Rationale for the proposed NVZ Action Programme measures

ADAS report to Defra – supporting paper D4 for the consultation on implementation of the Nitrates Directive in England

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1 Introduction

Earlier papers in this series demonstrate the need to tighten the 2002 NVZ Action Programme measures. Following this, a shortlist of potential mitigation measures, out of an assembled inventory of measures, was identified for inclusion in a revised Action Programme (see “developing the revised Action Programme” in the accompanying consultation document (Defra, 2007)). This paper defines the proposed Action Programme measures and provides a science-based justification for their definition.

It is essential to define the detail behind each measure for reasons of clarity. For example, whereas a description of a mitigation measure in a voluntary Code of Practice might suffice as ‘do not apply organic manure during high risk periods’, this definition would be inadequate for inclusion in Regulation. A precise definition is required, and so it would need to include details of specific dates, soil type restrictions, manure type restrictions, etc.

1.1 Proposed measures for reducing losses of nitrate

The proposed revisions to the NVZ Action Programme measures are outlined below and set out in detail in the Defra consultation document regarding the proposed revised NVZ Action Programme (Defra, 2007).

Action Programme measures are aimed at controlling when, where, how, and in what amount, nitrogen (N) can be applied to land. The key proposals for the revised Action Programme include:

- **Whole farm manure N loading limit**: Establishes a limit of 170 kg/ha of total N from livestock manures (applied and deposited during grazing) per calendar year, averaged across the farmed area.
- **Closed period (organic manures)**: Prohibits the spreading of organic manures with high available nitrogen content during specified periods. It is proposed to extend the length of the closed periods, and apply it to all soil types.
- **Manure storage**: Requires farms to provide sufficient storage facilities to store all slurry produced by livestock during a period of 26 weeks for pigs and 22 weeks for cattle, and to store all poultry manure for a period of 26 weeks.
- **Closed periods (manufactured nitrogen fertilisers)**: Prohibits the spreading of manufactured nitrogen fertiliser during specified periods unless there is a crop nitrogen requirement.
- **Crop nitrogen requirement limit**: Requires farms not to exceed crop requirements for nitrogen and assume a level of efficiency of nitrogen supply from any manure applications.
- **Spreading locations**: Requires farmers to undertake a written assessment to identify areas of land at risk of runoff and causing water pollution. Applications of nitrogen fertiliser and organic manures to areas of land identified as posing a high risk of runoff are prohibited.
- **Spreading techniques**: Prohibits the use of high trajectory, high pressure application techniques for spreading organic manure. Additionally, applications of organic manure to bare soil or stubble will require incorporation into the soil in certain situations.
- **Record-keeping**: Establishes a requirement to keep a record of all N applications to land to facilitate compliance checking.
- **Cover crops**: Requires farmers to establish cover crops before spring sown crops (e.g. potatoes, sugar beet).
1.2 Factors taken into account when defining the proposed measures

When defining the proposed Action Programme measures, many factors were taken into account:

- **Legal obligations**: The Nitrates Directive contains specific requirements regarding the measures to be included in an Action Programme (see Annex II and III of the Directive).
- **Losses of nitrogen**: The measures have been designed to reduce losses of nitrogen and to achieve the environmental objectives of the Nitrates Directive.
- **Pollution swapping**: The aim is to also minimise the negative impacts of measures on losses of other pollutants to both air and water (e.g. phosphorus, ammonia).
- **Environmental factors**: Many factors, for instance soil type, climate and crop type can all impact on the effectiveness of a mitigation measure.
- **Practicability**: The impacts of a measure on current practices, and on the ability to continue farming practices under the new Action Programme, were considered when defining the measure.
- **Simplicity and Clarity**: Some of the proposed changes are to improve clarity of the measure to ensure that farmers understand their obligations and clearly understand how the Environment Agency will interpret the measure and enforce compliance.
- **Consistency**: Some of the proposed measures are similar to those required under other Regulations. Therefore, it is necessary to ensure that the Action Programme proposals are consistent with other measures.
- **Flexibility**: There is a large variation in farming systems and practices in England. It was important, therefore, to build in a level of flexibility into the definitions, where feasible, to enable farmers to continue to make decisions that are best suited for their individual circumstances.
- **Cost-effectiveness** is clearly an important factor when considering proposed measures. The partial Regulatory Impact Assessment (supporting paper B) considered the cost-effectiveness of a range of possible nitrate mitigation measures.

The following sections consider each of the proposed Action Programme measures and the factors which were taken into account when these were being defined.

2 Closed periods for organic manures with high readily-available nitrogen

2.1 Proposed Action Programme measure

Organic manures with high available nitrogen (i.e. over 30% of the total nitrogen content) must not be applied to land during the following dates:
Table 4.1 Summary of proposed closed periods for applications of organic manure with high readily-available nitrogen in England

<table>
<thead>
<tr>
<th>Average annual rainfall (mm)</th>
<th>Grassland</th>
<th>Land that is not grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sandy and shallow soils</td>
<td>All other soils</td>
</tr>
<tr>
<td>Over 1050</td>
<td>1 Sep – 31 Dec</td>
<td>1 Oct – 31 Jan</td>
</tr>
</tbody>
</table>

It is proposed that the following exemptions will apply to the closed periods:
- in the autumn on land that is not grassland, applications during the closed period will be permitted on sandy and shallow soils where the manure is applied and a crop is drilled by 15 September.
- Organic manures with low available nitrogen (under 30% of the total nitrogen content) are not subject to the closed spreading period restrictions (e.g. FYM, composts, sewage sludge/biosolid cake).

2.2 Factors affecting the definition of this measure

In redefining the closed periods for applications of organic manures, a number of factors had to be balanced. These include:
- Legal obligations
- Current farm practice
- Minimising nitrate loss
- Avoiding unintended consequences to emissions of pollutants other than nitrate
- Practical constraints

2.2.1 Legal obligations

Annex III of the Nitrates Directive requires that measures must include rules relating to periods when the land application of certain types of fertiliser or organic manure is prohibited, taking into account the characteristics of the vulnerable zone concerned and, in particular:
- soil conditions, soil type
- climatic conditions, rainfall
- land use and agricultural practices, including crop rotation systems

2.2.2 Current practice

A substantial proportion of organic manures with high readily available nitrogen contents are applied in autumn (Figure 4.1). Autumn applications are at risk of nitrate loss and the revised Action Programme needs to address this.
2.3 Minimising nitrate loss to water

The broad results of recent research concerning the factors influencing nitrate loss from agricultural land are considered in earlier papers in this series. Some information related to closed periods is included again here for ease of reference.

