construction Methods (see Chapter 5).

Section	Approximate Chainage		Land type*	Description	Proposed Construction Method
	From	To			
Gleann an Ghad (Glengad)	83.40	83.88	Improved agricultural grassland	The proposed landfall valve installation location is at the west of this section. A small cliff face about 3m to 4m high is exposed at the western end fronted by a beach leading to the sea. Sand dunes are located to the north of the section. Ground conditions comprise generally shallow granular subsoil on psammite (metamorphosed sandstone) rock, which was encountered in boreholes between about 3.85m and 5m bgl. Psammite rock is exposed along the cliffs at the landfall site. Rock typically dips at 80^{o} to the south although close to the landfall there is a near perpendicular change in dip angle. The pipeline will be within a tunnel from the eastern Gleann an Ghad (Glengad) headland where a compound area with a reception pit will be constructed.	Spread technique
Tunnel	83.90	88.77	Wet grassland, marsh, estuary and intertidal, eroded/cutover blanket bog	This section of the pipeline passes beneath Sruwaddacon Bay and will be constructed using tunnelling methods (Segment Lining). Shallow granular and cohesive subsoils exist in the foreshore section. Geophysical and geotechnical surveying within Sruwaddacon Bay showed granular deposits consisting of mainly sands and gravels with occasional cobbles and small boulders to depths of about 25m overlying bedrock. The bedrock is exposed on the foreshore in the northern part of the bay.	Segment lined tunnel technique
South of Sruwaddacon Bay / na hEachú (Aghoos)	88.77	89.18	Modified cutover and eroding blanket bog-undesignated	The tunnel will be constructed from na hEachú (Aghoos) on the south eastern shore of Sruwaddacon Bay where a compound area associated stringing area and starting pit will be constructed.	'Stone Road' method
	89.18	89.36	Stream inlet and salt marsh/ improved agricultural grassland and wet grassland	This section comprises gently sloping peatland underlain by granular and cohesive subsoil to a depth of 8.2mbgl** in turn underlain by weak to moderately weathered schist bedrock to 16.4m bgl underlain by a strong slightly weathered psammite bedrock to depth as determined from a borehole in the area (IDL, 2009).	Spread technique
	89.36	89.55	Recovering Eroded blanket bog	Peat probing indicated peat depths of between about 1m and 4m. This section crosses peatland and a small valley associated with the Leenamore River, until it reaches a forested area at chainage 89.545.	'Stone Road' method
Forested Area	89.55	91.72	Coniferous forestry on blanket bog/ some trees recently felled	This section of the route runs south east crossing commercially forested land before changing direction where it crosses a road. It changes direction again to run south to south west falling towards a small valley and rising again to the Terminal site. Peat probing indicated peat depths of between about 2m and locally 5m. Trial pits indicated soft to very soft slightly to highly amorphous peat from 0m to 3.5mbgl. Slightly silty very gravelly sand was present at 3.5mbgl in one of the trial pits. Approximately 900m of stone road was constructed in this area (Ch. 90.73 to 91.69) during previous pipeline construction activities	'Stone Road' method

*Sections are generally based on land types as defined by habitat mapping (see Chapter 12).
**m bgl: metres below ground level

15.1.2.1 Bedrock Geology

According to the bedrock Geology of Mayo, Sheet No. 6[1], the proposed route is underlain by Dalradian Rocks, laid down over 600 million years ago. They were subject to massive compression and faulting over the first 200 million years, due to several periods of continental convergence. As a result, the Dalradian rocks consist of metamorphic and faulted sedimentary sandstones - quartzites, psammitic schists and pelitic schists with some marbles also present. The Dalradian rocks, having undergone a number of deformation events, are also characterised by extensive folding; therefore dips in the area are variable. The bedrock within the Sruwaddacon Bay area is shown in Figure 15.1.

From site walkovers psammitic rock exposures are evident along the foreshore particularly in the northern part of Sruwaddacon Bay. Rock exposures are also evident along the cliffs and wave cut platforms at the landfall site. Rock typically dips between 60° and 80° to the south along the beach close to the landing. Rock exposures of massive to moderately fractured psammite and weathered sandstone, highly fractured in places, occur closer to the mouth of the bay along the foreshore. Rock outcrops are less evident heading east and south into the bay.

The dip directions of rock joints within the exposures in the northern shoreline of the bay varied from those at the landfall location and are generally near vertical to steeply dipping to the southeast. There is notable variation in joint orientation which is considered due to localised folding. Rock joint spacing within the rock exposures in the bay is notably variable with spacing ranging from 5mm up to 500mm.

Ground investigations along the terrestrial section of the route (GES, 2007[2]) indicated psammite rock with bands of pelitic schist and pelite with rockhead between 1.4m and over 21.0m below ground level.

Ground investigations in Sruwaddacon Bay (IDL, 2008[3]) indicated psammite rock with bands of semi pelite, quartz muscovite schist, semi-pelitic schist and psammitic schist. Rockhead was encountered between 3.3m and 24.8m below seabed level. The recovered rock cores were generally highly fractured. Rock strength from Point Load and Unconfined Compressive Strength (UCS) testing varied from very weak to extremely strong. Cerchar abrasivity testing on samples from the bedrock indicated that the rock can be classified as very abrasive.

Geophysical surveying in Sruwaddacon Bay (Osiris, 2007[4]) indicated rockhead between about 1m and 25m below seabed level. The shallower rockhead was evident towards the edges of the bay with the deeper rockhead towards the bay centre. Several geophysical anomalies were recorded during the survey, which are likely to correspond to igneous dykes within the bedrock.

15.1.2.2 Soils/Subsoils

According to the GSI/Teagasc online subsoil map of Ireland (see Figure 15.2), the dominant subsoil in the area is peat. A small amount of soil derived from windblown sands is present, at the western edge of Sruwaddacon Bay and to the north of the bay, near the coast. Alluvial deposits comprising mixed granular material (sand to boulder sized particles) are present along river channels in the area.

At the landfall location at Gleann an Ghad (Glengad), site walkovers recorded topsoil underlain by aeolian sands and gravel over colluvium or weathered rock over weathered to fresh rock. Clayey sands were visible in the bay when the tide receded. On the foreshore cliffs, shallow peat underlain by sandy gravely clay was evident. Excavations undertaken at the landfall (close to the proposed location of the LVI) as part of the offshore pipeline works in late 2008, exposed sand and gravels with cobbles to a depth of between about 2.5m and 3.0m.

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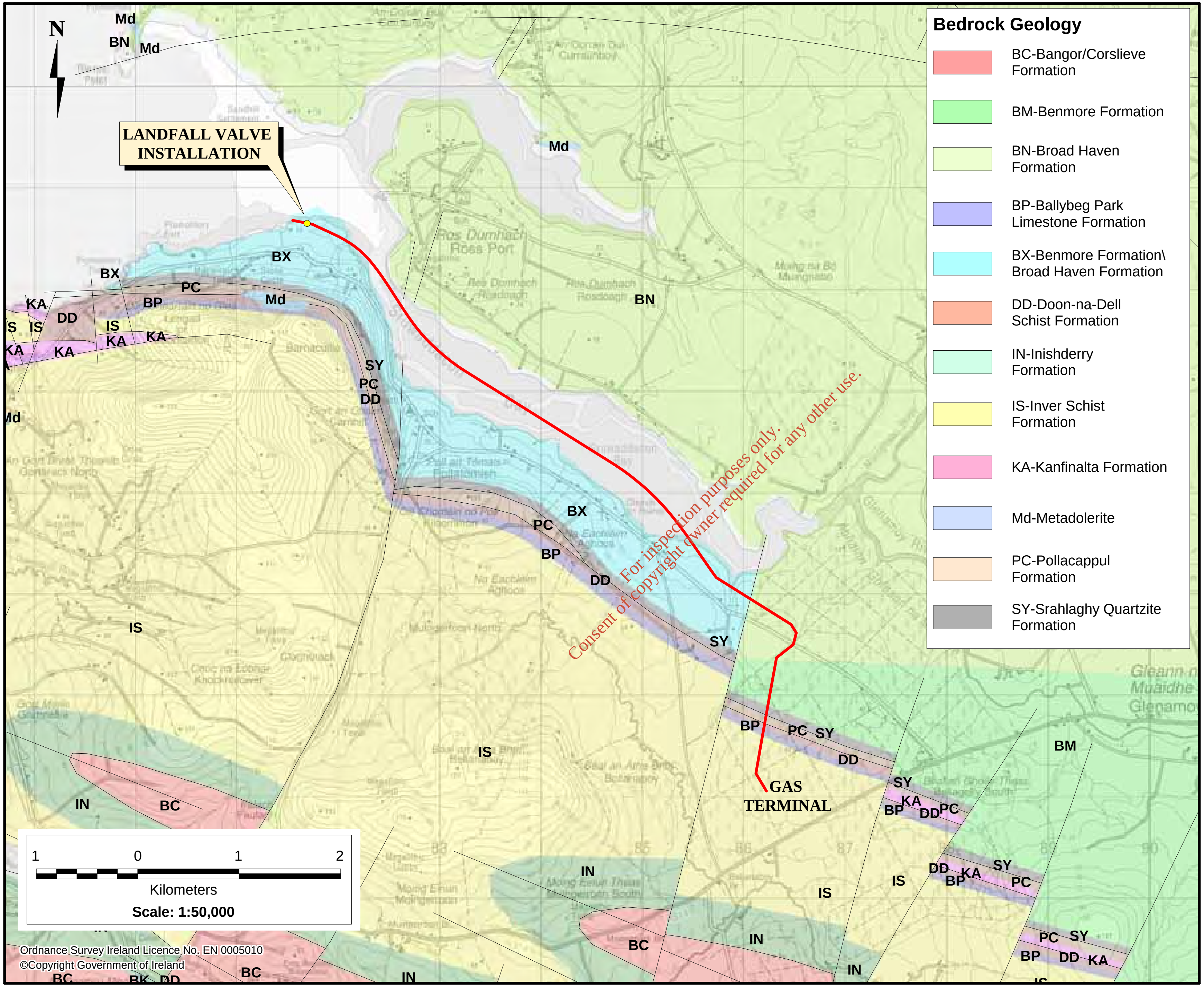
[1] Geological Survey of Ireland, 1992. Geology of North Mayo. Sheet 6
[2] Geotechnical and Environmental Services, 2007. Corrib Onshore Pipeline Onshore pipeline Route Selection Geotechnical Ground Investigation Factual Report (See Appendix M1)
[3] Irish Drilling Limited, 2008. Corrib Foreshore Pipeline Site Investigation Factual Report (See Appendix M1)
[4] Osiris Projects, 2007. Corrib Gas Pipeline Landfall Sruwaddacon Bay Geophysical Survey



LEGEND:

Proposed Pipeline Route

Fault Line

Bedrock Geology

Figure 15.1

File Ref: COR25MDR0470Mi2125A03

Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

Peat is present along the section of the pipeline route south of Sruwaddacon Bay, at na hEachú (Aghoos), and extends to the terminal site. Probing south of Sruwaddacon Bay, east and west of the Leenamore River, indicated peat depths of up to about 5m. Generally the peat was firm underfoot in this area with locally very soft and wet areas in cutaway strips. The peat along the section of the route within the forestry to the Terminal was also generally firm underfoot. An existing stone road, which has been trafficked by construction plant from the Terminal site, was constructed along part of this section of the route during previous pipeline construction activities. It has remained stable since construction. The pipeline will be placed within this existing stone road. This section of stone road is detailed in Appendix M3.

