Slurry Infrastructure Grant Air Quality Demand Layer (Round 1) Technical Documentation

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Evidence Quality Assurance:

This document is compliant with JNCC's Evidence Quality Assurance Policy
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The methods and outputs presented in this document have been developed with and approved by an expert group consisting of representatives from Arms-Length Bodies of DEFRA. The methods and outputs have also been externally peer-reviewed by a representative from the Agri-Food and Biosciences Institute.

Summary

This document sets out the methods proposed for and selected to identify the sites most vulnerable to ammonia emissions in England to prioritise the Slurry Infrastructure Grant's first round applications. The Slurry Infrastructure Grant, which DEFRA launched in October 2022, sets out to reduce ammonia emissions, a target within the Clean Air Strategy (DEFRA, 2018). Improving the infrastructure of slurry stores is an action that will directly reduce ammonia emissions and, thus, reduce exposure of habitats sensitive to ammonia that are close to slurry stores. The Grant is anticipated to be oversubscribed, therefore, it will prioritise projects based on environmental impact, where water and air quality are priorities for the benefit of local protected sites.

The selected approach identifies designated Sites of Special Scientific Interest (SSSIs) which have known features sensitive to ammonia emissions and that currently exceed the threshold at which adverse effects are known to occur, called their critical level. The method was chosen by an Expert Group made up of Air Quality specialists across DEFRA and its associated Arms-Length Bodies; the full rationale for its choice is outlined in the following sections. There are three notable limitations resulting from the selected method. First, a 2 km buffer zone has been applied around each sensitive site. Two kilometres might not encompass all ammonia emission sources that impact sensitive sites; however, this 2 km distance has been selected as a balanced decision for the first round of a targeted grant and the efficacy of emission reduction zones is supported by evidence such as the Nitrogen Futures project. Second, the method selected assumes that the most sensitive feature at a site is present across the entire site, for larger SSSIs this may overinflate the site's sensitivity. Third, there is a lack of critical level threshold information available for all SSSIs. This is either due to the absence of a survey of sensitive features or due to the need for site specific expertise to judge sensitivity. The implication of this is that the sensitivity of some SSSIs to ammonia emissions may be misrepresented, reducing the Grant's value for money.

With recognition of these limitations, but on balance as this approach uses an evidence-based method and the most recent data, the NE-led Air Quality Expert Group has approved and signed off the use of this methodology and the subsequent geospatial layer for use in the Slurry Infrastructure Grant.

This air quality layer will be overlaid with a layer identifying high priority areas for water quality developed by the Environment Agency; the area intersecting both layers will represent the priority locations for the grant. This document does not consider how the two layers could interact should the Grant need to prioritise actions beyond those which fall within the overlapping area.

Contents

1 Background

1.1 Slurry Infrastructure Grant

The Slurry Infrastructure Grant launched in October 2022, aims to improve slurry management, thereby both maximising crop nutrition and minimising nutrient losses into the environment. The Grant is being administered by the Rural Payments Agency, who in the event of oversubscription, “will prioritise projects that have the biggest environmental impact, focusing on those located near protected sites” (DEFRA, 2022). As environmental features that are sensitive to pollutants are spatially variable, the prioritisation of investment of slurry management near protected sites represents an opportunity for the grant to spatially target investment and thus deliver higher value for money.

Negative impacts from inadequate slurry management take two main forms: water pollution and atmospheric ammonia emissions. This document describes the approach to identifying areas where reduction of ammonia emissions is a particular priority.

1.2 Air quality in the context of the Slurry Infrastructure Grant

Air quality is a multi-faceted concept - there are different air pollutants, each with their respective sources and relative impacts on receptors such as people and the environment. In the context of the Slurry Infrastructure Grant the main pollutant of concern is ammonia (NH_3), which is harmful to sensitive habitats and also contributes to the formation of particulate matter – a secondary pollutant with significant negative effects on human health (Guthrie *et al.*, 2018). In the UK, 88% of ammonia emissions originate from agricultural processes such as the storage and spreading of manures, slurries, and fertilisers (DEFRA, 2018). The government has set a target of reducing ammonia emissions by 16% by 2030 (DEFRA, 2018). The Slurry Infrastructure Grant aims to contribute towards this target by reducing emissions from slurries, through contributing to the costs of constructing slurry stores and ensuring they have impermeable covers.

The impact of ammonia emissions on natural habitats is not spread evenly across the country, but varies due to two key factors:

1. **Pressure - The level of exposure of a habitat to ammonia and nitrogen deposition.** Modelled data are available from the UK Centre for Ecology and Hydrology (UKCEH) on both ammonia concentration levels and nitrogen deposition rates.
2. **Vulnerability - The level of sensitivity of different habitats to ammonia exposure and nitrogen deposition.** Data are available from UKCEH on sensitive habitats and protected sites across the UK, and their respective Critical Levels and Critical Loads.

