Farm scale diffuse pollution audit.

4.2.5. Pit and tower silage.
4.2.6. Straw bedded stock courts.
4.2.7. Slurry based stock housing.
4.2.8. Gaseuos pollution issues.
4.2.9. Fertiliser storage and handling areas.
4.2.10. Tanks for diesel, liquid fertiliser etc.
4.2.11. Good practice.

4.3. Field survey.
4.3.1. Field gradients
4.3.2. Evidence of soil erosion.
4.3.3. Evidence of soil structural problems and low organic matter content.
4.3.4. Potential problems related to land drainage.
4.3.5. Poaching.
4.3.6. Farm tracks.
4.3.7. Field middens.
4.3.8. Grazing practices likely to result in pollution by faecal indicator organisms.
4.3.9. Other.
4.3.10. Tidiness.
4.3.11. Good practice.

4.4 Riparian survey.
4.4.1. Water margins.
4.4.2. Boggy areas.
4.4.3. Potential problems related to flooding.
4.4.4. Other.
4.4.5. Tidiness.
4.4.6. Point sources.
4.4.7. Water quality.
4.4.8. Good practice.

4.5. Habitat survey.
4.5.1. Areas of natural or semi-natural vegetation.
4.5.2. Opportunities for improving or creating habitat for target species.
4.5.3. Good practice.

5. Reporting.

5.1. An overall description of the farm and farming system.
5.2. Planning issues.
5.2.1. Farm waste management plan.
5.2.2. Nutrient budgets.
5.2.3. Soil analyses.
5.2.4. Phosphorus recommendation.
5.3. Steading issues.
5.4. Field issues.
5.4.1. Soil protection.
5.4.2. Atmospheric pollution.
5.4.3. Nutrient pollution issues.
5.4.4 Faecal indicator organism (FIO) pollution.

1. Introduction.

Diffuse pollution of the environment resulting from agricultural activities is increasingly being recognised as one of the more important sources of environmental pollution. A systematic methodology for identifying such risks and for implementing strategies to alleviate problems is urgently needed. For this reason, SEPA has commissioned the preparation of three linked documents, the first setting forth a methodology for diffuse pollution audits on farms, the second a methodology for selecting appropriate measures to address the problems identified in the audits and the third, a catalogue of possible measures.

The guidance included below is meant to help those charged with addressing agricultural diffuse pollution issues in practice. It will prove useful to catchment management planners in priority or problem catchments, to regulators such as Scottish Environment Protection Agency staff and to advisors and consultants to farmers as they try to comply with a support regime which will increasingly stress environmental protection in compliance with government policy.

It is meant to supplement and compliment existing advice such as the PEPFAA code, the 4 Point Plan and various farm accreditation schemes, not to replace them. The target is diffuse pollution from agriculture and its control by means of Best Management Practices.

This guidance is the first of a three part series on addressing agricultural diffuse pollution issues. It sets out a methodology for carrying out diffuse pollution audits on farms and includes standard audit forms to aid this process. The second part, "Siting and suitability of BMPs" sets out guidance on selection of suitable mitigation measures for problems identified in the audit. The third part, "Handbook of BMPs for the Reduction of Pollutants Emanating from Diffuse Sources into Surface Waters" contains descriptions of a wide range of possible Best Management Practices to address diffuse pollution issues organised in a way to facilitate selection.

With effect from 2005, the granting of the majority of payments under the reformed CAP have been linked to respect of environmental, food safety, animal welfare and plant health standards.

The reform of the Common Agricultural Policy (CAP) and the introduction of the concept of Land Management Contracts (LMC) in January 2005 signalled a major shift in the support of Scottish agriculture with environmental and sustainability issues increasing in profile. Under CAP reform, payments to farmers are decoupled from production. Essentially this means that instead of having to produce crops or livestock to obtain payment of subsidy, farmers receive direct support in the form of a Single Farm Payment (SFP). The LMC concept has three tiers:

Tier 1 – The Single Farm Payment Scheme – This replaces most of the support schemes in the main sectors (arable, beef and sheep) which were in existence pre-January 2005. The receipt of the SFP will however be conditional on farmers complying with certain conditions known as 'cross compliance'. There are two elements to cross compliance:

1. Statutory Management Requirements - SFP recipients must comply with a number of specified legal requirements, known as Statutory Management Requirements (SMRs). To date there are 15 SMRs contained within cross compliance and include legislation relating to conservation, pollution prevention, identification and registration of animals and disease control.

2. Good Agricultural and Environmental Condition – SFP recipients must keep their land in Good Agricultural and Environmental Condition (GAEC). These factors reflect good practice and include 18 specific measures relating to;
   - Soil erosion – protection of soils.
   - Soil organic matter – maintenance of soil organic matter levels.
   - Soil structure – maintenance of soil structure.
   - Minimum level of maintenance – ensures a minimum level of maintenance and avoids the deterioration of habitats.

These requirements are not expected to change significantly in future years, although a further 3 SMRs relating to animal welfare requirements will be introduced in 2007.

Tier 2 – The LMC Menu Scheme – This is an optional scheme and is open to all IACS registered land managers in Scotland. There are currently 17 options to choose from aimed at delivering widespread benefits leading to economic, social and environmental improvement. Some of the options are one-offs, others such as the agri-environment measures involve a 5 year commitment.

Tier 3 – Development for 2007 - Likely to be based around existing agri-environment/RSS measures.

As far as possible, this guidance seeks to be consistent with and facilitate the delivery of GAEC and cross compliance in Scotland. Addressing diffuse pollution issues is likely to be a feature of all tiers of any contracts post 2007.

To engage farmers fully, the emphasis should be on rewarding good practice, as well as penalising bad practice, through measures within CAP reform in combination with enforcement of domestic legislation. Issues such as diffuse pollution, habitat enhancement, sustainable use of soils and water resources and flood-risk alleviation will require to be actively supported if progress is to be made in delivering on environmental targets and European Directives, particularly the requirements of the Water Framework Directive, which will set the broad framework for the protection and enhancement of the water environment in the future.

1.1. Diffuse pollution.

As point sources of pollution have increasingly been addressed and controls introduced, the relative importance of diffuse sources has increased. SEPA currently estimates that of the waterbodies in Scotland deemed to be ‘at risk’, diffuse pollution is a primary and/or contributory factor in up to 40% of cases (www.sepa.org.uk/wfd-characterisation). Agriculture is considered to be the predominant diffuse pressure, although not invariably the most severe.

A widely accepted definition of diffuse pollution is as follows: (D’Arcy et al. 2000):

"Pollution arising from land-use activities (urban and rural) that are dispersed across a catchment or subcatchment, and do not arise as a process industrial effluent, municipal sewage effluent, deep mine or farm effluent discharge."

Diffuse pollution therefore comprises true non-point source pollution together with inputs from a multiplicity of minor point sources. Examples of strictly non-point sources are comparatively limited, for example nitrates seeping into groundwater. Most water driven soil erosion results in contamination at a specific point via a rill or gully formed as water traverses fields to a watercourse. Point or non-point is really a matter of scale; a field of improved grassland in an upland rough grazing catchment is a nitrate point source for the underlying aquifer, just as each field drain is a point source for understanding inputs to a ditch or small stream. *Diffuse* is the key idea, rather than *non-point*. In loading terms most diffuse pollution enters watercourses via pipes, channels, gullies and rills, even atmospheric deposition, since it has to be washed from the land surfaces. The important characteristics of diffuse pollution therefore are NOT whether anyone can find the source/s, or whether a pipe is involved.

A useful way of thinking of diffuse pollution is that it is the often individually minor but collectively significant sources in a catchment. That is the key to the control options too; measures need to be focused on the land based activities, rather than on the point of discharge (see Campbell et al. 2004).

Diffuse pollution is a useful concept because it allows for estimation of important loads of pollutants in water bodies that are not from major industrial process and municipal effluent discharges (that are typically well characterized, monitored and quantified). The concept is also useful because it explains features of pollution in receiving water bodies, for example why concentrations of some pollutants actually increase with flow rather than are diluted, why pollution peaks are variable and difficult to predict, and why impacts are often slow to develop and become evident years later (e.g. contamination of groundwater, changes in trophic status of lochs).

1.2. Best Management Practices (BMPs)

Diffuse pollution sources are frequently individually relatively minor in nature. It is the combination of large numbers of such sources across a catchment that can cause problems. Because each source may be small, they can easily be overlooked. For this reason, an audit approach must be adopted to determine whence diffuse pollution problems arise. Because the problem is generally caused by the accumulative effect of a large number of sources across a catchment, a catchment wide approach is needed to address diffuse pollution issues. The methods being promoted here are referred to as “Best management Practices” or BMPs. They are applied at an individual farm or field level to address diffuse pollution issues which cumulatively give rise to problems at a catchment level.

The following definition of Best Management Practices was published in Novotny and Olem (1994):

“Best Management Practices (BMPs) are methods, measures, or practices selected by

an agency to meet its nonpoint (diffuse) source controls needs. BMPs include, but are not limited to, structural and nonstructural controls and operations and maintenance procedures. BMP can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants from diffuse sources into receiving waters."
The third part of this series, "Handbook of BMPs for the Reduction of Pollutants Emanating from Diffuse Sources into Surface Waters" describes a series of Best Management Practices to address a wide range of agricultural diffuse pollution issues.

