National Federation of Group Water Schemes

A Handbook of Source Protection and Mitigation Actions for Farming

Acknowledgements

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Organisations and Agencies represented on the Project Steering Group of the NFGWS Source Protection Pilot Project Phase II

- *Department of Agriculture, Food and the Marine*
- *Department of Housing, Planning and Local Government*
- *Dundalk Institute of Technology*
- *Environmental Protection Agency*
- *Geological Survey of Ireland*
- *Irish Creamery Milk Suppliers Association*
- *Irish Co-operative Organisation Society Limited*
- *Irish Farmers Association*
- *Irish Water*
- *Local Authority Waters Programme*
- *Monaghan County Council*
- *National Federation of Group Water Schemes*
- *An Fóram Uisce*
- *Roscommon County Council*
- *Teagasc*
- *Westmeath County Council*

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A Handbook of Source Protection and Mitigation Actions for Farming

1 Purpose of the handbook

Assisting group water schemes to manage and safeguard their drinking water sources is a critical task for us in the NFGWS. One of the main potential pressures on water is farming – this is inevitable, as farming occurs in the catchment areas and zones of contribution of virtually all our sources. Therefore, as a means of protecting our sources, group water schemes (GWSs) need to know what to do to prevent pollution and how to mitigate the impacts of pollutants that arise from human activity, including farming practices. We already have an overall approach outlined in the NFGWS Framework for Drinking Water Source Protection (2019)[1]. Appendix 6 in that document outlines possible mitigation options for agricultural activities.

This handbook provides additional guidance for GWS managers and for others involved in developing drinking water source protection plans who need to identify appropriate Actions to prevent or reduce nutrient (phosphorus, nitrogen), sediment, pesticides and microbial pathogen losses from agricultural activity. While the Actions described in the handbook focus on farming, the NFGWS would like to acknowledge that there are other significant non-agricultural related pressures that also impact on drinking water quality, which will be addressed separately.

In reading this handbook, keep in mind that the list of Actions described is not exhaustive and does not include detailed engineering descriptions. It is intended to provide 'common sense' information, with an indication of the likely effectiveness of various Actions that are based on the scientific literature and on practical experience in dealing with water quality issues. The handbook provides basic guidance that can be adapted to the particular circumstances found on Irish farms and farmland, with due regard to regional variations in topography, soil types and bedrock, as these will strongly influence the selection of 'the right measure in the right place'.

Finally, attention is drawn to the environmental co-benefits of the various mitigation options. These include biodiversity protection and enhancement, flood mitigation, carbon sequestration and greenhouse gas emission reduction, all of which are relevant to rural communities.

[1] https://nfgws.ie/a-framework-for-drinking-water-source-protection-2/

2 Background

Before considering what Actions might be needed on farms, there are four documents that may be examined for useful background information:

1. The NFGWS Framework for Drinking Water Source Protection.
2. The Source Zone of Contribution/Catchment report (hereinafter called the Source Report).
3. Regulatory measures; in particular the Good Agricultural Practices (GAP) Regulations (DAFM, 2017) and the Pesticides Use Regulations (DAFM, 2012).
4. A review of potential local measures for mitigating farm impacts in catchments (McNally (2017).

The **Framework document** provides the overall approach to group scheme drinking water source management and explains various relevant concepts, such as untreated water guide values, critical source areas for pollutants and what are called 'pathway conceptual models' (or the description of how pollutants might enter a drinking water source).

The **Source Report** gives: i) the details on the source itself; ii) a conclusion on the pollutants that either are or potentially could impact on the source; iii) a description of the pressures contributing these pollutants and their location; and iv) the pathways followed by pollutants in the landscape before reaching the source. In most circumstances, some recommendations on possible protection or mitigation options will be proposed.

The **European Communities (Good Agricultural Practice for Protection of Waters) Regulations** (often known as the GAP Regulations) set out a number of basic requirements designed to protect waters from pollution arising from agricultural activities. They include measures relating to storage of slurry, timing of landspreading, nutrient management, setback distances for the application of chemical and organic fertilisers, etc. Compliance with the Regulations is linked to a farmer's Single Farm Payment (SFP). Where breaches of GAP Regulations are identified, a farmer can be penalised all or a portion of the SFP, depending on the severity of the breach. While these are regulations aimed at protecting water, the fact that they are 'one size fits all' means that they may not be adequate for the particular circumstances that present in the catchment area or zone of contribution of a drinking water source.

The main measures in the GAP Regulations are summarised in Appendix 1. Compliance with these requirements is an essential 'starting point' for water management. Therefore, it is important to consider and understand these before starting to examine the Actions outlined in this handbook, particularly as they are not all repeated or dealt with under the Actions. An explanation of the Regulations is given in a Department of Agriculture, Food and Marine document that can be accessed at:
https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/2018Nitratesexplanatoryhandbook03042018.pdf

In outlining the Actions, this handbook does not generally give quantitative values for the possible reduction in pollutants arising from each action. However, in McNally (2017), percentage reductions based on a literature review are provided. The report can be accessed at: https://www.catchments.ie/download/review-of-potential-local-measures-for-mitigating-farm-impacts-in-catchments/

While these four documents provide valuable information, it is recommended that local advice and input be obtained from a farm advisor, such as the local Agricultural Sustainability Support and Advice Programme (ASSAP) advisor and from individual farmers who will have an in-depth knowledge of their lands. In addition, training and opportunities for discussion on the Actions will be provided by the NFGWS.

3 Deciding on the actions – what approach?

Undertaking the required Actions is generally time and resource intensive. Therefore, it is essential that thought and planning is undertaken to ensure that they are efficient and effective. As a starting point, ask the questions in Box 1. Details of the scientific basis for protection and mitigation Actions are summarised in Appendix 2.

3.1 Some basic principles for drinking water source management

There are certain principles for water, including drinking water, management that are the 'stepping stones' for achieving the outcomes needed. Some of these are outlined below.

1. Check (or evaluate, if necessary) if the objective is to **protect** or to **improve** the untreated drinking water source**:**
   i) Protection/maintenance, where water quality is satisfactory.
   ii) Improvement/restoration requiring mitigation, where the situation is unsatisfactory.

   Figure 1 illustrates the relevance of this subdivision, as the focus and the measures/activities will differ for each.

2. **Understand the land and landscape setting of the catchment area or zone of contribution (ZOC), including:**
   i) pathways for water movement in the fields.
   ii) the location of streams, ditches, wells, etc.
   iii) pollutants that might threaten or are causing water quality problems.
   iv) pressures, potential or actual.
   v) critical source areas and either the delivery points or zones where water is discharging to a watercourse, or the susceptible (e.g. extreme vulnerability) areas in ZOCs.

   Understanding of these is vital in ensuring that the Actions are efficient and effective.

3. **Pick important problems and fix them.** In any area, such as a catchment, there will be a multitude of environmental stressors (e.g. pollutants) and pressures. As it is unlikely that you will be able to immediately address them all, the key is to pick those that will 'make a difference' and to focus on them as a priority.

4. **Use "the right measure in the right place."** Measures and actions must be 'tailor made' and specifically targeted and prioritised on the environmental stressors and pressures and on the relevant areas, as the means of achieving desired environmental outcomes.

3.2 The 'right place' for measures and actions?

It is always worthwhile to give advance consideration to both land and landscape in a catchment, as this will determine the 'right place' to implement measures and actions, as well as the approach to and the substance of any intervention. There are three options when deciding where interventions may be needed:

1. At the pressure source (e.g. in a farmyard, or where fertiliser is applied).
2. Along the pathway, as pollutants such as i) phosphorus or MCPA become soluble or attach to soil particles and start the journey from the soil to a receptor, such as a stream, or ii) where nitrate is leached from the soil, moves down to the water table and then flows underground to a well.
3. At the water supply itself or the watercourse in the case of a surface water supply.

Box 1

Ask questions

Before any Action is implemented, 'stand back' and fully evaluate the situation; otherwise your efforts may be ineffective and an inefficient use of time and resources. The answers to the questions below will be in the Source Report.

1. What is the water quality objective? Is it to 'protect' as the untreated water is satisfactory, or is it to 'improve', where it is unsatisfactory?
2. What is the environmental stressor or pollutant? This has a major influence on assessing the implications for the drinking water supply.
3. Is the pressure from point sources (i.e. a pipe) or diffuse sources (e.g. landspreading) or both? This influences the approach to evaluating the actions and measures needed.
4. Is your source from groundwater or surface water?
5. What is the load (total nutrient inputs), and what reduction of nutrient (nitrate or phosphate) is required? Where the objective is 'improve', it may be helpful to know the nutrient (nitrogen or phosphorus) required load reduction, as this will inform decisions on areas to be targeted and the optimum actions.
6. What is the landscape setting and condition of the land in the source catchment area/zone of contribution? In particular, note the poorly draining and freely draining areas, as these influence the flowpaths for water and pollutants, which in turn determine the types of actions needed.
7. What are the optimum protection/mitigation options?
8. Where do the protection/mitigation Actions need to be implemented?
9. Lastly, am I sure that the pressure is significant and, therefore, needs to be dealt with?

3.3 The menu of protection and mitigation actions

A decision on the appropriate Action(s) depends on a number of factors: i) the environmental stressor or pollutant; ii) the farming activity; iii) the landscape and farm setting, in particular whether it is a freely draining or poorly draining scenario; and iv) the input of and acceptability to the farmer. In addition, the objective – protect or improve – may also be relevant.

There are four categories of protection/mitigation Actions that depend on their location in the landscape (see further details in Appendix 2):

1. Actions to reduce or eliminate the pollutants.
2. Actions to reducing mobilisation of pollutants on land.
3. Pathway interception Actions.
4. Receptor/instream works.

Table 1 lists the menu of protection/mitigation Actions described in this handbook.

In addition to the Actions that are categorised above, there is one vital overarching Action that applies to all them **–** farmer engagement and collaboration. This is outlined in Section 4.

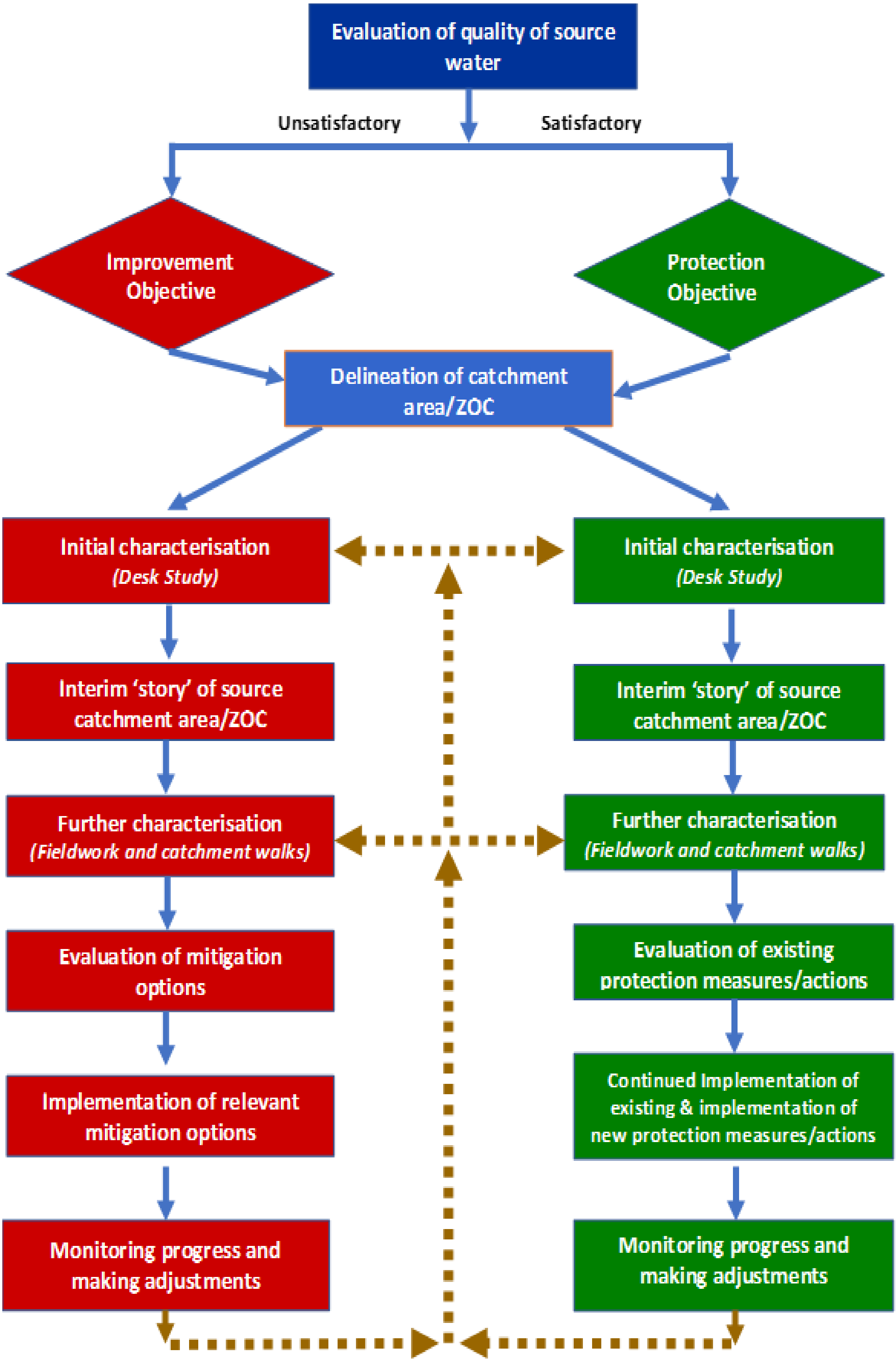

Figure 1. Summary of source protection framework

The suggested approach to deciding on the most appropriate, effective and acceptable action or actions to undertake is as follows:

i) Check what is the environmental stressor (pollutant or significant issue) that poses a threat to the drinking water source (i.e. is it nitrate, phosphate, sediment, MCPA and/or microbial pathogens?). This information should be available in the source report.
ii) Look up the appropriate table for the pollutant (either Table 2, 3, 4, 5 or 6) to find the list of relevant Actions. For instance, if nitrate is the pollutant of concern, examine Table 3.
iii) Details on the Actions that are relevant to each of the pollutants are given in Sections 5, 6, 7 and 8. Evaluate those Actions that are applicable to the identified problematic pollutant, taking account of the particular circumstances that may apply in the catchment area or ZOC.
iv) Decide on the Action (s).
v) Undertake the Action(s).

Two case studies are described in Appendix 3 as a means of illustrating certain of the Actions.

While the approach has been to categorise Actions based on where they are being implemented, an alternative approach is to consider them under the following categories:

i) farmyard management Actions.
ii) nutrient management Actions.
iii) pesticide management Actions.
iv) land management Actions.

The link between this categorisation approach and that used in this Handbook is shown in Table 7.

Table 1: Landscape locations, associated types of actions and protection/mitigation options

Location in landscape	**Category of action**	**Action**	**Protection/mitigation options**
All farmland	Discussion with farmers	1	Farmer engagement and collaboration (Section 4.1).
At the source of the pollution pressure	Pollutant reduction, or elimination	2	Farmyard management to prevent runoff to watercourses and/or infiltration to groundwater (Section 5.1).
		3	Appropriate application of N fertiliser (Section 5.2).
		4	Appropriate application of P fertiliser (Section 5.3).
		5	Use of precision technology (Section 5.4).
		6	Management of farm roadways, drinking troughs, supplementary feeders and gateways (Section 5.5).
		7	Using low crude protein animal feeds (Section 5.6).
		8	Integrated weed management (Section 5.7).
		9	Proper storing, handling and disposal of chemicals (Section 5.8).
		10	Use of boom sprayers (Section 5.9).
		11	Weed-wiping application (Section 5.10).
		12	Petrol/diesel & waste oil management (Section 5.11).
		13	Management of land reclamation (Section 5.12).
		14	Organic farming (Section 5.13).
	Reducing mobilisation of pollutants on land	15	Liming of soils (Section 6.1).
		16	Timing of fertiliser applications (Section 6.2).
		17	Low emission slurry spreading (Section 6.3).
		18	Use of protected urea (Section 6.4).
		19	Multi-species grassland swards (Section 6.5).
		20	Red and white clover (Section 6.6).
		21	Cover/catch crops (Section 6.7).
		22	Reducing soil compaction (Section 6.8).
		23	Land preparation for tillage and grassland (Section 6.9).
		24	Rewetting peat soils areas (Section 6.10).
Along the pollution pathway	Pathway interception	25	Riparian buffers (Section 7.1).
		26	In-field grass buffers (Section 7.2).
		27	Hedgerows (Section 7.3).
		28	Wild bird cover crops planted alongside watercourses (Section 7.4).
		29	Agro-forestry Section 7.5).
		30	Woodlands (Section 7.6).
		31	Drainage ditch management and sediment traps (Section 7.7).
		32	Low earthen mounds/bunds (Section 7.8).
		33	Farm ponds and wetlands (Section 7.9).
At the polluted watercourse	Receptor/instream works	34	Livestock exclusion from watercourses (Section 8.1).
		35	Bank stabilisation (Section 8.2).
		36	Removal of riparian invasive species (Section 8.3).

Table 2: Possible protection/mitigation options for microbial pathogens

Microbial pathogens as the environmental stressor (pollutant)			
Location in landscape	**Category of action**	**Action**	**Protection/Mitigation Options**
At the source of the pollution pressure	Pollutant reduction or elimination	2	Farmyard management to prevent runoff to watercourses or infiltration to bedrock beneath the farmyard (Section 5.1).
		4	Appropriate application of P fertiliser (Section 5.3).
		5	Use of precision technology (Section 5.4).
		6	Management of farm roadways, drinking troughs, supplementary feeders and gateways (Section 5.5).
	Reducing mobilisation of pollutants on land	16	Timing of fertiliser applications (Section 6.2).
		17	Low emission slurry spreading (Section 6.3).
		22	Reducing soil compaction (Section 6.8).
Along the pollution pathway	Pathway interception	25	Riparian buffers (Section 7.1).
		26	In-field grass buffers (Section 7.2).
		27	Hedgerows (Section 7.3).
		28	Wild bird cover crops planted alongside watercourses (Section 7.4).
		29	Agroforestry (Section 7.5).
		30	Woodlands (Section 7.6).
		31	Drainage ditch management and sediment traps to reduce sediment losses (Section 7.7).
		32	Low earthen mounds/bunds (Section 7.8).
		33	Farm ponds and wetlands (Section 7.9).
At the polluted watercourse	Receptor/instream works	34	Livestock exclusion from watercourses (Section 8.1).

Table 3: Possible protection/mitigation options for nitrate

Nitrate as the environmental stressor (pollutant)			
Location in landscape	**Category of action**	**Action**	**Protection/Mitigation Options**
At the source of the pollution pressure	Pollutant reduction or elimination	2	Farmyard management to prevent runoff to watercourses and/or infiltration to groundwater (Section 5.1).
		3	Appropriate application of N fertiliser (Section 5.2).
		5	Use of precision technology (Section 5.4).
		7	Using low crude protein animal feeds (Section 5.6).
		14	Organic farming (Section 5.12).
	Reducing mobilisation of pollutants on land	15	Liming of soils (Section 6.1).
		16	Timing of fertiliser applications (Section 6.2).
		17	Low emission slurry spreading (Section 6.3)
		18	Use of protected urea (Section 6.4).
		19	Multi-species grassland swards (Section 6.5).
		20	Red and white clover (Section 6.6).
		21	Cover/catch crops (Section 6.7).
Along the pollution pathway	Pathway interception	25	Riparian buffers (Section 7.1).
		28	Wild bird cover crops planted alongside watercourses (Section 7.4).
		29	Agroforestry (Section 7.5).
		30	Woodlands (Section 7.6).
		33	Farm ponds and wetlands (Section 7.9).

Table 4: Possible protection/mitigation options for sediment

Sediment as the environmental stressor (pollutant)			
Location in landscape	**Category of action**	**Action**	**Protection/Mitigation Options**
At the source of the pollution pressure	Pollutant reduction or elimination	2 6 13	Farmyard management to prevent runoff to watercourses. (Section 5.1). Management of farm roadways, drinking troughs, supplementary feeders and gateways (Section 5.5). Management of land reclamation. (Section 5.12).
	Reducing mobilisation of pollutants on land	20 21 23	Cover/catch crops. (Section 6.7). Reducing soil compaction (Section 6.8). Land preparation for tillage and grassland (Section 6.9).
Along the pollution pathway	Pathway interception	25 26 27 28 29 30 31 32 33	Riparian buffers (Section 7.1). In-field grass buffers (Section 7.2). Hedgerows (Section 7.3). Wild bird cover crops planted alongside watercourses. (Section 7.4). Agroforestry (Section 7.5). Woodlands (Section 7.6). Drainage ditch management and sediment traps to reduce sediment losses. (Section 7.7). Low earthen mounds/bunds (Section 7.8). Farm ponds and wetlands (Section 7.9).
At the polluted watercourse	Receptor/instream works	34 35 36	Livestock exclusion from watercourses (Section 8.1). Bank stabilisation (Section 8.2). Removal of riparian invasive species (Section 8.3).

Table 5: Possible protection/mitigation options for chemicals

Chemicals as the environmental stressor (i.e. pollutant)			
Location in landscape	**Category of action**	**Action**	**Protection/Mitigation Options**
At the source of the pollution pressure	Pollutant reduction or elimination	2 8 9 10 11 12 14	Farmyard management to prevent runoff to watercourses (Section 5.1). Integrated weed management (Section 5.7) Proper storing, handling and disposal (Section 5.8). Use of boom sprayers (Section 5.9). Weed wiping application (section 5.10). Petrol/diesel & waste oil management (Section 5.11). Organic farming (Section 5.12).
	Reducing mobilisation of pollutants on land	21 22 23	Cover/catch crops. (Section 6.7). Reducing soil compaction (Section 6.8) Land preparation for tillage and grassland (Section 6.9).
Along the pollution pathway	Pathway interception	25 26 27 26 29 30 32 33	Riparian buffers (Section 7.1) In-field grass buffers (Section 7.2) Hedgerows (Section 7.3). Wild bird cover crops planted alongside watercourses (Section 7.4). Agroforestry (Section 7.5). Woodlands (Section 7.6). Low earthen mounds/bunds (Section 7.8). Farm ponds and wetlands (Section 7.9).

Table 6: Possible protection/mitigation options for phosphate

Phosphate as the environmental stressor (i.e. pollutant)			
Location in landscape	**Category of action**	**Action**	**Protection/Mitigation Options**
At the source of the pollution pressure	Pollutant reduction or elimination	2 4 5 6 12	Farmyard management to prevent runoff to watercourses (Section 5.1). Appropriate application of P fertiliser (organic & inorganic) (Section 5.3). Use of precision technology (Section 5.4). Management of farm roadways, drinking troughs, supplementary feeders and gateways (Section 5.5). Management of land reclamation (Section 5.12).
	Reducing mobilisation of pollutants on land	15 16 17 21 22 23 24	Liming of soils (Section 6.1). Timing of fertiliser applications (Section 6.2). Low emission slurry spreading (Section 6.3) Cover/catch crops (Section 6.7). Reducing soil compaction (Section 6.8). Land preparation for tillage and grassland (Section 6.9). Rewetting peat soils areas (Section 6.10).
Along the pollution pathway	Pathway interception	25 26 27 28 29 30 21 32 33	Riparian buffers (Section 7.1). In-field grass buffers (Section 7.2). Hedgerows (Section 7.3). Wild bird cover crops planted alongside watercourses (Section 7.4). Agroforestry (Section 7.5). Woodlands (Section 7.6). Drainage ditch management and sediment traps to reduce sediment losses (Section 7.7). Low earthen mounds/bunds (Section 7.8). Farm ponds and wetlands (Section 7.9).
At the polluted watercourse	Receptor/instream works	34	Livestock exclusion from watercourses (Section 8.1).

Table 7: An alternative categorisation of protection/mitigation options

Location in landscape	Category of action	Action	Protection/mitigation options
At the source of the pollution pressure	Pollutant reduction, or elimination	2	**Farmyard management (Section 5.1).**
		3	**Appropriate application of N fertiliser (Section 5.2).**
		4	**Appropriate application of P fertiliser (Section 5.3).**
		5	**Use of precision technology (Section 5.4).**
		6	**Management of farm roadways, drinking troughs, supplementary feeders and gateways (Section 5.5).**
		7	**Using low crude protein animal feeds (Section 5.6).**
		8	**Integrated weed management (Section 5.7).**
		9	**Proper storing, handling and disposal of chemicals (Section 5.8).**
		10	**Use of boom sprayers (Section 5.9).**
		11	**Weed-wiping application (Section 5.10).**
		12	**Petrol/diesel & waste oil management (Section 5.11).**
		13	**Management of land reclamation (Section 5.12).**
		14	**Organic farming (Section 5.13).**
	Reducing mobilisation of pollutants on land	15	**Liming of soils (Section 6.1).**
		16	**Timing of fertiliser applications (Section 6.2).**
		17	**Low emission slurry spreading (Section 6.3).**
		18	**Use of protected urea (Section 6.4).**
		19	**Multi-species grassland swards (Section 6.5).**
		20	**Red and white clover (Section 6.6).**
		21	**Cover/catch crops (Section 6.7).**
		22	**Reducing soil compaction (Section 6.8).**
		23	**Land preparation for tillage and grassland (Section 6.9).**
		24	**Rewetting peat soils areas (Section 6.10).**
Along the pollution pathway	Pathway interception	25	**Riparian buffers (Section 7.1).**
		26	**In-field grass buffers (Section 7.2).**
		27	**Hedgerows (Section 7.3).**
		28	**Wild bird cover crops planted alongside watercourses (Section 7.4).**
		29	**Agro-forestry Section 7.5).**
		30	**Woodlands (Section 7.6).**
		31	**Drainage ditch management and sediment traps (Section 7.7).**
		32	**Low earthen mounds/bunds (Section 7.8).**
		33	**Farm ponds and wetlands (Section 7.9).**
At the polluted watercourse	Receptor/instream works	34	**Livestock exclusion from watercourses (Section 8.1).**
		35	**Bank stabilisation (Section 8.2).**
		36	**Removal of riparian invasive species (Section 8.3).**

Notes:

- Farmyard management Actions highlighted as brown shading.
- Nutrient management Actions highlighted as yellow shading.
- Land Management Actions highlighted as blue shading.
- Pesticide Management Actions highlighted as grey shading.

4 Farmer engagement and collaboration

<table>
<tr><th colspan="2">Farmer Engagement and Collaboration</th></tr>
<tr><td>Target pollutants</td><td>❖ All farm-based microbiological, chemical and physical pollutants, both naturally occurring, or occurring as a consequence of human actions, that are within the catchment and can negatively impact on a water source.</td></tr>
<tr><td>Description</td><td>❖ Farmers are one of a number of stakeholders within the catchment. Many such farmers are GWS members, while others may not be. As custodians of the land, farmers can play a vital role in protecting drinking water sources. The GWS sector respects this important role <u>and wants to work with farmers and other stakeholders to protect drinking water sources.</u>
❖ The group water scheme sector plays a unique role in the fabric of rural Ireland. GWSs are community owned and community managed. Established to provide water to families and their farm, GWSs continue to have a positive and essential impact on the daily lives their members.
❖ The overarching philosophy of the GWS sector is to work in partnership with farmers and other agencies in identifying pollution pressures and the pollutant pathways to water sources. We aim to assist individual group water schemes work with farmers, helping them implement solutions that will protect drinking water sources that are the lifeblood of rural communities, including farmers and their families.
❖ Everyone has a shared responsibility to protect water quality.</td></tr>
<tr><td>Land use</td><td>❖ All farmland.</td></tr>
<tr><td>Methods</td><td>Setting the scene
❖ The benefits of agricultural discussion groups, information meetings and farmers learning from each other has been used to great effect in Ireland since the early 90s. This mitigation Action aims to utilise existing social relationships and organisational structures in building understanding of the importance of water and how it can best be protected. This can be done in the following ways:
o Farmer discussion groups
o Catchment information meetings
o Interaction with the GWS, LAWPRO and the local ASSAP advisor
o Attendance at the GWS Annual General Meeting and other GWS events.
o Participating in a number of new awareness initiatives.
❖ The NFGWS has developed aids to assist communities identify activities that can impact a drinking water source. It has developed “Let it Bee” and “I’ve planted a tree and my garden is pesticide free” initiatives. Families within the source catchment and GWS supply area that agree to stop using pesticides in their gardens are given a native woodland tree to plant. Details of these initiatives are included in Appendix 3, while further information is available from: https://nfgws.ie/category/source-protection/
❖ A collaborative approach involves talking and listening. Farmers know their land better than anyone else.
❖ Information in the Framework document.
❖ It is important to seek advice from other experts such as ASSAP, LAWPRO and/or LAs if needed.
Recognition
❖ Publicly recognising the impact of the work that the farmer has done is important. It will encourage others to participate.</td></tr>
</table>

Key locations	❖ All locations within a catchment that may impact on a GWS source. It is important to state that the locations may be outside the boundary of the GWS supply zone.
Water quality benefits	❖ Our primary objective is to protect and/or improve the quality of the GWS water source for the members, families and others within the community.
Additional environmental benefits	❖ Many of the solutions may involve nature-based solutions that will enhance local biodiversity and have a positive climate action impact.
Farmer benefits	❖ These will include, but are not be limited to: o shelter for livestock. o river bank stabilisation and a reduction in soil loss from erosion. o potential alleviation of flooding. o improved soil conditions. o improved animal welfare ❖ Positive action will be promoted within the community.
Cost	❖ The costs associated with this measure are low. The GWS may be able to provide some assistance, as this action is directly protecting the water source. ❖ Many information and collaboration events are being organised directly by the local GWS, ASSAP and LAWPRO advisors and others. The most significant cost is the farmer's time.
Maintaining regular engagement and collaboration	❖ The relationship between the GWS and the farming community is longstanding and continues to be important. GWS representatives working with farmers must realise that farmers have different competing pressures for their time. Equally, farmers must recognise that they have an obligation to protect water quality. Regular communication between the GWS and the farmer is essential to develop and maintain positive working relationships.
Limitations	❖ Actions need to be located in optimum areas for water quality benefits.
Additional information	❖ https://nfgws.ie/category/source-protection/ ❖ https://www.teagasc.ie/rural-economy/farm-management/collaborative-farming/ ❖ https://www.agriculture.gov.ie/farmerschemespayments/knowledgetransferktprogramme/ ❖ https://thewaterforum.ie/app/uploads/2020/03/Water-Forum_Briefing-Note_Public-Engagement-1.pdf

David Nally, farmer, and Noel Carroll, GWS manager, discussing mitigation options (Photo: NFGWS)

Discussion between farmers and scientists at a swallow hole in Roscommon (Photo: NFGWS).

