

Best Practice Guide
**Operation and Maintenance of
constructed treatment wetlands**



Disclaimer

The contents of this Guide represent the best available information at the time of writing, following four decades of experience with sewage treatment wetlands in the UK and Ireland.

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1. Introduction

Treatment wetlands have been used to treat and manage water in the UK for over 40 years, and internationally for longer. Applications range from domestic and municipal sewage treatment to polishing of industrial effluents, managing agricultural runoff, and delivering nutrient mitigation in catchments under pressure from development. Like the grey technologies most operators will be familiar with — trickling filters and septic tanks — they rely on physical, chemical and biological processes to remove pollutants. **The same microbial communities that drive treatment in a trickling filter biofilm are at work in a treatment wetland;** the difference is that in a wetland, those communities are supported by a planted bed through which water passes slowly, over hours to days rather than minutes.

The longer residence time and physical buffering provided by the bed media and/or water column makes treatment wetlands inherently robust to short-term variations in flow and load. However, like any treatment process, they require regular inspection and preventative maintenance to remain effective and compliant throughout their design life. Neglected upstream processes, poor distribution, or unmanaged solids accumulation can all lead to performance problems — the same is true of a trickling filter or a septic tank.

This guide summarises the key operation and maintenance tasks for constructed treatment wetlands, their purpose, and the warning signs to look out for. It covers subsurface flow systems (horizontal, vertical and aerated), surface flow systems, and French vertical flow systems used for primary treatment. It is based on established textbook guidance (Kadlec and Wallace 2009, Dotro et al. 2017, Langergraber et al. 2020) and operational experience from UK wetland designers and operators. It should be read alongside the technology and site-specific O&M manual prepared by the designer, which will contain works-specific settings, alarm thresholds, and permit requirements.

The task-based structure was also chosen with digital operation and maintenance management systems in mind. Many water company and independent operator sites now use app-based or electronic scheduling tools to manage routine checks. In this context, the summary schedule in Section 2 functions as a library of tasks: an operator or asset manager can select the rows relevant to their wetland type and load frequency, and assign them to the appropriate visit schedule without needing to re-read the full guide. The guidance notes in Section 3 then provide the rationale and "what good looks like" detail that sits behind each scheduled task. A quick-reference table cross-indexing wetland type against applicable tasks and minimum visit frequencies is provided here (Table 1.1) for this purpose.

Table 1.1 Quick reference guide to tasks associated with each main wetland type

Wetland type	Sections to read	Any type-specific minimum visit frequency
Horizontal Subsurface Flow (HF)	3.1 - 3.6; 3.9 - 3.10	Weekly
Vertical Flow (standard VF)	3.1 - 3.7; 3.9 - 3.10	Weekly
French Vertical Flow (French)	3.1 - 3.7; 3.9 - 3.10	Twice weekly
Aerated wetland (AVF/AHF)	3.1 - 3.10	Weekly
Surface flow (SF)	3.1 - 3.6; 3.8 - 3.10	Weekly
Floating wetlands (FTW)	3.3, 3.4, 3.5	Weekly

Under each Task, the reader will find a colour-coded set of dots to indicate the severity of impact of neglecting to perform that particular task, ranging from limited impact (●), to medium impact (●●), to severe impact (●●●). Poor management is assessed against three key criteria: treatment impact, asset life, and remediation/fixing costs. Where necessary, an additional note is made regarding any catastrophic (i.e., complete) failure of the treatment wetland as a result of poor management associated with a particular task.

1.1 Health and Safety Considerations

Important note on Health and Safety

Operators should follow their organisation's risk assessments and safe systems of work at all times. Key hazards specific to treatment wetland sites include: open water and soft ground near surface flow cells and outlet chambers (lone working policy applies); confined space entry for any below-ground chamber; electrical isolation of blowers and pumps before maintenance; and biological hazard from contact with sewage (wear gloves and eye protection; follow your organisation's leptospirosis guidance). This Guide does not replace site-specific risk assessments.

This section is intended to inform the production of appropriate Risk Assessments and Method Statements (RAMS) required to complete necessary maintenance activities. The following information is not exhaustive and does not constitute a formal risk assessment.

Typical H&S items to be aware of include:

- Working with sewage
- Waterborne pathogens (e.g., Weil's Disease (Leptospirosis))
- Confined spaces
- Working adjacent to water of varying and fluctuating depths
- Steep slopes, marshy ground and uneven ground, particularly on the inner banks of ponds and wetlands
- Contact with potentially hazardous plant species (e.g., Giant Hogweed, Hemlock Water Dropwort)
- Buried/overgrown structures due to density of vegetation obscuring them
- Manual handling/labour for some activities such as lifting of chamber covers, pulling weeds, clearing cut vegetation etc.
- Working with electrical and mechanical plant (pumps, blowers etc.)
- Asbestos Containing Materials (ACMs) often present in old existing infrastructure

Although many standard maintenance tasks on wetlands are fairly straightforward and only require minimal training, certain activities require specific training, certification and PPE. These include confined space access, working on electrical equipment, dealing with chemicals etc. Any such activity should only be carried out by appropriately trained personnel and may require a permit to work.

Asbestos

Most constructed wetlands should have no asbestos used in construction. The risk comes from connecting infrastructure where wetlands have been installed on older wastewater treatment works. All works should have an asbestos survey and report available, which should be reviewed prior to undertaking any works. The most common sources of asbestos on wastewater treatment works are in buildings (roofing, soffit boards, walling panels, insulation), electrical cupboards and mounting

boards, scum boards on tanks, asbestos concrete pipes and gaskets. If in doubt, leave any suspicious material alone and have it tested to confirm if it contains asbestos or not.

Weil's Disease

Leptospirosis, also known as Weil's Disease, is a waterborne pathogen the source of which is the urine of rats. The risk of infection is via contact with rat urine and/or water that is contaminated by it. The key points to be aware of are:

- Any existing cuts, grazes or broken skin should be covered with waterproof plasters/bandages before undertaking any work.
- Thoroughly wash and disinfect hands before eating, drinking, touching face or mouth.
- Any cuts or wounds caused while working in these environments should be cleaned thoroughly and covered with a waterproof plaster/bandage before continuing work. If you cut yourself, stop work immediately, deal with the wound and ensure it is protected before starting work again.
- If you develop any flu-like symptoms after working in an environment where there is a risk of Weil's Disease, it is important to see a doctor and tell them you have been working in an environment where Leptospirosis/Weil's Disease is a hazard, especially if you had any cuts.

Hazardous Plants

There are two key species that can occur in constructed wetlands in the UK that can pose a risk to operators. These are Giant Hogweed (*Heracleum mantegazzianum*) and Hemlock water dropwort (*Oenanthe crocata*). See Appendix A for an identification guide to these plants.

Giant Hogweed poses a risk from contact with the sap which can cause severe blistering of the skin. Effects can take 24 to 48 hours to occur with the dense pigmentation, associated with exposure, visible after 3 to 5 days. The damaged skin can heal slowly and can leave a residual pigmentation which can develop into phytophotodermatitis. This is a form of skin sensitivity that will react and flare up when exposed to sunlight and can last for several years after exposure to the sap.

Giant Hogweed should never be cut with a brushcutter or strimmer as it results in a very high risk of contact with the sap of the plant. The most effective control methods are cutting of the tap root with hand tools (ideally early in the season before it grows too big), removal of seed heads to prevent seed dispersal, and herbicide application. Any work with hand tools to cut the plant should be carried out with appropriate PPE, the minimum recommendation of which is trousers, long sleeve shirt, protective gloves/gauntlets, and eye protection. To avoid cross contamination following work, it is advised that tools and clothing are cleaned after any management operations.

Hemlock water drop wort is becoming increasingly common in the countryside, particularly in wetland areas and along water courses. It is one of the UK's most poisonous plants and should be handled with care. One of the main risks is misidentification as it can be easily confused with similar umbellifers. The entire plant is poisonous, but the highest concentrations of the toxin are present in the tubers. It is highly toxic if ingested with severe symptoms which can result in fatality.

When handling the plant, appropriate PPE should be worn such as gloves and long sleeves. Hands should be washed thoroughly before consuming any food or water or handling any food preparation equipment. Any plant material and tubers should be removed and disposed of responsibly to avoid the risk of either people or grazing animals being able to access the material.