Diffuse pollution problems may arise at various points in a farming system. BMPs have therefore been devised to address problems at a number of points. These include:

- Planning measures
- Steading measures
- In field measures
- Riparian measures

A treatment train approach is frequently adopted whereby any given diffuse pollution issue is addressed by a series of BMPs acting at different points in the pollution process. For example, a soil erosion problems might be addressed at the planning stage by adopting crop rotations less susceptible to erosion, at the field stage by adopting conservation tillage techniques and at the riparian stage by leaving buffer strips between fields and water courses.

Not all BMPs are free from risks. Some, while addressing one problem may exacerbate another. For example, while injecting slurry into soil may reduce losses of ammonia to the atmosphere it may also increase the risk of nitrogen leaching, particularly if the land has underdrainage. Care should be taken to avoid such "pollution swapping" problems as far as possible.

1.3. Pollutants.

Diffuse pollution of water by agricultural activity usually involves one or more of the following pollutants:

- the plant nutrients nitrogen or phosphorus,
- pesticides,
- suspended solids, which are a pollutant in their own right but may also carry nutrients or pesticides,
- Faecal indicator organisms.
- oils and hydrocarbons

Further information is available in D'Arcy et al. (2000).

Diffuse pollution of air by agricultural activities usually involves one or more of the following pollutants:

- ammonia,
- greenhouse gases such as methane, oxides of nitrogen and carbon dioxide,
- odour problems,
- smoke.

Further information is available in the report of NEGTAP (2000).

Diffuse pollution of soil by agricultural activities will usually involve the inadvertent additions of undesirable chemicals in the process of other agricultural activities. These may include the following:

- heavy metals,
- pesticides,
- nutrients in certain circumstances.

In addition, soil quality can be impacted by management practices leading to erosion and compaction which can themselves then lead to water quality impacts.

Further information is available in SEPA (2001).

1.4. Source to pathway to receptor.

Diagram.

A useful way of considering diffuse pollution issues is to consider a three stage process. Without each stage being present, diffuse pollution does not occur. A treatment train approach to BMP implementation may address the problem at each stage in the process.

The three stages are as follows. Firstly there must be a **source** of the pollutant. This might be excess nitrogen in soil or the nutrients in slurry spread on the soil surface. A source in itself does not constitute pollution however.

Secondly, there must be a **pathway**. Excess nitrogen in agricultural soil is not a pollutant although it may be one in the soil of adjacent natural or semi-natural habitats. It only becomes a pollutant if there is a mechanism or pathway, determined by landscape characteristics such as slope, soil type and vegetation, for the excess nutrient to move from the soil, where it may be a desirable component of soil fertility, to a receptor. The pathway might be leaching of nitrates to a groundwater receptor, transfer of nitrates in drain flow to a surface water receptor or denitrification and transfer of oxides of nitrogen to the atmosphere acting as a receptor.

Thirdly, there must be a **receptor**. This is some region of the environment where the substance being considered has undesirable consequences and is a pollutant. Phosphorus in agricultural soil is not usually a pollutant. It is an essential plant nutrient and a component of soil fertility. Phosphorus in loch water may be a pollutant as it may cause eutrophication. Phosphorus in the soil in an area of land containing interesting assemblages of wild plants may also be a pollutant as it may tend to reduce the biodiversity of the habitat.

Diffuse pollution therefore consists of the transfer of substances from a source via a pathway to a receptor where that substance has undesirable consequences.

1.5. Critical areas.

On some farms, most of the transfer of certain pollutants arises from a relatively small proportion of the total farm area.

For example, soil erosion can transfer silt and adsorbed nutrients and pesticides from land to water. On farms where in field soil erosion occurs, it is typically present only in limited areas, usually moderate or steep slopes with susceptible soils which are in arable cropping. Control measures may be targeted at such areas leaving the rest of the farm unaffected.

Certain even more limited areas are sometimes termed “hot spots”. These may include such areas as stock feed rings, areas where stock habitually shelter and areas where sprayers are filled. The pollution arising from such hot spots may be out of proportion to their small area.

1.6. Small water courses.

When assessing diffuse pollution risks to surface water, there is a tendency to concentrate effort on the water body at risk. This may be a mistake. Any water course, however small, which is tributary to the main water body, is a potential risk area. If mobile pollutants get into even the smallest drainage ditch or drainage pipe they will rapidly be transferred to the main water body.

2. Assessment of catchment characteristics.

Before undertaking any field work, an assessment should be made of the catchment containing the farms in question. Certain catchments will be more sensitive to certain pollutants and it is important that an appreciation of such sensitivity be built into the subsequent field work. Some catchments will be more prone to certain types of diffuse pollution and this too should be bourn in mind when surveying. In other cases there are specific features such as Sites of Special Scientific Interest within the catchment which require to be taken into account.

2.1. Examples of catchment sensitivity.

Usually it is the nature of the receiving water body which will make a catchment particularly sensitive to a particular pollutant. Examples of specific sensitivities are given below but there will doubtless be others. None of what follows implies that such problems necessarily occur, just that they are more likely to occur and should be watched for. Information on the status of water is available at www.sepa.org.uk/wfd-characterisation.

Phosphorus sensitivity. Catchments containing lochs, particularly oligotrophic and to a lesser extent, mesotrophic lochs (of low and moderate nutrient status) are likely to be phosphorus sensitive. This is particularly the case if the lochs have a low flushing rate or are shallow. In such catchments, low rates of phosphorus pollution, are likely to cause eutrophication of the loch water.

Nitrogen sensitivity. Areas designated as Nitrate Vulnerable Zones are by definition, nitrogen sensitive (Scottish Executive 2003). This is particularly so in the case of catchments of public water supply including boreholes. Areas underlain by unconfined aquifers are also to be regarded as particularly sensitive.

Pesticide sensitivity. Land drained by small watercourses, where most of the catchment lies within agricultural land, tend to be most severely impacted by pesticide pollution.

Sensitivity to suspended solids. Salmon, trout and certain other fish require clean gravel with flowing water to spawn successfully. Such gravel beds can become choked with silt from agricultural or forestry runoff seriously damaging the fish. Such waters with significant spawning beds for salmonids and other fish are likely to be particularly sensitive to pollution by suspended solids.

Sensitivity to faecal indicator organisms. Areas with significant concentrations of livestock draining to designated bathing waters, or other water where people are likely to use in recreation are particularly sensitive to FIO pollution (SEPA 2003; Aitken *et al*. 2001).

2.2. Examples of catchment susceptibility.

Certain catchments may be susceptible to certain types of diffuse pollution. Depending on the nature of the pollutant, factors such as topography, soil type, land use etc may all be significant. Examples of catchments prone to certain types of diffuse pollution are given below. Again, there are likely to be others.

Susceptibility to soil erosion. Areas with predominantly arable farming including little rotational grassland, with top soils of a fine sandy loam texture, particularly if the parent material is Old Red Sandstone, and with steep (greater than 7 degrees) gradients are likely to be particularly susceptible to soil erosion. This does not mean erosion will not occur on other catchments . (Horne et al. 1999)

Susceptibility to nutrient input excesses. Areas with significant numbers of farms with livestock enterprises where large amounts of feed are brought in are likely to result in large phosphorus excesses. Dairy farming areas and areas with large poultry and pig enterprises are likely examples.

Susceptibility to runoff causing pollution by faecal indicator organisms. This is most likely where significant quantities of slurry must be spread, usually dairy farming areas.

Susceptibility to pesticide pollution. This is most likely to occur in areas with a high proportion of arable farms growing field vegetables.

Susceptibility to sheep dip. This is a potential problem in sheep farming areas.

2.3. Examples of special features within catchments.

Particular features or designations within a catchment which may be damaged by pollution may require to be considered. Examples which are likely to have an influence on diffuse pollution audits are given below.

Sites of special scientific interest. Not all SSSIs have any relevance to diffuse pollution audits. Some do however, for example, the presence of a moss or wetland might make the area particularly sensitive to nutrient pollution.

Special Protection Areas including “Ramsar” sites. The audit must specially take into account any potential pollutant likely to damage the site.

Special Areas of Conservation. The audit must specially take into account any potential pollutant likely to damage the site.

Nitrate Vulnerable Zones (NVZs). Action Programme measures to minimise nitrate loss to watercourses must be adhered to in NVZs and forms for recording details of livestock, crops, N fertilisers and organic manures are provided in SEERAD (2003). Completion of these forms will be an essential part of diffuse pollution audits in NVZs. Information on the location of NVZs is available on www.scotland.gov.uk/library4/ERADEN/WEU/00016675.aspx

2.4. Catchment wide approach.

Due to the individually minor but collectively significant nature of diffuse pollution, in order to have an impact on water quality, measures to address pollution should ideally be undertaken on a catchment wide basis. There is little point in address all the problems on one farm when the same problems remain unaddressed on the neighbouring farms. It will almost always be more effective to target the main problems on all of the farms within a catchment rather than all the problems on a proportion of the farms.