The closed period measure is designed to limit losses of nitrogen by leaching in the weeks immediately following manure application. Timing of application, climate, soil type and type of crop all affect the losses of N that can be expected and, therefore, influence how the closed period should be defined in terms of its length, applicability to different climatic regions of England, soil types, and manure types.

Effect of manure type

The quantity of nitrate leached due to recently applied manure is directly proportional to the quantity of ‘readily-available nitrogen’ that is applied, minus losses by ammonia volatilisation and nitrogen uptake by plants (Chambers et al., 1999).

The proposed closed periods apply only to manures with a high proportion of readily-available nitrogen (e.g. cattle/pig slurries, poultry manures and liquid digested sewage sludge/biosolids). Restrictions have not been placed on straw-based manures (FYM) because they contain little readily available nitrogen, especially when they have been stored. Similarly, restrictions have not been placed on other manures with low readily available nitrogen contents (e.g. composts, sewage sludge/biosolid cakes).

Experimental data confirm that nitrate leaching losses following applications of FYM are substantially smaller than for slurry. This provides the evidence for not having any closed period restrictions for manures with a low readily available nitrogen content (see Paper 3 in this series).

Effect of soil type

Soils in England range from poorly drained clays to free draining sandy soils. Sandy and shallow soils, which are the soils with greatest risk of nitrate leaching, represent about 70% of soils in the 2002 groundwater Nitrate Vulnerable Zones of England and Wales (Scott et al., 2004) and about 7% of the overall agricultural land within NVZs.
Water movement through deep sandy soils is a relatively straightforward process. Sandy soils are permeable to water, and nitrate is carried down through the soil profile with the percolating water, with only limited amounts of water movement as surface-runoff. In contrast, water movement through clay soils is considerably more complex, with potential for water movement by surface-runoff, laterally across the soil surface layers, rapidly downwards through cracks, channels and macropores (to drains), or slowly downwards through the bulk of the soil (the ‘soil matrix’). On sandy soils, applications of manures from late winter onwards do not usually increase nitrate loss, because the quantity of water moving down through the soil in the period between application and the end of the winter is not enough to move the nitrate out of the reach of roots.

Although the greatest risk of leaching is from sandy and shallow soils, risks from other soils are still substantial. Sandy and shallow soils represent a rather small proportion of agricultural land. In order to control nitrate leaching more fully, closed periods for other soils must also be considered.

Clay soils are generally more nitrate-retentive when the nitrate is held within the soil matrix. Consequently, losses of nitrate from autumn manure applications on clay soils are generally smaller than from free draining sandy soils. However, following recent research (e.g. Beckwith et al., 1998; Chambers et al., 2000), it has become apparent that, under some circumstances, the risk period for application of manures (and fertiliser) persists later into the winter. That is, some losses may occur even from applications in late winter and early spring on these heavier soils (in contrast with losses from sands as described above). Additionally, there is a greater risk of loss from winter applications of other pollutants, particularly phosphorus, ammonium-N and microbial pathogens.

These data support the need to redefine the closed periods to include soil types other than just sandy and shallow soils, and the need for closed periods to reflect the different risk of nitrate (and phosphorus) loss from freely draining sandy soils compared to heavier clay soils.

Effect of date of application

Nitrate loss to water is generally greater from autumn applications compared to spring applications of manure, as shown in Figure 4.2.

These data show that on arable soils, the earlier the application in the autumn, the greater the risk of nitrate leaching. On grassland soils, leaching risk is smaller for applications in September compared to October because of greater N uptake by the grass before winter, and leaching risk is even smaller for August applications. Research shows a trend for much smaller nitrate leaching losses from applications made from January onwards, and again losses from grassland sites are smaller than from arable. In the 2002 Action Programme measures, the closed period for a sandy or shallow soil ended on 1 November, but these data indicate that there is still a significant risk of leaching for applications after this date on at least some soils and in some winters. The leaching risk is, of course, a function of rainfall, and is therefore smallest in the driest winters.

The data presented in Figure 4.2 were based on experiments on sandy/shallow soils and sandy loams. As explained earlier, the hydrology of clay soils is more complex and, consequently, the interaction between manure applications and other factors is also more complex. For example, over three drainage seasons on a drained clay arable soil, measured nitrate losses due to slurry or poultry manure applied in September were equivalent to 13% of the total N applied (Chambers et al., 1999). Losses from applications in December and January averaged 11% of total N applied. This supports the need for a closed period through the winter.
**Effect of crop type**

Nitrate leaching is generally smaller from grassland than from arable land under equivalent conditions, and therefore shorter closed period dates are appropriate for grassland. Figure 4.2 shows that the risk of nitrate loss from September manure applications is smaller than from October applications due to crop uptake, but it is not zero. The current closed period for sandy and shallow soils under grass is 1 September to 1 November. These data show that there is a significant risk of leaching from applications during November, but a smaller risk for applications from December onwards. On grassland, the nitrate loss from late winter applications was smaller than from arable land, and on average the manure-derived nitrate loss from January applications was negligible.

**Figure 4.3** Nitrate leaching from pig slurry applied to oilseed rape (Williams et al., 2005).

Nitrate leaching due to manures applied before early-sown arable crops such as fodder catch crops and oilseed rape is reduced relative to those for applications before later sown crops. For example, Figure 4.3 shows that applications of pig slurry in autumn prior to oilseed rape (sown September) resulted in lower levels of nitrate leaching compared to applications in December. Manure applications before such early sown crops will result in less nitrate
leaching than if the manure is applied prior to a late-sown crop or where land will be bare over winter. Manure N applications in spring after the end of January also caused no leaching on these soils because the quantity of water passing through the soil after application was insufficient to move the nitrate below the root zone before it could be taken up by the crop. Such evidence supports an exemption for spreading organic manure in autumn before autumn sown crops (see Section 3.1).

Effect of climate

Annual rainfall in England varies from less than 600 mm to over 1300 mm. When applied in autumn/winter, the greater the rainfall after manure application, the greater the nitrate leaching from the manure. Thus, we have introduced rainfall bands to recognise this risk, with a longer closed period for the wetter areas. Table 4.2 shows that a relatively small area of land falls into the wetter category within current NVZs.

