Catchment Science and Management
A Guidance Hand Book

Volumes 2 & 3

Vol. 2: Pressures and Catchment Walks
Vol. 3: Observed Indicator Features and Catchment Walks

April 2022

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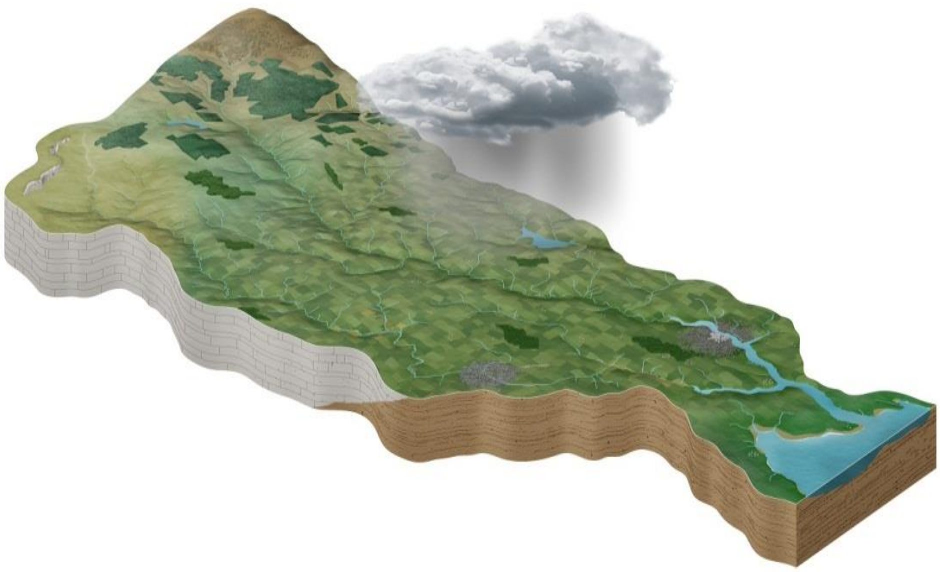
Department of Housing, Local Government and Heritage
LASNTG

Catchment Science and Management

A Guidance Handbook

Volume 2:
Pressures and Catchment Walks



November 2021

Version no. 2

Preface

This Volume was written originally in 2018 as **Guidance on Further Characterisation for Local Catchment Assessments Volume 2 (Version 1).** It was initiated by the Catchment Science and Management Unit of the Environmental Protection Agency (EPA). It was primarily intended for use by the LAWPRO catchment scientists and staff in Local Authorities, tasked with undertaking Local Catchment Assessments (originally called Investigative Assessment).

The content in the 2018 Guidance reflected a collaborative effort between invited specialists from several stakeholders with responsibility and vested interests in environmental research and management in Ireland. Contributions were made by members of an Investigative Assessment Development Group, led by the EPA and comprising representatives from public and WFD stakeholder organisations including: Department of Housing, Planning and Local Government; Department of Agriculture, Food and the Marine (Forest Service); Teagasc; Geological Survey Ireland; Irish Water; Inland Fisheries Ireland; Local Authority Waters Programme (LAWPRO); Limerick City and County Council; Meath County Council; Dublin City Council; Offaly County Council; Dun Laoghaire-Rathdown County Council; Wexford County Council; Tipperary County Council; as well as CDM Smith consultants. The membership of the Group is listed in Table 1.

In 2021, a review and updating of the Guidance Volumes were undertaken by LAWPRO and the EPA Catchments Unit.

Table 1 Membership of Investigative Assessment Development Group (2018)

Organisation	Representative
EPA	Marie Archbold Donal Daly Jenny Deakin Bryan Kennedy Anthony Mannix Conor Quinlan Emma Quinlan
Local Authorities	Paul Buggy, Dun Laoghaire-Rathdown County Council Emmet Conboy, Meath County Council Ruth Hennessy, Tipperary County Council Andrew Holmes, Limerick County Council Joan Martin, Offaly County Council Gerry O'Connell, Dublin City Council Mairéad Shore, Wexford County Council
LAWPRO	Fran Igoe
Forest Service	Ken Bucke
Inland Fisheries Ireland	Michael Fitzsimons
Teagasc	Edward Burgess Sara Vero
Department of Housing, Community & Local Government	Donal Grant
Geological Survey of Ireland	Taly Hunter Williams
Irish Water	Kate Harrington
Rivercrossing	Brendan Ward
CDM Smith	Pat Barrett Henning Moe

1 Contents

1 Introduction

As described in **Volume 1**, field-based assessments involve walkover surveys, or “catchment walks” for purposes of:

- Observation of relevant issues;
- Measurement and monitoring;
- Evaluation of pressures, pathways and impacts; and
- Identifying appropriate and possible mitigation amnd protection options.

The aim of **Volume 2** is to provide guidance on the issues that may be relevant for each of the significant pressures. The sections, pressures and main contributors are listed in Table 1-1.

Table 1-1: Main contributions for each section of significant pressures

Section	Significant Pressure	Main Contributor(s) 2018	2021 updates
2	Agriculture	Andrew Holmes, Mike Fitzsimons & Donal Daly	Donal Daly & Margaret Keegan
3	Hydromorphology	Emma Quinlan, Fran Igoe & Bryan Kennedy	Emma Quinlan
4	Urban wastewater	Joan Martin & EPA OEE Waste Water Enforcement team	Maeve Ryan
5	Diffuse urban	Paul Buggy & Gerry O’Connell	Margaret Keegan
6	Domestic wastewater	Joan Martin & Donal Daly	Margaret Keegan & Joan Martin
7	Forests	Ken Bucke	Ken Bucke
8	Peatlands	Donal Daly	Donal Daly
9	Quarries	Henning Moe	None
10	Mines	Henning Moe	None
11	Industrial discharges	Ruth Hennessy, Emmet Conboy, Marie Archbold, Nigel Hayes & EPA OEE	Ruth Hennessy
12	Invasive species	Fran Igoe	None
13	Landfills		Maeve Ryan

1.1 Staying focussed on the goals

A significant public sector resource is being allocated to the Local Catchment Assessment process. It is vital that this resource is effective in enabling successful water resources protection and management, and achievement of WFD objectives. Two points to keep in mind are given in the Boxes below.

Box 1 – Local Catchment Assessments

What a Local Catchment Assessment isn't: the collection of more data alone.

What a Local Catchment Assessment is: a critical means of enabling either protection or improvement, as relevant, of our water resources.

This aim is achieved by:

- Undertaking a desk study as the starting point.
- Undertaking catchment walks, if needed.
- Collection, assessment and recording of relevant information and data collected during the catchment walk.
- Concluding, in so far as is practicable, on the significant pressure and its location.
- Evaluating and proposing possible mitigation actions.
- Undertaking (in certain circumstances) the mitigation actions.

Remember: we need to stay focussed on the goals.

Box 2 – The Desk Based Assessment

The desk study is the key to ensuring that the Local Catchment Assessment process is focussed, efficient and effective.

The Role of the Desk Study

- To check the **WFD App** for details on: i) the significant pressure (e.g. domestic wastewater treatment systems); ii) the significant issue (e.g. phosphate); the location of the significant pressure (the specific location for large point sources and the general location for diffuse and small point sources).
- To search for and assess **new information** that may be available.
- If feasible, provide the conclusion on the **required mitigation actions**.
- Where a field-based assessment is needed to: i) **clarify** the objectives; ii) **compile** the information and maps that will assist the fieldwork; and iii) **plan** an appropriate fieldwork/catchment walk programme.

Further details on the Desk Based Assessment are available in Section 10 **Volume 1**. LAWPRO desk studies for Priority Areas for Action can be viewed on the EDEN Portal under WFD POMs, Area for Action, Step 1 Desk Study.

2 Catchment Walks - Agricultural Pressures

2.1 Purpose

This section provides a guide on indicators and visual clues of pressures arising from farming, supported by photo-documentation of good and bad agricultural practices from the field.

In considering and planning mitigation actions to resolve water quality issues arising from farming, it is important to distinguish between 'point' and 'diffuse' (or non-point) sources. Examples of both are given in Figure 2-1. Figure 2-1 also illustrates that while the source may be diffuse (e.g. fertilizer spreading) and may impact on water (both surface water and groundwater) in a dispersed manner, it also may enter a watercourse at a point often due to variations in the slope and topography of fields.

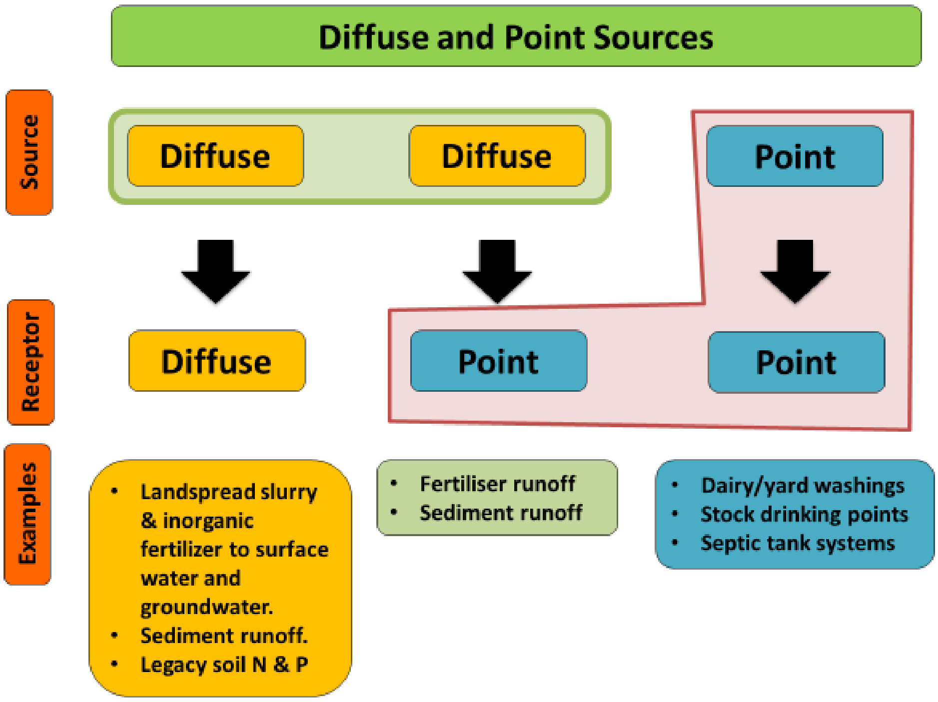


Figure 2-1: Distinguishing between point and diffuse sources (Diagram from Sara Vero (slightly amended))

Principal agricultural pressures are related to:

- Soiled water and dairy washings management;
- Silage effluent;
- Effluent breakout;
- Slurry and manure storage issues;
- Cattle drinkers;
- Land drains;
- Outwintering;
- Farm roadways;
- Fertilizer (inorganic, slurry and manure) spreading;
- Types of farming.

These are described below, together with brief 'common sense' details on 'what to look for', followed by useful references for further reading.

2.2 Significance

Farming takes place over a higher proportion of the country than any other landuse (Figure 2-2). According to the Draft River Basin Management Plan 2022-2027[1], agriculture is the most common *significant pressure* impacting 1,000 water bodies – see Table 2-1 and Figure 2-3. The overall number of waterbodies impacted by agriculture **has increased by 223**, since the start of the second cycle, and this represents the greatest increase in any individual significant pressure type.

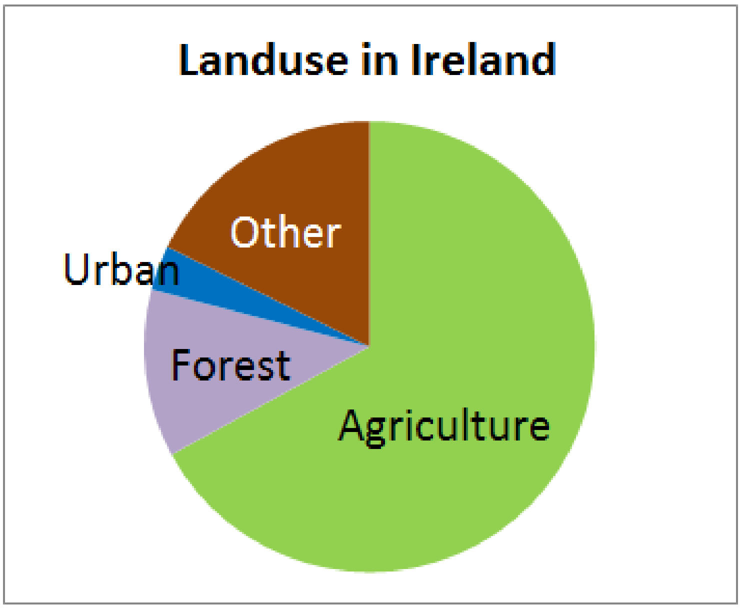


Figure 2-2: Landuse in Ireland

Table 2-1: Number of waterbodies in each waterbody type per significant pressure category. (Table copied from Draft RBMP 2022-2027)

Significant pressure category	Waterbody Type						
	River	Canal	Lake	Transitional	Coastal	Groundwater	Total
Agriculture	831		84	35	6	44	1,000
Hydromorphology	424		14	4			442
Forestry	215		14			4	233
Urban Waste Water	172	1	10	22	3		208
Urban Run-off	179		3	11	3		196
Domestic Waste Water	163		13	6		6	188
Unknown	118	1	22	2	3	18	164
Other*	75		45	2	1	16	139
Peat	103		2			1	106
Industry	70		1			18	89
Mines and Quarries	41					4	45
Total Significant Pressures	**2,391**	**2**	**208**	**82**	**16**	**111**	**2,810**
*Includes a range of other smaller pressures such as aquaculture, historically polluted sites and invasive species.							

[1] https://www.gov.ie/en/consultation/2bda0-public-consultation-on-the-draft-river-basin-management-plan-for-ireland-2022-2027/

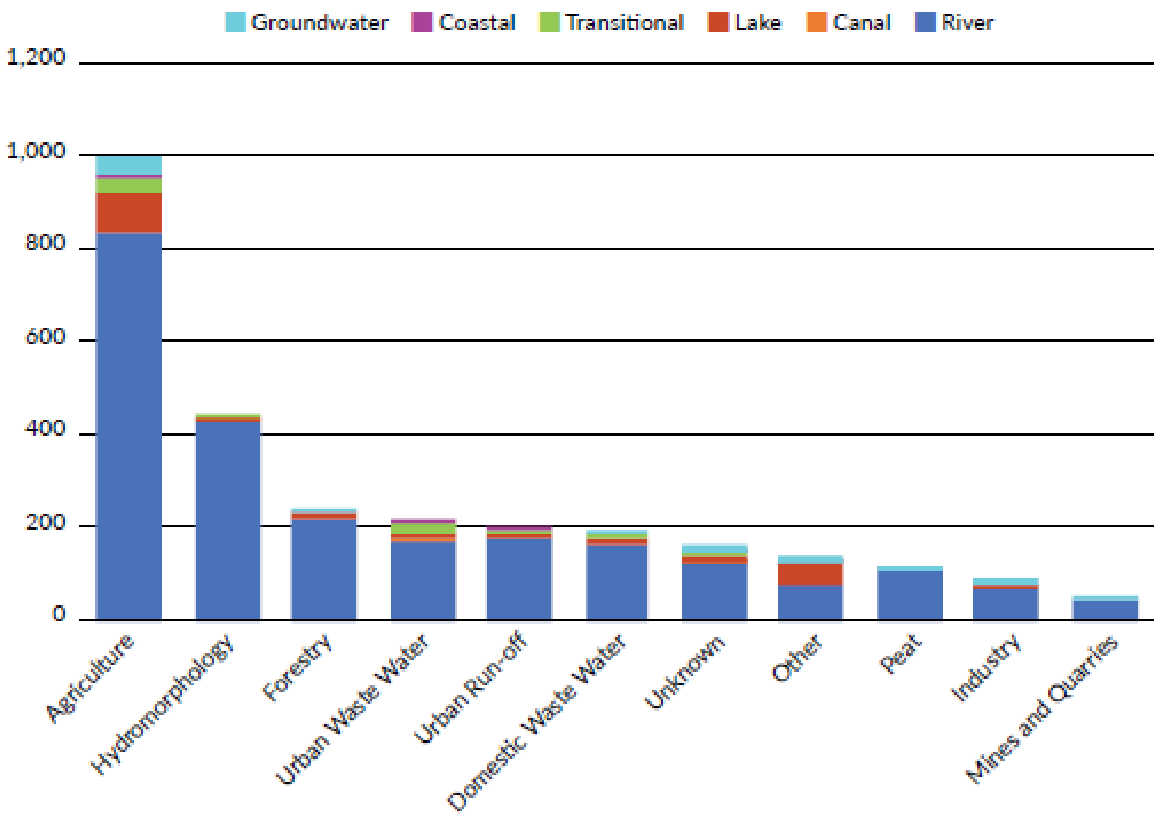


Figure 2-3: Number of waterbodies per significant pressure category. (Figure copied from Draft RBMP 2022-2027)

As an indication of the potential of various organic substances to impact on water quality, Biochemical Oxygen Demand (BOD) values are given in Table 2-1

Table 2-2: BOD values for various organic effluents and wastes

Source		BOD mg/l
Clean water		1 – 2
Treated domestic sewage		20 – 60
Raw sewage		300 – 400
Vegetable washings		500 – 3000
Dairy parlour and yard washings		1000 – 2000
Liquid waste from slurry tanks		1000 – 12,000
Sewage sludge		10,000 – 20,000
Cattle slurry		10,000 – 20,000
Pig slurry		20,000 – 50,000
Silage effluent		30,000 – 80,000
Brewers grain effluent		30,000 – 50,000
Whole milk		140,000

Agricultural activities can lead to the degradation of habitats and ecosystem health in three principal ways:

- Release of pollutants to the aquatic environment, mainly nutrient compounds, organic matter and pesticides;
- Release of fine-grained sediments to the aquatic environment;
- Physical alteration of habitats.

The main water quality *indicator parameters* of agricultural pressures are: turbidity (sediment), nutrients (specifically phosphorus, ammonium and nitrate), herbicide and pesticide compounds and microbial pathogens.

The main legislation governing agricultural practices and water quality is the ***European Union (Good Agricultural Practice for Protection of Waters) Regulations, S.I. No. 605 amended***[2]***,*** more commonly known as the GAP Regs. The GAP Regs provide significant controls on farming practices to ensure environmental sustainability. Details on the following are included in the regulations:

- Farmyard management;
- Storage requirements for effluent, soiled water and manure, including details on storage periods;
- Details on when fertilizer (slurry, manure and inorganic) should not be spread.
- Nutrient management;
- Setback distances;
- Useful tables, e.g. annual maximum fertilisation rates of phosphorus on various crops and periods when application of fertiliser to land is prohibited.

Knowledge of these regulations is needed when carrying out local catchment assessments in catchment areas of *At Risk* water bodies where agriculture is the significant pressure. The Department of Agriculture and Food published an explanatory handbook in 2020[3], which is a useful reference document. This Guidance should be read in conjunction with these two documents.

2.3 Walking the Catchment

2.3.1 Soiled water

Soiled (or dirty) water includes yard runoff (from uncovered yards that cattle or cows have access to), dairy washings and drained liquor from dungsteads. It is one of the most significant potential sources of pollution arising from farmyards. It is often produced in large volumes and has limited fertilizer value, but yet can cause significant impacts on streams and groundwater.

All modern dairy farms will have a holding yard often with a slatted tank to store the effluent generated on the yard and the dairy (see example in Figure 2-4). The milking systems need to be washed and cleaned using chemicals such Chloros or other proprietary products. Many farms have milk washing storage tanks, but sometimes the storage capacity is insufficient, and discharges can occur. This type of discharge has a distinctive “milky white” colour (Figure 2-5) and can have strong chlorine smell. The combination of high organic content and chlorine content can be particularly toxic to aquatic life. In addition, the holding yard in front of the milking parlour is usually uncovered. After each milking period the holding areas are power washed to minimise infection and contamination. Rainfall falling on this uncovered area can generate significant amounts of soiled water which also has to be dealt with on the dairy farm.

Sprinkler systems are sometimes used to spread soiled water from dairy yards. The submersible pumps in the collection tank can be operated manually or on a float switch. The sprinkler must be moved regularly to prevent the ground from being saturated with soiled water, resulting in excessive leaching of nutrients (mainly nitrate) to groundwater or runoff to surface water. One of the problems that can arise with sprinkler systems is when they work automatically on a float switch – if the tank is collecting runoff from open yards during periods of heavy rain, this will cause the level in the tank to rise triggering the sprinkler pump to switch on automatically. This can result in the soiled water being

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[2]https://www.gov.ie/en/publication/b87ad-nitrates-directive/
[3]gov.ie - Explanatory Handbook for Cross Compliance Requirements (www.gov.ie)

pumped to the sprinkler when conditions are not appropriate for spreading. This can result in the soiled water finding its way to surface water.

Figure 2-4: Slatted tank (Photo: Andrew Holmes).

Figure 2-5: Milk washings and other solids discharging to a river (Photos: Andrew Holmes).

2.3.2 Silage facilities and effluent

Silage is stored in pits or wrapped in bales. The effluent produced at silage pits has a high BOD (see Table 2-1). This oxygen demand can cause a reduction in the dissolved oxygen in the receiving water for several miles. This has been responsible for a large number of fish kills. Therefore, the effluent must be collected and not allowed to escape into the environment.

Silage effluent is highly corrosive to concrete and therefore can weaken the concrete causing cracks in the base of the pit, failure in the joints between the sections of the concrete, cracks in the walls and in the concrete channels (Figure 2-6), and therefore leakage of effluent. It should be noted that machinery may also damage the fabric of the silage pit.

Figure 2-6: A cracked silage effluent channel allowing leakage (Photo: Andrew Holmes).

Problems can occur when faults arise in the diversion systems which should normally channel silage effluent into a slurry/effluent tank (Figure 2-7). The pipe can be turned (red arrow) to divert the effluent when it is flowing to a tank. When the effluent has stopped flowing in this case, the pipe is turned down so that clean water is diverted to a clean water drain (blue arrow). Care must be taken to ensure i) that the clean water is not contaminated and is diverted to a watercourse, ii) that the effluent channels don't get blocked, and iii) that when effluent is no longer produced, soiled water is not allowed enter the clean water drains. It is important to check the clean water discharge pipes from a farmyard during silage making season to ensure there are no misconnections or break outs from the pit.

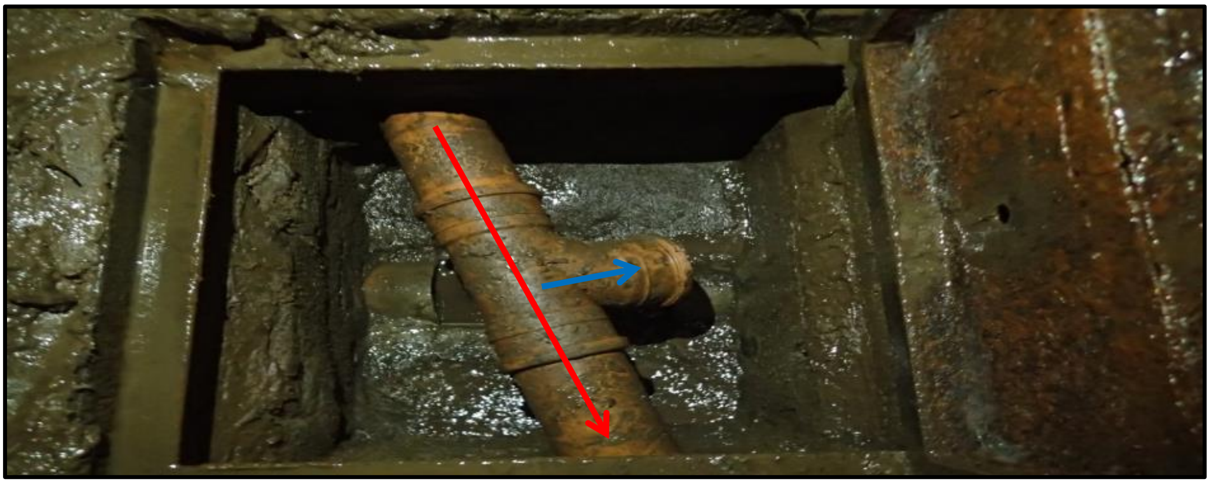

Figure 2-7: Diversion system for separating effluent from clean water (Photo: Andrew Holmes).

There must be adequate capacity to contain all silage effluent arising from the pit. Note, when the silage pit is opened, there may be a flow of effluent from the pit when rainwater falls on the open face. This effluent must be collected, stored and landspread at a suitable time.

Silage effluent can also arise from silage that is made in wrapped bales. These should be stored at least 20 m away from a watercourse or standing water body (Figure 2-8). There is a strong risk of silage effluent seepage and ponding around the base of the bales. This must not be allowed to discharge to a watercourse.

Figure 2-8: Wrapped silage bales located too close to a stream (Photo: Donal Daly).

2.3.3 Breakouts of Effluent

Adjacent to farmyards it may be possible to observe "breakouts" from some of the farm buildings (e.g. silage clamps (Figure 2-9) and overland flows of polluting or deleterious matter (Figure 2-10)). Overland flows usually carry nutrients and therefore will promote a stronger belt of grass production and will be easily recognisable by the lushness and more intense green colour of a grass strip and following a fall of ground towards an open watercourse (Figure 2-11).

Figure 2-9: Slurry flowing onto a field (Photo: Andrew Holmes).

Figure 2-10: Overland flow of effluent (Photo: Andrew Holmes).

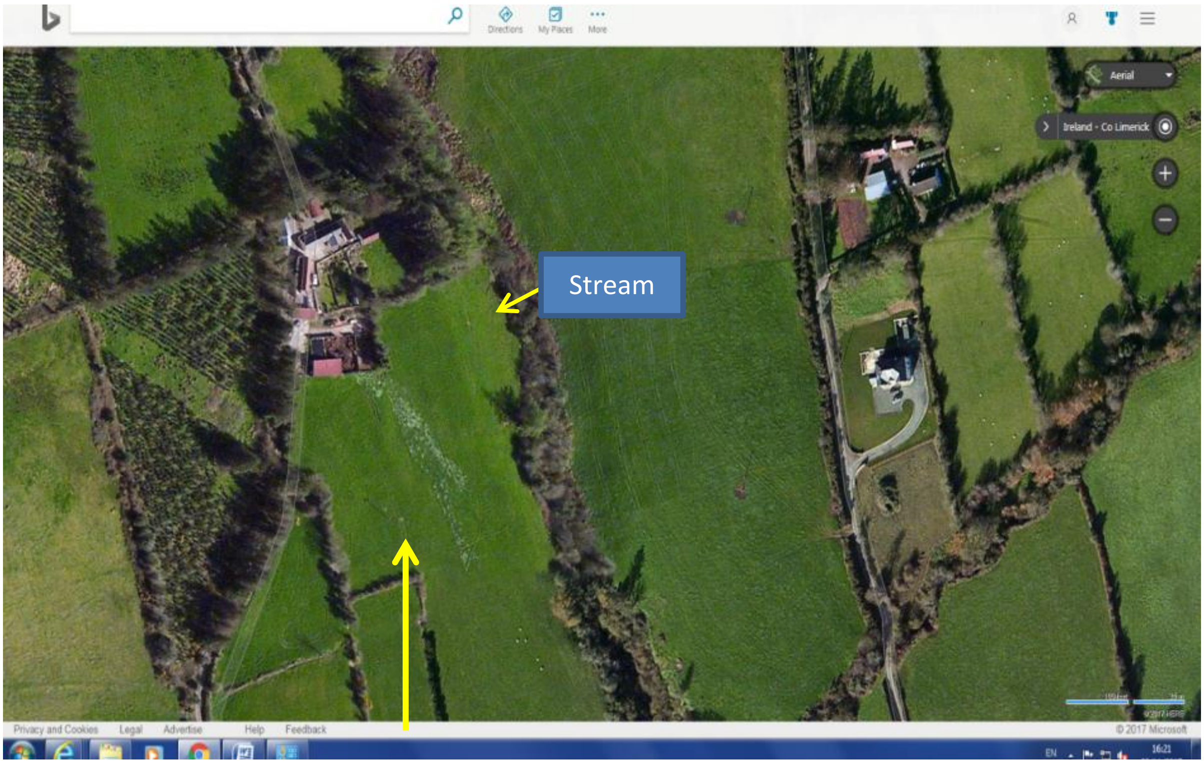

Figure 2-11: Aerial photo with discoloration indicating effluent breakout (Photo: Bing Maps).

2.3.3.1 What to look for – soiled water, silage effluent and effluent breakouts

At the stream:

- Presence of a pipe or evidence of a point discharge.
- Small drains present close to farmyards that might transmit pollutants.
- Presence of sewage fungus (Figure 2-12).
- Presence of effluent in nearby fields.
- Excessive nettle growth, green areas or burnt grass indicating discharges.

Figure 2-12: Presence of sewage fungus due to silage effluent entering the watercourse (Photo: Andrew Holmes).

At the farmyard:

- In general, the means by which soiled water and silage effluent is dealt with.
- Soiled water and silage effluent holding tanks.
- Presence/absence of gutters on farm buildings.
- Location of farmyard relative to the surface water body and to ditches entering the water body.
- The means of separating clean water from soiled water – all clean water on the farm needs to be diverted away from dirty yards and storage tanks, as this will reduce his slurry storage capacity.
- Presence of silage effluent adjoining the pit – it has an indicative smell and is coloured black (Figure 2-13).
- Presence of effluent flowing into swallow holes.

2.3.4 Slurry and manure storage issues

Slurry can be stored in a number of different ways:

- concrete slatted tanks;
- open concrete tanks;
- steel slurry towers (towers may also be made of concrete);
- Geo membrane lined lagoons;
- Earth lined slurry stores.

Different problems can occur, which can lead to overland flow of nutrients and/or organic matter to a watercourse.

Figure 2-13: Silage effluent flowing down a roadway from a nearby pit (Photo: Andrew Holmes).

2.3.4.1 Concrete slatted tanks

Modern slatted tanks are generally built to a high standard and most issues with them are down to farm management (Figure 2-14). However, issues can arise as described below:

- Open concrete tanks can become cracked due to faults in construction, for example, poor construction practices particularly the failure to fill "tie holes" (where pins were used in construction but not sealed). As illustrated in the Figures below, poor construction method resulted in the wall of the tank failing (Figure 2-15 and Figure 2-16).
- Walls can become cracked due to faults in construction, e.g. poor foundations due to insufficient reinforcement, etc.
- Wear and tear over time will also result in cracks appearing in tanks especially where machinery is operating in or beside the tank, e.g. where machinery has impacted on sidewalls causing a crack to take place.
- Poor construction practices particularly the failure to fill "tie holes" (where pins were used in construction but not sealed).

Figure 2-14: Roofed slatted unit (Photo: Andrew Holmes).

Figure 2-15: An extension to a slurry tank, approximately doubling its capacity, failed due to improper building techniques (Photo: Andrew Holmes).

Figure 2-16: Close-up of the jointing area, where the extension wall was built on top of the existing tank with inadequate 'tie-in' between the new and old construction (Photo: Andrew Holmes).

2.3.4.2 Steel slurry towers

The most common failing in steel slurry towers is the pipework and control valves connecting the steel tower to the reception tank. Bad practices around the management of the valves are also to blame in many incidents. As can be seen in Figure 2-17 and Figure 2-18, the pipework and valves are not properly embedded in concrete and when pressure was exerted on the valve, it moved resulting in the disconnection with the pipework. The result in this case was a catastrophic discharge causing a major fish kill.

Figure 2-17: Failure to close the valve nearest the tank caused pressure to build up in front of the 2nd valve. Because the second valve wasn't set in concrete, the valve was pushed out and slurry discharged from the breach in the pipe just before the 2nd valve (Photo: Andrew Holmes).

Figure 2-18: The arrow point to the area where the valve was pushed off the pipe and the leak occurred (Photo: Andrew Holmes).

2.3.4.3 Geo membrane lined lagoons

Accidental damage to lined lagoons can cause a discharge to groundwater especially in karst area (Figure 2-19 and Figure 2-20). The Department of Agriculture, Food and Marine have published guidance and specifications that must be complied with[4].

Figure 2-19: Tear in the geomembrane caused by a careless contractor when emptying the lagoon (Photo: Robert Imbusch).

Figure 2-20: A tear in the geomembrane (shown by the arrow) caused 180 m^3 to discharge overnight into groundwater, and subsequently reappearing in a local stream 500 m away (Photo: Robert Imbusch).

[4]https://www.gov.ie/ga/bailiuchan/28f4c-specifications/

2.3.4.4 Earth lined slurry store

Earth lined slurry stores (ELSs) are subsoil-based structures which are used as a method of slurry storage. They may be used to store neat, dilute or separated slurries and the storage and settlement of dirty water. The tank is formed by excavating soil and subsoil and using the excavated or imported material to form surrounding banks and subsoil liner. The subsoil liner must have a low permeability to prevent leakage to groundwater. The Department of Agriculture, Food and Marine have published guidance[5] and specifications for ELSs that must be complied with. However, many of the lagoons in the past were built by digging a hole in the ground and no consideration was given to the risk of contamination to ground or surface water bodies. This type of slurry storage poses a high risk of ground water contamination (Figure 2-21).

2.3.4.5 Dungsteads

If farmyard manure is stored on a farmyard, all effluents generated from the manure must be directed to the effluent tank.

2.3.4.6 What to look for

- The features described for each of the storage facilities are described above.

Figure 2-21: Earth lined slurry store (Photo: Andrew Holmes).

[5] https://www.gov.ie/ga/bailiuchan/28f4c-specifications/

2.3.5 Land drains

2.3.5.1 Stone drains

These are also often called French drains and are usually very old. Stone has been used to create an underground boxlike channel which because of its construction allows liquids into the void space whereby it can find its way to a watercourse. Even though they are old, they can be extremely effective at conveying pollutants to streams, particularly after slurry spreading.

2.3.5.2 Plastic land drains

This type of land drain comprises a plastic pipe set into its slit trench which is cushioned all around with crushed rock. The pipe generally discharges into an adjacent watercourse. A layer of approximately 10 cm of soil, above the crushed rock, acts as a filter particularly for slurry. In some areas where soils are very heavy there is a tendency by some operators to fill the slit trench completely to the top with stone. This results in a preferential flow path not alone for slurry but also for artificial fertilisers. Figure 2-22 and Figure 2-23 below show a land drain overfilled with stone and a location where slurry discharged from this type of over filled land drain.

Figure 2-22: A pipe land drain which has been overfilled with stone providing a preferential pathway (Photo: Robert Imbusch).

2.3.5.3 What to look for

- Pipes in stream banks (usually yellow).
- Evidence of pipe drains in fields – often shown by differences in grass colour.
- Evidence of impact in the stream.

Figure 2-23: Discharge of slurry from a 'stone overfill-land drain (Photo: Robert Imbusch).

2.3.5.4 Cattle drinking water points

Cattle will either have drinking water troughs in the field or will have access to a stream.[6] As poaching can occur around troughs, if the location is too close to a stream, this can result in sediment, nutrients and pathogens entering the stream. Of greater environmental significance are cattle access points to streams (Figure 2-24 and Figure 2-25). Animals arriving at a stream tend to defecate in or adjacent, with potential for significant pollution and enrichment arising. In addition, sediment is generated at the location as a result of bank erosion (Figure 2-26). One option is to fence off the stream and to use a nose pump drinker (Figure 2-27), particularly in less intensive areas. However, nose pump drinkers are not likely to be adequate for dairy cows.

[6] A LAWPRO Guide to assessing cattle access points is given in Appendix 1.

Figure 2-24: Cattle drinking water access point to stream (Photo: Donal Daly).

Figure 2-25: Drinking water access point (Photo: Andrew Holmes).

Figure 2-26: Bank erosion caused by cattle access (Photo: Robert Imbusch).

Figure 2-27: Nose pump drinker (Photo: Donal Daly).

2.3.5.5 What to look for

- Location, number per km length of stream, degree of erosion and impact.
- Presence of poaching close to watercourses.

2.3.5.6 Outwintering and supplementary feeding points

Animals such as sheep and cattle are often out wintered on lands and if managed properly this activity does not pose a risk to waters. If good practice is not followed, then out-wintering animals can pose a threat to water bodies. Firstly, the land may become heavily poached (Figure 2-28) and secondly, as cattle congregate around supplementary feeding points, such as ring feeders (Figure 2-29), these areas have relatively high loads of nutrients. These feeders need to be moved regularly to prevent poaching and nutrient build-up.

2.3.5.7 What to look for

- Presence of severe poaching in adjoining fields.
- Location of round feeders relative to watercourses to check for compliance with the GAP Regs ("Supplementary feeding points shall not be located within 20m of waters and shall not be located on bare rock.").

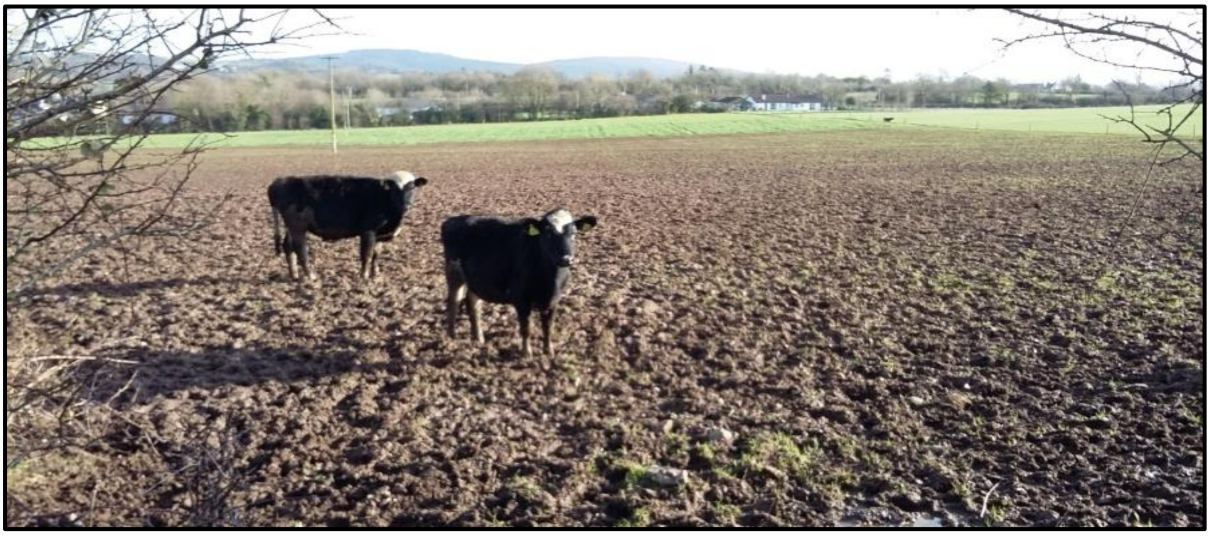

Figure 2-28: Field heavily poached by cattle tramping (Photo: Andrew Holmes).

Figure 2-29: Cattle fed by a round feeder. A water course is present to the left along the hedgerow (Photo: Aidan Leonard).

Assessors need to be aware of the requirements of Article 13 (2) of the GAP Regs[7] regarding outwintering.

2.3.6 Farm road passages

Rainwater falling on farm roads can be particular problem. The situation is exacerbated where agricultural effluents/run-off uses an agricultural road as a flow path. Often this leads to deleterious or polluting matter directly discharging to waters (Figure 2-30). The investigator needs to be aware of the following:

- Many farms, particularly dairy farms, have developed internal farm roads or passages. The primary reason is to reduce the impact of the regular cattle movement and machinery associated with modern dairying.
- These passages can receive a significant amount of organic material particularly from the cows as they walk along towards the dairy yard. The road itself provides a flow path and cow manure coupled with rainwater can run-off often into adjacent watercourses (Figure 2-31)
- The farmer can minimise runoff from farm passages to surface water by ensuring the camber of the roadway drains to the field or by placing ramps along the passage way diverting rainwater to the field.
- The runoff from the passage way is rich in nutrients and can support colonies of tubifex worms in the bed of the river/stream (Figure 2-32).
- Runoff of sediment is also a common problem arising from farm roads crossing streams. One way to limit this to channel the runoff water into a sediment trap (Figure 2-33).

Figure 2-30: Soiled water from a passage way flowing to a low point and then into a stream Photo: Robert Imbusch).

[7] https://www.gov.ie/en/publication/b87ad-nitrates-directive/

Figure 2-31: Runoff from a farm passage way onto a public road, which acts as a flowpath to an adjoining stream (Photo: Andrew Holmes).

Figure 2-32: Colonies of Tubifex worms in the stream bed, feeding on the organic material that runs off a farm passage way (Photo: Robert Imbusch).

Figure 2-33: Runoff from this farm road is channelled into the sediment trap on the left (Photo: Donal Daly).

2.3.7 Landspreading of Slurry and Manure

This section describes the various methods for landspreading of slurry and manure. Assessors should be familiar with the regulatory requirements, for instance, regarding buffer zones and timing of applications.

A wide variety of methods can be used for slurry spreading and the main forms are highlighted below. The percentage dry matter will dictate whether it can be pumped out from a tanker or if the dry matter is such that it must be spread with a side or rear delivery "muck spreader". The thrust of this operation has to be the appropriate recycling of nutrients in a sustainable and environmentally safe manner. For example, losses of ammonia, in particular, can be minimised by use of either band-spreading, trailing shoe, or direct injection methods.

2.3.7.1 Vacuum Tanker

- **Standard Vacuum Tanker** Spread by broadcasting through a **pipe and downward facing splash plate** (Figure 2-34).
- **Band spreading:** slurry is pumped out onto the land in a series of narrow bands. This can be attached to a vacuum tanker.
- **Trailing Shoe**: Also applies the slurry into the soil surface itself. The trailing shoe is may also attached to a vacuum tanker as in Figure 2.36.
- **Direct Injection**: as the name implies the slurry is injected underneath the grass sod and directly into the soil.
- **Umbilical pipe systems:** which can also use the above spreading mechanisms can be attached to a tractor with the slurry being pumped from the farmyard tank to the tractor unit. To use this method, the slurry needs to be very watery this can result in slurry running off if conditions for spreading are not optimum. The problem is that the umbilical systems can be (and often

are) used when ground conditions are inappropriate. The excess slurry will not be absorbed into the soil but simply run-off to surface watercourses

Figure 2-34: Standard vacuum tanker spreading by broadcasting through a pipe and a downward facing splash plate (Photo: Donal Daly).

The spreading of slurry/soiled water from passages roads when ground conditions make it impossible for the tractor and tank to travel the land (Figure 2-35) is not an acceptable practise. Similarly, the use of umbilical pipe systems to spread slurry on wetland when ground conditions are not suitable for slurry tanks is also a serious problem.

2.3.7.2 Band Spreading.

With this method slurry is pumped out onto the land in a series of narrow bands. This is done using an attachment on the rear of the vacuum tanker

2.3.7.3 Trailing Shoe

This is somewhat similar to the band spreading method as the “trailing shoe” equipment is also attached to a vacuum tanker but with this technique slurry is injected into the soil itself (Figure 2-36).

Figure 2-35: A vacuum tanker with a high level nozzle is pumping slurry onto ground that is often water logged due to heavy soil with resulting ground conditions that are unsuitable for the tractor to travel on the land. This is not acceptable practice (Photo: Andrew Holmes).

Figure 2-36: Band spreader/trailing shoe operating off a large vacuum tanker (Photo: Donal Daly).

2.3.7.4 Umbilical pipe systems.

This involves the pumping of slurry from the farmyard to the field. In many cases the fields can be up to 2 km from the yard. In the field, the pipe is connected to a tractor, which has an additional 100 to 200 m of pipe, which allows it to spread slurry in the field. The umbilical pipe system is a very quick and economic away for the farmer to spread large amounts of slurry whilst at the same time reducing the impact of heavy machinery (Figure 2-37).

Figure 2-37: Umbilical pipe system (Photo: Wikimedia commons – Chris Court)

2.3.7.5 Farmyard manure

Farm Yard Manure is a mixture of soiled animal bedding and waste hay or silage. In this system farm yard manure is loaded into a trailer and a rotating mechanical system operates to spread this manure out onto the land (Figure 2-38). There is usually very little run-off from this type of manure spreading.

Figure 2-38: Large industrial rear delivery muck spreader (Photo: from Agriland.ie)

2.3.7.6 Sludges/Bio-solids

The spreading of sludges/bio-solids on farmland must be undertaken in accordance with a nutrient management plan. It also requires that the supplier of the sludge should be in compliance with their EPA IPPC licence. In general stockpiling of sludge on land is not permitted (Figure 2-39). However, the above may be stored for a short period prior to land spreading (not more than 3 days). Land spreading must comply with the GAP Regs requirements.

Figure 2-39: Bio-solids stored on land (Photo: Aidan Leonard).

Assessors should be conscious of stockpiling of sludge onto land and the possibility that effluents can be released from the sludge causing pollution to waters. In addition, nutrient loads must be carefully monitored in the soil as excess nutrients may leach or discharge directly into watercourses or groundwater. The problem can be that the material is simply spread by a bulldozer and ploughed into the soil rather than equipment such as farm muck spreaders used to give a lighter dressing.

2.3.7.7 What to look for

The landspreading features that might be observed will depend on the time of the year that the catchment walk is undertaken; therefore, those listed below are general in nature:

- Compliance with the GAP Regs setback distances.
- Compliance with the prohibited periods for application of fertilizers.
- Presence of manure heaps stored in fields.
- Presence of organic matter on fence posts located close to streams.
- Physical evidence of runoff into streams, ditches and swallow holes (the indicator parameters, such as SEC, may provide evidence of impact).
- Presence of hedges, mounds, woodlands or other features that might break or hinder the runoff pathway.

2.3.8 Landspreading of inorganic fertilizers

The nutrients (N, P and K) in inorganic fertiliser is the main driver for farm outputs (milk and beef). Phosphorus and Nitrogen are also two of the main pollutants of water.

2.3.8.1 What to look for

- Presence of fertiliser granules with 2 m of watercourses (The GAP Regs require that 'Chemical fertiliser shall not be applied to land within 2m of any surface' waters.)

2.3.9 Spraying of pesticides

2.3.9.1 What to look for

Surface water sources

- Presence of the tillage crops without the required 2 m uncultivated setback distance.
- Presence of focussed runoff from tillage fields.
- Evidence of spraying of rushes close to water courses.
- Note: particular attention is advised in areas mapped as high pollution impact for Phosphorus and areas of poorly draining soils.

Groundwater sources

- Evidence of surface runoff to swallow holes.
- Evidence of rock outcrops in the zone of contribution of the well/spring.
- Note: particular attention is advised in areas of extreme vulnerability.

2.3.10 Types of farming

2.3.10.1 Sheep farming

Sheep are kept outdoors all year round with ewes being housed in the spring for short periods while lambing. The main issues with sheep farming are as follows:

- Overgrazing on poor soils adjacent to rivers and streams can leave the banks vulnerable with poor vegetation cover. As a consequence of this, during high flood flows, the banks can be eroded, riparian habitat lost and a braided channel results which will not support diverse fish communities.
- Proper disposal of spent sheep dip – spent sheep dip, whether from permanently sited or mobile facilities, must never be disposed of to a soak pit or dumped on sacrifice land. It should be land spread by slurry tanker, diluted l part dip to 3 parts slurry or water as soon as practicable after use.
- Empty dip concentrate containers must be rinsed when dip is being prepared so that rinsing liquid may be added to form part of the diluted dip. Where there is an outlet at the bottom of an existing tank, controlled by a stopper, the outlet must be permanently sealed.
- Storage of farm yard manure generated from lambing sheds can also become an issue if not properly managed.

At the turn-of-the-century, rivers were impounded and sheep dip took place in the river (Figure 2-40). Mobile sheep dip units (Figure 2-41) can be a means of preventing problems from arising.

Figure 2-40: River impounded for sheep dipping (Photo: Wikimedia commons – The National Library of Wales)

Figure 2-41: Mobile sheep dipping unit (Photo: Andrew Holmes).

Figure 2-42 and Figure 2-43 show poorly sited upland sheep pens directly adjacent to a river.

Figure 2-42: Pen for sheep dipping located close to a river (Photo: Robert Imbusch).

Figure 2-43: Pen for sheep dipping located close to a river (Photo: Robert Imbusch).

2.3.10.2 Pig Farming

Modern pig farming requires that all pigs are housed all year round. This leads to large volumes of pig slurry being collected and stored (26 weeks storage required for piggeries) in concrete tanks and steel towers.

The vast majority of pig slurry from each pig farm will be exported to neighbouring farms in accordance with a nutrient management plan; records of these movements need to be kept and are available from the Nitrates Section of DAFM.

Intensive pig farms must comply with an IPPC licence issued by the EPA. These are pig farms with 750 sow places, 285 places for sows in an integrated unit or 2000 places for production pigs.

2.3.10.3 Poultry Farming

Intensive poultry farming involves the production of eggs from layers (hens) and the rearing of broilers (young chicks) for meat. Egg and meat production involves the housing of thousands of birds in large houses. Layer houses are cleaned out every 12 to 18 months while broiler houses are cleaned out every 10 to 12 weeks.

- At the end of a production cycle in a poultry house, the bedding is cleaned out, this is known as poultry litter.
- The poultry litter is removed from each shed and land spread or composted. It is essential that a detailed nutrient management plan is agreed with the local authority before any land spreading takes place so that over enrichment of soils is avoided. If the soils are enriched with nutrients from poultry litter, they will eventually leach from the soils to the surrounding waterbodies. Poultry litter is extremely high in nitrates
- After poultry litter is removed, each shed is washed down and sterilised. All wash water must be collected in a wash tank and disposed of by land spreading. As can be seen in Figure 2-44, no tank was in place to collect the washings which flowed into the drain at the back of the house.
- Other wastes include waste from meal/chicken food storage areas and poultry mortalities. Botulism can be an issue, and these need to be borne in mind when examining watercourses or a location downstream of a discharge location.
- Intensive poultry farms with over 40000 bird places must have an IPPC licence issued by the EPA

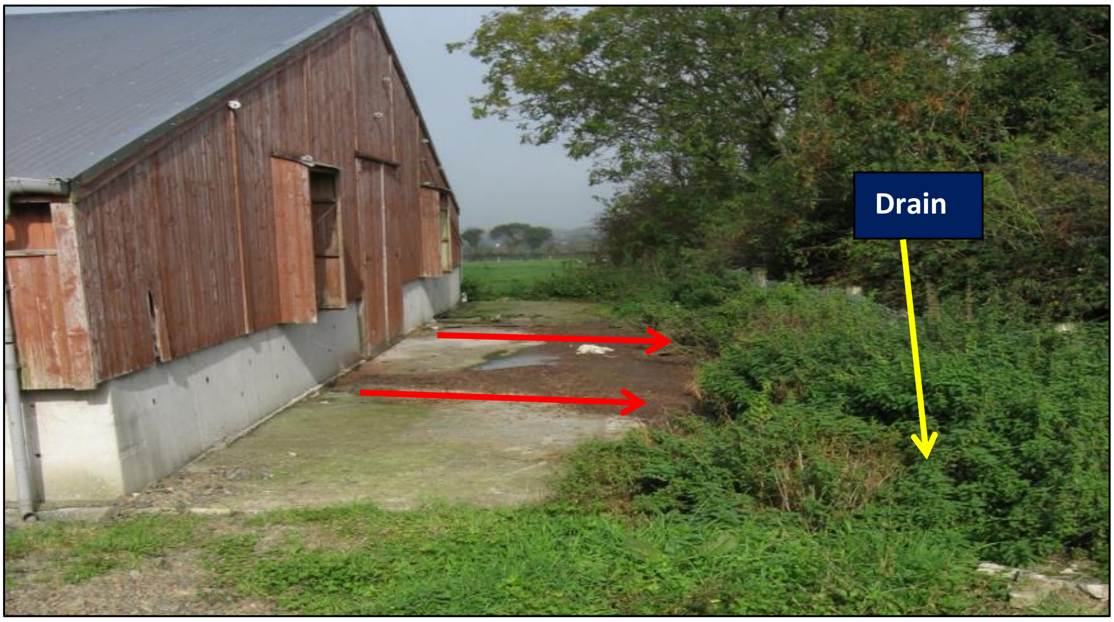

Figure 2-44: Effluent is flowing into the drain because there is no collection tank at the back of the chicken house (Photo: Andrew Holmes).

2.3.10.4 Tillage and reseeding

Arable land may be ploughed or pasture may be reseeded at certain times of the year. This results in the loosening of the soil structure and may increase the loss of fine sediment to watercourses where adequate buffering or attenuation is not provided. Figure 2-45 shows an example of field clearance followed by ploughing and reseeding, with loss of riparian vegetation and the buffering that this would have provided. Figure 2-46 show an example of a pond constructed and installed to trap fine sediment runoff in tillage areas.

Article 17 (16) of the GAP Regs stipulates that "*No cultivation shall take place within 2m of a watercourse identified on the modern 1:5,000 scale OSi mapping or better, except in the case of grassland establishment or the sowing of grass crops*".

Figurer 2-45: Reseeding of field (Photo: Andrew Holmes).

2.4 Protection and Mitigation Options[8]

Protection and mitigation options for agriculture are not described in detail in this Volume. Some summary recommendations and points are given, and attention is drawn to relevant reference material. A good general starting point is Section 14 in Volume 1.

[8] This Section has been redrafted in 2021.

The recommended thought process for considering options is outlined in Figure 2-47. Following this process, means considering protection and mitigation actions according to the point in the source-pathway-receptor continuum on which they take effect, as follows:

i) Actions to reduce or eliminate pollutants (for point and diffuse sources).
ii) Actions to reducing mobilisation of pollutants in land (for diffuse sources).
iii) Pathway interception actions (for diffuse sources).
iv) Receptor/instream works (for surface water receptors).
v) Treatment in the case of drinking water sources (as part of the multi-barrier approach).

The key regulatory measures are the GAP and Pesticide Use Regulations. A summary of the measures in the GAP Regulations is given in Appendix 10 in Volume 1.

Comprehensive details on protection and mitigation options are given in 'A Handbook of Source Protection and Mitigation Actions for Farming' published by the NFGWS (2020).

Buffer zones are one of the most common and important measures used to mitigate impacts of farming. A discussion on the location and width of buffers is given in Appendix 10 in Volume 1 in which it is concluded that, for mitigating impacts from phosphate, sediment and microbial pathogens in poorly draining areas, spatially targeted widened buffers should be considered.

Figure 2-46: Pond constructed on a small stream to trap sediment in a tillage area (Photo: Donal Daly).

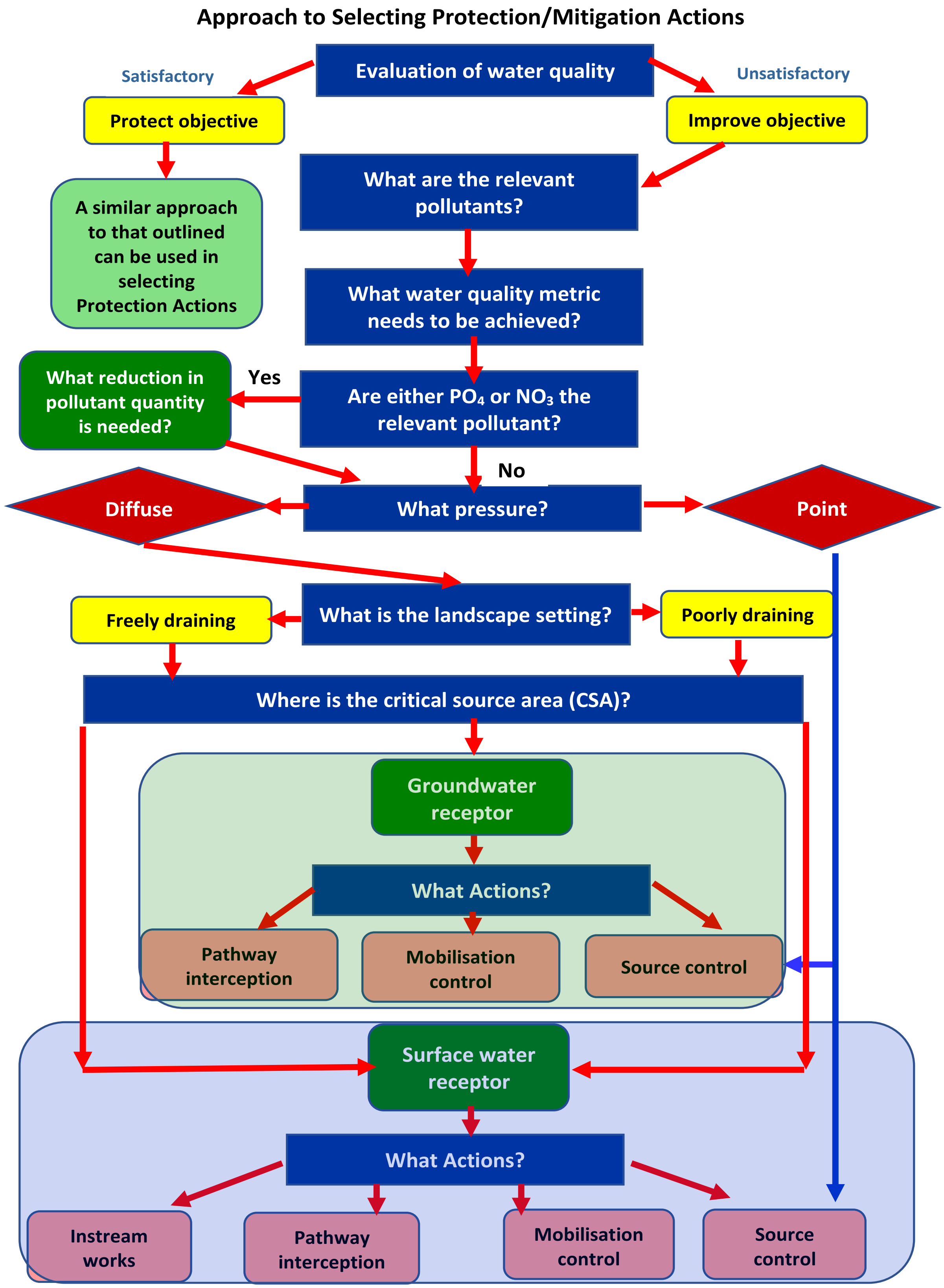

Figure 2-47: Process flowchart illustrating a recommended approach to deciding on appropriate mitigation Actions (Source: NFGWS, 2020).

2.5 Useful References

Good Agricultural Practices (GAP) Regulations & Information on Nitrates Directive at this link: gov.ie - Nitrates Directive (www.gov.ie)

DAFM (2020). An explanation of the GAP Regulations at this link: gov.ie - Explanatory Handbook for Cross Compliance Requirements (www.gov.ie)

DAFM Specification for Farm Roadways S199. See Teagasc youtube: https://www.youtube.com/watch?v=LBaMPDLtFs8

DAFM TAMS – Farm Buildings and Structures Specifications at this link:
[1]https://www.gov.ie/ga/bailiuchan/28f4c-specifications/

NFGWS (2020) 'A Handbook of Source Protection and Mitigation Actions for Framing' at this link: https://nfgws.ie/nfgws-source-protection-publications/

NFGWS (2019). 'A Framework for Drinking Water Source Protection'. See Appendix 6 at this link: https://nfgws.ie/a-framework-for-drinking-water-source-protection-2/

McNally (2017). Review of Potential Local Measures for Mitigating Farm Impacts in Catchments at this link: https://www.catchments.ie/download-category/objectives-and-measures/.

Codes of Good Practice for the use of Bio-solids in Agriculture.
https://www.tipperarycoco.ie/sites/default/files/Publications/Code%20of%20Good%20Practice%20Biosolids%20in%20Agriculture-Guidelines%20for%20Farmers.pdf

EPA (2013). Protection of groundwater from landspreading of organic wastes.
https://www.epa.ie/publications/compliance--enforcement/waste/groundwater-protection-responses-for-the-landspreading-of-organic-wastes.php

I.R.D. Duhallow, 2016. Towards sustainably and environmentally sound water management solutions for farms located in close proximity to river catchments.
https://www.duhallowlife.com/sites/default/files/A2%20Management%20guide%20for%20cattle%20management%20for%20riverine%20SACs.pdf

Environmental Impact Assessment (Agriculture) Regulations 2011
https://www.gov.ie/en/publication/5c8ed-advice-for-farmers-on-environmental-impact-assessment-regulations/

OPW Environmental Drainage Maintenance Guidance Notes.
https://www.floodinfo.ie/frs/media/filer_public/b0/5a/b05a1126-7de1-4921-bdb2-1c2579470171/environmental_guidance_-_drainage_maintenance_and_construction_2019_web_part-1.pdf

3 Catchment Walks – Hydromorphological (Rivers) Pressures

3.1 Purpose

This section provides a guide of indicators and visual clues of hydromorphological pressures, supported by photo-documentation of examples from the field. Principal hydromorphological pressures are related to:

- Channelisation;
- Land drainage;
- Cattle access;
- Invasive plant species impacting hydromorphological conditions;
- Barriers to water/sediment movement and fish migration;
- Bank protection and;
- Flood protection.

