Department
for Environment
Food & Rural Affairs

Implementation of the Nitrate Pollution Regulations 2015 in England

Method for designating Nitrate Vulnerable Zones for waters affected by eutrophication

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1. Introduction and Overview

1.1 Structure and focus of the report

This document describes the methodology for identifying waters affected by eutrophication for the purposes of the Nitrates Directive (hereafter termed Polluted Waters (Eutrophic)), leading to the designation of Nitrate Vulnerable Zones (NVZs). The methodologies used for identifying rivers and groundwaters which contain or could contain more than 50 mg/l nitrate are different and have their own method statements (Defra 2016, Defra 2016a)

The Nitrate Pollution Prevention Regulations 2015 (Defra 2015), which transpose the Directive into domestic law, require the Environment Agency to make recommendations to the Secretary of State as to areas of land which should be, or should continue to be, designated as NVZs.

This report describes the lines of evidence and criteria used by the Environment Agency in identifying relevant water bodies, and the process by which the evidence is gathered and evaluated. The methodology has been approved by a Defra Methodology Review Group (MRG)- it has evolved over time, in particular to take into account new methods of assessment developed for the Water Framework Directive (WFD), but the principles applied remain the same.

The report is divided into 5 main sections.

Section 1 is an introduction and overview, summarising the relevant provisions of the Nitrates Directive, the evolution of the methodology for identifying waters affected by eutrophication, and an overview of the steps involved in the process of designating eutrophication-related NVZs.

Section 2 sets out the criteria used in identifying waters affected by eutrophication.

Section 3 explains how the criteria are applied, how sources of nitrogen are assessed and how NVZs are defined.

Section 4 discusses the potential for de-designation and how this is approached.

Section 5 describes how the evidence for existing and potential candidate waters is collated and reviewed in formulating recommendations from the Environment Agency to Defra.

Further technical material is presented in Appendices A to E.

1.2 Requirements of the Nitrates Directive and the Nitrate Pollution Prevention Regulations 2015

The Nitrates Directive (91/676/EEC) is intended to reduce and prevent water pollution caused or induced by nitrates from agricultural sources. Member States are required to identify waters affected by pollution or which could be affected if action is not taken, and to designate the land draining to those waters and contributing to pollution, as Nitrate Vulnerable Zones (NVZs)[1]. Farmers in designated areas must follow an Action Programme to reduce pollution from agricultural sources of nitrate. High level criteria for identifying waters as polluted are established in the Directive, which also sets out monitoring requirements. NVZ designations must be reviewed at least every four years. The Nitrate Pollution Prevention Regulations 2015 implement the Directive in England.

Waters that are or could be affected by pollution are to be identified using, *inter alia*, the following criteria, the third of which is relevant in the context of this method statement:

- surface freshwaters which contain or could contain, if preventative action is not taken (i.e. Action Programme measures), more than 50 mg/litre nitrate;
- groundwaters which contain or could contain, if preventative action is not taken, more than 50 mg/litre nitrate;
- **natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or in the near future may become eutrophic if preventative action is not taken. (Termed “Polluted Waters (Eutrophic)” in this report).**

The Directive also specifies that the following considerations must be taken into account when applying these criteria:

- the physical and environmental characteristics of the water and land;
- the current (scientific) understanding of the behaviour of nitrogen compounds in the environment (water and soil); and,
- the current understanding of the impact of preventative action.

Under Article 6, for the purpose of designating and revising the designation of vulnerable zones at least every 4 years, Member States shall: “*review the eutrophic state of their fresh surface waters, estuarial and coastal waters every four years*”.

[1] Member States may, as an alternative to identifying specific vulnerable zones, establish and apply an action programme throughout their national territory.

Eutrophication is defined as ***"the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned"***.

The Directive requires that at each NVZ review, changes and factors unforeseen at the previous review must be taken into account. The periodic nature of reviewing NVZs means that each review necessarily presents a 'snapshot' assessment of nitrate pollution up to the time of the review.

1.3 Evolution of the assessment methodology

1.3.1 Interpreting and expanding upon the requirements of the directive

The Defra methodology for designating nitrate vulnerable zones on the basis of eutrophication was originally published by DoE/Welsh Office/MAFF in 1993. In the absence of any detailed EC guidance or criteria in the Directive for assessing eutrophication, a national approach was developed which reflected and expanded upon the legal definition of eutrophication, the requirement to identify waters which "are eutrophic or in the near future may become eutrophic" and an understanding of the relevant science.

The meaning of the term "eutrophic" was inferred from the definition of eutrophication. In this report a "eutrophic" water body is one that is expected to show symptoms of eutrophication (undesirable ecological change) in line with the definition. This should not be confused with the terminology sometimes used to describe the natural state of surface waters as oligotrophic, mesotrophic or eutrophic (generally equated to low, medium and high nutrient concentrations) – any water body may be affected by an increase in nutrient levels causing eutrophication. Eutrophication is recognised as one of the foremost problems for protection of water resources and dependent ecology.

The criteria comprise suites of quantitative and qualitative criteria for nutrients, plant/algal growth and secondary or other effects, broken down by water categories, and applied through a weight-of-evidence approach. Weight-of-evidence involves coming to an overall judgement on a balance of probabilities as to whether there is an undesirable disturbance to the balance of organisms or water quality, or the likelihood of such undesirable disturbances in the near future. Water bodies are considered individually against the nationally defined criteria and requirements in a structured way, maximising the use of environmental data together with local knowledge and information. The importance of particular symptoms depends on local circumstances, and judgements are based on an assessment of all relevant information. This remains the approach.

1.3.2 Refinement of the methodology

The methodology has been refined over time to take into account the development of new science-based methods and associated policies. From 2002 the criteria were refined to align them closely with the UK OSPAR criteria for eutrophication in saline waters. From the mid-2000s they were further refined to base them increasingly on the UK's methods for assessing ecological status under the Water Framework Directive (WFD) (2000/60/EC). This directive introduced concepts such as deviation of water bodies from reference (undisturbed) conditions and typologies. The reference-based WFD toolkit for assessing ecological status is underpinned by contemporary research and development, with the biological boundaries being subject to scrutiny through EU intercalibration (a legal requirement of the WFD to ensure comparability of status class boundaries between Member States). The WFD also brought a more structured and consistent approach to identifying waters of potential concern (those warranting more detailed assessment) through the use of risk assessments including for those affected by eutrophication.

With regard to the criteria for eutrophication assessment, the specifications for WFD ecological status for the algal/plant quality elements incorporate the definition of eutrophication from the Nitrates and Urban Waste Water Treatment Directives (UWWTD) and the nutrient conditions must support the biology. Assessing eutrophication is part of WFD ecological status assessment and an absence of eutrophication problems is a part of the specification for good ecological status.

The WFD good/moderate boundary values for ecological status of the relevant quality elements (nutrients, algae/plants and indicators of secondary effects) now provide our main thresholds for eutrophication assessment. However the Environment Agency continues to use a weight-of-evidence approach to eutrophication assessment, taking into account other relevant criteria and supporting evidence, which is now applied for Nitrates Directive, UWWTD and WFD purposes (as well as informing our position for Marine Strategy Framework Directive and OSPAR for saline waters).

1.3.3 Oversight by national expert groups

For the 2013 review, revisions to the previous methodology were discussed and agreed with a Methodology Review Group (MRG) chaired by Defra. The MRG comprised independent academic experts, farming industry representatives, Welsh Government, Environment Agency and Conservation Agency staff with expertise in this area. The final methodology was reviewed and accepted by the group including academic experts who are leaders in the field of surface water management. Subsequent updates to the method have been accepted by Defra and a national stakeholder group representing the agricultural sector. The updates relate to adoption of the most recent versions of Water Framework Directive assessment tools.

The methodology is applied by the Environment Agency in close consultation with Defra. It represents a robust and practical approach to the identification of polluted waters and NVZs.

In recognition of the degree of subjectivity in applying the weight-of-evidence approach for eutrophication, the use of national expert panels, to review and quality assure the collated evidence for potential candidate waters and existing designations, has been part of the NVZ and UWWTD methodologies since the 1990s. This ensures consistency of approach in recommending waters to government for formal identification at each review.

1.4 Overview of the steps in the process for reviewing eutrophication-related NVZs

Step 1 – Focusing in on water bodies of concern

The Environment Agency has a risk-based approach to monitoring and assessment for eutrophication. Information from national monitoring programmes, operational investigations, risk assessments and local knowledge is used to identify water bodies which warrant more detailed investigation. Information is considered for different water categories – freshwaters and transitional (estuarine) or coastal waters.

Step 2 – Detailed investigation of individual water bodies

For the waters identified under Step 1 and all existing Polluted Waters (Eutrophic), detailed evidence from monitoring and investigations is collected and compared against the suites of criteria for the different types of water under investigation. This is done through national level collation of classification data and gathering local evidence and knowledge about water bodies and their catchments.

The evidence for individual water bodies is collated on spreadsheets and, for existing or candidate waters, on standardised datasheets, summarising the data and the condition of water body as assessed against the relevant chemical, biological and other criteria, plus supporting information about the water body and its catchment. Information about the sources of nitrogen loading to existing and candidate water bodies is also collated.

Step 3 - Quality assurance and submission of evidence to a national panel

A national expert panel is convened by the Environment Agency for each water category towards the end of each NVZ review. It involves input from Environment Agency, Natural England and external experts. Observers from stakeholder groups are invited to attend. The aim of the panel is to assist the Agency in developing its recommendations and to help to ensure national consistency in the assessment process, recognizing that the assessment of eutrophication involves weighing up the various strands of evidence to come to an overall judgement on the case for designation.

Step 4 – Identification of land

The land draining to the Polluted Waters (Eutrophic) is defined as:

- land draining directly to the Polluted Water (Eutrophic), for which specific hydrological boundaries were drawn within the WFD catchment boundaries, plus
- the WFD catchments of surface waters upstream of (and therefore draining into) the Polluted Water (Eutrophic).

In common with the wider NVZ review, for the purposes of NVZ designation the hydrological or "soft" boundaries as delineated above are then converted to "hard" boundaries such as roads and field boundaries.

2. Criteria for assessing certainty of eutrophication in fresh and saline water bodies

2.1 Introduction

Eutrophication describes a process of change rather than a state and is controlled by a number of factors. These include nutrients, flow rate of waters, residence time, shading and turbidity, depth, temperature, stratification, and turbulence. The precise influence of many of these factors in the process is not easily quantified and eutrophication can express itself in different ways depending on the type of water body (e.g. estuary or lake). The assessment of whether a water body is eutrophic or may become eutrophic requires a number of symptoms to be considered. This is done, using a structured framework (see 2.2), in order to come to a rounded judgement, taking into account the weight of evidence, as to whether an individual water body is suffering an "undesirable disturbance" or may do so without preventative action.

In order to identify waters that are eutrophic, or that in the near future may become eutrophic if preventative action is not taken, it is necessary to consider:

- the current condition of the water body (ideally compared to a reference condition for nutrients and their impacts);
- whether undesirable effects, such as de-oxygenation, algal blooms, growth of particular plants, or other changes in species composition, have occurred;
- whether nitrogen is involved in causing such eutrophication, and
- whether such undesirable effects may occur if preventative action is not taken

The following sub-sections outline the criteria involved and later sections describe the application of the method for different water categories.

2.2 National suites of criteria

The approach adopted in England is to collate and assess evidence for individual water bodies against a national suite of criteria for eutrophication in the different categories/types of water for review. The criteria are both quantitative and qualitative and reflect scientific understanding of the process and effects of eutrophication. The WFD UK good/moderate ecological status boundaries for nutrients and their impacts provide the core criteria for use in the NVZ review, supplemented by other thresholds where relevant. The criteria are broken down in the same way for each water category, in line with the conceptual frameworks for eutrophication assessment developed by OSPAR and the EU [European Communities, 2009], as follows:

2.2.1 Category I – causative parameters – nutrients

Nitrogen and phosphorus are termed causative parameters. Both can contribute to eutrophication but, for the Nitrates Directive, we focus on identifying polluted waters where sufficient nitrogen is present to promote eutrophication alongside the effects of any phosphorus enrichment. Indicative thresholds or standards for nutrients have been established for the different types of waters, based on published scientific evidence/ literature and with reference to WFD UK Technical Advisory Group (UKTAG) and domestic UWWTD/Nitrates directives' guidance[2].