3. Farmer interviews.

Usually diffuse pollution audits will be carried out with a group of farmers in a particular catchment for a particular purpose. Working with individual farmers in isolation is rarely likely to be an effective approach. Arranging interviews should follow a set pattern of initial contact with the group, either individually or together followed by the setting up of a series of individual interviews.

3.1. Initial contact.

The nature of the initial contact is vital if cooperation is to be achieved. Depending on the type of audit being carried out, the initial contact might be by group meeting or by letter followed very shortly by a telephone call. It is important that the initial agreement to cooperate is followed up quickly, if not by the interview and audit itself then by a phone call fixing a definite date in the future for the interview. Initial contacts left "hanging" for long periods do not inspire cooperation.

The farmer must be made aware of the purpose of the audit, of its scope and of his part in it. If the local reasons for the audit are explained and the farmer realises that all the farmers in the catchment are being targeted to address the local problem, cooperation is more likely. It is important that the farmer understands why he has been chosen and that diffuse pollution is a feature of all farms, not just his. He must not feel unfairly singled out.

The farmer should be made aware at this stage that there are many ways to address any problems found and that his input to find an approach suited to his farming system will be sought and his views may form a significant part of any action programme. He should know he is involved fully in the process and that solutions will not be imposed on him from above.

He should also be made aware of efforts being made in other sectors (e.g. sewage treatment) to address the perceived problem.

3.2. Preparation for the interview.

When setting a date for the interview, it must be remembered that the work load on farmers over the year is very variable. Attempting to see a sheep farmer at lambing or a cereal farmer at harvest is not the way to achieve cooperation.

The interview is likely to take somewhere between one to three hours depending on the size and complexity of the farm and on how prepared the farmer is in advance.

When the date for the interview is set, the farmer should be told the nature of the questions he will be asked so he can gather the necessary information in advance. The questions are set out in detail below but include crop rotations, fertiliser use, crop yields, crop sales, stocking rates, animal feed, sales of stock, manure handling and spreading and soil and manure analyses if available. Any helpful sources of data such as NVZ Fertiliser and Manure Plans, Farm Waste Management Plans etc. should be made available. It is very useful if the farmer can supply a farm map showing fields with areas etc in advance. Having copies of this available for taking notes at the interview speeds the process.

The requirements of the Scottish Executive Biosecurity Code of Practice should be adhered to. These can be found on www.scotland.gov.uk/library5/agri/crwl-05.asp.

3.3. The interview.

The aim of the interview is to gain an overall impression of the farming system and to collect sufficient data as inputs to the audit. Appendix 1 contains a checklist of the areas to be covered and these will be examined in greater detail here.

3.3.1. Units. Ascertain immediately what units are being used. Most farmers prefer acres, units of fertiliser, but may quote yields in litres or tonnes. Be sure that the units are known and check any time there is doubt. Accept whatever the farmer is happy with and convert to metric units later. Conversions are included in Appendix 2.

3.3.2. Land areas. Find out the area of the farm and the area of different land use types within the farm. Possible categories appear on the audit forms but these will vary according to farm type. The various land uses are set out in a hierarchical structure. Record as much as possible. The data recorded here are very useful for checking figures supplied later.

Mark on a farm map the land use in the individual fields according to the same hierarchical structure. Also note the areas of each field taken preferably from the IACS map. Again, these data can be used to check figures supplied later.

3.3.3. Stock. Record numbers of stock of various types and ages. Table D in SEERAD (2003) is essential for farms within NVZs and provides a record of stock numbers and the total organic N that is excreted on the farm. Possible categories are as follows but these will vary according to farm type. Again record as much information as possible; it will be needed to calculate manure production and nutrient balances later. Realise that stock numbers vary throughout the year and an overall understanding of the system is what is aimed at. The names given to different ages of stock are remarkably regional throughout Scotland. Be sure you understand what is being described.

Numbers. Record numbers of stock kept and movements of stock onto and off farm. Include cast cows and ewes as movements.

Bought in feed. Record both type and weight of animal feed brought into the farm. Record weight of straw brought in as feed or bedding.
Record what home produced feed is used, including hay, silage, grain, brock potatoes etc.

Housing. Record detail of stock housing, including period of housing, numbers of stock housed, nature of housing (straw bedded courts, slats etc.).

Outwintering. Record the fields in which any stock are outwintered. Record fields where forage crops are grazed off in field.

Manure, slurry and other bulky organic additions. Record detail of manure handling and usage. Include timing of mucking out housing, position of middens and time manure remains in middens.

Record detail of slurry handling and storage systems including size of slurry store, separation of clean and dirty water and volumes and nature of other waste water going to slurry store.

Record detail of the use of manure from middens and slurry from stores including where spread, how spread, which crop, rate (often not known but can be calculated if manure production known), when spread, when incorporated and what changes in chemical fertiliser inputs are made as a consequence.

Record detail of any manure or slurry that leaves the farm.

Record detail of any organic manure (farm yard manure, slurry, sewage sludge, mushroom compost, municipal compost, any other bulky organic manure) which is imported onto the farm.

3.3.4. Crops. Record the different crops grown, including grass. Record the areas, the typical crop yields, the fate of crop residues such as straw (baled and removed, chopped and incorporated, burnt), fertiliser usage and animal manure inputs (where applied, what applied, what rate of application, when applied, whether incorporated immediately).

In grass, find out areas cut for silage and hay and find out how many silage cuts are taken. Try to find out yields of hay and silage, possibly in terms of numbers of bales or size of pit if yields are not known. Find out how silage is made (pit, tower, bales), positions of pits, towers or bales stores, proximity to water including drains and the effluent collection and disposal system.

Also record on map, fields where different crops or crop rotations are grown. If specific crop rotations are grown, find out what they are and which fields they are grown in. Examples of typical rotations are given below.

Rotation 1	**Rotation 2**
Grass	Winter wheat
Grass, silage, dunged	Winter wheat
Grass, silage	Winter barley
Grass	Spring barley
Winter wheat	Potatoes, dunged
Winter wheat	Set aside
Spring barley	

Note that fertiliser use is often different on, for example, second wheat compared with the first wheat crop out of grass. These differences should be recorded. Record also the use made of grass (grazing, hay, silage) and the associated fertiliser usage. Table H used on NVZ farms will provide records of fertiliser and organic use on each field, along with crops and sowing dates.

Record what crop is sold off the farm and what is retained on farm as, for example, animal feed. Record what is done with baled straw.

3.3.5. Soil and manure analyses. Find out what soil analyses are available. If none are available, it will be necessary to sample representative fields.

Find out if manure analyses are available. They very rarely are. If they are not, standard "typical" figures are available in the literature (Dyson 1992; Sinclair 2002).

3.3.6. Pesticide use. Record the usage of pesticides including herbicides, insecticides and fungicides.

- Record on a crop by crop basis usage on crops and record insecticide usage on stock. Record rates of application, whether reduced rates are used and what monitoring of pests is carried out to ascertain the need.

- Record the type of sprayer used, its LERAP's star rating and how and when it is calibrated. Find out if LERAP's reductions in buffer widths are used.

- Find out where the sprayer is filled, what provision there is for spillage and runoff, and the fate of pesticide residues and tank washings.

- Find out where the farmer gets his pesticide advice.

- Find out what spraying is done by outside contractors.

- Record whether the farmer has prepared and implemented a "Crop Protection Management Plan" (CPMP). Such plans are currently being promoted under the Pesticides "Voluntary Initiative", and aim to address a farm's crop protection policy, describe water quality protection measures taken, indicate a commitment to improve competency and consider how the direct and indirect impacts of plant protection products on non-target species could be minimised.

- Other Voluntary Initiative outputs should also be referred to in this section, particularly the National Register of Sprayer Operators (NRoSO) and the National Sprayer Testing Scheme (NSTS).

3.3.7. Sheep dipping. Ensure compliance with the Groundwater Regulations, 1998.

- Record whether sheep are dipped or what other alternatives are employed (pour ons, sheep showers).

- Record what chemical is used.

- Record the position of the dipper and the sheep draining area.

- Record where and how spent dip is disposed of.
- Determine if dipping contractors are used.

3.3.8. Cultivations. Record typical dates of ploughing (or other primary cultivations) for the crops grown. Find out the timing and methods of seedbed preparation. Find out typical sowing dates for each crop.

Find out when and how the ground left after potato harvesting, field vegetable harvesting and forage crop grazing is cultivated.

3.3.9. Drainage. Find out which land is likely to have field drains. It can safely be assumed that almost all improved farmland mapped as imperfectly, poorly or very poorly drained by the Soil Survey of Scotland (Soil Survey of Scotland Soil Maps, Macaulay Land Use Research Institute, Aberdeen) will have at least some underdrainage. Find out which fields may have more recent gravel backfilled drains. However, information on drainage frequently will not be available.

Find out which fields are flooded by adjacent rivers on occasion.

Find out if the farm has large "cundies" (large drainage channels built from stone slabs) and what their condition is.

