**VOLUME 11 ENVIRONMENTAL ASSESSMENT**

**SECTION 3 ENVIRONMENTAL ASSESSMENT TECHNIQUES**

## PART 1

## HA 207/07

# AIR QUALITY

**SUMMARY**

This Advice Note gives guidance on the assessment of the impact that road projects may have on local regional air quality. It includes a calculation method to estimate local pollutant concentrations and regional emissions for air including those for carbon. Where appropriate, this advice may be applied to existing roads.

**INSTRUCTIONS FOR USE**

1. Remove Contents pages from Volume 11 and insert new Contents pages dated May 2007.

2. Remove the document entitled ‘Air Quality’ dated February 2003 from Volume 11, Section 3, Part 1 which is superseded by HA 207/07 and archive as appropriate.

3. Insert the new Advice Note HA 207/07 into Volume 11, Section 3.

4. Please archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

# 1. INTRODUCTION

1.1 This Advice Note gives guidance on the assessment of the impacts that road projects may have on the air environment. This includes local air quality and emissions of pollutants including carbon dioxide ($CO_2$). Road transport sources account for a large proportion of the emissions of several air pollutants, although most of the pollutants emitted by road vehicles are also produced by a wide range of industrial, commercial and domestic processes. The vehicle-derived pollutants of concern, and the environmental effects to which they contribute, are summarised in Annex A. The pollutants of most concern near roads are nitrogen dioxide ($NO_2$) and particles ($PM_{10}$) in relation to human health and oxides of nitrogen ($NO_x$) in relation to vegetation and ecosystems.

1.2 Clean air is an essential ingredient for a good quality of life. The Government is committed to meeting health based air quality criteria for human health and for the protection of vegetation and ecosystems. In addition, the Government and EU Member States must reduce their national emissions of a range of pollutants as these can travel considerable distances and affect air quality across international boundaries. The Government also has targets to reduce emissions of greenhouse gases as these are linked with climate change.

1.3 Each year various projects are undertaken by the Highways Agency (HA), Transport Scotland, Welsh Assembly Government Transport Wales and Department of the Environment for Northern Ireland (referred to hereafter as the 'Overseeing Organisations'). These include major schemes, smaller improvements, technology improvements and maintenance projects. All these different classes of project may change the characteristics of the traffic in a locality, with corresponding impacts on pollutant emissions and air quality. These projects can have positive or negative effects on local air quality or, as is more often the case, beneficial effects in one area and adverse effects in another, depending on where traffic conditions change.

1.4 Every project entering the programme of an Overseeing Organisation requires some form of environmental assessment. The impacts of road projects on air quality are assessed in terms of their effects upon local air quality and change in total emissions across the highway network. An appropriate level of assessment should be undertaken to reflect the potential for a project to cause adverse environmental consequences. Not all projects will be subject to the same level of assessment in order to meet the requirements of the relevant legislation or guidance. For projects that are likely to have an adverse effect on air quality in a sensitive area, a detailed assessment is likely to be required early on in the assessment process so that the results can feed into the scheme design. Any modifications required can then be incorporated at an early stage thus minimising delays to the project. Reference should be made to DMRB 11.2.1 and 11.2.2 when carrying out an air quality assessment as these document the principles of environmental assessment.

# 2. AIR QUALITY MANAGEMENT IN THE UK

2.1 This section provides a summary of the relevant legislation that forms the basis for the assessment of impacts on air quality and the legislation in place to reduce emissions.

**Local Air Quality**

2.2 In 1996, the Council of the European Union adopted Framework Directive 96/62/EC on ambient air quality assessment and management, called the Air Quality Framework Directive[1]. This Directive covers the revision of previously existing legislation and introduces new air quality criteria for previously unregulated air pollutants. It sets the strategic framework for tackling air quality consistently by setting European-wide, legally binding limit values for twelve air pollutants in a series of daughter directives[2]. The first three Daughter Directives have been translated into UK law through the Air Quality Limit Value Regulations 2003 or equivalent regulations in the Devolved Administrations and the fourth Daughter Directive will be transposed into UK legislation in 2007 (see Annex A).

2.3 The Framework Directive, as well as its Daughter Directives, requires the assessment of the ambient air quality existing in Member States on the basis of common methods and criteria. Member States are required to report to the Commission each year whether or not the limit values set in the Directive have been achieved. The Department of the Environment, Food and Rural Affairs (Defra) and the Devolved Administrations are the "Competent Authorities" for air quality in the UK, with statutory powers and duties for managing air quality.

2.4 In 2001 the Commission launched "Clean Air for Europe" (CAFE), a programme of technical analysis and policy development, under the Sixth Environmental Action Programme (6EAP). The aim of CAFE was to develop a long-term, strategic and integrated policy advice to protect against significant negative effects of air pollution on human health and the environment. A new phase of CAFE – the implementation of the Thematic Strategy on Air Pollution – started in September 2005. The Thematic Strategy sets specific interim objectives for reducing air pollution impacts by 2020, in particular for fine particles. EU Member States are currently negotiating a proposed Air Quality Directive. The European Parliament's Environment Committee had adopted a formal recommendation in June 2006. The Council's 'common position' could be published later in 2006 and the directive is likely to be adopted in summer 2007 and come into effect in 2008.

2.5 In the UK, the introduction of the Environmental Protection Act 1990 and the Environment Act 1995 marked the biggest steps forward in controlling air pollution since the Clean Air Acts of the 1950s and 1960s. Part 1 of the 1990 Act provided regulators with powers to set emission limits and environmental quality standards for individual pollutants; and make plans setting limits on total amounts of pollutants that could be emitted. The 1995 Act required the UK Government and the Devolved Administrations to produce a national air quality strategy containing standards and objectives for improving ambient air quality.

2.6 The current Air Quality Strategy for England, Scotland, Wales and Northern Ireland[3] was published in January 2000 with an addendum[4] released in February 2003. A revision to the Strategy is expected in 2007. The Strategy establishes the framework for achieving further improvements in ambient air quality in the UK and identifies actions at local, national and international level to improve air quality. It sets health-based standards and objectives for nine pollutants to be achieved between 2003 and 2010. These standards define the level of pollution below which health effects are unlikely to be experienced even by the most sensitive members of the population. These are mainly

[1] Available at **http://ec.europa.eu/environment/air/ambient.htm**

[2] The HA made a commitment in its 2006-7 Business Plan that it would not progress with a major scheme that would worsen the situation overall with regards to compliance with the EU air quality limit values. The Business Plan is available at **http://www.highways.gov.uk** – search for "Business plan".

[3] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland – Working Together for Clean Air, January 2000 (Cm 4548, SE2000/3, NIA 7).

