

Summary of methodology for identifying Nitrate Vulnerable Zones 2006

**Environment Agency report to Defra – supporting paper D1 for the
consultation on implementation of the Nitrates Directive in England**

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1. Introduction

The purpose of this paper is to explain the process that was followed in 2006 to review the designation of Nitrate Vulnerable Zones (NVZ) under the Nitrates Directive¹. The Directive requires the review of NVZ designations at least every four years. The Nitrates Directive now sits within another Directive, the Water Framework Directive, which provides a framework to integrate all water related Directives and other measures to protect and improve the water environment. We therefore often refer to the Water Framework Directive below.

The Nitrates Directive requires that polluted waters and waters which could become polluted if protective action is not taken, are identified in line with criteria established in the Directive. All areas of land which are known to drain into these waters shall be designated as Nitrate Vulnerable Zones.

The Nitrates Directive sets the following criteria for polluted waters:

- Surface freshwaters, including those used or intended for the abstraction of drinking water, which contain or could contain more than 50 mg/litre nitrate if protective action is not taken (i.e. Action Programme measures).
- Groundwaters which contain, or could contain, more than 50 mg/litre of nitrate if protective action is not taken.
- Natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters which are eutrophic or may become so in the near future if protective action is not taken.

The Directive 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 protective action.

Regular monitoring of ground and surface waters in England enables the assessment of water quality against Directive criteria for designating NVZs.

A revised method for identifying polluted waters has been developed by the Environment Agency, and this is described in sections 2, 3 and 4 along with the way we identify the land draining to these waters. There is then discussion of how NVZs designated in 1996 and 2002 have been considered, and finally a description of how the boundaries on the ground (hard boundaries) have been set.

¹ Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources

2. Elevated Nitrogen: Surface Water method

The full method statement for the assessment of surface waters will be available by [autumn 2007]

The proposed surface water Nitrate Vulnerable Zones have been identified through an assessment that combines water quality monitoring data with the analysis of data and information on land-use and associated sources of nitrate. Where monitoring data are not available, nitrate concentration in receiving waters is forecast based on the associated catchment land-use only. Together this information is used to identify polluted waters. Finally, the land draining to these waters is identified for designation as an NVZ. The steps are described below.

2.1 Monitoring Data

- i. Nitrate concentration was sampled at points representative of all riverine surface waters in England at least monthly over the 1999-2004 period. Surface waters in Wales with land draining from England were also monitored.

A surface water was identified as polluted if we were confident that the annual concentration exceeded 50mg/l. (assuming that agricultural sources of nitrate make a significant contribution to the failure).

To determine if there may be a problem with surface water nitrate concentration in the future, data from the 15 year period 1989-2004 was assessed for a rising trend which we could confidently predict would fail the standard in 2010. The trend analysis took account of variation within each year and previous step changes which may represent permanent changes of nitrate input within the catchment.

2.2 Modelling Assessment

- i. A statistical model was developed to help explain how the observed surface water nitrate concentration are affected by the catchment land-use that gives rise to inputs of nitrogen. Datasets on agricultural and urban land-use, point source pollution, groundwater concentrations and baseflow indices were used to derive catchment specific predictors of surface water nitrate concentration. This approach enables forecasts of nitrate concentration for all rivers that are in Water Framework Directive catchments, including those for which surface water monitoring data are not available. This work also provides a means of evaluating the relative importance of sources (e.g. agricultural, urban and point sources), as well as surface water and groundwater pathways for each water body.
- ii. The final statistical model summarises the influence that different forms of agricultural land-use have on observed concentrations of nitrate in surface water. Overall, the model is a reasonable skillful predictor of surface water nitrate concentrations. It allows the observed concentrations to be compared to those expected on the basis of land-use. As with all models there are catchments where the model and the monitoring do not agree.