5 Actions to reduce or eliminate the pollutants

The following Actions are described in this Section:

1. Farmyard management to prevent runoff to watercourses and/or infiltration to groundwater (Section 5.1).

2. Appropriate application of nitrogen (N) fertiliser (organic & inorganic[2]) (Section 5.2).

3. Appropriate application of phosphorus (P) fertiliser (organic & inorganic) (Section 5.3).

4. The use of precision technology (Section 5.4).

5. Management of farm roadways, drinking troughs, supplementary feeding points and gateways (Section 5.5).

6. Using low crude protein animal feeds (Section 5.6).

7. Proper storing, handling and disposal of chemicals (Section 5.7).

8. Integrated weed management (Section 5.8).

9. Use of boom sprayers (Section 5.9).

10. Weed wiping application (Section 5.10).

11. Petrol/diesel & waste oil management (Section 5.11).

12. Management of land reclamation (Section 5.12).

13. Organic farming (Section 5.13).

[2] Examples of organic fertilizers are manure, slurry and sewage sludge, while inorganic fertilizers are sometimes referred to as synthetic or artificial fertilizers.

5.1 Farmyard Management

Farmyard Management	
Target pollutants	❖ Phosphorus, Biological Oxygen Demand (BOD), ammonium, sediment, MCPA, pesticides, manganese, and microbial pathogens[3]
Description	❖ Ensuring that farmyard practices and infrastructure don't negatively impact water quality. ❖ Compliance with Article 17 of GAP Regulations. ❖ Generation and storage of dirty water, manure, slurry, silage effluent ❖ Storage of pesticides and filling of sprayers
Land use	❖ Farmyards are more likely to be problematical for surface water in poorly-draining areas. Besides having greater runoff potential, the presence of a high density of streams and ditches in such areas increases the likelihood that farmyards are in close proximity to watercourses. ❖ Dairy farmyards are likely to pose a greater threat than drystock farmyards, given that cattle and sheep are not in farmyards for a significant portion of the year, while cows move from fields to the milking parlour twice daily for most of the year. Dairy farmyards therefore generate a significant volume of soiled water from washing down of yards, milking machines and parlours etc. ❖ In freely draining areas where bedrock is close to the surface, leakage of silage effluent to groundwater can cause high manganese concentrations and infiltration of soiled water can result in entry of microbial pathogens.
Methods	❖ Adequate design, construction, operation and maintenance of all facilities so that there are no losses of pollutants to water. ❖ Adequate storage for slurry, dirty water and silage effluent. ❖ Keep soiled water to a minimum: o Divert all clean water to a clean water outfall using roof gutters and interception channels & prevent clean water from becoming soiled. ❖ Ensure effluent from silage pits is captured. ❖ Fill pesticide sprayers away from surface water, drainage gullies and bedrock areas as a precaution. Water used to clean sprayers after use must be captured. ❖ Piping and covering over ditches in the vicinity of a farmyard reduces the likelihood of ingress of pollutants. ❖ Appropriate channelling of soiled water to storage tanks. ❖ Several further measures for farmyards are contained in the GAP Regulations – see summary in Appendix 1. Useful information on managing farmyards is also provided in the DAFM guidance on the GAP Regs – see link below.
Key locations	❖ Alongside watercourses and drainage ditches, where runoff to surface water can occur most readily. ❖ Where bedrock is at, or close to, the ground surface, potentially resulting in infiltration of pollutants to groundwater.
Water quality benefits	❖ 100% reduction in pollutant losses should be the objective and is feasible. ❖ Farm wells will not be impacted by microbial pathogens or by manganese from leaking silage effluent.

[3] Descriptions of the pollutants are given in Appendix 2 and in the NFGWS Framework for Drinking Water Source Protection.

Maintenance	❖ Checking of silage slabs and undertaking sealing repairs if necessary ❖ Checking nearby drainage ditches/watercourses for evidence of pollution shown by sewage fungus, algae and turbid coloration; locating the pollution source; and undertaking the required mitigation works.
Additional environmental benefits	❖ Reduced ammonia emissions to air.
Farmer benefit	❖ Helps ensure compliance with the Basic Payment Scheme (BPS) conditions and the GAP Regulations
Costs	❖ Extensive farmyard refurbishments can have a high capital cost, but significant grants are available.
Maintenance	❖ Regular farmyard maintenance is necessary to ensure this action succeeds.
Limitations	❖ Ensuring no losses from farmyards alone will generally not solve water quality problems; diffuse sources are often more important.
Additional information	❖ Chapter 2, Volume 2 in Local Catchment Assessment Guidance at this link: https://wfd.edenireland.ie/help/help for general information. ❖ Appendix 6 in the NFGWS Framework for Drinking Water Source Protection (2019). ❖ https://www.teagasc.ie/publications/2019/farmyard-management-to-avoid-pollution-for-the-winter-ahead.php ❖ https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/nitrates/2018Nitratesexplanatoryhandbook03042018.pdf
Comments	❖ Prevention of pollution from farmyards should be an early win in a source water protection strategy. While challenging, particularly for older farmyards and where a lot of wash water is produced, it is a good starting point and will result in compliance with the Regulations. ❖ Farm wells in proximity to farmyards are at risk to pollution by manganese if silage effluent if allowed enter bedrock.

A cracked silage effluent channel allowing leakage (Photo: Andrew Holmes).

(Acknowledgement: Photo copied from Chapter 2, Volume 2 in Local Catchment Assessment Guidance which can be accessed at this link: https://wfd.edenireland.ie/help/help .)

5.2 Appropriate applications of nitrogen fertilisers

Appropriate Application of Nitrogen Fertilisers (organic and inorganic)	
Target pollutants	❖ Nitrate (NO_3) and ammonium.
Description	❖ The application of nitrogen (N) on the land by chemical fertiliser and organic manure applications, as well as by grazing animals, is a critical factor in losses to water in freely draining areas. ❖ Nitrate is mobile in such areas, is easily leached from the soil and can readily impact on water if the losses are above a certain amount/load. ❖ The maximum concentration for nitrate in the drinking water regulations is 50 mg/l (11.3 mg/l as N); the guide value given in the NFGWS Framework is 28 mg/l (6.3 mg/l as N (mean)); the groundwater threshold value (TV) is 37.5 mg/l (8.5 as N (mean)}; the coastal water Environmental Quality Standard (EQS) is 2.6 mg/l as N. ❖ Leaching of nitrate is higher in fields with grazing animals than in silage or tillage fields. This is due to losses from urine patches. ❖ Less than 30% of applied nitrogen is taken up by grass on intensive farms, so for every 4 kg of N applied, only 1 kg is recovered as milk or meat. A proportion of the remaining 70+% will be lost through leaching to groundwater. ❖ For instance, in the ZOC of a well or spring, where the annual infiltration is 500 mm, a loss of 40 kg/ha will mean exceeding the TV of 8.5 mg/l in the groundwater. This is a relatively small proportion of the N applied on intensive farms. ❖ The reduction that is required in the amount of N lost to water in kg/ha across the catchment area of a watercourse or ZOC of a groundwater source can be estimated by loadings analysis (see Appendix 2). ❖ Farmers who wish to farm at higher stocking rates, above 170 kg livestock manure nitrogen/ha, must apply to the DAFM for a nitrates derogation.
Land use	❖ Both grassland and tillage crop areas in freely draining areas.
Methods	❖ Applications need to be proportionate to the needs of the crop. ❖ Nitrogen requirements should match stocking rates. Check this beforehand at the Teagasc link below. ❖ It is important to take account of the N availability contained in organic fertiliser applications. ❖ Use protected urea instead of urea and CAN (see Section 6.4). ❖ It is essential to have sufficient slurry storage capacity to meet the GAP requirements (see Appendix 1). ❖ Where mobilisation control measures are not adequate, reductions in LUs (livestock units) may be necessary to reduce the losses sufficiently. These should be targeted to the high nitrate pollution impact potential (PIP) areas (see Appendix 2). ❖ For those farmers that are availing of a nitrates derogation, compliance with conditions designed to protect the environment is essential.
Key locations	❖ For nitrate, freely draining soils and subsoils in general and high nitrate PIP areas, in particular ❖ Catchment areas of estuaries & coastal waters with excessive nitrate ❖ Catchment areas of drinking water sources with high nitrate ❖ For ammonium, poorly draining soils and subsoils.

Water quality benefits	❖ These depend on the scale of reduction in N application, but the benefits are potentially substantial.
Additional environmental benefits	❖ Greenhouse gas emission reductions.
Farmer benefit	❖ Loss of N to water is a waste of farmers' money.
Limitations	❖ Calculating the means of achieving the required N loading reduction is complex and precision may not be achievable.
Potential concerns and solutions	❖ Farmers may fear that by using less nitrogen, crop performance and productivity will be adversely affected. See Table 3 for potential solutions.
Additional information	https://www.teagasc.ie/media/website/publications/2020/Major--Micro-Nutrient-Advice-for-Productive-Agricultural-Crops-2020.pdf https://www.teagasc.ie/crops/soil--soil-fertility/grassland/ https://www.teagasc.ie/media/website/publications/2016/Beef-Manual-Section5.pdf See page 114 in LAWPRO course notes at: http://lawaters.ie/technical-resources/ https://www.agriculture.gov.ie/ruralenvironmentsustainability/environmentalobligations/nitrates/nitratesderogation/2020nitratesderogation/
Comments	❖ Reduction in N loading may be the only option to achieving the required concentrations where mobilisation control measures are not sufficient. ❖ It is important that application rates do not exceed that required for the stocking rates. See the Teagasc recommended rates at the links above.

Spreading of inorganic fertilizer (Photo: Teagasc)

5.3 Appropriate applications of phosphorus fertilisers

Appropriate Applications of Phosphorus Fertilisers (organic and inorganic)	
Target pollutant	❖ Phosphate (PO_4).
Description	❖ The application of phosphorus on the land by chemical fertiliser and organic manure applications and by grazing animals is a critical factor in losses to water in poorly draining areas. ❖ Phosphate is relatively immobile in soils and is not readily leached, but its availability means that it can be easily washed off into watercourses. ❖ Unlike mineral soils, peaty soils cannot store P and, therefore, losses can readily occur if it is over-applied. ❖ PO_4 impacts on water quality even at very low concentrations. The Environmental Quality Standard (EQS) for good status water bodies is 0.035 mg/l (similar to the guide value in the NFGWS Framework) and 0.025 for high status water bodies. ❖ Therefore, it takes very little to cause water quality impacts – 1 kg phosphorus when present as phosphate will pollute 29,000,000 litres of water (or 6.4 million gallons). Therefore, where between 20-30 kg P/ha is applied, a loss of 1-5% to a watercourse may cause eutrophication. ❖ The reduction in the amount of P lost to water in kg/ha in the catchment area of a watercourse that is needed to reduce the concentrations to the required levels can be estimated by loadings analysis (see Appendix 2).
Land use	❖ Both grassland and tillage crop areas in poorly draining areas and on peaty soils.
Methods	❖ Applications need to suit the crop needs in terms of amount. ❖ Soil testing (every 4 years) and fertiliser planning is essential. ❖ Achieving soil P index 4 should be avoided. ❖ Take account of the P loading in organic fertilisers being applied. ❖ It is essential to have sufficient slurry storage capacity to meet the GAP requirements (see Appendix 1). ❖ Soil P index 3 is the optimum for soil and crop management on intensive farms. However, losses to water can occur and cause the Environmental Quality Standard (EQS) to be exceeded. ❖ Soil P index 1 and 2[4] may be sufficient for the crop needs of extensive farms. Therefore, attempting to achieve Index 3 should be avoided. ❖ For peaty soils, regular low rate applications are recommended rather than a single high rate application. Such applications should coincide with conditions that ensure maximum plant P uptake.
Key locations	❖ Poorly draining soils and subsoils ❖ Peaty soils ❖ High PIP areas for phosphate to surface water.
Water quality benefits	❖ In general, the lower the soil P index the lower the concentration of PO_4 in runoff water. However, even when the soil P Index is 2 or 1, sufficient losses may occur in poorly draining areas to exceed the EQSs for watercourses. ❖ Significant when P Index 4 areas are reduced in poorly draining areas.

[4] The P index depends on the level of available P in soil. There are four soil P indices, with soil P index 4 indicating the highest level of available P and 1 the lowest. See information at: https://www.teagasc.ie/crops/soil--soil-fertility/soil-analysis/soil-index-system/

Additional environmental benefits	❖ Increased aquatic life in rivers, lakes, restoring and improving ecosystems and providing potential for recreational and amenities benefits ❖ Reduced proliferations of problematic species which thrive on nutrient enrichment.
Farmer benefits	❖ Losses of P to water is a waste of farmers' money and means loss of a valuable nutrient source
Limitations	❖ Using soil P index 3 as an environmental target is not recommended, as losses in poorly draining areas are likely to be sufficient to breach the EQS unless there is substantial dilution from surrounding extensive farming or afforested areas. Interception of P is usually needed.
Potential concerns and solutions	❖ Farmers may fear that using less P on poorly draining soils will impact adversely on crop performance and that productivity will be affected.
Additional information	❖ https://www.teagasc.ie/media/website/publications/2020/Major--Micro-Nutrient-Advice-for-Productive-Agricultural-Crops-2020.pdf ❖ https://www.teagasc.ie/media/website/publications/2016/Beef-Manual-Section5.pdf ❖ https://www.teagasc.ie/publications/2020/phosphorus-use-on-peat-soils-.php ❖ https://www.teagasc.ie/media/website/crops/soil-and-soil-fertility/Efficient-Use-of-Phosphorus-In-Agriculture-Tech-Bulletin-No.-4.pdf ❖ See page 114 in LAWPRO course notes at: http://lawaters.ie/technical-resources/
Comments	❖ While nutrient management planning to achieve a certain soil P index is an important approach to determining losses of P to water, this approach on its own is unlikely to be sufficient in poorly draining areas to prevent concentrations above the EQS. Pathway interception Actions will usually be needed in addition to nutrient management planning (see Table 6 and Section 7 for suitable Actions).

5.4 Use of precision technology

<table>
<tr><th colspan="2">Precision Technology</th></tr>
<tr><td>Target pollutants</td><td>❖ Nitrogen, phosphorus, ammonium, pesticides.</td></tr>
<tr><td>Description</td><td>❖ GPS-based applications in precision farming are being used for farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications and yield mapping. Use of GPS Technology reduces any overlap when applying fertilisers, slurry and pesticides.
❖ Variable rate application management systems work in tandem with crop analysis, fertiliser application, pesticides, etc. to ensure that the precise quantities required are applied in the exact locations required by the crop.</td></tr>
<tr><td>Land use</td><td>❖ All farmland</td></tr>
<tr><td>Methods</td><td>Appropriate application of fertilisers
❖ There is substantial within-field variability in soil fertility and precision farming is essential to optimise inputs and returns. The use of precision farming in tandem with soil sampling is essential to obtain an accurate measure of the underlying variation in a field.
❖ Using the results, colour coded maps are produced showing the variation in nutrient levels across the field. The maps are then used to create recommendations for:
o variable rate fertiliser application using the Global Positioning System (GPS) to apply a precise quantity of fertiliser in every hectare.
o one-off applications, using precision farming, of chemical fertiliser in easily identifiable areas of low fertility.
o Adjusting or eliminating flat rate applications where there is minimal variation in soil fertility.
Appropriate application of slurry
❖ Slurry is an important source of N, P & K and its effective use on farms can help to balance soil fertility levels and offset expensive chemical fertiliser costs. To maximise the nutrient value of cattle slurry and reduce N loss to the air a number of decisions must be made.
1. Where on the farm should slurry be applied to maximise slurry P and K benefits?
2. When is the most efficient time to apply slurry to maximise N recovery?
❖ Targeted application of slurry in the early growing season, or at silage closing time, based on soil test results, will ensure the most efficient use of the slurry N, P and K by grassland. The typical value of 1,000 gallons of cattle slurry applied by low emission slurry spreading (LESS) method (see Section 6.3) in springtime has an available N-P-K content equivalent to a 50 kg bag of 9-5-32. The main methods of application are:
o Dribble bar/band spreading.
o Trailing shoe.
o Shallow injection.
o Umbilical systems.
Appropriate application of Pesticides
❖ Automatic Section Control (ASC) is a technology that has reduced pesticide over-application.
❖ Sprayed areas are constantly monitored using GPS, with boom sections being turned on and off to compensate.
❖ There is accurate headland shut-off, thereby reducing over spray.</td></tr>
</table>

	❖ The sprayer automatically slows to reduced speeds. The pulsating system increases the size of the water droplets in the spray to keep pesticides from drifting in the air. The boom will self-level according to plant height, helping them float the right distance above the plants so that the spray reaches the leaves and doesn't drift. ❖ Mobile Apps are available to assist with pesticide mixing rates – enter field size, spray volume, tank size and product use rates and receive rate per acre, per tank and per field for accurate documentation and compliance.
Key locations	❖ All farmland
Water quality benefits	❖ Precision technology will help in applying the correct amounts of fertilisers, slurry and pesticides, thereby reducing excess application rates, surface runoff to watercourses and leaching to groundwater. ❖ Likely reduction in phosphate, nitrate, ammonium and pesticides in water
Additional environmental benefits	❖ Reduced carbon footprint. ❖ Less ammonia losses to air. ❖ Reduced adverse impacts on biodiversity and wildlife from pesticides.
Farmer benefits	❖ Better crop return through targeted application of product. ❖ Reduced input costs. ❖ Minimises redundant applications, skipped areas and overlapping. ❖ Eliminates the need for markers, increases spray efficiency and minimises over-spray. ❖ Improved environmental and economic performance of slurry management by using low emission slurry spreading (LESS) method.
Cost	❖ Costs of investment in GPS technology starts from €900, but can reach over €7,000 depending on the accuracy required. ❖ Investment in LESS equipment currently qualifies for DAFM grant assistance under Targeted Agricultural Modernisation Schemes (TAMS). ❖ Many agricultural contractors have already invested in this technology and therefore is available to the farmer at little if any additional cost.
Maintenance	❖ Calibration and maintenance as per manufacturer's guidelines. ❖ Updates for GPS Systems.
Limitations	❖ Access to grants for LESS equipment is conditional. ❖ Calibration of equipment is required. ❖ Access to a broadband internet connection is necessary for updates. ❖ Availability of locally-based contractors with this equipment.
Potential Concerns & Solutions	❖ Advanced technology can be difficult to keep up with, but training and setup is provided by all manufacturers and suppliers.
Additional information	❖ https://www.teagasc.ie/crops/crops/advisory/better-farms/ ❖ https://www.teagasc.ie/media/website/publications/2017/Precise-Application-Booklet-Final.pdf ❖ https://www.teagasc.ie/publications/2020/spread-accurately-and-evenly.php ❖ https://www.teagasc.ie/publications/2020/spreading-the-benefits--low-emission-slurry-spreading-less.php

5.5 Management of farm roadways, drinking troughs, supplementary feeding points and gateways

Management of farm roadways, drinking troughs, supplementary feeding points and gateways	
Target pollutants	❖ Microbial pathogens, sediment, phosphate, ammonium and BOD
Description	❖ Farm animals urinate and defecate on farm roadways and around drinking troughs, supplementary feeders and gateways. This results in emissions that are similar to those arising from dilute slurry or soiled water. ❖ On tillage farms, sediment is often deposited by farm machinery. ❖ Farm roadways are relatively impermeable. Therefore, after rainfall they form a pathway on which pollutants can readily be washed into watercourses and drainage ditches in the vicinity, particularly where the roadway is sloping and/or is crossing a watercourse or drainage ditch. ❖ In general, roadways on dairy farms are likely to be a greater threat to water quality in view of their regular usage. ❖ On poorly draining soils, poaching can occur around drinking troughs and supplementary feeders. This increases the likelihood of runoff and transport of accumulated pollutants to surface watercourses. Likewise, nutrients and sediment can be concentrated at gateways. ❖ Under the GAP Regulations, from the 1st of January 2021 no direct runoff of soiled water from farm roadways is allowed into watercourses or dry drainage ditches. In addition, direct runoff of soiled waters resulting from poaching is not allowed. Furthermore, supplementary feeding cannot be located within 20m of a watercourse, nor on bare rock. See summary in Appendix 1. ❖ On holdings with stocking rates of 170 kgs or more, bovines are not allowed to drink directly from watercourses, while supplementary drinking points must at least 20m from watercourses.
Land use	❖ All land uses.
Methods	❖ The DAFM "Minimum Specification for Farm Roadways' (S.199 July 2020) should be followed (see link below). The options listed to prevent overland sediment and nutrient runoff include cambering of the roadway to direct water to one side and away from the watercourse, putting in a berm of soil along the side and piping runoff to a sediment trap/pond or directly on to land. Farmers are advised to avoid laying a new roadway adjacent to a watercourse and, where there is no option, to have a 1.5m grass margin alongside. Detailed specification drawings are included, as are details on sediment traps. ❖ The GAP Regulations should be complied with. ❖ To break the hydrological link, supplementary feeders should, if possible, be repositioned regularly to more freely draining areas and as far as practicable from watercourses and drainage ditches. On land that is easily poached, consideration may need to be given to constructing hard standing areas. ❖ If gateways are known to contribute pollutants (for instance those at the bottom of slopes and near watercourses), they should, if practicable, be repositioned upslope and away from watercourses and drainage ditches.
Key locations	❖ In poorly draining areas in catchment areas of surface water sources ❖ In freely draining, extremely vulnerable areas in ZOCs of groundwater sources

Water quality benefits	❖ The scale of benefits will depend on the density of these features in the catchment area/ZOC of a drinking water supply. However, as they address what can be a significant threat, the recommended actions are very likely to be beneficial.
Farmer benefits	❖ Less poaching of productive land ❖ Compliance with the GAP Regulations
Cost	❖ These will vary depending on the work needed.
Maintenance	❖ Farm roadways will need to be maintained.
Limitations	In most situations, diffuse sources are likely to be principal causes of impacts. However, dealing with these point sources is likely to be beneficial.
Additional information	❖ https://www.teagasc.ie/publications/2020/what-is-in-farm-roadway-runoff.php ❖ https://www.teagasc.ie/publications/2020/farm-roadway-quality-indicators.php ❖ https://www.teagasc.ie/media/website/publications/2020/Buildings---New-regulations-on-farm-roadways-and-waters.pdf ❖ https://www.teagasc.ie/media/website/publications/2017/Dairy-Farm-Infrastructure-Handbook-Moorepark2017-(V3).pdf ❖ https://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/tamsx2ffarmbuildings/farmbuildingspecifications/pdfversions/S199July2020200720.pdf

Runoff from the farm road is channelled into the sediment trap on the left (Photo: Donal Daly).

5.6 Using low crude protein animal feeds

Using Low Crude Protein Animal Feeds	
Target pollutant	❖ Nitrate.
Description	❖ The crude protein (CP) content of animal feed is important for both milk production and animal welfare. Average Irish dairy cows have a requirement for a diet with a CP content of 15-17%. ❖ Of the N fed to cows, 20-30% is exported from the farm as milk and meat; therefore 70-80% is excreted as faeces and urine. Much is lost to the air as ammonia with some leached to groundwater as nitrate, particularly from urine patches. ❖ Reducing the crude protein in dairy cow diets by 3-4% could significantly reduce the nitrogen (N) excretion in urine by 45%. ❖ For pigs, every 1% decrease in crude protein reduces ammonia by 10%. ❖ Diet reformulations can reduce N excretions without affecting milk yields. ❖ Nitrates derogation will require crude protein of 15% in concentrate feeds between the 1st of April and the 15th of September 2021.
Land use	❖ Freely draining grassland used for dairying (mainly) and tillage areas that utilise organic fertilisers from pigs and chickens.
Methods	❖ A silage test can be used to determine the protein and energy content of silage. This will determine the amount of supplementary feed needed. ❖ A milk urea test will show where there is excess protein in the diet – excess protein is broken down into urea and excreted in the urine. ❖ The protein content in herbage can be managed through various techniques, such as balanced nitrogen fertilisation and grazing/harvesting the grass at a later growing stage. ❖ Use a lower-protein ration, which has a lower N content. For instance, rolled barley is a high-energy, high-starch, low protein (10-11% CP) ration.
Key locations	❖ For nitrate, freely draining soils and subsoils in general and high nitrate Pollution Impact Potential (PIP) areas in particular (see Appendix 2). ❖ Catchment areas/ZOCs of drinking water sources with high nitrate. ❖ Catchment areas of estuaries & coastal waters with excessive nitrate.
Water quality benefits	❖ On an intensive dairy farm located in free draining soils, the benefits for groundwater could be significant.
Additional environmental benefits	❖ Ammonia reductions. ❖ Reduced reliance on imported feedstuffs, particularly from countries with low environmental standards. ❖ Increased sustainability of Irish agriculture.
Farmer benefits	❖ Reduced concentrate feed costs for farmer.
Limitations	❖ Needs appropriate analyses of grass and milk, as well as careful planning & management.
Additional information	❖ Code of Good Agricultural Practice for reducing Ammonia Emissions at: https://www.agriculture.gov.ie/ ❖ https://www.teagasc.ie/media/website/animals/beef/concentrate-feeds.pdf ❖ https://www.teagasc.ie/media/website/publications/2017/Beef-Newsletter-December-2017.pdf

Comments	❖ Barley is a suitable home-grown low crude protein source. In contrast, soya meal is an imported high protein (48% CP) ration, often sourced from South America.

5.7 Integrated weed management

Integrated Weed Management	
Target pollutants	❖ Herbicides including but not limited to MCPA, MCPP, 2,4-D, Clopyralid, Dichlorprop
Description	❖ Integrated weed management (IWM) is an approach to managing unwanted vegetation using multiple control techniques. The use of herbicides is one such technique, however sustainable biological, physical or other non-chemical methods are preferred to chemical methods if they provide adequate control. ❖ An IWM approach also has the potential to reduce the onset of herbicide resistance. Recently in Ireland, the presence of herbicide resistance in grass weeds has been noted.
Land use	❖ All farmland.
Methods	❖ Encouraging grass growth and improving soil drainage will in turn limit the existence of unwanted vegetation such as rushes. Specific methods/ mitigations relating to grassland management are described in Section 6. ❖ Where herbicide use is required, the relevant measures detailed in Sections 5.7 – 5.9 should be adhered too. ❖ Mechanical control measures can also prove successful in controlling unwanted vegetation. For example, topping, cutting or mulching rushes can be an effective means of limiting their spread. Cut rushes should be removed from the field to discourage regrowth.
Key locations	❖ Integrated weed management is a farm wide approach.
Water quality benefits	❖ Reduces the potential for toxic impacts in watercourses.
Additional environmental benefits	❖ Reduces the potential for damage to wildlife, in particular pollinators.
Farmer benefits	❖ Compliance with the Regulations ❖ No financial penalties through BPS ❖ Substantially lower usage of Pesticides resulting in lower product costs.
Cost	❖ See Sections 5.8, 5.9 and 5.10 for details on the costs associated with herbicide usage.
Maintenance	❖ See Sections 5.8, 5.9 and 5.10, which describe the maintenance required when using pesticides as part of the IWM approach. ❖ Routine soil sampling should be carried out to ensure that the correct fertility and pH conditions exist. ❖ Where drainage forms an integral part of the IWM approach, maintenance is required as the performance of drains will deteriorate overtime. For example, jetting may be required to remove a build-up of iron ochre deposits that can occur naturally in certain soil types.
Limitations	❖ Under certain conditions (e.g. fields with a high-water table), improving soil drainage maybe the only long-term solution to preventing rush infestation. Therefore, it is imperative that drainage is installed correctly so as not to create a preferential flow path for other contaminants (e.g. stone backfill should not be filled to surface level).

Potential Concerns & Solutions	❖ Spraying of Rushes is not permitted on land parcels/fields associated with the Low Input Permanent Pasture (LIPP) or the Traditional Hay Meadow (THM) option in GLAS. However, spot treatment is permitted in these GLAS areas. ❖ Herbicide/pesticide spraying is not permitted in any Special Areas for Conservation (SAC). However, rushes can be controlled by topping after the 15th July. It is advisable to consult the assigned GLAS Planner if considering any control of Rushes in land parcels involved in the GLAS scheme.
Additional information	https://www.teagasc.ie/publications/2018/controlling-rushes-and-protecting-drinking-water-go-hand-in-hand.php https://www.teagasc.ie/crops/crops/grass-weeds/grass-weeds-and-control/ https://www.teagasc.ie/media/website/environment/soil/Land_Drainage_A4_brochure_3.pdf https://www.teagasc.ie/media/website/publications/2013/Land-Drainage-Manual.pdf https://www.teagasc.ie/media/website/publications/2017/11-Herbicide-resistance-in-Irish-grass-weeds.pdf

Topping rushes – a mechanical control measure (Photo: NFGWS).