Table 4.2  Percentages of livestock, arable and grassland within the 2006 English Nitrate Vulnerable Zones classified by mean annual rainfall (mm). Data derived from the MAGPIE environment database (Lord & Anthony, 2000).

<table>
<thead>
<tr>
<th>Rainfall (mm)</th>
<th>Arable</th>
<th>Grass</th>
<th>Pigs</th>
<th>Poultry</th>
<th>Dairy</th>
<th>Beef</th>
<th>Sheep</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤1050</td>
<td>99.0</td>
<td>88.0</td>
<td>98.3</td>
<td>96.5</td>
<td>88.5</td>
<td>89.8</td>
<td>83.1</td>
</tr>
<tr>
<td>&gt;1050</td>
<td>1.0</td>
<td>12.0</td>
<td>1.7</td>
<td>3.5</td>
<td>11.5</td>
<td>10.2</td>
<td>16.9</td>
</tr>
</tbody>
</table>

2.4 Modelling impacts of manure management on nitrate loss

Field experiments alone cannot explore every combination of factors and a core component of nitrate research has been the establishment of a nitrate loss modelling framework. Modelling allows a much wider range of scenarios to be tested compared with field experiments.

2.4.1 Modelling methodology

The MANNER model (Chambers et al., 1999) was developed to summarise experimental data on the impact of manure management practice on the fate of the nitrogen content in manure. It has been well tested against field measurements, both of crop response to fertiliser and of nitrate leaching. The results below include all losses of nitrate (i.e. leaching to groundwater, loss via drains, and surface runoff).

The MANNER model was used to test further the revised manure closed periods. To do this, a range of scenarios representative of conditions in England was selected:
- **Contrasting manure types:** manure with high readily-available nitrogen (pig slurry, cattle slurry, poultry manure) compared to those with low readily available nitrogen (cattle and pig FYM)
- **Contrasting climate:** range of rainfall 550 to 1500 mm
- **Contrasting soil types:** loamy sand compared to clay soils
- **Contrasting cropping:** grassland compared to arable land

Nitrate leaching estimates from these scenarios were calculated as the percentage of the total nitrogen applied. For example, nitrate leaching of 10% of an application of 250 kg/ha of manure total nitrogen (the field limit) would represent 25 kg/ha of nitrate-N.
2.4.2 Model results for effect of manure timing on nitrate leaching

Figures 4.4-4.6 present results of MANNER model runs to explore the effect of date of application of manures on nitrate losses under a range of conditions.

**Figure 4.4** MANNER results showing the effect of application date on nitrate losses following applications of pig slurry to a) sandy (left hand plots) and b) clay (right hand plots) soils in arable cropping, for a range of annual rainfall.

**Figure 4.5** MANNER results showing the effect of application date on N loss following applications of dairy slurry to a) sandy (left hand plots) and b) clay (right hand plots) soils under grass, for a range of annual rainfall.

**Figure 4.6** Modelled results showing the effect of date of application on N loss following applications of old farmyard manure (FYM) to a) sandy (left hand plots) and b) clay (right hand plots) soils under grass, for a range of annual rainfall.
The median rainfall conditions within NVZs in England are in the range 600-700 mm, with higher values in the wetter west of the country. The legend indicates the typical percentage of total manure N applied which may be lost for different average annual rainfall bands and soils for pig slurry applied to arable land (Figure 4.4) and for applications to grassland of dairy slurry (Figure 4.5) and old cattle farmyard manure (Figure 4.6). Losses in August are comparable to those in September under arable situations and are less than losses in September under grassland situations.

These graphs show examples of the way nitrate loss due to manure applications is affected by date of application, soil type, rainfall and land use. Although manures and slurries are variable materials in terms of nitrogen and dry matter contents, these patterns of loss are consistent across manure types. The actual quantity of nitrate leached depends on the initial quantity at risk of leaching. This depends on the following main factors:

- manure type (slurries and poultry manures > straw-based FYM)
- volatilisation of ammonia, which reduces the quantity of nitrate produced (less if manures are incorporated promptly; and weather-dependent)
- crop N uptake before winter (greater in grass than most arable crops).

The interplay between these factors determines the quantity of nitrate at risk of leaching. The soil type and subsequent weather determine how much of this nitrate actually leaches.

The MANNER model results shown in Figures 4.4-4.6 reveal:

- greater leaching losses where pig/cattle slurries are applied in September compared with winter/spring applications;
- greater losses from sands than from clays;
- greater losses from arable land than from grassland;
- losses from manures applied to clays persist longer into the winter compared to losses from sands;
- reduced losses from farmyard manure compared to slurry.

Thus, the combination of model evaluations and evidence from field experiments confirm that all of these factors need to be taken into account when defining the proposed closed period measure.

### 2.5 Emissions of pollutants other than nitrate

In determining the length of the closed periods, there is a need to balance the risk of increased emissions of other pollutants against the need to reduce nitrate loss. The main pollutants of concern are (a) emissions of other nitrogen sources to the atmosphere (ammonia and nitrous oxide) and (b) losses of phosphorus and microbial pathogens to water.

#### 2.5.1 Effect of closed periods on ammonia volatilisation

Ammonia volatilisation is much greater if manure is left on the soil surface than if it is promptly incorporated (MAFF, 2000), as is common following autumn applications.

Also, ammonia losses are affected by temperature and are greater during summer than autumn to spring timings on grassland (Figure 4.7). These direct measurements of ammonia emissions are consistent with experimental data on crop response which have been built into standard fertiliser recommendation systems (MAFF, 2000), indicating reduced availability of nitrogen to the crop where manures are left on the surface, with summer top-dressings to grass being especially inefficiently used.
Prohibiting applications of manure during the autumn and winter is likely to lead to a greater amount being applied to grassland in summer, and being topdressed to arable crops, compared with applications incorporated into the soil in autumn. This is likely to increase ammonia emissions to air.

However, overall crop recovery of nitrogen is likely to be better than from autumn/winter applied slurry because the nitrogen is being applied during a period of rapid crop demand in spring/summer.

The limited amount of research that has been undertaken to date (largely on free draining soils) has indicated that moving slurry applications from late autumn/winter to spring will reduce nitrous oxide emissions by half.