1.2 Ecological and environmental considerations

While undertaking maintenance on constructed wetlands there are some considerations that need to be given to ecological and environmental factors. These include, but are not limited to:

- Nesting birds
- Protected species
- Hibernating species
- Supporting pollinators
- Invasive and Non-Native Species (INNS)

Nesting birds

All wild birds, their nests, eggs and young are protected under the Wildlife and Countryside Act 1981. This covers all wild birds not just rare or endangered species. Under the act it is illegal to intentionally damage, destroy or disturb a nest while it is in use or being built.

Natural England officially considers bird nesting season in the UK to be between 1st February to 31st August. Depending on the latitude and species some birds can nest earlier or later than this with the peak season typically being between March and July.

Reed cutting and vegetation clearance should be undertaken outside the nesting season. However, if cutting near to the start or end, a walkover should be undertaken to check for nests. If carrying out work to remove vegetation, trees or shrubs that pose a risk to the structural integrity of the system or need to be removed for operational reasons, a nesting bird survey should be undertaken by a competent person.

Protected species

Wetlands can provide excellent habitat for a range of species which include those protected under legislation. The presence of protected species does not prevent operational and maintenance activities, but measures may need to be put in place to manage works around them. If protected species are found on site, specialist advice from a suitably trained ecologist should be arranged.

Some of the most likely protected species to be present in wetlands and their surrounding habitats include:

- Great Crested Newt *Triturus cristatus*
- Grass Snake *Natrix natrix*
- Common lizard *Lacerta vivipara*
- Slow Worm *Anguis fragilis*
- Adder *Vipera berus*
- European eel *Anguilla Anguilla*
- Nesting birds 1st February to 31st August

Smooth Newt (*Lissotriton vulgaris*) and Palmate Newt (*Lissotriton helveticus*) are protected under the Wildlife and Countryside Act against sale, barter, exchange and transportation but not to the same level as Great Crested Newts.

Invasive and Non-Native Species

There is a risk of INNS being introduced to any wetland system, there are several pathways for this including:

- Transfer of seeds by wildlife
- Windblown/water borne seeds
- Transfer of seeds and vegetative material by people and machinery accessing the site

One of the very manageable risks is via people and machinery. It is important that all equipment, boots and PPE are thoroughly cleaned and disinfected between sites. At the end of each work period on a site, a full clean down should be undertaken before moving equipment off site.

Many INNS either require or are best left to professional contractors to deal with, especially if present in large numbers. They will ensure the issue is dealt with effectively, dispose of any material and often provide a guarantee against reoccurrence for some species such as Japanese Knotweed.

Further information on identification and control methods is provided in Appendix B.

Herbicides

Herbicide use near water courses is controlled and specific restrictions can apply depending on the chemical being used. Only appropriately trained operators should apply herbicides and checks should be undertaken for the specific chemical being used for any controls related to the aquatic environment.

Spray drift can cause damage to constructed wetlands by killing the vegetation that is present and not the target of the herbicide application. Care should be taken to avoid spray drift and alternative methods such as leaf painting and stem injection used if spray drift is a risk.

Fuels and oils

Fuels and oils can seriously impact the aquatic environment and damage the function of a constructed wetland. The following guidance should be incorporated into any RAMS for work on site:

High risk areas such as fuel and chemical storage, refuelling areas, material stockpiles and site compounds should be located a suitable distance away from any sensitive receptor (wetlands, ponds, watercourses). Bulk fuel, oil and chemical storage containers should be stored on an impervious base with a bund capable of containing at least 110% of the stored volume. Fuel containers (e.g., 5 litre cans) should be stored in a secure, banded area with a capacity of at least 25% more than the total volume of all the stored containers. Emergency spill kits should be provided on site with appropriate equipment to contain a spill to a sensitive receptor.

Plant should be refuelled in a designated fuelling area at least 10.00m away from any watercourse. Any petrol pumps used for over-pumping, dewatering or moving water between wetlands should be placed in secondary containment with a minimum capacity of 25% more than the fuel tank of the pump. Pumps should be refuelled by hand using 5 litre containers or smaller within the secondary containment.

Vegetation management power tools such as chainsaws, brushcutters mowers etc should be refuelled/oiled by hand using 5 litre containers or combi-cans in a designated refuelling area with secondary containment. Where possible, chainsaws should use chain oil that is biodegradable.

2. Summary schedule of tasks

The routine O&M tasks have been summarised and organised first as tasks common to all wetland types and then by specific configuration (e.g., VF, French, etc). Details on each task's rationale and what it looks like can be found in Section 3.0 of this Guide.

Table 2.1. Summary of tasks

Task	Purpose	Applies to	Frequency	Key problem indicator	See section
Upstream treatment check (septic tank / settling tank emptying)	Prevent solids carryover to wetland	All	Monthly–quarterly (per manufacturer / permit)	Surface ponding or rapid clogging of inlet zone	3.1
Inlet distribution check	Ensure even loading of the wetland cell	All	Weekly	Uneven surface wetness; ponding near inlet only	3.2
Outlet structure and water level check	Maintain correct operating depth	All	Weekly	Water level above design; overland flow; short circuiting	3.3
Access pathways — clearance and inspection	Enable safe completion of all other tasks	All	Monthly	Overgrowth, standing water on bunds	3.4
Plant health and weed assessment	Ensure desired species are thriving; detect operational issues; maintain liner integrity	All	Quarterly (more frequent in years 1–2)	Poor reed growth; dominance of broad-leaved weeds and saplings; no new shoots in spring.	3.5
Sludge and litter depth measurement	Estimate remaining bed life; plan refurbishment	All	Annual	Depth approaching design maximum (see designer's report)	3.6
Batch volume and frequency check	Confirm beds drain between doses; maintain aerobic conditions in VF	VF (all types), AVF	Weekly	Persistent ponding between doses	3.7
Aeration system check — blower operation	Confirm air supply within design range	AVF, FBA	Weekly	Blower alarm; elevated or low back-pressure; noise; high temperature trips; excessive use of pressure release valve.	3.8

Task	Purpose	Applies to	Frequency	Key problem indicator	See section
Aeration system check - bubble pattern inspection	Detect blocked emitters or disconnected airlines	AVF, FBA	At commissioning (flood bed briefly to inspect). Check blower operating pressure and water quality thereafter.	Uneven, turbulent or absent bubbles	3.8
Oxygen checks	Monitor oxygen availability; ensure cascade/weir structures are functioning	Aerated VF, SF	Quarterly (more frequent if tight ammonia permit)	Low or declining DO at outlet; blocked or uneven cascade flow	3.8
Performance monitoring— comparison with permit / design values	Detect declining treatment before a breach	All	Per permit schedule; minimum quarterly	Deteriorating effluent quality trend	3.9
Refurbishment (surface scrape / gravel replacement)	Restore hydraulic conductivity	All	VF: 10–15 yr; HF: 15 yr (range 5–25+); SF: 5–20 yr (deep zones)	Persistent ponding unresponsive to operational changes	3.10

3. Guidance notes by task

3.1 Upstream treatment — septic tanks and settling tanks

What to do: Inspect sludge level; arrange emptying according to manufacturer's recommendation and site-specific schedule (minimum annually for septic tanks; 30–90 days for settling tanks ahead of any wetland type).

What to look for: Sludge depth approaching the desludge design threshold; any evidence of solids carry-over to the wetland inlet zone.

Type-specific notes:

- Subsurface flow systems (secondary and tertiary): Upstream settling/septic tank condition is critical, with premature clogging expected in systems that receive solids loads that are greater than the established design envelope. Clogging can develop at superficial levels for sporadic solids overload events or result in permanent surface blinding that requires drastic intervention for prolonged overload operation
- French systems (primary): There is no upstream solids management, other than a screen. Check screens are routinely maintained/cleaned. French wetlands can typically recover from influent solids or organic overloading due to their rotational operation with feed and rest cycles. However, recurrent shock loads and/or undersizing can result in permanent ponding and require intensive intervention to recover the system.
- Surface flow systems (sewage applications): Less sensitive to upstream solids overloads as solids are settled in the system rather than filtered. However, excessive TSS will shorten the interval

before deep-zone sediment removal is required, can contribute to the development of anaerobic conditions and emissions (odours), and potentially remobilise any trapped phosphorus.

