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AGRICULTURAL ATMOSPHERIC AMMONIA: IDENTIFICATION & ASSESSMENT OF POTENTIAL IMPACTS

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Front cover, small photographs from top row:

Limestone pavement, Bricklieve Mountains, Co. Sligo, Andy Bleasdale; **Meadow Saffron** *Colchicum autumnale*, Lorcan Scott; **Garden Tiger** *Arctia caja*, Brian Nelson; **Fulmar** *Fulmarus glacialis*, David Tierney; **Common Newt** *Lissotriton vulgaris*, Brian Nelson; **Scots Pine** *Pinus sylvestris*, Jenni Roche; **Raised bog pool**, Derrinea Bog, Co. Roscommon, Fernando Fernandez Valverde; **Coastal heath**, Howth Head, Co. Dublin, Maurice Eakin; **A deep water fly trap anemone** *Phelliactis* sp., Yvonne Leahy; **Violet Crystalwort** *Riccia huebeneriana*, Robert Thompson

Main photograph:

Birch trees near edge of raised bog, Raheenmore Bog, Co. Offaly, David Kelleghan.

Agricultural atmospheric ammonia: identification & assessment of potential impacts

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Executive Summary

Reactive nitrogen pollution, particularly ammonia (NH_3), when above critical limits adversely impacts biodiversity through eutrophication, acidification or direct toxic effect. Though total nitrogen deposition is a primary driver for species community changes and impacts, the concentration of ammonia should also be considered. Both total nitrogen deposition and ambient ammonia concentrations are above levels that can result in harm to biodiversity at many Natura 2000 sites across Europe and in Ireland. Reactive nitrogen is principally composed of both chemically reduced ammonia and ammonium (NH_4^+), alongside oxides of nitrogen (NO_x). While traffic is the primary source of oxides of nitrogen, agriculture accounts for virtually all ammonia emissions in Ireland.

Although there is substantial evidence that reactive nitrogen causes negative impacts on biodiversity, the relationship between exposure to reactive nitrogen (dose) and negative ecological indicators (effect) is not always straightforward. The complexity of understanding dose-effect relationships increases if multiple factors with negative effects occur concurrently (*e.g.* adverse effects of air quality occurring at the same time as adverse effects of climate change). Additionally, adverse impacts of reactive nitrogen are likely to occur over long periods of time and may not be immediately visible during a site survey. It is recommended that, although indicators of negative effects may be observed during field visits, these indicators should be used alongside other evidence (such as monitored or modelled concentration or deposition, local sources, local knowledge) to build evidence of adverse impacts on a site. Essentially, ecological indicators alone should not be used as evidence of adverse impacts but rather considered as part of a suite of indicators. Survey indicators could include algal proliferation, presence of nitrogen tolerant species, absence of nitrogen sensitive species, presence of pink or decaying Reindeer Lichen (*Cladonia portentosa*) or of decaying *Sphagnum* spp.

A guidance document describing a framework for the assessment of impacts of ammonia emissions from intensive agricultural installations has recently been published in the Republic of Ireland by the Environmental Protection Agency (EPA). Similar guidance has also been published in Northern Ireland, England, Scotland and Wales as well as other European Member States on how reactive nitrogen should be assessed in the context of Environmental Impact Assessment (EIA), Appropriate Assessment (AA) and AA screening. Recent court rulings in the Netherlands support the need to implement science-based and defensible approaches to the assessment and management of agricultural emissions of nitrogen to the atmosphere. There have been two broad approaches applied within Europe to the assessment of potential reactive nitrogen and ammonia impacts on Natura 2000 sites, namely the Critical Criteria Approach and the Integrated Approach.

The Critical Criteria Approach prevents the development of new sources that have a significant potential to adversely affect Natura 2000 Sites but allows the development of sources that do not have significant adverse effects. The Critical Criteria Approach is currently adopted by the majority of Member States who have a policy of dealing with such emissions. The Integrated Approach provides a framework for reducing emissions from existing sources to create room for new activities such as infrastructure, housing or intensive agricultural installations. The Integrated Approach was adopted by the Netherlands in 2015. However, because it allowed credits for reductions to be gained prior to the gains being realised, it was deemed illegal by the Dutch Council of State in 2019. As a consequence, modifications to the integrated approach are currently being investigated in the Netherlands. However, the European Commission commended the integrated approach highlighting it as the most appropriate method to deal with the issue of adverse impacts of reactive nitrogen from agriculture.

The assessment of emissions of ammonia from agricultural developments, required for planning or licence consent, is predominantly undertaken using air dispersion modelling techniques. A range of dispersion modelling approaches are available for the assessment of impacts from agricultural development. These dispersion modelling approaches vary in complexity and accuracy with simple approaches generally overestimating impacts to provide a highly conservative indication of potential

impacts and more advanced modelling approaches generally providing a more representative, yet conservative indication of potential impacts.

This Irish Wildlife Manual aims to summarise:

- The effects of emissions of ammonia from intensive agricultural sources and its deposition on biodiversity.
- The regulatory requirements for the assessment of these effects and the indicators of adverse effects including physical observations and theoretical limits used in modelling assessment.
- The approach recommended by the Irish EPA and approaches used in various European Countries that are currently used to assess and report on the potential effects of emissions of ammonia from agricultural development.
- A framework for high-level review of dispersion modelling assessment intended for non-expert users of dispersion models that details a non-technical basis to consider whether the critical components of a dispersion modelling study meet the requirements of dispersion modelling guidance issued by the Irish EPA.

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1 Introduction

After land-use and climate change, deposition of reactive nitrogen has been identified as the third greatest threat to global biodiversity (Payne *et al*., 2017). While four fifths of the atmosphere is nitrogen gas (N_2), this is unreactive and does not cause any ecological impacts. Nitrogen becomes reactive following either chemical reduction to form ammonia (NH_3) and ammonium (NH_4^+), or oxidation to form oxides of nitrogen (NO_x). While reactive nitrogen is essential for life on earth to exist, current anthropogenic activity is causing a surplus of such nitrogen, resulting in significant ecological impacts globally. Recent research has highlighted that both ammonia and ammonium have received very little attention compared to other potential air pollutants such as sulphur dioxide (SO_2), oxides of nitrogen, ozone, and particulate matter (Sutton *et al*., 2020). Sutton *et al*. (2020) go on to describe how successfully limiting emissions of sulphur dioxide and oxides of nitrogen has resulted in further proliferation of ammonia, which would normally react with these species in the air to form fine particulate matter ($PM_{2.5}$) as ammonium nitrate (NH_4NO_3), ammonium sulphate ($(NH_4)_2SO_4$), and ammonium bisulphate (NH_4HSO_4). While formation of ammonium reduces ambient concentrations of ammonia, the resultant fine particulate matter is particularly problematic for human health (Holst *et al*., 2018; Kim *et al*., 2015; Stokstad, 2014) and adverse ecological effects due to wet deposition further afield. Reducing emissions of nitrogen not only has benefits for human health and biodiversity, but also an economic benefit. Sutton *et al*. (2020) points out that halving nitrogen emissions would not only benefit the environment, but would also be worth US$100 billion per year globally by avoiding losses of a valuable fertiliser.

Under the Birds Directive (79/409/EEC) (EC, 2009) and Habitats Directive (92/43/EEC) (EEC, 1992) Ireland has selected a range of sites for designation as part of the pan European Natura 2000 network of protected areas. These Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) are referred to in Irish law as European sites, and internationally as the Natura 2000 network. European sites are subject to the provisions of Article 6(3) of the Habitats Directive as transposed by the Birds and Natural Habitats Regulations 2011 (S.I. No. 477 of 2011) which, among other things, requires an assessment to be undertaken of all plans and projects which are likely to have a significant effect on these sites.

It is well documented that both nitrogen deposition and atmospheric ammonia can cause potentially damaging impacts to biodiversity, including impacts to sites included in the Natura 2000 network. While total nitrogen deposition has been linked with negative ecological effects (Field *et al*., 2014; Stevens *et al*., 2004; Wilkins *et al*., 2016), ammonia is more harmful to biodiversity due in some part to direct foliar damage (Dise *et al*., 2011; Sutton *et al*., 2020). Sutton *et al*. (2020) state that the alkalinity of air laden with ammonia contributes to ecological impacts three to five times greater than the impacts of ammonium or oxides of nitrogen. It has been shown that nitrogen accumulation within ecosystems promotes fast-growing species suited for high nutrient environments, outcompeting sensitive species (Guthrie *et al*., 2018). The primary ecological impacts from excess nitrogen and/or ammonia are typically impacts on species composition and diversity, while also affecting some key ecosystem functions.

Recently published research has shown that ambient concentrations of ammonia in Ireland are above levels that can result in harm biodiversity at many Natura 2000 sites (Doyle *et al*., 2017; Kelleghan *et al*., 2019; Kelleghan *et al*., 2021a). This presents a challenge for the assessment and approval of new developments with emissions that increase ammonia concentrations and nitrogen deposition rates significantly where levels are already above critical limits and it cannot be ruled out in advance that there will not be significant consequences of the increase in concentrations of ammonia or nitrogen deposition rates.

There is no standard methodology for the assessment of impacts of ammonia on biodiversity in Europe. Current guidance and standard methodologies adopted in several countries across Europe for the assessment of effects of airborne emissions of ammonia on biodiversity are detailed in this report. Differences in approaches and in the scientific principles underpinning these approaches are examined here. This is a highly fluid field with government agencies across Europe constantly progressing and updating approaches for the assessment if impacts of ammonia on biodiversity in response to updated scientific research.

Screening dispersion models, detailed dispersion models, and hybrids of screening and detailed dispersion models are the most common tools used to assess air quality impacts as part of Air Quality Impact Assessment (AQIA). AQIA is used to inform a Natura Impact Statement (NIS) and Appropriate Assessment (AA) under the Habitats Directive and Environmental Impact Assessment (EIA) under the EIA Directive. AA and EIA form an integral part of permit applications in relation to industrial emissions and associated planning applications. AQIA can include screening and detailed dispersion modelling, air quality monitoring, and assessment of ecological indicators in the field. AQIA involves:

- The measurement and or prediction of ambient concentrations of air pollutants or rates of pollutant deposition
- The comparison of the measured/predicted concentration and deposition rates to pre-defined criteria that indicate significance or thresholds at which adverse impacts occur.

Proponents of new or expanding agricultural facilities and competent authorities face some key challenges in relation to cumulative impact assessment of ammonia impacts and nitrogen deposition. Current EPA guidance entitled "Assessment of the impact of ammonia and nitrogen on Natura 2000 sites from intensive agricultural installations" (EPA, 2021a) should be followed when assessing contributions of intensive agricultural facilities on a Natura 2000 site. Cognisance should be given to the following:

- The fact there is no single publicly available database in Ireland that quantifies and locates ammonia emitting activities. The establishment of such a database (*e.g.* as incorporated into the Netherland's AERIUS tool) would be an important step in ensuring that cumulative assessments of new or expanding facilities can be undertaken in a manner which consistently accounts for existing emissions and subsequent impacts. This database should also consider contributions to other forms of nitrogen deposition, including oxides of nitrogen.
- Emissions from individual projects that are determined to be insignificant in isolation can be approved using a critical criteria approach. The use of the same approach for multiple projects, either concurrently or consecutively can result in baseline creep, where over time the combined impacts of individually insignificant projects result in a significant adverse impact, that may not be identified using a critical criteria approach.

An AQIA is complex, being underpinned by meteorological modelling and dispersion modelling or monitoring of air quality or ecological impact. Such work should be completed by a qualified and competent team with specific expertise relevant to the modelling or monitoring methodology and meet the requirements of relevant guidance or robust scientific principles. The review of monitoring or modelling work done as part of an AQIA is also crucial, to check its validity and evaluate its suitability to identify the potential for adverse environmental impacts. Competent authorities may need to ensure that the specific expertise needed in relation to modelling or monitoring is available to them in undertaking a high-level technical review.

This document includes a framework (Framework) that is intended to provide a robust basis for the completion of a high-level review of AQIA submitted as part of AA Screening, AA, or as part of an EIA. The Framework provides a basis for the review of environmental assessment documents that involve atmospheric dispersion modelling. Adherence to the Framework will ensure that the basic principles, required to ensure robust air quality dispersion modelling assessment, have been followed.

Monitoring can refer to air quality observation (typically concentration of an air contaminant) on a site, or of ecological features (species community assemblages, indicators, *etc*.). Air quality monitoring can be used to assess whether critical levels of ammonia or dry deposition of nitrogen exceed relevant limits due to activities that occur over the course of the monitoring. Negative ecological effects may be long term and therefore may not always be evident during a site visit or during short-term monitoring campaigns. For this reason, short term observations should not be used in isolation to conclude that adverse effects are not occurring and that although there are several ecological indicators of adverse nitrogen effects it should be noted their absence is not indicative of no effect. A number of potential indicators of the adverse effects of airborne nitrogen pollution and its deposition are listed within this manual.

2 Sources of nitrogen pollution in Ireland

Although the various forms of nitrogen occur naturally, human activity has caused increased reactive nitrogen concentrations and deposition levels that have led to a number of negative impacts. Since the agricultural and industrial revolutions, such nitrogen emissions have increased fourfold (Fowler *et al*., 2005). The EPA has quantified the emissions of ammonia and oxides of nitrogen in Ireland for 2019 (EPA, 2021b). This report highlights agriculture as a source of both, accounting for 99.4% of ammonia and 34.4% of emissions of oxides of nitrogen. The primary source of oxides of nitrogen is traffic which contributes 38.6% of total national emissions. Other sources of oxides of nitrogen include industrial activities, power generation, and residential/commercial activities, which account for 8.4, 6.1 and 7.8% respectively.

The limits for total national emissions of ammonia and oxides of nitrogen are set under the National Emissions Ceiling Directive (NECD) (2016/2284/EU) (EU, 2016). The NECD requires a 1 % reduction in emissions of ammonia by 2020 and 5% by 2030, based on a 2005 baseline. Ireland was one of six Member States to exceed NECD ammonia emission limits since 2017. The other five countries which exceed limits are Germany, Spain, Austria, Croatia and the Netherlands (EEA, 2019).

In addition to limiting emissions, the NECD recognises the importance of monitoring air pollutant pressures and impacts on ecosystems. Its most recent update requires the development of long-term monitoring networks within each Member State. Ireland's response is called the National Ecosystem Monitoring Network (NEMN), which is currently being developed and implemented by the EPA (Kelleghan *et al*., 2021b).

The predominant source of ammonia in Ireland is cattle farming, which is well dispersed throughout the country. Intensive farming of pigs and poultry contributes a far lower proportion of total emissions of ammonia, but these activities are concentrated in a small number of high production areas, where the effects on biodiversity can be significant. Monitoring carried out in the UK identified areas with pig and poultry farms as having the highest ambient concentrations of ammonia (Tang *et al*., 2018). The increased cattle herd has been identified by the EPA as the primary reason for Ireland's NECD limit exceedance (EPA, 2021b). The poultry industry has also grown significantly in recent years. The number of poultry birds processed in export approved meat processing plants increased from 78.5 million birds in 2015 to 95.5 million birds in 2017 (DAFM 2017, 2018). Growth has been facilitated by increased intensive farming including the development of new farms and the expansion of existing farms. Developments with proposed capacities greater than set thresholds (40,000 birds; 2000 production pig or 750 sow places) require an Industrial Emissions Directive (IED) (2010/75/EU) (EU, 2010) licence issued by EPA to operate. These farms also require planning approval prior to the development and operation of new facilities. New farms with capacities below these thresholds also require planning approval from local authorities (and possibly NPWS), but do not require a licence from the EPA. Intensive agricultural facilities result in ammonia hotspots defined as discrete areas in close proximity to these sources of emissions where higher concentrations of ammonia are observed compared to regional background levels. Other agricultural practices (including grazing cattle, slurry spreading, fertiliser application, *etc.*) contribute to emissions which are more representative of regional background levels and the variances observed in these levels of ammonia across the country. The border counties of Cavan and Monaghan have the highest concentrations of IED licensed and sub-threshold intensive agricultural facilities (Kelleghan *et al*., 2020). Both Cavan and Monaghan also have high densities of cattle (cattle/km^2) compared to the average cattle density in Ireland (CSO, 2010).

There is limited data available on the spatial variability of concentrations of ammonia and nitrogen deposition rates across the Republic of Ireland. EPA conducted two national monitoring surveys to date in 1999–2000 and in 2013–2014. The 1999–2000 survey is reported in de Kluizenaar *et al*. (2000) and the 2013–2014 survey is reported in Doyle *et al*. (2017). The monitoring reported by Doyle *et al*., (2017) showed higher concentrations of ammonia observed towards the north-east midlands and the south-east. The station with the lowest mean concentration (0.48 μg/m^3) was Mace Head, Connemara, Co.

Galway, while the highest mean (2.96 μg/m³) was at Leiter, Co. Cavan. The annual average, 1.72 μg/m³, from all 25 sites. Doyle *et al*. (2017) states that concentrations proximal to sources will likely be higher. The level of ammonia in ambient air is affected by the gas-to-particle conversion process. Ammonia reacts with acid gasses including oxides of nitrogen and sulphur oxides to form ammonium particulate matter. A number of ammonium particulate matter types exist, specifically ammonium nitrate, ammonium bisulphate, and ammonium sulphate. Sutton *et al*. (2020) points out that where substantial emission controls have already been achieved for sulphur dioxide and oxides of nitrogen, increased concentrations of ammonia are observed as less ammonia is lost due to chemical transformations with oxides of nitrogen, and sulphur oxides. Ammonium particulate matter contributes to transboundary impacts as with predominant south westerly winds, sources of ammonia in the Republic of Ireland contribute to impacts in Northern Ireland. The total contribution of the Republic of Ireland to transboundary impacts has not yet been quantified. This highlights the need for international collaboration to manage both emissions and impacts of nitrogen.

3 Regulatory obligations to protect biodiversity

3.1 Overview

Since the 1970s, the European Union (EU) has prioritised environmental protection including the conservation of biodiversity. In relation to biodiversity, the EU has implemented two key Directives, the Birds Directive and the Habitats Directive. These directives are primarily transposed in Irish law by the Birds and Natural Habitats Regulations, 2011 (S.I. No. 477 of 2011) (as amended) and the Planning and Development Act, 2000 (as amended). There are also obligations in relation to the environmental assessment of projects in the Environmental Impact Assessment (EIA) Directive (85/337/EEC) (EEC, 1985) and its amendments which are reflected in Irish law across all sectors. Similarly, the Strategic Environmental Assessment (SEA) Directive (2001/42/EC) (EC, 2001) (transposed by both the Planning and Development (Strategic Environmental Assessment) (Amendment) Regulations 2011 (S.I. No. 201 of 2011) and European Communities (Environmental Assessment of Certain Plans and Programmes) (Amendment) Regulations 2011 (S.I. No. 200 of 2011)) is relevant to consider the environmental implications of proposed policy, plans or programs and to address adverse effects at the earliest stage of the decision making process.

3.2 Birds Directive and Habitats Directive

The Habitats Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. Together with the Birds Directive, it forms the cornerstone of Europe's nature conservation policy and establishes the EU-wide Natura 2000 ecological network of protected areas. The Habitats Directive requires EU Member States to take measures to maintain/restore natural habitats and wildlife species for which these protected areas are designated at/to favourable conservation status. Sites designated under the Birds Directive (Special Protection Areas) and the Habitats Directive (Special Areas of Conservation) form the Natura 2000 network. Maintaining and restoring the Natura 2000 network is an obligation that must be considered in relation to economic and social development including ambitions for increased food production and growth targets set for agricultural sectors in Member States (Schoukens, 2017).

The protection and conservation duties of EU Member States for Natura 2000 sites are specified in Article 6 of the Habitats Directive and are summarised below:

- Article 6(1): establish necessary conservation measures, management plans and appropriate statutory, administrative or contractual measures which correspond to the ecological requirements of the natural habitats and species present at the sites.
- Article 6(2): take appropriate steps to avoid deterioration of Natura 2000 sites.
- Article 6(3) and 6(4): assess the impact of plans and projects and only agree to a plan or project if it will not adversely affect the integrity of a Natura 2000 site unless there are no alternatives and the plan or project must be undertaken for imperative reasons of overriding public interest.

