Appendix A.8.1

Ecology Field Survey Methodologies

A.8.1

1 Ecology Field Survey Methodologies

This Appendix presents the field survey methodologies for the following ecological surveys:

- Section 1.1 Habitats
- Section 1.2 Rare and protected plant species
- Section 1.3 Mammals (excluding bats)
- Section 1.4 Bats
- Section 1.5 Invertebrates – White-clawed crayfish, Freshwater pearl mussel, other Annex II molluscan species, Marsh fritillary butterfly
- Section 1.6 Birds – breeding bird and wintering bird surveys
- Section 1.7 Amphibians
- Section 1.8 Reptiles
- Section 1.9 Fish

1.1 Habitat Survey

The habitat surveys comprised a number of different survey elements carried out between July 2013 and June 2017 to gather baseline data of all habitat areas within the ZoI of the proposed road development.

1.1.1 2013 Habitat Surveys

Lough Corrib cSAC – Selected Locations

A habitat survey was carried out by Botanical, Environmental & Conservation Consultants Ltd. (BEC) in 2013 to classify the habitats present in selected locations within the scheme study area[1] (see **Appendix A.8.4**): within the Lough Corrib cSAC east of Menlough Village, at areas adjacent to the River Corrib at Dangan Lower and Menlough, and at areas of limestone pavement at Ballygarraun (to the east of the currently defined Lough Corrib cSAC study area – see **Figures 8.1.1** to **8.1.2**). The habitat map and data from this survey was incorporated into the results from the 2014 surveys.

[1] The term "scheme study area", when used in this chapter, refers to the wider study area at which ecological constraints were initially identified for the constraints and route selection studies for the project (see **Figures 8.1.1** and **8.1.2**). This is the geographic scale at which many of the EIA level ecological surveys were initially carried out. For many of the ecological receptors, surveys were also carried out within a more restricted study area, focussed on assessing potential impacts within the Zone of Influence (ZoI) of the proposed road development.

1.1.2 2014 Habitat Surveys

Petrifying Springs Survey

A dedicated survey for this priority Annex I habitat type – Petrifying springs with tufa formation (*Cratoneurion*) – was carried out by BEC in 2014 (see **Appendix A.8.3**). A combination of desktop review and Geographic Information System (GIS) analysis was used to define the survey sites, which were then visited to establish the presence/absence of a petrifying spring feature. This was supplemented by the additional habitat survey work carried out in 2014 and 2015, as described below. Surveys in 2014 did not include Lackagh Quarry; an area that was subsequently surveyed in 2015 – see 2015, 2016 and 2017 Habitat Surveys, Lackagh Quarry Petrifying Spring Survey section below for details.

Lough Corrib cSAC Survey Area

Habitat surveys were carried out by BEC and Wetland Surveys Ireland Ltd. from May to September 2014 within the Lough Corrib cSAC habitat survey area. The extent of the Lough Corrib cSAC habitat survey area is shown on **Figures 8.1.1** and **8.1.2**. The survey methodology comprised two stages: Stage 1 comprised mapping to level 3 of the Heritage Council habitat codes (Fossitt, 2000 – a summary of the classification is provided in **Appendix A.8.6**) with areas of Annex I habitat also being identified; for Stage 2, all polygons were revisited and indicator species recorded, a rapid quality-assessment score was attributed to each polygon which contained an Annex I habitat type, and relevé data was collected across the survey area to support the habitat classification given during the mapping exercise and to provide additional data on the conservation value of habitats. All habitat polygons were also attributed with an ecological valuation as per the criteria set out in Guidelines for Assessment of Ecological Impacts of National Roads Schemes: Revision 2 (National Roads Authority, 2009).

The conservation status of each Annex I habitat within the Lough Corrib cSAC Survey Area was assessed. The assessment was based on guidelines available from the National Parks and Wildlife Service (NPWS) and on the approach used for the national conservation assessment of Annex I habitats, which is carried out according to guidelines published by the EU (Evans & Arvela, 2011).

Assessment criteria were available from NPWS for the majority of the Annex I habitats recorded but where not available, the criteria relating to similar habitats were used. Annex I habitats were defined with reference to recent national studies co-ordinated by NPWS and the Interpretation manual of European Union Habitats EUR28 (CEC, 2013). Vegetation communities were assigned to Annex I habitat areas based on the relevé data gathered and on published definitions. In cases where published vegetation community definitions were not available, novel classifications were assigned.

The full details of the survey and assessment methodologies used - including the assessment criteria, Annex I habitat definitions, and novel vegetation community classifications – are described in **Appendix A.8.5**.

Ecological Sites

The aim of the ecological sites habitat survey was to describe, classify and map the habitats of the Ecological Sites based on the Heritage Council classification (Fossitt 2000), with particular emphasis on habitats conforming to Annex I habitats (as listed in the EU Habitats Directive), and to assess their ecological importance. Any plant species of restricted distribution and ecological importance were noted.

Ecological Sites, in this case, were sites of potential ecological value; the boundaries of which were initially defined based on interpretation of orthophotography and collation of available existing habitat information, in conjunction with a ground truthing exercise to verify the orthophotography interpretation. These boundaries were then refined, where appropriate, based on the findings of the various habitat surveys undertaken.

The surveys were carried out by Dr Joanne Denyer, Dr John Conaghan, Dr Janice Fuller, Katharine Duff and Eamon O'Sullivan from the 15 June to the 15 October 2014. The locations of the Ecological Sites surveyed are shown on **Figures 8.1.1** and **8.1.2**.

Annex I Habitat Classification

Reference was made to the National and Regional habitat survey reports, in terms of the criteria for classifying the different Annex I habitats and assessing their condition:

- *Turloughs over 10 ha: vegetation survey and evaluation* (Goodwillie, R., 1992)
- *Turlough Hydrology, Ecology and Conservation* (Waldren, S. 2015, Ed.)
- *Summary of findings from the Survey of Potential Turloughs 2015* (O'Neill, F.H. & Martin, J.R., 2015)
- *The Irish semi-natural grasslands survey 2007-2012. Irish Wildlife Manuals, No. 78* (O'Neill et al., 2013)
- *Results of monitoring survey of old sessile oak woods and alluvial forests. Irish Wildlife Manuals, No. 71* (O'Neill, F.H. & Barron, S.J., 2013)
- *National survey of limestone pavement and associated habitats in Ireland. Irish Wildlife Manuals, No. 73* (Wilson, S. and Fernández, F., 2013)
- *Coolagh Lakes, Lough Corrib SAC, Co. Galway: Wetland Survey and Conservation Assessment* (Crushell, P. & Foss, P., 2014a: unpublished report)
- *Coolanillaun Bog, Lough Corrib SAC, Co. Galway: Wetland Survey and Conservation Assessment* (Crushell, P. & Foss, P., 2014b: unpublished report)
- *Guidelines for a national survey and conservation assessment of upland vegetation and habitats in Ireland. Version 2.0. Irish Wildlife Manuals, No. 79* (Perrin et al., 2014)

Assessment criteria for *Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* [7210] which were developed during the Constraints Study (by Crushell and Foss 2014a and 2014b) were used. The Annex I habitats surveyed are listed in **Table 1**.

Table 1: Annex I habitats recorded, the reference for assessment criteria used, and size of the assessment relevé

Annex I Habitat Code [1]	Habitat Name [2]	Reference	Relevé size (metres)
1220	Perennial vegetation of stony banks	n/a	n/a
1330	Atlantic salt meadows	McCorry & Ryle (2009)	2x2
4010	Wet heath	Perrin et al. (2014)	2x2
4030	Dry heaths	Perrin et al. (2014)	2x2
6210 *6210	Orchid-rich calcareous grassland (* important orchid sites)	O'Neill et al. (2013) O'Neill et al. (2013)	2x2 2x2
*6230	Species-rich *Nardus* upland grassland	O'Neill et al. (2013)	2x2
6410	*Molinia* meadows	O'Neill et al. (2013)	2x2
6430	Hydrophilous tall herb	O'Neill et al. (2013)	2x2
6510	Lowland hay meadows	O'Neill et al. (2013)	2x2
*7130	Blanket bog (active)*	Perrin et al. (2014	2x2
7140	Transition mires	Perrin et al. (2014)	2x2
7150	*Rhynchosporion* depressions	Perrin et al. (2014)	2x2
*7210	*Cladium* fen*	Crushell & Foss (2014a & 2014b); criteria developed for GCTP project	2x2
*7220	Petrifying springs*	Lyons & Kelly (2016)	n/a
7230	Alkaline fens	Perrin et al. (2014)	2x2
*8240	Limestone pavement*	Wilson & Fernández (2013)	5x5
*91E0	Residual alluvial forests	O'Neill & Barron (2013)	10x10
*3180	Turloughs*	Goodwillie (1992) Waldren, (2015, Ed.)	2x2

[1]Priority habitats, which are indicated with an asterisk, are those which the EU considers require particular protection because their global distribution largely falls within the EU and they are danger of disappearance

[2]Abbreviated Annex I habitat names are after NPWS (2013a, 2013b & 2013c), full Annex I habitat titles are available in *Interpretation manual of European Union Habitats EUR28 (*CEC**,** 2013). To distinguish between them, the term Calcareous grassland is used to refer to the non-priority variant of the 6210 Annex I habitat type with the full title referring to the priority variant.

Field sheets were prepared in advance for recording site notes and habitat descriptions, which included condition assessment criteria. Vascular plant nomenclature follows that of the New Flora of the British Isles 3rd Edition (Stace, 2010); bryophyte nomenclature follows the Checklist of British and Irish bryophytes (BBS, 2009).