3.3.10. Soil erosion. Soil erosion is a factor to be considered in applying the GAEC regulations (Scottish Executive 2004). Additional advice is available in the Scottish Soil Protection Plan (forthcoming).

Find out where the farmer has previously seen evidence of soil erosion by water. Awareness of erosion is frequently poor however. A photograph of low rate soil erosion can prompt answers. Do not assume that if erosion is not reported, it does not occur.

Find out which areas of the farm are liable to flooding. Find out the frequency and severity of such flooding. Try to find out the manner in which water enters the field. If water levels simply rise as the river or ditch rises and water does not flow across the land, erosion risks are reduced. If rivers or ditches rise and flood land with the water flowing over the land surface, erosion risks in arable cropping are very high.

Find out if wind erosion (blowing) is a problem. This is only likely in Scotland on very light land, particularly in coastal locations. The areas where it occurs are generally well known (small areas in East Lothian, small areas in the East Neuk of Fife, parts of the Howe of Fife, areas between Elgin and the sea, any area of machair in arable cultivation.)

3.3.11. Soil structural problems. Soil structural problems are a factor to be considered in applying the GAEC regulations (Scottish Executive 2004). Additional advice is available in the Farm Soils Plan (Scottish Executive 2005).

Ask whether soil structure is a problem. Again, awareness of structural problems is not good. In light soils, ask if capping of seedbeds occurs or if soil structure slumps rapidly. In heavy soils, ask if soil goes rapidly from being too wet to cultivate to being too hard and cloddy to cultivate. Find out if soil organic matter levels have been measured. If so, any value for organic matter (not organic carbon) below 2% will almost certainly indicate problems, between 2 and 4% is marginal and over 4% should be adequate.

Whatever the reply, look for soil structural problems in the field. See section 4.2.5 for description of how to do this.

3.3.12. Irrigation abstraction. Ask if the farmer irrigates crops. If so, find out what crops, what areas, where the water comes from, what storage reservoirs exist and what method, if any, of scheduling is used.

3.3.13. Other. Ask the farmer if any other issues which might give rise to diffuse pollution spring to mind.

3.3.14. Codes of practice and environmental legislation. Assess the farmer's awareness of and compliance with various codes of practice including PEPFAA code, 4 Point Plan and Scottish Soil Protection Plan (forthcoming). Find out what farm assurance schemes the farmer participates in.

Compliance with the various relevant environmental legislation (Groundwater regulations, Sludge (Use in agriculture) regulations, NVZ regulations) does not strictly fall into the remit of the audit but any breaches noted should be recorded.

3.3.15. Water courses. Ask the farmer to mark on the map any water courses, including ditches however small. This saves time in the field and avoids missing anything although, as always, the information should be checked.

Also ask the farmer where any wells or other water supplies are.

3.3.16. Further action. Explain to the farmer at this point what will happen next, (farm and steading audit, reporting to farmer and discussion of findings, further action to implement any recommendations). It is important to involve him as he will ultimately need to carry out any recommendations if the project is to have any value.

4. Steading and field survey.

4.1. Preparation.

It is useful if the farmer explains details of the steading such as slurry storage and handling systems, the use of buildings and the position of drains etc prior to the survey. This is best done actually on site rather than in an office.

However, try to avoid being accompanied by the farmer on the survey itself. He already knows his farm and you may feel hurried by his presence. Typically surveying a 200 hectare farm properly will take most of a day. Few farmers have that time to spare.

Do not attempt surveys in adverse weather conditions. Few will do a good job in freezing rain, although visits after heavy rain may reveal problems areas.

Appendix 3 contains a list of necessary equipment for a survey.

It is useful to mark soil boundaries from the Soil Survey of Scotland soil map on a farm map in advance but be aware that soil maps are not necessarily accurate on a farm scale. Indicative soil texture maps are now available from the MLURI for some NVZs.

It is useful to mark all the water courses indicated by the farmer onto a map in advance. **4.2. Steading survey.**

The steading survey involves a close inspection of the farm steading. Normally a sketch plan of the steading should be made, drawn to approximate scale. This should mark the main features of the steading including and drain inlets and open water courses. It will be helpful if the farmer initially explains detail of the steading. The following points should be especially noted.

4.2.1. Separation of clean and dirty water. As far as possible, clean runoff water, such as water from roofs, should be kept separate from runoff from potentially dirty surfaces. Where possible, dirty runoff water should be minimised, by for example roofing feed passages to which housed stock have access. The clean water may be led to drains or water courses while all slurry should be led to the slurry store in compliance with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 2003.

Subsequent runoff from the steading may be taken to a farm wetland system (see below).

For more information, see PEPFAA code and 4 Point Plan (SEERAD *et al*. 2002).

4.2.2. Farm wetland. Decisions must be made about routing of potentially dirty water. Heavily contaminated water must be led to the slurry store or a similar tank from whence it can be spread to land in compliance with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 2003. However, most steadings have surfaces only lightly or occasionally contaminated. If all the rainwater runoff from such surfaces is led to the slurry store, the result will be large volumes of dilute slurry to be spread which in itself may present a greater pollution threat. It may be feasible to install a wetland treatment system to deal with the lightly contaminated water. A possible design is shown in “Siting and suitability of BMPs” . Whether such a system is required needs careful consideration and consultation with the local SEPA office is advisable. Whatever is done must comply with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) Regulations 2003.

The proximity of the steading to surface water or to drains leading to surface water is an important consideration. If the steading is remote from surface water and runoff simply infiltrates into surrounding land, no system should be installed which provides a direct link to water, even if the runoff is treated en route.

Some stock farms which house cattle in straw based courts and where cattle movements to and from the courts occur only twice each year do not usually present sufficient risk to merit any system.

However, on many farms where stock movements are more frequent and on arable farms with large concrete areas with frequent movements of tractors and other machinery and the potential for spillages of fertiliser and other chemicals, farm wetlands are often desirable.

The same system might also be beneficially used to treat septic tank effluent from the farmhouse at little or no extra cost. Again consultation with the local SEPA office is necessary (SEPA Guidance Note 4).

4.2.3. Sprayer filling area. The area used to fill farm sprayers should be inspected. Frequently this will be a concrete area with a drain directly to a watercourse. The PEPFAA code makes recommendations concerning suitable areas. Consideration should be given to constructing some type of Biobed. These are specially constructed areas where sprayers may be filled and where any spillage will be adsorbed and degraded by an organic matter rich substrate. Further information and design guidelines are available at www.voluntaryinitiative.org.uk.

4.2.4. Baled silage storage. Baled silage can produce significant volumes of effluent, especially in wet silage seasons. The PEPFAA Code requires that baled silage be stored at least 10 metres from any watercourse. For the purposes of the survey, a drain inlet must also be considered to be a “watercourse”, as ingress of silage effluent to the drain will pollute the outfall from the drain.

However, in some circumstances 10 metres is insufficient to prevent silage effluent entering the watercourse. If the intervening ground is relatively steep and impermeable then a wider safety margin may be necessary.

4.2.5. Pit and tower silage. While not really within the scope of a diffuse pollution audit, the adequacy of pit and tower silage making facilities should be inspected. Particular attention should be paid to the collection and disposal of silage effluent. Guidance is available in the PEPFAA code and in the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) regulations 2003.

4.2.6. Covered straw bedded stock courts. These do not usually present much of a risk, provide adequate quantities of straw are used. They should be checked however to ensure that all areas to which stock have access are covered and to ensure that liquid effluent is not leaking from the court.

4.2.7. Slurry based stock housing. The adequacy of the slurry collection and storage system should be determined. In particular, the volume of slurry storage available must be determined. An estimate must also be made of the area of unroofed hardstanding or other surfaces open to rainfall draining to the slurry store and notes made of any other effluent, such as silage effluent, being led to the slurry store. These data will be needed for the farm waste management plan. Guidance is available in the PEPFAA code and in the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) regulations 2003.

4.2.8. Gaseuos pollution issues. Potential atmospheric pollution may also be a steading issue. Reduction in ammonia emissions in animal housing is largely a matter of good housekeeping, that is, keeping surfaces as clean as possible and keeping slurry scrapers in good condition. Even with the best housekeeping, the scope for emission reduction is not great. Limited further advice is available in the PEPFAA code.

4.2.9. Fertiliser storage and handling areas. Areas used for storing and handling fertiliser should be inspected and if they are open to rainfall, the fate of any spilled product should be considered. It should not be washed into a drain or watercourse. Guidance is available in the PEPFAA code and compliance must be ensured with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) regulations 2003.

4.2.10. Tanks for diesel, liquid fertiliser etc. These do not fall within the scope of a diffuse pollution audit but the opportunity should be taken to ensure that any tanks are well situated and properly bunded. Guidance is available in the PEPFAA code and compliance must be ensured with the Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) (Scotland) regulations 2003.

4.2.11. Good practice. Note areas of good practice observed in the course of the survey. These may include good housekeeping, good slurry management etc. It is important that these be included in the report to avoid being seen to be constantly negative.

4.3. Field survey.

The field survey involves walking the entire farm.

The following potential pollution issues are being examined.