- Surface flow (nutrient mitigation / polishing): These systems are typically fed from a watercourse or drain rather than a septic tank. In this application, "upstream treatment" means managing catchment inputs — sustained high solids or nutrient loading above the design envelope will accelerate sediment accumulation and exhaust sorption capacity earlier than projected. There is no single upstream tank to desludge, but the hydraulic and pollutant loading rate should be checked against design assumptions at least annually.

If this goes wrong: Solids carryover is the primary cause of premature clogging in subsurface flow systems. In VF systems, surface blinding restricts oxygen transfer and hydraulic conductivity and will directly impact treated water quality (by reduced treatment efficiencies or bypassing through emergency overflows). This is the one scenario where filtration failure can lead to permit breach other than triggering an intensive refurbishment intervention. In HF systems, clogging causes surface ponding but the system continues to provide some treatment as a hybrid surface/subsurface flow cell — permit compliance is at risk but the failure mode is less abrupt.

Remedial action: desludge upstream tanks immediately; assess extent of inlet zone clogging.

Upstream processes – Poor management consequences

Treatment Impact	● ● ●
Bed life impact	● ● ●
Remediation cost	● ● ●

Catastrophic failure risk: high for VF if prolonged; lower for HF&SF.

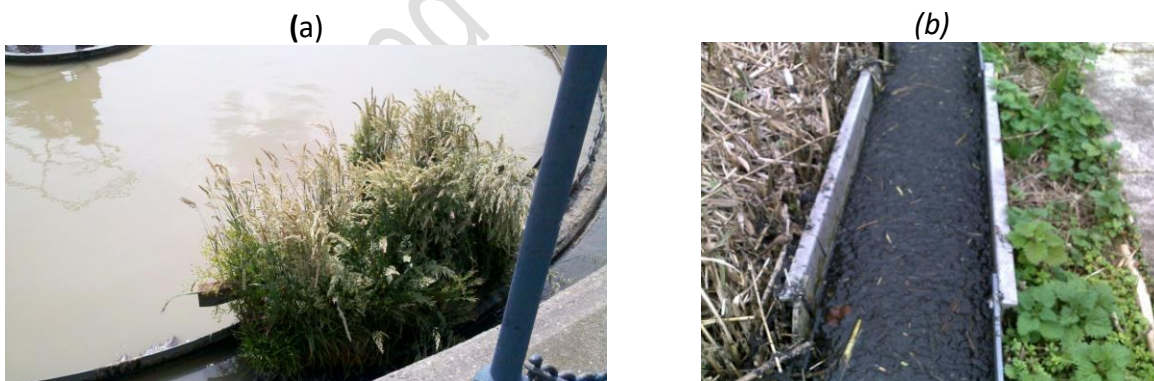


Figure 3.1 Evidence of poor upstream maintenance showing (a) plant growth on a settling tank ahead of wetland inlet, (b) biological solids accumulation in inlet trough that feeds a HF wetland. *All pictures credit NbS Future/G Dotro.*

3.2 Inlet distribution system

What to do: Visually inspect header pipes, troughs and/or risers and distribution points. Clear any accumulated solids. On HF systems with subsurface loading, flush inspection ports. Check that the full width of the cell is receiving flow.

What to look for: Blockages; preferential flow down one side; dry areas of the bed.

Type-specific notes:

- *VF (all applications):* Check that the tipping bucket, pump or dosing siphon is delivering the correct batch volume and that flow reaches all parts of the surface.
- *French VF:* Coarse screens upstream must be cleaned regularly (twice-weekly visits recommended during primary treatment operation).
- *HF:* Distribution gravel at inlet end should not be visibly dry.
- *SF:* Inlet structure and any baffles; check for short-circuiting.

If this goes wrong: Poor distribution causes hydraulic short-circuiting — flow takes the path of least resistance, reducing effective treatment area and contact time. Visible warning signs include preferential flow paths on the surface and uneven sediment deposition (heavy accumulation near the inlet on one side only). In SF systems, channelisation can become self-reinforcing as vegetation dies off in dry areas. Remedial action: clear blockages; rebalance distribution; consider baffles or berms if channelisation is established.

Inlet Distribution – Poor Management consequences

Treatment impact	●●
Bed life impact	●
Remediation cost	●

Catastrophic failure risk: No — but treatment efficiency is progressively reduced.



Figure 3.2 Examples of (a) good influent distribution on HF bed, (b) lack of maintenance of inlet riser pipes, (c) inlet pipe with sludge accumulation, (d) preferential flows developed as result of poor influent distribution in surface flow tertiary system. Credit: (a), (b), and (d) NbS Future/G Dotro, (c) Andy Freeman/ARM.

3.3 Outlet structure and water level

What to do: Check that the outlet control is set to the correct level (as per design drawings). Record actual water level within the bed.

What to look for: Water level at or above the surface when it should be subsurface; water level not responding when outlet is lowered (indicates clogging).

Type-specific notes:

- *HF*: Design water level is typically 5–10 cm below gravel surface.
- *VF (all types)*: Beds should drain fully between doses; check that the drainage layer is free and that the outlet is not blocked.
- *AVF*: Confirm the saturated zone depth matches the design setting (if adjustable).
- *SF*: Check that free-water depth is within design range; inspect spillway structure.
- *FTW*: Confirm the water body has not dropped to a level where the floating structure risks grounding on the bottom. Most raft structures have a draft of approximately 20 cm; the recommended minimum operating depth is 0.5 m. At sites with variable water levels (seasonal, tidal or storm-

driven), confirm anchor lines have sufficient slack to accommodate the full expected range without becoming taut or going slack enough to allow the structure to drift.

If this goes wrong: Water level above design in a subsurface system indicates either an incorrect setting of the control arm, an outlet blockage, temporary hydraulic overload, or clogging within the bed. If lowering the outlet does not reduce the water level, clogging is the likely cause and further investigation is needed. Persistent overland flow bypasses treatment media entirely. In VF systems, a waterlogged bed also prevents passive reaeration between doses, compounding biological process failure. In all cases, the water level has a direct impact on the plant communities that can survive or thrive in the wetland. A water level that is too high (especially common in SF systems) can drown out macrophytes; a water level that is too low means the plants cannot access the water and will suffer and eventually die.

Remedial action: clear outlet; if unresponsive, conduct sludge depth survey.

Outlet / water level – Poor management consequences

Treatment Impact	●●
Bed life impact	●
Remediation cost	●

Catastrophic failure risk: No in isolation, but can accelerate other failure modes

(a)



(b)



Figure 3.3 Example of operational water level checks, (a) Best practice has tags to clearly indicate where the normal operating water level setting should be for a HF or SF cell, (b) Rodding of effluent collection pipe in a HF cell. All pictures credit NbS Future/G Dotro.

3.4 Access pathways, bund and civil structures

What to do: Cut grass on bunds; clear pathways of encroaching vegetation. Check bund integrity (erosion, settlement, animal burrows).

What to look for: Slippery surfaces; vegetation obscuring inspection chambers; bund erosion; signs of leakage. Following significant storm or high-flow events, repeat this inspection — check for bund erosion, any unexpected seepage from bund faces, and confirm emergency overflows are clear. For

FTW, any section of the raft listing, partially submerged or touching the bottom; anchor lines that are slack (structure drifting) or visibly chafed; failed connectors between raft sections.

Type specific notes:

All of the above are standard task — no significant type-specific variation.

In addition, FTW require checks on the buoyant raft modules and inter-unit connectors for cracks, deformation, UV degradation or wildlife damage. Check anchor lines or chains for fraying, fouling and correct tension. Carry out additional checks after significant storm or high-wind events, when drifting or connector failure is most likely.

If this goes wrong: Poor access is primarily a health and safety risk rather than a treatment performance risk, but the two are linked — if a site is unsafe or difficult to access, routine checks are skipped, and problems go undetected. Specific hazards include: slippery bund surfaces (wet grass, algal growth), unstable ground near cell edges, obscured inspection chambers creating trip hazards, and animal burrows undermining bund integrity. In systems with deep open water zones (SF wetlands), edge access without appropriate barriers presents a drowning risk. Remedial action: restore safe access before any other maintenance task is attempted — no other checks should be conducted on a site where access is unsafe. *Catastrophic failure risk: No for treatment performance; Yes for operator safety if unmanaged.*



Figure 3.4 Examples of maintenance impacts on access paths to wetland cells, (a) well maintained grass access path (Photo credit D Naismith), (b) inundated wetland with water connecting two independent cells and unsafe pathways. Photo credits: (a) Dave Naismith and (b) G Dotro.