These pressures and associated issues are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes. It should be noted that hydromorphological observations made during catchment walks can be used to support separate, specialised hydromorphological assessments which are carried out by the EPA for WFD purposes, as follows:

- Hydromorphological classification (River Hydromorphological Assessment Technique (RHAT)); and
- Hydromorphological risk characterisation (Morphological Quality Index (MQI)).

Note that the *MQI end user report* dataset can be used as part of the desk study to help identify significant hydromorphological pressures. Details on how to interpret this dataset is available in Appendix 2.

3.2 Significance

Changes to hydromorphology are estimated to be a significant pressure for cycle 3 in 424 rivers, 14 lakes and 4 transitional water bodies nationally. It is ranked the 2nd most significant pressure in in river waterbodies.

The modification of hydromorphological (or physical) conditions of surface water bodies can lead to the degradation of habitats and ecosystem health in three principal ways:

- Release of fine-grained sediments (e.g. silt and clay) to the aquatic environment;
- Modify flow condition requirements;
- Physical alteration of habitats.

Water quality *indicator parameters* that are applicable to hydromorphological pressures are: suspended sediment/turbidity and colour.

The term ‘hydromorphology’ was coined by the WFD to describe the shape, boundaries and content of a surface water body. With respect to rivers, the term takes into consideration: a) the extent of modification to the flow regime; b) the extent of modification to the river channel, including constraints to connectivity with the floodplain and; c) the extent of modification to longitudinal connectivity (i.e. artificial barriers)9,10. While the term ‘hydromorphology’ is not directly used in the WFD, the WFD lists the supporting ‘hydromorphological’ elements that are required for the characterisation and risk assessment of surface water bodies.

Table 3-1: Hydromorphological quality elements for rivers[11]

Body type	Hydromorphological quality elements	
Rivers	Hydrological regime	Quantity and dynamics of water flow Connection to groundwater bodies
	River continuity	
	Morphological conditions	River depth and width variation Structure and substrate of the river bed Structure of the riparian zone

3.3 Walking the Catchment

3.3.1 Channelisation

Channelisation involves widening, deepening and/or straightening the river channel, in addition to the removal of in-channel obstructions (e.g. large wood, fallen trees) and both in-channel and riparian vegetation. Such works aim to reduce the roughness of the river bed in order to increase the ease of flow through the channel and hence, improve conveyance.

If over-widened, the river channel may no longer be able to transport sediment due to reduction of flows particularly within low gradient environments. In these scenarios, siltation will be evident as high levels of fine sediment will have settled on the river bed.

In the case of deepening a river channel, as water will no longer be able to spill out onto the floodplain, the volume of water in the channel increases, flood peaks are much greater and water rapidly transports itself through the system. This can lead to an increase in shear stress (i.e. the force of water on the river bed and banks), and therefore an increase in erosion. Furthermore, as water cannot spill out onto the floodplain and deposit its fine sediment load, siltation can occur during low flow conditions.

Similar to channelisation, peat land drainage and extraction are also examples of activities that can alter the hydromorphological conditions of rivers such as:

- modification of the channel and riparian area;
- increasing the level of fine sediment (i.e. peat) entering a river;
- diverting the river channel thus altering the river network;
- increase in the connectivity of land drains to the river network and therefore altering the flow and sediment regime.

[9] Sear, D.A., Newson, M.D. and Thorne, C.R., 2003. *Guidebook of Applied Fluvial Geomorphology*. Defra/Environment Agency Flood and Coastal Defence R&D Programme. R&D Technical Report FD1914: 233pp.

[10] Rinaldi, M., Surian, N., Comiti, F. and Bussettini, M., 2012. *Guidebook for the evaluation of stream morphological conditions by the Morphological Quality Index (MQI)*. Istituto Superiore per la Protoezione e la Ricerca Ambientale Roma: 90pp.

[11] European Commission, 2000. Annex V(1.1) of *Directive 2000/60 EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy*. Official Journal L 327, 22/12/2000: 73 pp.

Such alterations can lead to the degradation of habitat. See Section 8 for more information on peatland pressures.

Figure 3-1: Example of a river that has undergone channelisation. Note the limited riparian vegetation along both banks and how the channel is disconnected from its floodplain (Photo: Emma Quinlan).

Figure 3-2: Example of a river that has undergone channelisation. Maintenance has led to the disturbance of both banks and complete removal of riparian vegetation (Photo: Emma Quinlan).

3.3.1.1 What to look for - Channelisation

The following factors should be recorded (with photographs):

- Prior to the catchment walk, as part of the desk study, the assessor should check the presence of drainage schemes within the water bodies under investigation (e.g. OPW arterial drainage schemes and Local Authority drainage district schemes). If spatial datasets are not available, see http://maps.opw.ie/drainage/map/. Also, check whether channel maintenance databases are available for drainage district schemes. This will provide insight as to whether there has been recent disturbance to the river channel. Also, note whether there has been any modification to channels (e.g. straightening, diversions) by comparing aerial images with older ortho photographs and historic maps (http://map.geohive.ie/mapviewer.html). See **Volume 1** covering desk study preparation.
- The desk study should also note the geological setting of the water body (e.g. soils, subsoils and bedrock) so as to provide an indication of the type of sediment that will be found within the water bodies under investigation.
- Record disturbance or loss of river bed sediment, habitat and removal of in-channel vegetation as these will indicate hydromorphological impacts within the river channel.

If possible, depending on the depth of water, record whether there is any alteration to the sediment conditions of the river bed using indicators such as:

- Dominant sediment type (e.g. boulder, cobble, gravel, sand, silt, clay, peat);
- Sediment type not as expected for habitat/river type (e.g. pool-riffle, lowland meandering/) or gradient; and
- Signs of elevated levels of siltation (i.e. blanket of fine sediment accumulated on the river bed (i.e. 10mm in depth) or significant plume when bed is disturbed using a stick or foot))

See **Volume 4** for more information on sediment.
For hydromorphological impacts to the bank/riparian zone, record the following:

- Presence of exposed banks (e.g. fresh exposure indicates recent erosion)
- Removal of riparian vegetation (e.g. reducing bank stability)
- Spoil heaped on the banks (e.g. disconnection with the floodplain)

Such factors are also indicative of fine sediment sources and siltation. If possible, record any alteration to sediment conditions of the river bed. The presence of native plants such as nettles and butterbur may provide an indication of bank disturbance.

3.3.2 Land drainage

The purpose of land drainage is to remove excess water from the soil to avoid water logged conditions which in turn, allows the land to be used for such activities as agriculture, forestry, peat extraction and wind farm development.

The presence of land drainage (see **Volume 3** for details) may lead to an increase in the amount of water and fine sediment that enters a river water body if that feature is connected to the water body. This in turn can alter hydrological and sediment regimes which subsequently may alter morphological conditions. For example, an increase in fine sediment entering a river can lead to an increase in suspended sediment throughout the water column while siltation can occur as fine sediment settles onto the river bed during low flow conditions. As described above regarding channelisation, an increase in the volume of water reaching the river may lead to an increase in shear stress (i.e. force of water on the bed), and therefore an increase in erosion. Land drainage can also impact surface water-groundwater interactions and therefore, baseflow conditions, particularly in groundwater fed rivers, can be impacted.

3.3.3 Cattle access

Cattle access is a potential fine sediment source, as well as poaching of the river bank.

3.3.3.1 What to look for - Cattle Access

- The location of cattle access points should be captured using a handheld GPS. Poaching of the river bank should also be recorded.
- Record and photograph the extent and magnitude of these activities.

3.3.4 Invasive/alien plant species

Not only does the spread of invasive alien plant species reduce biodiversity, they can also impact the hydromorphological conditions of rivers and exacerbate siltation issues. Some examples are Knotweed (Japanese/ Himalayan/Giant), Himalayan balsam and Giant hogweed. Once established in an area, they spread along the river bank and out-compete the native fauna. As these plants die back during the winter months, this will lead to bare, exposed banks resulting in a reduction in bank stability and an increase in bank erosion. It is also useful to note that large stands of invasive alien plant species can often be indicators of historical modification.

3.3.4.1 What to look for - Invasive/Alien species

- The location of areas invaded by invasive alien plant species should be captured using a handheld GPS.

Location can also be captured using the smartphone app, ***Biodiversity Data Capture***[12]**. This National Biodiversity Data Centre app allows the public to map the location of invasive species** (such as Knotweed (Japanese/Himalayan/Giant), Himalayan balsam and Giant hogweed) which feeds into a national database.

Location can also be captured using smartphone apps developed by various county councils for their area. For instance, the *Report Invasive Plants* app was developed by Limerick City and Council to allow the public to map the location of invasive species so that the council and local community groups can plan for their control (https://www.catchments.ie/help-fight-alien-plants-invading-ireland-report-invasive-plants-tracking-app-iphone-android-launched/). Information from this app will feed into the National Biodiversity Data Centre national database in the future. Local authority staff are encouraged to check whether such an app is available for their organisation.

Photographs are useful to confirm identification of the plant(s) in question. See Section 12 for more information and the National Biodiversity Data Centre[13] for clear and concise identification keys.

3.3.5 Barriers

In-channel barriers can alter hydromorphological conditions and impede the movement of water, sediment (e.g. coarse sediment such as gravel, cobble and boulders) and aquatic species. Examples include dams, weirs, sluices, culverts, fords and bridge aprons (Figures 3-4, 3-5, 3-6, 3-7 and 3-8.

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[12] http://www.biodiversityireland.ie/downloads/apps

[13] http://www.biodiversityireland.ie/projects/invasive-species/id-guides/

A

B

Figure 3-3: Example of A) cattle access and B) poaching of the left river bank due to cattle access (right hand side of photo). Both scenarios will lead to an increase in fine sediment entering the channel (Photo: Emma Quinlan).

Figure 3-4: Example of a weir. This structure will impact the movement of bed load material (e.g. sand, gravel, cobble and boulders) and impact flow conditions directly upstream and downstream of the structure. It will also impede the movement of aquatic species. A fish pass is present on this weir (not visible in the photo) but it is not functioning (Photo: Emma Quinlan).

Figure 3-5: Example of a weir with a rock ramp (visible along the right bank) to allow fish passage (Photo: Emma Quinlan).

Figure 3-6: Example of a bridge apron. This will impede the movement of sediment and fish passage (Photo: Emma Quinlan).

Figure 3-7: Example of the downstream section of a bridge apron. The height of the apron lip may impede the upstream migration of some fish species (Photo: Emma Quinlan).

Figure 3-8: Example of a culvert. This structure will impede flow and the movement of sediment and fish (Photo: Emma Quinlan).

3.3.5.1 What to look for - Barriers

- The location of barriers should be captured using a handheld GPS, particularly if fish status is driving the risk of the water body under investigation. Take photographs with location and description.
- Location can also be captured using the smartphone app, *River Obstacles*[14] (https://www.catchments.ie/help-map-river-obstacles/). An UCD based project RECONNECT aims to assess the extent and impact of barriers to fish migration and hydromorphological conditions. They have taken a citizen science approach using this app to capture location of barriers across the country. The output from this work will feed into IFI's national barrier inventory. By placing 'spots on maps', IFI will be able to assess the risk of barriers to fish migration and prioritise barriers for mitigating measures. The output will also be useful for both WFD hydromorphological classification and risk characterisation.
- It is also important to record the presence of a fish pass (e.g. ladder, rock ramp, vertical slot, and elevator). The River Obstacles app also provides an option to record fish pass presence.
- Note if bridges have abutements within the channel or whether the channel is culverted through the bridge. Also note whether sediment has accumulated downstream of the structure.

[14] https://www.river-obstacles.org.uk/

3.3.6 Bank protection

While bank protection (e.g. walls, riprap, gabions and soft engineering protection such as tree logs) may prevent bank erosion in an area along the channel, erosion may be accelerated in another area as the river tries to adjust to its altered condition and Figure 3-10).

Figure 3-9: Example of the use of boulders as bank protection. By placing boulders along the river bank, this prevents lateral movement and in response, the river may erode the banks elsewhere (Photo: Emma Quinlan).

Figure 3-10: Examples of the use of rip rap as bank protection. By placing riprap along the river bank, this prevents lateral movement of the river and limits both riparian habitat and the input of sediment and wood (Photo: Emma Quinlan).

3.3.6.1 What to look for - Bank Protection

- Record the location and type of bank protection structures, including the extent of the structure along the bank (e.g. 2m along the right bank).
- Record evidence of severe/extensive bank erosion upstream and downstream of bank protection structures as these areas may be a source of fine sediment.
- Take photographs with location and description.

3.3.7 Flood protection

Flood protection structures (e.g. walls, embankments) are constructed to reduce flood risk by containing water within the river channel, limiting connectivity with the floodplain. As with channelisation, if water is no longer able to spill out onto the floodplain, the volume of water in the channel increases, flood peaks are much greater and water rapidly transports itself through the system. This can lead to an increase in shear stress (i.e. the force of water on the river bed and banks), and therefore an increase in erosion. Furthermore, as water cannot spill out onto the floodplain and deposit its fine sediment load, siltation can occur during low flow conditions.

Figure 3-11: Example of the use of flood walls as flood protection (Photo: Emma Quinlan).

Figure 3-12: Example of the use of embankments as flood protection. Note the spoil heaped onto the bank has disconnected the channel from its floodplain. If soil is bare, this can act as a sediment source (Photo: Emma Quinlan).

3.3.7.1 What to look for - Flood Protection

- Record the presence of flood protection structures during the desk survey (i.e. CFRAM areas of further assessment (www.cfram.ie), OPW embankments http://maps.opw.ie/drainage/map/)).
- Record the location and type of flooding protection structures, including the extent of the structure (e.g. embankment for 200m along the right bank and embankment height of 1m from the bank).
- If such structures are not mapped (i.e. works not under OPW remit), record the location.
- Record evidence of accelerated/extensive erosion within areas where flood protection structures are present. These areas may be a fine sediment source.
- If possible, depending on the depth of water, record any alteration of sediment conditions of the river bed. See **Volume 4** for information on sediment.
- Take photographs with location and description.

3.4 Possible Mitigation Options

With reference to the main types of Hydromorphological pressures described above for rivers, potentially applicable mitigation options are summarised in Table 3.2 below.

Possible Mitigation Options (or river rehabilitation techniques) to address hydromorphological modification have been implemented by various groups such as IFI (e.g. Environmental River Enhancement Programme (with OPW), Tourist Angling Measures), EU LIFE projects, angling groups and river trusts. These techniques have often focused on improving habitat for particular species (e.g. salmonids, freshwater pearl mussel), bank protection from excessive levels of erosion using soft engineering approaches (i.e. trees logs), natural water retention or restoring natural river processes.

Table 3-2: Pressures Hydromorphological Pressures – Possible Mitigation Options

Mitigation Option Category	Pressure Type	Mitigation Option	Example of outcomes
Pathway interception	Land drainage	Fine sediment traps	Reduce siltation further downstream.
Pathway interception/Receptor rehabilitation	Channelisation	Planting of riparian vegetation	Stabilise the bank. Act as a buffer to pollutants. Provide and/or improve habitat.
	Cattle access	Fencing the river bank	Removes cattle access. Stabilise the bank. Reduces siltation issues.
	Invasive plant species	Planting of riparian vegetation	Stabilise the bank. Act as a buffer to pollutants. Provide and/or improve habitat. Restore riparian vegetation diversity.
Receptor rehabilitation	Channelisation	Gravel augmentation	Improve river bed substrate/sediment conditions and habitat.
		Placement of boulders/weirs/rubble mats/large wood	Encourage heterogeneity of the river bed and improve and/or provide habitat. Encourage the rebalance of the sediment regime and control local flow patterns (i.e. reduce downcutting).
		Excavation of the river bed	Create pools which will improve the heterogeneity of the river bed and improve and/or provide habitat. Enhance fishing opportunities.
		Construction of deflectors	Encourage meandering which in turn improves local flow conditions and heterogeneity of the river bed. Slows down water through the channel particularly during high flow events.
		Reconnect or construct river meanders	Encourage heterogeneity of the river bed. Increase channel length. Slows down water through the channel particularly during high flow events.
		Creation of a two-stage channel	Improve channel width-depth variation.
		Reconnection of channels	Restore natural flow and sediment regimes and improve and/or provide habitat.
		Bank re-profiling	Improve connection to the floodplain.
		Self- rehabilitation/'leave river alone'	Cease activities (e.g. channel maintenance) to allow time for river processes to recover.
	Invasive plant species	Removal of invasive alien species	Restore riparian vegetation diversity. Stabilise river banks and reduce bank erosion.
	Barriers	Removal of barriers	Improve longitudinal connectivity of water, sediment and aquatic species. Restore river processes.
		Barrier modification/construction of a fish pass	Improve fish migration, water/sediment movement.
	Bank protection	Tree bank revetments	Protect the river bank from excessive erosion or replace hard bank protection. Improve riparian quality.
	Flood protection	Natural flood management	Mitigate flooding in certain areas for certain flood events)

3.5 Useful References

General information on hydromorphology:
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Perfect, C., Addy S. and Gilvear, D., 2013. *The Scottish Rivers Handbook: A guide to the physical character of Scotland's rivers*. CREW project number C203002.

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EPA and OPW (2020) *Natural Water Retention Measures (NWRM) Overview and Recommendations for Use in Ireland*. Report available on request.

EPA and OPW (2020) *NWRM Evidence and Opportunities for use in Ireland*. Report available on request.

IFI,2020. *River Restoration Works - Science based Guidance centred on Hydromorphological Principles in an Era of Climate Change*. IFISH: Fish and Habitats: Science and Management. Volume 2: 117pp. ISSN: 2565-6244 (online). Inland Fisheries Ireland.

O'Grady, M.F., 2006. *Channels and challenges. Enhancing salmonid rivers*. Irish Freshwater Fisheries Ecology and Management Series: Number 4, Central Fisheries Board, Dublin, Ireland.

UK River Restoration Centre. Factsheets and guidance notes on river restoration available at: http://www.therrc.co.uk.

Invasive Alien Species:
Irish National Biodiversity Data Centre (http://www.biodiversityireland.ie/projects/invasive-species/id-guides/)

GB non-native species secretariat (http://www.nonnativespecies.org)

4 Catchment Walks – Urban Wastewater Pressures

4.1 Purpose

This section provides a guide of indicators and visual clues of urban wastewater pressures, supported by photo-documentation of good and bad practices from the field or urban environment. Urban wastewater arising from wastewater treatment plants consists of domestic wastewater (from residential settlements) or the mixture of domestic wastewater with industrial wastewater (from premises used for trade or industry). The objective of urban wastewater treatment is to collect the wastewater generated within our communities, remove the polluting material and then release the treated water safely back into the environment.

The principal urban wastewater pollution pressures are related to:

- Plant itself; and
- Collection network

These pressures and associated issues are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes.

4.2 Significance

Urban wastewater is estimated to be a significant pressure for cycle 3 in 175 rivers, 3 lakes, 22 transitional and 3 coastal water bodies nationally. It is ranked the 2nd most significant pressure in transitional waterbodies (after agriculture) and the 4th most significant pressure in river waterbodies.

The collection and treatment of urban wastewater in Ireland operates within a tight legal and regulatory framework. This is in order to protect human health and the receiving waters and also to ensure that operations and activities are carried out in compliance with European and National legislation. The European Union's Urban Wastewater Treatment Directive and Ireland's Urban Wastewater Treatment Regulations set out requirements for the collection, treatment and discharge of urban wastewater, with the objective of improving quality of water, e.g. by reducing nutrient and chemical pollution before it enters water bodies and protecting the environment from the adverse effects of wastewater discharges.

The roles of the relevant agencies responsible for urban wastewater are detailed below:

1. Irish Water is the national water utility, responsible for the collection, treatment and discharge of urban wastewater in compliance with the requirements of EPA wastewater discharge authorisations.
2. The Environmental Protection Agency (EPA) is the environmental regulator of Irish Water. The EPA issues and enforces authorisations for wastewater discharges in accordance with the Wastewater Discharge (Authorisation) Regulations, 2007 as amended.
3. Each Local Authority is responsible for the surface water network in their respective Local Authority areas.
4. The Commission for Energy Regulation is the economic regulator of Irish Water. It ensures that Irish Water's revenue is spent efficiently and effectively to improve services.

In relation to water quality protection, the main purpose of local catchment assessment with regard to urban wastewater is to:

1. Capture, geo-reference and characterise all urban discharges from the agglomeration for those water bodies *At Risk.*
2. Determine if the impact from the agglomeration is making a significant contribution to a deterioration in the receiving water quality.

When specifically assessing urban wastewater as a potential significant pressure on the waterbody, the approach is slightly different, focusing on potential impact at the WFD monitoring point rather than directly downstream of the discharge mixing zone:

1. Assess the pressure at desk study stage in relation to: i) its likely contribution to the significant water quality issue causing the waterbody to fail to meet its WFD objective ii) the pollution risk posed by the discharge at the WFD monitoring point in 95%ile flows and iii) additional risk associated with the proximity of the discharge to the WFD monitoring point
2. Undertake field assessments to confirm/refute desk study conclusions
3. Where the discharge is confirmed as a significant pressure, refer the pressure to the EPA to address with the licensee.

Urban wastewater activities can lead to the degradation of habitats and ecosystem health in three principal ways:

1. Physical changes to receiving waters e.g. flows, pH, temperature, solids, erosion.
2. Chemical changes to receiving waters e.g emission of pollutants to the aquatic environment, mainly nutrient and organic compounds but also priority substances,
3. Biological changes to receiving waters: Increasing the microbial content of the receiving water e.g. increased levels of bacteria & viruses.

Water quality *indicator parameters* of urban wastewater pressures are detailed below:

1. Organic pollution by oxygen-consuming substances:
   - Biochemical Oxygen Demand (BOD) (mg/l),
   - Chemical Oxygen Demand COD (mg/l)
   - Total Ammonium as N (mg/l)
2. Dissolved Oxygen (mg/l)
3. Nutrient pollution:
   - Total Nitrate as N mg/l
   - Orthophosphate as P mg/l
   - Total Ammonia as N mg/l
4. Siltation pollution:
   - Total Suspended Solids mg/l

Details on indicator species and water quality parameters are described in **Volumes 3 and 4**.

4.3 Urban Wastewater Pressures from Plant (Works)

Typically, wastewater treatment plants are located on the outskirts of villages, towns and cities, the discharge locations of which can be found in the WFD App. The two types of authorisations issued by the EPA to Irish Water for urban wastewater are based on the size of the agglomeration served by the collection system:

- A wastewater discharge licence is required for discharges from areas with a population equivalent (P.E.) of 500 or more; and
- A certificate of authorisation is required for discharges from areas with a P.E. of less than 500.

The treatment of wastewater involves different physical, chemical or biological processes (Table 4-1), or combinations of these treatment processes, depending on the required effluent standards or Emission Limit Values (ELVs). It is important to understand the urban catchment (see Figure 4-1 and 4-2) and the main risks associated with it in order to be able to suggest possible mitigation measures to reduce its impacts. For urban-based local catchment assessments, it is important that up to date wastewater network maps are obtained – where available from Irish Water.

Field assessments for urban wastewater should be carried out both in dry and wet weather preferably in the Spring / Summer when growth and the effects of the eutrophication are at their highest and river flows are at their lowest to reflect the worse case scenario with regard to dilution factors. The main discharge points typically associated with a wastewater treatment plant are described below, however, reference should be made to the specific licence/certificate for the plant, as each treatment system is unique.

1. Primary Discharge Point; means the discharge point with the largest volumetric flow from the waste water works.
2. Storm water overflows; means a structure or device on a sewerage system, designed and constructed for the purpose of relieving the system of excess flows that arise as a result of rainwater or melting snow in the sewered catchment, the excess flow being discharged to the receiving water.
3. Secondary Discharge Point(s); means the discharge point where a potential, an occasional or continuous.

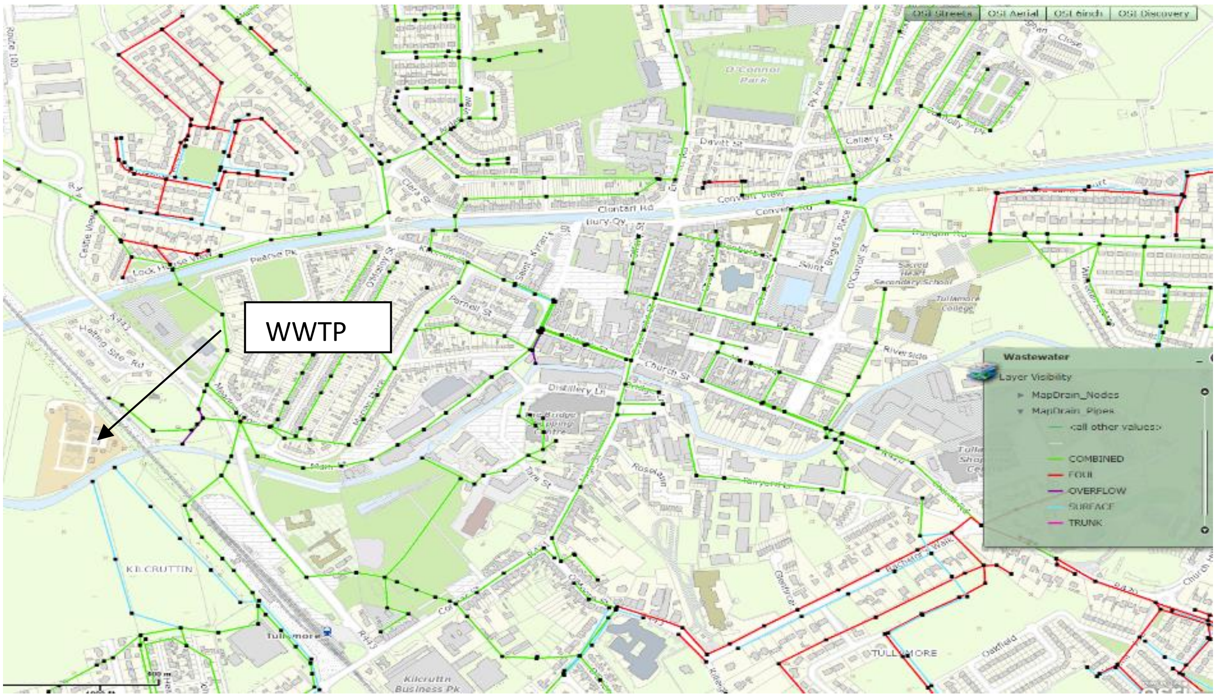

Figure 4-1: Typical urban catchment detailing the collection system in a medium sized town. Note the proliferation of combined sewer systems in the inner older section of the town. All flow is directed towards the wastewater treatment plant for treatment (Source: Irish Water).

Figure 4-2: Wastewater Network. Note the seperate surface (blue) and foul (red) networks for the newer developments on the outskirsts of the town (Source: Irish Water).

Table 4-1: Wastewater treatment levels (EPA, 2016)

Waste water treatment levels	**Preliminary treatment.** This is a basic form of treatment designed to remove large solids, floating debris, grit, oils, fats and grease. Waste water should receive further treatment after the preliminary treatment stage.	
	Primary treatment. A physical treatment process that involves the settling out and removal of a proportion of the suspended matter.	
	Secondary treatment. A biological treatment process where bacteria break down and remove organic matter to significantly reduce the risk of pollution.	
	Nutrient removal. This covers a variety of treatment processes aimed at minimising phosphorous and nitrogen in the waste water. The Directive refers to this type of treatment as 'more stringent treatment'.	
	Disinfection. A treatment system to kill or inactivate bugs and viruses in the waste water. It is often achieved by irradiating waste water with ultraviolet light.	Effluent quality improves

Table 4-2: Range of raw domestic wastewater influent characteristics (I.S. EN 12566-3:2005)

Parameter	**Typical Concentration mg/l (unless otherwise stated)**
Chemical Oxygen Demand (COD)	300-1000
Biochemical Oxygen Demand (BOD)	150-500
Total Suspended Solids	200-700
Total Ammonia as N	22-80
Total Phosphorous as P	5-20
Total Coliforms	106-109 (MPN/100ml)*

*Not from I.S. EN 12566-3:2005 (MPN, Most Probably Number)

4.3.1 Assessing Urban Wastewater Impacts from Plant (Works) Discharges > 500 P.E

In general, in order to determine whether a plant is impacting adversely on the downstream water course, the following assessments may be carried out:

1. Review the discharge licence for information on agglomeration discharges and any subsequent technical amendments. The licence details the location of the discharges, the frequency of monitoring of certain parameters and their emission limit values. The licence may also include a requirement to carry out infrastructural improvements within certain timeframes where they are needed to improve discharges and reduce environmental risks. Such improvements typically include upgrades to the wastewater treatment plant and collection system and the cessation of certain discharges. The licence may also include a requirement to carry out an impact assessment in relation to sensitive receptors and protected areas.
2. Review current compliance monitoring results. All wastewater discharges are monitored by Irish Water in accordance with the requirements of the EPA authorisation and are available to view. All samples should be representative i.e. taken with a composite sampler which may be flow or time based with flow based samples being more accurate. Also, recent or current incident notifications are available from Irish Water and the EPA.
3. Review the most recent Annual Environmental Report (AER) produced by Irish Water for the agglomeration. This report is located in the wastewater discharge authorisation section of the EPA website www.epa.ie . The report will detail the overall compliance of the wastewater treatment plant against the discharge licence for the previous year. The AER will detail any incidents i.e. discharges that do not comply with the requirements of the licence or any occurrence at a wastewater works with the potential for environmental pollution e.g. breakdown of critical equipment or requiring an emergency response by Irish Water and/or other relevant authorities. The AER will also provide information on the design capacity and current loading of the WWTP and the status/progress made in relation to any specified improvements programmes.
4. Determine if the agglomeration is included on any list of known deficiencies by Irish Water e.g., Constrained Networks list, Storm Tank Programme, Plant Bypasses list etc.
5. Review the WFD App information (trend graphs, map layers etc.) for the receiving water body. Where monitoring data is available, the WFD App will trend the upstream and downstream monitoring points of the wastewater treatment plant against Environmental Quality Standards as detailed in the Surface Water Regulations. For assessment purposes, it is preferable that upstream and downstream water samples are taken on the same day.
6. Review the current Urban Wastewater Reports on the EPA website www.epa.ie. The EPA reports on the performance of all urban wastewater treatment plants (> 500 P.E.) in Ireland on an annual basis. The EPA uses the BOD, COD and Total Suspended Solids effluent quality standards in the Directive to assess the performance of all urban areas with secondary treatment. The EPA also publishes “priority lists” where urban wastewater improvements

must be prioritised. Review the priority lists to determine the issues associated each each agglomeration.

7. Conduct a small streams risk survey as per guidance manual, as indicated in **Volume 4.** Check www.epa.ie to determine if a small streams risk survey is specified as a condition in the licence**.**
8. Conduct a simple mass balance river model or assimilative capacity as detailed in **Volume 4.** Note; this will have already been done for licensed sites, visit www.epa.ie for more information.
9. Speak to relevant staff (compliance teams/ process optimisation teams in Irish Water /Clerk of works & caretaker for the plant) about the overall compliance and capabilities of the plant. The EPA's licence enforcement team can provide information on previous incidents.
10. Complete and capture visual assessment in the field.

4.3.2 Assessing Urban Wastewater Impacts from Plant (Works) Discharges < 500 P.E (Certificates of Authorisation (COAs))

It is often more difficult to determine impacts from smaller agglomerations as they generally don't have flow data associated with discharges, and are required to be sampled only twice a year for BOD, COD and Total Suspended Solids (TSS). They do not have emission limit values specified in their authorisations. The main requirement of the authorisation is that discharges do not cause or have the potential to cause enviromental pollution or deterioration.

In order to assess if a COA is impacting adversely on the downstream water course, the following assessments may be carried out:

1. Review available monitoring data. All data pertaining to COAs are available from Irish Water on request. All samples should be composite in nature in order to be representative, however, many smaller works may only have grab sample data. Also, recent or current incident notifications are available from Irish Water and the EPA.
2. Review the WFD App information (trend graphs, map layers etc.) for the receiving water body. Where monitoring data is available, the WFD App will trend the upstream and downstream monitoring points of the wastewater treatment plant against Environmental Quality Standards as detailed in the Surface Water Regulations. If the distance to threshold for the waterbody for a particular parameter is far, and the EQS are met upstream and are breached frequently downstream (and other pressures are ruled out) then it is likely that the agglomeration is impacting adversely on the waterbody. For assessment purposes, it is preferable that upstream and downstream water sample are taken on the same day.
3. Conduct a small streams impact survey as per guidance manual, as indicated in **Volume 4**. Check www.epa.ie to determine if a small streams risk survey is specified as a condition in the authorisation.
4. Conduct a simple mass balance river model or assimilative capacity as detailed in **Volume 4**.
5. Speak to relevant staff (compliance teams/ process optimisation teams in Irish Water) about the overall compliance and capabilities of the plant. The EPA's licence enforcement team can provide information on previous incidents.
6. Complete and capture visual assessment in the field

4.3.3 Assessment of Urban Wastewater Discharges as a Significant Pressure on the Waterbody

The focus of this section is on the assessment of urban wastewater as a significant pressure at the WFD monitoring point. The recommended assessments and data sources referred to in 4.3.1 and 4.3.2 remain relevant but loading and assimilative capacity calculations are based on flows at the WFD monitoring point rather than downstream of the discharge. The decision tree (figure 4.3 below) and supporting information outlined in this section help to guide the assessor on the determination of significance and on the level of field assessment required.

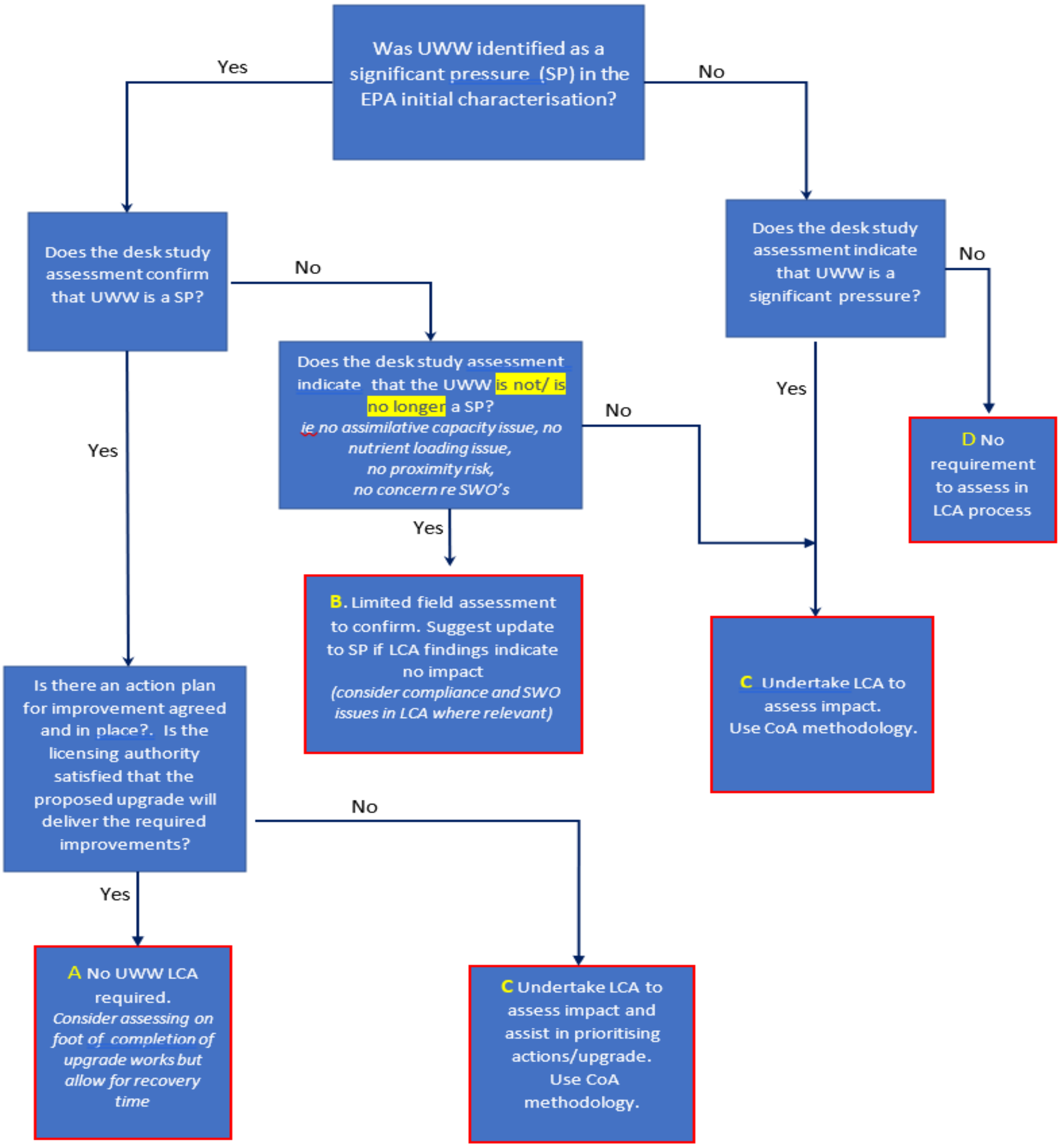

Figure 4.3: UWW Decision Tree

Decision Tree Notes:

- This decision tree approach is not intended to replace the desk based assessment of all potential pressures in the waterbody. It is a tool for the specific assessment of UWW pressures. Calculations outlined in the steps below assist in assessment of significance and in determining the extent of fieldwork required.

- The decision tree focuses on UWW primary discharge. Where there is evidence of SWO impact, particularly where SWO's have been identified as a significant pressure in the initial characterisation or the desk study indicates that this pressure exists, it will need separate assessment including field investigation.

- Where UWW is not identified as a significant pressure and assimilative capacity calculations are not indicative of pollution risk but available data indicate an issue associated with the discharge, further detailed assessment in the field will always be required. Issues may be SWO-related or due to other urban pressures such as urban diffuse or misconnections. This area is covered in more detail in the Urban Pressures volume.

- Desk-based assessment of urban wastewater pressure (four step approach):

I. Significant Pressure from initial Characterisation

Does the EPA initial characterisation identify urban wastewater as a significant pressure? Is it the sole significant pressure? The purpose of these questions is to 'split' the decision tree to allow us to select out those UWWTP's which are i) confirmed significant pressures, ii) with effective action plans in place and agreed with the licensing authority and iii) already on the Irish Water investment programme. The approach in relation to this type of UWW scenario is that we would not include the assessment of UWW in the waterbody local catchment assessment. However, UWW-focussed LCA could be undertaken after the upgrade works have been completed, to assess improvement.

II. UWW nutrient loading

Assess the significant issue 'average load' at the WFD monitoring point, using mean flow (normally Q30) and baseline monitoring data for the WFD monitoring point.

What is the load reduction required at the WFD monitoring point?

[(A-B)mg/l x C (lpd)] where

A= current nutrient MRP baseline

*B= desired conc (EQS *0.9)*

C= mean flow (Q30) litres per day. If flow data are not available, use EPA Hydrotool. Adjust for contributing catchment area where necessary

What is the contribution of the UWWTP in terms of the overall load and required load reduction? Is it significant?

Note that in scenarios where the point source is the main contributor to the significant issue driving water quality (e.g. phosphate), multiplying average or baseline pollutant concentration by average flow (Q30) can lead to an over-estimate of the significant issue load at the WFD monitoring point. This is turn can result in an underestimate of the percentage contribution of the UWW discharge. For these scenarios, try to obtain approximate flow data for each date that WFD sampling was undertaken. Use these approximate flows to estimate individual loadings for each date and from these data, obtain an average load over time.

III. Assessment of pollution risk in 95%ile flow conditions

Estimate the resultant concentration of the discharge at the WFD monitoring point using assimilative capacity calculations as detailed in **Volume 4**. Use 95%ile flow at the WFD monitoring point, real effluent data (from facility AER's) and notional clean background upstream water quality data. The use of notional clean upstream allows you to assess the pollution risk associated with the discharge in isolation.

The proposed limit indicative of potential pollution risk is 50% headroom utilisation. If the assimilative capacity calculations indicate that the discharge takes up more than 50% of the headroom (using notional clean for upstream water quality), this indicates an assimilative capacity issue specifically associated with the UWW discharge. Further field assessment will be required here, focusing particularly on low river flows. Also assess headroom utilisation using actual upstream water quality data (where available) to get an idea of overall low flow pollution risk associated with the combined upstream pollution sources.

Note re undertaking Steps II and III on COA facility discharges

Effluent nutrient data may not be available for COA facilities. However there have been many studies on the quality of wastewater influent and effluent from different systems. These data have been used to develop estimated effluent concentrations per PE as outlined in Table 4.3 below. In the absence of monitoring data for the facility effluent, you can use the loadings in Table 4.3 for the Step II and Step III calculations, selecting based on the level of treatment provided. Please note that these figures are estimates only.

Table 4.3: Treatment removal efficiency[15] and estimated effluent concentration[16]:

Level of Treatment		***Total PE***	***BOD***	***NH4-N***	***PO4-P***	***Flow (per PE[17]) lpd[18]***
Raw Sewage	*grams per person per day*		*60*	*8*	*2.18*	*NA*
	Influent concn (mg/l)		*300*	*20*	*10.9*	*200*
Primary Treatment	*Treatment redn factor*	*A*	*0.7*	*0*	*0*	*NA*
	Effluent concn (mg/l)[ii]		*210*	*20*	*10.9*	*=A*200*
Secondary Treatment	*Treatment redn factor[ii]*	*A*	*0.35*	*0.545*	*0.467*	*NA*
	Effluent concn (mg/l)		*105*	*10.9*	*5*	*=A*200*
Tertiary Treatment	*Treatment redn factor[ii]*	*A*	*0.2*	*0.3*	*0.1*	*NA*
	Effluent concn (mg/l)		*60*	*6*	*1.9*	*=A*200*

[15] *The P and N removal efficiencies applied to secondary and tertiary treatment systems in the table are as used by Irish Water in the COA Sole Pressure reports (see these reports for more information). For systems with primary treatment only, no treatment factor has been applied for ammonium and phosphate. This conservative approach is taken to ensure that desk top calculations do not prematurely eliminate UWW discharges from the requirement for local catchment assessment.*

[16] *The calculations in table 4.3 are based on domestic effluent only. This may result in errors where industrial contribution is significant but in general, industrial effluent is unlikely to be a significant component of a COA discharge.*

[17] *PE loadings may have changed between the COA certificate issue date and the present. It is important to be as accurate as possible with these data because they inform the COA facility nutrient and BOD loading estimates in the table. Check with the EPA/Irish Water for the most recent PE data for the facility. If this information is not available, check the CSO website for population change. Alternatively, compare most recent aerial imagery with imagery predating the facility application documents to look for increased/decreased development within the agglomeration boundary.*

[18] *Recent data suggest that per capita water consumption is less than 200 lpppd. However the critical figures here are the daily per capita BOD and nutrient load in grammes. The figure of 200 litres is only used to convert daily load to concentration. It does not have a significant bearing on the overall assessments as these are based on load rather than concentration.*

IV. Considering the proximity of the discharge to the WFD monitoring point

Where the WFD monitoring point is close to the discharge, occasional incidents have greater potential for impact (e.g. problems with the ferric dosing regime could result in low effluent pH or aeration system failure could result in low dissolved oxygen levels at the WFD monitoring point etc**).** It is unlikely that this can be properly assessed at desk study stage but the desk study report should note that there may be a proximity issue and it should of course be included in the scope of the local catchment assessment, using upstream and downstream biological monitoring to assess.

4.4 Visual Assessment of Plant Pressures

- Visually assess the primary, secondary and stormwater discharge locations to ensure that they are clear and free of gross contamination /solids (Figures 4-4, 4-5, 4-6, 4-7 and 4-8).
- Visually assess the receiving water to ensure that it is free of gross solids contamination e.g. "ragging" (Figure 4-9) on the river banks or on low hanging branches.
- Visually assess the receiving water to see if it exhibits any signs of eutrophication (especially in the Spring/Summer months), "sewage fungus"/grey water/strong odours/excess flies or vermin.
- Visually assess the receiving water to gauge the level of siltation e.g. sand banks/islands of silt in the waterbody.

Figure 4-4: Note, manholes downgradient of treatment plant can indicate the discharge locations which may be under the surface water level of the receiving water (Photo: Joan Martin).

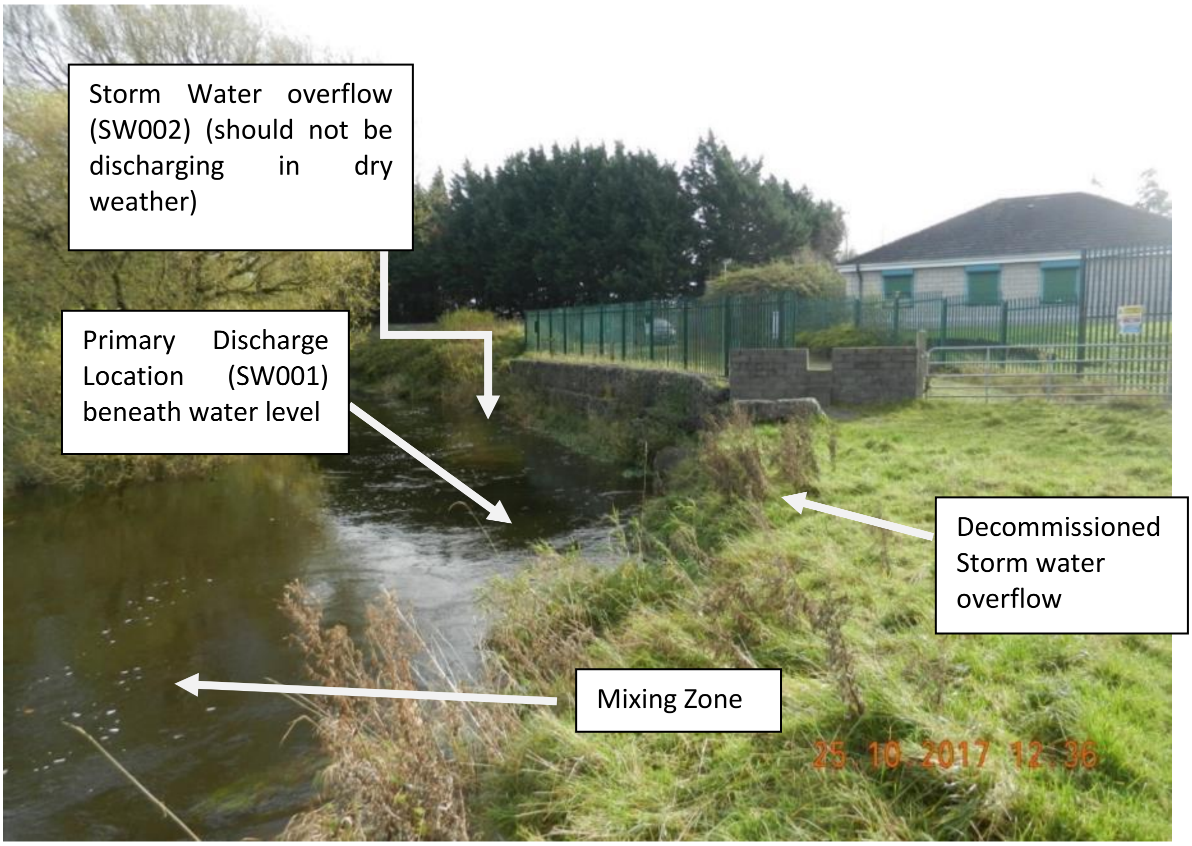

Figure 4-5: Good Practice - A typical medium sized licensed wastewater treatment plant. The final effluent in discharged into the middle of the receiving water to prevent erosion of bank and to promote proper assimilation / mixing into the receiving water (Photo: Joan Martin).

Figure 4-6: Primary discharge Location note the clear designation of the Primary Discharge Location (SW001) (Photo: Joan Martin).

Figure 4-7: Primary Discharge. Note the continous flow and discharges should be clear with no visible solids (Photo: Joan Martin).

Figure 4-8: Good Practice - Storm water discharge point. Note that it is not discharging in dry weather and there is no indication of solids in the immediate discharge vicinity which indicates good practice and indicates that the storm water has been screened and settled in a tank prior to discharge (Photo: Joan Martin).

Figure 4-9: Bad Practice – Note “ragging” on the lower branches of trees on river banks and the excessive euthrophication may indicate that unscreened storm water is being discharged to the receiving water (Photo: Joan Martin).

4.5 Walking the Catchment: Urban Wastewater Pressures from the Collection Network

4.5.1 Storm Water Overflows (SWOs)

A large proportion of urban sewer networks function as combined systems, which collect both wastewater and surface water runoff from impermeable hard-standings (e.g. roads, pavements and car parks). It is not possible for these combined collection systems to treat all wastewater during all precipitation events, which are increasing with frequency and intensity due to climate changeCollection systems therefore contain spill points, referred to as storm water overflows, which are designed to relieve the system of excess flows that can arise as a result of these precipitation events. The excess flows bypass the treatment plant and discharge to receiving waters via these spill points (Figure 4-10). In the absence of such overflow mechanisms, the wastewater treatment plant, as well as private properties, could be at risk of flooding during and after these precipitation events.

A single outfall point into a receiving water may receive flows from more than one SWO. Conversely, an overflow pipe from a SWO may diverge to more than one outfall point. In some locations, there are ‘clusters’ of SWOs. This often occurs where trunk sewers were built to intercept a series of crude foul discharges along a river or coast. Many SWOs in Ireland have not been improved since their creation at the time of original sewer construction – more than a hundred years ago in some cases (Figures 4-11, 4-12, 4-13, 4-14, 4-15, 4-16 and 4-17). Others have been modified by the addition of weirs, stoplogs, penstocks or some form of screening. In some areas, the location of SWOs may be unknown at present. In order to limit the impacts on receiving waters by discharges from storm water overflow points, EPA authorisations require all that storm water overflows are compliant with the Department of Housing Planning and Local Government (DHPLG) guidance; “Procedures and Criteria in relation to Storm Water Overflows". It is critical that all SWOs or suspected SWOs are captured during the local catchment assessment so that they can be checked against Irish Water GIS records and assessed in Drainage Area Plans (DAPs), where applicable.

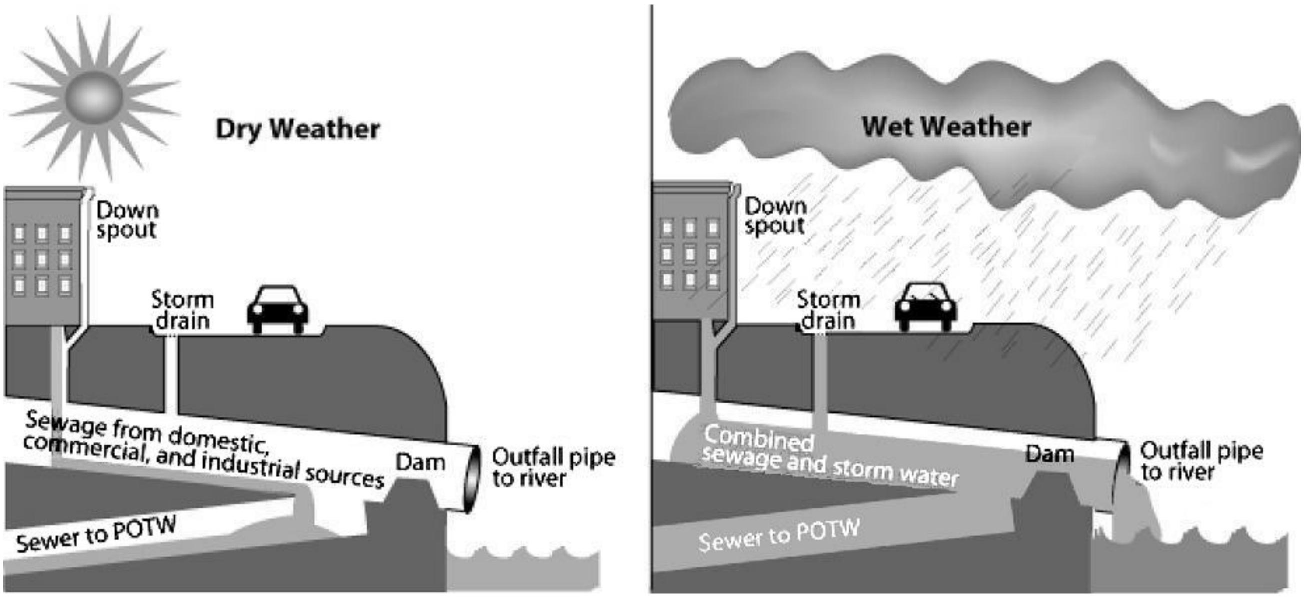

Figure 4-10: Schematic showing how a SWO works on a combined sewer network (Source: Wikicommons - US EPA)

Figure 4-11: Bad Practice – Example of a SWO on a combined network. Note the overflow pathway to the receiving water which receives no screening (Photo: Joan Martin).

Figure 4-12: Typical SWO. Normal flows run in the channel. When levels rise in the manhole, excess flow escapes via the overflow pipe to the right of the photo (Photo: Paul Buggy & Gerry O'Connell).

Figure 4-13: Example of a SWO on a combined network in dry weather – Note the evident eutrophication (Photo: Joan Martin).

Figure 4-14: Bad Practice – Example of a SWO on a combined network in wet weather. Note the contaminated overflow into the receiving water in moderate rain conditions (Photo: Joan Martin).

Figure 4-15: Bad Practice – Receiving water example of a direct discharge from a storm water network in low flow conditions (Photo: Joan Martin).

Figure 4-16: Storm water discharge on a combined network. Note physical discolouration of rock with indicates repeated contaminated overflows. CCTV surveying will be required in this instance to locate the SWO (Photo: Joan Martin).

Figure 4-17: Discharge of raw sewage from a SWO during dry weather conditions – caused by a sewer blockage (Photo: Paul Buggy & Gerry O'Connell).

4.5.1.1 What to assess / look for – Storm Water Overflows (SWOs)

- Has the SWO been identified and included in the EPA authorisation?
- Is it scheduled to be discontinued under the specified improvements programme in the EPA authorisation?
- Is it in compliance with Department Guidelines (Refer to Irish Water and www.epa.ie)?
- Where is the actual location of the discharge to the receiving water?
- What is the receiving water – is it designated sensitive /protected / at risk?
- Is there visual evidence that the overflow discharge is causing pollution?
- Speak to the relevant Local Authority and Irish Water regarding the location of SWOs and the occurrence and frequency of overflow events.
- Review any relevant incident notifications - available from the EPA and Irish Water.
- Note; A regularly occurring overflow will leave behind similar evidence to a misconnection. Also, it must be borne in mind that, in an urban catchment, it is highly likely that both may be present in the discharge from the one surface water pipe.

4.5.2 Pumping Station Emergency Overflow (PSEO)

Some agglomerations may require pumping stations(s) due to areas of low lying topography. In these instances, the wastewater is collected at these low points and is lifted by pumping and conveyed through a rising main to gravity sewers, to the point of treatment. In the event of operational failure (e.g. power, mechanical, electrical or control failure) and the pumps are disabled, they may emit an emergency overflow which results in a discharge of untreated wastewater. These emergency overflow mechanisms are constructed to protect infrastructure. The overflow may occur at the pumping station itself or at a chamber upstream on the incoming sewer. As the overflow may operate in dry weather or discharge to a relatively small watercourse, the environmental impact can potentially be greater than that of SWOs. Most pumping stations are now on telemetry and are alarmed and the relevant staff are alerted when there is a malfunction, so that the issue can be rectified in a speedy manner. Examples of pumping stations are shown in Figures 4-18, 4-19, 4-20 and 4-21.

4.5.2.1 What to assess / look for – Pumping Station Emergency Overflow

- Is the pumping station on telemetry and alarmed and is there an emergency response procedure in place in the case of a prolonged power failure?
- What is the pump configuration duty/standby or duty/assist stand-by?
- Is pumping capacity adequate for the incoming load?
- What is the storage capacity at the station? Is it adequate or undersized?
- What is the frequency, duration and cause of emergency overflows to receiving waters?
- Clarify the location where such discharges enter the receiving waters.
- Assess the area around the pump sump – are there gross solids and/or discoloration, which may be indicative of repeated overflows? Does the pumping station look clean and well maintained?
- Also, recent or current incident notifications are available from Irish Water and the EPA.

4.5.3 Exfiltration

The term “exfiltration” is used for water exiting the sewer system into the ground. Exfiltration leaves the sewer system through openings such as displaced or open pipe joints, cracks, fractures and breaks in the fabric of the main sewer and its lateral connections, and in manholes and chambers. This exfiltration may enter and contaminate groundwater, particularly where groundwater levels are below the sewage pipes. Exfiltration causes reduced flows in the sewerage system and is usually only identified during survey work, but if exfiltration is suspected in the urban environment, it is important to communicate possible exfiltration to Irish Water, as it can cause major pollution of the subsoils, groundwater and aquifers if not remediated.

Figure 4-18: Typical foul pumping station compound & control building (Photo: Joan Martin).

Figure 4-19: Typical pumping sump - Pumping stations usually has two pumps (duty and standby or duty/standby/assist in larger installations) which pump combined flows to the treatment plant (Photo: Joan Martin).

Figure 4-20: Bad Practice – Possible capacity issues – overflow from manhole is discharged to the receiving water (Photo: Joan Martin).

Figure 4-21: Good practice - Alarmed pumping station (Photo: Joan Martin).

4.5.3.1 *What to assess/look for – Exfiltration*

- Is there any evidence that pollution of groundwater is occurring near a foul /combined sewer line? (Note: evidence such as this is unlikely to be common, as wells are seldom located in town/urban areas. However, site investigations (either excavations or boreholes) and contaminated land investigations might provide evidence of impacts.
- Is there evidence that groundwater inputs are impacting on watercourses, particularly in low flow periods?

4.6 Possible Mitigation Options

Possible mitigation options related to urban wastewater system are listed in Table 4-44.

Table 4-4: Urban Wastewater– Possible Mitigation Options

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control	Increased urbanisation	Control Urbanisation	Relevant County Development Plan and National Planning Policies such as the National Planning Framework http://npf.ie/
		Increase Regulation Require pre- treatment of trade effluents to meet tightened ELVs prior to discharge to sewer & implement & enforce upper threshold restrictions on discharge volumes (e.g. Section 16 licences, IPPC & IED licences)	Irish Water www.water.ie & EPA www.epa.ie
		Promote SUDs for all new and exisiting developments.	National Planning policies & relevant Local Authorities Development Plans
		Promote reduction in infiltration and surface water inflows into combined wastewater collection systems	Irish Water Area Drainage Plans www.water.ie
		Introduce Polluter pays policies e.g. control excessive water use.	Irish Water www.water.ie
Pathway interception	Increased loadings of pollutants due to increased populations and economic activities & incidents.	Review & revise EPA authorisations through technical amendments. Note: a review or technical amendment is a matter for the EPA in line with statutory requirements.	EPA www.epa.ie
		Increase the capactiy of collection systems, pumping stations, storm water tanks& treatment plants	Irish Water – Drainage Area Plans & Wastewater Strategy www.water.ie
		Optimise treatment processes by improved operation and maintenance.	Irish Water - Wastewater Strategy www.water.ie

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
		Identify oppurtunties for 'bolt-on' technologies to be added to existing infrastructure e.g. SWO screening, advanced wastewater treatment processes etc.	Irish Water - Wastewater Strategy www.water.ie
		Review policy & procedures with regard to the replacement of critical parts of equipment (e.g. standardisation of processes, e.g. have spares in stock.	Irish Water - Wastewater Strategy www.water.ie
Receptor Rehabilitation		Implement "end of pipe" SUDS in all new and existing infrastructure, e.g. ICWs & residential populations.	Relevant Local Authority. Climate Change strategy www.epa.ie and National adaptation Framework www.dccae.gov.ie
		Decomissioning, relocate or upgrade of SWOs in sensitive areas.	EPA & Irish Water www.epa.ie Irish Water - Wastewater Strategy www.water.ie

4.7 Useful References

EEA, 2012. *European Environment Agency European waters — assessment of status and pressures*. EEA Report No 8/2012. Copenhagen. Available at: https://www.eea.europa.eu/publications/european-waters-assessment-2012.