4.3.1. Field gradients. Gradients should be measured in fields using an optical clinometer if available. Record information concerning slope steepness, slope direction, slope uniformity and whether the topography will tend to cause runoff water to be concentrated in hollows. Pay particular attention to water margins and note whether the slope flattens before the margin, steepens before the margin or remains uniform.

4.3.2. Evidence of soil erosion. Look for evidence of soil erosion. All the following indicate possible problems but none, apart from actual rills, are definitive.

Evidence of soil erosion includes the following:

- Rills.
- Areas of deposition (particularly sandy areas on flat land at the base of slopes.
- Tarmac roads showing significant accumulations of silt.
- Ditches with accumulation of sand and silt.
- Marked steps in level across field boundaries running across slopes (can also be caused by cultivations).
- Dykes partly buried on uphill side or with foundations washed out on downhill side.
- Trees or hedge roots showing above ground level.
- Evidence of soil structural problems and low soil organic matter. (Low soil organic matter can be both a cause and a result of soil erosion.)

Soil erosion will frequently occur in relatively small vulnerable areas in otherwise unaffected fields. Typically such areas are where water is concentrated by topographical features such as hollows. It can be addressed by taking these limited areas out of production.

Remember that low rate soil erosion is only a pollution problem if the eroded soil reaches a water course. Erosion is not usually sufficiently severe in Scotland to affect the long term productivity of the land itself. Be aware though that while sand will settle out in seconds in still or slowly flowing water, clay and organic matter particles may never settle. Most pollutants are bound to clay and organic matter particles, not sands.

4.3.3. Evidence of soil structural problems and low organic matter content. Look for evidence of soil structural problems and low soil organic matter content. These are only likely on arable farms with little or no grass in rotations. While not in themselves pollution issues, either will make soils more prone to erosion.

Evidence of soil structural problems includes the following:

- Capping of seedbeds.
- Rapid slumping of seedbeds or rough ploughed land after only one or two rainstorms.
- Presence of soil pans (can only be detected by digging and requires some experience to interpret results).

Evidence of low organic matter includes the following:

- Pale greyish coloured topsoil.
- Separation of sand grains on soil surface, visible as whitish deposits.
- Any of the signs of soil structural problems noted above.

If low organic matter is suspected, laboratory testing by loss on ignition is cheap and easy. Values below 2% indicate a likely problem, 2-4% indicates marginal levels and over 4% is usually adequate. Note though that this loss on ignition method gives approximate results only and that no method works well on soil developed on deposits of Carboniferous origin that contain grains of coal (frequent in the Central Belt of Scotland).

Look for signs of subsoil being ploughed up. While this does not in itself represent a pollution problem, it may rapidly reduce topsoil organic matter contents and give rise to consequent soil erosion.

4.3.4. Potential problems related to land drainage. Failure of old drainage systems is one of the most frequent causes of soil erosion in Scotland. Look out drain "blowouts". Look particularly for failing old "cundies" (built stone drains). These can carry very considerable volumes of water and can result in very large quantities of soil washing away if they fail. Failing cundies usually show as unexplained depressions lying along the line of hollows through fields.

Look for ditches running across slopes. Again, if these fail usually because of poor maintenance, large volumes of water can flow across land causing very severe erosion.

4.3.5. Poaching. Look for evidence of poaching. In itself it may not be a pollution problem but poached land close to a water course may be. It may indicate overstocking or outwintering of stock on inappropriate land.

Pay particular attention to fields where cattle are outwintered. Frequently this will be done on poorer land almost as a sacrificial area but serious pollution may result.

Look out also for the position of feed rings. These should be moved regularly and not situated close to water.

Stock watering access points are also potential trouble spots.

Look for areas where stock may shelter, note whether they are close to water and whether there is evidence of poaching.

Particularly on dairy farms, where cows walk regular routes, consideration should be given to the provision of constructed livestock trails. Pay particular attention to water crossing points or to areas where cows walk close to water.

4.3.6. Farm tracks. Poorly constructed farm tracks can be a source of eroded soil. Note signs of erosion on racks and consider provision of properly constructed tracks with adequate drainage.

4.3.7. Field middens. Properly placed field middens present little pollution risk. They should be situated at the top of fields (this also saves fuel in spreading) away from water.

4.3.8. Grazing practices likely to result in pollution by faecal indicator organisms. FIO pollution may be an issue both where animals directly graze swards and when manures and slurries are spread. It is likely that direct grazing presents the bigger problem as many potential pathogens are killed in the process of production of farmyard manure and storage of slurry.

The impact of direct grazing may be greatest when stocking rates are high.

4.3.9. Other. Note anything else that may have a bearing on diffuse pollution. In the course of walking farms, many practices may be noted that could be improved. Examples include excessively deep ploughing with significant quantities of subsoil being ploughed up (this can rapidly reduce soil organic matter content), inappropriate rubbish dumping and many others.

4.3.10. Tidiness. Do not confuse "untidiness" with increased pollution risk. In the past, good farming practice has often been judged by farmers themselves using "tidiness" as a measure. Evidence of incomplete ploughing down of crop residues, presence of weeds in crops or swards and other similar observations do not make diffuse pollution risks higher. Indeed, many best management practices, such as conservation tillage, will tend to increase this type of untidiness.

However, when untidiness consists of empty pesticide contains lying around, of failing land drainage systems etc. there is certainly an increased pollution risk.

4.3.11. Good practice. Note areas of good practice observed in the course of the survey. These may include good soil structure, good cultivation practices etc. It is important that these be included in the report to avoid being seen to be constantly negative.

4.4. Riparian survey.

Particular attention should be paid to riparian areas.

4.4.1. Water margins. Note whether margins are fenced. Note stock watering access points. Note widths and nature of existing buffers (none, grass strip, dyke, trees etc.). Note presence or absence of water troughs. Nutrient and FIO pollution from grazing is likely to be worst where stock have access to water courses.

Note land gradient of fields above water course or loch and note if land flattens at water edge, if so, note approximate width of flatter area.

4.4.2. Boggy land. Note wet boggy areas which might be better taken out of agriculture to provide wetland areas for habitat and potential water quality improvement.

4.4.3. Potential problems related to flooding. Look out for evidence of past flooding on river haughs. Evidence might include flood debris hanging on fences or trees, signs of gullying in fields, breaches in flood banks or areas of very stony soil. Asking local people can help. Flooding of haughs can be a very serious risk if they are in arable cropping.

Try to assess whether water entering haughland at upper end of field will flow across the field and leave further downstream. Such a situation gives the highest erosion risk. Land which floods should not be in arable cropping but frequently is because it is often contains the best soils and flattest fields on the farm.

4.4.4. Other. Note anything else that may have a bearing on diffuse pollution. In the course of walking farms, many practices may be noted that could be improved. An example would be poor manure spreading practice with dung being spread close to or into water courses.

4.4.5. Tidiness. Again, do not confuse “untidiness” with increased pollution risk. Overgrown ditches for example do not make diffuse pollution risks higher.

4.4.6. Point sources. In many cases, point source discharges of pollutants such as septic tank outfalls will be noted during the farm audit. They should be recorded even though they do not strictly form part of the audit.

4.4.7. Water quality. Whilst a detailed examination of water quality is beyond the scope of this audit, the water particularly in smaller ditches can give an indication of local sources of pollution. Look for and note presence of excessive plant or algal growth, sewage fungus, cloudiness, unusual water colour and evidence of silting of gravel beds.

4.4.8. Good practice. Note areas of good practice observed in the course of the survey.

4.5. Habitat survey.

A diffuse pollution audit will not normally include a full habitat survey. This is a different task requiring markedly different skills. However, as many possible best management practices to address diffuse pollution issues will also present opportunities for habitat enhancement, some level of habitat survey is desirable.

4.5.1. Areas of natural or semi-natural vegetation. Any areas of natural or semi-natural vegetation should be noted with key species recorded. This will enable later best management practices to avoid damage to such areas or to enhance them either by enlargement or by providing interconnecting strips of similar habitat, acting as wildlife corridors.

The regional context of the area should be noted, e.g. the catchment and its importance for wildlife, such as salmon, lampreys, otters etc. This may be linked in with any statutory designations of the catchment.

4.5.2. Opportunities for improving or creating habitat for target species. Opportunities to improve or create habitat for target species should be noted. Both local authorities and national government have lists of BAP (Biodiversity Action Plan) target species. Examples of species which might be targeted include water voles (where they are still present along burns) and farmland waders (creation of wet grassland buffer areas). The recommendations should be linked to funding sources, such as the Rural Stewardship Scheme, use of set aside or other local conservation projects where funding is available

4.5.3. Good practice. Note areas of good practice observed in the course of the survey. These may include areas of well managed habitat such as fenced off water courses etc. It is important that these be included in the report to avoid being seen to be constantly negative.

5. Reporting.

The report will usually comprise a written report along with several maps and plans. Sample reports are included in Appendix 4. The report should include all diffuse pollution issues noted in the course of the surveys. It should also make note of those areas of good practice seen on the farm. The following areas should be covered in the report.