3.5 Plant health and weed assessment

What to do: Walk the perimeter of each cell and assess the condition of the desired species (*Phragmites australis* or other design species). Record approximate percentage cover and note any invasive or undesired species. **Where invasive and non-native species (INNS) are found, these need to be reported formally to site owner/responsible manager.** See Appendix B for a list of key INNS that have been found in wetland systems in the UK.

What to look for: Poor or patchy reed growth; yellowing and/or curling of leaves; encroachment of broad-leaved weeds (especially years 1–2); species that indicate incorrect water levels (e.g., wet-

Link to wetland processes – the role of plants

Plants contribute to treatment in specific ways depending on wetland type — providing shading to limit algal growth (SF), reducing sediment resuspension (SF), supplying insulating mulch over winter (HF and VF), and contributing organic carbon that can support denitrification (HF and SF). It is important to note that **biological** treatment is driven by the microbial community, not the plant species present — a wetland will continue to treat wastewater regardless of which plant species dominates.

The exception is French VF systems, where reed health is essential to maintain the correct functioning of the sludge layer on primary beds and must be monitored closely.

A note on dormancy: In the UK and Ireland, wetland macrophytes die back above ground each autumn and look brown and apparently dead throughout winter. The plants are not dead — nutrients are stored in the roots and rhizomes, and new shoots will emerge in spring. Mature systems typically have a mixture of “standing dead” brown plant material and new, green growth through spring and summer. Do not intervene (cut, replant, or alter water levels) on the basis of a winter inspection.

tolerant grasses indicating too-shallow water in HF). In SF systems, check whether bare patches correlate with zones of permanent inundation — a sign the outlet level control may need adjustment.

Type-specific notes:

Trees should not be allowed to establish in any wetland cell unless specifically designed for. Roots can puncture liners, and high water demand can reduce measured flows and affect effluent concentrations. Remove any woody scrub annually before it becomes established.

Plant harvesting – Yes or No?

The decisions to harvest should be made in discussion with the site owner and/or designer and following regulations around bird nesting season. Plants can sometimes play critical roles in enabling the microbial processes that occur in the system (e.g., SF and FTW systems). This should be recorded in the site-specific O&M manual. The options are:

Harvest and remove off-site. Typically recommended where a system has a P permit to minimise remobilisation as plant matter decays in situ. Harvesting should happen before senescence (late summer/early autumn) to avoid this and maximise nutrient removal via this mechanism. Also positive for VF systems, where harvesting enables maintenance of the distribution system and quick identification of blockages or uneven flow distribution onto the bed surface.

Do not harvest. Standing dead stems and accumulated litter insulate the bed over winter and contribute organic carbon that supports denitrification. Harvesting on these systems increases maintenance cost for no treatment benefit and in some cases deterioration in performance.

Harvest and leave on site. A hybrid solution, it retains the insulation benefit *if cut in autumn*, as the material provides a mulch layer through the coldest period. It does not contribute to nutrient removal. If harvesting is carried out, cut to approximately 0.3 m above the bed surface. If cutting in autumn, leave the material on the surface. If cutting in late winter (January–February), material may be removed without loss of insulation benefit as the coldest period has passed.

Table 3.1 Summary of plant health management specific to each wetland type

System type	Watch for	Note
French VF — year 1	Weed dominance suppressing reed establishment	Reed health is critical to correct function of the sludge layer on primary beds. Weed control is intensive in year 1. Saturation flooding for 1–2 weeks during the growing season can suppress weeds and favour reed establishment. Do not allow the reed stand to degrade.
HF	Unexplained die-back in a mature, established stand	Can be an indicator of incorrect water levels or preferential pathways developing within the bed. Consider hydraulic checks on the bed.
VF and aerated VF	Distribution pipes becoming obscured by dense growth	Harvesting provides an opportunity to inspect the distribution system (see harvesting note below). To protect biodiversity, cut only half or a quarter of a system in any one year.
Aerated (any)	Poor vigour or patchy growth across the bed	May indicate incorrect water level or aeration intensity settings — check the site-specific O&M manual before intervening.
SF	Loss of plant cover; bare patches; no new growth in spring	Water level management is critical — plants need periodic lower water levels as well as inundation. Permanently elevated water levels will drown even established stands (see Figure 3.5d). Check that the outlet control is set within the design range and has not drifted. Greater diversity of macrophytes is generally acceptable; focus management effort on invasive species.
FTW	Patchy or declining cover on specific raft sections	Check for grounding (roots compacted into bottom sediments rather than hanging freely – see 3.3) or substrate degradation within the mat (e.g., planting media compaction). Where under-mat aeration is installed, similar checks as aerated systems apply.

If this goes wrong:

For most system types, imperfect plant cover does not directly harm treatment performance as the microbial community does the work. The notable exceptions are **first-stage French VF bed where the reed stand has failed; floating treatment wetlands where no roots develop from the floating mat; and surface flow wetlands where macrophytes fail to establish** (e.g., due to incorrect water levels) thus limiting the system's ability to biologically treat the water. In a French VF without a healthy sward the sludge layer cannot function correctly and treatment performance will decline. For SF and FTW systems, a healthy plant cover is needed to support the biological treatment processes which include biofilm development on plant roots and direct plant uptake (and plant litter cycling). In all these cases, contact the system designer if plant cover drops significantly or fails to recover after two growing seasons.

Plant health and weed management – Poor management consequences

Treatment Impact	●
Bed life impact	●
Remediation cost	●

Catastrophic failure risk: Only on systems reliant on macrophytes for treatment (i.e., first stage French, FTW and SF wetlands).



Figure 3.5 Examples of vegetation management, (a) mature trees growing in HF bed, (b) aerated wetland with poor reed growth and weed growth, (c) impact of aeration on plant establishment, showing identical tertiary beds with (front) and without (back) aeration. The aerated bed has poor plant growth and zones with algae and duckweed growth due to the absence of shading, (d) SF cell with no plant growth as the water level is set too high, (e) VF bed during harvesting, showing the distribution pipes, (f) harvesting of SF cell. *Photo credits: (a) to (c) NbS Future/G Dotro, (d) E Butterworth, (e) C Weedon, (f) Salix.*

3.6 Sludge, thatch and sediment depth measurement

What to do: Use a sludge judge or ruler to measure accumulated depth of sediments, sludge and/or thatch (leaf litter) at representative points across the cell. At a minimum this should include the inlet zone (risk of clogging, indicators of overloading) for all systems types, and the outlet zone for HF and SF. For the latter, it is important to take measurements from representative deep and shallow zones.

What to look for: Depth approaching the design maximum set by the designer. Record measurements annually to plot accumulation rate and forecast refurbishment timing.

Type-specific notes:

- *HF*: Solids removal typically required every 15 years. Range is 5–25+ depending on design and actual loading plus upstream management.
- *VF*: Surface scraping of 5–10 cm typically needed every 10 to 15 years. depends on design and actual loading plus upstream management.
- *SF*: Sediment removal from deep zones typically every 5–20 years.
- Chemically-dosed systems: Sludge accumulation rates are typically higher than in undosed systems, averaging around 2 cm per year across UK sites (range 0–3 cm/yr), with the highest rates observed where upstream solids management is poor.

If this goes wrong: Unmanaged solids accumulation will eventually reduce hydraulic conductivity and/or retention times in subsurface flow systems. In VF systems this means surface ponding and loss of oxygen transfer. In HF systems, this translates to progressive overland flow resulting in bypassing of treatment areas and potential short-circuiting direct to the overflow pipe. In SF systems, progressive solids accumulation reduces the retention time in the system. The rate of accumulation is not linear — systems can appear stable for years before deteriorating rapidly once a threshold is crossed. Annual measurement allows the trajectory to be identified early enough to plan refurbishment without an emergency intervention.

In SF wetlands, sediment accumulation results in reduced retention times which can impact treatment performance. In addition, solids accumulation increases the risk of solids washout during higher flow events. Where the system has been designed for phosphorus capture (see box below), it is possible to first impact the phosphorus limit before the TSS permit is breached.