Data on nitrogen loadings to the water body from different sources, derived by modelling and other methods, are also considered, to confirm whether agriculture is making more than an insignificant contribution to nitrogen loadings and thus pollution.

2.2.2 Category II – response parameters – direct effects on algae and plants

Elevated nutrient concentrations can have a range of impacts on the algal and plant life in waters. These are termed response parameters. The changes assessed include:

- increased abundance and biomass of algae (phytoplankton, macroalgae, benthic diatoms) and/or higher plants, or loss of sensitive higher plants;
- changes to species composition;
- exceptional algal blooms.

[2] Detailed references are given in the relevant sections of this report.

As for nutrients, indicative thresholds or standards for the indicators of algal/plant response to nutrients have been established for the different types of waters, based on published scientific evidence/ literature and with reference to WFD-UKTAG and domestic UWWTD/ Nitrates directives' guidance.

2.2.3 Category III – secondary and other indirect effects

Adverse water quality and ecological impacts resulting from excessive algal/plant growth are considered, including changes to dissolved oxygen, occurrence of toxic/harmful algal blooms and the effects on other flora and fauna. Information on any impacts of eutrophication on water uses (e.g. recreation, conservation value, drinking water supply) is also considered.

2.2.4 Bringing the evidence of eutrophication together for an individual water body

A case for identification of a Polluted Water (Eutrophic) is considered to exist where it is found that the Category I criteria are exceeded and some (or all) of the Category II and III criteria are exceeded, or may be exceeded, taking into account the influence of relevant environmental factors and considering the overall weight of evidence. For further details for each water category see **Section 3.**

2.3 Scale of assessments

In the main, the unit of assessment for the weight-of-evidence approach is the WFD water body (i.e. certainty of eutrophication has been assessed at that scale). However, some of the existing designated sites, e.g. estuarine areas, are smaller than the WFD water body in which they sit and eutrophication is reviewed at the scale of the identified Polluted Water (Eutrophic). If further "hot spots" for eutrophication are identified within larger WFD water bodies, then these smaller areas can be put forward for potential designation as NVZs.

2.4 Further information on the adoption of WFD tools and criteria

In recent years, we have increasingly used WFD methods of ecological status assessment as a key element of our approach to assessing eutrophication for the Nitrates Directive. This accords with EU guidance on assessing eutrophication under EU water policies, published under the WFD Common Implementation Strategy in May 2009 (European Communities, 2009). The guidance promotes a harmonised approach to eutrophication assessment across the policies, particularly WFD, UWWT and Nitrates Directives. The reference-based classification tools and risk-based monitoring requirements of the WFD are at the heart of the approach.

The UK supported and participated actively in developing the EU guidance. Our methods for Nitrates Directive eutrophication assessment have been updated over time and in the last two NVZ reviews, the UK WFD standards and criteria for nutrients and their impacts were introduced within our approach. This was in recognition that the reference-based ecological approach under WFD is well suited to the assessment of eutrophication as a process of ecological change, and for the other reasons set out in Section 1.3. In line with the EU Eutrophication Guidance, the relevant boundary values, in considering eutrophication based on WFD methods, are the good/moderate ecological status boundaries for the relevant nutrient, biological and other indicators.

The WFD approach to classification, standards and typology was originally laid out in a consultation that preceded the WFD Ministerial Directions on these matters for the first River Basin Plans (Defra, 2009), and was updated through another consultation (Defra 2014) and a new set of Directions for Cycle 2 of the WFD (Defra 2015a). There has been significant research and development undertaken under the direction of the WFD UK Technical Advisory Group (UKTAG) to improve the performance of the WFD biological tools. These tools have, in some cases, been substantially revised, and have been tested against the assessment methods used in other EU Member States through the process of intercalibration, ensuring that the good/moderate ecological status class boundaries set within different Member States to define good status are essentially equivalent.

The Ministerial Directions set out the process for (a) assigning water bodies to a type (b) the standards and other criteria that apply to each type including Good/Moderate boundary values for nutrients and biological quality elements and (c) the rules for WFD classification. The revised versions of the tools were adopted for use in reporting water body status for the WFD for the second River Basin Management Plans, published in 2015, after public consultations by both the WFD UK Technical Advisory Group (UKTAG 2013), and DEFRA (2014).

The WFD standards and boundary values for nutrients and their impacts are a key component of our approach. But we remain in a transition period between our former methods and a fully harmonised approach, so we continue to use some of our earlier measures of eutrophication alongside those developed for WFD. Further detail is provided in the following sub-sections for each water category.

The component WFD metrics are summarised in the sub-sections that follow. Further detail can be found in the relevant method documents, which are available on the WFD-UKTAG web site at: http://www.wfduk.org/resources/category/biological-standard-methods-201. Further detail is available in technical reports on the individual classification tools, for which the method documents provide references.

2.5 Estimation of nitrate from agricultural sources

We use the NEAP-N model to represent the losses associated with agricultural land in the NVZ designations process. The NEAP-N model (Anthony et al., 1996; Lord and Anthony, 2000; Silgram et al., 2001) was developed under Defra Water Quality funding as a policy tool to allow estimation of nitrate loss from agricultural land, applicable to any catchment in England and Wales. It is acknowledged as the foremost national nitrate leaching model in the UK and is widely used throughout the UK and in pan-European studies. It has been an important part of the last three NVZ reviews.

NEAP-N builds upon previous models and field experiments and is essentially an export coefficient model that varies according to land use, climate and soil type. Nitrate loss potential coefficients are assigned to each crop and livestock type and the model summarises these to predict a total annual loss from agricultural land, which can be split into losses of nitrogen and nitrates from;

- Fertiliser applications and losses due to other cropping practices on arable land
- Manures from housed animals applied to arable and managed grassland
- Excreta from grazing livestock to managed grassland and rough grazing land
- Atmospheric deposition on arable land, managed grassland, rough grazing land, woodland and open water.

NEAP-N includes a water balance model and a leaching algorithm, which calculates the proportion of the potential loss that is actually leached.

The input data to NEAP-N is the agricultural census (for each of the cropping and livestock categories), the dominant soil type (sourced from the Cranfield University NatMap soils dataset), mean annual rainfall (sourced from the UKCP09 1961-90 baseline climate dataset) and potential evapotranspiration for the different crop types. The version of NEAP-N used has been modified to better represent the impacts of atmospheric deposition (Lord et al., 2007) and the land use data in the model is the most recently available from the agricultural census (the most contemporary data available to this project).

The model produces predictions at the 1km² scale, but for the NVZ designations we aggregate these data to larger scales to represent the water bodies we are reviewing.

It is important to recognise that the outputs from NEAP-N we use for NVZ designations cannot **directly** predict nitrate levels in surface waters, groundwaters or marine waters. This is because;

- The output of the model is total annual nitrate-N loss from the soil profile for agricultural land. It makes no assumptions about the hydrological pathways that the nitrates then follow, either to groundwater or via surface flow pathways.

- It also does not consider the effects of de-nitrification once the nitrates are mobilised from the soil or the effects of previous losses in the groundwater returning to the surface.

- It does not consider any nitrate losses from non-agricultural land.

- The land use data is contemporary but the rainfall data that leads to the loss of nitrogen from the soil is based on the long-term average. It will therefore not consider the effect on nitrate-N losses if the year in question was particularly wet or dry.

- The model predicts the loss from the crops and livestock in the area but does not take into account any changes in farming practices due to mitigation options (such as NVZ Action Programme measures or Catchment Sensitive Farming).

For these reasons, NEAP-N is used as part of the evidence supporting NVZ designations and interpreted alongside other data.

2.6 Criteria for eutrophication in lakes/reservoirs

2.6.1 Introduction

This section describes the core suite of variables and criteria, both biological and chemical, that provide the principal evidence of eutrophication.

A range of factors influence the growth of plants in fresh waters. In accordance with the legal definition, an essential precursor to eutrophication is the presence of nutrients in sufficient quantity to support sustained algal and/or plant growth. Scientific studies by limnologists in the 1920s, and large-scale comparative analyses from the 1970s onwards (Vollenweider, 1968 and others) have provided a strong body of evidence that phosphorus is the key nutrient controlling production and excess algal biomass in most freshwater systems.

The potential for imposing nutrient limitation through control of external nutrient inputs (from both agricultural and human effluent sources) is also generally greatest for phosphorus (P). Threshold criteria for phosphorus in different types of freshwaters have been used by the UK for Nitrates and UWWT Directives purposes since the criteria were first developed in 1993 and P standards were introduced under the WFD in 2009.

In recent years it has been recognised that nutrient nitrogen (N) can play an important role in eutrophication of lakes in some situations. UK Eutrophication Steering Group commissioned a literature review of the role of nutrient N in freshwater eutrophication to assist the UK regulatory agencies in formulating recommendations to Government as to which waters may warrant identification under Nitrate and/or UWWT Directives.

The report (CEH, 2004) indicated that regulators should consider lowland lakes with high phosphorus concentrations, those with long residence times and few inflows, those dominated by submerged macrophytes and those where the inflow passes through a wetland. Site-specific assessment was recommended and the report summarised the tools and techniques available, whilst recognising the difficulties in applying the methods and interpreting the data in what is a developing area of science. For the 2009 NVZ review, thresholds for nitrogen concentrations in lakes were introduced as part of the suite of criteria for use within the weight-of-evidence based approach to eutrophication in the Defra methodology.

2.6.2 Nitrogen determinands used in lake assessment

Nitrogen is present in a number of different forms in freshwaters, and partitioning between the different forms varies over time. Historically, most lake monitoring in England involved the determination of total oxidised nitrogen (TON), a direct measurement of soluble nitrogen present in the water column as nitrate and nitrite, and available for uptake by algae and higher plants.

There are usually pronounced seasonal variations in TON related to inputs from the catchment driven by rainfall and run-off. Because soluble nutrients are absorbed and incorporated into plant material during the growing season, low concentrations of TON in the water column do not necessarily mean there is no nitrogen enrichment occurring. To account for the seasonal uptake into plant material, a measurement of the TON concentrations based on the winter mean value or the 75^{th} percentile of the annual values is considered to be representative of the true nitrogen load to the lake.

More recently, lake monitoring has included the determination of total nitrogen (TN), which includes all nitrogen present in the water column, both in soluble form and as organic material in algal cells. This also varies seasonally due to varying inputs and outputs from the lake, incorporation in sediment and denitrification. There is a close relationship between TN and TON concentrations in most lakes.

Where both TON and TN data are available both are used in the evaluation of evidence for elevated nitrogen levels in lakes. In all cases the concentration is reported as milligrams per litre of nitrogen (mg/l N), so the results are directly comparable with each other and with the threshold values established for assessment purposes.

2.6.3 Criteria to determine significantly elevated nitrogen

Taking into account the available scientific evidence, threshold values have been established for assessment of the status of lakes with regard to nitrogen. Lake data are assessed against these criteria based on results of routine water quality monitoring undertaken at monthly, or in some cases quarterly, intervals, over a period of four years.

For TN, mean values are calculated based on the available data. For TON, the 75th percentile of the annual data is used – this statistic is closely related to the winter mean value, which is taken to be representative of the soluble nitrogen available for plant growth at the start of the growing season. The 75th percentile was adopted as the appropriate statistic at a time when monitoring data were more limited and it was not always possible to calculate a true winter mean. Subsequent comparison of calculated winter mean values and 75th percentiles has shown that there is a very close relationship between these two summary statistics.

The Methodology Review Group (MRG) agreed in 2012 that a threshold value of 1-2 mg/l N should be adopted, for both TN and TON. This range reflects the uncertainty in the scientific literature over the exact point at which elevated N concentrations may play a role in accelerating the growth of plants and/or phytoplankton in lakes. When lake data are reviewed, a screening is carried out to determine initially if the nitrogen concentration (as N) is above 1 mg/l, and secondly if it is above 2 mg/l.

The agreed approach (as recommended by the MRG) is that where concentrations in standing waters exceed

- 2 mg/l (at face value, >= 50% confidence) there should be a presumption to designate, subject to evidence of eutrophication related disturbance.