Ecological Evaluation

The ecological importance of habitats was assessed using the criteria listed in the Guidelines for Assessment of Ecological Impacts of National Roads Schemes (National Roads Authority, 2009). For Annex I habitats recorded, a further rapid

quality assessment of the Annex I habitat (scale 1, 2, or 3) was made, based on the following criteria, whereby:

1 = the habitat was a poor example of the Annex I habitat
2 = the habitat was a good example of the Annex I habitat
3 = the habitat was an excellent example of the Annex I habitat

Field Survey

Field survey maps were prepared from aerial photographs of the Ecological Sites (1:5,000 scale minimum). The Ecological Sites were subject to a walkover survey by experienced botanists. Each habitat present was described and classified (after Fossitt for non-Annex habitats or for Annex I habitats, as per NPWS guidance from the relevant national Annex I habitat surveys) and the main plant species were listed on the habitat recording form. The habitat extent was mapped onto the aerial photograph, with GPS points taken where a habitat extent could not clearly be identified from the aerial photograph. For each Annex I habitat type encountered, a relevé(s) was (were) taken using a prepared form. The relevé size was $2m^2$ for all Annex I habitats except for woodland and limestone pavement habitats. The relevé form included a habitat condition assessment based on criteria which were drawn from the relevant national habitat surveys for the National Parks and Wildlife Service (NPWS). Where applicable, the Annex I habitat was assigned to a vegetation community.

A photographic record of the habitats and relevé(s) for each ecological site was taken; two photos per relevé – one for the relevé and one for a view from the relevé. Notes on management, threats and habitat condition were also taken.

For each Ecological Site the following were completed:

a) Site form: summary description of the Ecological Site, list of habitats and notable features
b) Habitat map: hand drawn polygons (attributed with the corresponding habitat codes) on aerial photograph
c) Field survey notes: hand written on habitat recording forms
d) Relevé forms: hand written and completed for Annex I habitats
e) Photographs: photographic record (digital) of habitats and relevé(s)
f) Habitat table: tabulated summary of all habitats, including habitat description, classification (Fossitt and Annex I), plant species list, habitat condition and ecological evaluation/importance

Other Areas

Within the scheme study area, those areas not covered by the surveys described above were subject to a walkover survey; the purpose of which was to determine the nature of the habitats present and establish whether any areas corresponded with Annex I habitat types. The survey was confined to terrestrial habitats in greenfield areas and excluded residential properties and associated gardens, and commercial and industrial complexes.

Notes were taken on the habitat types present (according to the habitat categories described in Fossitt, 2000) and where habitat plots were assessed to be of a high ecological value, with the potential to correspond to an Annex I habitat type, these

were subject to more detailed survey as described above under Ecological Sites. If appropriate, these were then incorporated into Ecological Sites for consideration as part of the route selection process.

Aquatic Habitats

Aquatic habitats were surveyed for the presence of Annex I habitat types by Cilian Roden, from the 16 June 2014 to the 8 September 2014.

The survey sites included the River Corrib corridor, Coolagh Lakes, Lough Inch, Ballindooley Lough, and the Terryland Stream. The locations of the survey sites are shown on **Figures 8.1.1** and **8.1.2**.

Sites were accessed either from the shore or by boat. Sub-littoral vegetation was examined by snorkelling. Smaller sites (such as the Terryland Stream) were examined by wading or by shore-based sampling. A list of species present, the depth of the sub-littoral vegetation and the exact position of each site was determined. Depths were measured using a SCUBAPRO depth gauge accurate to 0.1m and position determined using a hand held GPS recorder. GPS position shows approximate area surveyed by snorkel. Species present were recorded on an underwater writing slate. Samples for later examination were stored in plastic bags and identified within one day of collection. Underwater photographs were taken with a Panasonic Lumix DMC-FT3 underwater camera.

1.1.3 2015, 2016, 2017 and 2018 Habitat Surveys

Lackagh Quarry Petrifying Spring Survey

A dedicated survey of seepage lines in Lackagh Quarry to record the presence of Petrifying spring habitat was carried out by Dr Rory Hodd on the 3rd June 2015.

The aim of the survey was to determine whether or not any of these features corresponded with the priority Annex I habitat type **Petrifying springs with tufa formation (Cratoneurion)* [7220]. Plant species associated with each of the seepage lines were recorded and compared with the current definitions of the plant communities associated with this Annex I habitat type (CEC, 2013; and, NPWS, 2013b).

EIA Habitat Survey

The additional habitat surveys that were undertaken to supplement the baseline data already collected for the purposes of the EIA of the proposed road development, consisted of the following elements:

- Habitats within the ZoI of the proposed road development that were surveyed in detail in 2013/2014 (i.e. Lough Corrib cSAC Study Area and the Ecological Sites) were rechecked. Where habitats had changed from the 2013/14 baseline, they were resurveyed as per the methodology described above under 2014 Habitat Surveys – Ecological Sites.
- Areas that had not been surveyed in 2013/14 were subject to a full habitat survey as per the methodology described above under *Habitat Surveys 2014 – Ecological Sites*. This was carried out in 2015 with additional areas included in

2016 and 2017 as a result of changes to the proposed development boundary as a result of the on-going iterative design process. These surveys were carried out by Dr Janice Fuller, Eamon O'Sullivan, Michelle O'Neill, Dr Roger Goodwillie and Dr Mary O'Connor between September 2015 and October 2016, and by Scott Cawley Ltd in 2017.

- A review of wooded Limestone pavement polygons in the Menlough area was carried out by BEC in May/June 2017

1.2 Rare and protected plant species

Dedicated surveys for the following protected plant species were carried out: Slender naiad *Najas flexilis* and Varnished hook-moss *Hamatocaulis vernicosus*. Both of these plant species are listed on Annex II of the Habitats Directive and listed as qualifying interest species of Lough Corrib cSAC (with Slender naiad also listed on Annex IV of the Habitats Directive), and are protected under the Flora (Protection) Order, 2015.

Slender naiad

The Slender naiad survey was carried out by Dr Cillian Roden over the period June to September 2014, as part of the aquatic Annex I habitat survey, as described above under that section.

As a submerged aquatic plant species of clear, low-nutrient lakes, potential survey sites within the scheme study area were Lough Inch, the Coolagh Lakes and Ballindooley Lough. As described above for aquatic habitats, sub-littoral vegetation was examined by snorkelling.

Varnished hook-moss

The Varnished hook-moss survey was carried out by Dr Rory Hodd from the 2 to the 7 September 2014.

Potential sites for survey were selected in consultation with ecologists carrying out habitat mapping within the scheme study area. Potential sites were identified as those where fen occurred, and where brown moss species (i.e. a suite of moss species indicative of, and generally restricted to, fen habitats) had been noted. Sites where fen transitions into bog, or where transition mire or intermediate fen had been noted, were prioritised as they had the most potentially suitable habitat for the species.

Nine potential sites were surveyed for the presence of Varnished hook-moss (**Figure 8.2.1**). The nearest known site for Varnished hook-moss, at Gortachalla Lough, north of Moycullen, was also visited in order to establish the species' habitat preferences in this specific area. Each site was extensively searched for areas where conditions were suitable for the growth of this species, and areas where plant species with similar requirements were found. Any areas which were deemed potentially suitable were thoroughly searched and the moss flora of these areas was examined in detail.

Other Species

Records were kept of the locations of any other rare or protected plant encountered during the course of the habitat surveys, with a particular focus on Flora (Protection) Order, 2015 plant species, where there were existing or historic records.

1.3 Mammals (excluding bats)

Protected species – Otter and Badger

2014 River Corrib Otter Survey

The Otter survey was carried out by Scott Cawley Ltd. staff from the 15 April to the 7 May 2014.

The survey included Otter Habitat (as defined as being a 10m width of bankside each side of the river in the Threat Response Plan: Otter (2009-2011) (NPWS, 2009) within the boundary of the Lough Corrib cSAC between Lough Corrib (Coolanillaun/Tonacurragh) to the Salmon Weir in Galway City. The Otter survey study area, as it relates to the proposed road development, is shown on **Figures 8.3.1** to **8.3.14** (the full extent of that survey is shown on Figure 4.3.17 of the **Route Selection Report**). The status and activity of any Otter holts was recorded along with any evidence of activity, including paths, tracks, feeding signs, sprainting sites or couches (Otter resting places).

2015/2016 Otter and Badger Survey

The mammal survey was carried out by Scott Cawley Ltd. staff and Dr Chris Peppiatt over three survey periods: 30 April to 5 June 2015, from the 28 October to 8 November 2015, and from the 25 to 28 October 2016.

A corridor of approximately 500m along the route of the proposed road development was surveyed for Badger and Otter activity as part of the multi-disciplinary walkover survey – as shown on **Figures 8.3.1** to **8.3.14**. The status and activity of any Badger setts or Otter holts was recorded along with any evidence of activity, including paths, tracks, feeding signs, latrines or couches (Otter resting places).

As part of the survey, two infra-red motion-activated camera were installed between the 9 July and the 4 August 2015 (under NPWS Licence No. 024/2015) to monitor a number of small burrows along a stream bank located adjacent to playing fields at National University of Galway (NUIG).

No species specific surveys were undertaken for other protected mammal species for which field signs are less frequent and/or reliable than other larger mammals, such as Pine marten, Irish stoat and Irish hare. Nevertheless, during all surveys attention was paid to search for activity signs such as searching soft muds for tracks, and to look for droppings. Potential presence of these species in suitable habitat was recorded based on the habitat preferences described in Hayden & Harrington (2000).

