Restoring England’s Special Lakes

Natural England & Environment Agency Guidance on the Restoration of Lake SSSIs and Natura 2000 Network Sites

The Purpose of this Guidance

This guidance covers the strategic planning and implementation of measures to address adverse biological, chemical, physical and hydrological impacts on lakes. This guidance has been developed primarily for Sites of Special Scientific Interest (SSSIs) notified for lake habitat under the Habitats Directive (this includes sites additionally designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)), many of which are also Water Framework Directive (WFD) waterbodies. However, the general approach and measures can be equally applied to non-designated waterbodies.

This paper describes the process and measures applicable to the improvement of lake habitat quality. Whilst different measures will be required on individual sites, the process described should be implemented on all SSSI lakes which are currently not in favourable condition. Reaching these targets will also contribute to meeting obligations under the Water Framework Directive, in respect of achieving Protected Area objectives and reaching Good Ecological Status and Good Ecological Potential in the water bodies concerned. As all SAC lakes are also SSSI lakes this will contribute to reaching favourable conservation status for lake habitats.

The Environment Agency and Natural England have a joint national Lake Restoration Project (LRP) which supports, promotes and drives forward lake restoration activity. The guidance has been updated to reflect the project's experience of implementing lake restoration remedies and to incorporate the ambitions of Natural England's 'Conservation 21: Our Conservation Strategy For The 21st Century' and The UK Government's 'A Green Future: Our 25 Year Plan to Improve the Environment'.

We hope this guidance inspires you to take positive action, with others, to restore and conserve our remarkable English LakeScapes.

The Guidance has three parts:

<u>PART 1</u> : Provides the context and rationale for the Lake Restoration Remedy;

<u>PART 2</u> : Covers the detailed use of the Lake Restoration Remedy

<u>PART 3</u> : Summarises some key Lake Restoration techniques.

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PART 1: The Lake Restoration Project

1.1. Background

Lakes represent some of the most degraded and most challenging habitats to restore in England. There are around 326 lake water bodies which are notified for their lake habitat, 232 (71%) of which are in unfavourable condition. There are 580 WFD lake water bodies which have an overall classification, 483 (83%) of which are failing to meet their objectives (good ecological status/potential or above). Approximately 24% of the total number of lake WFD water bodies are SSSIs notified for their lake habitat and 71 % are in unfavourable condition. The majority of SSSI lake water bodies that are not WFD water bodies tend to be small. Whilst there is no direct relationship between favourable condition and WFD classifications, generally speaking work that will improve SSSI condition will also move it towards meeting WFD objectives and vice versa.

Natural England and the Environment Agency have shared objectives on improving the condition of SSSI lakes which relate both to meeting Biodiversity 2020 targets for SSSIs and achieving “Good Ecological Status/Potential” and “No Deterioration” for lake water bodies under the WFD.

The lake restoration project was initiated in 2011 by Natural England and the Environment Agency in acknowledgement of these issues, and funded by additional Grant in Aid (GiA), followed by Rural Development Programme for England (RDPE) funds made available by Defra specifically for the delivery of WFD objectives. The aim of the project is to address the dual objectives of restoring lake SSSIs to favourable condition and improving WFD status, via a prioritised programme of work to deliver the remedy. However, the planning, implementation and measures discussed are broadly applicable to the restoration of any lake. The project as a whole strengthens the knowledge base, develops guidance, facilitates the production of lake specific restoration plans, and delivers lake restoration action across a series of SSSI/WFD lakes. The techniques applied to restoring SSSI/WFD lakes could be used when prioritising resources for restoration across the wider lake resource in England.

1.2. Introduction

Naturally functioning freshwater and wetland habitats (including rivers, streams, lakes, ponds, bogs, fens, flushes, swamp, wet woodland and wet grassland) are moulded by natural environmental processes (hydrological, geomorphological, chemical and biological). These processes create intimate hydrological and biological connectivity between these habitats, generating natural ecological networks, so it is important to consider these habitats and their functioning together at a landscape scale.

Natural environmental processes support freshwater and wetland habitats for characteristic biological communities and their individual species. Rare and threatened species associated with freshwater and wetlands all have their niches within naturally functioning ecosystems.

Natural freshwater and wetland ecosystem function provides a sustainable basis for management at small and large spatial scales. It provides the foundation for helping freshwater and wetland ecosystems adapt to climate change together with a range of vital ecosystem services, including flood risk management, water retention in catchments to moderate the effects of drought and the provision of clean potable water. However, freshwater and wetland habitats are subject to a variety of anthropogenic pressures. Impacts include pollution from point and diffuse sources, modifications to water movement, physical modifications and invasion by non-native species.

This document aims to define and provide guidance on how the 'Lake Restoration Project' (LRP) 'remedy' should be used to restore natural ecosystem function within lakes and a process for taking the required restoration actions needed to conserve these habitats and their associated species. Protecting and restoring natural lake ecosystem function is liable to be an involved and long-term process. In many lakes there is great scope for protecting what remains and reversing past damage. As this guidance document will explain, an informed and strategic approach to decision making provides the basis for grasping opportunities and realising the ecosystem service benefits that may be gained from lake restoration.

1.3. Natural Functioning and Artificiality

Lakes exhibit great variety in terms of size, depth, productivity and characteristic biota, forming naturally via a range of hydrological and geological process. Human activity has created many additional standing waters, via excavation for resources such as marl, gravel and peat and purposeful creation of standing water such as reservoirs.

Standing water systems that are naturally functioning (in terms of water chemistry and quality, hydrological regime, morphology and biological assemblages) provide the best expressions of freshwater habitats and the biodiversity supported in them. Where naturally functioning standing waters can be restored, these will provide a more sustainable habitat to support this biodiversity. More detail on natural function and standing waters can be found in the Natural England document, 'A narrative for conserving freshwater and wetland habitats in England (NERR064)'.

However, it is acknowledged that lakes of artificial origin are of nature conservation value and the best of these will function relatively naturally, but the functioning of others will be constrained by their artificiality. In these cases the objective should be to move as close to natural functioning as these constraints allow, whilst bearing in mind that what might appear an immovable constraint in the short-term may have a solution if given sufficient time.

1.4. Specially Protected Wildlife & Earth Science Sites

The principal types of protected site in England are Sites of Special Scientific Interest (SSSIs) and European sites which make up the UK's contribution to the Natura 2000 network and which comprise Special Areas for Conservation (SACs), designated under the EC 'Habitats and Species' Directive, and Special Protection Areas (SPAs), classified under the EC 'Birds' Directive.

To this can be added 'Ramsar' sites, notified as wetlands of international importance under the Ramsar Convention. Around 85% of SSSIs are also European sites. Most SPAs are also Ramsar sites. As a matter of Government policy, Ramsar sites are treated with the same level of protection as Natura 2000 network sites. See the separate annex which lists all of those SSSIs which have 'Standing Water' as a notified feature which are also Ramsar sites. Water dependent N2K sites are considered protected areas under the WFD.

Lake habitat as a notified feature of these designations is defined in a holistic way, encompassing all physical components (the full habitat mosaic including marginal zones and other hydrologically connected areas) and the full characteristic biological assemblage. This means that the entire lake and its full hydrosere (regardless of where plants occur) and all the species it contains (including but not restricted to plants, fish and invertebrates) are protected and the aspiration is to restore the lake habitat to as close to natural conditions as possible enabling it to support all the species it would naturally be able to.

Decision-making on lake SSSIs and SACs designated for their freshwater habitat features is founded on the protection and restoration of natural ecosystem function thus limiting anthropogenic modifications to habitat integrity. This approach is embedded in UK Common Standards Monitoring guidance on setting targets for monitoring the condition of SSSI and Natura freshwater sites. Importantly, the approach promotes the nesting of individual species requirements within the habitat template provided by naturally functioning lake ecosystems.