In Europe, nitrogen deposition hampers the achievement of favourable conservation status for Natura 2000 sites (Anker *et al.*, 2019). Despite a general reduction in emissions of ammonia by 24% in Europe since 1990, predictions up to 2020 indicate that the risk of exceeding critical loads remains high, irrespective of the implementation of current policies and measures to reduce nitrogen emissions. It will be very challenging to reduce nitrogen deposition in all Natura 2000 sites to a level below the critical loads (Anker *et al.*, 2019).

Emissions of ammonia rose for the fourth year running from 2016 to 2017, increasing by 0.4% across the EU, according to the annual EEA briefing 'NECD reporting status 2019' (EU, 2016). Over the 2014–2017 period, the overall increase was about 2.5%. These increases are because of the lack of emission reductions in the agricultural sector. In 2017, 21 EU Member States were in compliance with the emissions of ammonia ceiling, six (Austria, Croatia, Germany, Ireland, the Netherlands, and Spain) were not and an increasing number of Member States are projected not to meet their 2020 and 2030 emission reduction commitments (EEA, 2019).

Schoukens (2017) states that in order to achieve favourable conservation status within the Natura 2000 network at both a site and national level, nitrogen deposition needs to be decreased. Schoukens (2017) goes on to recommend EU Member States take proactive management measures to protect Natura 2000 sites from nitrogen deposition, where preventative measures should be applied to avoid future impacts. An important consideration is sites which already exceed concentration or deposition limits, as precedent has been set for the need to assess impacts prior to site designation (CJEU, 2011a). It has been recommended that where such incidences occur of impacts to Natura 2000 sites arising from existing sources, a review or withdrawal of licenses for existing facilities may be required (Schoukens, 2015). Case law clarifies that generic economic or social reasons cannot be used to justify non-compliance with the Habitats Directive (CJEU, 2014a, b, 2011a, b).

The regulatory obligations arising from Article 6(2) of the Habitats Directive have major implications for the development of regulations and guidance for the assessment of ammonia impacts from agriculture in Member States. Article 6(2) requires that individual sites are protected from conditions that result in an unfavourable conservation status. In cases where atmospheric nitrogen emissions result in such conditions, impacts must be reduced. In the Netherlands a legal precedent has been set that an approved and permitted activity can have its permit revoked if the appropriate assessment under which the permit was granted does not meet the requirements of the Habitats Directive (Kegge & Drahmann, 2020). Schoukens (2017) states "*In cases of continuing environmental degradation, Member States will even have to consider the withdrawal of existing permits for major nitrogen polluters in the vicinity of a Natura 2000-site. The stark economic consequences of such actions for the holder of the permit could be mitigated through financial compensation or the availability of subsidy schemes.*" Applying the requirements of Article 6(3) of the Habitats Directive, the Court of Justice of the EU has held that authorities can only agree to projects that will not adversely affect the integrity of Natura 2000 sites. Allowing new significant sources of ammonia in proximity to sites that already have an unfavourable conservation status due to ammonia or nitrogen deposition may become impossible, especially when considering cumulative effects (Schoukens, 2017). The European Commission (EC) has highlighted that certainty of mitigation measures are required before they can be considered in an assessment. In cases where the Natura 2000 site at issue finds itself already at an unfavourable conservation status due to excessive nitrogen deposition, putting forward the required degree of certainty as to the absence of adverse effects for new nitrogen emitting activities will prove evermore difficult, if not impossible (Van der Feltz, 2015; Schoukens, 2015; Veltman & Smits, 2009).

3.3 EIA Directive

The EIA Directive was adopted in 1985 and has had three amendments since, in 1997, 2003 and 2009. The Directive of 1985 and its three amendments have been codified by Directive 2011/92/EU (EC, 2011) of 13 December 2011. Directive 2011/92/EU was amended in 2014 by Directive 2014/52/EU (EC, 2014). The EIA Directive requires environmental impact assessment of a wide range of projects as set out in Annexes I and II of the directive. Mandatory EIA applies to all projects listed in Annex I of the Directive. These project-types are considered as having significant effects on the environment and therefore require EIA prior to authorization (*e.g.* long-distance railway lines, motorways and express roads, airports with a basic runway length ≥ 2100 m, installations for the disposal of hazardous waste, installations for the disposal of non-hazardous waste > 100 tonnes/day, wastewater treatment plants > 150,000 population equivalents). In relation to projects listed in Annex II of the Directive, the Member State national authorities must screen projects to decide whether an EIA is needed. The screening procedure can be based on thresholds/criteria or can be undertaken utilizing a case by case examination of projects.

Intensive agricultural installations (primarily pig and poultry houses) listed in Annex I include those with more than 85,000 places for broilers (poultry for meat production), 60,000 places for hens, 3,000 places for production pigs (over 30 kg), or 900 places for sows. It is to the discretion of each Member State to consider if EIA should apply to "*Projects for the use of uncultivated land or semi-natural areas for intensive agricultural purposes*", or "*Intensive livestock installations (projects not included in Annex I)*" Directive 2014/52/EU states that measures taken should aim to avoid any net loss of biodiversity. In Ireland, the EU (Planning and Development) (Environmental Impact Assessment) Regulations 2018 (S.I. No. 296 of 2018) transpose the requirements of the 2014 EIA Directive into existing planning consent procedures. The EPA (Integrated Pollution Control) (Licensing) Regulations 2020 (S.I. No. 189 and 2020), EPA (Industrial Emissions) (Licensing) (Amendment) Regulations 2020 (S.I. No. 190 of 2020) and EU (Environmental Impact Assessment) (Environmental Protection Agency Act 1992) (Amendment) Regulations 2020 (S.I. No. 191 of 2020) Waste Licensing Amendment Regulations (SI. No 130 of 2020) transpose the requirements of the 2014 EIA Directive into licence consent procedures.

3.4 SEA Directive

The SEA Directive applies to a wide range of public plans and programmes (*e.g.* on land use, transport, energy, waste, agriculture) and aims to provide a high level of environmental protection by ensuring that environmental considerations are integrated into plans and programmes with a view to promoting sustainable development. A SEA should report the likely significant effects on the environment of a plan or programme and should include alternatives which were considered as part of the plan making process. While there are many considerations in SEA, the potential environmental impacts arising from ammonia and nitrogen emissions should be considered. These relate primarily to biodiversity, human health and air. It also relates to other environmental topics such as climate through secondary impacts. For example, nitrogen deposition may reduce the ability of peatlands to act as carbon sinks (Bragazza *et al.*, 2006). The Directive requires SEA for plans or programmes across a range of sectors, including agriculture, energy and transport (European Commission, 2018). This is particularly relevant in an Irish context to plans and programmes in relation to agriculture, and to land-use plans such as city/county development plans.

3.5 IE Directive

Industrial production processes account for a considerable share of the overall pollution in Europe due to their emissions of air pollutants, discharges of wastewater and the generation of waste. Directive 2010/75/EU of the European Parliament and the Council on industrial emissions (the Industrial Emissions Directive or IED) is the main EU instrument regulating air pollutant emissions from industrial installations. The IED aims to achieve a high level of protection of human health and the environment taken as a whole by reducing harmful industrial emissions across the EU, in particular through better application of Best Available Techniques (BAT)(Required approaches to be applied to reduce emissions). Around 50,000 installations undertaking the industrial activities listed in Annex I of the IED are required to operate in accordance with a permit across the EU. These permits are granted by the EPA in Ireland. Such permits contain conditions set in accordance with the principles and provisions of the IED. Permits are required for the classes of activity that are defined under the Annex 1 of the IED. Intensive agricultural activities are listed in Section 6.6 of Annex 1 of the IED as facilities with more than 40,000 places for poultry; having more than 2,000 places for production pigs (over 30 kg), or more than 750 places for sows. The IED requires operators to submit permit applications, which should allow the competent authority to set permit conditions for that facility. These permits should include measures necessary to protect the environment as a whole. These permits also require emission limits for harmful pollutants and outline monitoring requirements.

As part of the exchange of information between member states carried out in the framework of Article 13(1) of the IED, BAT have been developed for industrial activities that require IED permits. BAT reference (BREF) documents have been drawn up for industrial activities based on the exchange of information between member states. BAT conclusions (BATC) is a document for a specific industrial activity containing the parts of a BAT reference document laying down the conclusions on BAT. According to Article 14(3) of the IED transposed into Irish legislation in S.I. No. 138/2013–EU (Industrial Emissions) Regulations 2013, BATC shall be the reference for setting the permit conditions for installations covered by the Directive.

4 Impacts & indicators

Atmospheric reactive nitrogen pollution typically impacts biodiversity through either dry or wet deposition. Dry deposition is defined as occurring when nitrogen is directly absorbed into the soil or vegetation, and wet deposition occurs when the gas combines with precipitation (Anderson *et al*., 2003). Anthropogenic nitrogen is considered to be a primary driver of changes to species composition across the whole range of different ecosystem types (Bobbink *et al*., 2010). Both empirical critical loads and vegetation community change points (Wilkins *et al*., 2016) are derived from total nitrogen deposition, which is a combination of wet and dry deposition of ammonia, ammonium and oxides of nitrogen.

A unique field experiment on Whim Bog in Scotland has highlighted the severity of ecological effects from different types of nitrogen. Here contributions of ammonia, ammonium and nitrates (NO_3^-) to observed ecological effects are compared. This experiment has been in operation since 2002 allowing for long term effects from these three forms of nitrogen to be observed. This work clearly highlights a much greater impact from ammonia where the average eradication dose 50 (cumulative nitrogen deposition which results in a 50% reduction in a species) was three times faster than ammonium and five times faster than nitrates (Sutton *et al*., 2020). Sutton *et al*. (2020) emphasise the importance of considering the form of nitrogen when making assessments and suggests/states that assessments should not be based solely on contribution of total nitrogen deposition. In practice this highlights the importance of assessing critical level exceedance for ammonia in addition to critical load exceedance for total nitrogen deposition. The work on Whim Bog is not alone highlighting the importance of impacts from reduced compared to oxidised nitrogen. Reduced nitrogen has also been linked with damage to bryophyte species in the Netherlands, where no effect was observed from pollution due to oxides of nitrogen (Verhoeven *et al*., 2011).

Atmospheric ammonia has been linked to further ecological impacts such as leaf necrosis and the exacerbation of other abiotic stresses, in addition to causing a reduction in the presence and abundance of sensitive species, (Krupa, 2003). For example, impacts of ammonia were exacerbated on heather when concentrations exceeded 8 $\mu g/m^3$, including increased sensitivities to drought, desiccation, and frost, alongside an increase in pathogen outbreaks (Sheppard *et al*., 2008). Nitrogen deposition on peatlands specifically has been shown to potentially turn them from carbon sinks to carbon sources (Bragazza *et al*., 2006). This pan-European study identified increased deposition rates on bogs exposed to high nitrogen deposition, resulting in both higher emissions of carbon dioxide (CO_2) and higher dissolved organic carbon release. Emissions of carbon dioxide increased consistently from the lower dose of 2 kg N/ha/year to the higher end of the range at 20 kg N/ha/year. With increasing emissions of ammonia, and subsequent deposition of that reduced form of nitrogen (specifically from agriculture), this finding has important consequences for carbon cycling in Ireland.

Though not all impacts of nitrogen pollution are visible on a site visit (*e.g.* leaf nitrogen content, long term impacts, *etc.*), and vegetation community-changes may only become visible when compared to a national dataset, examples of potential visible indicators of nitrogen and ammonia impacts are listed in Box 2 and detailed in the following sections. It should be noted that the absence of negative indicators cannot be considered to indicate an absence of impacts. Examples of plant effects are available on the UK Air Pollution Information System (APIS) website (APIS, 2016a) which is currently (December 2020) being updated with evidence from across Ireland and the UK. An EPA funded research project “NEC Indicators” is currently underway in University College Dublin (UCD) aiming to develop ecosystem indicators for nitrogen pollution, intended to benefit site surveys. Outputs from this project will significantly help surveyors to identify impacts from reactive nitrogen during site visits. The JNCC have also developed a Nitrogen Decision Framework (JNCC, 2016) to analyse for confounding factors when deciding effects of nitrogen deposition.

Algae–proliferation of green algal slimes on trees, other plants (*e.g.* Heather), moss and lichens.

Indicator lichens–Indicator species (See "Guide to Lichen based index to nitrogen air quality" (CEH, 2016)), particularly *Xanthoria parietina* indicative of ammonia pollution

Cladonia portentosa–Reindeer Lichen turning pink has been reported as a result of ammonia and light exposure in combination, followed by breakdown and loss of structure.

Decay of *Sphagnum*–patches of decaying *Sphagnum* species (brown/dark green and slimy)

Vascular plants–bleaching, stunted growth, exacerbated fungal and frost damage to heather species most notably *Calluna vulgaris*, increase in tall vegetation.

Proliferation of Hare's-tail Cottongrass *Eriophorum vaginatum* on raised bogs is a potential indicator, eventually replacing heaths. Heathland can also undergo transition to grassland due to addition of nitrogen.

Box 1. Example indicators of ammonia and nitrogen impacts, details described in following sections.

4.1 Algae

Ammonia, specifically from point sources, has been linked to shifts from typical bacteria and fungi on bogs, to the proliferation of algae (Payne *et al*., 2013). Payne *et al*. (2013) carried out work on Whim bog, where after 9 years of exposure to gradients of ammonia samples were collected and analysed for microbial biomass. Here it was observed that only algae were positively correlated with ammonia concentration, with their abundance increasing significantly with concentrations of ammonia. The occurrence of algal slimes on sites being impacted by ammonia is well documented, where on Moninea Bog SAC (DAERA, 2017a) birch trees downwind from a poultry house were coated in thick layers of such algae (Hicks *et al*., 2011), replacing typical epiphytic lichens. Moninea Bog is an extreme example, where concentrations reached 10–40 $\mu g/m^3$. This effect has been observed on sites with much lower concentrations at 2.3 $\mu g/m^3$ in both Raheenmore Bog SAC (NPWS, 2015a) in Co. Offaly and Killyconny Bog SAC (NPWS, 2015b) in Co. Cavan (Kelleghan *et al*., 2021a). However, on both these sites nitrogen sensitive species such as *Ramalina* spp. were still present, albeit beginning to be encroached on by algae. This is likely to have been due to the lower relative concentration when compared to Moninea Bog SAC. Both these sites are potentially representative of intermediate impacts. On both Raheenmore Bog SAC and Killyconny Bog SAC algae was also observed growing on heather as well as birch (Figure 1). Algae can also be expected to grow amongst patches of decaying *Sphagnum* spp. It should be noted that the primary source of ammonia varied across the three sites mentioned. While Moninea Bog SAC was adjacent an intensive source of ammonia, Raheenmore Bog SAC and Killyconny Bog SAC are in receipt primarily of diffuse sources *i.e*., neighbouring cattle production and slurry spreading.

Figure 1 Examples of algae colonising birch trees, epiphytic lichens and heather. Photographs David Kelleghan.

4.2 Indicator lichens

Lichens are composite organisms formed from associations of algae and fungi, in intimate contact with a solid surface such as rock or tree bark, directly exposed to air and precipitation. In such a setting, nitrogen nutrition of the lichen depends on atmospheric deposition. While previously sulphur dioxide may have been the primary air pollutant impacting lichen communities across Europe, concern has shifted to impacts of ammonia (Sutton *et al*., 2020). Lichens are excellent indicators of ammonia and nitrogen pollution. If a nitrogen-tolerant species such as *Xanthoria parietina* is observed on a typically low nutrient habitat such as a bog as in Figure 2, it is an indicator of nitrogen pollution (van Herk, 1999).

Figure 2 Examples of epiphytic *Xanthoria parietina*. Photographs David Kelleghan.

The UK Centre for Ecology and Hydrology (UKCEH) has developed a web app and field guide to identify nitrogen sensitive and tolerant species in the field (CEH, 2016). This guide allows for the identification of relevant lichen species on birch and oak trees, and provides steps to identify the level of local nitrogen pollution. It includes *Xanthoria parietina* shown in Figure 2 as a nitrogen tolerant species. This guide provides examples of other nitrogen tolerant species indicative of impacts including *Candelariella reflexa*, *Physcia adscendens*, *Punctelia subrudecta* amongst many others. Additionally, it details nitrogen sensitive species such as *Usnea* spp., *Bryoria* spp. and *Hypogymnia* spp. In 2010 a survey of lichens on oak and birch trees showed lichens on birch trees had a stronger association with ammonia than oak. This was considered to be likely as a result of the bark pH, highlighting the importance of substrate pH when using such indicators (Lewis *et al*., 2010).

4.2.1 *Cladonia portentosa*

Cladonia portentosa (a lichen) also exhibits visible responses to ammonia and nitrogen pollution. When exposed to higher concentrations of ammonia *Cladonia portentosa* initially turn pink, and typically as concentrations or exposure increase, they lose structure and totally breakdown (Sheppard *et al*., 2011). Figure 3 shows slightly pink reindeer lichen amongst decomposing *Sphagnum* spp. Sheppard *et al*. (2011) recorded this occurring when exposed to strong sunlight in combination with ammonia though they noted it was a temporary change. At this point it was possible for the lichen to recover, so this colour change could be viewed as an early warning. It is possible that this could therefore be an indicator of short-term exposure to high concentrations, though that is currently not evidenced in the literature. Sheppard *et al*. (2011) describes symptoms of impacts on *Cladonia portentosa* as a greening of the thallus caused by algae, loss of structure, and eventually turning to slime. The loss of reindeer lichen occurs early when a site is exposed to elevated concentrations of ammonia but is also lost when a site is exposed to ammonium and nitrate pollution. Hence its loss is likely indicative of both nitrogen deposition and exposure to ammonia (Søchting, 1995).

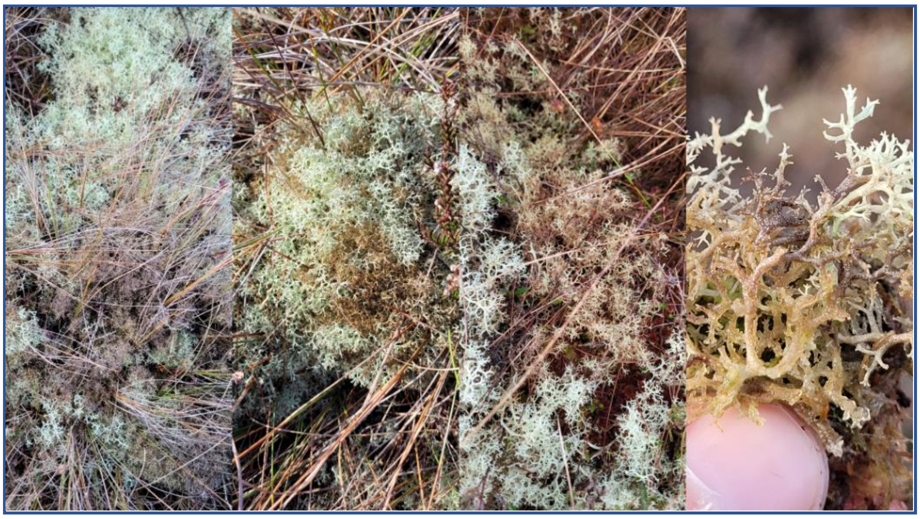

Figure 3 Examples of *Cladonia portentosa* with partial pink colouration. Far right shows *Cladonia portentosa* in the early stages of breaking down. Photographs David Kelleghan.

4.2.2 Decay of *Sphagnum*

A number of species of *Sphagnum* moss undergo a process whereby the structure of the moss breaks down when exposed to concentrations of ammonia above their critical level (Levy *et al*., 2019). Examples of patches of decaying *Sphagnum* spp. are shown in Figure 4. The end result of this process is visibly similar to green/brown slime. Work has shown that exposure to ammonia will inevitably reduce the presence of *Sphagnum* spp. on peatlands (Gunnarsson & Rydin, 2000). Where ammonium and nitrates also contributed to negative effects, the influence of ammonia was far more obvious (Levy *et al*., 2019).

However, the work by Levy *et al*. (2019) clarifies that though ammonia contributes to a greater effect, ammonium is more problematic to UK bogs due to deposition occurring on bogs in the UK primarily in remote areas. It is unclear if the same conclusion could be reached for bogs in Ireland, where raised bogs, for example, typically occur in areas with abundant local sources of ammonia.

Figure 4 Examples of decaying *Sphagnum* spp. Photographs David Kelleghan.