5.1. An overall description of the farm and farming system.

This should include the following:

- topography and soils and drainage,
- climate,
- land use including areas of crops and crop rotations,
- cultivations,
- fertiliser usage and crop yields,
- pesticide usage,
- sheep dipping,
- stocking, stock housing and imported feeds,
- manure production, storage and usage.

5.2. Planning issues

5.2.1. Farm waste management plan.

A farm waste management plan should be prepared. Methodology for doing this is available elsewhere (SEERAD *et al*. 2002). It must include the following:

- Estimate of annual production of manure and slurry.
- Estimate of the nutrient content of that manure and slurry.
- Detail of manure and slurry handling and storage facilities including volume of slurry storage available.
- Detail, including map, of land suitability for manure and slurry spreading taking into account proximity to surface water, wells and springs, land use, land gradient, soil texture and drainage status, climate including number of field capacity days, frost and snow and cropping regime and crop nutrient requirement.
- A plan showing where, when and on which crops the manures and slurry can safely be applied with recommendations for any changes in storage capacity, rates of spreading, timing of spreading, method of spreading, subsequent cultivations and subsequent rates of chemical fertiliser to be applied to the crops.
- A nutrient budget for the farm and also possibly for individual crop rotations within the farm will be necessary to produce a comprehensive waste management plan. A data collection scheme for a whole farm nutrient budget is shown at F in the Audit Form. This approach will allow account to be taken of the transfer of nutrients produced on the grass part of the farm to the cropped area, and vice versa.

5.2.2. Nutrient budgets.

A nutrient budget is an attempt to sum all the inputs of a particular nutrient or group of nutrients applied to a piece of ground and compare it to the sum of all the off-takes. Inputs may include direct fertilisers such as chemicals and organic manures, indirect inputs of fertility such as animal feeds and inputs such as atmospheric deposition. Off-takes may include the nutrients contained in the harvested part of the crop, nutrients contained in any animal product (live beasts, milk etc) sold off the farm and, in some circumstances, unintentional off-takes such as leached or denitrified nitrogen.

The method works best for relatively immobile nutrients, particularly phosphorus, losses of which frequently pose a threat to water quality. It also works well with potassium. It is rather less effective a tool for mobile nutrients such as nitrogen where the unintentional or uncontrollable inputs and off-takes in the forms of nitrogen fixation by legumes, mineralization of soil organic nitrogen, leaching, denitrification and volatilization will frequently exceed the farmer's inputs in fertiliser and off-takes in crop and animal products. It also has limitations where the soil itself contains considerable natural reserves of the nutrient in question as is frequently the case with nitrogen and sometimes potassium.

Nutrient budgets are employed for a variety of purposes ranging from identifying possible savings in fertiliser inputs to identifying possible causes of nutrient enrichment in river catchments. Depending on the purpose, a range of scales may be appropriate from micro areas of a few square metres in the case of precision farming through whole field and whole farm scales to entire sub-catchments of major rivers.

All have their place depending on the purpose for which the nutrient balance is being performed.

In this case, the purpose is to examine possible sources of increased nutrient input to the rivers and lochs close to the farm.

Budgeting may be limited to phosphorus budgets for the purposes of diffuse pollution audits. Many farmers apply more phosphorus in various forms than they remove from the land in sales etc. There are many historic reasons for this mainly related to the fact that almost all Scottish soils were deficient in phosphorus until the widespread use of phosphate fertilisers in the 1950 and 1960 gradually raised the overall phosphate status of soils. Today however, there is frequently no valid current reason for applying more phosphorus fertiliser than that required to replace the phosphorus removed in the crop or in stock. The inevitable result of the excess inputs is slowly rising soil phosphorus levels. Once soil phosphorus levels rise sufficiently, rates of loss of phosphorus by leaching and other pathways may increase markedly. It is therefore undesirable that soil levels be above those required for the land use in question.

Potassium budgets are useful to the farmer but potassium does not constitute a significant pollutant.

Nitrogen certainly is a significant pollutant but for the reasons given above, nitrogen budgets are of limited value and are difficult to use to formulate fertiliser policy. Therefore, an NVZ fertiliser and manure plan should be used instead for nitrogen.

Action Programme measures in NVZs in Scotland require that a fertiliser and manure plan to assess N fertiliser requirement for each crop and field be prepared and implemented; that N must not be applied in excess of crop need; and that organic manure applications must not exceed specified N limits (Scottish Executive 2003). Action Programme measures to minimise nitrate loss to watercourses must be adhered to in NVZs and forms for recording details of livestock, crops, N fertilisers and organic manures are provided by the Scottish Executive (2003).
Farm gate budgets. These are the simplest type of budget to produce and will almost always be needed. The farm is treated as a unit with inputs such as fertilisers, animal feeds etc being brought in and off-takes such as sales of crop, milk and stock leaving the farm. Internal movement of nutrients such as the spreading of animal manure produced on the farm onto particular fields does not feature in a farm gate budget. SAC's data collection sheets for nutrient budgets could be used (see F in Audit Form).

The content of the nutrient in question, usually phosphorus, is summed over the full range of inputs. It is necessary to know both the nutrient content of the input and the amount imported to the farm.

It is essential that there be consistency in what is being described and the units it is being quoted in. For example, figures for the phosphorus content of fertiliser are usually given in kilograms of P_2O_5 while the phosphorus content of animal feeds is usually expressed in term of kilograms of P. All must be converted to either P_2O_5 or P before any comparison may be made. Conversion factors are included in Appendix 5. There is ample scope for error here which must be avoided.

Inputs may include the following:

- chemical fertiliser,
- brought in animal manures and slurries,
- other brought in organic materials such as sewage sludge, mushroom compost etc.,
- brought in animal feeds (ignore farm produced feeds),
- brought in hay, silage and straw including straw fro animal bedding,
- brought in stock (the animals themselves contain nutrients).

The content of the nutrient in question is then summed over the full range of off-takes from the farm. Again it is necessary to know the nutrient content of the off-take and the amount exported from the farm. Again consistence of chemical description and units must be maintained.

Off-takes may include the following:

- sales of crop, including any straw leaving the farm,
- sales of other produce such as milk, eggs etc.,
- sales of stock including cast animals,
- any manure or slurry which is exported to neighbouring farms.

Where stock are brought onto the farm and then leave again, as for example fattening other peoples lambs, account can be made of nutrient transfer by assessing the nutrient content in the weight gained. Often though the figures will be small and may be ignored.

Once totals for inputs and off-takes of any given nutrient are calculated, any excess of input over off-take may be found by subtraction. The excess, if any, of input over off-take may then be divided by the farm area in hectares to give the mean annual excess nutrient per hectare.

For phosphates (that is expressed as P_2O_5), any figure below 5kg/ha excess P_2O_5 is unlikely to be the cause of any problem but figures higher than 5kg/ha require justification. The only likely justification is that soil phosphorus levels on the farm are lower than agronomically desirable and the excess is the result of attempting to build soil phosphate status.

Field budgets. Many farms are not uniform in the land use across the farm. There may for example be areas of hill land receiving little or no fertiliser and areas of intensively farmed arable land on the same farm. A farm gate budget as described above will give a misleading picture on such farms. Where a farm contains areas of markedly differing land use, more detailed field budgets are needed as well as farm gate budgets. It may be necessary to produce several to represent the variety of land uses on the farm.

Crop rotation budgets sum up nutrient inputs and offtakes to a sample hectare of land in a particular crop rotation or land use. Where as the farm gate budget sums all inputs and offtakes to the farm in a single year, field budgets sum all the inputs and offtakes to a field over the length of a crop rotation. This may vary from one year if only a single crop or permanent grass is grown to as much as ten or more years in the case of crop rotations including grass leys. Often farmers do not have set rotations but change cropping in response to markets but even in these cases some typical rotation can be examined.

With single field budgets, applications of manures and slurries produced within the farm are regarded as inputs to the field. Similarly crops removed for use elsewhere on the farm, e.g. grain used as feed or straw used as bedding, are regarded as offtakes from the field. Ideally the weight gain of stock grazing the field would be regarded as an offtake but grazing patterns are rarely simple enough to allow this as stock are moved from field to field. The errors involved in ignoring the nutrients removed from the field in the grazing animal itself are usually slight and can usually be safely ignored.

Calculations are usually done on a "per hectare" basis, again taking care over consistency with chemical description and units.

Inputs include the following:

- chemical fertiliser,
- animal manures and slurries spread on the field but not including the dung deposited by the stock actually grazing the field,
- any other brought in organic materials such as sewage sludge, mushroom compost etc.

Off-takes include the following:

- harvested crop including any straw removed from the field,
- hay and silage but not grass actually grazed off in the field by stock.

The inputs and off-takes are summed over the length of the rotation and then compared on a per hectare basis.

Again, for phosphates (that is expressed as P_2O_5), any figure below 5kg/ha excess P_2O_5 is unlikely to be the cause of any problem but figures higher than 5kg/ha require justification. The only likely justification is that soil phosphorus levels in the field are lower than agronomically desirable and the excess is the result of attempting to build soil phosphate status. An indication of the agronomically desirable levels is given in section 5.2.3 below. Soils should be analysed every five years to keep a check on changes in available nutrients.