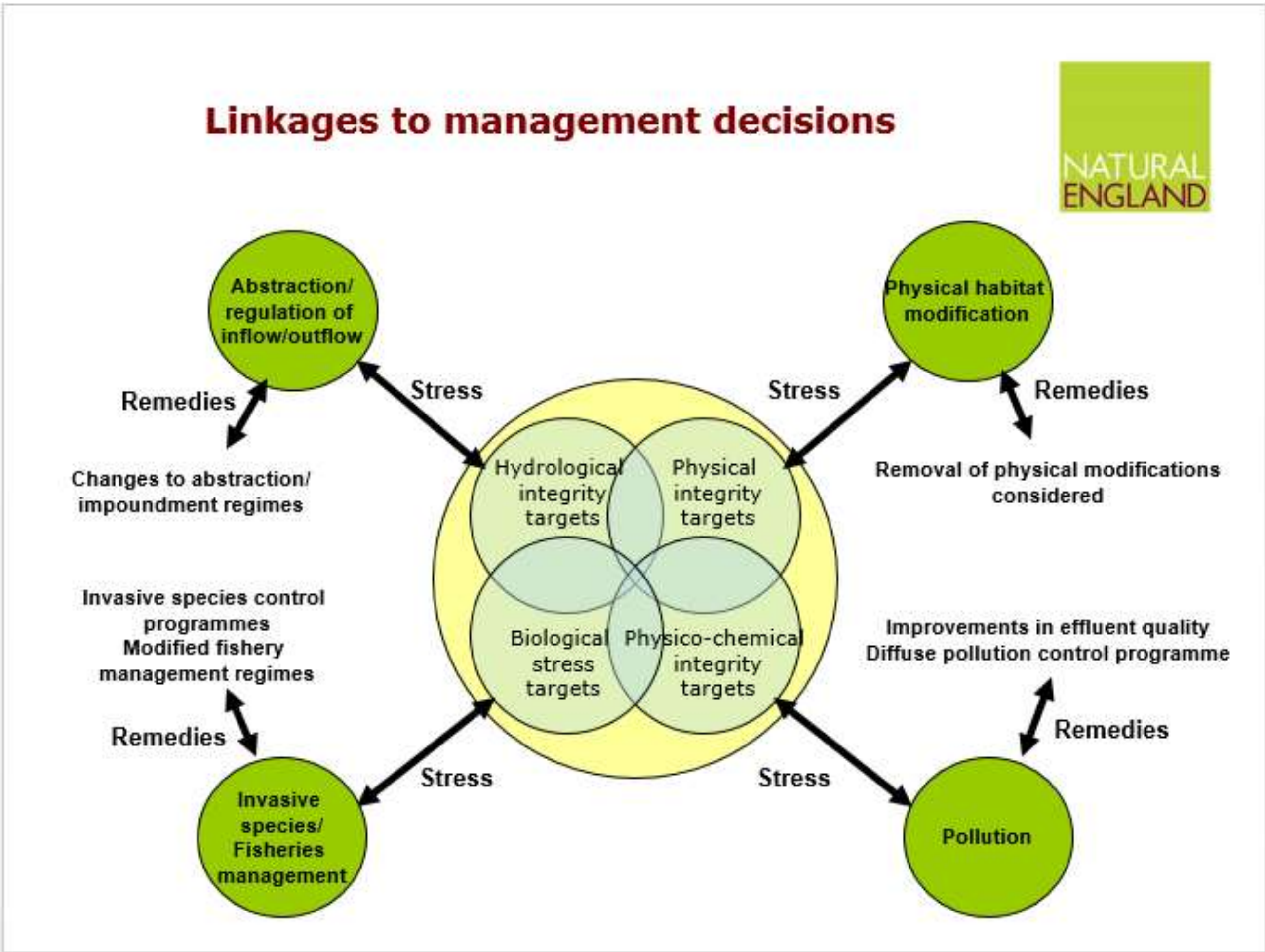


Figure 1: Components of condition of SSSI freshwater habitats and links to key remedies

Protected lake sites are a challenge for the protected site concept. They are highly connected to (and influenced by) the land within the catchment, including all of the activities taking place in the catchment. Traditional approaches to protected sites, consisting of delineating a land area and managing the vegetation within it, inadequately protect the natural function of a lake (unless the land area delineated is the entire catchment). Consequently when restoring lake function it is necessary to think at a large scale often beyond the designated site boundary.

1.5. The Water Framework Directive

The EC Habitats and Birds Directives provide the primary legal framework for biodiversity protection in Europe, however, decision-making in the freshwater environment is dominated by water legislation. The role of water as a common and critical resource, the management of which affects the whole of society, has generated a strong protection framework for the freshwater environment. The EU Water Framework Directive (WFD) provides the primary environmental decision-making framework for water management in England, based on the control of anthropogenic effects on the ecological status of waterbodies using minimally altered 'reference' conditions as a baseline. In principle, it is well aligned with the principle of protection and restoration of natural ecosystem function in lakes and provides a good foundation for the protection of lake habitats and their characteristic species across the wider freshwater resource. Consequently work undertaken to improve SSSI condition will also move sites towards meeting their WFD objectives.

For designated sites, the additional levels of precaution awarded to this small, high quality sub-set of the national lake resource drives a level of aspiration which is set on a bespoke site level but may exceed the WFD objective of Good ecological status or Good ecological potential. Additionally, SSSI objectives include consideration of parts of the ecosystem not directly monitored or assessed as part of WFD classification. This means that all the objectives both those for nature conservation and WFD need to be considered up front in any lake restoration planning stage to ensure any investment to reach a lower level of aspiration does not prevent future work to reach a higher aspiration.

It is of note that two aspects of the lake ecosystem generally not monitored and assessed by the WFD are the hydrosere and some aspects of hydromorphological integrity (e.g. drainage of surrounding land). Whilst these aspects do not inform the WFD classification directly any improvements to the natural functioning of these aspects of the habitat are likely to improve elements that are monitored and assessed, thus still contributing to the achievement of WFD objectives. At the time of writing fish are also not monitored and assessed, although tools are in the pipeline. As part 3 illustrates, fish assemblages have the capacity to affect lake condition and the success of any restoration attempts. Manipulation of fish assemblages are also a tried and tested lake restoration technique again illustrating that aspects currently not considered by WFD assessments still have the capacity to influence WFD classifications.

1.6. The Nature of Impacts on Lakes

Lakes are not generally lost from the landscape as a result of anthropogenic impacts, their size often preventing this, however, there are exceptions such as the draining of Whittlesea Mere. The quality of the remaining lakes can be damaged by pollution (both point and diffuse, from both air and water), physical habitat modification (mostly of the shoreline and littoral zone), hydrological modification (including abstraction, impoundment, drainage and alteration of inflows and outflows), non-native species and fisheries management.

Eutrophication is the process by which unnaturally high concentrations of nutrients may lead to increases in phytoplankton, reductions in water clarity and a reduction in macrophytes. The increased productivity of a lake, particularly in the form of short-term algal blooms, leads to an increase in dead organic matter accumulating on sediments. As bacteria mineralise this material they consume oxygen, depleting its concentration in the water. Eutrophication has led to the loss of many species from previously biodiverse water bodies, such as the Broads and the West Midland Meres, often resulting in turbid, algal-dominated lakes. It should be noted that water bodies do not need to become completely dominated by algae before macrophyte species are lost as they may begin to be eliminated from the assemblage over a range of nutrient concentrations.

On base-poor geology, predominantly in the uplands, there is a legacy from air pollution where lakes continue to experience acidic conditions. Historically deposited sulphur is still being leached from soils and pH is recovering very slowly due to a low buffering capacity in these lakes. Much of England continues to suffer from high nitrogen deposition; the consequence of this may be more pronounced in the uplands where other sources of nitrogen are limited. Continuing high levels of nitrate in upland waters in England is an additional barrier to recovery from acidification and may be a cause of eutrophication at some sites, although the exact nutrient impact of N deposition is still poorly understood.

Shoreline habitats can be impacted by many anthropogenic pressures including artificially modified water level fluctuations (e.g. from abstraction, compensation releases, hydropower generation or a desire for constant levels for aesthetic and/or recreational purposes), shore reinforcement, siltation, and also increased wave action and direct disturbance due to increased use. Littoral zones are extremely important for biodiversity and other ecosystem services at lake sites.

Abstraction directly from water bodies and from their catchments can result in a reduction in their extent. Drainage of surrounding land can also lower the water level, truncating the hydrosere and impoundments may reduce water level fluctuations.

Increased sediment and nutrient loads and/or water abstraction and drainage can lead to an acceleration of successional processes in lakes. It is particularly severe, but not limited to, small water bodies. It is therefore important not to presume that terrestrialisation is occurring naturally and to investigate whether anthropogenic influences are responsible.

Shoreline reinforcement interrupts the natural continuity of the substratum and moisture gradient, resulting in a loss of associated wetland species. Shoreline reinforcements often reduce littoral areas by truncating the hydrosere. Wave reflection at walls shifts wave energy to other areas of the shoreline, possibly resulting in increased erosion. Increased sediment loads from catchment sources or from within a lake, can lead to the reduction in quality of gravel substrata resulting in modified invertebrate communities and/or a reduction in spawning habitat for fish.

Increased wave action can be caused by greater boat activity or a change in boat type or use. It may lead to the erosion and re-suspension of the sediment and the destruction of macrophytes including submerged, floating and emergent species such as reeds. Increased use of the shoreline for activities such as boat moorings can impact on plants directly by breaking and dislodging them and indirectly by disturbing and shading the sediments when boats are moored.

Non-native species can damage lake habitats and may have direct impacts on species composition and abundance. Invasive species, such as the common carp, can significantly alter the habitat. Their feeding behaviour damages macrophyte beds and re-suspends the sediment releasing nutrients to the water column and potentially contributing to the problems associated with eutrophication.