Impact will be greatest where high levels of pressure (i.e. high ammonia concentrations) coincide with high levels of vulnerability (i.e. habitats that are sensitive to ammonia). These locations therefore provide the greatest opportunity to reduce those negative impacts by reducing atmospheric ammonia concentrations, through actions such as those being funded by the Slurry Infrastructure Grant.

Two metrics are commonly used to assess ammonia impacts on habitats – critical levels and critical loads. Critical levels are defined as "*concentrations of pollutants in the atmosphere above which direct adverse effects on receptors, such as human beings, plants, ecosystems or materials, may occur according to present knowledge*" (UN-ECE, 2004). Critical loads are *"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge*" (UN-ECE, 2004). In short, the critical level of a habitat relates to the gaseous concentration of the pollutant in the air, whereas the critical load relates to the quantity of pollutant deposited from the air to the ground. In England (2017 - 2019), 95.6% of nitrogen sensitive habitats had background nitrogen deposition loading above their critical load (Rowe *et al.,* 2021).

For critical levels, the following approach has been used to calculate demand, taking the spatial maximum concentration of ammonia across a site, and using the critical level of the most sensitive feature found at a given site:

$$Level\ of\ exceedance\ (\mu g/m^3) =$$

$$Atmospheric\ ammonia\ concentration\ (\mu g/m^3) - Critical\ level\ of\ site\ (\mu g/m^3)$$

For critical loads, the maximum average accumulated exceedance value has been taken directly from data produced by UKCEH. Exceedance is calculated using the average nitrogen deposition over a 3-year period. The maximum exceedance is taken from the most sensitive feature present across a site, as spatial locations of sensitive features within a site are not currently available. Please refer to the Trends Report 2021 (Rowe *et al.,* 2021: Section 1.3.2) for further details of how this value is derived. In short:

$$\text{Maximum Average Accumulated Exceedance (kg/ha/yr)} =$$

$$\frac{\text{Sum of maximum exceedance of a site} * \text{Maximum area of site exceeded}}{\text{Total area of the site}}$$

2 Method Development

2.1 Role of ‘NE-led Environmental Land Management Air Quality Expert Working Group’ in method proposal and selection

The method proposals listed here have been developed in collaboration with the NE-led Environmental Land Management Air Quality Expert Working Group (henceforth referred to as the NE-led Air Quality Expert Group). This group consists of air quality specialists from DEFRA, Natural England, JNCC and the Environment Agency. The group has advised on the development of methodologies to represent air quality in the Local Nature Recovery Spatial Prioritisation work since July 2021. This NE-led Air Quality Expert Group now works across DEFRA’s Future Farming and Countryside Programme, so the group also considers alternative approaches that may be beneficial for other DEFRA policies or requirements for air quality data. The group’s purpose has been to identify key datasets, propose approaches to use these datasets, review methods and generated outputs. The approaches explored by the NE-led Air Quality Expert Group consider previous approaches to spatial prioritisation, for example, those developed for Countryside Stewardship and Catchment Sensitive Farming, recent outputs from the Nitrogen Futures project, as well as novel methods.

2.2 Summary of methods considered by the NE-led Air Quality Expert Group

The Slurry Infrastructure Grant is explicitly focusing on protected sites in its first round of applications. As outlined above, two fundamentally different approaches to ammonia emissions and deposition have been explored – critical levels and critical loads (Table 1).

The NE-led Air Quality Expert Group recommends that prioritisation should focus on protected sites that have features that are sensitive to nitrogen deposition or exposure to ammonia, and where nitrogen deposition/exposure to ammonia exceed the relevant critical load/critical level. The protected sites used are SSSIs; these form the basis for all other terrestrial protected sites in England, meaning that this approach also covers these other designations. Habitats outside of protected sites are not being included for the first round of the Slurry Infrastructure Grant, although the group is considering methods to add these habitats in to later prioritisation iterations.

The group considered three possible levels of site vulnerability to include, and combined with the two different metrics (critical levels and critical loads) this gave four options for assessing the level of priority of ammonia emissions reduction around each site:

1. Include all sensitive sites – this approach includes all SSSIs that are designated for features (i.e. habitats or species) that are sensitive to atmospheric ammonia or to nitrogen deposition, regardless of whether the critical level/critical load is currently being exceeded.
2. Include sensitive sites where the atmospheric ammonia exposure exceeds the critical level of the protected features.
3. Include sensitive sites where the rate of nitrogen deposition exceeds the critical load of the protected features.
4. Include sensitive sites where the rate of nitrogen deposition exceeds the critical load for at least some of the protected features and local agriculture has been identified as a significant contributor to this exceedance (>40% N deposition due to local agriculture). Note that this option does not have a critical level equivalent as source attribution data for atmospheric ammonia is not available.