5.8 Proper storage, handling & disposal of chemicals

<table>
<tr><th colspan="2">Storage, Handling & Disposing of Chemicals</th></tr>
<tr><td>Target pollutants</td><td>❖ All pesticides – insecticides/herbicides/fungicides/rodenticides
❖ Veterinary/pharmaceutical products</td></tr>
<tr><td>Description</td><td>❖ The use of pesticides to target weeds, pests and fungi that may impact on agricultural crops, vegetables and grassland is common practice on most farms in order to ensure that production is not impacted or yields damaged during the growing season.
❖ In order to minimise the impact that these pesticides would have on water quality, care must be taken when storing, handling and disposing of each product.</td></tr>
<tr><td>Land use</td><td>❖ All farmland.</td></tr>
<tr><td>Methods</td><td>Storage of Chemicals
❖ The structure of the storage facility shall be such that:
i) it is not connected to a pack-house or area where food products are present.
ii) it is a dedicated chemical store and is not used for any purpose other than storage of pesticides and biocidal products and other chemicals.
iii) it is enclosed and of sound construction, has a secure lock and, in the case of walk-in stores, is well ventilated and well lit.
iv) shelving provided is made from non-absorbent materials.
v) a warning sign is displayed on the entrance to the store.
vi) there is correctly-sized bunding to contain any leakages or spillage.
❖ Facilities being used shall include at least:
i) a list of key emergency contact numbers displayed near the entrance of the store.
ii) recommended protective clothing and equipment, cleaned and properly maintained.
iii) a regularly calibrated weighing scales, designated and labelled for weighing pesticides.
iv) measures for liquid pesticides, designated and labelled for measuring pesticides only.
v) facilities for soaking up small spillages or leakages (e.g. a bucket of sand or peat).
❖ The operating procedures followed, shall include:
i) powders being stored separately from or above liquids.
ii) pesticides only being stored in their original containers.
iii) an appropriate area for measuring and mixing pesticides.
iv) The acquisition and storage of registered pesticides only.
Handling of Chemicals
❖ Take every precaution during mixing and preparation of pesticides to avoid spills and drips. Minimise water volumes (rain and washings) on the handling area.
❖ Ensure that all pesticide applications tasks are carried out by trained and qualified staff.
i) Know the location of drains, watercourses and vulnerable groundwater before spraying.
ii) Use personal protection equipment (PPE) – gloves, face protection, outer clothing and footwear.
iii) Ensure that all pesticide tasks are completed with care.
iv) Prepare pesticide solutions carefully, mixing, loading and cleaning equipment and containers in an area that is away from water sources and drains.</td></tr>
</table>

	v) To avoid runoff, do not apply pesticides when it is raining or when rain is forecast within 24 hours. vi) To prevent spray drift do not apply pesticides when it is windy (greater than 7 km/h). vii) Ensure that all equipment is properly maintained, is in good working order and is calibrated. viii) Have an emergency plan and kit available for any spillages. **Disposal of Chemicals & Containers** ❖ Triple rinse empty pesticide containers after use and wash container caps and threads. ❖ Inspect and fully drain the triple rinsed containers. ❖ Puncture empty pesticide containers. ❖ Purchase Farm Plastic Recycling Ltd. bags from your local co-op or agri-merchant. ❖ Place the triple rinsed, clean and punctured PPP containers and washed caps in the recycling bags. ❖ Recycling bags should be in a safe dry place while being filled. ❖ Take filled recycling bags to your local authorised bring centre. ❖ The location and dates of bring centres are available on the Farm Plastics Recycling website: www.farmplastics.ie
Key locations	❖ Farmyard – storage, mixing and filling areas ❖ Alongside watercourses ❖ In critical source areas, particularly in close proximity to watercourses, drains and drainage ditches where runoff is focused.
Water quality benefits	❖ Reduced amounts of pesticides will enter watercourses through surface runoff and groundwater as a consequence of leaching from both point and diffuse sources.
Additional environmental benefits	❖ Prevent damage to wildlife, pollinators, etc. ❖ Reduced potential for toxicity in watercourse
Farmer benefits	❖ Compliance with Regulation ❖ No financial penalties through DAFM support schemes ❖ H&S for farmer and those working on the farm while using Pesticides
Cost	❖ Storage Unit ❖ Personal Protection Equipment (PPE) ❖ Disposal costs are minimum if recycled
Maintenance	❖ Little maintenance required ❖ Good practice to carry out bund integrity testing every few years
Limitations	❖ Only effective if implemented properly by the end user
Potential Concerns & Solutions	❖ Training courses are available for anyone using pesticides.
Additional information	https://www.pcs.agriculture.gov.ie/media/pesticides/content/sud/professional/End%20User%20storage%20requirements%202014.pdf https://www.pcs.agriculture.gov.ie/media/pesticides/content/sud/Good_Practice_Guide_for_empty_pesticide_containers.pdf https://www.teagasc.ie/media/website/publications/2009/PesticidesCodeGoodPractice.pdf http://www.epa.ie/pubs/advice/drinkingwater/sourceprotectionleaflets/01987_EPA_PesticidesUse_leaflet_Proof_02.pdf

5.9 Use of boom sprayers

Application of Pesticides using Boom Sprayers	
Target pollutants	❖ All pesticides that are approved for use in boom sprayers
Description	❖ A professional user is any person who applies/sprays professional use pesticides, regardless of the quantity or the method of application. This includes operators, technicians, employees and self-employed people, both in the farming and other sectors. ❖ Since November 2015, only a DAFM-registered professional user can apply pesticides that are authorised for professional use. ❖ Since November 2016, it has been a requirement for sprayers to have passed a Pesticide Application Equipment Test before used applying professional use pesticides. ❖ Spraying pesticides (including fungicides, pesticides and herbicides) is considered a critical operation on most crop-producing farms. ❖ The products must be applied to the crop evenly and at the correct rate, with the appropriate spray quality (droplet size) in the correct volume of water and all at the right time. ❖ Loss of spray product to the environment through drift, spillages or incorrect sprayer cleaning has to be avoided.
Land use	❖ Tillage crops
Methods	❖ Users must always read and follow instructions on the product label and must comply with buffer zones. See STRIPE documentation at link below. They are also required to comply with safeguard zones around drinking water sources. ❖ The sprayer, whether it is a large new trailed sprayer costing €75,000 or a second-hand unit costing €3,000, has the task of applying the product evenly. While a sprayer consists of a tank, pump, boom and other components to load and clean the spray solution, the nozzles and a pressure gauge are key components. ❖ For further information on: i) rates of application of pesticides; ii) nozzles; iii) pressure gauges/transducers and forward speed sensors; iv) sprayer control systems, filling, filtration, cleaning and newer technologies, check Teagasc advice at: https://www.teagasc.ie/crops/crops/machinery-/using-sprayers-efficiently/
Key locations	❖ Poorly draining areas where weed cover develops and surface runoff occurs ❖ Alongside watercourses (outside of the 5m buffer. ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused ❖ Farmyard – hard standing areas, filling and cleaning areas, field entrances ❖ Spraying under electric fences should not be undertaken in the vicinity of drainage ditches and watercourses.
Water quality benefits	❖ Reduces the potential for toxic impacts in watercourses ❖ Targets specific weeds without killing/damaging non target pollinators (a consequence of using certain acid herbicides).
Additional environmental benefits	❖ Reduces the potential for damage to wildlife and pollinators in particular

Farmer benefits	❖ Compliance with the Regulations ❖ No financial penalties through BPS ❖ Substantially lower usage of pesticides resulting in lower product costs
Cost	❖ Cost will depend on area of land and amount of pesticides used. Larger sprayers will cost most, whereas smaller or second-hand sprayers will cost significantly less. However, all sprayers over 5-years-old will need to pass a Pesticide Application Equipment Test. ❖ The annual spend for a standard programme of plant protection products can vary from approximately €170/ha for spring barley to €300/ha for winter wheat. ❖ Many smaller farmers will use the services of an agricultural contractor to apply pesticides on their land.
Maintenance	❖ Maintenance of sprayers should be completed as per manufacturers guidelines and SUDs legislation. See Method Section. ❖ Equipment needs to be calibrated and tested by a qualified inspector.
Limitations	❖ Pesticide users are obliged to take appropriate measures to protect water at all times. ❖ Weather conditions – wind and rain can be unpredictable and difficult to work around.
Additional information	https://www.teagasc.ie/crops/crops/machinery-/using-sprayers-efficiently/ https://www.pcs.agriculture.gov.ie/sud/professionalusersprayeroperators/ http://www.epa.ie/pubs/advice/drinkingwater/sourceprotectionleaflets/01987_EPA_Pesticides Use_leaflet_Proof_02.pdf https://www.teagasc.ie/media/website/publications/2009/PesticidesCodeGoodPractice.pdf https://www.pcs.agriculture.gov.ie/sud/waterprotection/stripe-surfacewatertoolforreducingtheimpactofpesticidesintheenvironment/
Comments	❖ Keeping up-to-date with various legislation is recommended.

5.10 Weed-wiping application

Weed-Wiping Application	
Target pollutants	❖ MCPA, 2,4-D, Glyphosate.
Description	❖ MCPA-based herbicide products are the principal source of pesticide contamination in Irish drinking water supplies. It is extremely persistent, especially in wet fields where it can pollute a watercourse more than a year after application. ❖ The use of glyphosate applied through a weed-wiping machine as a means of controlling rushes, eliminates the use of MCPA and 2,4-D herbicides. Glyphosate applied through a weed-wiper directly targets the weed, resulting in lower herbicide losses to water via runoff and spray drift. ❖ Only glyphosate is licenced for use in a weed-wiping apparatus. No other herbicides are permitted for use by this method and their use will result in Basic Farm Payment penalties. ❖ Pesticides impact on water even at very low concentrations. The drinking water limit is. Bearing in mind that the drinking water limit is 0.1µg/l, one litre of MCPA will pollute 1,000,000,000 litres (220 million gallons) of water.
Land use	❖ Fields with rushes, ragworth and dockleaf.
Methods	❖ Fill and clean the weed-wiping machine in accordance with advice in Section 5.7. Also see the advice at links in Additional Information below. ❖ The dilution rates specified on the product label should always be followed. Typically, 1-part water to 10-20 parts glyphosate is specified. ❖ Target weeds should be a minimum of 10cm taller than the grass sward. This ensures a sufficient application on problematic weeds and reduces the potential for grass kill. ❖ A risk assessment should be conducted prior to commencement, taking account of all watercourses/drainage ditches and excessively steep areas. A buffer distance of 5m must be maintained between the area of application and all watercourses/drainage ditches. Where land is steep the assessment must determine if it is safe to proceed without the risk of toppling over. ❖ Sufficient herbicide must be applied to the carpet/brush apparatus for an effective treatment. As land with a heavy weed cover will require more herbicide than land with lesser cover the volume required should be evaluated on a site-by-site basis. Additionally, in fields with dense weed infestations, it may be beneficial to wipe in several directions. ❖ Speeds in excess of 5kmph may not be suitable in rough terrain, as bouncing may lead to herbicide dripping and grass damage as a consequence. ❖ Weed-wiping should not be practiced during rainfall, or where rain is forecast. Similarly, weed wiping should not occur under damp ground conditions, as glyphosate transferred via machinery wheels may result in water contamination and sward damage. ❖ Note: It is imperative that the user follows all directions and precautions detailed on the product label. ❖ Caution: it was observed during the weed-wiping pilot project on Stranooden GWS that some products on the market do not account for

	modern 'new generation' weed wiping machines and specify a 1 in 1 dilution applicable to conventional wick wiping machines. This is too concentrated for weed-wiping apparatus.
Key locations	❖ Poorly draining areas where weed cover develops and surface runoff occurs ❖ Alongside drainage ditches and watercourses (outside of the 5m buffer) ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused.
Water quality benefits	❖ A likely reduction in contamination by acid herbicides. ❖ Reduced potential for toxic impacts in watercourses. ❖ Following a weed wiping pilot project trialled by NI Water in the Seagahan Reservoir catchment, Markethill, County Armagh, an MCPA concentration reduction of over 50% was observed in the reservoir when compared with the results from previous years.
Additional environmental benefits	❖ Targets specific unwanted vegetation without killing/damaging other plants that are important to pollinators
Farmer benefits	❖ Land will still be eligible for payment under the DAFM support scheme. ❖ Substantially lower usage of herbicides will result in lower herbicide costs. ❖ Positive action will be promoted within the community.
Cost	❖ Based on experience garnered from the weed-wiping pilot project at Stranooden GWS, glyphosate was applied by weed-wiper in fields of dense rush cover at a rate of 350 ml/ha. This compares to an MCPA requirement of 2.7 l/ha. The glyphosate costs is €3 per ha, while MCPA costs €15 per ha.
Maintenance	❖ In some settings, a repeat application in year 2 will be required. ❖ Low soil pH conditions will limit grass growth, thus allowing weeds and rushes to grow. Note, where unwanted vegetation is extensive, reseeding may be the most sustainable solution. ❖ Like boom sprayers, weed-wiping machines must be calibrated and tested by a qualified inspector.
Limitations	❖ Weed-wiping service providers are not as common as contractors offering boom spraying services. All contractors offering a weed-wiping service must have completed a dedicated course (i.e. separate to the boom spraying course). See details in the additional information link below. ❖ Weed-wiping should not be used to treat plants at a height lower than 10cm above the grass sward. ❖ Note the current approval of glyphosate will expire in 2022 and its renewal after this date is currently uncertain.
Potential Concerns & Solutions	❖ As glyphosate is a non-selective herbicide there is concern that it will kill the grass sward. The pilot project has shown that it is a very effective method and, when used correctly, there is a very low risk of grassland damage. It is vital that the apparatus is in good working order (i.e. calibrated) and is routinely checked for dripping. ❖ Landowners may be concerned about the cost of completing an additional specialised weed-wiping course. It should be noted that landowners who intend to use a weed-wiper solely on their own land holdings do not need to have completed the dedicated course. They must, however, have completed the boom spraying course and be registered as a professional user by DAFM.

Additional information	❖ https://www.pcs.agriculture.gov.ie/media/pesticides/content/products/320190327ControllingrushesusingweedwipersfinalIssue162019200120.pdf ❖ https://www.youtube.com/watch?v=V41cuNG0ycs ❖ https://www.niwater.com/weedwiping/ ❖ https://www.pcs.agriculture.gov.ie/sud/professionaluserssprayeroperators/
Comments	❖ Consult with your farm advisor as the starting point when considering the control of weeds/unwanted vegetation. ❖ Non-chemical control of weeds/unwanted vegetation should always be considered, as should integrated pest management controls.

A weed wiper (Photo: NFGWS).

5.11 Petrol/diesel and waste oil management

Petrol/diesel and Waste Oil Management	
Target pollutants	❖ Polycyclic Aromatic Hydrocarbons
Description	❖ Management of fuel and oil to mitigate the risk of them entering watercourses and groundwater.
Methods	❖ **Bunding of oil tanks** ○ Modern diesel tanks are required to be installed with a 'double bund'. This is where there is an outside tank or 'bund' that will catch the fuel/oil should the tank burst or be tampered with. ○ Spill kits to absorb and hold oil should be made available for unbunded tanks located in vulnerable areas. ❖ **Storage of oils** ○ Both new and waste oil should be stored in line with the manufacturers guidelines and should be kept in an area where the risk of damage is minimal. ○ Waste oil filters should also be treated with care and stored in a sealed container until they can be disposed of correctly. Filters should never be placed in your domestic bin. ❖ **Maintenance of equipment** ○ Machinery should be serviced & maintained on a level surface that has no direct link to a watercourse or drain. This is to prevent any spillages having a direct pathway to either surface or groundwater.
Key locations	❖ Appropriate location of storage tanks is essential. Most are located in farmyards. High risk locations are as follows: ○ Extremely vulnerable areas in the ZOC of a drinking water source (see Section A7.3.1 for further details). ○ Upgradient of private wells in farmyards. ○ Close to watercourses.
Water quality benefits	❖ Likely reduction in risk of hydrocarbons from fossil fuels entering watercourses.
Farmer benefits	❖ Reduces risk of fuel spills. ❖ Reduces risk of penalties under cross-compliance.
Cost	❖ Cost of a typical bunded 1,000-litre oil tank start around €700 but can be higher depending on features (e.g. pumping station).
Additional information	❖ http://www.epa.ie/pubs/advice/licensee/EPA_storage_transport_hazardous_materials.pdf

5.12 Management of land reclamation

Management of Land Reclamation	
Target pollutants	❖ Sediment, Total Phosphorus
Description	❖ Management of land reclamation (drainage) is an important aspect of overall catchment planning, as the changing of flood plains increases the speed of stormwater run-off and can result in greater nutrient loading.
Land use	❖ Areas where land reclamation is undertaken
Methods	❖ Drainage projects should be assessed and planned so that they do not have a detrimental impact on watercourses, as high sediment loads can be generated. ❖ Steps to alleviate impacts include: o ensuring that drainage stone and drainage pipes are covered by a good layer of soil to prevent slurry/fertiliser/sprays entering unimpeded into land drains. o building of sediment traps to prevent sediment entering watercourses. o obtaining professional advice when completing a project. ❖ Land drainage works on lands used for agriculture are covered by the EIA Regulations and controlled by the Department of Agriculture Food & Marine (DAFM). Such drainage works include the following: o Installing open drains o Installing closed field drains, such as those using plastic piping with drainage stones or field drains with drainage stone only, or mole drains (no pipe or drainage stone), or gravel-filled mole drains (no pipe, but filled with gravel) o Opening of a drain within a short distance of watercourse o For the purposes of the Regulations, the area will be considered to be the area of works (drains plus immediate vicinity) rather than the area of the field. o Screening by DAFM is required where drainage work exceeds 15 ha. The thresholds will be the areas of works undertaken in any one year or the sum of such areas over a five-year period. o You must not discharge or allow water contaminated with silt to enter a watercourse or drain, as it can cause pollution. o Protect all surface water drains and watercourses with cut-off ditches or earth bunds when completing initial works. These should be at least 10 metres from the watercourse and will act as a sediment trap during construction works. o Dredging or deepening channels (open ditches etc.) should take place when the drain is dry (if possible). If not, it should be ensured that water carrying excess sediment is not released directly into a watercourse. o Cleaning or deepening of stream/river channels should only take place in consultation with the NPWS in a Special Areas of Conservation (SAC) or Special Protection Area (SPA) or in the catchment of an SAC/SPA. Otherwise consult IFI. ❖ Advice should be sought for works in a SAC or environmentally-sensitive area.
Key locations	❖ Poorly draining fields ❖ Where drainage systems provide a direct link to a surface watercourse or groundwaters within a ZOC.
Water quality benefits	❖ Successful management of land drainage activities will reduce the entry of sediment and Total Phosphorus to watercourses.

Additional environmental benefits	❖ Reduced impacts on environment and wildlife from drainage projects ❖ Reduced losses of soil and nutrients from reclaimed area
Farmer benefits	❖ Design of an efficient and long-lasting drainage system increases productivity. ❖ Can decrease incidences of diseases contracted by livestock in wet areas (e.g. fluke)
Cost	❖ The cost of installing a land drainage system is high, but the cost of designing a drainage system in a catchment-sensitive fashion is not.
Additional information	❖ https://www.teagasc.ie/media/website/publications/2013/Land-Drainage-Manual.pdf ❖ Teagasc Manual on Drainage (available from the local Teagasc offices)

5.13 Organic farming

Organic Farming	
Target pollutants	Pesticides, nitrate.
Description	❖ Organic agriculture is a systems-based approach to agricultural production that is working towards an environmentally, socially and economically sustainable production. ❖ It is undertaken in accordance with standards and without the use of artificial pesticides or synthetic fertilisers on farmland or the use of pharmaceutical products, including antibiotics in livestock (other than in exceptional circumstances). ❖ It follows the principle of maintaining a healthy soil, through use of animal manure, compost, catch crops, green manure and other natural measures to introduce nutrients and organic material. Weeds and pests are controlled through crop rotation techniques, physical methods and the protection and enhancement of the natural enemies of pests, such as birds. ❖ The EU Biodiversity Strategy is to achieve 25% of agricultural land under organic farming by 2030.
Land use	❖ Land farmed organically
Methods	❖ To become organic, a producer must become registered with one of the certification bodies and the land has to be converted to organic production – typically a two-year process. ❖ There are two certification bodies – the Irish Organic Association and the Organic Trust. ❖ Farmers must prepare a conversion plan that includes soils analysis. ❖ During the conversion period, the enterprise must adhere to all the Organic Standards concerning animal welfare, artificial fertilisers, pesticides and chemicals. ❖ Farmers can avail of a DAFM grant during the conversion period. ❖ Inspections are undertaken annually prior to licence renewal. ❖ Synthetic chemicals, fertilisers, pesticides and herbicides are all prohibited under the scheme. Organic material must be used as manure. However, liming is permitted. ❖ Treatment of healthy animals and the routine use of prophylactic drugs is prohibited. Antibiotics are not generally permitted and fertility drugs are not allowed. ❖ Organic farmers must have specific knowledge of organic methods.
Key locations	❖ Catchment areas/ZOCs of drinking water sources with either high pesticide concentrations or high nitrate concentrations.
Water quality benefits	❖ As pesticides are not permitted, they will not be present in water arising from farmland. ❖ Reduced nitrate leaching to groundwater per unit area of land, due to the adoption of practices that should decrease losses: maximising periods of green cover, crop rotations, use of straw-based manure, lower stocking densities. However, for a similar level of production, the differences in nitrate losses between conventional and organic farming may be relatively small.

Additional environmental benefits	❖ Biodiversity enhancement from a wide variety of habitats and organic methods of weed and pest control ❖ Better soil health and soil biodiversity ❖ Reduced carbon dioxide emissions ❖ Greater energy efficiency as synthetic fertilisers are not used ❖ Overall, the environmental impact of organic farming is i) seldom worse than conventional farming, ii) is invariably better per unit area, and iii) is often better per unit yield.
Farmer benefits	❖ Satisfaction from farming using a system that is more environmentally-friendly than conventional farming ❖ Many of the organic methods are Green Low Carbon Agri-environmental Scheme (GLAS) measures. ❖ Premium market prices can increase profitability. ❖ There may be increased EU supports for organic farming in the future. ❖ Additional income from the Organic Farming Scheme payment.
Cost	❖ According to the DAFM, there are conversion costs that can vary widely and are influenced by the following factors: ○ output reduction due to changes in production practices. ○ capital investment in machinery, livestock housing, etc. ○ certification and inspection costs. ○ inability to command premium prices during the conversion period. ❖ However, farmers can avail of a DAFM grant during the conversion period.
Maintenance	❖ Organic farming is generally labour-intensive, to meet the requirements of the standards for organic production.
Limitations	❖ Lower yields than conventional farming generally, but yields can vary ❖ More labour-intensive ❖ Natural pest and weed controls demand time and effort to develop. ❖ Premium market prices are often needed for profitability.
Additional information	❖ https://www.agriculture.gov.ie/farmingsectors/organicfarming/organicfarming-anoverview/ ❖ https://www.teagasc.ie/rural-economy/organics/steps-to-organic-conversion/ ❖ http://www.irishorganicassociation.ie/ ❖ https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/organics-glance_en ❖ https://www.teagasc.ie/media/website/publications/2017/Teagasc-Organic-Farming.pdf ❖ https://ec.europa.eu/info/files/eu-biodiversity-strategy_en ❖ https://pdfs.semanticscholar.org/6ad7/1300094d70ea6772b61f33d953a6b3c0d5b4.pdf?_ga=2.143170101.1411323278.1596993108-238865958.1576161292

6 Actions to Reduce Mobilisation of Pollutants on Land

The following Actions are described in this Section:

1. Liming of soils (Section 6.1).
2. Timing of fertiliser applications (Section 6.2).
3. Low emission slurry spreading (Section 6.3).
4. Use of protected urea (Section 6.4).
5. Multi-species grassland swards (Section 6.5).
6. Red and white clover (Section 6.6).
7. Cover/catch crops (Section 6.7).
8. Reducing soil compaction (Section 6.8).
9. Land preparation for tillage and grassland (Section 6.9).
10. Reactivating peatlands from peaty soils (Section 6.10).

6.1 Liming of soils

Liming of Soils	
Target pollutants	❖ Nitrate and phosphate
Description	❖ Soil pH[5] should be optimised to suit the crop. For instance, a pH between 6-6.5 is important for maximising the availability of nutrients (nitrogen (N), phosphorus (P) & potassium (K)). ❖ Lime is a soil conditioner and liming promotes soil micro-organisms and encourages earthworm activity that breaks down plant and animal residues to release plant nutrients, especially nitrogen. Lime improves the availability of phosphorus and aids its release from organic matter. ❖ For Nitrate Derogation farms, a liming programme is compulsory and must be implemented and be based on a current Nutrient Management Plan (NMP) and associated soil analysis results. ❖ Irrespective of farming intensity, liming should be considered based on crop needs.
Land use	❖ Grassland and tillage crop areas.
Methods	❖ Undertake a soil test to determine lime requirements and have a liming plan. ❖ In general, apply lime when the grass sward is low. ❖ For silage swards, apply before mid-March for first cut, or within one week after cutting on land that is closed (i.e. doesn't get a second cut). ❖ Leave 7 days between the spreading of urea/slurry and the application of lime. Where lime has been applied first, leave 3 months before applying urea/slurry. ❖ A 3-5 year liming plan is recommended by Teagasc – see links below for good advice and explanations. ❖ The recent nitrates derogation review states that in their current NMP, farmers must spread at least 50% of the lime requirement of their lands in 2020 and the remainder over the years 2021-2023.
Key locations	❖ Where soil testing shows that the pH is below the optimum for the soil type and crop type.
Water quality benefits	❖ Not feasible to estimate, but likely to be appreciable ❖ In optimising the utilisation of applied fertilisers, it therefore reduces the likelihood of wash-off of phosphate to surface water in poorly draining areas and leaching of nitrate in freely draining areas. ❖ It will help farmers to reduce the scale of fertiliser applications and, therefore, reduces the likelihood of losses to water.
Additional environmental benefits	❖ Reduces GHG emissions
Farmer benefits	❖ Potentially savings through reduced purchase for inorganic fertilisers ❖ Increased crop productivity ❖ Can help animals thrive

[5] Soil pH is a measure of the acidity or alkalinity of a soil. Soil acidity is a major limitation to the productivity of our soils, as it reduces the availability of major soil nutrients (N, P & K) and the uptake and efficiency of applied nutrients in manures or fertilisers.

Limitations	❖ Soil testing is needed every 3-5 years to check lime requirements. ❖ Need to take account of timing of applications and type of lime to suit the soil requirements.
Cost	❖ Generally, lime itself is low cost relative to fertiliser. ❖ There may be a cost implication where a contractor is required to apply it.
Additional information	❖ https://www.teagasc.ie/media/website/publications/2020/Major--Micro-Nutrient-Advice-for-Productive-Agricultural-Crops-2020.pdf ❖ https://www.teagasc.ie/media/website/publications/2018/114499-lime.pdf ❖ https://www.teagasc.ie/media/website/crops/soil-and-soil-fertility/Lime-the-forgotten-fertiliser.pdf ❖ https://www.agriland.ie/farming-news/lime-best-spread-autumn/
Comments	❖ The main benefits of liming are increasing crop production and utilisation of nutrients in fertilisers. This is likely to benefit water quality although the reduced loading to water cannot be quantified at present.

Liming of soils (Photo: Teagasc).

6.2 Timing of fertiliser applications

Timing of Fertiliser (P & N) Applications	
Target pollutant	❖ Nitrate and phosphate
Description	❖ There are two timing aspects to reducing nutrient losses to water: o Not applying at high-risk times when losses to water can occur o Applying when the crops can use the nutrients efficiently ❖ Periods and situations when application of fertiliser is prohibited are set out in the GAP Regs.
Land use	❖ Grassland and tillage crop areas.
Methods	❖ Strict adherence to the GAP Regs, ensuring that chemical fertilisers, livestock manure, soiled water and other organic fertilisers are **not** spread when: i) the land is waterlogged; ii) the land is flooded, or it is likely to flood; iii) the land is frozen, or covered with snow; iv) heavy rain is forecast within 48 hours. To further reduce the likelihood of losses to watercourses, farmers/contractors should consider extending the period as much as possible before and after very heavy rainfall before commencing spreading. ❖ Manure: aim to have 75% applied by the end of April and all of it by the end June. ❖ Nitrate: apply nitrogen fertiliser 'little and often' during the growing season, taking account of stocking density and crop needs – see Teagasc advice at link: https://www.teagasc.ie/media/website/publications/2020/Major--Micro-Nutrient-Advice-for-Productive-Agricultural-Crops-2020.pdf ❖ During summer drought conditions, it is best to hold fertiliser N applications until rain is forecast/occurs. ❖ Phosphate: o on mineral soils, apply the amount needed in 2-3 applications before the end of May. o on peaty soils, regular low rate applications are required as they cannot store P. ❖ Base the timing of application and the quantity required on a fertiliser plan. ❖ The main systems for application of fertilisers are outlined in Section 5.4.
Key locations	❖ In catchments areas/ZOCs where water quality improvements are needed, and particularly in CSAs[6].
Water quality benefits	❖ Likely to be highly effective in reducing nutrient losses to water ❖ >10% reduction of P losses is feasible.
Additional environmental benefits	❖ Reduces greenhouse gas emissions
Farmer benefits	❖ Reduced costs to farmer and increased outputs from effective utilisation of fertilisers
Limitations	❖ Weather events such as droughts and prolonged rainfall can hinder planned application timing. ❖ Forecasting of severe weather events is not always accurate.

[6] Critical source areas (CSAs) are the areas that are likely to deliver a disproportionally high amount of pollutants from diffuse sources compared to other areas of a catchment, subcatchment or zone of contribution (ZOC) to a drinking water source. They represent the areas with the highest risk of impacting on water.

	❖ If contractors are used, there may be less flexibility in timing of applications. ❖ While compliance with the advised application rates and timing is beneficial for water quality, it will not prevent losses to watercourses without further actions.
Potential concerns & solutions	❖ While some farmers might find managing appropriate timings of application challenging, this is an important action from a water quality perspective.
Additional information	❖ https://www.teagasc.ie/crops/soil--soil-fertility/grassland/ ❖ Code of Good Agricultural Practice for reducing Ammonia Emissions at this link: https://www.agriculture.gov.ie/
Comments	❖ Avoiding spreading fertilisers to fields at high risk times. This reduces the availability of nitrate through leaching to groundwater in freely draining areas and of P loss during surface runoff. ❖ Therefore, N fertiliser should not be spread between September and February when there is little or no crop uptake.

6.3 Use of low emission slurry spreading (LESS)

Low Emission Slurry Spreading	
Target pollutant	❖ Phosphate, ammonium and microbial pathogens
Description	❖ On farms with a Nitrates Derogation, low emission slurry spreading (LESS) equipment must be used for any slurry applications. ❖ LESS decreases the surface area of the manure in contact with the air. ❖ Grants for equipment purchase are available under the TAMS 2 scheme.
Land use	❖ Grassland and tillage crop areas.
Methods	❖ Utilise LESS equipment such as dribble-bar, trailing shoe/hose, shallow injection or umbilical systems rather than splash-plate equipment. ***Dribble bar/ band spreading*** ❖ The slurry is deposited by pipes that are situated above the crop. Ammonia losses and sward contamination are reduced, as the slurry is deposited in lines. ***Trailing Shoe*** ❖ The trailing shoe is an adaptation of the band-spreader, whereby each pipe has a ''shoe'' coulter attached at the base of the pipe. These shoes separate the sward canopy and apply slurry at the soil surface. The advantage of this application method is that sward contamination, is minimised, thereby facilitating application to taller grass swards with minimal effects on grass quality due to herbage contamination. The opportunity for spring application to grassland may be increased as a result. ***Shallow Injection*** ❖ The shallow injection method involves discs that cut slits into the soil. The slurry is then placed into these slits. This is the best method for reducing ammonia losses, as the exposure of slurry to the weather is minimal. ***Umbilical systems*** ❖ The umbilical slurry application system pumps slurry via a flexible pipe from the tank to an application unit in the field. Umbilical systems help reduce soil compaction as heavy tankers full of slurry are not required. Umbilical systems can be fitted with low emission application units.
Key locations	❖ In catchments areas/ZOCs where water quality improvements are needed, and particularly in critical source areas (CSAs).
Water quality benefits	❖ The precise placement of slurries can reduce runoff of nutrients and microbial pathogens.
Additional environmental benefits	❖ Slurry applied with a low emission method has been shown to reduce ammonia losses to air compared to splash plate application. Compared to splash plate application, a ≥25% reduction in ammonia losses has been achieved using the trailing shoe technique. ❖ Reduced odour emissions.
Farmer benefits	❖ Reduced purchases of N fertiliser, as the replacement value of slurry increases by 10-20% when using LESS methods ❖ Increased crop outputs from effective utilisation of fertilisers ❖ Reduced grass contamination.
Limitations	❖ Equipment is expensive

Additional information	❖ https://www.teagasc.ie/media/website/publications/2018/precision-sluffy-application.pdf ❖ https://www.gov.ie/en/publication/3c74e2-low-emission-slurry-spreading-less-equipment-scheme-conditions/ ❖ Code of Good Agricultural Practice for reducing Ammonia Emissions at this link: https://www.agriculture.gov.ie/ ❖ https://www.agriculture.gov.ie/farmerschemespayments/tams/lowemissionslurryspreadingequipmentscheme/
Comments	❖ LESS is an important means of reducing ammonia emissions to air with the added environmental benefit of reducing nutrient losses to water.