Fisheries management can promote or interfere with both physical and biological processes at a site. Fish stocking and bait use can alter characteristic biological communities and add nutrients to a water body, whilst fishing platforms and access routes can damage the waterside vegetation. However, anglers are often the custodians of these water bodies and their presence can limit anti-social behaviour, illegal stocking and monitor water quality.

Climate change is altering environmental conditions and biological assemblages in UK lakes with more extreme rainfall events and drier, warmer summers. The impacts of human activities in catchments greatly reduces the environmental resilience of lakes and their ability to cope with climate change.

These various impacts are widespread with some pressures more focussed in the uplands and others in the lowlands. Impacts typically occur in combination, confounding attempts to characterise and predict biological consequences at a local level.

1.7. Management of Multiple Pressures and the Restoration of Lakes

Lakes present a challenge due to the need to take account of off-site pressures (from within the wider catchment), the array of human activities operating in those catchments and the complex combined effects of these activities. These pressures require judgements to be made on the effects of current and proposed activities on lake condition.

If problems with the environmental integrity of a lake could be solely attributable to a particular human activity (e.g. a sewage discharge or a combination of discharges), the activity could be modified in a way that resolved the impact on the lake. This situation of a pressure leading to an impact and single management response is relatively rare in lakes. More typically, a lake is subject to a combination of pollution stresses, hydrological interventions, physical habitat disturbance and biological factors. Different human activities may contribute to the same ecological stress, although to differing degrees related to a range of spatial and temporal scales and all stresses combine in ways that may be difficult to differentiate. In addition to this complexity of stressors, many of the human activities involved may occur outside the protected boundary of the lake, necessitating a more widespread evaluation of these activities.

The approach that has been adopted to manage multiple stressors attempts to break down compound environmental problems into discrete impacts that can be apportioned to each relevant sector (e.g. water industry, agriculture), and specifying the contribution required from each sector to attain an overall solution. Consequently all pressures are dealt with, not just the pressure deemed to be the largest or easiest to deal with. There is also no need to order actions by magnitude of impact. Consequently all stressors should be acted upon as and when circumstances allow to enable continued improvement.

Limits of Liability provide a means by which sectors, organisations and individuals can be provided with clarity surrounding the action they need to take to deal with their contribution to the ecological problems of a lake site. This maximises the stability of business decisions concerning infrastructure or investment, which is vital for effective long-term business planning. From a nature conservation perspective, limits of liability provide a basis for identifying and planning all of the actions necessary to bring a site into 'Favourable' condition or Good ecological status / potential. This approach facilitates communication with all relevant parties and allows all parties to understand how their contribution fits into the wider programme of work at a site.

1.8. General Aspirations for Standing Water Habitats

Lakes operating under natural processes, free from anthropogenic impact and with characteristic habitat mosaics that caters for characteristic species assemblages, provide the best and most sustainable expression of standing water habitats. This condition comprises natural hydrological, nutrient and sediment delivery regimes, minimal physical modifications to the shoreline and littoral zone, natural hydrological and biological connectivity, an absence of non-native species, and low intensity fishery activities. These conditions provide resilience against climate change, maximising the ability of these ecosystems to adapt to changing conditions. They also provide high quality, sustainable interfaces with other habitats, including rivers and mires. They allow priority species to be distributed within lakes and ponds according to their natural habitat preferences and requirements. These conditions form the basis of the definition of reference conditions under the WFD. In addition, naturally functioning lakes have the potential to deliver high quality services and experiences for people. Examples of this include increased attenuation and buffering of flood flows for natural flood risk management or increasingly rare recreational angling opportunities. These lakes may offer angling for a diverse array of native fish species, including specimen individuals, due to the generally lower stock densities and more diverse assemblage associated with natural versus artificially stocked water bodies. In addition, these natural fish communities are more sustainable, resilient and require lower financial input, when compared with heavily managed fisheries.

The constraints to achieving naturally functioning lake habitat varies widely depending on population density and the spatial distribution of different anthropogenic activities. Immovable constraints must be recognised early on in any restoration process and the ability of any one lake to function naturally will therefore depend on site-specific circumstances. For example, lakes which have been formed by impounding a river will not exist without that impoundment so this constraint on natural hydrological function must be acknowledged, but the extent to which it can mimic a natural hydrological regime may be enhanced by allowing water level fluctuations, creating a drawdown zone which is an important habitat for many species. In other situations a weir on the outflow of a natural lake may be a constraint to natural functioning in the short term but in the long-term could be overcome.

1.9. Key Management Objectives for Lakes

The following management measures steer the actions we will take to conserve lake habitats and their characteristic species. By definition the following also represent the long-term ambition for any restoration plan, although site specific factors may limit the ability of individual sites to fully achieve each objective.

1. **Restoration of natural processes** – the top priority. Measures to restore natural processes, in terms of water quality, geomorphological and hydrological regimes, contribute towards lake habitat objectives. Where water quality is a threat to the site, measures must first include a reduction of the external pollutant loads but may then also include direct interventions such as removing sediment to reduce internal loads where appropriate.
2. **Large-scale perspective** – lake condition depends on many variables including catchment and atmospheric factors. This often requires investigation of the catchment as a whole, not just land holdings adjacent to the lake. Restoring natural water quality, sediment and hydrological regimes is key.
3. **Ordered actions** – direct interventions undertaken to restore lakes, such as sediment removal or biomanipulation, are effective only if external pollutant inputs have been reduced to acceptable levels. It is critical to ensure that external sources of excess pollutants are controlled prior to work within the water body. However other actions such as improving hydrological functioning or the hydrosere are no regrets measures that can be implemented as soon as circumstances allow.
4. **The long view –** there may be an impetus to restore lakes by active physical intervention (often required to trigger change), however, it may be appropriate to take a longer term approach. Visions for sites should not be restricted by their short term achievability as major socio-economic constraints may be resolved in the longer term. Natural recovery processes should be allowed to play the fullest role possible. This may include waiting for long periods of time (decades) as internal phosphorus re-cycling gradually reduces and/or legacy sulphur and nitrogen levels decrease in the catchment soils. However, external nutrient sources should still be tackled at the earliest opportunity (see point 1). These time scales for recovery are no reason to reduce aspirations in the long term.

5. **Species management** – biomanipulation techniques should be undertaken with the long-term aim of restoring native, balanced and sustainable fish, invertebrate and plant communities appropriate to the lake typology.
6. **Species distribution and abundance** – conservation measures based exclusively on the existing distribution of priority species can be flawed. The distribution of some species may reflect past and current impacts on lake habitat. Species conservation plans must take account of changes in the distribution and abundance of species that will result from restoration of natural processes. Ecosystem restoration plans based on natural processes must recognise implications for priority species, ensuring there are suitable habitat opportunities and colonists in a more naturally functioning system. If the survival of a species is threatened, interventions should be considered to assist the transition of a population to restored environmental conditions.
7. **Succession** – Where succession/infilling is attributable to increased sediment and nutrient loads, the source of this material should be addressed rather than repeatedly undertaking sediment removal. Where natural succession / infilling is occurring, leading to new habitats of conservation value, it may be appropriate to allow this to continue. If new water bodies are not being created via natural processes in the landscape, new early successional water bodies can be artificially created.
8. **In-water structures** – weirs and dams have a range of physical effects on lake habitats as well as blocking the free movement of biota. Structures on the inflow and outflow may impact on animals that use rivers and streams during their life cycle. To eliminate these impacts, eliminate the structure. Where removal is not possible, modification to minimise impacts maybe undertaken. Fish pass installation is species specific, expensive and does not address geomorphological issues. It may also act as a blocker to the future removal of a structure due to expenditure on pass installation.
9. **Shoreline structures** – reinstating a natural shoreline is a key step in restoring a naturally functioning water body with lateral connectivity to the wider environment. Non-natural shoreline structures should be removed. If removal is not achievable in the short term, modification of any shoreline structures to minimise impacts may be considered e.g. soft engineering options.
10. **Seasonality** – Seasonally exposed habitats support an array of characteristic flora and fauna. Natural seasonal water-level fluctuations are essential for their continued functioning.
11. **Waterside vegetation –** Waterside vegetation is part of a functioning hydrosere, providing habitat for characteristic fauna, stabilising the shoreline and reducing nutrient and sediment loads. Tree roots and woody debris are important habitats for many invertebrates. In addition tree cover provides shade, a mitigation measure against rising air temperatures. However, around smaller lakes, trees can shade almost the entire marginal habitat and leaf litter can increase infilling rates. For these lakes a mosaic of waterside vegetation incorporating some trees, but not dominated by them, may be preferable.
12. **Existing freshwater biodiversity** – To maximise the benefits of restoration work, and eliminate unwanted damage to populations of priority or endangered species, there must be detailed local knowledge of freshwater biodiversity at a landscape scale.