2.3 The Surface Water Designation method

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- i. The catchments used are defined in the Water Framework Directive as surface water body catchments. There are two types of surface water catchment:
 - Type 1. Those catchments that have monitoring data, trend data and model data (predictions of 95%ile nitrate concentration based on land-use and other sources of nitrate.)
 - Type 2. Those catchments that only have model data (predictions of 95%ile nitrate concentration).
- ii. **Type 1 catchments**
For type 1 catchments monitoring and trend data are used to define whether a surface water meets the Directive's criteria for identification as a polluted water. If a main river in any surface water catchment fails, the entire upstream catchment is designated as a nitrate vulnerable zone i.e. all land draining to the failing water is designated.
- iii. **Type 2 catchments**
For type 2 catchments, modelled data is used to indicate whether the surface water meets the Directive's criteria for identification as a polluted water. If a surface water catchment is identified, the upstream catchment is designated at least as far as the first monitoring point. From the first monitoring point upstream the type 1 rules apply.
- iv. **Review of catchments where model results conflict with monitoring**
Although the model performance is acceptable, it is inevitable that the model will be unable to predict nitrate values in some catchments. This may be due to unrepresentative monitoring or the fact that some catchments behave in a unique fashion due to a combination of physical features. The difference between model predictions and monitoring has been reviewed for all Type 1 catchments. Where there are clusters of catchments with significant differences the monitoring has been evaluated to ensure that it is both reliable and representative. Where the monitoring is found to be acceptable the normal Type 1 rules are applied. However, if the monitoring is found to be unrepresentative or unreliable the catchment is treated as a Type 2.

3 Elevated Nitrogen: Groundwater Method

The full method statement for the assessment of groundwaters will be released in [autumn 2007].

Proposed groundwater NVZs have been identified by analysing the monitoring data, and combining these results with reliable estimates of nitrate released from different sources in the area. Together these give a measure of the risk in each 1km square, and this risk assessment is used to identify polluted waters. Finally, the land draining to these waters is identified for designation as NVZ. The steps are described below.

3.3 Monitoring Data

- i. All available historic data up to the middle of 2005 from groundwater monitoring sites on the Environment Agency's Groundwater Quality Monitoring Network (GWQMN) has been used for this assessment. The length of this record varies widely from site to site because the GWQMN is still developing. For sites with long historic records we have used the same method as described above for the surface water method. For the remainder of the sites we have used the best technique that is statistically defensible to identify the trend.
- ii. What are the current nitrate levels at the monitoring point? For this assessment, the current value is the mean nitrate concentration in mid 2005. That is, the value given the trend line for the specified date.
- iii. What is the concentration of nitrate at the monitoring point likely to be by 2021? The predicted value is the mean concentration in 2021 as predicted by the trend method.
- iv. A reliable statistical method (called kriging) was then used to predict nitrate levels in the nearby groundwater that is not sampled. The result was current and predicted values of nitrate in groundwater for each 1km grid square across England.

3.4 Modelling Assessment

- i. **Calculated nitrate release**
A number of established and accepted mathematical models were used to calculate the amount of nitrate that is released to groundwater from the land. This assessment was made using the 2000 land use data to determine agricultural activity, and urban loading data from various studies. Again this assessment was carried out for each 1km grid square.
- ii. **The risk model for groundwater**
This model is used to combine the calculated amount of nitrate released with both the current and predicted future groundwater nitrate concentrations. The output from this risk model represents the risk that the groundwater nitrate concentration exceeds, or is likely to exceed (by 2021), 50mg/l and that the source of nitrate is current agricultural practice.

The risk associated with the monitored data is a combination of the current and the predicted nitrate concentrations. The current concentrations are given the greatest weight, followed by the predicted concentrations. The nitrate released from current agriculture is given the same weight as current monitoring data. The

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nitrate released from urban loading is given a negative weight. The risk is assessed for every 1km square in England and Wales. There are three levels of risk identified:

- High. Both monitoring data and calculated agricultural nitrate releases show that nitrate concentrations exceed or are likely to exceed 50mg/l
- Medium. Either monitoring or calculated agricultural nitrate releases show that nitrate concentrations exceed or are likely to exceed 50mg/l. This risk class highlights areas where the evidence from monitoring and loading conflict. It also captures areas where agriculture is not a significant source of nitrate.
- Low. Both monitoring and calculated agricultural nitrate releases show that nitrate concentrations are not likely to exceed 50mg/l

iii. The output from the groundwater risk model was reviewed and modified by area experts within the Environment Agency. This was to ensure that the risk model did not contradict local knowledge and represented the Environment Agency's best understanding of the risk posed to groundwater by agricultural nitrate. The following national datasets were used to inform this process; solid geology, drift geology, drift thickness, drift permeability, risk of solution features, depth of unsaturated zone, groundwater head, available water and mean surface water nitrate concentration from the surface water regression model.