- 1 mg/l but do not exceed 2mg/l that interpretation of the data should be at the discretion of a national expert panel. The panel considers the evidence for the different forms of nitrogen, together with that of eutrophic disturbance, the physical characteristics of the lake, the conservation and other amenity value of the site and the concentration of nutrient phosphorus. They also consider the seasonal pattern of nutrient nitrogen concentrations and whether this might indicate seasonal nitrate limitation of primary production.

These thresholds are above the levels expected naturally in the majority of lakes in the UK.

Not all lakes reviewed as potential candidates for designation have measurements of both TON and TN. The MRG agreed that the criteria of 1-2 mg/l could be evaluated by reference to either the 75th percentile TON and/or annual mean TN values. Where sites had one but not both metrics they would be considered further in terms of overall weight of evidence.

Account is also taken of any evidence of nitrogen limitation during the growth season (where TON values reach a minimum, indicating N supply is limiting to plant growth). However the dynamics of nutrient limitation of phytoplankton and macrophyte communities, and the interaction between nitrogen and phosphorus, is complex (Moss et al 2013). It is important to understand that evidence of nutrient-N limitation is not evidence that elevated concentrations of nutrient N are not contributing to eutrophic disturbance. Where a lake is enriched with nutrient-P, additional nutrient-N helps support increased production and may directly suppress the growth of certain macrophyte species (e.g. James et al., 2003, 2005). Under circumstances of seasonal nutrient-N limitation within a P-enriched eutrophic lake, increased loadings of nutrient N are expected to increase total primary production and hence lead to increased risk of eutrophic disturbance. Likewise, reductions in N loading are expected to help reduce primary production and possibly increase the period of seasonal nutrient N limitation, leading to a reduced risk of eutrophic disturbance.

The criteria for lake nitrogen, set out above, were derived from a review of the relevant, recent scientific literature pertaining to the role of nitrogen in promoting changes to the ecology of UK lakes. The review is provided in Appendix C.

2.6.4 Other parameters used in the assessment of eutrophication in lakes

The component WFD metrics for lakes are briefly described in the sub-sections below.

The Conservation Agencies have established their own systematic approach to monitoring the condition of SSSI's and SAC/SPA designated sites (JNCC, 2015). For lakes, both WFD and Common Standards Monitoring (CSM) assessments may be based on shared data sets, although standards and metrics applied for CSM may differ, and in some cases the CSM standards may be more stringent that the WFD Good status requirements. Where appropriate, a consideration of site condition as assessed by Natural England has been included in the detailed investigation of each candidate lake.

Total Phosphorus

Total phosphorus is a key indicator of freshwater lake eutrophication; it represents the available soluble phosphorus and the phosphorus contained in particulate matter suspended in the water column, including the phytoplankton. For WFD classification site-specific boundary values (standards) for total phosphorus have been established. These depend on the alkalinity and mean depth of the lake and the procedure for determining them is given in the Ministerial Directions (Defra, 2015a). See also WFD-UKTAG (2008a) for details of the derivation of the standards.

Total phosphorus is typically measured from water samples collected at monthly intervals, although in some cases quarterly sampling may be undertaken.

Dissolved Oxygen

In thermally stratified lakes the concentration of oxygen can become depleted in the deeper cold waters of the hypolimnion. This can have detrimental impacts on fish and invertebrates and is an indicator of eutrophication. An oxygen concentration depth profile is measured at the deepest point in selected lakes on at least one occasion in the late summer (July-August). In shallower thermally mixed lakes the mean oxygen concentration of the whole water column is determined and in stratified lakes the mean oxygen concentration of the hypolimnion (the lower layer of water) is determined. Mixed lakes are very unlikely to experience dissolved oxygen issues, so in practice these standards are largely applied to deeper lakes that stratify for at least part of the year. The values are compared with standards given in Defra (2015[3]) and shown in Table 2.1.

Table 2.1 Dissolved oxygen standards for freshwater lakes

Dissolved oxygen standards for freshwater lakes		
Status	mean in July – August (mg/l)[(i)]	
	Salmonid	Cyprinid
High	9	8
Good	7	6
Moderate	4	4
Poor	1	1

[(i)] The mean for mixed lakes is throughout the whole water column and the mean for stratified lakes is for readings taken in the hypolimnion

Phytoplankton

The WFD lake phytoplankton classification tool was substantially revised for implementation in Cycle 2 of the WFD; the tool now in use is referred to as PLUTO (Phyto**pl**ankton Classification with **U**ncertainty **To**ol). This includes three metrics:

- phytoplankton abundance is measured with chlorophyll *a* (an indicator of algal biomass)
- species composition is assessed using the Plankton Trophic Index (PTI)
- bloom intensity is assessed from the biovolume of cyanobacteria.

Ecological quality ratios (EQRs) are calculated for the individual metrics, as a ratio of the observed values to the expected (reference condition) values, and then combined to produce an overall EQR and hence an ecological status class for phytoplankton. It is

[3] Defra (2015) The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015

possible to derive a classification based only on the chlorophyll metric if detailed taxonomic information is not available to calculate the PTI and biovolume metrics – in this case the calculated EQR is adjusted automatically to take account of the impact of the missing taxonomic data.

Chlorophyll data are collected monthly or quarterly, and an annual mean value is used for classification. Taxonomic information is obtained from samples collected each year in July, August and September. Data from multiple years are combined for the assessment. The Environment Agency routinely collects phytoplankton data each year as part of its WFD operational and surveillance monitoring in lakes, as well as from any Polluted Water (Eutrophic) lakes not identified as WFD water bodies. The WFD classification is based on data from the preceding three years. Boundary EQR values are given in Defra (2015), and in the detailed phytoplankton method statement (WFD-UKTAG 2014a).

Table 2.2 Class boundary values in relation to the PLUTO phytoplankton method

Class boundary values in relation to the PLUTO phytoplankton method				
Lake Type	High/Good EQR	Good/Mod EQR	Mod/Poor EQR	Poor/Bad EQR
All types	0.80	0.60	0.40	0.20

Macrophytes and Phytobenthos

Classification of lake macrophytes (higher plants and filamentous algae) and phytobenthos (benthic diatoms) is carried out using the WFD tools Lake LEAFPACS 2 and DARLEQ 2. Further details of the methods are provided in WFD-UKTAG (2014b) and WFD-UKTAG (2014c).

Lake LEAFPACS 2 is a revised version of the original WFD macrophyte tool, based on the same survey methodology, and comprising five metrics describing different aspects of the lake macrophyte community. The metrics reflect species composition (Lake Macrophyte Nutrient Index (LMNI), number of functional groups, number of taxa) and abundance (average percentage cover of macrophytes, relative percentage cover of filamentous algae). Ecological quality ratios (EQRs) are calculated for each metric and then combined to produce an overall EQR and status class.

The Environment Agency collects macrophyte survey data from WFD surveillance and some operational monitoring sites, and any Polluted Water (Eutrophic) lakes that have not been identified as WFD water bodies, typically one year in every three. The WFD classification is based on data from the preceding 6 years.

The method is designed to distinguish the anthropogenic effects of nutrient enrichment from a natural nutrient gradient. The value observed for each indicator is compared with its reference value and expressed as an EQR. Reference values specific to each lake are determined from a set of environmental predictors. The predictors have been derived from a model based on a population of lakes considered to represent reference conditions. Boundary values for EQRs are given in Defra (2015) and are shown in Table 2.3.

Some lakes are designated as SSSIs or SAC in order to protect particular plant species or communities associated with particular lakes. LEAFPACS 2 does not provide a specific indication of the condition of such species. Hence, where relevant, information from Conservation Agency's condition assessments based on the Common Standards Monitoring method (JNCC 2015) are separately considered where designated aquatic interest features may include plant species which may be sensitive to the effects of eutrophication and whose unfavourable condition may indicate eutrophic disturbance.

Table 2.3 Class boundary values in relation to the Lake LEAFPACS 2 method

Class boundary values in relation to the Lake LEAFPACS 2 method				
Lake Type	High/Good EQR	Good/Mod EQR	Mod/Poor EQR	Poor/Bad EQR
All types	0.80	0.60	0.40	0.20

The lake phytobenthos tool (DARLEQ 2), is based on a single metric, the Lake Trophic Diatom Index (LTDI). There was some revision of the LTDI scores during the development of DARLEQ 2, based on a re-analysis of diatom/nutrient relationships using an improved data set for lakes. DARLEQ2 is based on changes in the species composition of the benthic diatom flora (the bio-film) in response to nutrient enrichment. The dynamic nature of bio-films means their composition and abundance can change over relatively short time scales. DARLEQ 2 estimates reference LTDI values by making a site-specific prediction. This is compared with the observed values to produce an EQR. Boundary values for EQRs are given in Defra (2015) and are shown in Table 2.4.

The Environment Agency collects phytobenthos data each year from WFD surveillance lakes, resulting in a smaller dataset than that available for phytoplankton or macrophytes. The WFD classification is based on data from the preceding three years.

Table 2.4 Class boundary values in relation to the Lake DARLEQ 2 method

Class boundary in relation to the Lake DARLEQ 2 method				
Lake Type	High/Good EQR	Good/Mod EQR	Mod/Poor EQR	Poor/Bad EQR
High and low alkalinity	0.92	0. 70	046	0.23
Low alkalinity	0.93	0.66	0.46	0.23

Chironomid Pupal Exuviae Technique (CPET)

The chironomid pupal exuviae technique (CPET) is a method for assessing the impact of nutrient enrichment on lake invertebrates (Ruse 2010). Chironomids are a very diverse group of insects that include a wide range of feeding modes and thus represent a broad range of functional groups. They are sensitive to the secondary effects of eutrophication, such as reduced oxygen concentration and changes to physical habitat caused by impact on lake vegetation, which is an important physical habitat. These insects are thus used to assess the indirect effects of eutrophication.

Reference conditions were derived from a combination of pressure threshold limits and ratio of pressure-sensitive to tolerant species presence. Class boundaries are defined by relative frequencies of sensitive to tolerant species. Boundary values for EQRs are given in Defra (2015) and are shown in Table 2.5. Further details of the method are provided in WFD-UKTAG (2008b).

Table 2.5 Class boundaries in relation to the CPET method

Class boundaries for the CPET method in relation to nutrient enrichment				
Lake Type	High/Good EQR	Good/Mod EQR	Mod/Poor EQR	Poor/Bad EQR
All types genus tool	0.77	0.64	0.49	0.36

Additional Indicators of Eutrophication Impact

Number of reports of cyanobacteria blooms

The Environment Agency investigates reports it receives of algal blooms. The number of confirmed reports of cyanobacteria blooms between 1990 and 2014 which were above the World Health Organisation warning thresholds for safe use of recreational waters (WHO, 2003) has been used to indicate the incidence cyanobacteria blooms. Note that this is based on data from a reactive monitoring approach and the absence of reported blooms cannot be used to infer evidence of no impact. Other reliable evidence of blooms not formally recorded on the Environment Agency archive may also be included in the overall assessment.

Palaeolimnological Data

In lakes, sediment is gradually laid down in layers and the sedimentary diatom record provides a long-term record of changes in the lake (Bennion and Simpson 2010). Diatoms are sensitive to water quality and the degree of floristic change of diatom species between samples taken from the bottom of sediment cores (reference conditions) and the surface sediment can be used to assess the extent of change over time. This is quantified using a dissimilarity coefficient (squared chord distance) which can take values between 0 and 2.0, where a value of 0 represents perfectly similar and 2 perfectly dissimilar samples. Based on an analysis of 106 UK lakes Bennion and Simpson (2010) propose that squared chord distance of >0.48 as a boundary representing significant change. For the lakes subject to review that were included in the Bennion and Simpson study the squared chord distance is considered.

2.7 Criteria for eutrophication in rivers

For rivers, since 1993 the methodology has allowed for sites to put forward (by the Environment Agency) for potential designation on a local case by case basis against the eutrophication criteria for the (UWWTD) and in recent years the WFD, and an assessment of the involvement of nitrogen from agricultural sources. This remains the case for this NVZ review. However, in contrast to the evolving science and our position for lakes, it has not proved possible to develop a more detailed science-based approach and criteria such as nitrogen thresholds to facilitate the identification of situations in which nitrogen (N) is playing a causal role and where designation would thus be appropriate and beneficial.