2.3 Approach selected for first round of the Slurry Infrastructure Grant

For the first round of the Slurry Infrastructure Grant applications, the NE-led Air Quality Expert Group have selected the following method as the most suitable for identifying priority areas for Grant applications: sensitive sites where the atmospheric ammonia exposure exceeds the critical level of protected features.

The NE-led Air Quality Expert Group has proposed and agree to the use of the final methodology for specific use in the Slurry Infrastructure Grant. Any future use of this proposed methodology must receive approval from the NE-led Air Quality Expert Group to ensure data are used appropriately. For instance, the group suggests further rounds of funding should consider possible future developments to the layer, such as the addition of Site Nitrogen Action Plans and sensitive SSSIs currently not exceeding their critical level. However, any update is expected to follow the same broad method chosen. Therefore, the grant's use of this layer in round one of applications should allow for iterative progress upon this approach, rather than encouraging the proliferation of conflicting methodologies.

The selection criteria used by the NE-led Air Quality Expert Group when making this decision, limitations in the layer's use, and full details of how the layer was generated are detailed in the following sections.

2.3.1 Considerations, implications, and limitations arising from use of a critical levels or critical loads approach

The Air Quality Expert Working group were mindful of several factors when selecting between a critical level or load approach, summarised in Table 1. Ultimately, a critical level option was chosen because critical level exceedance explicitly focuses on ammonia emissions, of which 88% are produced by the agricultural sector, and improving slurry storage is an action which directly curbs agricultural ammonia emissions (DEFRA, 2018). Unlike Nitrogen deposition which can be the result of long-range transport, exposure to ammonia emissions is associated with close proximity to the source of emissions. Additionally, the critical levels are based on the most up to date information available for UK habitats, which clearly represents the most relevant information thus enabling the grant to maximise value for money. Nonetheless, these data may change, especially in the context of climate change, so future uses of this layer should consider any updates to critical level information that may be available.

The critical level exceedance approach is based on the most sensitive feature for an SSSI recorded in the APIS dataset and assumes the most sensitive feature is found across the entire site. This means that some locations within an identified site may have lower levels of exceedance than the layer represents, which could reduce the impact of the grant upon improving habitat condition. However, the NE-led Air Quality Expert Group took this risk-averse approach to ensure protected areas are prioritised as desired by the Grant given the lack of other data that more precisely locates sensitive features.

Some sites and features miss critical level information or state that further assessment from local site experts may be required. Where site expertise was suggested (673 sites), a critical level of 3ug was assumed. The expert group felt this was a balanced decision between overestimating sensitivity for a large number of sites and removing them entirely by assuming they are not sensitive. More information about the implications between selecting a critical level and critical load approach, particularly the number of SSSIs which would have been initially eligible for the Grant, can be found in Appendix 2's table.

2.3.2 Considerations, implications, and limitations arising from the selection of vulnerable sites

The option containing only SSSIs currently exceeding their critical level was chosen as these represent the areas with the highest demand for interventions, making 2146 sites eligible for grant (Appendix 2's Table). As the first round of the grant is expected to only be able to fund a limited number of applications, the expert group decided a higher level of spatial targeting was required. Evidently, this approach assumes prioritisation of funding should be directed to sites exceeding their critical levels. This decision by the expert group to not prioritise sites which are in decline and may be at risk of exceedance has been made with the knowledge this is the first round of funding for slurry stores. Therefore, the expert group would advocate the exploration of widening the selection criteria for future grant rounds. For instance, non-designated habitat areas were not included here, yet there are areas that nonetheless are impacted by air pollutants. Should the scheme's focus expand upon its initial concentration on sensitive protected habitats, these non-designated could be a route the grant could explore to improve its value for money.

Table 1. Comparison between critical level and critical load approaches and the considerations made by the Air Quality Expert Working Group in their method selection for the Slurry Infrastructure Grant's first round of applications.