### 2.5.2 Effect of closed periods on phosphorus loss to water

Manure-derived pollution of surface waters by phosphorus and microbial pathogens (also ammonium-N and organic matter) may occur due to surface-runoff and, in the case of drained clay soils, by crack flow to drains.

Phosphorus is lost to waters following manure applications chiefly through rapid flow pathways i.e. surface-runoff or rapid flow through cracks and field drains in clay soils. The greatest risk period for this is the winter when soils are wet and drains are flowing.

At the Brimstone Farm site in Oxfordshire, cattle slurry was applied for 3 years to a drained clay soil under arable and grass cropping. In each year, and on both land uses, phosphorus losses from the winter application were much greater than from applications in autumn or spring (Figure 4.8).
2.6 Practical constraints on the closed period

As heavy soils are prone to compaction, the best time to travel on them to spread manure is the autumn when they are dry. This is likely to lead to more nitrate leaching compared with later timings, as described earlier.

Other practical constraints which make applications in early spring difficult are that:

- Incorporation of manure is not possible to growing crops in the spring. Topdressed applications in the spring lead to greater odour and fly nuisance problems (associated with public health issues), and increased ammonia emissions.
- There are practical difficulties with applying manure in the spring to growing crops (e.g. running over crops) and grass (e.g. contamination of grass).

It may therefore be preferable, in some circumstances, to leave a window open for applications in early autumn.

Farmers may have to construct additional manure storage facilities to store manure during the closed periods. As it will take some time for farmers to construct these new facilities (section 3.2.2) the closed period will only apply two years after the Regulations come into force.

2.7 Summary

From the data outlined above and information included in accompanying documents, evidence indicates that under equivalent conditions:

- Leaching losses are generally greater from autumn compared to spring applications.
- Although nitrate leaching from sandy soils is greater than from clay soils, for autumn and winter applications, nitrate losses from clay soils do occur. Therefore the closed period has been extended to cover all soil types.
- Nitrate losses from applications in January onwards from sandy soils are very small for annual rainfall of 900 mm or less. In drier areas, losses are very small for applications in
December onwards. Therefore the closed period will end in either December or January (depending on rainfall band, soil type etc.).

- The balance of environmental risk favours permitting some manure application in autumn (e.g. September) on other soils, when it can be incorporated prior to crop establishment. This will reduce the pollution by surface-runoff from manures that would otherwise be applied in winter/spring. Phosphorus losses are likely to be less from autumn than from winter/spring applications (Figure 4.8). It will also prevent an increase in ammonia emissions that would otherwise occur due to an increase in summer top-dressing on grassland; and in top-dressing onto established crops in spring.

- The quantity of nitrate leached and the application date after which leaching risk is small, both increase with annual rainfall. Different patterns of loss are also observed between different soil types and between arable land and grassland. Therefore the length of the closed period will be determined according to rainfall bands, land use and soil type.

- Leaching due to slurries and poultry manures is much greater than that due to FYM, for the same quantity of total N applied. Therefore, the closed period will not apply to manures with a low availability of N.

- Crop uptake by autumn sown crops can mitigate nitrate leaching risk to some extent. Therefore an exemption from the closed period will permit manure applications before autumn-sown crops in some circumstances.

The proposed closed period definition is based on sound science and takes into account the legal requirements of the Nitrates Directive. Factors such as pollution swapping risk and practicality have also been considered.

3. Slurry storage requirement

3.1 Proposed Action Programme measure

Farms that produce livestock manures with high available N (>30%) must provide the following storage capacity requirements:

a) 26 weeks storage capacity for pig slurry and poultry manure
b) 22 weeks storage capacity for all other slurry

Farmers will be required to use a standard procedure to calculate the volume to which this 22/26 weeks equates. The calculation procedure will be broken down into the following steps:

a) Calculate the volume of excreta produced by animals on the farm over the 22/26 week period. Farmers will be required to use standard excreta volumes (see Annex A2 of the consultation document).

b) Calculate the volume of water collected and stored (if any) during the 22/26 week period.

c) The sum of these two amounts represents the (potential) required capacity of manure storage.

d) The following deductions from this potential capacity will be permitted to provide the actual volume of storage required:

   i. Volume of manure exported off the farm
   ii. Volume of solids separated from the slurry
   iii. Amount of poultry litter which is stored in an appropriately located, temporary field heap

3.2 Factors affecting the definition of this measure

The following factors were considered during its definition:

- Legal requirements
3.2.1 Legal requirements

Annex III of the Nitrates Directive specifies that adequate storage is required in excess of the longest closed period.

3.2.2 Practicability

Manure has to be stored if it cannot be applied to land (or disposed of in some other manner). As the new Action Programme will prevent applications of manures with high available N during the closed periods and at times when the risk of runoff is high (e.g. soils are waterlogged, frozen etc. which is often immediately preceding / following the closed period), it is likely that large volumes of manure may need to be stored for substantial periods of the year. Farms will therefore need to ensure that their manure storage facilities are of a sufficient capacity to cover these periods otherwise they could breach these rules. Additionally, farmers will be encouraged to shift applications of manure to the spring to increase the efficiency with which the nitrogen in the manure is taken up by the crop.

The length of time for which either the closed period or inappropriate soil conditions can persist (given climatic conditions in the UK), means that in a typical year farms may need to store manure for up to 22 or 26 weeks. It is important that farmers are able to store manure for a greater length of time than the closed period to ensure that they are not forced to spread immediately following the end of the closed period when soil conditions, ground cover and other factors are such that the risk of runoff is high which could lead to losses of nitrate and ammonium-N.

Pig and poultry units require 26 weeks storage compared to 22 weeks for cattle because there are more opportunities for spreading manures on grassland than arable crops (pig and poultry manures are associated mostly with arable cropping; cattle with grassland). And given the preponderance of winter crops (drilled in Autumn) may mean having storage October through to March – particularly on the heavier soils. Additionally, cattle are grazed for much of the year (meaning manure is not collected and handled) whereas pig and poultry units are usually housed (meaning all manure is collected and handled).

It will take time for farmers to construct any additional storage facilities required to comply with this requirement (e.g. obtaining planning permission, actual construction of store etc.). Therefore, farmers will be given two years to comply with this requirement providing they can demonstrate that they are actively taking steps to move towards compliance.

3.2.3 Clarity

A standard calculation procedure (supporting paper E1) and standard manure excreta volumes (Annex A2 of the consultation document) for calculating the manure storage requirement have been developed to ensure clarity and consistency. Supporting paper F2 provides the evidence underpinning the standard figures.