Area staff were given the choice of four modifications which they could make to improve the risk model. These modifications were:

- De-nitrification or mixing. If there are processes which will reduce the nitrate concentration before it reaches the groundwater this modification allows us to downgrade the risk.
- Point source pollution. If monitoring is representative of point source pollution this modification allows us to downgrade the risk.
- Groundwater monitoring is unrepresentative of diffuse nitrate pollution from agriculture. Groundwater monitoring depends on the depth of water being sampled. Sampling at depth can be representative of very old water. This modification allows us to both increase and decrease the risk.
- Surface water monitoring is representative of groundwater quality. Where groundwater monitoring is infrequent surface water data can be used to identify groundwater quality. This modification can be used to upgrade the risk.

Evidence was required before a modification could be made. The level of evidence required for each test was set out initially to ensure that all local modifications were consistent and justified.

3.5 The Groundwater Designation Method

- i. The final phase of the work was to put boundaries around the land draining to the high risk areas identified by the risk model. These boundaries must be set from our knowledge and best interpretation of the underlying geological and groundwater data.
- ii. Identification of land draining to the high risk groundwater (contributing area)

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To identify land draining to the high risk groundwater, all the catchment characterisation datasets used in section 3.4iii were re-used. The boundaries listed below were used to de-lineate groundwater NVZs in reducing order of preference.

- Solid or drift geology 1:50k
- Risk of solution features 1:50k. Where solution features are present it can be more appropriate to use this layer than solid geology. This is because the solution feature layer includes a three dimensional aspect at the edge of an aquifer. If the rock at the surface is non aquifer but it is prone to solution features then it is important that the NVZ is extended to include this area
- Feature where groundwater flows out into surface water (river, lake, sea). These features often define a groundwater divide (i.e. the line from which groundwater will flow in different directions). Where nitrate risk is high on one side of such a feature they can be used to define catchments.
- Urban areas do not represent a hydraulic boundary, however they can be useful as a boundary beyond which there is no agricultural nitrate contributing to the high risk area.
- Finally flow lines can be used to delineate within an aquifer. A flow line represents a line across which groundwater does not flow. Flow lines are drawn perpendicular to contours of the level of groundwater. This type of boundary is subject to professional judgement and has only been used when none of the other boundaries are appropriate.

iii. Final checks for groundwater.

Groundwater monitoring is different from surface water monitoring in a number of ways. It is carried out less frequently, which can give less context for high values. Like surface water, a catchment can be identified from which water may drain to the monitoring point, but due to subtle changes in groundwater flow, slightly different parts of the catchment may be sampled on different occasions. To ensure the highest level of reliability of the outcome of this method, each proposed NVZ has been checked to see if it has more than one monitoring point that is exhibiting high nitrate. If there is only one monitoring point within the NVZ it must have a reasonable record (at least one full season) to enable us to be confident that the readings are representative.

It is theoretically possible that monitoring points with high current and predicted nitrate could be identified as high risk by the model even though the agricultural loading is low. Each NVZ has been checked to ensure that a significant proportion of the NVZ has an agricultural loading of greater than 30mg/l.

If an NVZ fails either of these tests it is not proposed as an NVZ at this review.

3 Eutrophication

This section sets out the methods and proposed identification of waters subject to eutrophication for the purposes of the Nitrate Directive 2006 review.

4.1 Interpretation and application of the term “eutrophic”

The definition of "eutrophication" in the Nitrates Directive is;

“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.”

Thus we consider the definition has three elements:

- (a) enrichment of water by nitrogen;
- (b) causing an accelerated growth of algae and higher forms of plant life ; and
- (c) producing an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.

The criteria require consideration of 3 categories before a site is thought to be eutrophic, or may become eutrophic in the near future:

Category	Parameter type	Parameters describe:	Case for designation if:
I	Causative	Nutrients & degree of nutrient enrichment	Criteria <u>are</u> exceeded
II	Response	Plant/algal response to nutrients (direct effects)	Some (or all) criteria are exceeded, or may be exceeded (taking account of relevant environmental factors and weight of evidence)
III	Secondary	Other (indirect) effects of nutrients (e.g. strong diurnal oxygen fluctuations)	

Eutrophication describes a process of change rather than a state and studies have shown that it is controlled by a number of factors. These include nutrients, flow rate of waters, shading and turbidity, depth, temperature and turbulence. The precise influence of many of these factors in the process is not easily quantified. The assessment of whether a water is eutrophic or may become eutrophic is not possible simply by reference to absolute numeric criteria. It is necessary to consider the current condition of the water body (ideally compared to a reference condition) and whether undesirable effects due to nitrogen inputs and the growth of algae or plants have occurred, and to predict whether such effects may occur if preventive action is not taken. A number of symptoms need to be considered in order to come to a rounded judgement, taking into account the weight of evidence, as to whether an individual water is suffering an “undesirable disturbance” or may do so without preventive action. Although national guidance and criteria for each water body type is provided, the importance of particular symptoms depends upon local circumstances.