Consideration	**Critical Levels**	**Critical Loads**
Uncertainties in exposure estimate	Fewer factors/variables involved so less complex. But is associated with lower uncertainty in exposure estimates than a deposition-based measure (derived from deposition velocities and wet/dry deposition).	Using deposition introduces additional uncertainties both in terms of deposition velocities and atmospheric chemistry.
Targeting slurry storage actions – focus on nutrient pollution	More directly relates to farm emissions compared with deposition and critical loads. Does not rely on source attribution data. So, sites with high ammonia levels *assumed* to have significant local agricultural emission sources, given that 88% of the UK's ammonia emissions are produced by agriculture.	Utilises source attribution dataset, which is from 2012 and is at 5x5 km resolution – with associated temporal and spatial uncertainties. A critical load-based demand map also accounts for other air pollutants contribution to N deposition. This may be less relevant to slurry storage grant which is specifically targeting ammonia emissions.
Area Coverage	Layer covers a smaller area than critical loads (36.8% of England), and misses some terrestrial areas designated as SPAs, SACs or Ramsar sites. Very few areas not already covered by the critical load layer.	Layer covers larger area than critical levels (41.8% of England) and covers almost all terrestrial areas designated as SACs, SPAs or Ramsar sites
Data availability	Data openly available from APIS Partners and UKCEH. Ammonia concentration data is modelled by UKCEH using the EMEP4UK model at 1x1 km spatial resolution, giving average ammonia concentrations over a three-year period (2017-2019: the latest data available). Critical level information has been generated by APIS partners and is from 2017. Exceedance is generated manually.	Data openly available from APIS partners as generated for the N futures project. Critical load exceedance is calculated directly by UKCEH using deposition data at 1x1 km resolution and averaged over a three-year period (2016-2018). Source attribution data is also available from APIS but is at 5x5 km resolution and is from 2012.

SSSI datasets	Based on most recent SSSI dataset from 2021.	Based on 2017 CL exceedance dataset (N futures), this means any changes to the SSSI dataset since 2017 are not included.
Further prioritisation by Slurry Infrastructure Grant	More challenging to perform further prioritisation of sites if needed by the Grant team. Arbitrary thresholds could be set to screen out locations below a certain level of exceedance or the buffer sizes around exceeding sites could be altered.	Could use the source-attribution data in combination with exceedance figures to further prioritise sites for applications, but given this dataset is 10 years old this may not be the most suitable dataset for attribution.
Communication and understanding	Relatively straight-forward to understand and communicate.	More difficult to explain, especially because of considering both reduced and oxidised forms of nitrogen.
Multiple CL per site – assumption that most sensitive feature covers whole site	Interest features are either not sensitive or have 1µg/m^3 or 3µg/m^3. There could be a range of sensitivity for across the site interest features. As there is no mapping of interest feature location on site therefore the approach assumes the most sensitive feature is present across the whole site. This is a precautionary approach but could distort the true risk to the site. This is usually likely to be more problematic in large sites.	There are multiple critical loads. There could be a range of sensitivity for across the site interest features. There is no mapping of interest feature location on site therefore the approach assumes the most sensitive feature is present across the whole site. This is a precautionary approach but could distort the true risk to the site. This is usually likely to be more problematic in large sites. This problem is greater for critical loads than levels because of the broader suite of critical load values available, and therefore potential for greater variation between site features.
Emissions inventory estimates	Any potential error in emission estimates would impact both assessment of critical loads and critical levels exceedances, but a critical level approach may be more sensitive to this as it solely relies on ammonia concentrations. However, models are calibrated using measurements, so the extent of the issue is uncertain.	This potential error in emission estimates would impact on both our assessment of critical loads and critical levels exceedances.

2.3.3 Considerations, implications, and limitations arising from buffer size selection

For mobile pollutants such as slurry in waterways and ammonia emissions, buffer zones help ensure that sources most likely to impact a particular protected area are made eligible for the Grant. The buffer distance of 2 km applied to all sites chosen by the expert group was based on their expert judgement and previous evidence from Nitrogen Futures (Dragosits *et al.,* 2020). This targeted approach identifies a suitable local area, within which actions to reduce ammonia emissions would reduce the likelihood of a sensitive SSSI exceeding its critical level. This will improve the condition of the natural capital asset, its ecosystem function and hence the services it can provide to people. Spatial targeting through emission reduction zones has also previously been associated with greater cost-benefit ratios (Dragosits *et al.,* 2020), clearly beneficial for the grant.

Projects like Nitrogen Futures demonstrate that uniform rules such as a 2 km buffer zone may not be appropriate for all sources of ammonia emissions, or all receptors impacted by those emissions (Dragosits *et al.,* 2020). However, the Slurry Infrastructure Grant is one approach to facilitate the reduction of ammonia emissions, other schemes or policies within the Future Farming and Countryside Programme will assist in these reductions or mitigate their impact. The final Slurry Infrastructure Grant target areas will represent the area of overlap between water quality and air quality priority areas. The expert group therefore felt this 2 km buffer zone was an appropriate, evidenced-based compromise to ensure a sufficient number of prospective first round applicants are within the final target areas, whilst still targeting the most vulnerable protected areas, should the Grant be oversubscribed. The group advised that this buffer radius should be re-evaluated for future rounds of the Grant once the highest priority locations have been addressed and scheme uptake has been evaluated. Further evaluation would also be required if the layer was used for other purposes to ensure it is a suitable distance for the proposed use.