Band spreader/trailing shoe operating off a large vacuum tanker (Photo: Donal Daly).

6.4 Use of protected urea

Use of Protected Urea	
Target pollutant	❖ Nitrate
Description	❖ Protected urea is urea that is treated with an active ingredient called a urease inhibitor. This blocks the active site of the urease enzyme, thereby moderating the rate at which urea converts to ammonium which, in turn reduces to low levels ammonia loss to air. The result is that the conversion occurs over a period of a few days, rather than a few hours, as would be the case with conventional urea. ❖ Protected urea takes days to convert to nitrate and, unlike calcium ammonium nitrate (CAN), is not immediately available to leach to groundwater. ❖ Protected urea does not deliver N directly as nitrate to the soil. It, therefore, reduces the risk of nitrate losses in heavy rainfall post fertiliser application.
Land use	❖ Grassland and tillage crop areas.
Methods	❖ Protected urea should be used on grassland instead of CAN or urea.
Key locations	❖ In catchments areas/ZOCs where water quality improvements are needed, and particularly in CSAs.
Water quality benefits	❖ Application of protected urea instead of CAN will reduce leaching of nitrate to groundwater.
Environmental co-benefits	❖ Lower ammonia and nitrous oxide emissions ❖ Reduced ammonia in the air also reduces the risk of ammonia N being deposited from the atmosphere onto sensitive habitats or into sensitive water bodies.
Farmer benefits	❖ While there may not be economic benefits, there is the satisfaction of knowing that you are contributing to improved air and water quality and to climate action.
Limitations	❖ Protected urea is more expensive than urea, but less expensive than CAN.
Potential concerns & solutions	❖ Use of single nutrient fertilisers may be seen as a concern due to farmers having to make additional applications. However, it is beneficial in that it allows applications to be more targeted at the crop needs.
Additional information	❖ https://www.teagasc.ie/media/website/environment/climate-change/Andy-Boland--Patrick-Forrestal-Protected-Urea-April-2019-resized.pdf
Comments	❖ According to Teagasc, the use of protected urea nitrogen fertiliser is the largest single avenue currently open to Irish agriculture to meet the commitments to reduce GHG and ammonia emissions.

6.5 Multi-species swards

Multi-species Grassland Swards	
Target pollutant	❖ Nitrate
Description	❖ Multi-species grassland includes a combination of more than 2 plant species – some mixtures contain up to 12. These typically include perennial ryegrass, white clover, red clover, plantain, chicory, yarrow and timothy. ❖ Different species have different growth patterns and swards maintain a steady growth rate at reduced fertiliser application rates. ❖ A clover content in the sward (20-40%) can reduce inorganic fertiliser application by more than half in summer. ❖ Plantain & chicory help reduce losses of nitrogen by leaching, better use of N by animals and less emissions from urine patches. ❖ Grass mixtures should be chosen based on objectives – see Teagasc advice at link below. ❖ Multi-species swards are more resistant to drought conditions than are ryegrass swards. For instance, chicory has a deep tap root. ❖ They also produce higher grass yields than single species ryegrass swards.
Land use	❖ Grassland for both silage and grazing
Methods	❖ Multi-species seed can be sown in a new seedbed or over-sown after a silage cut or a tight grazing, but the latter is less successful. ❖ Sow between April and early August. ❖ Post-emergence herbicides cannot be used. ❖ It is important not to over-apply inorganic fertiliser on multi-species swards.
Key locations	❖ In ZOCs of wells/springs with high nitrate concentrations ❖ In high nitrate PIP areas, catchment areas of estuaries, coastal waters and watercourses that are impacted by high nitrate
Water quality benefits	❖ By reducing nitrate peak, multi-species swards also reduce losses to groundwater by up to 20%. However, they are less effective when grazed, as losses from urine patches dominate. Keeping the clover content below ~40% of sward may be necessary.
Additional environmental benefits	❖ Reduces GHG emissions and carbon footprint ❖ Enhances biodiversity by building ecosystems and providing a habitat for pollinators ❖ Good source of protein and it increases feed intake and performance ❖ Improves soil fertility and structure
Farmer benefits	❖ Reduces costs to farmers as it replaces inorganic fertiliser ❖ By eating herbs, the risk of bloating in livestock is reduced. ❖ A longer grazing season is feasible
Limitations	❖ A reduced range of weed control options ❖ Certain of the herbs can be less persistent than perennial ryegrass, having a life span of 3-5 years. ❖ Reseeding may be needed more frequently (relative to ryegrass). Loss of nitrate to groundwater is greater following reseeding.
Additional information	❖ https://www.teagasc.ie/publications/2020/grassland-re-seeding-how-to-establish-multi-species-swards.php (description above based on this).

	❖ https://www.teagasc.ie/media/website/publications/2018/6456_Multi-species_grassland_swards_POKiely_AGRIP.pdf ❖ https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf

Multi-species (plantain, chicory, clover, ryegrass) sward (Source: Paddy Morris, www.tykillenfarm.ie)

6.6 Red and white clover

Red and White Clover	
Target pollutant	❖ Nitrate
Description	❖ Nitrogen fixing – bacteria that live in nodules on clover roots convert nitrogen from the air into nitrates. These stored nitrates are released to the companion plants and following crops through the root decay and the new roots and nodules that grow to replace them. ❖ White clover is best suited to grazing; red clover is best suited for silage. ❖ In a well-balanced and stable grass/clover sward, it is estimated that red clover can fix between 150-250kg N/ha per year compared to about 100-150kg N/ha per year for white clover. ❖ New grass reseeding completed by derogation farmers must include clover.
Land use	❖ Grassland for both silage and grazing
Methods	❖ Clover is best sown as a grass mixture (e.g. with ryegrass). ❖ It can be sown in a new seedbed or over-sown. ❖ White clover persists for 5-10 years; red clover for 3-6 years. ❖ Soil pH should be 6.0-6.5. ❖ Aim for 30% clover content of sward. ❖ Farmers need to ensure that it doesn't outcompete other grasses in the sward.
Key locations	❖ In ZOC of wells/springs with high nitrate concentrations ❖ In high nitrate PIP areas in catchment areas of estuaries, coastal waters and watercourses that are impacted by high nitrate.
Water quality benefits	❖ By reducing nitrate peak, multi-species swards also reduce losses to groundwater by up to 20%. However, they are less effective when grazed, as losses from urine patches dominate. Keeping the clover content below ~40% of sward may be necessary.
Additional environmental benefits	❖ Reduces Nitrous Oxide and Ammonia emissions ❖ Reduces carbon footprint. ❖ Enhances biodiversity, providing a source of nectar for pollinators ❖ Reduces costs to farmers, as it replaces inorganic fertiliser ❖ Improves soil fertility and structure.
Farmer benefits	❖ Reduced costs for inorganic fertiliser ❖ Grass and clover swards can increase milk solids.
Potential concerns & solutions	❖ Clover is not easy to establish in existing swards. However, careful over-sowing can be effective. ❖ Effective management can minimise or eliminate the risk of bloat in livestock grazing clover-dense swards. Follow these three steps: 1) Limit access for stock when first introduced to the field. 2) Do not turn hungry stock out onto clover-rich pastures. 3) Feed fibre such as hay or straw before or after turnout.
Limitations	❖ Needs good management ❖ Requires soil temperature of 8°C minimum for growth ❖ Not suitable for peaty soils
Additional information	❖ https://beefandlamb.ahdb.org.uk/wp-content/uploads/2016/07/BRP-Managing-clover-manual-4-150716.pdf

	❖ https://www.teagasc.ie/media/website/publications/2017/6-Red-clover-agronomy-and-management.pdf ❖ https://www.teagasc.ie/media/website/publications/2017/8-Introducing-white-clover-into-existing-swards-and-getting-variety-choice-right.pdf ❖ https://www.teagasc.ie/media/website/publications/2020/Clover-Handout.pdf ❖ https://www.teagasc.ie/publications/2020/webinar---low-carbon-dairy-farming.php ❖ https://www.teagasc.ie/media/website/publications/2017/Teagasc-Organic-Farming.pdf
Comments	❖ Sowing clover will link with the EU Green Deal requirements. ❖ The primary benefit of this measure is greenhouse gas (GHG) emission reduction rather than water quality.

White clover (Photo: Teagasc).

White clover in a multi-species sward (Photo: Teagasc).

6.7 Catch crops

Catch Crops	
Target pollutants	❖ Nitrate, sediment, Total Phosphorus and ortho-phosphate.
Description	❖ Autumn planting of catch (or cover) crops such as radish, vetch, mustard, turnip, tillage radish, rape, kale, oats ❖ As bare soil is prone to erosion after heavy rainfall, particularly in poorly draining areas, catch crops reduce sediment losses. ❖ Growing cover crops are a GLAS 'greening' measure. ❖ There is a difference between catch crops and crops grown specifically for outwintering.
Land use	❖ Tillage crop areas where spring sowing is planned.
Methods	❖ Two cover crop species need to be selected. Species mixtures should be chosen carefully with regard to the function for which they are required (e.g. nutrient capture) and the impact they may have on crop rotation. ❖ Sow early for optimum effectiveness (in August, if possible). ❖ No fertiliser should be applied, as the plants are simply a means of mopping up surplus nutrients over the winter. ❖ The GAP Regulation requirements for green cover need to be complied with – see summary in Appendix 1.
Key locations	❖ All tillage areas intended for spring planting
Water quality benefits	❖ Cover crops can typically reduce leaching to water by 60-120 kg N/ha, which is a significant reduction. ❖ 50% reductions in sediment losses to watercourses have been reported.
Additional environmental benefits	❖ Soil enhancement – improved structure and compaction resistance ❖ Provides green manure when tilled ❖ Erosion and loss of soil is reduced. ❖ Biodiversity enhancement through the provision of habitat and a food source for wildlife ❖ Reduced loss of carbon from the soil during the winter months
Farmer benefits	❖ Reduced costs for inorganic fertilisers ❖ Additional fodder benefit
Limitations	❖ Needs to be sown before 15th September and must remain until at least 1st December.
Additional information	❖ https://www.teagasc.ie/crops/crops/break-cover-crops/cover-crops/ ❖ https://www.youtube.com/watch?v=o6F1ehttsz8 ❖ https://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/basicpaymentscheme/greeningdocuments/Greeningmanual200215.pdf ❖ file:///C:/Users/Donal%20Daly/Downloads/PE0206_7935_FRA%20(1).pdf
Comments	❖ This is a vital environmental action in tillage fields. It reduces nitrate leaching in freely draining areas and reduces sediment and Total Phosphorus losses in poorly draining areas. It also improves the soil structure. ❖ Arable silage – mix of a tillage crops (Oats, Wheat, Barley) and grass crop – can act as a temporary buffer alongside watercourses. Once the crop is harvested in August/September, there is a growing grass crop which will take up any excess nitrogen and phosphorus lingering from the main tillage crop.

Tillage Radish helping to improve soil structure and water infiltration.

Photo source: Fiona Doolan, Teagasc, in Issue 11, Autumn 2019 Catchments Newsletter (https://www.catchments.ie/catchments-newsletter/)

6.8 Reducing soil compaction

Reducing Soil Compaction	
Target pollutants	❖ Nitrogen, phosphorus, sediment and pesticides
Description	❖ Reducing the level of soil compaction must become a key part of grassland management for farmers. Apart from the reduction in grass/crop yield, soil compaction reduces rainwater percolation into the soil, resulting in overland flow during rain/storm events. ❖ Sources of soil compaction include: ○ poaching from livestock. ○ use of inappropriate machinery in saturated soils.
Land use	❖ All farmland
Methods	❖ Methods to prevent/alleviate soil compaction include: ○ trafficking the soil when dry. ○ the use of low-pressure tyres/tracks. ○ creating conditions in which earthworms thrive (through the addition of organic material). ○ applying lower stocking rates in wetter fields. ○ preventing smearing of soil when ploughing. ○ using deep rooted crops as a break crop, such as beans or oil seed rape. ○ having a good system of farm roadways/hard surfaces around gateways/water troughs etc. ○ ensuring that water troughs are adequate to prevent stock congregating. ○ avoiding outwintering of livestock by housing animals over the winter months and. If outwintering is unavoidable, only the lightest stock should kept outside. ○ ripping/subsoiling and aeration, but only in dry soils.
Key locations	❖ Poorly draining areas where surface runoff occurs ❖ Alongside watercourses ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused ❖ Around gateways/water troughs/feeders ❖ Where animals congregate ❖ Tramlines
Water quality benefits	❖ Maintaining a good soil structure will reduce surface runoff, leading to reduced nutrient, sediment and microbial pathogen losses to surface water. ❖ Likely reduction in pollutants such as sediment, Total Phosphorus, pesticides and microbial pathogens.
Additional environmental benefits	❖ Reduction in soil erosion ❖ Increase in soil biota and, therefore, improved soil health.
Farmer benefits	❖ Better soil structure as a result of reduced compaction, leading to improved crop yields and grazing time.

Limitations	❖ Potential to relocate water troughs may be limited in some fields
Cost	❖ Costs associated with reducing soil compaction (e.g. aeration etc.) may not be large. Depending on the farming system, however, some methods of preventing soil compaction may be high cost (e.g. providing housing and fodder for livestock over the winter months).
Additional information	https://www.teagasc.ie/publications/2020/trafficking-intensity-index-for-soil-compaction-management-in-grassland.php https://www.teagasc.ie/environment/soil/research/square/compaction/#:~:text=The%20compaction%20process%20is%20generally,due%20to%20wet%20soil%20conditions. https://www.teagasc.ie/crops/crops/break-crops/
Comments	❖ See related Action described in Section 5.5.

6.9 Land preparation for tillage and grassland

Land preparation for tillage and grassland	
Target pollutants	❖ Total phosphorus, sediment and pesticides
Description	❖ The preparation of land for the growth of crops (tillage/grassland) should be completed in a way cognisant of water quality. Methods should include minimal soil disturbance and maintaining a crop cover on soils. ❖ Traditional methods of ploughing and land preparation for cropping can result in overland flow, allowing sediment, phosphate and pesticides to enter watercourses. ❖ Landowners could consider over sowing of grass seed/clover to avoid traditional reseeding techniques, which also reduces risk of pesticide pollution.
Methods	❖ Landowners should consider the use of conservation (minimum) tillage methods when cropping. Conservation tillage is any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water. ❖ The use of no till or min till methods allow for minimum disturbance of soil when sowing, maintaining an organic soil cover and the use of crop rotation for weed prevention (thus reducing requirement for pesticide control of unwanted plants). Examples of methods might include No-till, 'In-row subsoiling, strip–till, and ridge-till. Further information is available from the link below. ❖ Where ploughing is unavoidable, contour ploughing techniques should be used. ○ Contour ploughing is the farming practice of ploughing and/or planting across a slope following its elevation contour lines. These contour lines create a water break which reduces the formation of rills and gullies during times of heavy water run-off, which is a major cause of soil erosion.
Key locations	❖ In poorly draining areas, where surface runoff occurs. ❖ On slopes leading to watercourses. ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused.
Water quality benefits	❖ The adoption of these method, in conjunction with other methods will help to slow overland flow to watercourses. ❖ The adoption of conservation tillage, in particular the use of minimum inversion and maintenance of an organic cover helps to reduce soil erosion and reduces the risk of nutrient and sediment loading in surface waters ❖ The use of contour ploughing helps create a physical barrier and avoids preferential flow of floodwater down furrows. ❖ Likely reduction in phosphorus, nitrogen, ammonium, pesticides and sediments.
Additional environmental benefits	❖ Reduction in soil erosion ❖ Better soil structure
Farmer benefits	❖ Less soil erosion and loss of nutrients ❖ Conservation tillage techniques can result in reduced weeds being present in crops.

Cost	❖ The practise of contour ploughing should not incur an extra cost. ❖ The use of conservation tillage methods can result in a cost saving for the farmer due to reduced weed occurrence and less ploughing costs. However, the equipment required for some processes may mean the services of a contractor may be required.
Limitations	❖ Where the hill slope is too steep for contour ploughing. ❖ Inversion ploughing may be required to level fields damaged by poaching/machinery. ❖ Ploughing may be required to break up soil pans, where formed. ❖ Conservation tillage is still a new approach with differences to traditional land preparation techniques.
Additional information	❖ https://www.sare.org/publications/conservation-tillage-systems-in-the-southeast/Chapter-1-Introduction-to-Conservation-Tillage-Systems/What-is-Conservation-Tillage/ ❖ https://www.teagasc.ie/crops/crops/grass-weeds/enable-conservation-tillage-ect/ ❖ https://tstor.teagasc.ie/bitstream/handle/11019/446/BIology%26environemnt%20112B%281%29p157.pdf?sequence=1&isAllowed=y

6.10 Rewetting peat soils areas

Rewetting Peat Soils Areas	
Target pollutants	❖ Colour, dissolved organic carbon (DOC), particulate organic carbon (POC)[7], ammonium (NH_4), phosphate and peat sediment. Also, trihalomethanes (THMs) can be a biproduct of treatment.
Description	❖ There are between 300,000-375,000 ha peaty soils used for grassland. ❖ Peat is a geological material that, in its natural state, consists of over 90% water by volume and less than 10% organic matter. It contains more water than milk! Therefore, it is only found in areas that are or were waterlogged. ❖ Peatlands store carbon and sequester carbon dioxide (CO_2) from the atmosphere through plants, especially Sphagnum mosses, by trapping it as carbon. ❖ Lowering of the water table by drainage allows the entry of air (oxygen), which causes the peat to decompose. The DOC and NH_4 released by the process of decomposition are flushed out in the drainage water, impacting on watercourses. In addition, drainage causes subsidence of the land surface. ❖ DOC causes high colour levels in drainage water. This is costly to treat. While colour does not, of itself, pose a high health risk. However, unless removed during treatment, it may become a health issue following disinfection with chlorine. Depending on the nature of the DOC trihalomethanes (THMs) are created. These include chloroform [CHCl3], bromodichloromethane [CHBrCl2], dibromochloromethane [CHBr2Cl] and bromoform [CHBr3]. Chloroform is the most common THM. Because of their suspected toxicity, THMs have a parametric limit under the Drinking Water Regulations. ❖ Peaty soils cannot store phosphorus (P) and, therefore, losses can readily occur if it is over-applied (see Section 5.3). Therefore, a reduction of grassland on peaty soils would reduce phosphate losses. ❖ Land reclamation can mobilise peat sediment (see Section 5.12). ❖ Peatland rewetting is considered an important climate change mitigation measure. ❖ The objective is to raise the water table in the ground to within a few cms – no deeper than 10-15 cms – of the surface, or as close to it as practicable.
Land use	❖ Grassland on high organic or peaty soils.
Methods	❖ A combination of blocking drainage ditches, raising the water level in small watercourses by damming, impeding land drains and, in places, constructing mounds to reduce runoff. ❖ Guidance is provided in the links to reports and YouTube videos listed in Additional Information. While these deal mostly with cutover bogs and blanket bogs, the techniques will be relevant to peatland soils. In practice, farmers are likely to know best how to raise the water table on their lands.
Key locations	❖ High organic/peaty soils used for agriculture
Water quality benefits	❖ Reduced DOC, particulate organic carbon (POC), colour, ammonium, sediment and phosphate. ❖ Better aquatic ecosystems.

[7] The combination of DOC and POC gives the total organic carbon (TOC).

Additional environmental benefits	❖ As decomposition of peatland releases CO_2 into the atmosphere, rewetting will reduce emissions. It is, therefore, a climate change mitigation measure. ❖ High biodiversity value generated ❖ Reduces summer flooding in particular, as even a small depth of unsaturated zone can store significant quantities of water ❖ Creation of a wetland has an aesthetic value.
Farmer benefits	❖ The land may still be suitable for summer grazing at the initial stages. ❖ Paludiculture (i.e. the cultivation of biomass in wet conditions), may be an option. ❖ There may be payments in the future for the environmental benefits of rewetting peatlands.
Cost	❖ Low in most instances
Maintenance	❖ Checking of wetness and the water table will be needed, with some maintenance being required where there is evidence of a lowering of the water table.
Limitations	❖ Where the water level in the main channel has been lowered by arterial drainage, it may be difficult to raise the water table. ❖ The Forest Service have listed various categories of unsuitable land for afforestation (see link below), which include land with more than 50 cm peat and sites with shell marl within 70 cm of the surface. ❖ In general, planting of trees is not recommended, as they will lower the water table.
Potential Concerns & Solutions	❖ Farmers may be concerned about the phasing out of direct payments on reclaimed peatlands unless it is incentivised as a payment for the 'public goods' listed above. ❖ Raising the water table in a peaty soil area might also impact on an adjoining mineral soil area, thereby reducing the farming productivity. Therefore, any planned incentives may need to include these areas. A hydrological survey may be needed in some circumstances.
Additional information	❖ https://www.npws.ie/sites/default/files/publications/pdf/IWM99_RB_Restoration_Best%20Practice%20Guidance.pdf ❖ http://www.epa.ie/pubs/reports/research/biodiversity/Research_Report_236.pdf ❖ https://www.ramsar.org/sites/default/files/documents/library/strp22_7.2_draft_rtr_peatland_restoration_e.pdf ❖ https://www.nature.scot/sites/default/files/2019-03/Guidance-Peatland-Action-installing-peat-dams.pdf ❖ https://www.eurosite.org/wp-content/uploads/CAP-Policy-Brief-Peatlands-in-the-new-European-Union-Version-4.8.pdf ❖ https://www.youtube.com/watch?v=iIAYku2G1yw ❖ https://www.youtube.com/watch?v=Gmoji9SYheE ❖ http://www.ipcc.ie/advice/peatland-management-diy-tool-kit/restoration-of-drained-peatlands/ ❖ https://www.moorsforthefuture.org.uk/our-work/restoring-blanket-bog/working-with-water ❖ http://www.epa.ie/pubs/reports/research/climate/Research_Report_250.pdf ❖ https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/schemecirculars/2016/LandTypesAfforest020316.pdf
Comments	❖ Reduction of colour in a surface drinking water source by reactivating peatlands would be a major benefit to a GWS.

7 Pathway Interception Actions

The following Actions are described in this Section:

1. Riparian buffers (Section 7.1).
2. In-field grass buffers (Section 7.2).
3. Hedgerows (Section 7.3).
4. Wild bird cover crops planted alongside watercourses (Section 7.4).
5. Agroforestry (Section 7.5).
6. Woodlands (Section 7.6).
7. Ditch management and sediment traps (Section 7.7).
8. Low earthen mounds/bunds (Section 7.8).
9. Farm ponds and wetlands (Section 7.9).

7.1 Riparian buffers

Riparian Buffers	
Target pollutants	❖ Phosphorus, nitrogen, sediment, pesticides and microbial pathogens
Description	❖ A riparian area is the strip of land alongside watercourses where moisture-loving vegetation is either growing or could grow. Typically, it is the flood plain of a watercourse (a flat area that is either prone to flooding now or where flooding has occurred in the past) where the water table is close to the surface. This area is illustrated in 1a in Figure 2. ❖ A riparian buffer is a strip of managed vegetation between farmland or an afforested land and a watercourse. ❖ This buffer can be planted by a variety of vegetation – trees, bushes, grasses, etc. ❖ Riparian buffers reduce the momentum and magnitude of surface runoff, thereby reducing soil and sediment losses, allowing nutrient removal and enabling uptake of nutrients in the runoff water. ❖ Riparian buffers remove land from intensive agricultural activity, thereby reducing the area of nutrient and pesticide applications, and potential losses. ❖ Frequently in this area, discharging of groundwater in seeps (small springs) and springs occur. If the groundwater contains high nitrate, denitrification can reduce the nitrate input to surface water. Likewise, in this 'wet' environment, denitrification will reduce nitrogen losses in surface runoff.
Land use	❖ All farming enterprises
Methods	❖ Establish either a vegetated grass or a woodland strip (see Section 7.6 for details,) or a combination of both. ❖ It is recommended that riparian buffers should be at least 2 m wide and preferably 6 m to be effective, but should be wider if feasible, particularly where they are perpendicular to the delivery paths of water and pollutants that are shown on the PIP maps, or are located during catchment walks. ❖ Planting native species increases the biodiversity benefits. ❖ As a build-up of nutrients can occur in this strip over time, to avoid this being available to be washed off, short-term grazing or other harvesting is advisable to maintain functionality. The watercourse should, however, be left untouched.
Key locations	❖ Alongside watercourses in flood plains, usually in wet areas and relatively unproductive farmland ❖ In critical source areas, particularly in focussed delivery zones to watercourses and ditches, where runoff is concentrated, but also in dispersed delivery zones (see Section A7.1 in Appendix 2 for details).
Water quality benefits	❖ Effectiveness depends on hydrology, vegetation and buffer width, but the benefits can be substantial. ❖ Riparian buffers reduce surface runoff, reduce connectivity to watercourses, intercepting and trapping pollutants. In general, the greater the buffer width, the greater the effectiveness. ❖ They reduce the likelihood of spray drift contaminating watercourses.

	❖ There is likely to be significant reduction in losses of microbial pathogens, sediment, phosphate and Total P, and pesticides, and a small reduction in nitrogen.
Additional environmental benefits	❖ Enhances biodiversity by creating habitats for farmland birds, mammals and beneficial insects ❖ Provides habitat and a food source for pollinators ❖ Reduces the risk of flooding downstream (by slowing the flow in storm events) ❖ Captures carbon and lowers farm carbon footprint ❖ Improves aesthetics, as vegetative buffers are attractive features
Farmer benefits	❖ Stabilises river banks ❖ Provide shelter and shade for livestock
Cost	❖ Variable, depending on existing situation ❖ If currently used for crop production, the buffer area will need planting of suitable vegetation and trees.
Maintenance	❖ Low maintenance once installed
Limitations	❖ Need to be located in optimum areas for water quality benefits ❖ May take time to mature ❖ Can be by-passed by ditches and land drains – see 1b in Figure 2.
Additional information	❖ https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf ❖ https://catchmentbasedapproach.org/learn/natural-flood-management-measures-a-practical-guide-for-farmers-north-west/ ❖ http://nwrm.eu/ ❖ https://www.cost869.alterra.nl/Report2141.pdf ❖ https://www.dairynz.co.nz/media/254172/5-9_sediment_traps_2012.pdf
Comments	❖ An EPA-funded 'Smarter_BufferZ' research project on riparian buffers is being undertaken by Teagasc and the James Hutton Institute. This will produce detailed advice on the mitigation options that are most effective and acceptable.

Riparian buffer in flood plain alongside watercourse (Photo: NFGWS).

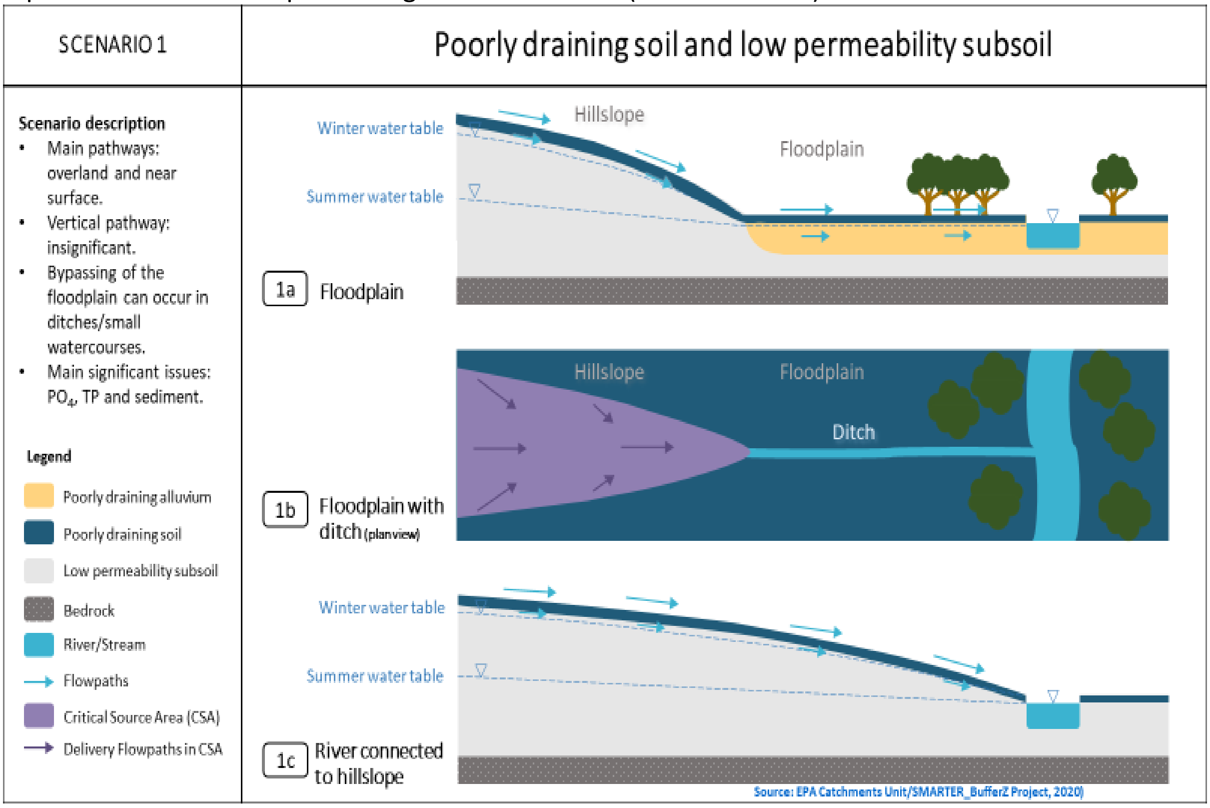

Figure 2. Illustration of settings for riparian and in-field grass buffers.

Riparian buffer alongside reservoir (Photo: Donal Daly).