[4] The Air Quality Strategy for England, Scotland, Wales and Northern Ireland: Addendum, February 2003.

based upon recommendations of the Expert Panel on Air Quality Standards (EPAQS). The objectives are targets for air pollution levels which take account of the costs and benefits of achieving the standard. The Strategy also sets objectives for oxides of nitrogen and sulphur dioxide for the protection of vegetation and ecosystems. The Strategy's objectives are largely the same as EU limit values but in some cases are tighter than the EU legislation.

2.7 There is a significant difference between the status of the EU limit values and the UK Air Quality Strategy objectives. As a member of the European Union, the UK Government is obliged to achieve the requirements of European air quality directives and their legally binding limit values. However, the air quality objectives in the Air Quality Strategy are a statement of policy intentions or policy targets set by the UK Government and the Devolved Administrations. As such, there is no legal requirement to meet the Air Quality Strategy objectives except in as far as these mirror any equivalent legally binding limit in EU legislation. The Strategy's objectives are implemented though the Air Quality Regulations and are given in Annex A.

2.8 Part IV of the Environment Act 1995 requires local authorities to review and assess the current and likely future air quality within their area, against objectives for seven of the main air pollutants. These reviews are known as the "review and assessment" process and are described in Defra's Policy Guidance on Local Air Quality Management (LAQM)[5]. This information is reported back to Defra and the Devolved Administrations, to help them meet their duties under the EU Framework Directive.

2.9 Where any of the prescribed objectives are unlikely to be achieved by the required date within any part of a local authority's area, the authority concerned is required to designate an Air Quality Management Area (AQMA). The AQMA must include the area expected to exceed the objective(s) but the boundaries can be much larger than this. AQMAs range in size from one property to an entire borough. Care should therefore be taken when assessing the impact of a scheme as the area actually exceeding the Air Quality Strategy objective is often smaller than the AQMA.

2.10 The Strategy objectives apply at locations which are situated outside buildings or other natural or man-made structures above or below ground level and where members of the public are regularly present and might reasonably be expected to be exposed over the relevant averaging period. To aim to achieve the objectives at locations where the highest measurable concentrations occur without regard to whether or not the public might be exposed would be inappropriate and highly inefficient. For example, for a long term (annual mean) objective, an exceedence would be relevant at a property façade but not at a kerbside site; while for a short term (hourly mean) objective, exceedences on the pavement might be relevant for a high street. Relevant locations for each air quality objective are defined in Defra's Technical Guidance on LAQM[6].

2.11 There are around 470 local authorities in the UK, of which about 200 have declared AQMAs for one or more pollutants. In England, the vast majority have been declared for nitrogen dioxide with a third also declaring for $PM_{10}$. A small number have declared for sulphur dioxide or benzene. The situation is similar in Scotland and Wales although the number of local authorities that have declared AQMAs is considerably lower with less than ten in each. In Northern Ireland, in contrast to England, Scotland and Wales, the majority of AQMAs have been declared for $PM_{10}$ with a few also declaring for nitrogen dioxide, with a similar number of declarations as Scotland and Wales. The latest information on which local authorities have declared AQMAs is available from the National Air Quality Archive[7].

2.12 An Air Quality Action Plan[8] (AQAP) covering the designated area must be prepared by local authorities in response to the declaration of an AQMA. The AQAP sets out which actions have been considered and which will be implemented in pursuit of the achievement of the prescribed objectives. It is prepared in conjunction with the stakeholders, including the highways authorities. For England, guidance is available on the role of the Highways Agency (HA) in local air quality management[9].

[5] Part IV of the Environment Act 1995 – Local Air Quality Management: Policy Guidance LAQM.PG(03). Defra, 2003.

[6] Part IV of the Environment Act 1995 – Local Air Quality Management: Technical Guidance LAQM.TG(03). Defra, 2003.

[7] **http://www.airquality.co.uk/archive/laqm/laqm.php**

[8] Under the Government's freedoms and flexibilities' agenda, those local authorities classed as excellent are no longer required to produce an air quality action plan; however, they still have to take action to work towards meeting the air quality objectives. These freedoms and flexibilities will shortly be extended to those authorities classed as 4*.

[9] Highways Agency – The Role of the HA in Local Air Quality Management, available at **http://www.highways.gov.uk**

## Regional Impacts

2.13 Local air quality is characterised by pollutants with short term, immediate impacts, but many of these pollutants can also travel longer distances, and can have impacts on a regional, national, or international scale. These impacts, which include acidification, excess nitrogen deposition and generation of tropospheric (ground level) ozone, may be felt by humans or ecosystems at considerable distances from the source of the emissions.

2.14 The UK Government has international commitments to reduce national emissions of oxides of nitrogen, oxides of sulphur, volatile organic compounds (VOCs), ammonia ($NH_3$), heavy metals and persistent organic pollutants through UNECE protocols. The European Union's Auto-Oil programme of research and legislation is very influential in defining emission limits for road transport and is driven by the need to reduce emissions on a European scale. The European Commission National Emission Ceilings Directive (NECD), and the UNECE Gothenburg Protocol, set emission ceilings for the above pollutants. The Gothenburg Protocol also sets emission limit values for certain sources of the pollutants. These agreements are part of a series of complementary international measures addressing transboundary air pollution.

2.15 As a result of the long range nature of the impact of some pollutants, a consideration of the change in emissions resulting from a scheme is therefore useful in the context of regional air pollution. This is called the regional impact assessment.

### *Climate Change*

2.16 Climate change is increasingly recognised as a serious threat to our environment, as well as the economy. As part of its Climate Change Programme[10], the UK Government is committed to reducing emissions of the gases responsible for climate change. The UK has a legally-binding target known as the Kyoto Protocol, to cut the emissions of a basket of six greenhouse gases to, on average, 12.5% below 1990 levels, between 2008 and 2012. The Government also has a domestic goal to achieve a 20% reduction in emissions of carbon dioxide, the most important greenhouse gas, below 1990 levels by 2010.

2.17 Carbon dioxide ($CO_2$) accounted for about 85% of the UK's man made greenhouse gas emissions in 2004. In this year, the percentage of total emissions accounted for by the transport sector was 28%, to which road transport is by far the biggest contributor (21% of total). Since 1990, road transport emissions of this pollutant have increased by 9%. Two other of the six greenhouse gases of importance to climate change are nitrous oxide ($N_2O$) and methane ($CH_4$). Nitrous oxide is emitted by road transport as a result of the use of catalytic converters and methane is released from some fuel combustion, albeit in much smaller quantities than carbon dioxide.

2.18 As noted above, carbon dioxide is considered the most important greenhouse gas and, therefore, is used as the key indicator for the purposes of assessing the impacts of projects on climate change. The change in carbon emissions is included in the regional impact assessment.