1.4 Bats

The following sections describe the methodologies employed to carry out the various bat surveys undertaken to inform the various stages of Constraints, Route Selection and EIA (refer also to **Appendices A.8.7**, **A.8.8**, **A.8.9** and **A.8.10** for stand-alone technical reports for discrete elements of surveys e.g. radio-tracking studies). The bat surveys were carried out under the following licences, issued by the NPWS[2]:

- DER/BAT 2014-17 - Derogation licence to disturb bat roosts throughout the State (valid until 31 December 2018)
- DER/BAT 2014-39 - Derogation licence to disturb bat roosts in Galway County and City
- DER/BAT 2015-02 - Derogation licence to disturb bat roosts in Galway County and City
- DER/BAT 2015-03 - Derogation licence to disturb bat roosts throughout the State
- DER/BAT 2015-24 - Derogation licence to disturb Menlo Castle bat roost and bat roosts north of Galway City and from Oranmore to Furbogh to the west and from the coast to Moycullen to the North
- DER/BAT 2016/09 Derogation licence to disturb bat roosts throughout the State
- DER/BAT 2017/06 Derogation licence to disturb bat roosts throughout the State
- C056/2014 - Licence to capture protected wild animals (bats) for educational and scientific purposes throughout the State
- C098/2014 - Licence to capture protected wild animals (bats) for educational and scientific purposes in an area bounded by Oranmore and Claregalway to the east across to Moycullen and Furbogh to the west, Galway
- C009/2014 - Licence to attach a ban, ring, tag or other marking device to a wild animal bat) in an area bounded by Oranmore and Claregalway to the east across to Moycullen and Furbogh to the west, Galway
- 027/2014 - Licence to use an acoustic lure to capture bats in an area bounded by Oranmore and Claregalway to the east across to Moycullen and Furbogh to the west, Galway, including Menlo Castle roost and night/satellite roosts in Galway
- C004/2015 - Licence to attach a ban, ring, tag or other marking device to a wild animal bat) in an area including Menlo Castle, north of Galway City and from Oranmore to Furbogh to the west and from the coast to Moycullen to the north, County Galway
- C033/2015 - Licence to capture protected wild animals (bats) for educational and scientific purposes throughout the State
- C085/2015 - Licence to capture protected wild animals (Lesser horseshoe bats) for educational and scientific purposes in an area including Menlo Castle, north

[2] The individual licences that applied to individual survey elements are listed under the relevant survey sections.

of Galway City and from Oranmore to Furbogh to the west and from the coast to Moycullen top the north, County Galway

1.4.1 Winter hibernation surveys

As part of preliminary investigations to identify potential winter hibernation roosts for bats, particularly Lesser horseshoe bats which hibernate in caves and cellars, desktop data on such features was researched to draw up a short list of likely locations.

A cave database compiled by David Drew (Drew, 2004), formerly of Trinity College (http://www.ubss.org.uk/irishcaves/irishcaves.php), and the Geological Survey of Ireland (GSI) karst features Geographical Information System (GIS) layer were consulted to locate caves within the wider scheme study area. The National Monuments Service database (http://www.archaeology.ie) was consulted to determine if man-made underground sites (souterrains, mines, ice houses) or unoccupied structures, such as caves and manor houses that may have underground structures or large chimneys, were present within the wider scheme study area.

Potential hibernation sites identified from the desktop study were surveyed internally on the following dates; 11 - 14 March 2014, 21 March 2014, 6 February 2015, 24 February 2016, 8 and 11 January 2018. Sites were visited during daytime and inspected for the presence of hibernating bats and evidence of bat presence (e.g. droppings, staining).

In addition, bat detectors were deployed at potential winter hibernation sites (Cooper's Cave, Newry's Cave, Prospect Hill Railway tunnel, and Menlo Castle) to record bat activity both during the mating season (September-October 2014) and the hibernation period (February-March 2015). Surveys were conducted under licence from the NPWS (DER/BAT 2014-17 and DER/BAT 2015-02 and DER/BAT 2016-09) and care was taken not to disturb bats or to affect access to and from these potential roost sites.

1.4.2 Building surveys

In 2014, a list of potential bat roost buildings was compiled following a vehicle-based survey in areas within, and adjacent to, the scheme study area. Buildings regarded to have high potential to support Lesser horseshoe bat roosts were identified as a priority early in the Constraints and Route Selection phase, with structures that offered roosting opportunities to other bat species identified subsequently. The physical characteristics (construction material, roofing material, estimated age etc.) and GPS locations were recorded and a photograph of each building was taken. The building inspections were undertaken between July and October 2014.

In 2015, 2016 and 2017, buildings within or immediately adjacent to the proposed road development, and specific buildings within 1 km of the proposed road development, that were identified as being of high potential for roosting bats (as guided by Collins, 2016) (i.e. buildings with an obvious, or high, likelihood to support roosting bats, their size, shelter, protection, conditions and surrounding

habitat) were also surveyed. Daytime building inspections and dusk/dawn surveys were conducted in August and September 2015, July and August 2016 and May-June 2017.

The locations of all buildings surveyed are shown on **Figure 8.17.1**.

The daytime building inspections involved a full examination of the internal and external areas of the structures to search for the presence of bats and identify potential roost sites. Bat activity is usually detected by the following signs:

- Bat droppings (these will accumulate under an established roost or under access points)
- Insect remains (under feeding perches)
- Oil (from fur) and urine stains
- Scratch marks
- Bat corpses

Surveyors filled out a standardised roost survey form and these were compiled into a Potential Bat Roost (PBR) building database.

In some situations, where a building had a high potential as a Lesser horseshoe bat roost but no physical evidence was found, a frequency division ultrasound detector (for example an Anabat SD1, Wildlife Acoustic Song Meter 2 or SMZC, or similar) was left in-situ for several nights.

Any bat droppings that were found were placed in 1.5ml eppendorf tubes with silica and sent to Waterford Institute of Technology for genetic analysis to identify the bat species.

The roost surveys were carried out under licence from the NPWS (DER/BAT 2014-39, DER/BAT 2015-03, DER/BAT 2016-09, DER/BAT 2016-28 and DER/BAT 2017-06).

For bat activity surveys conducted in 2015, bat activity around buildings was monitored using a hand-held bat detector (Pettersson 240x, Wildlife Acoustics EM3, or similar) to determine if bats were exiting/entering buildings. Dusk activity surveys were conducted for up to two hours after sunset, while pre-dawn surveys were generally conducted from 2hrs before sunrise. For buildings inside, and within 1km of, the proposed road development at least one internal survey and dusk or dawn survey was conducted. Where internal access was not possible, up to three activity surveys were conducted on a building, subject to accessibility.

Two additional counts of Lesser horseshoe bats at Menlo Castle, Cooper's Cave and the roost at Aughnacurra (PBR178) were undertaken in August 2018: the first count on the 22 August 2018 and the second count over the 27/28 August 2018.

1.4.3 Surveys of bats using Eborhall House and Ballymaglancy Cave cSAC

Eborhall and Ballymaglancy Cave, located to the north of Lough Corrib, are both important roost sites for breeding and hibernating Lesser horseshoe bats respectively. Eborhall House is the "qualifying" roost for the Lough Corrib SAC whilst the nearby Ballymaglancy Cave is a cSAC in its own right (No. 000474) and is thought to provide hibernation roosts for the bats from the Ebor Hall and Stables site.

As part of the assessment of the potential movement of this bat species across the landscape, it was deemed important to determine if any of the ringed bats[3] that were roosting near the scheme study area were also using these roosts, even though they are located a considerable distance to the north (more than 30km).

Surveys were undertaken at Eborhall House and Ballymaglancy Cave to determine the presence of Lesser horseshoe bats that were ringed at roosts within the scheme study area were undertaken under licence DER/BAT 2015-03, DER/BAT 2016-09, DER/BAT 2016-28 and DER/BAT 2017-06) on 21 October 2015, 23 August 2016 and 14 July 2017. Surveys in 2015 were undertaken by Paul Scott (Scott Cawley Ltd) with Mr John Higgins (NPWS Local Conservation Ranger) and in 2016 by Dr Daniel Buckley and in 2017 by Paul Scott. Daytime visual surveys were undertaken to count and identify any marked bats. Only the October 2015 surveys included Ballymaglancy Cave. No ringed bats from the scheme study area were recorded during these visits.

1.4.4 Tree Surveys

Trees within, or immediately adjacent to, the proposed road development (see **Figure 8.16.1** to **8.16.14**) were assessed for their potential as bat roosts as part of multidisciplinary surveys carried out from April to June 2015 and in October/November 2015. The suitability of each tree to support roosting bats was classified using the categories outlined in *Bat Surveys: Good Practice Guidelines* (Hundt, 2012). Whilst these guidelines have been superseded by Collins (2016) the overall approach and valuation criteria are still valid:

- Category 1*: Trees with multiple, highly suitable features capable of supporting larger roosts
- Category 1: Trees with definite bat potential, supporting fewer suitable features than Category 1* trees, or with potential for use by single bats
- Category 2: Trees with no obvious potential, although the tree is of a size and age that elevated surveys may result in cracks or crevices being found; or the tree supports some features which may have limited potential to support bats
- Category 3: Trees with no potential to support bats

Trees assigned a category of 1*, 1 or 2 were re-inspected from 10 to 25 September 2015. Trees with crevices accessible by ladder were surveyed using an endoscope

[3] See **Section 8.3.8** of **Chapter 8**, **Biodiversity** for details on bats that were ringed.

to determine if bats were roosting in the trees, if there was evidence of bats or simply if the potential roost feature offered good conditions for roosting.