3 Layer generation for chosen approach

3.1 Method overview

A summary of the input datasets and processing steps used to generate a demand layer based on critical level exceedance is provided below:

- Modelled ammonia concentrations – 1x1 km resolution (UKCEH, 2022)
- Site-relevant critical levels for exposure to Ammonia (UKCEH, 2017)
- SSSI spatial boundaries (Natural England, 2021)

1. **Establishing critical levels**: The critical level for individual features within an SSSI was provided in the UKCEH 2017 dataset. The most sensitive feature was identified for each SSSI and used to assign the SSSI a critical level. This critical level was then mapped spatially by joining this information to the SSSI boundaries spatial layer using the site codes. Notes:

    - Where the critical level was noted as '1µg or 3µg', the higher sensitivity of 1µg was assigned to the features present
    - Where no critical level was assigned and it was noted to seek 'site expertise', a critical level of 3µg was assumed.

2. **Calculating exceedance:** Gridded average ammonia concentration data at 1 km resolution was provided by UKCEH. Ammonia concentrations for each SSSI were extracted from this layer. Where an SSSI covered more than one 1 km grid cell, the cell with the highest concentration of ammonia was used. Exceedance for each SSSI was then calculated where: Exceedance = Concentration – Critical Level. Sites where ammonia concentration did not exceed the critical level of the most sensitive features were removed from the dataset.

3. **Buffering site boundaries:** Each SSSI was buffered by a distance of 2 km. This distance was chosen by the expert group based on work done for the Nitrogen Futures Project (Dragosits *et al.*, 2020). Where buffers extended beyond the border or coastline of England, these were clipped to the border.

4. **Resolving overlaps:** Where SSSIs are within 2 km of another site, their buffers will overlap. This means that a land parcel could sit within the buffers of multiple SSSIs and thus have multiple exceedance scores assigned to it. To ensure that each land parcel is only associated with a single score, the buffers were split into smaller polygons containing the boundaries of all overlapping buffers. These polygons were then assigned the highest exceedance score from all of the buffers with which they overlapped.

3.2 Input datasets

Details of the input datasets used in the generation of the layer are provided below. Each of these datasets undergoes its own internal QA process by the organisation producing it before it is published. In addition to this, upon receipt of the spatial data it is visually inspected in QGIS to ensure it aligns with its associated metadata. Coordinate Reference System (CRS), spatial extent and the distribution of data values are all examined to check that the data are fit for purpose.

3.2.1 Ammonia concentrations dataset from UKCEH

Attribution Statement: © UKCEH [2022].

Published by: UKCEH

Licence: OGL – publication imminent

Format: Raster

Temporal resolution: 2017-2019

Spatial resolution: 1x1 km

Coordinate Reference System: British National Grid (EPSG:27700)

Ammonia concentration levels dataset produced by UKCEH for the annual Trends Report. This is a modelled output from the EMEP4UK model at 1x1 km spatial resolution, giving average ammonia concentrations over a three-year period.

3.2.2 Site-relevant critical levels for Ammonia

Attribution Statement: © UK Centre for Ecology & Hydrology, Natural Resources Wales, Environment Agency, the Northern Ireland Environment Agency, Natural England, the Joint Nature Conservation Committee (JNCC), Scotland and Northern Ireland Forum for Environmental Research (SNIFFER), the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage (SNH)

Published by: UKCEH

Licence: OGL

Format: Comma-separated values (CSV)

Temporal resolution: 2017

Spatial resolution: N/A

Coordinate Reference System: British National Grid (EPSG:27700)

Interest features and linked critical load/level values for UK protected sites. (Bealey and Roberts, 2017)

3.2.3 2021 SSSI site boundaries

Attribution Statement: © Natural England copyright.

Published by: Natural England

Licence: OGL

Format: Shapefile (Polygon).

Temporal resolution: 2021

Spatial resolution: N/A

Coordinate Reference System: British National Grid (EPSG:27700)

The latest boundaries for all designated Site of Special Scientific Interest (SSSIs) designated under the Wildlife and Countryside Act (1981). Available from: https://naturalengland-defra.opendata.arcgis.com/datasets/f10cbb4425154bfda349ccf493487a80_0

3.3 Code review

The code script used to generate the layer was internally checked by another member of the Ecosystems Analysis Team. The code review process is initiated through a 'pull request' on GitHub which is sent to the relevant reviewer. They then carry out the checks described below and record the results, along with any comments or requirements for improvement. This feedback is captured within the pull request, creating an audit trail which will also include any resulting amendments to the code.

