OR/16/033 NVZ designations under the Nitrates Directive

The first designations were made in 1996. A major review of the designation process was carried out in 2002 with further reviews in 2008 and 2012. The following sections discuss the methods used and results in each of the designation rounds.

1996

Methodology

Under the Nitrates Directive, Member States were required to identify ‘polluted water’ or water at risk of pollution if no controls were applied. The land draining into these areas and contributing to pollution was then designated as nitrate vulnerable zone. The Directive’s criteria were as follows:

- whether surface freshwaters, in particular those used or intended for the abstraction of drinking water, contain or could contain more than 50 mg NO$_3$ l$^{-1}$ (on the basis that 95% of samples should comply with this limit) if protective action were not taken;
- whether groundwaters contain, or should contain more than 50 mg NO$_3$ l$^{-1}$ if protective action were not taken;
- whether freshwaters, estuaries coastal and marine waters are eutrophic or may become so if protective action were not taken.

The following considerations were to be taken into account when supplying these criteria:

- the physical and chemical characteristics of the waters and land;
- the current understanding of the behaviour of nitrogen compounds in the environment (water and soil);
- the current understanding of the impact of the remedial action.

The quality of the water was to be established by regular monitoring and there were different provisions for surface and groundwaters. The original designation process is described in MAFF et al. (1994)[1] and an outline is shown in Figure 3.1.
Surface fresh water

The Directive required that the monitoring of the nitrate concentration should take place at least monthly over a 12-month period. For this assessment the National Rivers Authority (NRA) used monitoring data for the calendar year 1992 for sampling points used for the Surface Water Abstraction Directive.

The lower extremity of a polluted water was determined by an abstraction point which exceeded the 50 mg NO$_3^{-}$ l$^{-1}$ limit. The upper point was either the first upstream sampling point which complied with the 50 mg NO$_3^{-}$ l$^{-1}$ on a 95 percentile approach using five years’ data or the source of the headwaters, if all sampling points failed. The vulnerable land was the land draining into this polluted water. The land was defined by delineating the boundary of the natural catchment, upstream of the abstraction, and reducing this catchment as appropriate to exclude land draining to the first upstream passing point. Defining the natural catchment in this way assumed the drainage follows the lie of the land. Where man-made drainage arrangements rendered this approach invalid (particularly in low-lying areas) these were taken into account in defining the land draining to the abstraction point.

Groundwater

All groundwater boreholes, wells and springs used for public water supply in England and Wales were examined by the then NRA to see if there was evidence that nitrate levels already exceeded the 50 mg l$^{-1}$ limit or were on a trend to exceed it by the year 2010. Data over recent years were examined and assessed relative to the likely position by the year 2010.

For each well or spring system, which had exceeded or was expected to exceed the 50 mg l$^{-1}$ limit, the groundwater source catchment was identified. This was based on the area within which all water would flow to the abstraction. The source catchment was defined both by modelling and by the study
of relevant hydrogeological factors. An area became a potential groundwater zone where the location of the majority of the land draining into the abstraction was known and where agriculture was the principal factor in determining nitrate levels in the water.

Sources were grouped into common vulnerable zones in a number of cases. The most straightforward cases were those where separate catchments adjoined each other and it was possible to extend the boundary to cover more than one catchment. In a number of other cases where catchments lay close together, the amount of the groundwater resource used for public supply was not sufficient to provide definitive guidance for a clear division of land into catchment and non-catchment. In such cases geological features provided the basis for much of the vulnerable zone boundary. The groups of sources were placed in common vulnerable zones only where the amount of land forming catchments to polluted waters constituted a high proportion of the area of land which can be defined by reference to geological features.

**Eutrophic waters**
Eutrophication is defined in the Directive as the enrichment of water by nitrogen compounds. It causes an accelerated growth of algae and higher forms of plant life to produce and undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. There were no designations under this heading.