For lakes there is a body of recent science on the role of N (alongside phosphorus (P) as the main causal nutrient in freshwaters) including N thresholds associated with eutrophication related impacts, notably to protect against reduced species richness of lake macrophytes. This was taken into account in refining the lake methodology for the 2009 NVZ review.

For rivers there is not a similar body of literature suggesting N concentrations to prevent eutrophication and there are considerable difficulties separating the effects of P and N. Relationships between nutrients and ecology in rivers are also much more complex and variable than those in lakes. The case for science based N thresholds looks much less clear than for lakes but the position is being kept under review.

2.8 Criteria for eutrophication in estuaries and coastal waters

The assessment of eutrophication in saline waters has been considered and addressed for many decades by international bodies including the Paris Commission (1972), OSPAR (since 1992) and the International Council for the Exploration of the Sea (ICES). Our approach to assessing eutrophication in English saline waters, for the purposes of the Nitrates Directive, was first set out in 1993. It closely reflected the concepts and criteria resulting from the international science-based body of work.

Our methodology, which is published as part of each NVZ review, has been updated over time to reflect more recent developments. These included the OSPAR Strategy to Combat Eutrophication (from 1998) which included a Common Procedure setting out criteria and an assessment methodology for eutrophication in saline waters. Then the Water Framework Directive (2000/60/EC) which, as discussed earlier (see Section 1.3, 2.2 and

2.4), now provides our principal criteria for nutrients and their impacts although the criteria developed prior to WFD are also considered.

In common with the methodology for lake/reservoir eutrophication, the criteria continue to be applied by comparing the evidence for individual water bodies against the national suites of criteria through the use of a weight-of-evidence approach (see Section 1.3).

The criteria are summarised in the following tables – see **Appendix A**. **Table A1** covers coastal waters and **Table A2** covers estuaries (termed transitional water bodies under the WFD). Further details of the WFD tools and boundaries are available from the WFD UKTAG website – see links in Section 2.4.

3. Applying the eutrophication criteria and defining NVZs

3.1 Lakes and reservoirs

3.1.1 Evidence used in the assessment of eutrophication

The evidence used in the assessment of eutrophication of each lake is structured into four parts. These are

1. information on the physical and chemical characteristics of the lake and hydrological catchment;
2. evidence regarding the ecosystem service benefits provided by the lake which might be impacted by eutrophication;
3. quantitative and qualitative evidence regarding the level of exposure of the lake and its flora and fauna to nutrient nitrogen and phosphorus, and evidence of the relative importance of nitrate sources (Category I from Section 2.2); and
4. evidence of chemical and biological responses of the lake and impacts on the flora and fauna that may indicate eutrophic disturbance (Category II and III from Section 2.2).

The evidence is collated from a variety of national and local sources. It includes chemical and biological monitoring data collected and analysed according to established and quality assured protocols (i.e. those metrics described in Section 2). It draws upon a variety of other national datasets, data assembled from the peer reviewed scientific literature, local investigations and reports, local knowledge and expert judgement.

Characteristics of the water body

The principal physical and chemical characteristics of the lake and its catchment are identified. This includes some or all of the following information:

Lake physical attributes include latitude and longitude; altitude; surface area; mean depth; whether the lake is known or believed to undergo seasonal, thermal stratification; whether classified as heavily modified under WFD and whether it is a man-made or artificial lake. The latter category includes lakes derived from historical or more recent gravel, clay or peat extraction (but which may have naturalised over time). It may also include damned river valleys and other forms of storage reservoir and their associated characteristics.

Lake chemical attributes. Mean alkalinity (alkalinity and depth are key characteristics used as part of the WFD typology and these are used to determine appropriate reference criteria – see Section 2).

Catchment physical attributes include lake catchment area. The hydrology of a lake is important to understanding the source of water and hence source of nutrient loading. Significant seasonal draw down, perhaps due to the use of the lake for water supply or flow regulation, can impact on lake ecology and marginal flora. Unfortunately, hydrological models are not readily available for every candidate lake. A "natural" catchment boundary for the lake is determined using GIS methods, based on a digital land-surface elevation model. Local Environment Agency operational staff provide additional information on lake hydrology, including engineered abstractions providing water to the lake. They also help identify whether the lake is primarily dependent on surface water run-off, groundwater or, in some cases, direct rainfall.

Uses/Ecosystem services

This information describes the main uses of the standing water and includes those that may be impacted as a consequence of eutrophication. Uses include:

Water supply and other water uses. Lakes are identified if used for public water supply, and whether they are designated as a Drinking Water Protected Area (under WFD), Storage reservoirs and reservoirs used for other purposes (e.g. hydroelectric power, flow regulation) are also identified.

Recreational/amenity use. Information is collated on a range of amenity uses that might be affected by eutrophication and access to the lake by the public. Amenity uses include recreational angling, contact water sports, tourist visits (bird-watching, walking, etc).

Conservation status. It is particularly important to protect standing waters with significant conservation value. Information is collated on statutory and non-statutory designations (European, National and local) and the conservation features (communities, populations and species) for which the site is protected, with an emphasis on aquatic interest features that are believed to be directly sensitive to eutrophic disturbance.

Aquatic interest features. Information on any aquatic interest features and conservation objectives is collated for each lake. Local EA operational staff have the opportunity to provide additional evidence regarding the condition of the aquatic interest features and whether they are affected by eutrophication or other causes. In doing so they may consult other relevant parties that may include the conservation agencies and lake managers, Water Companies and other landowners.

Potential causes of eutrophication

This information describes the level of exposure of the lake to elevated levels of nitrate as a potential causative agent of eutrophication.

Water chemistry. For the majority of lakes this comprises monthly water quality monitoring information and associated statistics on the concentration of total phosphorus, TON and TN for a number of years. In some cases data are only available from quarterly monitoring.

Nitrate sources. Annual total nitrate loadings within the natural catchment of the lake are determined from the NEAP-N model (see Section 2.5 above, and Lee *et al* (2015) for further detail). The data used are updated as appropriate at each NVZ review. From this it is determined whether a lake has a particularly high or low estimated loading from agriculture per unit of rainfall to the area of its catchment. Lakes are then ranked in terms of the relative load per unit area of catchment from agricultural or non-agricultural nitrate sources. Consideration of the agricultural contribution is made alongside other data and information on the nature of the catchment.

Responses and Impacts

This information provides evidence of the direct and indirect chemical and biological responses of the lake that might be expected to result from eutrophication, as assessed by the methods described in Section 2. It is recognised that such responses may not always represent symptoms of eutrophication as changes in the component metrics can sometimes result from other causes. For example, the macrophyte metrics are sensitive to changes in lake level. Such confounding factors are evaluated during detailed investigation and discussion by the National Expert Panel.

3.1.2 Identification of candidate lakes

Candidate lakes are identified by three different routes.

Firstly, all lakes previously designated as eutrophic waters are included.

Secondly, Natural England may nominate any lakes they considered might qualify for designation under the Nitrates Directive. This could include coherent, localised groups of lakes with similar physical, chemical attributes and with similar ecologies, but where direct monitoring evidence may not be available for all lake(s) within the group (see Appendix D for details).

However, the majority of lakes are identified from analysis of the monitoring data collected through the Environment Agency's WFD lake monitoring network. The network consists of long-term surveillance lakes and a risk-based operational network. The primary pressure identified as affecting lakes in England is nutrients, so the network reflects the risk of eutrophic impact. The lakes in the WFD network consist of large water bodies (>50ha in area), or smaller lakes (5-50ha) that are WFD Protected Areas for conservation status or drinking water supply.

3.1.3 Initial Screening of lakes with monitoring data

Data for the period since the last NVZ review was analysed for all lakes where sufficient nitrogen results are available. Lakes are assessed with a simple risk scoring system, based firstly on nitrogen concentration exceeding the lower threshold value of 1 mg/l and secondly based on a Weight of Evidence assessment of eutrophic impact undertaken for WFD purposes. This assessment was developed for Cycle 2 of the WFD, (see Table 3.1 below for details) and is based on the WFD metrics of eutrophication described in Section 2.5, combined with a structured evaluation of wider evidence of impact. It results in an assessment of the certainty of eutrophic impact.

To be included as a candidate lake for the next stage of detailed assessment, the following was required:

Annual mean TN > 1 mg/l (as nitrogen) or 75%ile TON > 1 mg/l (as nitrogen)

And

Certainty of eutrophic impact = “very” or “quite” certain.

A scoring system was applied as in Table 3.1 below to assist in the screening process. Any lake fulfilling one but not both of the above criteria was not automatically excluded at this stage, pending consultation and review by Environment Agency local operational staff.

Table 3.1 Initial screening criteria for lakes

Evidence score	Criteria			
	TON > 1 mg/l	TN > 1mg/l	Weight of evidence: very or quite certain	Action
6	Y		Y	Definite candidate
5		Y	Y	Possible candidate
4	N	N	Y	Further check
3	Y		N	Further check
2		Y	N	Further check
1	N	N	N	No further consideration

3.1.4 WFD Weight of Evidence

In addition to the updated biological classification tools, the Environment Agency has developed an improved assessment of the Weight of Evidence (WoE) of eutrophication impact in lakes. A Weight of Evidence spreadsheet tool is used to assess the likelihood of eutrophication impact. This is based on the relevant WFD classification results (and reported statistical confidence in those results), but allows a “wider weight of evidence” to be taken into consideration, including a specified range of non-WFD indicators and evidence from third parties if available.

The method has four elements:

1. Combination of the core eutrophication sensitive WFD classification results (total phosphorus, phytoplankton overall, chlorophyll, macrophytes, diatoms) using their reported statistical confidence of class, to produce a certainty of eutrophication impact based on the classification tools alone. (This is similar to the confidence of eutrophication assessment used in the previous NVZ (2012) method).

2. Pressure indicators – a weighted score is allocated to a restricted range of pressure indicator data, primarily related to wider evidence of phosphorus pressure, to give a “pressure related score”.

3. Ecological indicators – weighted scores are allocated to evidence from other WFD tools which reflect nutrient pressure (e.g. CPET), and a wider set of ecological indicators (e.g. algal blooms, fish kills, palaeoecological evidence) to give an “ecological indicator score”.

4. Use indicators - scores allocated to e.g. Drinking Water Protected Area risk, Conservation condition assessment, to give a “use related score”. For the purposes of the Nitrates Directive assessment, existing designations under Nitrates and Urban Wastewater Treatment Directives are not considered, although they do form part of the evidence considered for the WFD assessment of eutrophication.

Indicator scores are combined into a total score for the wider weight of evidence, which is then translated into a recommendation on whether the certainty obtained from the core WFD classification tools should be increased or decreased, to give a final certainty of eutrophication impact.

Certainty of impact is reported as “very”, “quite” or “uncertain”, or “certain no impact”.

Environment Agency Area operational staff added information for their lakes to this WoE assessment, which is used to inform risk assessment for eutrophication for the WFD River Basin Plans (Environment Agency, 2015). For water bodies where this WoE assessment has been completed, this protocol brings a more formal and structured process to the consideration of the wider evidence.

3.1.5 Identification of lakes affected by eutrophication involving elevated nitrogen

Lakes that are identified through the initial screening exercise on the basis of elevated nitrogen and the weight of evidence of eutrophication impact are subject to more detailed investigation. Nationally collated data are checked and supplemented by local information and knowledge, and the available information is used to update datasheets for each candidate lake. Local staff are also asked to make a recommendation on the case for designation, based on their assessment of the evidence.

Following the gathering of local evidence and information, national experts review each lake on a case by case basis. A provisional recommendation regarding designation is produced by the EA’s national experts and the evidence for all candidate lakes are subsequently reviewed by the National Expert Panel, including external experts.

During this review a detailed consideration of the evidence is undertaken. This includes an expert evaluation of the strength of evidence available, for example by considering how close to the 1-2 mg/l threshold the nitrogen concentration is, how many samples the mean values are based on, what the seasonal pattern of nitrogen availability is and whether there is any evidence of nitrogen limitation occurring. Experts also consider how many biological elements have contributed to the overall weight of evidence assessment, and take into account the catchment characteristics and the evidence for the contribution of nitrogen from agriculture.