Ground investigations carried out at Gleann an Ghad (Glengad) and Ros Dumhach (Rossport) (IDL, 2002 and GES, 2007) generally indicated topsoil overlying sand and gravel with some clay/silt bands. Overburden deposits varied in depth between about 1.4m and 10.1m. Investigations along the section of the route towards the Terminal east of the Leenamore River (GES 2007[5], AGEC 2004[6], IDL 2002[7]) indicated peat depths of between about 2m and 5m. Trial pits indicated soft to very soft, slightly to highly amorphous peat from 0mbgl to 3.5mbgl. Slightly silty, very gravelly sand was present at 3.5mbgl in one of the trial pits.

Ground investigations carried out in Sruwaddacon Bay (AGEC 2004[8], IDL 2008[9]), which comprised boreholes and some trial pits, indicated fluvial sediments of dominantly sands and gravels with some cobbles. These sediments, where encountered in boreholes, extend to a depth of about 25m below river/seabed level within the northern part of the bay. In the southern part of the bay, boreholes encountered occasional clay/silt layers and, at shallow depth between about 0.1m and 0.7m, some peat layers. The clay/silt layers become more prominent towards the southwest shoreline of the bay.

Geophysical investigation survey results for Sruwaddacon Bay (Osiris, 2007[10]) indicated fluvial sediments of dominantly granular material to a depth of about 25m below river/seabed level in the northern part of the bay and to a depth of about 10m below river/seabed level in the southern part of the bay. These sediments become shallower towards the margins of the bay. The sediments comprised a mixture of reworked medium to fine sand through the central part of the bay and mixed gravel sediments, derived from glacial tills and weathered bedrock, at the bay margins and in areas of stronger current flow. The mixed gravel sediments are incised by the Glenamoy and Muingnabo River channels, which enter the bay as one channel at its extreme southeast point.

15.1.2.3 Pipeline in Non-Peat Areas

It is proposed that the pipeline between the landfall at Gleann an Ghad (Glengad), (Ch. 83.38) and where the pipeline enters the proposed reception pit for the tunnel under Sruwaddacon Bay to the east (Ch. 83.91) will be installed using conventional pipelaying construction methods. This involves laying the pipeline in an open excavation approximately 2m deep but could be up to 5.5m deep approaching the landfall valve. Excavation may encounter the upper layer of bedrock due to the low elevation of the landfall valve.

Conventional pipe laying construction methods are described in Chapter 5 of this EIS.

15.1.2.4 Pipeline in Peatland

It is proposed that the pipeline where it emerges from the tunnel at na hEachú (Aghoos) (Ch. 88.77) to the Terminal site (Ch. 91.72) will be installed within a stone road constructed through the peatland found within this section of the route.

The stone road comprises the excavation and removal of peat along the line of the pipeline route and replacement with suitable stone fill to form a stable roadway through the peat. The peat will be

[5] Ibid, pg.15-5
[6] Applied Ground Engineering Consultants, Sept 2004. Final Report on Onshore Gas Pipeline – Glenamoy River Estuary Crossing – Site Investigation Factual Report
[7] Irish Drilling Limited, 2002. Bellanaboy Bridge Co. Mayo Factual Site Investigation
[8] Ibid, pg. 15-6
[9] Ibid, pg. 15-5
[10] Ibid, pg. 15-5

removed over a width of about 12m to form the stone road but reduced to 9m wide in a short section (190m) of recovering eroded bog (Ch. 89.35 to 89.54) east of the Leenamore River.

The peat thickness for the section typically ranges from about 2m to about 5m locally, except where a stream is crossed (Leenamore Inlet) where peat is absent. Based on site investigation data about 60% of the route within the peatland will be within peat depths ranging from 2 to 3m.

Where the route passes across the Leenamore River inlet there is some reclaimed agricultural land with some localised peat cuttings. To the southeast of the peat cuttings, the route passes into an area of open peatland that extends to an area of commercial forestry (Ch. 89.55).

The peat surface condition in the section outside of the commercial forestry varies from surface hummocks with some water-logging to reclaimed peatland. Close to where the peat has been cut, the peat is relatively drier.

Within the commercial forestry the pipeline route generally follows forest breaks that run through the forestry plantation. The peat surface condition within the commercial forestry varies from some local water-logging to well-drained peat. There is extensive man-made surface drainage within the forestry which comprises regularly spaced forestry drainage.

An assessment of peat stability along the route within the peatland including a detailed analysis of the proposed stone road method of construction in peat areas (see Chapter 5) is provided in Appendix M2. The stone road stability report demonstrates that the stone road can be safely constructed in the peatland.

The use of a stone road within peatland is, in many cases, the preferred construction method as it greatly reduces the risk of peat failure and also essentially eliminates subsequent settlement. The stone road construction method will provide a robust and stable platform for the safe construction and installation of the pipeline and will protect the pipeline from any possible peat movement or instability.

15.1.2.5 Tunnelling

It is proposed that the pipeline between Gleann an Ghad (Glengad) (Ch. 83.91) and na hEachú (Aghoos) (Ch. 88.77) is installed within a segment lined bored tunnel and which will be constructed using a Tunnel Boring Machine (TBM). Tunnelling by the Segment Lining method is described in Chapter 5.

The proposed tunnel will be approximately 4.9km long and have an outside diameter of 4.2m. Approximately 4.6km of the tunnel will be underneath Sruwaddacon Bay. The proposed tunnel alignment is mainly through sands and gravels as shown in Appendix M1-A (Drawings Dg0401 – Dg0404). The horizontal alignment of the tunnel may deviate by up to 8m on each side. The vertical alignment of the tunnel may vary between a minimum cover of 5.5m and a maximum depth of 10m below the indicated centreline.

The geophysical and geotechnical data that is now available provides sufficient basis for the selection of the proposed construction method (segment lined tunnelling). The size of the TBM required to construct the proposed tunnel and the inherent flexibility of these machines will ensure that all ground conditions likely to be encountered can be managed. Where potential difficulties arise, e.g. large boulders, igneous dykes etc, these will only result in delays in tunnelling progress.

No surface construction works are anticipated in Sruwaddacon Bay and it is understood that such requirement has only ever arisen on similar projects (but not with segment lined tunnels) due to exceptional site specific circumstances. Therefore it is considered that the probability of there being a requirement for surface intervention as a contingency measure is remote.

Notwithstanding the above, additional geotechnical site investigations will be carried out (subject to Foreshore Licence). Information gathered during these works will serve to verify existing data with respect to ground conditions and ranges of values for various parameters. Rockhead profile will be verified also. The full set of geotechnical data gathered will be made available to the tunnelling contractor. This will enable the tunnelling contractor to optimise the design of the tunnel and the TBM.

15.1.2.6 Tunnelling in Superficial Deposits

Ground conditions within the bay comprise dominantly fluvial sediments of varying thickness. Sediments range from coarse gravels to firm silts and occasional thin bands of peat. Most of the deposits are fluvial in origin. Glacial cohesive soils may also be present within the superficial deposits in the bay. Sediment thicknesses vary from about 2m near na hEachú (Aghoos) to up to 25m at the mouth of the bay near Gleann an Ghad (Glengad).

The existing ground investigation data within the bay indicates the possible presence of boulders within the sediment deposits. Detailed site investigation within the bay may provide more information on the size, distribution or strength of any boulders, if present.

The design of the tunnel boring machine (TBM) will take into account the nature of the fluvial sediments present in the bay area; that is fluvial sediments with mixed silt but dominantly coarse soil up to possible boulder size. The tunnel cutter head will be optimised for these fluvial soil conditions and other soil or rock conditions encountered along the line of the proposed tunnel.

15.1.2.7 Tunnelling in Rock

Geophysical surveying has been undertaken throughout Sruwaddacon Bay (Osiris, 2007[11]) to determine the depth of sediments and the rockhead profile. The geophysical rockhead profile along the central part of the bay shows the rockhead profile between typically about -25 to -10 m below OD. The current borehole ground investigation information comprises data from 14 boreholes (at previously proposed crossings) at the mouth of the bay and another at the southern end of the bay (AGEC 2004[12], IDL 2008[13]).

Faults in the rock are shown on the GSI 1:100,000 scale map of the bay area running north-south across the northern part of the bay, and the geophysical survey also identified possible faults through the bay. Walkover survey of the rock exposures in the northern part of the bay did not identify any significant shear or disturbed zone associated with faulting. Where faults are encountered in tunnel works within rock there is the possibility of localised fractured rock and increased water inflow. TBM design will take into account the possibility of encountering faults.

Several linear geophysical anomalies, possibly igneous dykes[14], were identified during the geophysical survey generally aligned across the bay. If these dykes are present they are likely to represent localised areas of igneous rock of the order of several metres wide. Igneous rock may be harder than the dominant rock within the bay area. As part of the detailed site investigation, boreholes will be carried out to determine the extent and presence of such dykes. Igneous dykes would not represent a risk where encountered in tunnel works, though where igneous rock is notably hard this may locally slow the rate of tunnelling. TBM cutter design will take account the possibility of locally encountering harder rock within igneous dykes.

Rock condition with respect to tunnelling has been assessed from the available borehole descriptions and test results from investigations carried out within the bay. Using the Rock Quality Designation (RQD) values and the rock descriptions, an assessment of the rock condition has been carried out using the Tunnel Quality Index system (Q system). Rock 'Q' values range from about 0.2 to 5, which would be as expected considering the fractured nature of the rock.