EPA Urban Wastewater Treatment. Available at: https://www.epa.ie/our-services/compliance--enforcement/waste-water/urban-waste-water/

Moreira et al., 2014. *Assessment of impact of storm water overflows from combined wastewater collecting systems on water bodies (including the marine environment) in the 28 EU Member States.* Specific Contract No. 070201/2014/SFRA/693725/ENV/C. Milieu Ltd. Available at: https://circabc.europa.eu/sd/a/c57243c9-adeb-40ce-b9db-a2066b9692a4/Final%20Report.

Irish Water Services Strategic Plan. Available at: https://www.water.ie/projects-plans/our-plans/water-services-strategic-plan.

Irish Water Greater Dublin Drainage Plan. Available at: http://www.greaterdublindrainage.com/.

Urban Wastewater Treatment Directive (91/271/EEC). Available at: https://ec.europa.eu/environment/water/water-urbanwaste/legislation/directive_en.htm

5 Catchment Walks – Diffuse and Small Point Urban Pressures

5.1 Purpose

This section provides a guide of indicators and visual clues of diffuse and small point urban pressures, supported by photo-documentation of examples from the field. Principal urban pressures are related to:

- Combined sewer and foul sewer overflows (see Section 4);
- Misconnections – domestic and industrial;
- Pollution incidents;
- Dumping;
- Contaminated overland flow from paved and unpaved areas;
- Construction sites (oil and silt) and;
- Contaminated groundwater.

These pressures and associated issues are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes.
Volume 5 *Urban Local Catchment Assessments* contains a companion document to the guidance contained below. The guidance in Volume 5 covers the LCA process for urban areas and outlines how urban pressure data and information from desk studies and catchment walks might be identified, recorded, evaluated and reported. It is recommended that the Volume 5 guidance be read as a supplement to the LCA Guidance below.
A separate online training course, *Urban Pressure Local Catchment Assessment,* with more detailed courseware, was developed by LAWPRO and the EPA. The online course information is available alongside this LCA course material on a dedicated training page on the LAWPRO website.

5.2 Significance

As documented in **Volume 1**, the diffuse and small point urban pressure category is estimated to be a significant pressure in 179 river, 3 lake, 11 transitional water bodies and 3 coastal water bodies nationally, and is ranked the 5th most significant pressure within river water bodies, 8th for lake water bodies, 3rd for the transitional and 2nd coastal water bodies in the 3rd Cycle River Basin Management Plan.

In built-up urban areas, rivers and streams have been channelised and culverted to make way for development. Urban wastewater in the form of overflows and poorly performing wastewater treatment plants ranked the 3rd most significant pressure on urban streams and rivers.

Urban pollution enters water bodies via point and diffuse sources. Three forms of point sources enter urban water bodies, each the responsibility of different parties:

- Combined sewer overflows since 1st January 2014 are the responsibility of Irish Water (Water Services Act 2013).
- Surface water sewers are the responsibility of the Local Authorities (Water Services Act 2007).
- Private surface water sewers, foul and combined sewers - public nuisances (including blocked sewers and pollution therefrom) are the responsibility of the owner(s)of the private pipe (Public Health Act 1878).

Local Authorities have powers and responsibilities under the Water Pollution Acts (1977 and 1990) and the Water Services Act 2007 to prosecute those responsible for the discharge of polluting matter to water bodies. The foul and combined sewer networks and treatment plants operated and controlled by Irish Water are subject to the conditions in the Discharge Licences for each agglomeration under the Wastewater Discharge Authorisation Regulations 2007 by the EPA.

Diffuse pressures in the urban environment are more difficult to pin down and observe. They include pollution leaking sewers and oil leaks impacting groundwater, overland flow of soiled water from building sites, industrial sites, roads and land impacted by dumping. This section will highlight examples of these pressures.

In summary, the rivers and streams in urban areas are impacted by liquid and solid wastes from various human activities, making their way to water bodies. Because of the combined nature of urban drainage systems, heavy rain is a very important factor in the frequency of spills to streams and should be borne in mind on river walks. The sins of the network appear in the stream. Also, flows from diffuse and point sources are not the only pressures on urban stream. Culverting, channelisation (whether natural banks/bed or concrete) significantly impact upon potential for life in streams to flourish. Hydromorphological pressures are described in Section 3. The purpose of this section is to describe the pressures on urban streams and rivers from diffuse and small point sources, and to aid in the detection of each by means of a river walk.

5.2.1 General Advice

Urban streams are particularly vulnerable to heavy rain. An urban walk after or during rain will reveal pressures different in nature to those that are observable in dry conditions. For this reason, river walks should be carried out in wet and dry conditions. Cognisance should also be given to the time of the day as flows in sewers (and consequent possible overflows) follow a diurnal pattern.

On a river walk in an urban area, whatever the source, most commonly the pollution will enter the stream through a pipe. In this case, there are three pieces of information available to the assessor that will be of assistance in determining the next steps. These are:

- What kind of pipe, coming from where?
- Analysis of the discharge.
- The discharge's effect on the stream and the life within it.

It is impossible to overemphasise the importance of a rigorous desk-based assessment. This work will identify the kind of pipe in question or indeed if it is of an unknown nature. Knowledge of the nature of the pipe will govern the interpretation of any discharges and further assessment actions. On a dry day, overflow pipes to the river should be dry. A properly designed overflow should only operate under very heavy rain conditions – perhaps three times a year. Any evidence to the contrary is worthy of note and further enquiry.

A surface water pipe entering a stream on a dry day ideally should be dry. This is rarely the case due to groundwater infiltration. If the flow is small and is clear, it is possible that the flow is groundwater. Analysis in the lab will confirm this. Any "non-clear" flow from the pipe is evidence of likely pollution. Analysis of the effluent will be a guide to the source (e.g. leachate from a landfill entering the surface water pipe via cracks and open joints).

Samples should be taken of the suspicious discharge – and of the stream upstream and downstream of the discharge also.

Knowing in advance the nature of the pipe, having to hand analysis of the discharge and observing the impact of the discharge of the stream are a good guide for further investigation of the source.

5.3 Walking the Catchment

5.3.1 Misconnections

Houses built after approximately 1965-1970 are served by two pipes, namely the foul drain and surface water drain. The foul drain carries the sewage away from the property to the wastewater treatment plant. The surface water drain takes rainwater from the roof and hard surfaces and transfers it to the local stream, in most cases. A misconnection occurs when the foul drain is mistakenly connected to the surface water pipe. Thus, sewage is discharged to the local stream.

The experience of the Dublin Local Authorities is that approximately 8% of homes are misconnected in areas with separate sewers (Table 5-1). The majority occur when a property is being extended or adapted –typically the addition of a utility room. Most frequently, the misconnected pipe carries effluent from a washing machine, dish washer, shower or wash basin. Toilet effluent can be present also although more often than not, this is not the case. It is rare for misconnections to occur in the original build although there are cases where a whole estate or groups of houses have been misconnected.

Older urban areas have combined systems whereby foul and surface water flows are carried in the one combined pipe to the wastewater treatment plant. Consequently, misconnections can only be found in areas with separate systems.

Illustrations of satisfactory and unsatisfactory situations are given in Figures 5-1, 5-2, 5-3, 5-4 and 5-5.

Table 5-1: Results from surveys of misconnections undertaken by John Collins, Dublin City Council

Misconnections by Type n = 2602 (210 misconnections – 8%)

Washing Machines	**Sinks**	**Dishwashers**	**Showers**	**Toilets**	**Baths**
100	63	22	18	4	3
48%	30%	10%	8%	2%	2%

Appliance	B.O.D. (mg/l)	PH	Solids (mg/l)	Phosphate (mg/l)	**Population Equivalent**
Washing Machine	1,534 (58.5 litres)	10.0	366	0.53	**1.5**
Dishwasher	313 (25 litres)	9.2	19	0.32	**0.13**
Car Wash	3,160 (7 litres)	-	-	0.36	**0.36**

These results are typical of the on-going pollution of streams – misconnection rate is 8%

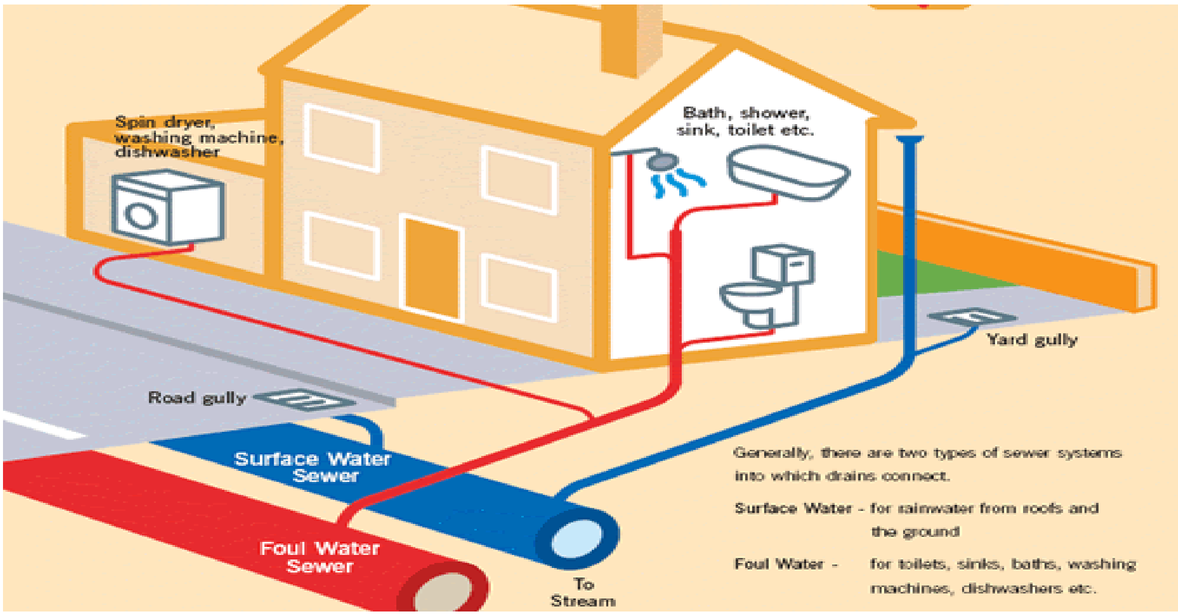

Figure 5-1: Typical correct drainage of a modern house (Photo: UK Environment Agency - www.connectright.org.uk).

Figure 5-2: Correctly Plumbed (Photo: Tony Falkiner).

Figure 5-3: Misconnected drain to surface water gully (Photo: Tony Falkiner).

Figure 5-4: Misconnected pipe to gutter (Photo: Tony Falkiner).

Figure 5-5: An Industrial Estate. Printing machine outlet directed onto the footpath eventually making its way to the surface water gully and to the local stream (Photo: Gerry Cullen).

5.3.1.1 What to look for - Misconnections

Desk-based assessment:

By examining the drainage records for the area, outline the catchment for each surface water pipe that discharges to the local water body. This will enable the surveyor to identify the source catchment of any misconnections found.

Catchment Walk:

Visually, grey or other colour water discharging to the stream via a surface water pipe is the most common evidence of misconnections (Figure 5-6 and Figure 5-7). If toilets are misconnected, toilet paper and sanitary products may be present also – although this is less common. The indicator parameters (**Volume 4**) will assist in locating the input point where a pipe is not obvious in the stream bank, and will enable the degree of impact to be determined. Sampling for analysis may be needed in some instances, and these may show the presence of *E.coli*, and elevated NH_4 and MRP. Clean surface water / rainwater will have a conductivity reading between 50-100 µS/cm and if contaminated, values may be in excess of this.

Figure 5-6: Characteristic grey cloud of misconnections entering the Shanganagh River (Photo: Paul Buggy).

Figure 5-7: Downstream from the outlet of a surface water outlet carrying domestic misconnections. (Photo: Gerry Cullen).

There may be grey sewage fungus on the bed of the stream, where the pipe discharges, lining the pipe or on the concrete apron upon which the pipe discharges (Figure 5-8 and Figure 5-9).

Figure 5-8: In this picture a surface water pipe discharges to the Dodder from approximately 1m above river level. Note the stream of sewage fungus that runs down the wall to the river – evidence of long term misconnections in the upstream catchment. (Photo: Paul Buggy).

Figure 5-9: Sewage Fungus within a surface water pipe showing evidence of misconnections (Photo: Paul Buggy).

5.3.2 Misconnection Survey Process

1. The results of river walk will identify the catchment in which the survey is required. In principle, misconnection surveys should be started at the upstream end of the catchment.
2. Identify the properties to be surveyed in the catchment and issue a notice to each property in advance of the survey. It is typical to call on every home. If resources are insufficient to do

this, examine the Google maps satellite map for the catchment and identify homes that have been extended and focus on these properties first as the hit rate will be higher.

3. Call to each home and carry out the survey by means of visually examining the drains at the property and carrying out dye tests where necessary.
4. Inform the home owner of the outcome of the survey. In the case of a misconnection, explain the responsibilities under the Water Pollution Act and agree a period for the repairs to be carried out.
5. Resurvey after this period.
6. If the home owner refuses to comply, write explaining their responsibilities and the consequences of non-compliance – prosecution under the Water Pollution Acts 1977 and 1990. A Section 12 Notice under the Act may be necessary.

Industrial estates, manufacturing and commercial, are typically served by separate drainage systems. Consequently, misconnections are a pressure to waters in these environments also. The industrial nature of discharges to misconnected drains means that the discharge to stream may be of a very different kind to that of domestic misconnections. The system for the detection and removal of the misconnections described above is very similar.

One of the solutions to mitigating the impacts of misconnections is the installation of integrated constructed wetlands (Figure 5-10).

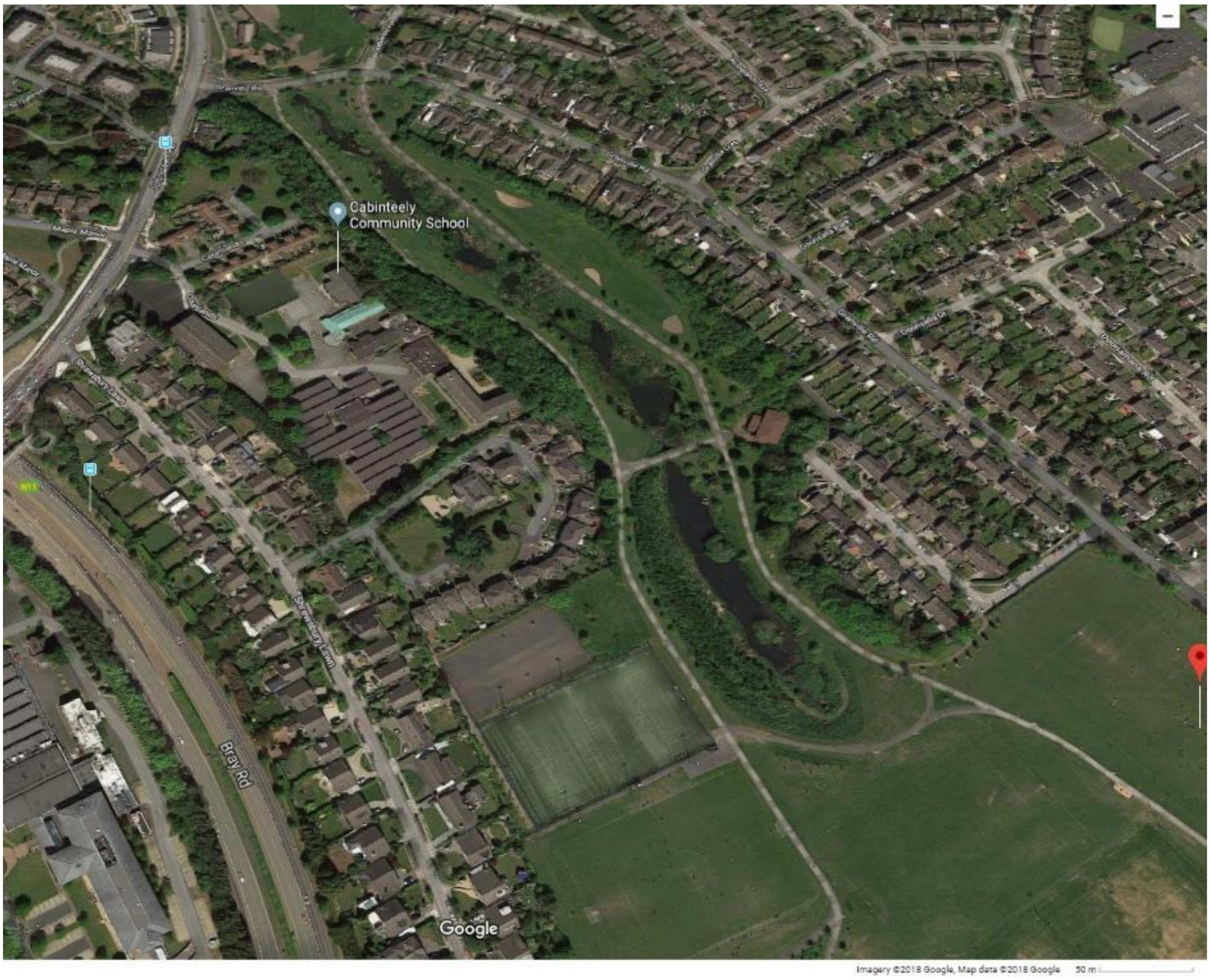

Figure 5-10: Kilbogget Park Integrated Constructed Wetland on the Deansgrange River treating surface water impacted by urban pressures – primarily misconnections. MRP (mg/l) is halved from inlet to outlet of the wetland. (Photo: Google Maps).

5.3.3 Contaminated Run-off from Surface Areas and Oil

The unfiltered, unattenuated nature of the drainage of large hard surface areas means that any pollutants in the path of rainwater are swept into the stream either directly by means of overland flow or via the surface water network. This includes spillages of hydrocarbons from oil, petrol, diesel, spilled paint and chemicals, metals from car engines, domestic car washing, dumped rubbish. Spillages in industrial estates can be a hazard also. Solids and spills, swept up by rain, sit in surface water gully pots and pipes and eventually are flushed to the river in the first 20 minutes of heavy rainfall. These first flushes are particularly toxic after a dry spell. If an industrial unit has an effluent discharge licence under Section 16 of the Water Pollution Acts, a licence condition will require that all potentially spillable chemicals must be bunded (Figure 5-11). However most industrial units are not licenced and spills on hard surfaces commonly make their way to the surface water system. Some car parks have petrol interceptors to catch spills of oil and petrol although they are rarely properly maintained.

A 

B 

Figure 5-11: A) Bunded (Photo: www.kaiserkraft.ie) and; B) Unbunded Chemical Storage (Photo: www.buerkle.de).

Sustainable urban drainage systems (SUDs) is now a requirement for all new development. This is to attenuate flows from new hard surface areas and protect to intercept pollution. Various green infrastructure methods such as swales, green roofs and ponds retain rainwater from developments filtering out contaminants and attenuating flows to rivers to reduce flooding. SUDs have become common in the past 10 years and do mitigate the impacts of the drainage of increased area of hard surfaces in urban areas. However, streams have to deal with a legacy of “traditional” methods of draining roofs and roads – essentially piping them to the local stream.

5.3.3.1 What to look for – Contaminated Runoff

A diverse range of pollutants can potentially be picked up and carried to the local stream from the large areas of hard surfacing in the urban environment. Oil is very evident from the thin sheen that is spread for kilometres downstream of the discharge (Figures 5-12, 5-13 and 5-14). The most common sources of hydrocarbons are leaking home heating oil tanks, oil dumped into road gullies and unmaintained oil interceptors. The odour and visible surface film make it very possible to find the source when the discharge is relatively large. Harder to find are small intermittent discharges from unmaintained interceptors, unbunded diesel tanks on construction sites and from car washing.

Other pollutants will leave traces on the bottom of the stream and the source is often evident by the nature of the deposit e.g. paint, silt, sludge.

Figure 5-12: Leaking oil pipe between the tank and boiler at a swimming pool. (Photo: Gerry Cullen).

Figure 5-13: The oil entered the surface water system through a broken surface water pipe (now repaired) (Photo: Gerry Cullen).

Figure 5-14: One mile downstream of the incident (see oil absorbent pads and boom) at the top of the photo (Photo: Gerry Cullen).

5.3.4 Construction Sites

There are five principal threats presented to water quality in streams adjacent to construction sites:

- Stripping of topsoil for construction on the site makes the stream vulnerable to clay and silt being washed in during heavy rain
- Excavations below the groundwater table when basements and trenches are dewatered. The local stream is a tempting outlet for this flow. Silt and clay deposits on the bed of the stream are devastating to flora and fauna in the stream
- Unbunded diesel tanks used to refuel construction vehicles can contaminate groundwater and either directly or through surface water pipes enter the stream. Spills of hydraulic oil also pose a threat.
- Washing out of concrete lorries and site wheel washes or concrete construction in a stream can potentially flush cementitious material to the stream. Also, depending on the nature of the ground water and the concrete used, it is possible for cement to leach out of blinding concrete and structural concrete beneath the groundwater table.
- Works carried out in the stream, including pipe and culvert laying, stream diversions, wall and bridge construction unless planned meticulously will lead to deposition of silt and disturbance to life on the stream.

All of the above threats can be planned for and managed through a Surface Water Management Site Plan. Ideally the planning conditions for the development will require the submission and acceptance of the plan in advance of the works to the Local Authority. This plan will set out the mitigating principles to ensure that work is carried out with minimal impact on the water environment. The overall guiding principle is that the contaminated water on the site must be controlled and treated. If necessary, a Section 4 licence which sets out limits for any discharges to waters, can be issued.

5.3.4.1 What to look for – Construction Sites

Silt on the bottom of the stream or silty water flowing in the stream is the most common evidence. Follow the silt to the source, which in most cases will be a surface water pipe or perhaps a pump discharge pipe sitting in the river. During heavy rain, watch out for sites with stripped topsoil and poor management (Figure 5-15 and Figure 5-16). Signs of hydrocarbons, as mentioned above, may be present. Cementitious material will raise the pH of the river and depending on the amount may cause a grey cloud (Figure 5-17). Calcium carbonate may precipitate out and line the bed of the stream and pipes with a white chalky substance.

Figure 5-15: Pumped water from a road trench making its way to the surface water gullies and then to the local stream (Photo: Gerry Cullen).

Figure 5-16: Dewatering for basement construction. Silt contaminated groundwater is treated by means of 2 settling tanks (with baffles) in series, each with filter bags at the entry to the tanks. Final effluent is discharged to the local stream. Discharge is subject to a Section 4 effluent licence (Photo: Gerry Cullen).

Figure 5-17: Groundwater of pH 11 discharging to the River Slang via the surface water system from a groundwater pumping system to enable construction of a basement (Photo: Gerry Cullen).

5.4 Contaminated Groundwater

Older surface water systems were commonly laid in an "open jointed" fashion to facilitate land drainage. Many tradition systems allow exfiltration due to cracks and faulty joints. The consequence of this is that leaking foul and combined sewers can contaminate groundwater. In addition, old landfills, which were not lined, have contaminated groundwater. This groundwater will inevitably enter nearby streams, with the potential to impact on the streams. The quality of the groundwater will be determined by the amount of leakage and the hydrogeology of the subsoil and/or bedrock in the vicinity of the sewer pipes or beneath the landfill material.

5.4.1 What to look for

- Identifying that the cause is a leaking sewer is very difficult. A CCTV is an effective way of confirming suspicions. A CCTV survey will also reveal if the discharge is caused by uncharted connection.
- Some of the indicator parameters described in **Volume 4** can be used to identify groundwater input to streams; temperature and conductivity in particular. The average temperature of groundwater in Ireland varies between 9-11°C, but might be slightly higher in urban areas. Therefore, during either warm or cold weather, a temperature contrast could indicate the presence of groundwater. In addition, groundwater generally, but not always, has higher SEC levels than surface water.

5.5 Possible Mitigation Options

Potentially applicable mitigation options are summarised in Table 5-1 below.

Table 5-1: Urban and Small Point Pressures – Possible Mitigation Options

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control	Misconnections	• At Taking in Charge, the developer must supply a sample surface water pipe with very low E.Coli, ammonia or MRP present • CCTV surveys at Taking in Charge • Public Information Campaign • Misconnection Surveys	
Pathway Interception	Contaminated Runoff from Surface Areas and Groundwater	SUDS	
	Contaminated ground water from building sites	• Section 4 Discharge Licence • Onsite Settlement Tanks • Gravel/Stone filtering	
	Contaminated groundwater infiltration through leaky surface water pipes.	• Relay pipes • Reline pipes • Repair pipes	
Receptor Rehabilitation	Misconnections	Integrated Constructed Wetlands	Collins and McEntee (2009)
	Contaminated Runoff from Surface Areas and Groundwater	Integrated Constructed Wetlands	
	Oil contaminated groundwater	• Contaminated groundwater extraction • Removal of oil contaminated soil	
	Oil in streams rivers	Oil Absorbent Booms and Pads	

5.6 Useful References

IFI, 2016. *Guidelines on protection of fisheries during construction works in and adjacent to waters*. Inland Fisheries Ireland. See link: http://www.fisheriesireland.ie/

Collins, J. and McEntee, D., 2009. *Integrated Constructed Wetland Tolka Valley Park Dublin.* Original paper presented at meeting in Engineers Ireland, Clyde Road (January 2007) and International Conference on Wetland Systems, Padua, Italy (June 2007).

6 Catchment Walks – Domestic Wastewater Treatment Systems

6.1 Purpose

This section provides a guide of indicators and visual clues of pressures arising from domestic wastewater treatment systems (DWWTSs). Domestic wastewater means wastewater, which originates predominantly from the human metabolism and from household activities. It is treated in individual septic tanks or effluent treatment systems, followed by an infiltration area. It comprises wastewater from toilets, showers, sinks, wash-hand basins, washing machines and dishwashers from single houses or small businesses in the countryside.

DWWTSs can threaten public health and water quality when: i) they are in unsuitable areas and; ii) when they fail to operate satisfactorily.

Site suitability is determined by two issues arising from the hydrogeological conditions:

- The **hydraulic** issue, where there is inadequate percolation, which may cause surface ponding of effluent, bypass directly to surface water and the associated threats to human health and surface water quality.
- The **attenuation** issue, where there is insufficient subsurface treatment of the effluent prior to reaching a water receptor, such as groundwater, wells/springs and/or indirectly impacting on surface water.

Many DWWTSs are not operating satisfactorily. The national inspection programme undertaken by local authorities has shown several reasons for failure, such as insufficient de-sludging, inadequate operation and maintenance, roof water and surface water entering the systems, leakage, and surface ponding. Further details are given in EPA (2018 and 2020)[19]. Inadequate operation of DWWTSs can cause pollution of both surface water and groundwater and can pose a health hazard.

Homeowners and builders who propose to build houses in unsewered areas are required to undergo site suitability assessments in line with the EPA's Code of Practice[20] to ensure that the site is suitable for an off-mains system. New installations have to be designed, constructed and installed in line with the Code of Practice (CoP) and Technical Guidance Document H which calls up requirements under S.R. 66:2015 - Standard Recommendation providing guidance to wastewater treatment products in compliance with the EN 12566 series of standards for treatment systems.

The risks from domestic wastewater arises from existing systems as the site was not suitability assessed or designed correctly or from treatment systems that are not adequately maintained under a maintenance contract or regularly de-sludged. Untreated domestic wastewater can lead to water pollution, risk to public health and to degradation of habitats and ecosystem heath, where inadequately treated effluent is piped to streams, flows via overland flow or shallow groundwater flow to streams where percolation is inadequate or by entering groundwater.

The typical concentration of raw domestic wastewater is summarised in Table 6.1 and the principal pressures to waterbodies are:

- Microbial pathogens;

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[19] Domestic Waste Water Treatment Systems (DWWTS) Inspections and Enforcement 2019 https://www.epa.ie/publications/monitoring--assessment/waste-water/domestic-waste-water-treatment-systems-dwwts-inspections-and-enforcement-2019.php
National Inspection Plan 2018-2021 https://www.epa.ie/publications/monitoring--assessment/waste-water/national-inspection-plan-2018-2021.php

[20] https://www.epa.ie/publications/compliance--enforcement/waste-water/2021-code-of-practice-for-domestic-waste-water-treatment-systems.php

- Phosphorus, primarily MRP;
- Nitrogen, present as ammonia and nitrate;
- Biological Oxygen Demand (BOD).

Table 6-1: Range of raw domestic wastewater influent characteristics (I.S. EN 12566-3:2005)

Parameter	Typical Concentration mg/l (unless otherwise stated)
Chemical Oxygen Demand (COD)	300-1000
Biochemical Oxygen Demand (BOD)	150-500
Total Suspended Solids	200-700
Total Ammonia as N	22-80
Total Phosphorous as P	5-20
Total Coliforms	106-109 (MPN/100ml)*

*Not from I.S. EN 12566-3:2005 (MPN, Most Probably Number)

6.2 Significance

As documented in **Volume 1**, domestic waste water systems are estimated to be a significant pressure in 163 river, 13 lake, 6 transitional, and 6 groundwater bodies nationally, and are ranked the 6th most significant pressure for river water bodies; 4th for transitional water bodies, 6th for lake water bodies and 5th for groundwater bodies in the 3rd Cycle River Basin Management Plan.

There are over 500,000 domestic wastewater treatment systems in Ireland, and they generally can be divided into two categories depending on their treatment capacities or population equivalents:

- Wastewater Treatment Systems that are designed to treat a population equivalent from 1 to 10 - these are generally serve single residential houses and are governed by The Water Services (Amendment) Act, 2012 (S.I. No. 2 of 2012).
- Wastewater Treatment Systems that are designed to treat a population equivalent from 10 to 500 – these are generally designed for small communities, businesses, leisure centres and hotels and are governed by the Water Pollution Acts 1977-1990.

6.3 Domestic Wastewater Treatment Systems (PE 1-10).

The discharges from DWWTSs are exempted from discharge licensing under Regulations made by the Minister in accordance with Section 4(10) of the Local Government (Water Pollution) Act, 1977 as the volume of these discharges are typically less than 5 m^3 /day to an infiltration area (discharges direct to surface water require Section 4 licensing). The Water Services (Amendment) Act, 2012 (S.I. No. 2 of 2012) requires homeowners connected to a DWWTS to register and ensure that the system does not constitute a risk to human health or the environment through compliance with standards for the performance and operation of DWWTSs. Owners shall ensure that the DWWTS is not leaking or has an unauthorised discharge to surface waters, that there is no ponding of effluent on the ground surface and that they ensure that greywater enters the system and rainwater, and clean surface water is excluded. The Water Services Authorities (WSAs) (local authorities) are required to maintain a register of DWTWSs and undertake inspections to assess the treatment system.

The EPA is responsible for the development of the National Inspection Plan (NIP), the appointment of inspectors and the establishment and maintenance of a register of inspectors and is the supervisory authority over the WSAs in the performance of their functions under the Act. Inspectors assess treatment system in accordance with the NIP. Full adherence to modern standards, such as those set out in the EPA's 2021 Code of Practice, are not required for older systems. Where an on-site system fails an inspection, the remediation work required will be based on factors such as the nature of the problem, the extent of risk to public health or the environment, existing site size, and the hydrological and geological conditions present.

The inspection assesses compliance with Section 70C(1)(b) of the Water Services (Amendment) Act, 2012 – namely is the DWWTS likely to constitute a risk to human health or the environment? The inspector risk-assess the system by checking if there is evidence to show that the system constitutes, or is likely to constitute a risk to human health or the environment, and , in particular:

1. To water, air, or soil or to plants and animals.
2. Through a noise or odour nuisance.
3. By affecting the countryside or places of special interest.

If the treatment system fails the inspection and is issued with an Advisory Notice and the owner of the occupancy registered the treatment system prior to before 1st February 2013, a grant may be available under the Domestic Wastewater Treatment Systems (Financial Assistance) Regulations 2013 (S.I. No. 222 of 2013), providing certain qualifications and criteria are met.

6.4 Wastewater Treatment Systems for Small Communities, Businesses, Leisure Centres and Hotels (PE 10-500).

Where small communities, business, leisure centres are being constructed in un-sewered areas and wastewater to be treated on-site, as a site characterisation form must be completed by a suitable qualitied person (i.e. a person who has attended and passed the WSNTG course on Site Suitability Assessment). This is done as part of the planning application process. The system must be designed and constructed and installed in accordance with the 1999 EPA Wastewater Treatment Manual (Treatment Systems for Small Communities, Businesses, Leisure Centres and Hotels).

Treatment systems are not subject to the domestic regulations but may be subject to a Section 4 discharge licence which is obtained under the 1977 Local Government (Water Pollution) Act as the discharges of wastewater to an infiltration area are typically greater than $5m^3$ in any period of 24 hours. Licenses are required for all wastewater discharges which are discharged to surface water.

6.5 DWWTSs in the Source-Pathway-Receptor Framework

The risk assessment method uses the source -pathway-receptor (SPR) model. The SPR model is based on the concept that for a risk to exist, there must be a source of potential pollution, a receptor that may be impacted by that pollution and a pathway by which the pollution can get from the source to the receptor. Figures 6.1 and 6.2 show how a discharge from a DWWTS can find its way to a river or groundwater used for drinking water.

In Figure 6.1 the discharge moves through thin subsoil and fractures in the rock to reach a drinking water well. The soil and bedrock cannot treat the pollution and therefore it can end up in the drinking water well. In Figure 6.2, the ground is not able to treat the wastewater as it cannot travel down into the soil. This can result in ponding of the wastewater from the DWWTS at the surface which can be a potential threat to human health. There is also the potential in such a situation for the wastewater to move over the land and enter a drinking water well by flowing down the outside of the well casing, if it has not been properly installed. This can cause contamination of the water supply.

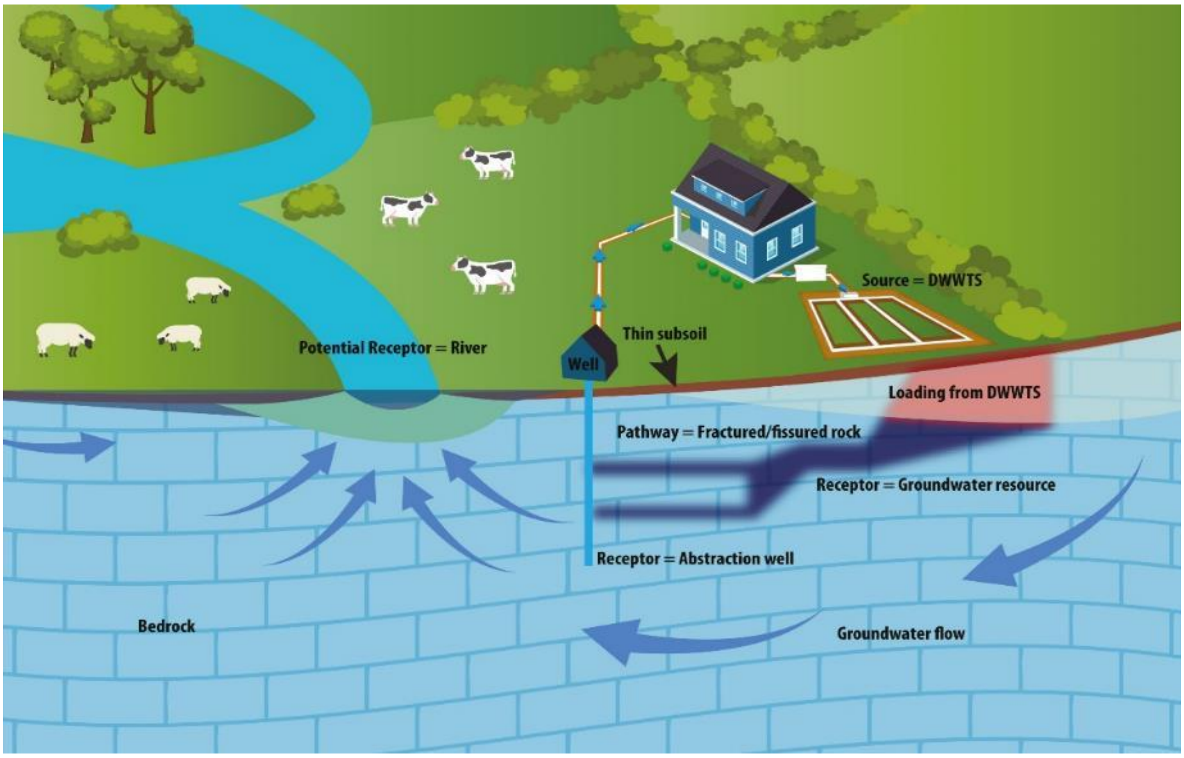

Figure 6-1: SPR model for domestic waste water treatment system with subsurface pathways (EPA).

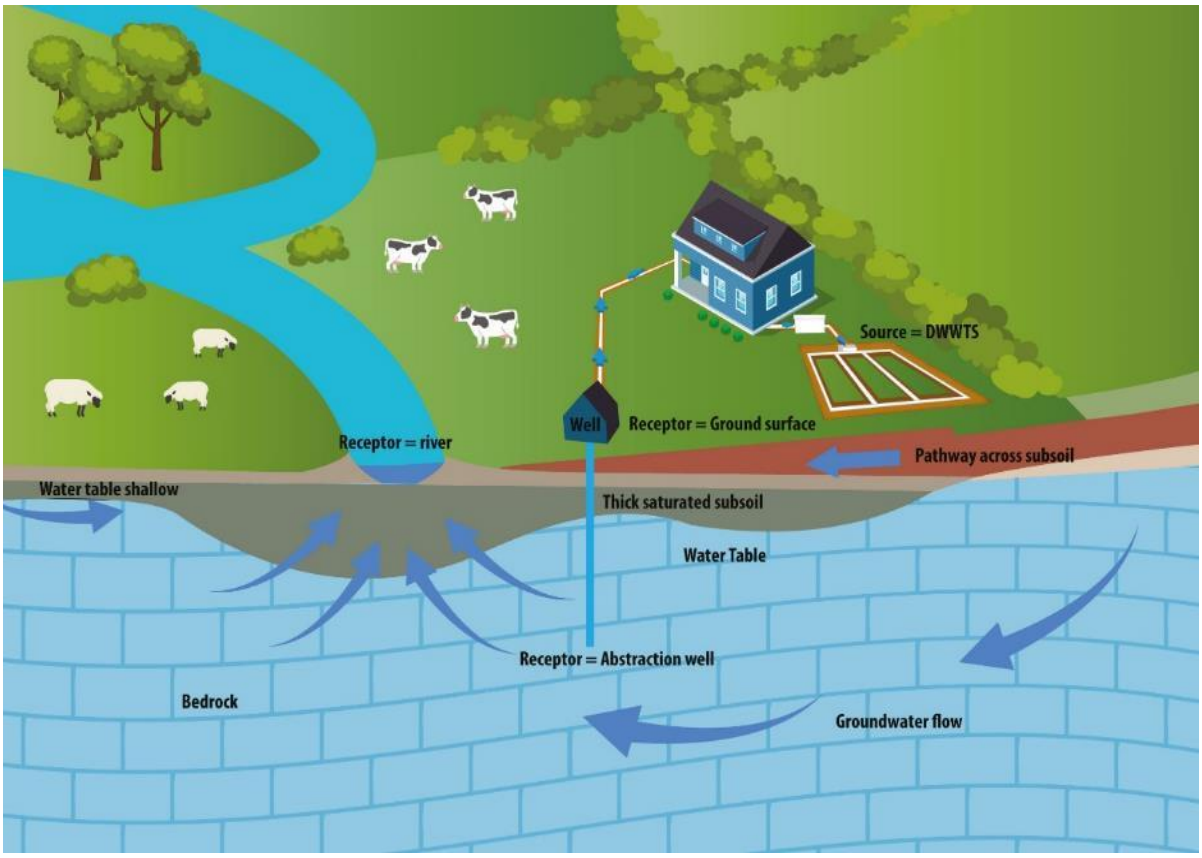

Figure 6-2: SPR model for domestic waste water treatment system with surface pathways (EPA[21]).

[21] Both Figure 6-1 and 6-2 are sourced from :
https://www.epa.ie/publications/monitoring--assessment/waste-water/NIP-2018-to-2021_web.pdf

6.6 Desk Study

The desk study can assist in targeting areas where DWWTS are likely to be posing an environmental risk, and therefore, inform subsequent catchment walks.

Besides the information and maps already available, the Domestic Wastewater Assessment (DWWA) portal in EDEN is a valuable source for local authorities. The DWWA system holds information on risk categories and details, including location and results of LA inspections of DWWTS under the National Inspection Plan.

The desk study assessment should include a review of the following data sources and recommendations on the areas that should be evaluated during the catchment walk.

- DWWA risk categories – **NIP Risk Zone maps should be reproduced in the desk study and not the Sanicose as they contain aggregated results and not individual houses.**
- DWWA LA inspection locations and findings, – **these maps show individual houses and are NOT to be included in desk study reports.**
- Sanicose model outputs that give the relative risk from nutrient pollution arising from DWWTSs – **these maps show individual houses and are NOT to be included in desk study reports**.
- Previous physio-chemical monitoring results showing elevated ammonium and BOD concentrations, which can be indicators of nearby organic pollution. Phosphate can be elevated in water bodies due to inputs from groups of houses with unsatisfactory DWWTSs. In situations, where there is a nearby drinking water source with microbial pathogen data for the raw water, high numbers might indicate impact by DWWTSs.
- Proximity of houses/ clusters of houses to the WFD monitoring point.
- Proximity to an open drain or water course, i.e., where the house site is adjoining.
- Clusters of systems.
- Drinking Water Source Protection Zones.
- Relevant components of the pathways conceptual model. There are several circumstances that may need to be considered:
    - Where a surface water body is the receptor, inadequate percolation and attenuation is the most common cause of runoff of DWWTS effluent to water courses. This arises in poorly draining areas and therefore the soils drainage maps and phosphate susceptibility maps should be checked for houses. In some circumstances, low transmissivity bedrock overlain by thin soils/subsoils can be problematical. Therefore, a combination of the aquifer map – poor aquifers – and X-extreme vulnerability zones might show this circumstance. (An example of this circumstance might be the granite area west of Galway city.)
    - Where either a groundwater body or a surface water body are *At Risk* because of inputs of pollutants from groundwater*,* the groundwater vulnerability map (X-extreme and Extreme (E) areas) and karst features maps give the most useful information. (An example of this circumstance might be the karst area east of Galway bay.)

All this information should help determine whether there is a likelihood of a DWWTS discharge to drain/watercourse or directly to bedrock affecting groundwater and therefore posing an environmental risk.

6.7 Walking the Catchment

What to look for:

- Houses located near a watercourse (e.g. using the geo-directory database).
- Presence of vertical pipes, mounds or other structures that might indicate the presence of a DWWTS near the stream.
- Pipes or land drains in stream banks that might be linked to the system.
- Presence of 'sewage fungus' and other ecological indicators, as well as hydrochemical indicators.
- Presence of toilet paper in stream.
- Presence of suds that might indicate detergents.
- Ditches entering stream that run close to a house.
- Ponded effluent at ground surface.
- Evidence of ponding shown by green patches on lawns indicating presence of nutrients.
- Pump house indicating the presence of a well.
- Presence and type of bedrock either on the site or in the stream banks and channel. The presence of outcropping bedrock may indicate an inadequate thickness of soil and subsoil to treat the effluent. In addition, the bedrock type is also relevant; some such as granite, metamorphic rocks and shales can indicate a risk to surface water as they tend to have a relatively low permeability, while others such as limestone may indicate a risk to wells, groundwater and associated ecosystems.
- Presence of small seeps or springs indicating a high water table.
- Presence of rushes on the site or on nearby fields indicate likelihood of poor percolation.
- Poaching in an adjacent field potentially indicating poor percolation.
- Topographic location and slope – a flat site adjoining a stream or ditch may indicate a high water table during wet weather.

Examples of unsatisfactory and inadequate situations are illustrated in Figures 6-3 to Figure 6-8.

Figure 6-3: Bad Practice – piped discharge from treatment system to watercourse (Photo: Joan Martin).

Figure 6-4: Bad Practice – Ponding of partially treated effluent from treatment system (Photo: Joan Martin).

Figure 6-5: Bad Practice – Discharge of partially treated effluent from treatment system (Photo: Joan Martin).

Figure 6-7: Bad Practice – Open tanks which allow ingress of rainwater into the system and constitutes a risk to human health (Photo: Joan Martin).

Figure 6-8: Bad Practice – Piping of “greywater” to watercourse (Photo: Joan Martin).

Figure 6-9: Bad practice due to ponded effluent (Photo: Andrew Holmes).

Figure 6-10: Bad practice due to inadequate percolation and ponding (Photo: Andrew Holmes).

Figure 6-11: Ponded effluent shown by lush green grass in front garden of house (Photo: Donal Daly).

6.8 Possible Mitigation Options

Possible Mitigation Options are summarised in Table 6-2.

Table 6-2: DWWTSs – Possible Mitigation Options

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control (incl. mobilisation control)	DWWTS for single house System <10PE	Arrange for homeowner to seek expert advice Options are dependent on circumstances, but include: • Installing a suitably sized & constructed infiltration area. • Installing raised percolation area. • Replacing with a secondary treatment or package system. • Repairing & replacing defective parts.	EPA, 2021
	DWWTS for single house System >10PE	Arrange for premises to seek expert advice and arrange for the site to have a site suitability assessment in line with EPA Guidance. Then install a suitable system.	*EPA, 2021*
Pathway interception	DWWTS	Options include: • Replace pipe discharge with a suitable system. • Increase setback distances. • Install integrated constructed wetland.	EPA, 2021

Receptor Rehabilitation		River restoration programmes to allow rivers to "self clense"	www.opw.ie & IFI www.fisheriesireland.ie

6.9 Grant Scheme

The Department of Housing, Local Government and Heritage have introduced a new grant scheme for faulty septic tank systems that may affect water quality. A homeowner may be eligible for this grant in one of three ways:

1. If an inspection by the Local Authority (LA) under the National Inspection Plan finds that there are problems with the wastewater system. The LA will inform the homeowner at the time of inspection of what to do next.
2. If the DWWTS is in a High Status Objective Catchment Area. These are areas where the water quality is excellent and needs protection or is failing to meet excellent quality and requires restoration. To see if the DWWTS is in one of these areas by inputting the EIRCODE in a map at this link. The homeowner can apply directly to their Local Authority for the grant.
3. If LAWPRO catchment scientists identify that there is a water quality issue in a nearby river and we believe defective DWWTSs may cause or make the problem worse, we may provide the homeowner with a letter advising on what to do next.

The grant is not means tested and covers 85% of eligible and pre-approved works (up to a maximum of €5,000). More grant details are available from the Department of Housing Local Government and Heritage.

The local authority manages the grant scheme on behalf of the Department, and LAWPRO supports them.

6.10 Useful References

EPA, 1999. *Wastewater Treatment Systems for Small Communities, Businesses, Leisure Centres and Hotels (PE 10-500).* Environmental Protection Agency. Available at: https://www.epa.ie/publications/compliance--enforcement/waste-water/EPA_water_treatment_manual_-small-comm_business1.pdf

EPA, 2021. *Code of Practice. Wastewater treatment and disposal systems serving single houses (p.e. ≤ 10).* Environmental Protection Agency. Available at: Compliance & Enforcement: Wastewater | Environmental Protection Agency (epa.ie)

EPA, 2011. *Guidance on the authorisation of discharges to groundwater*. Environmental Protection Agency. Available at: http://www.epa.ie/pubs/reports/water/ground/dischgw/.

EPA, 2015. *National inspection plan 2015-2017. Domestic Waste Water Treatment Systems*. Environmental Protection Agency. ISBN 978-1-84095-578-1. Available at: http://www.epa.ie/pubs/reports/water/wastewater/National%20Inspection%20Plan_Web_Amended.pdf.

EPA, 2018. *National Inspection Plan 2018-2021. Domestic Waste Water Treatment Systems.*. Environmental Protection Agency. Available at: https://www.epa.ie/publications/monitoring--assessment/waste-water/nip-2018-2021.php

Department of Housing, Planning, Community and Local Government, 2010. *Building Regulations 2010. Technical Guidance Document H – Drainage and Wastewater Disposal*. ISBN 978-1-4064-2338-9. Available at: gov.ie - Technical Guidance Documents (www.gov.ie)

Department of Housing, Local Government and Heritage, 2021. Domestic wastewater treatment systems (septic tanks) gov.ie - Domestic waste water treatment systems (septic tanks) (www.gov.ie)

7 Catchment Walks – Forestry Pressures

7.1 Purpose

This section provides a guide of indicators and visual clues of Forestry pressures, supported by photo-documentation of good and bad forestry practices from the field. Principal forestry pressures are related to:

- Afforestation (new planting);
- Access/road construction;
- Tree felling, extraction and reforestation;
- Public access resulting in other types of environmental risks or impacts (e.g. fly-tipping) and;
- Aerial fertilization

These pressures and associated issues are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes.

7.2 Significance

Afforestation in Ireland commenced shortly after the foundation of the State and was primarily undertaken on the land that was not suitable for agricultural use, which resulted in the planting of many uplands and peat soils. In addition, prior to the 1990s, there was little requirement for water setbacks. However, the early 1990s, after the creation of Coillte, saw the beginning of the introduction of environmental guidelines, which included the requirements for water setbacks. These have been revised and updated a number of times since then, and water setbacks are now fully integrated into normal forest practice.

Since the 1990s, almost all afforestation has been undertaken by private landowners on agricultural land. The Land Types for Afforestation also ensure that these upland peats are no longer afforested. However, forestry is long term and as a result many legacy issues still remain, and these are being worked through as forests are felled and replanted. Legislation and new policies introduced in 2017 provide for more flexibility with how these forests are managed and allow for restructuring post harvesting.

The national forest estate covers more than 770,000ha and accounts for 11% of the land area in Ireland. Just over half of forests are in public ownership with approx. 380,000ha in private ownership. Approx. 40% of the national forest estate is on peat, but the peat land planted is proportionally higher in publicly owned forests.

The commercial forest cycle has long periods where there may be no activity within a property. Furthermore, there are more than 3 million cubic metres of timber harvested annually, facilitated through thousands of licences issued each year, therefore it is important to note that the presence of a forest does not necessarily equate to a pressure.

As documented in Volume 1, forestry is estimated to be a significant pressure in 215 river and 14 lake water bodies nationally, and is ranked the 3rd most significant pressure in the 3rd Cycle River Basin Management Plan.

Poor forest practice can lead to the degradation of habitats and ecosystem health in three principal ways:

- Physical alteration of habitats;
- Release of fine-grained sediments to the aquatic environment;
- Release of pollutants to the aquatic environment, mainly nutrient compounds and pesticides.

Water quality *indicator parameters* of Forestry pressures are: turbidity (sediment), nutrients (specifically ammonia and phosphorus), pH and pesticide compounds. Details on indicator parameters are described in **Volume 4**.

Forestry in Ireland operates within a legal and regulatory framework. This is necessary in order to protect forests and also to ensure that forestry operations and activities are carried out in compliance with the principles of sustainable forest management. The primary legislation governing forestry activity is currently the Forestry Act, 2014 and S.I. 191 of 2017 (Forestry Regulations 2017). A forest is defined in the European Communities (Forest Consent and Assessment) Regulations 2010 (S.I. 558 of 2010) as land under trees with (a) a minimum area of 0.1 hectares, (b) tree crown cover of more than 20 per cent of the total area, or the potential to achieve this cover at maturity.

The Forest Service Environmental Requirements for Afforestation, introduced in December 2016, updated inter alia the previous Forestry and Water Quality Guidelines with the aim of protecting water and aquatic habitats and species during afforestation (new planting stage) and throughout the remainder of the forest rotation. The Requirements specify a number of measures which much be employed at afforestation in order to protect aquatic zones, (natural streams, rivers and lakes shown on OSI 6-inch maps), that may potentially be negatively impacted upon by forestry activity. Additional measures are required to protect *relevant watercourses,* (i.e. often artificial watercourses, including older existing drains, that are potential pathways). Adherence is specified as a condition of any approval (with or without grant support) for afforestation under S.I. 191 of 2017. The Standards for Felling and Reforestation were introduced in 2019, updating the previous Forest Harvesting and the Environment Guidelines and apply to thinning, felling and reforestation operations. As with the Environmental Requirements for Afforestation, these are included as minimum conditions for any licence issued. Additional conditions are routinely attached to all licences, specific to the site.

7.3 Walking the Catchment

7.3.1 Afforestation (new planting locations)

Typically, afforestation is the planting of new, green field sites, which were previously in agricultural use. A new forest is generally not considered “established” until it is free growing, which usually occurs around year 4. In accordance with the Environmental Requirements for Afforestation, and the previous Forestry and Water Quality Guidelines, there are certain conditions which must be adhered to, and water setbacks applied.

The use of a water setback is a central measure. As defined in the Requirements, its purpose is to **create at the outset, a buffer of natural ground vegetation positioned between defined water features and the forest crop and associated operations, in order to protect water quality and aquatic ecosystems from possible sediment and nutrient runoff from the site at afforestation and throughout the remainder of the forest rotation**. Key factors include soil type, slope, available pathways for water, the erodibility of the soil and subsoil, downstream designated sites, and the status objective of the waterbody itself. Regarding the latter, particular regard is needed if the proposed afforestation site is within the catchment area of a High Status Objective Waterbody or a waterbody at risk of decline in status.

On afforestation sites, an unplanted water setback should be evident on the ground, with no new drains crossing the setback connecting directly to the aquatic zone. New drains should stop on the upside of the setback with an appropriate silt trap. *New drains opening into an aquatic zone may be acceptable on very flat sites, and in very limited circumstances, as defined in the Environmental Requirements for Afforestation.*

The setbacks from aquatic zones, relevant watercourses (a watercourse that is not shown on an OS 6-inch map but is connected to an aquatic zone, or has the potential to carry significant amounts of silt/nutrients etc.), hotspots and water abstraction points are set out in Table 7-1 and apply to new planting (see the Environmental Requirements for Afforestation for full definitions).

The potential pressures on aquatic zones at this stage of the forest cycle are silt arising from ground preparation and/or drainage operations, nutrient enrichment from fertiliser application and run-off of chemicals following herbicide application (insecticides are not applied during afforestation).

Fertiliser is not required on all afforestation sites, and its application is based on soil fertility. Fertiliser application is not permitted within the water setback or within 20 metres of an aquatic zone, whichever is greatest. In general in forestry, fertiliser (*if used*) is applied once during the establishment period, is in granular form, and is applied by hand directly to the base of trees. (For these reasons, if a watercourse is eutrophic at an afforestation location, it may be as a result of previous or neighbouring land uses or pressures). As lands being afforested have historically been in agricultural use, fertiliser is often not required however, if applied it is typically ground rock phosphate.

Similarly, herbicides are not required on all sites, and when applied, it is by knapsack, directly at the base of trees and not broad-brush. Herbicides are not to be applied if heavy rainfall is predicted, is not to be applied within a water setback or within 20 metres of an aquatic zone (whichever is greatest), or within 15 metres of a landscape feature known to be a groundwater vulnerable area, including karst areas, sinkholes, collapse features or abstraction points.

Extracted from the table below:

Slope leading to the aquatic zone (apply as appropriate, where slope varies over the site)	Setback width	**Setback width for peat soils and for sites within the catchment area of high status objective waterbodies**
Moderate (even to 1-in-7 / 0-15%)	10 metre	20 metre
Steep (1-in-7 to 1-in-3 / 15-30%)	15 metre	25 metre
Very steep (1-in-3 / >30%)	20 metre	25 metre

7.3.1.1 What to look for - Afforestation

- Unplanted and undisturbed water setbacks should be evident on the ground
- Silt traps should be present and functioning correctly
- Existing land drains should be intact and not clogged with fresh sediment
- Appropriate water crossing points should be used; there should be no evidence of direct machine traffic through an aquatic zone or relevant watercourse
- There should be no evidence of machinery use or transit within the water setbacks.
- There should be no fertiliser bags, containers or site litter left behind
- There should be no evidence of storage or preparation of hazardous material, refuelling or machine repair within 50 metres of a watercourse
- There should be no evidence of herbicide use within the water setback (non-herbicide methods permitted, to establish native riparian trees)
- Relevant watercourses (existing land drains and other pathways entering aquatic zones, which have the potential to carry significant sediment / nutrients) – 5m unplanted and undisturbed setback apparent on both sides (this is a new measure under the Environmental Requirements for Afforestation)
- New afforestation drains should not be opened directly into aquatic zones
- Main crop trees should not be planted within setbacks (small pockets and individual riparian native trees are permitted within the water setback)
- Inappropriate fencing should not be present, e.g. fencing crossing aquatic zones and catching debris, deer fencing along aquatic zones leading to ground poaching along stream edges, fences in areas susceptible to flooding.

Table 7-1: Setbacks from aquatic zones during afforestation

WATER SETBACK

Purpose: To create at the outset, a buffer of natural ground vegetation positioned between defined water features and the forest crop and associated operations, in order to protect water quality and aquatic ecosystems from possible sediment and nutrient runoff from the site at afforestation and throughout the remainder of the forest rotation.

Minimum setback width, as measured from the nearest bank / edge of the water feature, as observed on-the-ground (setback applies to each side of the water feature, e.g. to both banks of an aquatic zone):

Aquatic zone (as per Table 1):

Slope leading to the aquatic zone (apply as appropriate, where slope varies over the site)	**Setback width**	**Setback width for peat soils and for sites within the catchment area of high status objective waterbodies (see note opposite)**
Moderate (even to 1-in-7 / 0-15%)	10 metre	20 metre
Steep (1-in-7 to 1-in-3 / 15-30%)	15 metre	25 metre
Very steep (1-in-3 / >30%)	20 metre	25 metre

Relevant watercourse: 5 metre

Hotspot: 5 metre

Drinking water abstraction point: 20 metre

Additional design:

- Widen the water setback at various points along its length, to include adjoining wet hollows and other low-lying areas where water gravitates towards as it drains from the land.
- Based on the immediate landform / topography, vary the setback to avoid artificial lines and to create a naturally undulating forest edge.

NOTE, if the afforestation site is within the catchment area of a high status objective waterbody, the required setback width (as per the 3rd column opposite) can be reduced by 10 metres (from the landward side) if an appropriate GPC9 or GPC10 plot is included instead of this 10 m strip. For example, where a 25 m setback applies, this can be reduced to 15 m by applying the following sequence: aquatic zone → 15 m unplanted water setback → GPC9 or GPC10 plot. Standard requirements for GPC9 & GPC10 plots apply, as per *NWS Establishment GPC9 & GPC 10: Silvicultural Standards.*

HABITAT SETBACK

Purpose: To create adequate space adjoining a retained habitat to avoid or reduce any impacts arising from the emerging forest and its canopy.

Different habitats identified as retained habitats (either as biodiversity plots or as linear or point biodiversity features) may require an unplanted habitat setback to prevent undue impact (such as shading) from the emerging forest. Setback width depends on the habitat and the potential impact(s). Apply careful design, e.g. focus the habitat setback mainly on the south-western, southern and south-eastern side of the habitat, to minimise the blockage of sunlight as the adjoining forest canopy grows. Note that the retained habitat itself must remain undisturbed (unless otherwise agreed or prescribed).

Figure 7-1: An appropriate silt trap at the end of a mound drain, on a newly developed afforestation site. The mound drain ends at the aquatic buffer zone with a vegetated, uncultivated buffer between the end of the drain and the waterbody (Photo: Forest Service, DAFM).