**Boundaries**
The proposed boundaries of vulnerable zones were based on ‘hard features’ such as roads and field boundaries. The following criteria were accepted:

- where a proposed zone is large enough — so that minor erosion of the boundary does not affect its environmental impact — the hard boundary lies inside the hydrological boundary;
- in groundwater zones the proposed designation corresponds to a reasonable proportion of the theoretical catchment required to recharge the water abstracted.

**Designated NVZ areas**
Land draining into 11 river systems and land being identified as the catchment of 141 groundwater abstraction zones were put forward as candidate vulnerable zones, giving 72 NVZs in total. An outline of these zones is shown in Figure 3.2. Four of these were surface water catchments, some were joint, but the majority were groundwater catchments. The total area of the proposed NVZs was about 6500 km². Action plans related to these designations came into effect in 1998.
Figure 3.2 Zones in original designation (derived from MAFF et al., 1994[1]).

Appeals to independent review panel

Appeals against designation were heard by an independent review panel appointed by the Secretary of State and their report is published in MAFF (1995)[2]. This report reviewed the number, range and nature of the submissions. Objections were received to 29 of the proposed 72 NVZs. These covered a wide variety of themes, including boundary location, sampling point location and possible effects of non-agricultural sources. Others raised issues of principle. These included:

- arbitrariness of the limit;
- frequency of testing;
- trend estimation in groundwater;
- non-agricultural sources;
- marginal failures;
- boundary definitions;
- grouped sources;
- absence of compensation;
- non-representative monitoring data.

Of the 29 NVZs which were contested, the panel’s conclusions were that:

- 1 was considered to be too small;
- 1 had inadequate monitoring data;
- 1 needed better boundary definition;
- 1 was not significantly shown to be due to agriculture;
- 1 surface water not accepted but an associated groundwater NVZ was;
- 2 were deferred
The others were all considered to be valid under the specified procedure. The final agreed changes are set out in MAFF et al. (1995).

**2002 Review**

In December 2000, the European Court of Justice held that the UK had failed to designate sufficient NVZs for the protection of all waters, not just for drinking water sources. On 27 June 2002, the Government announced the intention to designate additional NVZs in England. Except for the purposes of identifying waters that are eutrophic or are likely to become eutrophic, new criteria replaced the methodology for designating NVZs in Department of the Environment et al. (1993) and were set out in Defra (2002).

**Revised methodology**

*Surface water*

Surface waters with nitrate concentrations exceeding 50 mg NO$_3$ l$^{-1}$, or which could exceed 50 mg NO$_3$ l$^{-1}$, were identified through the following steps:

a. sampling nitrate concentrations between 1996 and 2000 at water quality monitoring points representative of all major surface waters in England. This dataset contained about 60 samples for each of 7000 sites. This was a major change as previously only public supply sources had been used;

b. analysing the monitoring data over the 1996 to 2000 period to identify those points where there was 95% statistical certainty that the level of 50 mg l$^{-1}$ of nitrate had been exceeded at least 5% of the time. This was done by calculating a 95 percentile from the dataset and constructing a 90% confidence interval around this. If the lower confidence interval on the calculated the 95 percentile exceeded the 50 mg NO$_3$ l$^{-1}$ level, then the sample point was judged, with 95% certainty, to be affected by nitrate pollution;

c. trend analysis to identify any additional points which could exceed 50 mg NO$_3$ l$^{-1}$ in the future if action is not taken. This work used a ten-year dataset from 1991 to 2000 to extrapolate future trends. Points predicted with 95% confidence to exceed the level of 50 mg/L at least 5% of the time by 2004, which was the year of the next monitoring review required under the Nitrate Directive, were judged to be waters that could be affected by pollution if no action is taken;

d. identification of all known areas of land draining into all the tributaries of the river network upstream from each polluted monitoring point. Although nitrate concentrations in some of these upstream tributaries may have fallen below 50 mg NO$_3$ l$^{-1}$, land draining into these waters still needed to be included because nitrate loss throughout the catchment will be contributing to the downstream pollution.