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[11] Ibid, pg. 15-5
[12] Ibid, pg. 15-6
[13] Ibid, pg. 15-5
[14] An Igneous Dyke is a body of intrusive igneous rock that cuts across the structural fabric of the host bedrock

15.1.2.8 Tunnel Compound Areas

Aghoos Tunnelling Compound

The Aghoos tunnelling compound comprises the tunnel starting shaft / pit, the main tunnelling compound and an adjacent pipe stringing area. Ground conditions in the area are summarised in Table 15.1. The ground surface gently falls to the north at about 2 degrees. To the east of the compound the ground falls to the Leenamore River inlet, which is surrounded by agricultural fields used for grazing.

Construction of the Aghoos tunnelling compound and stringing area is described in Chapter 5. A detailed analysis of the proposed construction approach (stone road method) is contained in Appendix M2.

Where heavily loaded equipment or materials are required to be placed onto the compound, additional measures may be required to support the equipment or materials in order to provide adequate bearing capacity. These additional measures could comprise localised removal of peat to the underlying soil and replacement with granular fill or the use of piled support structures.

The tunnel start pit at Na hEachú (Aghoos) consists of an excavation approximately 10m deep x 9m wide by 20m long (including sealing body) with an access ramp approximately 75m long by 5.5m wide. Given the ground conditions, the excavation will be supported by temporary support such as sheet piles (and bracing where necessary) in soil and fill, or battered slopes where more competent ground or bedrock is encountered.

Glengad Reception Pit and Compound

Ground conditions in the area of the Glengad reception pit and compound are summarised in Table 15.1 and in Appendix M1. The ground surface in the area falls gently to the north.

The tunnel reception pit at Gleann an Ghad (Glengad) consists of an excavation approximately 10m deep x 7.5m wide by 28m long (including sealing body) with access ramp. Given the ground conditions, the excavation will be supported by temporary support such as sheet piles in soil or battered slopes where more competent ground or bedrock is encountered.

15.1.2.9 Topography

At Gleann an Ghad (Glengad) headland the topography of the proposed route comprises gently sloping ground with an elevation range from 0 to 10m above sea level.

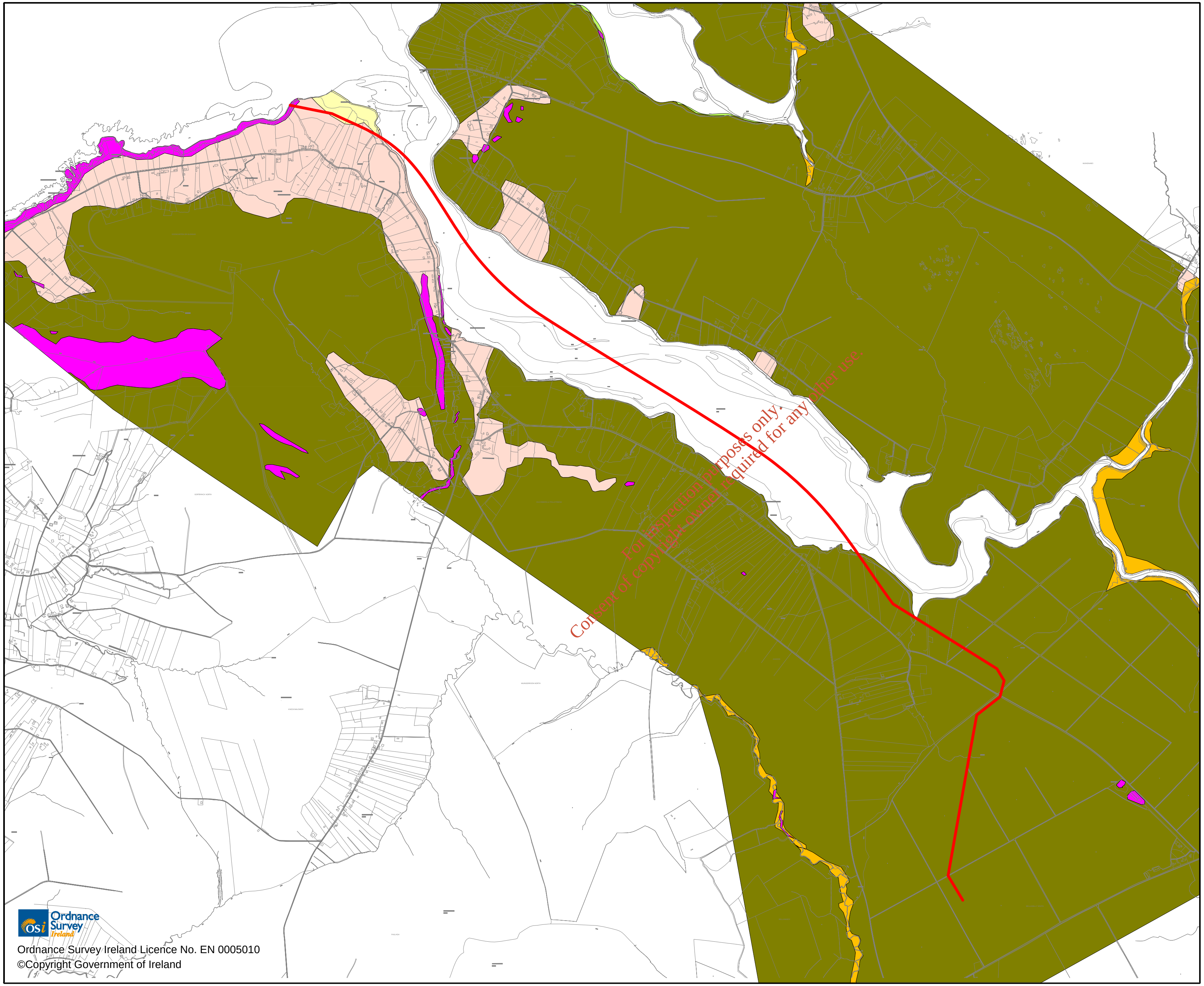
South of Sruwaddacon Bay at na hEachú (Aghoos) the elevation generally increases, reaching a maximum of approximately 38m above sea level close to the Terminal site at Béal an Átha Buí (Bellanaboy). The slope gradients along the route generally vary between less than 2^o and 4^o for most of the route with relatively steeper slopes close to river crossings at the Leenamore River inlet (Ch. 89.25) and at a tributary of the Leenamore River (Ch. 90.66).

15.1.2.10 Groundwater

Groundwater strikes were recorded during drilling of boreholes along the route between about 1.1m and 3.8m below ground level in the inorganic soils and between 0m and 0.4m below ground level in the peat areas south of Sruwaddacon bay at na hEachú (Aghoos).

Groundwater has been monitored in borehole piezometers since their installation in 2007 by GES.

See Section 15.3 for details on hydrogeology.



LEGEND:

SUBSOILS

- Alluvium
- Blanket Peat
- Estuarine/Marine Deposits
- Rock
- Till Derived from Metamorphic Rocks
- Water
- Wind Blown Sand

Proposed Pipeline Route

Subsoils Geology

Figure 15.2

File Ref: COR25MDR0470Mi2131A03
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

15.1.2.11 Landslides

In establishing the proposed route of the pipeline and the construction method employed in peat a number of key landslide events were examined, namely the 2003 Dún Cheartáin (Dooncarton) landslide event and the 2003 Derrybrien peat slide.

The adoption of a stone road construction method for installing the pipeline eliminates the risk of placement of load onto the peat surface where weaker peat may be present.

The construction methodology in peat for the Corrib Onshore Pipeline is the stone road method within which the pipeline will be installed (see Chapter 5). The stone road will be constructed on competent ground and will be inherently stable as detailed in the assessment of the stone road construction method (Appendix M2). A Geotechnical Risk Register (Appendix M4) has been compiled which includes construction in peat areas and appropriate mitigation measures determined to minimise geotechnical risk (See Section 15.1.3).

15.1.3 Geotechnical Summary

The installation of the proposed pipeline, services and outfall pipeline will use several different construction methods as set out in Chapter 5 and indicated in Table 15.1 above. From the geotechnical assessments carried out it was determined that around one third of the proposed route will be within peat areas. Assessment of the route through peat areas shows that the proposed stone road construction method provides a stable platform for the installation of the pipe (see Appendix M2).

Bedrock will only be encountered during construction of the landfall valve at Gleann an Ghad (Glengad) and in the construction of the proposed pipeline tunnel under Sruwaddacon Bay, where part of the tunnel will pass through bedrock.

Where the pipeline is constructed in inorganic soils it will be founded within medium dense to dense sand or gravel. These deposits have adequate strength to support the pipeline loads. A detailed geotechnical assessment of the sections of the route in inorganic soils and within Sruwaddacon Bay is included in Appendix M1. The assessment of factual data and analyses carried out demonstrates that the pipeline can be constructed in the proposed environment.

Geophysical surveying has already been undertaken throughout Sruwaddacon Bay (Osiris, 2007[15]) to determine the profile of the interface boundary between the superficial sediments and bedrock. Geotechnical site investigations were also carried out in Sruwaddacon Bay in 2008. The ground conditions through Sruwaddacon Bay consist of:

(1) Varying depths (up to approximately 25m) of fluvial and glacial sediments, mainly consisting of sand and gravel, with possible boulders present near the base of the sediments.

(2) Bedrock consists of weak to very strong psammitic and pelitic schists of Dalradian age, which has been significantly folded. Geophysical surveys indicate the possible presence in the bedrock of igneous dykes at various locations within the bay.

Within Sruwaddacon Bay, the pipeline will be installed within a segment lined tunnel. The proposed tunnel will be approximately 4.9km long and have an outside diameter of 4.2m. Approximately 4.6km of the tunnel will be underneath Sruwaddacon Bay. The proposed tunnel alignment is mainly through sands and gravels as shown in Appendix M1-A (Drawings Dg0401 – Dg0404). The horizontal alignment of the tunnel may deviate by up to 8m on each side. The vertical alignment of the tunnel may vary between a minimum cover of 5.5m and a maximum depth of 10m below the indicated centreline. Previous survey work will be further supplemented by borehole investigation within the bay, which will allow the appointed tunnelling contractor to optimise the design of the tunnel.

In peat areas, due to the inherent weak strength of peat, it is proposed to construct a stone road within which to lay the pipeline and also to act as a working platform for construction plant. This stone road method provides long term stability and protection of the pipeline.

[15] Ibid, pg. 15-5

A detailed assessment of peat stability and the stone road stability in peat is included in Appendix M2. The stone road stability report demonstrates that the stone road can be constructed in the proposed peat environment. The stone road will provide a robust and stable platform for the safe construction and operation of the pipeline.