Internal inspection of trees was carried out under licence from the NPWS (DER/BAT 2015-03).

1.4.5 Vehicle transect surveys

Vehicle transect surveys took place in June and July 2014. Three transect routes were designed within the scheme study area; an eastern transect (east of the River Corrib), a western transect (west of the River Corrib) and an urban transect (roads within Galway City). The locations of the vehicle transect routes are shown on **Figures 8.4.1** to **8.4.2**. The survey methodology was designed with reference to that used by the All-Ireland Car-based Bat Monitoring Scheme (Roche et al., 2012). The only deviation from that survey methodology related to the use of a GPS unit to georeference the call records, removing the requirement to survey a section and stop to record location references on a map.

Prior to the first survey, surveyors mapped out their driving route during the day, identifying potential hazards. Roads that were unsafe (carrying large volumes of traffic) were excluded from the survey. Surveys were conducted on nights with potential for high levels of bat flight activity (i.e. warm, dry, calm conditions).

Surveying commenced 45 minutes after sunset with roads being driven at approximately 25km/h. Bat activity was recorded using EM3 bat detectors (Wildlife Acoustics) with a GPS unit (Garmin) attached to record the location of bat calls and to plot the transect route. Detectors were mounted on the passenger window of the survey vehicle. Detectors were set to record continuously, saving call files in the compressed WAC format. Each transect was surveyed twice (eastern and western transects on the 17 and 18 June 2014; the urban transects on the 26 June and 1 July 2014). For the second night of surveying, the transect start and end points were reversed.

Bat calls were analysed using the Kaleidoscope auto-identification software (Wildlife Acoustics) and were all manually verified to ensure the software identified calls correctly.

1.4.6 Walked transect surveys

Walked transect surveys took place in June and July 2014. Twenty-one survey sites were selected and a transect route was designed within this to encompass a representative sample of the habitats within the scheme study area. These areas are shown on **Figures 8.4.1** to **8.4.2**.

Prior to the detector survey commencing, the survey sites were walked during the day to plot a route and identify any health and safety issues. Surveys were conducted on nights with potential for high levels of bat flight activity (i.e. warm, dry, calm conditions).

Surveying commenced 45 minutes after sunset. Bat activity was recorded using EM3 bat detectors (Wildlife Acoustics) with a GPS unit (Garmin) attached to record the location of bat calls and to plot the transect route. Detectors were set to record

continuously, saving call files in the compressed WAC format. Each transect was walked once. In addition, an Anabat SD1 or an SM2 detector was placed overnight in suitable bat habitat along the transect routes.

Bat calls recorded using EM3 detectors were analysed using the Kaleidoscope auto-identification software (Wildlife Acoustics) and were all manually verified to ensure the software identified calls correctly. Bat calls recorded on the Anabat detectors were analysed using the software AnalookW (Titley Scientific).

1.4.7 Static detector activity surveys

In 2014, as part of the Constraints and Route Selection studies, static detector surveys of bat activity in selected locations within the scheme study area were conducted from the 12 August to the 2 November 2014. Twenty-four sites for static detector deployment were selected across the scheme study area to survey the bat species present at different locations, as well as to collect comparative data on species richness and general levels of bat activity. The locations of the static detectors are shown on **Figures 8.4.1**, **8.4.2** and **8.22.1**. These locations were selected to cover a range of habitat types and to cover locations that might be crossed by potential route options. The static detectors used were SM2 or SM2+ bat detectors (Wildlife Acoustics). Detectors were set to record in WAC format from half-an-hour before dusk to half-an-hour after dawn set to automatically trigger in response to potential bat calls.

Static monitoring using SM3BAT bat detectors (Wildlife Acoustics) was also conducted at three underground sites in the scheme study area (Cooper's Cave, Newry's Cave and Prospect Hill Railway Tunnel) in the autumn period from the 29 September to the 31 October 2014 and in winter from 4 February to 26 March 2015, in order to determine their use during the autumn mating and winter hibernation periods. An additional bat detector (Wildlife Acoustics SMZC) was placed in the chimney flue in Menlo Castle in winter, underneath the known maternity roost, to determine if bats were present there during the hibernation period. Whilst Lesser horseshoe bats are generally inactive in winter, they do wake up to move around the roost space, and to feed and drink water, and can be detected doing so by the installed equipment. Licences specifically permitting these winter surveys, under certain conditions to protect the roosts and bats, were acquired from the NPWS (DER/BAT 2014-39 and DER BAT 2015-02).

In order to collect long-term data on the bat species flying in specific locations along the route of the proposed road development) in 2015, 42 locations were monitored from the 7 July to the 23 September 2015 using a range of static detectors: seven SM2, one SM3 and one SMZC detector – for locations see **Figures 8.4.1** to **8.4.2**. Detectors were left to record at each location for a five-night survey period and this was repeated twice providing three survey periods. The static detectors were deployed at locations where the corridor of the proposed road development intersected linear features or woodland edges in the proximity of known bat roosts, or in areas where bats had previously been recorded. The siting of detectors also targeted areas where less-common species were known to occur

such as the Lesser horseshoe bat and also for recording the "quieter"[4] Brown long-eared bat and *Myotis* bat species.

Of the 42 locations, 19 were subject to further long-term static detector surveys (10 September to 9 October 2015) to determine if bats were flying near linear features and woodland severed by the proposed road development (see **Figures 8.4.1** to **8.4.2** for locations). Whilst bat flight paths are not restricted to always following linear features, these were regarded to be landscape features that could be severed by the proposed road development. The locations were chosen based on the results of the long-term static detector monitoring carried out earlier in the year, as outlined above. Locations that had suggested very high bat activity and those with records of less common and quieter species were prioritised; e.g. Lesser horseshoe bats, Brown long-eared bat and *Myotis* bats. For these "crossing point surveys", an SM2 with two microphones was deployed for three consecutive nights at each location. One microphone (fixed to the SM2 unit) was placed on one side of the proposed road development, a second was placed on the opposite side of the proposed road development and connected to the same SM2 unit by a 50m cable. Analysis of bat calls and their temporal relationship were then used to support the identification of bats likely to have crossed the proposed road development – i.e. a bat call recorded at one microphone, followed by a call from the same species within a certain recording interval (between 8 and 30 seconds), was a "potential crossing". The choice of time period was based on a variety of sources of data which quotes bat flight speeds of "small species" of 3-8m/s (18-29km/h), Pipistrelle species 4.4m/s, Lesser horseshoe bats 3.5m/s and Natterer's bats 4.5m/s (Baagøe, 1987 and Jones and Rydell, 1994). This method also varies in effectiveness for different species and for different flight characteristics as fast commuting bats with loud echolocation calls (e.g. Leisler's bats) would be detected almost simultaneously by both microphones. Quieter bats (echolocation calls only detected at close range) which may have more weaving flight patterns, such as Lesser horseshoe bats when foraging, could take much longer to pass between the two detector microphones.

In order to ground-truth the results of the crossing point surveys, manual surveys were also conducted on one night when the static detectors were recording. Surveyors recorded bat flight activity at each location, over a period of 2 hours after sunset, from a vantage point using a hand-held bat detector (Batbox Duet) and recorded the time bats were recorded on the detector and/or visually along with the direction of bat flight. Surveys concluded when bats could no longer be seen.

Bat calls were analysed using the Kaleidoscope auto-identification software (Wildlife Acoustics) and were all manually verified to ensure the software identified calls correctly.

In order to record and assess bat activity within the lands proposed for habitat enhancement at Menlough, four SM2BAT+ detectors placed along hedgerows from 28 July - 11 August 2017, and again from 2 – 15 May 2018.

[4] Presence/absence of Brown long-eared bats and some *Myotis* species of bats can be problematic in manual, roving surveys as their echolocation calls have limited volume and range. Longer-term monitoring increases the chances of encountering them.

1.4.8 Radio-tracking studies

Radio-tracking of bats allows accurate recording of where bats are flying from their roosts, where they feed and other roost sites. It is an intensive method of data collection but provides very useful and reliable data for impact assessment purposes. Radio-tracking work undertaken as part of the collection of baseline data for the purposes of impact assessment was undertaken over four sessions, over two seasons in 2014 and 2015:

- Session 1: 30 July - 7 August 2014 and was led by Greena Ecological Consultancy Ltd., with the aim of radio-tracking Lesser horseshoe bats and (to a lesser extent) vespertilionid bats in order to identify the location and extent of foraging areas and the location of day/night/transitional roosts in the scheme study area
- Session 2: 19 - 29 August 2014 and was led by Geckoella Environmental Consultants Ltd. with the aim of locating vespertilionid bat roosts within the scheme study area
- Session 3: 2 - 9 September 2014 and was led by Greena Ecological Consultancy Ltd., with the aim of identifying and mapping vespertilionid and rhinolophid bat movements to mating sites or winter roosts
- Session 4: 16 - 23 May 2015 and was led by Greena Ecological Consultancy Ltd., with the aim of determining movements of the Lesser horseshoe bats in Menlo Castle during the spring period and to locate day roosts for this species in the western part of the scheme study area

Lesser horseshoe bats were captured at two sites in the wider scheme study area during sessions 1 and 3: Menlo Castle and Cooper's Cave. Bats were captured using mist nets and harp traps as they emerged or arrived at roosts after sunset. Vespertilionid bats were captured at six sites (Bearna Woods, Cooper's Cave, Menlo Woods, Merlin Woods, NUIG, and the NUIG Recreational Facilities) using mist nets, harp traps and an acoustic lure (Sussex Autobat) that attracts bats by emitting artificial foraging and social calls (Hill and Greenaway, 2005).