PART 2: The Lake Restoration Project (LRP) ‘Remedy’

2.1. Introduction

The Lake Restoration Project (LRP) SSSI 'remedy' is an umbrella 'remedy' aimed to capture all the diverse management activities which might be required to get lakes into favourable condition. Whilst the lake restoration remedy is part of the SSSI management process, the principles of this remedy can also be applied to non-designated WFD waterbodies when planning lake restoration. This 'remedy' may cover actions required within in the lake body, around its margins and/or in the catchment. This definition also applies to the LRP 'mechanism' on 'unfavourable recovering' SSSIs, where continued lake restoration work is required to maintain recovering condition. For WFD waterbodies this would be applicable to preventing deterioration.

The LRP remedy should enable the requirements of the lake to be considered in an integrated way, allowing engagement with stakeholders regarding the issues affecting the lake and approaches to tackle them. Consequently the LRP remedy includes, bringing lake stakeholders together, articulating a simple vision for the site, collating information on the current functioning of the lake, identifying all issues affecting the lake, potential actions to address these issues, appraising their feasibility and planning and managing their implementation.

As lakes are affected by multiple stressors using the LRP remedy ensures that all stresses are addressed, and work undertaken at appropriate times where the order of action implementation is critical to their success. The LRP 'remedy' and 'mechanism' provides a framework for planning and overseeing all necessary remedies. It also provides a home for actions not picked up by other remedies and programmes. In most cases some of the actions identified will form other remedies. The LRP 'remedy' can run simultaneously alongside these other 'remedies', as often multiple 'remedies' will be required to achieve favourable condition. Several 'remedies' may also be applied which relate to the same action. This explains why the lake LRP remedy is considered an umbrella remedy, as these additional remedies will still need to be applied and acted on, but they will be informed by the work establishing the requirements of the lake and benefitting from the stakeholder engagement conducted under the lake restoration remedy.

The findings, outcomes and evaluation of success of the additional remedies must feed back into the LRP remedy where additional work requirements can be considered and undertaken. It may appear that there are times when the LRP remedy is dormant whilst activity on other remedies is undertaken, however, the overarching plan is to get the lake into favourable condition and the LRP remedy is not concluded until it is clear no more work on the lake is required.

Examples of remedies which may be required in addition to the LRP remedy:

- PR/ AMP (Price Review/ Asset Management Plan);
- DWPP (diffuse water pollution plan);
- Catchment Sensitive Farming (CSF) Delivery initiative;
- Countryside stewardship agreement;
- Invasive species control programme; and
- River restoration project;

2.2. When to apply the LRP Remedy

A LRP remedy should be triggered by the failure of a condition assessment or the site failing its WFD objectives. All lakes in unfavourable condition should have a LRP remedy logged.

Progress against the LRP ‘remedy’ has been agreed with the Environment Agency and is defined as follows:

‘*The remedy can be changed to underway/complete once the costed plan is in place, money has been committed and works have commenced on the ground. Note that remedies are identified for individual SSSI units. There may be SSSIs where work has been funded and commenced on the ground in only some of the units with the lake restoration remedy. The remedy on these units can be changed to underway/complete but there may be other units where funding is still being sought or where work is planned for future years, which must remain Agreed’*.

The LRP ‘remedy’ cannot be considered ‘underway/complete’ until direct management actions are underway and there is a plan in place identifying any other required actions.

On some sites plans and actions may have been underway for a number of years, but may not have followed the format laid out in this revised guidance. In such cases it is important that all aspects of natural functioning are considered in the plan. If all aspects are covered in an existing plan and action is underway then the lake restoration remedy should still be logged but can immediately be considered underway. If all aspects of natural function are not considered, the remedy should be logged and the plan should be updated. Once plan implementation is underway the remedy can again be considered underway/complete. If the remedy has previously been logged and considered underway/complete, but there is no lake restoration plan or action is not underway, the remedy status should be moved to ‘Agreed’ until a plan is in place and action has begun. This approach ensures no required actions are overlooked or potential opportunities missed and allows future funding schemes to be directly linked to a current lake restoration plan. This may increase the potential of a successful project bid to fund the delivery of further actions.

Condition Threats may relate to challenges in implementing ongoing recovery work or where there is a reasonable probability of new factors having an impact. The trigger for consideration of whether a LRP ‘remedy’ might be required could be a CSM or WFD lake habitat assessment showing a decline in condition. Investigations and survey results associated with these assessments should give an indication of likely impacts. For each Condition Threat the level of risk that it poses to the condition of a lake should be assessed, with threats that pose a High (will lead to a decline in condition) or Medium (may lead to a decline in condition) level of risk given maximum priority.

There are a range of ‘adverse condition reasons’ on the Natural England Site Information System (CMSi) which may indicate a need for a LRP ‘remedy’ including:

- Water Pollution – Agriculture;
- Water Pollution – Discharge;
- Inappropriate Weed Control;
- Siltation;
- Inappropriate Scrub control;
- Inappropriate Water Levels;
- Other;
- Fish Stocking;

- Inappropriate Weirs Dams and Other Structures;
- Inappropriate Cutting/Mowing; and
- Inappropriate Pest Control;

2.3. Relationship to the delivery of Water Framework Directive Objectives

WFD lake 'water bodies' are part of the Environment Agency led WFD 'programme of measures' to achieve Good Ecological Status / Good Ecological Potential. This programme of measures involves WFD water bodies which are not achieving Good status and has four stages:

1. Confirm classification (confirm whether there is a WFD status failure)
2. Establish reasons for failure (e.g. via source apportionment studies)
3. Identify required actions (Programme of Measures)
4. Implement actions to deliver objectives of the WFD (GES/GEP)

On SSSI lakes which are also WFD water bodies the Environment Agency and Natural England staff should work together to ensure actions are suitable for both the WFD programme of measures and the SSSI LRP remedy, as both will have similar final objectives. For example an investigation being carried out under the Environment Agency investigations programme to identify the main source of nutrient enrichment for a particular SSSI lake/WFD water body would provide evidence to inform an LRP and a DWPP plan. Equally if Natural England has already drawn together existing evidence as part of a LRP, which identifies the main issues and possible solutions, then the Environment Agency investigation need not repeat this work, but instead work with Natural England to identify and fill any further evidence gaps. Investigations of the reasons for not achieving good status have been completed at many sites.

The Natural England CMSi SSSI reporting system (accessed via the Designated Sites View system by Environment Agency and other Major Landowner Group members) should contain reference to both the LRP 'remedy', the Environment Agency 'Investigation' 'remedy' (if it is a WFD water body), and any other remedies (or 'mechanisms') which may be in place to improve the lake habitat. The LRP 'remedy' and 'mechanism' could be assigned to both Environment Agency and Natural England on CMSi, as both agencies may have a role in implementing it. This may also be the case on non-WFD SSSI lakes, as the Environment Agency have a role in helping achieve Biodiversity 2020 targets. Natural England staff should liaise with Environment Agency Biodiversity, Integrated Environmental Planning, Analysis & Reporting and Sampling & Collection teams to achieve the level of resource coordination often required for lake restoration.

Natural England will generally be expected to identify and register the need for a LRP 'remedy' or 'mechanism' on CMSi, initiating and managing the lake restoration project. The Environment Agency will provide and interpret any existing water quality and biological data or carry out additional monitoring and water quality modelling to deliver lake management / restoration actions. The Environment Agency will also provide advice on, and licences for, sediment disposal and biomanipulation. However, the exact structure of a lake restoration project may vary between areas and exact roles should be agreed as part of the restoration planning process.

2.4. Implementing the LRP Remedy

As an 'umbrella' remedy the LRP must capture all pressures acting on a lake and causing a deviation from a naturally functioning ecological system. In order to achieve this and articulate objectives to stakeholders, an overall **'Lake Vision'** should be produced. This will define the objectives of a restoration plan in a more accessible format than a Favourable Condition Table, although it will be informed by it and be based on the lake in its natural state. The lake vision should include a description of the site including underlying and surrounding catchment geology, natural hydrological regime, natural nutrient conditions, natural biological communities related to lake typology, site ownership details, designations, conservation objectives, SSSI condition and WFD status.

A generalised lake vision is given below:

Lake Name is a SSSI for its lake habitat, because it is one of the best examples of lake habitat in England. Broadly speaking, Natural England's aspirations for *Lake Name* are for the lake to function naturally and support the species that would naturally occur in this environment. The specific detailed targets for this site are in Natural England's favourable condition table, but a summary is given below.

Lake name is naturally a nutrient *rich/poor/ moderately nutrient rich* lake, and consequently should be relatively biologically *productive/unproductive/moderately productive.* A lake of this type should have clear water and support a diverse aquatic flora of native under-water, floating and emergent plants (*e.g. list any species known to occur at the site when in favourable condition*). The varied structural habitat created by these plants should support a diversity of invertebrates *and a balanced, self-sustaining, native fish community*,* representative of this particular lake typology. Algal growth should be limited, so as not to outcompete the higher plants for light and nutrients. There should be relatively high dissolved oxygen concentrations throughout the water column to support the invertebrate *and fish** communities. The water quality must reflect the natural catchment geology and not be overly influenced by pollution, particularly by nutrients which enable excessive algal and bacterial growth. Natural substrates and shorelines provide habitat and spawning sites. When transitional wetlands and terrestrial habitats adjoining the lake are undisturbed, the more likely the lake will function naturally. Under these conditions the lake will support the greatest species assemblage as the fauna can utilise a diverse habitat mosaic and move freely between its constituent parts. A natural hydrological regime is integral to the functioning of the lake and its margins and should consist of both the natural (*unimpeded/absence of an*) inflow and outflow and the natural unenhanced drainage of surrounding land.