15.1.4 Potential Impacts & Mitigation Measures

15.1.4.1 Geotechnical Risk Register

A Geotechnical Risk Register is provided in Appendix M4. The register has been compiled to show the degree of uncertainty associated with various elements of the proposed pipeline construction on a qualitative scale derived from Clayton (2001)[16]. This register has been compiled to address geotechnical hazards and risk control measures during the design and construction stages of the project. These findings have been used to identify the potential impacts/risks of the hazard, to identify the design and construction controls to be implemented in order to minimise geotechnical risk (i.e. mitigation measures), and to identify residual impacts and appropriate remedial measures.

The register will be used actively throughout the detailed design and construction and will be updated to reflect additional data and experience as it is gained.

15.1.4.2 Potential Leak from Water Outfall Pipe

In the unlikely event that the water outfall pipe leaks, water will be released into the pipeline backfill material. Due to the limited flow within the outfall pipe any effect will be very local and will have no adverse effect on the stability of any part of the pipeline system or surrounding land.

A review of potential stability risk arising from leakage of the water outfall pipe where it is installed within the stone road in peat areas is provided in Appendix M2.

15.1.4.3 Geotechnical Monitoring of the Pipeline

Construction Monitoring

All site works will be monitored thoroughly during the construction period. Site staff will be made fully aware of the ground conditions expected along the route of the pipeline. A dedicated geotechnical engineer will be employed to oversee construction monitoring with respect to ground movements.

Ground survey markers will be installed at regular intervals along the length of the stone road in peat to monitor movement during stone road construction and following installation of the pipe. In areas of deeper peat inclinometers will be installed in peat adjacent to the stone road to monitor any possible lateral movement of the peat. Groundwater levels will be monitored from drive-in piezometers installed in deeper peat areas in advance of stone road construction, see Appendix M2 for details. Visual sighting lines as a minimum will be installed adjacent to the working areas within peatland and monitored for any excess movements. If necessary, remediation measures will be implemented and the movement/ground conditions/groundwater levels monitored until they stabilise again.

An observational method of monitoring will be adopted by all personnel, where any unexpected changes in ground conditions, groundwater levels and/or ground movement is noted and the appropriate construction management personnel made aware of said changes.

The above measures are included in the geotechnical Risk Register (see Appendix M4)

[16] Clayton, C.R.I., (2001). Managing Geotechnical Risk. Thomas Telford, London.

Post Construction Monitoring

Post construction visual inspections will be carried out regularly along the pipeline route to identify any indications of movement. At selected locations and where possible, ground survey markers installed within the stone road during construction will be extended above the finished peat restoration level to enable long term monitoring of movement (see also Appendix M4)

15.2 HYDROLOGY

A report on the assessment of the potential impact of the proposed onshore pipeline on the existing hydrological regime is provided in Appendix M5. The assessment was undertaken by RPS. The following section describes the existing environment from a hydrological perspective and outlines the potential impacts and mitigation measures. A separate assessment has been undertaken of the peatland hydrology of the blanket bog traversed by the proposed route and this is described in Section 15.4 and Appendix M6.

15.2.1 Existing Environment

15.2.1.1 River Catchments & Flooding

The proposed pipeline route lies mainly within the Sruwaddacon Bay catchment area. The two largest rivers draining into Sruwaddacon Bay are the Glenamoy River and the Muingnabo River. The Sruwaddacon Bay catchment forms part of National Hydrometric Area – 33 and falls within the Western River Basin District (WRBD). Figure 15.3 shows the extent of the associated river catchment areas draining into Sruwaddacon Bay along with a layout of the proposed pipeline route. A short section of the route within the Terminal is not shown within any catchment as it is understood to be facilitated by the surface water drainage in the Terminal site, which discharges to the Carrowmore Lake Catchment.

The Glenamoy River rises in a mountain located at Gleann an Ghad (Glenagh), Co. Mayo (land elevation 304mOD Malin Head), approximately 20km northeast of its confluence with Sruwaddacon Bay. The Glenamoy River has an approximate catchment area of 87km^2 upstream of this confluence. The Muingnabo River rises in high ground at Gleann an Ghad (Glenagh) (at land elevation of 265mOD Malin Head) approximately 15km upstream of its confluence with Sruwaddacon Bay. This river has an approximate catchment area of 40km^2 upstream of the confluence. Both river catchments are steeply sloped towards Sruwaddacon Bay with an approximate main channel slope of 1 in 85. The soil types within both of the catchment areas vary between the FSR (The UK Flood Studies Report, NERC 1975) soil types 3 and 5, suggesting moderate to very low winter rain acceptance potential.

In addition to the two main river catchments mentioned above, a number of smaller local river/stream catchments and some lands surrounding Sruwaddacon Bay drain directly into the Bay.

The Glenamoy and Muingnabo rivers generally flood every winter after heavy prolonged rainfall. These catchments have experienced a number of high floods in the past. The worst flooding in this catchment occurred in 1984 (21st September), 1989 (27th October) and in 2003 (19th September). Much of the low lying flood plains of the river catchments flooded during these flood events. However, the Office of Public Works (OPW) flood hazard map (see Appendix M5) does not show any areas prone to flooding in the vicinity of the proposed pipeline route.

15.2.1.2 Rainfall

Observed long term average annual rainfall at Bangor, Gleann na Muaidhe (Glenamoy), Ros Dumhach (Rossport) and Béal and Mhuirthead (Bellmulet) are 1352mm, 1416mm, 1339mm and 1173mm, respectively (source Met Éireann). The estimated 100 year return period hourly rainfall at Béal and Mhuirthead (Bellmulet) is 34mm, while the maximum observed hourly rainfall at Poll an tSómais (Pollatomish) is approximately 40mm, recorded in September 2003.

The west of Ireland experienced notably high rainfall in November 2009, along with other many parts of Ireland. The most extreme rainfall occurred over the period from 16th to 18th November 2009. The observed daily total rainfall on 16th November 2009 at Béal and Mhuirthead (Bellmulet) was 23.20mm. The estimated return periods of the November 2009 rainfall totals for the 4, 8 and 16-day periods at

Béal and Mhuirthead (Bellmulet) are 2, 3 and 5 years respectively (source Met Éireann- Climatological Note No. 12, February 2010).

15.2.1.3 Drainage

The lands along the proposed pipeline route drain directly into Sruwaddacon Bay as overland flows and also via the above-mentioned main rivers, their associated tributaries and other land drains located within the Sruwaddacon Bay catchment area. These drainage systems form part of the regional OPW arterial drainage network.

15.2.1.4 Water Quality

Water quality records for the watercourses in the vicinity of the proposed pipeline route were sourced from the Environmental Protection Agency (EPA). An assessment carried out by the EPA on these water quality records showed that the Glenamoy River at Gleann na Muaidhe (Glenamoy) (located approximately 5km upstream of the confluence with Sruwaddacon Bay) has "good" water quality status (Biotic Index of Q4) (source - *Water Quality in Ireland 2001-2003, EPA 2005)*. Bathing water quality in Gleann an Ghad (Glengad) in the vicinity of the proposed Landfall Valve Installation has been assessed as "*good"* and complies with EU Guide Values under the EU Bathing Water Directive. Risk assessments carried out by the WRBD have identified both the Glenamoy and Muingnabo Rivers in the immediate upstream vicinity of the confluences with Sruwaddacon Bay as "*1b- probably at significant risk of not achieving good status"* under the Water Framework Directive (2000/60/EC) by 2015, while Sruwaddacon Bay (which is classified as a transitional water) has been assessed as "*probably at risk of not achieving good status by 2015*".

15.2.1.5 Recreational & Amenity Value

The recreational and amenity value of the waters in the study area are discussed in detail in Chapter 6 of this EIS.

15.2.2 Potential Impacts

The potential impacts on various hydrological aspects, such as flooding, drainage and water quality, associated with construction of the proposed pipeline have been examined and appropriate mitigation measures have been proposed in accordance with the "*Guidelines on Procedures for Assessment and Treatment of Geology, Hydrology and Hydrogeology for National Road Schemes (Draft)*" (NRA 2007). These potential impacts are discussed in detail in the following sections.

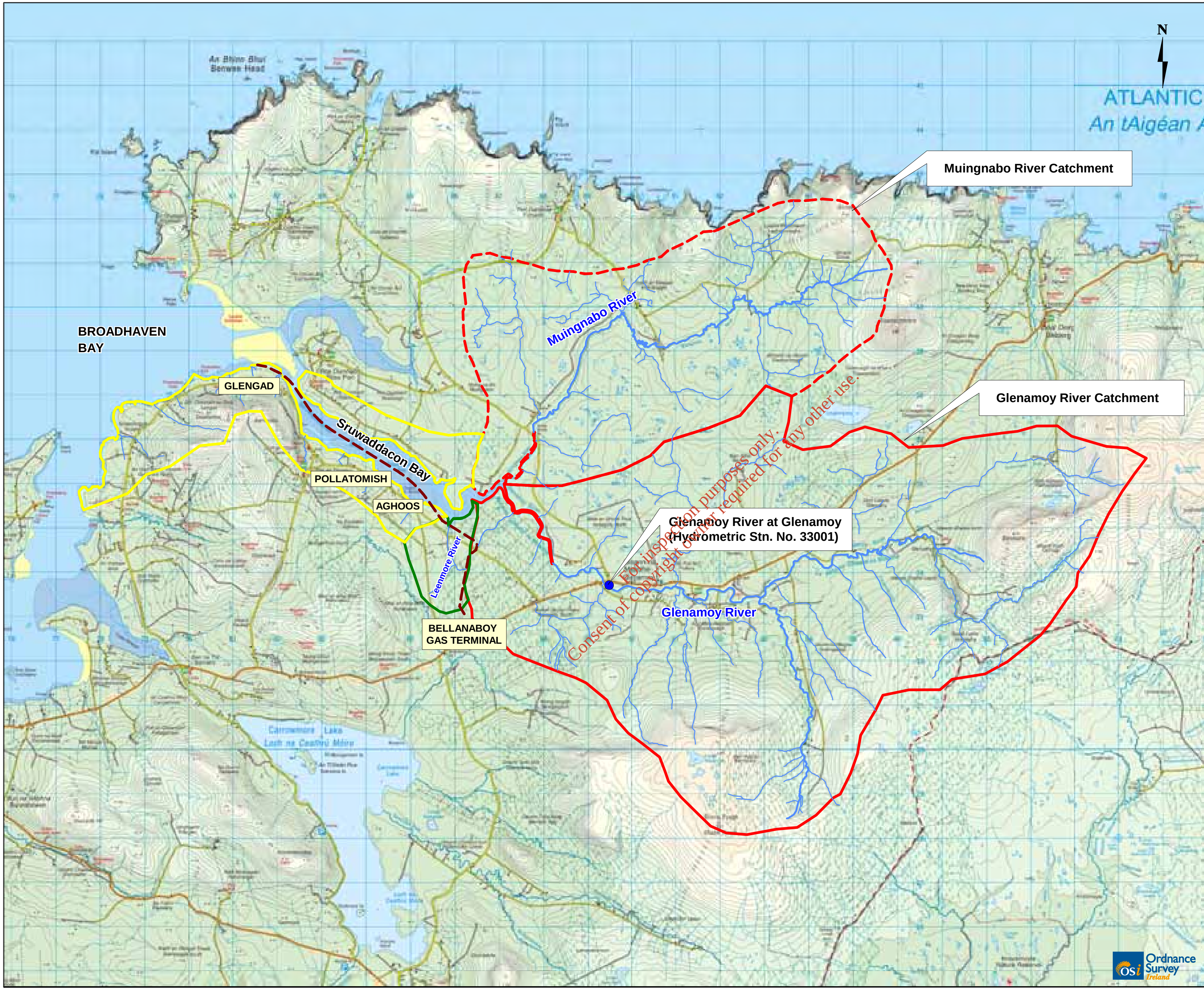
15.2.2.1 During Construction

Flooding

During the construction phase of the works, there is the potential for temporary, localised flooding of lands to occur in the vicinity of the proposed river/stream crossings. The causes of flooding could be due to:

- Obstruction to surface water flow paths caused by the pipeline alignment and the stone road construction works;
- Obstruction to flow paths to the natural drainage system and river channels at the location where open-cut technique will be used for laying pipe in the river bed (at Leenamore River crossing); and
- Blockage of surface water flow paths by collapse of unstable river/stream/trench banks, specifically in the peatland areas.