The review followed the steps outlined in the team's guidance on quality control for code. This includes the following:

- Confirm that the script includes metadata on software versions and packages used to carry out the analysis.
- Confirm that code is clearly documented with comments and accessible for others to follow and reuse.
- Check that the methods used make sense for the problem being tackled.
- Check any calculations or equations are analytically sound.
- Check that input and output datasets are stored in the correct location in the file system and named according to team naming conventions.
- Check that as far as possible, coding style is in line with the tidy style guide for readability and standardisation across the team.
- Check that processes that are used multiple times are written as functions to reduce duplication and error risk and improve code readability.
- Confirm that inputs and outputs of all operations in the script are as expected. In particular:
    - Outputs from operations joining tables together should be subjected to spot testing of several rows to ensure the join has worked correctly.
    - Intermediate and final spatial outputs should be visually checked in GIS software (e.g. QGIS) to confirm that values from input datasets have been correctly transferred, and also checked for any projection or topology errors (invalid polygons, slivers etc).
- Where a greater level of QC is required or processes are quick to run, code can be re-run to confirm that it gives the expected results.

Due to the processing time required to perform data transformation steps, these processes were not repeated by the code reviewer. However, the rest of the code was re-run and the outputs of each step checked to ensure the outputs were as expected.

4 Limitations of the air quality layer

4.1 Layer suitability assessment

This suitability assessment below is for the selected method's applicability to Round 1 of the Slurry Infrastructure Grant.

Confidence ratings:

3 = High confidence in value for money / low risk of increased scheme admin costs – all or most of the criteria appropriate for the study have been fulfilled.

2 = Moderate confidence in value for money / some risk of increased scheme admin costs – some of the criteria appropriate for the study type have been fulfilled and those criteria that have not been fulfilled or not adequately described are thought unlikely to alter the conclusions.

1 = Low confidence in value for money / high risk of increased scheme admin costs – few or no criteria have been fulfilled. The conclusions are thought likely or very likely to alter.

Table 2. Layer suitability assessment.

Aspect of quality	Description	Confidence rating
Methodology Has method been independently checked? If the original data source was created by other organisation, is the method clear, well documented, or peer reviewed? How well does the proposed method cope with the complexity of the natural environment?	The chosen method has been reviewed and approved by the NE-led Air Quality Expert Group. In addition, the method and outputs were independently checked by an external peer reviewer at the Agri-food and Biosciences Institute. The implementation of the method has been independently checked internally via a code review process to check that the agreed steps have been correctly implemented. Critical levels for ammonia were developed by a workshop of international experts for the executive body for the Convention of Long-range transboundary air pollution (UN-ECE, 2007).	3 The layer has been developed in consultation with an expert group and has been externally peer-reviewed by an independent expert in ammonia.

	Modelled ammonia concentrations were obtained from the EMEP4UK model, a peer-reviewed model developed by UKCEH to map annual average concentrations of air pollutants across the UK.	
Accuracy of content What factors affect the accuracy of the representation of subject of interest e.g., statistical levels of confidence, level of survey or modelling, spatial variation in accuracy? How do these factors affect its intended use? i.e., does the uncertainty varies with type of content in layer, does the layer covers most of the subject of interest but miss significant parts etc.?	Several factors influence the accuracy of the content. These include: 1. The most sensitive feature has been chosen for each SSSI and assumed to be located across the entire site. This is due to a lack of spatial information on the locations of sensitive features within sites. This will not alter the sites included in the layer but will potentially inflate their level of exceedance. 2. Non-designated habitats have not been included in this layer. This means there are several sensitive habitats that may have been omitted from this layer. Given that the scheme is targeting protected sites in the first round, this is an acceptable omission. 3. Not all sites have critical levels established for them: 1056 SSSIs had no critical level assessment and 673 required site-specific expertise which as detailed, were assumed to have a sensitivity of 3ug/m^3. This means some sensitive sites may be inappropriately represented. 4. Not all SSSIs have had a critical level identified yet (approximately 25%, although many of these are likely to be insensitive geological SSSIs). 5. A 2 km buffer has been suggested by the group based on previous work under the Nitrogen Futures Project (Dragosits *et al.,* 2020). For the purposes of targeting funding in the first round of applications this was deemed appropriate and pragmatic, but a larger buffer may capture additional slurry storage areas which have a negative impact upon sensitive features.	2 Although the datasets used have been identified as the best available to use by the expert group, their limitations currently prevent this from being scored a 3. Furthermore, the lack of spatial information available on sensitive features means that features are assumed to be present across the entire site. Although less important for small SSSIs, this is an important implication for larger SSSIs. Similarly, the 1x1 km spatial resolution of the modelled ammonia emissions assumes emissions are constant across the grid cell, therefore this variation cannot be captured or utilised by the Grant.