*Groundwater*

Geostatistical analysis was used to interpolate nitrate concentration data between monitoring sites in England. Future nitrate concentrations were predicted by extrapolating from the actual nitrate monitoring data. These, together with modelling of nitrate leaching vulnerability, were used to identify land draining into groundwaters which exceeded 50 mg NO$_3$ l$^{-1}$, or were expected to exceed this if no action was taken.

Identification of groundwaters which were nitrate polluted or which could become polluted used the following steps:

a. gathering historic nitrate concentration data from groundwater monitoring sites (boreholes,
wells and springs) in England between 1990 and 2000. This included all available data for 3714 monitoring sites in England and Wales from both the Environment Agency and Water Companies;

b. subjecting actual groundwater data to predictive computer analysis to produce a map estimating the probability of any location exceeding 50 mg NO$_3$ l$^{-1}$ by 2017. This was 25 years from 1992, the first full year in which the Nitrates Directive was in force. Groundwater residence times are longer than surface waters and therefore responses to changes in nitrate losses from agricultural land will take longer. This involved the collation of trend values and disjunctive kriging to provide local estimates and also probabilities.

The final areas are shown in Figure 3.3.

**Figure 3.3** Areas with probability of exceeding 50 mg l$^{-1}$ nitrate in groundwater ≥0.2 in 2002 assessment (from Defra, 2002[4]).

Identification of all known areas of land which drained into these groundwaters involved the following steps:

a. modelling the nitrate leaching vulnerability using a GIS model which took account of climate, nitrate loading, soil characteristics, and superficial and bedrock geology. Nitrate leaching vulnerability was estimated using the ADAS MAGPIE model (Lord and Anthony, 2000[5]; Lord et al., 1999[6]) and the Environment Agency’s published vulnerability maps. The model structure is shown in Figure 3.4;

b. combining the map of the predicted future nitrate levels with the calibrated model of groundwater vulnerability and applying a buffer. The overall effect was to identify areas of land draining into groundwaters which could exceed the 50 mg/L nitrate concentration limit by 2017 and where it was possible that the groundwaters are vulnerable to nitrate leaching from agricultural land. These areas of land were therefore those which drained into groundwaters that are affected by pollution, or could be affected by pollution if no action were taken. The threshold vulnerability was set using the cumulative percentage of high nitrate boreholes.
Figure 3.4  Combination of data layers within GIS to derive nitrate leaching vulnerability in 2002 (from Defra, 2002[4]).

**Designated areas**

The areas derived from the 2002 assessment are shown in Figures 3.5 and 3.6.

Figure 3.5  NVZs identified in 2002 for: a) surface water and b) groundwater (from Defra, 2002[4]).
2008 Review

Methodology

Changes in methodology for application in this round are set out in Environment Agency (2007)\(^4\) and the finalised methodology is set out in Defra (2008)\(^5\). A new surface water method was developed, and the monitoring network also developed, mainly in line with the requirements of the Water Framework Directive. The minimum dates for collection of monitoring data were 1999–2004, with samples dating to 1980 used where these were available to determine concentration in mid-2005. The date for the statistical modelling of trends which would fail the 50 mg NO\(_3\) l\(^{-1}\) value became 2021.

Most of the already existing NVZs drained to waters that the 2008 method also showed to be polluted waters. However some were not, for two reasons:

- there were areas where the water quality had apparently improved and did not meet the designation criteria;
- there were existing groundwater NVZs which would not be designated 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. Moreover, short-term improvements in quality may have been only temporary, resulting from climate variations or temporary agricultural changes (such as de-stocking after the foot and mouth disease outbreak). Hence, although the 2008 groundwater method contained options for identifying land for removal from designation, no such case was assessed as sufficiently strong, and so all the pre-existing (i.e. 1996 and 2002) NVZs remained designated.