3.1.6 Assessing sources of nitrogen loading to lakes

Sources of nitrogen loading from the lake catchment are assessed in order to evaluate the relative contribution of agricultural sources and confirm that agriculture makes a significant contribution to the total load.

In common with the methods for other types of NVZs, outputs from the ADAS NEAP-N model (see Section 2.5) are used for lakes – data from the model are applied to each lake catchment to calculate the load to the lake, and the lakes under consideration are also ranked to show their relative position in the overall list of lakes in terms of N load from agricultural sources.

Additional information on nitrogen sources is also taken into account. Where a candidate lake catchment lies within an existing or proposed surface or groundwater NVZ then that other designation is taken as strengthening the evidence for an agricultural contribution to the lake NVZ, since the nitrogen sources for the wider NVZ will have been assessed separately. Other available information, such as EA records of consented discharges, and published source apportionment models are also considered to develop an informed view on the contribution from agricultural sources.

3.1.7 Artificial lakes and reservoirs

Through the local review, Environment Agency staff are asked to apply the following guidance in considering candidate lakes:

DEFRA consider it inappropriate to designate certain man-made lakes under the Nitrates Directive, but naturalised artificial lakes and reservoirs should be considered, particularly where they have significant value to society for their ecological function, for direct conservation value, or for recreation. The natural catchments of these waters should be designated if the waters themselves were affected by eutrophication, but the source of any pumped water should not because the pumping or other engineering breaks the ecological link between catchment and water body.

The following guidance is applied when screening candidate lakes:

Excluded

Non-natural lakes. The prime examples being purpose-built water storage reservoirs which basically provide temporary water storage in concrete/stone/clay lined bowls. More generally, those reservoirs where the majority of the water is derived by engineered means (e.g. pumped or large inter-catchment transfers). These will generally be Artificial Water Bodies under the WFD.

Included (possible exceptions)

- Impounded catchment reservoirs, particularly where they have significant value to society, e.g. for recreational or conservation wildlife reasons. Most are likely to be Artificial Water bodies under WFD

- Man-made lakes (e.g. broads, gravel and clay pits), especially where they are of long standing such that they are "naturalised". e.g. Norfolk broads.

Catchment definition

Where a lake/reservoir is included as an NVZ and it has a mix of engineered and natural water supply, the natural (topographically defined) catchment of these waters should be designated as an NVZ, but the source of any pumped water should not be included. The engineered process supplying water breaks the environmental link between catchment and water body - pumping is not a natural draining process as described in the Directive.

3.2 Estuaries and coastal waters

3.2.1 Evidence used in the assessment of eutrophication

The evidence used in the assessment of eutrophication of each estuarine or coastal water body is structured into four parts. These are

1. information on the physical and chemical characteristics of the water body and its hydrological catchment;
2. evidence regarding the ecosystem service benefits provided by the water body which might be impacted by eutrophication;
3. quantitative and qualitative evidence regarding the level of exposure of the water body and its flora and fauna to nitrogen and phosphorus, and evidence of the relative importance of nitrate sources (Category I from Section 2.2); and
4. evidence of chemical and biological responses of the water body and impacts on the flora and fauna that may indicate eutrophic disturbance (category II and III from Section 2.2).

The evidence is collated from a variety of national and local sources. It includes chemical and biological monitoring data collected and analysed according to established and quality assured protocols (e.g. those metrics described in Section 2). It draws upon a variety of other national datasets, data assembled from the peer reviewed scientific literature, local investigations and reports, local knowledge and expert judgement.

Characteristics of the water body

The principal physical and chemical characteristics of the water body and its catchment are identified. This includes some or all of the following information:

Physical and chemical attributes include latitude and longitude; the geomorphological nature of estuaries (e,g, broad and flat, deep and fjord like), water retention/flushing time, surface area; tidal and salinity regimes, etc, Some of these e,g, salinity and turbidity are part of the WFD typology and used to determine appropriate reference criteria and to define appropriate nitrogen standards – see Section 2).

Catchment physical attributes include the water body catchment area and the nature of the catchment. A “natural” catchment boundary is determined using GIS methods, based on a digital land-surface elevation model, with input from local Environment Agency operational staff.

Uses/Ecosystem services

This information describes the main uses of the standing water and includes those that may be impacted as a consequence of eutrophication. Uses include:

Fishery or shellfishery. Water bodies are identified if used for commercial fisheries or shellfisheries including whether they are designated under the Shellfish Hygiene Directive (91/492/EEC).

Recreational/amenity use. Information is collated on a range of amenity uses that might be affected by eutrophication. Amenity uses include bathing (e.g. designated under the EC Bathing Waters Directive), other water contact sports, boating, angling, tourist visits (bird-watching, walking, etc).

Conservation status and aquatic interest features. Information is collated on statutory and non-statutory designations (European, National and local) and the conservation features (communities, populations and species) for which the site is protected, with an emphasis on aquatic interest features that are believed to be sensitive to eutrophic disturbance. Local Environment Agency operational staff have the opportunity to provide additional evidence regarding the condition of the aquatic interest features and whether they are affected by eutrophication or other causes. In doing so they may consult other relevant parties that may include the conservation agencies and others.

Potential causes of eutrophication

This information describes the level of exposure of the water body to elevated levels of nitrogen as a potential causative agent of eutrophication.

Water chemistry. For the majority of water bodies this comprises winter monthly water quality monitoring information and associated statistics on the concentration of dissolved inorganic nitrogen and dissolved inorganic phosphorus for a number of years.

Nitrate sources. Annual total nitrate loadings within the natural catchment of the water body are determined by source apportionment from a variety of methods (see section below on assessing sources of nitrogen loading) including the NEAP-N (see Section 2 above, and Lee *et al* (2015) for further detail) and SAGIS (Source Apportionment GIS, Comber *et al*, 2012) models. From this we determine whether a water body has a particularly high or low loading hazard from agriculture in the catchment.

Responses and Impacts. This information provides evidence of the direct and indirect chemical and biological responses of the water body that might be expected to result from eutrophication, as assessed by the methods described in Section 2.

3.2.2 Screening of saline water bodies for eutrophication

The Environment Agency and its predecessor organisations have been periodically reviewing the extent of eutrophication in the estuarial and coastal waters of England for several decades. Since 1993, such reviews have been undertaken for the purposes of the Nitrates and UWWT Directives and more recently for the WFD. The results of monitoring for individual water bodies are compared to the criteria for eutrophication to identify potentially affected waters. Ongoing monitoring and assessments of ecological status of water bodies for the purposes of the WFD now provide the main basis for the Nitrates and UWWT Directive reviews. The Agency's programmes for data collection and assessment, in the context of eutrophication, have become increasingly integrated to serve the purposes of all the policies. Up until the creation of Natural Resources Wales (NRW), the reviews considered waters in both England and Wales, but for this latest review (2015/16), the Environment Agency considers only waters in England.

The monitoring and assessments undertaken for the 4 yearly reviews for Nitrates and UWWT Directive, together with risk assessments during the 1st cycle of WFD River Basin Management Planning, have enabled us to identify those water bodies where the risk of eutrophication is low and those where more detailed assessment is required.

The identification of potential new candidate Polluted Waters (Eutrophic) and review of existing designations has been based on recent monitoring and assessment of estuaries and coastal waters across the country for the purposes of the WFD, Nitrates and UWWT Directives. A major programme of nutrient impact monitoring was implemented from 2010 to 2012 inclusive, to assess potential eutrophication issues in water bodies which exceeded their WFD nitrogen standard for good ecological status. This programme was a key component of the Agency's WFD investigations of water bodies at less than good status due to nitrogen and the results informed the development of programmes of measures for the 2nd cycle of River Basin Management Plans. Ongoing monitoring is also undertaken in order to classify water bodies in terms of ecological status under the WFD.

The data from these programmes provide a good basis for the 2017 NVZ review. This is referred to as the 2017 review because the resulting designations are due to come into force in January 2017.

The evidence from nationally processed classification outputs (for the 2017 NVZ assessment this was mainly the 2015 and 2014 WFD classifications) is brought together with local evidence of eutrophication from WFD investigations and other sources. The evidence is assessed using our weight-of-evidence approach, to determine the certainty of eutrophication at a water body level, and the results are collated in a spreadsheet. The approach is described in more detail in the section below.

3.2.3 Assessing the certainty of eutrophication in saline water bodies

The certainty of eutrophication in estuaries and coastal waters is assessed using a weight-of-evidence approach. This considers information about the levels of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus– as measures of exposure pressure – together with information on eutrophication-related impacts based primarily on the WFD classification tools for phytoplankton and opportunistic macroalgae and compliance with the associated good/moderate ecological status boundaries. Wider evidence of eutrophication pressure and impacts is also considered, to improve certainty in the assessments.

A structured, expert-judgement based approach, using matrices and scoring systems, is used to combine the results for nutrients, impact indicators and other evidence in a consistent way to determine certainty of eutrophication. This results in outcomes in terms of simple categories from ‘very certain of a eutrophication’ problem through to ‘certain of no problem’ for each water body. The lines of evidence are collated in a spreadsheet. The weight-of-evidence spreadsheet used for the 2017 Nitrates Directive assessment, outlining the approach taken and the results, was a version using the 2015 WFD classifications. This superseded the version issued alongside the final WFD 2nd Cycle RBMPs, which used the 2014 classifications as the main WFD evidence.

The WFD classification tools are not suitable for assessing lagoons so we do not use the following method to assess saline lagoons. We assign a level of certainty of eutrophication to the Fleet Lagoon based on expert judgement and previous studies carried out for the Nitrates Directive.

The process of assessment

Step 1 - Assess nutrient pressure using WFD classification results.

The most recent classification results for dissolved inorganic nitrogen (DIN) were used to assess if:

- DIN data indicate no problem (good ecological status or better)

- DIN data indicate a possible problem (moderate ecological status or worse)
- There is no DIN classification data

In the few cases where there was no DIN data for a water body, expert judgement is used to decide whether to expect the status to be the same as adjacent water bodies.

Compliance with other recognised UK threshold concentrations for nutrients - notably those developed for Nitrates and/or UWWT Directives is also considered.

Step 2 - Assess if there is evidence of a potential eutrophication problem using WFD classification results for the primary biological indicator

Classification data are not generally available for both phytoplankton and opportunistic macroalgae in all water bodies as only one or other biological element tends to be relevant. Expert judgement is applied to decide which of these ecological elements is expected to be the most responsive to elevated nutrients in each water body (the quality element or "QE" in Table B1). In general opportunistic macroalgae are the most responsive in water bodies with suitable intertidal areas for the algae to attach and grow, whilst phytoplankton are the most responsive element in other water bodies.

The element expected to be most responsive to elevated nutrients is recorded in the Evidence and Results spreadsheet. The most recent opportunistic macroalgae and phytoplankton classification results are used to assess whether:

- the most responsive quality element does not indicate a problem (good status or better);
- one or both of the primary biological elements indicate a possible problem (moderate status or worse);
- it is uncertain whether there is a problem because the biological quality element is close to the good/moderate boundary or the status is variable or there is some evidence of a changing trend;
- it is uncertain whether there is a problem because data for the most responsive element are limited*;
- there are no data for the most responsive quality element.

**WFD opportunistic macroalgae classifications are flagged as uncertain if there is less than 2 years of data. WFD phytoplankton classifications are flagged as uncertain if there is only data for one metric, or if samples need to be collected in more years or months. Three years is required for coastal waters with at least nine months in each year. Five years is required for estuaries with at least ten months in each year.*

Step 3 - Assess further supporting evidence

If data for phytoplankton or opportunistic macroalgae indicate there is potential for eutrophication to occur, as nutrients appear to be fuelling at least some excess plant growth, wider evidence is considered to help assess whether secondary effects are occurring or likely. Wider evidence could include indications that algal growth is causing for example: dissolved oxygen problems, algal scums, entrained and/or overwintering macroalgae, effects on invertebrates/seagrass. Wider evidence is gathered from local investigations carried out to investigate WFD moderate status classifications. Evidence collected for other purposes such as for Habitats and UWWT Directives assessments is also used, as was appropriate evidence collected by other organisations such as Natural England which has responsibilities for SAC/SSSI estuaries and coastal waters at risk from or impacted by eutrophication.