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4.2 Focussing in on sites of potential concern

In order to identify those waters which are, or may become, eutrophic, the Environment Agency have in place appropriate monitoring and assessment programmes built on existing risk based programmes. Any potential concerns over eutrophication, identified through strategic surveillance networks, operational investigations or local knowledge, are followed up by more intensive and targeted monitoring and assessment.

A water which is, or may become eutrophic due to nitrogen is termed a polluted water (eutrophic). To constitute a case for identification of a polluted water (eutrophic) the Environment Agency collated evidence which comprised the following elements:

- (a) **General information** about the nature of the proposed area/water.
- (b) **Chemical** data/information
- (c) **Ecological** data/information.
- (d) A demonstration that an "**undesirable disturbance**" is occurring or may soon occur. This can be demonstrated through information about adverse effects upon the uses of the waters, and / or by changes in the ecology.

Although it is necessary to make a case in support of candidate sites, it was not essential to collect data / information for every one of the identification criteria. Their relative importance was dependent on local circumstances. Every proposal is assessed on its merits, as to whether the overall balance of evidence constitutes a case for identification.

All case reports included a nutrient budget study which assesses the relative contribution from point sources and diffuse agricultural pollution.

In order to collate, assess and present the various sources of evidence in a comprehensive and consistent format, reporting proformas have been developed which encompass all the relevant information required. Local Environment Agency staff compile reports using the above information, and submit the reports to a national expert panel. The national expert panel ensure that identified waters have been reviewed consistently and that the evidence supports the identification of a polluted water (eutrophic).

All land draining into waters identified as a polluted water (eutrophic) is designated as a Nitrate Vulnerable Zone. As with the surface water elevated nitrate method, surface water catchments defined in the Water Framework Directive are used to delineate the catchments draining into the polluted water (eutrophic).

5 **Designation of Nitrate Vulnerable Zones 2006**

5.1 Treatment of existing NVZs

Previous designations were made in 1996 and 2002. A new method has been developed this time, and the monitoring network has also developed, mainly in line with the requirements of the Water Framework Directive.

Most of the existing NVZs drain to waters that the new method has shown to be polluted waters. However some have not, and there are two reasons for this:

- There are areas where the water quality has apparently improved and existing NVZs have not met the designation criteria in 2006.
- There are existing groundwater NVZs which would not be designated using the 2006 method due to the improvements in the method or the form of monitoring.

The Nitrate Directive has no specific provision within it to allow de-designation of NVZs. If de-designation were ever to be proposed, a very strong case would have to be made, to show that the waters were no longer vulnerable to nitrate pollution. Short-term improvements in quality may be only temporary, resulting from climate variations or temporary agricultural changes (such as de-stocking after the foot and mouth disease outbreak). No such case could currently be made for the situations described above, and so all the existing (i.e. 1996 and 2002) NVZs remain designated.

5.2 Establishing the final boundaries of Nitrate Vulnerable Zones

The “soft” boundaries identified by implementing the earlier parts of the methodology are based upon hydrological and hydrogeological features, and as such do not follow any landscape features such as hedges, fences, roads etc. It is therefore quite common for these boundaries to dissect a field. To make the boundaries more practical and workable, they are adjusted to follow field boundaries. This “hard” boundary forms the basis for designating NVZs.

Converting the soft boundaries into hard boundaries can be achieved by laying the soft boundary areas over large scale, detailed, Ordnance Survey (OS) digital map data (Landline) and matching the soft boundaries to the most appropriate mapped boundary features.

The detailed rules and supporting guidelines by which the outer soft boundaries are converted into hard boundaries are as follows. In these rules, references to waters should be taken to mean waters that are polluted or could become polluted.

Inclusion/exclusion of individual fields

Rule 1 - For land draining into surface water and eutrophic water areas, individual fields with 50% or more area within the outer soft boundary are to be wholly included in the final NVZ area.