Prolonged extreme rainfall event and joint occurrences of an extreme rainfall event in the catchments and a high tidal event in Sruwaddacon Bay.



Legend

- Proposed Pipeline Route
- Muingnabo River Catchment
- Glenamoy River Catchment
- Leenmore River Catchment
- Additional Catchment Areas
- River Station
- River

Client

Corrib natural gas

Project

Corrib Onshore Pipeline

Title

River Catchments

Figure 15.3

RPS

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Checked by: U. Mandal		File Ref. COR25MDR0470Mi2194A03	
Approved by: C. Cahill			
Scale: 1:80,000 @ A3		Drawing No. Mi2194	Rev. A03
Date: May 2010			

Notes
1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin Head.
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Drainage

The existing land drainage system in the vicinity of the proposed pipeline route, which forms part of the regional OPW arterial drainage network, could be affected during the construction period of the project. Impacts on the existing drainage system could include:

- Change in the pattern of runoff, with some existing drains and ditches receiving significantly more or less flow than they receive currently;

- Rainfall on elevated areas washing peat and silt into the surrounding watercourses. Localised erosion and scouring could occur, while reduced flow may result in stagnation in some drains and ditches;

- Obstruction to upland flow paths causing localised water logging in the upstream vicinity of the pipeline route; and

- Slight changes in the existing surface and subsurface drainage flow paths along the blanket bog areas during the construction phase of the project. (The potential impact of the stone road construction on the peatland hydrology is covered in Appendix M6).

Water Quality

There is potential for the water quality and fisheries of Sruwaddacon Bay and its tributaries to be affected by construction of the proposed pipeline. Impacts could arise from the following sources:

- Mobilisation of sediments and harmful substances during the construction phase, due to exposed soil and peat/soil movement/storage, particularly from construction of the stone road in the peat bog areas, which may block local streams and drains and could be flushed into the adjacent surface watercourses during heavy rainfall events;

- Accidental spills of harmful substances, such as petrol or oil and liquid cement, during delivery and storage or by leakage from construction machinery; and

- Increased pollutant and nutrient input due to an increase in surface runoff and removal of existing vegetation.

The above potential adverse impacts may affect aquatic habitats by: reducing light penetration, thus affecting primary production; displacement of aquatic invertebrates, which act as a fish food source; and smothering of spawning substrates. Disturbance of the peat could also result in increased oxidation and the release of a greatly increased level of humic acids.

Amenity Values

Impacts on the recreational and amenity value of the waters in the study area are discussed in detail in Chapter 6 of this EIS.

15.2.2.2 During Operation

There will be no impacts on hydrology as a result of operation of the proposed pipeline. In addition, during operation the proposed pipeline will not be impacted by the existing hydrological character of the area along the route for the following reasons:

- The pipeline will be buried with a minimum depth of cover of 1.6m beneath all watercourses traversed by the proposed route. Therefore, it will not be at risk from potential interferences from watercourses, e.g. erosion of stream/river bed, which might expose the pipeline. Furthermore, in the unlikely event of the pipeline at stream/river crossings being exposed, it is covered with impact protection in the form of a concrete slab to further safeguard the pipeline;

- The pipeline will be buried in the ground with a minimum depth of cover of 1.2m (see Chapter 5 of this EIS). At such depths it is not likely to be at risk from groundwater. However, even if it were to become surrounded in water for a period of time, the pipeline has been designed to withstand potential corrosion risks as it is protected by a 3-layer polypropylene coating. The pipeline has also been designed to ensure that it will not float.

- In areas of peatland, it is proposed to construct the pipeline within a stone road. Therefore, the hydrology of the peatlands will not impact on the pipeline during operation as it will be maintained within a stable platform and therefore will not be at risk from alterations in the surrounding drainage regime, i.e. flooding. The potential operational impact of the stone road on hydrology in the area of blanket bog traversed by the route has been addressed in Section 15.4 and Appendix M6.

15.2.3 Mitigation Measures

15.2.3.1 Flooding and Drainage

During Construction

The following mitigation measures will be implemented to manage flooding and storm water drainage during the construction phase of the project.

- Surface water runoff from the lands and green areas up-gradient of the working area will be conveyed via existing drainage channels where they occur along the route. These channels will be piped under (or in the case of compounds, around) the working area through a series of pipes to connect to existing outfalls and drains. Where drainage channels do not occur, a shallow interceptor ditch or barrier will intercept overland flows and discharge to the outfalls without any further attenuation and/or treatment as this runoff will be from undisturbed areas;

- Storm runoff will be conveyed via a swale or vee drain located on the down slope of the working area. Flow will be intercepted and a number of attenuation features (silt traps or check dams) will be located intermittently along the swale to encourage the sedimentation of any potential silt. At the outfall the discharge will be passed through a graded stone chamber encased in geotextile fabric as a final silt control mechanism;

- Where significant runoff from the stone road and compound locations is anticipated, sedimentation management is required. The sedimentation management system will be sized for a 10 year 24 hour storm event (CIRIA Report 142, 1994; CIRIA Report 532, 2001; CIRIA C648, 2006 & CIRIA Report B14, 1993);

- Any temporary ditches down slope from the construction works shall be designed to drain to a sediment pond. For the construction works, a return period of 10 years is appropriate (CIRIA 648, 2006); and

- Stockpiles will be kept at a minimum reasonable distance (minimum 50m) from any stream crossing, particularly from the Leenamore river crossing, to prevent any blockage to flood water flow paths from occurring during high rainfall events. Given the steep nature of the catchment slope, a flash flood in the Leenamore River could occur. Thus, adequate flood diversion works will must be designed and put in place for this. Pumping of floodwater may be also be considered as necessary.

Further details of the stormwater management measures proposed during the construction phase of the works have been provided in Appendix M5.

During Operation

Minimal to no impact on the existing flooding and drainage regime is expected during the operation phase of the project. Therefore, no remedial or reductive measures are considered necessary.

15.2.3.2 Water Quality

During Construction

The following measures are proposed for protecting water quality and aquatic habitats during the construction phase:

- A series of ditches and drains will be installed during the construction phase, to collect runoff. Temporary and permanent ditches will be used. Localised pumping may also be required;

- Fuels, oils, greases and hydraulic liquids will be stored within enclosed concrete/bunded areas and as far as possible from drainage ditches, surface water drains and watercourses. These bunds will be designed in accordance with the EPA Guidance Note on Storage and Transfer of Materials for Scheduled Activities (requirement for 110% storage volume for all tanks storing petroleum products). For the construction phase appropriately sized hydrocarbon interceptors will also be placed at outfall locations along the surface water drainage system;

- Runoff from construction areas will be will be collected and managed so that no direct discharges to watercourses occur;

- Stockpile areas for sands, gravels, excavated mineral soil and peat will be kept well away from any watercourses;

- Runoff will only be routed to the watercourse via suitably designed and sited sedimentation ponds, swales and channels,

- Sedimentation ponds will be inspected daily and maintained regularly,

- Watercourse banks will be left intact where possible. If they have to be disturbed, all practicable measures will be taken to prevent soils from entering the watercourse,

- A pollution prevention plan will be implemented at commencement of the construction phase;

- Weekly, and where necessary, daily inspections and maintenance of the above measures will be carried out to ensure that they are maintained in a satisfactory condition, and discharges will be monitored prior to discharge; and,

- Strict control of erosion, sediment generation and other pollutants associated with the construction process will be implemented including silt barriers and ditches downslope from construction works to intercept waters with high sediment loads and accidental leakages/ spillages of harmful substances.

Further details of the stormwater management measures proposed along the pipeline route during the construction phase of the works have been provided in Appendix M5.

During Operation

The risk to surface water quality during the operational phase of the works is expected to be minimal.

15.2.3.3 Water Quantity and Water Abstraction

The proposed pipeline (both during construction and operation) will not pose any risk to either the quantity or quality of existing sources of raw water that are currently being used for the regional water supply system. No remedial or reductive measures are proposed.

15.3 HYDROGEOLOGY

An assessment of the potential impacts of the proposed pipeline development on hydrogeology was carried out by RPS. The assessment addresses the groundwater in the bedrock along sections of the route in non-peat areas. An assessment of peatland hydrology is provided in Section 15.4.

15.3.1 Existing Environment

The Geological Survey of Ireland (GSI) classifies the groundwater in the underlying bedrock as a Poor aquifer, which is generally unproductive except for localised zones. Bedrock groundwater flow occurs predominantly through a limited and poorly connected network of fractures, fissures and joints. Shallow groundwater encountered within the peatland area is discussed in detail in Section 15.4. Shallow zones of higher permeability may exist within the upper levels of the fractured/weathered rock and along fault zones. These zones may provide locally important supplies of water but in general, the lack of connection between the limited fissures/fractures results in poor aquifer storage and flow paths that may only extend a few hundred metres.

Regional groundwater flow in the bedrock is expected to follow the regional topography of the area.