* *Fish populations are a natural component of the biota in many lake types, however, they may be absent from certain waterbodies such as hydrologically isolated lakes or lakes which periodically dry out.*

When developing a lake vision it is important that it is tailored to the specific requirements of the site and contains information on any special characteristics or features of the site which must be considered in a restoration programme. Lake vision development should include engagement with all relevant stakeholders at an early stage to gain buy-in and support for the vision. Potential stakeholders may include:

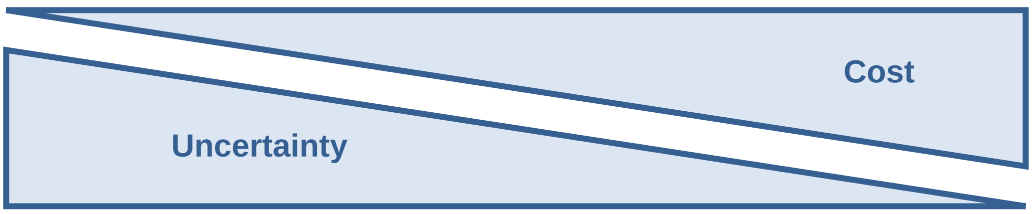
- Environment Agency
- Site owners
- Local residents
- Local angling clubs
- Sailing clubs
- Local authorities
- Wildlife Trusts
- National Trust
- Water companies

In order to identify actions and remedies required, the lake vision must be compared to the current condition and functioning of the lake. Information may be available from recent condition assessments and WFD monitoring. Additionally a number of lakes have been the subject of previous studies by the Environment Agency, Natural England, academia and interested individuals. The available information should be collated to gain an understanding of current condition and function. This has the potential to highlight evidence gaps or outdated information that may need to be filled or updated by an investigation. This work may require a contractor, however, it may also be possible to do this in-house. The results of this investigative work should be shared with stakeholders. It is important that this work takes advantage of previous studies and does not reiterate previous efforts.

The comparison between the current condition and functioning of the lake and the lake vision should identify any further remedies to be applied and actions that can be undertaken. A Lake Management Plan should be developed that defines which remedies, actions and investigations, will be undertaken and their timetabling to achieve the ambitions of the vision. It is important to highlight that some ‘no regrets’/low risk actions should be undertaken at the earliest opportunity to begin the delivery phase of lake restoration activities, however, others may require feasibility studies or may not be appropriate immediately.

Measures to improve hydrology, morphology, riparian land and manage invasive non-native species can usually be progressed as resources allow and do not need to wait for other remedies and actions to be implemented first. However, nutrient enrichment is often a long-term, complex issue. Whilst this has the potential to be improved by the actions above, reduction of external sources of nutrients will require coordinated actions to address all nutrient inputs. Any in-lake measures to tackle internal nutrient cycling, such as sediment removal or sediment capping, are likely to be unsuccessful if external loads have not been reduced sufficiently. Additionally attempts to manipulate and / or establish the desired biological assemblage are unlikely to be successful in the long-term if nutrient concentrations have not yet been controlled. If the fish community, particularly non-native high impact species such as common carp, is considered likely to be a contributory factor to water quality deterioration and/or damage to aquatic features such as macrophytes actions should be taken at the earliest opportunity to minimise the risk of further fish recruitment, regardless of whether all nutrient inputs have been effectively controlled. This enables opportunities such as lack of current angling interest or draw down for maintenance purposes to be utilised for stock management, potentially avoiding more complex restoration/fishery management strategies in the future.

2.5. Assessing Uncertainty and Risk of Management Measures



Investigations included under the lake restoration remedy can reduce uncertainty surrounding the probability of the success of restoration. If they are sufficiently evidence based they may be used to justify actions. Higher risk (high cost, innovative or untested) actions will require less uncertainty / a greater weight of evidence. The extent of investigation required for the lake management plan and associated detailed lake restoration plan depends on this trade-off. For example it is likely that high risk operations, such as desilting works, will require further investigation to confirm it is the preferred option, to understand the contribution to recovery, to avoid environmental harm and to plan delivery of the work. However, there are many low risk, no regrets interventions which can be implemented with minimal investigation as they are inexpensive, well documented and likely to result in rapid benefits with very little risk of causing long-term / irreversible environmental damage.

2.6. Lake Restoration Planning

The process can be broken down into three discrete steps:

Step 1 - Pre-Restoration Planning

First consider the following questions:

1) Is the SSSI lake unfavourable and/or WFD water body not achieving Good ecological status?
2) Are there Common Standards Monitoring (CSM) assessments and/or WFD status assessments which corroborate this?
3) Agree condition assessment / WFD status between Natural England and Environment Agency.
4) Log the LRP remedy.

If questions cannot be answered definitively or agreement reached, then commission a CSM assessment or WFD investigation to confirm condition/status. Log the LRP 'remedy'.

Step 2 – Development of a Lake Vision and Management Plan

1) Identify local leads from Natural England (Responsible Officer) and Environment Agency (Fisheries Biodiversity and Geomorphology team leader/nominated team member or Catchment Coordinator) and any local stakeholders;
2) Identify and agree responsibilities between local leads;
3) Agree a lake vision incorporating conservation objectives and environmental outcomes;
4) Collate lake data (e.g. land ownership details, contacts, Environment Agency monitoring data, previous reports, CSM assessments, stakeholders knowledge);
5) Identify all attributes that are failing to achieve the objectives of the vision and use this to identify actions required. This may include logging additional remedies, undertaking further investigations, assessing feasibility of options, acquiring funding and undertaking management actions;
6) Produce a lake management plan ordering actions where necessary and assigning responsibilities;
7) Agree lake management plan with stakeholders.
8) Register remedy as underway on CMSi and update (MLG website;

Outputs	❖ A lake vision and management plan

Step 3 – Plan Delivery and Implementation

1) Agree ownership of actions between stakeholders.
2) Implement recommended no regrets, low cost, high certainty management outlined in the lake management plan at the earliest opportunity;
3) Undertake or commission further investigations to inform high risk (high cost / low certainty) actions as required. these may include:
    a. Identification of nutrients sources and nutrient cycling mechanisms;
    b. Sediment investigation (for assessment of internal sources of nutrients or disposal options);
    c. Fish community assessment;
    d. Hydrological surveys.
4) Consult with stakeholders over investigations, recommendations and plan development;
5) Work in parallel with other remedies, assess their progress and any additional action required. Log progress against the LRP remedy on CMSI and assess success of actions.
6) Identify additional actions and amend the plan as required to achieve objectives;
7) Repeat until all actions are complete and the lake is in favourable condition and/or meeting WFD objectives.
8) Log the LRP remedy as complete on CMSi. Currently this is only possible in the 'comments' field.
9) Ensure that Environment Agency colleagues are informed about any proposed changes to remedies which they own.

Outputs:

- A continually revised and updated management plan based on the work completed and any further investigations;
- A lake in favourable condition and/or meeting WFD objectives.
- Stakeholders fully engaged throughout the process;
- All actions implemented;

PART 3: Lake Restoration Techniques

3.1 Introduction

This part of the guidance describes a range of restoration measures which can be used to restore the natural functioning of lakes, some of which manage the symptoms of lakes which are not functioning naturally. As described earlier the objective for designated lakes is to restore their natural processes and this includes the nutrient and hydrological regime as well as the morphology and biological assemblages.

It is important for all stakeholders involved in the management of a lake to be consulted when deciding on which particular actions will be undertaken at a site. Some end points required for the restoration of a designated site may be acceptable to one group and wholly unacceptable to another. This conflict is common in lake management. Examples include sailing enthusiasts being limited by large stands of submerged macrophytes, visitors gaining enjoyment from feeding wildfowl and anglers wishing to protect fish stocks, especially common carp. Any management strategy should take account of all user groups, however, it must also be considered that some uses may be incompatible with the ultimate aim of reinstating a naturally functioning lake ecosystem.

As nutrient enrichment affects many lakes and much has been written about the restoration of shallow lakes, it is worth considering the difference between shallow and deep lakes. An understanding of the way they respond to nutrient enrichment will enable the selection of the most appropriate restoration method. With nutrient enrichment all lakes follow a similar biological response, unnaturally high concentrations of nutrients leads to increases in phytoplankton, reductions in water clarity and a reduction in macrophytes. The increased productivity of the lake, particularly short-term algal blooms, leads to an increase in dead organic matter accumulating on sediments. As bacteria mineralise this material they consume oxygen, depleting its concentration in the water which can lead to fish kills. This results in turbid, algal-dominated lakes.