Remedial action: schedule refurbishment (see 3.10) before operational failure; in SF systems, consider targeted dredging of inlet zones and sediment testing before full-system intervention. Excavated solids (sediment or sludge) will need disposal in agreement with waste management regulations.

Link to wetland processes – phosphorus removal in wetlands

Phosphorus in wetland sediments can be found in association with iron, calcium or aluminium, depending on upstream processes and, in SF systems, the chemistry of the rooting soils. The binding mechanism determines the nature of the sediment-associated risk:

- **Iron-bound phosphorus** is sensitive to redox conditions. Under aerobic or nitrate-rich conditions, iron holds phosphorus tightly. If conditions become anaerobic — which sediment accumulation can accelerate by increasing oxygen demand within the bed — iron releases bound phosphorus back into the water column. This mechanism is reversible and can cause the wetland to become a net phosphorus source rather than a sink without any visible change in the bed.
- **Calcium and aluminium-bound phosphorus** is more stable across typical wetland redox and pH ranges and is not vulnerable to chemical release under normal operating conditions. However, the phosphorus is physically bound to the sediment particles themselves — so in SF systems, accumulated sediment and the phosphorus it carries must be managed as a solids washout risk, particularly during high flow events. Sediment removal (section 3.10) is therefore both a hydraulic and a phosphorus management intervention in these systems.

Regular sediment depth monitoring and effluent quality checks (section 3.9) are important in all systems designed for phosphorus capture, but the priority intervention differs: for iron-based systems, watch for anaerobic conditions; for calcium and aluminium-based systems, watch for sediment accumulation and flow events.

Sludge, thatch and sediment – Poor management consequences

Treatment impact	● ● ●
Bed life impact	● ● ●
Remediation cost	● ● ●

Catastrophic failure risk: Yes for VF if unmanaged long-term; No for HF (degrades to hybrid surface flow); Moderate for SF — treatment continues but the wetland becomes a nutrient source rather than a sink if sediment management is neglected

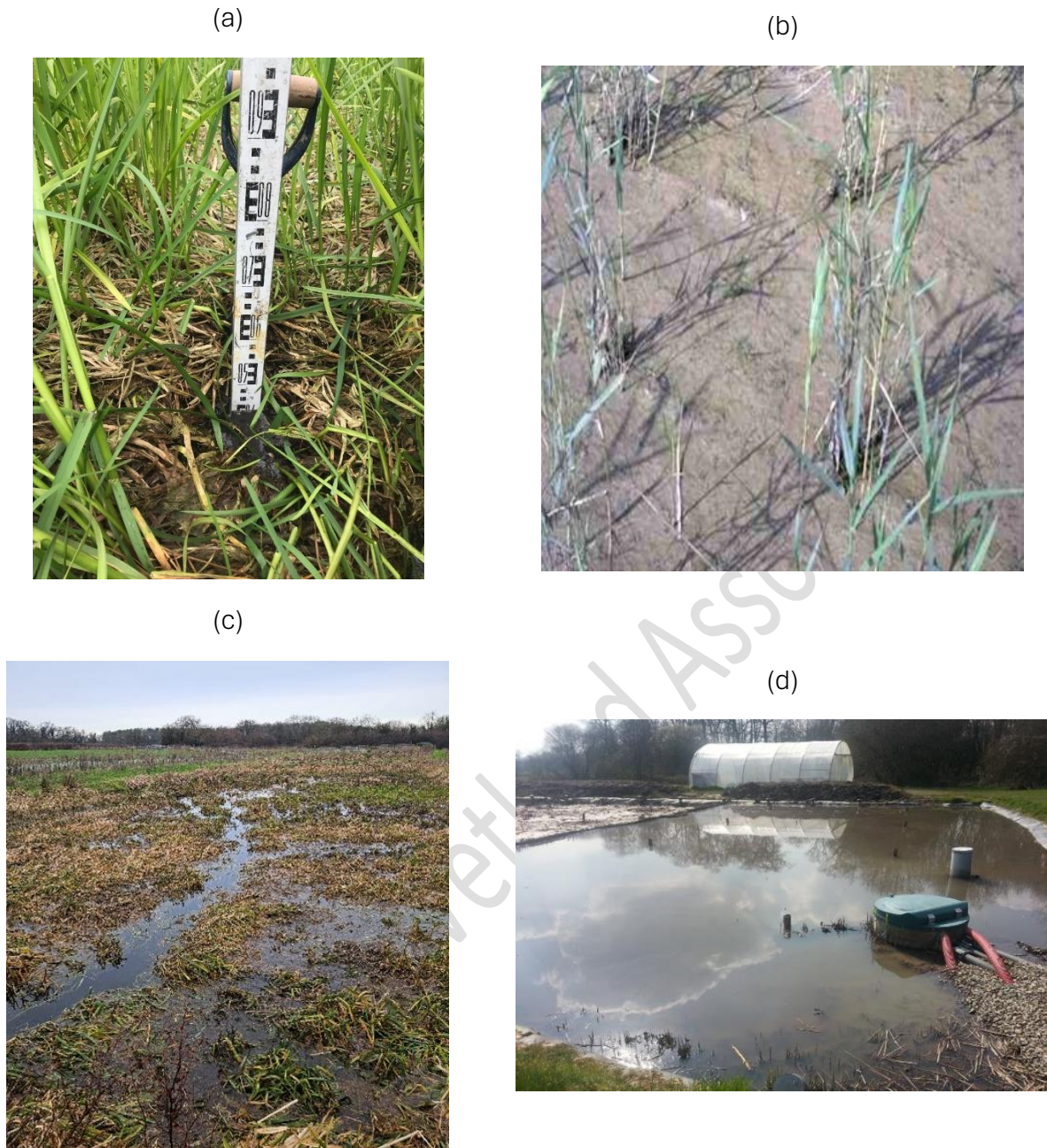


Figure 3.6 Examples of sediment and sludge accumulation in wetland cells, (a) 450 mm of sludge on top of media surface (b) HF wetland with surface sludge accumulation restricting oxygen input onto the bed, (c) SF cell with preferential flow pathways initially triggered by poor influent distribution and exacerbated by sediment accumulation and uneven vegetation establishment, (d) complete surface blinding of first stage French VF. The plants could not establish in time and a shock load was received from the network, completely blocking the media pores. The top of the media had to be scrapped off and reeds re-planted. Photo credits: (a) ARM, (b) and (c) NbS Future/G Dotro, and (d) Dotro and Chazarenc (2015).

3.7 Batch volume and dosing frequency (VF and AVF systems)

What to do: Confirm that the dosing siphon or pump is delivering the correct volume per dose to temporarily flood the bed during feeding and that the interval between doses is sufficient for the bed to drain fully (confirmed by outlet flow ceasing between doses).

What to look for: Persistent ponding between doses; clear wet areas close to distribution points and dry areas further away from distribution points; dosing frequency drifting from design values; siphon not triggering correctly; system operating under “storm” conditions therefore temporary surface ponding that should subside after the event ends.

Type-specific notes:

- *French VF:* Filter alternation as per site-specific design guidance (typically every 3.5 days, though site-specific constraints may require longer rotation — always check with the system designer before changing the regime). Rest periods that are too long are harmful to the microbial community. Never alter the feed:rest regime without checking with the system designer.
- *Standard VF:* Confirm the surface of the bed “floods” during feeding but then drains in the interval prescribed by the designer.
- *AVF:* The saturated zone retains water by design; confirm only the unsaturated upper zone drains freely. Do not keep the bed flooded as this will result in algae/duckweed growth.

If this goes wrong: If a VF bed does not drain fully between doses, anaerobic conditions develop within the media. This impairs nitrification — ammonia in the effluent will rise, often before any other visible sign of a problem. Prolonged waterlogging in a standard VF system can damage the microbial community in ways that take weeks to recover from after the dosing issue is corrected. If the system is treating septic tank effluent, odour could develop and sewage fungus could grow in the outlet from the oxygen-deprived VF cell. In French VF systems, incorrect filter alternation (resting one stage for too long) has a similar effect.

Remedial action: restore correct dosing regime; check siphon or pump; allow recovery period before assessing treatment performance.