7.2 In-field grass buffer strips

In-field Grass Buffer Strips	
Target pollutants	❖ Phosphorus (P), nitrogen (N) (both nitrate and ammonium), sediment, pesticides and microbial pathogens
Description	❖ An in-field buffer strip is a band of unfertilised vegetated land located along a contour or on sloping land alongside watercourses. These sloping areas in the landscape are illustrated in Figure 2. ❖ It can reduce sediment and associated particulate P losses by slowing runoff and intercepting sediment delivery. ❖ In-field grass buffers remove a small proportion of land from intensive agricultural activity, thereby reducing the area of nutrient applications.
Land use	❖ Tillage crops and grassland.
Methods	❖ Article 17(16) of the GAP Regs requires that no cultivation should take within 2m of a watercourse. A grass buffer can be used to comply with this requirement. ❖ In general, the grass buffer should at least be 2m wide, with greater widths (>10m) recommended, if feasible, particularly perpendicular to the delivery paths of water and pollutants that are shown on the PIP maps or are located during catchment walks. ❖ In grassland areas, fencing is likely to be required. ❖ As a build-up of nutrients can occur over time in this strip, which then become available to be washed off, short-term grazing or other harvesting is advisable to maintain functionality. For pasture, one method is to use a single strand electric fence that will allow some grazing of the buffer strip. In tillage fields, cutting and removal of the grass is likely to be needed to reduce nutrients, control weeds and encourage new growth. ❖ Vegetation in buffer strips should not be sprayed with herbicide.
Key locations	❖ Alongside watercourses and drainage ditches, particularly alongside tillage fields, in sloping poorly draining areas. ❖ In critical source areas, particularly in focussed delivery zones to watercourses and ditches where runoff is concentrated, but also in dispersed delivery zones (see Section A7.1 in Appendix 2 for details on these zones).
Water quality benefits	❖ In-field grass buffers slow and reduce surface runoff, reduce connectivity to watercourses, and trap and intercept pollutants. The effectiveness of mitigating against nutrient loss is greatly enhanced by maximising the width of buffer strips in the delivery areas for water and pollutants. ❖ Likely reduction in microbial pathogens, sediment, phosphate and Total P, nitrate and pesticides.
Additional environmental benefits	❖ Enhanced biodiversity by creating habitats for farmland birds, mammals, pollinators and other beneficial insects
Farmer benefits	❖ Species-rich grass buffers provide, when harvested, nutritious fodder for livestock. ❖ They reduce soil losses in tillage areas
Cost	❖ This depends on the type of fencing installed. Single strand electric fences might be sufficient, which is relatively inexpensive.

Maintenance	❖ To encourage uptake of nutrient in the following season, buffer vegetation that has not been grazed needs to be cut and removed, as described under methods.
Limitations	❖ Buffers need to be located in optimum areas for water quality benefits. ❖ Land drains and erosion at low points can result in bypassing. ❖ They are not effective generally in freely draining areas as surface runoff is uncommon.
Potential Concerns & Solutions	❖ Concern over loss of DAFM payments
Additional information	❖ https://catchmentbasedapproach.org/learn/natural-flood-management-measures-a-practical-guide-for-farmers-north-west/ ❖ http://nwrm.eu/ ❖ file:///C:/Users/Donal%20Daly/Downloads/MitigationMethods-UserGuideDecember2011FINAL.pdf
Comments	❖ Main benefit for water quality is in poorly-draining areas. ❖ Essential as an action in tillage areas.

In-field grass buffer (Photo: Donal Daly).

7.3 Planting and managing hedgerows

Planting & Managing Hedgerows	
Target pollutants	❖ Phosphorus, sediment, MCPA and microbial pathogens
Description	❖ Hedges slow (and reduce) surface runoff, increase infiltration, reduce connectivity to watercourses, trap and intercept pollutants. Planting new hedges should be positively considered in conjunction with the action for livestock exclusion from watercourses (Section 8.1). ❖ Derogation farms must either leave a mature whitethorn or blackthorn bush every 300 m along a hedge or only cut the hedge on a three-year cycle.
Methods	An example of the NFGWS Source Protection Pilot Project where a new hedgerow was planted is as follows: ❖ Prepare the ground along a 1.5m wide strip to provide good soil conditions and as little competition from other vegetation as possible. **(Do not use herbicides.)** ❖ Plant a double staggered hedgerow, using 3 plants per metre. ❖ Up to 75% of the species can be hawthorn/blackthorn. ❖ Use a mix of shrub species to enhance the hedgerow for wildlife. Add in native deciduous trees every ~50 m to grow out into a single landscape tree for additional future shade and shelter. ❖ Rabbit netting may be needed, either on its own or with stock fencing, if there is a known problem with rabbits.
Key locations	❖ Poorly draining areas where surface runoff occurs ❖ Alongside watercourses and across slopes, following a contour, and alongside existing and new fences that are being erected ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused ❖ Livestock access points on watercourses
Water quality benefits	❖ Hedgerows slow and reduce surface runoff, increase infiltration, reduce connectivity to watercourses and intercept/trap pollutants. Their effectiveness in mitigating against nutrient loss is greatly enhanced by increasing the buffer areas between hedgerows and watercourses. ❖ Hedgerows can provide a natural barrier to pesticide spray drift. ❖ Planting and managing hedgerows have the added benefit of increasing bank stabilisation. ❖ Likely reduction in microbial pathogens, sediment, phosphate and Total P, nitrate and pesticides.
Additional environmental benefits	❖ Shading for rivers ❖ Reduced downstream flooding ❖ Enhanced biodiversity by creating habitats for farmland birds, mammals and beneficial insects ❖ Provides habitat and a food source for pollinators and nesting sites for birds ❖ Captures carbon and lowers farm carbon footprint
Farmer benefits	❖ Multiple benefits for livestock ❖ Stabilises river banks and reduces soil loss from erosion ❖ May alleviate on-farm flooding ❖ Improves soil moisture conditions

	❖ Improves animal welfare (e.g. reduces risk of losing of livestock through drowning). ❖ Reputational enhancement for implementing positive action that will be recognised by the community.
Cost	❖ Costs of planting will vary depending on the type of hedgerow being planted. Whitethorn/blackthorn quicks cost about €25 per hundred. The example outlined in the method above can cost between €10-15 per metre where a contractor is employed.
Maintenance	❖ Newly planted hedgerow requires annual maintenance until at least 1.5m tall (about 4 years), particularly regarding weed control and watering in the first growing season. ❖ May need protection from rabbits in the first year ❖ Can side trim every two years once established ❖ The laying of hedgerow every 12-15 years will increase wildlife benefits and the overall health of the hedge and improve stock proofing.
Limitations	❖ Needs to be located in optimum areas for water quality benefits ❖ Can be by-passed by ditches and land drains.
Potential Concerns & Solutions	❖ Cost: o An assessment should be made to determine if existing projects or schemes can provide financial aid (e.g. Future REPS/GLAS schemes and initiatives such as the Catchment Care Project). ❖ Maintenance: o Maintenance agreements should be agreed with the landowner at the outset.
Additional information	❖ https://www.thebrideproject.ie/wp-content/uploads/2020/04/BRIDE-Project-Farm-Habitat-Management-Guidlines.pdf ❖ https://catchmentbasedapproach.org/wp-content/uploads/2018/08/EA-NFM-Toolbox-Final-Draft.compressed.pdf ❖ https://catchmentbasedapproach.org/learn/natural-flood-management-measures-a-practical-guide-for-farmers-north-west/ ❖ http://nwrm.eu/ ❖ https://www.biodiversityireland.ie/wordpress/wp-content/uploads/Farmland-Actions-to-Help-Pollinators.pdf ❖ https://www.teagasc.ie/media/website/environment/biodiversity-countryside/teagasc_farmhedge_management.pdf
Comments	❖ Main benefit for water quality is in poorly draining areas ❖ Excellent advice and illustrations are given by the Bride project Farm Management Guidelines – see link above.

Hedgerow alongside watercourse (Photo: Donal Daly).

A hedgerow and field with wild bird cover providing protection for the stream (Photo: Donal Daly).

7.4 Wild bird cover planted alongside watercourses

Wild Bird Cover Crops Planted alongside Watercourses	
Target pollutants	❖ Sediment, Total Phosphorus, phosphate, MCPA, microbial pathogens. ❖ Minor reduction of nitrate losses to water as fertilisers are not spread in these areas.
Description	❖ Planting of wild bird cover is designed to provide a food source to birds and other fauna throughout the winter period. ❖ This is a GLAS measure.
Land use	❖ All farming land uses
Methods	❖ Needs to be sown before the end of May and be left unharvested over the winter ❖ Specific seed mixes are required. ❖ Crop must remain in the ground until at least the 15th of March of the following year. ❖ Fertiliser can be applied at a maximum of half the rate for a spring oats cereal crop. ❖ Pre-sowing weed control is permitted, but herbicides cannot be applied post-sowing.
Key locations	❖ If planted alongside watercourses (both perennial and intermittent), it provides an effective buffer zone. ❖ If planted in a critical source area (CSA) where delivery of water and pollutants are focussed, it provides excellent protection for the watercourse.
Water quality benefits	❖ If planted in optimum locations – CSAs – the benefits are likely to be significant, but even when planted alongside watercourses, wild bird cover crops will be beneficial.
Additional environmental benefits	❖ This is a biodiversity measure that benefits both birds and pollinators. ❖ GHG emission reduction ❖ Soil conditioning
Farmer benefits	❖ Payment for up to 3 ha is available under the agri-environmental scheme.
Potential concerns & solutions	❖ Farmers may be concerned about the difficulty of 'reinstating' the fields years for productive purposes after 2 years and about the potential migration of certain plants to adjoining fields.
Limitations	❖ There are limited benefits for water quality in freely draining soils areas. ❖ Benefits are short-term – one or two years – depending on the duration of the cover. ❖ Planting for two years is more beneficial than for one year. ❖ Care needs to be taken that sowing doesn't take place before heavy rainfall is forecast, as this can result in sediment wash off in poorly draining areas.
Additional information	❖ https://www.agriculture.gov.ie/farmerschemespayments/glas/glastranche3/
Comments	❖ If located upgradient of delivery points in CSAs, this measure will provide substantial protection for watercourses.

Wild bird cover (Photo: Catherine Keena, Teagasc).

7.5 Agro-forestry

Agro-forestry	
Target pollutants	❖ Phosphates, ammonia, sediment, coliforms, herbicides
Description	❖ Agro-forestry is the practice of combining forestry and agriculture in a mutually beneficial way.
Land use	❖ All farmland
Methods	❖ Acceptable species include oak, sycamore and cherry, as well as 15% fruit and nut trees. Other species can also be considered on a site-by-site basis. ❖ Large saplings should be used (90cm-120cm). Establishment should be carried out using pit planting. The use of an auger is another option ❖ The initial stocking rate should be between 400 and 1,000 trees per hectare, equally spaced out (e.g. 5m x 5m or 7m x 3.5m). Minimum plot size is 0.5 ha, with a tree-to-tree width of 20m. ❖ Ground preparation is largely limited to inverted mounding, scrap mounding, shallow ripping, pit planting and auger planting. ❖ Each tree should be protected by two sturdy posts and a tree shelter. The tree shelter should be rigid, 1.5m tall and checked regularly. ❖ Grazing in the planted area by sheep or young domestic stock is permitted during spring and summer for the first six to eight years. Once the trees are of a sufficient size, tree shelters can be replaced with plastic mesh and larger stock can graze the area. ❖ Silage and hay production is also permitted. It is important that appropriate machinery is used when cutting silage and/or hay so as to ensure that the trees are not inadvertently damaged. The incorporation of headlands to facilitate the turning of machinery should form part of the plan. ❖ Ideally, sites should contain free-draining mineral soils and should have no requirement for additional drainage or additional fertiliser for tree growth. ❖ However, additional nitrogen (up to 100kg/ha) may be required to promote grass growth for spring/summer grazing. This can be assessed on a site-by-site basis.
Key locations	❖ Farmland in catchment areas where water quality needs to be either protected or improved.
Water quality benefits	❖ Likely reduction in in P and N as a result of lower livestock or tillage intensity ❖ Improved soil infiltration and a reduction in overland flow ❖ Reduced soil erosion & machinery related soil disturbance.
Additional environmental benefits	❖ Increases in native woodland biodiversity ❖ Provides plants for pollinators ❖ Habitat linkage within the wider landscape ❖ Captures carbon and lowers farm carbon footprint ❖ Improves soil quality ❖ Provides an 'outdoor classroom' for environmental education and awareness.
Farmer benefits	❖ Livestock grazing, silage/hay production and tillage is permitted. ❖ Improved livestock weight gain and animal welfare ❖ Encourages poultry to range, improving their welfare. Creates a more natural environment and more natural behaviours have been noted, such as a reduction in pecking and earlier egg laying.

	❖ Improved marketability of eggs, with some major companies encouraging tree planting and "Tree Range Eggs" (see Woodland Trust articles at links below) ❖ Offers some protection against land erosion ❖ Possibility of increased prices for livestock because of reduced environmental impacts ❖ Improvement in soil quality ❖ Shelter for livestock ❖ Longer outdoor grazing season ❖ Land will still be eligible for payment under Basic Payment Scheme (BPS) using this method. ❖ Additional grants are available (80% of eligible costs can be funded). Grant rates and payment structure are paid on a fixed grant basis. A premium payment of €640/ha rising to €660/ha for areas greater than 10ha, will be paid directly to the farmer for 5 year. ❖ The afforestation grant is a fixed grant to cover 80% of the costs incurred in the establishment of a forest and is paid exclusive of VAT in two instalments as outlined below. An additional allowance for fencing (to the maximum rates detailed below) is payable with the first grant instalment. ❖ Potential for future wood production and income generation ❖ Increased visual/landscape values ❖ Reputational enhancement for implementing positive action that will be recognised by the community.
Cost	❖ The landowner will receive grants to cover both the costs to a maximum of 80% of woodland establishment and an annum premium for 5 years (see Additional information). ❖ The annual premium equates to €640/ha and rises to €660/ha for forestry cover greater than 10 ha.
Maintenance	❖ Maintenance is required at an early stage to protect the saplings from competing vegetation and to ensure no damage to the trees or their shelters from livestock. ❖ Management may be required in some cases to control excessive woody growth.
Limitations	❖ Generally, sites that flood are excluded from this scheme. However, some types of native woodland establishment may be permitted (see additional information).
Potential Concerns & Solutions	❖ There is concern that the fencing allocation grant included in the scheme may not cover the costs on certain types of plot sizes/shapes. ❖ Agro-forestry must remain under forestry and therefore is subject to a replanting obligation, however trees are thinned as they mature to ensure continuous grass growth. ❖ Concerns over the duration of the grant (5 years).
Additional information	❖ Forestry Approvals Section, Department of Agriculture, Food and the Marine, Johnstown Castle Estate,Co. Wexford Y35 PN52. Telephone 053 916 3400 or 0761 064 415 **www.agriculture.gov.ie/forestservice/grantsandpremiumschemes2015-2018** ❖ https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2016/6AgroforestryRPC010894ENPRL1150319.pdf ❖ https://www.teagasc.ie/crops/forestry/grants/establishment-grants/agroforestry/

	❖ Soil Association Agroforestry Handbook: https://www.soilassociation.org/media/19141/the-agroforestry-handbook.pdf ❖ https://www.woodlandtrust.org.uk/publications/2014/04/tree-planting-for-poultry/ ❖ https://www.woodlandtrust.org.uk/media/1785/trees-mean-better-business-for-egg-production.pdf

Farming and forestry in combination (Photo: Eugene Curran, Forest Service, DAFM).


Sheep grazing among newly planted trees (Photo: Eugene Curran, Forest Service, DAFM).

7.6 Woodlands

Woodlands	
Target pollutants	❖ Phosphates, ammonia, sediment and pesticides
Description	❖ A Native Woodland Establishment Scheme (NWS), is available from the DAFM. ❖ This measure promotes areas of new native woodland planting in conjunction with an undisturbed water setback, as one of the aims is to protect and enhance water quality.
Land use	❖ All farmland
Methods	❖ Typically, sites and individual plots proposed for native woodland establishment must be 0.1 ha or greater in area and 20 metres or greater in width. A minimum water setback distance of 10 metres is required. ❖ Native tree species that would naturally occur on the selected site (e.g. due to soil conditions) are promoted. ❖ Ground preparation is largely limited to inverted mounding, scrap mounding, shallow ripping, pit planting and auger planting. ❖ A once-off hand application of slow release fertiliser at establishment on marginal lands is permitted. ❖ Control of competing vegetation (e.g. grasses, bramble, bracken) is vital for the rapid establishment and growth of young trees. Herbicide application is not permitted within 20 metres of an aquatic zone.
Key locations	❖ Poorly draining areas where surface runoff occurs ❖ Alongside watercourses ❖ In critical source areas, particularly in the delivery areas to watercourses and ditches where runoff is focused ❖ In the zone of contribution for sources with high nitrate ❖ Where watercourse bank erosion or poaching is identified.
Water quality benefits	❖ Woodlands slow and reduce surface runoff, increase infiltration, reduce connectivity to watercourses and intercept/trap pollutants. The effectiveness of mitigating against nutrient loss is greatly enhanced by the depths of buffer/undisturbed setback distances specified in the scheme. ❖ Woodland can provide a natural barrier to pesticide spray drift. ❖ Woodland and setbacks have the added benefit of increasing bank stabilisation. ❖ They will reduce the loss of nitrate by leaching to groundwater in freely draining areas. ❖ A reduction is likely in microbial pathogens, sediment, phosphate and Total P, nitrate and pesticides.
Additional environmental benefits	❖ Increased native woodland biodiversity ❖ Riparian restoration enhances biodiversity by creating habitats for farmland birds, mammals, pollinators and other beneficial insects ❖ Habitat linkage within the wider landscape ❖ Protection and food input into the aquatic ecosystem ❖ Shading/cooling rivers ❖ Regulation of flood water ❖ Captures carbon and lowers farm carbon footprint

	❖ Provides an 'outdoor classroom' for environmental education and awareness.
Farmer benefits	❖ Land planted is still be eligible for payment under Basic Payment Scheme (BPS). ❖ An additional grant/premium is paid for 15 years to landowners in the scheme. ❖ Potential for future wood production and income generation ❖ Increased visual/landscape values ❖ Reputational enhancement for implementing positive action that will be recognised by the community.
Cost	❖ The landowner will receive grants to cover the costs of the woodland establishment and an annual premium for 15 years. ❖ The annual premium equates to €665/ha and rises to €680/ha for forestry cover greater than 10 ha.
Maintenance	❖ Maintenance is required, usually to year 4 or to when the trees are considered free growing. The cost of this is covered in the capital grant paid by the Department and normally forms a standard component of the contract with forestry companies. ❖ Many woodlands created under the NWS Establishment are suitable for future harvesting. Wood production can only be pursued using a 'close-to-nature' continuous cover forestry system, such as selection, shelterwood and coppicing. ❖ The water setbacks must be maintained throughout, allowing natural ground vegetation to develop. Periodic mowing/strimming of vegetation and removal of cuttings would be useful in reducing the build-up of nutrients in the water setback buffer. ❖ Ongoing monitoring is recommended for invasive species such as Japanese knotweed, Himalayan balsam and rhododendron. Where best practice involves herbicide use, consult with Inland Fisheries Ireland and other relevant bodies. ❖ Management may be required to control excessive woody growth.
Limitations	❖ Generally, sites that flood are excluded from the scheme. However, some types of native woodland establishment may be permitted (see Additional information). ❖ May not be allowed in close proximity to archaeological monuments.
Potential Concerns & Solutions	❖ There is concern that the fencing allocation grant included in the scheme may not cover the costs on certain types of plot sizes/shapes. The GWS may be able to provide assistance, as this action is protecting the source. ❖ Where small areas are being planted, it may be more financially viable to combine a number of applications together. ❖ In a lot of cases, a 0.1ha plot will be sufficient to intercept a critical source area in a given land parcel. As a result, a €65/ha premium will apply. To subsidise this, other marginal lands distant from watercourse could be investigated for establishment as a means of increasing premiums. ❖ There is also scope within the Native Woodlands Establishment Scheme for local businesses to contribute to an upfront payment to the landowner, receiving substantial recognition in return, through the Woodland Environmental Fund

Additional information	❖ https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2018/WoodlandWaterLoRes06June18270618.pdf ❖ https://www.teagasc.ie/crops/forestry/grants/establishment-grants/interaction-of-forestry-with-other-farm-schemes/#Eligibility_for_forestry_premium_payments ❖ https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2016/NativeWoodlandEstablishmentGPC9AndGPC10SilviculturalStandardsSept15050117.pdf ❖ https://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2018/DAFMWEFleaflet14Sept18250918.pdf ❖ Management Guidelines for Ireland's Native Woodlands (July 2017), https://www.agriculture.gov.ie/forestservice/publications/
Comments	❖ During the Source Protection Pilot Project, it was found that the proposal to locate woodland in the corner of a field, or on a meander of a watercourse, to intercept overland flow was well received by landowners.

Woodland alongside stream with vegetated setback (Photo: Kevin Collins, Forest Service, DAFM).

Sequence of photographs showing the emergence of native woodland and the associate water setback on a site planted in 2001 under the Native Woodland Establishment Scheme. Top photo shows the site before planting; middle shows the woodland emerging onsite at year 7 (approx.); and bottom shows the woodland at closed canopy stage, year 17. Site at Ballyvary, Co. Mayo, on the Toormore River. (Photos: Kevin Collins, Forest Service, DAFM).

7.7 Drainage ditch management and sediment traps

Drainage Ditch Management and Sediment Traps	
Target pollutants	❖ Sediment and Total Phosphorus
Description	❖ In poorly draining areas in particular, drainage ditches and small streams are common and are used to drain fields and transfer water to watercourses. ❖ They can transport sediment in wet weather and, in the process, impact on water quality and stream ecology. ❖ These situations are common in high P Pollution Impact Potential (PIP) areas. ❖ Whether by 'engineering' the drain or installing barriers, sediment traps can be effective in reducing watercourse contamination from sediment and associated Total Phosphorus. ❖ Denitrification will occur due to the saturated conditions.
Land use	❖ All land and where land drainage or drain cleaning is taking place, especially tillage fields
Methods	❖ The key process is to slow the water flow so that sediment settles out and can then be removed. ❖ One option is to widen and deepen the drainage ditch (see diagram). ❖ Another is to install a physical barrier, either impermeable or semi-permeable. ❖ Usually located on low gradient land. ❖ Use multiple locations, if practicable, including one close to the watercourse. ❖ Cleared sediment should be spread on the land at a distance of a few metres from the drain.
Key locations	❖ Alongside tillage fields, particularly those underlain by clayey subsoil. ❖ All land where reclamation and drainage are being undertaken.
Water quality benefits	❖ Significant for coarse to medium sediments and associated P, provided it is installed properly and maintained. ❖ Greatest effectiveness in tillage areas and areas with poorly draining soils and clayey subsoils.
Additional environmental benefits	❖ Reduced soil loss
Farmer benefits	❖ Reduced soil loss
Maintenance	❖ Needs to be inspected regularly, with periodic sediment removal, as necessary.
Limitations	❖ Effectiveness depends on the volume of inflow, shape, and size of incoming particles. ❖ As fine clayey sediment may not settle out, the effectiveness of traps is reduced. ❖ Can be ineffective at high flows (e.g. during a severe rainfall event).
Potential concerns & solutions	❖ Care has to be taken to avoid localised flooding in high density drainage areas ❖ Removal of sediment from traps can be challenging
Additional information	❖ https://www.dairynz.co.nz/media/254172/5-9_sediment_traps_2012.pdf ❖ https://www.wwt.org.uk/uploads/documents/1429707026_WWTConstructedFarmWetlands150422.pdf

	❖ https://www.duhallowlife.com/sites/default/files/C4%20Final%20Technical%20Report%20-%20Provision%20of%20Silt%20Traps.pdf ❖ http://www.horizons.govt.nz/HRC/media/Media/Agenda-Reports/Strategy-Policy-Committee-2017-9-08/17143%20Annex%20L%20Mitigations%20Outside%20OVERSEER.pdf ❖ Chapter 2, Volume 3 in Local Catchment Assessment Guidance at this link: https://wfd.edenireland.ie/help/help for general information.
Comments	❖ Sediment can be problematic at water intakes during wet weather. Therefore, actions to deal with it are advisable and are achievable.

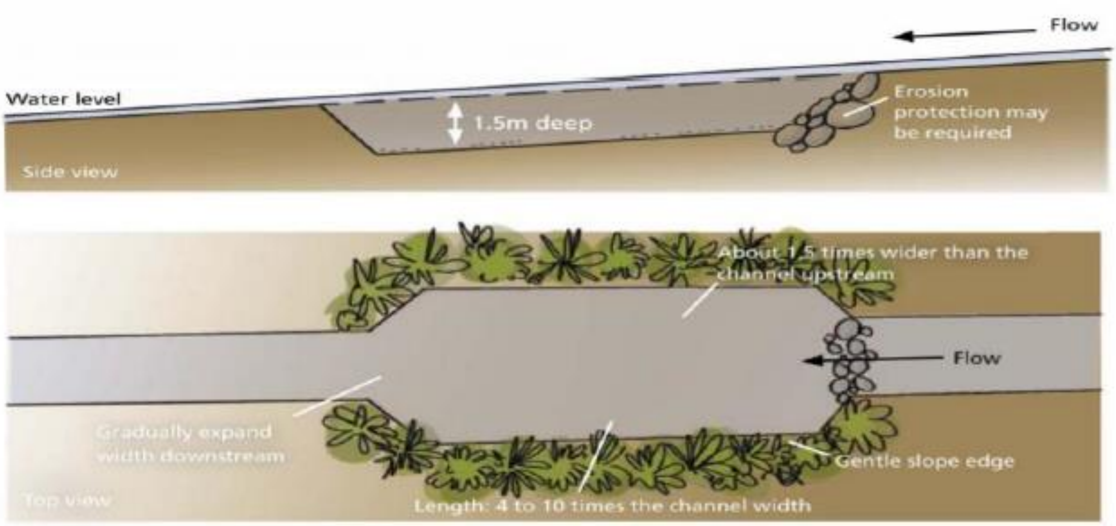

Figure 3. Cross-section and plan views of a sediment trap (Source: https://www.dairynz.co.nz/media/254172/5-9_sediment_traps_2012.pdf)

Interception pond along a farm drainage channel, Allerton Farm, Leicestershire (Photo: Donal Daly).

Figure 7 Silt trap installed in stream at Kilberrihert

Sediment trap in a small watercourse constructed to protect the Freshwater Pearl Mussel in the River Allow. (Image: Fran Igoe)

A low earthen bund or bank reducing or preventing overland flow entering the watercourse. (Photo: SMARTER_BufferZ project)

7.8 Low earthen bunds/mounds

Low Earthen Bunds/Mounds	
Target pollutants	❖ Sediment, Total Phosphorus, pesticides, microbial pathogens
Description	❖ Bunds are low earth mounds or berms that are built across known run-off pathways (delivery zones), thereby intercepting water flowing over the ground, slowing the flow and enabling sediment to be deposited. ❖ Water is held by the bund and allowed to disperse through a combination of infiltration into the soil, evaporation and slow release.
Land use	❖ All land uses, but particularly tillage ❖ Areas where land reclamation is occurring (see Section 5.11)
Methods	❖ The key objective is to 'slow the flow'. ❖ Use local soil to build up a low mound. ❖ Allow the mound to 'grass-over' and become stable.
Key locations	❖ Alongside watercourses and ditches in CSAs where water is flowing overland over a wide area in wet weather ❖ Areas where heavy sediment load in runoff is known to occur
Water quality benefits	❖ Beneficial, but variable depending on sediment load, water flows and efficiency of mound
Additional environmental benefits	❖ Minor reductions in rapid runoff, thereby helping to mitigate flooding peaks.
Farmer benefits	❖ Reduced soil loss
Maintenance	❖ Sediment may build up and would need to be removed, although build-up may take many years. ❖ Occasional inspections are required to check for bypassing of the bund and repairs if necessary.
Limitations	❖ Erosion of the bunds can occur due to overtopping following heavy rainfall. ❖ Berms are not suitable in areas of focussed runoff, such as the delivery points in CSAs, as they are likely to be eroded and bypassed.
Additional information	❖ https://catchmentbasedapproach.org/wp-content/uploads/2018/11/North-West-NFM-handbook.pdf ❖ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291508/scho0612buwh-e-e.pdf
Comments	❖ Low earthen mounds are easy to construct and maintain in circumstances where there is a broad area of overland flow (i.e. a dispersed delivery zone) to a watercourse (see Figure A2). Farmers will usually know the location of such areas.

7.9 Farm ponds and wetlands

Farm Ponds and Wetlands	
Target pollutant	❖ Phosphate, sediment, Total Phosphorus, nitrate, pesticides, BOD, microbial pathogens
Description	❖ Constructed ponds/wetlands in poorly draining areas immediately upgradient of watercourses and ditches in floodplains to intercept overland flows during and after storm events. ❖ They can be used to intercept land drains close to watercourses, thereby removing sediment from the flow. ❖ They can attenuate pollutants. For example, denitrification will occur due to the saturated conditions. ❖ They should preferably hold some water all year round, thereby contributing to biodiversity. In most circumstances this will occur naturally, as the water table in floodplains and riparian areas will generally be within 1-1.5m below ground level in summer.
Land use	❖ Poorly drained areas where overland flows occur ❖ Areas with land drains flowing directly into a watercourse
Methods	❖ The key objective is to intercept the flow off the land. ❖ Locate in flood plain (flat area alongside watercourses) or in a low-lying area that is frequently wet. ❖ Dig a trial pit to check the depth to the water table. Alternatively, keep the base of the pond close to the summer water level in the nearby watercourse. ❖ Excavate a shallow trough with the long axis parallel to the watercourse/ditch. ❖ The area can be left to colonise naturally with plants or could be planted using native species of local provenance.
Key locations	❖ Close to watercourses and ditches in CSAs where water flows concentrate (delivery points and zones) during storm events ❖ Where land drains can be intercepted
Water quality benefits	❖ Variable, depending on location, size, hydrological regime and relevant pollutant type; could be substantial in optimum locations
Additional environmental benefits	❖ Ecological and biodiversity – both wildlife and plant. ❖ Aesthetic – they are attractive features
Farmer benefit	❖ Reduced soil loss
Cost	❖ Costs are relatively low as they can be constructed quickly with a digger.
Maintenance	❖ Sediment will need to be removed occasionally to maintain effectiveness.
Limitations	❖ Topography and land availability are critical factors ❖ Some land is removed from production
Additional information	❖ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/2915/08/scho0612buwh-e-e.pdf ❖ https://www.wwt.org.uk/uploads/documents/1429707026_WWTConstructedFarmWetlands150422.pdf ❖ https://www.crew.ac.uk/sites/www.crew.ac.uk/files/sites/default/files/publication/Rural%20SuDS%20Design%20and%20Build%20Guide%20December%202016.pdf
Comments	❖ In circumstances where overland flows occur, there are invariably 'wet', relatively unproductive areas close to watercourses where ponds could be established. ❖ Ponds may also be used to intercept land drains, with an overflow pipe to the watercourse.