## Vehicle Emissions

2.19 The introduction of tighter European vehicle emission and fuel quality standards since 1993 has been the most important way of reducing vehicle emissions and improving air quality. Vehicle emission standards are tightened every five years or so resulting in a steady decrease in emissions of oxides of nitrogen, carbon monoxide, hydrocarbons and particles. The legislation, vehicle emission rates and vehicle fleet composition are described in Annex B.

[10] Climate Change The UK Programme 2006. HM Government. CM6764. March 2006.

# 3. PROCEDURE FOR ASSESSING IMPACTS

**Introduction**

3.1 DMRB 11.1.1 sets out the aims and objectives of environmental assessment. The overall objective is to define the depth of assessment necessary to enable informed decision-making at as early a stage of the project as possible. This necessitates a 'fit-for-purpose' assessment method and relies on four 'Assessment Levels':

- scoping;
- simple;
- detailed; and
- mitigation/enhancement and monitoring.

3.2 For air quality, each assessment level has two components. The first is for local air quality, that is, estimation of pollutant concentrations that could change as a result of the proposals (nitrogen dioxide, oxides of nitrogen, fine particles ($PM_{10}$)), carbon monoxide, benzene and 1,3-butadiene) at specific locations. These concentrations are compared with the air quality criteria set to protect human health or vegetation, as appropriate. Both construction and operational effects should be considered for local air quality. The second component is for the regional impact assessment and examines the change in emissions of a range of pollutants (oxides of nitrogen, particles, carbon monoxide, hydrocarbons and carbon) as a result of operation of the scheme as these can have impacts on the regional, national or international scale. The two components may require different assessment levels. Both components are intended to be consistent with Department of the Environment, Food and Rural Affairs (Defra's) Technical Guidance on Local Air Quality Management (LAQM) and the National Atmospheric Emissions Inventory[11] (NAEI) and this guidance should be referred to as required. An Excel spreadsheet[12] is available to carry out the DMRB local and regional air quality calculations at the simple assessment level.

3.3 Throughout the assessment process consideration should be given to the minimisation of any negative impacts of the project on air quality. Information on how this can be achieved is provided in this guidance note under the section on Mitigation/Enhancement and Monitoring. If at any stage of the assessment process, it becomes apparent that there is likely to be a new exceedence or a worsening of an existing exceedence of a mandatory EU limit value, then the Overseeing Organisation must be notified immediately. Mitigation measures should then be developed and discussed with the Overseeing Organisation.

3.4 The results and a summary of the worksheets from the local air quality appraisal prepared for the Appraisal Summary Table using the Transport Appraisal Guidance (as described in web-TAG for England[13], STAG for Scotland[14] and WelTAG for Wales[15]) gives a very useful indication of the overall change in air quality and should be included in the reports prepared for this environmental assessment. Care should be taken to ensure that an entirely consistent message is being delivered in the air quality environmental assessment and the reporting strands of the TAG appraisal, or where differences become apparent that they are fully explained.

**Assessment Scenarios**

3.5 The assessment should be carried out using traffic data for the "Do-Minimum" (without the scheme) and "Do-Something" (with the scheme) scenarios, for the opening year and possibly for a further future year. The worst year in the first 15 years from opening needs to be assessed. The base case should also be assessed.

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11 Available at **http://www.naei.org.uk**

12 Available at **http://www.highways.gov.uk** – search for "air quality spreadsheet"

13 Available at **http://www.webtag.org.uk**

14 Available at **http://www.transportscotland.gov.uk**

15 Available at **http://new.wales.gov.uk/splash.jsp?orig=/** – available in draft, advice on its application should be sought from the Overseeing Organisation.

3.6 For local air quality, this will be the opening year and possibly a later year if more stringent air quality criteria come into effect at a later date. The earlier years tend to be worst for local air quality as vehicle emissions are set to decrease in the future due to increasingly stringent vehicle emission legislation. Cumulative effects from other projects may also need to be considered as discussed in DMRB 11.2.5 as this could result in a large increase in traffic in a year after the opening year. In addition, the existing year (base case) should also be assessed so that model results can be verified with monitoring data. If construction is expected to last for more than six months, then traffic management measures and the effect of the additional construction vehicles should also be assessed as an additional scenario although this may need to be a qualitative assessment where details of traffic flows are not available.

3.7 For regional impacts, the scenarios for assessment are the opening year and design years, both for the Do-Minimum and Do-Something scenarios and the base case. Carbon emissions are expected to decrease between 2005 and 2020 due to increased vehicle efficiency and the use of biofuels but this will be offset to some extent by traffic growth.

3.8 The air quality assessment should be based on the most likely forecast traffic flows.

## Reporting

3.9 At each reporting stage as discussed in DMRB 11.2.6, a report describing the assessment is needed. This should contain:

(i) a network diagram indicating roads affected by the proposals, together with information, either on the diagram on in tabular form, for existing year, and future year Do-Minimum and Do-Something traffic flows and speeds;

(ii) a constraints map for local air quality showing:

- which roads will be affected by the proposals;
- the 200 m boundary of roads affected by the proposals with properties and Designated Sites shown;
- boundaries of Air Quality Management Areas (AQMAs) and Designated Sites (see para 3.13);
- Air Quality Strategy objectives and limit value exceedence areas without the proposals and a comment on whether these are likely to deteriorate or improve with the scheme and if known, the exceedence areas with the proposals;

(iii) assessment of any existing air quality monitoring data or monitoring data collected as part of the scheme design;

(iv) a description of the methodology used for any modelling and the verification of the approach used;

(v) results of any future year modelling and a description of that work;

(vi) results of the TAG appraisal for local air quality;

(vii) an outline of further work, either modelling or monitoring, to be carried out at the next stage;

(viii) identification of potential mitigation for any exceedences and what effect it is likely to have;

(ix) for the regional assessment, the total and change in emissions expected with and without the proposals.

## Assessment Level – Scoping

3.10 The principles of scoping are described in detail in DMRB 11.2.4. In summary, scoping seeks to decide which environmental topics are to be examined in environmental impact assessments and environmental assessments and how much effort should be expended – either a simple or detailed assessment. Scoping can be an ongoing activity that is re-activated at key stages in the project planning process as new information or available alternatives are narrowed to a preferred approach to the project.

### *Local Air Quality*

3.11 The objective of this scoping exercise for local air quality is to indicate whether there are likely to be significant impacts associated with particular broadly-defined routes or corridors, as developed by the design organisation and the Overseeing Organisation. The steps to be taken are as follows:

3.12 Obtain traffic data for the Do-Minimum and Do-Something scenarios for the years to be assessed. Identify which roads are likely to be affected by the proposals. Affected roads are those that meet any of the following criteria:

- road alignment will change by 5 m or more; or
- daily traffic flows will change by 1,000 AADT or more; or
- Heavy Duty Vehicle (HDV) flows will change by 200 AADT or more; or
- daily average speed will change by 10 km/hr or more; or
- peak hour speed will change by 20 km/hr or more.