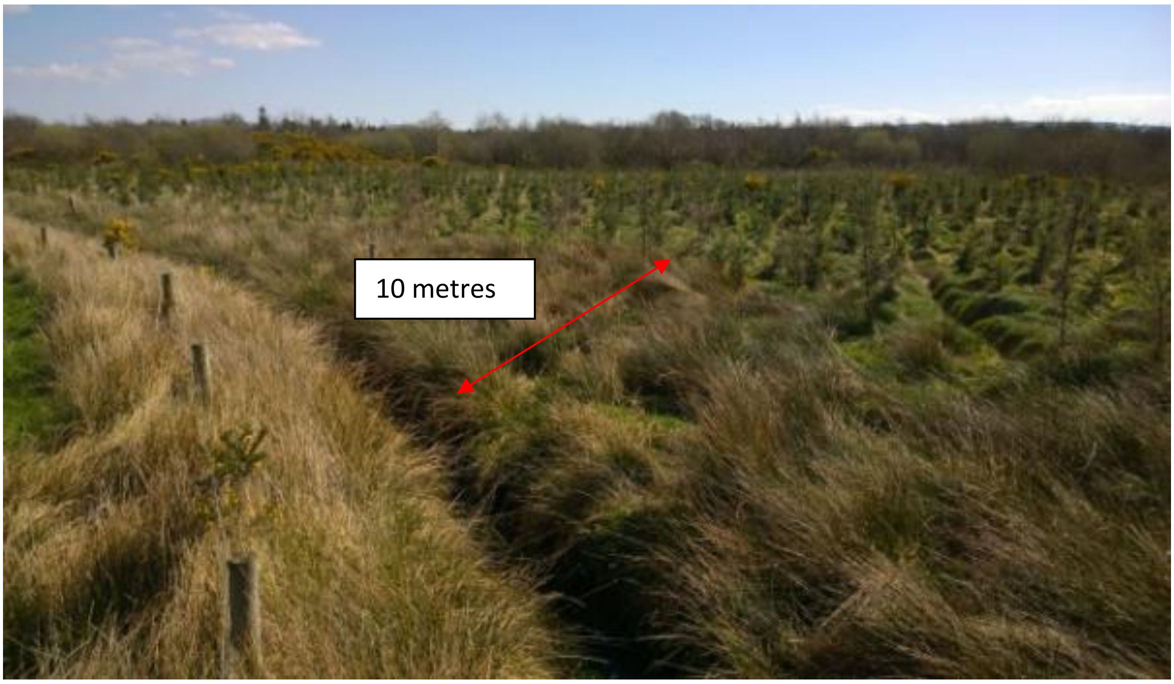

Figure 7-2: Example of a correct water setback. Note its unplanted and undisturbed nature (Photo: Forest Service, DAFM).

Figure 7-3: A functioning silt trap in a 'greened up' forest drain on a 4 year old afforestation site (Photo: Forest Service, DAFM).

Figure 7-4: A forest drain opened directly into watercourse creating a pathway for sediment. This is poor practice and is not permitted (Photo: Forest Service, DAFM).

Figure 7-5: Fine silt on a stream bed arising from an open forest drain within an older pre-Forestry Water Quality Guidelines plantation (Photo: Forest Service, DAFM).

7.3.2 Forest Roads (New/existing)

Roading involves the construction and maintenance of forest roads, tracks and ancillary structures such as landings, turntables, bridges and culverts. The creation of a forest road provides opportunities to forest owners to improve access to forests in order to facilitate forest management and the harvesting and extraction of timber. Forest roads also provide additional biodiversity opportunities by increasing the amount of open space and forest edges, but also by facilitating thinning, which can open up the canopy, as increased light levels contribute to the development and enhancement of ground vegetation.

The construction of forest roads requires consent under S.I. 191 of 2017. Relevant safeguards are set out in the Standards for Felling and Reforestation, the COFORD Forest Road Manual and the Environmental Requirements for Afforestation. However, inappropriate forest roads constructed without adherence to the legislation, Guidelines or due consideration of aquatic zones, can potentially become a pressure, both during construction and throughout their existence, primarily through the creation of silt from run-off.

Road construction should give due consideration to any aquatic zones in the vicinity. There should be correct engineering solutions in place where required, including the appropriate contour alignment of the road and roadside drains, adequately proportioned culverts and bridges capable of facilitating storm events, correct roadside drains, silt traps or silt fences. There should be no material taken from a stream bed or banks, and no excavations within the vicinity of aquatic zones.

Roadside drains are required at the edge of road formations. In general, the angle between the toe of the cutting and the edge of the cambered road formation will be adequate to control the runoff from the road formation area itself. There may also be sub-soil drains 2m from the edge of the roadway and interceptor drains 3m from the edge of the excavation. No silt should be entering aquatic zones as a result of these drains, and silt traps and/or silt fences should be in place along the length of the roadside drains, as required.

Forest roads should only be used by road vehicles including cars, 4x4s and timber lorries. Poor road construction, management or planning, or excessive tracking on the road from forest machines, can lead to furrowing on the road and the mobilisation of silt.

During the planning and construction stages, crossing of aquatic zones should be avoided or minimised. Correct bridges and culverts must be constructed where the crossing of aquatic zones is unavoidable. In general, the maximum gradient of a forest road should not exceed 1 in 10 (10%) on straight sections, or 1 in 12 (8.3%) on curved sections.

7.3.3 Harvesting: Tree felling and extraction (thinning/clearfell/forwarding) and reforestation

Tree felling is a licensed activity under the Forestry Act, 2014. On a typical forest harvesting site, tree felling and extraction is undertaken using specialised low bearing pressure machinery, in the form of a harvester and a forwarder. Other methods such as motor manual (chainsaw operators) may be used and cabling is used occasionally, on steep sites. If felling and extraction of trees is undertaken poorly or not in compliance with licence requirements, it has the potential to negatively impact on aquatic zones through the generation of silt, the deposition into water of plant debris, damage to soils, or the potential for pollutants such as oil or fuel to enter aquatic zones. The breakdown of brash after the operation may also lead to nutrient pulses on certain site types, in particular on peat soils. Conditions in relation to water are stipulated in felling licenses issued.

Figure 7-6: An appropriate forest road formation on a steep cross slope (Photo: Forest Service, DAFM).

Figure 7-7: A concrete beam forest bridge with adequate clearance for storm events (Photo: Forest Service, DAFM).

Figure 7-8: A culvert pipe installed under a forest road to facilitate passage of a stream (Image: Forest Service, DAFM)

Figure 7-9: Evidence of a flooding event reaching a forest road (Photo: Forest Service, DAFM).

Figure 7-10: Forest road culvert to facilitate the crossing of a small stream, with an inappropriate step preventing fish movement upstream (Photo: Forest Service, DAFM).

Figure 7-11: Cable extraction Wicklow. (Photo: Forest Service, DAFM)

Figure 7-12: Brash windrowed post harvesting. (Photo: Forest Service, DAFM IFORIS System / OSI)

7.3.3.1 What to look for – Thinning, Clearfell and Reforestation

- There should be no sediment run-off into aquatic zones. Sediment may be released through the lack of, or non-functioning of, silt traps.
- Machinery should not be operating within water setbacks as this may also generate silt through rutting.
- Felling and extraction operations should cease during periods of poor weather conditions in areas where the operations could potentially pose a threat to aquatic zones.
- Machinery should not drive/transit directly through aquatic zones. There should be temporary log bridges constructed where crossings are necessary. These bridges are typically constructed using logs and geotextiles with brash (to catch soil falling off vehicles), and span bank-to-bank. Crossings should be kept to a minimum and the bridges should be removed following completion of operations.
- Brash mats should be used along all harvesting and extraction routes throughout the forest, to protect soil and to minimise rutting, which can otherwise lead to silt and sediment run-off. Difficulties can arise in late thinnings, when brash material is limited.
- The location of machine maintenance, refuelling and repair areas as well as storage areas for fuel, motor oils, lubricants and chemicals, must be on dry areas at least 50 metres from the nearest watercourse.
- There must be no disturbance at existing water setbacks or damage to existing drains. There must be no silt build up and an appropriate number of appropriate silt traps should be installed, monitored and maintained.
- Logs should not be stacked within water setbacks, and they should be presented in a manner that avoids the entry of machinery into these setbacks.
- Debris such as brash and branches, generated from felling and extraction operations, must not be permitted to enter aquatic zones, and must be removed promptly, if this occurs.
- Individual or small groups of main crop trees should not be left standing adjoining aquatic zones, where they have become exposed and liable to windblow as a result of the surrounding trees being felled, and should be removed as soon as possible. Any native trees left unstable following felling of the surrounding trees should be pollarded 3-4 m above ground level, to prevent windthrow and yet retain a valuable seed source.
- For reforestation post harvesting, brash material is often windrowed (i.e. gathered into lines to allow space for replanting and to create a safer work area for replanting teams). This can lead to ground disturbance and concentrated areas of decaying wood, which can lead to phosphorus loss on peat soils. Therefore windrowing should be done in a manner sensitive to nearby waterbodies on all soils types.
- Replanting also often requires some ground preparation, such as mounding, and so conditions relating to the replanting operations are also contained in licences issued.
- On reforestation sites there is usually sufficient deadwood material on the site and therefore there is often no requirement for additional fertiliser.
- Occasionally, insecticide may be needed in relation to the re-planting of clearfelled sites, to tackle pine weevil. Ordinarily, in order to tackle pine weevil, plants are generally dipped offsite in the forest nursery before being dispatched to planting locations. Any onsite application of insecticide must adhere to safeguards regarding water setbacks and chemical usage generally, as set out in the Forest Protection Guidelines. It is important to note that reforestation after clearfell is the only stage in the forest cycle where insecticide may be required.

Figure 7-13: A clearfell site considerate of the adjoining watercourse. Fencing demarcates group planting of native trees (Photo: Forest Service, DAFM).

Figure 7-14: Brash mat on an extraction rack, created and used for driving on by forwarding machinery in order to minimise damage to soil and to reduce rutting (Photo: Forest Service, DAFM).

Figure 7-15: Re-structured forest with setbacks applied following clearfell, 3 years post-harvesting (Photo: Forest Service, DAFM).

Figure 7:16: Example of a log bridge used for timber forwarding on a harvesting site (Photo: Forest Service, DAFM).

Figure 7-17: An insensitive felling operation undertaken in proximity to a stream, illustrating poor practice. However, reforestation presents an opportunity to permanently restructure this forest with functioning, biodiverse water setbacks. (Photo: Forest Service, DAFM).

Figure 7-18: An example of a water setback inappropriately used for machinery access (Photo: Forest Service, DAFM).

7.3.4 Forests where there is no recent intervention evident

Many existing forests were planted prior to the 1990s and the introduction of the Forestry and Water Quality Guidelines. Felling licences present an opportunity to restructure these forests, by installing appropriate protective measures, including water setbacks and native woodland buffers at reforestation. However, where planting up to the banks of streams, rivers and lakes occurred in the past, and where the trees remain, there is the potential for pressure on those aquatic zones during the current rotation, before this opportunity arises.

7.3.4.1 What to look for – No Recent Interventions:

- Windblown trees and plants across the watercourse, which can cause damage to banks and release silt or debris into the water.
- Prior to the introduction of Guidelines, drains may have been created entering directly into aquatic zones, and these may still be delivering silt into the aquatic zone
- Needle drop into aquatic zones.
- Root plate pumping, where fine silt is pushed to the ground level as the root plate of trees rock back and forth in strong or high winds.
- There may be shading of the aquatic ecosystem, either by conifer trees planted too close, or by tunnelling created by native species such as alder. If present along long stretches, this could impact negatively on aquatic life.

Figure 7-19: Windblow across a watercourse from trees planted up to the streams banks. Felling licences can provide an opportunity to remove trees planted to banks in a controlled manner, and for the appropriate setbacks to be created. (Photo: Forest Service, DAFM).

Figure 7-20: Semi-mature conifer plantation overhanging a stream, creating the potential for needle drop, excessive shading and future instability. Current practice does not permit planting in this manner. (Photo: Forest Service, DAFM).

Figure 7-21: Historic planting to a stream bank, with undercutting evident (Photo: Forest Service, DAFM).

7.3.5 Fly Tipping

Fly tipping at forest locations is an ongoing and nationwide issue. There is real potential for fly tipping at forest locations to become a pressure on aquatic zones through the dumping of oil containers, construction debris and waste, etc. The use of forests as a dumping ground for biohazard waste (e.g. carcasses) can also occur.

Figure 7-22: Fly tipping at a forest in close proximity to a stream (Photo: Forest Service, DAFM).

Figure 7-23: Fly tipping into a stream within a forest (Photo: Forest Service, DAFM).

Figure 7-24: Animal carcass within a young forestry plantation (Photo: Forest Service, DAFM).

7.3.6 Pressure from Public Access

There are approx. 43 way-marked-ways in Ireland, many of which cross through forest land. The busier ones, for example in the Dublin and Wicklow mountains, can experience high pressure and this can lead to soil erosion and exposure of bare rock, which in turn can cause soil and sediment run-off to aquatic zones through over land flow. In many upland and forested areas, there are also unofficial and unmarked walking trails which can also experience heavy use. In these cases, as the trails have not been planned per se, but have developed over time, there is often little control over the route, or the potential impact to aquatic zones.

There are a number of forest parks with car park facilities and a high degree of vehicular traffic which could potentially be a source of pollutants such as hydrocarbons.

Forests are also sometimes used by recreational motorised vehicles such as quads and scrambler motorbikes, (rally cars have even been known to be tested on forest roads). The use of these is prohibited in Coillte forests as they can be very damaging to soil and roads, and are a potential source of sediment in watercourses; however, it is very difficult to police.

Figure 7-25: Rut created from unauthorised use of scrambler motorbikes, leading down to a river. (Photo: Forest Service, DAFM).

7.3.7 Aerial Fertilisation

Aerial fertilisation is undertaken occasionally in Irish forestry. Where undertaken, it is invariably on historical sites with areas of low increment. These types of areas are not planted anymore as they would not meet the requirements of the "Land Types for Afforestation". Aerial fertilisation is a licensed activity under the Forestry Act, 2014, and the Forestry Regulations 2017 (S.I. No. 191 of 2017) as the process is a potential source of nutrients entering aquatic zones, and is undertaken in accordance with the Environmental Requirements for Afforestation and the Aerial Fertilisation Requirements. In accordance with these requirements, water grab samples are taken before and after application and a GPS map of the flight paths submitted. Sample buckets are also positioned within any aquatic exclusion zones onsite, in order to verify the accuracy of the aerial drop and the flightpath data. Sample buckets must be in place before the application commences, positioned in pairs 25 metres and 50 metres back from the water's edge at 100 metre intervals along the aquatic zone. This paired arrangement allows for an assessment of any fertiliser drift that might occur, (see the Aerial Fertilisation Requirements for details). Specific water setbacks for aerial fertilisation are required, as set out below:

Table 7-2: Aerial fertilisation water setbacks

Feature	Minimum exclusion zone
Abstraction point of a source of water intended for human consumption	100 metres
Aquatic zone (defined as a permanent or seasonal river, stream or lake shown on an Ordnance Survey 1:5,000 scale map)	50 metres
Special Area of Conservation (SAC), Special Protection Area (SPA), Natural Heritage Area (NHA)	30 metres (unless with the written permission Of the Minister of Housing, Local Government and Heritage)
Non-forested land	30 metres (unless with the written permission of the owner or occupier).

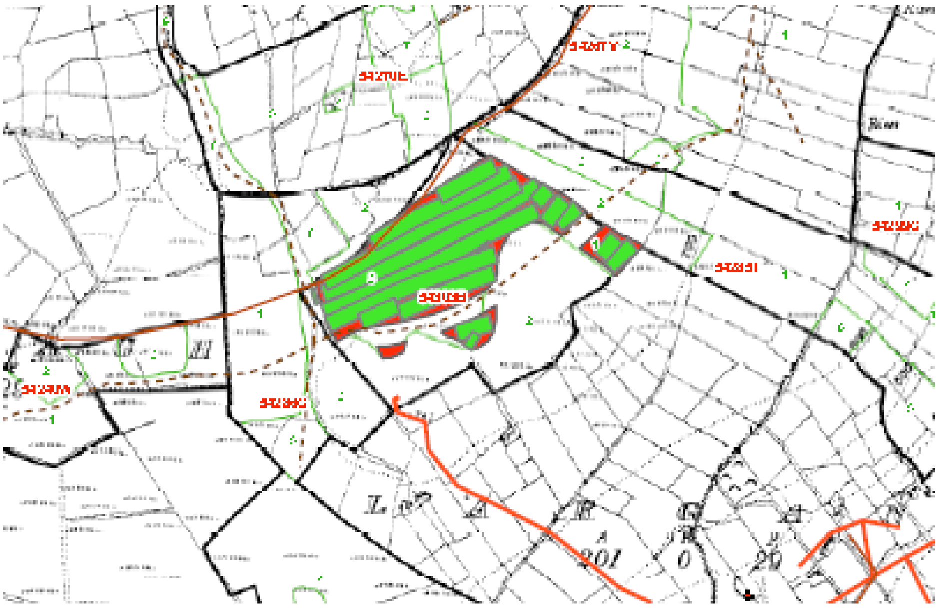

Figure 7-26: An example of the flight path map for an application of urea, to accompany the Aerial Fertilisation Completion Form. (Sample map not-to-scale.) (Image: Forest Service, DAFM/Coillte).

7.3.8 Acid Sensitivity

Applications for afforestation approval (with or without grant aid) on sites located within certain 6 inch Ordnance Survey sheets designated as acid sensitive areas require a site-specific assessment of the acid sensitivity of watercourses. This sensitivity of the water to acidic inputs is determined by alkalinity, as measured using the Gran Titration Method.

Sampling and analysis are carried out on at least four separate occasions within the period 1st February to the 31st May inclusive, with each sample taken at least 28 days apart. Sampling must follow a set procedure, and analysis must be undertaken by an accredited laboratory independent of the applicant. Samples must be taken from all watercourses shown on the 6 inch OS map(s) as being within or adjoining the proposed afforestation site. If there are no watercourses within or adjoining the proposed site, samples must be taken from watercourses elsewhere on the applicant's property. (Water sampling is not required for afforestation applications within acid sensitive areas that comprise solely of Native Woodland Establishment).

The results of the analyses of all samples carried out in the context of this protocol are available to the applicant, the Forest Service of the Department of Agriculture, Food & the Marine, Inland Fisheries Ireland, the relevant Local Authority, and to the Environmental Protection Agency. Persons taking water samples must notify the relevant Forestry Inspector at least two full working days prior to sampling, stating the proposed location and the proposed date and time of sampling and the Forest Service may take additional samples to compare with alkalinity results submitted. Water samples submitted without prior notification are not accepted.

Please refer to Appendix 11 of the Forestry Standards Manual for further detail (link in Section 7.5).

7.3.8.1 Six-inch Ordnance Survey sheets designated as being Acid Sensitive Areas

All map ranges listed are inclusive, and their extents are shown in Figure 7-25.

Clare OS sheets Southern half of 31 Southern half of 32 39 to 41 Northern half of 48 Northern half of 49	Donegal OS sheets 34 to 36 41 to 44 49 to 51 57 to 60 67 to 69 77
Galway OS sheets 9 to 13 21 to 27 34 to 40 48 to 55 62 to 68 75 to 81 89 to 93	Kerry OS sheets 56 62 to 64 69 to 72 78 to 83 87 to 92 96 to 100 105 to 107
Offaly OS sheets Southern half of 16 23 to 24	Sligo OS sheets 24 to 25
Wicklow OS sheets 7 to 8 11 to 13 17 to 19 23 to 25 29 to 31 33 to 36 39 and 40	

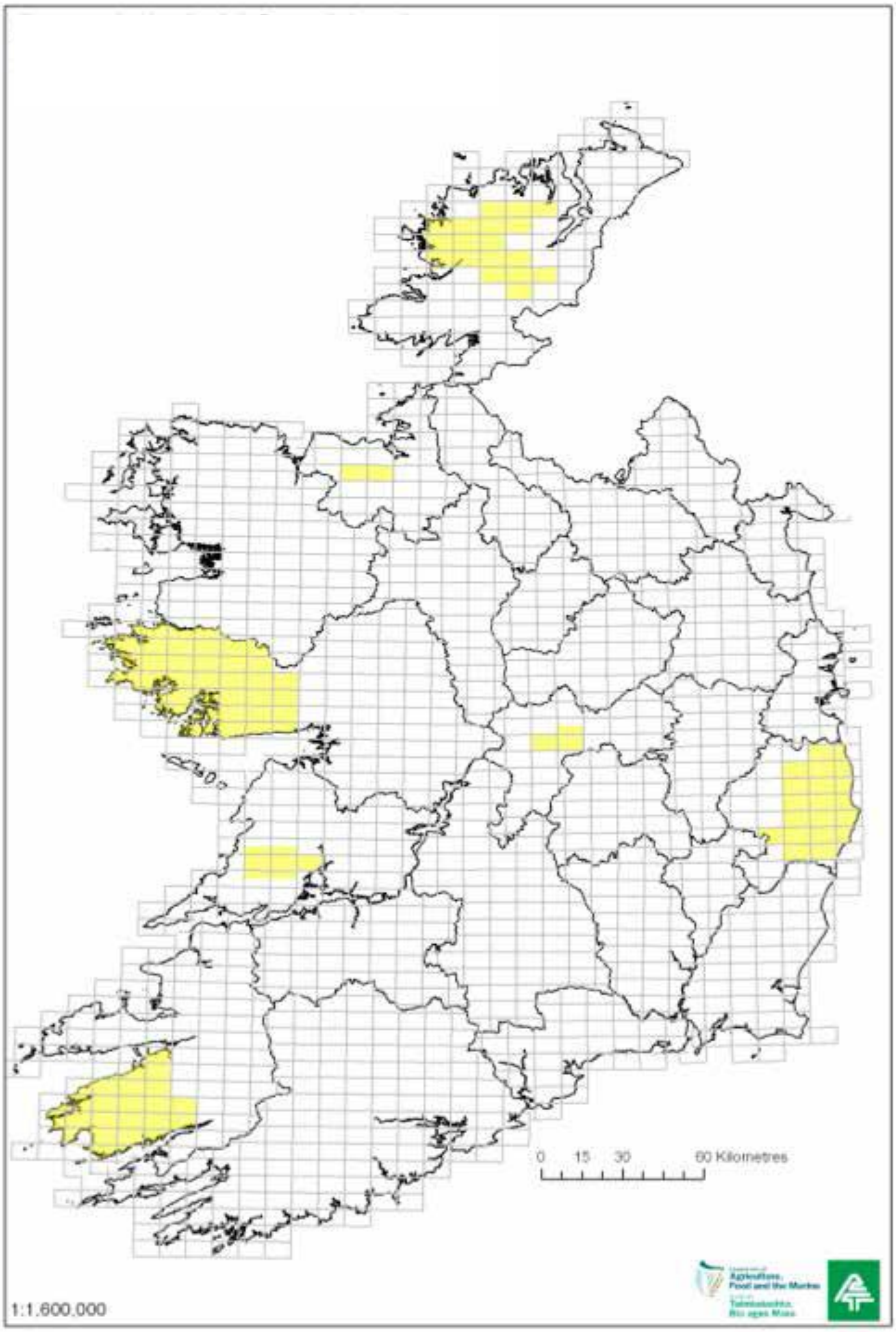

Figure 7-27: Six inch Ordnance Survey sheets designated as acid sensitive areas (Image: Forest Service, DAFM).

7.3.9 Forests Planted at Licensed Facilities

In accordance with many grants of planning permission, quarry operations and at some facilities operating under licenses such as IPC and Waste, there may be forests planted for landscape screening or noise abatement, etc. There may be a potential for these forests to become locations for dumping of overburden, soil and inert material, which may become a source of silt and sediment. There is also the potential for other issues to go undetected such as unauthorised discharge points. Although these issues arise, they are rare.

Figure 7-28: Unauthorised discharge point within a grant aided forest beside an IPC licensed facility (Photo: Thomas Sexton, EPA).

Figure7-29: Flooding and poor tree growth within a grant aided forest as the result of an unauthorised/unlicensed discharge (Photo: Forest Service, DAFM).

Figure 7-30: Grant aided broadleaf plantation at a licensed landfill facility (Photo: Forest Service, DAFM).

7.4 Possible Mitigation Options

With reference to the main types of Forestry pressures described above, potentially applicable mitigation options are summarised in Table 7.3 below.

7.5 Useful References

All relevant forestry legislation and publications listed below are available here:
[gov.ie - Forestry (www.gov.ie)](www.gov.ie)

Forestry and the Law

Environmental Requirements for Afforestation.

Land Types for Afforestation.

Forestry Standards Manual.

Felling and Reforestation Policy.

Woodlands for Water: Creating new native woodlands to protect and enhance Ireland's water.

Forests and Water: Achieving the Objectives under Ireland's River Basin Management Plan 2018-2021.

Standards for Felling and Reforestation

Forestry and Water Quality Guidelines
Forest Protection Guidelines
Forest Biodiversity Guidelines

Forestry and Otter Guidelines.

Code of Best Forest Practice.

Coford Forest Roads Manual

Aerial Fertilisation Requirements.

Relevant Forestry Schemes, 2015 -2020 Programme (extended to end of 2022):

- Afforestation Scheme
- Native Woodland Establishment Scheme (incorporated into the Afforestation Scheme as GPCs 9 and 10)
- Native Woodland Conservation Scheme
- Forest Roads Scheme
- Woodland Improvement Scheme
- NeighbourWood Scheme
- Innovative Forest Technology Scheme – Central Tyre Inflation

Table 7-3: Forestry Pressures – Possible Mitigation Options

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control	Afforestation	Fertilizer and pesticide management. Alternative ground preparation methods such as ripping or scrap mounding, (can be targeted to specific areas). Increased aquatic buffer zone widths. Planting of native or riparian woodland buffers. Installation of silt fences if required.	Environmental Requirements for Afforestation. Forestry Standards Manual Forestry Act, 2014 S.I. 191 of 2017 Code of Best Forest Practice Forest Protection Guidelines
	Fly-tipping	Signage CCTV Entrance Barriers Engaging neighbours, (e.g. as a caretaker)	
	Aerial fertilization	Manual or no application where AF is identified as a pressure. Do not replant post harvesting (Permanent Forest Removal) Increase aquatic buffer widths	Aerial Fertilisation Requirements Felling and Reforestation Policy Land Types for Afforestation Forestry Act, 2014 S.I. 191 of 2017 Forestry and Water Quality Guidelines
	Tree felling/harvesting	Alternative, more sensitive extraction methods, (e.g. cabling on appropriate sites). Seeding of buffer zones with grasses or riparian tree species Installation of silt traps and/or silt fences. Where nutrient enrichment is identified as a result of deadwood breaking down on peat – rapid replanting to facilitate uptake of nutrients, and/or seed dispersal. Employ alternative silvicultural systems such as continuous cover forestry, where appropriate.	Felling and Reforestation Policy Forestry Act, 2014 S.I. 191 of 2017 Forestry Harvesting and the Environment Guidelines. Forestry and Water Quality Guidelines. Code of Best Forest Practice

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
	Trees planted to banks	Removal of trees through the felling licence process, and installation of aquatic buffer zones when replanting. Structured felling and replanting with native, riparian species for long term retention to maintain bank stability and prevent erosion. Create/increase buffers with long term retention broadleaf plots between commercially managed conifers. Alternative ground preparation on replanting, such as scrap mounding or flat planting.	Felling and Reforestation Policy
Pathway Interception	Afforestation (planting)	Setback buffers Silt traps Planting of native or riparian woodland buffers.	The Forest Service Environmental Requirements for Afforestation Forestry Standards Manual Woodlands for Water
	Access/road construction	Installing appropriate culverts and bridges, and maintenance of same. Appropriate aquatic setbacks adhered to. Functioning roadside drains and silt fences/traps. Forestry machinery prohibited from using forest roads. Maintaining and repairing road surface to prevent ponding or rutting developing. Use of CTI technology on haulage vehicles	Coford Forest Roads Manual Forestry Act, 2014 S.I. 191 of 2017 Innovative Forest Technology Scheme – Central Tyre Inflation
	Land drains/ relevant watercourses	Installation or repair of silt traps Installation of silt fences Block drains Create setback buffers if none are present	Environmental Requirements for Afforestation
	Channels created through rutting on clearfell site	Level rutting Re-seed Block channel pathway Installation of silt traps/ silt fences	Standards for Felling and Reforestation Code of Best Forest Practice
Receptor Rehabilitation	Land drains/ relevant watercourses may also be a receptor as well as a pathway	Installation or repair of silt traps Installation of silt fences Block drains	

8 Catchment Walks – Peatland Activities

8.1 Purpose

This section provides a guide of indicators and visual clues of pressures arising in peatland areas, supported by photo-documentation. The principal peatland pressures are related to peatland drainage, peat extraction and overgrazing.

These activities can result in degradation of the physical habitats of streams, elevated levels of fine sediment and nutrient concentrations, primarily ammonia but also phosphate, which can impact on the ecology of rivers and lakes, as well as groundwater quality. In acid-sensitive regions, organic acids have a role in episodic acidification and dissolved organic carbon (DOC) is important in ameliorating the detrimental effects of metal toxicity. Additionally, while water draining from intact bogs (unaffected by human activity) has varying degrees of natural colour (giving a slight reddish-brown colour), peatland activities substantially increase the colour and dissolved organic carbon (DOC) content, thereby increasing the treatment costs where the water is sourced for drinking water purposes. Peat drainage also results in lowering of water levels within peat bogs, and the drying up of peat areas results in loss of the environmental supporting conditions for peat, and loss of habitat.

These pressures and associated issues are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes.

8.2 Significance

According to the Draft River Basin Management Plan 2022-2027[22], the peat category is estimated to be a significant pressure in 103 river and 2 lake water bodies nationally, and is ranked the 9th most significant pressure within both river and lake water bodies (see Table 2-1 and Figure 2-3).

Peatlands cover 17.2% of the land surface of the Republic of Ireland (Hammond, 1981). Peat is an unusual geological material in that it not only requires waterlogged, reducing conditions to form, but is comprised of at least 88% water by volume. Water is, therefore, part of the structure of the peat, and in intact bogs, the water table will be at or within a few centimetres of the ground surface. Lowering of the water table by drainage facilitates oxidising conditions and mineralisation whereby breakdown of the organic matter releases ammonia, phosphate, dissolved organic carbon (DOC), organic acids, colour and occasionally ochreous deposits of iron and manganese. In addition, peaty soils are poor at retaining phosphate (and certain pesticides), and where phosphate is applied for agricultural production and afforestation, loss of phosphate to surface water readily occurs. Another breakdown product resulting from drainage is carbon dioxide, which therefore contributes to Ireland's greenhouse gas emissions.

Peatland in the intact state will not act as a significant pressure on water quality. However, once drained for whatever purpose, there is the potential for detrimental impacts. There are four scenarios for which peatlands are drained and impacts may arise:

1. Industrial scale mechanised peat extraction (Figure 8-1 and 8-2);
2. Local scale peat cutting for domestic use (Figure 8-3);
3. Forests on peat soils (see Section 7); and
4. Peaty soils used for agricultural production, mainly pasture (Figure 8-4) and occasionally vegetable growing.

While scenarios 1, 2 and 3 are evident during catchment walks, scenario 4 may not be immediately evident. Therefore, prior to undertaking the catchment walk, where peatland is considered to be the

22 https://www.gov.ie/en/consultation/2bda0-public-consultation-on-the-draft-river-basin-management-plan-for-ireland-2022-2027/

significant pressure, it is advisable to check the soils or subsoils map for the presence of peat as part of the desk study and to have this map available during the catchment walk. *[Note: drainage of peat for agriculture will mean that the peat, as an organic deposit, will subside, usually preferentially, and waste away completely over a period of decades. The degree of wastage (and therefore loss of ammonia) will depend on the degree of aeration/oxidation and consequently on the water level in the peat.]*

Figure 8-1: Mechanised peat extraction, with rows of milled peat and regularly spaced drains lowering the water table in the peat (Photo: Donal Daly).

Figure 8-2: Area of milled peat with row of milled peat on right awaiting transfer to a power station, drain on left and pasture on cutover bog in the background, with a stream running along the boundary (Photo: Donal Daly).

Figure 8-3: Peat cut for local use – a typical situation around many raised and blanket bogs (Photo: Donal Daly).

Figure 8-4: Pasture on peaty soil, with peat thickness decreasing along the channel where grey subsoil (glacial till) is exposed. In this circumstance, relatively high ammonia concentrations are likely in the stream (Photo: Donal Daly).

In the case of a mechanised peat extraction area, this may be regulated by an EPA Licence. This licence should be checked as part of the desk study and relevant information from the licence recorded, particularly the conditions set in the licence. For instance, there are specific details concerning the density of silt pond network required, cleaning intervals for ponds, bunds, setback distances/buffer zones, etc., that may be relevant to the Local Catchment Assessment and in particular, the stream walk.

The main potential significant issues arising from peatland drainage and extraction that may need to be checked during a catchment walk are as follows:

- Release of fine-grained sediments to the aquatic environment;
- Release of pollutants to the aquatic environment, mainly ammonia but occasionally phosphate. Where there is a downstream drinking water source, colour may be an issue;
- Physical alteration of habitats.

While all three might be relevant for consideration during a catchment walk, it is recommended that, during the desk study, the significant issue that has been recorded during the characterisation process should be checked as this will help focus on the relevant attributes that need to be examined.
Peatland drainage and extraction can also impact on lakes, although assessment of this impact will not generally be feasible during catchment walks. For instance, there is potential for de-oxygenation in lakes from bacterial breakdown of organic matter, and increased colour and turbidity in slow flowing deeper river channels and can impact on depth of colonisation of macrophyte communities in lakes

8.2.1 Peat silt

Peat silt arising from human activities can mask and build up on stream bottoms (Figure 8-5) and can clog interstitial gravels in streams, thereby impacting on fish spawning and on invertebrates. The deposited ova of salmonid fish are particularly vulnerable during the sensitive incubation period, when mortality has been shown to be high. In armoured channels, the stream bed will look to be visually unaffected, but when the bed is disturbed, large plumes of peat silt will emanate from the gravel interstices. The most likely situations for generation of peat silt are:

- Mechanised peat extraction where the processes of milling, drying and harrowing, and peat harvesting creates loose peat particles which can be washed and blown into streams.
- Installation of drainage channels in peat.
- Erosion following heavy rainfall as peat is a soft geological material which is prone to erosion.
- Poaching by cattle and sheep on peaty soils close to streams.
- Overgrazing by sheep in blanket bog areas.
- Poorly maintained wind farm developments in areas of blanket peat.

8.2.2 Nutrients

The main problematical nutrient is ammonia, although on occasions phosphate may be the significant issue, particularly in the case of high status waterbodies. Water quality *indicator parameters* of Peatland pressures are, therefore, nutrients (specifically ammonia and phosphorus) as well as turbidity (sediment) and colour. Details on indicator parameters are described in **Volume 4**.

8.2.3 Alteration to Physical Habitat

Extraction of peat, particularly industrial scale extraction, can impact on the physical habitat (hydromorphology) of streams (see further details in Section 3.3.1.).

8.3 Walking the Catchment – Areas of Bogs and Fens

8.3.1 What to look for

- Presence of peat:
    - Relatively intact.

    - Local cutover.
    - Large scale mechanised peat extraction.
- Presence of silt ponds (*Figure 8-7* and *Figure 8-8*) and an evaluation of how they are functioning.
- An assessment of the degree that the water table in the peat is drawn down by drainage and the area affected (on the basis that the greater the potential for oxidation of the peat and the greater the area, the greater the likelihood of the presence of ammonia and perhaps phosphate in nearby surface waters). This should include areas that have rewetted, if present, as pollutant losses are likely to be reduced in these areas.
- Drains and a (rough) assessment of drain flows entering the stream from the peatland areas relative to stream flows.
- Evidence of erosion of peat of in the banks of the stream and incoming drains, and gully erosion in blanket bog areas.
- Evidence of recent installation of drains shown by 'fresh' peat, as this may have caused recent silting problems.
- Evidence of burning, which can increase sediment and DOC runoff.
- Evidence of peat silt in the stream and particularly within gravel interstices when disturbed.
- Low pH and low specific electrical conductivity (SEC) indicating a high proportion of peaty water. However, care should be taken in interpreting these data as the subsoil underlying the peat may have an influence and fen peat has a higher pH than sphagnum peat.
- Elevated turbidity.
- Elevated colour.
- Presence of wind farms. Where there is evidence of impacts, for instance from sediment, from these areas, it might be advisable to check for compliance with the planning conditions.
- For licenced peat extraction, check that the relevant conditions are being complied with (but keep in mind that this is not an inspection of the conditions. It is a check on issues that might be relevant to the peatland activities as a significant pressure).

Figure 8-5: Peat silt deposited in stream (Photo copied from Kennedy et al., 2012).

Figure 8-6: Cutover bog on left side; grassland with cattle poaching on right side. Note peat erosion of right bank in foreground (Photo: Donal Daly).

Figure 8-7: Silt (settlement) pond at Bellacorrick Bog, Co. Mayo (Copied from Kennedy et al., 2012).

Figure 8-8: A silt pond west at Bellacorick Bog in the process of being emptied in 2002 (Photo copied from Kennedy et al., 2012).

8.4 Walking the Catchment – Areas of Peaty Soils

8.4.1 What to look for

- Presence of peaty soils and peat thickness in stream bank and drain exposures.
- An assessment of the area of peaty soils and therefore of drained peat – this will generally be the flat area adjoining the stream, which should be confirmed by soils and subsoils maps of the area. The greater the area, the greater the likelihood of the presence of ammonia and perhaps phosphate in nearby surface waters.
- Drains and, if feasible, a (rough) assessment of drain flows entering the stream from the peaty soils area relative to stream flows.
- Presence of land drains as these would aid oxidation and act as a pathway for ammonia to the stream.
- Evidence of erosion of peat in the banks of the stream and incoming drains.
- Evidence of recent installation of drains shown by 'fresh' peat, as this may have caused recent problems.
- Evidence of peat silt in the stream.
- Low pH and low SEC indicating a high proportion of peaty water. However, care should be taken in interpreting these data as the subsoil underlying the peat may have an influence and fen peat has a higher pH than sphagnum peat.
- Presence of bare peaty soils in an adjacent field, either due to poaching or impact of farm machinery, which could result in peat silt runoff.
- Presence of bare peaty soils.

- Presence of hedges and woodlands alongside the stream that might act as a buffer.
- Animal access points and fencing to prevent animal access.
- If the pasture area appears to be used intensively for grassland production, loss of phosphate to surface water might be an issue.

8.5 Mitigation Options

The potentially applicable mitigation options are summarised in Table 8-1 below.

8.6 Useful References

Hammond, R.F. 1981. The peatlands of Ireland. An Foras Talúntais (now Teagasc). 60pp. (Available online).

Kennedy, B., McLoughlin, D., and Caffrey, J 2012. A physical, chemical and biological assessment of fluvial habitat draining the Oweninny Peatlands, North Mayo with reference to peat siltation. Inland Fisheries Ireland.

Jillian Labadz, Tim Allott, Martin Evans, David Butcher, Mike Billett, Simon Stainer, Adrian Yallop, Peter Jones, Mike Innerdale, Neasa Harmon, Kieron Maher, Richard Bradbury, David Mount, Helen O‟Brien and Roger Hart. Peatland Hydrology Draft Scientific Review October 2010 Review_6_Peatland Hydrology_0.pdf (iucn-uk-peatlandprogramme.org)

NPWS, 2014. National peatland strategy. National Parks and Wildlife Service. https://www.npws.ie/sites/default/files/general/Final%20National%20Peatlands%20Strategy.pdf

Shannon River Basin District, 2007. Draft peatlands report. Available from the Catchment Science and Management Unit.

Information on the rehabilitation of Bord na Mona bogs and the mitigation actions that they are undertaking can be accessed at the following links:
https://www.gov.ie/en/publication/136a7-bord-na-mona-bog-rehabilitation-scheme/
https://www.bnmpcas.ie/
https://www.bordnamona.ie/peatlands/peatlands-rehabilitation/

Table 8-1: Examples of mitigation options for peatland pressures.

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control (incl. mobilisation control)	Mechanised peat extraction	• For licenced activities, compliance with the measures in the licence. • Cessation of peat extraction followed by raising the water table in the peat to close to ground level by damming ditches, bunding, etc., resulting in rewetting of the peatland area which should mean a reduction in ammonia, phosphate, carbon dioxide and silt losses. • Care with machinery used in vicinity of streams and ditches to reduce silt generation, if feasible by having setback distances as a means of reducing the likelihood of silt runoff • Bunds in appropriate locations to prevent runoff of peaty water. • Cleaning out of settled silt in drainage channels before heavy rainfall washes the silt into a stream.	Check relevant licence
	Local peat cutting	• Cessation of peat extraction followed by raising the water table in the peat too close to ground level by damming ditches, bunding, etc., resulting in rewetting of the peatland area which should mean a reduction in ammonia, phosphate, carbon dioxide and silt losses. • Care with machinery used in vicinity of streams and ditches to reduce silt generation, if feasible by having setback distances as a means of reducing the likelihood of silt runoff • Bunds in appropriate locations or use of localised depressions or vegetated areas or buffers to prevent runoff of drains and peaty discharges directly to watercourses.	
	Agriculture on peaty soils	• Raising the water table as close as practicable to the ground surface to minimise the unsaturated zone in the soil. • During excavation of new drains or cleaning of drains, damming of the drains at suitable locations to enable peat silt settlement. • Compliance with the GAP Regulations regarding setback distances.	
Pathway Interception	Mechanised peat extraction	• Silt lagoons installed at the appropriate density and maintained frequently to enable effective peat silt settlement. • During excavation or cleaning of drains, damming of the drains at suitable locations to enable peat silt settlement.	Check relevant licence for details
	Local peat cutting	• During excavation or cleaning of drains, damming of the drains at suitable locations to enable peat silt settlement.	
	Agriculture on peaty soils	• Installation of silt traps in drains entering the stream. • Planting of suitable riparian woodland and willow buffers. • Blocking drains to a sufficient degree and at suitable intervals to enable peat silt settlement which can then be excavated at appropriate intervals.	
Receptor Rehabilitation	Mechanised peat extraction		
	Local peat cutting		
	Agriculture on peaty soils	• Planting with subsequent management of suitable plants, e.g. willow, to stabilise stream banks.	

8.7 Addendum

Two reports published in 2021 have added substantially to our understanding of peatlands, particularly on aspects such as:

- The role of peatland in influencing water quality, biodiversity and greenhouse gas emissions.
- The co-benefits of effective peatland management for water quality improvements, biodiversity enhancement and climate change mitigation.
- The relevance of cultural and social values of peatlands.
- The contrasting peatland water flow regimes in wet and dry weather. (Peatlands are often described as sponges that mitigate flooding. However, note the following conclusion given below '*Blanket bogs may act as sponges, buffering against flooding, but only during periods of high available storage, principally in summer. Conversely, little buffering will occur during periods of limited storage in peat, principally in winter.'*)

8.7.1 Optimising Water Quality Returns from Peatland Management while Delivering Co-Benefits for Climate and Biodiversity

An excellent report was produced for An Fóram Uisce/The Water Forum by a group of scientists led by Florence Renou-Wilson. The report provides guidance on how peatland management can be reimagined in order to optimise water quality improvements, while delivering co-benefits for climate change and biodiversity. This study was split into five key work packages: 1) Rewetting degraded peatlands; 2) carbon cycling in intact, degraded and rewetted peatlands; 3) Cultural ecosystem services and social values of peatlands; 4) Alternative management options for degraded peatlands; and 5) strategic guidance and resources for integrated peatland management.

Reference

Pschenyckyj, C., Riondato, E., Wilson, D., Flood, K., O'Driscoll, C. Renou-Wilson, F. 2021. Optimising Water Quality Returns from Peatland Management while Delivering Co-Benefits for Climate and Biodiversity. Report produced for An Fóram Uisce.
https://thewaterforum.ie/app/uploads/2021/04/Peatlands_Full_Report_Final_March2021b.pdf
https://thewaterforum.ie/app/uploads/2021/04/Peatlands_Synthesis-Report_Final_April2021.pdf

8.7.2 Blanket bogs

Over the last 30 years a good understanding of the hydrological/hydrogeological/hydrochemical supporting conditions for **raised bog** ecosystems has been developed. However, this is not the case for blanket bogs even though they cover ~11% of the Irish landscape, are an important ecosystem and landscape feature, and are in the catchment areas of many drinking water sources and a high proportion of the high status objective water bodies. The characterisation of peatlands is a vital precursor to i) understanding their hydrological, hydrogeological and hydrochemical attributes, ii) their role in influencing and determining catchment water flows and water quality, iii) determining their role in estimating carbon losses and sequestration, iv) enabling a quantification and valuation of the ecosystem services provided to be determined as part of natural capital accounting, v) understanding the impact of pressures such as afforestation and farming, and vi) their protection and management.

An EPA-funded project on blanket bogs in Ireland '**Towards the Quantification of Blanket Bog Ecosystem Services to Water'** was undertaken by QUB and UCD researchers between 2017 and 2021. One of the outcomes has been a greater understanding of water flows in blanket bogs area. This is illustrated in a new conceptual model for these areas, as illustrated in the diagram below, which is copied from EPA Report No. 378.

The Conclusions in the End of Project Report are given in italicised text below.

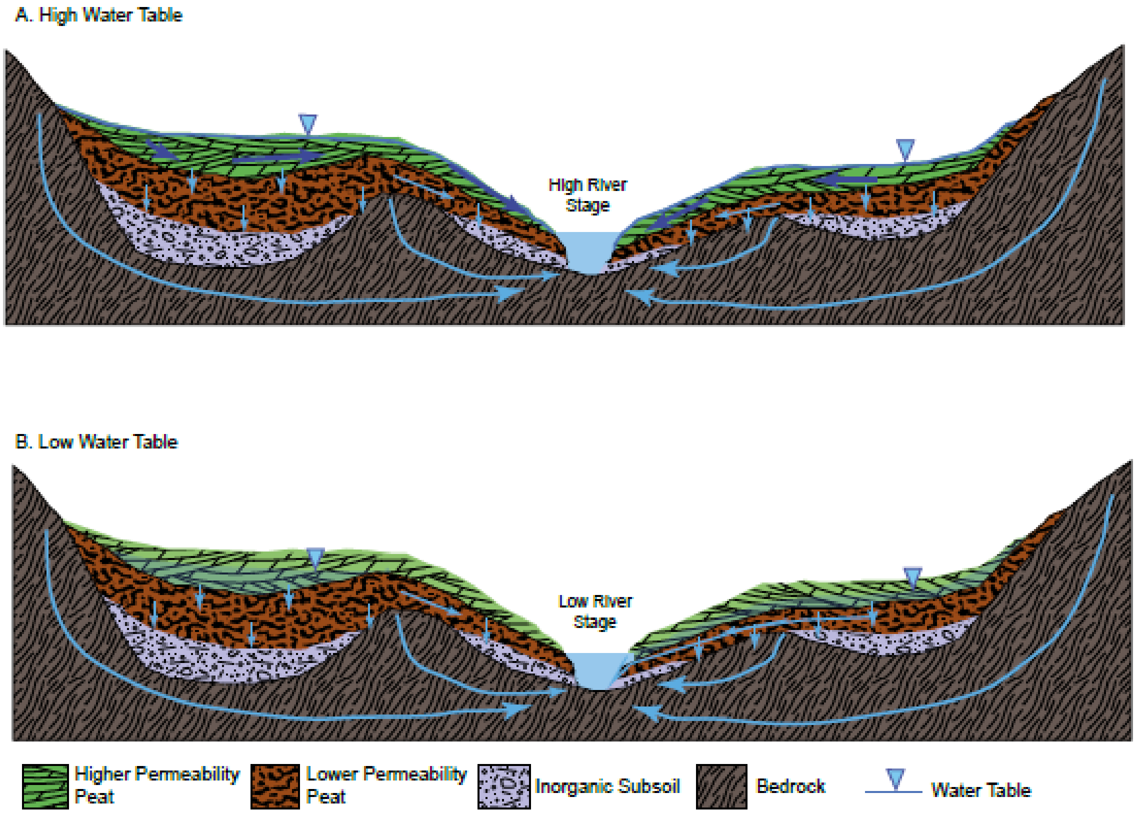

Figure 6.2. Schematic conceptual model of contributions of peat and substrate groundwater to stream flow in blanket peat-covered catchments. (A) Rainfall during period of high water table and limited available storage passes rapidly to streams as runoff; (B) low water tables isolate intervals of more permeable peat, requiring storage deficits to be met before interconnection and discharge as runoff.

Conclusions

The results of the QUBBES investigations at the three test sites have considerably improved current understanding of hydrological process operating on Irish Blanket Bogs. At the outset of the research programme, this investigation aimed to examine the processes operating on blanket bogs unimpacted by direct human interventions, most notably those involving installation of artificial drainage. (Aerial) Image surveying, multiple criterion analysis, and site visits indicated that across the Island of Ireland there no longer remains any blanket bog catchments with areas greater than 1km^2 that have not been affected by physical human interventions. As a result, subsequent field investigations have focused on three catchments displaying the least levels of disturbance, while conditions in nearby degraded areas permitted characterisation of the impacts of human activity, with increased confidence. Studies at these catchments aimed to collect sufficient data to re-appraise existing conceptual models of blanket bog hydrology, which in turn underpin numerical models needed to confidently quantify ecosystem services provided by these areas to water.

Further geological characterisation of the QUBBES test sites demonstrated the geochemical variability of substrate materials, compared to the relatively homogeneous conditions in the overlying peat. Despite the limited compositional variation in peat, hydrological investigations and monitoring have demonstrated all three QUBBES sites to exhibit considerable spatial and temporal variability in hydrological processes. Onsite measurements indicated that all three sites received high levels of rainfall (>1000mm/yr) over the 2017-2019 monitoring period, which was roughly evenly distributed throughout the year, as observed in studies completed elsewhere in Britain and Ireland. Incorporating these findings as the main input into catchment flow balances revealed that during the winter period (End October to End March), groundwater levels were close to (<5cm) or at the ground surface for over 90% of the time, reflecting the limited availability of supplemental storage capacity. Precipitation *during this period closely matched water losses through runoff to within 10%. By contrast the importance of evapotranspiration during the summer period resulted in greater declines in water tables in the peat , generating increased storage capacity.*

Lysimeter measurements, observed over the range of groundwater fluctuation, revealed significantly higher levels of specific yield, compared to the inorganic deposits frequently encountered across Ireland. This in turn implies that comparable ranges of water table fluctuation in peat stores and releases greater quantities of water. As a consequence, rainfall during the summer period can result in significantly lower runoff rates than those observed for comparable levels of precipitation in winter.
Conclusion: *Blanket bogs may act as sponges, buffering against flooding, but only during periods of high available storage, principally in summer. Conversely, little buffering will occur during periods of limited storage in peat, principally in winter.*

Findings at high flow rates, complement those noted during base flow, during which overall flow and the proportion of water directly derived from peatland both declined after peak flow. Nonetheless, direct discharge from peat to streams continued to contribute significantly to runoff, even during prolonged dry periods, e.g. May-July 2018. Comparison of results from Intact catchments, relative to their degraded counterparts revealed that Intact areas provided a greater proportion of bog water to total flow; this is believed to be a reflection of the change in peat properties arising from human disturbance, which resulted in changes in its capacity to store/transmit water.
Conclusion: *Less degraded blanket bogs better support base flow during prolonged dry periods.*

Intact catchment scale flow balances reveal significant variations in the importance in evapotranspiration between sites, with averaged actual evapotranspiration at the Garron site proving significantly lower than potential rates, calculated using the Penman Monteith Equation (PME). By contrast, data for Letterunshin better corresponded with the PME. Flow balances for degraded catchments have not proved possible, due in part to the absence of reliable rating data for higher discharge rates. However, the most reliable data, collected for the Garron degraded site, suggested that the runoff regime in the Degraded area proved flashier than that in the Intact catchment. However, the influence of contrasting topography in each catchment requires consideration, ideally through distributed numerical modelling.
Conclusion: *Run off regimes from more degraded catchments appear flashier than in Intact areas. However, further work is required on (a) populating the upper end of rating curves, and (b) hydrological modelling to remove the influence of topography, to draw firmer conclusions on this issue.*

Tracer testing, completed to assess groundwater velocities in peat, revealed high levels of variability both in space and time. Results point to marked increases in velocity associated with rainfall, although velocity changes are not always synchronous with increases in head, suggesting head thresholds must be reached before local flow rates increase. Overall results are consistent with field observations, with little evidence of overland flow observed at the ground surface during prolonged periods of intense rainfall, rather increased discharge contributing to runoff occurs through permeable peat horizons in the subsurface. The absence of higher permeability peat is expected to limit infiltration and result in greater (and more rapid) discharge over the ground surface. This is consistent with available data from degraded catchments
Conclusion: *Tracer test results suggest that changes in peat properties associated with degradation alter pathways to surface water, resulting in increases intensity of stream discharge.*

Monitoring of peat groundwater quality reveals significant variations in colour across all catchments, with significant spatial variability occurring within distances of less than 10m, i.e. in the same vegetation community and hydrological setting. However, levels in significantly degraded locations, such as closed canopy coniferous forest, prove significantly higher than those in open settings, where groundwater fluctuations prove significantly lower.

Conclusion: *Large levels of groundwater fluctuation in peat give rise to elevated colour levels in groundwater. Areas with more stable groundwater levels have lower colour content. The water from these areas thus incurs lower treatment costs.*

Overall, organic carbon fluxes increase with flow rate, although this process is non-linear and may link to changes in source water concentration during events, as corroborated by SEC data. As a result, predicting DOC levels in water requires further investigation. Nonetheless, data suggest that accumulated DOC levels in peat are lost following the onset of intense flow. This takes longer to accumulate following flushing, giving rise to the non-linear patterns observed. Data suggest that more stable water levels and/ or more frequent flushing, gives rise to lower overall colour levels.
Conclusion: *A disproportionate amount of organic carbon is exported from catchments during high flow periods. Consequently, treating water from high flow events, for use as drinking water, will result in disproportionately higher water treatment costs for colour removal.*

In contrast to DOC, levels of mineralisation in runoff appear relatively easy to predict, given the strong and consistent relationship between flow and ionic content. The consistency of this relationship, and the relatively minor fluctuations in driving heads and hydraulic gradients in the peat, point to a constant input of this more mineralised water to stream flow. At higher flows, its influence proves negligible. However, during longer drier periods, its contribution can significantly alter stream water chemistry and may help explain spatial variations in aquatic biota in higher status water bodies.
End member mixing analysis has suggested broadly consistent recharge rates, and associated discharge from mineralised substrates, across all catchments, irrespective of their condition. However, the condition of the overlying bog will determine the contribution of less mineralised bog water to streams. This can give rise to contrasting base flow stream water chemistry for equivalent substrates, but where the condition of the peat differs.
Conclusion: *Substrate geochemistry strongly influences the base flow chemistry of streams draining blanket bog covered catchments. Although the condition of the overlying bog has little influence on the contribution of mineralised water to the stream during low flows, it significantly influences levels of dilution made by bog water to overall baseflow. This may affect aquatic biodiversity and stream water status.*

Combining water quality data with the results of hydrological monitoring has permitted an update to the conceptual model of blanket bog hydrology. This includes addition of storage elements within the bog, that act on an intermittent basis to supply additional water and organic carbon during higher energy hydrological events. Isotopic data suggest highly variable residences times for this water, depending on the time of year, with a significant proportion added within a day during winter events when peat has limited storage capacity.
Conclusion: *Drainage reduces the capacity of peat to store water, resulting in more intense runoff and less stable base flow, thus elevating flooding risk and placing greater physical-chemical stress on aquatic ecosystems (and their WFD status). Further work is necessary to quantify this issue.*

Ecological investigations examined the link between terrestrial ecology (notably vegetation but also nanotopes) and hydrological processes. A new adapted, revised vegetation survey protocol, comprising PFT and associated environmental variables, provided a robust assessment tool for predicting the condition of a blanket bog and revealing biogeochemical processes. While a clear pattern was apparent in linking habitats at the extreme gradient of the hydrology (namely very hydrologically sensitive and degraded), the capacity to link plant communities to hydrological processes was limited.
Conclusion: *The results of existing vegetation surveys have limited capacity to predict blanket bog processes in typical blanket bog vegetation communities but show linkages in associated habitats such as flushes and heath. These initial results need to be supported by additional monitoring whereby deployment of piezometers would be informed iteratively through vegetation mapping and restoration potential modelling.*

Hydrological correlations to date have focused on the relationship between vegetation and water level fluctuations. Qualitative ecological analysis indicates that fluxes through peat, determining the total load of nutrients as well as organic carbon passing a plant community, can be reflected by plant communities, e.g. Rhynchosporion alba communities, flushes and wet heath. The results of tracer dilution testing, coupled with water quality/water table monitoring show considerable potential to develop this topic.
Conclusion: *Considerable potential exists to better constrain hydrological influences on plant communities and thus to (a) employ vegetation mapping to better identify hydrological processes, (b) identify appropriate restoration targets to allow restoration measures to comply with the HD.*

On the other hand, hydrological correlations to date have focused on the relationship between vegetation and water level fluctuations. Qualitative ecological analysis indicates that fluxes through peat, determining the total load of nutrients passing a plant community can be reflected by plant communities, e.g. flushes. The results of tracer dilution testing, coupled with water quality monitoring, show considerable potential to develop this topic.
Conclusion: *Considerable potential exists to better constrain hydrological influences on plant communities and thus to (a) employ vegetation mapping to better identify hydrological processes, (b) identify appropriate restoration targets to allow restoration measures to comply with Habitats Directive requirements for the restoration of active blanket bog.*

Modelling has provided a means of integrating the findings of field investigations, and the associated conceptual models. Activities aiming to assess the capacity of different approaches suggest that current lumped parameter modelling, e.g. MIKE NAM, may not be appropriate at the small catchment scale. By contrast, distributed modelling displays significantly greater capacity to incorporate spatial variability to reproduce runoff patterns observed. Moreover, further development of this approach allows the influence of complex variables such as topography and surface roughness to be incorporated.
Conclusion: *Distributed hydrological modelling provides a means of pulling together the findings of QUBBES research. This will prove essential for linking ecosystem services with economics, e.g. assessing the change in risk associated with peatland restoration.*

Economic analysis of data collected over the course of the QUBBES project have identified elements that can make blanket bog conservation and restoration economically viable, compared to more conventional economic activities. The results obtained to date demonstrate the capacity of activities such as exotic forestry to impact ecosystem services, including flow, water quality and aquatic status. Published figures suggest that conservation/restoration is particularly viable on deep peat (>1m) where the products obtained from more conventional activities yield little to no profit when subsidies are removed. Moreover, incorporating wider ecosystem services, e.g. carbon sequestration, makes payback times shorter and more profitability.
Conclusion: *Blanket bog conservation and restoration to promote ecosystem are financially viable activities on deep peat, when compared to other (unsubsidised) economic activity.*

Reference

Flynn, R., Mackin, F. and Renou-Wilson, F. 2021. Towards the Quantification of Blanket Bog Ecosystem Services to Water. EPA Research Report 378.
https://www.epa.ie/publications/research/water/Research_Report_378.pdf

Flynn, R., McVeigh, C., Mackin, F. and Renou Wilson, F. 2021. Sources of stream base flow in blanket peat covered catchments.
https://www.sciencedirect.com/science/article/pii/S0022169421010155

9 Catchment Walks - Extractive Industry – Quarries

9.1 Purpose

This section provides a guide of indicators and visual clues of pressures arising from quarry activity, supported by photo-documentation. The significant pressures are mainly related to:

- Sediment load to, and re-activation (erosion) of sediments in, streams at discharge locations;
- Release of pollutants to surface water and groundwater and;
- Abstractions from dewatering operations.

These activities can result in the degradation of physical habitats and environmental supporting conditions of surface waters and groundwater dependent wetlands, as well as the pollution of both surface water and groundwater receptors (e.g. public water supply wells). Lowering of groundwater levels from dewatering operations can furthermore affect the baseflow of streams (particularly during the drier summer months), groundwater levels beneath wetlands, and water well owners, if these are located within the zone of influence of quarry dewatering operations. The associated discharges of water from quarries can also cause or contribute to flood risk downstream of quarry sites.

These pressures are described in turn below, followed by summary of possible mitigation options, and useful references for further reading and information-gathering purposes.

Water quality *indicator parameters* of active quarry activity are turbidity (sediment) and nutrients, mainly ammonia and nitrate from septic tank systems and/or use of explosive compounds.

The main water quality *indicator parameters* of quarrying are turbidity and sediment. Releases of fuel compounds and other contaminants are possible in the form of spills. Details on indicator parameters are described in **Volume 4**.

9.2 Significance

As documented in **Volume 1**, quarries and mine pressures are estimated to be significant in 41 river water bodies and 4 ground water bodies, and are ranked 11th nationally within both river and lake water bodies in the draft River Basin Management Plan for Ireland 2022-2027.

More than 230 active quarries are recorded in a 2014 publication by the GSI[23]. Quarries are of two basic types: rock quarries and sand and gravel pit quarries. Rock quarries tend to be deep, and may involve dewatering so operators can access and extract materials from deeper “benches” rather than expanding laterally. Rock faces are often broken by mechanical or controlled blasting techniques. Large trucks subsequently transport materials to stone crushing machines where they are broken down into aggregates of different sizes.

Sand and gravel pits are much shallower than rock quarries but may also involve dewatering operations. The material is excavated mechanically and carried by trucks or conveyor belts to a plant where it is crushed, washed and screened into different sizes.