Several licences were issued by the NPWS to permit capture of bats using the traps and use of the acoustic lure and the fitting of the radio transmitters - Refs: C098/2014, C009/2014, 027/2014, C004/2015, C033/2015, C085/2015, DER/BAT 2015-24.

Captured bats were identified to species level and weighed to determine if they were suitable for tagging with radio transmitters. Radio transmitters (Biotrack and Holohil) were glued between the fur-clipped shoulder blades of the bats using latex adhesive and usually detached from the tagged bat within two weeks of being attached. Priority was given to tagging female Lesser horseshoe bats, *Myotis* bats and Common pipistrelles as at that time little was known about where these species were flying, feeding and roosting.

Bats were tracked using Australis 26K and Sika UHF radio receivers with Yaggi rigid aerials. Omni-directional antennas were used to search for bats by vehicle. Both receivers were able to automatically scan through different frequencies, which made it possible to search for a number of tagged bats at any one time. For sessions

1 and 3, bats were tracked at night while they were foraging to determine home ranges, core foraging areas and identify night roosts; bats were also located using the telemetry signal during the day to identify roosts. For session 2, bats were only tracked during the day to locate roosts. For sessions 1 and 3, foraging and commuting bats were observed from fixed (often elevated) points where suitable radio reception was available, such as at elevated or other suitable vantage points. Where possible, surveyors made close approaches to bats to ascertain the exact foraging area and behaviour, or to attempt pursuit if the bat was moving away. Accurate bearings of bat locations were simultaneously taken, by two or more surveyors, from hand held sighting Silva Expedition 54 compasses. These bearings were then used to calculate a location, using the Locate software. GPS units (Garmin) were used to increase the speed and accuracy of the surveyors recording their locations. Over survey nights, surveyors built up a picture of bat commuting routes and of bat foraging areas. Foraging areas were estimated using minimum convex polygons (MCP) and multi-lateral polygons (MLP) generated from the outermost locations radio-tracked bats were recorded. A MCP is defined as an animal's home range size, with the shape, and position represented by joining the outermost fixes (Mohr, 1947). A MLP is defined as the minimal area between all confirmed points of an animal's occurrence during a radio-tracking session.

1.4.9 Marking studies

In order to provide long-term data on bat movements that may be recaptured or rediscovered in other roosts (such as hibernation roosts), several bats that were caught as part of the radio-tracking surveys, over both seasons, were fitted with special anodised aluminium rings, each with a unique serial number. The rings were fitted over the forearm of the bat by experienced bat workers under licence from the NPWS (Licence No. C009/2014 and C004/2015). All Lesser horseshoe bats that were fitted with radio transmitters were also marked with rings so that, if captured again within the same survey session, they would not be re-fitted with transmitters. Bats other than Lesser horseshoe bats were also ringed, in an effort to locate mating or winter hibernation sites if these bats were subsequently recaptured in the mating season.

As stated previously, surveys of roosts in winter 2014 and 2015 included looking for Lesser horseshoe bats that were fitted with rings. In order to identify if ringed bats from the scheme study area were interacting with roosts further north – and in particular the roost at Eborhall (the Qualifying Interest roost for the Lesser horseshoe bats in Lough Corrib cSAC) – internal surveys were conducted on the 21 October 2015, 23 August 2016 and 14 July 2017 at Eborhall (and Ballymaglancy Cave on 21 October 2015), which are located more than 30km from Menlo Castle on the northern shores of Lough Corrib. Locating ringed bats at sites like these would provide valuable data as to the relationship between winter roost sites and the location where the bat was originally caught and tagged.

1.4.10 Collection of data on Lesser Horseshoe bat population and distribution

An analysis of the NPWS's Lesser horseshoe bat roost database was conducted to estimate the importance of the maternity colony at Menlo Castle for the Lesser horseshoe bat population at a local, regional and national level. The most recent counts and distribution of all summer roosts in counties Galway, Mayo, Clare and Limerick, which make up the northern sub-population of this species in Ireland according to Dool (2016), were used to determine the proportion that the Menlo Castle roost contributes to the summer population in these counties and therefore its strategic importance for the sub-population at a regional level.

Previous records for Lesser horseshoe bats within the scheme study area were sourced from the Bat Conservation Ireland database and the NPWS's Lesser horseshoe bat database. Mr Conor Kelleher, Mr Brian Keely, Dr Kate McAney, Dr Catriona Carlin (Galway Bat Group) and local NPWS conservation ranger Rebecca Teesdale were also consulted to collate any additional summer and winter roost records that were not in the above databases.

This initial desktop assessment was supplemented by data collected during subsequent field surveys.

1.5 Invertebrates

1.5.1 White-clawed crayfish

The White-clawed crayfish survey was carried out by Scott Cawley Ltd. and Julian Reynolds, under licence from the NPWS, from the 23 August 2014 to the 6 September 2014.

The watercourses surveyed are shown on **Figure 8.5.1**. Depending on the size of the waterbody, it was either surveyed using sweep-netting with hand nets (following Reynolds *et al*. 2010) or trapped using crayfish traps of appropriate mesh size. Where trapping was undertaken, traps were checked for crayfish and baited each morning and were left out over two or three nights.

1.5.2 Freshwater pearl mussel

The Freshwater pearl mussel *Margaritifera margaritifera* survey was carried out by Dr Evelyn Moorkens and Dr Ian Killeen, under licenses from the NPWS, from the 11 to the 24 August 2014.

The level of survey undertaken was determined in consideration of the potential for the presence of the Freshwater pearl mussel from a review of the following maps: OSI Discovery Series mapping, and the Geological Survey of Ireland's (GSI) Bedrock Geological Map of Ireland. Suitable habitat potential was considered to include areas of acid rock with sufficient gradient to have the potential for good flow in the river channel, including riffle habitat.

The main channel of the River Corrib and the area east of the River Corrib were discounted through not having the appropriate underlying geology to support the

Freshwater pearl mussel. The watercourses west of the River Corrib which were surveyed as part of the Constraints Study for the proposed road development are shown on **Figure 8.5.1** – see also the full report in **Appendix A.8.11**.

In each stream a rapid assessment was undertaken of river stretches identified from the desktop assessment, following the current standard methods for Freshwater pearl mussel survey (Anon., 2004). As the streams were small, the survey was carried out by wading in an upstream direction using a bathyscope according to published Stage 1 survey techniques (Anon., 2004).

1.5.3 Other Annex II molluscan species

The molluscan survey work was carried out by Dr Evelyn Moorkens and Dr Ian Killeen, under licenses from the NPWS, from the 11 to the 24 August 2014.

This element of the survey work included the following four Annex II molluscan species (surveys for the Freshwater pearl mussel were carried out separately, as described under the relevant section above):

- *Vertigo geyeri* (Geyer's whorl snail)
- *Vertigo angustior* (Narrow-mouthed whorl snail)
- *Vertigo moulinsiana* (Desmoulin's whorl snail)
- *Geomalacus maculosus* (the Kerry slug)

The molluscan survey sites were chosen based on a review of habitats within the scheme study area from recent aerial photography in combination with the results of habitat mapping surveys carried out within Lough Corrib cSAC, the Ecological Sites, and the wider scheme study area (as described above under *Habitats*), to locate habitat types with potential to support Annex II molluscan species. The survey sites are shown on **Figure 8.5.1** – see also the full report in **Appendix A.8.12**.

The habitat requirements for each of the four species concerned are described in detail in *Monitoring and Condition Assessment of Populations of Vertigo geyeri, Vertigo angustior and Vertigo moulinsiana in Ireland* (Moorkens & Killeen, 2011) and in *Database of association with habitat and environmental variables for non-shelled slugs and bivalves of Britain and Ireland* (Moorkens & Killeen, 2009).

Overall, initial surveys and the aerial photography review indicated that there were four main areas of potential habitat for *Vertigo* snail species:

- Areas of reed swamp, wet grassland and fen along the River Corrib corridor
- Coolagh Lakes area
- Ballindooley Lough area
- Turlough features east of the River Corrib

No potential suitable habitat was recorded for the Kerry slug within the scheme study area.

At each survey site a wide area was investigated and the main habitats with the potential to support *Vertigo* species were sampled. Habitats were sampled by hand, (i.e. examination of litter, stems and the underside of timber). Suitable habitat vegetation was sampled by banging leaves onto a white tray, and by the removal of amalgamated litter samples from areas of best potential for *Vertigo* species.

Approximately 2-3 litres of litter (e.g. dead/decomposing vegetation) were taken from each sampling site, air dried in the laboratory, and then sieved through two mesh sizes (3mm and 0.5mm). The contents of each sieve was examined for snails. An Olympus 40X binocular microscope was used to examine the smaller species.

1.5.4 Marsh fritillary

2013 Survey

The field work was conducted in two stages. An initial vehicle based survey was carried out with reference to OSI aerial photographs and a number of areas with suitable habitat were recorded. Areas which appeared on the photographs to have a similar appearance to these locations were then selected as survey sites. A total of 57 survey locations were identified. The locations of these sites are presented in **Appendix A.8.14**.