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Rule 2 - For land draining into groundwater areas, if any part of the field falls within the soft boundary, the whole field is to be included in the final NVZ area.

In situations where part of a field drains into a surface water or eutrophic water and partly drains into groundwater, rule 2 takes priority over rule 1. If the field is partially covered by a NVZ, which is a combination of a surface water/eutrophic water and a groundwater NVZ, then rule 2 must be applied.

When applying rules 1 and 2, this may, in some situations lead to designation of isolated fields.

Where Rule 1 or 2 creates isolated areas outside the main boundary

Rule 3 - Individual, isolated single fields outside the main boundary are removed. This does not extend to clusters of fields or very large land areas.

Defining boundaries at heads of watersheds can be difficult, especially in more extensive agricultural areas where no field boundary runs close to the catchment boundary. An additional problem is that the nearest field boundary may be into the next catchment and is therefore an inappropriate boundary to use in hydrological terms.

Rule 4 - Fix boundary of heads of watersheds as the nearest field boundary on the inside of the watershed, where this lies within a reasonable distance (e.g. up to 400m) from the soft boundary.

Rule 5 - For watersheds where there is no field boundary on the inside of the watershed within a reasonable distance, the NVZ boundary will remain as shown on the soft map and will not be linked to the nearest Landline feature. In such cases the hard boundary will effectively follow the natural watershed boundary of the designated catchment.

Rule 5 above is likely to be workable in most cases because such areas with no field boundaries are unlikely to be in intensive agriculture and therefore unlikely to have difficulty complying with the Action Programme rules.

General guidelines in support of Rules

- Only solid (identifiable) features on the ground as identified on the O.S. Landline data are to be used for hard boundary definition. In most instances this will be represented by a continuous line on the Landline data. (E.g. wall, fence, hedge, road edge, byway)
- Areas of woodland, copse and plantation that are unfenced can be used in forming the hard boundary, providing they are depicted as such on the OS Landline data.
- Areas of commercial woodland will be included within the NVZ hard boundary to ensure all isolated parcels of agricultural land, as appears on the Rural Land Register, are included.
- When interpreting the aim should be to keep to the true hydrological boundary.
- Decisions can only be based on the representation of features on the ground as mapped within OS Landline data, but can be helped by using Rural Land Registry data, UK Perspectives (UKP) aerial photography data and other recognised datasets such as the Moorland Line. However, there will be

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occasions where the boundary has to cross a feature such as a road, railway line or airfield, to link the hard boundary between two land parcels. In this situation the procedure is to cross the feature in a straight line, at the same time as minimising the amount of the feature to be included within the hard boundary

- Areas of urban conurbation can be omitted where they fall on the boundary. The NVZ hard boundary can cut across an urban area by the road system in order to ensure that isolated parcels of agricultural land, as identified on the Rural Land Register, are captured if appropriate to the soft boundary. The Urban area should be identified within OS Landline, but it can be confirmed by using OS 1:10,000 mapping, the Rural Land Register mapping and UKP aerial photography.
- Where the soft boundary crosses the coastline the hard boundary must follow the Mean High Water Line. At estuaries the hard boundary can cross the water course where the width of the channel between the high water marks becomes less than 750m. This is a practical solution which captures the appropriate agricultural land, whilst avoiding the creation of an unnecessarily long and complex perimeter to the NVZ.
- Interpretation must be driven by a clear combination of the basic Rules above, the supporting guidelines and the OS data. In some instances implementation of the rules and guidelines will not result in a definitive location for the hard boundary. In such instances, the digital map data is interpreted to include land draining into waters that are polluted or could become polluted. In the case of a discrepancy between OS maps and features on the ground, the features on the ground must prevail.

Specific guidelines in support of Rules

- Tracks and other features clearly splitting a field can be used to define the hard boundary. (E.g. ditches, hedges, fences, walls, byways – but not footpaths / nominal public rights of way).
- Internal redundant field boundaries (pecked) are to be ignored.
- If an area is clearly labelled such as a wood and is clearly defined, this can be used to identify smaller fields than would be possible without the named area.
- In tidal areas the mean high water line can be used as a defining line, if no other feature is available.

The existing NVZ boundary (designated in 2002) was digitised using Landline mapping, with revisions made following an appeal process. This line is not to be re-interpreted using current mapping or any other supporting datasets.