It has been noted that red pigmented *Sphagnum* spp. are more resistant to ammonia damage than the green *Sphagnum* spp. Sheppard *et al*. (2011) showed that within 40 m of an ammonia source all green *Sphagnum* spp. were lost or damaged, where the red species remained at distances greater than 24 m. This variation was due to the pigment of the *Sphagnum*, not the species which occurred. All *Sphagnum* spp. have been shown to respond similarly to nitrogen deposition (Gunnarsson & Rydin, 2000). Mosses other than *Sphagnum* spp. are also sensitive to concentrations of ammonia above critical limits. Negative correlations between species richness and nitrogen deposition have been shown on Welsh heathlands (Edmondson *et al*., 2010).

4.3 Vascular plants

Vascular plants are also sensitive to nitrogen deposition though typically the response varies from species to species. Heather (*Calluna vulgaris*) is impacted by ammonia at concentrations above 2 μg/m^3 (Sheppard *et al*., 2009), with high rates of dry deposition of ammonia (above 17 kg N/ha/year) linked to bleaching of foliage (Sheppard *et al*., 2011). This reduces the photosynthetic material within the plant and its overall health. Sheppard *et al*., (2011) also highlighted the number of brown shoots on heather was proportional to the concentration of ammonia and its deposition. Heather abundance was observed to significantly reduce from either long-term exposure to ammonia or immediate exposure to high concentrations (Levy *et al*., 2019). This is likely a combination of a direct impact on the heather itself, while affording a competitive advantage to grass species.

While the indicators below should be considered alongside other parameters, typical indicators of nitrogen pollution on *Calluna vulgaris* (Figure 5) are;

- bleaching,
- stunted growth,
- exacerbated fungal and frost damage,
- colonised by algae.

Conversely it has been shown that the common bog species in Ireland Hare's-tail Cottongrass (*Eriophorum vaginatum*) responds positively to additional ammonia and its abundance will increase at higher concentrations. Slightly higher cover of *E. vaginatum* was recorded for dry-deposited ammonia of 6.4 kg N/ha/year (Levy *et al*., 2019), though cover did not significantly respond to ammonium and nitrates. Dominance of a bog by Hare's-tail Cottongrass could potentially indicate higher concentrations of ammonia as a result of nearby sources. Though it's noted Hare's-tail Cottongrass can be a predominant species on some upland bogs in Ireland, where impacts from nitrogen deposition are expected to be low. It has been shown that nitrogen favours the growth of tall light competitive species, where short vegetation is lost as a result (Hodgson *et al*., 2014). Species community composition and species diversity are also associated with nitrogen deposition, where they are both negatively affected due to increasing deposition (Bobbink *et al*., 2010; Butchart *et al*., 2010; Henry & Aherne, 2014). These effects however may not become visible until compared as part of national datasets (Wilkins *et al*., 2016).

Figure 5 Examples of bleached Heather (also colonised by algae) on Raheenmore Bog SAC. Photographs David Kelleghan.

5 Critical limits

A critical limit, in its simplest form, is a threshold set to indicate when impacts on the terrestrial environment occur from air pollution. These can be used as part of the regulatory process for the assessment of impacts of air quality on terrestrial ecology. This report will refer to three critical limits, including critical levels and empirical critical loads, in addition to the recently developed vegetation community change points. Both critical levels and loads are international guidelines used to protect habitats, primarily across Europe. It is essential that both are considered when carrying out any environmental assessment of atmospheric nitrogen pollution. Critical limits relevant for assessing negative effects from atmospheric ammonia (critical levels) and nitrogen deposition (critical loads and vegetation community change points) are shown in Box 2. While all are based on best available scientific evidence, critical levels and loads are pan-European thresholds recommended by the United Nations (UNECE, 2007).

Critical levels here, refer specifically to the threshold for impacts which can occur directly from atmospheric ammonia, allowing for an acute measurement of direct effects. Critical levels are defined as "the concentration in the atmosphere above which direct adverse effects on receptors, such as plants, ecosystems or materials, may occur according to present knowledge" (Posthumus, 1988). Critical levels are applied specifically to ammonia within the air, where annual averages of 1 $\mu g/m^3$ and 3 $\mu g/m^3$ (2–4 $\mu g/m^3$) are required to protect lichens/bryophytes and higher plants respectively (UNECE, 2007).

Empirical critical loads are based on total nitrogen deposition. The application of critical loads is more complex compared to critical levels, because it is inclusive of wet/dry deposited ammonia and ammonium, and wet/dry deposited oxides of nitrogen (Aherne *et al*., 2017). A critical load is defined as a deposition rate below which, significant harmful effects do not occur "according to present knowledge" (Posthumus, 1988). They are intended to account for long term effects and resilience of ecosystem function. Habitat-specific critical loads are shown for Ireland's Annex I habitats in Appendix 1, derived from Bobbink & Hettelingh (2011) and applied following the UK APIS (CEH, 2016).

In practice the use of critical levels and loads are similar, where negative effects are likely when exceeded. When carrying out assessments of nitrogen pollution it is important that both critical levels and loads are assessed, as the exceedance of either is indicative of a negative ecological effect. The consideration of both critical loads and critical levels is essential in environmental assessments for reactive nitrogen. It has been pointed out that negative effects can arise from the exceedance of either limit and it is possible that one could be exceeded but not the other (Jarvis *et al*., 2011).

Vegetation community change points are similar to critical loads in the sense that they reflect change in the species composition of vegetation in response to total nitrogen deposition. These have been calculated for a number of Irish habitats using relevé data collected by NPWS (Wilkins *et al*., 2016). This work is ongoing with expected updates intended to cover additional habitats (Aherne *et al*. 2021). These values are set following a detailed statistical review of relevés (vegetation samples) collected through NPWS biomonitoring schemes, and the application of modelled total nitrogen deposition on these sites (Wilkins *et al*., 2016). These change points (also shown where available in Appendix 1) are potentially relevant to determining impacts on Natura 2000 sites, as they indicate the amount of nitrogen deposition eliciting an impact on plant communities. Wilkins *et al.* (2016) identified vegetation change points in Ireland (using modelled nitrogen deposition) within a range of 3.9–15.3 kg N/ha/year compared to empirically derived critical loads 5–30 kg N/ha/year (Bobbink & Hettelingh, 2011). For example the vegetation change points of 4.9 kg N/ha/year and 4.1 kg N/ha/year were estimated for Northern Atlantic wet heaths with *Erica tetralix* [Annex I Habitat Code 4010] and European dry heaths [Annex I Habitat Code 4030] respectively, which are both significantly lower than the empirical critical load ranges of 10–15 and 10–20 kg N/ha/year (Bobbink & Hettelingh, 2011).

Critical level for NH_3: Annual average concentration of atmospheric NH_3 above which impacts are likely to occur;

- where lichens and bryophytes are a significant component 1 µg/m^3
- other ecosystems 3 µg/m^3

Critical load of nitrogen deposition: The level of deposition of reactive nitrogen below which significant harmful effects to sensitive components of the ecosystem do not occur. Estimate derived from observation of changes in terrestrial vegetation. Since deposition depends on canopy roughness, and ecosystem buffering varies by soil weathering rates, critical loads are habitat specific, and critical load exceedance is derived similarly.

Vegetation Community Change Point: Inflection point in a curve representing occurrence of positive indicator species at modelled nitrogen deposition rates, using TITAN analysis (Baker & King, 2010) from a review of relevés in Ireland, ordered across the gradient of deposition of reactive nitrogen (Wilkins *et al.*, 2016).

Box 2. Critical limits for evaluating nitrogen impacts.

In relation to agriculture, critical loads for nitrogen and critical levels for ammonia are important because emissions from livestock farming lead to increased pollutant loads which could cause harmful effects to biodiversity. A summary of critical loads and level values is provided by the UK's APIS. APIS has been developed through a partnership between the UK conservation agencies, regulatory agencies and UKCEH (APIS, 2016b) and applies the internationally used empirical critical loads (Bobbink & Hettelingh, 2011) to Annex I habitats. All critical thresholds used to represent ecological impacts are typically derived from impacts on vegetation (Wilkins *et al.*, 2016; Bobbink & Hettelingh, 2011; Cape *et al.*, 2009). The EC have highlighted that expanded assessments are required to better represent ecosystem health, including potential impacts on microbial communities, animals and other species presence/absence/diversity, *etc*. (EC, 2013).

6 Irish Natura 2000 sites & nitrogen deposition

Natura 2000 is an international network of sites designated for the protection of internationally important rare and threatened species and habitats in accordance with the requirements of the EU's Habitats Directive SACs and Birds Directive SPAs. In 2019 NPWS published the latest review of the status of habitats and species protected by the Habitats Directive (NPWS, 2019). In relation to nitrogen deposition this national analysis identified Blanket Bogs, Alpine heath and Wet heath as particularly sensitive. However, Ireland is host to a suite of other potentially sensitive habitats which are listed here in Appendix 1.

The assignment of critical loads to Irish Annex I habitats in this report is based on work by Bobbink & Hettelingh (2011) as interpreted by the UKCEH through their APIS website (APIS, 2016b) Splitting Irish Annex I habitats based on their lower empirical critical load threshold led to the identification of 6 broad categories, with rates of 3–10; 5–10/15; 8–10/15; 10–15; 10–20; and 15–20/25/30 kg N/ha/year. The two most sensitive Annex I habitats are Natural dystrophic lakes and ponds [3160] and Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* [3130]. Both habitats have a lower empirical critical load of 3 kg N/ha/year, and currently have an overall conservation status as inadequate (NPWS, 2019). Additionally, there are 13 Annex I habitats with lower empirical critical load range of 5–10 kg N/ha/year, which notably include bogs, limestone pavements, screes, rocky slopes and heaths amongst others (see Appendix 1). Two habitats are listed as having a lower threshold of 8 kg N/ha/year including fixed coastal dunes and perennial vegetation on stony banks. There are 15 habitats currently listed with empirical critical loads with a lower range of 10 kg N/ha/year, including dunes, heaths, oak woodlands, grasslands, *etc*. In many cases, vegetation change points generated for these habitats using Irish specific data identify effects at rates below the listed empirical critical load (Wilkins *et al*., 2016). The authors of this report recommend that in practice consideration should be given to both the empirical critical load and where available, to the vegetation community change point. Vegetation community change points are based on the amount of nitrogen deposition required to illicit a community change response. Whether such change is reflective of a significant negative impact as required under the Habitats Directive is the subject of much debate, though it is likely that such a change indicates a negative effect. Empirical critical loads are set based on the review of multiple studies across Europe and set based on a combination of best available international evidence and expert opinion (Bobbink & Hettelingh, 2011). Studies such as Wilkins *et al*. (2016) have defined change points for numerous habitats in Ireland are likely to inform future revisions of empirical critical loads. When carrying out assessments on the exceedance of critical thresholds as indicators for negative effects on a Natura 2000 site, such an assessment should be based on the lower of either the empirical critical load or the vegetation community change points.

The critical load adopted for a site and or habitats therein should be clearly justified by the author of any environmental assessment applying them. Without clear justification based on evidence, the lower of the range should always be adopted. A clearly articulated statement should always be required to justify a critical load above the minimum of the range. For example, bogs have an empirical critical load range of 5–10 kg N/ha/year where the critical load for sites with high rainfall is set at 10 kg N/ha/year and 5 kg N/ha/year for areas with low rainfall (Bobbink & Hettelingh, 2011). An exception is required for sites which are already impacted (*i.e.* bogs which have been cut or drained) which always require the lowest critical load of 5 kg N/ha/year. Additionally, recent work on blanket bogs supports the use of 5 kg N/ha/year, as the vegetation community across Irish blanket bogs was impacted at 4.9 kg N/ha/year (Wilkins *et al*., 2016).

The SCAIL (Simple Calculation of Atmospheric Impact Limits)-Agriculture ambient concentration model (1 x 1 km grid) has been updated to include modelled 2018 emissions by the UKCEH on behalf of the EPA. Similarly, the coarser international 2018 European Monitoring and Evaluation Programme (EMEP) national concentration and deposition models for Ireland have been made available through the AmmoniaN2K website (AmmoniaN2K, 2021). Both these models currently rely on the MapEIre emissions model which utilises cattle and sheep distribution from 2010 and locations of pig and poultry farms up to 2015. Both these limitations should be considered when using these models. Recently, the MARSH (Mapping Ammonia Risk on Sensitive Habitats) model was used to estimate the concentrations of atmospheric ammonia at all Natura 2000 sites (Kelleghan *et al*., 2019). This site-specific information is freely available through the UCD research repository (Kelleghan *et al*., 2020), and was applied to all terrestrial Natura 2000 sites in Ireland. The MARSH model identified that 80.1, 34.3 and 5.9% of all Natura 2000 sites exceeded concentrations (critical levels) of 1, 2 and 3 μg /m^3 respectively. Both the MARSH and EMEP models are available to be downloaded and used in Geographical Information Systems (GIS) software. However, any national ambient map of concentrations will always underestimate concentrations proximal to hotspot sources due to the resolution of final models. Hence, depending on the locations of such sources, predicted concentrations of ammonia on Natura 2000 sites could potentially be higher (Vogt *et al*., 2013). Hence requirement in current EPA guidance to screen in any developments within 500 m of a Natura 2000 site (EPA, 2021a). Ambient ammonia monitoring was conducted across 12 Natura 2000 sites in 2017 (Kelleghan *et al*., 2021a), where total nitrogen deposition was also calculated. While these sites were used to validate the MARSH model (Pearson correlation co-efficient of 0.7), they are also important as the first network of Natura 2000 sites to be monitored for atmospheric ammonia. Of these sites ten exceeded their critical level, and 11 exceeded either their critical load or vegetation community change point. The NEMN monitoring network which is currently being established intends to carry out both air-pollution and ecological-effects monitoring on sensitive sites, primarily from the Natura 2000 network. This network will improve Ireland's understanding not only of the concentration and deposition of nitrogenous pollution on Natura 2000 sites, but will also monitor the subsequent negative ecological effects. Additionally, this monitoring can be used to validate any future concentration and deposition modelling in Ireland, improving the models' accuracy to predict air pollution impacts on Natura 2000 sites.

Although it was previously presumed recovery from impacts from nitrogen deposition could take several decades (Stevens, 2016), Sutton *et al*. (2020) highlight evidence from Northern Ireland where recovery on a bog appears to be occurring much more quickly with recovery observed within years of stopping emissions. Moninea Bog SAC had high (10–40 μg/ m^3) concentrations of ammonia as a result of a neighbouring poultry farm. Since the closure of the farm concentrations have reduced to 1.5 μg/ m^3. Species previously lost from the SAC within 400 m of the farm have started to return, including both *Cladonia portentosa* and *Sphagnum*, within 2–4 years of the farm's closure. A very clear indicator of recovery was the obvious reduction in algal slimes which had previously coated birch trees and sphagnum proximal to the poultry house. Though 1.5 μg/m^3 still exceeds the required critical level for bogs (*i.e.* 1 μg/ m^3), this seems to indicate that by reducing concentrations close to these levels, some recovery can be observed. The ultimate goal should be to achieve concentrations and deposition levels below the required critical thresholds, since indicators of ammonia pollution still exist on Moninea Bog. Though Stevens' (2016) work supports the evidence from Moninea where plant tissue N showed quick recovery across all habitat types excluding conifer plantations (Similarly, nitrates and ammonium soil concentrations diminished relatively quickly), both species community composition and total nitrogen concentration in the soil take much longer to recover. There is still ambiguity about how quickly habitats will recover fully from atmospheric ammonia but stopping or reducing local emissions is a clear path to reducing these impacts.

7 Regulatory approaches

7.1 Overview

Nitrogen emissions from agriculture, industry and traffic appear to be a major problem for achieving favourable conservation conditions at Natura 2000 sites across Europe (de Heer *et al.*, 2017). In the last decade there has been a significant body of research work done to quantify adverse effects of atmospheric nitrogen emissions on biodiversity and to understand how to regulate emissions to avoid adverse effects. This research is being used as the basis for the development of regulation and guidance for the assessment of impacts of ammonia. There is a significant body of ongoing research that forms the basis for the development of regulation in this area. A number of EU Member States have produced regulatory guidance in the last number years to deal specifically with the impacts of emissions of ammonia from intensive agriculture. Within much of this regulatory guidance is the sense that it is provisional, pending the outcomes of ongoing research. Given that elevated levels of ammonia can result in negative effects on biodiversity, regulatory guidance should aim to maintain levels of ammonia below critical levels and nitrogen deposition below critical loads on Natura 2000 sites. Two main approaches are used by EU Member States to assess impacts of emissions of ammonia at the permit application stage are;

- The critical criteria approach
- The integrated approach

7.2 Critical criteria approach

The critical criteria approach provides a framework for assessing the impacts of emissions of ammonia on sensitive receptors. The technical tool underpinning the critical criteria approach is the dispersion model. When adopting the critical criteria approach the levels predicted by a dispersion model are compared to critical criteria to determine if a proposed development meets relevant regulatory requirements. In general, when considering the impact of ammonia or nitrogen deposition the critical criteria approach can take two forms as follows:

- A percentage of the critical level or load below which the predicted model result is deemed to indicate that significant effects on receptors are not likely
- The critical level or load that is not to be exceeded

7.2.1 Technical elements underpinning a critical criteria approach

This section provides an overview of approaches to dispersion modelling assessments in the context of the requirements of the Habitats Directive to assess the potential impacts of plans and projects on Natura 2000 sites, and the requirements of the EIA Directive to assess the potential effects of a proposed project on the environment. The critical criteria approach is the most widely adopted approach in the EU in this context. The following assessments are generally used as part of the critical criteria approach to determine if and how dispersion modelling assessments may be used in the planning or licensing approvals process for intensive agricultural installations:

- A distance screening assessment
- A screening threshold assessment
- A cumulative screening threshold assessment
- A detailed modelling assessment

- A detailed assessment with abatement

The approaches are listed above in order of complexity with the last requiring significantly more work, expertise and cost than the first. In general, if the applicant can demonstrate compliance using any of the approaches listed above, there is no requirement to move onto a more complex level of assessment.

i Distance screening assessment

The distance screening assessment is simple. The competent authority defines an acceptable buffer distance between proposed developments and sensitive sites. If the distance between any sensitive site and a proposed development is greater than the acceptable buffer distance, then further assessment is not required.

ii Screening threshold assessment

The screening threshold assessment involves the determination of the Process Contribution (PC) of the proposed development at all sensitive sites within the acceptable buffer distance. The PC is a term adopted by the Environment Agency (EA) in England and other regulators to define the contribution to ambient concentrations and deposition rates due to the emissions from the process being considered for permission. The PC should be determined using a screening dispersion model or a hybrid dispersion model (see section 0). In the UK and Ireland, the SCAIL-Agriculture model is used. Generally, the national environmental protection authority in each jurisdiction (*e.g.* EPA in the Republic of Ireland, the Scottish EPA in Scotland, the EA in England *etc*.) defines the screening threshold for each nature sensitive site as the product of the following:

- The critical load or critical level for the sensitive site
- The screening percentage defined as a percentage, below which the PC of a development is deemed by the competent authority to be insignificant

In some UK jurisdictions, if the PC is less than the screening threshold, further assessment is not required. The IAQM, which is the professional body for air quality professionals in the UK states *"In the case of Environment Agency permitting, an increment of 1% (or less) of the relevant long term critical level or critical load alone is considered inconsequential. A change of such magnitude, i.e. two orders below the criterion for harm to occur, is challenging to measure (even by the most precise air quality instrument) and difficult to distinguish from natural fluctuations in measured data (due to other variables such as variations in emissions and weather). For this reason, and others, it has been used as a precautionary screening criterion. The 1% threshold has become widely used throughout the air quality assessment profession to define a reasonable quantum of long-term pollution which is not likely to be discernible from fluctuations in background/measurements. For example, for many habitats, 1% of the critical load for nitrogen deposition equates to a very small change of less than 0.1 kgN/ha/yr, well within the expected normal variation in deposition. Its use has not been challenged by the courts, but it should be used in the context of an in-combination assessment"* (IAQM, 2019).

iii Cumulative screening threshold assessment

A cumulative screening threshold assessment involves the identification of all other intensive agricultural plans or projects within the acceptable buffer distance. The PC of each other intensive agricultural plan or project within the acceptable buffer distance is calculated using a screening dispersion model or a hybrid dispersion model. The cumulative impact of the proposed development in combination with all other intensive agricultural plans or projects is calculated as the sum of the following;

- The PC of the proposed development, as determined in the previous step
- The PC of all other intensive agricultural plans or projects within the acceptable buffer distance

The competent authority defines the cumulative screening threshold as the product of the following:

- The critical load or critical level
- The cumulative screening percentage, below which the cumulative impact of the proposed development in combination with all other intensive agricultural plans is deemed by the competent authority to be insignificant

A cumulative assessment may need to consider potential contributions from a number of sources, including but not limited to;

- Applications lodged but not yet determined
- Projects subject to periodic review e.g. annual licences, during the time that their renewal is under consideration
- Refusals subject to appeal procedures and not yet determined
- Projects authorised but not yet started
- Projects started but not yet completed
- Known projects that do not require external authorisation
- Proposals in adopted plans
- Proposals in finalised draft plans formally published or submitted for final consultation, examination or adoption
- Plans or projects which became operational after the most recent update to background model

IAQM recommends a cumulative screening threshold of 1% (see quoted text from IAQM in previous section). If the cumulative impact of the proposed development in combination with all other intensive agricultural plans and projects is less than the cumulative screening threshold, then further assessment is not required.

iv Detailed modelling assessment

If the requirements of the above steps are not met, then a detailed modelling assessment, completed in accordance with regulatory guidance is required to determine if the Predicted Environmental Concentration (PEC) of the proposed development, in combination with background levels and other plans / projects within the acceptable buffer distance, result in exceedances of the critical load or critical level for any sensitive site. The advanced modelling assessment used to determine the PEC should also include emission sources at developments with planning/licence approval that are not yet built or operational.

v Detailed modelling assessment with abatement

If the PEC determined using detailed modelling (*e.g.* AERMOD, ADMS, *etc*.) indicates exceedances of the critical load or critical level of any sensitive site within the acceptable buffer distance, then abatement must be considered to reduce the PEC below the critical load or critical level of all sensitive sites with exceedances within the acceptable buffer distance.