3.13 Identify on an appropriate map (typically 1:25,000 or 1:10,000 scale) all existing and planned properties where people might experience a change in local air quality, near the affected roads. Particular attention should be paid to the locations of the young, the elderly and other susceptible populations, such as schools and hospitals. In addition, areas likely to experience higher-than-average pollution concentrations, such as tunnel portals, roundabouts and junctions, should be identified. Also identify any nature conservation sites (Designated Sites) and their characteristics. The Designated Sites that should be considered for this assessment are those for which the designated features are sensitive to air pollutants, either directly or indirectly, and which could be adversely affected by the effect of local air quality on vegetation within the following nature conservation sites: SACs (SCIs or cSACs), SPAs, pSPAs, SSSIs and Ramsar sites. Sites designated for geological purposes need not be assessed. Further information on Designated Sites is given in Annex F. Only properties and Designated Sites within 200 m of roads affected by the project need be considered.

3.14 If none of the roads in the network meet any of the traffic/alignment criteria or there are no properties or relevant Designated Sites near the affected roads, then the impact of the scheme can be considered to be neutral in terms of local air quality and no further work is needed.

3.15 If any roads are affected by the proposals and have relevant properties or Designated Sites nearby, then examine the available monitoring data and LAQM reports for the area likely to be affected by the project. If an AQMA has been declared for the pollutants of interest, the LAQM report should be carefully studied to identify the boundaries of the AQMA, where the actual Air Quality Strategy objective exceedence area is within the AQMA and whether the EU limit values are likely to be met at relevant properties in the relevant year. Identify areas where it is likely that air quality will improve or deteriorate as a result of changes to traffic flows and traffic speed, or as a result of reduced congestion or queuing times, due to the proposals.

3.16 The judgement of someone with relevant air quality expertise should be used to identify possible locations alongside affected roads and new roads where there may be exceedences of the Air Quality Strategy objectives or limit values. If such locations are identified then undertake a few calculations for the pollutants of concern using the 'Local' application of the DMRB Air Quality Screening Method spreadsheet for the 'worst' affected properties and identify the extent of mitigation required. The instructions for using the spreadsheet are provided in Annex D. The worst affected properties are those that are likely to have the highest pollution concentrations or the largest increases in pollution due to the proposals. The aim of this screening assessment is to quickly identify impacts on a small sample of properties early in the assessment, so that any potential problems are identified. If the proposals are likely to cause a new exceedence of a limit value or a worsening of an expected exceedence, check the calculations and assumptions made and liaise with the Project Team and Overseeing Organisation immediately.

3.17 Determine whether there is sufficient monitoring data already available or whether further monitoring should be undertaken. Measured concentrations, whether from a scheme survey or from existing monitoring, will be needed to verify the model results and to establish a firm baseline. Prepare a brief for further monitoring if needed remembering to include a background monitoring site and to co-locate any passive samplers with a continuous analyser. The extent and complexity of the monitoring will depend upon the size of the project and the risk of exceeding the air quality criteria. Diffusion tubes should be deployed for nitrogen dioxide as a minimum, as these can give a large spatial coverage which will be needed to verify the model results. In complex cases for very major projects and where time permits, a continuous analyser may also be required but this will be rare. Advice on air quality monitoring techniques, monitoring locations, model output verification procedures and application are contained within Defra's Technical Guidance on LAQM.

3.18 If the proposals are expected to alter traffic or road alignment as set out in 3.12 and there are relevant properties or Designated Sites near the affected roads but no exceedences are identified from the monitoring data, LAQM reports or from the few DMRB screening calculations, then prepare a brief for a simple assessment.

3.19 If the monitoring data or the few DMRB screening calculations indicate that an exceedence of an Air Quality Strategy objective or EU limit value is likely or if the proposals cannot be assessed properly using the DMRB screening method, prepare a brief for the detailed assessment.

***Regional Impacts***

3.20 For the scoping stage of the regional assessment, identify roads that are likely to be affected by the proposals. Affected roads are those that are expected to have:

- a change of more than 10% in AADT; or
- a change of more than 10% to the number of heavy duty vehicles; or
- a change in daily average speed of more than 20 km/hr.

3.21 If no roads meet these criteria, then it is not necessary to undertake any calculations. However, a qualitative assessment should be made as to whether the project is likely to have a marginal improvement or marginal deterioration in emissions based on the change in distance travelled with the scheme.

3.22 If any roads are likely to be affected by the proposals, then the scoping assessment should recommend that a simple assessment is carried out. An estimate should be made of the change in distance travelled with the scheme in the opening and design years as this will be linked to the change in emissions.

**Assessment Level – Simple**

3.23 This activity is based on the assembly of data and information beyond that which is readily available. It should enable an understanding to be reached as to the effect of the project or to reach an understanding of the likely effect that identifies the need for a detailed assessment. A simple assessment would be sufficient if it established confidently that the forecast environmental effect would not be a fundamental issue in the decision making process.

3.24 If the scoping assessment indicates that a simple assessment is needed, then the following steps should be followed for local and regional impacts.

***Local Air Quality***

3.25 Revise as necessary the maps produced during the scoping stage for the various options under consideration, to take account of any project changes and further traffic information. Estimate the number of properties in 50 m bands from the road centre to 200 m from the road centre for each road expected to be affected by the proposals.

3.26 Estimate pollutant concentrations at a wide range of properties that are likely to be affected by the proposals. This should include those that are likely to have the highest concentrations, those that are likely to have the largest changes in concentrations (either decrease or increase), those that are representative of large numbers of properties and those that house the young, the elderly and other susceptible populations. Estimates should be made for a base year and should, where possible, include nearby monitoring locations. The estimates should be made using the 'Local' application of the DMRB Screening Method. The instructions for using the spreadsheet are provided in Annex D.

3.27 Compare the base year model results with measured concentrations and adjust the modelled results as necessary. Care needs to be taken when doing this as it is not straightforward; advice is given in Defra's Technical Guidance on LAQM. The adjusted modelled concentrations should then be compared with the air quality criteria.

3.28 If any of the air quality criteria are estimated to be exceeded with the project in any of the years in which they apply, further calculations should be carried out to determine the first year in which the criteria would be achieved. Furthermore, a detailed assessment will be required.

3.29 If a Designated Site has been identified as likely to be affected by the proposals, $NO_x$ concentrations and nitrogen deposition rates should be calculated within the site. Further guidance is given in Annex F and in summary involves:

1) Calculating annual average $NO_x$ concentrations in the Designated Site(s) in a transect up to 200 m away from each of the affected roads within or near the Designated Sites. The calculations should be carried out for the opening

year for the Do-Minimum and Do-Something scenarios, and the base year. The DMRB Screening Method should be used to carry out the calculations unless this method is not appropriate for the project being assessed.