9.2.1 Water Management

Quarry operations typically involve one or more of the following water management actions:

- Collection of rainfall-runoff waters in sumps at topographic low points within a quarry footprint.

[23] The GSI maintains a Quarry Database of active stone quarries and sand pits, which is periodically updated and available as digital products on their website (www.gsi.ie). The database contains information such as quarry products, location and contact details and production data.

- Temporary storage, for sediment settling purposes, of water that is used for washing of aggregates, cleaning of equipment, dust suppression and cooling of machines.
- Dewatering to keep deeper working areas (below the groundwater table) dry and safe.

Dewatering may involve pumping of groundwater from boreholes specifically drilled and installed for that purpose, or may involve pumping of water from sumps (e.g. when quarries intercept water-bearing fissures, fractures or conduits). Dewatering operations in karstified limestones can significantly upset the natural hydrological conditions of streams where streams are hydraulically connected to water bearing conduits that are dewatered in quarries (Figure 9-1: Part of a 1 km long dry river bed section in Co. Kerry resulting from a quarry dewatering).

Figure 9-1: Part of a 1 km long dry river bed section in Co. Kerry resulting from a quarry dewatering operation (Photo: David Ball).

Water that is collected, temporarily stored in settlement ponds (engineered or simply occupying the lowest points in quarries), and/or is pumped from wells or sumps, is typically discharged to nearby streams under terms and conditions of discharge licenses which specify discharge location(s), discharge quantities (as a daily mean flow), and water quality (e.g. suspended solids and/or settleable solids as a proxy for sediment content, nutrients such as ammonia and nitrate, and pH, SEC, BOD, COD and hydrocarbons). Discharges of effluent to surface waters are regulated under the Local Government (Water Pollution) Acts.

Water discharges to streams can contribute to flood risk and water pollution. Flood risk should be evaluated as part of an environmental impact assessment. The quality of the discharge water should meet license conditions. Finally, the discharge of quarry water should be engineered such that the energy of the water is broken to reduce erosion and re-activation of stream banks and sediments (Figure 9-2).

Figure 9-2: Fine-sediment plume in river resulting from discharge of sediment-laden water (Photo: David Ball).

9.2.2 Waste Management

Under license terms, quarry operations must avoid pollution of the aquatic environment. Accordingly, septic tank systems are often installed to manage ablution water, and strict rules are placed on the storage, handling and use of chemicals (e.g. fuels) to avoid or minimize risks of spills and pollution events (e.g. bunding of fuel tanks).

Quarries, mostly disused, are sometimes accessed for illegal waste disposal practices that contribute to water pollution (Figure 9-3 and Figure 9-4).

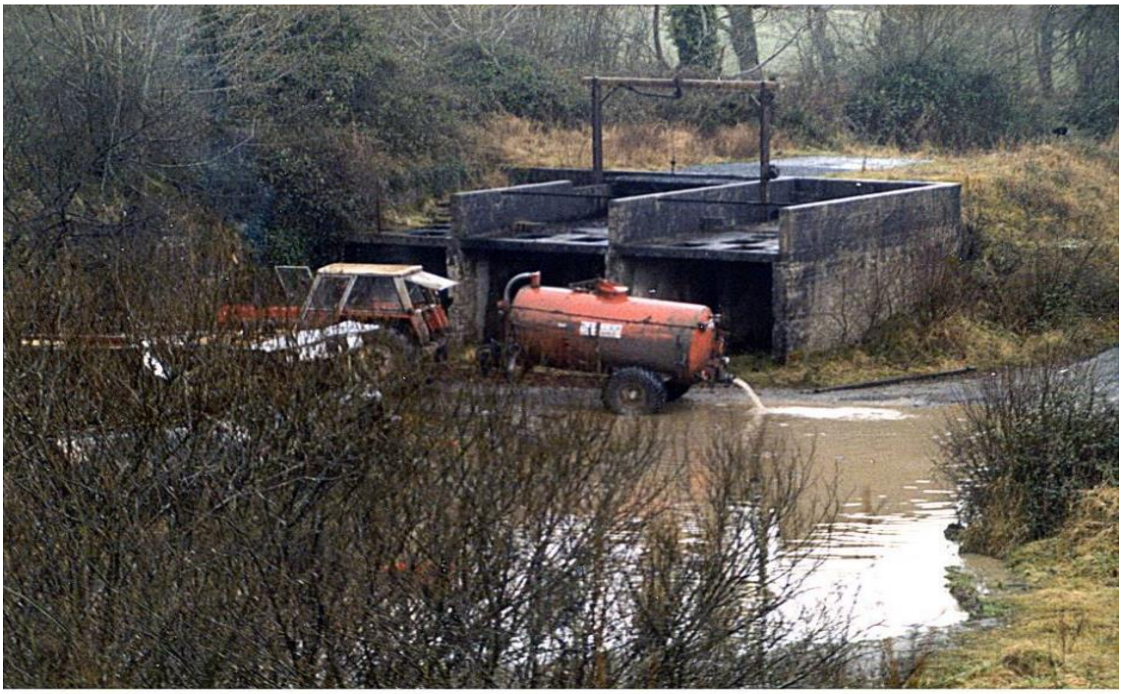

Figure 9-3: Private contractor discharging excess effluent from a wastewater treatment plant in a disused quarry, soaking into the groundwater system (Photo: David Ball).

Figure 9-4: Dumping of bitumen and diesel mixture, with creosote, in a disused quarry (Photo: David Ball).

9.3 Walking the Catchment

9.3.1 What to look for

- Location, type and nature of quarry discharge to stream.

- Engineered discharge structure (to break water energy).
- Check that discharge volume is consistent with discharge license.
- Check that sediment/slurry from onsite settling basins are contained and not being discharged to streams.
  - Settlement ponds should provide adequate retention time for settlement of solids in the discharge. Excessive flow rates through the settlement ponds reduces retention time and settlement efficiency. Retention time = pond volume/flow rate. Typically, 11 hour retention settles medium silt; 24 hour retention time settles fine silt.
  - If sediment-laden runoff from certain areas of the quarry (e.g. stockpiling, roadways) is not directed through adequate settlement ponds, then polluting discharges occur.
- Signs or evidence of stream sediment and bank erosion at discharge point.
- Siltation of stream beds downstream of discharge point, akin to that described and shown for Forestry.
- Signs or evidence of stream bank discoloration at and downstream of discharge point.
- Signs or evidence of stream bank vegetative loss at and downstream of discharge point.
- Evidence or anecdotal accounts of sections of streams periodically or seasonally drying up.
- Presence of multiple discharge points, possibly unauthorised (unlicensed) discharges, from the quarry.
- Evidence of recent installations of pipes or drains, indicative of additional quarry pumping.
- Bunding of fuel tanks and drum storage areas.
- Loading/unloading of fuels in designated area to protect against spillage/run-off (fuel pumps and attachments to be located within bunded areas).
- Functioning septic tanks, without piped wastewater discharges directly to streams.
- Piped wastewater discharges directly to streams.
- In disused quarries, signs or evidence of solid and liquid waste dumping, including dangerous substances.
- Calcification of the stream bed downstream of the discharge point might arise if dewatered groundwater with high dissolved solids/hardness is discharging to the stream.
- Exposed rock in shale quarries can lead to acid mine drainage (sulphur bearing minerals in shale oxidised to sulphuric acid, with resulting acid leaching metals from the rock materials). Treatment in these cases might involve dosing to raise the pH and precipitate dissolved metals, dosing to neutralise pH and final settlement. Untreated acid rock drainage is evident as low pH and highly coloured orange staining from oxidised iron. (See acid mine drainage in Section 10.)

If unusual sightings of vehicles carrying potential waste materials are made, e.g. heading down a small side road, it is worth finding out why such vehicles are driving down laneways.

9.4 Possible Mitigation Options

Potentially applicable mitigation options associated with quarries are summarised in Table 9-1 below.

9.5 Useful References

EPA, 2006. *Environmental Management Guidelines: Environmental Management in the Extractive Industry (Non-Scheduled Minerals)*. Environmental Protection Agency. Available at: https://www.epa.ie/pubs/advice/general/EPA_management_extractive_industry.pdf.

Irish Concrete Federation, 2005. *Environmental Code for Quarrying Operations*. Second Edition, October 2005. Available at: www.irishconcrete.ie/wp-content/uploads/2017/01/Environmental-Code.pdf.

Table 9-1: Examples of mitigation options for quarry pressures.

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source Control	Abstraction for water supply and dewatering purposes	• Compliance with licence conditions; • Thorough understanding of environmental impacts of abstractions, with offsite monitoring.	Check relevant licence; See Section 9.5
	Discharges	• Compliance with discharge licence conditions (quantity, quality); • Adherence to best practice guidelines; • Silt controls (properly functioning settlement ponds or tanks); • Regular maintenance of settlement ponds (silt removal and controlled disposal); • Care with machinery used in vicinity of discharge points, streams and ditches to reduce erosion and sediment generation. Consider set-back distances if problems are observed. • Bunds and silt fences in appropriate locations to prevent runoff of silty water. • Maintenance of drainage channels before heavy rainfall events to prevent washing of silt into streams.	
	Storage, handling and use of chemicals	• Compliance with licence conditions; • Use of bunding and spill pallets - fuel and chemical storage and handling areas; • Adherence to best practice guidelines.	
	Water pollution	• Check that septic tank(s) or other controlled means of wastewater discharge is in place (i.e. is not directly piped and discharged to streams). • Minimise blasting operations (check blast design and implementation if ammonia/nitrate licence conditions of discharge water are not being met). • Adherence to best practice guidelines.	
	Spills	• Compliance with licence conditions; • Check that safety, spill control and clean-up protocols are in place; • Signposting of prohibition to discharge or dump solid and liquid waste.	
Pathway Interception	Onsite water management	• Adherence to best practice guidelines.	Check relevant licence; See Section 9.5
Receptor Rehabilitation	Stream sediment control	• Engineered discharge mechanism to break energy of discharged water prior to entry into stream. • Ensure settling of sediment prior to discharge in stream.	Check relevant licence; See Section 9.5
	Stream bank control	• Embankment rip-rap at discharge location. • Planting of suitable plants to stabilize stream banks, e.g. willow.	
	Flood control	• Check water transmitting capacity of stream into which discharge occurs (also a sediment control item).	Check EIA for quarry

10 Catchment Walks - Mines

10.1 Purpose

This section provides a guide of indicators and visual clues of pressures that are associated with abandoned or closed mine sites, supported by photo-documentation. The significant pressures are mainly related to the legacy of past mining activity, for example, discharge of acid mine drainage, which can result in the degradation of physical habitats and ecologies of surface waters, as well as the pollution of both surface water and groundwater receptors.

These pressures are described in turn below, followed by a brief introduction on possible mitigation options, followed by useful references for further reading and information-gathering purposes.

Water quality *indicator parameters* of depends on what is being or what was extracted in the past, but common indicators are pH values, SEC values, sediment and metal concentrations, especially iron, copper and lead. Biological indicator parameters of pollution from mine sites are fish kills and impacted macroinvertebrate populations in streams. Details on biological and water quality indicator parameters are described in **Volume 4**.

10.2 Significance

The locations and status of present and abandoned/closed mine sites are well known[24]. Active mining is taking place at the Tara Mines[25] (zinc, lead) in Co. Meath and Knocknacran Saint Gobain Construction Products (Ireland) Ltd[26] (gypsum) in Co. Monaghan, while Galmoy Mines[27] in Co. Kilkenny ceased production in 2012 and Vedanta Lisheen Mine[28] (zinc, lead) in Co. Tipperary ceased produced in December 2015 and both are currently in a rehabilitation phase. Their pollution risks and impacts are actively monitored and managed under existing licenses.

Some disused (abandoned/closed) mines are also monitored, and certain disused mines represent pollution hot-spots, notably Avoca, Silvermines and Tynagh. The main water pollution issues are discharges from underground workings (acid mine drainages) and runoff from spoil heaps. These contribute to low pH conditions and metals loading to streams (especially lead).

10.3 Walking the Catchment

Acid mine drainage (AMD) emanates from mine adits (Figure 10-1) but also from smaller seeps and discrete discharge locations which, at first glance, can appear as regular clean-water springs or seeps. AMD is often clear (sediment free) and colourless (Figure 10-2). However, AMD is often of low pH, so simple pH measurements using hand-held instruments can help to distinguish AMD from unpolluted springs or seeps.

AMD that contains dissolved metals, especially copper and iron, will be identifiable by a characteristic orange to rust-coloured discoloration of streams when metals are exposed to oxygen and metals

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[24] The EPA, GSI and the Exploration & Mining Division of the then Department of Communication, Marine & Natural Resources undertook a joint project entitled "Historic Mine Site - Inventory and Risk Characterisation (HMS - IRC)", published in 2008. Available at: http://www.epa.ie/enforcement/mines/
[25] IPC Register Number P0516-04
[26] IPC Register Number P0519-03
[27] IPC Register Number P0517-02
[28] IPC Register Number P0088-04

precipitate out from solution (Figure 10-3). The precipitates settle to the stream bottom at and downstream of the AMD discharge location, either as a fine mud or as (cemented) ferricrete.

AMD can discharge from different locations depending on seasons and climatic conditions. Underground workings can also change in time (e.g. collapses), creating new pathways, resulting in new discharge locations. Unexpected or previously unknown discharges can, therefore, occur.

Figure 10-1: Acid mine drainage from the Deep Adit at the Avoca Mine, Co. Wicklow (Photo: Pat Barrett).

Figure 10-2: Clear acid mine drainage from a flooded shaft at Silvermines, Co. Tipperary (Photo: Pat Barrett).

Figure 10-3: Iron precipitation downstream of the Deep Adit discharge in the Avoca River, Co. Wicklow (Photo: Pat Barrett).

Spoil piles can also contribute to water pollution, from:

- Metals leaching from the spoils through contact with rainwater.
- Runoff, with surface erosion and transport of sediments to streams.
- Diffuse groundwater movement through spoils, if these are below the groundwater table or comprise perching layers that impede vertical infiltration of rainwater.

Spoil materials are typically heterogeneous and can have different appearances, but they are mostly composed of loose to weakly cemented waste rock (Figure 10-4 and Figure 10-5)

Figure 10-4: Spoil materials, Silvermines, Co. Tipperary (Photo: EPA/GSI, 2008).

Figure 10-5: Runoff across spoil materials, Avoca, Co. Wicklow (Photo: Pat Barrett).

There are incidents and records of disused mine pits used for waste dumping, both legally and illegally, similar to what was described for quarries in Section 9.2. Examples are the “drum dump” at the Shallee mine site (Silvermines, Co. Tipperary) and one of the open pits at Avoca was used as a municipal landfill for Co. Wicklow in the 1980s.

10.3.1 What to look for

- Location, type and nature of discharges to stream.
- pH changes in streams.
- Stream sediment and stream embankment discolouration.
- Fine rust-coloured mud or ferricrete at base of streams.
- Spoil piles.
- Evidence of runoff gullies and transport of sediment to streams.
- Changes in stream/river flow rates (e.g. upstream and downstream of a discharge).
- Poor stream macroinvertebrate populations (based on SSRS survey) .

During a catchment walk, changes in pH and SEC values of a stream are useful indicators that mine discharges are occurring. Rusty coloured staining of the stream bottom is a useful visual of metals precipitation. If pH changes are noted, the cause should be established by detailed survey of the section of stream in question. Mostly, locations of AMD discharges and spoils heaps are already mapped and can be accessed from site-specific studies[29].

10.4 Possible Mitigation Options

Mines operating post-1994 require closure and aftercare plans, per the IPC licenses issued by the EPA. Abandoned (older) mine sites are the responsibility of the landowner, and most of these sites are owned by private landowners. A small number of complex sites are under the management of the

[29] Queries for reports and data can be made with the EMD of the Department of Communications, Climate Action and Environment.

State or local authority, and management, remediation and monitoring activities are being undertaken at the Avoca and Silvermines sites.

Mitigation options for abandoned mine sites exist, but these largely depend on the extent of the problems at specific sites. Any site management options require a thorough understanding, supported by targeted studies and data, of the nature and scale of actual impact, as well as technical and financial feasibility of remediation. Abandoned mine sites are also different from other types of environmental pressures in that problems are not confined to water quality issues, and problems can also involve stability concerns, dust and other airborne contaminants and a variety of human health concerns.

However, the most important issue with respect to the aquatic environment is acid mine drainage. Where this exists, some form of treatment is generally necessary. Typically, a treatability study would be undertaken to assess available treatment options and achievable effluent concentrations. Two broad forms of treatment exist: passive and active treatment. Both are effective, but have ranges of advantages and disadvantages, and the selection of the most appropriate means of treatment is site-specific.

10.4.1 Passive Treatment

Passive systems utilise organic substrate (e.g. processed manure, wood chips, and straw) and bacterial activity (sulphate reducing bacteria) to adsorb and precipitate metals as sulphides. These typically require no pumping (gravity flow cells) and little operation/maintenance. However, depending upon the location, pumping of water to the treatment cells may be necessary. The passive treatment system may require large areas, pre-treatment for iron and aluminium and potential periodic disposal of large quantities of organic substrate. A range of different passive treatment systems exist, such as limestone systems or biochemical reactors (BCR) but in general, these systems are passive or semi-passive (e.g. requiring only renewable energy), allowing for minimal maintenance, or only minimal power requirements from the local grid. All movement of water through the treatment system would typically be by gravity flow with no power required. Passive treatment systems have a relatively long treatment life (10-15 years) before media replacement is required. The advantages of these systems are that less sludge is produced, and the operating costs are much lower. The disadvantages include the requirement for a much larger site and the need for periodic replacement of the treatment media.

10.4.2 Active Treatment

A treatment facility where chemical addition to the acid mine drainages occurs resulting in removal (precipitation) of the metals. A sludge is produced that requires regular disposal. Routine monitoring, operations and maintenance is required. Active treatment systems continuously control process variables in direct response to the characteristics of the water being treated or the desired quality of the discharge. Active treatment processes utilize combinations of mechanical equipment, chemicals, electricity, light energy and storage to achieve the treatment objectives. The overall system can range from a simple process that requires minimal adjustments to be effective over a wide range of water characteristics to a very complex system that has to be precisely controlled over a wide range of processes to perform satisfactorily. The advantage of this system is that it requires a relatively small site. The disadvantages include the higher operating costs and the large quantities of sludge produced through the processes, which requires disposal.

10.5 Useful References

Stanley, G., Gallagher, V., Ní Mhairtín, F., Brogan, J., Lally, P., Doyle, E., Farrell, L., 2009. *Historic Mine Sites – Inventory and Risk Classification (Volume 1).* Environmental Protection Agency and Geological Survey Ireland. ISBN: 1-84095-318-3. Available at: http://www.epa.ie/pubs/reports/land/mines/.

Mine-specific reports and data. Available from the Exploration and Mining Division of the Department of Communications, Climate Action and Environment.

EPA, 2002. *Expert Group on Lead in Silvermines County Tipperary*. Interim Report. ISBN 1-84095-082-X. Environmental Protection Agency.

Jane Brogan, 2003. *Report of the investigation into the presence of lead and other metals in the Tynagh mines* area, County Galway. Environmental Protection Agency. ISBN 1-84095-125-7.

EPA 2004. *Final Report of Expert Group for Silvermines County Tipperary - Lead and Other Relevant Metals*. Environmental Protection Agency. ISBN 1-84095-128-1.

Reports from 2017-2018 Interagency Group available at [Silvermines | www.tipperarycoco.ie]

11 Catchment Walks – Industrial Discharge Pressures

11.1 Purpose

This section provides a guide to local catchment assessments in catchments where there are industrial discharges that might impact on water quality. This chapter is intended to guide the assessor on:

1. Assessing if the industry is impacting negatively on the waterbody;
2. Gathering information about the industrial discharge;
3. Guiding the assessor on what to look out for when carrying out a local catchment assessment in proximity.

This section is intended to guide the assessor on discharges from industrial and commercial operations, which includes waste facilities, but excludes quarries and mines.

11.2 Significance

As documented in **Volume 1**, industry is estimated to be a significant pressure in 62 rivers and 1 lake water bodies and 18 groundwater bodies nationally. It is the 9th most significant pressure within river water bodies in the draft River Basin Management Plan for Ireland 2022-2027.

Many industrial and commercial facilities will require an environmental consent; large scale facilities with multiple emissions such as air, wastewater and waste will require licensing by the EPA under either the Industrial Emissions Directive (IED) or Integrated Pollution Control (IPC) processes. In general, it is the category and scale of activity that will determine if IED or IPC licensing is required. Where an IED/IPC licence is not required, a Water Pollution Act Section 4 Licence, which is issued by the Local Authorities, may be required, if the facility is generating a trade or sewage effluent and discharging to surface or groundwater. In urban areas, if facilities are discharging trade effluent to the sewer, a Water Pollution Section 16 licence may be required. Waste sector activities such as, transfer stations, landfills, hazardous waste disposal and other significant waste disposal and recovery activities are licensed by the EPA. A waste licence is a single integrated licence dealing with emissions to all environmental media and the environmental management of the facility.

Where a facility is already licensed (IED/IPC/S4/Waste), the impact of the discharge has been assessed and considered by the licensing authority (EPA or Local Authority). This information will be available from the licensing authority. Visit www.epa.ie to view available licence documentation for facilities licenced by the EPA. Where a facility is not regulated, the local catchment assessment will provide an opportunity to determine what discharges are occurring, whether or not they should be regulated, and whether or not they are impacting on water quality.

11.3 Desk Study

Once the water bodies *At Risk* have been identified for further characterisation, a desk study to determine what activities are occurring within the catchment will be carried out. In addition to the WFD App, EPA Maps, (https://gis.epa.ie/EPAMaps/) can be used to identify all EPA licensed and authorised activities within the water body of interest.

Where a licensed industry has been identified as a pressure, a review of the associated licence documentation e.g. mass balance and assimilative capacity assessments, AERs, site visit reports etc. should be undertaken, if this information is available. Visit www.epa.ie to view available licence documentation for facilities licenced by the EPA. As required by the EC Environmental Objectives (Surface Waters) Regulations 2009 and the EC Environmental Objectives (Groundwater) Regulations 2010, the emission limit values specified in EPA licences were reviewed to ensure they were compatible with the receiving waters achieving WFD objectives. This file review may help provide evidence that the facility is not likely to be contributing to water quality problems, for example, if all wastewater from the site discharges to the sewer. However, in the absence of representative upstream and downstream monitoring results, the desk assessment **cannot** conclude that the licensed discharge is not likely to be a significant pressure on water quality. An impact could still be occurring if there are undetected issues such as contamination to storm drains at a site, which would not be evident in routine monitoring of the primary discharge.

Refer also to the Guidance set out in 4.3 Urban Wastewater Pressures from Plant (Works) to inform the Desk Study assessment of the industrial discharge as a significant pressure at the WFD monitoring point.

11.4 Walking the Catchment

The purpose of the catchment walk is to gather evidence to confirm if a facility is impacting negatively on water quality.

11.4.1 Assessing impact of the facility

Select locations up and downstream of the entire site and not just the primary (authorised) discharge points, ensuring they are unlikely to be impacted by other activities. This is not always possible, but locations should be selected to help isolate what activities are having the greatest impact. More detailed investigation of individual sites may ultimately be required, however, the evidence complied during this stage of the assessment may be used to justify the need for more detailed on-site inspections of the facility by the appropriate regulatory authority e.g. Local Authority or EPA.

Use the following water quality indicators to determine water quality impacts:

- Visual indicators (e.g. sewage fungus, sediment, discolouration, turbidity, grease, malodours etc.) (**Volume 4**).
- Physico-chemical indicators (i.e. DO, pH, temperature, nutrients, SEC, BOD, COD, thermal imaging etc.) (**Volume 4**).
- Ecological indicators (**Volume 4**).
- Hydromorphological observations (**Volume 2**).

River assessments should be carried out when water levels are low to help locate submerged discharge pipes.

A profile of discharges over a period of time may be beneficial, as some industries may do wash downs at weekends. In stream temperature loggers could help identify variations in discharge times etc.

Use detailed field scale maps and field sheets to record sampling locations and other observations. These maps will be critical to guiding any site inspections that may result. Inspection at the storm drain network or storm drain network outfall serving an industrial estate can be used to check for polluting inputs arising within the industrial estate.

At this stage of the local catchment assessment, you should conclude one of the following:

- The facility is not impacting on water quality.
- The impact is uncertain and further assessment of the facility and a detailed site inspection by the appropriate regulatory authority e.g. Local Authority or EPA, may be required.
- The industry is impacting on water quality and this evidence should be referred to the appropriate regulatory authority e.g. Local Authority or EPA on the WFD App so that an appropriate mitigation action can be identified.

11.4.2 Confirm that the facility is appropriately regulated

Many smaller facilities that require licensing under Section 4 of the Water Pollution Acts may not have been captured under the licensing process. For example, this could arise at small scale business premises in unsewered areas, where the main business activity does not generate a process effluent, but the business uses a wash-down area for vehicles or equipment, with wash water effluent discharging to waters. A stream walk may identify specific piped polluting inputs and aerial photography or site inspections may identify a wash bay area or wash equipment.

11.5 Site Inspections

The site inspection is essentially a source-pathway-receptor risk assessment:

- To understand the processes being carried out within the facility (sources).
- To determine the layout of the site and the locations of foul and surface water networks (pathway).
- To identify the locations of wastewater treatment, waste storage, chemical storage, raw materials storage, wash bays, etc. (sources).

Liaison with the relevant regulatory authority will be essential, as they may be able to answer any site specific questions – contact the relevant Regional EPA Enforcement office for information on EPA licensed facilities. If this is not the case, an inspection of the facility may be required and should be undertaken by the appropriate regulatory authority. For sites licensed by the EPA, no site inspections should be carried out in the absence of inspectors from the Office of Environmental Enforcement. Examples of unsatisfactory and inadequate situations are illustrated in Figures 11-1 to 11-8.

11.6 Possible Mitigation Options

Measures to mitigate discharges from industry can only be determined after a site inspection.

Table 11-1: Mitigation options

Mitigation Option Category	Mitigation Option
Source Control	Emergency responses are in place
	Improved treatment through adequate maintenance and or simple repairs
	Improved treatment through upgrade or replacement of treatment system
	Connect to municipal system
	Review and/or enforce discharge consent
	Suitable collection system to capture and retain waste for authorised collection
Pathway Interception	Remove foul/trade effluent from storm system
	Connect to municipal system
	Connect isolated systems to larger treatment units to achieve improved treatment
	Capture and treat soiled water
Receptor Rehabilitation	Site specific solutions will be required

11.7 Useful References

FIRST SCHEDULE to EPA Act 1992 (as amended). Available at:

Licensing & Permitting: Integrated Pollution Control (IPC) Publications | Environmental Protection Agency (epa.ie).

Local Government (Water Pollution) Acts 1977-1990. Available at: http://www.irishstatutebook.ie/eli/1977/act/1/enacted/en/html and http://www.irishstatutebook.ie/eli/1990/act/21/enacted/en/html.

For details of the categories and scale of activities that require IPC/IED and waste licensing, see Licensing & Permitting | Environmental Protection Agency (epa.ie)

Water Services Training Group 2010. Guidance, Procedures and Training on the Licensing of Discharges to Surface Waters, and to Sewer for Local Authorities. Manual not available, contact the Local Authority Services National Training Group.

EPA, 2011. Guidance on the authorisation of discharges to groundwater. Version 1. Environmental Protection Agency, 154pp. Available at epa-preprinted-cover.qxp.

EPA Best Available Technical Guidance Notes available at: www.epa.ie.

Figure 11-1: Surface water drainage channel impacted by sediment/silt arising from washing of root vegetables (Photo: Emmet Conboy).

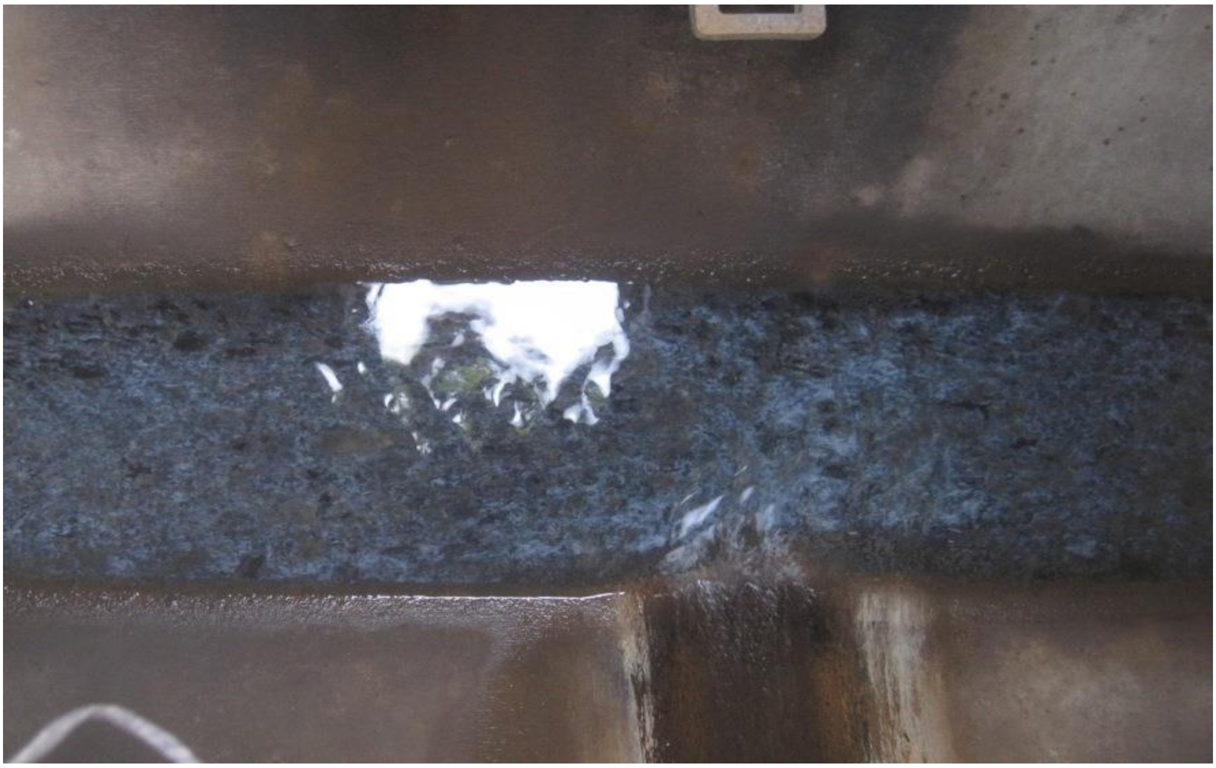


Figure 11-2: Storm drain with indication of polluting inputs – sewage fungus at base of drain (Photo: Emmet Conboy).

Figure 11-3: Interceptor on surface water drainage system. Note bubbles in the floating scum in the interceptor. Some scum on an interceptor surface is normal but presence of numerous bubbles such as this indicates an organic waste of some strength is entering the interceptor, with microbial degradation in the chamber resulting in gas bubbles. This would require further investigation into contamination of the surface water drains with an organic-type waste (Photo: Emmet Conboy).

Figure 11-4: Outlet drain fitted into base of bund around above-ground wastewater storage tank. Note outlet leads to surface water gully. The outlet connection creates a high risk to waters as it could potentially be used to facilitate emptying polluted contents from the bund into storm drains. Outlet should be removed / sealed (Photo: Emmet Conboy).

Figure 11-5: Constructed wetland receiving wash-down effluent from a food processing premises. Note detergent-type suds. The wetland was not providing adequate treatment of the effluent in this loading scenario resulting in a polluting input to surface waters, characterised principally by high ammonium in the discharge (Photo: Emmet Conboy).

Figure 11-6: Surface water gulley receiving polluting matter as contaminated runoff from industrial premises yard. (Photo: Emmet Conboy).

Figure 11-7: Waste materials and IBCs stored at rear of industrial facility in a haphazard manner – an indication of poor environmental management at a site creating a risk to waters (Photo: Emmet Conboy).

Figure 11-8: Wash bay area at rear of industrial premises (Photo: Emmet Conboy).

12 Catchment Walks – Invasive Species

12.1 Purpose

This section provides a guide to the most commonly encountered high impact invasive plant species found along flowing watercourses. All were introduced as ornamental plants which have subsequently spread to the natural environment. Invasive species associated with lakes are not covered here, as these are less likely to be encountered during river Local Catchment Assessments. The reader is referred to the National Biodiversity Data Centre (http://www.biodiversityireland.ie/) for more detailed information.

Please note that the shape, height and foliage for each species varies seasonally and so this should be considered when attempting to record the presence of these species during your survey. The surveyor is reminded that biosecurity precautions should be followed always.

These include:

- Planning your itinerary;
- Anticipating what species to expect in the field and;
- Planning around known invasive species outbreaks (e.g., Crayfish plague).

Before leaving the site follow **'Check, Clean, Dry'** protocols, making sure that no seeds of fragments are left attached to clothing, equipment or footwear before leaving a site.

12.2 Giant hogweed Heracleum mantegazzianum

Looks like Common hogweed and related native hogweed species, but grows much taller (usually between 2m to 5m) in height. It is a perennial with ridged, stout, purple blotched stems which carry numerous cream-white flowers (10mm) in large umbels (50cm across) in June and July. The leaves are pinnately (leaves arranged on either side of the stem) divided and long (1m) arranged.

A

Figure 12-1**:** Giant hogweed plant in flower - note height of plant. Butterbur to foreground (Photo: Fran Igoe).

Figure 12-2: Stand of Giant hogweed along banks of the river; River Mulkear, Co Limerick (Photo: Fran Igoe).

Location: On river banks, farm drains and floodplains especially on flood embankments.

Impact: Plants quickly form monocultures shading out native riparian vegetation during the summer but dying back in autumn leaving river banks vulnerable to erosion. Hazardous especially to children playing along river banks.

Spread: Spreads by seeds. Produces up to 50,000 seeds per plant and so can spread rapidly along watercourses. Care should be taken to ensure that seeds do not adhere to clothes or footwear if walking along watercourses where Giant hogweed is present.

Treatment: Glyphosphate. Can be controlled mechanically but care needs to be taken as sap is toxic causing severe burns on contact with skin.

Note: Giant Hogweed produces a phototoxic sap, which on contact with skin can cause severe reactions. Exposure of skin to sunlight after contact can result in severe blistering and scarring so avoid contact if possible. If you do happen to be in contact, wash skin in cold water and soap immediately. Keep affected area away from sunlight for at least 48 hours after contact.

Figure 12.3: Young Giant hogweed plants emerging on river bank (Photo: Fran Igoe).

Figure 12-4: Stand of Giant hogweed in seed dwarfing other plants along the River Cahernahaille, Co Tipperary (Photo: Fran Igoe).

12.2.1 What to look out for:

Spring: Emergent plants. New foliage – large hogweed shaped leaves emerge from ground. Summer: Tall plants which produce distinctive white flower on long stems – up to 5m tall.

Autumn/winter: Flowering heads with thousands of seeds clearly visible. Plants die back leaving remnants of seed heads on dead bamboo like stems.

12.3 Japanese knotweed *Fallopia japonica*, Giant knotweed *Fallopia sachalinensis* and hybrids

This is a vigorous perennial commonly found along road sides and waste ground. It is commonly featured in the media due to its potential to cause structural damage to buildings and road networks. Plants can reach 2m in height and are distinctive: large, stalked, triangular heart shaped leaves on reddish, stout "bamboo like" stems. Plants flower from August to October, forming clusters of small white flowers. Giant knotweed looks like Japanese knotweed, but has larger leaves. Hybrids also occur between the knotweeds.

Figure 12-5: Japanese knotweed in flower (Photo: Fran Igoe).


Figure 12.6: Stand of Japanese knotweed infestation along both banks of the river; upper reaches of the River Blackwater, Co Cork (Photo: RaptorLIFE).


Figure 12-7: Young Japanese knotweed plants emerging from the ground (Photo: Fran Igoe).

Figure 12-7: A).; B) Broken vegetative fragments remain after winter dieback (Photo: Fran Igoe).

Location: River banks, embankments. Often occurring around bridges and associated with ground disturbance due to maintenance works.

Impact: On river banks the plants tend to form monocultures often shading out smaller streams entirely. Plants dieback in winter leaving stems, leaving exposed ground vulnerable to erosion. Can cause structural damage to built infrastructure.

Spread: Spreads either by rhizomes or vegetative fragments, so should never be cut with cuttings left in situ as these will regenerate.

Treatment: Difficult to control. Most effective method is by spraying or injecting with Glyphosphate - usually requires more than one application.

12.3.1 What to look out for:

Spring: Emergent plants. New foliage usually amongst broken and dead stems.

Summer: Plants up to 2m tall. Creamy white flowers later summer.

Autumn/winter: Plants turn rusty colour in autumn and by winter have died back leaving dead bamboo like stems on exposed ground.

Figure 12-8: Japanese knotweed stand collapsing into river leading to bank erosion (Photo: Fran Igoe).

Figure 12-9: Island of Japanese knotweed forming in middle of river from fragments broken away from original stand along river bank. River Araglin, Co Cork (Photo: RaptorLIFE).

Figure 12-10: Method for treatment of Japanese knotweed – spraying of glyphosphate herbicide using a lance and backpack (Photo: RaptorLIFE).

Figure 12.13: Stem injection is a more precise but slower method of glyphosphate herbicide delivery. There are other control methods which can be carried out, but these require more specialist expertise (Photo: RaptorLIFE).

12.4 Himalayan balsam Impatiens glandulifera

An annual plant producing numerous flowers which look similar to orchids (hence common names: poor man's orchid, policeman's helmet). Flowers (25-40mm long) are normally shades of pink but can be white. The upper petal is helmet-like and the two lower petals form a lip. The leaves are hairless and arranged opposite or in whorls of three to five, with the flowers growing out of the leaf axils. Plants root at the base but can set roots from nodes along the stem where leaves occur. Flowering from July to October, plants can grow more than 2m in height.

Figure 12-14: Himalayan balsam in flower (Photo: Fran Igoe/DuhallowLIFE).

Figure 12:15: Stand of Himalayan balsam growing along River Allow, Co Cork (Photo: Fran Igoe /DuhallowLIFE).

Location: River banks, farm drains, floodplain, damp woodland especially riparian woodland and flood embankments.

Impact: Plants dieback in winter leaving stems and exposed ground, vulnerable to erosion. Plants also outcompete native plants for pollinators as they produce considerably more nectar than native riparian plants.

Spread: Normally spread by seed but can spread by broken plant fragments with nodes. Plants can produce up to 2,000 seeds. The seed distribution method is very efficient: the fruit capsule explodes when ripe projecting the seeds up to 7m from parent plant. Seeds float and spread rapidly along watercourses. Care should be taken to ensure that seeds do not adhere to clothes or footwear if walking along watercourses where Himalayan balsam is present.

Figure 12-16: Young Himalayan balsam plants growing in shaded riparian woodland. These plants will flower later than those growing in open sunlight (Photo: Fran Igoe).

Figure 12-17: Illustration of the impact of H. balsam on native vegetation. Plants removed show extent of native vegetation exclusion by a dense stand of H. balsam (Photo: Fran Igoe (DuhallowLIFE).

Treatment: Simplest and most effective method is by pulling plant including the root.

12.4.1 What to look out for:

Spring: Emergent plants. Pointed leaves in whorls with reddish vein along centre.

Summer: Plants up to 2m tall. Flowers very distinctive.

Autumn/winter: Plants have died back – may be residual stems on exposed ground.

12.5 Gunnera or Giant Rhubarb *Gunnera tinctoria*

Large herbaceous plant with leathery umbrella shaped leaves, with spikes on the back of these leaves and along the stems; similar in appearance to Rhubarb. Forms dense colonies and can grow up to 2m in height. Produces large distinctive leaves up to 3m long and a large cone shaped flower head from spring to early summer, made up of small flowers. The fruit is orange.

Figure 12-18: Gunnera growing adjacent to a river (Photo: Zoe Devlin)

Figure 12-19: Stand of Gunnera (Photo: Wikicommons – Stan Shebs)

Location: River banks, roadsides, moist disturbed ground. Most abundant along areas with less frost exposure (e.g. west coast of Ireland (especially Galway and Mayo)).

Impact: Plants form monocultures often shading out native vegetation. Dies back in winter potentially leading to river bank erosion.

Spread: In Ireland, it is spread mostly by creeping surface rhizomes and fragments of vegetation in contaminated soil. Can also spread by seed. Plants can produce up to 250,000 seeds each.

Treatment: Most effective method is treatment with Glyphosphate. Small plants can be dug out but care must be taken to take all rhizomes out and disposed of appropriately. Cutting off and safely disposing of flower will reduce potential spread by seed.

12.5.1 What to look out for:

Spring: Emergent distinctive rhubarb shaped leaves.

Summer: Plants up to 2m tall. Produces large distinctive leaves up to 2.5m long and a large cone shaped flower head from spring to early summer, with small flowers. The fruit is orange.

Autumn/Winter: Plants die back leaving residual stems on exposed ground.

12.6 Himalayan knotweed *Persicaria wallichii*

Perennial plant with leaves (lance like leaves with reddish mid-rib) similar in appearance to Himalayan balsam. Can grow to 1.8m producing loosely clustered pinkish or white flowers from July to September. Stem similar to bamboo in appearance. Not as common as other knotweeds.

Figure 12-20: Himalayan knotweed in flower (Photo: RPS group Plc - GBNNSS).

Figure 12.21: Himalayan knotweed from a monoculture onto bare ground – shown after it has been sprayed with Glyphosphate for control (Photo: UK Crown Copyright 2009 - GBNSSS)

Location: River banks, outside gardens along roadsides.

Impact: Low impact but locally form monocultures often shading out native vegetation. Dieback in winter can leave areas vulnerable to erosion.

Spread: Spreads by rhizomes and vegetative propagation.

Treatment: Has shallow roots so can be pulled up easily. Disposal needs to be managed and cutting without proper site management is not advised. Treatment with Glyphosphate also an option.

12.6.1 What to look out for:

Spring: Emergent plants. New foliage usually amongst broken and dead stems.

Summer: Flowers in July to September.

Autumn/winter: Plants die back in winter leaving brittle brown stems.

Fragrant (vanilla-scented). Flowering from November to March.

Aerial view of Himalayan Knotweed infestation – reddish growth along river.

Figure 12.22: Field view of same monoculture of Himalayan knotweed monoculture growing along flood embankments on the Mulkear River – note location of pylon on both images (Photo: Ruairí Ó Conchúir (Mulkear LIFE)).

12.7 Winter heliotrope *Petasites fragrans*

Winter heliotrope has distinctive shiny-green kidney shaped leaves (20-30cm) which are hairless above and hairy below. Forms carpets along the ground. Flowers (white to lilac) are fragrant (vanilla-scented); flowering from November to March.

Figure 12-23: Winter heliotrope which displays distinctive flowers in Winter (Photo: Fran Igoe)

Figure 12.24: Butterbur, a native plant not to be confused with Winter heliotrope – displays larger flowers and less smooth leaves (Photo: Fran Igoe)

Similar in appearance to the native Butterbur which has larger leaves (50cm-1m on stalks, 1.5m high) with small whitish or pink-red flowers on thick stems up to 40cm. Flowers unscented, flowering from March to May.
Location: River banks, outside gardens along roadsides.
Impact: It is very invasive as it can regenerate itself from a very small part of its fleshy rhizome, blocking out light from native plants and dominating the area.
Spread: Spreads rapidly by rhizomes underground. No males in Ireland so seeding is not known to be an issue.
Treatment: Most effective treatment is with Glyphosphate. Can be removed and buried, however there is risk of spread by rhizomes.

12.7.1 What to look out for:

Spring: Flowers (white to lilac) until March.
Summer: No flowers, smooth green kidney shaped leaves visible.
Autumn/winter: Flowers (white to lilac) visible.

Figure 12.25**:** Winter heliotrope spreading beside a hedge – this can also happen along a riparian zone of a river (Photo: Wikimedia Commons – Jane White).

12.8 Useful References

Invasive species information and identification keys available at:

- http://www.biodiversityireland.ie/projects/invasive-species/id-guides/
- http://www.nonnativespecies.org/index.cfm?sectionid=47
- www.fisheriesireland.ie
- www.invasivespecies.com

Examples of on the ground management available at:

- www.duhallowlife.com
- www.raptorlife.com
- www.mulkearlife.com

13 Catchment walks – Landfills and Unauthorised Waste Disposal Sites

13.1 Purpose

This section provides guidance on local catchment assessments in catchments where municipal waste landfills or unauthorised waste disposal sites are potential significant pressures on water quality. It is intended to guide the assessor on:

- Understanding the risks associated with these pressures to allow for a more detailed desk-based assessment of their potential impact.
- Guiding the assessor on what to look when carrying out a local catchment assessment in the vicinity of these pressures.

13.2 Significance

13.2.1 Landfills

13.2.1.1 Landfills and Water Quality Risk

Landfill water quality impacts are mainly related to the following:

- Leachate breakout to surface waters (risk associated with older unlined landfill cells).
- Leachate migration to groundwater (risk associated with older unlined landfill cells).
- Discharge of contaminated surface water.

Different types of municipal landfills pose different levels of risk in relation to leachate breakout/migration/risk of stormwater contamination. For simplicity, they are divided here into three categories:

i. licensed engineered facility with all cells appropriately lined (operational or closed).
ii. licensed engineered facility which includes some older unlined cells (operational or closed).
iii. historic unregulated landfills (all closed).

Note that whether a landfill is still operational or closed in the recent past is not hugely relevant in terms of leachate pollutant concentrations because high strength polluting leachate can be produced for decades after waste deposition. Operational facilities may pose a greater potential risk of stormwater contamination due to sediment loss to stormwater during earthworks or accidental spillage etc but this risk is offset by the high level of monitoring and enforcement to which licensed facilities are subject.

i. Licensed engineered facilities with all cells lined

Municipal landfills in this first category can be assumed to be lowest risk. These sites are subject to stringent EPA licence conditions and are designed, constructed, managed, operated and maintained under licence to minimise environmental risk. In brief, while leachate may contain very high levels of pollutant substances, risk of leachate migration is minimised because the leachate is collected from lined cells by level-controlled pumps and piped to holding tanks for treatment offsite (or onsite in some cases). Licence conditions specify a maximum acceptable head of leachate in the waste cells and all steps in the process are SCADA controlled. Stormwater is generally held in lined stormwater ponds under continuous monitoring for key parameters and discharged from approved locations on site only when parameter concentrations are within licence limits. The EPA licence will include stringent conditions for monitoring and managing environmental risk. EPA licence files will hold large volumes of data on these sites including monitoring data for surface and groundwater. Groundwater gradient will have been established by the licensee, enabling you to determine the most likely surface water receptor at desk study stage. There should also be a groundwater risk report on the files where the EPA considered this to be warranted.

ii. Licensed engineered facilities with older unlined filled cells

Landfills in the second category may include engineered lined cells in the newer landfill section (as for the first category) but they also have older unlined cells with associated risk of water pollution, particularly to groundwater; surface water risk will be managed under the site licence. Stringent EPA licence conditions will apply to these facilities. However, they may have been in operation since the 1960's and 1970's with waste deposited in cells with no barrier to protect against leachate migration. In some of the higher risk sites, the scope of the facility's EPA licence issued in the early 2000's may have restricted operation to closure and capping only. The EPA licences for these facilities may include conditions for retrofitting abstraction wells into the waste body in the unlined cells but leachate abstraction from an unlined system is more difficult to control and manage effectively. As for i) above, EPA licence files will hold considerable volumes of data on these sites.

iii. Historic unregulated waste disposal sites

Landfills in the third category are those local authority waste disposal sites which were in operation after entry into force of the Waste Framework Directive in 1977 but which closed prior to the introduction of the Waste Management Licensing Regulations in 1997. The local authority will have an inventory of these facilities. They may also have an inventory of older unlicensed private waste disposal facilities that were in operation after 1977.
Risk assessments have been undertaken for these sites in accordance with the EPA Code of Practice for environmental risk assessment of unregulated waste disposal sites (2007). Tier 1 Risk Assessments should have been carried out for all sites. This was an initial (mainly desk based) screening process that allowed for the prioritisation of sites into high, moderate and low risk. Tier 2 and Tier 3 assessments were undertaken in accordance with the Code if warranted by the level of environmental risk. For highest risk sites, applications have been made to the EPA for Certificates of Authorisation. To date, twenty-two sites have had certificates issued and local authorities have made applications for a further ten sites. Where applications have been made to the EPA, you can view relevant documents on their website via this link Environmental Protection Agency (epa.ie)

13.2.1.2 Landfill Leachate

Landfill leachate is produced when rainwater percolates down through the waste body or, in older unlined landfills, where groundwater infiltrates the lower waste body. The water gathers contaminants as it moves through the waste. The concentration of these contaminants is driven by a number of factors including the type of waste, the age of the waste and the amount of water percolating/flushing through it. These three factors are briefly described below but other variables also play a part, including temperature, rainfall, moisture content of the waste, level of compaction, waste depth and landfill design etc.

- **Waste type**

The focus of this chapter is on municipal solid waste landfills but some general information on different waste types is provided below for background information:

All wastes are classified under EU law. Each waste stream is assigned a six-digit code in the European List of Waste (LoW), based on the source (type of industry) and activity which gave rise to the waste.

Municipal waste is defined as household and similar commercial, industrial and institutional waste. Waste streams are described in Chapter 20 of the European List of Waste and include some hazardous waste streams (marked with an asterix against the six digit code). Landfill of these hazardous streams is prohibited in modern, licensed facilities.

Inert waste is specifically defined in the Waste Management (Facility Permit and Registration) Regulations, 2007, as amended, as waste that:

- doesn't undergo any significant physical, chemical or biological transformations,
- will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter, or be adversely affected by other matter, including waters, with which is comes into contact in a way that causes or is likely to cause environmental pollution, or
- in particular will not endanger the quality of surface water or groundwater.

Inert waste landfills therefore present a very low risk of water pollution (other than possible elevated sediment in stormwater runoff). One exception which has caused problems in the past is where the waste is contaminated with a high content of gypsum. Gypsum breakdown under anaerobic conditions produces hydrogen sulphide. This is a toxic and odorous gas with potential to significantly deplete dissolved oxygen concentrations in receiving waters if discharged directly to waters.

Hazardous waste is defined as waste which displays one or more of the hazardous properties listed in the second schedule of the Waste Management Act 1996, as amended. Classification is based on the EU List of Waste (LoW) mentioned above. Any entry in the LoW that has an asterisk is a hazardous waste (until proven otherwise). There are currently no operational hazardous waste landfills in Ireland although older landfills which operated pre-licensing may have included a component of hazardous waste.

Modern municipal waste landfill facilities are licensed to landfill non-hazardous residual municipal waste (i.e. waste from which the recyclable and hazardous fractions have been removed) with limitations also on the biodegradable content of the waste stream. The scope of the EPA licence will specify the type of waste permitted for landfill and whether other (non-hazardous) streams can also be accepted. Older unlicensed landfills would not have had restrictions in terms of waste acceptance and may possibly have accepted industrial non-municipal waste streams if there were industries operating within a reasonable distance of the facility.

- **Waste age**

  Waste age impacts on leachate constituent concentrations because at different stages of degradation, different compounds are produced by the microorganisms breaking down the waste. The stages of waste degradation are (i) aerobic, (ii) hydrolysis and fermentation, (iii) acetogenesis (iv) methanogenic and finally (v) aerobic phase again. Stages iii and iv are most significant in terms of leachate organic and ammonium contaminant concentrations and can take many decades to complete. Table 13.1 gives an example of the range of key parameter concentrations in methanogenic leachate.

- **Leachate volume**

  The amount of water percolating through the waste body obviously affects the leachate concentration. Higher volumes will result in a more dilute leachate. In newer engineered lined landfills, groundwater infiltration should not be an issue because the facility will have been designed and constructed in accordance with EPA standards to minimise groundwater risk. The only driver in terms of leachate volume in this type of facility should be the amount of rainfall falling on the waste body and whether or not the waste has been capped (sealed) with a synthetic liner and/or clay. Properly lined and capped landfills will produce lower volumes of a more concentrated leachate, which is pumped out of the landfill cells for treatment in a SCADA-controlled process in accordance with the operator's EPA licence conditions. In landfills with older unlined waste cells, leachate is produced both by rainwater percolating vertically down through the waste body and by groundwater moving horizontally through the lower waste body, assuming that the lowest level of waste is below the maximum water table height. Leachate volumes may be quite high but concentrations of pollutant parameters should reduce more rapidly with time because of the flushing effect. In some older landfills adjacent to tidal waters a deliberate 'dilute and disperse' strategy has been applied under the EPA licence.

13.2.1.3 Leachate indicator parameters

The range of key parameters in methanogenic landfill leachate is shown in table 13.1. Parameters shown in bold font are potentially better indicators of leachate contamination. For municipal landfills, ammonium is probably the most useful leachate indicator parameter because levels can be extremely high and also because concentrations can remain elevated for decades after waste deposition has ended. The concentration of ammonium in methanogenic leachate has been reported to range from low hundreds to greater than 2,000ppm.

Other parameters which may indicate leachate contamination are conductivity, chloride, alkalinity and metals, particularly iron, calcium, sodium, magnesium and potassium. Leachate can also contain high levels of organic material. However BOD is not always a useful indicator of organic pollution from landfill leachate because of the inhibitory effect of some of the leachate constituent parameters. Leachate COD and TOC results are more reliable. Low pH can be a useful indicator of leachate migration in early stage waste degradation but in landfill cells in which waste degradation has reached the methanogenic stage, leachate pH levels return to normal range.

Phosphate levels are rarely particularly elevated in landfill leachate because phosphate is less mobile through the waste body.

Table 13.1: Summary of composition of methanogenic leachates sampled from large landfills with a relatively dry high waste input

	Overall Range		**Overall Values**	
Parameter	**Minimum**	**Maximum**	**Median**	**Mean**
pH (pH units)	6.8	8.2	7.35	7.52
Conductivity (us/cm)	**5,990**	**19,300**	**10,000**	**11,502**
Alkalinity ($CaCO_3$) (mg/l)	**3,000**	**9,130**	**5,000**	**5,376**
COD (mg/l)	**622**	**8,000**	**1,770**	**2,307**
BOD_5 (mg/l)	**97**	**1,770**	**253**	**374**
TOC (mg/l)	**184**	**2,270**	**555**	**733**
Ammonium (mg/l N)	**283**	**2,040**	**902**	**889**
Nitrate (mg/l N)	0.2	2.1	0.7	0.86
Nitrite (mg/l N)	<0.01	1.3	0.09	0.17
Sulphate (mg/l)	5	322	35	67
Phosphate (mg/l P)	0.3	18.4	2.7	4.3
Chloride (mg/l)	**570**	**4,710**	**1,950**	**2,074**
Sodium (mg/l)	**474**	**3,650**	**1,400**	**1,480**
Magnesium (mg/l)	**40**	**1,580**	**166**	**250**
Potassium (mg/l)	**100**	**1,580**	**791**	**854**
Calcium (mg/l)	**23**	**501**	**117**	**151**
Manganese (mg/l)	0.04	3.59	0.30	0.46
Iron (mg/l)	**1.6**	**160**	**15.3**	**27.4**

Data source: 'Landfill Manuals, Landfill Site Design', EPA 2000. Original source UK Department of the Environment (1995)

13.2.2 Unauthorised waste disposal sites

This section deals with fly tipped sites. While there in no single or legal definition of fly tipping, it is generally viewed as the illegal act of discarding larger quantities of waste, and can be differentiated from littering and dumping, which are typified by single or small items of waste.

Dumping may go unnoticed for long periods because individuals involved in this activity tend to use remote rural areas like forestry or bogs. Drainage ditches and natural water courses in such areas seem especially prone to this activity, presumably chosen in an effort to further conceal the dumping.

Fly tipped waste can include domestic, construction, industrial or agricultural wastes. It can also include hazardous substances such as oils, paints, waste chemicals and other 'problem' waste streams that a person may consider expensive or difficult to dispose of correctly.

Given the varying nature of fly tipping incidences, it is difficult to predict the scale or particular risks posed to the environment by such incidents. Inert waste poses minimal risk to waters but waste with a hazardous component poses a direct threat to waters where a pathway exists. Significant volumes of dumped domestic, food or green waste can cause water pollution incidents when allowed to degrade over time, while waste materials containing gypsum can interact with organic materials that result in the release of hydrogen sulphide.

The greater the volume of waste deposited, the greater the associated risk. Whether or not the fly tipping should be considered a significant pressure on the waterbody will depend on the volumes deposited and proximity to the WFD monitoring point. Runoff from fly tipped areas will be somewhat like 'young' leachate in composition. Methanogenic leachate is unlikely to form because of higher oxygen levels although there may be anaerobic pockets in the waste body. pH levels may be low in runoff from fly tipped waste. The runoff may also have an organic and nutrient load and a hazardous component if hazardous materials have been deposited with the waste.

13.3 Walking the catchment

13.3.1 What to look for

13.3.1.1 Landfills

Walk the streams in the vicinity of the site footprint. Note that for licensed landfills which continue to operate either as a landfill or a civic amenity site, access will be restricted as for an industrial facility, so you will not be free to walk the site. However, your desk study should have enabled you to identify licensed discharge locations for stormwater or treated leachate so you can check water quality up and downstream on the main channel, outside the facility footprint. There may also be biological monitoring results upstream and downstream undertaken in compliance with the facility licence.

Groundwater pathways may be significant. Available data for licensed facilities should include information on groundwater flow direction. This will enable you to identify at desk study stage the reaches of the relevant surface water receptor that are upstream and downstream of the groundwater contribution from the landfill footprint. This information may not be available for the historic unregulated sites, but the risk assessments undertaken for these sites will have identified whether leachate migration to groundwater is a significant risk. If so and if no groundwater well data are available, assume that the groundwater flow direction follows the topography so identify the most likely upstream and downstream assessment locations on that basis.

Use SSIS where possible to assess upstream and downstream of the discharge point/s and of the facility footprint.

Look for signs of organic input (low dissolved oxygen).

Ammonium is a very useful indicator of contamination with untreated leachate, either via surface or groundwater pathways.

Iron may also be a useful indicator parameter

Visual indicators closer to the waste body:

- Iron seepage (orange staining) may indicate leachate breakout.
- Brown/burnt looking vegetation may also indicate leachate breakout


Figure 13.1: Leachate breakout from an unlined landfill (Photo: Kate Tynan).

In the above example, leachate breakout was observed during a stream walk in a priority area for action. The pathway was found to be an old stormwater pipe discharging directly from the landfill site to the river (figure 13.2). Ammonium and BOD levels were elevated in the leachate but not in the receiving waters because leachate flow was quite low. The scientists concluded that landfill is unlikely to be a significant pressure on this waterbody. However the issue has been referred to the local authority as a protect referral.


Figure 13.2: Leachate breakout from an unlined landfill (via an old stormwater pipe) (Photo: Kate Tynan).

Landfill was identified as a significant pressure in one PAA waterbody by means of SSIS assessment supported by ammonium and chloride monitoring. The landfill is situated 2.5km upstream of the WFD monitoring point driving status in this waterbody. River channel SSIS assessment results were indicative of impact along the 2.5km stretch from the landfill site down to the WFD monitoring station. Ammonium levels were significantly elevated immediately downstream of the landfill. The levels decreased with distance from the landfill but they remained in breach of the Environmental Quality Standard for ammonium at the WFD monitoring station. A similar pattern was observed with chloride levels. Other notable observations included low dissolved oxygen and elevated conductivity immediately downstream of the landfill relative to other sites. The results were provided to the EPA and the landfill has now been added as a new significant pressure in the WFD app further characterisation page for this waterbody.

13.3.1.2 Unauthorised waste disposal sites

While fly tipping is always an unsightly and polluting activity and it carries a public health risk, it is only likely to be a significant pressure on a good status objective waterbody if the volumes dumped are large relative to the watercourse or if the location is close to the WFD monitoring point. High status sites will obviously be more sensitive to impact (see figure 13.1).

If fly tipping has gone on at the location for many years without clean up, the volume of waste could be quite significant. Even if no waste is visible at the time, the presence of a 'no dumping' sign might suggest ongoing issues here, possibly with a recent clean up. Check with the Local Authority.

Look for evidence of septic runoff to the river/stream.

Undertake SSIS or rapid assessment upstream and downstream of the tipping area. If this is located beside a tributary, also assess the main channel upstream and downstream of the confluence.