If it is not possible to reduce the PEC below the critical load or critical level of all sensitive sites within the acceptable buffer distance, then it might not be possible for the competent authority to approve the proposed development without reductions in the level of impact from other intensive agricultural sites within the acceptable buffer distance.

7.2.2 Critical criteria approaches in European countries

The critical criteria approach "can provide an initial estimate of the exceedance of critical loads and levels at specific designated sites and provide a risk assessment of air pollution impacts on the integrity of designated sites." (SEPA, 2018). A crucial component of the critical criteria approach is the use of thresholds or setback distances to exclude projects from detailed impact assessment requirements if a project is not likely to have a significant effect. Thresholds refer typically to a percent contribution of critical level and habitat specific critical loads (*i.e.* 1 % of 1 $\mu g/m^3$ is 0.01 $\mu g/m^3$, as applied in the UK). Setback distances have also been used, where Natura 2000 sites within a set distance from a source are automatically screened in for assessment (*i.e.* Natura 2000 sites within 10 km). This approach is employed across a number of countries, including the United Kingdom, Denmark and Germany. Within the UK the approach varies, with all jurisdictions applying different though similar approaches.

In the Republic of Ireland, its EPA has published and assessment procedure to consider the effects of ammonia emissions from IED licenced Intensive Agricultural Installations (IAI) on Natura 2000 sites (EPA, 2021a). EPA (2021a) states that the assessment procedure will be reviewed regularly, at least annually, and if any new information becomes available. This assessment procedure describes steps to be adhered to, to consider the impact of ammonia emissions from an IAI on nearby Natura 2000 sites. The first step screens in IAI located within 500 m of a Natura 2000 site boundary or an IAI within 10 km of a Natura 2000 sites on which site-specific critical levels or loads are already exceeded. If the assessment meets the requirements of Step 1, the second step (Step 2) requires SCAIL-Agriculture modelling to determine whether the magnitude of impacts from the IAI (in isolation and without mitigation) at Natura 2000 sites within 10 km of the IAI exceeds of either of the following criteria:

- 0.3 kg N/ha/year,
- 4% and 5% for critical levels and loads respectively.

If either of these thresholds are exceeded a full appropriate assessment and NIS is required. The EPA currently recommends SCAIL-Agriculture as the appropriate tool for Stage 3 assessment provided it is configured in conservative mode with mitigation for fan rate and stack height only (no other mitigation measures) are recommended for Step 3 modelling. The results of the SCAIL-Agriculture assessment are assessed against the same criteria defined in Step 2.

If the assessment criteria for Step 3 are not met, Step 4 stipulates that detailed dispersion modelling of the IAI that meets the requirements of EPA AG4 Document is required. The criteria for Step 4 are that the process contribution of the IAI must be less than 1% of the critical load or critical level for Natura 2000 sites within 10 km of the IAI.

If the criteria for Step 4 cannot be met, Step 5 requires a detailed dispersion model inclusive of in-combination effects where the sum of all contributing sources cannot exceed 20% of a critical level or load for each Natura 2000 sites within 10 km of the IAI. The sites that need to be considered in an in-combination assessment undertaken as part of Step 5 are defined in EPA (2021a) as:

1) Developments that have planning permission and/or licences but are not yet (fully) operating; including those both above and below licensing thresholds that may contribute to ammonia and nitrogen emissions
2) Developments that started operating/increased their numbers, after the most recent update of background levels; including those both above and below licensing thresholds, that may contribute to ammonia and nitrogen emissions

If the criteria stipulated in Step 5 cannot be met control measures need to be identified which following detailed modelling:

A. Demonstrate that the PC + Sum of other PCs (identified in Step 5) levels are reduced to avoid exceedance of 20% of the ammonia critical level or nitrogen critical load at a Natura 2000 site
B. Demonstrate that there will be no adverse effect on the integrity of Natura 2000 site(s) & demonstrate that there will be no damage to the qualifying interest(s) of the Natura 2000 site(s)
C. In the case of an upgrade to a site, demonstrate that emissions overall from the new installation will be less than those from existing installation due to the use of new technologies/BAT (e.g. low emission housing).

- Included in design to demonstrate contributions are less than 20%, there will be no adverse effects on qualifying interests of Natura 2000 sites, or if a house is being upgraded the total emissions overall inclusive of new emissions are lower than previous installation (due to new technologies such as low emission housing)

In Northern Ireland, Northern Ireland Environment Agency (NIEA) planning advice for livestock installations was issued by Department of Agriculture, Environment and Rural Affairs (DAERA) in June 2017 (DAERA, 2017b). This describes a critical criteria approach for the assessment of ammonia impacts from livestock installations in Northern Ireland. Screening, typically using the SCAIL-Agriculture model only, is required if a designated site is within 7.5 km of the development, or a priority habitat (outside designated site network) is within 2 km. According to DAERA (2017b) a proposed development within 7.5 km of a Natura 2000 site that is already exceeding its critical level has the potential for significant effects if its PC is equal to or greater than 1% of the critical level or load of qualifying features for the Natura 2000 site. Additionally, a threshold of 50% of the critical level is applied to priority habitats outside the designated site network. Where a site already exceeds its critical thresholds detailed atmospheric dispersion modelling is typically requested. It is the current working position of the NIEA to only accept applications that produce up to 10% of the critical level for all designated sites that could be impacted (DAERA, 2017b). This includes potential cumulative and in combination impacts with other applications and installations that could also produce ammonia pollution. If the in-combination threshold of 10% is exceeded using SCAIL modelling to assess the proposal, detailed modelling is typically requested. If detailed modelling is required it should follow the guidance issued by the NIEA (NIEA, 2019). This indicates that if detailed air dispersion modelling is carried out and shows PC < 1% then it is considered insignificant and can be screened out and an in-combination impact would not be required. Where the PC ≥ 1% then the PC should be combined with that for any other plans or projects currently proposed or operational since January 2012. The guidance indicates that the sum of all the included PC impacts at each of their closest points at the relevant habitat needs to be calculated and that any development with a PC < 1% does not need to be included. If, after detailed modelling, applications which contribute more than 10% of a critical level (in-combination) will be recommended for refusal. DAERA's operational protocol is currently under review.

In September 2018, the Scottish Environmental Protection Agency (SEPA) issued guidance in relation to the assessment of emissions from intensive agriculture (SEPA, 2018). This SEPA guidance recommends using SCAIL-Agriculture modelling for sites within 10 km of a development and using a percent threshold of 4% of a critical level for designated sites. The SEPA guidance considers contributions from other sources by including any additional sources within 10 km, and screening-in cumulative contributions less than 20% of the lower critical load and critical level.

In October 2017, Natural Resources Wales (NRW) issued a guidance note on emissions of ammonia and the assessment of impacts on biodiversity (NRW, 2017). The Welsh approach requires first a distance-based assessment, where sites within 250 m, 5 km and greater than 5 km of a facility, require full detailed modelling, simple screening and no modelling required respectively. If the PC of emissions of ammonia from the proposed development are above 1% of either a critical level or load then a detailed modelling assessment is required.

In England, the Department for Environment, Food & Rural Affairs (DEFRA) and the EA have produced guidance for assessing emissions of ammonia from intensive agricultural activities (EA, 2018). This guidance was initially published on 1 February 2016 and the latest update is dated 4 May 2018. Assessments are conducted using a critical criteria approach for the assessment of impacts of ammonia from what the EA describes as *"your farm"*. A critical element of the EA approach is the concept of *"your farm"*. The assessment of impacts from *"your farm"* in isolation from background sources should include all existing and proposed sources of emissions. Similar to Wales a distance threshold is initially applied to screen in designated sites within 5 km of the development, but also includes some nature reserves within 2 km. Following this, simple screening (SCAIL-Agriculture) is applied. If this predicts that the PC from "*your farm*" is less than the lower threshold (4%) of the relevant critical level or load, then no further assessment is required. However, detailed modelling is required if the PC from "*your farm*" is more than the upper threshold (20%) of the relevant critical level or load. If the simple screening of emissions predicts the PC from "*your farm*" falls between both the thresholds the EA will determine the cumulative effect of the proposed development with any other sources in the area. If the combined effect is less than the upper threshold, no further assessment is required. If the combined effect is more than the upper threshold, detailed dispersion modelling of ammonia from the proposed development is required. Detailed modelling is automatically required for permit application when the proposed activities are within 250 m of a designated site. This modelling must meet the requirements specified in EA guidance (EA, 2021).

Shropshire County Council in England has developed its own interim guidance note for assessing the impacts of ammonia and nitrogen from livestock units which was published on 1 April 2018 (Shropshire Council, 2018). This is due primarily to a significant increase in intensive livestock units in the area, a high number of designated sites, clusters of livestock units proximal to designated sites and high ambient concentrations of ammonia (200–600% of sites' critical thresholds). The Shropshire guidance requires a stricter approach than that in the rest of England, where proposed livestock units within 250 m of a designated site must conduct detailed dispersion modelling. Within 5 km of a designated site, it needs to be demonstrated that livestock units in combination with the sum of contributions from other units are less than 1% of a site's critical thresholds, otherwise detailed dispersion modelling is required. This modelling must demonstrate that the sum of the new developments and existing units PC are less than 1% the critical thresholds. If modelling fails to meet this requirement modelling including BAT or other avoidance/mitigation measures is required to show either no additional nitrogen deposition or, a reduction in background nitrogen deposition at the sensitive receptor (Shropshire Council, 2018).

In Denmark, all farms that are expanding or rebuilding a livestock installation need a permit. Permit applications need to be submitted for farms emitting more than 750 kg NH_3/ha/year which must consider BAT and other requirements for ammonia reduction when proximal to a Natura 2000 site. The Danish Environment Agency has determined that total nitrogen deposition should not be above 1 kg N/ha/year for Natura 2000 sites. Accordingly, a limit of 0.7 kg N/ha/year has been specified for proposed farm developments in the vicinity of Natura 2000 sites if there are no other farms in close proximity to the site. If one existing neighbour caused a deposition of 0.3 kg N/ha/year, a proposed farm development could only contribute 0.4 kg N/ha/year. With two neighbours, the permissible contribution of an individual proposed farm is 0.2 kg N/ha/year (Anker & Baaner, 2017). This accumulation approach depends on both the size of farms and their proximity to the Natura 2000 site and each other, where the larger the farm the larger the area included. For example, a farm with 15 livestock units would need to include other farms within 200 m, but a larger 1500 livestock unit farm would need to include those within 500–1000 m as "neighbours". While the contributions from a neighbour's farm are not estimated in an application, their presence sets a lower limit as described above (Leusink & Michels, 2017).

In Germany, a level of 0.3 kg N/ha/year, known as the *cut-off criterion*, is used as a threshold for screening in assessments. Germany also uses a 3% threshold of critical levels and loads on a site, which needs to consider contributions from the project individually or in combination with other plans or projects. Both the cut-off criterion and 3% threshold are used to trigger a full detailed assessment (Möckel, 2019, personal communication). If a significant number of agricultural installations, with individual impacts below the cut-off criterion, are added in the vicinity of an ammonia sensitive site there is a possibility that it could exacerbate negative effects where critical loads/levels are already exceeded at the sensitive site. (Möckle, 2019, personal communication). An assessment against the *de-minimis* threshold must consider additional impacts from other sources in the vicinity of a Natura 2000 site. Additional contributions from multiple sources, which collectively add more than 3% of the critical load a site, are viewed as causing significant adverse effects if the site already exceeds its thresholds (Balla *et al.*, 2013). The determination that predicted impact above 3% of the critical load are deemed to constitute a significant impact in German regulation is based on case law (Case BAB A 44 VKE 32) (BVerwG, 2010).

7.3 Integrated approach

The integrated approach provides a framework for enabling increased economic activity by facilitating the development application process and regulatory approval, while simultaneously protecting and restoring Natura 2000 sites to favourable conservation status. The integrated approach is the most advanced assessment approach applied in the EU. Development can only be approved if its impact will not result in an exceedance of the critical load or critical level of a Natura 2000 site. At Natura 2000 sites where the critical load or critical level is currently exceeded the integrated approach provides a framework to reduce impacts below these thresholds through the reduction of emissions from sources currently impacting on the Natura 2000 site, which, in turn, creates room for new development.

The only example of an integrated approach by an EU Member State was developed by the Dutch Ministry of Economic Affairs & Ministry of Infrastructure and the Environment in 2015 (de Heer *et al.*, 2017). In the Dutch context the integrated approach is a national plan that combines generic source measures to reduce nitrogen emission levels and ecological restoration measures in Natura 2000 sites, which creates room for economic development. The approach provides a mechanism for undertaking AA at national level, removing the need for project level AA. This approach places the burden of assessment on the state, rather than on the individual applicant.

The Dutch integrated approach, known as the Programmatische Aanpak Stik-stof (PAS) took six years to develop and came into force on 1 July 2015 (de Heer *et al.*, 2017). It aims to reduce impacts of ammonia while concurrently facilitating new development. In 2019 the PAS was found to be illegal by the Dutch Council of State following on from judgements of the Court of Justice of the European Union (CJEU) in response to questions submitted by the Council of State. The comprehensive judgements of the CJEU in these cases provide a good indication of how aspects of an integrated approach to reduce and assess impacts of ammonia should be considered when developing this approach in the future. In the judgement of the Dutch Council of State the framework of an integrated assessment approach was considered to be legal, but the AA that underpinned the PAS was judged not meet the requirements of the Habitats Directive. Despite this the EC commended the Dutch on developing the integrated approach. The Dutch government is currently further developing the PAS to address the nitrogen challenge the country faces.

In order to be successful, PAS needs to be feasible and robust from both a societal, scientific, juridical and practical perspective (de Heer *et al.*, 2017). The basis of the PAS is detailed in de Heer *et al.* (2017) which states that the PAS "*is a national plan combining generic source measures to cut nitrogen emission levels and ecological restoration measures in the Natura 2000 areas while creating room for economic development. The aim of the PAS is to ensure that conservation goals can be achieved, while economic development is facilitated around Natura 2000 areas within strict environmental limits*". Elements of the PAS include:

- **Reducing emissions**–developing and implementing strategies to reduce emissions of ammonia (Ammonia Reduction Strategies).
- **Appropriate assessment**–PAS includes an AA mechanism, at the time it came into force, to quantify the reduction in concentrations of ammonia and nitrogen deposition achieved by implementing Ammonia Reduction Strategies. An AA was completed at all nitrogen sensitive Natura 2000 sites (habitats with a critical load of less than 2400 mol/ha/year (equivalent to 33.6 kg N/ha/year)) in the Netherlands.
- **Room for deposition**–Measures that reduce nitrogen deposition below levels that result in harm to biodiversity creates capacity for new development. This is known as 'room for deposition'. The 'room for deposition' of the PAS is subdivided into four parts: a reservation for autonomous developments, a reservation for notifications, a reservation for priority projects and a free amount of room for deposition that project initiators can apply for (Ministry of Economic Affairs & Ministry of Infrastructure and the Environment, 2015). The last two parts are called 'room for development' (de Heer *et al.*, 2017).

- **Site specific thresholds**–Developing site specific critical loads based on evidence from site.
- **Expanded monitoring**–An increase in the monitoring of atmospheric pollution across the Natura 2000 network.
- **Ecological restoration investment**–Substantial investment to remove nitrogen from habitats and improve ecological conditions on sites, supplementing the reduction in emissions allowing for greater "room for development". To facilitate development with low impacts (de Heer *et al.*, 2017) the PAS does not require permits for projects contributing less than 1 mol/ha/year (0.014 kg/ha/yr); or 0.05 mol/ha/year (if 95% of the load has been reached) (Ministry of Economic Affairs, 2015).

Since the PAS was deemed to be non-compliant with the requirements of the Habitats Directive, the Dutch system for permitting projects that emit nitrogen (ammonia and oxides of nitrogen) is, at present, limited to essential housing and infrastructure projects. Currently a nitrogen assessment and registration system is used to assist the competent authority, for example Dutch provinces, in granting permits. Each permit requires an AA. A precondition for the system is that nitrogen space is first created by measures that reduce nitrogen deposition below the level that protects sensitive nature sites before a permit can be granted. Authorities in the Netherlands are working towards developing a system that covers a wide range of activities. At present, the Emergency Nitrogen Approach Act only applies to residential construction and a limited number of large infrastructure projects. Currently all other projects that emit nitrogen to the atmosphere cannot be permitted. This system has been operational since 24 March 2020.

7.4 Regulatory approach in Ireland

The Irish EPA published guidance that is available to consent authorities that describes a stepwise procedure for the assessment impacts of ammonia and nitrogen deposition from IAI as part of environmental assessments, specifically AA Screening and AA (EPA, 2021a).

If ammonia and airborne nitrogen emissions occur as part of an intensive agricultural project or a plan in Ireland they must be considered as part of a screening for AA, AA and EIA. Dispersion modelling approaches are used to quantify the levels of ammonia, airborne nitrogen and rate of nitrogen deposition due to emissions from a plan or project in the surrounding environs The levels of ammonia, airborne nitrogen and rate of nitrogen deposition predicted using the dispersion model can then be considered against criteria defined by the EPA to indicate if the threshold for significance or the threshold for adverse impacts are breached. Dispersion modelling is a complex process. Robust dispersion modelling is underpinned by guidance issued by regulatory authorities. In Ireland dispersion modelling guidance is published by the EPA in its AG4 guidance note (EPA AG4 Document) (EPA, 2020). It states:

- *"Atmospheric dispersion modelling is an important tool in determining the impact on air quality of a proposed or existing activity. However, the reliability of results from dispersion modelling studies is dependent on many factors such as the robustness of the input data used in the model, the suitability of the model itself and the appropriate interpretation of the model results.*
- *This guidance document sets out recommended approaches for the completion of modelling studies and should allow for improved consistency and reliability in modelling reports submitted to the EPA. Whilst this guidance should typically be regarded as best practice, the recommendations are not in any way binding, though justification should normally be provided where significant deviations from best practice are applied."*

The EPA AG4 Document (EPA, 2020) stipulates that all approaches should adopt cautious principles to ensure a conservative (an overestimate) prediction of impacts. The level of conservatism depends on both the dispersion modelling approach adopted and its configuration.