3.2.4 Flexibility

To ensure that farmers do not need to construct more storage than they require, a number of deductions are permitted during the calculation procedure. For example, a poultry unit that
regularly exports its manure to a power station can take this into account when calculating how much manure storage they require under the Action Programme.

The proposed deductions are in relation to issues that do not vary significantly over time in recognition that storage capacity is fixed and non-variable (i.e. many farmers have long standing export arrangements; slurry separation reduces volumes by similar levels over time).

4. Storage of solid manures

4.1 Proposed Action Programme measure

Poultry litter and solid manures with low readily available nitrogen content (<30%) must be stored in an appropriate manner as follows:

- In the livestock house
- At a suitable, temporary field site, or
- On concrete constructed to the appropriate standard.

The requirements for a suitable field site, for the temporary field storage of poultry litter and other solid livestock manures, include the following:

- Temporary field heaps will not be permitted within 50m of a spring, well or borehole or within 10m of a watercourse or land drain.
- Temporary field heaps must not be located in any single position for more than 12 successive months.
- There must be a 2 year gap before returning to the same field site.

4.2 Factors affecting the definition of this measure

The following factors were considered during its definition:

- Legal requirements
- Nitrate loss and other pollutants
- Consistency
- Practicability
- Flexibility

4.2.1 Legal requirements

Annexes II and III of the Nitrates Directive specify that storage, of adequate capacity and standard, be constructed for the storage of livestock manure and collection of effluent.

4.2.2 Nitrate loss and other pollutants

Limitations on the storage of low available N content manures in temporary field heaps is necessary to minimise the risk of loss of nitrate and other pollutants to water bodies, including ditches, rivers, and drains.

4.2.3 Consistency, practicability and flexibility

Providing options for storage of solid manure enables farmers to make use of their existing storage arrangements, where these are appropriate. This avoids unnecessary investment in new facilities.

The requirements for a ‘suitable field site’ are consistent with guidance contained within the Code of Good Agricultural Practice.
Permitting field heaps for 12 months of the year is in recognition of the fact that winter cropping on livestock/arable farms means the opportunities for spreading on those areas arise mainly in late summer. IPPC for larger pig/poultry farms also allows temporary storage for 12 months and therefore our proposed measure is consistent with this existing Regulation.

5. Closed periods for manufactured nitrogen fertiliser

5.1 Proposed Action Programme measure

The current Action Programme prohibits applications of manufactured fertiliser between specified dates, except where there is a crop demand. Minor changes to the existing rule are proposed as follows:

• Applications of fertiliser during the closed period will be permitted to listed crops and at a specified maximum rate (see Annex A1 of the consultation document)

• Applications during closed periods will also be permitted on the basis of written advice from a FACTS qualified adviser.

5.2 Factors affecting the definition of this measure

The evidence for the need for closed periods has been presented in Papers 2 and 3 in this series. The length of the closed periods for manufactured fertilisers has not been altered, but more guidance is given on what exemptions are permitted. The following factors were taken into account when defining the proposed measure:

• Legal
• Clarity
• Flexibility

5.2.1 Legal obligations

Annex III of the Nitrates Directive requires that measures must include rules relating to periods when the land application of certain types of manufactured fertiliser is prohibited.

5.2.2 Clarity

We have provided a clearer definition of the exemptions that are permitted. This includes details of crops (e.g. winter oilseed rape, early-sown fodder catch crops and over-wintered brassicas) for which there is a proven nitrogen requirement during the closed period (insert ref). Such applications may indeed reduce nitrate loss as described in supporting papers D2 and Paper D3.

5.2.3 Flexibility

We recognise that there may be occasions when application of nitrogen during the closed period may be justified and this will still be permitted when recommended in writing by a FACTS qualified adviser. This may be relevant for example where phosphate and potash applications are made in the autumn using liquid fertilisers as these always contain a small amount of nitrogen.
6. Whole farm manure nitrogen loading limit reduced to 170 kg N/ha

6.1 Proposed Action Programme measure

Loadings of livestock manure shall not exceed 170 kg/ha of total N each calendar year, averaged over the farm.

Compliance with the 170 kg N/ha limit must be calculated using a standard procedure as set out in guidance (Defra, 2007). In undertaking the calculation, it should be noted that standard values for manure N production must be used, except where alternative values are obtained using permitted methods.

For individual fields, there is still a requirement that spread applications of organic manure should not exceed 250 kg N/ha in any calendar year.

6.2 Factors affecting the definition of this measure

In defining this proposed measure, the following factors were taken into account:

- Legal obligations
- Nitrate loss
- Impacts on other pollutant losses
- Clarity
- Flexibility

6.2.1 Legal obligations

Annex III of the Nitrates Directive contains a specific provision requiring the inclusion of the 170 kg N/ha limit within the Action Programme. The Nitrates Directive permits member states to set a higher limit for applications of organic manures. Such derogations are temporary in nature (around four years) and are only permitted if it can be demonstrated that applying a higher limit will not undermine the achievement of the environmental objectives of the Directive.

6.2.2 Nitrogen loss

The rationale for this measure is that efficient use of nitrogen derived from livestock excreta or manure is more likely where these inputs are not too large. Within grassland systems, the nitrogen returns as excreta plus manure serves an index of the intensity of stocking. The more intensively stocked the system, the less efficiently the nitrogen is used, and the greater the nitrate leaching per unit area and per unit of production. The same applies for arable systems receiving manure from animal production systems. The whole farm manure nitrogen loading limit will ensure that the manure nitrogen supply does not exceed the crop nitrogen requirement, which would increase the risk of nitrate leaching.

Regular additions of manure will build up the organic nitrogen status of the soil. Some of this organic N will be mineralised (converted to nitrate) and, if mineralised in the autumn under conditions of small or zero crop uptake, will contribute to the nitrate leaching risk. Restricting the annual N loading will reduce this risk.

6.2.3 Impacts on losses of other pollutants

This measure will reduce the rate of build-up of the soil phosphorus status. Excessive levels of soil phosphorus can occur when repeated manure applications are made to land, and will
increase the risk of phosphorus losses to water. A reduced limit on N loadings at farm level has the potential to reduce the loss of ammonia and other pollutants associated with manure and slurry applications.