What differs between lakes is the exact point at which these shifts occur, whether they are gradual or sudden and the resilience of the plant or algal dominated state to change. The presence of macrophytes is known to buffer the effects of nutrient enrichment by stabilising sediments, providing refugia to grazers and competing with algae. This appears to hold true for both shallow and deep lakes, but deep lakes naturally have less of their area dominated by macrophytes due to their depth. This helps explain why deep lakes appear to suffer the effects of eutrophication at lower nutrient concentrations (they have less of a buffer) and this is reflected in CSM and WFD nutrient targets. Consequently the nutrient concentration at which shallow and deep lakes exhibit signs of eutrophication is different.

There is evidence to suggest that this shift from a plant to algal dominated state may be relatively rapid, both in shallow and deep lakes. However, in deep lakes different parts of the lake may respond in different ways. In deep lakes the littoral zone (with the potential to be dominated by macrophytes) may respond quickly as a nutrient concentration threshold is reached, as in shallow lakes, whereas the limnetic zone responds in a more linear way in response to increasing nutrient concentrations (although these responses may be exacerbated by the loss of buffering vegetation within the littoral zone).

The existence of two alternative stable states, one dominated by clear water and aquatic macrophytes, the other by a turbid, blue-green algal dominated community, both able to exist over a range of nutrient concentrations, is well documented for shallow lakes. In such situations a switch can move the lake from one state to another without a change in nutrient concentration. Examples of switches are a loss of macrophytes due to the addition of herbicide or benthivorous fish such as common carp or bream. However, it is important to realise that at sufficiently low or sufficiently high concentrations of nutrients it is only possible to sustain a single state. The existence of the alternative stable state is due to both the macrophyte and the algal dominated states being buffered and therefore resilient to change.

This has repercussions for the restoration of these water bodies as you are likely to need to reduce the nutrient concentration below the concentration where the forward switch occurred to regain a macrophyte dominated state and you may need to intervene by altering the biology to switch it back. There is little evidence that deep lakes have this same ability to exist in different states at the same nutrient concentrations, but it has been suggested that the littoral zone of deep lakes may behave in a similar way in contrast to the limnetic zone which will not.

Any resistance to return to pre-nutrient enrichment conditions in the limnetic zone of deep lakes has generally been ascribed to low flushing rates, problems with internal loading - exacerbated by low oxygen levels in the hypolimnion of stratified lakes, and climate change. Deep lakes appear more sensitive than shallow lakes to climate change, not least because it affects stratification. Due to these differences in lake character lake management measures in deep lakes, in addition to nutrient load reduction, tend to be centred on increasing flushing rates, disrupting the thermocline or oxygenating the water. The techniques applied to shallow lakes generally still have the capacity to improve deep lakes, but due to the depth and size of many of these lakes they may be infeasible.

3.2 External Nutrient Source Reduction

Eutrophication is often described as, *'the enrichment of waters by inorganic plant nutrients which results in the stimulation of an array of symptomatic changes. These include the increased production of algae and/or other aquatic plants, affecting the quality of the water and disturbing the balance of organisms present within it. Such changes are undesirable and interfere with water uses*' (Environment Agency, 1998).

Algal production in freshwaters is normally considered to be phosphorus limited, this is particularly true of blue-green algae as they possess the ability to fix atmospheric nitrogen. However, a number of lakes are also known to be nitrogen limited, indicating the importance of understanding lake function. Nutrient sources can be broadly segregated into point sources, such as sewage discharges, and diffuse sources, such as run off from land. However, it should be noted that while this segregation is often quoted and may be useful for managing a water body, diffuse sources are often formed of a large number of smaller point source discharges. If this change in spatial scale is understood, it may make it much easier to tackle a higher number of discrete discharges than to simply state that nutrients are being input to a water body from a generalised area.

Many of the measures to reduce nutrient inputs from the surrounding catchment will be covered by the DWPP for the site, however, a useful tool to consider the potential pathways and their associated risks of excess nutrient contribution to the site is the catchment walkover.

Catchment Walkovers

Before undertaking any form of site walkover a desk based review of both map and survey data should be used to gain an understanding to the catchment and topography. This allows potential sources of nutrients, or other pollutants, to be identified including areas of farmland, sewage treatment works, combined sewer overflows and angling lakes etc. The outputs from this work will inform the delivery of the walkover survey, improve its efficiency and identify any gaps in the catchment data. The principle of ‘time spent in reconnaissance is rarely wasted’ is certainly applicable to delivery of walkover surveys.

The general methodology for catchment walkovers is outlined by the Environment Agency in their Operational Instruction 356_12, Environment Agency, 2013. Where accessible, the full perimeter of a water body and both banks of any tributaries should be walked to facilitate identification of inputs. Where this is not possible, binoculars can be used to identify features on the opposite bank.

At many sites the input of pollutants will not be stable throughout the year, it will often take the form of low level inputs punctuated by a series of high concentration spikes. These spikes may correlate with increased flow in tributaries due to heavy rainfall events and a first flush of highly polluting material. Therefore it is important that a walkover is conducted either during or immediately following a period of wet weather to allow the detection and assessment of otherwise minor discharges. When walking the shoreline and tributary banks carefully note the following features that may directly influence water quality. These may include:

- Any likely inputs of point or diffuse pollution;
- Channel character;
- Adjacent land use;
- Management of land;
- Erosion and depositional features;
- The extent of buffer strips including fencing;
- Tree cover; and
- Invasive species.

Photographs illustrating the site character and adjacent land are extremely useful and can either be georeferenced within the camera or the location recorded using a handheld GPS device. This will allow the locations of features of interest to be added to a GIS model of the catchment. Photographs and/or video footage of potential sources of nutrients and sediment also provide strong evidence when working with landowners to reduce inputs.

If resources allow, targeted water chemistry sampling can be undertaken during a wet weather event with the location of sampling sites determined through a review of the catchment walkover survey data, desk study and consultation with individuals holding specialise local knowledge. It is important to ensure that the analytical limits of detection are appropriate for the study and that the sampling methodology is followed precisely.

Basic determinants to be analysed by a laboratory may include:

- Total Phosphorus;
- Alkalinity
- Total Nitrogen; and
- Suspended solids.

in addition to the determinants above, If water a quality meter or hand held test kits are available, the following In situ physico-chemical readings may also be useful:

- pH;
- Conductivity;
- Water temperature; and
- Dissolved oxygen.

Wildfowl

Large populations of birds can promote a forward switch to an algal dominated community due to both nutrient enrichment and habitat modification. Birds feeding on the surrounding land and generally resident on the lake excrete phosphorus in a readily bioavailable form. This may lead to a net increase in the trophic status of a lake (guanotrophy). Visitors to easily accessible lakes often enjoy feeding wildfowl. If done conservatively, this seldom creates a problem and is indeed seen as a benefit due to the education of children in ecology and the wider environment. However, if feeding becomes excessive food may remain un-eaten and decompose on the lake bed, more birds will be encouraged to feed at the site, a net increase in nutrients will occur and anoxic sediments may promote outbreaks of Avian Botulism. Wildfowl may also agitate and disturb shallow lake sediments, releasing nutrients back to the water column.

If wildfowl numbers become excessive at a site, over grazing of aquatic and marginal vegetation may occur. This pushes the competitive advantage towards an algal dominated community and may trigger a forward switch.

It should also be considered that a reasonable population of wildfowl is unlikely to be the sole cause of a water quality problem and should be treated as one part of a wider restoration strategy. It can be useful to calculate the nutrient load from the birds observed using bird survey data and nutrient loading figures from the literature. Birds and their faeces are a very visible potential source of nutrients and it is often valuable to assess their actual nutrient input numerically to allow an informed decision to be made.

Removal of bird populations is highly contentious in the UK. Swans and ducks are much loved by residents and their continued presence is often defended fiercely. The most common way of controlling bird populations within an urban setting is via education. Signs should be erected to educate the public as to why feeding should be restricted, not simply a blanket prohibition. Once the majority of individuals have an understanding of the water quality problems which may result, the minority that continue to feed wildfowl are unlikely to have a significant impact on overall water quality.

The exception to this is large flocks of Canada geese. These birds tend to heavily graze surrounding land and have the potential to deposit large quantities of readily bioavailable phosphorus in to the lake. Active management of Canada geese is difficult, time consuming and covered by a various pieces of legislation such as the Wildlife and Countryside Act 1981. However, it may include habitat mitigation to increase cover for predators, removal of secure nesting sites such as islands, increasing disturbance / scaring, egg destruction (removal, pricking and mineral oil application) and shooting. It is unlikely that one management technique alone will be fully effective and the adoption of an integrated management strategy which incorporates a variety of actions is recommended. Although still highly contentious, public opinion is often more easily swayed towards discouraging or removing geese. A technical information note (TIN009 The Management of problems caused by Canada geese: a guide to best practice) is available from Natural England.