Measure ammonium, chloride, nitrate, BOD, pH and conductivity upstream and downstream of the fly tipped area. Note that chemistry sampling may not generate useful information because of fluctuations in the volume of runoff from the fly tipped waste. Sampling for field and nutrient parameters should ideally be undertaken when river levels are low and during or after rainfall when there is more likely to be runoff from the dumped waste. However this ideal weather/river level scenario is not likely to frequently coincide with field assessments. Note that biological assessment (SSIS or rapid assessment) will be a much more useful indicator of impact than chemistry when assessing this type of pressure.

Figure 13.3: Fly tipping on a tributary stream upstream of the WFD monitoring point on a high status objective waterbody (Photo: Mairead Shore).

In the above example, extensive fly tipping was observed in a forested area on two tributary streams flowing into the main river channel one kilometre upstream of the WFD monitoring point. Local catchment assessment confirmed this as the significant pressure impacting on water quality at the WFD monitoring point. Conclusions were drawn based on biological assessment findings. pH levels downstream of the discharge were lower than normal for the catchment but otherwise chemistry sampling results were inconclusive.

Figure 13.4: illegal dumping and waste burning adjacent to river bank approximately 1.5km upstream of the WFD monitoring point on a high status site. (Photo: Paul O'Callaghan).

In the above example, waste has obviously been burned at the site. This pressure is still under investigation but ash thickness and layers suggest long term use of this site for waste disposal/burning.

13.4 Mitigation options

13.4.1 Landfills

If landfill is confirmed as a significant pressure in the local catchment assessment, the details should be notified to the relevant authority for further investigation. This is the EPA in the case of a licensed facility and the local authority or the EPA in the case of historic unregulated sites (depending on whether a certificate of authorisation has been issued for the site). The relevant agency can then determine from their own investigations if the impact is associated with above ground leachate breakout and migration. These breakouts can be fairly easily addressed by improved capping and (possibly) additional leachate abstraction. Leachate migration via groundwater pathways is much more challenging to address and is not covered in this manual. Providing robust evidence of downstream impact should help the responsible authority prioritise measures to minimise losses via this pathway e.g. installation of additional abstraction wells.

13.4.2 Unauthorised waste disposal sites

In instances where fly tipped waste is encountered, the appropriate action is to report the incident to the waste enforcement unit of the relevant Local Authority. Removal is the only appropriate mitigation measure where fly tipped waste has been uncovered. Ultimately the removal of illegally dumped waste is the responsibility of the landowner i.e. local authority, forestry owner, farmer, etc. A failure to take adequate action is considered an offence under the Waste Management Act.

There is no acceptable form of in situ treatment or mitigation. All illegally dumped waste must be removed and directed to an appropriately authorised waste facility.

13.5 Useful References

Landfill Manuals Landfill Site design, EPA 2000. Link: Landfill Site (epa.ie)

Landfill Manuals Landfill Restoration and Aftercare, EPA 1999. Link: EPA-Landfill-Restoration-and-Aftercare.pdf

CODE OF PRACTICE Environmental Risk Assessment for Unregulated Waste Disposal Sites, EPA 2007. Link: Microsoft Word - CoP WASTE FINAL Publication300307.doc (epa.ie)

EPA Research Report No. 214 Suitability of Municipal Wastewater Treatment Plants for the Treatment of Landfill Leachate, Brennan et Al, 2017. Link: EPA-RR-214_web-Essentra.pdf

Persistent Organic Pollutants, Landfill Leachate Sampling Study. Final report for EPA, AECOM, 2021 Link: POPs-in-landfill-leachate-final-report.pdf (epa.ie)

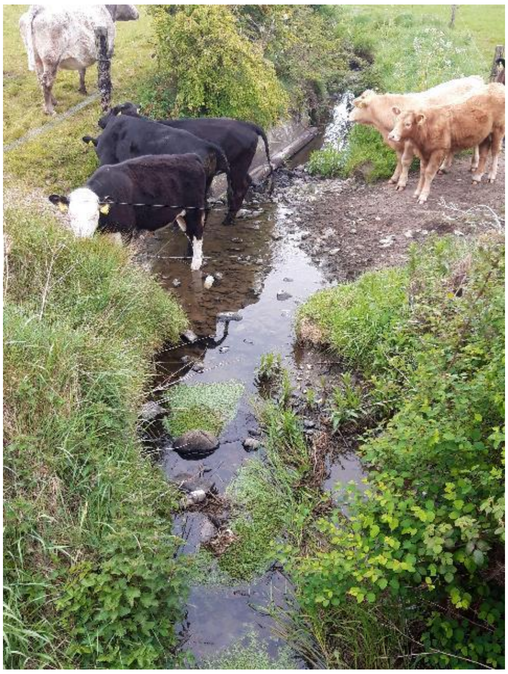
Waste Classification List of Waste & Determining if Waste is Hazardous or Non-hazardous, EPA 2018 Link: 2019--FULL-template.pdf (epa.ie)

Note that detailed information about licensed landfill sites (and all EPA licensed sites) can be accessed on the EPA website at the Search for a Licence/Permit | Environmental Protection Agency (epa.ie) portal. This includes both licence application information – the inspector's report is a valuable document – and enforcement documents, site visit reports, licensee and EPA monitoring etc. If any of these have been submitted since 2013, they'll be accessible on this resource. Older submissions (pre-2013) are available in EPA archives, but there would be a retrieval period of possibly a few weeks, as well as a trip to an EPA office to view and copy them. For additional information, EPA enforcement teams can be contacted in their offices in Castlebar, Cork, Dublin, Kilkenny and Wexford, details on www.epa.ie

Link to search for a certificate of authorisation for a closed (historic) landfill Environmental Protection Agency (epa.ie)

14 Appendix 1: A Guide to Assessing Animal Access Points






Produced by Ruth Hennessy and the LAWPRO Agricultural Working Group

Local Authority Waters Programme

vibrant communities | catchment assessment | healthy waters

1. Introduction

The purpose of this briefing note is to provide guidance to catchment scientists in assessing the relative importance of animal access points in a water body where agriculture is a significant pressure so that the most appropriate mitigation action is identified.

Animal access points along the riverbank can be deleterious to water quality and are regularly cited as an issue by our key partners and stakeholders. Access points have different functions on the farm; provide a source of water for livestock, provide an unfenced natural field boundary or as a navigation route required for access to separated land parcels. Access is predominantly by animals often cattle, sheep or horses but may also be mechanical by farm machinery.

While access points are visually unappealing and do result in an environmental impact, there are limited circumstances in which their impacts are the primary driver of the Significant Issue[30] when considered at waterbody scale. This briefing note is intended to support catchment scientists in determining when animal access should be included in the fieldwork plan for a waterbody and in support of the level of fieldwork required to confirm animal access as the driver of the Significant Issue and requiring mitigation.

What do we know about the impacts of animal access in the waterbody?

A review of existing literature has confirmed animal access has a clearly defined impact on sediment and morphology in the waterbody. Morphological changes in the waterbody due to access (both animal and mechanical) is regularly noted during Local Catchment Assessment (LCA). This morphological impact can result in artificial widening and shallowing of the stream, removal of riparian vegetation, compaction and can provide a pathway for increased runoff from adjoining land. Suspended sediment or sediment accumulation is often visible at these points. Nutrient input to waterbodies is also expected at animal access points, as cattle are known to preferentially defecate in streams. However, findings on nutrient impact in these events are mixed and often depend on other nutrient pressures being present such as adjoining Critical Source Areas (CSA) for phosphorous or sediment. The morphological changes described above often provide a direct pathway for overland flow to deliver nutrients and sediment to the waterbody from the surrounding landscape.

More clearly defined in research is the impact due to the deposition of microbes (Cryptosporidium, Giardia spp., E. Coli etc) with sediment also acting as a reservoir for these microbes with clear concerns for human health particularly in areas of drinking water supply, bathing areas and shellfish feeder streams. While the overall impacts on ecology are not as clear with limited literature almost entirely focused on macroinvertebrates, it is accepted that access is likely to negatively impact ecology locally while wider catchment scale effects are less clear. In high status water bodies and where particularly sensitive species are present (e.g. Freshwater Pearl Mussel) animal access to the stream is likely to be having a significant impact.

An overview of the process

The flow chart (**Figure 1**) is provided to guide catchment scientists in the assessment of access pressures in their Priority Area for Action (PAA) from desk study stage to referral process through three main steps explained below.

Step 1: Desk Study: Tools to assess access issues
Step 2: Field assessment observations
Step 3: Decision tree for the assessment of animal access points

[30] The significant issue is the environmental stressor that is known to be causing reduced status, usually nutrients (phosphate/nitrogen), sediment, but could also be pathogens, toxic chemicals (pesticides) etc.

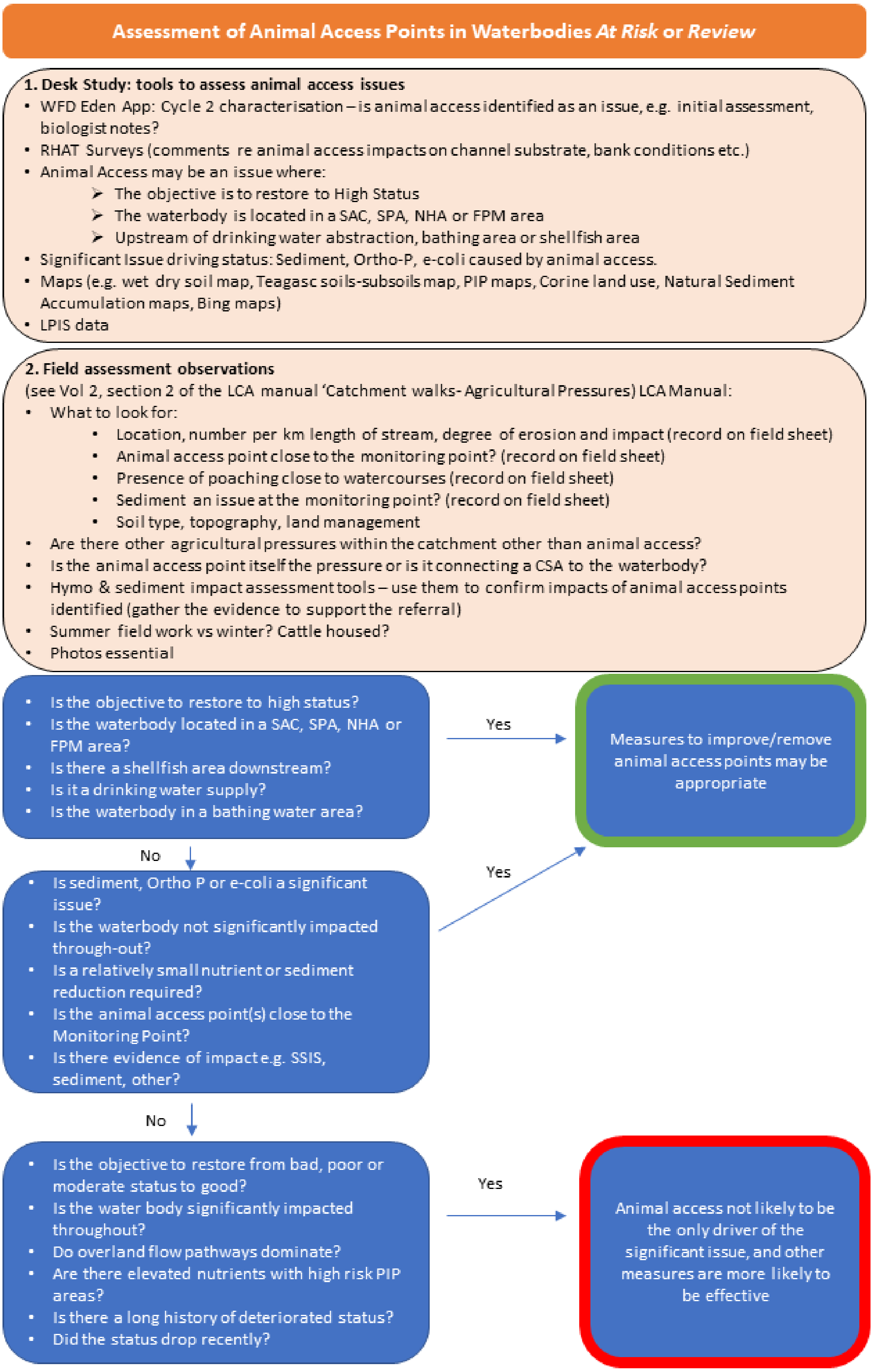


Figure 6 Flow Chart Summarising Steps in the Assessment of Animal Access Points

2. Step 1 The Desk Study: Tools available to identify Access as a Possible Pressure

A Desk Study prepared for each PAA includes a summary of the key datasets which are relevant to water quality in the catchment. A review of these datasets combined with consultation with the main stakeholders may highlight waterbodies where issues of access to the waterbody have already been identified and should provide an understanding of the expected agricultural pressures at a local, reach and/or catchment scale. **Table 1** below summaries the key indicators in the Desk Study which point towards access to the waterbody as a possible pressure.

Table 2 Key Indicators from the Desk Study which suggest access to the waterbody may be a Possible Pressure

Access points to the waterbody should be considered ONLY where the desk study indicates some/all of the following:

- **The waterbody downstream is particularly sensitive (high status objective, water dependent protected species, drinking, bathing, or shellfish water dependent supplies).**
- **where agriculture is the <u>only</u> *Significant Pressure*.**
- **where phosphate, sediment or microbes are the *Significant Issue*.**
- **where animal access points act as pathways linking critical source areas to the waterbody.**
- **where animal access points are in close proximity to sensitive receptors such as monitoring stations.**

Where these scenarios are identified in the desk study access to the waterbody may be deemed as possibly having a *significant impact* and Local Catchment Assessment work in assessing access should be focused in these waterbodies.

Many of the datasets reviewed in the desk study can provide clues or pointers that allow catchment scientists to rule in or out Animal Access as a pressure within a waterbody. These tools should be used to determine if further assessment of this issue in the field is required, or to help in the interpretation of results after carrying out LCA. These datasets provide information on the Receptor, the Pathways linking to the waterbody and on the Pressures within the catchments. While this document touches on some of the tools available in assessing animal access points, this is not an exhaustive list and other measures, or tools may also be appropriate in certain circumstances.

2.1 Receptor Information

The nature of the waterbody is a key determinant

The sensitivity of the waterbody is an important factor to be considered with animal access. Animal access points are more likely to be a pressure in high status waterbodies, waterbodies supporting water dependent sensitive species or feeder streams to drinking water abstraction, bathing or shellfish waters. Any such designations either within the subject waterbody or downstream of the waterbody must be considered.

Phosphate, sediment, or microbes are the Significant Issues

In determining the impact of animal access points, it is important to keep the focus on the significant issue in the waterbody. Phosphate, sediment, or microbes are the significant issues which could be as a result of animal access to a waterbody. Hydromorphological impacts may also be observed due to access, both animal and mechanical. Other significant issues such as nitrogen will not be as a result of animal access thereby ruling out animal access as a pressure in Nitrate impacted waterbodies.

Proximity to Monitoring Stations

Access points located immediately upstream of monitoring stations can have a significant impact on the water quality status of the overall waterbody. Where animal access points are known to exist at the monitoring point or a short distance upstream of the monitoring point, consideration should be given to whether these access points are reducing the status of the waterbody due to their proximity. In certain cases, proximity to monitoring stations will mean that these access points are having an impact on the waterbody. While the distance from the monitoring point should be considered on a case by case basis, certainly access points within 100 metres of the monitoring station should be given greater consideration and the impact on the monitoring station should be assessed. The localised impact of one access point may be sufficient to bring down the overall status of the entire waterbody.

2.2 Pathways

Animal Access Points act as Pathways linking Critical Source Areas

The *Significant Issues* of phosphate, sediment, and *E. coli* mentioned above are linked to specific pathways which may be from point or diffuse sources. The animal access points in themselves can act as a pathway linking critical source areas to streams or waterbodies. They often create a depression in the landscape which act as a breakthrough point in the field margin to the stream. As a result, it is important to consider if the animal access point itself is the pressure or is it a pathway linking the actual pressure such as a CSA for phosphate loss etc. to the stream. In these instances, removing the animal access points may be the appropriate measure to mitigate the pressure (e.g. nutrient loss from land) and break the pathway. It will be important to be explicit in detail when recording the animal access points as pathways so as to determine which impact is occurring. This will allow the development of targeted measures.

Natural Sediment Accumulation Maps

Natural Sediment Accumulation GIS layers were derived from the soils, subsoils permeability and channel gradient datasets and show propensity for a waterbody to accumulate fine sediment naturally. These are useful as a guide at desk study stage but also should be consulted following LCA where sediment has been recorded to determine if this sediment may be a natural phenomenon or is aggravated by animal access in the waterbody.

- Data description and interpretation protocol available in Sediment Accumulation Maps Guidance located in LAWSAT - Documents\10.0 Working Groups\Hymo Sediment WG\1. Guidance Documents

RHAT datasets (local scale – High Status Objective)

River Habitat Assessment Technique (RHAT) is currently being used to assign hydromorphological status at high status waterbodies or surveillance sites only. This assessment is carried out at the site scale (i.e. < 500 m).

RHAT assessments include assessor comments in relation to (i) channel form, (ii) channel vegetation, (iii) channel substrate conditions, (iv) channel barriers to connectivity, (v) bank structure, (vi) bank and (vii) riparian landcover vegetation, and (viii) floodplain connectivity. These comments may refer to the presence of animal access and where they may be having an impact.

- RHAT datasets available at: GISData - Documents\Excel_NationalData \RHAT_datasets

Many other datasets used as standard in the desk study will help in informing the reader in the assessment of animal access within a waterbody and these should also be considered including the normal geological and physiological datasets which we have in our tool kit to determine the significance of impact.

2.3 Pressures

Agriculture is the only Significant Pressure

The impact of individual animal access points on an entire waterbody is probably limited, but cumulatively animal access points can have a significant impact. This is particularly the case where there are no other *Significant Pressure*s i.e. where agriculture has been deemed the sole *Significant Pressure* and all other pressures have been assessed as not significantly impacting. Where other *Significant Pressures* exist, these are likely to be having a greater impact than animal access points. It is advised to discern whether the impact on the waterbody is localised or extensive based on the amount of reach the animals have access to. A rule of thumb ask the question "if this individual or multiple access point pressure(s) were removed would water quality improve to good / high status?"

Pollution Impact Potential Maps V3: PIP-P and Critical Source Areas

Animal access points can lead to or coincide with depressions in the landscape which facilitate easy access to the waterbody for livestock. These depressions may act as funnels collecting water from the surrounding land before discharging it to the waterbody at these locations. This should be considered where overland flow is the pathway and phosphate or sediment are the significant issues and where sources of phosphate or sediment are available on the surrounding lands. The Pollution Impact Potential Maps: PIP-P V3 provide a useful tool in considering this, both ahead of LCA work and following observations in the field. These depressions would be expected to coincide with the focused Delivery Paths/Points illustrated in the PIP-P maps. Assessing delivery points and corresponding pathways as indicated in these maps will help to identify the animal access points which are facilitating such pathways (**Figure 2**). It must be remembered that in waterbodies with High PIP areas for phosphate the animal access point on its own is unlikely to be the driver of phosphate issues in the waterbody, overland flows are likely to be a significant factor facilitated by animal access points acting as pathways.

Use of LPIS and Bing Maps

Where animal access is potentially a pressure in the catchment, an assessment of Bing Maps and LPIS data sets may assist in identifying potential animal access locations. Animal access at or close to the monitoring point is likely to be of most significance. Starting at the monitoring point carefully review satellite imagery and carry out a virtual stream walk. Where resolutions are good, or access points are particularly pronounced, it may be possible to identify these points for further assessment in LCA. Satellite imagery often provides clues to farming enterprise e.g. dairy farm where farm roadways and paddocks are evident, main grazing platform attached to a yard versus out farm with no buildings, rushy fields versus intensively managed, highly fertilised perennial ryegrass swards, even clearly visible livestock in a field all can provide indications as to the enterprise practiced at the time of imagery.

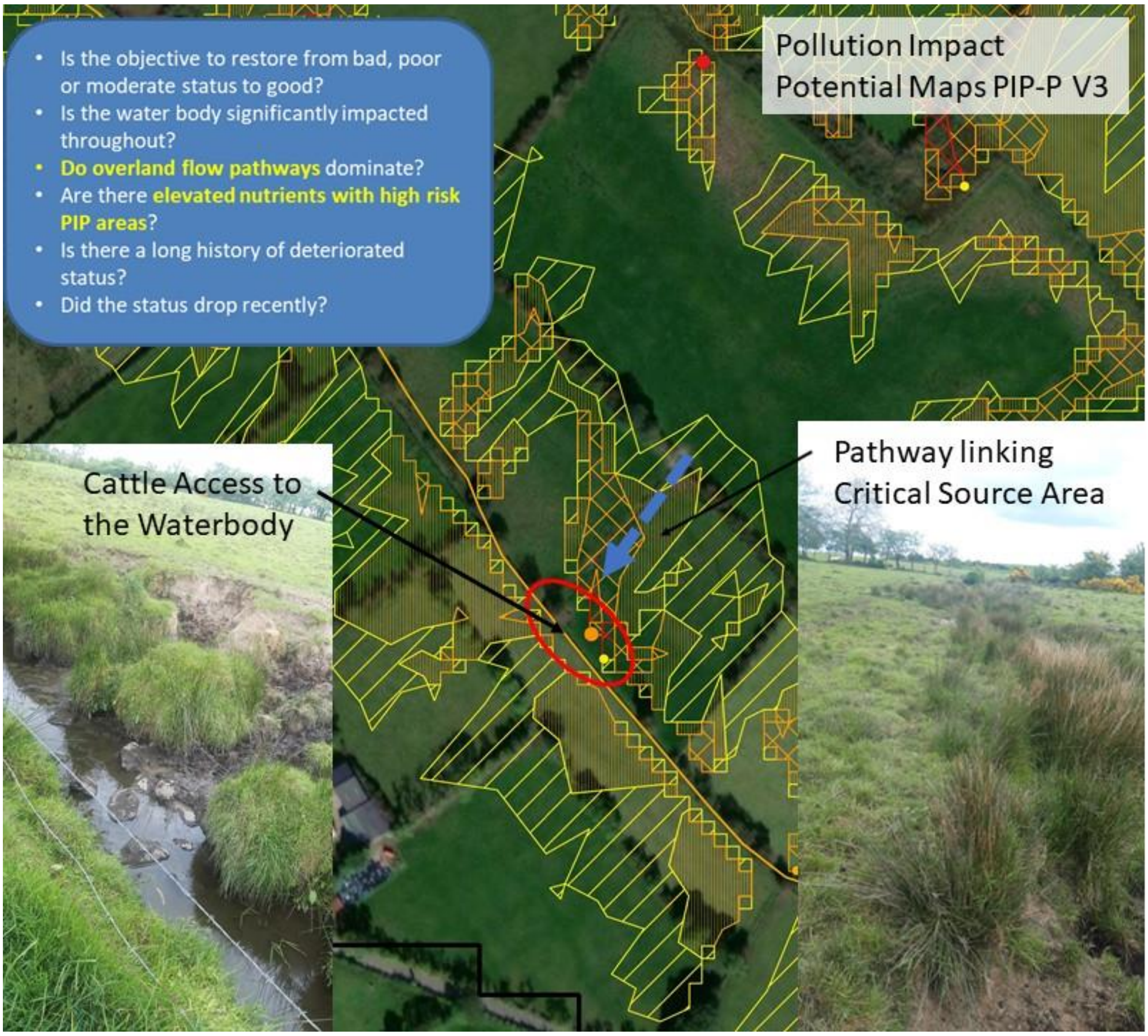


Figure 7 Pollution Impact Potential Maps indicating Cattle Access Points acting as a Pathway Linking Critical Source Areas to the waterbody

Use LPIS data information in addition to the satellite imagery to identify:

- Crop type – distinguish between permanent or recently laid pasture, tillage crops, habitat etc.
- Is there bovine livestock on this farm i.e. NPH figure indicates bovine livestock present. A word of caution is that this does not take account of other non-bovine livestock e.g. Ovine, equine etc) nor does it include imported slurry (cattle, pig or poultry manure) which may be applied.
- Consider the stocking rate? Kg/Nitrogen/ha/yr e.g. A dairy cow excretes 89 kg N/ha/yr and a lowland ewe and lamb excretes 15 kg N/ha/yr. Stocking rates below 50kg N/Ha are likely to result in very low pressure on drinking points while stocking rates of greater than 150kg N/ha would make it very difficult to manage livestock watering in the waterbody and you would expect it to be associated with alternative piped water supplies. The exception typically being where the issue is associated with an out farm and grazing intensity is lower than on the main farm. In very general terms impacting animal access points are more likely to be associated with stocking rates between 50 and 140kgN/Ha but of course there are exceptions. Assess surrounding land for intensity of use and consider if it corresponds with LPIS indicated stocking rate.

- A further clue might be a farmyard associated with the holding and this is evident in both satellite imagery and associated LPIS information. Is a piped water supply likely to be available or is the land dependent on the waterbody for water for animals? LPIS can be used to show all parcels belonging to an individual farmer and this quickly highlights the centre of the farm's main enterprise. An existing farmyard associated with the land would usually suggest that piped water is available. Indications that this is not the farmers main holding may suggest grazing at a lower intensity than that suggested by LPIS data.
- Look out for gaps in LPIS data, there are farms operating without submitting Single Farm Payment Applications which show obvious gaps when viewed on the map. Bear these gaps in mind when considering LPIS information and shortcomings that might exist in this dataset.

An analysis of the satellite imagery in combination with LPIS data on farms may yield valuable information and should always be studied ahead of LCA work where you have already identified animal access as a potential issue. Maintaining a focus upstream of the monitoring point is likely to be of most value in this process.

3. Step 2: Field Assessment Observations

The Fieldwork Plan outlines the key indicators of animal access pressures in the field and the tools to support the assessment of pressures and associated issues. It is intended to be used in conjunction with the following section of the LCA manual:

- Volume 2: Pressures & Catchment Walks, Section 2 Catchment Walks – Agricultural Pressures

Also refer to:

- The Environmental Impact of Cattle Access to Watercourse: A review[31]
- Think Soils Manual, Department for Environment, Food and Rural Affairs, UK. http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=263233

In waterbodies where the desk study indicates animal access to the waterbody may be a pressure it is important to identify stretches of the waterbody where detailed LCA should be carried out to determine the number and intensity of animal access and impact observed. This LCA should be focused initially in the stretch upstream of the monitoring station and then on other stretches which the assessment of the datasets has identified as potential locations for access. It is important to ensure that a representative sample of the waterbody is selected for assessment and a systematic approach should be used ahead of LCA.

When walking selected stretches of the waterbody to assess the impacts of access points, regular and detailed field measurements and recordings should be carried out to assess changes in the waterbody. Use of the field sheet (**Annex 1**) at each point encountered will help record the relevant detail. Each access point should be noted with location (grid coordinates) recorded. Characteristics of the waterbody at this point should be recorded along with surrounding land use, soil type and topography and drainage. The physical characteristics of the access point including access type, purpose, and level of access to the stream should also be recorded.

[31] Paul O' Callaghan, Mary Kelly-Quinn, Elanor Jennings, Patricia Antunes, Matthew O'Sullivan, Owen Fenton, & Daire Ó.hUllacháin

*Types of Access (**Figure 3**)*

- Type 1 Restricted Access, 1 bank, no feet in the river
- Type 2 Restricted access, 1 or 2 banks, standing in water
- Type 3 Access both banks, movement across stream
- Type 4 Unrestricted access with movement up/down stream

*Purpose of the access (**Figure 4**)*

- For animal drinking water
- For movement
- Waterbody acts as field boundary
- Unfenced waterbody with no clear purpose to access

Hydrological connection with surrounding land

- Sloped profile with moderate fall, connectivity to a wide surface area
- Sloped profile with minimal fall from surrounding land, connectivity to moderate area
- Surrounding land slopes away from waterbody at this location

The recording sheet included in **Annex 1** is provided to support the assessment of animal access in the field. Each access point encountered during LCA should be assessed alongside the normal LCA recording. A scoring system in the field has been considered but not included due to the complexity in assessing various points in and across waterbodies. An assessment is subjective and will vary from waterbody to waterbody and often points can only be compared within individual waterbodies and sometimes only in stretches of that waterbody. The cumulative impact of these access points is probably more relevant. It is considered that only on reflection over all the LCA work in the catchment is it possible for catchment scientists to rank animal access points, and this may be undertaken when documenting a conclusion on your LCA work within the LCA Report.

	
Type 1 – Restricted access, 1 bank, no feet in the water	**Type 2 – Restricted access, 1 or 2 banks, permits standing in water**
	
Type 3- Access both banks, movement across stream	**Type 4 Unrestricted access with movement up/down stream.**

Figure 8: Types of Animal Access

	
Provide Drinking Water for Animals	**Provide for Vehicle or Animal Movements**
	
Waterbody acts as a Field Boundary	**No clear purpose to Access**

Figure 9 : Purposes of the Access to the waterbody

4. Step 3: Decision tree for Assessment of Animal Access Points

Step 3 in the Flow Chart (**Figure 1**) is a decision tree to guide catchment scientists in the assessment of animal access points in a waterbody. Two options for addressing animal access issues are provided for in the decision tree. Option one outlines the various conditions, if present, where measures may be appropriate to address access issues. Option two is for waterbodies where access is not deemed to be significant and measures to address other issues may be more effective.

Following the LCA, a review of all data gathered in relation to animal access points is required. The captured evidence will support whether the animal access points assessed are the driver of the significant issue or not. The animal access points should be presented in a map to understand their individual locations in relation to the EPA monitoring points and sensitive areas but also to see if they are having a cumulative negative impact. While in general animal access points do not have an impact on a waterbody scale, those located close to a monitoring point may have a disproportionately high impact due to their proximity to the monitoring point. Animal access points located in close proximity upstream of the EPA monitoring point should be detailed in a referral to ASSAP where there is evidence that the access point is having a localised impact.

In cases where the animal access points are located in sensitive areas, (high status objective waterbodies, waterbodies with water dependent protected species, drinking water abstractions, bathing or shellfish waters) and the significant issues are associated with animal access points/CSAs then a referral to ASSAP should be made. Where animal access points have historically existed in a waterbody, a recent drop in status will probably not be connected. Where the waterbody is significantly impacted throughout and historically has been of moderate or poor status then removal of animal access points will probably result in negligible improvements in water quality, if any. In waterbodies that are dominated by overland flow pathways (e.g. poorly drained soils) or elevated nutrients associated with high risk PIP areas, the fencing off of animal access points would not result in a significant reduction of nutrients or sediment entering the waterbody.

Where referrals to ASSAP are being made, it is important to specify what the mitigation measures are aiming to achieve i.e. fencing animal access points to stop animal faeces entering the waterbody directly versus stopping the animal access points acting as a pathway for nutrients and sediment from CSA.

Annex 1: A field sheet to support the assessment of Access to waterbodies

Date:	**Waterbody Type:**			**Assessors:**
Time:	**Waterbody Code:**			
Recent Rain:	**Waterbody Name:**			
Site ID. & Coordinates		**X**		**Y**
Location	**Waterbody Status Objective**			
	Distance from Monitoring Station (tick relevant)	**< 100m**	**100m - 1000m**	**>1km**
	Upstream of Sensitive Area (Type)	**Y**		**N**
	Access from which Bank	**Left**	**Right**	**Both**
Stream Characteristics	**Wet Width/depth**	**Width (m):**		**Depth (m)**
	Flow (slow, moderate, fast)			
	Habitat			
Landscape features	**Agricultural Enterprise** (Enterprise, level of intensity if known)			
	Land Use	**LB:**		**RB:**
	Soil Type			
	Topography			
	Surrounding Drainage Density (H,M,L)			
Access Point Physical characteristics	**Access Point Type** (Include Photo and description)	• Type 1 ☐ Restricted Access, 1 bank, no feet in the river • Type 2 ☐ Restricted access, 1 or 2 banks, standing in water • Type 3 ☐ Access both banks, movement across stream • Type 4 ☐ Unrestricted access, movement up/downstream		
	Access Purpose			
	Animal/Vehicle Type			
	Associated Sediment (Level, Type) (H, M, L)			
	Animal Access Width/depth	**Width (m):**		**Depth (m)**
	Vegetated/Unvegetated			
	Poaching (H, M, L)			
	Level of damage to the bank (H,M,L)			
	CSA (Yes/No)			
	Significant Impact (Yes/No)			

4. Further Reading:

Kilgarriff, P., Ryan, M., O'Donoghue, C., Green, S., and Ó hUallacháin, D. (2020) Livestock Exclusion from Watercourses: Policy Effectiveness and Implications. Environmental Science and Policy. Accepted

O'Callaghan, P., Kelly-Quinn, M., Jennings, E., Antunes, P., O'Sullivan, M., & Ó hUallacháin, D. (2018) The environmental impact of cattle access to watercourses: a review. Journal of Environmental Quality, 48: 340-351

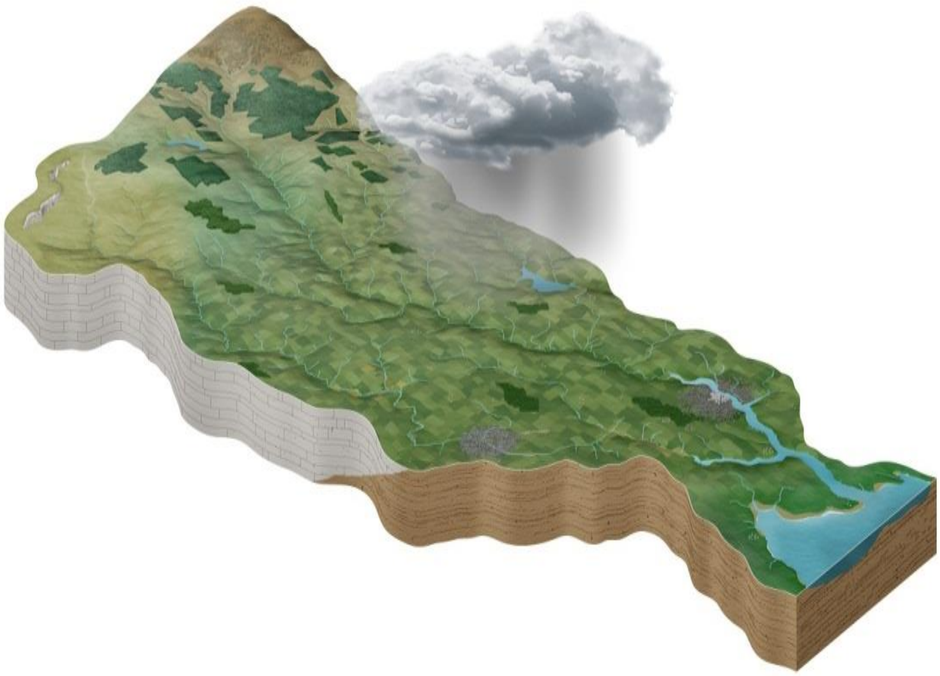
O'Callaghan, P., Kelly-Quinn, M., Jennings, E., Antunes, P., O'Sullivan, M., Fenton, O. and Ó hUallacháin, D. (2018) Impact of Cattle Access to Watercourses: Literature review on behalf of the COSAINT project. EPA report No. 260

O'Sullivan, M., Ó hUallacháin, D., Jennings, E., Antunes, P. & Kelly-Quinn, M. (2019) The impacts of cattle access points on deposited sediment levels in headwater streams in Ireland. River Research and Applications. 35, 146-158

O'Sullivan, M., Ó hUallacháin, D., Antunes, P., Jennings, E., & Kelly-Quinn, M. (2019) The impacts of cattle access to headwater streams on hyporheic zones. Biology and Environment 119B, 13-27

O'Sullivan M. (2019) The ecological impacts of cattle access to headwater streams on freshwater ecosystems. Unpublished PhD thesis.

15 Appendix 2: MQI-Ireland end user report – guidance document



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October 2020

Version no. 4

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15.1 Context

This document provides guidance on interpreting the output of the river hydromorphological condition assessment tool, Morphological Quality Index for Ireland (MQI-Ireland), with particular emphasis on the MQI end user report. The tool is a **desk-based assessment** carried out at a **national level**, supported by current available spatial datasets. It **addresses hydromorphological condition at the reach scale** (*i.e*. 1-10km), rather than water body or site/field scale. Therefore, due to reasons of scale, it will not address specific local issues or issues related to fine sediment. Nevertheless, the MQI-Ireland tool is one of many tools that can support the desk study of catchment assessments prior to field visits. The following sections will address various components of the MQI-Ireland tool – it is advised to pay particular attention to the information boxes throughout, highlighting key points on interpreting the output.

Existing tools to support the hydromorphological component of a catchment assessment include: physical habitat assessments to assess local conditions (*RHAT survey*); low flow and abstraction assessment (*Qube)*; barriers to fish migration (*IFI barrier tool*); sediment accumulation mapping.

15.2 MQI-Ireland

The MQI-Ireland tool has been developed and implemented nationally by the EPA Catchment Science and Management unit to provide an overview of the hydromorphological condition of rivers, at a larger scale to the RHAT assessment. The tool was adapted to suit an Irish setting from the original Italian-derived method, which has been the official morphological assessment in Italy since 2010. To be morphologically meaningful, this assessment considers multiple temporal and spatial scales, where the reach scale is the basic spatial unit (*i.e.* approximately 1-10km). Most importantly, processes are also considered (*e.g.* sediment production, water/sediment/wood flux, river channel adjustment), along with the features, or habitats, that these processes create.

The MQI-Ireland relies on remote sensing and GIS and comprises of four components: reach segmentation (or delineation); data capture of hydromorphological pressures; generating hydromorphological condition indicators and; calculating hydromorphological condition assessment scores based on these indicators.

15.2.1 MQI-Ireland reaches

In order to carry out a hydromorphological condition assessment, the river network is delineated, or broken into reaches, as mentioned above. The OSi Prime 2 water line dataset is the primary dataset for this component. Currently, reach length varies up to 15.5km and is based on:

- Catchment area (*i.e.* catchment ID)
- Landscape setting (*i.e.* based on GSI's physiographic unit map)
    - Flat to undulating (FU)
    - Undulating to Hill (UH)
    - Hill to Mountain (HM))
- Presence and position within the floodplain
    - Unconfined (UC - majority of the channel is within the floodplain)
    - Partly-confined (PC - channel is partially within the floodplain)
    - Confined (C - channel is outside the floodplain)
- Channel pattern
    - Straight (Str)
    - Sinuous (Sin)
    - Meandering (Mnd))

The reach code reflects these segmentation attributes. For example, 16_FU_UC_Sin_xxxx is a reach located in Catchment 16 (the Suir), within a flat to undulating landscape unit. It is completely positioned within a floodplain and is therefore unconfined (*i.e.* potential for lateral mobility). The reach also has a sinuous channel pattern.

- **Reach segmentation** in the MQI version V2.0.0 will be **revised in the future**, once an improved Prime 2 water line dataset is available. A fully connected river network will allow for refinement of this component and reduce the number of reaches under 1km.

15.2.2 MQI-Ireland hydromorphological features

To generate hydromorphological condition indicators, identification of hydromorphological features were required (*e.g.* weirs, bridges, bank protection, drainage schemes). This involved extracting spatial data from various sources such as OSi and OPW, in addition to using aerial imagery, ortho photography and historic maps as an aid to manually digitise such features.

15.2.3 MQI-Ireland indicators

The MQI-Ireland tool comprises of 15 hydromorphological condition indicators (MQI indicators) related to:

- longitudinal connectivity;
- lateral connectivity;
- channel morphology and;
- riparian vegetation condition.

Individual MQI indicator scores are grouped into impact categories for communication and mapping purposes (*i.e.* High, Medium, Low), ranging from high impact (100%) to low impact (0%), depending on the hydromorphological pressure gradient that exists within the reach. **Appendix A** provides information on each MQI indicator and the data (including hydromorphological pressures) involved in the generation of these indicators.

15.2.4 MQI-Ireland condition assessment score

The individual MQI Indicator scores are combined to generate a hydromorphological condition assessment score that are grouped into hydromorphological quality classes from 0% (poor quality) to 100% (high quality) (Table 1).

- Avoid the term 'status'. Refer to MQI class as 'hydromorphological quality' or 'hydromorphological condition'.
- RHAT is the current tool used for hydromorphological classification, or hydromorphological status. This tool is carried out at the site scale (*i.e.* <500m), on high status water bodies or surveillance sites only.

Table 1: MQI-Ireland hydromorphological quality classes and associated MQI scores.

MQI-Ireland hydromorphological quality class	Range
High	≥80-100%
Good	≥60 - <80%
Moderate	≥40 - <60%
Poor	≥20 - <40%
Bad	≥0 - <20%

15.3 MQI-Ireland end user report

The MQI-Ireland end user report is a spatial dataset primarily to support the desk-based component of catchment assessments. The output provides a national overview of hydromorphological condition. It highlights the overall hydromorphological condition of a **reach (*not* water body)** but also highlights the MQI indicators driving the overall hydromorphological quality class. **Appendix B** provides metadata information for the MQI-Ireland end user report.

The MQI-Ireland tool also considers certain settings, or weighting groups, which fit into a hierarchical framework: 1) whether a reach is downstream of a dam and/or reservoir; 2) within peat; 3) within an urban area and; 4) all other reaches (standard). For each weighting group, indicators are allocated a weighting score. This ensures that relevant pressures to a certain setting are not masked by other pressures. Table 2 highlights the MQI indicators that are included in each weighting group, while **Appendix C** provides more information on weighting allocations.

Table 2: MQI weighting groups and associated MQI indicators.

Hierarchy	Weighting Group	Weighting Group criteria	Reach type	MQI indicators excluded from overall score
1	Dams and reservoirs	Reaches where >5% of the upstream catchment of the reach is impacted by dams and reservoirs	Partly confined/unconfined	A13
			Confined	F5, A7, A13
2	Peat	≥40% of reaches within peat based on EPA/Teagasc subsoil dataset (RsPt, BktPt, Cut, FenPt)	Partly confined/unconfined	A1m, A2, F7, A8, F12, F13
3	Urban	≥25% of reaches within an urban area (based on 2018 CORINE).	Partly confined/unconfined	A1m, A2, A13
			Confined	A1m, A2, F5, A7, A13
4	Standard	All other reaches.	Partly confined/unconfined	A1m, A2
			Confined	A1m, A2, F5, A7

- It is vital that the version of the **MQI-Ireland tool is referenced** (*e.g.* MQI V2.0.0). The tool is being continuously updated and versioning is important to keep track.
- The MQI end user report uses the Irish Transverse Mercator (ITM) geographic coordinate system.
- The MQI end user report provides MQI-Ireland output at a **reach scale, not water body scale**.
- It is recommended that the river sub-basin spatial dataset is switched on so as to identify the rivers reaches within a WFD river water body.
- It is also recommended that the EPA river monitoring station dataset is also switched on so that the reach, where the WFD monitoring station is located, can be identified.
- Regarding catchment assessments and interpretation of the MQI-Ireland end user report, it is advised to **focus on the reach where the EPA monitoring station is located. It is also important to consider whether the hydromorphological impact within a reach(es) influence the ecological status of a monitoring station.**
- Note that the MQI-Ireland indicators do **not consider local or fine sediment issues**. This requires field scale assessment.
- Each MQI-indicator has certain hydromorphological pressures linked to it depending on the component of hydromorphological condition being assessed (See *Associated hydromorphological features* under **Appendix A**). These can be identified within various fields of the MQI end user report attribute table (*i.e.* associated point, culvert, line, polygon, feature or structure type) (See **Appendix B**).
- Check what 'weighting group' has been allocated to the reach as not all MQI indicators will be considered in the overall MQI score and hydromorphological quality class (See Table 2 and **Appendix C**). However, look at the impact category of indicators in the attribute table as this information is still useful for supporting catchment assessments (*i.e.* drainage schemes can be still noted, even if in a Peat Weighting). Note that the longitudinal connectivity indicator 'F1' has a low weighting score for all weighting groups as whether a crossing structure (*e.g.* bridge, weir) is a barrier has not been confirmed in the field. **If a 'bridge' is the feature driving High impact for the F1 indicator, due to the weighting score, it is unlikely that this indictor will drive the overall MQI score.** Further work is planned to refine this indicator once data becomes available (*e.g.* link with the IFI national barrier inventory database).
- Note that the channel morphology indicator that focuses on 'historic modification' refers to rivers flowing through modified peatland (*i.e.* reclaimed, cut). This is used as a proxy to capture **<u>historic modification</u>** not captured by Cassini or the 6" OS historic maps. It **does not necessarily mean direct impact from extractive or harvesting activities**.
- For riparian vegetation condition indicators (F12 and F13), proxy datasets (based on commercial plantations and heath habitat) have been used until riparian vegetation data is available from the National Landcover and Habitat mapping programme. **Take care when interpreting these particular indicators**. These will be updated in a future version as soon as data are available.
- Figure 1 and 2 illustrates how the MQI-Ireland end user report can be interpreted.

15.4 Other supporting information

15.4.1 RHAT survey

The River Hydromorphological Assessment Technique (RHAT) is a field based physical habitat assessment, used by the Republic of Ireland and Northern Ireland for WFD classification. The standard RHAT survey is carried at 500m, but the technique is used to assess a range of site scale lengths from 50m where appropriate. For example, EPA monitoring uses the 'spot check' RHAT on various lengths depending on access to the river. The method classifies river hydromorphology based on a departure from naturalness, or undisturbed condition, based on eight criteria (Table 3).

The individual RHAT attribute scores are grouped into five categories: High; Good; Moderate; Poor and; Bad (Table 4). When these attributes are combined, they are directly related to WFD classes, or hydromorphological status classes. The same RHAT status class thresholds are similar to the MQI hydromorphological quality class thresholds (See Table 1).

Table 3: RHAT attributes

RHAT attributes	RHAT attribute summary
Channel morphology and flow types (form)	Considers the channel pattern expected for the river type; the presence/absence of geomorphic units expected for the river type; presence of man-made interventions that may impact channel pattern and geomorphic units.
Channel vegetation	Considers the presence of in-channel vegetation and wood expected for the river type; presence of in-channel vegetation management.
Substrate diversity and condition	Considers bed sediment size as expected for the river type; presence of alteration to bed sediment structure (*e.g.* sedimentation, armouring).
Barrier to continuity	Considers longitudinal connectivity for water, sediment, and fish; presence of barriers; presence of channel modification (*e.g.* widening) that will impact upstream/downstream connectivity due to water supply.
Bank structure and stability	Considers the shape and stability of the bank; presence of bank modification due to man-made interventions; presence of hard engineering structures on the bank; presence of poaching.
Bank and bank top vegetation	Considers the presence of vegetation along the bank as expected for the river type; extent of vegetation along the bank; type of vegetation; variety of vegetation types; presence of vegetation management; presence of alien species.
Riparian land use	Considers the landcover type adjacent to the river (20m from bank); presence of human activities.
Floodplain interaction	Considers the degree of lateral connectivity between river and floodplain; presence of bank modification due to man-made interventions.

Table 4: RHAT attribute scores and associated classes.

RHAT Attribute	RHAT Attribute Scores				
	High	Good	Moderate	Poor	Bad
Channel form	4	3	2	1	0
Channel vegetation	4	3	2	1	0
Channel substrate	4	3	2	1	0
Channel barriers to continuity	4	3	2	1	0
Bank structure Left	2	1.5	1	0.5	0
Bank structure Right	2	1.5	1	0.5	0
Bank Vegetation Left	2	1.5	1	0.5	0
Bank Vegetation Right	2	1.5	1	0.5	0
Riparian Landover Left	2	1.5	1	0.5	0
Riparian Landover Right	2	1.5	1	0.5	0
Floodplain Connectivity Left	2	1.5	1	0.5	0
Floodplain Connectivity Right	2	1.5	1	0.5	0

15.4.2 Future tools

Additional tools will be developed in the future to address other elements of hydromorphological condition (*e.g.* sediment regime).

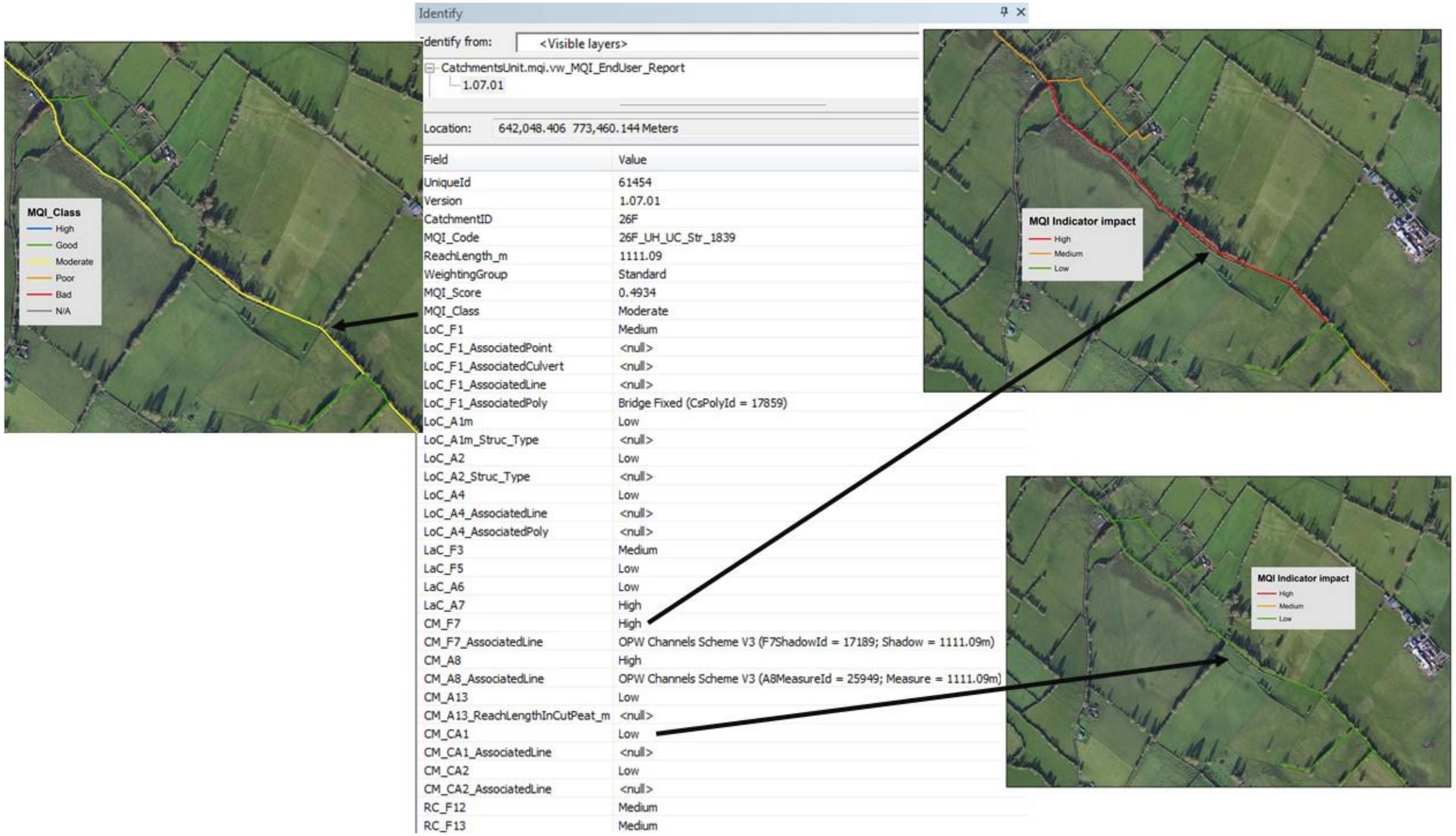


Figure 1: Example of output from the MQI end user report (*v1.07.01*). The attribute table informs that the MQI end user report output is version 1.07.01. A 1111m MQI reach is of Moderate hydromorphological quality (denoted by the yellow polyline). The reach is located in Catchment 26F (the Inny) and based on the MQI_Code, the reach is within an undulating to hill (UH) landscape unit. It is unconfined (UC) and has been allocated a standard weighting (therefore, based on Table 2, MQI indicators A1m and A2 are excluded from the overall MQI score). The MQI score is 0.49 (or 49%) which sits within the Moderate morphological quality class range (Table 1). MQI indicators of High impact are driving Moderate hydromorphological quality. These particular indicators are related to lateral connectivity (A7 -driven by the presence of embankments) and channel morphology (F7 and A8 – driven by the presence of drainage schemes). ***Note that associated feature information for lateral connectivity indicators will be available in the V1.08.01 release and other future releases*.**

Waterbody: Glennagannon_010

MQI-Ireland (*V1.08.01*): MQI reaches within this water body range between High and Moderate hydromorphological condition.

The operational WFD monitoring station is located at the outlet within a short 748m reach of Moderate hydromorphological condition (40_HM_PC_Mnd_229).

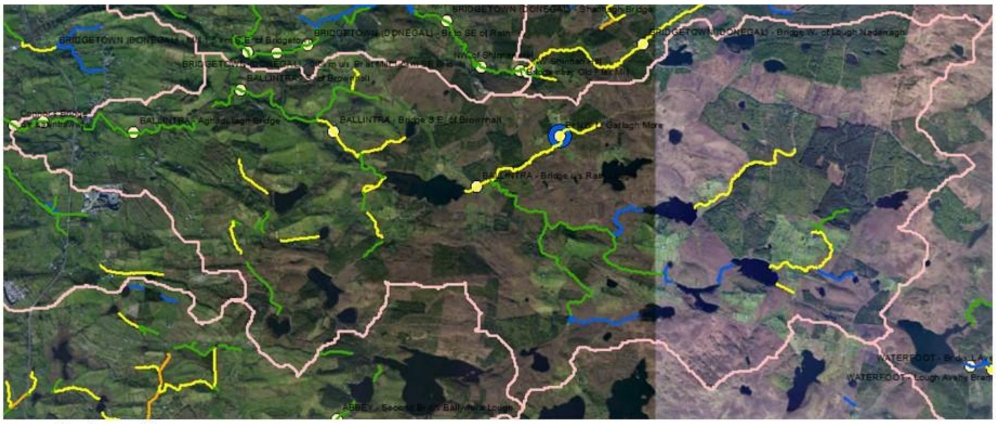
The <u>'High impact'</u> MQI indicators driving Moderate condition (considering the peat weighting) are related to lateral connectivity (*i.e.* F3 and F5, due to the presence of roads within 20m of the river bank) and channel morphology (*i.e.* A13, due to the presence of historic modification as indicated by the extent of cut/reclaimed peat along the reach).

Waterbody: Dunmoran_010

MQI-Ireland (*V1.08.01*): Reaches along the main channel range between Good and Moderate hydromorphological condition.

The operational WFD monitoring station is located at the outlet within a short 1134m reach of Moderate hydromorphological condition (35_FU_PC_Sin_345).

The <u>'High impact'</u> MQI indicators driving Moderate condition (considering the standard weighting) are related to channel morphology (*i.e.* F7 and A8, due to the presence of a drainage scheme within the reach).



Waterbody: Ballintra_010

MQI-Ireland (*V1.08.01*): Reaches range between High and Moderate hydromorphological condition.

The upstream operational WFD station (37B020007; Br NW L. Garlagh More) is within a 2194m reach of Moderate hydromorphological condition (37_UH_UC_Sin_507). Note that at this station, there is a 50m 2018 RHAT survey of High hydromorphological status, reflecting specific local conditions. The downstream operational WFD station (37B020200; Connor's Bridge) is within a 2316m reach of Good hydromorphological condition (37_UH_PC_Mnd_533).

The <u>'High impact'</u> MQI indicator driving Moderate condition (considering the peat weighting) is related to channel morphology (*i.e.* A13, due to the presence of historic modification as indicated by the extent of cut/reclaimed peat along the reach).

Figure 2: Examples how the MQI end user report (*V1.08.01*) can be interpreted to support catchment characterisation at a water body level. ***As highlighted in the information box within the MQI end user report section, the focus should be on the reach where the WFD monitoring station driving ecological status is located.*** Note that the pink polyline represents the water body boundary (*i.e.* river sub-basin). The light-yellow point data represents the locations of the biomonitoring stations. MQI reach polylines are colour coded to represent hydromorphological quality classes (*i.e.* High (blue), Good (green), Moderate (yellow), Poor (orange), Bad (red)). For the Ballintra_010 example, the larger blue point represents a site scale RHAT survey - RHAT survey points also use the WFD colour code for hydromorphological status classes.

Appendix A: MQI indicators and associated features.