6.2.4 Clarity

Calculation of manure nitrogen production figures to ensure compliance with this measure can be complex and time consuming. To assist in the process and to improve clarity, we have introduced a requirement to use a standard calculation procedure (supporting paper E2) and standard values for manure N production (see Annex A2 of the consultation document).

The evidence supporting the standards has been presented in recent reports to Defra by Smith & Cottrill (2007) and Cottrill & Smith (2007) – see supporting paper F2. The new manure N production figures make allowances for N losses in livestock housing and storage.

6.2.5 Flexibility

We recognise that the standard values for manure nitrogen production may not be appropriate for all farming systems, especially where different dietary systems are used. Therefore, we are permitting farmers to calculate their own standards for manure N production using a bespoke software programme \(^1\) or by analysis of manures applied to land.

We are currently compiling evidence to investigate whether there is a case for establishing a higher limit (e.g. 250kg total nitrogen per hectare each calendar year averaged over the farm in relation to grazing systems on grassland farms).

A higher limit such as this will reduce the immediate economic pressure on grassland farms by enabling them to maintain current stock levels and make adjustments to the lower application rate of 170kgN/ha over a longer time period.

7. Limits on the quantity of manufactured fertiliser nitrogen

7.1 Proposed Action Programme measure

Farmers must balance, at the field level, the foreseeable nitrogen requirements of the crops with the nitrogen supply to the crops from all sources including the soil, mineralization of reserves of organic nitrogen in the soil, additions of organic manures, and additions of manufactured fertiliser and other fertilisers.

To this end, farmers must be able to demonstrate (via the use of field records) that they have undertaken the following mandatory steps when planning their nitrogen fertiliser applications:

- Assessed the soil nitrogen supply
- Assessed the nitrogen requirement of the crop (taking into account Soil Nitrogen Supply)
- Assessed the nitrogen supplied to the crop from applications of organic manures
- Calculated the need for manufactured fertiliser nitrogen by deducting the contribution from organic manures from the nitrogen requirement of the crop

Compliance with this measure will also be assessed by checking that the average nitrogen application rate (from both manure and fertiliser) made to a particular crop type across the whole farm is not greater than crop requirement. Farmers will be required to use a standard

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\(^1\) The Decision Support Tool “poocollator” is under development - Defra-funded project WQ0117
procedure to undertake this assessment (supporting paper E3). The calculation procedure can be summarised as:

\[
\text{Crop requirement (Nmax)} > \text{supply from manure (Total manure N x manure N efficiency)} + \text{supply from manufactured fertiliser}
\]

7.2 Factors affecting the definition of this measure

The following factors were considered when redefining the proposed measure:
- Legal obligations
- Nitrate loss
- Environmental factors
- Clarity
- Flexibility
- Consistency

7.2.1 Legal obligations

Annex III of the Nitrates Directive requires that limitation of the land application of fertilizers, be based on a balance between the foreseeable nitrogen requirements of the crops, and the nitrogen supply to the crops from the soil and from fertilization.

7.2.2 Nitrate loss

Application of nitrogen is highly effective in increasing the productivity of many crops. Cereal yields are commonly doubled through careful application of nitrogen, and crop quality (e.g. protein concentration) can be also be increased through application of nitrogen. However, application of nitrogen at a rate that is above the crop nitrogen requirement will increase the risk of causing nitrate pollution of waters. This is illustrated in Figure 4.9 and discussed in more detail in supporting papers D2 and D3 in this series.

![Figure 4.9 Example of the relationship between nitrogen fertiliser input and subsequent N loss to water, for arable crops](image)

Effective use of nitrogen has been the subject of much research over several decades. This research underpins the 7th edition of the ‘Fertiliser Recommendations for Agricultural and
Nitrates Consultation Supporting Paper D4: Rationale for the proposed revisions to the 2002 NVZ Action Programme measures

Horticultural Crops (RB209)’ (Defra 2000) book (hereafter called RB209) which contains the current national standard recommendations for the application of lime and major nutrients (including nitrogen) for all major field grown crops. It also contains standards for the nutrient content of a wide range of organic manures.

Nmax will be the maximum nitrogen application rate permitted for a particular crop. The farmer will have to use standard reference figures when calculating Nmax for the main arable crops and grass (see Annex A3 of the consultation document). It will prevent farmers applying nitrogen to crops in excess of the crop requirement and therefore reduce the risk of nitrogen loss.

Nmax is broadly based upon recommendations contained within RB209, and a paper describing national scientific evidence that supports the setting of Nmax standards for the major crop types was published alongside the Defra consultation (supporting paper F1).

It is very important to take account of the supply of nitrogen from applications of manure when calculating how much manufactured fertiliser to apply to a crop otherwise there is a risk that more nitrogen will be applied than can be used by the crop. This would increase the risk of nitrate losses.

The new closed period for organic manures will mean that timings of applications will generally shift from the autumn/winter to the spring or summer. These are times of the year when the nitrogen in the manure is taken up by the crop with greater efficiency. Additionally, a number of other measures (e.g. incorporation of manure on bare soil) will also increase the supply of nitrogen to the crop from manures. This increased supply of nutrients from manures must be taken into account otherwise there is a risk of oversupplying the crop with nitrogen.

To ensure this risk is addressed, the revised Action Programme will introduce a standard calculation procedure and standard figures for the assumed supply of nitrogen from manures (manure N efficiency) that must be used by farmers to demonstrate their compliance with the crop requirement limit (see Annex A4 of the consultation paper). The scientific evidence supporting the manure N efficiency targets is set out in a paper that was published alongside the Defra consultation document (supporting paper F3).

7.2.3 Environmental factors

The crop nitrogen requirement is influenced by the nature of the crop, the expected yield, any requirements of the target market for the crop produce (e.g. protein concentration, quality grade), and the economics of growing the crop. Typical crop outputs, and the nitrogen requirement needed to achieve these outputs, are also strongly influenced by the natural environment which includes the climate and soil type.

Lower nitrogen recommended rates according to variations of soil nitrogen supply and other factors, as contained within Defra’s fertiliser recommendations (RB209), are not dealt with by Nmax (which is merely an upper limit). The new AP therefore includes a rule which requires farmers to follow a number of mandatory steps when planning their nitrogen fertiliser applications to take account of these factors (essentially this is a Nutrient Management Plan).