Sample budgets. Sample budgets of both farm gate and field type are included in Appendix 4.

5.2.3. Soil analyses. The interpretation of nutrient budgets is dependent on soil analytical result being available.

The following recommended soil phosphorus levels may be used as a guide. They are expressed in terms of SAC's soil phosphorus indices. Note that different soils laboratories may use different methods of extraction of phosphorus from soil and that results from different laboratories frequently cannot be directly compared.

Land in improved grassland: no need to be higher than the middle of moderate category, (9mg/l).
Land growing combinable crops: no need to be higher than the upper part of moderate category, (13mg/l).
Land growing potatoes and many field vegetables: no need to be higher than the lower part of high category, (20 mg/l).

Interpretive scale for SAC extractable phosphorus and potassium soil levels (mg/l).

Soil Status	Phosphorus	Potassium
VL Very Low	Less than 1.8	Less than 20
L Low	1.8 – 4.4	40 - 75
M Moderate	4.5 - 13	76 - 200
H High	14 - 90	201 - 1000
EH Excessively High	Greater than 90	Greater than 1000

The uptake of soil phosphorus can be affected by poor structural condition of the soil, by low pH and by poor drainage. However, if any of the above are present, the approach to be recommended is to improve the structure, lime or drain rather than increase soil phosphorus status to compensate. If in doubt, further advice is available from SAC or from independent soil scientists.

5.2.4. Phosphorus recommendation. Usually where significant excesses of inputs over offtakes occur, and soil levels are adequate for the cropping being practiced, phosphate inputs may be reduced without risk of yield loss and with benefits both to the environment and the farmer's pocket. However, any reductions in inputs must be done with care if yield losses are to be avoided. For example, in a rotation with potatoes, it may not be desirable to reduce the input to the potatoes even though there is likely to a very large excess with this crop but rather it is better to reduce to zero input of phosphorus to one or even two subsequent cereal crops. Specialist advice is needed.

5.3. Steading issues. There should follow a description any actual or potential diffuse pollution issues noted in the steading.

These may include such items as the position and nature of the sprayer filling area, potential steading runoff problems, cleanliness problems giving rise to atmospheric pollution etc.

Problems such as inadequate slurry storage will already have been highlighted in section 5.2.1 above.

5.4. Field issues. There should follow a description any actual or potential diffuse pollution issues noted in individual fields. Any field issues which are widespread over the farm should also be included here.

Widespread issues might include the following:

- Soil protection issues
    - Soil erosion
    - Soil compaction
    - Soil organic matter content
    - Soil contamination
- Atmospheric pollution issues
    - Ammonia
    - Greenhouse gases
    - Odour problems
    - Smoke
- Nutrient pollution issues
- FIO pollution issues
- Irrigation abstraction issues.

5.4.1. Soil protection issues. The term "Soil protection" normally embraces such topics as the avoidance or control of soil erosion, the enhancement of soil structure and the avoidance or control of soil compaction, the maintenance of soil organic matter content etc. In themselves, they are not diffuse pollution issues although they frequently become so when, for example, eroded soil enters a river. These areas of soil protection are embraced by the old fashioned term "Good husbandry". If the land use is appropriate to the land capability, if soil compaction is avoided by suitable and timely farming operations, if soil fertility is maintained at desirable levels by appropriate and timely use of lime, fertilisers and manures, if the soil organic matter content is maintained by such practices as incorporation of crop residues and organic manures then few pollution problems associated with soil protection will occur. Many of these topics are likely to be covered by GAEC requirements and necessary for cross compliance but at the time of writing these are only in draft form. Any general problems observed during the course of the field survey or noted by the farmer should be recorded here. (Scottish Soil Protection Plan forthcoming).

Beside the above issues, soil protection in the context of diffuse pollution control is mainly concerned avoidance of pollution of the soil itself, that is with preventing the build up of undesirable substances in the soil. Such substances include impurities in chemical fertilisers such as the cadmium usually present in low levels in phosphatic fertiliser, impurities in organic fertilisers such as the heavy metals potentially present in sewage sludge (Code of Practice for Agricultural Use of Sewage Sludge, 1996) and pesticide residues and their breakdown products.

All the above are really beyond the scope of this type of diffuse pollution audit and generally are controlled off the farm by the guidelines and regulations referenced above. If the regulations regarding the use of sewage sludge in agriculture are adhered to and if pesticides are used in accordance with the manufacturer's recommendations, problems of build up of pollutants in the soil to undesirable levels should not occur.

5.4.2. Atmospheric pollution issues. The background data to assess the likelihood of atmospheric pollution problems has been recorded in the course of the interview and farm and steading surveys. It includes such information as types of fertiliser used, manure handling systems in steadings and middens, timing of spreading of manures and subsequent incorporation, general steading housekeeping etc. Any problems noted should be recorded here. Some guidance is given below.

Atmospheric pollution risks fall into four main categories.

Ammonia. Ammonia volatilisation is a problem both on livestock farms and on arable farms where certain types of nitrogen fertiliser are used. Some of the ammonia is likely to be deposited locally and some is likely to be distributed fairly widely. Ammonia contains nitrogen which is an undesirable addition to sensitive habitats such as heather moorland and wetlands. It is also acidifying which again is undesirable in many habitats. Emissions from animal housing are most significant and are dealt with under steading issues. Also important are emissions arising from spreading manures and slurries, emissions from grazing livestock and finally emissions from nitrogenous fertilisers.

When farm yard manure is spread, ammonia emissions can be reduced by incorporating the manure as soon as possible. The problem is worst in summer when volatilisation is likely to be rapid in the warm conditions and losses high unless the manure is incorporated at once, with the plough more or less following the dung spreader. In practice, it will be rare for farms to incorporate manure quickly enough to greatly reduce ammonia volatilisation.

Dilution of slurries is known to reduce ammonia losses but dilution of slurry is likely to increase other problems associated with slurry use. Injection is a good method of reducing ammonia emissions but is likely to increase problems of losses of nutrients and pathogens to piped underdrainage. Band spreading also reduces ammonia losses although not by as much as injection. Weather conditions are also a factor with cool still days being best. Application during or just prior to rainfall also reduces emissions but this would be highly undesirable on many soils, because of the increased risk of pollution of surface water. The slow infiltration rate characteristic of many Scottish till soils increases the risk of ammonia losses significantly.

Some forms of nitrogen fertiliser are more likely to result in ammonia emissions at the time of spreading than others. In particular, urea, particularly if applied to dry warm alkaline soils may result in very significant losses of ammonia. Such soils are not particularly prevalent in Scotland.

Several of the measures which might reduce atmospheric pollution by ammonia are likely to increase the risks of water pollution from runoff or leaching. It is not clear where the balance should be struck.

Greenhouse gases. On a global scale, emissions of greenhouse gases from agriculture are significant. Carbon dioxide, methane and nitrous oxide are all released in significant quantities. See Scottish Pollutant Release Inventory (2004) and Intergovernmental Panel on Climate Change (2004) for further information.

Carbon dioxide is emitted by the use of fossil fuels in tractors etc, by the breakdown of limestone added to soils to reduce acidity and by oxidation of soil organic matter when, for example, permanent pasture is ploughed up or peatland is drained. It is also released when fossil fuels are used in fertiliser production, particularly nitrogen fertiliser production which is an energy intensive process. Conversely, carbon dioxide can be fixed in soils farmed in a way that causes soil organic matter levels to rise, for example by maintaining longer grass leys in a rotation. Significant amounts of carbon dioxide could be removed from the atmosphere by the widespread adoption of such practices.

Methane is emitted directly from animals due to fermentation caused by bacteria in their stomachs. Emissions are particularly high from dairy cows with their greater food consumption but are high from all ruminants. Direct emissions from animals account for about 90% of methane emissions from agriculture. Methane is also released by bacteria in manures and slurries.

Nitrous oxide is released from nitrogen compounds in fertilisers, manures, crops and soils. It is most likely to be produced in anaerobic conditions. Any farm which incorporates significant quantities of nitrogenous material (chemical fertiliser or animal manure and slurries or nitrogen rich crop residues such as legumes) into wet soils is likely to produce significant nitrous oxide emissions. The problem is worse when organic carbon is present with the nitrogenous material (manures, slurries and plant residues) as the carbon acts as an energy source for the bacteria producing the nitrous oxide. Any additional factors which decrease oxygen flow into soils increases nitrous oxide production. Such factors include compaction caused by animal hoofs or machinery, poor drainage, wet climates or irrigation and heavy soils. Use of nitrogen in excess of crop requirements is also likely to increase losses of nitrous oxide.

Odour problems. Spreading of slurry and certain other livestock wastes may result in local pollution from unpleasant odours. These are considered to be fairly trivial (although they may not seem so to householders close to a farm spreading slurry on a still day). Significant improvements in the odour associated with slurry spreading could be realised either by aerobic digestion or by anaerobic digestion of the slurry prior to spreading. The latter would have the added benefit of producing biogas. However, the investment involved will frequently be excessive to treat a relatively minor problem. The PEPFAA code contains further advice.

Improvement could also be realised by changing the slurry spreader to a band spreader or to slurry injection. Injection might not be desirable because of the increased risk of pollution of surface water via underdrainage.