Field maps were prepared for each of the survey locations identified. At each of the sites the occurrence of sufficient amounts of the food plant of the Marsh fritillary, Devil's-bit scabious *Succisa pratensis*, were mapped by annotating the field maps and taking a series of waypoints on handheld GPS units or handheld computers (Trimble Nomads). At sites with suitable habitat, notes were made on:

- Habitat type
- Management (grazing intensity and stock type)
- Sward height
- Cover of *S. pratensis*
- Cover of scrub

Where suitable habitat was recorded, a search for Marsh fritillary larval webs was conducted. This comprised a meandering walk, covering as much of the suitable habitat as possible, targeting areas most likely to support webs e.g. south-facing slopes, dense patches of *S. pratensis*, structured vegetation patches and sheltered locations. When larval webs were encountered assessments were carried out according to the Marsh fritillary Larval Web Survey/Monitoring sheet prepared by the National Biodiversity Data Centre (NBDC) and NPWS (http://butterflies.biodiversityireland.ie/rare-species/marshfritillary/larval-web-form/). The locations of larval webs were recorded on the Trimble Nomads.

All field work was completed by the 28 September 2013, within the recommended survey period for Marsh fritillary larval webs (National Roads Authority, 2009).

2014 Survey

Large scale larval web and habitat suitability surveys for Marsh fritillary were carried out by Woodrow Environmental Consultants Ltd. between the 15 September and 10 October 2014 (see **Appendix A.8.13** for full report), with the vast majority of the work completed by 26 September 2014.

The selection of areas for survey within the scheme study area was informed by:

- Desktop records for the species
- Results from Marsh fritillary surveys of the area undertaken in 2013 (Barron et al., 2013) – see **Appendix A.8.14**
- Results of the large scale habitat surveys across the scheme study area which yielded useful information on potential suitability of habitat based on the presence of the species' food plant Devil's-bit scabious *Succisa pratensis*
- A review of orthophotography within those habitat polygons known to support Devil's-bit scabious - for example, where areas were clearly improved they were discounted as being unsuitable areas for priority survey included those close to the existing known population, or areas holding habitat similar in character to known suitable habitat polygons

Based on this information, large areas within the scheme study area which were either known or considered likely to support Marsh fritillary, were selected for survey as indicated on **Figures 8.6.1** and **8.6.2**.

Habitat condition and larval web surveys followed approaches adopted by NPWS in 2010 with amendments agreed following the 2011 National Marsh Fritillary report (Woodrow *et al*., 2012).

Larval Web Survey

Larval web surveys were undertaken during targeted walks of each site relying on the experience of the surveyors to identify potential areas of search while in the field. Experience has shown that, given highly experienced surveyors, this can be a very effective and reliable survey method where the intention is to identify the presence of colonies rather than undertaking a full population survey.

The method for larval web surveys relied on the high level of experience of the survey team and was undertaken as follows:

- Site surveys were undertaken with two or more surveyors. Each surveyor was responsible for undertaking habitat condition surveys and larval web surveys
- Larval web surveyors walked a zig-zag route through the most appropriate habitat, concentrating on the most likely features and aspects for larval webs
- Where a larval web was found, surveyors undertook a short more intensive zig-zag search of the neighbouring area to ascertain whether it was a significant colony
- After three or four larval webs were recorded, or if no more were located immediately, the surveyors continued to cover the remainder of the site in a zig-

zag pattern, until all the habitat survey was completed and then moved on to the next site

- Handheld GPS units were used to record 12 figure grid references for each larval web
- Habitat condition was recorded at all web locations

Habitat Condition Survey

Habitat condition parameters were recorded only at sites where larval webs were recorded. While habitat condition assessments are particularly useful in Marsh fritillary monitoring programmes and habitat management assessments, since they allow for analysis of the selection of different sites (or sub-sites) by Marsh fritillaries based on different criteria, such assessments were not central to this study which aimed to identify any *potentially suitable* habitat. The extensive experience of the survey team allowed this to be done for all sites, based on identification of areas of dense and/or extensive Devil's-bit scabious within a reasonably open sward.

Habitat condition assessments involved the collection of data on the following criteria:

- Vegetation height recorded by the average band in which the sample fell into (A = <12cm, B = 12-25cm, C = 25--50cm, and D = >50cm)
- Devil's bit Scabious abundance (A = 1-2 plants /m2, B = 3-9 plants /m2, C=10+ plants /m2, and D = no plants)
- Presence of habitat structure - tussocks/dominant tussock-forming species present
- Presence of low invading scrub (<25cm tall and >10% cover)
- Evidence of stock grazing (poaching, dung etc.)

Survey Limitations

Safe access to the whole of one area (at the western end of the Western Distributor Road) was not obtained due to blocking watercourses. In this instance, where access was not feasible, the surrounding area was surveyed for potentially suitable habitat from vantage points using binoculars. Much of the area comprised fairly improved pasture, scrub, woodland and wetland and so would have held very little potential for the species. No flowering Devil's-bit scabious was observed. This area is not directly impacted by the proposed road development and this limitation does not affect the impact assessment of the proposed road development on the local March fritillary population.

2015 and 2016 Surveys

The 2015 Marsh fritillary butterfly survey was carried out by Woodrow Environmental Consultants Ltd. on the 8, 9 and 15 September 2015. The 2016 survey was carried out by Woodrow Environmental Consultants Ltd. on the 14, 15 and 26 September 2016.

Surveys were undertaken for potentially suitable Marsh fritillary habitat, and larval webs, in targeted areas within and adjacent to the proposed road development – for survey locations see **Figures 8.6.1** and **8.6.2**. Areas were initially surveyed in 2013 (Barron *et al.*, 2013) and again in 2014 (Woodrow Sustainable Solutions Ltd., 2015). These initial surveys identified habitat suitability for Marsh fritillary butterflies, within areas where the Marsh fritillary food plant (*Succisa pratensis*) had been recorded during botanical surveys, and also Marsh fritillary larval web locations to ascertain the status of the species locally.

The general approach to the work was to undertake intensive larval web surveys within known suitable habitat within the proposed development boundary, in addition to 'rapid' larval web surveys over areas in proximity to these areas. The latter surveys were to provide a wider context for the surveys within the proposed development boundary and an understanding of the wider metapopulation. This is useful in order to inform the baseline for any future population monitoring, inform on the potential impact of removal of suitable habitat areas from the metapopulation network, and also to inform on the potential likelihood of future use of areas within the proposed development boundary prior to construction.

In addition, habitat condition points were gathered at regular locations in order to ascertain habitat suitability for Marsh fritillaries within all polygons.

Larval web and habitat condition surveys followed approaches adopted by NPWS in 2010 with amendments agreed following the 2011 National Marsh Fritillary report (Woodrow, *et a*l. 2012).

Larval web field surveys

Larval web population surveys were undertaken using two approaches. Firstly, intensive surveys were undertaken on all suitable habitat falling within the proposed development boundary. Secondly, 'rapid' assessment surveys were then undertaken on suitable habitat in the surrounding locality. In some instances, this was immediately adjacent to the proposed road development, in others it included surveys up to c.500m from the proposed development boundary (where such areas occurred in significant clusters of suitable habitat).

Intensive larval web surveys were undertaken as follows:

- After an initial walkover of the site to ascertain potentially suitable habitat, a survey boundary edge was established and marked with bamboo canes
- Fieldworkers formed a line, with each fieldworker no more than 2m from the next, and walked an initial transect along the length of the survey area, inside the boundary line, marking the inside of the transect with marker canes
- Transects were repeated, each inside the previous, until the entire survey area had been surveyed
- Hand-held GPS units were used to record 12 figure grid references for each web. Bamboo canes were used to mark webs and routes taken and the track logged on a GPS unit in order to ensure that there was no double-counting. Webs were noted as active, inactive or parasitized as appropriate

'Rapid' larval web surveys were undertaken during targeted walks of each site, relying on the experience of the surveyors to identify potential search areas while in the field. Experience has shown that, given highly experienced surveyors, this can be a very effective and reliable survey method where the intention is to identify the presence of colonies, rather than undertaking a full population survey. The method for 'rapid' larval web surveys was as follows:

- Site surveys were undertaken with two surveyors. Each surveyor was responsible for undertaking habitat condition surveys and larval web surveys
- Larval web surveyors walked a zig-zag route through the most appropriate habitat, concentrating on the most likely features and aspects for larval webs (based on experience)
- Where a larval web was found, surveyors undertook a short more intensive zig-zag search of the neighbouring area to ascertain whether it was a significant colony
- After three or four larval webs were recorded, or if no more were located immediately, the surveyors continued to cover the remainder of the site in a zig-zag until all the habitat survey was completed and then moved on to the next site
- Hand-held GPS units were used to record 12 figure grid references for each larval web

Habitat condition was recorded at all recorded larval web locations.

Habitat condition surveys

Habitat condition surveys followed approaches adopted by NPWS in 2010 with amendments agreed following the 2011 National Marsh Fritillary report (Woodrow, *et al*. 2012).

Habitat condition assessments involved the collection of data as per the habitat condition criteria described above under the 2014 survey methodology (with an intention to take a minimum of five survey points per site for small sites and five survey points per hectare for larger sites).

1.6 Birds

1.6.1 Breeding birds

Red grouse

The Red grouse survey was carried out by Dr Chris Peppiatt from 18 June 2014 to the 9 August 2014 after the methodology outlined in Murray *et al.*, (2013).

The Red grouse survey sites were chosen based on a review of recent aerial photography of the scheme study area to identify areas of potentially suitable habitat (i.e. areas of blanket bog and heath). Within each of the survey sites, transects spaced 100m apart were walked such that the surveyor came within 50m of all parts of the survey site. The location of any flushed birds, or evidence of Red

grouse such as droppings, was recorded and mapped. The survey sites are shown on Figure 4.3.21 of the **Route Selection Report**.

Barn owl

Barn Owl Survey and Monitoring 2014

The Barn owl survey was carried out by BirdWatch Ireland from 26 June 2014 to 18 July 2014.