Batch volume and dosing frequency – Poor management consequences

Treatment impact	●●
Bed life impact	●
Remediation cost	●

Catastrophic failure risk: No — recoverable once correct dosing is restored.

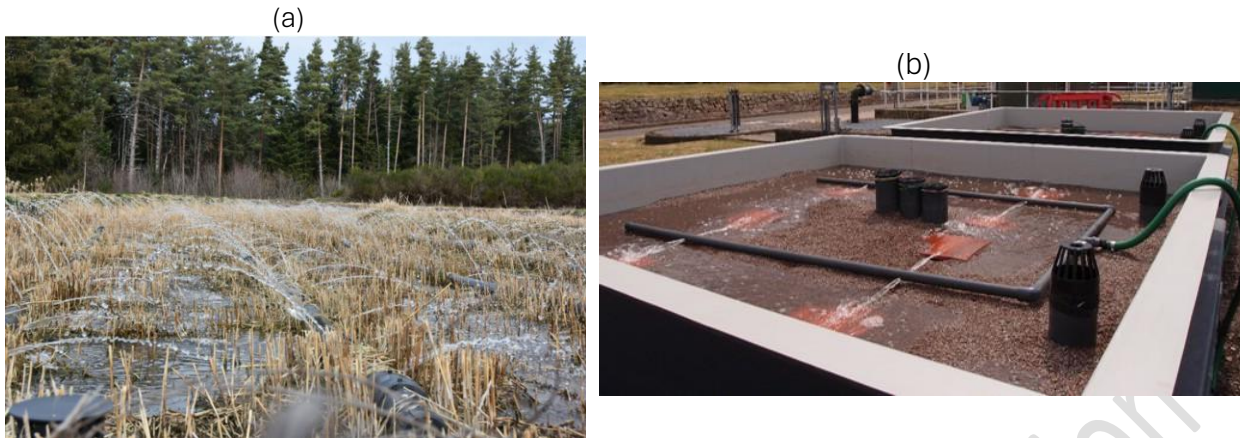


Figure 3.7. Examples of water distribution in VF cells, (a) Correct feeding of secondary VF cell, (b) inadequate VF dosing in an unplanted pilot system during drainage system checks, showing zones where the surface is not wet and therefore bypassing of biological treatment in the media. Photo credits: (a) P Molle, (b) G Dotro.

3.8 Aeration and oxygen management

What to do – aerated systems (blower): Check blower is operating within the manufacturer's specified pressure and flow range. Log run hours. Service according to manufacturer's schedule.

What to do – aerated systems (bubble pattern): On commissioning, flood the surface of the bed to check bubble pattern. Once satisfied with this, lower the water level for subsurface operation. Where effluent ammonia is deteriorating, check the influent loading is within the design envelope, the blower is operating and the pressure release valve is not discharging excessively. Temporarily raising the water level to inspect the bubble pattern can help diagnose the cause – always remember to return the system to normal subsurface operation afterwards.

Important note on surface flooding in aerated systems: Aerated wetlands are designed for subsurface operation. When the bed is surface-flooded, aeration creates mixing that increases the risk of short-circuiting compared to normal plug-flow conditions. Surface flooding should only be used temporarily for bubble pattern inspection.

What to do – VF, SF and FTW systems: Measure DO at the inlet and outlet of each cell periodically. For SF, where cascade or weir structures are present, check they are free of blockages and that flow is distributed evenly across the full width. For FTW, measure DO in the water column beneath the floating mat and compare to DO in adjacent open water.

What to look for – aerated systems (blower): Alarm activation; elevated back-pressure (indicative of blocked emitters or need for filter replacement); overheating; unusual noise.

What to look for – aerated systems (bubble pattern):

- Even distribution across the full bed = correct operation.
- Large turbulent bubbles from one point = disconnected airline or manifold connector.
- Sparse or absent patches = blocked emitters. This is most common in industrial effluents or iron-rich wastewaters due to ferric hydroxide precipitation. It can also occur in aeration if turned off for prolonged periods (months to years).

What to look for - SF and FTW systems: Low or declining DO at the outlet relative to the inlet, particularly during warm weather or where BOD and/or ammonia loading is high. Uneven flow or

blockages at cascade or weir structures. For FTW, very low or near-zero DO throughout the full water column depth may indicate organic overloading or insufficient open water area to maintain site-wide oxygen balance.

If this goes wrong: Loss of aeration in artificially aerated wetlands receiving significant oxygen demand (BOD and/or ammonia) results in rapid depletion of oxygen and a subsequent deterioration in effluent quality. Effluent ammonia can begin to rise within 36 hours of blower failure in sewage treatment systems, as demonstrated in controlled shutdown trials. However, the biological community recovers reasonably quickly once aeration is restored - typically days to a couple of weeks for full nitrification recovery. Prolonged (days to weeks) outage switches the main pollutant cycling processes to anoxic/anaerobic. Blocked emitters are a slower failure mode as performance can degrade gradually as the proportion of unaerated zones increases. If this occurs, contact the system designer for cleaning the system (minor and fast intervention).

In SF and FTW systems, low DO does not necessarily indicate system failure — it may reflect seasonal variation, high BOD loading, or the normal oxygen demand of a maturing system. Interpret DO readings alongside ammonia and TON data before concluding there is a problem.

Remedial actions: restore blower operation within one residence time; identify and clear blocked emitters; treat wetland as an anoxic system if outage is prolonged (e.g., bring in temporary treatment). Good design practice recommends a second standby blower where the site relies on the aerated wetland to permit compliance. For FTW, increase the proportion of open water if possible to enhance the oxygen balance.

Link to wetland processes – nitrification and oxygen management

In SF wetlands, nitrification is less predictable than in VF or aerated systems because oxygen transfer depends on surface reaeration and plant-mediated transfer, both of which are harder to control. Performance can be variable — particularly in warmer conditions when oxygen solubility is lower, or where BOD demand competes with nitrification for available oxygen.

In all wetland types, **ammonification** — the conversion of organic nitrogen from proteins, urea and other compounds into ammonia — can cause effluent ammonia to be *higher* than influent ammonia. This is not nitrification failure; it is the wetland mineralising organic nitrogen. It is most relevant in river water treatment applications (where incoming water may carry significant dissolved organic nitrogen) and secondary sewage treatment. Monitoring total oxidised nitrogen (TON) alongside ammonia is essential in these cases — rising TON confirms nitrification is still functioning despite rising ammonia.

Artificial aeration – Poor management consequences

Treatment Impact	●●●
Bed life impact	●
Remediation cost	●●

Catastrophic failure risk: No — recoverable, but if the flowsheet depends on the aerated system to achieve an ammonia permit limit, there is risk to compliance within ~ one residence time from the point of blower loss.



Figure 3.8 Aeration bubble patterns in new systems (a) uneven air distribution, (b) even bubble pattern, (c) Pressure gauge check on PD blower in need of maintenance (d) Aeration manifold leak.
 Photo credits: (a) and (b) NbS Future/G Dotro, (c) ad (d) ARM.

3.9 Performance monitoring

What to do: Collect effluent samples at a minimum as per the permit schedule but preferably on a monthly basis. Wherever possible, collect influent to the wetland as well as effluent from the wetland to enable performance assessment, not just compliance. Measure permitted water quality parameters as well as temperature, water flows, weather conditions at time of sampling, sludge levels and vegetation appearance. Compare measured concentrations and pollutant loads with design assumptions and permit limits. Maintain an auditable log.

What to look for: Sustained deterioration in one or more parameters; seasonal patterns that exceed design expectations; sudden step-changes (often indicate upstream process failure). Wetlands are biofilm reactors with long water residence times (days not hours) and even longer biomass retention times (“SRTs” in years rather than days). As such, they can typically buffer peaks in poor performance from upstream processes and tolerate short term hydraulic shock loads. However, the inherent resilience of these systems varies with wetland type, application and normal operating conditions. It is important to understand what is “normal” for a particular site and the design objectives and operating envelope to assess whether the issue lies with the wetland or is more fundamental to the entire flowsheet.