A key component of a critical criteria approach is to define the percentage of critical loads or levels below which 'likely significant effects' are not anticipated to occur. Percentages of the critical level or load that indicate significance have been published in guidance in various jurisdictions of the UK. These range from 1–4%. The Irish EPA have set varied thresholds for significance depending on model and assessment type These are described in detail in Section 0 in this report and range from 1–5% for developments in isolation, and 20% for in-combination assessments. IAQM state *"The 1% threshold has become widely used throughout the air quality assessment profession to define a reasonable quantum of long term pollution which is not likely to be discernible from fluctuations in background/measurements"* (IAQM, 2019).

In the context of screening for AA, the impact of 'likely significant effects' also needs to be considered in combination with other plans or projects that emit ammonia. An example of this is two or more new poultry farms, in close proximity to a Natura 2000 site seeking planning or licence approval from the competent authority at the same time. The competent authority needs to know if the in-combination effect of emissions from these farms may result in likely significant effects. The EPA have outlined an approach for the requirement of cumulative assessments, but contributions from other sources should always be given cognisance in order to reduce the potential for cumulative impacts.

If a screening threshold assessment or a cumulative screening threshold assessment indicates the potential for likely significant effects a proponent could undertake a dispersion modelling assessment to demonstrate that the PEC (cumulative impact of all existing, approved and proposed developments) will not exceed 20% of a critical level or load. The current EPA guidance specifies what other sources should be considered as part of a cumulative assessment (EPA, 2021a).

7.5 Conclusions

Compared to the critical criteria approach, the integrated assessment approach offers a means of working towards reducing impacts of atmospheric nitrogen emissions thereby helping to achieve environmentally sustainable development. The Dutch and CJEU court cases highlight the complexities facing regulators in the development of regulation and related guidance to manage the impacts of atmospheric nitrogen emissions from agriculture. An integrated approach to the management of atmospheric nitrogen emission such as PAS is desirable because:

- The assessment of impacts is specific to each Natura 2000 site and is based on local emissions that are likely to have the greatest impact.
- The integrated approach will result in emission abatement and reductions in impacts. Reducing and managing emissions is a tangible way of reducing impacts that will increase the likelihood of achieving favourable conservation status at Natura 2000 sites.
- The approach provides a simplified planning approach for new developments.
- All critical criteria approaches focus on assessing local impacts from ammonia, there is currently no assessment process for contribution to particulate matter which is deposited further away from the source *via* wet deposition contributing to total nitrogen deposition. This is an area that should be expanded upon in future research.

The ruling of the Dutch Council of State (which took into account relevant CJEU case-law) in relation to the thresholds in the PAS indicated that the thresholds were void because the AA on which they are based was not valid and therefore it could not be established that the thresholds adopted met the requirements of the Habitats Directive. Although this ruling is specific to the Netherlands, it implies that distance or threshold limit values must meet the requirements of AA and there must be certainty that small incremental increases in ammonia or nitrogen deposition that meet distance or threshold limit values will not in isolation or in combination with other plans or projects impact Natura 2000 sites.

This report highlights that most of Europe, including Ireland's closest neighbours in the UK, adopt the critical criteria approach to planning and development of new or expanding agricultural facilities. The approaches allow development if the impacts are less than a percentage of the critical levels and loads at nearby Natura 2000 sites. The adoption of the critical criteria approach in the UK is very recent (England and Scotland in 2018; Wales and Northern Ireland in 2017). Whilst it is too early to gauge their success, discussions with regulators in Wales and Northern Ireland have indicated that:

- The percentage of the critical criteria allowed is already under scrutiny as not providing adequate protection.
- The setback distance approach needs improved consideration of the scale of developments. In some instances, the setback distances are insufficient to eliminate from consideration potential adverse impacts of very large farms.

A limitation of the critical criteria approach is that it does not address situations where ambient or baseline levels of ammonia and nitrogen exceed critical limits. This issue would have to be resolved through other approaches adopted concurrently with the critical criteria approach. A summary of elements of the critical criteria approach's adopted in Northern Ireland, England, Scotland, Wales and the Republic of Ireland are presented in Table 1. Table 2 provides a summary of critical thresholds (*i.e.* 1–4%) on critical limits (*i.e.* critical loads) for a number of example habitats. This table also compares thresholds applied in the UK critical threshold approach and the Dutch integrated approach in the PAS. Although the PAS is no longer in force, Table 2 is presented for comparison purposes to illustrate that the PAS had stricter thresholds for developments that were deemed to require a permit compared to current screening levels adopted in the UK that determine if a full AA is required. The Netherlands was the first country in Europe to adopt an integrated approach for the assessment of ammonia impacts, providing benefits including:

- A programmatic approach to AA, which removes this burden from the developer
- Provision of a basis for reducing the impacts of ammonia at Natura 2000 sites
- Better consideration of potential cumulative effects when compared with the standard critical criteria approach
- Site specific nitrogen management plans developed for each Natura 2000 site, in order to support the integrated system. This approach is vital to protect against existing impacts and manage future contributions.

The Irish EPA currently have guidance on how to assess impacts from atmospheric ammonia and nitrogen deposition on Natura 2000 sites from above IED threshold pig and poultry farms. This guidance should also be applied to below threshold facilities in order to reduce smaller farms potentially having a greater impact on Natura 2000 sites depending on their location. Additionally, the broad approach could be adapted for screening of other agricultural sources providing modelling is conducted appropriately (*e.g.* cattle housing, slurry spreading, *etc.*).

Table 1 Critical levels, distances within which simple screening and detailed modelling are required and the screening levels below which PC of atmospheric nitrogen levels are not considered significant in various jurisdictions in Ireland and the UK

Jurisdiction	Applicable Sites	Critical Level - lichens and bryophytes	Critical Level - higher plants	Automatic setback distance within which detailed modelling is required	Screening distance requirement	Screening level below which the PC of atmospheric nitrogen is not considered significant
		μg/m³	μg/m³	km	km	%
Northern Ireland	Designated site	1	3	-	7.5	1
	Priority Habitat	1	3	-	2	10
England	SACs, SPAs*, Ramsar Sites	1	3	250	5	4
	SSSI**	1	3	250	5	20
	NNRs, LNRs, LWS, AW***	1	3	250	2	100
Scotland	SACs, SPAs, Ramsar Sites, SSSIs	1	3	-	10	4
Wales	SACs, SPAs, Ramsar Sites, SSSIs	1	3	250	5	1
Republic of Ireland	SACs, SPAs	1	3	500	SCAIL-Agriculture zone of influence	4 (SCAIL-Agriculture) 1 (Detailed model)

*Special Areas of Conservation (SAC), Special Protection Areas (SPA)s.

**Site of Special Scientific Interest (SSSI).

***National Nature Reserves (NNRs), Local Nature Reserves (LNRs), Local Wildlife Sites (LWS), Ancient Woodland (AW).

Table 2 Examples of thresholds of critical loads in kg N/ha/year below which PC of nitrogen deposition is deemed acceptable in the UK or was deemed acceptable according to the PAS in the Netherlands.

Habitat	Relevant Nitrogen Critical Load Class Range (Lower - Upper)	Screening level (Range Lower - Upper) below which PC of nitrogen deposition is not considered significant in the UK		Limit Value specified in the Dutch PAS (2015)	
		1% of Critical Load	4% of critical Load	Up to 95% of the reservation for the notifications used	95% or more of the reservation for the notifications used
Natural dystrophic lakes and ponds [3160]	3–10	0.03–0.1	0.12–0.4	0.014	0.0007
Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* [3130]	3–10	0.03–0.1	0.12–0.4	0.014	0.0007
Blanket bog (*active only) [7130]	5–10	0.05–0.1	0.2–0.4	0.014	0.0007
Calcareous rocky slopes with chasmophytic vegetation [8210]	5–10	0.05–0.1	0.2–0.4	0.014	0.0007
Alpine and Boreal heaths [4060]	5–15	0.05–0.15	0.2–0.6	0.014	0.0007
Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*) [8120]	5–15	0.05–0.15	0.2–0.6	0.014	0.0007
Siliceous rocky slopes with chasmophytic vegetation [8220]	5–15	0.05–0.15	0.2–0.6	0.014	0.0007
Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*) [8110]	5–15	0.05–0.15	0.2–0.6	0.014	0.0007
Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe) [6230]	10–15	0.1–0.15	0.4–0.6	0.014	0.0007
Humid dune slacks [2190]	10–15	0.1–0.15	0.4–0.6	0.014	0.0007
Machairs [21A0]	10–15	0.1–0.15	0.4–0.6	0.014	0.0007
Transition mires and quaking bogs [7140]	10–15	0.1–0.15	0.4–0.6	0.014	0.0007

Habitat	Relevant Nitrogen Critical Load Class Range (Lower - Upper)	Screening level (Range Lower - Upper) below which PC of nitrogen deposition is not considered significant in the UK		Limit Value specified in the Dutch PAS (2015)	
		1% of Critical Load	4% of critical Load	Up to 95% of the reservation for the notifications used	95% or more of the reservation for the notifications used
Decalcified fixed dunes with *Empetrum nigrum* [2140]	10–20	0.1–0.2	0.4–0.8	0.014	0.0007
Dunes with *Salix repens ssp.argentea* (*Salix arenariae*) [2170]	10–20	0.1–0.2	0.4–0.8	0.014	0.0007
European dry heaths [4030]	10–20	0.1–0.2	0.4–0.8	0.014	0.0007
Calaminarian grasslands of the *Violetalia calaminariae* [6130]	15–25	0.15–0.2	0.6–0.8	0.014	0.0007
Calcareous fens with (*Cladium mariscus*) and species of the *Caricion davallianae** [7210]	15–30	0.15–0.25	0.6–1	0.014	0.0007
(*Salicornia*) and other annuals colonizing mud and sand [1310]	20–30	0.2–0.3	0.8–1.2	0.014	0.0007
Coastal lagoons [1150]	20–30	0.2–0.3	0.8–1.2	0.014	0.0007
Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) [6510]	20–30	0.2–0.3	0.8–1.2	0.014	0.0007
Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*) [1420]	20–30	0.2–0.3	0.8–1.2	0.014	0.0007

8 Air quality assessment–technical review framework–overview

This following sections aim to provide NPWS staff with a robust basis to complete a high-level review of AQIA submitted as part of AA Screening, AA or EIA for the following:

- Planning applications for intensive agricultural developments
- EPA licence applications for intensive agricultural installations.

As part of the Department of Housing, Local Government and Heritage (DHLG), the NPWS is the competent authority in relation to the protection and management of sites designated under the EU Habitats (92/43/EEC) and Birds Directives (2009/147/EC). The NPWS has a role as a prescribed authority in the planning code, which includes providing observations in relation to proposals for development, and is also a statutory consultee in relation to development proposals relating to forestry and agriculture, and in relation to EPA licensing, where nature conservation issues and concerns arise.

The NPWS's role is primarily advisory in the context of statutory notifications or referrals to the Minister by various consent authorities and involves review of certain environmental elements of development and licensing applications. In its reviews, NPWS considers a variety of legislative provisions that apply to the applications in question (*e.g.* Wildlife Acts, Planning and Development Acts, European Communities (Birds and Natural Habitats) Regulations), and any accompanying environmental assessments (*e.g.* NIS, Environmental Impact Assessment Reports (EIAR) and Ecological Impact Assessments (EcIA)).

NPWS guidance (NPWS, 2009) in relation to AA states:

> *"The first test is to establish whether, in relation to a particular plan or project, appropriate assessment is required. This is termed AA screening. Its purpose is to determine, on the basis of a preliminary assessment and objective criteria, whether a plan or project, alone and in combination with other plans or projects, could have significant effects on a Natura 2000 site in view of the site's conservation objectives. The need to apply the precautionary principle in making any key decisions in relation to the tests of AA has been confirmed by European Court of Justice case law. Therefore, where significant effects are likely, uncertain or unknown at screening stage, AA will be required."*

It is well documented that the deposition of certain forms of atmospheric nitrogen is a significant threat to biodiversity. Emissions of ammonia from agriculture are recognised as having the most substantial threat to biodiversity globally, alongside oxides of nitrogen. Threats to biodiversity from nitrogen deposition have been described in sections 4, 5 and 6 of this report.

A guidance document and framework is required to:

- Ensure the NPWS fulfils its statutory role in a competent manner
- Provide transparency to its review process
- Ensure the public are aware of the steps involved in its review processes
- Ensure its review process is consistent
- Ensure the assessment approach is fit for purpose
- Ensure its review process is scientifically robust and adheres to relevant legal requirements, national guidance and international best practice
- Ensure that Natura 2000 sites are protected from the impacts of ammonia and nitrogen deposition

The framework described in this chapter sets out principles and suitable methodologies that may be used to quantify, assess and report on the potential impacts of atmospheric nitrogen deposition and ammonia as part of an AA Screening, AA or EIA. Dispersion modelling is the primary tool adopted by regulatory authorities to quantify concentrations of ammonia and nitrogen deposition rates in the vicinity of a proposed development. The Framework focuses on the use of dispersion modelling and aims to ensure that an appropriate modelling approach is adopted for assessments, and that the dispersion model used is configured to meet the requirements of the EPA AG4 Document (EPA, 2020).

The Framework draws upon the generic AQIA and dispersion modelling guidance issued by EPA, scientific literature and guidance issued by the software developers that produce dispersion models. It provides a basis for review of AQIA that involves atmospheric dispersion modelling and will determine whether the basic principles required for a robust air quality dispersion modelling assessment have been followed. The basic principles are defined in:

- Guidance published by the developers of dispersion modelling software
- Dispersion modelling guidance published by EPA
- Dispersion modelling guidance published by regulators in other jurisdictions
- Reports published by EPA
- Reports published by regulators in other jurisdictions

In contrast to the EPA AG4 Document, this Framework is aimed at people with little or no specific understanding of the theory that underpins dispersion modelling and the tools available to undertake an air quality assessment. The Framework aims to assist NPWS staff to allow to them apply their knowledge of physical, chemical and biological principles to understand if the elements of a dispersion modelling assessment have been configured and reported in a scientifically robust manner as described in both national and international guidance.

The Framework provides a simple set of steps that allow a high-level review of the dispersion modelling and assessment of the predictions of the dispersion model that underpin AA Screening and AA to ensure that appropriate technical and reporting requirements, defined in the EPA AG4 Document (EPA, 2020).

The rationale underpinning the Framework is described in the subsequent sections. Dispersion modelling is fundamental to quantify the time-averaged concentrations of ammonia and deposition rates of nitrogen at Natura 2000 sites in Ireland. The time-averaged concentrations and deposition rates are compared to criteria levels that either indicate the air quality standard, or a percentage of the air quality standard, that identifies whether the magnitude of the time-averaged concentrations or deposition rate is significant.

Section 0 provides an overview of dispersion modelling, its role in the assessment of impacts and the approaches to dispersion modelling for AQIA. Section 0 provides some context to the use of the various dispersion modelling assessment approaches in the context of AA Screening and AA.

The ability of a dispersion model to accurately quantify the time-averaged concentrations of ammonia and deposition rates of nitrogen is fundamental to a robust AQIA. There are a range of components that need to be configured in a dispersion model. Section 0 lists and describes the important components of a dispersion model and it provides recommendations and a framework for a high-level review of each component to ensure that the models meet the requirements of the EPA AG4 Document (EPA, 2020). There are also implications for model configuration if the modelling outputs are to be used as part of an AQIA for AA Screening or AA. This is also discussed in Section 0.

9 Dispersion modelling

9.1 Overview

A dispersion model is the tool that is used to quantify the impacts of air emissions from a plan or project. EPA (2020) defines an air dispersion model as

> *"a tool that is used to assess the air quality impact of an emission source within a defined modelling domain. Rather than replicating atmospheric processes in detail, the purpose of a dispersion model is to perform a mathematical approximation of dispersion and to provide a means for estimating ambient pollutant concentrations at a given location"*

The assessment of impact from ammonia or nitrogen deposition as part of AA Screening or AA is undertaken exclusively using dispersion modelling techniques.

It is crucial to adopt relevant guidance and scientifically robust input parameters when configuring screening, detailed or hybrid dispersion models. All modelling configuration and input parameters should be justified in the context of the recommendations from guidance and best practice dispersion modelling techniques for the modelling approach adopted *e.g.* the inputs to a screening dispersion model should be justified as being highly conservative.

The outputs of a dispersion model include a concentration and/or deposition rate attributed to the proposed development in isolation (its PC), at locations around the proposed development. A development located in an area where other developments are being considered by competent authorities or developments have been approved but not yet operating will have to consider the impacts of these developments as part of an assessment. The PC of each proposed development can be determined using dispersion modelling. When modelling the release of pollutants, it is important to consider whether the specific pollutants are already present within the modelling domain and at what concentration. The PC from a proposed development and other proposed developments should always be added to the appropriate background concentration in order to obtain the PEC.

9.1.1 Approaches to dispersion modelling

Approaches to dispersion modelling assessment as defined in the EPA AG4 Document (EPA, 2020) include both screening and detailed dispersion modelling assessments. In the context of AA Screening, a third approach is commonly adopted. This approach involves the use of SCAIL-Agriculture which is a hybrid of a screening and detailed dispersion modelling assessment.

In summary:

- Screening dispersion modelling is generally a highly conservative modelling approach that produces a significant overestimation of impacts
- Detailed dispersion modelling is a significantly less conservative approach compared to screening dispersion modelling that aims to produces a realistic estimate of impacts
- SCAIL-Agriculture modelling when run using the conservative meteorological setting presumes the prevailing wind is fixed with habitats downwind. The result is a conservative model appropriate for AA screening. It should not be run using realistic met data for assessment process.

The critical criteria approach defines a threshold level as a percentage of the critical load or critical level for the Natura 2000 site. If the PC predicted by the hybrid model is less than the threshold level (*e.g.* 1 %), then the competent authority can approve the proposed development without requiring detailed modelling. The threshold level is set by the competent authority as the level, below which it deems likely significant effects are not anticipated to occur. The thresholds that have been published by competent authorities in various jurisdictions (*e.g.* Republic of Ireland, Northern Ireland, England, Scotland, Wales, Germany and Denmark) vary considerably from each other. This approach alone fails to consider existing impacts from either background conditions or contributions from other PCs. Considering such contributions, in line with the requirement for in-combination assessment under the Habitats Directive, requires a scientifically robust modelling assessment to demonstrate that the PEC is less than the critical load or critical level for near-by Natura 2000 sites, before the competent authority can consider approving the proposed development.

9.1.2 Screening dispersion model

A screening model is described in the EPA AG4 Document (EPA, 2020) as follows:

> *"A screening air dispersion model is a simple tool for the conservative assessment of single sources. Screening dispersion models provide a more simplified representation of atmospheric dispersion than the more advanced models but are more straightforward to use as the input requirements are less complicated. Because of their conservative nature they represent a first-step in the assessment of point sources, although they can have many limitations (e.g. with regard to receptor locations, pollutant averaging times, and output options). Should the results of a screening model predict an exceedance of the air quality standards then a more advanced model should be used."*

A screening dispersion model can be used as part of AA Screening or AA to provide a highly conservative indication of the PC due to a plan or project and the PEC of the plan or project in combination with other plans or projects. Screening dispersion models are regulatory tools that calculate 1-hour average concentrations of pollutants downwind of a source (*e.g.* AERSCREEN which is the screening model recommended by USEPA). Though SCAIL-Agriculture is frequently used for screening in Ireland, it is not a screening dispersion model in the context defined in the EPA AG4 Document EPA.

In Europe it is uncommon for screening air dispersion models (such as those defined by USEPA or in the EPA AG4 Document (EPA, 2020)) to be used for the assessment of potential impacts of ammonia or nitrogen deposition because of the inconsistency in averaging times between the models and criteria. Screening models generally predict maximum short-term (1-hour) pollutant levels, whereas the assessment criteria for ammonia and nitrogen deposition have long term averaging periods (typically 1-year).

9.1.3 Detailed dispersion model

A detailed model is described in the EPA AG4 Document (EPA, 2020) as follows:

> *"Advanced air dispersion models are usually based on more complex mathematical formulations than screening dispersion models. Advanced models can assess the impact of large installations with multiple sources and numerous buildings. Detailed input data regarding meteorology, land use and terrain are required by these models in order to allow them to represent the atmospheric processes contributing to pollutant dispersion. Significant data preprocessing is often required to prepare the input files used by these models.*
>
> *Advanced models may have limitations in their ability to assess certain scenarios (such as calm hours, terrain downwash and coastal fumigation). In circumstances where these scenarios may have the potential to lead to high ambient concentrations, it is important to determine the suitability of the particular advanced model in assessing the maximum impact from an installation."*

A detailed dispersion model can be used as part of AA Screening or AA to provide a representative indication of the PC due to a plan or project and the PEC of the plan or project in combination with other plans or projects.