Surface water
The catchments used are defined in the Water Framework Directive as surface water body catchments. There were two types of surface water catchment:

**Type 1.** Those catchments that had monitoring data, trend data and model data (predictions of 95 percentile nitrate concentration based on land-use and other sources of nitrate). For Type 1 catchments monitoring and trend data were 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 failed, the entire upstream catchment was designated as a nitrate vulnerable zone i.e. all land draining to the failing water was designated;

**Type 2.** Those catchments that only had model data (predictions of 95 percentile nitrate concentration). For Type 2 catchments, modelled data was used to indicate whether the surface water met the Directive’s criteria for identification as polluted water. If a surface water catchment was identified, the upstream catchment was designated at least as far as the first monitoring point. From the first monitoring point upstream the Type 1 rules applied.

**Groundwater**
This followed a similar process to that used in the previous round. Following determination of concentration and trends, kriging was used to provide some indication of potential levels across all the land surface.

A risk model for groundwater was 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 represented the risk that the groundwater nitrate concentration exceeded, or was likely to exceed 50 mg NO\textsubscript{3} l\textsuperscript{-1} by 2021, and that the source of nitrate was current agricultural practice.

The risk associated with the monitored data was 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 nitrate released from urban loading was given a negative weight. The risk was assessed for every 1 km square in England and Wales. Three levels of risk were identified:

- **High.** Both monitoring data and calculated agricultural nitrate releases showed that nitrate concentrations exceed or are likely to exceed 50 mg NO\textsubscript{3} l\textsuperscript{-1};
- **Medium.** Either monitoring or calculated agricultural nitrate releases showed that nitrate concentrations exceed or are likely to exceed 50 mg NO\textsubscript{3} l\textsuperscript{-1}. This risk class highlighted areas where the evidence from monitoring and loading conflicted. It also captured areas where agriculture was not a significant source of nitrate;
- **Low.** Both monitoring and calculated agricultural nitrate releases showed that nitrate concentrations are not likely to exceed 50 mg NO\textsubscript{3} l\textsuperscript{-1}.

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.

Agency area staff applied four modifications which they could make to improve the risk model. These modifications were:
• de-nitrification or mixing. If there were processes which will decrease the nitrate concentration before it reaches the groundwater this modification allows the risk to be downgraded;
• point source pollution. If monitoring was representative of point source pollution this modification allows the risk to be upgraded;
• groundwater monitoring was 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 the risk to be both increased and decrease;
• surface water monitoring was 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.

The final phase of the work was to put boundaries around the land draining to the high risk areas identified by the risk model using catchment characterisation datasets. The boundaries listed below were used to de-lineate groundwater NVZs in decreasing 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;
• 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 is appropriate.

To ensure the highest level of reliability of the outcome of this method, each proposed NVZ was checked to see if it has more than one monitoring point that was exhibiting high nitrate. If there was only one monitoring point within the NVZ it must have a reasonable record (at least one full season) to enable confidence that the readings were 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 30 mg l\(^{-1}\). If an NVZ fails either of these tests it is not proposed as an NVZ at this review.

**Designated area**

A total area of 32 047 km\(^2\) for NVZs was identified in the 2008 review (31 821 km\(^2\) in England and 226 km\(^2\) in Wales) for groundwater (Figures 3.7 and 3.8). The comparable figures were 66 190 km\(^2\) (65 950 km\(^2\) in England and 240 km\(^2\) in Wales) for surface water. NVZs covered 3.4 million hectares arable and 1.8 million hectares managed grassland (ADAS, 2011[9]).
**Figure 3.7** NVZs identified in 2008 for: a) surface water and b) groundwater (from Environment Agency, 2008[10]).