Geotechnical survey information (IDL, 2008) and geophysical survey information (Osiris, 2007) from Sruwaddacon Bay show rock head between 1.4 and 21.0m bgl. The superficial deposits under Sruwaddacon Bay comprised predominantly sands and gravels with some cobbles and boulders. The deepest depths to bedrock were recorded near the centre of the mouth of Sruwaddacon Bay. Rock exposures of massive to moderately fractured psammite and weathered sandstone, highly fractured in places, were recorded at the mouth of the Bay along the foreshore and at the LVI site. Rock outcrops were less evident heading east and south into the Bay. Bedrock information for the area from the GSI, including previously identified fault lines, is presented in Figure 15.1.

The geophysical survey of Sruwaddacon Bay (see geophysical cross sections in Appendix M1-A) also identified geophysical anomalies underlying the Bay. These anomalies are likely to correspond to igneous dykes within the bedrock, which in general restrict the flow of groundwater within bedrock.

Groundwater levels were recorded in monitoring wells along the northern shoreline of Sruwaddacon Bay and to the south of the Glenamoy River Estuary using a number of automated data loggers between December 2007 and October 2008. The highest recorded water levels in these boreholes ranged between 2.7 and 16.8m OD. Groundwater variations in a number of wells, impacted by tidal water, varied up to 2.5m in magnitude.

15.3.2 Potential Impacts

15.3.2.1 During Construction

Groundwater levels were measured at the proposed LVI site at Gleann an Ghad (Glengad) in December 2007 and January 2008 (representing periods of elevated rainfall and associated elevated groundwater levels). The highest water levels recorded during this period were 5.73m OD (Malin Head) at the proposed LVI site and 10.09m OD (Malin Head) up gradient of this location. There is potential for ground water levels to reach the floor level of the LVI during extreme conditions (inclement weather, high ground water levels and tides).

Bentonite is used for lubrication, cooling of the drill shield, removal of cuttings and stabilisation of the cut. The use of bentonite will be managed at a bentonite-handling unit, which will be located within the site compound, close to the start pit. This facility will circulate and recycle bentonite throughout the tunnelling process via dedicated hoses in the sleeving pipe to and from the TBM and includes areas for settlement and filtration. Tunnelling is likely to progress through both alluvial deposits and bedrock along the pipeline route. In the unlikely event of bentonite loss, bentonite is unlikely to migrate beyond the immediate vicinity of the tunnel bore based on the likely low permeability of the alluvial deposits, the composition of the bentonite slurry and the hydrostatic pressure of overlying water bodies. As such, impacts to groundwater in the unlikely event of bentonite loss would be imperceptible. If major water-bearing fractures are encountered, migration of bentonite may occur in these areas resulting in slight to moderate impacts on groundwater. However, based on encountered and surveyed geological conditions (i.e. sediment-laden fracture zones and geophysical anomalies which appear to be dykes) as well as information from the GSI, the likelihood of encountering major water-bearing fractures is deemed to be low.

Localised and temporary dewatering works will be required at the starting pit at na hEachú (Aghoos) and the reception pit at Gleann an Ghad (Glengad). Dewatering works in these areas may temporarily alter groundwater flow conditions in these areas; however, impacts are not likely to significantly impact on the groundwater flow regime of the area as a whole. In addition, silt laden groundwater discharge may impact on surface water quality.

Accidental spillages of fuels, lubricants and hydraulic fluids from construction refuelling facilities, chemical and waste storage or handling areas pose a significant risk to groundwater should inadequate prevention measures be installed.

15.3.2.2 During Operation

No impacts to groundwater are anticipated during the operation stage of the proposed pipeline.

15.3.3 Mitigation Measures

15.3.3.1 Construction Stage

The mitigation measures listed below will be implemented to address potential impacts to groundwater during the construction stage.

- It is proposed that effective water management be implemented during construction to avoid contamination of groundwater. It is also recommended that an Emergency Response Plan to deal with accidental spillages be contained in within the Environmental Management Plan (see Chapter 18 of this EIS).

- Detailed site investigation works along the pipeline route will be carried out to confirm the conditions along the route and identify, if any, major-water bearing fractures.

- Continual monitoring of bentonite volumes during the tunnelling works will be undertaken throughout to ensure maximum reuse at all times and to prevent the release of bentonite into the subsoils. In addition, visual monitoring of potential evidence of bentonite migration into the Bay shall be undertaken throughout the works.

- Treatment of discharge from dewatering operations shall be undertaken and is discussed in Section 15.4.4.

- Waste fuels and materials will be stored in designated areas that are isolated from surface water drains or open waters. Skips will be closed or covered to prevent materials being blown or washed away and to reduce the likelihood of contaminated water leakage. Hazardous wastes such as waste oil, chemicals and preservatives, will be stored in sealed containers and kept separate from other waste materials while awaiting collection by a registered waste carrier. Fuelling, lubrication and storage areas and site offices will not be located within 15m of surface water features and shall take place in a designated area of the compound. Fuel interceptor tanks will be installed on the site to treat any runoff.

- All waste containers (including all ancillary equipment such as vent pipes and refuelling hoses) will be stored within a secondary containment system (e.g. a bund for static tanks or a drip tray for mobile stores and drums). The bunds will be capable of storing 110% of the tank capacity. Where more than one tank is stored, the bund must be capable of holding 110% of the largest tank or 25% of the aggregate capacity (whichever is greater). Drip trays used for drum storage must be capable of holding at least 25% of the drum capacity. Where more than one drum is stored the drip tray must be capable of holding 25% of the aggregate capacity of the drums stored. Drainage of bunded areas shall be diverted for collection and safe disposal off site by an appropriately licensed contractor.

- Refuelling of construction vehicles and addition of hydraulic oils or lubricants to vehicles will be undertaken at a designated area of site.

- All water from the tunnelling compound at na hEachú (Aghoos) is collected via a closed drainage system and will be past through a petrol interceptor and settlement tanks / ponds.

15.3.3.2 Operational Stage

A perforated drainage pipe network will intercept both groundwater and surface water and divert elevated groundwater from the LVI site to a concealed outfall in the cliff face (refer to Chapter 4 for details). As such, only imperceptible impacts on local groundwater levels and groundwater flow in the area would be expected during the operational stage of the proposed project. Therefore, no remedial or reductive measures are proposed.

15.4 PEATLAND HYDROLOGY

15.4.1 Introduction

A peatland hydrological impact assessment has been undertaken for the peatland areas traversed by the revised pipeline route. This assessment, which was undertaken by Hydro-Environmental Services (HES), describes the physical processes (hydrological and hydrochemical) that support and control peatland environments and evaluates direct and indirect impacts on these processes in the peatland area traversed by the proposed pipeline. The methodology used in the peatland hydrology impact assessment is presented in a report in Appendix M6 of the EIS.

15.4.2 Existing Environment

This section relates only to the interval of the pipeline route which traverses peatland habitats. Due to revision of the pipeline route under Sruwaddacon Bay, the first peatland habitat encountered along the revised pipeline route from the landfall at Broadhaven Bay occurs at na hEachú (Aghoos) (Ch. 88.622).

From na hEachú (Aghoos) to the Terminal the revised pipeline route traverses various habitat types that are underlain by peat.

The following sections provide the regional context for the study area with regards to surface water hydrology and peat hydrology as well as the local characteristics of blanket peat. Further detail on climate in the region along with the subsoil geology, bedrock geology and bedrock hydrogeology is provided in Appendix M6.

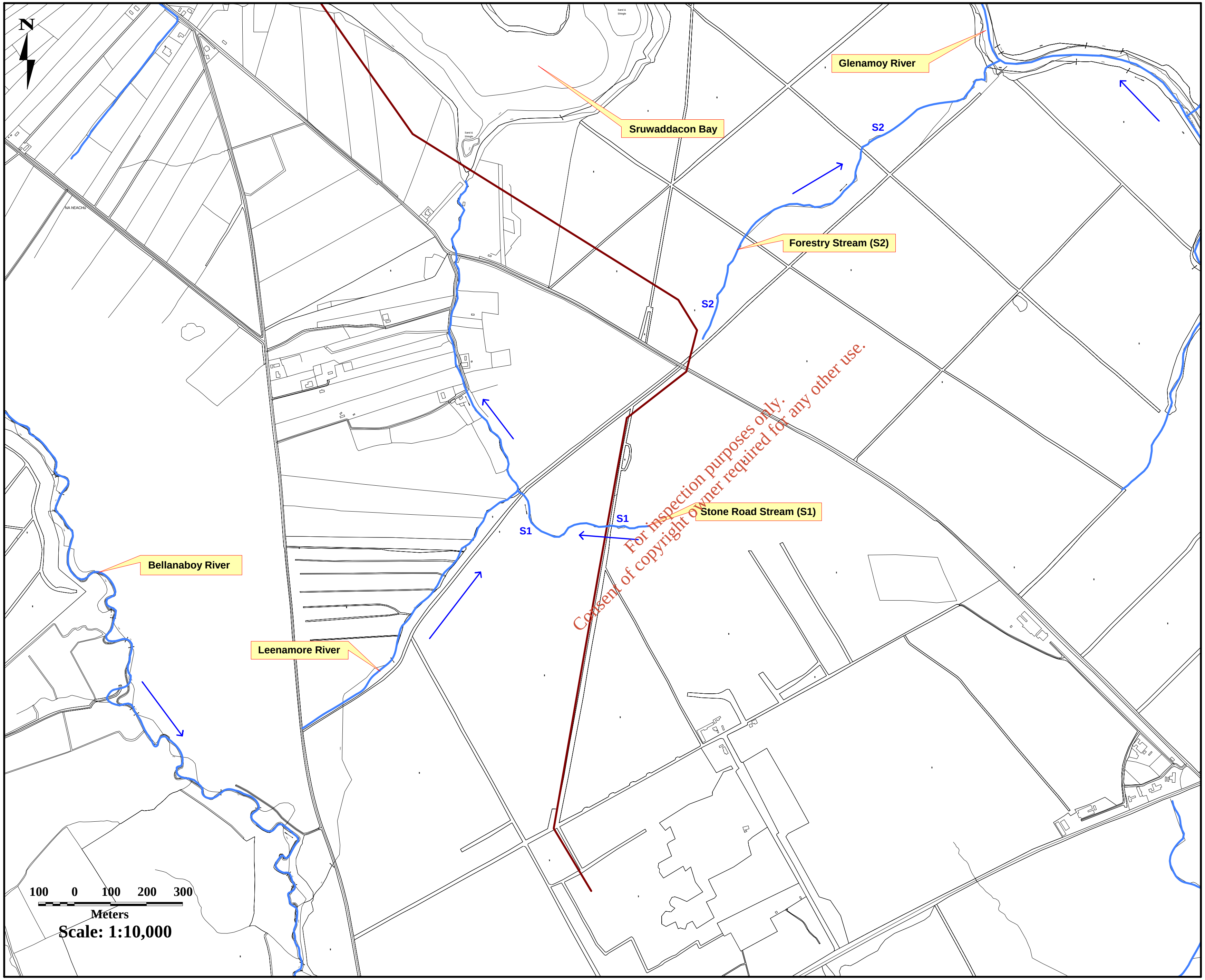
15.4.2.1 Surface water hydrology

Regional surface water hydrology is described in Section 15.2. Local streams and rivers along the pipeline route between na hEachú (Aghoos) and the Terminal are shown on Figure 15.4. The following sub-catchments drain towards these rivers and streams.