Smoke. Straw burning produces significant smoke pollution. It is generally an undesirable practice and in any case is relatively uncommon.

5.4.3. Nutrient pollution issues. Inappropriate manure and fertiliser spreading practices may give rise to nutrient pollution issues.

5.4.4. FIO pollution. Inappropriate grazing or manure spreading practices may give rise to FIO pollution.

5.4.5. Irrigation abstraction issues. Although not strictly a diffuse pollution issue, the effects of abstracting water from small watercourses may be similar, resulting in declining water quality downstream where there may remain insufficient dilution for further inputs of pollutants. Report if increased storage of winter water would be appropriate or if water might better be abstracted from boreholes. A check on the groundwater hydrology will be necessary before suggesting the possibility of boreholes.

Some form of irrigation scheduling should be in place. From the farmer's standpoint scheduling increases the benefits of irrigation and reduces the risks of soil damage and from an environmental standpoint, scheduling reduces water use and reduces the risk of runoff of pollutants.

Under the Water Framework Directive and resulting Water, Environment and Water Services (Scotland) Act (WEWS), SEPA will be given controls from 2005 onwards to regulate abstraction and impoundment activities. This will include abstraction from surface and groundwaters and will cover all existing and new activities. Under the new regulatory regime farmers along with all other water users will be required to illustrate an efficient and effective use of water. Scheduling will therefore become an essential part of their water resource management routine. More information on the Water Framework Directive is available on www.sepa.org.uk/wfd.

5.4.6. Issues in specific fields. As well as the general field issues noted above, problems related to specific fields should be noted here. These might include evidence of soil erosion, evidence of drainage failures etc.

5.5. Riparian issues. Issues noted in the riparian survey should be included here. These may include eroding river banks, inappropriate stock access to water etc.

5.6. Habitat and biodiversity.

5.6.1. Existing habitat. A report should be prepared on the existing habitat features on the farm noting what is present, its current condition, what might be done to improve it and what species might be expected to come in if conditions were made more suitable.

5.6.2. Existing agri-environment schemes. Note should be made of any existing participation in agri-environment schemes and what prescriptions are currently being followed.

5.6.3. Habitat creation/enhancement/preservation proposals. Measures should be proposed to create, enhance or preserve habitat and bio-diversity on the farm. As far as possible, these should tie into the diffuse pollution control measures. For example, if permanent grass is being proposed in certain areas as an erosion control measure, it can be managed for wildflowers and birds, usually at no additional cost.

5.7. Maps.

The following maps are likely to form part of the report.

Plan of steading.
Map showing current land use.
Map showing land gradients.
Map showing land suitability for spreading manure and slurry.
Map showing diffuse pollution issues encountered.
Map showing proposals to address these issues.

Additional maps might include the following as part of a habitat enhancement initiative.
Map showing existing habitat.
Map showing proposed new habitat, including those features of the proposals map above which have a habitat benefit.

6. Feedback to farmer.

Once the draft diffuse pollution audit report has been produced and the draft BMP selection report is also available, both should be sent to the farmer. They should go together as there is no point in highlighting problems without accompanying solutions.

The diffuse pollution audit report will almost certainly contain sections highlighting a number of problems or potential problems. This will be the case even on the best run of farms with environmentally aware farmers. It is important to point this out to the farmer in an accompanying letter. It is also important to highlight areas of good practice found on the farm.

The issues highlighted should be prioritised in order of importance. Generally it will be sufficient to divide them into high, medium and lower importance.

The draft should be sent to the farmer for his inspection and he should be contacted by telephone about one week later to get his comments. Sometimes this can be done by telephone but frequently a second meeting will be necessary.

The aim of the feedback is to gain agreement from the farmer that the various diffuse pollution issues highlighted are in fact present on the farm and require to be addressed. Normally this will be accepted without much argument.

The main part of the discussion and the area where the farmer's input is vital is in the selection of appropriate measures to address the problems. There are usually many ways in which any given problem may be tackled. The aim of the discussion is to find a measure or series of measures which will both address the problem and cause the minimum of problems for the farmer. The farmer himself will frequently provide an appropriate solution. The task of the advisor is to offer possible BMPs or trains of BMPs, to steer the discussion in the right direction and to assess the likely outcome of any suggested series of measures in addressing the problem.

Opportunities for solving some of the issues by using agri-environment schemes such as RSS should be highlighted as a means of funding the work. Use of buffer strips and any local river based conservation projects should be discussed.

Once agreement has been reached both on the problems to be addressed and the methods of addressing them, a final version of the report should be produced and sent to the farmer. There must then be consideration of how the proposed measures are to be introduced and in particular where the finance will come from. Some BMPs will be self-funding (e.g. balancing nutrient budgets) but most will not.

Appendix 1. Audit forms.

Appendix 2. Imperial to metric conversion.

The following conversion factors are approximate but are adequate for most purposes.

Area
1 hectare = 2.5 acres

Length
1 metre = 40 inches

Height
100 metres = 328 feet

Volume
1000 litres = 220 UK gallons
or 1 cubic metre

Yield
1 tonne/hectare= 8 cwt/acre

Fertiliser rate
1kg/ha = 0.8 units/acre
50kg = 100 units

Fertiliser nutrient content

1 bag of fertiliser contains 50 kg or about 100 units of fertiliser.

1 bag of 20:10:10 contains 10 kg of N, 5 kg of P_2O_5 and 5 kg of K_2O or about 20 units of N, 10 units of P_2O_5 and 10 units of K_2O.

For example: 3 bags per acre of 20:10:10 fertilisers supplies 60units/per acre of N, 30 units per acre of P_2O_5 and 30 units per acre of K_2O.
This is equivalent to 75kg/ha of N, 37kg/ha of P_2O_5 and 37 kg/ha of K_2O.

Appendix 3. Check list for survey equipment.

Spade.
Dutch auger. (not essential but saves time)
Optical clinometer (to measure land gradients).
Measuring tape. (to measure soil depths etc)
Farm maps
Note book, pencil and rubber.
Camera (not essential but useful)
Compass (useful for a range of purposes)
Hand held GPS (not essential but very useful for recording positions)
Screw auger, sample bags and marker pen (if soil analysis samples to be taken)

Appendix 4. Sample reports.

Appendix 5. Data for nutrient budgeting.

Useful conversions:
1 kg P_2O_5 contains 0.44 kg P
1 kg K_2O contains 0.83 kg K
1 kg protein contains 0.16 kg N

Livestock.

	Typical weight*	P content	N content
Ewe	70 kg	0.74%	0.63%
Hogg	70 kg	0.74%	0.63%
Lamb at sale	41 kg	0.74%	0.63%
Cow	550 kg	0.74%	0.63%
Calf at 6 months	285 kg	0.74%	0.63%

* in all cases, it is better to use actual weights than these typical figures.

Some commonly imported animal feedstuffs.

	%Dry matter	P %Dry matter	N %Dry matter
Beet pulp	89	0.10	1.9
Silage	23	0.23	2.2
Straw	83	0.16	0.78
Sheep nuts*	91	0.63	4.1
Cattle cobs*	91	0.63	4.1
Barley/soya/beet pulp feed mix*	90	0.50	4.8

* typical figure but variable.

Milk.
P content: 0.10% P or 2.3 kg P_2O_5 per 1000 litres.
N content: 0.5% N or 5 kg N per 1000 litres.

Crops.

Crop	**Nutrient removed, kg/tonne harvested**	
	P_2O_5	K_2O
Spring cereal		
Grain	7.8	5.6
Straw	1.5	12.6
Grain+straw[1]	8.8	13.8
Winter cereal		
Grain	7.8	5.6
Straw	1.3	9.3
Grain+straw[1]	8.6	11.6
Oil seed rape	12.5	7.5
Potatoes	0.9	5.0
Carrots	0.6	3.5
Swede roots	0.7	2.0
Grass		
Silage	1.4	4.8
Hay	4.8	16.0

1: Grain + straw refers to 1 tonne of harvested grain plus associated 0.65 tonnes of straw.

Appendix 6.

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Appendix 7. Acronyms and abbreviations.

BAP	Biodiversity Action Plan.
BMP	Best Management Practice.
CAP	Common Agricultural Policy.
CPMP	Crop Protection Management Plan.
FIO	Faecal Indicator Organism(s).
GAEC	Good Agricultural and Environmental Condition.
IACS	Integrated Administration and Control System.
LERAP	Local Environmental Risk Assessment for Pesticides.
LMC	Land Management Contract.
MLURI	Macaulay Land Use Research Institute.
NroSO	National Register of Sprayer Operators.
NSTS	National Sprayer Testing Scheme.
NVZ	Nitrate Vulnerable Zone.
PEPFAA	Prevention of Environmental Pollution from Agricultural Activities.
RSS	Rural Stewardship Scheme.
SAC	Scottish Agricultural College.
SEERAD	Scottish Executive Environment and Rural Affairs Department.
SEPA	Scottish Environment Protection Agency.
SSSI	Site of Special Scientific Interest.
WEWS	Water, Environment and Water Services (Scotland) Act.