A desktop study, in combination with field assessment, was conducted on the 26 June 2014 to determine the extent of the scheme study area potentially suitable for Barn owls. This initial assessment identified an area of c.30km^2 within Galway City and surrounds as largely unsuitable for nesting Barn owls, which was based on knowledge of nest site selection and requirements in Ireland. Although Barn owls may use urban areas for foraging, nesting within built up areas is unusual (Copland & Lusby, 2012). In addition, survey work is less effective due to access to buildings and, for these reasons, this area was excluded from further survey work. Therefore, the overall scheme study area, considered as potentially suitable and which was the focus for further survey work, comprised an area of c.195km^2. A map of the Barn owl study area is shown in the Barn owl survey report in **Appendix A.8.15** (see Figure 2.1 of that report).

Prior to beginning the fieldwork, all relevant information on existing and previously active Barn owl sites and sightings from within the Barn owl survey area were extracted from relevant BirdWatch Ireland databases; including the Barn owl registered site and sightings database and the recent Breeding Birds Atlas (2007 – 2011) database (refer to Balmer *et al*., 2013). All data was collated and the details included on suitable large-scale Ordnance Survey maps.

A detailed survey sheet for use in the field was drafted to take account of the following aspects for each site surveyed; date, county, grid reference, site type, site name, suitability rating (0 – 3), status, nesting opportunities, signs, and whether a roost watch was required and/or carried out. Additional information was recorded relating to the suitability and presence of other raptors, corvids, or other species of note.

All roads within the survey boundaries were systematically traversed by vehicle and the suitability of all buildings and quarries within the Barn owl study area was assessed. Sites that were considered to be potentially suitable were comprehensively searched for signs of the presence of Barn owls. All sites were categorised on a scale of 0 – 3 based on potential nesting and roosting opportunities for Barn owls: 0, for unsuitable; 1, representing potentially suitable sites for roosting but unlikely for nesting; 2, being suitable roosting or nesting sites; and 3, representing sites considered to be very suitable for nesting Barn owl.

At each site, a thorough search was conducted inside and outside of the building, or within a quarry, in order to locate signs indicating the presence of Barn owls (particularly pellets, evidence of whitewash splashings and moulted feathers). Depending on the site characteristics, adjacent buildings and potential perches in the immediate vicinity of the site were also assessed. At certain active Barn owl sites, due to the concealed nature of nest and roost sites (e.g. blocked chimneys,

deep cavities etc.), signs are not always obvious or accessible. Therefore, at the particular sites where this was judged to be an issue, it was necessary to conduct a vantage point watch lasting a minimum of one hour and commencing at dusk (i.e. a 'roost watch') in order to confirm activity. These sites were then recorded as active if calls from an adult or owlets were heard, or if a Barn owl was observed either within the site, or entering/exiting the site. These methods were designed to locate all Barn owl sites in buildings and quarries within the Barn owl study area. All signs and sightings of other raptors encountered during fieldwork were also recorded.

Potential tree sites were not assessed as part of this study[5]. However, information on Barn owl activity was sought whenever landowners were encountered over the course of survey work and on an opportunistic basis during fieldwork. Interviews with landowners have been successfully used to assess Barn owl occupation in previous Barn owl surveys (Toms *et al*., 2001). Landowners were asked a series of standardized questions, shown images of Barn owls, and played vocalizations of the species for identification purposes. An assessment was made as to the reliability of each individual report, based on the account, the observer's description and their relevant level of knowledge. Reports that were considered to be potentially unreliable were discarded. Reliable reports were divided into two categories, "breeding season" which consists of the period March to July and "non-breeding season" which comprises the remainder of the year. Greater importance was afforded to those sightings which originated from within the defined breeding season period as these are likely to represent birds holding territory, as opposed to non-breeding season sightings which could represent dispersing juveniles.

At all active or potentially active sites, or those where it was deemed necessary to conduct a roost watch to accurately determine status, additional nocturnal visits were carried out to confirm activity and breeding status.

Barn Owl Survey and Monitoring 2015 and 2016

The results of the Barn Owl survey in 2014 informed the methods for the 2015 and 2016 surveys. All sites classed as suitable (Category 2 or 3) within the 2014 study area were re-visited between June and August of 2015 and 2016 to determine suitability and occupancy (see **Appendix A.8.15**). The same survey methods were employed as per 2014, whereby each site was visited by day and checked for signs of occupancy by Barn Owls. Where the status of a site could not be accurately determined by a day time inspection, a dusk watch was conducted. At all sites where evidence of Barn Owls was confirmed, dusk watches and/or nocturnal surveys were conducted as necessary to establish breeding activity. As in 2014, all raptor species which were encountered during survey work were also recorded.

Barn Owl Survey 2018

A Barn Owl survey was undertaken at Menlo Castle over the 2018 breeding season to continue the monitoring of the breeding status of the site that took place in 2015 and 2016, The survey was carried out according to best practice methods as defined

[5] Note: all trees within the fence line were assessed as part of the bat surveys (see Tree Survey section above under the bat survey methodologies) and none were deemed to be suitable to support nesting Barn owl

by 'Barn Owl Surveying Standards for National Road Projects' (http://www.tiipublications.ie/library/RE-ENV-07005-01.pdf).

The survey was undertaken from late May to September 2018, during which time four visits were carried out (28 May, 20 June, 15 August and the 9 September 2018) to determine occupancy of Barn Owl via searching for signs to indicate presence (all visits) and dusk watches to confirm activity on the first three visits.

Peregrine falcon Survey 2016

Prior to conducting survey work, available information on the recent use of quarry sites (n = 5) by Peregrine falcon within the survey area was collated through records from survey work for the proposed road development in addition to interviews with National Parks and Wildlife Service (NPWS) and local experts who independently monitor Peregrine falcon populations in County Galway. For the survey area and site locations, refer to Figure 3.1 of the Peregrine falcon survey report in **Appendix A.8.16**.

The survey methods followed best practice survey techniques for Peregrine falcon as defined by Hardey et al. (2009) and were adapted for the specific requirements and time scale of this survey. The survey was carried out between the 12 May 2016 and the 10 June 2016. Before the surveys commenced, it was confirmed through communications with the NPWS that the Roadstone Quarry site was occupied by a breeding pair. A vantage point watch was carried out at the other four quarries with recent records for Peregrine falcon. Watches were initiated between 06:00 to 10:00 in the morning or 18:00 to 19:00 in the evening and were conducted in suitable weather conditions. A vantage point watch was conducted from an appropriate and discrete position either within or outside the quarry to provide the best view of suitable rock faces. Searches were carried out in accessible areas to locate signs indicating use of the site by Peregrine including fresh kills, moulted feathers, and pellets, with particular attention given to suitable perches and areas where white-wash was observed. Sites were confirmed as occupied if a bird or pair were observed or if fresh signs were confirmed, and unoccupied if no evidence of Peregrine was recorded.

For sites which were confirmed to be occupied on the first visit, further visits were conducted between the 15 of May and the 10 of June 2016 to establish breeding activity, nest site location and breeding success as required. All follow up survey visits employed vantage point watches of between one to three hours to record Peregrine falcon activity to determine breeding status, including defensive behaviour, attending or visiting a nest, food passes, prey deliveries and the presence of young. At sites where breeding was confirmed, the location of the nest was recorded where possible.

Breeding sites were confirmed to be successful if fledged young or young which were close to fledging were recorded. Sites were classed as failed if, based on the evidence it was apparent that a pair was present at the site and a breeding attempt had likely taken place but young were not successfully raised to fledging. Failed breeding attempts can be difficult to confirm, and can require monitoring from the early stages of the breeding cycle. As the survey was initiated after the typical courtship and laying stages for Peregrine (Ratcliffe, 1993), the presence and behaviour of birds recorded during the monitoring period, in addition to knowledge

of the breeding status at the site in previous years was used to inform the likelihood that a breeding attempt had taken place.

Peregrine falcon Survey 2018

A Peregrine falcon survey was undertaken at Lackagh Quarry over the 2018 breeding season to follow up on the monitoring of the breeding status of the site that took place in 2016. The survey methods followed best practice survey techniques for Peregrine as defined by Hardey et al. (2009) and were adapted for the specific requirements and time scale of this survey, and based on existing knowledge of use of the site by Peregrine. The survey was initiated on the 30 May 2018 and a vantage point watch was carried out which located nesting activity. Subsequent visits on the 20 June and 5 July 2018 focused on monitoring the confirmed breeding location.

General Breeding Birds

Breeding bird surveys were conducted by Dr. Chris Peppiatt, Gerry Murphy and John Small over three visits in May/June 2015 using a methodology adapted from the Breeding Bird Survey (Gilbert et al., 1998). Lands within, and adjacent to, the proposed development boundary were slowly walked in a manner allowing the surveyor to come within 50m of all habitat features – see **Figures 8.7.1** to **8.7.14** for survey corridor. Birds were identified by sight and song, and general location and activity were recorded using the British Trust for Ornithology (BTO) species and activity codes. The conservation status of the bird species recorded is as per:

- Birds of Conservation Concern in Ireland (BoCCI) lists which classify bird species into three categories: Red List – birds of high conservation concern; Amber List – birds of medium conservation concern; and Green List – birds not considered threatened (Colhoun & Cummins, 2013)
- Bird species listed on Annex I of the EU Birds Directive (2008/144/EC)
- SCI species of SPAs within the ZoI of the proposed road development

Woodcock Survey (Breeding)

Woodcock surveys were conducted by Dr. Chris Peppiatt at two woodland sites (Menlough Woods and Bearna Woods), over three visits from 24 May 2015 to 12 June 2015, in line with the methodology outlined for a breeding season Woodcock survey (Gilbert et. al., 1998). Due to access issues one area was resurveyed in June 2016. Surveys commenced one hour before sunset and continued until one hour after sunset. The woodland area was slowly walked and any roding (display in flight) behaviour was recorded.