The Leenamore River sub-catchment is very small, comprising approximately 2.4km^2. It rises to the north west of the Terminal Site and flows northwards to discharge into Sruwaddacon Bay. A small tributary to the Leenamore River (S1 on Figure 15.4, and referred to as the ‘stone road stream’) drains forestry to the north of the Terminal Site and this stream crosses the pipeline route at Ch.90.66. The natural hydrology of this catchment has been significantly altered by drainage for forestry and peat extraction.

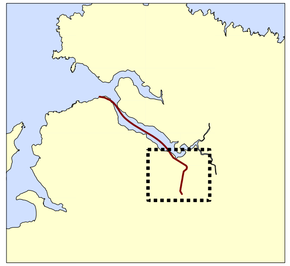
Another small tributary (S2 on Figure 15.4, and referred to as the ‘forestry stream’) of the Glenamoy River rises north of the proposed pipeline route in coniferous forestry north of the L1202. This stream flows north east and discharges to the Glenamoy River.

At the southern end of the pipeline route, at the Terminal, approximately 200m of the route drains south into the Bellanaboy River via the terminal surface water system, draining eventually into Carrowmore Lake. The total catchment area of the site draining towards the Bellanaboy River is 0.05km^2 (approximately 5 ha).



LEGEND:

- Proposed Pipeline Route (2010)
- River / Stream
- Stream/River Flow Direction



Local Hydrology Bellagelly

Figure 15.4

File Ref: COR25MDR0470Mi2496A01
Date: May 2010

CORRIB ONSHORE PIPELINE

Corrib natural gas

RPS

15.4.2.2 Peat hydrology

The original extent of post glacial peatland (Fens, Raised Bogs, Atlantic Blanket Bog and Mountain Blanket Bog) cover in Ireland was estimated by Hammond (1979) as being 11,456km^2. Of this area 3,292km^2 was classified as Atlantic Blanket bogs. Peatland comprises 1,938 km^2 of the land area of Co. Mayo (5,586 km^2). These peats comprise mountain and lowland blanket bogs, raised bogs and cutover raised and blanket bogs (Teagasc/EPA, 2004). A portion of these peatland types has been planted with coniferous plantation forestry. In the environs of the proposed pipeline, the Glenamoy Bog Complex cSAC of 127 km^2 is designated predominantly for the priority Annex 1 habitat of lowland blanket bog and also includes the marine and coastal margin of Sruwaddacon Bay. The area of the cSAC supporting lowland blanket bog is located north of Sruwaddacon Bay on the northern side of the Glenamoy River. There is no hydrological connection between the area of the proposed pipeline route and this Annex 1 habitat.

Blanket bog develops in areas where the ratio of precipitation to evaporation is typically greater than 2:1 (i.e. there is excess precipitation over evapotranspiration), with rainfall spread throughout the year, cool summer temperatures and low evapotranspiration rates (Doyle, G.J. and O'Criodain, C., 2003) as well as where a low permeability layer exists to retain the rainfall and cause water logging. This can consist of low permeability bedrock and / or the presence of a clay soil or subsoil layer.

Peat water flow directions are strongly controlled by topographic gradient, including the micro-topography of the underlying substrate. Localised flow gradients in the peat will occur in response to sub-surface micro-topography, and also as a result of drainage and ditches resulting from peat cutting and forestry. Within the peat profile, peat water gradients are generally vertically downwards, resulting in downward flow of water through the peat. Upward gradients can also occur, but are generally localised and occur as a result of local changes in peat type or morphology.

15.4.2.3 Local Characteristics of Blanket Peat

15.4.2.3.1 Hydrological and Hydrochemical monitoring at 'control' sites

This section provides a summary of the results of hydrological and hydrochemical monitoring that was completed as part of the peat hydrology impact assessment, and also provides a summary outline of the baseline assessment of peatland hydrology along the pipeline route. Detailed descriptions of baseline hydrological and hydrochemical characteristics of the route as well as the methodology used to determine these are provided in Appendix M6.

Baseline hydrological and hydrochemical monitoring was completed at 3 no. 'control' sites at Aghoos Bog, Bellagelly and Bellanaboy Terminal during 2008[17]/2009 (refer to Figure 1 of Appendix M6 for locations). This monitoring was completed by QMEC (QMEC, 2010) and included:

- Water level monitoring – weekly (January to April 2009) and monthly thereafter;
- Field hydrochemistry – bimonthly (February, April, June, August, October, and December 2009); and
- Analytical hydrochemistry – biannual (6th/7th May and 15th/16th/17th December 2009).

Baseline water level monitoring

The peat at the site is generally saturated, with phreatic[18] water levels at or close to ground level for much of the year.

Temporal trends in peat water levels throughout the 2009 monitoring period indicate that water levels were highest during January to February and October to December. Notable increases in water levels occurred in August and in May 2009. These increases coincide with high monthly total rainfall values.

[17] Some initial hydrological monitoring (water levels only) began in December 2008.

[18] The water surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric.

The lowest levels for the period were recorded in July 2009, which was preceded by a dry month of June.

The annual groundwater levels indicate that phreatic water levels are sensitive to seasonal fluctuations, with below average rainfall in June and July resulting in dry phreatic tubes. Phreatic water levels at Aghoos Bog and Béal an Ghoile (Bellagelly) show less seasonal fluctuation than those at Bellanaboy Terminal, and also indicate slightly higher water levels (closer to ground level) with more frequent waterlogging above ground level. Larger seasonal ranges were recorded at the Bellanaboy Terminal transects. The maximum range at the Bellanaboy Terminal transects could not be recorded in all of the phreatic tubes as the screens were too short.

There is a predominant pattern of downward vertical gradients within the peat profile across the three hydrological 'control' monitoring sites throughout the 2009 monitoring period. Some local variations occur in the shallower peat profile following rainfall and these are related to recharge and possible peat water flow within localised higher permeability zones (due to changes in peat stratigraphy or structure).

The seasonal range of phreatic and piezometric water levels is small (<0.5m), and this is indicative of a relatively static low permeability wetland environment. The dominant process is surface water runoff, with limited water flow or recharge occurring within the peat profile. Deeper levels of peat show slower response to rainfall events and indicate minimal water movement below 0.5m.

By way of comparison, seasonal water level monitoring in local bedrock indicates a range of 1-1.5m (poor aquifer), while a limestone (regionally important) aquifer may have seasonal fluctuation in water levels of up to 10m.

The main peat mass (the catotelm) and immediately underlying subsoils are of relatively low permeability and this impedes water movement. Vertical leakage from the base of the stone road will be minimal if a layer of basal peat is left in-situ and the underlying mineral soil remains undisturbed.

Baseline field hydrochemistry monitoring

The average EC (electrical conductivity) and pH values at the Bellanaboy Terminal, Béal an Ghoile (Bellagelly) and na hEachú (Aghoos) monitoring locations remained relatively stable throughout the 2009 monitoring period. In general, the average EC values in the peat water at the 3 no. 'control' monitoring sites increase with depth and demonstrate a slow downward seepage of rainwater.

The average pH recorded during 2009 was slightly acidic (5.47 pH units), comprising an average of pH 5.74 in the peat/subsoil interface groundwater, an average of pH 5.58 in the deep peat installations (P2-P4) and an average of pH 5.35 in the phreatic tubes.

The peat has higher EC and pH values than would be expected for inland blanket peat. This is a consequence of mineral enrichment from sea spray and wind blown sediments during and post peat formation. This gives a characteristic hydrochemical profile for blanket peat in coastal areas.

Comparison of the up-gradient and down-gradient hydrochemistry of the existing stone road (within the Bellanaboy Bridge Gas Terminal site) indicates that the stone road does not have any discernable impact on the hydrochemistry of the surrounding peat.

Baseline analytical hydrochemistry analysis

The analytical data for peat water samples indicates a predominant sodium-chloride (Na-Cl) signature with varying proportions of calcium and bicarbonate ions. The variation in the water types reflects the combination of the acidic peat environment and the proximity of the coastline, which can alter the chemical signature through the contribution of sea spray and wind blown sediments.

The majority of peatland water samples have elevated concentrations of ammoniacal nitrogen, which is typical for peat groundwater, due to the decomposition of organic material.

Elevated concentrations of orthophosphate in the peat water were recorded at piezometers at na hEachú (Aghoos), Béal an Ghoile (Bellagelly) and the Bellanaboy Terminal site. This is most likely due to the use of rock phosphate fertilizer in the adjacent forestry plantations.

A comparison of the hydrochemical data up-gradient and down-gradient of the existing stone road (within the Bellanaboy Bridge Gas Terminal site) indicates that the stone road has not had any discernable impact on the hydrochemistry of the surrounding peat.

15.4.2.3.2 Summary of peat permeability testing

Permeability tests in peat have been completed at the 'control' hydrological monitoring sites by QMEC. K-tests were completed at all the piezometers listed in Table 2.1 of Appendix M6. A summary of the results obtained are presented in Table 15.2.

Table 15.2. Summary of QMEC k-test results. (Source: QMEC, 2009)

Location	Shallow Peat/Phreatic	Mid/Deep Peat	Deep Peat/Subsoils
	Permeability range (m/s)	Permeability range (m/s)	Permeability range (m/s)
Aghoos	$2.1 \times 10^{-8} – 1.7 \times 10^{-11}$	$1.7 \times 10^{-8} – 4.3 \times 10^{-10}$	$1.2 \times 10^{-7} – 8.0 \times 10^{-11}$
Bellanaboy Terminal	$7.8 \times 10^{-5} – 4.4 \times 10^{-10}$	$1.3 \times 10^{-7} – 9.5 \times 10^{-10}$	$2.7 \times 10^{-10} – 1.6 \times 10^{-11}$
Bellagelly	3.6×10^{-6}	$2.7 \times 10^{-8} – 7.6 \times 10^{-10}$	$2.2 \times 10^{-10} – 9.4 \times 10^{-11}$

15.4.3 Potential Impacts

The potential impacts from all proposed aspects of the infrastructure development (e.g. access road, pipeline trench, site compounds, movement of plant, drainage, and excavated materials re-location) have been examined in the context of peatland hydrology. Table 15.3 summarises the potential impacts of the development on the peatlands traversed by the pipeline route. Section 15.4.4 summarises the proposed mitigation measures for identified significant impacts. Other mitigation measures for moderate or slight impacts are detailed in Section 6.2.1 of Appendix M6. Details on the impact classification system used in peatland impact assessment are provided in Section 1 of Appendix M6 of this EIS.