Pond intercepting land drains in a tillage area beside a stream at Allerton Farm, Leicestershire (Photo: Donal Daly).


Two ponds immediately upgradient of a watercourse and downgradient of a pitch and putt area in Newmarket, County Cork. (Photo: Donal Daly).

8 Actions at a Watercourse Source

The following Actions are described in this section:

1. Livestock exclusion from watercourses (Section 8.1).
2. Bank stabilisation (Section 8.2).
3. Removal of riparian invasive species (Section 8.3).

8.1 Livestock exclusion from watercourses

Livestock Exclusion from Watercourses	
Target pollutants	❖ Microbial pathogens (e.g. coliforms), sediment, total phosphorus.
Description	❖ Preventing livestock from entering watercourses or critical source areas within a catchment requires the erection of a physical barrier such as a stock proof fence. This action should ideally be implemented in conjunction with Actions to break the pathway, such as planting a hedgerow where possible (see Section 7.3). ❖ By 2021, farmers in a derogation or those that are stocked higher than 170 kg organic N/ha, will have to prevent animals from entering watercourses to drink water and all watercourses must be fenced back 1.5 m from the top of the bank.
Land use	❖ All pasture alongside water courses
Methods	❖ The type of fence barrier required will depend on the site, terrain, meandering nature of a watercourse, livestock type etc. It is important to design the fence as a long-term barrier and not as a temporary installation. The fence should be robust enough to keep livestock out. ❖ Access may be required where vegetation needs to be removed periodically. ❖ In ecologically sensitive areas, alternative fencing methods should be considered. This will become apparent at the catchment characterisation stage. ❖ When erecting a fence barrier, planting a hedgerow alongside the fence may have additional water quality and environmental benefits (Section 7.3).
Key locations	❖ Alongside watercourses ❖ In critical source areas, particularly the immediate area around karst features such as swallow holes and sinking streams
Water quality benefits	❖ Erecting barriers, such as a permanent fence, has the direct benefit of preventing contamination of the watercourse by faecal coliforms from defecating livestock. ❖ Reduced bankside erosion prevents siltation of the watercourse and the release of total phosphorus.
Additional environmental benefits	❖ Results from the COSAINT project showed that fencing/exclusion of cattle from watercourses can help improve the quality of environmental indicators over the short and long term. ❖ Provides an area for a wildflower habitat to develop for pollinators
Farmer benefits	❖ Improved fence infrastructure adds value to the farm. ❖ Improved animal welfare, as there is less risk of loss of livestock by drowning. ❖ A better quality raw water supply can be provided to drinkers, where necessary. ❖ Reputational enhancement for implementing positive action that will be recognised by the community.
Cost	❖ Costs will vary depending on the type and length of fence being installed. Local quotations should be sought to take into consideration all influencing factors.

	o An assessment should be made to determine if existing projects or schemes can provide financial aid (e.g. future REPS/GLAS schemes or regional/project initiatives such as the Catchment Care Project). The local GWS may be able to provide some assistance. ❖ Please note that fencing of water courses is a requirement for farmers applying more than 170 kg nitrogen per hectare from 1st January 2021.
Maintenance	❖ Where total phosphorus is a concern, vegetation should be removed periodically. ❖ Fences should be checked regularly, especially prior to livestock entering the field. ❖ Where hedgerow is planted in addition to a fence, periodic maintenance will be required (see Section 7.3).
Potential Concerns & Solutions	❖ Cost o Areas being fenced off to protect water sources should be highlighted by the farm advisor on the farmer's application for the BPS, as per Article 32 of the BPS terms and conditions. BPS payments will not be impacted by measures taken to protect water quality as long as the terms and conditions are adhered to. o Where larger areas of land are being fenced off, farmers should consider entering other subsidy schemes to provide additional income e.g. woodlands (Section 7.6) ❖ Where livestock have no other access to drinking water an alternative piped water supply may be available from the GWS. In the absence of an accessible mains supply, an alternative supply such as nose pumps or solar powered drinkers can be investigated.
Additional information	❖ http://www.epa.ie/pubs/reports/research/water/Research_Report_330.pdf ❖ https://www.teagasc.ie/environment/biodiversity--countryside/research/current-projects/cosaint/ ❖ https://www.teagasc.ie/media/website/environment/biodiversity-countryside/2_O_hUallachain_et_al_Eand_E.pdf ❖ https://www.teagasc.ie/media/website/environment/biodiversity-countryside/4_Antunes_et_al_GLEON.pdf ❖ https://www.pearlmusselproject.ie/resources/farm-advisor-resources.html
Comments	❖ The results of the COSAINT project indicate that providing greater knowledge to farmers improves confidence in their own ability to implement water protection measures, such as fencing off watercourses.

Cattle access point (Photo: NFGWS).

Partial cattle access point (Photo: Donal Daly).

8.2 Bank stabilisation

Bank Stabilisation	
Target pollutants	❖ Sediment, total Phosphorus
Description	❖ Riverbank erosion is a natural process that is important in the functioning of river ecosystems. However, excessive erosion as a result of land management practices and livestock access to the river can cause the degradation of a watercourse channel and have a direct impact on water quality by contributing sediment and phosphorus that is bound on the sediment.
Land use	❖ All farmland adjoining watercourses and drainage ditches
Methods	❖ Numerous techniques are available. Their appropriateness largely depends on the severity of the erosion and velocity of the river channel flows. Please see Additional Information below for alternative techniques. An example of a methodology for riverbank reprofiling is as follows: o Rock is placed at the base of the eroding bank, parallel with the river flow. o The grass sod is peeled back approx. 1.5m in the field (top of eroding bank). o Soil is then carefully pulled back with a track machine and stored adjacent to the site to be replaced immediately after the re-profiling is complete. Typical desired slopes will range between 45 and 30. o The banked sod is then placed back onto the new sloped bank and watered to encourage growth. o Large willow stakes (10cm – 30cm) are placed at 1m intervals to accelerate the growth. o Other projects have used old Christmas trees to further protect more vulnerable portions of the bank. These trees are screwed to timber posts on the lower portion of the bank to provide initial buffering and protection from flooding. o The site is then fenced off to livestock. o A silt curtain should be installed parallel to the riverbank and water flow to contain silt plumes.
Key locations	❖ Watercourse banks where erosion is taking place due to livestock access ❖ Livestock drinking points
Water quality benefits	❖ The principal benefit of adapting this mitigation measure will be a reduction in suspended sediments/turbidity concentrations. Likely reductions will also occur in sediment bound (i.e. particulate) phosphate. Bank rehabilitation in conjunction with riparian margin establishment also serves to break overland flow pathways.
Additional environmental benefits	❖ Ensures riverbed substrates are free from siltation. This provides a quality habitat for macroinvertebrates, juvenile pearl mussels and salmonoid fish. ❖ Riparian restoration enhances biodiversity by creating habitats for farmland birds, mammals and beneficial insects.
Farmer benefits	❖ Prevents loss of ground through erosion ❖ Limits the potential for injury to livestock ❖ Increased visual/landscape values
Cost	❖ Costs will depend on the technique selected. Soft engineering techniques such as willow spiling are considerably cheaper than approaches that use larger quantities of hard engineering materials. o The principle costs are associated with the hire of a digger and operator.

Maintenance	❖ Visual monitoring of future erosion to ensure the effectiveness of the mitigation measure. ❖ Where flooding occurs soon after the completion of works, some willow stakes may need replacing. ❖ Maintenance of fencing, where installed (see Section 8.1).
Limitations	❖ A level of knowledge of the river energy/flow velocities is needed to select the most appropriate method. This can be problematic in ungauged catchments. ❖ It is good practice to complete such works during low water flows to reduce the risk of silt loss. ❖ Instream works are generally only permitted during the Inland Fisheries of Ireland (IFI) open season (i.e. March to September). ❖ Prior consultation is advised with the IFI and the National Parks and Wildlife Service as planned works may require the completion of a detailed Appropriate Assessment Report where the relevant watercourse is located within or flowing into an SAC.
Additional information	https://www.duhallowlife.com/sites/default/files/C1%20Final%20Technical%20Report%20-%20Reduction%20of%20Bank%20Erosion.pdf http://www.epa.ie/pubs/reports/research/water/Essentra%20EPA%20RR%20230_web.pdf https://westcumbriariverstrust.org/projects/pearls-in-peril/pip-projects/willow-spiling

8.3 Removal of riparian invasive species

Removal of Riparian Invasive Species	
Target pollutants	❖ Sediments, total Phosphorus (bound to the sediment)
Description	❖ Invasive species, such as Himalayan balsam (*Impatiens glandulifera*), Giant hogweed (*Heracleum mantegazzianum*) and Japanese knotweed (*Fallopia japonica*), can rapidly establish within the riparian margins of our watercourses. These plants typically outcompete native flora, resulting in dense monospecific (i.e. one species) stands. These stands die back during the winter months, leading to bare, exposed banks that are more vulnerable to erosion and the consequent loss of sediment and phosphorus.
Land use	❖ All areas alongside watercourses
Methods	❖ As a starting point, it is important that invasive species are identified correctly given that treatment/mitigation solutions differ between species. ❖ For example, manual cutting/pulling of Himalayan balsam should be performed prior to the formation of the seed pods, as these explode at the slightest disturbance when ripe. ❖ Infestations of Giant hogweed need to be controlled by digging out the whole plant, as cutting through the stem must be done below ground level to ensure damage to the root stock. ❖ Where *in situ* physical removal is not feasible, chemical control such as the use of systemic herbicides maybe required. It is important to note that only herbicides approved for use near water are allowed. Operators must be trained in the relative treatment technique (i.e. PA6AW – Handheld near water course, PA6INJ – Pesticide injection Japanese Knotweed course). ❖ Personal protective equipment (PPE) should be worn where appropriate. For instance, full protective clothing should be worn when cutting Giant hogweed to prevent skin contamination by the sap.
Key locations	❖ Alongside watercourses
Water quality benefits	❖ Identification and control of invasive species can help to reduce excess sediment entering watercourses during the winter months when vegetation dies back.
Additional environmental benefits	❖ Improves riparian biodiversity and enhances wildlife habitats, as native species will have an opportunity to re-establish. ❖ A reduction in sedimentation in rivers will prevent the silting up of fish spawning grounds and smothering of freshwater pearl mussels. ❖ Invasive species such as Giant hogweed and Japanese knotweed can grow to heights ranging from 2m–5m, thus potentially causing excess shading along waterbodies. ❖ Avoids impacts on infrastructure
Farmer benefits	❖ Reduces the loss of agricultural lands as a consequence of bank erosion ❖ Prevents the loss or damage to fencing as a result of subsidence due to erosion ❖ Reduction of risk of invasive species spreading to productive grass/tillage land

Cost	❖ The cost of controlling invasive species is related to the type of plant and extent of infestation. Many plants are easy to control (e.g. hand pulling), but some require specialist teams (e.g. Japanese knotweed).
Maintenance	❖ Himalayan balsam seeds are not robust and only survive for up to 18 months. Therefore, a two-year control programme can be successful in eradicating this plant provided there is no further infestation from upstream or adjacent sites. ❖ Herbicide treatment of Himalayan balsam could be used as a follow up to hand pulling (e.g. later in the year to deal with any missed plants or regrowth). ❖ Previously infested sites should be surveyed for a number of years after the last growth, as remaining seeds may be viable and regrow.
Limitations	❖ As invasive species growing along riparian areas have access to a good route for movement via the watercourse, the risks of reintroduction from upstream sites can prevent long-term eradication. It is, therefore, imperative that a catchment scale approach is considered, with the co-operation of individual landowners.
Additional information	❖ https://www.biodiversityireland.ie/projects/invasive-species/. ❖ https://invasivespeciesireland.com/ ❖ https://www.npws.ie/sites/default/files/publications/pdf/Stokes_et_al_2004_IAS_Ireland.pdf ❖ Section 12, Volume 2 in EPA Local Catchment Assessment Guidance which can be accessed at this link: https://wfd.edenireland.ie/help/help. ❖ https://tweedforum.org/wp-content/uploads/2020/05/TF_invasives_manual_web-FINAL.pdf ❖ https://www.duhallowlife.com/sites/default/files/INVASIVES%20BROCHURE.pdf

Stand of Himalayan balsam growing along River Allow, Co Cork (Photo: Fran Igoe (LAWPRO)).

Stand of Giant hogweed along banks of the River Mulkear, Co Limerick (Photo: Fran Igoe, LAWPRO).

Japanese knotweed in flower (Photo: Fran Igoe, LAWPRO).

Appendix 1: Summary of Measures in the GAP Regulations

	MEASURE	GAP REF.	CATEGORY
1	Chemical fertiliser shall not be applied to land within 2m of any surface waters.	17 (1)	SETBACK DISTANCES
2	Organic fertiliser or soiled water shall not be applied to land within 200m of an abstraction point supplying 100m3 or more of water per day or serving 500 or more persons; 100m for schemes supplying 10m3 or more or serving 50 or more; 25m of any abstraction of water for human consumption; 20m of lake shoreline, or a turlough likely to flood; 15m of exposed cavernous or karstified limestone features; 5m of any surface water (not a lake), or 10m where slopes are >10%, or for 2 weeks preceding and following the periods specified in Schedule 4.	17 (2)	
3	Alternative landspreading setback distances may be set by the Local Authority or Irish Water on the basis of technical and risk assessments and prior assessments.	17 (3)-(7)	
4	Organic fertiliser or soiled water shall not be applied to land within 10m of any surface waters where the land has an average incline greater than 10% towards the water	17 (12)	
5	Where farmyard manure is held in a field prior to landspreading it shall be held in a compact heap and shall not be placed within 250m of an abstraction point supplying 10m3 or more of water per day or serving 50 or more persons; 50m of any other abstraction source; 20m of a lake shoreline or turlough likely to flood; 50m of exposed cavernous or karstified limestone features (such as swallow-holes and collapse features); 20m of other surface waters (other than a lake).	17 (13)	
6	Farmyard manure shall not be held in a field at any time during the periods specified in Schedule 4.	17 (14)	
7	Silage bales shall not be stored outside of farmyards within 20m of waters or a drinking water abstraction point in the absence of adequate facilities for the collection and storage of any effluent arising.	17 (15)	
8	No cultivation shall take place within 2m of a watercourse identified on the OSI 1:10560 map except in the case of grassland establishment or the sowing of grass crops.	17 (16)	
9	Supplementary feeding points shall not be located within 20m of waters and shall not be located on bare rock.	17 (17)	
10	On holdings with stocking rates of 170kgs of nitrogen or more: bovines shall not be allowed to drink directly from water from 1 January 2021; Where bovines have direct access to water, a fence at least 1.5m from the waters edge shall be installed by 1 January 2021;Livestock can be moved to isolated land parcels across a watercourse if both sides are fenced; Supplementary drinking water points must be at least 20m from watercourses by 1 January 2021.	17 (18) (19)	
11	Take steps to minimise soiled water produced in a farmyard	5(1)	SOILED WATER
12	Ensure that rainwater from roofs and clean yards and water flowing from higher ground onto a farmyard is diverted without contamination to a clean water outfall and is not allowed to enter soiled yards or storage areas for soiled water. Ensure rainwater gutters and downpipes are maintained in good working condition.	5(2) (a)(b)	
13	There shall be no runoff of soiled water from farm roads to any waters from 1 January 2021.	18 (20)	
14	There shall be no direct runoff of soiled waters resulting from poaching to any waters.	18 (21)	
15	All slurry, soiled water, effluents, farmyard manure etc produced in a building or yard, shall be collected and held in a manner that prevents run-off or seepage, directly or indirectly, to groundwaters or surface waters.	6(1)	COLLECTION AND HOLDING
16	Thew occupier of a holding shall not cause or permit slurry, soiled water, effluents, farmyard manure etc., to enter waters.	6(2)	
17	All storage facilities (including out-wintering pads, earthen-lined stores, and integrated constructed wetlands) for slurry, soiled water, farmyard manure etc. shall be maintained and managed in good condition.	7(1) (3) (4)	PROVISION AND MANAGEMENT OF STORAGE
18	New storage facilities shall be designed, sited, constructed, maintained and managed to prevent run-off or seepage into groundwaters or surface water, and comply with construction specifications of DAFM.	7 (2) (a)(b)	
19	The capacity of storage facilities for livestock manure and other organic fertilisers, soiled water and effluent from dungsteads, farmyard manure pits and silage pits shall be adequate to provide for storage for such a period as to comply with these Regulations and to avoid water pollution.	8 (1)(3)(4); 9; 10; 11; 12; 13; 14	
20	An occupier shall have due regard to the storage capacity which may be required during periods of adverse weather conditions. The application to land of livestock manure or soiled water is precluded.	8 (2)	
21	The capacity of facilities for the storage of effluent produced by ensiled forage and other crops shall equal or exceed the capacity specified in Table 5 of Schedule 2, and for soiled water being shall equal or exceed the capacity required to store all soiled water likely to arise on the holding during a period of 15 days.	9 (a)(c)	

22	The capacity of facilities for storage of livestock manure may be less than that specified in Article 10, 11, 12 or 13, as appropriate, in the case of a holding where the occupier has a contract providing exclusive access to adequate alternative storage capacity located outside the holding, or for access to a treatment facility for livestock manure, or a contract for the transfer of the manure. Storage capacity may also be less in certain cases where deer, goats, sheep and livestock (other than dairy cows) are outwintered subject to specified maximum stocking rates and other conditions.	14 (1) (2) (3) (4)	CAPACITY OF STORAGE
23	The amount of fertiliser applied to promote the growth of a crop or grassland shall not exceed that specified in the Regulations.	15; 16	NUTRIENT MANAGEMENT – CROPS & GRASSLANDS
24	Livestock manure, other organic fertilisers, effluents, soiled water and chemical fertilisers shall be applied to land in as accurate and uniform a manner as is practically possible.	18 (1)	MANNER OF APPLICATION
25	Organic and chemical fertilisers or soiled water shall not be applied to land in any of the following circumstances— (a) the land is waterlogged; (b) the land is flooded or likely to flood; (c) the land is snow-covered or frozen; (d) heavy rain is forecast by Met Eireann within 48 hours, or (e) the ground slopes steeply and there is a risk of water pollution having regard to factors such as surface runoff pathways, the presence of land drains, the absence of hedgerows to mitigate surface flow, soil condition and ground cover.	18 (2) (3)	
26	(4) Organic fertilisers or soiled water shall not be applied to land— (a) by use of an umbilical system with an upward-facing splashplate, (b) by use of a tanker with an upward-facing splashplate, (c) by use of a sludge irrigator mounted on a tanker, or (d) from a road or passageway adjacent to the land irrespective of whether	18 (4)	
27	Soiled water shall not be applied to land— (a) in quantities which exceed in any period of 42 days a total quantity of 50,000 litres per hectare, or by irrigation at a rate exceeding 5 mm per hour.	18 (5)	
28	In an area which is identified on maps compiled by the Geological Survey of Ireland as "Extreme Vulnerability Areas on Karst Limestone Aquifers", soiled water shall not be applied to land— (a) in quantities which exceed in any period of 42 days a total quantity of 25,000 litres per hectare, or (b) by irrigation at a rate exceeding 3 mm per hour unless the land has a consistent minimum thickness of 1m of soil and subsoil combined.	18 (6)	
29	Application of fertiliser to land is prohibited during the periods specified in Schedule 4 (Closed Periods).	19 (1)	CLOSED PERIODS
30	Closed periods do not apply in relation to the application to land of soiled water, or chemical fertilisers to meet the crop requirements of Autumn-planted cabbage or of crops grown under permanent cover, or fertilisers whose application rate or usage rate is less than 1kg per hectare of available nitrogen or phosphorus.	19 (2)	
31	The amount of livestock manure applied in any year to land on a holding, together with that deposited to land by livestock, shall not exceed an amount containing 170 kg of nitrogen per hectare.	20 (1)	APPLICATION LIMITS
32	Where arable land is ploughed between 1 July and 30 November the necessary measures shall be taken to provide for emergence, within 6 weeks of ploughing, of green cover from a sown crop. A rough surface shall be maintained prior to a crop being sown in the case of lands ploughed between 1 December and 15 January.	21 (1)	CULTIVATION AND GREEN COVER
33	Where grassland is ploughed between 1 July and 15 October the necessary measures shall be taken to provide for emergence by 1 November of green cover from a sown crop.	21 (2)	
34	Grassland shall not be ploughed between 16 October and 30 November.	21 (3)	
35	When a non-selective herbicide is applied to arable land or to grassland in the period between 1 July and 30 November the necessary measures shall be taken to provide for the emergence within 6 weeks of the application, of green cover from a sown crop or from natural regeneration.	21 (4)	
36	Where green cover is provided for in compliance with this Article, the cover shall not be removed by ploughing or by the use of a non-selective herbicide before 1 December unless a crop is sown within two weeks of its removal.	21 (5)	

Acknowledgement: This table is copied from McNally (2017), which can be accessed at this link: https://www.catchments.ie/download/review-of-potential-local-measures-for-mitigating-farm-impacts-in-catchments/

Appendix 2: The Scientific Understanding for Protection and Mitigation Actions

A1 Introduction

In advance of undertaking any Actions, it is advisable get as full an understanding of the situation as possible as part of work planning. In evaluating the Actions that are needed, take account of the following factors:

1. Is the objective to 'protect' or 'improve'?
2. What pollutant is posing a threat to the source?
3. Is it a groundwater or a surface water source?
4. Is the pressure a point source or diffuse or both?
5. Are there details on pollutant loadings and on the load reductions required?
6. What is the landscape setting in which pollutants reach the drinking water source?

Descriptions of some relevant aspects of each of these factors are given below.

A2 Water quality objective

The Source Report will have concluded whether the objective is to 'protect' where the untreated water is satisfactory or to 'improve' where it is unsatisfactory. The differences between these objectives are given in Section 3 of the NFGWS (2019) Framework for Drinking Water Source Protection. Clearly, where the objective is to 'improve', greater resources and efforts are needed. However, protecting the source water and ensuring that the quality is maintained is equally important; there is a danger of complacency in these situations.

A3 Relevance of the pollutant type

In most circumstances, one or more of the following pollutants may be the stressor: microbial pathogens, nitrate, ammonium, phosphate, BOD, colour and pesticides such MCPA. Summary information on each of these pollutants is given below; when considering them, think in terms of relevance for protection/mitigation options. Greater detail is given in Appendix 1 of the NFGWS (2019) Framework document. Each pollutant has particular characteristics that influence its movement and attenuation; an understanding of these characteristics is helpful in deciding on the strategies and actions for dealing with them in an effective and efficient manner.

A3.1 Microbial pathogens

The two main pathogens that pose a threat to both groundwater and surface water sources are *E. coli* and Cryptospiridium. The aim is to ensure that there isn't gross pollution by keeping numbers of *E. coli* in the untreated water below certain guide values (100/100 ml for groundwater and 1,000/100 ml for surface water) by undertaking suitable protection or mitigation Actions.

Microbial pathogens die off and are attenuated in the landscape. However, they can get into groundwater readily in freely draining areas where there is outcropping and shallow bedrock, and into surface water in poorly draining areas where there is rapid (or flashy) runoff from the land. In addition, urban wastewater treatment systems, farmyards and septic tank systems can be a source of microbial pathogens.

A3.2 Nitrate

Nitrate readily leaches from the soil in freely draining areas and where these coincide with relatively intensive farming, nitrate concentrations in underlying groundwater can be problematical – either above or close to the guide value of 28 mg/l as a mean value[8]. As well as noting nitrate concentrations, it is worthwhile plotting them to check for trends; for instance, by doing this for sources where concentrations are satisfactory but are approaching 28 mg/l, an upward trend helps forewarn that some actions might be needed to reduce leaching. It is particularly important not to allow average concentrations to exceed 37.5 mg/l as it would be highly likely that there would be breaches of the 50 mg/l limit in that circumstance.

A3.3 Ammonium

For surface water sources, high ammonium concentrations generally indicate that pollution is occurring from an organic waste source, such as farmyard dirty water or runoff after slurry spreading or untreated effluent from septic tank systems. For groundwater sources, it usually indicates a localised source such as a septic tank system or farmyard in situations where the bedrock is close to the ground surface, such that the ammonium doesn't have the time or opportunity to be oxidised to nitrate (when it converts to nitrate the concentrations as nitrate are not problematical). The presence of ammonium often indicates that microbial pathogens might be an issue as well.

Ammonium in watercourses can also arise for drained peatlands and peaty soils areas due the decomposition of the peat. It is usually associated with dissolved organic carbon (DOC).

A3.4 Phosphate

High phosphate concentrations cause eutrophication of surface water, which is often indicated in summer by slimy growths in watercourses. This can cause taste, odour and treatment operational issues. They occur in poorly draining areas due to runoff from the land and from farmyards or from inadequate septic tank systems.

Phosphate is relatively immobile in soils. In poorly draining areas, it is prone to being 'washed off' into ditches and watercourses after heavy rainfall.

One feature to note about phosphate is that it takes very little to cause water quality impacts – 1 kg phosphorus when present as phosphate will pollute 29,000,000 litres of water (or 6.4 million gallons). Keeping in mind that farmers might apply between 20-30 kg P/ha, a loss of 1-5%, depending on the circumstances, could cause eutrophication in the nearby watercourse.

A3.5 Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) generally represents how much oxygen is needed to break down organic matter in water. Healthy water needs the presence of some oxygen, which sustains aquatic life, such as fish and plants, and the aesthetic quality of streams and lakes.

Organic pollutant sources, such as effluent from wastewater treatment plants and septic tank systems, dirty water from farmyards and runoff of slurry from fields, can use up the oxygen in the water and then impact of the aquatic life. Silage effluent and milk have very high BOD concentrations, and entry to water is likely to cause fish kills.

A3.6 Manganese

Manganese is found naturally in groundwater, usually at low concentrations. Pollution of groundwater by high BOD sources, such as silage effluent and milk, can dissolve the manganese from bedrock resulting in high concentrations which cause aesthetic problems such as a metallic taste and a black precipitate.

[8] The Maximum Admissible Concentration (MAC) for nitrate is 50 mg/l. By keeping the mean values below 28 mg/l, it is unlikely that any 'one-off' concentrations will exceed 50 mg/l.

A3.7 Colour

Colour, while not a health risk in itself, can be problematical in some surface water and spring sources as the treatment process can react with chlorine to form trihalomethanes which are a potential threat to human health. It arises mainly from peaty areas, particularly where they have been drained and are used for peat extraction, farming or afforestation.

A3.8 MCPA

MCPA is used mainly to control rushes. It is soluble in water and is slow to break down in saturated conditions. Therefore, in poorly draining areas it can be carried off the land after heavy rainfall. The limit for MCPA is very low – 0.1ug/l or 0.1 of a part per billion, which is the equivalent of one drop of MCPA in an Olympic-sized swimming pool.

A4 Pressure type

There are two categories of pressures – point and diffuse (non-point). Distinguishing between them is helpful as the approaches to understanding, locating and mitigating them, while having some similarities, have substantial differences. Point pollution sources are normally easier to locate and deal with than diffuse sources.

1. **Point** pressures are discharges from <u>localised</u> areas such as sites, soakage pits and percolation areas, discharging as runoff or from pipes to watercourses. They can be subdivided into 'large' and 'small'.
    - <u>Large:</u> UWWTPs, IPPC licenced discharges, storm overflows, major spillages and leakages.
    - <u>Small:</u> Farmyards, domestic wastewater treatment systems (DWWTSs), cattle drinking points, ring feeder areas, misconnections in urban areas, areas where sprayers are filled and/or washed out, minor spillages and leakages.

2. **Diffuse** pressures are <u>widespread</u> activities in the landscape. Examples include: fertiliser (organic & inorganic) application, faeces & urine from grazing animals, spraying of pesticides, leaking sewers in urban areas, polluted groundwater in urban areas.

A5 Drinking water source type

Group scheme surface water sources are either rivers or lakes, whereas groundwater sources are wells or springs. The main difference is that with one you can see the water from the headwaters to the intake, whereas with the other the water is hidden and is emerging from underground, either at a well or a spring. Clearly, this is a major difference when considering protection/mitigation Actions, but there are also many similarities. Furthermore, in the case of some spring (groundwater) sources in karst limestone areas, there may be a surface runoff component to a swallow hole with the water re-emerging at the spring. Both surface water and groundwater sources have catchment areas contributing water to the source intake; in the case of groundwater sources, this is called the zone of contribution (ZOC).

A6 Nutrient load reductions

Where the objective it to 'improve' and the pollutant is either nitrate or phosphate, it can be worthwhile knowing the approximate reduction needed to return the water to satisfactory quality, as this can help focus consideration of the mitigation Actions. For instance, farmers will be able to relate to this as they know the application rates that they use. Two 'back of envelope' calculations are given below.

A6.1 Nitrate example

Source: well in a freely draining area.

Abstraction rate: 500 m^3/d (182,500 m^3/year) (Requires a catchment area of ~38 ha where the recharge is 500 mm/year)

Mean nitrate concentration: 10 mg/l as N (44 mg/l as NO_3) (Usually this would imply some spikes above 50 mg/l NO_3)

Target mean nitrate concentration: 6.2 mg/l as N (28 mg/l as NO_3).

Reduction required: 700 kg N/year.

Implication: Consideration can now be given to the type of action needed, the optimum locations (using the EPA pollution impact potential map (PIP) for nitrate in groundwater) and likelihood of success. This analysis helps focus on the 'what' mitigation options question and 'where' they need to be implemented. For instance, if the area of high PIP was 50% of the catchment area, the average annual nitrate load reduction needed would 35 kg/ha, which would be a substantial proportion of the nitrogen applications.

A6.2 Phosphate example

Source: intake from a river.

Stream flow: 160 l/s (average flow in a river with a catchment 10 km^2 in size and with effective rainfall (rainfall less actual evapotranspiration) of 500 mm/year).

Mean phosphate concentration in river: 0.07 mg/l as P.

Target mean phosphate concentration: 0.03 mg/l as P.

Reduction required: 200 kg P/year.[9]

Implication: One the one hand, this is a small amount to be reduced in an area of 1,000 ha; on the other hand, in circumstances where 20-30 kg/ha/year might be applied, it is difficult to prevent losses. However, the reduction required can be targeted at high phosphate PIP areas. For instance, if 50% of the area was high PIP, then the annual reduction needed would be 0.4 kg/ha.

A7 The landscape setting

Each of the five factors described above are influenced by the particular landscape setting in the catchment area/ZOC of the source. Therefore, thinking of and evaluating the landscape setting of your source is a good starting point for considering protection and mitigation strategies and Actions.