9.1.4 SCAIL-Agriculture

SCAIL-Agriculture is a tool for assessing impacts of atmospheric nitrogen from agricultural installations in the UK and Ireland. It is a model underpinned by a detailed air dispersion model, AERMOD. A SCAIL assessment differs from a detailed air dispersion modelling assessment by simplifying aspects of the detailed dispersion modelling process such as the model inputs. SCAIL has simplified components of the detailed dispersion modelling process including but not limited to emissions, background concentrations, source characterization, meteorology, land use and terrain. SCAIL assessments, if configured appropriately, will intentionally over predict the likely impacts of new agricultural developments by adopting overly conservative dispersion modelling assumptions such as worst-case emissions and meteorology. SCAIL developers and the regulators who have developed critical criteria approaches underpinned by SCAIL intend for it to be overly conservative in line with the precautionary principle of the Habitats Directive.

The developers of SCAIL-Agriculture state that the model produces an estimate of the nitrogen deposition (and concentrations of ammonia) at a certain distance downwind of the source, using a 'deposition velocity' specific to the habitat of interest. The model also estimates the potential for critical load exceedance at the nearest edge of the habitat, taking into account the background deposition at that location and the critical load of the habitat. To do this, the model uses both UK critical load/level maps and habitat information held within the APIS.

The estimate of the nitrogen deposition (and concentrations of ammonia) produced by SCAIL-Agriculture is considered to be highly conservative. The estimates produced by SCAIL are determined using AERMOD, a detailed dispersion model configured with conservative components including:

- Meteorological data
- Source characterisation
- Source Emission Rates
- Assessment Criteria

10 Assessment approaches in the context of the Habitats Directive

10.1 Screening dispersion model approaches

There are a number of potential weaknesses in SCAIL-Agriculture and screening dispersion model approaches in the assessment of impacts in the context of the Habitats Directive in Ireland. Some are described in this section.

If background levels exceed critical loads or critical levels for a qualifying feature within a Natura 2000 site, the approval of further developments in the vicinity of this site potentially breaches the requirements of the Habitats Directive. Further development may not be allowed until background levels at the site are reduced below the critical loads and critical levels of qualifying features. If background levels are reduced below these thresholds, further development can be approved if the PC of the development, in-combination with background levels, does not result in such exceedances. The use of SCAIL-Agriculture as part of screening threshold assessments or cumulative screening threshold assessments potentially allows for additional impacts, deemed to be insignificant, above the critical load or level. The use of SCAIL-Agriculture in Ireland for new source assessment is recommended only for AA screening, with limited usage as part of a full AA. While in use for AA screening the EPA require models to be run with 0 m^3/s ventilation rate, with stack height excluded and using conservative meteorological data. A number of thresholds for significance of negative effects have been set by the EPA, these are;

- Screening using SCAIL-Agriculture in conservative mode, with 0 $m^3\ s^{-1}$ ventilation rate and stack height excluded: 4% of the critical level, 5% of the critical load, and 0.3 kg N/ha/year total nitrogen deposition
- SCAIL-Agriculture as part of detailed NIS permitted provided only ventilation rate, stack height and exhaust diameter are altered (conservative meteorology required): 4% of the critical level, 5% of the critical load, and 0.3 kg N/ha/year total nitrogen deposition
- Detailed dispersion model (i.e. AERMOD, ADMS, *etc*.) as part of NIS: 1% critical level and / or critical load
- Cumulative assessment using detailed dispersion modelling: 20% critical level and / or load for the sum of PCs

It is recommended that SCAIL-Agriculture should be used only as described above where defined regulatory guidance levels for insignificance have been issued by EPA. The objective of SCAIL-Agriculture, is detailed in the user manual (Hill *et al*., 2014) as follows:

> *"The objective is to screen environmental permit applications from farm units and to assess impacts from agricultural developments applying for planning permission to determine if there is the possibility of adverse impacts. Should such impacts be found then this would indicate that more detailed dispersion and deposition modelling is required."*

For these reasons, and others not listed here, SCAIL-Agriculture should **NOT** be used for proposed developments in the vicinity of Natura 2000 sites:

- In areas with intensive agricultural installations within 500 m to the site boundary
- With background levels already above the critical load or critical level
- In areas with higher densities of intensive agricultural installations (*i.e.* within 10 km of Slieve Beagh SPA, Kilroosky Lough Cluster SAC, or Lough Oughter SPA & SAC).

It should be noted that updated high resolution (1 x 1 km) EMEP modelling, which includes hotspot sources developed up to 2015, has been developed for Ireland by the UKCEH. This model has been integrated into SCAIL-Agriculture. This updated model should still be interpreted with caution, as its development relied upon the 2010 spatial distribution of cattle which, with two agricultural expansions since then, has likely changed. It does however apply up-to-date emission rates as calculated for the increased herd size. Additionally, it should be noted that even at this resolution, high concentrations directly proximal to hotspot sources are averaged out over the 1 x 1 km grid.

10.2 Detailed dispersion modelling approaches

Detailed dispersion modelling offers a pragmatic and robust approach to determine the impact of ammonia and nitrogen deposition in the context of the Habitats Directive. It provides a basis for the cost-effective determination of the magnitude of impacts from multiple sources of emissions, across extensive spatial areas. Many modern dispersion models are highly refined tools that provide a statistically accurate representation of atmospheric dispersion and the level of impacts that occur due to an emission source. Dispersion modelling is subject however to potential flaws, primarily associated with the accuracy of input data. Some such potential flaws are described in this section.

The potential flaws associated with the use of detailed modelling approaches in the context of the Habitats Directive are the same as the potential flaws associated with detailed modelling approaches for any detailed modelling assessment. Detailed dispersion modelling tools are complex. Proper and accurate use of dispersion models requires that the models are configured in accordance with:

- Updated developer user guides
- Recent research
- Rules specified in regulatory guidance published by national regulators

The potential flaws in the use of detailed dispersion modelling approaches in the assessment of impacts, in the context of the Habitats Directive, result from not adhering to the relevant guidance. The most important components of any detailed modelling assessment in the context of the Habitats Directive include the configuration of the model with accurate source emission rates, source characterization, meteorological data and background data (including ambient levels that result from sources outside the modelling domain and levels from existing and approved sources within the modelling domain). If NPWS staff have any doubts about appropriateness of modelling carried out, they should request both model input and output files from the applicant (these should be provided with upon submission) and consult with experts.

11 Components of a dispersion model

This section focuses on the input data used in the model and the interpretation of model results. It lists and describes the important components of a dispersion modelling assessment and provides recommendations and a framework for a high-level review of each component. The recommendations and framework are based on:

- Modelling guidance published by EPA
- International best practice
- Recommendations made by the developers of dispersion modelling software

In the context of dispersion modelling, the EPA AG4 Document (EPA, 2020) states:

"*…the reliability of results from dispersion modelling studies is dependent on many factors such as the robustness of the input data used in the model, the suitability of the model itself and the appropriate interpretation of the model results*."

A complete technical review of a dispersion modelling assessment is a complex process that requires input from a qualified expert. This high-level review framework is intended for non-expert users and aims to provide a non-technical basis to understand whether the critical components of a dispersion modelling study meet the guidance issued by EPA in the Republic of Ireland.

The important components of a dispersion model include:

- Source emission rates
- Source characterisation
- Meteorological data
- Geophysical data (land use and terrain)
- Background concentrations & cumulative impacts
- Cumulative assessment
- Assessment criteria
- Treatment of deposition

Each of these components is discussed in the following sections in the context of Irish dispersion modelling guidance, international best practice and the requirements of the Habitats Directive.

A more technical basis for the configuration of the modelling components in a dispersion model is provided in Appendix 2Components of a dispersion model – technical considerations Source emission rates.

The EPA AG4 Document (EPA, 2020) highlights that emission rates are directly proportional to the modelled outputs, hence an increase in the emission rate entered into a model will result in a proportionate increase in the magnitude of the predicted concentrations at downwind locations for that source.

There is no specific guidance in Ireland on the emission rates of ammonia that should be adopted in a detailed dispersion modelling assessment. Careful consideration should be given when developing an ammonia emissions inventory for intensive agricultural installations. Research has indicated that there are a wide range of emissions that vary depending on factors such as:

- Housing system used
- Partially/fully slatted floors

- The type of litter/bedding
- Ventilation system (*e.g.* side ventilated or roof fans)
- Manure management system
- Type of abatement

In 2018, the CJEU handed down a judgement in the People Over Wind case (Case C-323/17) (CJEU, 2017) after a request by the High Court (Ireland) for a preliminary ruling concerning the interpretation of Article 6(3) of the Habitats Directive as it relates to mitigation measures in the context of screening for AA. The CJEU ruled that it was not appropriate to take mitigation measures into account at the screening stage. Hence, the calculation and use of emission rates must be considered carefully when considering potential impacts on Natura 2000 sites. The inclusion of measures in the proposed project for the purpose of reducing emission rates will automatically trigger a requirement for a full AA. Sources for rates used must be provided along with adequate descriptions of the source and its design.

It is also relevant that the emission rate of ammonia from intensive agricultural installations increase with increasing ventilation rate, which is heavily influenced by temperature, ventilation system and number of animals. The generation and expulsion of emissions from intensive agriculture is highly complex and many elements are not fully understood.

If the proposed development is an extension to an existing farm, the report should clearly state if the modelling only incorporates the new development or considers existing sources within that site. If the existing sheds are not included in the detailed modelling assessment a clear, scientifically robust justification for this should be provided in the report (*e.g.* the existing sheds are included in the modelled background).

11.1 Source characterisation

The characterisation of emission points in the dispersion model that underpins AA Screening must consider the fundamental requirements of dispersion modelling to ensure that the source characterisation is representative of the point of emission. Source characterisation needs to be provided, including details such as building heights, fan diameter/effective fan diameter, flowrate, building height, *etc.* SCAIL-Agriculture states that multiple sources can be modelled at once (Hill *et al.*, 2014). A fan flow rate of 0 m^3/s is recommended as this will increase modelled concentrations locally, acting sufficiently precautionary. This is line with recommendations of case C-323/17, as alteration of fan flow rate can also alter modelled outcomes of SCAIL-Agriculture.

The exit velocity and diameter are combined to determine the airflow rate through the stack in a dispersion model. In agricultural buildings that airflow rate varies consistently to remove heat and air contaminants from the building. The airflow rate is an important component in determining the maximum height the plume rises to in the atmosphere before levelling off. It therefore has a significant effect on the level of impact that occurs downwind. The exit velocity should be set at a level that reflects the required airflow rate and as a minimum it should vary depending on season.

The temperature of the exhaust is also a key modelling input that is used to calculate the buoyancy of the plume upon release. It therefore is a key component of in the calculation of the maximum height of the plume. The exhaust temperature should be included in the modelling input file as:

- The minimum target temperature required over the course of the growth cycle of the birds/animals in the building
- A variable that changes with time to reflect the differences in the target temperature required by the birds/animals as it changes over the course of the growth cycle

The use of varying temperatures in a modelling assessment to reflect the differences in the target temperature required by the birds/animals as it changes over the course of the growth cycle requires significant modelling expertise. The EPA currently recommend in practice that the lowest temperature possible within housing be applied, as this would contribute towards modelling the worst-case scenario as required.

11.2 Meteorological data

Meteorological data is one of the most important components of a dispersion modelling assessment. The EPA AG4 Document (EPA, 2020) requires 5 years of meteorological data from a synoptic met station which has similar annual mean wind speed of the site, to be used in assessments. In this case, each year should be modelled separately rather than all 5 at once. From this, the year with the worst modelled output should be used. Where there is no comparable meteorological station, site specific meteorological data may need to be collected. When carrying out AA screening using SCAIL-Agriculture, conservative meteorological data should always be used. A modelling report should clearly state that conservative meteorology has been used if the SCAIL-Agriculture model has been used as part of AA Screening of emissions of ammonia.

The geophysical features that have the greatest influence on the meteorological parameters that affect dispersion are listed below. These need to be detailed for any meteorological station used in an assessment.

- Complexity of the terrain
- Proximity to elevated terrain
- Proximity to rivers (the orientation of river basins significantly affects local wind conditions)
- Proximity to the sea

11.3 Terrain

Terrain is an important consideration for atmospheric dispersion modelling as it alters how the air moves through the landscape. SCAIL-Agriculture excludes a terrain component, due to the required complexity (Hill *et al., 2014)*. Hill *et al*. (2014) goes on to state "*Intensive agricultural installations that would be included in the Industrial Emissions Directive would be likely to require detailed modelling to account for the influence of complex terrain."* This suggests that SCAIL-Agriculture was not intended to model facilities of this size, and detailed dispersion modelling should be required for these sites as a default. It is recommended that if the SCAIL-agriculture is used as part of AA Screening, the report clearly describes the local terrain of the modelling domain. If the site is in an area where terrain could affect dispersion the assessment report should clearly indicate why SCAIL-Agriculture result are suitable to consider the extent of impacts.

11.4 Land use

The use of land use data in the detailed dispersion modelling conducted as part of AA is a complex process that is underpinned by highly complex geo-meteorological and atmospheric turbulence theory. Due to the complex nature of land use and its integration into a detailed dispersion modelling assessment it is not appropriate to include the technical elements of land use as part of a high-level review. The land use data incorporated into a dispersion modelling assessment should be clearly described in the AA report. This should include:

- A graphical representation of:

    - The land use of the modelling domain
    - The land use data adopted as input for the dispersion modelling assessment.
    - The land use data adopted as input for the meteorological dataset generated for the dispersion modelling.
- A description that demonstrates the mechanism for the incorporation of land use into the dispersion modelling assessment.
- Justification for the land use parameters used in the context of the requirements of the EPA AG4 Document (EPA, 2020) and the requirements of best international modelling practice.

11.5 Background concentration & cumulative impacts

The EPA guidance "Assessment of the impact of ammonia and nitrogen on Natura 2000 sites from intensive agricultural installations" (EPA, 2021a) requires assessment of cumulative impacts if as part of detailed dispersion modelling (within an NIS) if the PC is > 1%. This cumulative assessment requires the summation of the proposed PC with other local PCs (the EPA guidance provides specifications for which developments to include). The EPA currently consider a cumulative PC of ≤20% to represent contributions below which a significant ecological effect will not occur.

A study by Natural Resources Wales (Aazem *et al*., 2015) identified that smaller (below IED threshold) farms had a greater impact on local concentrations of ammonia when compared to regulated facilities.

A representative background concentration should also be adopted in the modelling assessment to account for emissions from non-intensive agricultural installations and activities. Cognisance needs to be given to input data used to generate any national models, while the inclusion of modelled EMEP concentrations from 2018 in SCAIL-Agriculture is a welcome advancement, it should be noted that this model apportions 2018 emissions to the locations of pig and poultry farms in 2015, and the location of cattle and sheep in 2010.

Any modelling conducted should clearly:

- List all intensive agricultural farms (licenced and unlicenced) included in the dispersion modelling assessment.
- List the source parameters used to configure these farms and the sources on these farms in the modelling assessment.
- Justify a background concentration of ammonia that is representative of other agricultural activities such as land spreading, dairy/beef production, *etc.*

11.6 Assessment criteria

It is likely for critical loads and critical levels to vary across Natura 2000 sites especially sites with a range of spatially varying land uses and ecosystems. An example of this is designated riparian sites where the qualifying interests of the site vary at different points along the river course. The SCAIL-Agriculture model determines the qualifying interest with the lowest critical load or critical level and this is assumed for the entire spatial extent of the site. This approach is conservative and is considered acceptable for AA Screening.

It is recommended that the assessment criteria be considered in more detail for plans or projects that require detailed modelling as part of AA. In this instance the criteria required to protect the qualifying interest of the Natura 2000 Site should be adopted. An ecologist should clearly define if the species and habitats protected under the EU Birds and Habitats Directives at a Natura 2000 site (qualifying interest), the habitat containing the qualifying interest, or both need to be protected and the critical load or critical level that needs to be achieved to protect the qualifying interest.

The use of percentages of critical loads or levels below which 'likely significant effects' as a basis for AA will continually be reviewed by the scientific community to:

- Ensure the percentages adopted protect the qualifying interest(s) on Natura 2000 sites
- The approach does not result in the approval of multiple developments with 'insignificant impacts' when assessed in isolation, that contribute to exceedances of relevant thresholds when assessed as part of a cumulative assessment

It is up to regulatory bodies such as EPA, NPWS, NRW, SEPA, *etc.* to enforce any updates to scientific knowledge on the appropriateness of these thresholds in practice. If the critical criteria approach is used systematically to approve developments, the limitations of such an approach should be understood to ensure that the system delivers results that ensures compliance with the requirements of the Habitats Directive. This means that a systematic approach itself should be subject to AA prior to adoption or approval.

11.7 Treatment of deposition

A method for the calculation of deposition flux to consider the impact of developments on critical loads is described in Appendix F of the EPA AG4 Document (EPA, 2020). It calculated the deposition flux as the product of the predicted PC and the deposition velocity. A table of recommended deposition velocities are provided for a range of chemical species and different land uses in in Appendix F of the EPA AG4 Document (EPA, 2020). It is recommended that the values published in this table be adopted in dispersion modelling assessment that underpins both AA Screening and AA.

The dispersion modelling report should clearly articulate:

- The dry deposition velocities for each sensitive location being assessed
- The context of the dry deposition velocities adopted considering height of the vegetation at the sensitive location

11.8 Overview

This section provides an overview of the important components of a dispersion model configured for the assessment of impacts from an IAI and a simple set of questions that together provide a framework for a high-level review of a dispersion modelling report for people with limited dispersion modelling experience. The Framework is presented in Figure 7 and Figure 8. Although this framework is developed for IAI many of its requirements and principles are relevant to dispersion modelling assessments undertaken for other sources of ammonia. EPA AG4 provides a more comprehensive set of instructions that should be referred to in addition to this framework when reviewing a dispersion modelling assessment undertaken for IAI or other types of facilities.

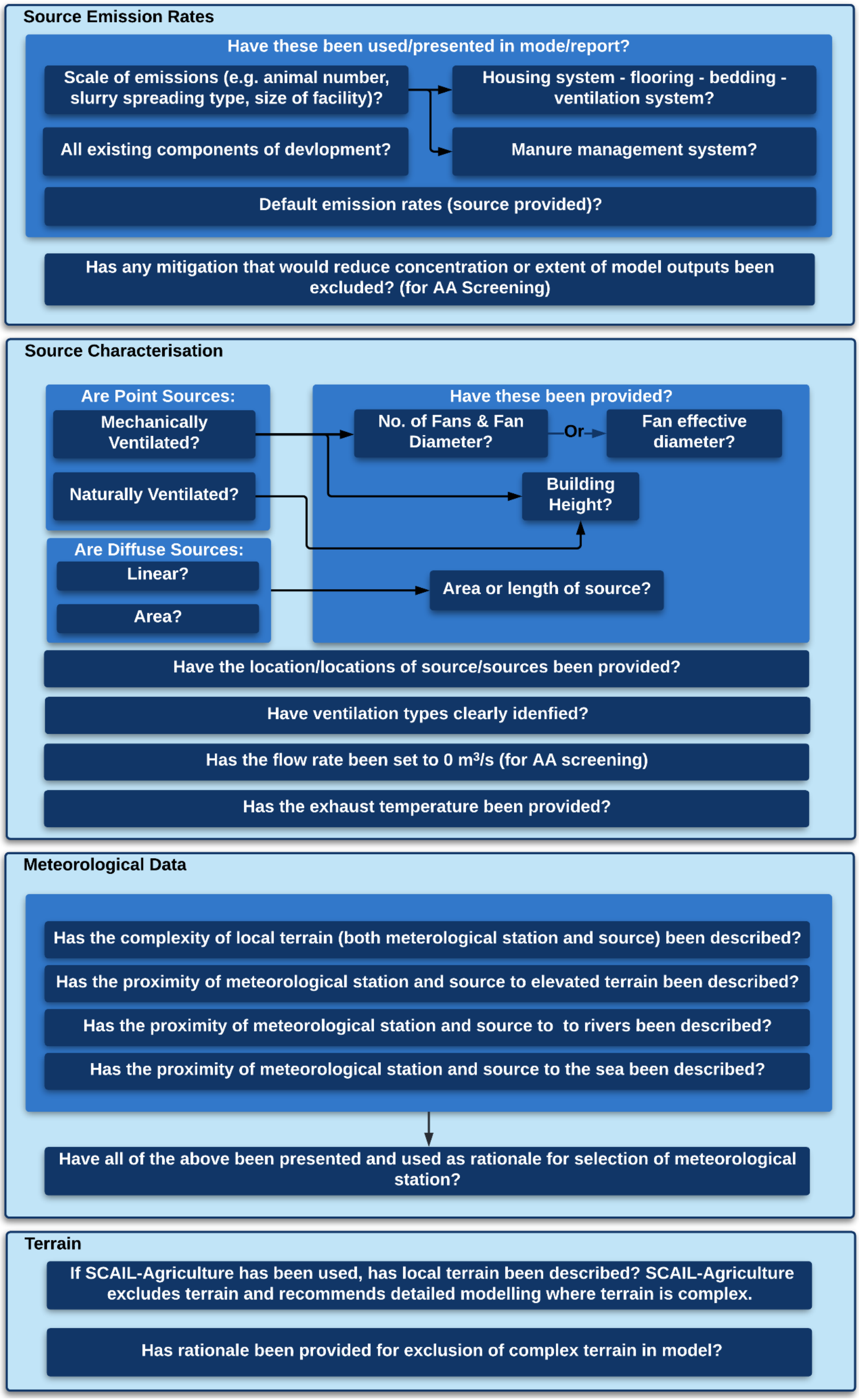

Figure 7 Part 1/2 – Summary of modelling requirements for IAI.