Indicator Group and Code		Indicator name and summary	Associated hydromorphological features	Indicator Impact Classes (for communication and mapping)	
Longitudinal connectivity	F1	***Longitudinal continuity in sediment and wood flux:*** Consideration of artificial in-channel structures impacting the movement of sediment and wood.	Bridges; Farmbridges; Footbridges; Fishery enhancements (weirs); Sluices; small scale HEP; Weirs; Culverts; Sediment traps; Dams	Presence of artificial in-channel structures within the reach. *(∑(Feature type count *weighting) / (River Reach length in km))*10* *Each feature will have a pressure weighting (Bridge, Farmbridge, Footbridge, Fisheries enhancements = 2; Weirs, Culverts, Sluices, Sediment traps, Small scale HEP = 5; Dams = 10)*	
				Low	≤34%
				Medium	>34% And ≤67%
				High	>67%
	A1M	***Upstream alteration of flows (relevant effects on channel morphology):*** Assesses whether flow to the reach is interrupted by major artificial in-channel structures (*i.e.* dams and reservoirs) *. ****High impact structure:*** *Structure reducing peak discharges or reservoirs functioning only for infrequent charges.* ****Medium impact structure:*** *Structure reducing peak discharges or reservoirs functioning for relevantly frequent charges*	Dams; Reservoirs (allocated impact structure category through discussions with the EPA Hydrometrics and Groundwater unit)	Presence, type and percentage of upstream area of reach impounded by artificial in-channel structures.	
				Low	Absence of structure within the upstream area of the reach, or high/medium impact structure impounding <5% of upstream area of reach: 0%
				Medium	Medium impact structure impounding >5% of upstream area of reach: 50%
				High	High impact structure impounding >5% of upstream area of reach: 100%
	A2	***Upstream alteration of sediment discharges:*** Assesses whether the natural supply of sediment delivered to the reach is interrupted by major artificial in-channel structures (*i.e.* dams and reservoirs).	Dams; Reservoirs	Presence, type and percentage of upstream area of reach impounded by artificial in-channel structures.	
				Low	≤33%
				Medium	>33% And ≤66%
				High	>66%
	A4	***Alteration of sediment discharge in the reach:*** Assesses whether the movement of sediment is interrupted along the reach by artificial structures or enhanced by hard surfaces due to runoff.	Dams; Reservoirs; Weirs; Sluices; Sediment traps, small scale HEP, Corine 2018 urban areas (amended for MQI-Ireland)	Presence of artificial in-channel structures, the type and frequency of these structures, depending on the slope of the reach. Also considers percentage of urban area within the reach. *((Feature count / River Reach length in km)*x) + % urban area* If slope is >3%, x = 5 If slope is <3%, x = 10	

Indicator Group and Code		Indicator name and summary	Associated hydromorphological features	Indicator Impact Classes (for communication and mapping)
				Low ≤34% Medium >34 And ≤67% High >67% (100% if dam/reservoir present)
Lateral connectivity	F3	***River-corridor connectivity:*** Consideration of development/man-made structures (*e.g.* buildings, roads) impacting the interaction between the river corridor and channel, including sediment and wood delivery.	Buildings; Culverts; Embankments; Pavements; Roads; Rail	Percentage of the total reach length with development features present within 20m from both river banks. The 20m buffer aligns with the Irish RHAT survey when considering activities outside the channel. *(Sum of lengths of features on a Reach / Reach Length) * 100 / 2*
				Low ≤34% Medium >34 And ≤67% High >67%
	F5	***Presence of a potentially erodible corridor:*** Consideration of development/man-made structures (*e.g.* buildings, roads) impacting lateral mobility of a river. **Considering unconfined/partly confined reaches only.*	Buildings; Bridge walls and bank protection (confining walls); Culverts; Embankments; Fishery enhancement (bank protection); Pavements; Roads; Rail; OPW flood protection structures	Percentage of the reach length (*i.e.* total reach length within the floodplain (or 'unconfined margin')) with development features present 20m from both river banks. The 20m buffer aligns with the Irish RHAT survey when considering activities outside the channel. *(Sum of lengths of features on a Reach within Unconfined Margin / Reach Length within Unconfined Margin) * 100 / 2*
				Low ≤34% Medium >34% And ≤67% High >67%
	A6	***Hard bank protection:*** Accounts for the presence of hard bank protection structures (*e.g.* hard engineered structures such as walls, rip-rap, gabions). Such structures impact the natural supply of sediment to the channel and reduces the channels ability to migrate laterally.	Bridge walls and Bank protection (confining walls); Fishery enhancement (bank protection); Gabions; OPW flood protection structures	Percentage of the total reach length with hard bank protection structures present either side of the river bank. A 3m buffer is ensure that features along the bank face and top are captured. *(Sum of lengths of features on a Reach / Reach Length) * 100 / 2*
				Low ≤5% Medium >5% And ≤33% High >33%
	A7	***Artificial embankments:***		Percentage of the total reach length with embankment features present, within 20m from both river banks. The 20m buffer aligns

Indicator Group and Code		Indicator name and summary	Associated hydromorphological features	Indicator Impact Classes (for communication and mapping)
		Accounts for the presence of embankments. Embankments have an effect on lateral connectivity as they can reduce interaction between the channel and the floodplain. Also reduces habitat diversity. **Considering unconfined/partly confined reaches only.*	OPW Embankment schemes; Embankments outside schemes	with the Irish RHAT survey when considering activities outside the channel. *(Sum of lengths of features on a Reach / Reach Length) * 100 / 2* Low ≤5% Medium >5% And ≤33% High >33%
Channel morphology	F7	***Planform pattern and cross section variability:*** Considers the impact to river channel pattern, geomorphic features (*e.g.* sediment bars, islands, benches) and channel dimension. **Note that drainage scheme/channel management data has been used as a proxy for channel alteration for this iteration of the MQI-Ireland tool.*	Drainage scheme spatial data; Navigation channel management spatial data; evidence of sediment accumulation, boat moorings/fish farms/platoons	Percentage of the total reach length where natural morphological condition has been altered. *(Sum of lengths of features on a Reach * pressure weighting⁺ / Reach Length) * 100* *Each feature will have a pressure weighting: OPW arterial drainage, Local Authority drainage or digitised feature = 1; Waterways Ireland channel management (=1 if management confirmed, =0.5 if not confirmed, =0 no management).* Low ≤5% Medium >5% And ≤33% High >33%
Channel morphology	A8	***Artificial changes of the river course:*** Assesses the extent of modification to the channel of the reach (*e.g.* meander cut-offs, channel straightening, diversions, dredging). Such changes will alter the natural channel morphology (*e.g.* alter level of sinuosity), hydromorphological processes and in turn loss or degradation of physical habitat. **Note that drainage scheme/channel management data has been used as a proxy for channel alteration for this iteration of the MQI-Ireland tool.*	Drainage scheme spatial data; Navigation channel management spatial data; Changes to the channel based on Cassini 6" historic map (and OS 6" map for reaches downstream of dams).	Percentage of the total reach length where man-made interventions to the river channel is present. *(Sum of lengths of features on a Reach * pressure weighting⁺ / Reach Length) * 100* *⁺ Each feature will have a pressure weighting: OPW arterial drainage, Local Authority drainage or digitised feature = 1; Waterways Ireland channel management (=1 if management confirmed, =0.5 if not confirmed, =0 no management).* Low ≤34% Medium >34% And ≤67% High >67%
Channel morphology	A13	***Historic modification (within cut/reclaimed peat):***	Teagasc subsoils ('Cut' peat), Teagasc Habitat map	Percentage of the total reach length within modified peat. *(Sum of lengths of features on a Reach / Reach Length) * 100*

Indicator Group and Code		Indicator name and summary	Associated hydromorphological features	Indicator Impact Classes (for communication and mapping)
		Considers the extent of modification to the river channel due to peat modification – used as a proxy to capture historic modification not captured by Cassini or the 6" OS historic maps.	('reclaimed', 'cutover', 'eroded')	Low ≤5% Medium >5% And ≤33% High >33%
	CA1	***Adjustments in channel pattern:*** Takes into account the extent of channel pattern changes within a reach (*e.g.* meandering to straight) over the last few decades due to human intervention.	Changes to the channel based on Cassini 6" historic map (and OS 6" map for reaches downstream of dams)	Percentage of the total reach length where channel pattern has changed due to human intervention. *(Sum of lengths of features on a Reach / Reach Length) * 100* Low ≤5% Medium >5% and ≤33% High >33%
	CA2	***Adjustments in channel width:*** Takes into account the extent of channel width changes within a reach over the last few decades due to human intervention.	Changes to the channel based on Cassini 6" historic map (and OS 6" map for reaches downstream of dams)	Percentage of the total reach length where channel width has changed due to human intervention. *(Sum of lengths of features on a Reach / Reach Length) * 100* Low ≤5% Medium >5% and ≤33% High >33%
Riparian condition	F12	***Width of functional riparian vegetation (absence):*** Assesses absence of functional riparian vegetation within 20m from the river bank top. Functional vegetation is native/deciduous vegetation (including heath) that interacts with the river and river banks (erosion, deposition, flooding). **Excluding reach length within peat.* *+Partially functional vegetation is 50% of the value of fully functional riparian vegetation.*	Awaiting riparian vegetation output from the National Landcover and Habitat mapping programme. Coillte and Forest Service data used as a placeholder for now.	Percentage of (functional and partially functional) riparian vegetation within 20m buffer from both river banks (considering absence). The 20m buffer ensures close linkages with hydromorphological measures and the current agri-environmental schemes. *1 - (Sum of area vegetation in Buffered Reach / Buffered Reach Area) * 100* Low ≤33% Medium >33% and ≤90% High >90%
	F13	***Linear extent of functional riparian vegetation (absence):*** Assesses absence of functional riparian vegetation along the bank top of a river. Functional vegetation is native/deciduous vegetation (including heath) that interacts with the river and river banks (erosion, deposition, flooding). **Except for reaches within peat.*	Awaiting riparian vegetation output from the National Landcover and Habitat mapping programme. Coillte and Forest Service data used as a placeholder for now.	Percentage of (functional and partially functional) riparian vegetation along the bank top of a river reach (considering absence). A 3m buffer is used to capture vegetation along the bank top. *1 - (Sum of area vegetation in Buffered Reach / Buffered Reach Area) * 100*

Indicator Group and Code		Indicator name and summary	Associated hydromorphological features	Indicator Impact Classes (for communication and mapping)
		+Partially functional vegetation is 50% of the value of fully functional riparian vegetation.		Low ≤33% Medium >33% and ≤90% High >90%

Appendix B: Metadata for the MQI-Ireland end user report.

MQI End User Report field names	Field description
Version	MQI Version release number of dataset
Catchment ID	Catchment identification number (*e.g.* 16 (Suir))
MQI_Code	MQI reach identification number
Reach length_m	Length of MQI reach
Weighting group	See Table 2
MQI_Score	Overall MQI score (combining MQI indicator scores, including weightings)
MQI_Class	Overall hydromorphological quality class (*i.e.* High, Good, Moderate, Poor, Bad)
LoC_F1	Longitudinal connectivity – F1 indicator impact (High, Medium, or Low)
LoC_F1_AssociatedPoint	F1 feature description (represented by point data)
LoC_F1_AssociatedCulvert	F1 feature description (culverts)
LoC_F1_AssociatedLine	F1 feature description (represented by line data)
LoC_F1_AssociatedPoly	F1 feature description (represented by polygon data)
LoC_A1m	Longitudinal connectivity – A1m indicator impact (High, Medium, or Low)
LoC_A1m_Struc_Type	A1m feature description (type of structure – dam or reservoir)
LoC_A2	Longitudinal connectivity – A2 indicator impact (High, Medium, or Low)
LoC_A2_Struc_Type	A2 feature description (type of structure – dam or reservoir)
LoC_A4	Longitudinal connectivity – A4 indicator impact (High, Medium, or Low)
LoC_A4_PercentUrban	A4 feature description (represented by CORINE 2018 urban polygon)
LoC_A4_AssociatedLine	A4 feature description (represented by line data)
LoC_A4_AssociatedPoly	A4 feature description (represented by polygon data)
LaC_F3	Lateral connectivity – F3 indicator impact (High, Medium, or Low)
LaC_F3_BuffA_AssociatedFeature	F3 feature description (represented by line/polygon features within 20m buffer from Bank A)
LaC_F3_BuffB_AssociatedFeature	F3 feature description (represented by line/polygon features within 20m buffer from Bank B)
LaC_F5	Lateral connectivity – F5 indicator impact (High, Medium, or Low)
LaC_F5_BuffA_AssociatedFeature	F5 feature description (represented by line/polygon features within 20m buffer from Bank A)
LaC_F5_BuffB_AssociatedFeature	F5 feature description (represented by line/polygon features within 20m buffer from Bank B)
LaC_A6	Lateral connectivity – A6 indicator impact (High, Medium, or Low)
LaC_A6_BuffA_AssociatedFeature	A6 feature description (represented by line/polygon features within 20m buffer from Bank A)
LaC_A6_BuffB_AssociatedFeature	A6 feature description (represented by line/polygon features within 20m buffer from Bank B)
LaC_A7	Lateral connectivity – A7 indicator impact (High, Medium, or Low)
LaC_A7_BuffA_AssociatedFeature	A7 feature description (represented by line/polygon features within 20m buffer from Bank A)
LaC_A7_BuffB_AssociatedFeature	A7 feature description (represented by line/polygon features within 20m buffer from Bank B)
CM_F7	Channel morphology – F7 indicator impact (High, Medium, or Low)
CM_F7_AssociatedLine	F7 feature description (represented by line data)
CM_A8	Channel morphology – A8 indicator impact (High, Medium, or Low)
CM_A8_AssociatedLine	A8 feature description (represented by line data)

CM_A13	Channel morphology – A13 indicator impact (High, Medium, or Low)
CM_A13_ReachLengthInCutPeat_m	Length of MQI reach within cut peat.
CM_CA1	Channel morphology – CA1 indicator impact (High, Medium, or Low)
CM_CA1_AssociatedLine	CA1 feature description (represented by line data)
CM_CA2	Channel morphology – CA2 indicator impact (High, Medium, or Low)
CM_CA2_AssociatedLine	CA2 feature description (represented by line data)
RC_F12	Riparian condition – F12 indicator impact (High, Medium, or Low)
RC_F13	Riparian condition – F13 indicator impact (High, Medium, or Low)

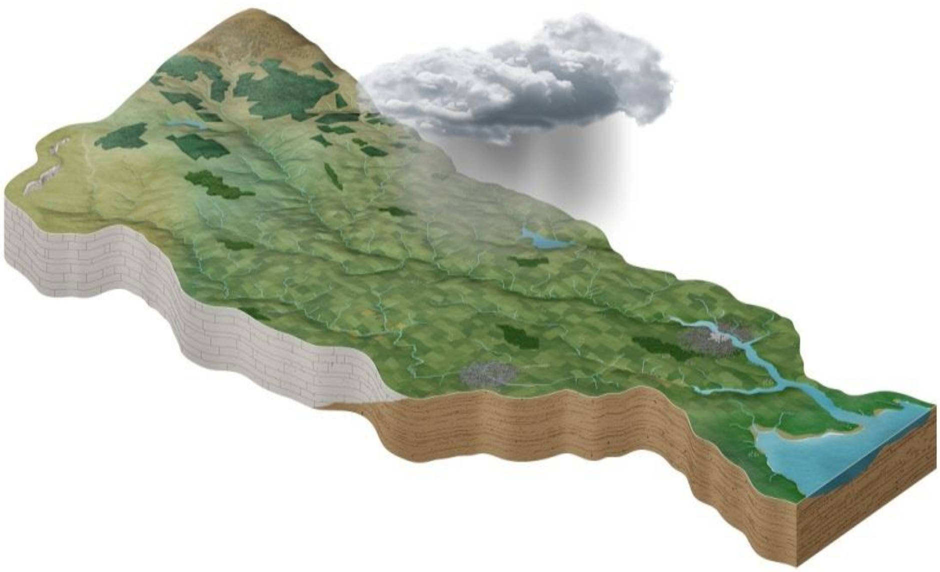
Appendix C: MQI weighting groups, weighting scores and associated MQI indicators (MQI weighting group version V2).

Weighting group hierarchy			**1) Dam and Reservoirs**		**2) Peat**	**3) Urban**		**4) Standard**	
Weighting group criteria			*Reaches where >5% of the upstream catchment of the reach is impacted by dams and reservoirs*		*≥40% of reaches within peat (natural/modified) based on EPA/Teagasc subsoil dataset*	*≥25% of reaches within an urban area (modified urban data from 2018 CORINE)*		*All other reaches*	
Indicator			**PC/UC**	**C**	**PC/UC**	**PC/UC**	**C**	**PC / UC**	**C**
Longitudinal connectivity	**A1M**	Upstream alteration of flows	20.0%	20.0%	0.0%	0%	0%	0%	0%
	A2	Upstream alteration of sediment discharges	20.0%	20.0%	0.0%	0%	0%	0%	0%
	F1	Longitudinal continuity in sediment and wood flux	2.5%	2.5%	5%	5%	5%	5%	5%
	A4	Alteration of sediment discharge in the reach	2.5%	2.5%	5%	10%	10%	5%	5%
Lateral connectivity	**F3**	River-corridor connectivity	5.0%	5%	10%	15%	25%	10%	15%
	F5	Presence of a potentially erodible corridor	5%	0%	10%	15%	0%	10%	0%
	A6	Hard bank protection	5%	5%	10%	15%	30%	10%	15%
	A7	Artificial embankments	5%	0%	15%	10%	0%	5%	0%
Channel morphology	**F7**	Planform pattern and cross section variability	5.0%	7.5%	0%	5.00%	5.00%	10%	15%
	A8	Artificial changes of the river course	5.0%	10%	0%	5.00%	5.00%	15%	*15%*
	A13	Historic modification (within cut/reclaimed peat)	0.0%	0.0%	45%	0%	0%	10%	10%
	CA1	Adjustments in channel pattern	2.5%	2.5%	0.0%	2.5%	2.50%	2.5%	2.5%
	CA2	Adjustments in channel width	7.5%	10.0%	0.0%	2.5%	2.50%	2.5%	2.5%
Riparian condition	**F12**	Width of functional riparian vegetation	7.5%	7.5%	0.0%	7.50%	7.50%	7.5%	7.5%
	F13	Linear extension of functional riparian vegetation	7.5%	7.5%	0.0%	7.50%	7.50%	7.5%	7.5%

Catchment Science and Management

A Guidance Handbook

Volume 3:
Observed Indicator Features and Catchment Walks



April 2018

Version no. 1

Preface

This Volume was written in 2018 as **Guidance on Further Characterisation for Local Catchment Assessments Volume 3 (Version 1).** It was initiated by the Catchment Science and Management Unit of the Environmental Protection Agency (EPA). It was primarily intended for use by the LAWPRO catchment scientists and staff in Local Authorities, tasked with undertaking Local Catchment Assessments (originally called Investigative Assessment).

The content in the 2018 Guidance reflected a collaborative effort between invited specialists from several stakeholders with responsibility and vested interests in environmental research and management in Ireland. Contributions were made by members of an Investigative Assessment Development Group, led by the EPA and comprising representatives from public and WFD stakeholder organisations including: Department of Housing, Planning and Local Government; Department of Agriculture, Food and the Marine (Forest Service); Teagasc; Geological Survey Ireland; Irish Water; Inland Fisheries Ireland; Local Authority Waters and Communities Office (LAWCO); Limerick City and County Council; Meath County Council; Dublin City Council; Offaly County Council; Dun Laoghaire-Rathdown County Council; Wexford County Council; Tipperary County Council; as well as CDM Smith consultants. The membership of the Group is listed in Table 1.

Table 1 Membership of Investigative Assessment Development Group (2018)

Organisation	Representative
EPA	Marie Archbold Donal Daly Jenny Deakin Bryan Kennedy Anthony Mannix Conor Quinlan Emma Quinlan
Local Authorities	Paul Buggy, Dun Laoghaire-Rathdown County Council Emmet Conboy, Meath County Council Ruth Hennessy, Tipperary County Council Andrew Holmes, Limerick County Council Joan Martin, Offaly County Council Gerry O'Connell, Dublin City Council Mairéad Shore, Wexford County Council
LAWCO	Fran Igoe
Forest Service	Ken Bucke
Inland Fisheries Ireland	Michael Fitzsimons
Teagasc	Edward Burgess Sara Vero
Department of Housing, Community & Local Government	Donal Grant
Geological Survey of Ireland	Taly Hunter Williams
Irish Water	Kate Harrington
Rivercrossing	Brendan Ward
CDM Smith	Pat Barrett Henning Moe

Contents

1 Introduction

This volume provides an overview of visual indicators in Irish catchments. It also provides guidance on how risk of water quality impact to groundwater can be screened using a simplified method for estimating zones of contributions of groundwater to natural springs and pumping wells. Specifically, the guidance covers the following topics:

- Land Drains;
- Vegetation indicators of Natural Drainage;
- Biodiversity Indicators;
- Karst Landscape Features and;
- Assessing Risk of Water Quality Impacts to Groundwater.

The aim of **Volume 3** is to provide guidance on the issues that may be relevant for each of the visual indicators.

Section	Indicators	Main Contributor(s)
2	Land Drains	Mairead Shore
3	Vegetation	Monica Lee & Taly Hunter Williams
4	Biodiversity	Fran Igoe
5	Karst landscapes	Taly Hunter Williams, Conor Quinlan & Caoimhe Hickey
6	Groundwater indicators	Anthony Mannix, Taly Hunter Williams & Donal Daly
7	Field photography	Conor Quinlan

1.1 Staying focussed on the goals

A significant public sector resource is being allocated to the Local Catchment Assessment process. It is vital that this resource is effective in enabling successful water resources protection and management, and achievement of WFD objectives. Two points to keep in mind are given in the Boxes below.

Box 1 – Local Catchment Assessments

What a Local Catchment Assessment isn't: the collection of more data alone.

What a Local Catchment Assessment is: a critical means of enabling either protection or improvement, as relevant, of our water resources.

This aim is achieved by:

- Undertaking a desk study as the starting point.
- Undertaking catchment walks, if needed.
- Collection, assessment and recording of relevant information and data collected during the catchment walk.
- Concluding, in so far as is practicable, on the significant pressure and its location.
- Evaluating and proposing possible mitigation actions.
- Undertaking (in certain circumstances) the mitigation actions.

Remember: we need to stay focussed on the goals.

Box 2 – The Desk-based Assessment

The desk study is the key to ensuring that the Local Catchment Assessment process is focussed, efficient and effective.

The Role of the Desk Study

- To check the **WFD App** for details on: i) the significant pressure (e.g. domestic wastewater treatment systems); ii) the significant issue (e.g. phosphate); the location of the significant pressure (the specific location for large point sources and the general location for diffuse and small point sources).
- To search for and assess **new information** that may be available.
- If feasible, provide the conclusion on the **required mitigation actions**.
- Where a field-based assessment is needed to: i) **clarify** the objectives; ii) **compile** the information and maps that will assist the fieldwork; and iii) **plan** an appropriate fieldwork/catchment walk programme.

Further details on the Desk-based Assessment are available in Section 10 **Volume 1**. LAWPRO desk studies for Priority Areas for Action can be viewed on the EDEN Portal under WFD POMs, Area for Action, Step 1 Desk Study.

2 Land Drains

2.1 Description

Land drainage and drains serve to reduce waterlogging and overland flow. They are most prevalent in heavy clay-rich soils which saturate easily. Therefore, drainage density can be a useful indication of soil type and of the natural propensity for an area to become saturated and generate overland flow – which is an important pathway for phosphorus and sediment loss.

On a field scale, ditch length per field perimeter can provide an indication of the connectivity of that field to downstream waterbodies. This assumes that only fields with channels along the edges can connect to the downstream channel network and that the longer the channels, the less chance the surface water in fields has to infiltrate before reaching the channel.

2.2 Processes

Depending on their features, ditches can subsequently attenuate or augment the transfer of nutrient elements, and phosphorus especially, from upstream sources to receiving waterbodies. Generally flat drains (slopes less than 2%) have the greatest potential to retain sediment and associated phosphorus, reducing the chances of these pollutants moving into downstream rivers or lakes where ecological impacts are likely greater. However, flat ditches can get clogged up with sediment, and this sediment can hold (store) large amounts of phosphorus, which will eventually begin to be released back into the drainage water. Regularly cleaning out ditches would ensure that this sediment and phosphorus is kept on the farm where it can be spread on a dry area away from drains to add to soil fertility and prevent it getting back into drains. Drains with steeper slopes are more vulnerable to sediment and phosphorus being washed downstream during rain storms. Encouraging vegetation growth on the drain beds would help to stabilise the sediment and reduce the potential for movement during storms. Streams (marked in blue on O.S. map) don't tend to retain much sediment but can erode the bank sediment, causing water-quality problems downstream. Planting and maintaining hedgerows alongside channels could stabilise banks and reduce erosion, as well as acting as a buffer for sediment and nutrients in surface runoff.

Surface drainage channels (open drains and subsurface pipes) are a common feature of agricultural landscapes which have high annual precipitation and poor natural drainage. Drainage channels are generally unmapped. In Ireland, increased pressure for more food production (DAFM, 2010) and wetter winters predicted in coming years under climate-change scenarios (Semmler *et al.*, 2008; Dunne et al., 2009), are expected to result in increased drainage of agricultural land in the near future.

Open drains are designated as landscape features for the purposes of the single farm payment and are protected under the requirements of Good Agricultural and Environmental Conditions (GAEC). For the purposes of cross compliance, an open drain is defined as an open trench which is dug to improve the drainage of agricultural land. It generally starts within the holding and is linked directly or indirectly through other drains, to a stream or river which passes through or alongside the holding. It may contain water permanently or only following heavy rain. Under this designation normal maintenance can be carried out as required. Drains under this designation cannot be piped and closed in. Where, in exceptional circumstances, it is necessary to fill in a drain for good reasons such as farmyard expansion, the farmers may do so provided a new drain of equal length is dug in advance of the removal of the old drain on the farmers holding.

In Ireland, agricultural land drainage projects are regulated under the Environmental Impact Assessment (EIA) (Agriculture) Regulations, 2011 (SI 456/2011). Thus, screening is required before farmers are permitted to drain land, if the intended drainage works exceed 15 ha or if they are to be carried out in a proposed Natural Heritage Area, near a monument or where they may have a significant effect on the environment.

2.3 Drainage Pressures

Principal drainage pressures are described by:

- Hydrological connectivity;
- Sediment (and associated phosphorus) sources; and
- Cattle access.

2.3.1 Hydrological connectivity

The extent of drains in an area can be a useful indication of soil type and of the natural propensity for an area to become saturated and generate overland flow - an important pathway for phosphorus and sediment loss. The greater the drainage density, water flow within the drains, and number of culverts in an area, the greater potential there is for the surrounding farmyards and fields (and the fertilisers and pesticides applied to these fields) and local point sources to be connected to downstream water-bodies. Hydrological connectivity is, therefore, an indication that pathways exist for nutrient and sediment loss.

2.3.1.1 Features to look for:

1. On a field scale, *ditch length per field perimeter* can provide an indication of the connectivity of that field to downstream waterbodies. This is based on the assumption that only fields with channels along the edges can connect to the downstream channel network and that the longer the channels, the less chance the surface water in fields has to infiltrate before reaching the channel.
2. *The number of culverts* flowing into a drain provides an indication of how heavy the surrounding soil is and reflects the natural propensity for an area to become saturated and generate surface/near surface flow. Note if the culverts are flowing or not and if there is a particularly high flow as shown on the bottom right – this indicates the extent and activity of the underlying pathways.
3. Water flow:
    a. Dry (least connected)
    b. Standing water
    c. Flowing water (most connected)

Dry ditches tend to indicate poorly permeable biophysical settings, where groundwater baseflow is relatively low and where runoff is high. Therefore, they are usually dry in summer/dry weather and function as streams during the Winter/wet weather. In the latter period, they can be a major contributor of nutrients and sediment to permanent watercourses. Therefore, when undertaking a catchment walk, account should be taken of the time of the year and its relevance.

2.3.2 Drains as sources of sediment (and phosphorus)

Depending on their features, ditches can attenuate (behave as sinks) or augment (behave as sources) the transfer of sediment and associated pollutants from upstream sources to receiving waterbodies.

2.3.2.1 Features to look for

1. Slope. Drains with steeper slopes are more vulnerable to sediment and phosphorus being washed downstream during rain storms. Conversely, flat drains (slopes < 2% have the greatest potential to retain sediment and associated phosphorus, reducing the chances of these pollutants moving into downstream rivers or lakes where ecological impacts are likely greater.
2. Substrate type. A lack of fine sediment on the channel bed indicates that a drain is eroding rather than depositing fine sediment. Conversely, the greater the cover of fine sediment on a

channel bed, the more likely it is that the drain is acting as a sink for sediment. Record the following along three $1m^2$ sections of each drain:

   a) % cover of fine sediment (sand/silt/clay)
   b) % cover gravel, cobble, boulder

3. Evidence of (or high potential for) bank erosion. Exposed banks (absence of vegetation) or recently dredged channels (e.g. far right), bank undercutting or bank collapse.

Figure 2-1: The presence of 3 flowing culverts here indicates high hydrological connectivity (Photo: Mairead Shore).

Figure 2-2: The presence of a very strong flow from a culvert indicates high hydrological connectivity (Photo: Mairead Shore).

Figure 2-3: Exposed bank vulnerable to sediment loss (Photo: Mairead Shore).

Figure 2-4: Bank undercutting – may cause bank collapse (Photo: Mairead Shore).

Figure 2-5: Bank collapse–delivers sediment to river (Photo: Mairead Shore).

Figure 2-6: Recent dredging – temporarily exposes banks to sediment loss and removes vegetation which may have anchored sediment (Photo: Mairead Shore).

The presence of a fence generally promotes the growth of vegetation alongside the bank, thus acting as a buffer for sediment and nutrient losses in overland flow. Furthermore, it serves to exclude animals from the watercourse and associated impacts.

The presence of a hedgerow generally stabilises the bank and acts as a buffer for sediment and nutrient losses in overland flow. Note if there are breaks in the hedge where overland flow could enter the drain.

2.3.3 Cattle Access

Cattle access points cause poaching and bank collapse and are a source of sediment in streams. Cattle access can also elevate levels of nutrients and pathogens in the water. While cattle access is less common in intermittent streams/ditches, nevertheless where this occurs, the same issues will arise.

2.3.3.1 Features to look for:

1. Poaching
2. Evidence of animal manure on the bank or in the drain

Figure 2-7: Evidence of animal poaching and animal manure at edge of drain/stream (Photo: Mairead Shore).

2.4 Mitigation Options

Flat, slow-flowing drains or ditches can get clogged up with sediment, and this sediment can hold or store phosphorus, which will eventually begin to be released back into the drainage water during wet weather events. Regularly cleaning out drains and ditches would ensure that this sediment and phosphorus is kept on the farm where it can be spread on a dry area away from drains to add to soil fertility and prevent it getting back into drains.

If cleaning a drain/ditch, remove vegetation from the bed and one bank only. The other bank should be left undisturbed throughout that season. Where drains are providing a habitat for fish, removal of channel bed vegetation and sediment should be kept to a minimum. Where sediment removal is necessary, this work should be undertaken between mid-May to mid-September, to protect fish eggs and small salmonids. The Fisheries Act states that it is an offence to disturb channels beds where fish may spawn during the autumn or winter.

Enlarging ditches may reduce flow velocities, thus further enhancing phosphorus retention. In addition, it would increase their capacity to accommodate high flows, thus achieving both soil drainage and environmental objectives.

Another design option is to implement a two-stage ditch system (e.g. Västilä and Järvelä, 2011a; 2011b) which carries most of the flow in the main channel and uses vegetated benches to remove sediment and nutrients from overflow during rain events. Sediment traps/debris dams could also be used to enhance sediment retention in drains.

Figure 2-8: Examples of possible mitigation options for land drains (Photos: IFI (http://www.fisheriesireland.ie/fisheries-management-1/463-minding-our-watercourses/file).

Drains with slopes greater than 2% are more vulnerable to sediment and phosphorus being mobilised and washed downstream during rain storms. Encouraging vegetation growth on the drain beds would help to stabilise the sediment and reduce the potential for movement during storms. Small headwater streams don't tend to retain much sediment due to the faster flow of water through them. However, the faster flow rates can erode a lot of the bank sediment, causing water-quality problems downstream. Planting and maintaining hedgerows alongside channels could stabilise these banks and reduce this erosion.

Table 2-1: Drains – Possible Mitigation Options.

Mitigation Option Category	Pressure Type	Mitigation Option	Information Source
Source control	Cattle Access	Fence water course and supply drinking water troughs	Minding our watercourses IFI
	Sediment delivery to drain	Mounding/bunding, buffer-strips, hedgerows, fencing	
Pathway interception	Sediment transfer in drain	Dredging, sediment traps, enlarging channels, two-stage design, debris dams, encouraging vegetation growth, stabilising bank	Shore et al. 2015, 2016; Västilä and Järvelä, 2011a, 2011b; Minding our watercourses IFI
Receptor Rehabilitation		Dredging/Clearing	Minding our watercourses IFI

2.4.1 Drainage Design

Current design of agri-drainage solutions in Ireland is based on two soil profile types: those with or without a shallow water table.

- Enlarging (widening and deepening) ditches in soils with a shallow water table may lower the water table, thus reducing the potential for phosphorus mobilisation in surface runoff. However, enhanced drainage of groundwater flows may increase flow volumes and velocities in the ditches thus reducing their phosphorus retention capacity.
- Enlarging ditches in soils without a shallow groundwater table may reduce flow velocities, thus enhancing phosphorus retention. In addition, it would increase their capacity to accommodate high flows, thus achieving both soil drainage and environmental objectives.

These scenarios would, however, need to be validated and the effects on aquatic ecology would also need to be considered. It is important to bear in mind that in both soil types the level of ditch deepening will always be restricted by the level of the outfall (where the water exits the farmers land). Aside from over-engineering ditches, another design option is to implement a two-stage ditch system (e.g. Västilä and Järvelä, 2011a; 2011b) which carries most of the flow in the main channel and uses vegetated benches to remove sediment and nutrients from overflow during rain events.
Note: To protect fish eggs and small salmonids, maintenance of open drains likely to contain these species should be carried out between mid-May and mid-September. Hedgerows adjacent to drains should not be cut between 1st of March and 31st of August.

2.5 Further Reading

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https://www.teagasc.ie/publications/2013/land-drainage-manual.php

Land Drainage: Maintenance Q&A. https://www.teagasc.ie/crops/grassland/heavy-soils/publications/
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A smart approach to managing open drains protects water quality. EPA Catchments Newsletter. August 2016.
https://www.catchments.ie/smart-approach-managing-open-drains-protects-water-quality/

Environmental Impact Assessment (Agriculture) Regulations 2011. Guide for farmers
https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/environmentalimpactassessment/EIAGuideforFarmers200212.pdf

Environmental Impact Assessment (EIA) (Agriculture) Regulations, 2011 (SI 456/2011).
https://www.agriculture.gov.ie/media/migration/ruralenvironment/environment/environmentalimpactassessment/SI456of2011200911.pdf

Hedgerows, ditches and open drains are designated as Landscape Features for the purposes of the Single Payment Scheme.
https://www.agriculture.gov.ie/media/migration/farmingschemesandpayments/crosscompliance/landscapefeatures/Hedges%20and%20drains%2012%2008%2009.pdf

3 Vegetation Indicators of Natural Drainage

3.1 Significance of Vegetation and Land Use

Vegetation can be used as an indicator of soil drainage and the potential for rainfall to become groundwater recharge or to run off overland. This in turn indicates whether it is surface waters or groundwaters that are potentially at risk of any contamination. Where species indicative of poor drainage are found near rivers or in low-lying areas, it may be reflective of a high groundwater table rather than low permeability soils or subsoils. In contrast, where vegetation indicators of poor drainage occur on slopes, this provides evidence of low permeability soils or subsoils. Either way, poor drainage can be used to assess land areas at risk of overland flow of soils and contaminants.

3.2 What Am I Looking For?

There are a number of studies which highlight the link between vegetation and hydrology. For Irish conditions, Lee (1999) has listed species thought to be of most use. These are mainly from the White and Doyle (1982) and McGovern (undated) lists. These species are easily identifiable in the field and can be associated with different rainfall, topography and, where evident, soil type.

Drainage	Indicator Species	
Poor Drainage	Common/Soft rush *(Juncus effusus)*	Compact rush *(Juncus conglomeratus)*
	Jointed rush *(Juncus articulatus)*	Sharp flowered rush *(Juncus actiflorus)*
	Marsh thistle *(Cirsium palustre)*	Creeping buttercup *(Ranunculus repens)*
	Yellow flag Iris *(Iris pseudacorus)*	Purple loosestrife *(Lythrum salicaria)*
	Meadowsweet *(Filipendula ulmaria)*	Marsh birdsfoot trefoil *(Lotus uliginosus)*
	Wild Angelica *(Angelica sylvestris)*	Marsh horsetail *(Equisetum palustre)*
	Ragged Robin *(Lychnis flos-cuculi)*	Common alder *(Alnus glutinosa)*
	White willow *(Salix alba)*	Self-heal *(Prunella vulgaris)*

Drainage	Indicator Species	
Good Drainage	Yarrow *(Achillea millefolium)*	Creeping thistle *(Cirsium arvense)*
	Poppy *(Papaver rhoeas)*	Ox-eye daisy *(Leucanthemum vulgare)*
	Cowslip *(Primula veris)*	Common ragwort *(Senecio jacobaea)*
	Wild carrot *(Daucus carota)*	Meadow buttercup *(Ranunculus acris)*
	Common daisy *(Bellis perennis)*	Dandelion *(Taraxacum officinale)*
	Bluebell *(Endymion non-scriptus)*	Cow parsley *(Anthriscus sylvestris)*

3.3 Photos of poor drainage vegetation indicators

Figure 3-1: Compact rush (*Juncus conglomeratus*) (Photo: Wikimedia commons – James K. Lindsey).

Figure 3-2: Soft rush *(Juncus effusus)* (Photo: Wikimedia commons – Christian Fischer).

Figure 3-3: Sharp flowered rush (*Juncus actiflorus*) (Photo: Wikimedia commons – James K. Lindsey).

Figure 3-4: Meadowsweet (*Filipendula ulmaria*) (Photo: Naturespot.org.uk – Graham Calow).

Figure 3-5: Marsh thistle (*Cirsium palustre*) (Photo: endonwildlife.blogspot.ie – Wendy Birks).

Figure 3-5: Yellow flag iris (*Iris pseudacorus*) (Photo: first-nature.com – Pat O'Reilly)).

Figure 3-7: Purple loosestrife (*Lythrum salacaria*) (Photo: Wikimedia commons – GartenAkademie).

Figure 3-8: Ragged Robin (*Lychnis flos-cuculi*) (Photo: first-nature.com – Pat O'Reilly).

Figure 3-9: White Willow (*Salix alba*) (Photo: Wikimedia commons – Crusier kingsco.co.uk).

Figure 3-10: Common alder (*Alnus glutinosa*) (Photo: Wikimedia commons – Willow / Wikimedia commons – Nikanos).


Figure 3-11: Self-heal (*Prunella vulgaris*) (Photo: Wikimedia commons – Karelj).


Figure 3-12: Marsh birdsfoot trefoil (*Lotus predunculatus*) (Photo: Wikimedia commons – Harry Rose).

Figure 3-13: Jointed rush (*Juncus articulatus*) (Photo: Wikimedia Commons – Christian Fischer)

Figure 3-14: Marsh horsetail (*Equisetum palustre*) (Photo: Wikimedia commons – Mars 2002)

Figure 3-15: Wild Angelica (*Angelica sylvestris*) (Photo: Wikimedia commons – Franz Xaver).

Figure 3-16: Creeping buttercup (*Ranunculus repens*) (Photo: Wikimedia commons - Agilmente).

3.4 Photos of good vegetation drainage indicators

Figure 3-17: Yarrow (*Achillea millefolium*) (Photo: Wikimedia commons - Lorenzarius).

Figure 3-18: Creeping thistle (*Cirsium arvense*) (Photo: Wikimedia commons – Isidre Blanc).

Figure 3-19: Common poppy (*Papaver rhoeas*) (Photo: Wikimedia commons – Jean-Poi Grandmont)

Figure 3-20: Ox-eye daisy (*Leucanthemum vulgare*) (Photo: Wikimedia commons – Friedrich Bohringer).

Figure 3-21: Cowslip (*Primula veris*) (Photo: Wikimedia commons – Andreas Eichler)

Figure 3-22: Common ragwort (*Senecio jacobaea*) (Photo: Wikimedia commons - Rasbak)

Figure 3-23: Wild carrot (*Daucus carota*) (Photo: Wikimedia commons – Tigerente).

Figure 3-24: Meadow buttercup (*Ranunculus acris*) (Photo: Wikimedia commons - Kebman

Figure 3-25: Common daisy (*Bellis perennis*) (Photo: Wikimedia commons – Willow).

Figure 3-26: Dandelion (*Taraxacum officinale*) (Photo: Wikimedia commons – Tomas Kuran aka Meteor2017)


Figure 3-27: Bluebell (*Endymion non-scriptus*) (Photo: Wikimedia commons – Anthony Appleyard)


Figure 3-28: Cow parsley (*Anthriscus sylvestris*) (Photo: Wikimedia commons – Qwert1234)

3.5 Influences on the Distribution of Vegetation Indicators of Drainage

The link between vegetation and soil moisture is not always clearly defined because many species can flourish over a range of moisture gradients. In addition, land management practices such as agriculture and forestry tend to modify the natural conditions of the underlying substrate by drainage, fertilisation and herbicide usage. These activities may affect or even dominate the impact on the vegetation over that of the moisture content. The following factors influence the soil drainage or wetness, tendency for soakage or overland flow, and the distribution of different plants.

3.5.1 Soil and Subsoil Texture and Permeability

Soil texture describes the relative proportions of the various sizes of particles (mainly sand, silt and clay) in the mineral fraction of the soil. The soil structure influences pore space, and therefore aeration and drainage conditions (Gardiner and Radford, 1980). Closely packed and well cemented structures, such as the horizontal platy types, impede downward movement of water while less densely packed crumb structures enable good drainage capacity (Brady, 1990).

Subsoil permeability is controlled by the finest grains, and low permeability subsoils (as defined by GSI) have more than 13% CLAY and 50% fines (SILT plus CLAY), as a proportion of the sand and finer-grained sediment fraction. The amount of compaction by the movement of ancient ice sheets that emplaced glacial tills ('boulder clays') also affects the subsoil permeability.

3.5.2 Topography

Topography influences soil moisture and vegetation through: climatic variability, slope aspect, the rate of infiltration and slope.

Rainfall and evapotranspiration are affected by topography. As the altitude increases, rainfall increases. The aspect of the slope affects the amount of incoming radiation, which is one of the factors influencing evaporation. North-facing slopes can have 14% less solar radiation than south-facing slopes. The elevation and amount of incoming solar radiation also influences the plant communities.

Within a rainfall event, once the infiltration capacity of the surface is exceeded, ponding occurs. The ponding depth increases until it is sufficient to overcome the hydraulic resistance of the surface, at which time overland flow begins (Dingman, 1994).

As the slope increases, the resistance to overland flow decreases and therefore the flow is more readily initiated. If the down-slope flow encounters a reduction in slope angle, such as at the base, the velocity of the flow decreases which encourages infiltration or surface ponding. On flatter surfaces, there is a larger resistance to overland flow. Therefore, any ponding remains until it evaporates or the water stored in the upper topsoil horizons has percolated down through the profile which facilitates further infiltration.

3.5.3 Net Annual Rainfall and Rainfall Intensity

In Ireland, research has shown that, in general, in the summer months all but gley topsoils have an infiltration capacity which exceeds 18 mm per hour. In the winter months, very few topsoils have an infiltration capacity which exceeds 18 mm per hour (Diamond and Shanley, 1998) (18 mm per hour is equivalent to a high-intensity 60 minute rainfall with a return period of 5 years (Logue, 1975)). Therefore, it can be assumed that high intensity rainfall will infiltrate all topsoils except for gleys in summer, and, in winter, high intensity rainfall is more likely to runoff all types of topsoils equally.

3.5.4 Land management

A further potential influencing factor is land management (i.e. drainage, tillage, cutting, fertilisers, herbicides and pesticides will have an impact on either the properties of the soil or directly on the plant species). One of the land uses which requires a high level of land management is arable cropping. Arable crops generally require both favourable climatic and soil conditions, and are managed to maximise productivity. Therefore, where they occur, they are *likely* to reflect good topsoil and subsoil drainage properties, which will potentially indicate a moderate or high permeability subsoil, or low effective rainfall. Grasslands and pastoral farming dominate the remainder of agricultural land and generally require less management. However, evidence of management is important in the assessment of vegetation. An example of this is where well-managed fields in low permeability subsoil, drumlin areas are adjacent to unmanaged slopes covered in rushes.

3.5.5 How do I know if what I measuring or reading is normal or wrong?

As noted above, the link between vegetation and soil moisture and, therefore, the tendency for infiltration or overland runoff is not always clearly defined. This is because plants may have a wide environmental range and land management practices may have modified the natural conditions. However, particular plants or plant communities can indicate the tendency of the soil beneath an area of land to be wet or dry. In turn, the likelihood of overland runoff or soakage into the ground can be assessed. This then indicates whether any contaminants are likely to be transported by the overland pathway (for example, phosphorous), or by subsurface pathways (for example, nitrate).

Acknowledgements: much of this material has come from Monica Lee's M.Res. thesis (Lee, 1999) and from Geological Survey Ireland's Groundwater Protection and Groundwater Vulnerability Mapping Programme

3.6 Further Reading

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4 Biodiversity Indicators

This section highlights a selection of species which can be easily identified during a catchment walk and by their presence provide additional information on the water quality and biodiversity along stream channels.

4.1 Biodiversity

The biodiversity of surface waterbodies will generally reflect its condition or health. Certain wildlife species can be easily identified and mapped to provide an insight into both the physical and chemical quality of streams, and are particularly useful in giving a longer term (months even years) assessment of environmental quality. Certain iconic species can also help the public relate to their local waterbody, and thus foster greater interest in efforts to protect it. In addition, the information if recorded systemically can: a) provide a baseline against which future changes can be measured and; b) provide information relevant to other regulatory concerns (e.g. Heritage and EU Habitats Directive).

4.2 Indicator Species and Water Quality

Typically, the cleaner the water, the greater the diversity and abundance (e.g. invertebrates) of aquatic and riparian species it supports – however the story is not so simple as riparian animals which are not exclusively aquatic, can range over large areas foraging even in terrestrial habitat. Biomass can often increase in enriched water prior to the tipping point that leads to acute events such as fish kills or loss of other species. The abundance of certain species may not correlate positively with increasing water status. Take for example the otter where enrichment may result in a higher biomass of pollution tolerant species and so an increase in available food to otters (e.g. increased abundance of coarse fishes or biomass). However, it is worthwhile recording the presence of all the species in this document, where evidence is presented on the ground, as their occurrence collectively will not only give an indication of water quality but will also give a better indication of the wider biodiversity health of the water body (river reach etc.). It also makes the survey exercise itself more interesting!

Other indicator species such as the dipper or certain invertebrates (some mayfly and stonefly) do correlate strongly with water status (Information on invertebrates is given in **Volume 4**). For Local Catchment Assessments, it is recommended to focus efforts on the following terrestrial species:

1. Otter (but record other mammals where evident) and;
2. Birds (dipper, kingfisher, and sandmartin).

4.3 Timing of Survey

Timing of the survey relative to recent high water events will determine the extent of the evidence for mammal activity that may be recorded in a specific survey area. Ideally monitor during drier periods or wait several days after heavy rain events as floods can wash away evidence of activity along the river margins. Record the condition of the river - if the river has been recently in flood (e.g. fresh signs of flooding, flattened riparian vegetation along river edge, increased wetted area along river bank, silt on vegetation etc.)

4.4 Mammals and Birds

Key mammalian species of conservation significance include otter, mink (invasive species) and to a lesser extent fox, pine martin and badger. Mammals and birds associated with fast flowing water are mostly predators – predating on mammals, amphibians, birds, fish and or invertebrates.

4.4.1 Otter

There is no fixed relationship with water quality. Distinguishing features of otter include trails (compressed grass and trampled paths) parallel to the river bank (**Error! Reference source not f ound.**) These may also be used by other mammals such as badger and fox. However, tell tail signs for otter include “slides” to the river associated with these trails (**Error! Reference source not found.**) and “couches” or rest areas (compressed vegetation) and obvious crossing points between pools used for feeding. Trails will usually also be marked with “spraints” and occasionally bile.

Figure 4-1: Figure 4-1: Otter run across a field linking two otter slides (river access points). Pathway visible as trampled grass. These runs or trails often follow the river bank and cross between river access points (Photo: Fran Igoe).

Figure 4-2: Otter slide. Flattened grass and eroded point in river bank associated with regular otter egress and entry to the river (Photo: Fran Igoe).

Otter footprints are distinctive and can be distinguished from domestic dogs by the number of toes. Otter prints normally show five toes versus the four associated with a dog's footprint. Badger footprints may be confused with otter but are narrower and the nails on each toe are more pronounced. Dog prints in urban areas will be very common, so be on the lookout for them. Check soft silty areas, such as back eddies and under bridges, or overhanging trees where vegetation is absent (**Error! Reference source not found.** and **Error! Reference source not found.**).

Figure 4-3: Otter footprint in silt along river edge (Photo: Fran Igoe).

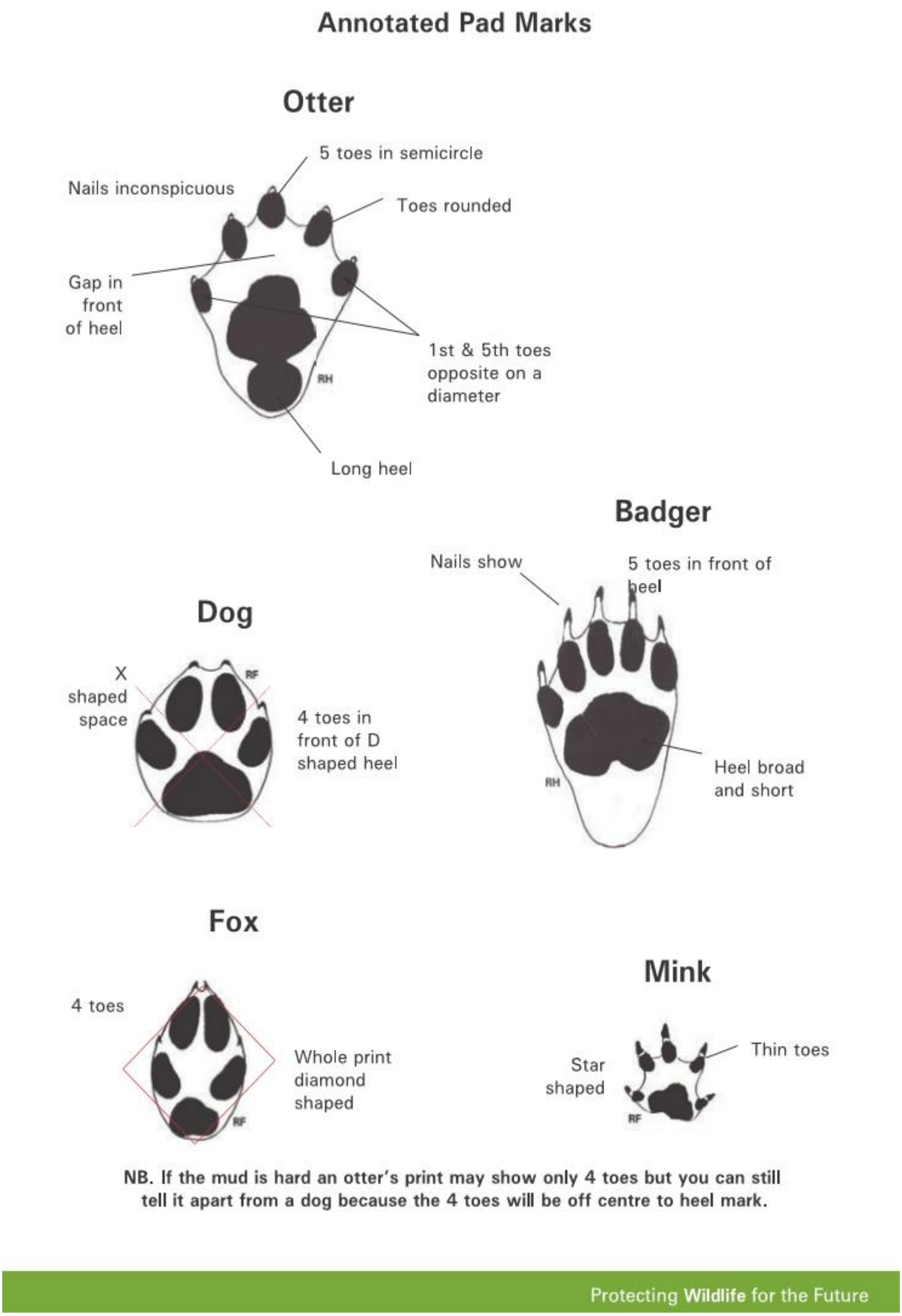

Figure 4-4: Mammal footprints.

4.4.1.1 Otter Spraints

Possibly the most useful otter sign to record is the presence of spraints. Otters are territorial and mark their territory by sprainting (pooh) on key landscape features, such as protruding boulders, trees stumps or bridge ledges. Egress and ingress points from the river are often marked (**Error! Reference source not found.** and **Error! Reference source not found.**). They may also mark the entrance of their nesting areas known as holts (Figure 4-).

Otter spraints differ from those left by mink (**Error! Reference source not found.**). Otter are larger, and the content is more readily distinguishable. Fox scats look more like dog poop and often contain quite visible hairs whereas the otter spraint will often contain undigested bones, fish scales, feathers and/or pieces of crayfish exoskeleton. The otter spraint smell has been described as smelling like jasmine - however, it is not recommended to sniff otter spraints as the occasional otter may be a TB carrier.

Make sure to note the content of the spraint however (crayfish, fish scales, mammal or bird bones) as this can give some indication of what the surrounding food availability might be.

Figure 4-5: Otter spraint and ball of grass (associated with otter activity) (Photo: Fran Igoe).

Figure 4-6: Otter spraint on left and fox scat on right. Bones of a small mammal or bird are visible in the otter spraint (Photo: Fran Igoe).

Figure 4-7: Otter holt entrance. Normally located close to the river but usually above the flood prone area. Often accompanied with other signs of otter activity such as runs or sprainting. (Photo: Fran Igoe)

Figure 4-8: Mink scat (Photo: Fran Igoe).

4.4.2 Birds - Dipper

The Dipper (Figure 4-) is generally an indicator of good water quality. Dipper are small black birds with a white bib. They usually display bobbing behaviour.

Figure 4-9: Dipper (Photo: John Murphy (BirdWatch Ireland))

Dipper nests are very distinctive and easy to identify. Generally, they are round balls of moss, the size of a football with a single entrance, but they will build their nests to fill the available cavity (Figure 4-), if constructed under or around bridges or other supporting platforms. Nest building normally occurs in early February.

Figure 4-10: Dipper nest. Large spherical shaped nest constructed out of moss with a single entrance/exit hole (Photo: Fran Igoe).

4.4.3 Birds - Kingfisher

There is no fixed relationship, but Kingfishers (Figure 4-11) are indicators of river bank stability. Most people are familiar with this brightly coloured bird associated with rivers.

Figure 4-11: Kingfisher (Photo: IRD Duhallow).

Kingfishers require water which can support fish. They are often only noticed as a bright blue flash that momentarily passes the observer. They select high banks adjacent to rivers and canals to construct their nests, which take the form of burrows (Figure 4-). A single burrow in a bank about 1m or more above the low watermark may be an indication of kingfisher. Look out for signs of discoloration below the nest hole or a nearby perch site (branch) as this is a sure sign of a kingfisher nest site.

Figure 4-12: Kingfisher nesting hole in an earthen river bank (Photo: Fran Igoe).

4.4.4 Birds - Sand Martins

A relationship between sand martins and water quality has not been established but sand martins are an indicator of river bank stability. Sand martins are a sandy brown bird similar to house martin or sparrow. They are communal birds nesting in eroding river banks or escarpments close to rivers (Figure 4-13). These banks are normally sandy or earthen banks but on occasion they will nest in crevices of concrete in certain locations, such as under road bridges. Nesting is normally from April to August. Tell-tale signs are the number of holes close to each other (tens to several hundred). During the nesting season, adults can be observed entering and leaving the nesting holes usually flying close by or over the water body feeding on insect.

Figure 4-13: Sandmartin breeding colony in “relatively stable” eroding bank along a river in South West Ireland (Photo: Fran Igoe)

4.5 Freshwater Pearl Mussel

Healthy reproducing populations of freshwater pearl mussel indicate High ecological status. Its formal conservation status is “highly threatened”.

These are large black or dark brown coloured freshwater bivalve found in fast flowing water (not to be confused with swan mussel (Figure 4-14)). They require High status, pristine environments (water quality and habitat) but adults can survive in Good status and even linger on in Moderate status waterbodies. However, the population will fail to recruit new mussels under these conditions as the juveniles require pristine water conditions, in terms of sedimentation, hydrology and nutrient content to survive.

Where populations are present, empty shells may be deposited up on river banks. Record number of shells, location and photograph for identification.

	
Freshwater Pearl Mussel	Swan mussel

Figure 4-14: Comparison of freshwater pearl mussel shell (dark shell) compared to the swan mussel (light shell). The latter normally inhabits slower moving reaches of rivers and canals compared to freshwater pearl mussel and their shells are less dense (Photo: Wikimedia commons – Tom Mejer / Wikimedia commons - Boldie)

5 Indicators of Karst Landscapes

"Karst" is a landscape created by the dissolution of soluble rocks such as limestone, dolomite, and gypsum. It is characterised by underground drainage systems, with a very low surface water drainage density and significant groundwater–surface water interaction. Karst features that can be seen on the land surface include swallow holes (or sinkholes), depressions, turloughs (temporary lakes) and caves.

Karst is relevant to water pollution studies because karst conduits act as preferential pathways for groundwater flow and pollutant transport underground. In karst systems, pollutants can travel large distances (kilometres) in short periods (hours, days). Water supplies in karst systems are, therefore, vulnerable to pollution events.

5.1 Significance and Purpose of Recognising Karst Features in the Landscape

The identification of karst features in a catchment is important for the following reasons:

1. **To construct a coherent conceptual model of how the combined groundwater–surface water system operates within a catchment.** In karst areas, the groundwater and surface water systems are usually closely linked and these linkages must be identified and characterised in order to construct a sound and comprehensive conceptual understanding of how the catchment hydrology operates under different conditions.
2. **To identify points or reaches where karst groundwater discharges to a surface water channel (springs or gaining streams).** Water commonly enters karst aquifers via swallow holes and then proceeds to move through conduits in the aquifer relatively quickly and with little or no attenuation or buffering before re-emerging to the surface drainage system via springs. These typical karstic groundwater–surface water connections provide pathways where contaminated waters can get into, move through, and discharge from aquifers very quickly (almost as quickly as they would move through surface channels in some cases) and with little or no reduction in the concentration of contaminants they contain.
3. **To identify points where surface water becomes groundwater recharge (swallow holes or losing streams).** Common features of karst areas in Ireland are sinking streams. In such areas, streams may continuously or periodically provide groundwater recharge, either at points via a swallow hole or along a losing stretch of channel. The accurate mapping and characterisation of such features is important for a meaningful conceptual understanding to be constructed for such a catchment.
4. **To identify streams that are receiving groundwater that has been transferred via the karst aquifer from a source area outside that topographic catchment.** In many karst catchments spring catchments are defined by the altitude of the bedrock surface and the structural geology of the aquifer as opposed to the surface (topographic) catchment of a river. The topographic catchment may be delimited by overlying glacial deposits and such boundaries commonly do not reflect groundwater catchments in karst areas. These catchments are identified by mapping karst springs and swallow holes in combination with flow measurements that allow water balances to be constructed. If stream flows in a catchment are greater than they should be based on catchment size, then the source area where this water originated from should be identified. This is important, as contaminants originating from outside the topographic catchment may be impacting water quality at a location where they would not be expected to under normal (non-karst) circumstances.
5. **To identify and characterise dynamic karst connections to a stream that operate under certain hydraulic conditions.** Under certain conditions inter- and intra-catchment surface water–groundwater connections may flow or cease to flow depending on changing water levels from high winter levels to drought conditions. It is important to characterise such interactions in karst areas so that the time period(s) when linkages are active and inactive

are clearly understood. This can have important consequences when investigating impacts from other temporally constrained activities such as land spreading etc.

While spot flow measurements can be used for all five purposes listed above, **the main function of karst feature identification during catchment walks will be to identify the location of points where karst groundwater is discharging to the surface drainage network. This information can be used to help rule in or out areas of the catchment that may be contributing pollutants of concern** (particularly phosphate and microbial pathogens) **to surface water via the groundwater pathway.**

5.2 What Am I Looking For?

The main karst landforms are springs, swallow holes, enclosed depressions, caves and turloughs. Other features include dry valleys and estavelles. These are all surface expressions of an underground drainage network of solutionally-enlarged fissures and conduits within the underlying limestone bedrock.

Karst feature	**Direction of water flow**	**Size and function**
Spring or seep	Groundwater – surface water	A few litres/minute to >10,000 m^3/d, often >1,000 m^3/d. Seeps often shallow lateral flow along bedding planes. Large springs are convergence of regional groundwater flow.
Enclosed depression (sinkhole) • Doline • Uvala • Polje	Surface – groundwater	Dolines are basin- or funnel-shaped hollows a few to tens of metres wide by less than a metre deep (shallow) to several metres deep (steep). Uvalas and Poljes are km scale.
Swallow hole	Surface – groundwater	A hole or hollow that has surface water permanently or periodically flowing into it. Can be less than a metre or doline-sized.
Estavelle	Both	A hole in base of a turlough that is a spring and a swallow hole depending on groundwater level.
Turlough	Both	A seasonal shallow lake that may empty completely or partially.
Dry valley	Both	Valley can be permanently dry, or spring point can migrate up catchment as groundwater level rises.
Limestone pavement	Surface – groundwater	Exposed karstified limestone layers with deep cracks between “paving stones”.
Epikarst	Both	A few metres thickness of heavily weathered limestone can allow vertical and lateral movement of water underground above regional water table. Water can emerge as seeps and in surface waters.
Conduits and caves	Both	Conduits and caves transmit water into, through and out of underground. Caves are generally large enough to fit into, conduits are smaller.

Karst features can be seen in the field, but sometimes it is easier to see them in aerial photographs or identify them from the six inch:one mile OSi maps.

The main source of information on karst and karst features is the Geological Survey of Ireland website (https://www.gsi.ie/en-ie/data-and-maps/Pages/Groundwater.aspx) and the karst database, which contains information on karst features and tracing results. Figure 5-1 shows a typical screenshot showing karst features and Figure 5-2 illustrates the information on available water tracing.