Step 4 – Bringing the evidence together to assign a level of certainty of eutrophication to each waterbody

A matrix (**See Appendix B - Table B1**) is used, applied using expert judgement, to assign one of the following outcomes to each coastal and estuarine waterbody:

- **Very certain there is a eutrophication problem**
- **Quite certain there is a eutrophication problem**
- **Uncertain there is a problem (statistical)**[1]
- **Uncertain there is a problem (data)**[2]
- **Certain there is not a eutrophication problem**
- **Not assessed**

[1.] *This could be because biological status is near the good moderate boundary or there is high variability in the data or we are not yet sure if quality is improving or deteriorating)*

[2.] *This is because biological data are limited*

For each water body, the reason that a particular outcome was assigned was recorded in an "Evidence and Results" spreadsheet.

3.2.4 Assessing sources of nitrogen loading to saline water bodies

As part of the assessment for NVZs which are already designated or may warrant designation, the sources of nitrogen to the water body are estimated, to inform decisions on whether agriculture (and/or sewage effluent) were contributing significantly to the nutrient loadings in the water. This is relevant to decisions on whether and under which directives designations may be appropriate and on whether designations need to be retained. In line with ECJ case law, designation of NVZs is appropriate when agriculture makes more than an insignificant contribution to nitrogen loadings in a polluted water.

For existing Polluted Waters (Eutrophic), the main diffuse and point source nutrient control measures in place within the relevant catchment are also identified and the effect of the measures on water and ecological quality is reviewed. The potential for removing the control measures is also considered.

As part of this assessment annual total nitrate loadings within the natural catchment of the water body are determined from one or more of several different methods, including the NEAP-N (EA, 2012) and SAGIS (Source Apportionment GIS, Comber *et al*, 2010) models. These models provide estimates of N loading from both urban/human population and agricultural sources. Additional source apportionment information is provided through partnerships such as the Strategy for Managing nitrogen in the Poole Harbour catchment to 2035 (Bryan et al 2013). Finally where data is available, recent load estimates have been calculated directly using monitoring data from direct industrial or STW discharges into the waterbody combined with the freshwater stream input. In several estuaries, these direct estimates have then been combined with the SAGIS model output.

3.2.5 Delineating the NVZs

The land draining to the Polluted Waters (Eutrophic) is defined as:

- land draining directly to the eutrophic water, for which specific hydrological boundaries were drawn within the WFD catchment boundaries, plus
- the WFD catchments of surface waters upstream of (and therefore drain into) the eutrophic water.

In common with the wider NVZ review, the hydrological boundaries (referred to as “soft” boundaries) as delineated above are then converted to “hard” boundaries such as roads and field boundaries using a common set of rules. The conversion is an automated GIS-based process, and the resulting boundaries are checked manually. An illustration of the conversion process is given in Appendix E.

4. Assessing the potential for de-designation of existing eutrophication-related NVZ

De-designation of existing NVZs on grounds of improved water quality is potentially possible under the Nitrate Pollution Prevention Regulations (Defra 2015). The Environment Agency must advise Defra, at each NVZ review, whether existing designations should be retained. The following approach is applied in considering whether de-designation is appropriate for the existing NVZs. The principle applied is that in contrast to the approach to designation, where there needs to be sufficient certainty of eutrophication, for removing a designation there needs to be sufficient certainty that there is no longer a eutrophication problem and removing the NVZ will not lead to the problem returning. Each potential case is considered against the following criteria, all of which must be met.

- There are no longer any eutrophication impacts in the water body (on the ecology or water uses). Good or high ecological status under the WFD.
- Reduction of nitrogen to levels below the thresholds/standards associated with eutrophication (defined in this method statement).
- The above two requirements should be maintained for at least two NVZ reviews in order to show sustained improvement.
- In cases where eutrophication related impacts are no longer present but the nitrogen remains above the threshold/standard, there will be more detailed case specific consideration of the risks of removing the zone.
- There needs to be an understanding of the cause of the water quality improvements and that removing the NVZ would not present a risk of the eutrophication reoccurring.

There must also be no risk to progress towards, or maintenance of, WFD objectives in removing the NVZ. This is in recognition of the role of the Nitrates Directive as a basic measure (alongside UWWTD as another example) within the WFD programmes of measures.

5. Collation of evidence and quality assurance

5.1 Summarising the evidence for individual water bodies

Standard datasheets are completed for existing designated NVZs and any new candidate NVZs associated with eutrophication. These collate the evidence for each candidate or designated NVZ and are completed by close working between National and Area Environment Agency staff, the latter having knowledge of the water bodies and their catchments. The datasheets are structured to provide information as follows.

1. **Water body and catchment characteristics** – including a map of the candidate or existing Polluted Water, information about the geomorphological nature of the water body, catchment area etc.

2. **Water body uses** – e.g. fishery or shellfishery, conservation designations and features, recreational uses.

3. **Nutrient concentrations** – data assessed against nitrogen and phosphorus threshold values assessed according to the UK standards established for the WFD or criteria developed for UWWT/Nitrate Directives.

4. **Responses - plants/algae, secondary and other effects** – data for the primary biological response to increased nutrients, in the higher (macrophytes in freshwaters, macroalgae in saline waters) and/or lower plants (phytoplankton, diatoms). Data are assessed against the criteria established for determining ecological status under the WFD, with criteria developed for UWWT and Nitrates Directives also considered.

   Data and evidence of secondary and other effects – including any impacts on dissolved oxygen, toxic/nuisance algal blooms, effects on other fauna and flora, and adverse impacts on water uses, together with a local assessment of the scale of impact.

5. **Sources of nitrogen** – an assessment of the relative contribution of nitrogen from different sources in the catchment.

6. **Effects of nutrient reduction and any potential for de-designation**

Review of evidence and recommendations – including the Weight of Evidence assessment, comments from national panel discussions etc.

5.2 Ways of working and quality assurance

Recommendations to Defra, regarding potential new designations and the review of existing designations, are developed through close working between national and local Environment Agency teams. This applies to the screening process and the more comprehensive assessment of water bodies. Nationally produced classification results for water bodies are supplemented by locally held evidence of eutrophication and understanding of water bodies and catchments in order to identify potential candidate NVZs and to review existing ones, collating the evidence on a datasheet for each case.

The local understanding of water bodies and their catchments is provided by Environment Agency Area operational staff with knowledge of water quality planning, ecology and conservation, water resource management, local farming practices and catchment management, as appropriate. The local staff liaise with the Conservation Agencies, National Park authorities , Water Companies, Internal Drainage Boards and other landowners, as appropriate, to ensure the evidence in the datasheets is as accurate as possible.

The detailed datasheets and provisional recommendations are reviewed by Environment Agency expert panels for fresh and saline waters. The panels also involve input by experts from Natural England, together with academic experts for freshwaters. The panels assist the Agency in developing its recommendations and help to ensure national consistency in the assessment process. This is in recognition that the assessment of eutrophication involves weighing up the various strands of evidence to come to an overall judgement on the case for designation. Representatives from national stakeholder organisations including the NFU are invited to attend the national panel meetings in observer capacity, to ensure an open transparent process.

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Appendix A

Table A1 Coastal Eutrophication Criteria for WFD and UWWT/Nitrates Directives

	WFD Guidance **(Coastal)**	**UWWTD / Nitrates** **UK Comprehensive Studies Task Team (1997)/** **DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)**
Nutrients (Category I)	Chemical nutrient status is assessed from winter nutrient data to determine the degree to which nutrient concentrations are elevated. This was considered in the context of the relevant Water Framework Directive good ecological status standard for dissolved inorganic nitrogen. The thresholds for nitrogen and phosphorus defined in the UK Comprehensive Studies Task Team report, 1997, were also considered as supporting information.	
	Requirement to prevent deterioration of status which implies a need to consider whether water bodies may become eutrophic due to increasing nutrient pressures (loadings).	Any substantiated trend of increasing nutrient inputs should trigger consideration of the need to assess the potential for the area to be identified as one which may become eutrophic.
	Nutrient Regulatory Standard tool – standards for dissolved inorganic nitrogen Exceedence of Good/Moderate ecological status boundary, winter mean for coastal water normalized to salinity of 32 = 18umol N A 99 percentile is also used in waters depending on the level of turbidity: Intermediate - 70 umol N Turbid - 180 umol N Very turbid - 270 umol N	Winter nitrate-nitrogen and DIP concentrations significantly enhanced (> 50%) relative to a background concentration for the associated coastal water based on salinity. Concentration DAIN > 12umol N [Frequency 3 x in winter (Dec-Feb) samples]

	WFD Guidance **(Coastal)**	**UWWTD / Nitrates** **UK Comprehensive Studies Task Team (1997)/** **DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)**
	[Frequency monthly 3 winter (Nov-Feb) samples]	
	N/A	Concentration DAIP >0.2umol P [Frequency 3 x in winter (Dec-Feb)
Algae/plants (Category II)	The biological status of the water body is determined using the phytoplankton and/or macroalgal status depending on the nature of the water body and whether the conditions are most conducive to phytoplankton or macroalgal growth.	
Phytoplankton (Category II)	Less than good ecological status	
Chlorophyll-a (Category II)	90 percentile tool in WFD Phytoplankton toolkit: Exceedence of Good/Moderate boundary 10 or 15 μg/l [Frequency monthly during the growing season Mar.- Oct. min 8 samples] Chlorophyll is also part of elevated count tool (see below)	Sustained summer blooms >10μg/l (mg/m^3) Considered exceptional if normal spring blooms algal densities persist through summer until the autumn bloom without the typical nutrient-limited decline. [Frequency 5 summer samples]
Phytoplankton cells (Category II)	Elevated count tool % occasions Chlorophyll > 10 μg/l % occasions single taxa > 250,000 cells/l % occasions total taxa > 10^6 G/M boundary > 30% failure of thresholds	Total counts > $5x10^5$ over summer [Frequency 5 summer samples]

	WFD Guidance (Coastal)	UWWTD / Nitrates UK Comprehensive Studies Task Team (1997)/ DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)
	Frequency: monthly sampling 12x per annum	
	Elevated count tool % occasion Phaeocystis > 10^6 (under review)	Unusual phytoplankton blooms (public complaints of nuisance from scums)
	Partly by Phytoplankton Seasonal Succession tool % of times diatom and dinoflagellates fall inside a reference curve. Good/Moderate boundary < 60% [Frequency: monthly 12x per annum]	Unusual taxa or changes in composition
Green macroalgae (Category II)	Opportunistic Macroalgae tool: Less than Good ecological status 1a. Affected area of macroalgae or 1b. Affected area/AIH 2. % cover 3. Biomass/m^2 in Affected area 4. Biomass/m^2 in available habitat 5. % quadrats with entrained weed [Frequency ideally 3 x in the 6 year reporting period, minimum 2 x in the reporting period]	Areas > 10 hectares with >25% cover For example dense and widespread growth of Enteromorpha spp. Concern is focussed on the consequences of the excess algal coverage on the function of the ecosystem, for example whether to macoalgae overwinter making the underlying mud anoxic and affecting the invertebrates which are an important food source for birds. [Frequency: 3 years in 4]

	WFD Guidance **(Coastal)**	**UWWTD / Nitrates** **UK Comprehensive Studies Task Team (1997)/** **DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)**
Additional information – secondary and other effects **(Category III)**	N/A	N:P:Si ratios N:P >25, N:Si >2 Summer depletion of nutrients
	Dissolved Oxygen (DO) supporting element – less than good ecological status 5 percentile DO Good/Moderate >4mg/l	DO: median DO <7mg/l during growing season.
	Consider results from benthic invertebrate tool if appropriate	Changes in fauna (usual zoobenthic and fish mortality)
		Occurrence and magnitude of paralytic shellfish poisoning (PSP)
		Depth of anoxic layer
	Intertidal seagrass tool – less than good ecological status. Loss of seagrass may be related to nutrients: 1. Change in number of seagrass taxa 2. Change in extent of beds 3. Change in density (% cover of bed)	