One important factor to consider when implementing habitat restoration measures, is that of not attracting more undesirable bird species to the lake by creating additional feeding or roosting sites. If planting schemes are adopted, they may need to be actively protecting from bird damage.

3.3 Internal nutrient cycling

The internal cycling of nutrients from the sediment within a water body may represent an important source of nutrients to the water column and, plant and algal production. Therefore, lakes can take many years to recover once external nutrient loads have been reduced.

Three main physico-chemical options are available to reduce the internal cycling of nutrients:

- Sediment removal – dredging;
- Chemical precipitation of nutrients; and
- Increased flushing rates.

Sediment removal

The first option of sediment removal is normally undertaken by either mechanical excavator or hydraulic / suction dredging. Mechanical dredgers use mechanical excavation equipment such as backhoes or grabs to loosen the lake sediment and raise it to the surface. Hydraulic / suction dredgers use a centrifugal pump and pipe system to raise loosened material in suspension to the surface.

Dredging has the advantage of physically removing sediment and creating deeper water, however, it has a number of serious disadvantages. It is an expensive, dirty and time consuming operation. The costs alone may prove prohibitive. Should the funds be available for carrying out the work, disposal of dredgings represents a problem that must be solved before any lake restoration plan is finalised.

At many sites it may prove difficult to find sufficient areas for on-site disposal of the dredged arisings to land. At designated sites, and any other standing water, the surrounding land is likely to be sensitive and integral to the functioning of the lake itself. Should suitable land be available, the activity would become a disposal activity, necessitating the requirement for an environmental permit from the Environment Agency. The costs requested by the Environment Agency for determining the permit alone may be high and will require detailed sediment analysis to determine that the material does not represent a threat to the health of humans, livestock or the wider environment.

Off-site disposal of dredgings is problematic for a number of reasons. Once a decision is made to remove the material from the site where it was generated, it becomes a waste and is therefore subject to duty of care legislation devoted to waste activities such as transport, hazard assessment and ultimate disposal method.

Disposal to third party land would again require an environmental permit. The logistics of physically moving dredgings require careful consideration as they are normally in the form of a slurry and require a specialist waste haulier to transport them. In this condition they cannot be disposed of to landfill as liquids and slurries are not permitted under the Landfill Directive. Pre-treatment of the dredgings would be required to dewater or thicken them. Space and sufficient security may not be available for the construction of suitable lagoons. A number of novel techniques exist involving flocculants and porous membranes which can be used to either accelerate the drying process or reduce the space required for storage. However, all require secure storage areas to stop vandalism and risks to public health and safety. In addition, studies carried out on the Norfolk Broads have demonstrated that sediment removal alone may not result in a sufficient nutrient reduction within the water column to achieve the desired objectives of favourable condition / good ecological status.

Chemical precipitation of nutrients

Chemical precipitation involves treating the lake with a material to precipitate the nutrients out of the water column and lock nutrients within the sediment in an insoluble, non-bioavailable form. The most common methods for binding up phosphorus involve the use of iron or aluminium salts and bentonite / lanthanum compounds. The method can prove effective as it may promote clear water conditions for a long enough period to reverse the forward switch back to a clear water, plant dominated community. It is potentially less expensive and logistically difficult than dredging and may be less damaging to the ecology of the lake. However, there are a number of serious disadvantages. The method does not address loss of water depth as the compounds used tend to form a covering over the lake bed. Should a number of treatments be required, it may further compound this problem due to the accumulation of material which may eventually need to be dredged out of the lake. The smothering effect of the material may harm aquatic fauna and flora and, although potentially cheaper than dredging, applications are relatively expensive.

The treatment may not be a permanent solution if nutrients continue to enter the lake or anoxic sediment conditions allow phosphorus to be solubilised. Bottom feeding species such as common carp may disturb deeper phosphorus rich sediments which were not treated with the binding agent. A similar effect may occur due to bioturbation caused by benthic invertebrates such as oligochaete worms and chironomid larvae which have the potential to move underlying nutrient rich sediments up to the water / sediment interface, allowing transfer into the water column. In addition, there may be resistance from regulatory authorities or public interest groups over environmental or toxicity risks associated with some of the binding agents such as lanthanum and aluminium.

A treatment that is gaining popularity in the UK and Europe is Phoslock, marketed by Phoslock Water Solutions Ltd. This is a bentonite / lanthanum compound that is applied to the water surface and binds up soluble phosphorus as it sinks through the water column. Once on the lake bed, any active sites on the particles will continue to bind phosphorus from the sediment until the active binding sites are exhausted.

The cost of treatment is dependent on many factors such as phosphorus loading in both the water column and the sediment, therefore, it is difficult to give accurate costs without detailed investigation. However, there is one over-riding principle that must be adhered to before considering any form of precipitation treatment, **additional inputs of phosphorus from the catchment must be limited permanently as chemical precipitation can only be effective on in lake-nutrient cycling processes.**

> At the time of writing (2018) the cost of Phoslock is around £2000 - £2400 per tonne. Freight costs of around £50 per tonne can be achieved with sufficient lead in time, plus an application cost of £4000 - £8,000. VAT at 20% will also apply.

Flushing rates, residence times and natural hydrological regime

The reinstatement of a natural hydrological regime will allow water levels to fluctuate naturally. In some cases, the removal of impoundment and water level control structures may increase flushing rates, decreasing residence times. This can be a very effective way of reducing nutrient concentrations within the water column, providing the inlet feed is low in nutrients. In addition flushing with low nutrient water has the effect of both diluting nutrient concentrations and removing phosphorus from internal cycling processed from the lake. This management strategy is often impossible due to a lack of low nutrient source water but where this option can be deployed it may be very effective, when combined with other management actions. Artificially increasing flushing rates, even with nutrient rich water, can help prevent the formation of algal blooms as algae is flushed through the system before it can reproduce to form blooms. This does not help restore natural conditions but deals with one of the symptoms of eutrophication.

In addition, natural water level fluctuations create high quality marginal habitats for macrophytes and invertebrates. These may rely on periods of drawdown during dry periods or an extension of the hydrosere due to the inundation of surrounding land associated with higher flows. Many water bodies have control structures on them. Although these range in size, a simple no regrets measure is to adopt a hydrological regime that mimics a natural one with higher levels in winter and lower levels in summer, if the structure cannot be removed altogether. This not only helps create good marginal habitat, but lower summer water levels can help macrophytes establish if water clarity is an issue (although the cause of this should also be dealt with).

The integrity of the surrounding land may also be impacted hydrologically. When draining surrounding wetlands ditches may have been created which directly feed into a lake accelerating nutrient and water delivery to it. Inflowing and outflowing streams may also have been modified often being deepened and straightened to accelerate inflows and outflows from the lake. When applied to inflows this can lead to accelerated nutrient delivery and when applied to outflows it can reduce the size of the lake and the extent of any marginal wetlands. Restoring a natural hydrological regime to the lake surroundings in such situations can allow water to naturally percolate through surrounding wetlands often reducing nutrient and sediment loads whilst improving adjacent habitat which also benefits the many species that utilize both the lake and its surroundings.

In circumstances where manmade structures control water levels on an otherwise natural lake, a full options appraisal should be undertaken to identify the best option for restoration. In any appraisal the first option must be barrier removal, where technically feasible. However, in some circumstances, particularly with artificial lakes and reservoirs, the constraints surrounding the removal of an impounding structure would make it impossible to remove the barrier completely. In this case the restoration option would be to re-establish the greatest level of natural function possible within site specific constraints. In many cases it is the presence of a physical barrier which removes or reduces connectivity between habitats. Loss of connectivity may impact on physical habitat, an example of this is a loss of geomorphological processes such as downstream sediment transfer, and/or an impact on resident species. Fish are one of the most commonly impacted species due to physical barriers to migration in the freshwater environment. Where physical barriers are present that cannot be fully removed, it may be possible to modify them to make them less of a blockage to fish movement and allow the downstream transport of sediment. This may take the form of lowering structures or changing their profile in the case of weirs. Where there are no options for direct modification of a structure, or in addition to a modification, a technical fish pass may be considered. A fish pass should not be seen as a permanent solution to a barrier, it is simply a way of mitigating its impact and, should an option for the complete removal of the barrier become possible at a future date, the presence of a fish pass should not hinder the removal process.

When assessing fish pass design, it should be considered that no design is 100% effective for all fish species and ascending the pass will impart an energy cost on the fish. In addition, they may increase exposure to predation or behavioural factors may delay movements through the pass. As a general rule, the pass should be passable to the greatest number of fish species expected to be normally resident in the area. In addition, there may be a need to predict which species are not currently resident in an area but should be if current environmental pressures were removed. This is often the case where a downstream barrier exists but may be removed or mitigated for in the future.