Take a helicopter view of the situation in a source catchment or ZOC. See the situation in terms of what is called 'the pollutant transfer continuum', which has the following four elements (see Figure A1):

1. The presence of a pressure (or pressures) with an associated load of pollutants. This pressure can either be a point or diffuse (non-point) source.
2. Mobilisation, whereby in the case of diffuse pressures, the potential environmental stressor or pollutant – such as nitrate or MCPA – becomes soluble or attaches to soil particles and starts the journey to a receptor, such as a stream or well.
3. Delivery/transport in a pipe in the case of many point sources or more diffusely along pathways, underground or over ground, to a receptor, such as watercourse, aquifer or drinking water source.
4. The receptor which is impacted; in the case of surface water, it can vary for instance, in terms of flow rates, upstream water quality and sensitivity (e.g. high or good status or pearl mussel objectives), whereas in the case of groundwater in an aquifer, the existing water quality and dilution potential can vary.

The reason for making the distinction between these elements is that it is more effective to consider protection and mitigation options (measures and actions) according to the point in the source-

[9] Target load reduction = 160 x 86400 x 365 x 0.04/1,000,000 = 200 kg

pathway-receptor continuum on which they take effect. The recommended relevant points along the continuum for consideration of specific measures and actions are:

i) Pollutant source reduction or elimination.
ii) Mobilisation control.
iii) Pathway interception.
iv) Receptor/instream works.
v) Treatment. (Treatment is not dealt with in this Handbook.)

In considering which point along the continuum that an Action to protect or improve the source water quality would be most effective, account needs to be taken of the properties of the pollutant of concern as well as the landscape setting. For instance, if nitrate is the issue of concern and as it is highly mobile in freely draining soils and travels vertically from the soil into groundwater, source reduction and mobilisation control actions are needed. By contrast, if phosphate is the issue, while source and mobilisation control measures (such as nutrient management planning) are beneficial and necessary, pathway interception measures are essential. For MCPA, both source reduction and pathway interception are needed. **Therefore, careful analysis of the mitigation and protection options is essential if the effort undertaken is to be effective and justifiable.**

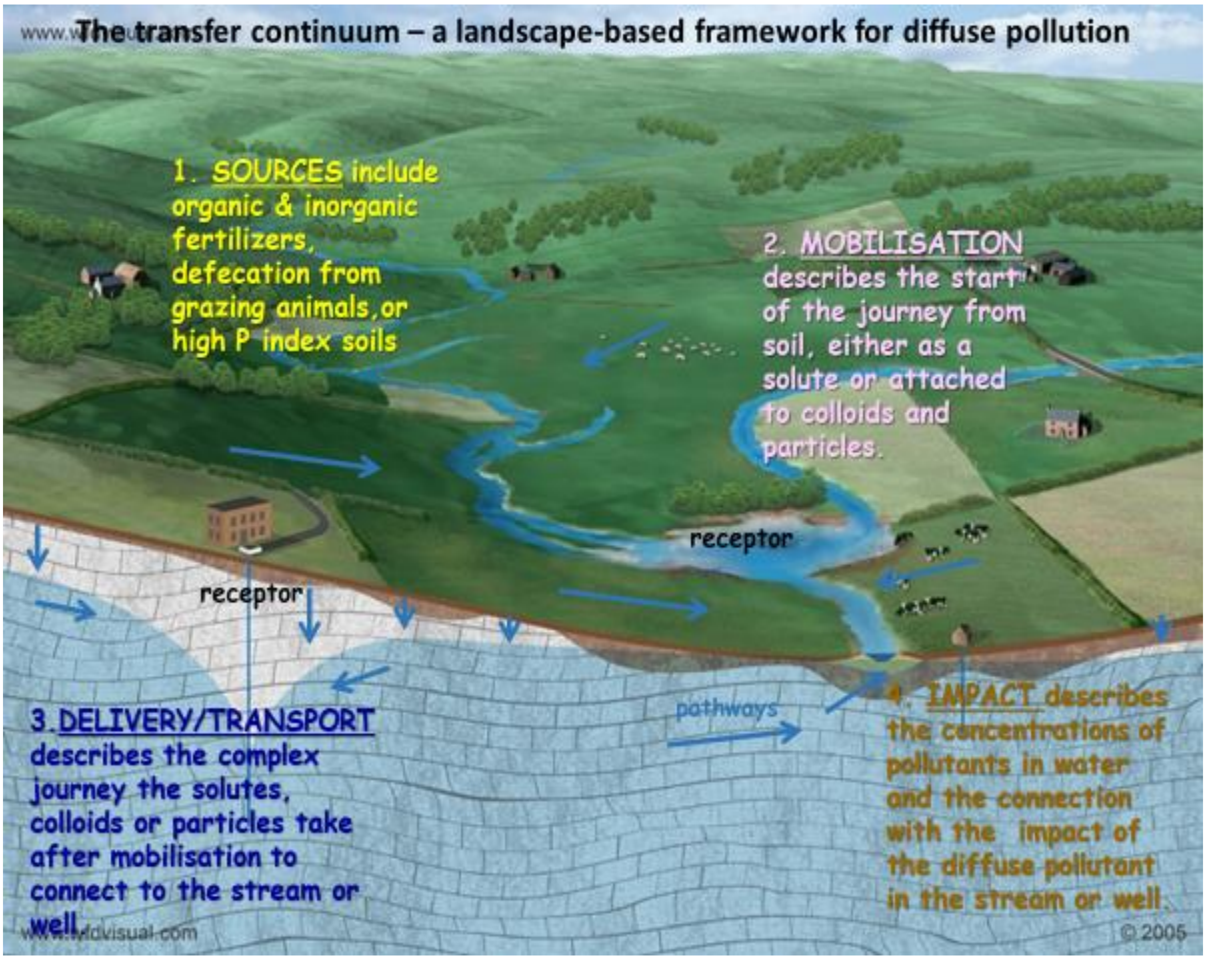

Figure A1: Representation of the pollutant transfer continuum (copied from NFGWS, 2019)

The effectiveness of the Actions will vary depending on the properties of the point at which they are undertaken. This is illustrated in Table A1 and Table A2. Table A1 outlines the point along the continuum where protection and mitigation Actions are most effective for dealing with pollutants in the catchment areas of surface water sources; Table A2 provides the information for the ZOCs of groundwater sources.

Box 2

Visual indicators of water movement – getting the overview

Every farmer knows that happens to water on their land. Why? They know from the natural vegetation and from the crops that the land is suitable for as well as the presence/absence/density of ditches and land drainage pipes. If they go onto another farmer's land, they will also know by just looking around at these indicators. Therefore, in any catchment or ZOC it is usually possible by checking the vegetation and the drainage indicators to tell whether most water flows off the land to a watercourse or percolates underground, becomes groundwater and then flows underground to wells, springs and watercourses. If there are many small streams (sometimes intermittent) and drainage ditches (often dry for proportions of the year), it means that runoff occurs after heavy rainfall. If there are no or virtually no drainage ditches, then rainfall largely percolates into the ground to become groundwater. This is a good starting point when considering what and where protection/mitigation Actions are needed for dealing with the pollutants of concern.

A7 Critical source areas

The term 'critical source areas (CSAs)', which is often used by catchment scientists, is a useful concept and phrase. Why? Because CSAs are the areas that are likely to deliver a disproportionally high amount of pollutants from diffuse sources compared to other areas in a source catchment or ZOC. Therefore, **they are the areas that need to be focussed on for targeted Actions**. Appendix 3 in the NFGWS Framework for Drinking Source Protection (2019) gives further details on CSAs.

Maps of CSAs, called **Pollution Impact Potential (PIP) maps**, have been produced by the Catchments Unit of the EPA for two pollutants – phosphate and nitrate – to assist in targeting Actions to the areas where they will be most effective. Note the word 'Potential' in the title: i) the map scale is 1:25,000 and so they are not field-scale maps; and ii) they are based on the best readily available information and not on either 'walking the land' or on direct discussions with farmers. In addition to the PIP maps, **groundwater vulnerability maps** produced by the Geological Survey of Ireland (GSI) can assist in locating CSAs particularly for well or spring sources where microbial pathogens are the pollutant. The location of farmland in a CSA does not mean that a significant pressure is present, as either best management practices are already in place or the farming system might have changed. Therefore, their value is that they act as a signpost to where there is a potential CSA and so should be considered as a **guide** to the situation on any farm, which needs 'ground truthing' before any Actions are decided on and established.

The following three situations that may arise for GWS managers are described below:

i) River source with high phosphate arising from farmland.
ii) Well with high nitrate.
iii) Well/spring with high numbers if E. coli.

A7.1 River source with high phosphate arising from farmland

In this circumstance, the issues that need to be resolved are as follows:

i) What is/are the source/s contributing significant loads of phosphate?
ii) Where are the main areas/locations contributing phosphate?
iii) What are the options for reducing the phosphate concentrations in the watercourses?

Table A1: Summary of types of options and their effectiveness in surface water catchments

Pollutant	Protection & Mitigation Options				Comment
	Source Reduction	Mobilisation control	Pathway interception	Instream works	
Microbial pathogens	Low	Very low	High	Low	Excessive pathogen numbers are likely to arise mainly from land runoff, dirty water from farmyards and cattle in streams.
Nitrate	High	Low	Very low	Very low	NO_3 is mobile in free draining areas and enters surface water from underground.[10]
Ammonium	High	Very low	High	Very low	NH_4 usually indicates a nearby pressure as it readily converts to nitrate.
Phosphate	Moderate	Moderate	High	Very low	PO_4 issues arise in poorly draining areas. Pathway interception and NMP are needed.
Sediment	High	Very low	High	Very low	Sediment arises mainly from drainage activities and runoff in poorly draining tillage areas.
MCPA	High	Low	High	Very low	MCPA can readily runoff the land in wet, poorly draining areas.

Note: The symbol size indicates the likely effectiveness of options in each category.

High Moderate Low Very low

Table A2: Summary of types of options and their effectiveness in ZOCs

Pollutant	Protection & Mitigation Options			Comment
	Source Reduction	Mobilisation control	Pathway interception	
Microbial pathogens	Low	Very low	High	Soil/subsoil attenuates pathogens as they move underground.
Nitrate	High	Moderate	Very low	NO_3 is mobile and enters groundwater readily in free draining areas.
Ammonium	High	Very low	High	Indicates a nearby organic pollution source.

Note: The symbol size indicates the likely effectiveness of options in each category.

High Moderate Low Very low

[10] Along every stream, groundwater is slowly percolating, usually unnoticeable except where there are springs, into the stream bottom throughout its length. Groundwater contributes between 20-70% of average stream flows, depending on the geology in the catchment – a higher proportion where the stream is underlain by a Regionally Important or productive aquifer and a lower proportion where underlain by a poor aquifer.

In order to get high phosphate concentrations, there must be i) a source of phosphate and ii) points and areas where phosphate is lost to a watercourse either directly from point sources, such as a farmyard, farm roadway or cattle access or crossing point or from diffuse sources via runoff from farmland. EPA Pollution Impact Potential (PIP) maps for phosphate to surface water from diffuse agricultural sources are available. Figure A2 provides an illustration of the elements in these maps.

Phosphate PIP maps are based on a combination of:

i) The susceptibility of the land to loss of phosphate to watercourses in overland flow and shallow subsurface flow, which is derived from;
   - integration of map information on the soils, subsoils and bedrock, all of which influence designating the fields as poorly draining, thereby allowing runoff of phosphate in the soil to surface water.
   - an understanding, based on research results, on phosphate movement in soil, subsoil and bedrock.

ii) Estimated phosphorus applications to the soil based on information on farming intensity for 2018.

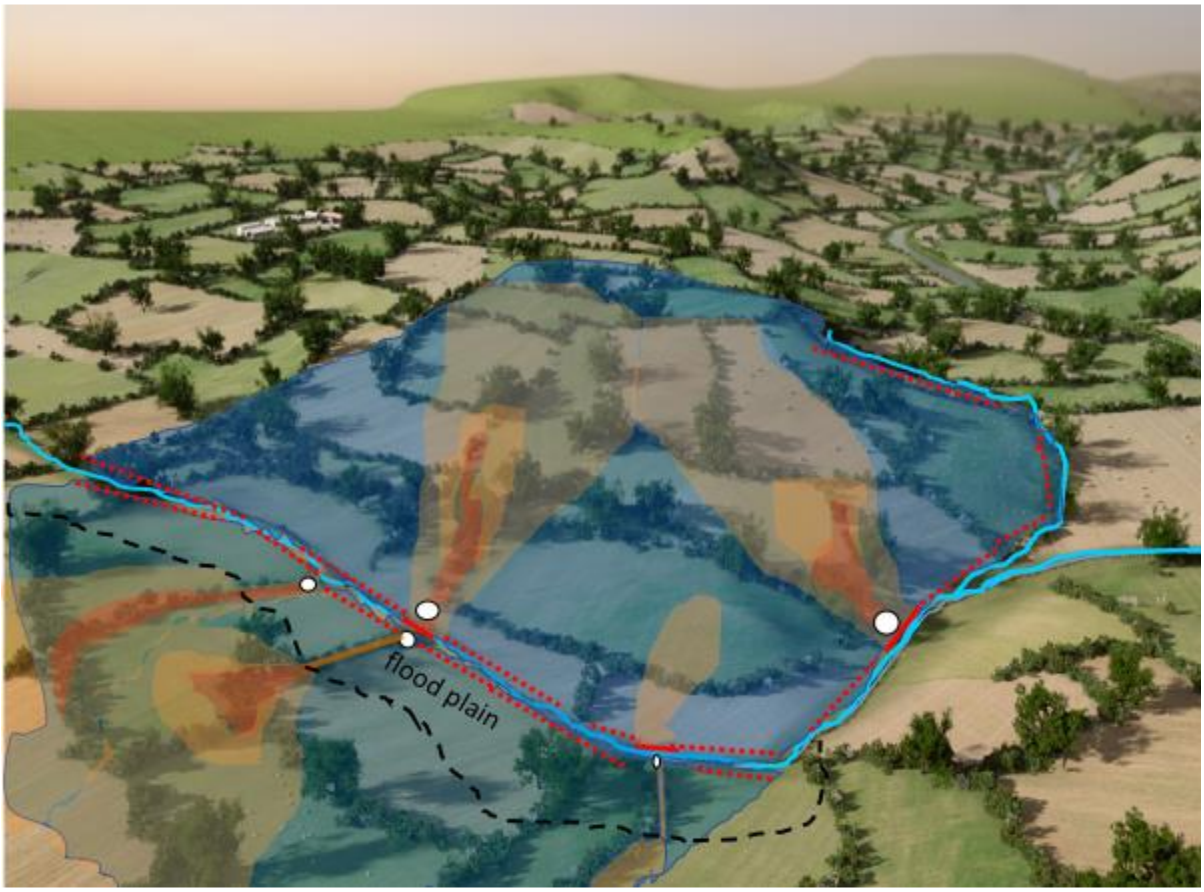

Figure A2: Illustration of a phosphate critical source area (CSA), flow delivery points, flow delivery paths, focussed flow delivery zones and dispersed flow delivery zones. (Produced in consultation with Eva Mockler, Catchments Unit, EPA.)

A7.1.1 PIP map explanation

- All of the coloured area is the **critical source area (CSA)** with a P PIP Ranking of 2 (due to the presence of poorly draining soils and moderate livestock intensity) alongside an *At Risk* water body in which phosphate is the *significant issue* and farming is the *significant pressure*.
- Surrounding (uncoloured) area is freely draining and is not a phosphorus CSA.
- Pale blue area is **high PIP** where runoff doesn’t converge into focussed delivery paths.

- Three categories of focussed **flow delivery paths** are indicated by variations in brown/orange colours. These areas have the same PIP ranking as the blue area. These flow delivery paths are initiated by a varying topography and associated changes in slope, and the poorly draining nature of the fields that cause overland and shallow subsurface runoff after heavy rainfall. In these delivery path areas, variations in topography cause the runoff to progressively increase and converge down slope, resulting in an increasing accumulation of higher P loadings in the runoff water in the lower areas. The orange delivery paths have the highest surface runoff and P load accumulations as these are the lowest areas in the fields. A drainage ditch can sometimes be located in these areas.
- White dots = **flow delivery points** to the watercourse from either drainage ditches with intermittent flows or small watercourses, with the size of the points indicating relative loads of P being delivered to the watercourse.
- Solid red lines = **focussed flow delivery zones**.
- Dashed red line = **dispersed flow delivery zones**

A7.1.3 What potential Actions are available to reduce phosphorus losses to the watercourse?

The most appropriate and effective protection/mitigation Actions will vary in the landscape depending on the location. In this Figure, all the area has been given the same PIP ranking and therefore the same assumed availability of P for loss to water. In real situations, the PIP ranking would vary depending on livestock (LU) units per hectare, but this variability is not included as this Figure is intended to describe key features and concepts.

A7.1.3.1 Potential Actions in the CSA

Pollutant reduction/elimination and **mobilisation reduction** Actions are applicable throughout this area (i.e. total coloured area). Options include:

i) Farmer engagement and collaboration. (Section 4.1)
ii) Farmyard management to prevent runoff to watercourses. (Section 5.1)
iii) Appropriate application of P fertilizer (organic & inorganic). (Section 5.3)
iv) Use of precision technology (Section 5.4)
v) Management of farm roadways, etc (Section 5.5)
vi) Management of land reclamation. (Section 5.12)
vii) Liming of soils. (Section 6.1)
viii) Timing of fertilizer applications (Section 6.2)
ix) Use of LESS (Section 6.3)
x) Cover/catch crops. (Section 6.7)
xi) Reducing soil compaction (Section 6.8)
xii) Agroforestry (Section 7.5)
xiii) Woodlands (Section 7.6)

A7.1.3.2 Potential Actions at the delivery points

Generally, these are drainage ditches taking overland and shallow surface water flows from upgradient. The main in-ditch options are:

i) Ditch management and sediment traps to reduce sediment losses. (Section 7.7)
ii) Farm Ponds and Wetlands (Section 7.9)

A7.1.3.3 Potential Actions at and up-gradient from the focussed delivery zones

After heavy rainfall, overland and shallow surface inflows to the watercourse may occur over a relatively wide area (several 10s metres), and might sometimes be associated with a drainage ditch. In addition to the pollutant reduction/elimination and mobilisation reduction Actions listed above, **pathway interception** Actions such as the following are options:

i) Riparian buffers in the flatter areas alongside the watercourse. (Section 7.1)

ii) In-field grass buffers where the land slopes to the watercourse. (Section 7.2)
iii) Hedgerows (Section 7.3)
iv) Wild bird cover crops planted alongside watercourses. (Section 7.4)
v) Low Earthen Mounds/Bunds (Section 7.8)
vi) Farm Ponds and Wetlands (Section 7.9)

In this area, the interception needed will be significant because of the focussed nature of water flows and pollutant inputs; for instance, if a buffer is being established, it would need to be relatively wide or alternatively a number of Actions in combination would be needed. Also, keep in mind that the Actions do not need to be located just close to the watercourse; certain Actions will be appropriate upgradient of the watercourse.

<u>A7.1.3.4 Potential Actions at and up-gradient of the dispersed delivery zones</u>

These areas are likely to generate approximately the same losses of P/ha as in the delivery pathways, but the delivery of P to the watercourse will be over a wide area. Similar to the situation in the focussed delivery zones, some of the Actions can be in the fields uphill from the watercourse.
Possible **pathway interception** Actions include:

1. Riparian buffers in the flatter areas alongside the watercourse. (Section 7.1)
2. In-field grass buffers where the land slopes to the watercourse. (Section 7.2)
3. Hedgerows alongside the watercourse. (Section 7.3)
4. Wild bird cover crops planted alongside watercourses. (Section 7.4)
5. Low Earthen Mounds/Bunds (Section 7.8)
6. Farm Ponds and Wetlands in the lowlying area adjoining the watercourse. (Section 7.9)

Due to the dispersed mature of water flows, a relatively narrow buffer will generally be sufficient.

<u>A7.1.3.5 Recommended approach</u>

The recommended approach is to:

i) Assess the phosphate concentrations at the surface water source and, in certain circumstances, in the tributaries, check for trends and estimate the load reduction required (see Section A6.2 for further details). This helps set the target reduction in kg/ha needed from the high PIP fields. This information might be in the Source Report or can be requested from the consultant assisting the NFGWS.
i) Access the phosphate PIP map for the catchment area of the river source.
ii) Locate the fields with high PIP ranking (1, 2 and 3).
iii) Note the protection/mitigation Actions for phosphate listed in Table 6.
iv) Check the details on each potential Action in Sections 5, 6, 7 and 8.
v) Locate and evaluate the delivery paths and delivery points.
vi) Visit the area and talk to the farmers with land in the high PIP areas. This is a critically important step. Firstly, farming practices and fertiliser applications might have changed since 2018. Secondly, input on solutions and agreement on the Actions is needed from the farmers.
vii) Always think of the Actions in the context of where they would be undertaken as outlined in the Sections above.
viii) Decide on and undertake appropriate Actions.

A7.2 Well with high nitrate

In this circumstance, there are two issues to be resolved and questions to be answered:

i) Where are the main areas contributing nitrate?
ii) What are the options for reducing the nitrate concentrations in the well?

In order to get high nitrate concentrations in the well, there must be i) a source of nitrate and ii) areas where the nitrate can be lost from the soil to groundwater via leaching. While nitrate arising from a septic tank system percolation area might be sufficient to raise the nitrate concentrations in a well with a small abstraction rate immediately downhill of the system, such as a domestic supply well, for group scheme wells the source will generally be fertilisers, usually a combination of organic (manure, slurry and/or soiled water) and inorganic.

The EPA have produced a Nitrate Pollution Impact Potential (PIP) maps (or critical source area (CSA) maps) that show the areas that are likely to be contributing most nitrate to groundwater. An example is shown in Figure A3.

A7.2.1 Using the nitrate Pollution Impact Potential (PIP) maps

Nitrate PIP maps are based a combination of:

- i) The susceptibility of the land to leaching of nitrate to groundwater, which is derived from;
    - o integration of map information on the soils, subsoils and bedrock, all of which influence designating the fields as freely draining, thereby allowing leaching and movement of any excess nitrate in the soil to groundwater.
    - o an understanding, based on research results, on nitrate movement underground in soil, subsoil and bedrock.
- ii) Estimated nitrogen applications to the soil based on information on farming intensity for 2018.

Nitrate PIP maps can be used to locate the areas where targeted mitigation Actions are needed.

A.7.2.2 Recommended approach

The recommended approach is to:

- i) Assess the nitrate concentrations in the well, check for trends and estimate the load reduction required (see Section A6.1 for further details). This helps set the target reduction in kg/ha needed from the high PIP fields. This information might be in the source report or can be requested from the consultant assisting the group water scheme.[11]
- ii) Access the nitrate PIP map for the general area around the source.
- iii) Locate the well and the ZOC on this map.
- iv) Locate fields in the ZOC with high PIP ranking (1, 2 and 3) – these are the fields where mitigation Actions need to be targeted.
- v) The protection/mitigation Actions listed in Table 3 that are suitable for reducing the impacts of nitrate in wells are given in Table A3 below.
- vi) Consider the details on each Action described in Sections 5, 6 and 7.
- vii) Visit the area and talk to the farmers with land in the high PIP areas. This is a critically important step. Firstly, farming practices and fertiliser applications might have changed since 2018. Secondly, input on solutions and agreement on the Actions is needed from the farmers.
- viii) Decide on and undertake appropriate Actions in collaboration with the farmers.

A7.3 Well/spring with high numbers of E. coli

While the drinking water standard for E. coli is 0, where numbers are >100/100 ml in wells or >1,000/100 ml for springs in karst areas[12], this is considered to be 'gross' pollution and therefore requires that the water quality should to be improved and the numbers of E. coli reduced – see Appendix 1 in the NFGWS Framework document (NFGWS,2019) for more details. In this circumstance, how might GWS managers decide on the appropriate mitigation Actions?

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[11] For further information on the role and benefit of nutrient loadings analysis, see Section 11 in LAWPRO Course Notes at this link: https://lawaters.ie/technical-resources/

[12] Where a portion of the outflow from karst springs arise from sinking streams, the appropriate E. coli guide value is 1,000/100 ml, similar to that for surface water sources.

Table A3: Possible mitigation options for reducing nitrate concentrations in wells

Category	Mitigation option
Nitrate reduction	➢ Farmyard management to prevent infiltration to groundwater (Section 5.1). ➢ Appropriate application of N fertiliser (Section 5.2). ➢ Use of precision technology (Section 5.4). ➢ Using low crude protein animal feeds (Section 5.6). ➢ Organic farming (Section 5.12).
Reducing mobilisation of nitrate in soils	➢ Liming of soils (Section 6.1). ➢ Timing of fertiliser applications (Section 6.2). ➢ Low emission slurry spreading (Section 6.3) ➢ Use of protected urea (Section 6.4). ➢ Multi-species grassland swards (Section 6.5). ➢ Red and white clover (Section 6.6). ➢ Cover/catch crops (Section 6.7).
Pathway interception	➢ Wild bird cover crops (Section 7.4). ➢ Agroforestry (Section 7.5). ➢ Woodlands (Section 7.6).

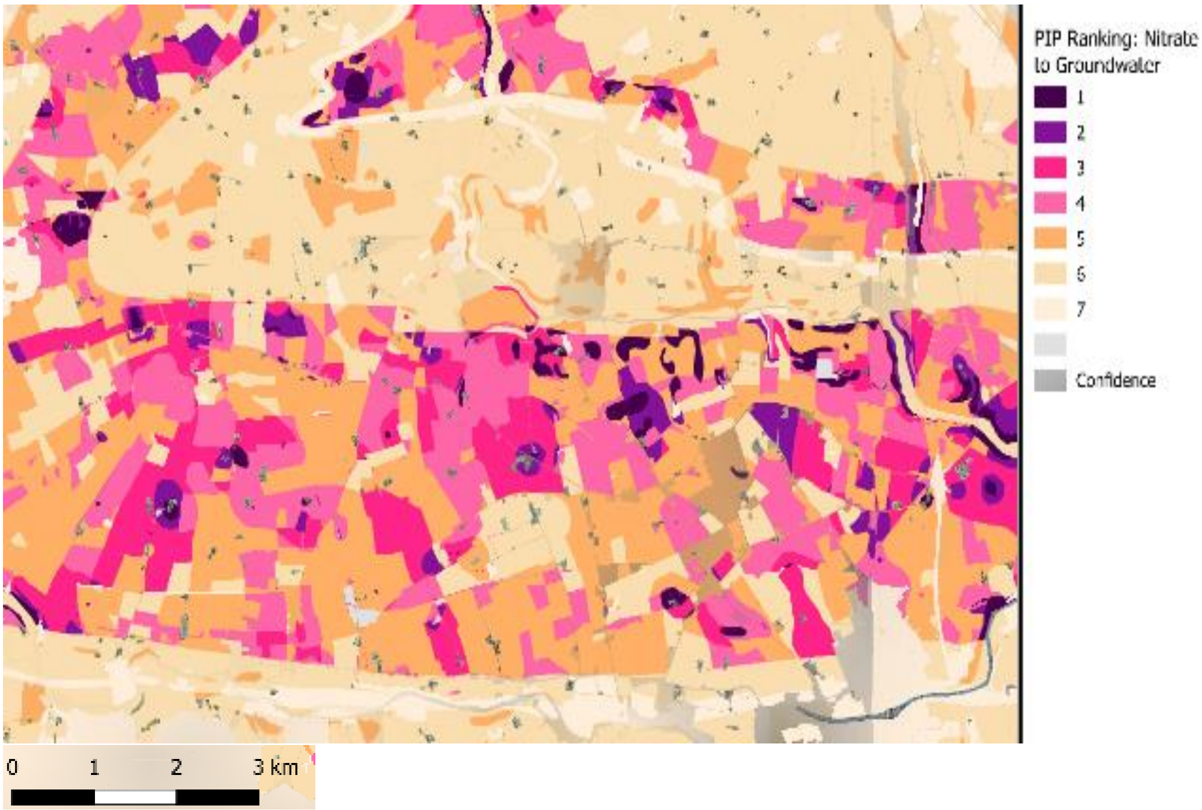

Figure A3: Pollution impact potential (PIP) map for nitrate entering groundwater arising from diffuse agricultural sources such as spreading of fertilisers and grazing animals. PIP ranking 1 is the highest with 7 the lowest. Therefore, the darker the area, the higher the risk to groundwater, with fields in PIP ranking 1, 2, 3 and perhaps 4 being the critical source areas.

The sources of microbial pathogens in any rural areas are numerous – from point sources, such as septic tank systems, farmyards, and cattle access points and crossings and/or from diffuse sources, such as landspreading of manure/slurry/soiled water and/or grazing animals. However, high numbers of E. coli in wells and springs are mainly likely to arise in the following scenarios:

1. Where infiltration of soiled water enters directly into bedrock beneath a farmyard that is upgradient of the well or spring.
2. Where the limestone bedrock is outcropping or shallow (<1 m of soil/subsoil, i.e. extreme vulnerability – rock at or close to the surface) and manure/slurry is landspread prior (within a few days) to an intense rainfall event.
3. Where some of the well/spring water comes from surface water entering a swallow hole in karst limestone areas.
4. Where sanitary protection of the well or spring is poor thereby enabling surface water to flow down the outside of the well casing – a scenario is not considered further in this Handbook.

Therefore, mitigation Actions are needed for whichever of these scenarios that are present in the Inner Protection Area of the ZOC, and particularly in the area delineated as the CSA.

A7.3.1 Using groundwater vulnerability maps

The groundwater vulnerability concept is based largely on the question 'can water and contaminants move in the subsurface materials (soil and subsoil) and get down to groundwater in a bedrock or sand/gravel aquifer easily?' The vulnerability category assigned to a site or an area is thus based on the relative ease with which infiltrating water and potential pollutants, such as microbial pathogens, may reach groundwater in a vertical or sub-vertical direction. Groundwater that readily and quickly receives water (and pollutants) from the land surface is considered to be more vulnerable than groundwater that receives water (and pollutants) more slowly, and in lower quantities. The slower the movement and the longer the pathway, the greater is the potential for attenuation of many pollutants, particularly microbial pathogens such as E coli.

There are five vulnerability categories: i) extreme – rock at or near ground surface (X); ii) extreme (E); high (H); moderate (M) and low (L). A way to conceptualise the different categories, from a groundwater contamination perspective, is as follows:

- Extreme (X and E): microbial and chemical pollution can occur.
- High (H) vulnerability: chemical pollution by mobile pollutants can occur, such as by nitrate. Microbial pollution uncommon as the subsoil enables filtration and die-off.
- Low (L) vulnerability: generally no contamination, with minimal groundwater recharge, excellent protection from pollutants (in fact only in exceptional circumstances would pollutants reach groundwater as it would take >10 years for water at the surface to reach a bedrock aquifer and the clayey material provide good attenuation).