	6. The modelled ammonia emissions dataset is only at a 1x1 km resolution. This means that there could be variation in ammonia emissions within each grid cell, but this is not captured.	
Timeliness What is the age of data set? Is it likely to represent the current state of the subject of interest?	The datasets used are the most recent ones published by UKCEH, covering the period of 2017-2019, whilst the SSSI dataset is from 2021. The site-relevant critical level dataset is from 2017 but is the latest one available. There is an inevitable time-lag between dataset production of modelled ammonia emissions, and inclusion in the targeting here. However, this is an acceptable lag time for the purposes of the Grant and there is now a standardised method used to report on critical level and load exceedances.	3 These are the latest datasets available for use.
Overall assessment of appropriateness How well does the layer represent the subject of interest conceptually? How appropriate is the layer for its intended use? Review of method, timeliness, and accuracy.	The layer has been developed with an expert working group using the most recent data available and externally peer-reviewed. There are some uncertainties and limitations with the input data, notably the lack of critical level threshold information available for all SSSIs and assumption that the most sensitive feature at a site is present across the entire site. However, given the first round of the slurry storage scheme is targeting sensitive, protected sites, the layer developed here is deemed a good representation of demand for the scheme and is appropriate for use.	3
Rating Our overall QA score.	Although there are some limitations with the input datasets and the method has not been peer-reviewed, the method to identify demand for the Slurry Infrastructure Grant is appropriate and will support the targeting of farms located close to sensitive, designated areas exceeding their critical level for ammonia. This targeting will improve the allocation of funding and represents good value for money.	11/12 possible points = 92% or 11 points across 4 categories gives an average score of 2.75

4.2 Limits of interpretation

Several assumptions and limitations have been identified in this document for the first iteration of this layer. In the interests of clarity and transparency, they are repeated here:

- Critical level exceedance is based on the most sensitive feature for an SSSI recorded in the APIS dataset and assumes the most sensitive feature is located equally across the entire site. This is a risk-averse approach, resulting in some identified areas that may have lower levels of exceedance than the layers reports.
- Some sites and features missing critical level information or state that further assessment from local site experts may be required. Where site expertise was suggested (673 sites), a critical level of 3µg was assumed. This is a middle ground between overestimating sensitivity level for many sites and removing them entirely by assuming they are not sensitive.
- The critical levels are based on the most up to date information available for UK habitats, but it should be recognised that these may change with time, especially in the context of climate change. Future uses of this layer must consider if any updates to critical level information may be available.
- The maximum concentration of ammonia found at a site has been taken from the 1x1 km ammonia emissions data. For large sites, ammonia may be lower in certain areas than others if it falls within a different grid cell, but the maximum level has been assumed constant across the site. Both of these assumptions are risk-averse approaches to dealing with limitations in the input datasets.
- The buffer distance of 2 km chosen is based on expert judgement and previous evidence from Nitrogen Futures (Dragosits *et al.,* 2020). It is assumed constant across all sites, although it should be acknowledged that Site Nitrogen Action Plans suggest a 5 km buffer around a site. Altering buffer size may want to be considered for future application rounds of the grant should it become less targeted.
- Prioritisation in the grant focuses solely on sites exceeding their critical levels and doesn't consider sites which are in decline and may be at risk of exceedance. Nor are non-designated habitat areas not considered. However, this is in line with the stated aim of the grant.

4.3 Outcome of the quality assessment for this approach

As outlined in Table 2, the authors of this document have a high confidence that this method will likely achieve the intended outcomes of the Slurry Infrastructure Grant, and that the noted limitations will not unduly impact the Grant's delivery of reducing ammonia emissions.

This assessment is also supported by members of the NE-led Air Quality Expert Group and an independent peer-reviewer who agree and approve for this method to be used to prioritise the first round of applications to the Slurry Infrastructure Grant.

References

Bealey, W.J. and Roberts, E.M. (2017) *Interest features and linked critical load/level values for UK protected sites.* NERC Environmental Information Data Centre. Available at: https://doi.org/10.5285/0c04050d-ed79-4864-a164-5eb25f8c6ebd.

DEFRA (2019) *Clean Air Strategy*. Available at: https://www.gov.uk/government/publications/clean-air-strategy-2019.

DEFRA (2022) *Slurry Infrastructure Grant: guidance for applicants*. Available at: https://www.gov.uk/government/publications/slurry-infrastructure-grant.

Dragosits, U., Carnell, E.J., Tomlinson, S.J., Misselbrook, T.H., Rowe, E.C., Mitchell, Z., Thomas, I.N., Dore, A.J., Levy, P., Zwagerman, T., Jones, L., Dore, C., Hampshire, K., Raoult, J., German, R., Pridmore, A., Williamson, T., Marner, B., Hodgins, L., Laxen, D., Wilkins, K., Stevens, C., Zappala, S., Field, C. and Caporn, S.J.M. (2020) *Nitrogen Futures JNCC Report No. 665*. Peterborough, UK: Joint Nature Conservation Committee. ISSN 0963-8091.

Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B. and Manville, C. (2018) *The impact of ammonia emissions from agriculture on biodiversity: An Evidence Synthesis*. Santa Monica, CA: RAND Corporation. Available at: https://www.rand.org/pubs/research_reports/RR2695.html.

Rowe, E.C., Sawicka, K., Tomlinson, S., Levy, P., Banin, L.F., Martín Hernandez, C. and Fitch, A. (2021) *Trends Report 2021: Trends in critical load and critical level exceedances in the UK.* Report to Defra under Contract AQ0849, UKCEH project 07617. Available at: https://uk-air.defra.gov.uk/library/reports?report_id=1020.

UN-ECE (2004) *Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks, and Trends.* Berlin, Germany: Federal Environmental Agency. TEXTE 52/04, ISSN 0722-186X. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/4038/dokumente/manual_complete_english.pdf.

UN-ECE (2007) *Report on the Workshop on Atmospheric Ammonia: Detecting Emission Changes and Environmental Impacts.* Geneva, Switzerland: United Nations.

Appendix 1: Critical loads method overview

A summary of the input datasets and data processing steps used to generate a demand layer based on critical load exceedance is provided below. **Note that this method was not chosen by the expert group for use in the Slurry Infrastructure Grant as stated above**.

- Site-relevant critical load exceedances – raw values (UKCEH, 2017)
- SSSI boundaries used in the calculation of critical load exceedances (Natural England, 2017)
- Source attribution data for the deposition of nitrogen and sulphur on UK designated sites (UKCEH, 2012)

1. **Establishing critical load exceedance:** The site-specific critical loads exceedance data were provided by UKCEH in CSV format. These were joined to the SSSI boundaries using their site codes. The maximum average accumulated exceedance (Max AAE) value for a given SSSI was then used. Non-sensitive SSSIs were not included.

2. **Buffering site boundaries:** The sites were buffered by a distance of 2 km. This distance was chosen by the expert group based on work done for the Nitrogen Future Project (Dragosits et al., 2020). Where buffers extended beyond the border or coastline of England, these were clipped to the border.

3. **Adding source attribution data:** The % of N deposition attributed to local agriculture was taken from the source attribution data and joined to sensitive SSSIs. Critical Load exceedance is based on N deposition data, some of which may have originated from other pollutants and their sources (e.g. NOx emissions from car exhausts). Should the Slurry Infrastructure Grant Scheme need to further prioritise applications, they can use the source attribution data to focus more explicitly on locations where local agriculture is a significant source of nutrient nitrogen.

4. **Resolving overlaps:** Where SSSIs are within 2 km of another site, their buffers will overlap. This means that a land parcel could sit within the buffers of multiple SSSIs and thus have multiple exceedance scores assigned to it. To ensure that each land parcel is only associated with a single score, the buffers were split into smaller polygons containing the boundaries of all overlapping buffers. These polygons were then assigned the highest exceedance score from all of the buffers with which they overlapped.

Appendix 2: Summary comparison of output from proposed critical level and critical load methods

Table 3: Summary of the number of SSSIs included in each option.

Critical Load or Critical Level	Option	Removed sites	Total sites included	Exceedance scores
Critical Level	Option 1 (Sensitive SSSIs exceeding critical level)	1977	2146	0-1: 1210 1-2: 765 >2: 171
	Option 2 (Sensitive SSSIs)	1064	3059	<0: 913 0-1: 1210 1-2: 765 >2: 171
Critical Load	Option 1 (Sensitive SSSIs exceeding their threshold and with >40% of N deposition attributed to local agriculture)	1717	2398	0-14: 1171 14-28: 1032 >28: 195
	Option 2 (Sensitive SSSIs exceeding critical load)	1479	2636	0-14: 1280 14-28: 1158 >28: 198
	Option 3 (Sensitive SSSIs)	1161	2954	0: 318 0-14: 1280 14-28: 1158 >28: 198
Notes:	Removed sites includes sites which are not sensitive to ammonia or nitrogen deposition (Option 3) plus those which are either not exceeding their threshold (Option 1 & 2) or have <40% of their nitrogen deposition attributed to local agriculture (Option 1). Critical Level: 1056 SSSIs had no critical level information and were excluded. 673 sites required site expertise and so the lower level of 3ug was assumed. 8SSSIs were not sensitive. Critical Load: 1161 SSSIs had either no critical load information of were not sensitive to nitrogen deposition.			