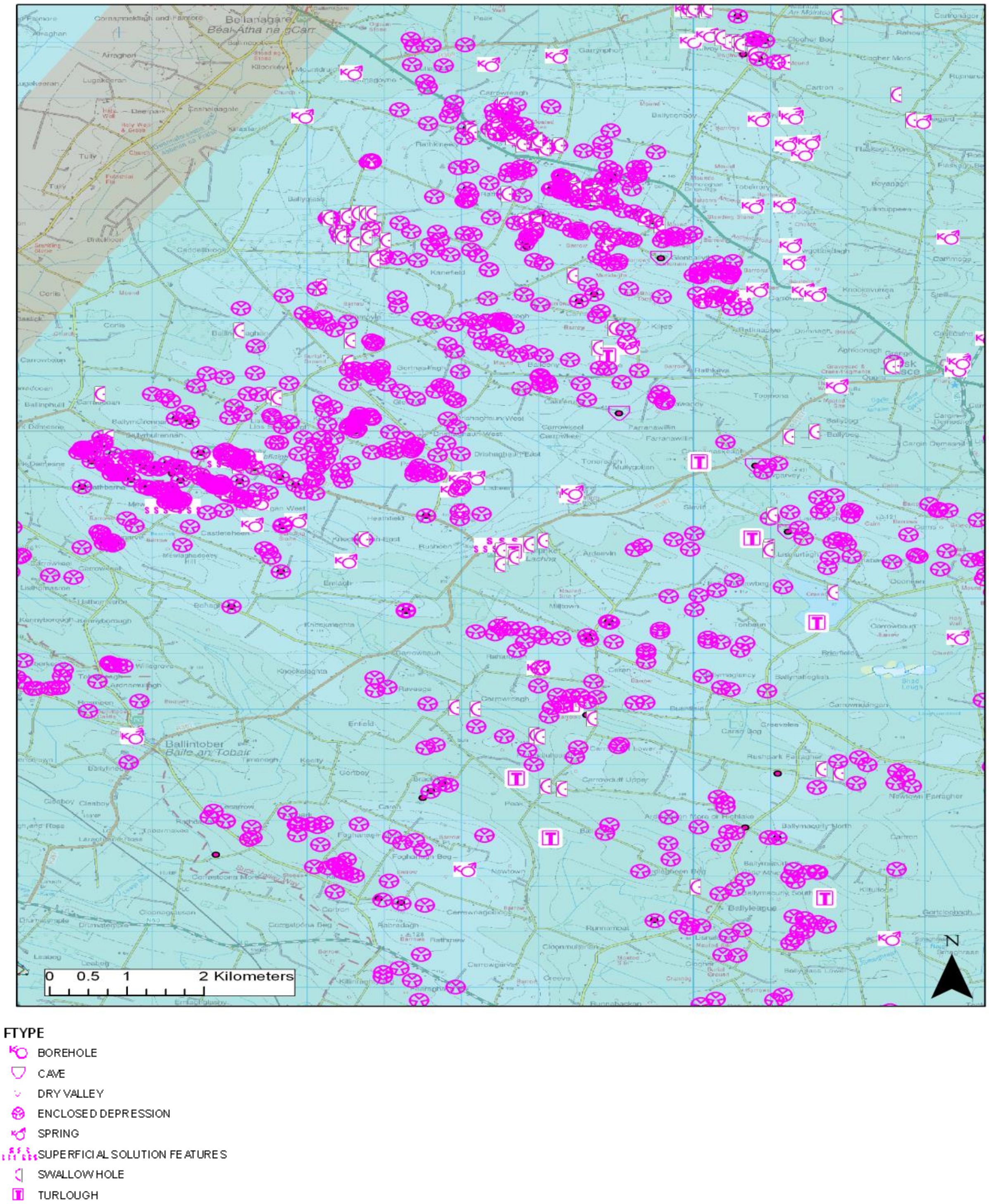

Figure 5-1: A typical screenshot from the karst database (See link: https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=3400f393afa844538e5b81679552205d).

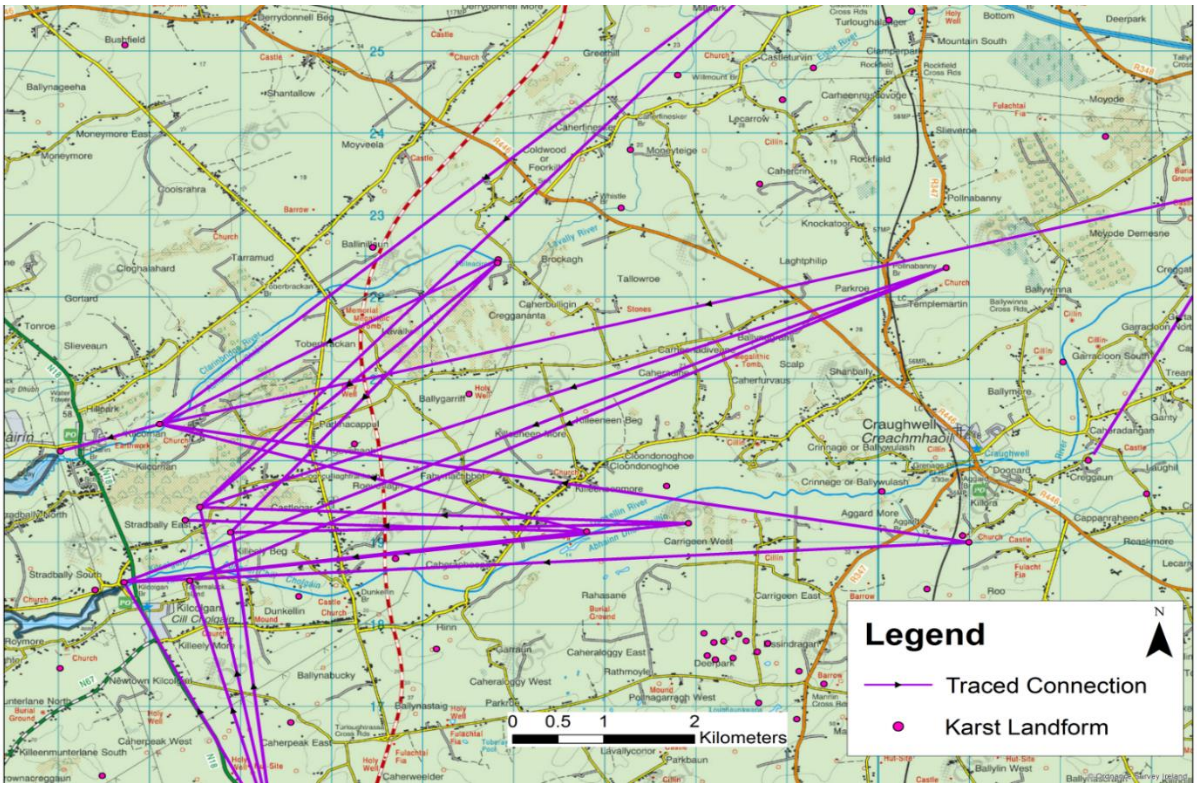

Figure 5-2: An example of tracing results shown on the GSI karst water tracing database (See link: [https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=3400f393afa844538e5b81679552205d)](https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=3400f393afa844538e5b81679552205d)

5.3 Photographs of karst features

Figure 5-3: Small spring on the bank of a river (Photo: David Drew).


Figure 5-4: Large spring emerging in low-lying landscape at head of stream (Photo: Donal Daly).


Figure 5-5: Seeps at base of epikarst[1] in quarry (shown by orange-beige streaks) (Photo: GW3D/GSI).

[1] Epikarst is the uppermost (2-5m typically) part of the limestone bedrock where maximum dissolution of limestone has taken place.

Figure 5-6: Seeps at bedding planes in quarry (shown by orange streaks) (Photo: Robbie Meehan).

Figure 5-7: Medium-sized upland doline (Photo: Caoimhe Hickey).


Figure 5-8: Small collapse feature (Photo: GSI).


Figure 5-9: Doline field in north Roscommon (Photo: Donal Daly).


Figure 5-10: Swallow hole, taking run-off from an upland area in County Kilkenny (Photo: David Drew).

Figure 5-11: An intermittent swallow hole near Killeglan Spring, Roscommon (Photo: Donal Daly).

Figure 5-12: A medium sized swallow hole in Roscommon (Photo: Donal Daly).


Figure 5-13: Brock turlough (summer low ground-water levels) (Photo: Owen Naughton).


Figure 5-14: Brock turlough (winter high ground-water levels) (Photo: Owen Naughton).

Figure 5-15: Epikarst (Photo: GW3/GSI).

Figure 5-16: Epikarst (Photo: Katie Tedd).

Figure 5-17: Vertical cave of several metres (Photo: GSI).

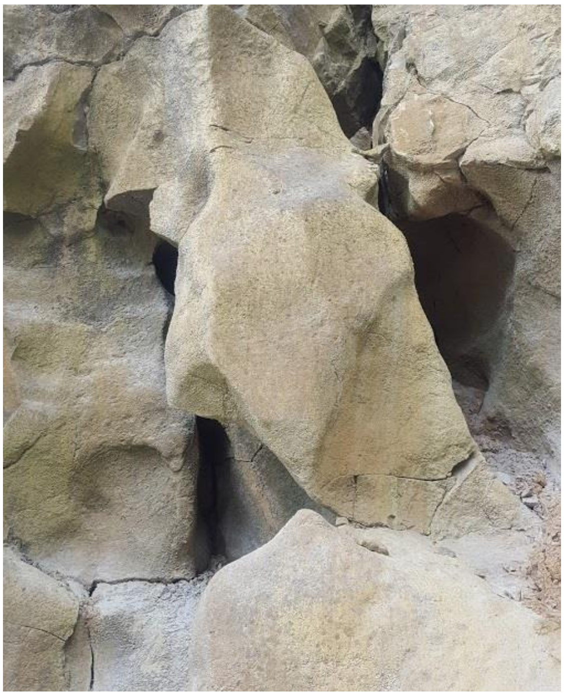

Figure 5-18: Conduits at decimetre scale (Photo: GSI).

5.4 What Do I Measure and What Can Influence My Observations?

Because groundwater typically flows for a significant distance underground, often it will be the desk study or catchment wide assessments that highlight the presence of karst and known underground connections between swallow holes and springs or streams in the catchment.

Where groundwater emerges at a point to become surface water, or streams sink to become groundwater, the springs and swallow holes are readily identifiable. However, where rivers sink gradually, or gain flow from groundwater seeping into the river base over a reach, other methods may be needed to identify the groundwater–surface water interaction. These methods include flow gauging (see **Volume 4**), and taking conductivity and temperature measurements along a length of surface water. Measurements and readings can be made every several hundred metres to check for losing or gaining reaches of stream.

Discrete groundwater inflows to streams are indicated by spikes in temperature and electrical conductivity (see **Volume 4**).

Determining contrasts in groundwater inflow volumes, temperature and electrical conductivity is easier at certain times of year. For volume estimation, it is usually easier to see the extra contribution of groundwater during periods of low rainfall. However, over prolonged dry periods, the water table may fall below the base of the stream or river, and it will dry out entirely.

Temperature contrasts are best noted during low flow conditions in summer or, even better, in winter. Groundwater temperatures are generally a steady 10°C (except for rapidly sinking and remerging waters); this contrasts with summer or winter temperatures of 15-18°C and 2-5°C respectively. During rainy periods, recent rainfall will typically dilute and mask the contrast.

5.5 How Do I Know if What I Measure or Read is Normal or Wrong?

Karst features are generally quite unambiguous. However, field assessments may miss karst features due to masking by topography or vegetation, and inflows to or outflows from the stream can be subtle and not easy to definitively identify. Occasionally, man-made features may be mistaken for karst (e.g. dug pits may be mistaken for enclosed depressions, or piped drains mistaken for springflows, if the pipework is not visible).

As noted above it is the typically large size of stream and spring catchments in karst limestone areas, where groundwater can travel several kilometres in a few days, that can present difficulties in linking observations in a surface water body to land-use activities in the catchment. Existing information, such as that available from Geological Survey Ireland on known underground karst connections, can be very useful in understanding what pathways are dominant in a catchment, and how those pathways operate.

5.6 Useful References

Drew, D., Hötzl, H. (1999). *Karst Hydrogeology and Human Activities*. Impacts, Consequences and Implications. Balkema, Rotterdam.

Drew, D. et al. (in prep) *Karst of Ireland: Landscape and Hydrogeology*. Geological Survey of Ireland.

Ford, D., Williams, P., (2007), Karst Hydrogeology and Geomorphology. Wiley, 576 p.

Geological Survey Ireland, Karst feature and karst underground connections geodatabases and maps. https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=3400f393afa844538e5b81679552205d).

Goldscheider, N., Drew, D. (Eds.) (2007), Methods in Karst Hydrogeology. Taylor & Francis, London, 264 p.

Irish Karst Working Group (2000), The Karst of Ireland: Limestone Landscapes, Caves and Groundwater Drainage Systems. Geological Survey of Ireland.

6 Groundwater Indicators

6.1 Purpose

The role of groundwater in Local Catchment Assessments is threefold:

1. As a receptor itself used for provision of drinking water from wells and springs;
2. As a pathway for pollutants to surface water bodies;
3. As a factor that reduces flows and/or levels due to abstraction of groundwater.

The purpose of this section is to help investigation of groundwater quality issues both for water supplies (wells and springs) and for groundwater flowing to and discharging in surface water bodies. The potential impact of groundwater abstraction is not dealt with.

6.2 Significance

As documented in Section 4.2.8 in **Volume 1**, 13 groundwater bodies are *At Risk* for failing to meet their drinking water objectives, and a further 37 are *At Risk* due to the groundwater contribution of phosphate to surface water, with 82 in *Review* for the same reason.

For assessment of any groundwater quality issue, it is important to understand the problem in a Source-Pathway-Receptor (SPR) framework, which is illustrated in Figure 6-1 and described in Section 3 of **Volume 5**. The elements of this need to be understood to focus measures as a means of achieving "the right measure in the right place".

- The **receptor** in this case is groundwater for abstraction or groundwater flowing to surface water bodies and groundwater dependent ecosystems. The impact on this may be known through the results of sample analysis or suspected through others means such as ecological impacts in surface waters.
- The impacts on the receptor will point towards the **source** of the impact (e.g. high nitrate concentrations in well samples potentially relating to diffuse use of organic or inorganic fertilisers in the catchment, or high phosphorus concentrations in a spring potentially related to phosphorus loss from soils in areas with thin soil/subsoil cover).
- This also introduces the **pathway** that links the source and the receptor, and allows an impact to occur. Different pollutants can have varying level of mobility in the environment depending on their characteristics and the pathways involved. An example of this is phosphorus which may travel through a thin layer of soil and subsoil (e.g. <0.5m), into a karstic groundwater system and quickly to a surface water receptor, but will not generally travel through thicker subsoil.

To prevent an impact from occurring the SPR link can be broken through removing the source (e.g. reducing pollutant losses (point or diffuse)), breaking the pathway through disrupting the movement of a pollutant from source to receptor (e.g. using a barrier to restrict the flow of contaminated groundwater) or through protection/remediation/treatment of the receptor (e.g. treatment of abstracted drinking water). Source and pathway information can be combined to give relative potential for impact for different areas within the catchment. This can be used to determine Critical Source Areas (CSA), those areas within a catchment more likely to be contributing to a water quality issue, to help focus on the ground investigation.

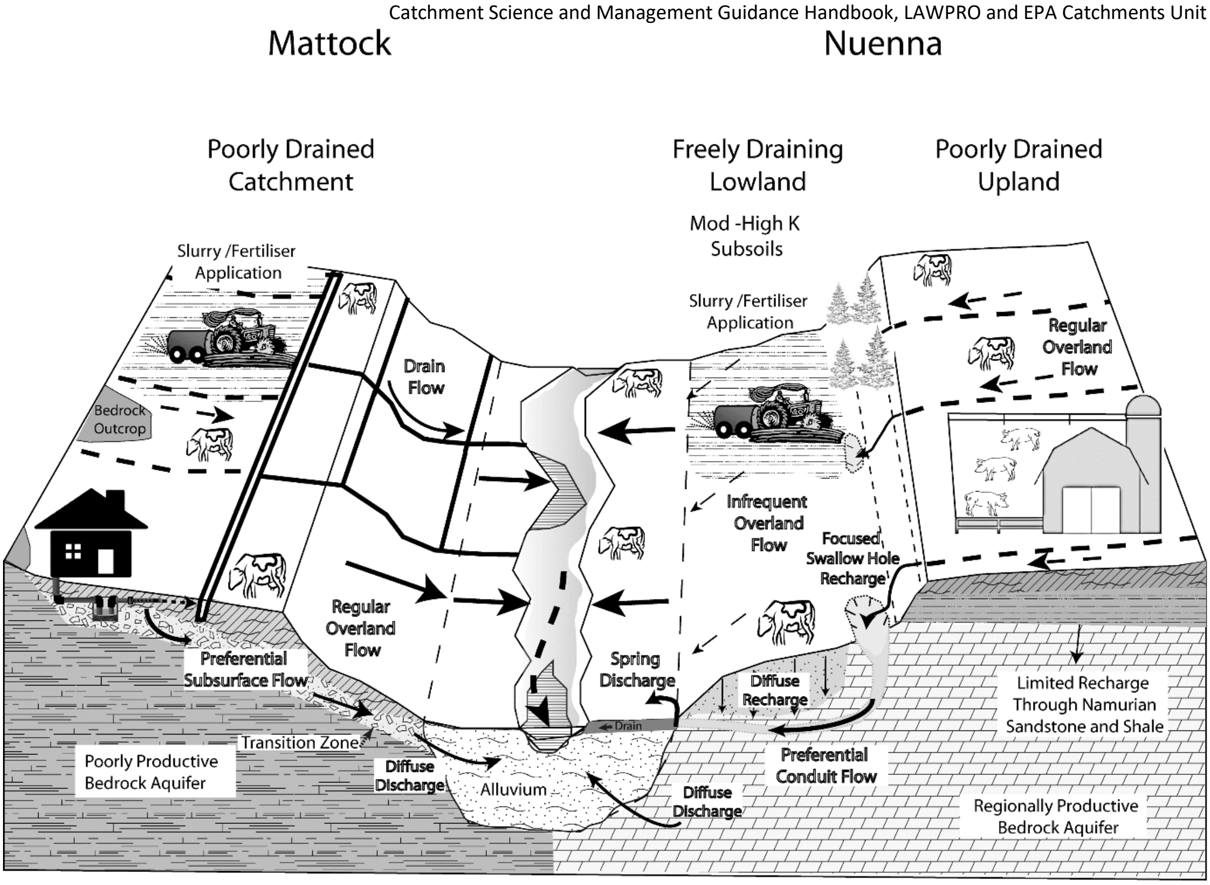

Figure 6-1: Schematic representation of the contrasting hydro(geo)logical pathways contributing flow and nutrients to the stream in the poorly drained Mattock catchment (left) and freely draining karst catchment (right). The thicker arrows represent a larger relative flow component than the thinner arrows. Dashed arrows represent intermittent flow (Copied from Deakin *et al.*, 2016[2]).

6.3 General Indicators

There are a number of groundwater quality and pathways elements that have an overall relevance and that may provide a context for the groundwater components of IAs.

6.3.1 Groundwater Quality

Let us assume that either groundwater quality data are available or that samples will be taken and analysed. The following is some 'basic' advice, which is not intended to be complete or comprehensive. The following parameters are good groundwater pollution indicators: *E.Coli*, Nitrate, Ammonia, Orthophosphate, Potassium, Chloride, Iron and Manganese. For comprehensive details on natural background levels for chemical parameters in Irish groundwater, see the report by Tedd*, et al*., 2017[3].

6.3.1.1 E.Coli

This is the parameter used to check for the presence of faecal bacteria and perhaps viruses in groundwater. The presence of *E.Coli* indicates pollution by organic wastes from warm blooded animals, e.g. humans, bovines, birds, and therefore from a wide variety of pollution sources.

The natural environment, in particular the soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and absorption. However, there are three high risk situations where pathogens can move readily in the groundwater: i) where there are permeable sands/gravels

[2] Available at: http://www.jstor.org/stable/10.3318/bioe.2016.19

[3] https://www.epa.ie/researchandeducation/research/researchpublications/researchreports/EPA%20RR%20183%20Essentra_web.pdf

with a shallow water table; ii) where fractured bedrock is present close to the ground surface; and iii) karstic limestone areas where there are sinking streams. All these three scenarios are present in areas where the groundwater is classed as 'extremely' vulnerable to pollution. In addition, the 'point of release' of the contaminants may be relevant. For instance, it is the ground surface for slurry spread on the land and 0.8 m+ for septic tank effluent and 2m+ for leaking tanks.

6.3.1.2 Nitrate
Nitrate is one of the most common contaminants identified in groundwater. The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached from free-draining soils and subsoils (note: not poorly draining soils and subsoils). As the normal concentration in uncontaminated groundwater is low (less than 5 mg/l as NO3), nitrate can be a good indicator of contamination by fertilizers and waste organic matter. In Irish groundwater, by far the main source is spreading of fertilizers (organic and inorganic).

6.3.1.3 Ammonia
Ammonia has a low mobility in soil and subsoil, and its presence at concentrations greater than 0.1 mg/l in groundwater indicates a nearby waste source (as the ammonia will normally readily convert to nitrate) and/or vulnerable conditions. (Note: when a high ammonia concentration converts to nitrate, it is not significant as an environmental issue, as relevant nitrate concentrations are approx. three orders of magnitude higher.)

In certain circumstances, where there are reducing conditions in the groundwater, the nitrogen may be present in the ammoniacal form.

6.3.1.4 Phosphate
Phosphorus is relatively immobile in soils and subsoils because the orthophosphate anion precipitates readily in soil and subsoil (although recent Teagasc research (Mellander *et al*. (2015) has shown that well-drained iron-rich soils favour P mobilisation into soluble form and transfer to groundwater).

While there isn't a limit given in the Drinking Water Regulations, the WHO recommends a limit of 5 mg/l for phosphate (equivalent to 1.96 mg/l of phosphorus). Except for circumstances where there is gross contamination, phosphate concentrations in groundwater would not be close to this concentration.

However, the environmental quality standards (see Table 9.1 in **Volume 4**) are far lower, and groundwater could provide a pathway for significant phosphate loads where the bedrock is at or close to the surface and where there are sinking streams.

6.3.1.5 Potassium
Potassium is relatively immobile in soil and subsoil. Consequently, the spreading of fertilizers is unlikely to significantly increase the potassium concentrations in groundwater. In most areas in Ireland, the background potassium levels in groundwater in Ireland is generally less than 3.0 mg/l (if not 2 mg/l). Higher concentrations are found occasionally where the bedrock contains potassium (e.g. certain granites and sandstones). The background potassium:sodium (N:Ka) ratio on most Irish groundwater is less than 0.4 and often 0.3. The K:Na ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4. Consequently, a K:Na ratio greater than 0.4 in groundwater can be used to indicate contamination by plant organic matter – usually from farmyards. However, a K:Na ration lower than 0.4 does not indicate that farmyard wastes are not the source of contamination (or that a domestic wastewater treatment system is the cause) as potassium is less mobile than sodium.

6.3.1.6 Chloride
The principle source of chloride in uncontaminated groundwater is rainfall and so in any region, depending on the distance to the sea and evapotranspiration, chloride levels in groundwater will be fairly constant. Potassium chloride fertilizer can also be a source. Chloride, like nitrate, is a mobile

(sometimes called conservative) cation. Also, it is a constituent of organic wastes. Consequently, levels appreciably above background levels (~20mg/l), for example, 30 mg/l, can be taken to indicate contamination by organic wastes.

6.3.1.7 Iron and Manganese
Iron and manganese are present in trace amount in all bedrock types. They may be present in groundwater under natural conditions in circumstances where there are reducing conditions in the subsoil or bedrock due to the absence of oxygen. Iron is more common than manganese in groundwater.

Effluent from wastes can cause deoxygenation in the ground, which results in dissolution of iron and manganese from the soil, subsoil and bedrock into groundwater. With reoxygenation in the well or water supply, the iron and manganese precipitate, giving a strong, metallic taste, and a reddish precipitate in the case of iron and a black precipitate in the case of manganese. High manganese concentrations can be a good indicator of pollution by high BOD wastes, such as silage effluent.

6.3.2 Pathway Elements
In assessing the role of groundwater, there are two main questions/issues:

1. Is the water (either rainfall or effluent discharged onto/into land) moving away: i) as underground; ii) as overland flow; iii) at or close to the land surface? (The hydraulic issue)
2. Will pollutants be treated adequately in the ground before a relevant receptor is reached? (The attenuation issue)

Both of these questions can be answered as part of both the desk study and the catchment walk. **As 3-D conceptualisation is essential for successful IAs, understanding and answering these questions, either as part of an Assessors 'mental model' of the area of the catchment being considered or as part of a written report, is essential**. For Assessors who are not geologists or hydrogeologists, this may appear daunting at first; however, it is largely 'common sense' once some of the basic principles are understood. And, there is a lot of readily available information to help answer the questions.

6.3.2.1 The hydraulic issue
Question: how would we know if a significant proportion of water (rainfall less actual evapotranspiration) and associated pollutants are infiltrating underground?

Answer: by looking and assessing the drainage characteristics – essentially, we need to locate the free-draining areas. This is done both at the desk study and catchment walk phases of IAs. In pathway terms, it is the vertical pathway that is being considered, although in concluding on this pathway, the horizontal pathway is being determined, as this is the 'flip side of the (water movement) coin'. Some information that may assist is given below.

6.3.2.1.1 Desk Study
The following maps help assess the vertical pathway (see Volume 1 for the sources of the maps).

Topographic map: A low density of streams indicates that groundwater is a significant pathway for water to streams.

Teagasc soils map: check the different soil types and essentially distinguish between well drained and poorly drained.

GSI subsoils map: Sand and gravel have a high permeability, and so those areas will be well drained and recharge to groundwater can readily occur. The permeability of till will vary, usually depending on the rock parent material. However, when combined with the soils map, it will often be possible to decide whether they have a moderate or low permeability.

GSI subsoil permeability map: This distinguishes areas of subsoil >3 m thickness as either 'high', 'moderate' or 'low' permeability. In areas of 'low' permeability, recharge to groundwater will be limited.

GSI groundwater vulnerability map: 'Groundwater vulnerability' is the term used to represent the intrinsic geological properties that determine the ease which groundwater may be contaminated by human activities. There are five groundwater vulnerability categories; X (rock at or near surface and karst features; E (extreme, where the subsoil/bedrock boundary is the 3 m contour); H (high); M (moderate) and L (low, where there is >10 m low permeability (clayey) subsoil). The basis for the categories is shown in Table 6-1. In summary, vulnerability depends on the permeability and thickness of subsoil, the presence of point recharge via karst features in limestone areas and the thickness of the unsaturated zone in the case of sand/gravel aquifers. The vulnerability map represents a conceptual model of any area based on those factors. These categories assume that the contaminant is conservative or mobile. Further details are given in DELG/EPA/GSI (1999)[4].

Table 6-1: Vulnerability Mapping Criteria (adapted from DELG/EPA/GSI, 1999)

Depth to rock	**Hydrogeological Requirements for Vulnerability Categories**				
	Diffuse recharge			**Point Recharge**	**Unsaturated Zone**
	high permeability (*sand/gravel*)	Moderate permeability (*sandy subsoil*)	low permeability (*clayey subsoil, clay, peat*)	*(swallow holes, losing streams)*	(*sand & gravel aquifers only)*
0–3 m	**Extreme**	**Extreme**	**Extreme**	**Extreme (30 m radius)**	**Extreme**
3–5 m	**High**	**High**	**High**	**N/A**	**High**
5–10 m	**High**	**High**	**Moderate**	**N/A**	**High**
>10 m	**High**	**Moderate**	**Low**	**N/A**	**High**

i *N/A = not applicable.*
ii *Release point of contaminants is assumed to be 1–2 m below ground surface.*
iii *Permeability classifications relate to the engineering behaviour as described by BS5930.*
iv ***Outcrop and shallow subsoil (i.e. generally <1.0 m) areas are shown as a sub-category of extreme vulnerability.***
(amended from DELG/EPA/GSI (1999))

Aquifer map: There are nine aquifer categories[5], which are listed below:

Regionally Important (R) Aquifers
- (i) Karstified aquifers (**Rk**)
- (ii) Fissured bedrock aquifers (**Rf**)
- (iii) Extensive sand/gravel **(Rg)**

Locally Important (L) Aquifers
- (i) Sand/gravel (**Lg**)
- (ii) Karstified bedrock (**Lk**)
- (iii) Bedrock which is Generally Moderately Productive (**Lm**)
- (iv) Bedrock which is Moderately Productive only in Local Zones (**Ll**)

Poor (P) Aquifers
- (i) Bedrock which is Generally Unproductive except for Local Zones (**Pl**)
- (ii) Bedrock which is Generally Unproductive (**Pu**).

The productive and more transmissive aquifers are the Rk, Rg, Lg, Lk and Lm aquifers. Land overlying these aquifers will often be free draining. However, in some circumstances they are overlain by

[4] Further details on the vulnerability concept are given at this link: https://www.gsi.ie/Programmes/Groundwater/Projects/Protection+Schemes+Guidelines.htm#summary
[5] https://www.gsi.ie/documents/IrishAquifersPropertiesAreferencemanualandguideVersion10March2015.pdf.

poorly permeable soils and/or subsoils. In addition, the remaining poorly productive aquifers, while having a low bulk permeability or transmissivity, often have a permeable 'upper fractured zone' and can also have a relatively permeable 'transition zone', and therefore can be overlain by free draining soils. In areas where the poor (P) aquifers outcrop at the surface, there tends to be minimal infiltration to groundwater.

6.3.2.1.2 The attenuation issue

A useful concept in thinking of attenuation is '**pathway susceptibility**', which is a measure of the degree of attenuation between source and receptor[6]. It is a measure of the ability of the pathway factors to reduce the impact of a pressure, in terms of time to reach the receptor, proportion of pollutant load reaching the receptor, pollutant concentration level in the receptor, and duration of the pollution event.

The pathway susceptibility depends on:

- The hydro(geo)logical properties of the area; and
- The properties of the pollutants.

The relevant hydrogeological properties are captured in the following maps, which have been described in the previous section – soil type, subsoil permeability, groundwater vulnerability and aquifer category.

The groundwater vulnerability map is particularly useful. One way to conceptualise the different categories, from a groundwater contamination perspective, is as follows:

- 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).
- High (H) vulnerability: chemical pollution by mobile pollutants can occur, such as nitrate. Microbial pollution uncommon.
- Extreme (X and E): microbial and chemical pollution can occur.

However, keep in mind that the vulnerability maps are based on the assumption that the potential pollutant is mobile, such as nitrate and chloride. **Susceptibility maps** have now been developed by the EPA for two pollutants – nitrate and phosphate – and these take account of the hydro(geo)logical properties and the properties of both these pollutants. They are generated by linking soils, subsoils, groundwater vulnerability and aquifer types with nutrient attenuation and transport factors. These maps are now available for nitrate along the near surface and groundwater pathways, and phosphate along the near surface pathway. (When the susceptibility maps are combined with nutrient loadings data provided by the Department of Agriculture, Food and the Marine and the Central Statistics Office, the Pollutant Impact Potential (PIP)maps (or critical source area maps for diffuse nutrient losses) described in Section 4.4.1 of **Volume 1** are obtained.) An example of a susceptibility map is shown in Figure 6-2

[6] https://www.epa.ie/pubs/reports/water/wastewater/EPA_DWWTS_RiskRanking.pdf

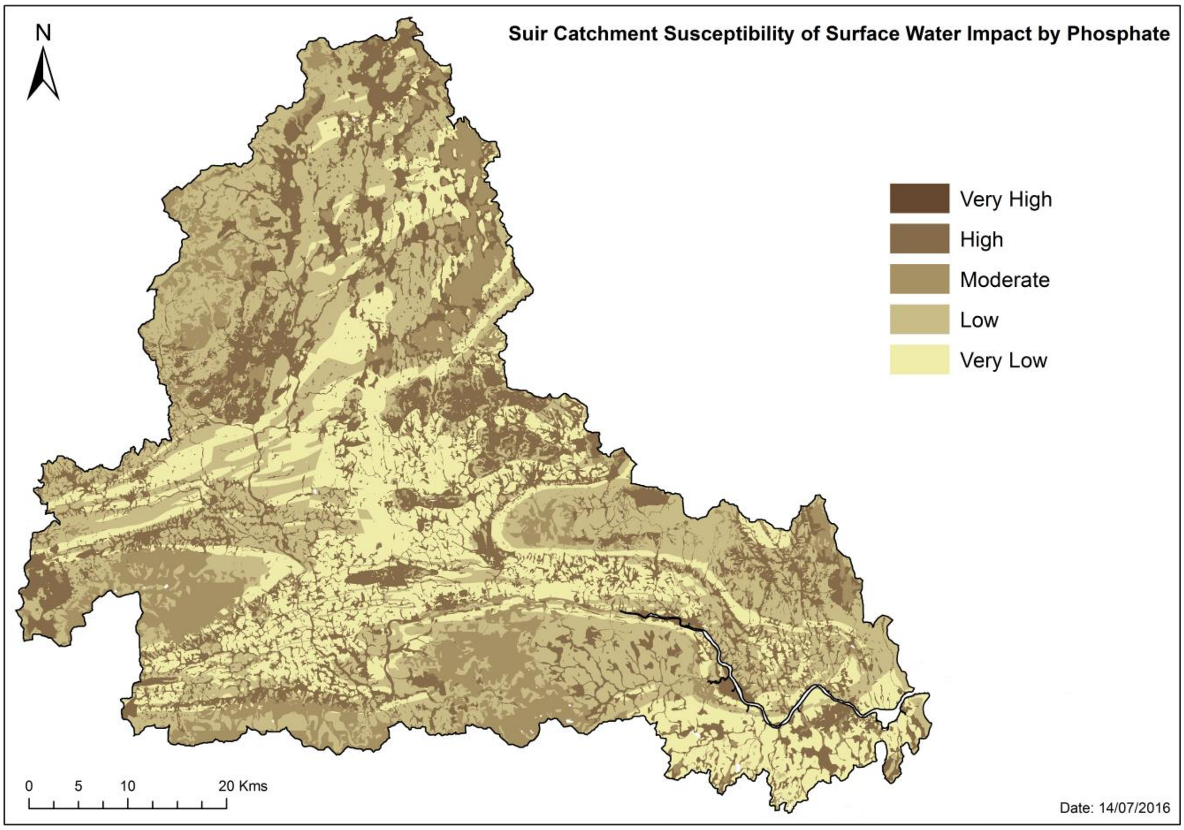

Figure 6-2: Map indicating the susceptibility of surface water to impact by phosphate for the Suir catchment. (High hydro(geo)logically susceptibility areas are areas from which nutrients (phosphate or nitrate), if present or applied, have a high probability of reaching a water body of interest due to the underlying hydrogeological conditions (i.e. the areas that have significant pathway linkages from the source of pollution or pressure to surface water or groundwater receptors). The darker areas (or Very High and High categories) are areas that are most susceptible to transporting phosphate along near surface pathways to rivers and lakes.

6.4 Groundwater Drinking Water Sources

This section provides information and advice for situations where there is a water quality issue with well water. (Springs are not covered here, but most of the information applies to them.)

6.4.1 Desk Study

The first step in any investigation is a desk based assessment of the available data using the SPR framework relating to groundwater from a borehole, dug well or spring. Using the SPR framework, four factors should be considered:

1. The groundwater quality.
2. Zone of Contribution (ZOC) (Hunter Williams et al, 2017). This is the land area over which some of the rainfall percolates downwards to the groundwater table that eventually ends up at the well or spring.
3. Pathway information, using groundwater vulnerability and/or susceptibility maps. These maps indicate where greater or lesser amounts of a particular pollutant can move downwards into the groundwater system.
4. Hazard/pollution source location maps. These give the position(s) of potentially polluting activities within the Zone of Contribution.

Where the situation is complex and/or where the Assessor has limited experience with groundwater issues, then refer to a hydrogeological specialist (Scenario IA11, see Volume 1).

6.4.1.1 Existing Groundwater Quality

Using existing knowledge of groundwater quality and the information given in Section 6.3.1, evaluate the water quality data to get an overview of what the issues might be.

6.4.1.2 The Zone of Contribution (ZOC)

The following steps are recommended:

1. Is there a Zone of Contribution (ZOC) delineated?
   - Check GSI groundwater webviewer[7] and EPA site folders[8]
   - Ask owner (especially for public, group scheme or industrial/commercial supply)

2. If not, can a simple "preliminary ZOC" be estimated? (DELG/EPA/GSI, 1999)
   - Depending on the level of complexity and experience, a "preliminary ZOC" could be approximated. While this may not be definitive it can provide a good starting point for a local catchment assessment with limited resources. **Where the situation is complex and/or experience missing then refer to a groundwater expert (Scenario IA11, see Volume 1). In particular for karst areas it will be difficult, if not impossible, for a non-expert to delineate a ZOC with reasonable confidence.**
   - The area contributing water to the well can be estimated using a water balance approach (see information box). This balances the average abstraction or spring flow volume with the annual average recharge to groundwater. A simple ZOC could be delineated to match this required area.
   - A simplified ZOC shape is shield- or shuttlecock-shaped is shown in Figure 6-3, with a more complex one shown in Figure 6-4.
     - The size of the ZOC shape is determined by water balance (see Information Box).
     - The location of the ZOC shape around the well or spring is not symmetrical. Generally, a far smaller proportion of the ZOC will be delineated downgradient (downhill) of well abstractions, depending on the setting, with the majority of the catchment upgradient (all for a spring). The flatter the topography (and inferred water table gradient) the greater proportion of the ZOC that will be downgradient.
     - The orientation of the ZOC shape is guided by topography. This assumes that the groundwater flow direction follows the topography. The lateral ZOC boundary lines are generally drawn perpendicular to the topographic contours.

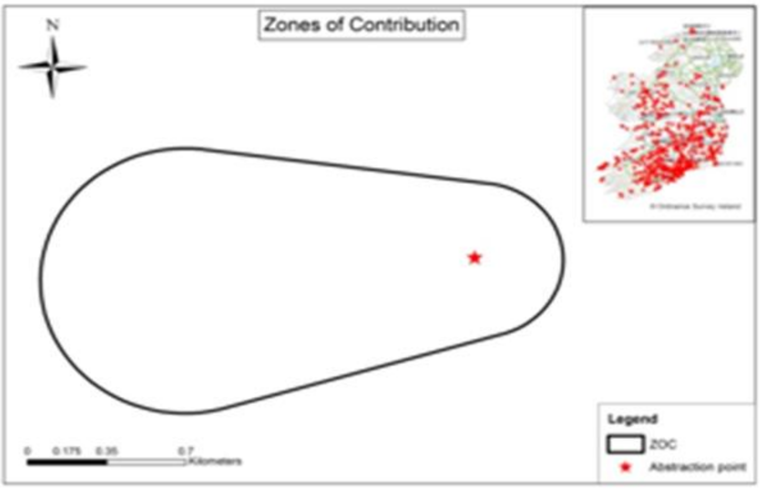

Figure 6-3: Example of simple tear drop or shuttlecock shaped zone of contribution (ZOC) (from Carey *et al*., 2017).

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[7] http://www.gsi.ie/mapping
[8] http://www.epa.ie/pubs/reports/water/ground/gwmpinfo/

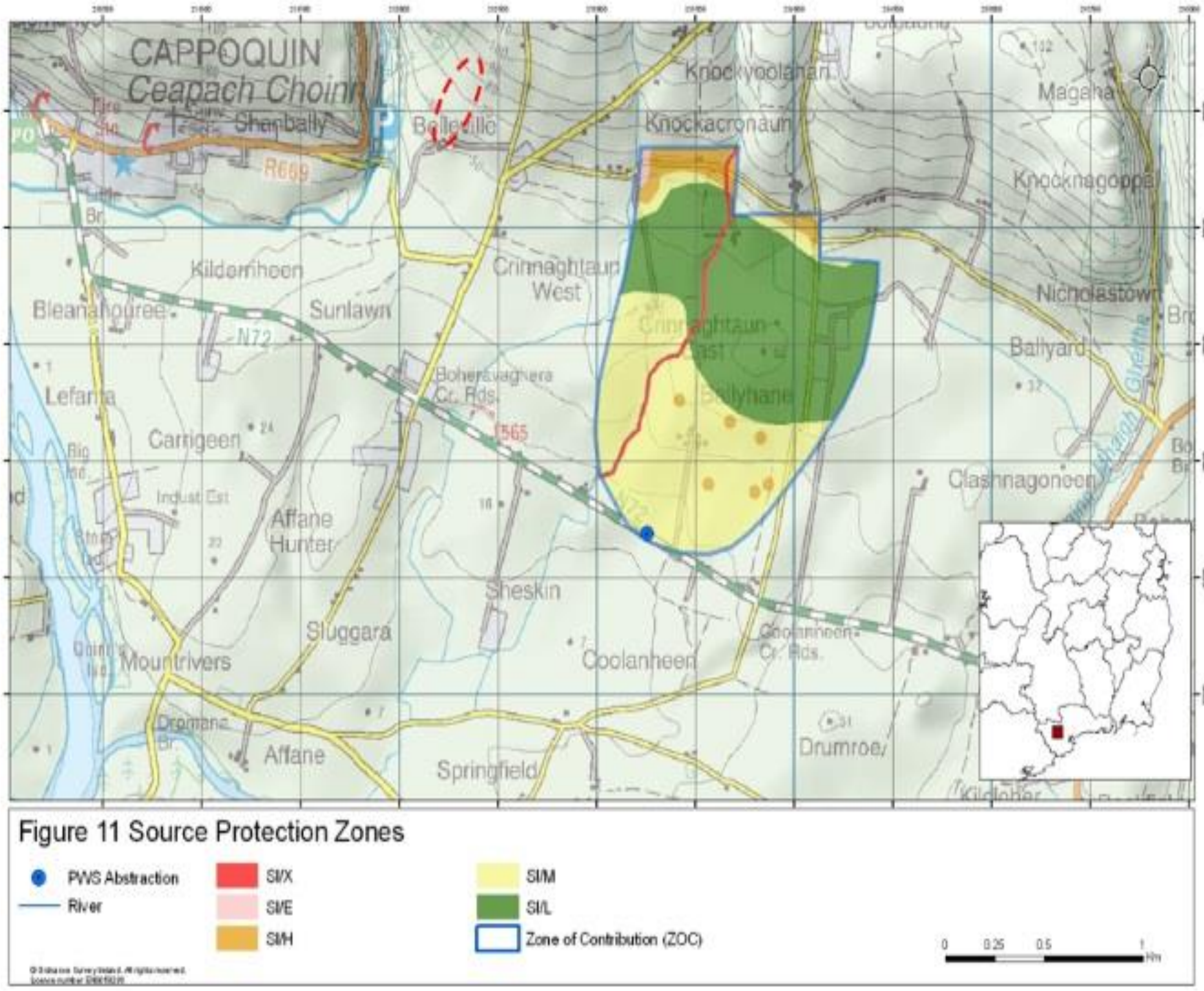


Figure 6-4: Example of a more complex source protection zone (Geological Survey of Ireland http://www.gsi.ie/Programmes/Groundwater/Projects/Groundwater+Protection+Scheme+Reports.htm)

6.4.2 Pathway assessment

Once the ZOC is known (even if only approximately for circumstances that it has not been delineated already), then check the groundwater vulnerability map. Groundwater vulnerability must be interpreted relative to the pollutant of concern, for example:

- A relatively thin layer of subsoil is likely to prevent migration of excess phosphorus to groundwater (e.g. > 1 metre deep – i.e. vulnerability category other than Extreme X). There is also potential to reduce (but not eliminate) microbial load where recharge is through even a relatively thin layer of subsoil.
- In many cases looking at the source activities in the Extreme Vulnerability areas of the ZOC is a good starting point. However, this may not be the case for some pollutants such as nitrate which can move through deep free draining subsoil to groundwater.

If the source protection zones have been delineated, the 100-day time of travel boundary is the boundary of the Inner Source Protection area (SI). As microbial die-off can occur where water is moving slowly through the aquifer, this will occur for most pathogens in that time. However, this does not apply to some parasites, such as Cryptospiridium, which are resistant to die-off.

Information Box: Worked Example of Zone of Contribution Area Calculation

Abstraction of 100 m^3/d where there is average recharge of 250 mm/yr (0.250 m/yr). Calculation will be for the abstraction plus 50% (150 m^3/d) as a safety margin and to allow for expansion of the ZOC during dry weather.

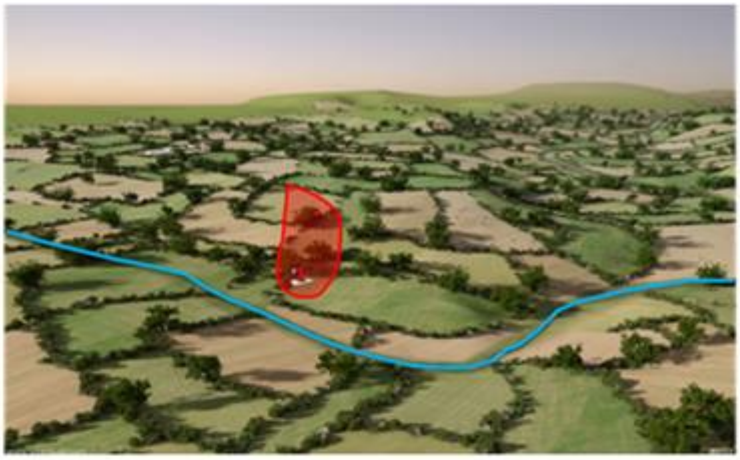
$$(150m^3/d \times 365\ days/year)/0.250\ m/year = 219{,}000\ m^2 = 0.219km^2$$

The result is an area of 0.219 km^2 or 21.9 ha to be delineated.

Recharge values can be sourced from the GSI groundwater recharge map, available on the webviewer and to download.

Example of area delineated for Zone of Contribution with varied abstraction and recharge rates (from Hunter Williams *et al*, 2017):

a)



ZOC Area = 6.5 ha

Approximately 1 ½ fields

b)

ZOC Area = 19.5 ha

Approximately 5 fields

ZOC area	ZOC a 6.5 ha	ZOC b 19.5 ha
Recharge rate	280 mm/yr	280 mm/yr
Abstraction rate	50 m³/d	150 m³/d
Abstraction rate	50 m³/d	50 m³/d
Recharge rate	280 mm/yr	93 mm/yr

]

6.4.3 Hazard assessment

Prior to undertaking fieldwork, it is worthwhile checking maps to locate potentially polluting activities in the ZOC (see the list of available maps and sources in Table 4-1 in **Volume 1**). By combining this information with the pathway maps – groundwater vulnerability and/or susceptibility – the potential critical source areas (CSAs) can be delineated for pollutants of concern. The aim is to differentiate areas of the ZOC that are more likely to contribute pollutants of concern to the well or spring.

6.5 Walking the ZOC

There is no definitive advice that can be given and Assessors will either have or will develop their own approach. Therefore, this section consists of some suggestions based on experience. It is usually worthwhile arranging to meet some local authority or group scheme staff, as appropriate, at the well or spring location. The most important and relevant person to talk to usually is the Caretaker as he/she will have more knowledge than anyone else on the source itself and on the surrounding area. In addition, the engineer and environmental scientist that deal with the source will have relevant information and advice.

It is often worthwhile doing a quick overview of the ZOC area by driving around the catchment.

6.5.1 What to look for

- The area in the immediate vicinity of the well/spring should be looked at in terms of protection from direct input of pollutants e.g. surface water flowing down the outside of the well casing (EPA, 2011b; EPA, 2013 and; IGI, 2007) or to the spring.
- The quick overview will give an indication of the pressures and the likely pathways. Vegetation and landscape features (see Section 3 and 5) give an immediate impression: for instance free-draining vegetation or poorly draining; intensive or extensive farming; a high or a low density of streams and ditches.
- Within the ZOC, note the relevant hazards and look at the pathways from these hazards to the well or spring. This SPR approach helps to find potential CSAs for the pollutants of concern. The aim is to differentiate areas of the ZOC that are more likely to contribute the pollutants of concern to the well/spring (CSAs). If this cannot be readily achieved it may be necessary to defer to expert assessment (IA11).
- Use the maps and information prepared during the desk study. The groundwater vulnerability and susceptibility maps are particularly relevant in providing pathway information. In addition, the PIP maps give information on i) diffuse pressure, ii) the pathway and iii) the CSAs. Keep in mind that the maps are 'only as good as the information that they are based on' and that they are at a scale no more detailed than 1:25,000 and are not designed or suitable to be used on their own as the basis for decisions at site or field scale.
- During the walkover, focus primarily on the pressures and pollutants of concern in the likely CSAs.
- The potential sources to be considered depend on the contaminant of concern (e.g. nutrients/hydrocarbons/pathogens/pesticides). Point and diffuse sources of pollution (hazards) (Figure 6-5) should be considered and can be guided by the contaminant(s) of concern (e.g. nutrients/hydrocarbons). The following are examples of sources to consider:
    - Farmyards including silage/slurry pits (point sources).
    - Septic Tanks (small point sources).
    - Diffuse losses of nutrients from agriculture (pasture, landspreading, arable).
    - Sewers (point/linear sources).
    - Agricultural chemicals (point source in storage/preparation or diffuse as applied).
    - Landfills.
    - Direct recharge of streams to groundwater (swallow holes/losing streams).
    - Industry (Manufacturing Facilities/Mines/Quarries) - point sources (both active and historic).
    - Road drainage (point/linear sources).

- Petrol Stations.
- Golf Courses.

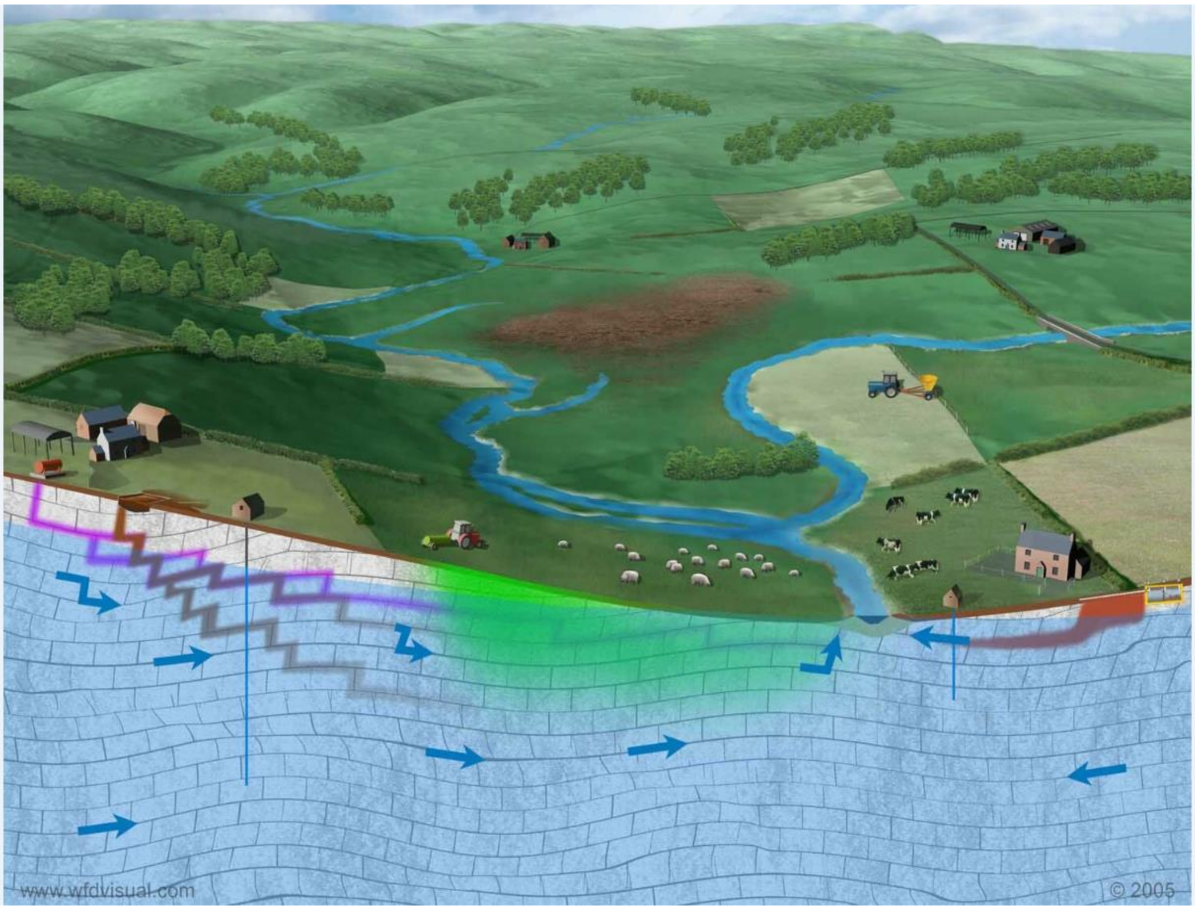


Figure 6-5: An illustration of pressures on groundwater in wells in the rural landscape

6.6 Groundwater as a pathway for pollutants to surface water

Groundwater is considered to be contributing a significant load of phosphate to a number of *At Risk* and *Review* water bodies. Therefore, locating the areas that infiltration of phosphate is occurring and proposing mitigation actions to reduce the infiltration will be a role that Assessors will be undertaking. Consequently, when doing the desk study and the catchment walk, keep in mind the sources, pathways and mitigation options that are relevant to phosphate entering groundwater and flowing to streams. (It is likely that, in the future, the contribution that nitrate in groundwater is making to estuaries and coastal waters will need to be considered.)

6.6.1 Desk study

The various relevant maps and information which would enable the CSAs for phosphate entering groundwater to be delineated have already been described and so are not repeated here.

6.6.2 Walking the Catchment – What to look for

6.6.2.1 Landscape features

- Presence of sinking streams in karst areas.
- Outcropping bedrock.
- Potential pollution sources in the CSAs.
- Management of these sources, in so far as is practicable to assess.

6.6.2.2 In-stream features

- Indications of groundwater input from springs, seeps and upwellings, using visual, water quality/chemistry and thermal indicators.
- Presence of tufa (precipitated calcium carbonate ($CaCO_3$)).
- Ecological indications of impact in vicinity or groundwater inputs.
- Bedrock exposures, indicating shallow bedrock and susceptibility to infiltration of phosphate to groundwater.
- Changes in flow along streams in the absence of surface drain input.
- Evidence of loss of water in the stream to a swallow hole.

While the in-stream features listed above are relevant to phosphate entering groundwater, close examination of the geology can assist in assessing the likelihood of rapid runoff from the land and, therefore, of the impacts that might arise and the mitigation actions needed. Useful features to examine and, if deemed relevant, record are:

- Presence of clayey/gley soils.
- Presence of clayey, poorly permeable subsoils.
- Presence of bedrock, noting whether it is fractured and therefore relatively permeable or 'solid' and therefore relatively impermeable.

6.7 Conceptualising in 3-D

As mentioned already in Section 6.3.2, one of the essential requirements for Assessors in undertaking IAs is the ability to **understand** and **conceptualise** water and contaminant movement in **three dimensions** for the area being assessed. The information in this section and Section 5 provides some information to enable this. However, for Assessors who are not geologists or hydrogeologists, this may not occur easily initially. Therefore, practice as both a mental and/or written exercise is recommended, as is discussion with colleagues. Please do not underestimate the importance of this!

6.8 Further Reading

Carey S., Tedd K., Kelly C., Hunter Williams N., 2017. Developing a Useful Hydrogeological Tool with Python; An Irish Example. Geopython 2017 Conference, FHNW – University of Applied Sciences and Arts Northwestern Switzerland.

DELG/EPA/GSI, 1999. Groundwater Protection Schemes. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland.
https://www.gsi.ie/Programmes/Groundwater/Projects/Protection+Schemes+Guidelines.htm#summary

EPA, 2011. Advice Note No. 7: Source Protection and Catchment Management to Protect Groundwater Supplies. Office of Environmental Enforcement, EPA, Wexford, Ireland.
https://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno7.html

EPA, 2011b. Advice Note No. 8: Advice on constructing a Water Safety Plan and on its content. Office of Environmental Enforcement, EPA, Wexford, Ireland.
https://www.epa.ie/pubs/advice/drinkingwater/epadrinkingwateradvicenote-advicenoteno8.html

EPA, 2013. Advice Note No 14: Borehole Construction and Wellhead Protection. Office of Environmental Enforcement, EPA, Wexford, Ireland.
https://www.epa.ie/pubs/advice/drinkingwater/EPA_DrinkingWater_AdviceNoteNo14b_web.pdf

EPA 2013. A risk-based methodology to assist in the regulation of domestic waste water treatment systems. Environmental Protection Agency. 64p.
https://www.epa.ie/pubs/reports/water/wastewater/EPA_DWWTS_RiskRanking.pdf

Hunter Williams N., Kelly C., and Daly D., 2017. Know your ZOCs from your SPAs – Groundwater Source Protection Terminology and Usage. Proceedings of IAH (Irish Group) Conference

"Developments in Irish Hydrogeology in a Changing Water Services and Planning Environment", Tullamore, April 2017. http://www.iah-ireland.org/conference-proceedings/2017.pdf

IGI, 2007. Guidelines on Water Well Construction. http://www.igi.ie/publications/codes-guidelines.htm

S.I. No. 31/2014 - European Union (Good Agricultural Practice for Protection of Waters) Regulations 2014. http://www.irishstatutebook.ie/eli/2014/si/31/made/en/print

7 Field Photography

7.1 Purpose and Objective

Photographs taken in the field provide a rich and valuable source of evidence of conditions at a site at a point in time and can be used for the following purposes:

- To provide a record of locations visited and their condition during the visit.
- To provide a clear and easily understood visual record of a location or river.
- To provide a visual record of the state of and changes over time at sites that can be used by future workers for assessment and characterisation purposes.

While field photographs can be used for all purposes listed above, **the main function of taking field photographs during catchment walks will be to collect a photographic record that can be easily understood and used to clearly identify features of interest in the river channel by current and future workers.** When taking pictures during a site visit, bear in mind that the aim is to provide a visual record of the trip that describes the route taken and contains images of the main features and findings of interest during the visit.

7.2 Significance

Properly taken site photographs form a valuable evidential data set that provides a record of conditions at a given time. Such a record is highly valuable for many reasons. If a site is altered or damaged subsequently, photographic evidence exists that shows the pre-impact condition of a site. Future workers can use the photographic record to assess past conditions at a site. This ability to reassess a photographic record allows experts with additional skills to the original site surveyor to assess past conditions at a site. Such experts may include hydrologists, hydromorphologists, civil engineers, hydrogeologists, ecologists, soil scientists, and fisheries experts etc. A well taken and properly archived photographic record can therefore multiply the value and insight gained from a single site survey into the future and should form a foundational element of all site surveys.

7.3 Methods and Approaches

7.3.1 Methods

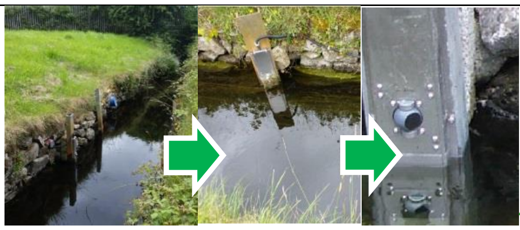
1. **FOCUS** The autofocus of the image should be set on the subject of interest in the frame.
2. **RESOLUTION** All photographs should be taken and stored at the highest resolution available.
3. **LIGHTING** Images should be taken facing away from the sun (i.e. with the sun behind the photographer where possible). The light metering should also be set so that the features of interest in the image are neither too dark, nor washed-out looking.
4. **SCALE** All photographs must include a means of establishing scale. This can range from including a person, vehicle, range pole or staff gauge in the frame for wide landscape shots, to a trowel, clipboard or coin for close up detail shots.
5. **LOGICAL STORYLINE** Photographs should be taken on site in an order that follows a logical progression from far out to close in. For example, to photograph a waste pipe discharging into a river, first the wider scene showing the setting of the pipe should be photographed. Then intermediate shots, and finally close up shots of the pipe should be taken.
6. **COLOUR** Colour enhancement filters should never be used when taking technical photographs (e.g. portrait, landscape, fluorescent, saturation filters contained on most digital cameras). Where photographs of soils are being taken, Munsell colour charts should be included in the picture to enable accurate future reference.
7. **METADATA** Most cameras offer the option of stamping the date and time on the photo itself. This option should be turned on by default to capture this important information on the image in a way that is unlikely to be altered by subsequent saving or editing of the image. Additionally, many cameras (most smartphone cameras) offer the ability to save geographic coordinates in the image data and thus allow the image location to be mapped. This option should also be turned on by default where possible.

1. **Focus** on the object of interest in the frame.

2. Save the image at the highest **Resolution** available.

3. Ensure the **Lighting** is set to properly capture the object of interest.

4. Always include a **Scale** object in the image for reference.



5. Follow a **Logical Storyline** from far-out to close-up when taking pictures.

6. Always take **Natural Colour** pictures and never use digital colour filters.

7. Always ensure the correct data and time are set and display them on the image when it is taken where possible.

7.3.2 Approaches

The preeminent question in carrying out field photography is: what should be photographed? While this was a practical issue in the days of film photography when development costs were substantial, this is no longer the case. Memory card, cloud and server-based storage volumes are now so large that there is no longer a (practical) upper limit on the number of images that can be taken on a site visit. The simple answer to the question of what should be photographed is everything of interest. The features and objects described in this guide provide a good starting point; weirs, dams, barriers of any kind across the channel, eroded or modified channel banks, piped discharges, leaking pipes wastewater seepages, groundwater springs and seeps, river confluences, staff gauges (in focus so the water level can be read), bridges and culverts, any features of interest in the riparian zone such as slurry spreading adjacent to the bank, encroaching forestry, drains improperly constructed, discharges of silt or other material, animals in the channel, waste in the channel, evidence of illegal or historic dumping, evidence of historic or illegal quarrying etc. The list is open-ended, but any feature that could be remotely of interest should be photographed for future reference.

Remember that such a photographic record provided evidence not only of the conditions and past impacts on the channel at the time a survey is carried out, but forms a visual record baseline that can be used to identify subsequent changes and impact in the channel or lake.

7.4 Useful references

http://munsell.com/color-products/color-communications-products/environmental-color-communication/munsell-soil-color-charts/