Therefore, the vulnerability categories and areas that are relevant to high levels of E. coli in a well or spring are the extreme X and E categories and areas (areas of outcrop and shallow rock and where sinking streams enable bypassing of the soils and subsoils) – the CSAs for E. coli will occur within these categories. An example of a vulnerability map is given in Figure A4.

A7.3.2 Recommended approach

The first step is to check the Source Report for the location of the Inner Protection Area (SI)[13] if delineated[14] and for the vulnerability categories in this area. If it is a karst aquifer, check for karst features, in particular for swallow holes and sinking streams. Alternatively, access the groundwater vulnerability map and the karst features map on the GSI website for the general area around the

[13] Microbial pathogens will only arise from activities within this area – it is defined by a 100-day time of travel boundary and therefore E. coli entering groundwater outside of this area will have died off before the water enters the well.

[14] If the Inner Protection Area (SI) has not been delineated, it is recommended that this be undertaken, particularly where E. coli is a pollutant. If the drinking water source is in a karst limestone aquifer, as is the case with many groundwater GWS sources, then all of the karst limestone area will be in the Inner Protection Area (SI). More information on groundwater protection zones is provided at this link: https://www.gsi.ie/documents/Groundwater_Protection_Schemes_report.pdf

source at this link: https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx#Vulnerability. Input from a hydrogeologist is recommended.

A7.3.2.1 Scenario 1: Farmyards

i) The pathway for E. coli is vertically beneath or in the vicinity of the farmyard to groundwater underneath.
ii) Locate any farmyards present in extremely vulnerable areas (X and E)[15] within the Inner Protection Area.
iii) Visit these farms.
iv) The main possible source of E. coli entering groundwater would be soiled water entering directly into bedrock in the vicinity or beneath slurry and soiled water holding tanks where ready access can sometimes occur around the outside of the tanks as this area is often backfilled with crushed rock or other permeable material. While it is advisable to query possible leakages, in most circumstances the tanks are well sealed and even if a small leak occurs, self-sealing is likely to prevent losses. Therefore, it is worthwhile checking the area around slurry holding tanks.
v) If there is evidence of possible infiltration of soiled water to groundwater, then follow the advice given for Farmyard Management in Section 5.1 and work with the farmer to undertaken remediation actions. This is a source control mitigation Action.

A7.3.2.2 Scenario 2: Landspreading of slurry/manure prior to heavy rainfall

i) The pathway for E. coli is vertically through freely draining soil and permeable subsoil to bedrock.
ii) The GAP Regulations require that organic fertilizers should not be applied to land within 48 hours of heavy rainfall forecasted by Met Éireann (see Measure 25 in Appendix 1). However, with the improvements in weather forecasting in recent years, it is often possible to predict heavy rainfall up to five days in advance.
iii) Locate the areas of X vulnerability (rock at or near ground surface) within the Inner Protection Area. This is the CSA where Actions need to be targeted.
iv) Ask the farmer to avoid landspreading slurry in this area if feasible – this is a source mitigation Action.
v) Request farmers to increase the two days required by the Regulations to as long a time as possible to enable pathogen die-off in the soil, thereby reducing the likelihood of pathogens entering bedrock. This is a mobilisation control Action.

A7.3.2.3 Scenario 3: Karst limestone area with swallow holes in the ZOC

i) Check for farmyards in the extremely vulnerable areas (X and E) and follow the advice for Scenario 1 above.
ii) There are two main potential pathways for E. coli in karst areas[16]:
    - Vertically through shallow freely draining soil and permeable subsoil into limestone underneath. This is dealt with it in Scenario 2 above.
    - Where the pathway for E. coli is surface runoff (overland and shallow subsurface), usually in a poorly draining area, to a drainage ditch or water course that enters the karst aquifer via a swallow hole. Advice on this setting is given below.
iii) Locate swallow holes within the ZOC on the GSI karst features map in the Source Report.

[15] In these areas, the soil and subsoil thickness can vary from 0-3 m. Therefore, the bottom of tanks can reach the top of bedrock. Once microbial pathogens enter bedrock, there is only limited attenuation.
[16] For further information on karst limestones in Ireland, see book 'Karst of Ireland' at this link: https://www.gsi.ie/en-ie/publications/Pages/Karst-of-Ireland-Landscape-Hydrogeology-Methods-David-Drew.aspx

iv) Examine these swallow holes during fieldwork and check whether there are others in the area. In some circumstances, it may be necessary to undertaken tracing to ensure that the swallow hole is linked to the well or spring. This may already have been undertaken by the GSI.

v) Locate the catchment areas of the swallow holes. If there a number of swallow holes, then focus on the catchment areas of those with the largest catchment areas and flows as these are likely to be the main contributors of E. coli from diffuse sources. Some of these watercourses may only have intermittent flows and therefore winter field checking may be needed to enable them to be assessed properly.

vi) Examine the soil drainage map for the area and locate the poorly draining areas within the catchment areas of the swallow holes. It is probable that microbial pathogens will arise from surface runoff in these areas. Therefore, the CSA is likely to be the poorly draining areas within the catchment areas to the swallow holes, with areas close to watercourses and swallow holes posing the greatest threat. An example of a soil drainage map is shown in Figure A5.

vii) Assess whether further water samples need to be taken from the source and/or from sinking streams and analysed before decisions are made on mitigation Actions. Also, it might be beneficial to plot the E coli data to ascertain the time of the year with the highest numbers, for example whether the high numbers are in Spring after landspreading or in the Autumn when recharge to the limestone commences.

viii) The suggested options for consideration are given in Table A4 – these are a subset of those given in Table 2.

Table A4: Possible mitigation options for reducing E. coli numbers in wells/springs in karst aquifers

Category	Mitigation option
Pollution reduction or elimination	➢ Farmyard management (Section 5.1). ➢ Management of farm roadways etc (Section5.5).
Reducing mobilisation	➢ Timing of fertilizer applications (Section 6.2). ➢ Low emission slurry spreading (Section 6.3).
Pathway interception	➢ Riparian buffers (Section 7.1). ➢ In-field grass buffers (Section 7.2). ➢ Hedgerows (Section 7.3). ➢ Wild bird cover crops planted alongside watercourses (Section 7.4). ➢ Agroforestry (Section 7.5). ➢ Woodlands (Section 7.6). ➢ Low earthen mounds/bunds (Section 7.8). ➢ Farm ponds and wetlands (Section 7.9).
At swallow holes with links to spring sources and at spring sources	➢ Livestock exclusion.

A8 Co-benefits

The NFGWS Framework for Drinking Water Source Protection advises that, when considering protection or mitigation Actions, consideration should be given to additional environmental benefits that might be achieved; for instance for biodiversity, carbon sequestration and greenhouse gas (GHG) emission reductions. Table A5 illustrates how the Actions described in this Handbook have several other environmental benefits.

A9 Selecting mitigation actions – conclusions

Ensuring the 'right measure in the right place' is critical to achieving a desired water quality outcome, as well as optimum use of resources. Failure to achieve a water quality outcome from efforts undertaken can mean wasted time and money, disenchantment and reputational loss. Deciding on the right Action or Actions and achieving a desired outcome is challenging in the complex farming, land and landscape settings in Ireland. However, the likelihood of success is increased if a systematic approach is taken to deciding on and undertaking the Actions. This Appendix outlines our recommended approach, and a summary is shown in the process flowchart in Figure A6.

Table A5: Illustration of the range of environmental benefits provided by different farming and forestry practices.

Management option to address pressures	**Water quality**	**Biodiversity**	**Flood mitigation**	**Soil conservation**	**Landscape**	**Climate Change Mitigation**	**Climate Change Adaptation**
Creation of buffer strips, e.g. riparian zones, grass margins.	●	●	○	●	○	●	○
Planting of clover and multi-species grasses	●	●	–	●	–	●	–
Planting hedges alongside watercourses across slopes	●	●	○	●	○	●	○
Liming of soil to ensure optimum pH	●	–	–	●	–	●	○
Agroforestry	●	●	○	●	○	●	○
Reforestation with native species	●	●	●	–	○	●	○
Interception ponds and constructed wetlands	●	●	○	○	●	●	●
Rewetting peatlands	●	●	○	–	○	●	●

● **= Management option contributes directly to an environmental benefit**

○ **= Management option contributes indirectly to an environment benefit**

(Source: An Fóram Uisce, 2020. Link: https://thewaterforum.ie/app/uploads/2020/07/An-Fóram-Uisce_Framework-for-Integrated-Land-and-Landscape-Management.pdf)

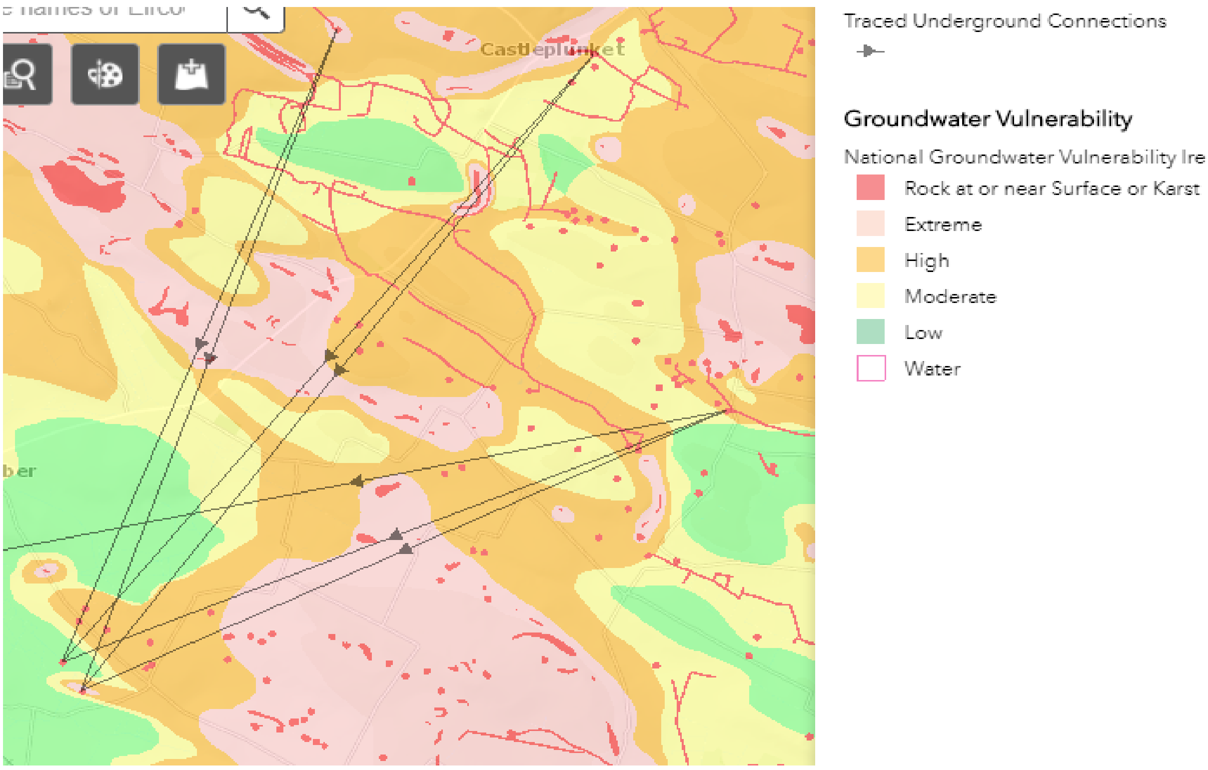

Figure A4: Groundwater vulnerability map showing five vulnerability categories and traced connections from swallow holes to springs (Downloaded from https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx)

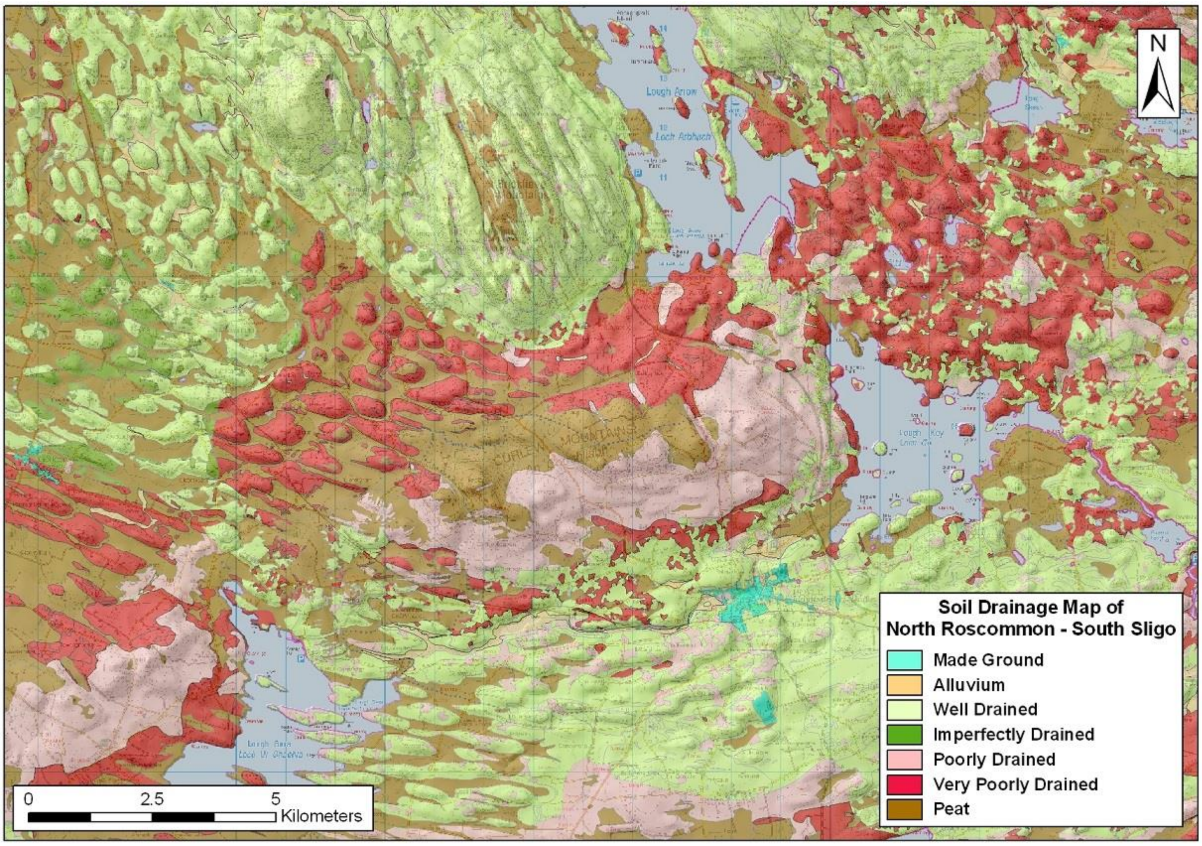

Figure A5: An example of map showing six soil drainage categories; one freely draining, four different grades of poorly draining mineral soils (alluvium is usually poorly draining) and one poorly draining organic (peat) soil. Map is available at a scale no greater than 1:40,000. (Map created on behalf of EPA Catchments Unit, by Robbie Meehan)

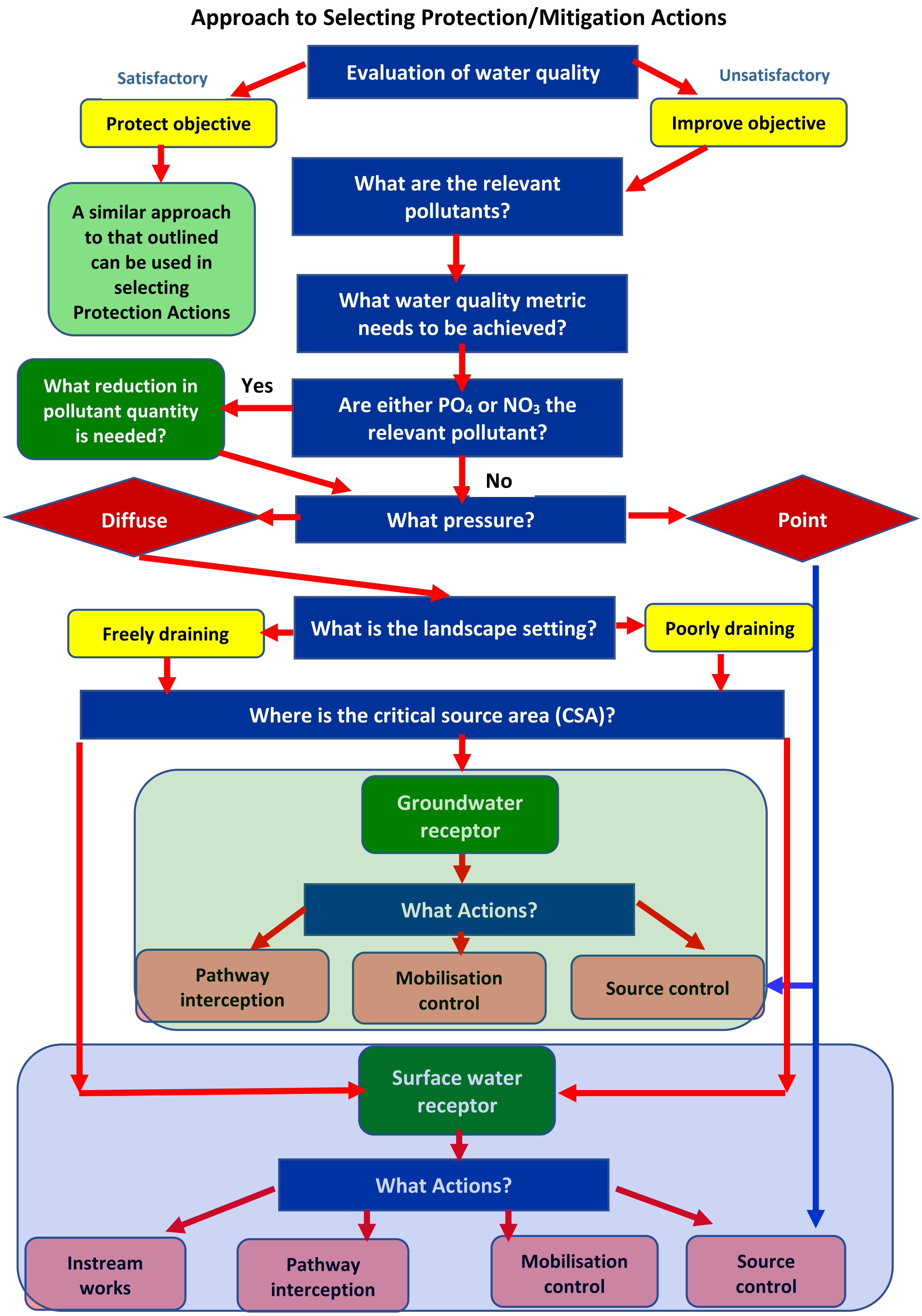

Figure A6: Process flowchart illustrating a recommended approach to deciding on appropriate mitigation Actions.

Appendix 3: Case Studies

Case Study 1 – Identifying Mitigation Actions on Stranooden Group Water Scheme, County Monaghan

Introduction

As part of the NFGWS Source Protection Pilot Project – Phase II, a comprehensive source protection report was prepared for the Stranooden GWS which:

- evaluated untreated water quality in White Lough;
- compiled and assessed existing information as part of initial characterisation;
- carried out further characterisation involving fieldwork and water sampling;
- completed an evaluation of possible mitigation options; and
- made recommendations for mitigating Actions to be implemented.

This case study summarises the outcomes.

Evaluation of water quality

A review of untreated water quality determined that the condition of the scheme's abstraction source, White Lough, as being unsatisfactory. Two principle contaminants of concern were identified, namely phosphorus and the acid herbicide MCPA. Each are considered below.

Phosphorus

While enhanced phosphorus concentrations are not perceived to have a human health impact, as evident by the lack of a drinking water parametric value, excess phosphorus can stimulate algae production. In turn this can impact on the effectiveness of water treatment processes. Total phosphorus concentrations measured weekly from January 2019 to October 2019 within White Lough ranged from 0.075mg/l to 0.14mg/l, far in excess of the guide value of 0.025 (mean) mg/l. High *chlorophyll a* concentrations were recorded in 2015, 2016 and 2019, and an algal bloom was observed in July 2018.

In addition, phosphate concentrations were assessed in the catchment. Mean concentrations above the guide value of 0.035 mg/l as P were present in the Dromore River and its tributaries located within the Derryvalley sub-catchment. Mean P concentrations were below the guide value in the Lough Major Stream which forms the other significant sub-catchment of White Lough.

MCPA

On multiple occasions throughout the 2018 – 2020 period, MCPA concentrations were detected well in excess of the NFGWS framework guide value of 0.075 µg/l (mean) and of the Drinking Water Directive limit of 0.1 µg/l. One sub-catchment in particular – the Derryvalley sub Catchment – was delivering a disproportionately larger load MCPA to the lough than other tributaries.

The objective

As a consequence of the unsatisfactory water quality due to phosphorus and MCPA, the objective is to 'improve' the water quality by implementing appropriate mitigation Actions.

Required phosphorus load reduction

A load reduction assessment was undertaken for the Derryvalley subcatchment. The mean phosphate concentration was 0.067 mg/l and the mean flow available from the hydrometric station located on the outflow from this sub-catchment was estimated as 0.0532 m^3/s. Therefore, in order to reduce the concentration to below 0.035 mg/l, a phosphorus load reduction of approximately 540 kg/year is needed.

Pressures causing the unsatisfactory water quality

From the catchment characterisation process completed on the catchment area, two significant pressures were identified as affecting the Dromore River which are a point source – Ballybay WWTP – and diffuse sources arising farming.

The Critical Source Areas (CSA)

Within the Derryvalley sub-catchment, over 75% of the lands are highly susceptible to near surface phosphate runoff, as identified by the EPA's susceptibility mapping. Additionally, a substantial portion of the sub-catchment has been attributed a high Pollution Impact Potential (PIP) risk score (i.e. Rank 1 – 3) – this area therefore is the CSA for phosphate loss, and therefore is the area where mitigation Actions need to be targeted. Conversely, the remainder of the overall catchment is recognised as being mostly free draining in nature with a predominance of PIP scores ranging from 5 – 8, thus explaining the lower P concentrations found within the associated watercourses. Whilst free draining, annual average concentrations of nitrate and ammonium where below their respective NFGWS source protection framework guide values.

The phosphate susceptibility map was used to locate the potential CSAs for MCPA loss, as this map is based largely on poorly draining soils, which can result in rush growth and from which losses of MCPA can occur.

Mitigation Actions

Phosphorus

It was decided to focus on pathway interception Actions and instream works as the means of reducing phosphorus losses to water both as phosphate and as phosphorus attached to sediment in runoff. Eighteen farmers, who were identified within a critical source area (CSA) for phosphorus overland flow, agreed to implement a series of measures to break the diffuse pathway. For example, dynamic, field specific buffer margins were established, meaning that extended buffers were specified at the perceived runoff discharge points, whilst reduced buffer distances were to be created outside of these zones. This approach, as an alternative to a generic buffer width, was met with a greater approval from the landowner, who recognised the compromise needed to meet the water quality objective. A number of landowners also opted for inclusion within the existing Native Woodland Establishment Scheme, whereby the woodlands are to be strategically planted within phosphorus CSAs.

MCPA

Source control measures are being implemented to tackle pesticide exceedances. Commencing in May 2019, the group water scheme offered all farmers within the Derryvalley sub-catchment the opportunity to avail of a weed / rush wiping service as an alternative to the use of MCPA. During the 2020 spraying season, approx. 65 farmers within the sub-catchment partook in the pilot, agreeing to eliminate their MCPA usage.

Monitoring and future plans

In order to measure the effectiveness of the implemented mitigation measures, a catchment wide sampling programme is being continued by the scheme. Early results would suggest that MCPA concentrations emanating from the Derryvalley sub-catchment are still of concern. The '*I planted a tree and my garden is pesticide free*' project initiated as part of the NFGWS groundwater Pilot Protect is scheduled for expansion into the White Lough catchment in 2021. It is envisaged that a greater insight into peoples' practices and attitudes towards the domestic usage of pesticides will be garnered. It is also understood that the Ballybay UWWTP, which discharges into the Dromore River a short distance upstream from White Lough, is scheduled for a plant upgrade to meet their new discharge obligations. The continued monitoring programme will also inform the effectiveness of these future scheduled measures.

Example of mixed species hedgerow establishment and stock proof fencing installed along the Dromore River within the Derryvalley sub catchment (Photo: Patrick McCabe, NFGWS).

Aerial view of newly established buffer margin along the Dromore River within the Derryvalley sub catchment (Photo: NFGWS).

Case Study 2 – Implementing Mitigation Actions using Co-benefits in County Roscommon

Background

One of the challenges implementing successful source protection measures is encouraging farmers to participate and implement actions. Collaboration and improving awareness of the water quality issue is key to the successful implementation of any source protection programme. The NFGWS Source Protection Pilot Project Phase 2 in Roscommon is trialling initiatives aimed at improving water quality using a novel approach involving collaboration and awareness raising through biodiversity enhancement.

As part of the characterisation process, elevated levels of MCPA and glyphosate were identified as significant pressures on a number of GWS catchments. Two of the GWSs agreed to pilot a different and innovative approach attempting to improve water quality.

Let it Bee

The "Let it Bee" initiative, is being trialled in the Corracreigh and Mid Roscommon Group Water Schemes. The initiative gives a selected number of farmers beehives, equipment, mentoring and training with a view to changing the mindsets and practices on pesticide usage on their farm ultimately improving water quality through biodiversity enhancement.

The Let it Bee initiative commenced in 2020 when three families farming in the Corracreigh GWS ZOC received honey beehives and began learning how to become beekeepers as they spread the word on the danger of pesticides to their bees, the local drinking water source and the wider environment.

Local GWS manager, Thomas Rushe, became the driving force behind the Corracreigh project, raising local consciousness about the importance of environmental appreciation and protection. As an organic farmer and manager of the local group water scheme, Thomas understood the damage pesticides can pose to drinking water and biodiversity generally. Bees are a very visible reminder which people can relate to and understand the importance of having protected areas in the local landscape. The theory behind the project, and the belief of those taking part, is if the community look after and protect the bees, the water will also be protected as a co-benefit.

Thomas pointed out that 'the project is generating huge interest locally'; he added 'there are already other farmers looking to join the initiative which I hope will have a significant impact on improving our water quality and biodiversity'.

Cattle and sheep farmer, Jude Walsh, is mentor to the beekeepers of Corracreigh whose expertise has been essential to the success of the project so far. Jude draws a parallel between 'honey bees that work together for the benefit of their hive – their community', and the people of Corracreigh who, he says, 'need to work together for the benefit of their drinking water supply'. He added: 'As farmers we have a love and a respect for the land. It sounds obvious, but we also like to produce food'. Jude has introduced clover onto his land for the bees, but it also has many benefits for livestock and for water quality.

Associated projects

Creating habitats for wild bees, butterflies and other pollinators has the potential to change attitudes to farming practices. People are less likely to spray dangerous chemicals when they understand the harm that can be caused. In a bid to further enhance awareness of the damage of pesticides in the community, work is underway as part of the project to construct 330 "bee hotels" to be distributed to every family on Corracreigh GWS, thereby providing multiple nesting sites for solitary bees and other pollinators.

Similarly, a campaign called “I’ve planted a tree and my garden is pesticide free” has been developed as a national school project being rolled out across County Roscommon, targeting the domestic use of pesticides. A tree is given to school children along with information on how to go pesticide free in their garden. Every child attending national school in Roscommon will receive online information about the damaging consequences of pesticide use and about the importance of biodiversity enhancement. They will also receive a tree as well as a certificate recognising the child’s role as ‘an advocate for biodiversity’ in their own homes.

Mid Roscommon GWS manager, Noel Carroll who is championing the initiative explains its importance: ‘Pesticide usage in gardens and on verges outside households poses a threat to the quality of water that comes out of our taps and to biodiversity in general. When children understand this, they can play a vital role in persuading their parents, uncles and aunts to stop spraying these toxic substances. This initiative is intended to inspire the next generation and their families to think about sustainability’.

Further Information

- https://youtu.be/vVhToYvoUeU
- https://www.youtube.com/watch?v=BnGxRTY7BBs&feature=youtu.be
- https://nfgws.ie/category/source-protection/

The Kelly family with their bee hives (Photo: NFGWS).

Appendix 4: Glossary

Catchment

1. A basin shaped area of land, bounded by natural features such as hills or mountains from which surface and sub surface water flows into streams, rivers and wetlands. Water flows into, and collects in, the lowest areas in the landscape. The outlet of a catchment is the mouth of the main stream or river.
2. A multi-functional, topographically-based, dynamic, multiple-scale socio-biophysical system; defined by over ground and underground hydrology; connecting land, water, ecosystems and people; and used as the basis for environmental analysis, management and governance.

Eutrophication

Eutrophication arises from the oversupply of nutrients, most commonly as nitrogen or phosphorus, which leads to overgrowth of plants and algae in aquatic ecosystems, and then to oxygen depletion. Algae feed on the nutrients and can then grow into an unsightly scum on the water surface and slime on stones in watercourses, decreasing the recreational value and clogging water intake pipes. Decaying algae can produce foul tastes and odours in the water, and their decay consumes dissolved oxygen, sometimes causing fish kills.

Nutrient management planning

Nutrient Management Planning is a best management practice, aiming to optimize crop yield and quality whilst minimizing fertilizer input (nitrogen, phosphorus, sulphur and potassium, and any others of importance to specialist crops) and thereby protecting soil and water resources. For further information, check the Teagasc website: https://www.teagasc.ie/environment/soil/nmp/

Soil pH

Soil pH is a measure of the acidity or alkalinity of a soil. Soil acidity is a major limitation to the productivity of our soils, as it reduces the availability of major soil nutrients (N, P & K) and the uptake and efficiency of applied nutrients in manures or fertilisers. See link to Teagasc (2020) publication for further details. https://www.teagasc.ie/media/website/publications/2020/Major--Micro-Nutrient-Advice-for-Productive-Agricultural-Crops-2020.pdf

Soil P Index

The P index depends on the level of available P in soil. There are four soil P indices, with soil P index 4 indicating the highest level of available P and 1 the lowest. See further details at: https://www.teagasc.ie/crops/soil--soil-fertility/soil-analysis/soil-index-system/

Source Protection Area

The catchment area around a groundwater source which contributes water to that source (Zone of Contribution (ZOC)), divided into two areas: the Inner Protection Area (SI) and the Outer Protection Area (SO). The SI is designed to protect the source against the effects of human activities that may have an immediate effect on the source, particularly in relation to microbiological pollution. It is defined by the 100-day time of travel (TOT) from any point below the water table to the source. The SO covers the remainder of the zone of contribution of the groundwater source.

Zone of Contribution (ZOC)

The land area over which some of the rainfall percolates downwards to the groundwater table that eventually ends up at the well or spring.