2) The $NO_x$ concentrations at the Designated Site(s) should be compared with the vegetation criterion for $NO_x$ and the change in concentration due to the project determined in the opening year. If the project is expected to cause an increase in concentrations of at least 2 $\mu g/m^3$ and the predicted concentrations (including background) are very close to or exceed the criterion, then the sensitivity of that species to $NO_x$ should be commented upon. Advice from an ecologist or the statutory body should be sought at this stage. The results of this assessment should also be passed to an ecologist for inclusion in the ecological impact assessment (Environmental Statement/environmental report; and or Appropriate Assessment). The ecologist should consider the potential cumulative effects of the various impacts such as air pollution, water pollution and habitat loss and comment upon the effect of the project on the integrity of the Designated Site. If the designated features are at risk of being adversely affected by the project, mitigation measures should be considered to minimise the scale of impact.

3) Calculating nitrogen deposition at the location of the Designated Site(s) as described in Annex F and comparing with the critical loads, also given in Annex F.

***Regional Impacts***

3.31 Calculations should be made of the change in total emissions that will result from the project, as compared with the base and future year ‘Do-Minimum’ condition. This step should incorporate all affected roads as identified at the scoping level. The ‘Regional’ application of the DMRB spreadsheet can be used. The traffic models COBA and TUBA can also be used to estimate carbon emissions. However, the TUBA model should be used cautiously as it uses trip average speeds rather than link average speeds. TUBA should not be used in Scotland to estimate carbon emissions from trunk road schemes and further guidance should be sought from Transport Scotland.

**Assessment Level – Detailed**

3.32 A detailed assessment should be applied where there exists the potential to cause significant effects on environmental resources and receptors. The objective is to gain an in-depth appreciation of the beneficial and adverse consequences of the project and to inform project decisions. A detailed assessment may also be required where the scheme cannot be assessed using simple methods, for instance where there are features that would affect the dispersion of pollution (e.g. tunnels, street canyons) or proposals that would significantly affect peak hour congestion in areas with concentrations estimated to be close to the air quality criteria. Note that it is not always necessary to undertake a detailed modelling assessment for the whole study area but to combine the detailed modelling for complex areas of the scheme with screening methods for the wider affected network.

***Local Air Quality***

3.33 If the assessment so far has indicated that there is a reasonable risk of EU limit values or Air Quality Strategy objectives being exceeded at relevant locations, or the project includes significant features that cannot be assessed at the simple level, then a detailed level assessment should be carried out by someone with relevant expertise.

3.35 A detailed assessment is expected to take into account all of the parameters that are expected to change as a result of the proposals. It should include representative meteorological data, diurnal variation in flows and speeds and changes to road alignment. If the proposals are likely to result in a change to the way the vehicle is operated without the hourly average speed changing, then advice should be sought from the Overseeing Organisation as to how to assess this.

3.36 The model results must be compared with measured concentrations and adjusted as necessary. Care needs to be taken when doing this as it is not straightforward, advice is given in Defra’s Technical Guidance on LAQM. The adjusted modelled concentrations should then be compared with the relevant air quality criteria. Detailed modelling is discussed further in Annex E and in Defra’s Technical Guidance.

3.37 An assessment should be made of the significance of the changes in air quality. The assessment should bring together the earlier conclusions about existing and forecast pollution levels in relation to air quality criteria, and the populations and locations affected. Any change in the extent or severity of exceedences should be carefully noted.

*Regional Impacts*

3.38 A detailed regional assessment would be one that takes account of diurnal speed changes and changes in emissions from all roads, however small, within the study area. It is unlikely that a detailed assessment would be required for regional emissions as the changes expected will be small in relation to the national emissions and are likely to be adequately assessed at the simple level. The only exception might be where there is a large change in peak hour speeds on a major road due to the proposals, as this cannot be assessed using the DMRB regional impact spreadsheet which uses daily average speeds.

3.39 The COBA traffic model will automatically calculate carbon emissions at a detailed level by taking into account diurnal and seasonal variations across the entire modelled road network.

**Assessment Level – Mitigation/Enhancement and Monitoring**

3.40 This assessment level involves the iterative design, assessment and identification of measures that could be taken to avoid or reduce adverse impacts or enhance the positive environmental performance of the project, in terms of both health and ecological impacts from construction and operation. Consultations with the Overseeing Organisation will usually be necessary to confirm the appropriateness of extensive and/or atypical mitigation measures. The main design and assessment tasks are to:

- examine the performance of the measure through either predictive techniques or on the basis of experience gained elsewhere; and

- assess whether the measure would give rise to any subsequent environmental consequences not thus far assessed;

- follow up work to monitor or evaluate the effectiveness of the measures to meet the requirements of legislation, guidance or to learn how to do things better in the future.

3.41 The air quality assessment of a road project must include any mitigation measures, as agreed with the Overseeing Organisation’s project manager. Consideration must also be given to any impacts on non-strategic roads. A quantification of the likely benefits resulting from mitigation is required, although for some measures, this may not be possible.

3.42 The scope for mitigating adverse impacts on air quality via route choice, design or operation is limited in comparison with that associated with improved vehicle technology. However, possible mitigation measures might include the following:

*Route Alignment*

- Increasing the distance between the road and the sensitive location. Realignment by only a few tens of metres may provide significant benefits.

- Orientation of the road relative to locally prevailing winds. If a route can be chosen so that a sensitive location tends to be upwind of the road, average concentrations at that location will be lower than if the sensitive location tends to be downwind.

- Junctions and intersections should be sited to minimise the impact on air quality at sensitive locations. Slow traffic negotiating intersections generally produces greater amounts of pollution than freely flowing traffic.

- Tunnel portals and ventilation shafts should be sited so that the openings do not impact on air quality at sensitive locations. The build-up of pollution in tunnels means that the air expelled from them contains higher concentrations than those observed near open roads. Therefore there is considerable scope for optimising portal design to facilitate improved dispersion and dilution.

- Placing the road in a cutting or on an embankment can increase the distance between a roadside receptor and the vehicles thus allowing more time for dispersion and reducing concentrations at the receptor.

*Landscape Works*

- The use of vegetation screens or barriers. There is some evidence that concentrations are slightly reduced in a small area on the leeward side (downwind) of a large screen or barrier, but also that pollutant concentrations may actually increase if the wind speed is reduced. Consequently, an understanding of specific effects and their relevance to the local conditions is crucial.

- The use of bunds or screens can divert pollution away from receptors or increase the distance to receptors, thus allowing greater dispersion.

***Traffic Management***

- Traffic management measures include active traffic management, fixed and variable speed limits, dedicated lanes, hard-shoulder running and ramp metering. Such measures can modify the traffic behaviour so that vehicles operate in a mode that produces lower emissions in free-flow conditions and with less aggressive driving.