7.2.4 Clarity

The current AP rules require that farmers do not apply nitrogen in excess of the crop nitrogen requirement, taking account of the soil nitrogen supply. Use of the RB209 recommendations is encouraged but other information sources may be used to justify nitrogen application rates.
to individual crops. It was therefore unclear how the ‘crop requirement limit’ would be
enforced against these different systems.

To address this lack of clarity, maximum nitrogen application rates (Nmax) will be set for the
main arable crops and grass. Nmax will represent the upper level that must not be
breached, and farmers would be expected to undertake field-level N planning and operate
within this limit.

The targets for manure N efficiency provide a clear indication that the change in manure
management, as a result of the new Action Programme measures, is expected to lead to a
greater supply of nitrogen from manure to the crop and that farmers must take this into
account when calculating how to meet crop demand.

7.2.5 Flexibility

The Nmax calculation will be done at the farm level. It should therefore provide the farmer
with sufficient flexibility to make adjustments in application rates in relation to individual fields
to take account of field-specific factors (e.g. soil type). Applications of nitrogen to an
individual field can exceed Nmax provided the average application rate to that crop type
across the farm is below the Nmax limit.

Nmax for some crops will have a ‘yield adjustment’ factor. This will enable farmers to apply
nitrogen at specified rates above the normal Nmax if they can achieve higher yields than
those assumed when deriving Nmax.

The targets for manure N efficiency have been set at a level that we would expect farmers to
be able to achieve through adjusting the timing and technique of manure applications. This
level of realism is important because if the new rules start to impinge on yields and quality of
crop (as a result of assuming a greater level of nitrogen supply from manures than can be
achieved), then there is a risk that arable farmers will become reluctant to continue importing
organic manures from livestock farms and other sources. This could lead to a number of
undesirable consequences such as excess manure on livestock farms, increased reliance
upon manufactured fertiliser on arable farms (with knock-on effects upon levels of organic
matter in the soil, increases in greenhouse gas emissions etc).

7.2.6 Consistency

This measure is in line with the Code of Good Agricultural Practice, and is in the interests of
the farmer as fertiliser inputs in excess of crop requirements waste money; and the surplus
nitrogen (N) not taken up by crops is at risk of loss to water.

Nutrient Management Plans are required by a number of Farm Assurance schemes and
other schemes such as Entry Level Stewardship (ELS). The requirement to plan nitrogen
applications described above are consistent with good farming practice as described in the
existing Code of Good Agricultural Practice and with other guidelines for preparing NMPs.

8. Measures controlling where nitrogen is applied

8.1 Proposed Action Programme measures

Manufactured fertiliser and organic manures must not be spread in locations which will cause
either nitrate-enriched surface run-off to enter, or nitrogen compounds to directly
contaminate, water courses.
To this end:

- All farmers must undertake a written risk assessment procedure (based upon the Defra “Manure Management Plan - Step by Step Guide for Farmers”) to demonstrate they have considered locations on their farm suitable for spreading organic manure.
- Applications of nitrogen fertiliser to land with a very steep slope (defined as land with an incline greater than 12 degrees (equivalent to 20% or 1 in 5) or more) will be prohibited where, taking into account factors such as proximity to watercourse, soil condition, ground cover and rainfall, there is a significant risk of causing water pollution via runoff.
- Applications of organic manure within 50m of a spring, well or borehole shall be prohibited.
- Applications of organic manure within 10m of a surface water shall be prohibited.
- Applications of manufactured fertiliser within 2m of a surface water shall be prohibited.

Farmers must also undertake a field inspection to consider the risk of runoff prior to spreading (taking account of the factors listed above).

8.2 Factors affecting the definition of these measures

The following factors were considered when redefining the proposed measure:

- Legal obligations
- Nitrate loss (and loss of other pollutants)
- Clarity
- Consistency
- Flexibility

8.2.1 Legal obligations

Annexes II and III of the Nitrates Directive require that measures must include rules:

- relating to the application of fertiliser near water courses
- limiting the land application of fertiliser consistent with good agricultural practice and taking into account soil conditions, soil type and slope.

8.2.2 Nitrate loss and other pollutants

The restrictions with respect to slope and ground conditions and proximity to surface waters are all designed to reduce the risk of direct runoff. Avoidance of runoff is important not only from an environmental viewpoint but is also of value to the farmer as it avoids loss of valuable nutrients (from manufactured fertiliser or manure). The risk of runoff is a function of slope angle together with other factors including ground cover and infiltration rate (which is influenced by soil type and soil conditions).

Most losses of manure-derived pollutants to water resulting from surface runoff are likely to occur immediately after manure application. Manures with a high liquid content pose a greater risk of nitrate loss through surface runoff than do solid manures. Liquid chemical fertilisers are also slightly more prone to higher nitrate losses in runoff than are solid fertilisers (e.g. prill), because the nitrate is already in soluble form.

The key to managing pollutant loss resulting from surface runoff is therefore to limit fertiliser and manure applications when climatic and ground conditions are poor and to encourage measures to improve ground conditions (e.g. maximise infiltration) or reduce surface runoff (e.g. using buffer strips) which therefore allow reasonable application rates of manure and fertiliser to be maintained.
8.2.3 Clarity

Providing a definition of steep slopes will help farmers identify any such slopes on their farm and undertake the risk assessment procedure.

8.2.4 Consistency

The proposed measures are consistent with the recommendations contained in Defra’s Codes of Practice for the protection of Air, Soil and Water.

The written risk assessment is based upon the existing Manure Management Plan. It is likely that many farmers have already completed a similar plan as this is a requirement of many Farm Assurance schemes and Environmental Stewardship.

8.2.5 Flexibility

By linking the limitation on applications of nitrogen fertilisers to slopes over 12 degrees to a field assessment of risk, this measure is flexible in accommodating a farmer’s judgement of prevailing ground conditions and associated likelihood of surface runoff.

9. Measures controlling how nitrogen is applied

9.1 Proposed Action Programme measures

Manufactured fertiliser and organic manures must not be spread in a manner which will cause either nitrate-enriched surface run-off to enter, or nitrogen compounds to directly contaminate, water courses.

To this end:
- The use of high trajectory, high pressure techniques for making applications of organic manures will be prohibited.
- Nitrogen fertiliser must be applied in as uniform and accurate manner as possible.
- Organic manures with low available N applied to bare soils or stubbles prior to crop planting or drilling must be incorporated within 24 hours on all steeply sloping land that is located within 50m of a watercourse which could receive run-off from that land.
- Organic manures with high available N applied to bare soils or stubbles by broadcast methods prior to crop planting or drilling, must be incorporated within 24 hours.