**Figure 3.8** Final and new zones in 2008 (from Environment Agency 2008[10]).

**Appeals results**

A summary of the NVZ appeals panel at 7th April 2010 (Defra, 2010[11]) showed that of 626 appeals made with complete information provided 47% of appeals were upheld or partly upheld (Table 3.1).
The majority (78%) were made on the grounds — (AB) Does not drain to specified water & water not polluted and (B) Water not polluted. The summary is shown in Appendix 1 - Summary of the decisions made by the NVZ appeals panel (as at 7 April 2010).

Overall the success of surface water appeals was much higher than for groundwater appeals with only 16% of groundwater only appeals being successful.

Table 3.1  NVZ appeal summary 2010 (from Defra, 2010\cite{11})

<table>
<thead>
<tr>
<th>Appeal Class</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water (S)</td>
<td>360</td>
</tr>
<tr>
<td>Groundwater (G)</td>
<td>76</td>
</tr>
<tr>
<td>Surface water &amp; groundwater (SG)</td>
<td>36</td>
</tr>
<tr>
<td>Type of appeal</td>
<td></td>
</tr>
<tr>
<td>Eutrophic groundwater (GE)</td>
<td>9</td>
</tr>
<tr>
<td>Eutrophic surface water &amp; groundwater (SGE)</td>
<td>2</td>
</tr>
<tr>
<td>Eutrophic (E)</td>
<td>11</td>
</tr>
<tr>
<td>Not specified (NS)</td>
<td>132</td>
</tr>
<tr>
<td>Grounds</td>
<td></td>
</tr>
<tr>
<td>Does not drain to specified water &amp; water not polluted (AB)</td>
<td>252</td>
</tr>
<tr>
<td>Water not polluted (B)</td>
<td>234</td>
</tr>
<tr>
<td>Does not drain to specified water (A)</td>
<td>133</td>
</tr>
<tr>
<td>Not specified or obscure (N)</td>
<td>7</td>
</tr>
<tr>
<td>Decision</td>
<td></td>
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<tr>
<td>Rejected</td>
<td>336</td>
</tr>
<tr>
<td>Upheld</td>
<td>261</td>
</tr>
<tr>
<td>Partially upheld</td>
<td>29</td>
</tr>
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</table>

Table 3.2  Appeal success per type (upheld or partly upheld) in 2010 (from Defra, 2010\cite{11})

<table>
<thead>
<tr>
<th>Success rate</th>
<th>AB</th>
<th>B</th>
<th>A</th>
<th>N</th>
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<tbody>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>S</td>
<td>58% (93/160)</td>
<td>49% (58/118)</td>
<td>71% (58/82)</td>
<td>-</td>
<td>58% (209/360)</td>
</tr>
<tr>
<td>G</td>
<td>16% (6/38)</td>
<td>13% (3/23)</td>
<td>71% (58/82)</td>
<td>-</td>
<td>16% (12/76)</td>
</tr>
<tr>
<td>SG</td>
<td>41% (9/22)</td>
<td>17% (1/6)</td>
<td>0% (0/7)</td>
<td>100% (1/1)</td>
<td>31% (11/36)</td>
</tr>
<tr>
<td>E</td>
<td>33% (1/3)</td>
<td>0% (0/3)</td>
<td>75% (3/4)</td>
<td>0% (0/1)</td>
<td>36% (4/11)</td>
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<tr>
<td>GE</td>
<td>33% (1/3)</td>
<td>0% (0/6)</td>
<td>-</td>
<td>-</td>
<td>11% (1/9)</td>
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<tr>
<td>SGE</td>
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<td>0% (0/1)</td>
<td>-</td>
<td>-</td>
<td>0% (0/2)</td>
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<tr>
<td>NS</td>
<td>20% (5/25)</td>
<td>53% (41/77)</td>
<td>28% (7/25)</td>
<td>0% (0/5)</td>
<td>40% (53/132)</td>
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<td>45% (103/234)</td>
<td>54% (71/133)</td>
<td>14% (1/7)</td>
<td>47% (290/626)</td>
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</tbody>
</table>

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