- Demand management measures include access control, junction closures, high occupancy vehicle lanes, travel plans and car/bus interchanges at junctions. Such measures can reduce demand for the strategic road network alone or across the wider network.

- Linking the motorway and trunk road signage with those on the local authority receiver/feeder roads to enable better route planning, thus reducing road miles per journey.

- Providing real-time information on severe congestion and road closures so that travellers can avoid these queues and hence adding to emissions.

3.43 Where a route alignment cannot be altered to increase the distance between the road and receptor, speed management may be the most effective measure for a motorway. Enabling vehicles to travel at a steady speed rather than with periods of acceleration is likely to reduce emissions as transient conditions tend to lead to large increases in emissions in modern vehicles. Reducing the speed from 70 mph to 60 mph or 50 mph is also likely to deliver emission reductions but it does depend on the vehicle fleet composition. The effectiveness of a speed change can be assessed by estimating the emissions for each hour of the day for the Do-Something scenario and then with the speed management strategy in place. It is important to undertake the calculations hour by hour as the flows and speeds will change and in peak hours, speeds may be too low for a reduced speed limit to have any effect. A speed management strategy is likely to be implemented as part of a controlled motorway[16] and could potentially be linked to real-time pollution measurements so that speeds can be reduced when pollution is worst.

3.44 The impact of a road network or project on air quality is just one of the factors to be considered in route choice and design, and conflicts can occur. For example, mitigation measures must also perform to an acceptable level in road safety and economic terms.

***Construction Dust***

3.45 In addition, dust generated during construction should be mitigated. The locations of any sensitive receptors within 200 m of a construction site should be clearly identified, such as housing, schools, hospitals or designated species or habitats within a Designated Site, so that mitigation measures to reduce dust emissions can be rigorously applied. Examples of good practice for mitigation are given in the Annex 1 of the Minerals Policy Statement[17]. Appropriate measures should reflect the nature of the construction activity (type, dust source points, construction operation periods and calendar dates) as well as ameliorating conditions (such as prevailing wind directions and speeds, typical precipitation and the dampening effect of retained soil moisture). Mitigation measures should be incorporated into the Construction Environmental Management Plan (CEMP), reflecting the requirements of best practicable means (BPM).

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[16] Controlled motorways are where the mandatory speed limit of 70 mph can be lowered bringing vehicles closer together as their stopping distance is reduced which can keep the traffic flowing at a higher capacity than would otherwise be achieved (albeit at a lower speed) and so reduces flow breakdown.

[17] ODPM. Minerals Policy Statement 2: Controlling and mitigating the environmental effects of mineral extraction in England. Annex 1: Dust. Office of the Deputy Prime Minister, London. 2005.

# ANNEX F ASSESSMENT OF DESIGNATED SITES

## F1 Background

F1.1 As well as impacts on human health, some air pollutants also have an effect on vegetation. Concentrations of pollutants in air and deposition of particles can damage vegetation directly or affect plant health and productivity. Deposition of pollutants to the ground and vegetation can alter the characteristics of the soil, affecting the pH and nitrogen availability that can then affect plant health, productivity and species composition. Increased greenhouse gas emissions on a global scale can affect the global climate, such that the ability of existing species to tolerate local conditions can change.

F1.2 The pollutant of most concern for sensitive vegetation near roads, and perhaps the best understood, is $NO_x$. The First EU Daughter Directive set a Limit Value for $NO_x$ for the protection of vegetation (an annual mean of 30 $\mu g/m^3$) to be met by 2001. This value was based on the work of the UNECE and WHO, and has been incorporated into the UK Air Quality Limit Value Regulations 2001. The policy of the UK statutory nature conservation agencies[35] is to apply the 30 $\mu g/m^3$ criterion in internationally designated conservation sites and SSSIs on a precautionary basis[36].

F1.3 $NO_x$ is composed of nitric oxide (NO) and its oxidation product nitrogen dioxide ($NO_2$). The latter is taken up by plants principally through their stomata. Concentrations of $NO_2$ are higher close to roads so vegetation in these areas is exposed to a larger source of nitrogen (N).

F1.4 Critical loads for the deposition of nitrogen, which represent the exposure below which there should be no significant harmful effects on sensitive elements of the ecosystem (according to current knowledge), have been established for certain habitats dependent on low nitrogen levels. Critical loads are expressed in deposition units of kg N $ha^{-1}$ $year^{-1}$.

F1.5 Deposition of particles, ammonia, metals and salt will also be increased close to the road. This could affect vegetation in a number of ways:

i) Dust or particles falling onto plants can physically smother the leaves affecting photosynthesis, respiration and transpiration. The literature suggests that the most sensitive species appear to be affected by dust deposition at levels above 1000 $mg/m^2/day$ [37] which is five times greater than the level at which most dust deposition may start to cause a perceptible nuisance to humans. Most species appear to be unaffected until dust deposition rates are at levels considerably higher than this. Without mitigation, some construction activities can generate considerable levels of fugitive dust, although this is highly dependant on the nature of the ground and geology, time of year construction occurs in, length of time specific construction activity (e.g. boring) occurs for and prevailing meteorology during this activity.

ii) An increase in the saltiness of roadside soils due to winter maintenance activities could lead to an accumulation of chloride ions in the plant.

iii) Ammonia emissions from road vehicles (from petrol-driven vehicles fitted with catalytic converters and heavy duty vehicles fitted with selective catalytic reduction), although small in a national context, can lead to significant additional deposition of nitrogen to vegetation in immediate vicinity of roads (typically within 10 m).

iv) Small quantities of heavy metals released during combustion and from vehicle wear and tear, may accumulate in soils near the road. However, such emissions cannot be reliably quantified or the negative ecological effects determined.

F1.6 Some of the pollutants emitted by vehicles will react over time to form secondary pollutants such as ozone and particles, which can also affect vegetation. Ozone is toxic to plants but concentrations tend to be

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35 Natural England, the Countryside Council for Wales, Scottish Natural Heritage.

36 The Limit Value applies only to locations more than 20 km from towns with more than 250,000 inhabitants or more than 5 km from other built-up areas, industrial installations or motorways.