Table 15.3 Summary of Potential Peatland Hydrological Impacts

Impact Description	Type of Potential Impact	Hydrological or Hydrochemical	Direct or Indirect	Receptor	Magnitude of Potential (unmitigated) Impact
Excavation: Dewatering / Diversion	Change in water flow and magnitude (dewatering, diversion).	Hydrological	Direct	Recovering Blanket Bog	Significant
				Cutover Bog and forestry plantation	Slight
				Aghoos Compound	Imperceptible
Water Quality: Dewatering discharges	Increased silt content runoff to habitats and watercourses.	Hydrochemical	Direct	Recovering Blanket Bog	Slight
				Cutover Bog and forestry plantation	Moderate
			Direct and Indirect	Downstream water courses or surface water receptors	Significant
Excavation: Vertical leakage	Vertical hydraulic leakage of water through base of stone road.	Hydrological	Indirect	Recovering Blanket Bog	Significant
				Cutover Bog and forestry plantation	Moderate
Placement of stone road	Disturbance of natural hydrology. Stone road acting as barrier or conduit for water flow. Increase in runoff rates during construction.	Hydrological	Direct	Recovering Blanket Bog	Slight
				Cutover Bog and forestry plantation	Imperceptible
Placement of stone road	Introduction of foreign chemistry construction material to disturbed or recovering blanket bog (e.g. imported stone).	Hydrochemical	Indirect	Recovering Blanket Bog	Significant
				Cutover Bog and forestry plantation	Moderate
				Downstream water courses or surface water receptors	Significant
Storage of peat scraw or turves for reinstatement excavation works	Runoff entrainment of peat suspended solids resulting in sediment outwash onto peatland habitats, or to downstream receiving waters.	Hydrochemical	Direct and Indirect	Peatland habitats	Slight
					Slight
				Downstream water courses or surface water receptors	Significant
Fuel Storage / Usage on Site	Accidental spillage of contaminants leading to localised pollution of peat water or downstream surface water.	Hydrochemical	Direct	Peatland habitats	Significant
			Direct & Indirect	Downstream water courses or surface water receptors	

15.4.4 Mitigation Measures

The following mitigation measures are proposed to prevent significant hydrological impacts:

- Stone road construction method will be used whilst retaining a minimum of 0.5m of peat below the excavation invert. Leaving a minimum of 0.5m of peat in-situ above the mineral subsoil will avoid exposure or disturbance of the sub-peat mineral soils.
- The proposed stone road construction includes transverse peat plugs, and a basal peat layer, which will control vertical and longitudinal drainage.
- Leakage into the underlying sub-soil/bedrock, in excess of natural leakage rates, will be minimised to baseline conditions by retaining a minimum of 0.5m of low permeability peat at the base of all excavations in peat.

- Low permeability peat plugs will be inserted along the length of the stone road construction to retard longitudinal flow, thus forming virtually isolated cells in the road and preventing the road becoming a longitudinal preferential pathway for drainage. Plugs shall be placed at such intervals so as to negate the possibility of upward seepage of water from the stone road core at the down-gradient end of any cell.

- The stone road shall be reinstated with either turves or a peat layer of up to approximately 600mm. The re-instatement of peat turves and/or peat layer will prevent rapid recharge of rainwater into the stone road stone/peat core.

- Where turving is proposed, transverse (perpendicular to the line of the stone road) slightly elevated and contoured turve ridges coincident with peat plugs shall be placed to divert surface water flow gathering along the reinstated stone road onto downstream peatland habitat (i.e. preventing the reinstated stone road acting as a channel for surface water, reducing surface water flow velocities and removing the potential for erosion). These shall be integrated with the patchwork array of peat turves across the alignment of the stone road. These details are presented on Figure 16 of Appendix M6.

- Similar transverse slightly elevated turve ridges will be placed at minimum 50m intervals along sections of the stone road that will be reinstated with peat. They will have the same dual function of deflecting surface water runoff laterally and preventing longitudinal erosion along the reinstated stone road.

- Where turving is proposed the turves will be placed on a regulation layer of peat, and shall be placed using a patchwork array. Any remaining gaps shall be hand packed with peat to prevent inter-turve flow of surface water.

- The resulting retention of water in the individual cells will result in high peat water levels, as naturally occurs, and prevent changes to hydraulic gradients and resultant flow direction in the peat, i.e. to mimic the natural hydrology. Regeneration or retention of habitat on the re-instated peat will be facilitated by these conditions.

- Where natural drainage gullies or local significant micro-relief runoff pathways for surface water are encountered during stone road construction these shall be marked (by stakes and marker boards) and this pathway for surface water flow shall be restored as part of the reinstatement works.

The following mitigation measures are proposed to prevent significant hydrochemical impacts:

- Discharge from dewatering will not be discharged directly to any watercourse.

- Discharge will be routed into the 'dirty' water collection system and treated in a system which shall include in–line settlement and storage elements, such as including check dams, straw bale filters, settlement ponds, storage ponds and other suitable filtration facilities if required. At higher risk areas such as Aghoos Compound appropriate storage, settlement and treatment shall be designed for a 1 in 20 year return period rainfall event before being discharged to Sruwaddacon Bay.

- Silt fences, straw bales and biodegradable geogrids will be used to control surface water runoff and erosion from temporary stockpiles and storage areas for peat scraw and turves.

- The stone road in the area of recovering eroded blanket bog (PB5/PB3, see Appendix M6) at Aghoos Bog (ch.89.350 to 89.540) shall be composed of suitable locally sourced materials.

- The stone road in the area of habitats PB5/PB4 (see Appendix M6) and in forestry plantation will include cuttings from tunnelling (under Sruwaddacon Bay) as these areas are less sensitive from a hydrochemical and ecological perspective. The stone road shall be encapsulated by peat along the margins (in-situ peat) and by peat plugs longitudinally. The fill will also be covered during reinstatement with a layer of peat so the stone road fill will be isolated from surface vegetation or surface water flows. The reinstatement cover of peat shall prevent erosion of the fill material during high runoff events.

- Retention of a minimum of 0.5m of peat substrate in all excavations shall protect the groundwater aquifer from potential hydrocarbon contamination via any exposed excavations.

- Specific hydrocarbon storage and re-fuelling areas shall be designated at the site compounds. Refuelling shall only be completed in a controlled manner at the site compounds.

- Fuel storage areas shall be bunded appropriately for the volume of fuel stored and have suitable storm drainage and oil interceptor mechanisms. Spill kits and absorbent pads shall be available on site for cleaning up minor spills.

- The site compound surface water drainage system shall have an oil interceptor in advance of any proposed discharge point.

- An emergency response plan for the construction phase to deal with accidental spillages shall be contained within Environmental Management Plan.

- Temporary stockpiling of peat turves for re-instatement on the stone road shall only occur on the site up-gradient of the stone road excavation.

- Drainage from up-gradient of the stone road shall be intercepted on the up-gradient side of the stone road by an interceptor drain. This prevents up-gradient surface water run-off from crossing the excavation and becoming contaminated with suspended sediment. Collected clean water shall be discharged to Sruwaddacon Bay via stilling ponds with appropriate attenuation.

- Run-off from across the stone road excavation shall be intercepted on the down gradient side of the road. It shall be directed through the site 'dirty' water collection system, which shall include in-line settlement and storage elements, i.e. check dams and settlement ponds. This will be routed via stilling ponds with appropriate storage and settlement before being discharged to Sruwaddacon Bay.

- Aghoos Compound will have a site specific drainage system (See Section 6 of Appendix M6 and Appendix M7) which develops as the compound construction proceeds.

- The Aghoos Compound drainage system comprises an interceptor ditch system for the small volumes of clean up-gradient runoff and a 'dirty' water collection and treatment system for site drainage. This will be routed to an oversized swale and settlement pond with appropriate storage and settlement designed for a 1 in 20 year return period rainfall event before being discharged to Sruwaddacon Bay. Discharge will be automated and controlled by water quality sonde.

15.5 "WORST CASE" SCENARIO

In the event that a pollution incident occurs, it could have a significant negative impact on habitats, including peatland habitats, surface waters and underlying groundwater.

In the event that the mitigation measures for peatland areas (as outlined above) failed to work, the worst-case scenario would be a slight dewatering impact on adjacent peat within 10-15m of the edge of the stone road and a moderate change in vertical gradients.

Another worst-case scenario impact would be the absence of runoff control and drainage during the construction phase, resulting in accelerated runoff and potential erosion of the surface vegetation (i.e. gullying), and also an increase in sediment discharge to Sruwaddacon Bay.

15.6 "DO NOTHING" SCENARIO

It is likely that areas of undesignated blanket bog would continue to be subject to damage from localised peat extraction (manual and mechanised), sheep and cattle grazing and afforestation. There is little pressure on land for development in the area apart from one-off housing. There are no expected large-scale changes in the area. Thus, it would be expected that the area would undergo changes in a 'do-nothing' scenario.

15.7 RESIDUAL IMPACT

Soils & Geology (including Geotechnical Assessment)

The Geotechnical Risk Register (see Appendix M4), which was compiled to address geotechnical hazards and risk control measures during the design and construction stages of the project, includes a description of the residual impacts (or potential risk) once mitigation measures have been implemented.

Hydrology

Following implementation of the proposed mitigation measures, minimal to no residual impacts on the existing hydrological/drainage regime are expected as a result of construction and operation of the proposed project.

Hydrogeology

There will be no residual impact on hydrogeology during the operation of the proposed development, except at the LVI, where there is potential for groundwater to reach the floor level of the LVI during extreme conditions (inclement weather, high ground water levels and tides).

Peatland hydrology

Based on experience from peatland hydrology studies in blanket bogs and in particular the experience from the BGE Pipeline at Glencullin Upper, Co. Mayo, the peatland hydrological impact assessment predicted that the proposed development would have a short-term and slight negative impact on the hydrology of peatland areas along the route with some slight and very localised, changes to water levels and hydraulic gradients. However, in terms of residual impact on peatland hydrology the proposed development will have an imperceptible impact on the non-designated Annex 1 habitats present, which in this case is recovering blanket bog.