Type-specific notes:

- *All systems*: Compare measured hydraulic loading rate against design. Checks are available for all wetlands in the CWA Sewage Treatment Best Practice Guide (2026) and/or international literature. Further checks on organic and TSS loading are available for specific wetland types.
- *Aerated and VF*: Ammonia breakthrough is the key indicator of nitrification failure or overloading event. Check aeration system (blowers and bubble pattern for AVF or AHF; passive aeration pipes for VF).
- *Chemically-dosed systems*: When iron is used to capture phosphorus upstream of the wetland, aerobic conditions within the bed are important to maintain long-term iron-bound P retention — see the process box in section 2.6 for detail on the underlying mechanisms. Where aerobic conditions cannot be guaranteed (e.g., SF systems), monitor residual organic carbon and nitrate at inlet and outlet as early warning indicators.

Standard principles for the general maintenance of sampling points applies to wetland systems, to prevent septicity and/or solids accumulation in effluent collection chambers.

If this goes wrong: The specific warning signs depend on the process at fault. A step-change in BOD or TSS usually points to an upstream process failure, sludge dump, or a system reaching the end of its design life (i.e., needing refurbishment). Gradual ammonia deterioration points to aeration or loading issues in aerobic systems, or clogging in passive VF. In SF systems, seasonal phosphorus spikes can occur due to plant senescence and redox-driven release from sediments — these are expected and should be designed for, not treated as system failure.

Remedial action: systematic diagnosis by parameter; check loading rates against design values first.

Performance monitoring – Poor management consequences

*Monitoring exists to catch problems **before** failure occurs. It is not a failure mode itself.*

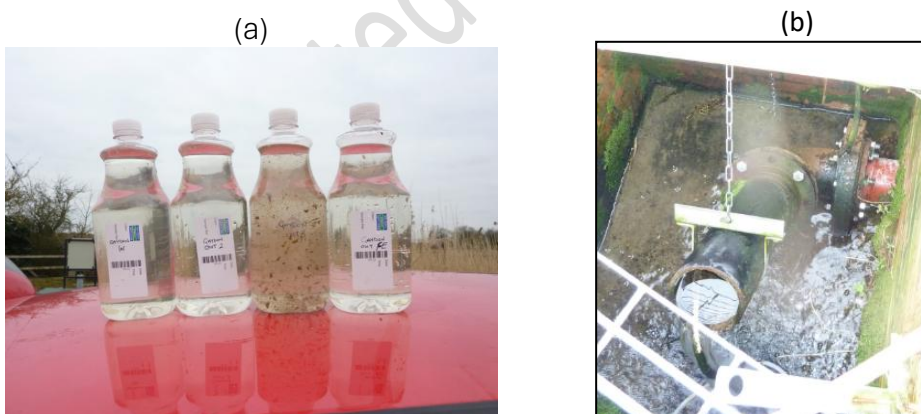


Figure 2.9 Importance of sampling point location on performance assessment. (a) Four sampling points at the same works, from left to right: wetland influent; effluent taken from the outlet of the water level control pipe; effluent sampling pipe with autosampler; and the regulatory final effluent point. Solids accumulating at the base of the HF cell are periodically disturbed by the autosampler flushing cycle, affecting sample quality. (b) Effluent chamber for the same site, showing solids accumulation in the level control chamber alongside visibly clear effluent cascading from the control pipe. Photo credits: E Butterworth.

3.10 Refurbishment and/or sediment removal

What to do: When sludge and/or sediment accumulation measurements indicate that remaining capacity is approaching exhaustion, commission a full refurbishment assessment. Plan for media removal, reinstatement or replacement, and replanting for subsurface flow systems (HF and VF), or sediment dredging and replanting for SF systems.

What to look for: Persistent surface ponding on HF or VF systems that does not respond to operational interventions; hydraulic conductivity tests confirming reduced permeability. For SF systems, significantly reduced retention times, visible solid accumulation and/or soil formation that results in dry patches and/or development of marginal/terrestrial plants.

Type-specific notes:

- *HF:* Gravel removal and replacement or site-specific deep cleaning. Some companies are able to either clean in-situ or wash and reuse the gravel to reduce costs and carbon footprint.
- *VF:* Surface scraping (5–10 cm) is usually sufficient to restore performance; full media replacement is rare.
- *SF:* Targeted sediment removal from inlet and deep zones using long-reach excavator.
- *French VF:* The organic deposit layer on stage 1 is normal and beneficial — do not remove unnecessarily; only the deepest accumulated material need be scraped after freeboard is reduced to trigger values.

If this goes wrong: Delaying refurbishment beyond the point where operational interventions can no longer restore performance risks permit breaching. In practice, most systems give adequate warning through the sludge accumulation trend and should exhibit progressive ponding. The key risk is underestimating the lead time needed to plan and procure a refurbishment — excavation of wetland cells requires heavy plant access, time to dredge the cells (SF) and/or replace the gravel (HF or VF), and a contingency treatment arrangement. Lowering the water level may also be required which adds further logistical considerations.

Refurbishment – Poor management consequences

Treatment impact	● ● ●
Bed life impact	● ● ●
Remediation cost	● ● ●

Catastrophic failure risk: Yes if refurbishment is deferred indefinitely in a VF system; lower for HF and SF but likely impact on performance due to reduced retention times and/or contact with microbial communities.

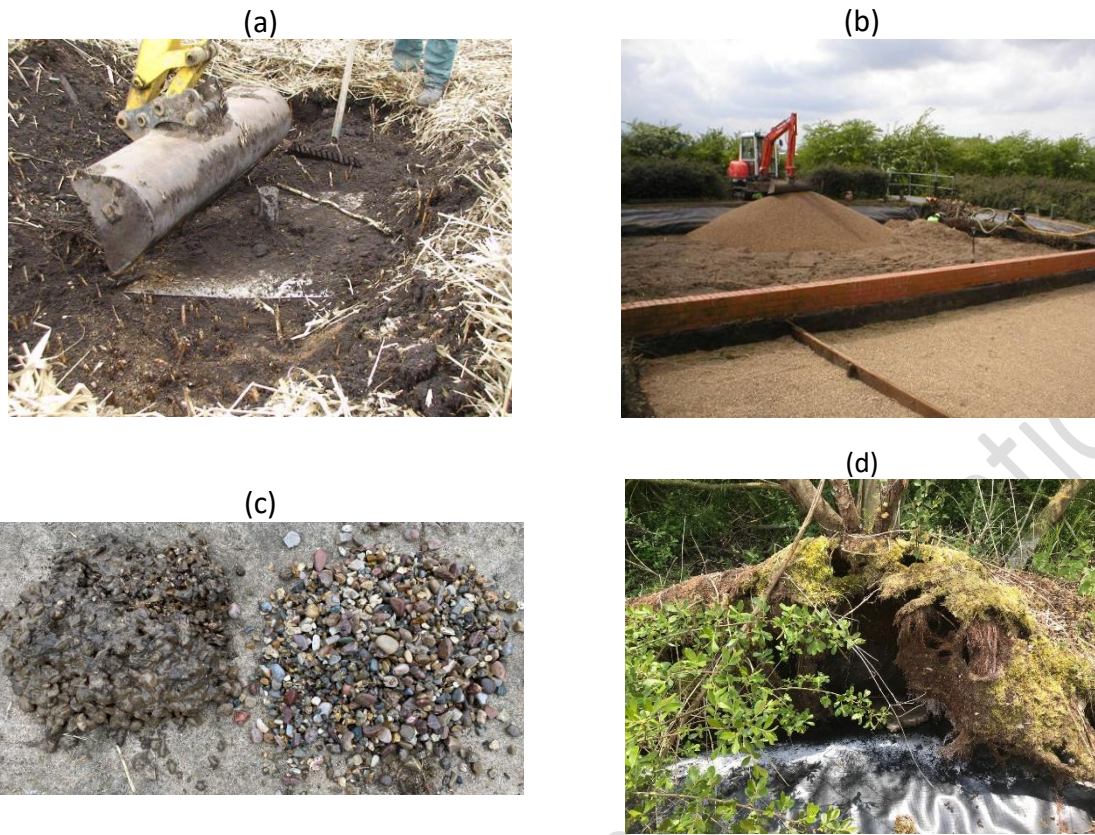


Figure 3.10 Examples of refurbishment operation or triggers: (a) sludge removal operation after 20 years of operation from first stage of French VF, (b) Refurbishment of HF wetland. (c) gravel before and after in-situ cleaning operation, (d) liner punctured by mature tree. *Photo credits: (a) F Chazarenc, (b) C Murphy/ARM, (c) Abydoz. (d) ARM.*

4. Troubleshooting reference guide

Symptom	Likely cause	First action
Surface ponding on HF / VF	Upstream solids carryover; clogging	Check and desludge upstream tanks; check inlet distribution
Water level not responding to outlet adjustment	Clogging within bed	Sludge depth measurement; consider refurbishment assessment
Surface ponding or poor effluent quality developing within 24–48 hours of a storm	Sludge mobilised from upstream tank by hydraulic surge	Check and desludge upstream settling/septic tanks; check inlet distribution for displacement.
Poor reed growth in year 1–2	Inadequate water level; weed competition; aeration intensity	Check water level setting (too high/too low). Weed control: consider temporary saturation flooding (in subsurface systems). In aerated systems, also consider intermittent aeration until plants are established.
Blower alarm	Blocked emitters; disconnected airline; overheating	Inspect bubble pattern; check back-pressure; service blower; clean aeration system.
Ammonia breakthrough (aerated or VF)	Aeration failure; organic overload	Check blower (if aerated) or dosing regime (VF); compare influent load to design assumptions and operational envelope.
Declining performance (all)	Hydraulic overload; upstream process failure; clogging; saturation of sorption sites (P)	Check loading rates against design; inspect upstream processes.