Figure 8 Part 2/2 – Summary of modelling requirements for IAI.

12 Summary AA process

The approach currently outlined by the EPA to assess contribution to potentially significant negative effects from atmospheric ammonia to Natura 2000 sites from IAIs is summarised in Figure 9 below. This figure should only be used in tandem with the full report and guidance issued by the EPA (EPA, 2021a). It is intended that this guidance will be reviewed and potentially updated annually, hence it is important to check currently available guidance at the time any applications are being reviewed. While EPA guidance is intended solely for above IED threshold facilities (40,000 birds or 2000 finisher pigs / 600 sows) it should be considered for other sources of ammonia, principally sub-IED threshold facilities but also potentially contributions from slurry spreading or cattle,

AA Screening should always adopt conservative inputs (baseline levels, meteorological data, emission rates and source parameters) and each input should be clearly justified as being conservative in the AA screening report. SCAIL-Agriculture should only be run using conservative meteorological inputs. The inclusion of mitigation measures as part of a project proposal cannot be considered in the dispersion modelling that underpins AA screening. In the context of agricultural emissions, measures to reduce the impact of emisisons such as the use of ventilation stacks to increase stack height or the use of fans to exhaust emissions vertically to reduce impacts should not be considered in the dispersion modelling that underpins AA Screening. While the EPA approach does not require cumulative assessment as part of AA Screening (it does however consider sites already exceeded and those currently noted to be receiving cumulative impacts), it is recommended that cognisance be given to existing, new and proposed facilities. This is important to avoid "baseline creep" where over time the addition of multiple below threshold facilities could result in local threshold exceedances.

The baseline concentrations of ammonia vary considerably across Ireland. The spatial variation of which is also significantly higher in close proximity to hotspot sources. Consultants should clearly articulate the limitations of any national baseline model from which background concentrations of ammonia are extracted as part of a modelling assessment. The current (November 2021) SCAIL-Agriculture model accounts for below and above threshold pig and poultry farm developments up to 2015 and the distribution of cattle and sheep in 2010. While the model has been updated to represent 2018 emissions, it lacks the locations of any developments since the generation of these model inputs. It is important that any future updates to models are detailed, as the date of model components are likely to vary. Even application of the updated 1 x 1 km grid EMEP model (and any available national models) fails to accurately represent high concentrations directly proximal hotspot sources, hence recommendation in current EPA guidance to immediately screen in assessments within 500 m of a Natura 2000 site. All presumptions of models used should be outlined in all modelling assessments. Where background concentrations do not account for local hot-spot sources of emissions, these can be included directly in the dispersion modelling assessment. Detailed dispersion modelling can be used to determine if proposed mitigation measures are sufficient to reduce the magnitude of impacts to acceptable levels.

Determining the level of additional ammonia concentration or nitrogen deposition that is insignificant is complex. Critical criteria approaches across Europe adopt percentages of the critical load/level below which additional contributions are considered inconsequential. These are discussed in Section 7 of this report. Figure 9 refers to "inconsequential" thresholds which have been selected by the EPA. These thresholds are not based on scientific evidence but provide a reasonable means to estimate potential contributions to significant effects. These may be updated in the future as scientific evidence develops in this field. For AA screening using SCAIL-Agriculture (with conservative meteorology, a ventilation rate of 0 m^3/s, exclusion of stack height (use roof height)) the EPA recommend a threshold of ≥4% for critical levels or ≥5% for critical loads. Additionally, a threshold of 0.3 kg/ha/year is recommended for contribution to total nitrogen deposition. Where if a developments PC is below these thresholds, > 500 m from a Natura 2000 site, the Natura 2000 sites within its zone of influence are not already exceeded and the development is not within 10 km of specific Natura 2000 sites, the development can be screened out. If the development cannot be screened out, a full detailed NIS is required. The EPA will allow the use of SCAIL-Agriculture in a detailed NIS allowing for inclusion of ventilation rate, potential alteration of exhaust diameter and inclusion of stack height. These are the only modifications permitted to SCAIL-Agriculture models used as part of a detailed NIS, where the same thresholds from screening can still be applied. If modelling still indicates an exceedance of these thresholds, a detailed dispersion model (*e.g.* AERMOD, ADMS, *etc*.) is required where an exceedance threshold of 1% for both critical levels and loads is required. This is due to the model no longer being conservative, allowing for inclusion of meteorological data following AG4 guidance. If this 1% threshold is exceeded, the EPA require a cumulative assessment where the PC from proposed development and other PCs (see EPA guidance which details PCs required for inclusion) (EPA, 2021a). If the cumulative PC is ≤20% the development is considered to not have a significant effect on the Natura 2000 site (though cognisance should be given to the concentration and deposition across the site). If the development's cumulative PC exceeds 20% it is required for them to review control measures to reduce emissions and subsequent impacts. However, the EPA state that if the development is an extension to an exisitng source; if the total emissions inclusive of extension can be reduced during this development that may be sufficient for approval. This would likely be on a case by case basis and the extent by which emissions could be reduced.

While it is recommended that qualifying IAI developments follow the EPA stepwise guidance, it is possible for developments which fall outside this remit (sub IED threshold facilities, cattle farms, landspreading, *etc*.) to include detailed dispersion modelling (*i.e.* AERMOD, ADMS, *etc*.) in an AA screening model, provided the same restrictions regarding ventilation rate, stack height, *etc.* are applied. In this case, because detailed dispersion modelling is being used it is recommended that a 1% threshold be applied due to the conservative nature of SCAIL-Agriculture modelling. Ideally all sources being developed should maximise emissions reductions and thereby impacts.

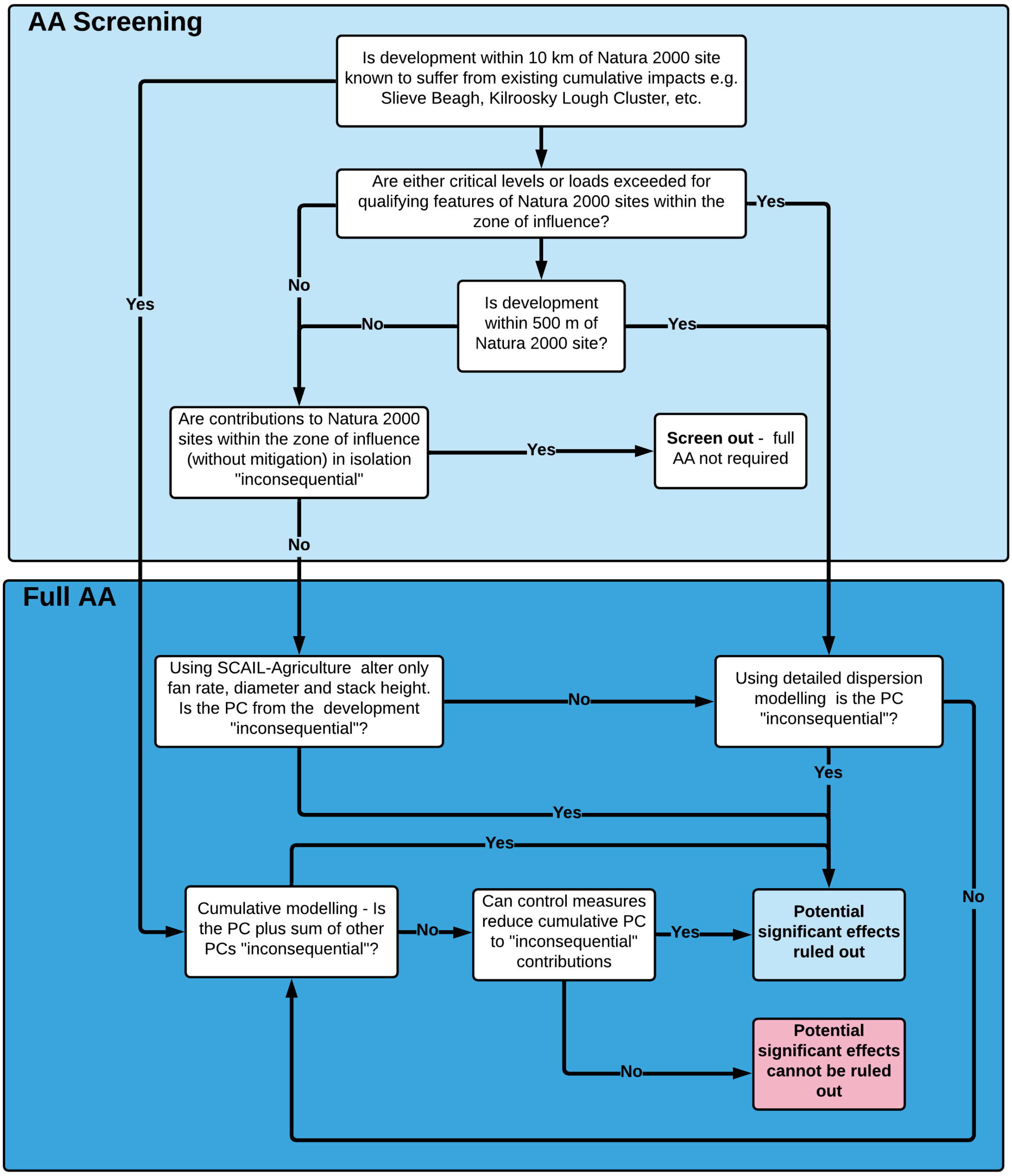

Figure 9 Summary of recommended steps for AA process based on EPA guidance.

13 Conclusions

This Irish Wildlife Manual draws a number of conclusions from the review of practices, relevant legislation and academic research in relation to identifying and assessing ecological impacts from reactive nitrogen. These conclusions are summarised below:

- This document supports the critical criteria approach developed by the EPA to assess impacts from atmospheric ammonia, to best comply with requirements of the Habitats Directive.
- A critical criteria approach is the easiest method to incorporate into AA screening in Ireland. However, this approach hinges on the definition of "*de minimis*" contributions from a source. There is much debate on this matter, with various values applied across UK and Europe. The Joint Nature Conservation Council currently have an ongoing project to better define this value in the UK and its progress should be monitored by interested parties. This critical criteria approach does not consider existing impacts or contributions from other sources, thereby not considering cumulative impacts on Natura 2000 sites. While this method is recommended, an integrated approach such as that being considered for use in the Netherlands should be the ultimate goal.
- The use of percent thresholds to represent "*de minimus*" contributions to a Natura 2000 site will need to be reviewed at least annually in line with EPA's internal review of guidance. As these figures are not based on scientific evidence, when such evidence presents itself either nationally or internationally it will need to be considered when defining these thresholds for impacts.
- It is vital that "baseline creep" is avoided and that cumulative assessments adequately identify cumulative contributions to Natura 2000 sites. Sources in isolation may not contribute to significant impacts, but overtime new additional sources can eventually cause an exceedance of critical levels and/or loads.
- Background ambient concentration and deposition modelling needs to be conducted to represent the current distribution of cattle and sheep alongside up to date locations of above and below IED threshold pig and poultry farms.
- Irish dispersion modelling guidance requires that atmospheric dispersion modelling undertaken as part of the approvals process must be documented and replicable. This includes the provision of and rationale for all parameters used as model inputs, modelling input files and resulting model output files.
- Based on recommendations from the CJEU, all exogenous sources of reactive nitrogen need to be considered when conducting AA. In the Netherlands the CJEU highlighted the need for assessment of emissions from grazing cattle and land spreading of slurry. In Ireland, this recommendation should be expanded to include assessment of reactive nitrogen emissions from cattle housing and below-IED-threshold pig and poultry farms. It is recommended that assessment of these sources could form part of site-specific nitrogen management plans for Natura 2000 sites. Input should be sought from the Department of Agriculture, Food and Marine to develop such plans, to focus on how existing impacts can be reduced and highlight where there is room for further development.
- A better understanding of nitrogen pollution across Natura 2000 sites in Ireland is required. Where the NEMN will support this, additional atmospheric monitoring should be considered to reflect impacts across the Natura 2000 network of designated sites.
- When selecting critical criteria by which to gauge negative effects of nitrogen deposition, the authors recommend selecting the lower of either the vegetation community change points or empirical critical loads. Where empirical critical loads are used, the appropriate end of the scale should be selected with reasoning for its selection provided. In some cases, it may be appropriate to apply the higher end of the range. Reasoning should be based on Bobbink & Hettelingh (2011) and any subsequent critical load reviews.

- Additionally, the opinion of the EC in relation to the Dutch Nitrogen Case (C 293/17 & C 294/17) (CJEU, 2019) highlighted that if a Natura 2000 site is already in exceedance of its critical level or load, any additional contribution could be deemed as a significant effect on the site. It specifically noted that even a contribution below 0.0014 kg N/ha/year could be termed a significant effect if the site is already impacted (Anker *et al*., 2019). It is therefore essential when assessing for potential impacts to a Natura 2000 site that both the ambient concentration and deposition are understood, in addition to any neighbouring emission sources, intensive or otherwise. Modelling and monitoring should be conducted in order to better understand background levels, and the existing contribution of sources to impacts across Natura 2000 sites. These could be integrated to provide references for SEAs of Local Authority Development Plans.
- The CJEU has highlighted it is not appropriate to include mitigation, or any measure to wholly or partially reduce potential impacts with the AA screening process. In the context of atmospheric emissions of ammonia from intensive agriculture, this judgement means that measures that are intended to reduce the loss of ammonia to the atmosphere should not be included when conducting AA screening. Measures not to be taken into account can include "Best practice measures", which may not be regarded as "mitigation measures" by practitioners. The intended purpose of measures needs to be determined objectively.
- Consideration should be given to the development of support tools for ecologists and regulators dealing with impacts from reactive nitrogen. The integration of Irish Natura 2000 sites into the APIS in the UK would be an ideal first step, providing site specific information for future developments. Additionally, the AERIUS tool (used within the Netherlands as part of their integrated approach) is currently being developed for application in the UK. The authors of this manual highly recommend developing this tool for Ireland. AERIUS could act as database for emission sources, which is also required.
- Much nitrogen deposition work focuses on direct impacts to vegetation, hence the application of critical load considerations to Annex I habitats. There are also species for which SACs are designated that are potential recipients of trophic or secondary impacts. Trophic impacts of nitrogen deposition are poorly understood and have potential to influence the conservation objectives of certain species. Research has begun to link nitrogen deposition with a loss of invertebrates (Feest *et al*., 2014; Wallisdevries & van Swaay, 2006), and future work is required to link this with food availability for certain animal and bird species protected within the Natura 2000 network. This absence of available evidence should require the adoption of the precautionary principle, where the critical loads and levels for habitats which species occupy should be applied.
- Work is also required to quantify the effect of nitrogen deposition on the role of peatlands as carbon sinks in Ireland, alongside plans to maximise their ability to function as carbon sinks. Such work could be achieved through linking functions of the NEMN with ICOS carbon flux monitoring programme currently setting up sites in Ireland.

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Appendix 1 Empirical critical loads & species community change points

Table A1 below lists Habitats Directive Annex I habitats occurring in Ireland, alongside relevant critical loads from Bobbink & Hettelingh (2011) as applied through the UK's Air Pollution Information System (CEH, 2016). Community Change Points developed by Wilkins *et al*. (2016), where currently available, are presented also presented alongside relevant Annex I Habitat. These community change points are currently in development to be applied to further Irish Annex I habitats (Aherne, *et al*., 2021). The EPA currently requires the use of vegetation community change points, where available.

Table A1 Annex I Habitats, critical loads and vegetation community change points in kg N/ha/year.

Annex I Habitat	Critical load	Vegetation community change point
Active raised bogs [7110]	05-10	
Alkaline fens [7230]	15-30	
Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae) [91E0]	-	15.3
Alpine and Boreal heaths [4060]	5-15	5.5
Annual vegetation of drift lines [1210]	-	
Atlantic decalcified fixed dunes (Calluno-Ulicetea) [2150]	10-20	
Atlantic salt meadows (Glauco-Puccinellietalia maritimae) [1330]	20-30	
Blanket bog (*active only) [7130]	5-10	4.9
Bog woodland [91D0]	05-10	
Calaminarian grasslands of the Violetalia calaminariae [6130]	15-25	
Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii) [8120]	5-15	
Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae [7210]	15-30	
Calcareous rocky slopes with chasmophytic vegetation [8210]	5-10	5.7
Caves not open to the public [8310]	-	
Coastal lagoons* [1150]	20-30	
Decalcified fixed dunes with *Empetrum nigrum* [2140]	10-20	
Degraded raised bogs still capable of natural regeneration [7120]	05-10	
Depressions on peat substrates of the Rhynchosporion [7150]	10-15	
Dunes with *Salix repens* ssp. *argentea* (Salix arenariae) [2170]	10-20	
Embryonic shifting dunes [2110]	10-20	
Estuaries [1130]	20-30	
European dry heaths [4030]	10-20	4.1

Fixed coastal dunes with herbaceous vegetation (Grey dunes) [2130] (Acid Type)	08-10	
Fixed coastal dunes with herbaceous vegetation (Grey dunes) [2130] (Calcareous Type)	10-15	
Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. [3140]	-	
Humid dune slacks [2190]	10-15	
Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels [6430]	5-10	
Juniperus communis formations on heaths or calcareous grasslands [5130]	10-20	4.8
Large shallow inlets and bays [1160]	-	
Limestone pavements [8240]	05-10	
Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*) [6510]	20-30	7.5
Machairs [21A0]	10-15	
Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi) [1420]	20-30	
Mediterranean salt meadows (Juncetalia maritimi) [1410]	20-30	
Molinia meadows on calcareous, peaty or clavey-silt-laden soils (Molinion caeruleae) [6410]	15-20	6.3
Mudflats and sandflats not covered by seawater at low tide [1140]	-	
Natural dystrophic lakes and ponds [3160]	3-10	
Natural euthrophic lakes with Magnopotamion or Hydrocharition-type vegetation [3150]	-	
Northern Atlantic wet heaths with *Erica tetralix* [4010]	10-15	4.9
Old sessile oak woods with *Ilex* and *Blechnum* in British Isles [91A0]	10-15	8.8
Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea [3130]	3-10	
Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae) [3110]	05-10	
Perennial vegetation of stony banks [1220]	08-15	
Petrifying springs with tufa formation (Cratoneurion) [7220]	15-25	
Reefs [1170]	-	
Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation [3270]	Not available	
Salicornia and other annuals colonizing mud and sand [1310]	20-30	
Sandbanks which are slightly covered by sea water all the time [1110]	-	
Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco Brometalia)(*important orchid sites) [6210]	15-25	8.3

Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes) [2120]	10-20	
Siliceous rocky slopes with chasmophytic vegetation [8220]	5-15	
Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsietalia ladani) [8110]	5-15	
Spartina swards (Spartinion maritimae) [1320]	20-30	
Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe) [6230]	10-15	3.9
Submerged or partly submerged sea caves [8330]	-	
Taxus baccata woods of the British Isles [91J0]	05-15	
Transition mires and quaking bogs [7140]	10-15	
Turloughs [3180]	Not available	
Vegetated sea cliffs of the Atlantic and Baltic coasts [1230]	-	
Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation [3260]	-	

Appendix 2 Components of a dispersion model – technical considerations

This section focuses on the input data used in dispersion modelling and the interpretation of model results. It lists and describes the important components of a dispersion modelling assessment and provides recommendations for a high-level review of each component. The recommendations and framework are based on:

- Modelling guidance published by EPA
- International best practice
- Recommendations made by the developers of dispersion modelling software.