Table A2 Estuarine Eutrophication Criteria for WFD and UWWT / Nitrate Directives

	WFD Guidance **(Transitional waters)**	**UWWTD / Nitrates** **DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)**
Nutrients (Category 1)	Chemical nutrient status is assessed from winter nutrient data to determine the degree to which nutrient concentrations are elevated. Hypernutrification (elevated nutrient concentrations) was considered in the context of the relevant Water Framework Directive good ecological status standard for dissolved inorganic nitrogen. [CSTT hypernutrification was only for coastal waters.]	
	Need to prevent deterioration of status which implies a need to consider whether water bodies may become eutrophic due to increasing nutrient pressures (loadings).	Any substantiated trend of increasing nutrient inputs should trigger consideration of the need to assess the potential for the area to be identified as one which may become eutrophic
	Nutrient Regulatory Standard tool – standards for dissolved inorganic nitrogen Exceedence of Good/Moderate ecological status boundary winter **mean** for transitional water normalized to salinity = 25 = 30 μmol N A **99%ile** is also used in waters depending on turbidity Intermediate - 70 mμol N Turbid - 180 μmol N Very turbid - 270 μmol N [Frequency monthly 3 x winter (Nov-Feb) samples]	Winter nitrate-nitrogen and DIP concentrations significantly enhanced (>50%) relative to a background concentration for a defined geographical area based on salinity. Concentration DAIN N Coastal reference 12 μmol [Frequency 3 winter (Dec-Feb) samples]
	N/A	Concentration DAIP P Coastal reference 0.2 μmol

	WFD Guidance (Transitional waters)	UWWTD / Nitrates DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)
		Frequency 3 x Winter (Dec-Feb) samples]
Algae/plants (Category II)	The biological status of the water body is determined using the phytoplankton and/or macroalgal status depending on the nature of the water body and whether the conditions are most conducive to phytoplankton or macroalgal growth.	
Phytoplankton (Category II)	Less than good ecological status	
Chlorophyll (Category II)	WFD transitional waters phytoplankton toolkit: Exceedence of Good/Moderate ecological status boundary. Chlorophyll statistics per salinity zone (Low, High): 1. Mean (15,10 μg/l) 2. Median (12,8 μg/l) 3. % samples <10 (70, 75%) 4. % samples <20 (80,85%) 5. % samples >50 (5, 5%) [Frequency: monthly 12x per annum]	Sustained blooms: Annual average >25μg/l (mg/m^3) (max 100 μg/l) at the freshwater end down to 10μg/l at the seaward end [Frequency, ideally 12 monthly samples if annual average being used or 5 summer samples with a max ref]
Phytoplankton cells (Category II)	WFD transitional waters phytoplankton toolkit Elevated counts: 1.% occasions single taxa > 500,000 cells per litre 2. Total taxa % exceedance 10^6 cell/l [Frequency: monthly 12x per annum]	Total counts >5x10^5 over summer [Frequency 5 summer samples]

	WFD Guidance (Transitional waters)	UWWTD / Nitrates DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)
		Unusual phytoplankton blooms (eg public complaints of nuisance from scum on beaches)
	N/A Inspection of elevated count data	Unusual taxa or changes in composition
Green macroalgae (Category II)	Opportunistic macroalgae tool: Less than good ecological status 1a. Affected area of macroalgae or 1b. Affected area/AIH 2. % cover 3. Biomass/m^2 in Affected area 4. Biomass/m^2 in available habitat 5. % quadrats with entrained weed [Frequency ideally 3x in the 6 year reporting period, minimum 2 times in the reporting period]	Areas > 10 hectares or 25% of intertidal with> 25% cover in summer (June-Aug) For example dense and widespread growth of Enteromorpha spp. Concern is focussed on the consequences of the excess algal coverage on the function of the ecosystem, for example whether to macoalgae overwinter making the underlying mud anoxic and affecting the invertebrates which are an important food source for birds. [Frequency: 3 years in 4]
Additional information – secondary and other effects **(Category III)**	N/A	N:P:Si ratios N:P >25, N:Si >2 Summer depletion of nutrients
	Dissolved Oxygen (DO) supporting element - less than good ecological	DO: median DO <7mg/l during growing season.

	WFD Guidance (Transitional waters)	UWWTD / Nitrates DoE Guidance (1993 and supplement of 2004) and Defra NVZ methodology (April 2012)
	status 5 percentile DO Good/Moderate >4mg/l	
	Consider results from benthic and transitional fish tools	Changes in fauna (usual zoobenthic and fish mortality)
		Occurrence and magnitude of paralytic shellfish poisoning
		Depth of anoxic layer
	Intertidal seagrass tool – less than good ecological status Loss of seagrass may be related to nutrients: 1. Change in number of seagrass taxa 2. Change in extent of beds 3. Change in density (% cover of bed)	

Appendix B

Table B1 - Decision Matrix for assessing eutrophication in estuaries and coastal waters

Biological Evidence

	No data on most responsive QE	Most responsive QE is good status	Insufficient data on most responsive QE	Most responsive QE varies in status or is close to good/moderate boundary	Most responsive QE fails good status	**Most responsive QE fails and there is further supporting evidence of adverse effects from the elevated plant growth**
DIN is good status, or assumed to be good	Certain there is not a problem	Certain there is not a problem	Certain there is not a problem	Uncertain there is a problem (statistical)		
No DIN data	Not assessed	Certain there is not a problem	Uncertain there is a problem (data)	Uncertain there is a problem (statistical)	Quite certain there is a problem	
DIN status is uncertain or close to the good moderate boundary	Uncertain there is a problem	Certain there is not a problem	Uncertain there is a problem (data)	Uncertain there is a problem (statistical)	Quite certain there is a problem	
DIN is moderate status	Uncertain there is a problem	Certain there is not a problem	Uncertain there is a problem (data)	Uncertain there is a problem (statistical)	Quite certain there is a problem	Very certain there is a problem

Appendix C Review of the scientific evidence for nutrient nitrogen thresholds relevant to UK standing waters

The role of nitrogen in eutrophication of standing waters has been less widely investigated than that of phosphorus, but there is an increasing body of scientific evidence indicating that both nutrients should be considered. A key finding of the European Nitrogen Assessment's consideration of nitrogen processes in aquatic ecosystems (Durand et al, 2011) was that in eutrophicated standing freshwaters control of both nitrogen and phosphorus loading is often needed if ecological quality is to be restored.

Studies in the UK (James et al, 2005, Moss et al 2013), The Netherlands (van der Molen et al., 1998) and Denmark (Søndergaard et al. 2005; González Sagrario et al., 2005) have stressed the importance of nitrogen in controlling eutrophication in lakes, particularly shallow lakes. Shallow lakes (<3m), in their macrophyte-dominated state are structurally more complex than deep lakes, so need to be considered separately.

Van der Molen et al. (1998) found that a summer mean TN <1.35 mg/l would be required to reduce phytoplankton sufficiently to allow light to the sediments and therefore recolonization by the submerged macrophytes (based on a data set of 682 lake-years for lakes in The Netherlands). They proposed a combined lake-specific approach of nitrogen and phosphorus emission reduction to combat eutrophication, due to atmospheric nitrogen fixation by blue-green algae in lakes with a growth limiting nitrogen concentration.

Correlations among macrophyte species richness, phytoplankton and periphyton standing stock with N and P concentrations in 42 small (<75 ha), shallow, macrophyte dominated lakes within the UK also suggest that some lakes are N–limited (James et al., 2005). For these lakes it was found that winter nitrate was the most significant variable in explaining a reduction in macrophyte species richness, while no significant relationship between an increase in phosphorus concentration and reduced macrophyte species richness was found. Winter concentrations effectively give a measure of the amounts available in spring for plant growth; uptake and denitrification complicate the relationship if summer concentrations are used. Reasonably diverse plant communities were found only at winter nitrate below 1-2 mg NO_3-N/l.

Søndergaard et al. (2005) used chemical and biological data from 709 Danish lakes to investigate whether and how different lake types respond to eutrophication. Ecological classification into high, good, moderate, bad and poor ecological quality was based on TP values; within each TP category, median values for 22 other biological and environmental indicators were determined, including TN. A mean depth of 3m was used to separate shallow (S) and deep (D) lakes. TN values ranged from <1.0 mg TN/l for high and good status lakes to >2.0 mg TN/l for bad status (see Table A1). TN responded markedly to changes in TP, suggesting TN is a potential indicator for the classification of lakes relative to eutrophication. However, strong correlation was found between TP, TN, total alkalinity and pH, emphasising the problem of correlation between indicators for defining ecological classes.

Table C1. Concentrations of total phosphorus (TP) and total nitrogen (TN) associated with a classification 709 deep (D) and shallow (S) lakes by ecological quality (High-Low). From Søndergaard et al. (2005)

Concentrations of total phosphorus (TP) and total nitrogen (TN) associated with a classification 709 deep (D) and shallow (S) lakes by ecological quality (High-Low)										
	High		Good		Moderate		Poor		Bad	
	D	S	D	S	D	S	D	S	D	S
TP (µg P/l)	<12.5	<25	<25	<50	<50	<100	<100	<200	>100	>200
TN (mg N/l)	-	<1.0	<1.0	<1.0	<1.0	<1.4	<1.4	<2.0	<2.2	<2.9

González Sagrario et al. (2005) undertook a 3-month (summer) mesocosm experiment on a shallow Danish lake to investigate the effect of TN and TP loading on trophic structure and water clarity (natural lake concentrations of 0.1 mg P/l, 2 mg N/l). Minor or no effects on the biomass of macrophytes and phytoplankton were observed in treatments with single nutrient addition; in contrast, a strong effect was observed with high P addition (0.2 mg P/l) when accompanied by N addition (4 or 10 mg N/l). The shift to a turbid phytoplankton dominated state with low plant coverage occurred at an overall mean TN between 1.2 and 2 mg N/l and TP>0.13-0.2 mg P/l, suggesting high nitrogen loading may be important in the loss of submerged macrophytes in shallow lakes. Using empirical relationships between summer mean lake N concentrations, discharge-weighted inlet concentrations and an annual mean lake retention time of 3 months, a lake N concentration of 1.2 mg N/l corresponds to an inlet concentration of 2.5 mg N/l (similarly, 2 mg N/l corresponds to 5.7 mg N/l); inlet concentrations of 2.5-5.7 mg N/l are well below the 11.3 mg N/l drinking water limit. The authors note that as the data stems from a cold northern temperate region, the results should not be transferred directly to other regions; N thresholds may be higher due to high plant growth efficacy in warmer climates.

Increased nitrogen loading may lead to changes in productivity or biodiversity in freshwater systems. Field surveys have shown reduced species richness of submerged and floating-leaved plant communities in shallow lakes as winter nitrate concentrations, a surrogate for nitrate loading, have risen above 1-2 mg NO_3-N/l.

Barker et al (2008) reported the use of experimental tank mesocosms, containing about 3 m^3 of water and sediment from Hickling Broad, Norfolk, UK that were initially planted with eleven submerged plant species from the lake and its connected waterway. Constant phosphorus loadings (designed to give added concentrations of 50 µg P/l) were provided to all tanks. Four nitrate loadings were given in a randomised block design with twelve-fold replication. Loadings were designed to increase the concentration in the water by 1, 2, 5 and 10 mg NO_3-N/l (treatments identified as N1, N2, N5 and N10, respectively). Nitrate loading increased phytoplankton and periphyton chlorophyll a in the N2, N5 and N10 treatments compared with N1. In contrast, total plant volume decreased and treatments had varied effects on different species, with most species indifferent, a few (mostly charophytes) declining above the N1 treatment, and one (*Elodea canadensis*) performing best in N2 and N5 compared with N1 and N10. Species richness of submerged macrophytes declined with time in all treatments and with increasing nitrogen load in the first year. In the second year, species richness did not further decline in the N1 treatment but declined at increasing rates with increasing nitrogen load in others. The rate of decline in the second year, plotted against nitrate load, fitted an exponential relationship, allowing calculation in inflow water, or of an empirically determined equivalent TN concentration in the lake water of about 1.50 mg N/l. This value broadly corresponds with estimates from field data for concentrations associated with declining species richness and is much lower than values currently often found in lowland agricultural areas in Europe.