37 Farmer A.M. The effects of dust on vegetation – a review. Environmental Pollution, 79, 63-75, 1993.

lower close to a road as it is scavenged by nitric oxide emitted by vehicles. As emissions of $NO_x$ decrease in the future, ozone concentrations are expected to increase in urban areas and adjacent to roads and may pose an increased threat to vegetation in these areas. The reaction products of $NO_x$, $SO_2$ and $NH_3$ (nitrate, sulphate and ammonium) have the potential to acidify the soil unless mineral weathering, chemical or microbial processes within the soil or liming can neutralise the acid. The nitrogen that is deposited in the UK is derived from oxides of nitrogen (oxidised nitrogen) and ammonia (reduced nitrogen) in roughly equal proportions (although the contribution of road transport is more in the form of $NO_x$). Nitrogen is eventually deposited onto surfaces through wet and dry deposition. The components of nitrogen deposition are summarised by the equation:

$$N\ deposition = NO_2\,dry + NO_2\,wet + NH_3\,dry + NH_x\,wet$$

F1.7 The mean residence time in the atmosphere of reduced nitrogen is five hours, while that of oxidised nitrogen is approximately 30 hours; mean travel distances for reduced and oxidised nitrogen before it is deposited are 150 km and 1,000 km respectively. In the case of reduced nitrogen, which has a relatively short atmospheric lifetime, the effects of UK emissions occur largely within the UK, whereas 70% of oxidised nitrogen is exported from the UK. Similarly, some of the nitrogen deposited in the UK is produced by continental sources. Nitrogen deposition in terms of acidification and wet deposition is therefore a regional issue. The change in primary emissions as a result of a project are already assessed in the DMRB Screening Method, and so this guidance addresses only local impacts.

## F2 Assessment Procedure

F2.1 This assessment procedure was prepared in collaboration with the Joint Nature Conservation Committee and Natural England. The sites that should be considered for assessment are those for which the designated features are sensitive to air pollution, either directly or indirectly, and which could be adversely affected by the effect of local air pollution on vegetation within the following nature conservation sites SAC (SCI or cSAC), SPA, pSPA, SSSIs and Ramsar sites.

F2.2 Since little is known about the interactive effects of the different pollutants emitted from road transport the primary focus of the assessment is on reactive nitrogen compounds. However, impacts are likely to be as a result of the suite of emitted pollutants. Emissions of $NO_x$ and $CO_2$ are already calculated for their contribution to regional effects and global warming respectively, as part of the regional impact assessment, and so do not need to be considered further here.

F2.3 The simple assessment methodology in Chapter 3 of this guidance note describes how $NO_x$ concentrations should be estimated. Therefore, the paragraphs below describe how to calculate nitrogen deposition within the Designated Site. The results of the assessment should be included in the intermediate assessment reports, the Environmental Statement, Appropriate Assessment if required, and be used in ecological impact assessments where appropriate.

### Method for Assessing Nitrogen Deposition

Step 1: Identify sensitive sites

Examine the Designated Sites to determine if any of these are sensitive to increases in nitrogen deposition. Sensitive sites include various types of woodland, heathland, grassland, bog and sand dune listed in Table F1. If there are no Designated Sites that are sensitive to nitrogen deposition, then there is no need to proceed any further with the nitrogen deposition assessment.

[38] **http://www.apis.ac.uk**

Step 2: Obtain total average N deposition for 5 km grid square

The average deposition rate from all sources of nitrogen (including the road of interest) should be obtained for the area of interest. Maps of total deposition rates can be found in the Air Pollution Information System (APIS)[38]. These are mapped on a 5 km x 5km basis so the area covered by each 5 km grid square should be noted. The data currently available on the system are for 1999-2001, which should be taken to be equivalent to those in 2000. The total average deposition rates obtained from the Air Pollution Information System for 2000 should be reduced by 2% per year to estimate deposition rates for the assessment years[39].

Step 3: Obtain background $NO_2$ and $NO_x$ concentrations

These should be obtained from the Air Quality Archive. Concentrations in the assessment years should be estimated using the year adjustment calculator available from the website. The usual procedures should be followed when obtaining background rates for $NO_2$ predictions near a road, i.e. background concentrations should be obtained for 1 km squares up to 4 km away from the road so that the road contribution is not double counted. The average $NO_2$ concentration in the 5 km APIS square (i.e. average of the 25 one km grid squares) should also be calculated as this is included in the APIS deposition rate.

Step 4: Calculate $NO_2$ concentrations in a transect near the road

Calculate the annual mean $NO_2$ concentration in a transect up to 200 m away from each of the affected roads within or near the Designated Site. The calculations should be carried out for the opening year both with and without the project and the base year and should include the background concentration in the usual way. The DMRB Screening Method should be used to carry out the calculations unless the method is not appropriate for the scheme/project being assessed.

Step 5: Estimate dry deposition of $NO_2$ in a transect near the road:

The rate of nitrogen deposition due to dry deposition of $NO_2$ at each of the receptor sites should be estimated using the equation given below. The deposition rate in the 5 km x 5 km APIS square should also be calculated. Dry $NO_2$ deposition rates should be estimated using the following scaling factor which is based on a deposition velocity for $NO_2$ of 0.001 m/s (taken from EMEP Eulerian photochemistry model). 1 $\mu g/m^3$ of $NO_2$ = 0.1 kg N $ha^{-1}$ $yr^{-1}$.

Step 6: Determine the road increment to $NO_2$ dry deposition

The dry $NO_2$ deposition rate for the APIS 5 km x 5 km square should be deducted from the receptor dry $NO_2$ deposition rate to give the increase in deposition rate at each receptor in the road corridor. This road increment should be added to the APIS average total deposition rate to give the total deposition rate at each receptor.

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39 Reduced nitrogen generally contributed about 45% of the total nitrogen deposited in Britain in 1997 with oxidised nitrogen contributing the remainder, although the proportion will vary depending on the location of the site and sources. Based on the results of transboundary deposition modelling for 1997 and 2010, deposition of reduced and oxidised nitrogen is expected to decrease on average across Britain by 1.5% and 2.6% per annum respectively due to increasingly stringent emission limits (National Expert Group on Transboundary Air Pollution on behalf of Defra and the devolved administrations. Transboundary Air Pollution: Acidification, eutrophication and ground level ozone in the UK. ISBN 1 870393 61 9, 2001). As the deposition of oxidised nitrogen is expected to decrease faster than that of reduced nitrogen, the proportion of the total nitrogen deposited from reduced nitrogen will increase in the future. It is expected to have reached 60% by 2010. If reduced and oxidised nitrogen are assumed to contribute to total deposition in equal proportions, then the annual decrease in nitrogen deposition can be assumed to be 2% (estimated in a non cumulative manner, i.e. decrease over five years is 5 x 2% = 10%) However, the deposition changes will not be linear across the country but 2% should be indicative of the typical change.

Step 7: Compare with critical loads.

The total deposition rate at each receptor should then be compared with the empirical critical loads for nitrogen set by the UNECE in 2003[40] that are shown in Table F1. Further information on critical loads for forest habitats is given in Table F2. Local factors such as phosphorus availability, site management (e.g. grazing) and rainfall will also affect the responsiveness of a site to altered nitrogen availability. Information on how these are likely to affect the critical load for selected ecosystems are given in the footnote to the Table. The Status of UK Critical Loads report[41] contains information on the applicability of the UNECE critical loads to sensitive UK habitats.