9.2 Factors affecting the definition of these measures

The following factors were considered when redefining the proposed measure:
- Legal obligations
- Nitrate loss (and loss of other pollutants)
- Consistency

9.2.1 Legal obligations

Annex II of the Nitrates Directive requires that measures must include rules relating to procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.
9.2.2 Nitrate loss and other pollutants

Uneven or inaccurate spreading of fertilisers and manures increases the risk of nitrate loss by about 6-12% compared with perfect spreading. This is equivalent to about 2-5 kg N/ha for cereals and more for other crops.

Measures relating to the evenness of spreading of fertilisers and manures are clearly good practice and in the farmers’ interest as they reduce waste of nutrients and promote even crop growth. These measures reinforce the current trend towards improved calibration of spreading machinery and accuracy of application of manures and fertilisers.

The prohibition concerning high trajectory high pressure techniques for spreading organic manures is also introduced to reduce losses of ammonia via volatilisation and the risk of accidental contamination of adjacent areas (such as water courses) through atomisation of the manure and subsequent drift.

Incorporating manure within 24 hours of applications will reduce ammonia emissions and the risk of manure derived pollutants (e.g. phosphorus, ammonium-N) via runoff.

9.2.3 Consistency

The proposed measures are consistent with the recommendations contained in Defra’s Code of Good Agricultural Practice.

Guidance will be provided in relation to spreading techniques that will help farmers achieve improved accuracy and uniformity of spreading patterns, and help achieve the manure N efficiency targets set under the new Action Programme.

10. Cover crops

10.1 Proposed Action Programme measure

Under the revised Action Programme, it is proposed that it will be a requirement to grow a cover crop on land which would otherwise be left bare over-winter in situations where the preceding crop is harvested before 1 September (i.e. not after late-harvested crops).

The definition of a ‘cover crop’, and the latest establishment date and earliest destruction date for cover crops, will be based on the evidence and practical experience gained from the earlier Nitrate Sensitive Areas scheme, which operated from 1990 until 2003 in a number of areas overlying vulnerable groundwaters (see earlier papers in this series).

10.2 Factors affecting the definition of this measure

The following factors were considered when redefining the proposed measure:

- Legal obligations
- Nitrate loss (and loss of other pollutants)
- Consistency, practicability and flexibility

10.2.1 Legal obligations

Annex II of the Nitrates Directive provides Member States with the option of including a measure regarding the maintenance of a minimum quantity of vegetation cover during (rainy) periods in their code of good agricultural practice and Action Programme. Article 5(5) of the Nitrates Directive also requires Member States to take such additional measures or
reinforced actions as they consider necessary if, at the outset or in the light of experience gained in implementing the action programmes, it becomes apparent that the existing AP measures will not be sufficient for achieving the environmental objectives of the Directive.

10.2.2 Nitrate loss and other pollutants

This measure is proposed to avoid situations where bare ground remains vulnerable to leaching over the winter months. A similar measure proved highly effective in the Nitrate Sensitive Areas (NSA) scheme, resulting in a potential reduction in nitrate leaching of around 50% (Lord et al., 1999). A cover crop is grown, typically between September and February, and is then destroyed (e.g. by incorporation, grazing, or spraying) prior to the establishment of a spring sown crop. The cover crop takes up the nitrate which would otherwise be lost by leaching over-winter, thereby conserving nitrogen otherwise lost from the farming system. The subsequent decomposition of the cover crop residues can release this nitrogen to the subsequent crop(s). However, cover crops are only suitable at the stage in a rotation after a crop which is not harvested late and before the planting of the next spring sown crop. In practice, this limits the use of cover crops in rotations to around one year in four.

10.2.3 Consistency, Practicability and Flexibility

Research emerging from the NSA scheme and elsewhere has demonstrated that cover crops are most effective in reducing nitrate leaching if they are established sufficiently early in the autumn to take up nitrate before it is leached below the root zone. For this reason, a flexible and pragmatic approach is needed which only requires the use of cover crops where they can be used effectively i.e. where good ground cover can be established early. Consequently, cover crops will not be required after late harvested crops (such as sugar beet).

In the consultation for the revised NVZ Action Programme, consideration will be given to the relationship between this measure and existing schemes, such as aspects of the Environmental Stewardship Scheme which require the retention of cereal stubble over winter months.

Guidance will be developed to provide advice on the establishment, management and destruction of cover crops to ensure they are effective at preventing nitrate losses and do not negatively impact other environmental objectives (e.g. habitats for birds).
11. Record keeping

11.1 Proposed additional measure

All records must be kept for a minimum of five years and include the following:

- the calculation of the whole farm N limit, which will need to be updated when circumstances change.
- the storage capacity calculation, which will need to be updated when circumstances change.
- the Nmax calculation for each crop type grown on the farm.
- the fields in which poultry litter and other solid manure is stored.
- a copy of the written field risk assessment.
- annual field records of the balance between crop requirement and supply of nitrogen from all sources. The field records must contain details of:
  - The type of any crop grown and the date the crop is sown
  - Results of the assessment of soil nitrogen supply
  - Results of the assessment of the nitrogen requirement of the crop
  - The quantity and type of any organic manure applied to the field, the date of application, and the estimated supply of nitrogen to the crop.
  - The quantity of any manufactured fertiliser applied to the field, the nitrogen content, and the date of application.

Farmers who import livestock manures onto the farm must keep details of:

- The type (animal origin and whether slurry or solid manure), quantity and their total nitrogen content.
- The name and address of the supplier.

Farmers who export livestock manures from the farm must keep records of:

- The type (animal origin and whether slurry or solid manure), quantity and their total nitrogen content.
- The name and address of the recipient
- Details of a contingency plan (e.g. land in reserve or available for spreading) in the event that an export agreement fails.

11.2 Factors affecting the definition of this measure

11.2.1 Legal obligations

Record keeping is necessary both to support farm management activities and to enable compliance monitoring under the scope of the Nitrates Directive and other agricultural and environmental legislation.

11.2.2 Consistency and Flexibility

Elements of these additional measures are consistent with the Integrated Pollution Prevention and Control Directive, and measures such as nutrient management plans developed under cross-compliance.
12. References