In the context of dispersion modelling, the EPA AG4 Document (EPA, 2020) states:

…the reliability of results from dispersion modelling studies is dependent on many factors such as the robustness of the input data used in the model, the suitability of the model itself and the appropriate interpretation of the model results.

A complete technical review of a dispersion modelling assessment is a complex process that requires input from a qualified expert. The high-level review framework is intended for non-expert users and aims to provide a non-technical basis to understand whether the critical components of a dispersion modelling study meet the guidance issued by EPA in the Republic of Ireland.

The important components of a dispersion model include:

- Source emission rates
- Source characterisation
- Meteorological Data
- Geophysical data (land use and terrain)
- Background concentrations
- Cumulative assessment
- Assessment criteria
- Treatment of deposition.

Each of these components is discussed in the following sections in the context of Irish dispersion modelling guidance, international best practice and the requirements of the Habitats Directive.

Source emission rates

In relation to ammonia emission rates, the EPA AG4 Document (EPA, 2020) statements include:

- *"Errors in the emission rate can lead to large errors in the modelling results*
- *Emission rate (typically in g/s) – emission rates are directly proportional to modelled concentration (for inert pollutants) and thus any errors in emission rates will feed directly through to the final result;*

AA Screening

In the context of dispersion for AA Screening, the emission rates of ammonia adopted in the SCAIL-Agriculture model are considered appropriately conservative.

In 2017, the European Court of Justice handed down a judgement case C-323/17 after a request by the High Court (Ireland) for a preliminary ruling concerning the interpretation of Article 6 of the Habitats Directive as it relates to mitigation measures in the context of screening for AA. The following question was put to the Court for a preliminary ruling:

> *"Whether, or in what circumstances, mitigation measures can be considered when carrying out screening for AA under Article 6(3) of the Habitats Directive?"*

The European Court of Justice ruled that it was not appropriate to account for mitigation measures at the screening stage. Specifically, the court found:

> *"Article 6(3) of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora must be interpreted as meaning that, in order to determine whether it is necessary to carry out, subsequently, an AA of the implications, for a site concerned, of a plan or project, it is not appropriate, at the screening stage, to take account of the measures intended to avoid or reduce the harmful effects of the plan or project on that site.*
>
> *This judgement means that mitigation measures that are intended to reduce emissions of ammonia to the atmosphere should not be incorporated when conducting AA Screening."*

The emission rates calculated using the SCAIL-Agriculture model are based on the type and number of animals included in the dispersion modelling assessment and details about house design (*e.g.* fully slatted floors, naturally ventilated, mechanically ventilated, manure flushing systems). The dispersion modelling report should clearly:

- Identify the number of birds/animals included in the modelling assessment
- Describe the housing system used to hold birds/animals. The housing system described should match any design documentation submitted with the planning/licence application.

If the existing sheds at the site are not included in the screening assessment a clear, scientifically robust justification should be provided in the report (*e.g.* the existing sheds are considered in the modelled background (see Section on Background concentrations and Section on **Error! Reference source not found.**).

Detailed Dispersion Modelling

There is no specific guidance in Ireland on the emission rates of ammonia that should be adopted in a detailed dispersion modelling assessment. Careful consideration should be given when developing an ammonia emission inventory for intensive agricultural installations. Research has indicated that there are a wide range of emissions that vary depending on factors such as:

- Housing system used
- Partially/fully slatted floors
- The type of litter/bedding
- Ventilation system
- Manure management system
- Type of abatement

It is also relevant that the ammonia emission rate from intensive agricultural installations increase with increasing ventilation rate, which is heavily influenced by:

- The target temperature of the bird/pig (varies with bird/pig type and age)
- The ambient temperature (varies consistently with weather conditions, time of day and season *etc*.)
- The type of ventilation system (*e.g.* mechanical or natural ventilation)
- The number of pigs/birds in the building being ventilated

The generation and expulsion of emissions for intensive agriculture is a highly complex and many elements are not fully understood based on current research. This report does not aim to establish emission rates from intensive agricultural activities. The emission rates that are adopted in a detailed dispersion modelling assessment as part of AA, can be either:

- Consistent for each hour of the modelled year
- Time varying with emissions varying depending on:
  - Season
  - Ambient temperature/target temperature.

The dispersion modelling report should:

- Provide clear details of the source of the data that underpins the emission rate adopted for each source in the modelling assessment.
- Clearly justify why the emissions adopted in the modelling assessment are representative of emissions at the subject site. This should include details of some or all of following and how they compare for the subject site and the sites that underpin the emissions adopted in the assessment:
  - Housing system used
  - Partially/fully slatted floors
  - The type of litter/bedding
  - Ventilation system
  - Manure management system
  - Type of abatement

If time varying emissions are used, the report must clearly state:

- The emission rates adopted
- The reasons that the emission rates vary and how this has been incorporated into the model
- A scientifically sound basis for varying the emission rates (*e.g.*, by season, based on ambient weather conditions) and the research that justify why this is appropriate for the subject site

If the proposed development is an extension to an existing farm, the report should clearly state if the modelling:

- Only incorporates the proposed sheds and additional birds/animals
- Incorporates the existing and proposed sheds and existing and additional birds/animals

If the existing sheds are not included in the detailed modelling assessment a clear, scientifically robust justification should be provided in the report (*e.g.* the existing sheds are considered in the modelled background (see Section on Background Concentrations and Section on Cumulative Impact Assessments).

Source characterisation

AA Screening

The characterisation of emission points in the dispersion model that underpins AA Screening must consider:

- The fundamental requirements of dispersion modelling to ensure that the source characterisation is representative of the point of emission
- European Court of Justice case law (e.g. case C-323/17).

The SCAIL-Agriculture model requires basic information to represent emissions sources including:

- Point sources:
    - Building height
    - No. of Fans (optional)
    - Fan Diameter
    - Fan Flowrate
- Volume Sources:
    - Building height.

The SCAIL-Agriculture user guide states:

> *"Emissions from more than one installation can be modelled if, in the user's judgement, they are sufficiently close to each other or to a sensitive receptor that there is sufficient benefit in modelling the contribution from each facility.*
>
> *If the fans are located at roof level, the user will have an option to input a fan flow rate. If the fan flow rate is not specified then a default of 0 m3/s should be used as this will result in higher concentrations being recorded in the output and is therefore appropriate for a screening model."*

European Court of Justice case law (case C-323/17) ruled that it was not appropriate to account for mitigation measures at the screening stage. The configuration of SCAIL-Agriculture with measures aimed at mitigation of impacts of emissions must therefore be avoided. This includes the use of fans which mitigate the effects of emissions by increasing:

- The height at which emissions are released
- The effective plume height (due to mechanical and thermal plume rise).

In accordance with these requirements, it is recommended that SCAIL-Agriculture, used as part of AA screening, be configured with:

- The fan speed set to zero
- A building height that accurately reflects shed design documentation.

The dispersion modelling report needs to clearly state each of these values.

It should be noted that a lower air flow rate is more precautionary than higher flow rates. For example, a farm presuming its fans are continuously running at maximum ventilation will underestimate potential impacts. This is due to the model increasing the dispersal of ammonia thereby reducing its modelled concentrations. This is why as part of AA screening the EPA recommend using a ventilation rate of 0 m^3/s as this is the most precautionary ventilation rate to include in a dispersion model.

Detailed Dispersion Modelling

Source characterisation in detailed dispersion models is complex. To ensure a model produces a representative indication of impacts it is vital:

- That the sources are configured to accurately represent operations
- Where there is uncertainty, configuration using a conservative approach is adopted.

The configuration of a point source in a modelling assessment includes the following input data:

- Stack height
- Exit velocity
- Stack diameter at exhaust point
- Temperature
- An indicator of the use of a rain hats or mechanism that impedes the mechanical momentum of the plume.

The data entered to represent these parameters should be as accurate as possible and reflect:

- Building design
- Height of the stack above the building
- The type and model of fan that will be installed
- The target temperature of the animals or birds
- The use or absence of rain hats.

The exit velocity and diameter are combined to determine the airflow rate through the stack in a dispersion model. In agricultural buildings that airflow rate varies consistently to remove heat and air contaminants from the building. The airflow rate is an important component in determining the maximum height the plume rises to in the atmosphere before levelling off. It therefore has a significant effect on the level of impact that occurs downwind. The exit velocity should be set at a level that reflects the required airflow rate and as a minimum it should vary depending on season as follows:

- Winter – Stack velocity calculated based on an airflow rate set at 20% of the maximum airflow rate
- Spring and Autumn - Stack velocity calculated based on an airflow rate set at 50% of the maximum airflow rate
- Summer - Stack velocity calculated based on an airflow rate set at 20% of the maximum airflow rate.

The stack velocity can also be entered as an hourly varying parameter with the air flowrate varying based on the

- Target temperature of the birds/animals in the shed at the specific time of the growth cycle
- The ambient temperature of outside air.

Adopting such a method requires significant modelling expertise. The approach should be clearly presented in the modelling report with reference to the data and scientific literature that underpins the approach.

It is recommended that:

- The stack height be based on design documentation
- Exhaust exit velocity is varied with season as described in this section
- The type of fan and fan model is clearly identified in the report
- The capacity of the fan to exhaust air is clearly identified in the report

The temperature of the exhaust is also a key modelling input that is used to calculate the buoyancy of the plume upon release. It therefore is a key component of in the calculation of the maximum height of the plume. The exhaust temperature should be included in the modelling input file as:

- The minimum target temperature required over the course of the growth cycle of the birds/animals in the building
- A variable that changes with time to reflect the differences in the target temperature required by the birds/animals as it changes over the course of the growth cycle.

The use of varying temperatures in a modelling assessment to reflect the differences in the target temperature required by the birds/animals as it changes over the course of the growth cycle requires significant modelling expertise. If such an approach is adopted it should be clearly presented in the modelling report with reference to the data and scientific literature that underpins the approach. The target temperature of the animals/birds should be clearly stated in the modelling report. The target temperature should be referenced to published data for the type and breed of animals/birds as published by organisations such as Teagasc or the suppliers of day-old poultry birds.

Meteorological data

Meteorological data is one of the most important components of a dispersion modelling assessment. In relation to meteorological data AG4 states:

> *"The dispersion process is dependent on the underlying meteorological conditions and ensuring that the air dispersion model includes representative meteorological data is critical.*
>
> *The USEPA[21] has defined meteorological representativeness as:*
>
> > *"the extent to which a set of {meteorological} measurements taken in a space-time domain reflects the actual conditions in the same or different space-time domain taken on a scale appropriate for a specific application""*

The guidance in relation to meteorological data is summarised as follows:

> *"Five years of meteorological data from an appropriate station should be used in the assessment. The station should be the nearest one that has a similar annual mean wind speed (preferably between 0.9 – 1.1 of the site annual mean wind speed).*
>
> *The most recent year of the five-year dataset should be within the last ten years (i.e. for an assessment undertaken in 2019, the oldest 5-year dataset should be 2005 – 2009).*

> *When modelling using multiple years of data each year should be individually reported rather than reporting the overall averages.*
>
> *For each relevant averaging period (99.8th %ile of 1-hour values, annual mean etc.) the highest result of any of the five years should be reported. It is likely that different averaging periods will have maxima in different years.*
>
> *Missing data should be replaced where feasible and the methodology employed detailed in the report alongside the frequency of calms, the conditions which lead to the highest ground level concentrations and any implications due to the level of missing or calm data (including corrections to the percentiles for short-term limit values).*
>
> *Prognostic meteorological data should be considered in locations where there is no comparable representative Met Eireann station particularly in areas of complex terrain or at a land / sea interface. "*

Site-specific meteorological monitoring may be required in particularly complex locations where there is no comparable representative Met Eireann station.

AA Screening

There are two approaches allowed when running the SCAIL-Agriculture model for the assessment of impacts namely:

- *Conservative Met* (conservative meteorology)
- *Realistic Met* (realistic Meteorology).

The SCAIL-Agriculture user guide states *"Conservative Met run mode must be used where reporting results for regulatory purposes"*. The use of conservative meteorology as part of a SCAIL-Agriculture modelling assessment is considered sufficiently conservative for the purpose of AA Screening. A modelling report should clearly state that conservative meteorology has been used if the SCAIL-Agriculture model has been used as part of AA Screening of ammonia emissions.

Detailed Dispersion Modelling

The generation and review of the meteorological data that underpins detailed modelling assessment is a complex process. These tasks should be undertaken by persons with the relevant skills, experience and expertise to ensure that the data used is representative and provides a scientifically robust approach to the prediction of impact downwind of emission release.

The technical modelling report is required to clearly articulate the reasons the:

- Meteorological data meets the requirements of AG4
- Is representative of meteorological conditions on the modelling domain

The geophysical features that have the greatest influence on the meteorological parameters that affect dispersion include:

- Complexity of the terrain
- Proximity to elevated terrain
- Proximity to rivers (the orientation of river basins significantly affects local wind conditions)
- Proximity to the sea

In relation to coastal influences on meteorological conditions AG4 states:

> *"Due to the proximity of many meteorological stations to the coast, the land/sea interface will be an important consideration. Installations located more than 10 kilometres from the coast may be more appropriately assessed with an inland station which may be further from the modelling domain than a nearby coastal station. Alternatively, it may be more appropriate to use prognostic meteorological data as outlined in Section 6.1.5."*

In addition to the guidance in relation to meteorological data published by EPA the technical modelling report should:

- Provide a description of the terrain features of the modelling domain and compare it to the terrain features of the meteorological station
- Describe the local terrain features such as hills and mountains in the context of effects on the observed meteorological data and justify why the data adopted in the assessment is representative of the modelling domain
- Describe the location of the monitoring station in relation to local rivers, and the orientation of valleys or terrain features that are likely to influence the meteorological observations to justify that the data used is representative of the modelling domain in the context geophysical features of the modelling location
- Discuss the proximity of the modelling domain to the sea and justify the choice of the meteorological data if:
    - The modelling domain is within 10 km of the coast
    - The meteorological station is within 10 km of the coast and the modelling domain is further inland

Geophysical data (Terrain)

In relation to terrain AG4 states:

The presence of terrain can lead to significantly higher ambient concentrations than would occur in the absence of the terrain feature. In particular, where there is a significant relative difference in elevation between the source and off-site receptors large ground level concentrations can result. Thus, the accurate determination of terrain elevations in air dispersion models is vital.

AA Screening

The SCAIL-Agriculture model for the assessment of impacts does not incorporate terrain data. The SCAIL user guidance states:

> *"SCAIL-Agriculture will not include terrain (topographical) effects due to the limitations in the availability and ease of use of such data for screening purposes. Complex terrain effects would be expected where terrain gradients of 1:10 or greater apply (Hill et al., 2007). Intensive agricultural installations that would be included in the Industrial Emissions Directive would be likely to require detailed modelling to account for the influence of complex terrain."*

It is recommended that if the SCAIL-agriculture is used as part of AA Screening, the report clearly describes the local terrain of the modelling domain in the context of the above statement.

AA

Terrain data in Ireland is freely and readily available for use in dispersion modelling assessments. It is recommended that detailed dispersion modelling assessments undertaken to underpin AA should incorporate terrain data. It is recommended that the AA report:

- Clearly indicate the source and resolution of terrain data used in the dispersion modelling assessment.
- Present the terrain data as a graphic that illustrates the range and complexity of the terrain on the modelling domain.
- Justifies the modelling approach in the context of the terrain of the modelling domain including its effect on:
    - Local meteorology
    - Predicted ground level concentrations and deposition rates

Geophysical data (Land use)

AA Screening

Land use in modelling assessment influences aspects of the model such as meteorological data and deposition velocities. The approaches to these components in SCAIL-Agriculture is considered conservative. In relation to deposition velocity the SCAIL modelling user guide includes the following statements:

> *"The updated SCAIL-Agriculture tool uses a simple approach of ignoring plume depletion and applying a land-cover-specific dry deposition velocity to the undepleted plume (as recommended by the EA Stage 1 guidance (EA, 2010)) and, therefore, it is not necessary to validate deposition processes. However, a review of land-cover-specific dry deposition velocities was necessary to ensure that the most appropriate values are used in the tool.*
>
> *SCAIL-Agriculture produces an estimate of the nitrogen deposition (and ammonia concentrations) at a certain distance downwind of the source, using a 'deposition velocity' specific to the habitat of interest. The model also estimates the potential for critical load exceedance at the nearest edge of the habitat, taking into account the background deposition at that location and the critical load of the habitat."*

If the SCAIL-Agriculture modelling approach is used to underpin AA screen no additional consideration of land use in the AA screening report is required.

AA

The use of land use data in the detailed dispersion modelling conducted as part of AA is a complex process that is underpinned by highly complex geo-meteorological and atmospheric turbulence theory. Due to the complex nature of land use and its integration into a detailed dispersion modelling assessment it is not appropriate to include the technical elements of land use as part of a high-level review. The land use data incorporated into a dispersion modelling assessment should be clearly described in the AA report. This should include:

- A graphical representation of:
    - The land use of the modelling domain
    - The land use data adopted as input for the dispersion modelling assessment
    - The land use data adopted as input for the meteorological dataset generated for the dispersion modelling
- A description that demonstrates the mechanism for the incorporation of land use into the dispersion modelling assessment.

- Justification for the land use parameters used in the context of AG4 requirements and the requirements of best international modelling practice
-

Background concentrations

The EPA AG4 Document (EPA, 2020) includes the following statements in relation to background concentrations:

> *"When modelling the release of pollutants from an industrial installation,- it is important to consider whether the specific pollutants are already present within the modelling domain and at what concentration. The process contribution (PC) from industrial sources should always be added to the appropriate background concentration (BC) in order to obtain the predicted environmental concentration (PEC).*
>
> *For pollutants regulated under ambient air quality legislation (such as NO_2, SO_2, PM_{10}, CO and benzene) sufficient information should be available from a range of representative monitoring stations operated by the EPA or Local Authority stations either within the modelling domain or at a location which would be expected to be exposed to similar levels of these pollutants.*
>
> - *The main considerations relating to background concentrations are:*
> - *Is existing data adequate or will site-specific monitoring be required?*
>
> *The guidance in relation to background concentrations is as follows:*
>
> - *The appropriate background concentration (BC) should always be added to the process contribution (PC) in order to obtain the predicted environmental concentration (PEC) with which compliance with the ambient air quality standards can be determined.*
> - *All available sources of background data should be reviewed for suitability prior to initiating a site-specific monitoring programme."*

The use of the background data should be undertaken with a high level of caution. This is especially true if locations with large numbers and/or a high density of:

- Intensive agricultural installations of both above and below IED thresholds
- Dairy farms
- Beef farms
- Land receiving slurry/fertiliser

It is vital that consultants carrying out assessments display an understanding of the components that make up any background concentration models used in an assessment. There is no model that will perfectly account for the high spatial variability of ammonia across the country. The currently used (February 2022) national concentration model integrated into SCAIL-Agriculture for Ireland is the best that has yet been produced. However, as highlighted within this Irish Wildlife Manual this has a number of limitations, namely;

- Cattle and sheep distribution are from 2010 CSO livestock census to which 2018 emissions were applied, likely to underestimate in some areas and overestimate in others
- Locations of pig and poultry farms both above and below IED threshold farms developed up to 2015 included. Though 2018 emissions were applied, locations with houses developed since then will be overlooked by the model

- The model averages emissions over 1 km^2 grid squares, and hence will miss out on local variation within that grid