Step 8: Reporting

The change in deposition due to the project should be noted and discussed in relation to the critical load relevant to the interest features of the site, the background deposition and the extent of any exceedence. The results of this assessment should also be passed to an ecologist for inclusion in the ecological impact assessment (environmental impact assessment and/or Appropriate Assessment). The ecologist should consider the potential cumulative effects of all of the various impacts such as air pollution, water pollution and habitat loss and comment upon the effect of the project on the integrity of the Designated Site.

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[40] UNECE. Empirical Critical Loads for Nitrogen - Expert Workshop, Berne 2002, Eds. Acherman and Bobbink. Environmental Documentation No. 164, SAEFL, 2003.

[41] UK National Focal Centre, CEH Monks Wood. Status of UK Critical Loads. Critical Loads Methods, Data and Maps. Available at **http://www.airquality.co.uk/archive/reports/cat11/maintext_7may.pdf**

## Table F1 UNECE Critical Loads for Nitrogen

| Ecosystem type | Critical load (kg N $ha^{-1}$ $y^{-1}$) | Reliability | Indication of effects of exceedence |
|---|---|---|---|
| **Forest habitats** | | | |
| Temperate and boreal forests | 10-20 | # | Changes in soil processes, ground vegetation, mycorrhiza, increased risk of nutrient imbalances and susceptibility to parasites |
| **Heathland, scrub and tundra habitats** | | | |
| Tundra | 5-10[a] | # | Changes in biomass, physiological effects, changes in species composition in moss layer, decrease in lichens |
| Arctic, alpine and subalpine scrub habitats | 5-15[a] | (#) | Decline in lichens, mosses and evergreen shrubs |
| Northern wet heath<br>• 'U' *Calluna* dominated wet heath (upland moorland)<br>• 'L' *Erica tetralix* dominated wet heath | <br>10-20<br><br>10-25[a,b] | <br>(#)<br><br>(#) | <br>Decreased heather dominance, decline in lichens and mosses<br><br>Transition heather to grass |
| Dry heaths | 10-20[a,b] | ## | Transition heather to grass, decline in lichens |
| **Grassland and tall forb habitats** | | | |
| Sub-Atlantic semi-dry calcareous grassland | 15-25 | ## | Increase tall grasses, decline in diversity, increased mineralization, N leaching |
| Non-Mediterranean dry acid and neutral closed grassland | 10-20 | # | Increase in graminoids, decline typical species |
| Inland dune pioneer grasslands | 10-20 | (#) | Decrease in lichens, increase biomass |
| Inland dune siliceous grasslands | 10-20 | (#) | Decrease in lichens, increase biomass, increased succession |
| Low and medium altitude hay meadows | 20-30 | (#) | Increase in tall grasses, decrease in diversity |
| Mountain hay meadows | 10-20 | (#) | Increase in nitrophilous graminoids, changes in diversity |
| Moist and wet oligotrophic grasslands<br>• *Molinia caerulea* meadows<br>• Heath (*Juncus*) meadows and humid (*Nardus stricta*) swards | <br>15-25<br>10-20 | <br>(#)<br># | <br>Increase in tall graminoids, decreased diversity, decrease of bryophytes<br>Increase in tall graminoids, decreased diversity, decrease of bryophytes |
| Alpine and subalpine grasslands | 10-15 | (#) | Increase in nitrophilous graminoids, biodiversity change |
| Moss and lichen-dominated mountain summits | 5-10 | # | Effects upon bryophytes or lichens |
| **Mire, bog and fen habitats** | | | |
| Raised and blanket bogs | 5-10[a,c] | ## | Change in species composition, N saturation of *Sphagnum* |
| Poor fens | 10-20 | # | Increase sedges and vascular plants, negative effects on peat mosses |
| Rich fens | 15-35 | (#) | Increase tall graminoids, decrease diversity, decrease of characteristic mosses |
| Mountain rich fens | 15-25 | (#) | Increase vascular plants, decrease bryophytes |

## Table F1 UNECE Critical Loads for Nitrogen (continued)

| Ecosystem type | Critical load (kg N ha$^{-1}$ y$^{-1}$) | Reliability | Indication of effects of exceedence |
|---|---|---|---|
| **Inland and surface water habitats** | | | |
| Permanent oligotrophic waters<br>• Softwater lakes<br>• Dune slack pools | <br>5-10<br>10-20 | <br>##<br>(#) | <br>Isoetid species negatively affected<br>Increased biomass and rate of succession |
| **Coastal habitat** | | | |
| Shifting coastal dunes | 10-20 | (#) | Biomass increase, increase N leaching |
| Coastal stable dune grassland | 10-20 | # | Increase tall grasses, decrease prostrate plants, increased N leaching |
| Coastal dune heaths | 10-20 | (#) | Increased plant production, increase N leaching, accelerated succession |
| Moist to wet dune slacks | 10-25 | (#) | Increased biomass, tall graminoids |
| **Marine habitats** | | | |
| Pioneer and low-mid salt marshes | 30-40 | (#) | Increased late-successional species, increase productivity |

Reliability key: ## reliable, # quite reliable, (#) expert judgement

[a] Use towards high end of range at phosphorus limitation, and towards lower end if phosphorus is not limiting.

[b] Use towards high end of range when sod cutting has been practiced, use towards lower end of range with low intensity management.

[c] Use towards high end of range with high precipitation and towards low end of range with low precipitation.

## Table F2 Detailed Information on the UNECE Critical Loads for Forest Habitats

| Forect habitats | Critical load (kg N ha$^{-1}$ y$^{-1}$) | Reliability | Indication of effects of exceedence |
|---|---|---|---|
| **Soil processes** | | | |
| Deciduous and coniferous | 10-15 | # | Increased N mineralization, nitrification |
| Coniferous forests | 10-15 | ## | Increased nitrate leaching |
| Deciduous forests | 10-15 | (#) | Increased nitrate leaching |
| **Trees** | | | |
| Deciduous and coniferous | 15-20 | # | Changed N/macro nutrients ratios, decreased P, K, Mg and increased N concentrations in foliar tissue |
| Temperate forests | 15-20 | (#) | Increased susceptibility to pathogens and pests, change in fungistatic phenolics |
| **Mycorrhiza** | | | |
| Temperate and boreal forests | 10-20 | (#) | Reduced sporocarp production, changed/reduced below-ground species composition |
| **Ground vegetation** | | | |
| Temperate and boreal forests | 10-15 | # | Changed species composition, increase of nitrophilous species, increased susceptibility to parasites |
| **Lichens and algae** | | | |
| Temperate and boreal forests | 10-15 | (#) | Increase of algae, decrease of lichens |