Appendix A: Hazardous and injurious plants to be aware of

Giant Hogweed *Heracleum mantegazzianum*

The sap of this plant is phytotoxic and will cause serious skin burns under sunlight.

There is a native Hogweed (known as just 'Hogweed') *Heracleum sphondylium* which does not grow as tall. It is often found on road verges, alongside hedgerows, and on waste ground and rough grassland.

Key Identifying features of Giant Hogweed:

- Stem – Large thick stems, 5-10cm in diameter and blotchy purple in colour usually with sharp bristles. Grows up to 5.00m in height.
- Leaves – Up to 3.00m in length, sharply divided/serrated and often have bristles on the underside.
- Flowers – Large umbrella flowers up to 80cm across and containing many flower heads, white in colour, rarely pinkish.

Main control methods:

- Plants should not be cut with brushcutters, strimmers or other mechanical means as this will spread the sap and put the operator at risk, hand tools should be used with appropriate PPE.
- Herbicide application using spot spraying with Glyphosate is the most effective control method. Spraying should be undertaken on the emerging leaves in the spring and early summer. A follow up application may be necessary to treat any re-growth, late emerging or missed plants.
- If plants have grown and herbicide application would not be as effective or would risk drift onto surrounding vegetation/habitat, then flower head cutting is an effective method to prevent seed production and further propagation. This activity should be undertaken with hand tools and appropriate PPE to prevent contact with the sap. If the flower head has started to produce seed, it should be covered with a bag before cutting to capture seed and reduce the risk of spreading the seed further around the site.
- Stem injection with Glyphosate is also an effective method of control for established plants where foliar spraying is not practical, or risks of drift make it inappropriate.
- During the first stage of the growing season and on young plants, it is effective to dig the plants up. The tap roots must be cut at least 15cm below ground level.

Hemlock water dropwort *Oenanthe crocata*

This is one of the UK's most poisonous plants and should be handled with care, one of the main risks is misidentification as it can be easily confused with similar umbellifers. The entire plant is poisonous, but the highest concentrations of the toxin are found in the tubers. It is highly toxic if ingested with severe symptoms which can result in fatality. The risk to operators is low providing appropriate care is taken and PPE worn, with hands washed before touching the face, drinking, eating or smoking/vaping.

Key identifying features:

- Stem – Bright green and hollow with grooves longitudinally, up to 3.5cm across and growing up to 1.5-2.0m in height
- Leaves – Bright green and fern/carrot like with 2-4 pinate divisions.
- Flowers – Small, white and in umbels

Control methods:

- The plant should not be cut with brushcutters/trimmers as this can cause sap to be sprayed into the face of the operator, risking ingestion.
- Given the toxic nature of the plant, it is advised that professional contractors are brought in to remove and dispose of the plant.
- Herbicide application and digging out are the most effective control measures, though any cut material and tubers must be disposed of to a licenced waste processing site or incinerated under controlled conditions.

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Appendix B: Invasive non-native species that can grow in treatment wetlands

Japanese Knotweed *Reynoutria japonica*

Japanese Knotweed was introduced to the UK in the 1850's as an ornamental and fodder plant. It is very invasive with seeds and plant fragments dispersed easily along watercourses.

It is an offence under the Wildlife and Countryside Act to plant or otherwise cause the plant to grow in the wild. Given its very invasive nature and ease of propagation, it is recommended that professional contractors are used to remove and dispose of the material, especially if there are large stands of it. Individual plants are best controlled using herbicide.

As the plant can easily propagate from shards of stem and cut material, it should not be cut using brushcutters/strimmers or other mechanical plant as this will spread it more widely.

Identification:

- Stem – Grows up to 2-3 metres in height, green with red/purple speckles and hollow with distinct nodes much like bamboo. It forms dense clumps and when it dies back in the winter, the stems persist as upright brown, hollow stalks.
- Leaves – Alternate green, heart shaped leaves which are up to 12cm long.
- Flowers – Delicate creamy sprays in August to September.

Control methods:

- The most effective method is stem injection using a glyphosate-based herbicide. This ensures all the herbicide is applied directly to the target plant and reduces impact on surrounding vegetation.
- Foliar spraying is also very effective, particularly on young/emergent plants early in the season.
- Regular pulling or cutting will eventually exhaust and kill the rhizome and kill the plant. As stated above, any cutting should be done with hand tools, ideally a sharp hook, and not with brushcutters or other mechanical plant.
- Cut material must not be removed from the site unless being disposed of to a licensed waste handling site. It cannot be composted but can be burned on site under controlled conditions, though burning of cut vegetation is now often prohibited on sites.

Himalayan balsam *Impatiens glandulifera*

This plant very easily propagates and spreads, especially along rivers, streams and flowing water courses. The seed pods are 'spring loaded' and, when ripe, will explode open expelling the seed up to 6 meters from the plant. They also float so will spread rapidly down flowing water courses.

Identification:

- Stems – Pinky red colour growing up 3 meters in height, they are hollow and jointed with obvious nodes and are sappy and brittle.
- Leaves – Spear shaped, shiny dark green with a dark red midrib and can be up to 15cm long arranged opposite in stems or in whorls of three.
- Flowers – Purplish pink to pale pink, slipper shaped on long stalks and appear in June to October.

Control measures:

- Plants should be removed before the seed to reduce the risk of them seeding and spreading further.

- Hand pulling is one of the most effective methods of removal as the plants pull out easily, especially in wet marshy ground.
- Young plants can also be cut with a hand scythe or brushcutter but can be prone to regrowth if not pulled out. Plants should be cut before flowering in June, it is not advised to cut earlier than this as it can promote greater seed production in regrowth.
- Plant material can be disposed of by composting (providing there are no seeds) or via a licenced waste handling facility.

Orange balsam *Impatiens capensis*

This plant is very similar to Himalayan balsam but is less common and much less aggressive, it forms smaller less dense stands.

Identification:

- Stems – Almost identical to Himalayan balsam but grows slightly smaller up to 1.2m in height.
- Leaves – Very similar to Himalayan balsam but slightly smaller with fewer serrations.
- Flowers – The most easily differentiating identifier, they are similar in shape and form to Himalayan balsam but are orange in colour.

Control methods are exactly the same as that for Himalayan balsam.

New Zealand pigmyweed *Crassula helmsii*

Crassula is a very invasive species and it is illegal to cause it to grow in the wild. It is very difficult to remove and will require a specialist contractor to deal with it. It can grow from a tiny fragment of material and is spread very easily on boots, wheels and plant so if it is found on a site, proper biosecurity measure should be put in place to clean all equipment before leaving a site. It is a floating aquatic species so would only be found in open water, ponds and free water surface wetlands.

Identification:

- Leaves – Small, fleshy, almost succulent like growing in tightly packed pairs on the stem up to 2cm in length. When submerged they can appear to be sparse and flat with greater space between the pairs than when on the surface.
- Flowers – Small whiteish flowers that have four petals and grow above the surface of the water on long stalks.

If you discover this species on a site seek professional advice and a specialist contractor to deal with it as it is very difficult to remove and so easily distributed to other sites.

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