1.6.2 Wintering birds

Winter bird field surveys were conducted by Dr. Chris Peppiatt, Gerry Murphy, John Small, Tom Cuffe and Scott Cawley Ltd. staff, once a month during daylight hours from September 2014 to March 2015. Due to the diverse nature of the sites surveyed, surveys were conducted using a combination of methodologies. In general, the approach was a 'look-see' methodology (based on Gilbert *et al.* 1998). The survey sites are shown on **Figure 8.9.1**.

Wetland and Peatland Sites

Where possible, sites were surveyed from vantage points (e.g. Ballindooley Lough and Coolagh Lakes) and any species utilising the area, and their activity, were recorded. Larger sites were surveyed using a hybrid methodology of thorough walks through the site with point counts and/or vantage points undertaken along the route of the proposed road development, where possible. The sites covered included:

- River Corrib
- Terryland Stream
- Ballindooley Lough
- Coolagh Lakes
- Moycullen Bogs NHA at Ballagh and Tonabrocky
- Moycullen Bog pNHA at Tonabrocky
- Cappagh Road Peatland
- Lough Inch north-eastern peatland
- Lough Inch southern peatland
- Lough Inch south western peatland

Hen harrier Winter Roost Surveys

Hen harrier Roost Surveys were undertaken at Ballindooley Lough and the Coolagh Lakes. This involved vantage point surveys of the area from 1.5 hours before sunset to 0.5 hours after sunset to record any Hen harriers in the area.

Quarries, Agricultural Areas, and Amenity Areas

Three quarries were surveyed using a hybrid methodology of walks and/or vehicle-based transects through the site with point counts and/or vantage points undertaken along the transect.

Agricultural and amenity areas were surveyed using a combination of vehicle-based surveys and roadside views where possible, with some areas requiring a walk-through to determine usage by wintering birds.

1.7 Amphibians

The amphibian survey was carried out by Scott Cawley Ltd. staff in April and May 2015 with the survey of an additional feature by Dr Chris Peppiatt in June 2016 at Kentfield.

All suitable watercourses, drainage ditches and ponds located within the survey area (see **Figures 8.10.1** to **8.10.8**) were surveyed for the presence of amphibians, in accordance with methodology described in the National Roads Authority's guidelines (National Roads Authority, 2009). An initial assessment of the suitability of surface water features was carried out during the multi-disciplinary walkover in April and May 2015. Suitable features were then subsequently surveyed on two

occasions from 6 May 2015 to 4 June 2015, using a combination of torchlight inspections and manual egg searches (under licence from the NPWS: licence number C010/2015). These surveys were augmented by searches of suitable features over the course of other ecological surveys carried out along the route of the proposed road development.

1.8 Reptiles

Lizard surveys were undertaken by Scott Cawley Ltd. staff in late September/early October 2015. Surveys were undertaken in accordance with the methodologies described in the TII[6] and Highways Agency guidance documents (National Roads Authority, 2008a; and, Highways Agency, 2005). The survey sites were selected to cover a representative range of suitable habitat types for the species along the route of the proposed road development. Ten survey sites were selected, which were located entirely within, partially within, or in close proximity to the proposed development boundary – see **Figures 8.10.1** to **8.10.8**. The outer boundary of each survey site was defined by a square hectare (100m x100m area) and within each site, 10 artificial refugia (roofing felt tiles, each *c.* 0.5m^2 in size) were placed in suitable habitat most likely to be used by basking reptiles. The location of each tile was recorded using a 12 figure GPS co-ordinates. Each tile was also given a unique reference number to aid in recording the survey results. Each survey site was visited a total of five times and involved the surveyor checking each tile for the presence of Lizard at a distance and then close-up. These surveys were augmented by searches of suitable habitat features over the course of other ecological surveys carried out along the route of the proposed road development.

1.9 Fish

All of the surveys described below were carried out by Triturus Environmental Services Ltd. in September 2015. The main waterbodies surveyed are listed in **Table 2** below, with the locations of all surveyed watercourses and survey sites shown on **Figure 8.11.1** - see also the full report in **Appendix A.8.17**. All surveys were undertaken from the 22 – 30 September 2015, during the optimal survey period for the survey type/species involved.

Table 2: Waterbodies surveyed as part of the fisheries assessment

Watercourse type	EPA Code	Hydrometric Area
Sruthán na Líbeirtí (Liberty Stream)	31F01	31
Trusky Stream	31B02	31
Bearna Stream (forms tributary with ‘An Sruthán Dubh at Ballard)	31B01	31
Knocknacarragh	31K16	31
Terryland Stream	30T01	30

[6] The Minister for Transport, Tourism and Sport has signed the order for the merger of the National Roads Authority (NRA) with the Railway Procurement Agency (RPA) to establish a single new entity called Transport Infrastructure Ireland (TII). The National Roads Authority is known as Transport Infrastructure Ireland (TII) since 1 August 2015.

Watercourse type	EPA Code	Hydrometric Area
Merlin Stream	No EPA code	29
Coolagh Lakes & river tributary	No EPA code	30
Ballindooley Lough	No EPA code	30

All equipment and Personal Protective Equipment (PPE) used was disinfected with Virkon® prior to and post-survey completion, and best practice precautions were employed to prevent the potential spread of invasive species and water-borne pathogens, according to standard Inland Fisheries Ireland (IFI) biosecurity protocols (available at http://www.fisheriesireland.ie/fisheries-research-1/73-biosecurity-protocol-for-field-survey-work-1).

Electro-fishing Survey

An electro-fishing survey of the existing fish stocks within each watercourse was undertaken between the 22 of September and 30 September 2015 under licence from IFI. The surveys were undertaken along sections of watercourses crossed by the proposed road development or, where the channel was seasonal or inaccessible, at the closest location downstream. The survey sections were 50m lengths and sealed off with stop nets, effectively acting as fish barriers for the depletion survey.

The lower conductivity waters to the west of the River Corrib (i.e. Liberty, Trusky & Bearna Streams) were fished between 250-300 volts for salmonids and at 100 volts for lamprey. In the more alkaline watercourses to the east of the River Corrib electro-fishing was conducted at 225 volts for salmonids and at 100 volts for lamprey. Where no suitable upstream habitat was available, as was the case at two locations, the high conductivity transitional riverine reaches were surveyed using a lower voltage of 75-100 volts: adjoining estuaries in the lower Trusky Knocknacarragh Streams). Other settings – i.e. frequency, duty cycle etc. – are discussed in the detailed methodology text in **Appendix A.8.17**.

Depletion electro-fishing of each site was conducted by two operators in an upstream direction using a single anode Smith-Root LR24 backpack (12V DC input; 300V, 100W DC output). In order to minimise potential damage and undue stress to lamprey species and Atlantic salmon, electro-fishing settings were modified to target specific species at the site (see detailed methodology text in **Appendix A.8.17**). Larval lamprey species, for example, were specifically targeted in areas of low/reduced flow and with a higher proportion of soft sediment. However, this habitat was recorded as very localised or entirely absent in many watercourses with the exception of the Terryland River.

Typically, salmonids require a higher frequency (and also voltage) than lamprey species in order to sufficiently stun them for capture. Unless amended, these settings can result in the inadvertent electro-narcosis of buried ammocoetes, resulting in failure to emerge and recording of absence, as well as damage to the fish (Thompson *et al*. 2010). Therefore, soft sediment areas were identified and targeted first, following stop netting.

Multiple-pass depletion electro-fishing methodology was employed and followed those outlined by Carle & Strub (1978) and Lockwood & Schneider (2000). The

equations used to calculate the population estimates are provided in **Appendix A.8.17**.

Fyke Netting Survey

Boat based fyke netting surveys were undertaken at Ballindooley Lough and Coolagh Lakes. In advance of setting the nets a high resolution transducer was used to locate fish markings and establish a depth profile of the lake basins. This facilitated the positioning of the fyke nets near shelf drop offs and helped establish distributional patterns of fish. Five 1.5m diameter (D shaped) fyke nets, with multi panel mesh, were placed in the margins of the lakes in the littoral zones (windward bank) and in shallow bay areas overnight, and retrieved within 24 hours. The fish captured were measured by two personnel and length frequency graphs and species composition graphs were constructed. All fish were processed quickly and returned alive to the lakes.

Aquatic Macro-invertebrate Survey (Q-Sampling)

Macro-invertebrate samples were collected at the watercourses crossed by the proposed road development between the 22 and 30 September 2015, in advance of the fisheries surveys. Samples were collected at the nearest location containing riffle/glide habitat downstream of proposed crossings. The samples were collected by 'kick' sampling for approximately 2.5 minutes in the faster flowing areas (riffles) of the river using a standard hand net (250mm width, mesh size 500µm). The samples were taken moving across the riffle zone and sampling also involved washing large rocks from the riffle zone, to ensure a full representation of the species composition. Collected samples were elutriated, and fixed in 70% ethanol prior to identification.

The macro-invertebrates were later identified using a Nikon SMZ 1000 stereo microscope and Freshwater Biological Association invertebrate keys. Invertebrate taxa were identified to species level where possible and grouped based on the EPA categories from pollution intolerant to very pollution tolerant on a scale from A to E (see Appendix I of Toner *et al*., 2005).

1.10 References

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