A study commissioned by Natural England (2010) tried to understand the lack of response of macrophyte species richness to variation water chemistry in certain SSSI designated meres. Macrophyte species were converted to trophic ranking scores using the systems of Palmer et al. (1992) and Willby (pers comm.). The two TRS systems were strongly correlated and had a slope of 1.0 but the Palmer et al. (1992) system produced scores that were greater than the Willby system by 1.5. Relationships between the two Trophic Ranking Scores, based on the average for all the species present at a site, and winter concentrations of NO_x-N or total phosphorus were not significant (see Fig. 6.4 in Natural England 2010). The data suggest, however, that above winter concentrations of about 0.5 mg NO_x-N/l and about 0.08 mg TP/l, there was not a major increase in Trophic Ranking Score. This may possibly explain the lack of response in the meres: most of the meres had concentrations of nitrogen and phosphorus that were characteristic of eutrophic water bodies. This lack of sites at lower nutrient concentrations truncates the macrophyte response to the higher, more insensitive end of the nutrient gradient. This result suggests that macrophyte species-richness in the meres cannot be used as a response to set nutrient targets, although the values obtained from the combined study of UK and Polish lakes (James et al. 2005; Barker et al. 2008) could still be applicable, suggesting targets of around 1.5 mg/l NO_3-N.

The presence of nitrogen limitation or co-limitation in the meres means that nitrogen targets are also appropriate at some of the sites. Total nitrogen targets were derived from European datasets relating concentrations of chlorophyll a to total nitrogen for different types of lakes. In turn, the chlorophyll a target was derived from Water Framework Directive standards for different lake types. The Good/ Moderate total nitrogen target varied between 0.4 - 1.4 mg/l.

Lambert & Davy (2010) investigated the relationship between aquatic vegetation and water quality at the principal sites for charophyte biodiversity in the UK. They used hierarchical partitioning to discriminate independent effects of pollutants on their occurrence. A laboratory experiment examined the growth responses of a representative species (*Chara globularis*) to nitrate. Nitrate-N exerted the greatest detrimental effect on charophyte occurrence in the field. Furthermore, growth of *C. globularis* in the laboratory was inhibited above very low concentrations. Smaller independent effects of certain trace metals and phosphate-P on charophyte occurrence were discriminated. The study demonstrated that it is possible to separate the deleterious effects of phosphorus and nitrogen on aquatic plant species in the field. Nitrate is a critical factor. The upper limit for charophyte persistence was shown to be c. 2.5 mg/l nitrate-N. An *in vitro* experiment showed that a concentration of 1-2 mg/l NO_3-N might be necessary to protect charophytes and their services within wetland ecosystems.

Schindler et al. (2008) reported the results of experimental nutrient enrichment (nitrogen and phosphorus) of a single, small Canadian lake. The study concluded that controlling N alone may have limited benefits in controlling eutrophication and, under conditions of P enrichment, N limitation may provide N-fixing cyanobacteria with a competitive advantage.

The experimental nutrient enrichment of the lake was undertaken for approx 20 years and peak total nitrogen concentrations of c. 1.2 mg-N/l were recorded towards the end of this time. The highest peak concentrations of total inorganic nitrogen (nitrate plus nitrite plus ammonium) were observed to be 0.128 mg/l. These peak concentrations are considerably lower than the threshold of 1-2 mg.N/l used to help identify and screen lakes with elevated nutrient N as part of this review. Indeed, 75%ile TON concentrations in the vast majority of candidate lakes considered as part of this review are x10-x80 higher (see Fig 2.1) than the maximum TIN concentrations reported in the Schindler et al. (2008) study.

Whilst the need to focus on phosphorus is accepted as important in tackling freshwater eutrophication it should be noted that the Schindler *et al.* (2008) study relates primarily to a single Canadian lake and his conclusions may not be directly relevant to nutrient enriched lakes in England and Wales. It also focussed on the effects of nutrient enrichment on the phytoplankton without considering the effects, indicated in other recent studies on higher plant (macrophyte) communities (e.g. James *et al.*, 2005). Jeppesen *et al.* (2005) concluded that control of both N and P may be necessary to improve the ecological status of shallow lakes.

A more recent review of the nutrient standards adopted by EU Member States for the Water Framework Directive (Phillips and Pitt, 2015) is in close agreement with the range of values suggested by the scientific literature. The range of Good/Moderate boundary values adopted by member states for all lake types was 0.8 – 2.0 mg/l for total nitrogen, and 0.5 – 1.2 mg/l for nitrate nitrogen.

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Appendix D Criteria for nominating groups of lakes as candidates for designation as Nitrate eutrophic waters

The conservation agencies asked the Defra MRG whether it would be possible to designate groups of similar lakes located within a geographically localised area. The Environment Agency worked with the Conservation Agencies to identify what principles and evidence might be appropriate and sufficient to support such designations. In order to consider groups of lakes for designation, the Defra/WAG MRG agreed the following principles.

D.1 The following ***minimum*** set of evidence should be provided.

- There should be monitoring data on TON and/or TN, demonstrating elevated levels of nitrogen, for at least one lake included within each group.
- There should be monitoring data or other evidence of eutrophic disturbance in one or more lakes within each group. This may include but is not restricted to the lines of evidence included in the Eutrophic waters risk assessment report.
- There should be evidence that the lakes form a relatively homogenous natural grouping. It is anticipated that this evidence will be primarily typological and ecological. It might include lists of characteristic species or species communities.
- There should be a description of the principal physical-chemical characteristics of each lake within the group, as outlined in the Eutrophic water proforma reports.
- There should be a description of the hydrological catchments of each lake. This should include an assessment of the principal sources and pathways of nutrient nitrogen and phosphorus input to the lakes. Where possible, individual lakes should be ranked in order of the risk of nutrient delivery.

- It will be important to identify any groundwater dependent waters. This should identify those that are dependent on groundwater levels but whose principal (natural) source of nutrient inputs may be atmospheric.

- The Conservation Agencies should provide suitable GIS catchment boundaries for the drainage catchments for the group of lakes. The EA will then aim to provide estimates of nitrate loadings to each lake, where appropriate.

D.2 The evidence should be summarised in a written statement of case to be prepared by the conservation agencies.

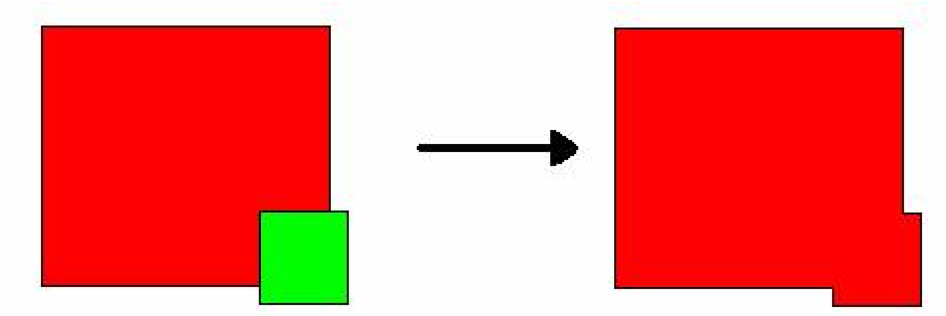
D.3 The statement of case should highlight any dissimilarity between lakes within the group, by reference to the evidence in D1 above.

D.4 The statements of case would be provided to the National Panel for their consideration on a case-by-case basis.

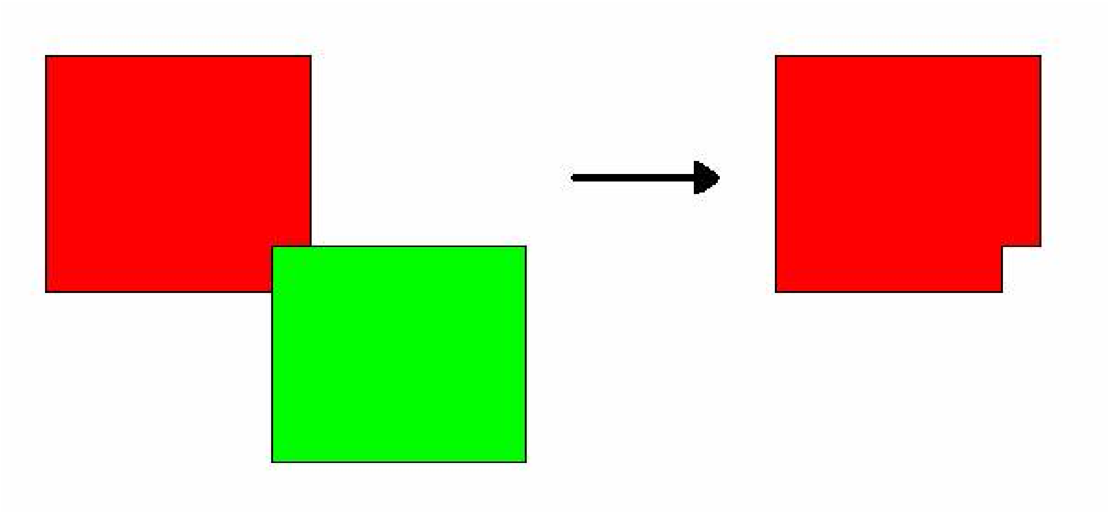
Appendix E Hard boundary conversion rules

The rules for the automatic mapping from soft to hard boundaries are:

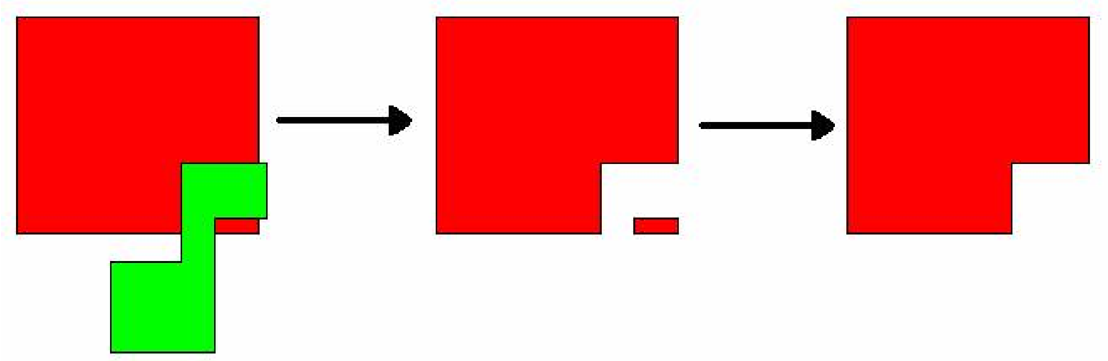
1) If a soft boundary edge intersects a field and 50% or more of the field is covered by NVZ the whole field will be added to the NVZ (Red = NVZ, Green = Field):



If a soft boundary edge intersects a field and less than 50% of the field is covered by NVZ the field will be removed from the NVZ:

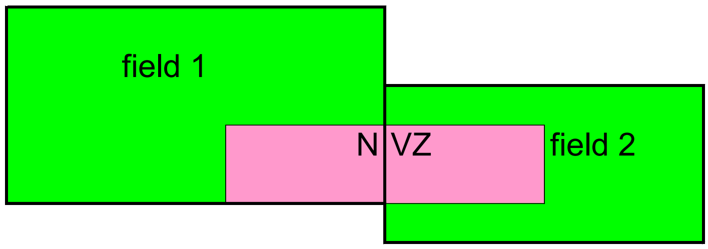


3a) If such a subtraction results in a disconnected 'island' of NVZ that doesn't intersect any fields the island will be removed from the NVZ:



3b) However, if an entire NVZ does not intersect any fields (i.e. it was not created by rule 4, but already existed as a distinct NVZ) then it will be kept.

3c) If an entire NVZ intersects with <50% of any field it will be removed, e.g.



4) Where the soft boundary crosses the coastline the hard boundary must follow the Mean High Water Line

5) If a soft boundary edge does not intersect a field it will be retained where it is – edges follow field boundary, or in the absence of a field boundary, follow the soft NVZ boundary.