To achieve these objectives, the pass design which mimics the natural outflow of the lake most closely is likely to best cater for the resident fish assemblage. In many cases this will be a nature like by-pass structure. If this is not possible a range of increasingly technical designs exist which are documented in the Institute of Fisheries Management Fish Pass Manual, the final choice being dictated by a combination of fish assemblage (present and future), fish species behaviour, fish swimming speed, site conditions, funding, maintenance, design life, monitoring requirements and health and safety considerations. The early consideration of these factors within the options appraisal process will ensure that unsuitable passes are not installed in sensitive locations which exclude species with slower swimming speeds.

3.4 Biomanipulation, Fish Stocks and Habitat Restoration

Biomanipulation may be defined as the, "*restructuring of the biological community to achieve a desirable response*" (Environment Agency & Broads Authority, 1996). In the case of algal dominance, the aim is to enhance the population of grazers such as *Daphnia sp.* by decreasing the predation pressure from fish and reducing the release of nutrients to the water column from sediment disturbance.

Species of fish belong to different functional feeding groups including piscivores, benthivores and zooplanktivores. To encourage grazing zooplankton populations, zooplanktivorous fish populations should be reduced or rendered less efficient predators. To reduce the release of nutrients, benthivorous fish should be limited or removed. Typically small roach and bream are considered the highest priority zooplanktivores, with large bream and carp the highest priority benthivores. Piscivores such as pike and perch can be encouraged to increase predation pressure on smaller zooplanktivorous fish. Unfortunately, pike are ambush predators and often use macrophytes for cover. In algal dominated lakes macrophytes may be absent, reducing the hunting efficiency of pike. In addition, pike are relatively intolerant of the low dissolved oxygen conditions, which may be found in algal rich lakes and may suffer high mortality rates.

Fish removal can be undertaken by methods including netting, electric fishing or piscicides such as rotenone. Complete fish removal from a lake by physical methods is extremely difficult, however, good levels of control can be achieved if planned carefully and undertaken regularly as part of an overall lake management plan. Recruitment in fecund species such as roach is extremely rapid and populations may recover quickly unless cropped regularly. The removal of the largest and most damaging benthivorous fish may be much more successful. Piscicides are by far the most effective solution to complete fish removal, however, their use is often limited by public and regulatory resistance. The removal and disposal of potentially large quantities of fish carcasses may render the use of piscicides alone impossible in many circumstances. They have been used successfully as a secondary action, following intensive removal by other means such as netting.

Due to the operational difficulties in effectively removing fish and the potentially contentious nature of such plans due to recreational angling interests, an option which has been used effectively at a number of sites such as the Cheshire Meres and Norfolk Broads, involves introducing a barrier to a water body which is impermeable to fish movement. This allows fish to be removed from a section of the water body, allowing intensive fish removal techniques to be deployed over a smaller area. This fish free exclosure then acts as nursery area for zooplankton grazers, allowing submerged macrophyte growth to develop in clear water conditions. This increase in habitat structure and cover for zooplankton may be sufficient to promote a switch back to a macrophyte dominated community throughout the lake once the barrier is removed. Alternatively, an incremental increase in macrophyte coverage may be achieved by moving the barrier to another location within the water body, once it is felt that the original area of protection has a fully established macrophyte assemblage and has the resilience to withstand exposure to the resident fish population. While the effectiveness of these barriers has been demonstrated, in practice, a number of difficulties may be experienced including vandalism of barrier structures, movement of fish by anglers back into the exclosure and the ability of small fish to utilise any defect in the barrier and recolonise the exclusion area. Due to the inherent fecundity of native fish, particularly zooplanktivorous species such as roach, these species are likely to rapidly expand in number following successful spawning periods. In addition, it is often the younger year classes of these species which are most likely to favour zooplankton over and above other potential food sources.

Whilst biomanipulation is often cited as a method for restoring shallow lakes, it has been successfully trialled in the Cheshire meres which are of intermediate depth. The ability to isolate parts of a deep lake can be technically difficult, due to both the production of sufficiently large barriers and the installation methods required.

Artificial refugia

To mitigate for the difficulties associated with fish removal, an option is to decrease their zooplanktivore predation efficiency. Larger zooplankton that would otherwise heavily graze algae often struggle to maintain their population densities at a high level due to a lack of macrophyte cover, allowing heavy predation by zooplanktivorous fish. To mitigate for this, attempts have been made to develop artificial cover to enhance grazer survival. This may take the form of cages, netting or frayed strands of polypropylene rope. These artificial refugia have been combined with floating islands of macrophytes, giving the additional potential benefit of nutrient uptake from the water column.

These structures / floating islands are available in a multitude of different designs and their benefits to overall lake restoration programmes are poorly evidenced. However, the following factors must be considered if contemplating deploying any form of floating islands:

- Biosecurity;
- Cost of construction;
- Ease of maintenance;
- Entry and egress to the water body;
- Secure anchor points / method of attachment;
- Size;
- Bird protection;
- Plant species;
- Structure of species assemblage; and
- Sustainability of materials.

Biosecurity: It is vital that any introduced plant material is free of contamination by potentially invasive species. Non-native plant species such as Australian swamp stonecrop (*Crassula helmsii*) and invasive invertebrates such as non-native shrimps (*Dikerogammarus villusus* and *D. haemobaphes)* represent a risk to biodiversity. A rigorous biosecurity protocol must be implemented and macrophytes should be sourced from the water body itself if at all possible.

The islands must be securely anchored and a full appreciation must be given to the power of wind action on a mature island. The anchor warp / chain must also be long enough to accommodate any increase in water level but not too long as to allow the island to drift out of the desired location. The islands anchors must be sited to make maximum use of any available shelter from the prevailing wind and wave action.

A potential problem with floating islands is their tendency to offer roosting or nesting areas for water fowl and gulls. Water fowl may damage the plant community on the island and large numbers of gulls may add an additional phosphorus load to the lake. The impact of birds can be mitigated against by fencing the perimeter of each island and placing wires / cord laterally in a chequer board pattern. This will discourage perching while allowing plant growth to continue unhindered. In addition to offering additional bird habitat, the principle of adding structural complexity for the benefit of zooplankton grazers may be hampered by the fact that floating islands may offer more effective cover for young fish such as roach, thus increasing the zooplankton grazing pressure in the same area that you wished to develop as a zooplankton nursery environment.

All floating islands require maintenance. Periodic harvesting of biomass is required to achieve any potential nutrient removal from the lake and some level of wear and tear is inevitable on such an exposed structure.

3.5 Shoreline Restoration

Wherever possible natural shorelines should be maintained or restored. Shorelines can be degraded by excessive erosion or artificial reinforcement. When restoration of a naturally functioning shoreline is required, factors such as fetch, wave energy, geographic location, exposure, substrate, water depth and surrounding land use must be considered as these will determine the level of intervention required and techniques to be used.

If conditions allow, the most desirable option is to allow natural processes to re-establish. This may be achievable by reducing pressures on bankside and littoral vegetation such as cattle poaching and geese grazing. However, shoreline fencing should be avoided where livestock grazing intensity is low and may increase the habitat mosaic. If grazing intensity requires management, set-back fencing should be established to provide a sufficiently wide zone to allow the development/maintenance of the hydrosere. Access for periodic and selective grazing, cutting or other management of the waterside vegetation is recommended. In addition the energy driving erosional processes may be reduced by measures such as limiting boat numbers, reducing their speed or using a less damaging method of propulsion.

For more seriously degraded margins bio-engineering solutions such as coir rolls or matting may be required to allow natural vegetation to re-establish. Hard engineered banks should be avoided or minimised wherever possible due to their ability to reflect wave energy, increasing erosion at other locations. This type of bank reinforcement will limit colonisation by macrophytes, greatly effecting vegetation assemblages.

Planting may be required to reintroduce previously present, but now extinct, species or where extensive areas of reed bed may have been lost prior to improvements in water quality or other habitat restoration measures. If planting schemes are to be considered it is vital that the natural (reference) macrophyte assemblage is known, locally sourced plant varieties are used (preferably from the lake itself) and no new invasive species are introduced. When designing a reed bed planting scheme, the bed profile and water depth of the lake, together with areas sheltered from wind and wave action should be used to guide the locations of new reed beds to maximise establishment. If the objective is to use the reed bed to improve water quality within the lake by removing excessive nutrient or fine sediment inputs from upstream, establishing the reed bed across inlet streams would be a sensible approach. Although reed planting schemes can be very effective, it is a time consuming operation requiring attention to detail with the planting process and a full consideration of the health and safety considerations associated with working from boats and in water with deep, soft sediments. If the newly planted reeds are to become successfully established, In addition, it is likely that a newly planted reed bed will require protection from damage caused by water fowl and livestock. This may take the form of fencing, netting or a combination of the two.

In some lakes there may be a considerable recreation pressure due to angling, boat use, dog walking and swimming. These activities may increase erosion or necessitate areas of hard reinforcement. If each form of recreation is to be maintained at a site, careful consideration should be given on how to minimise damage to the shoreline. This may include speed and propulsion restrictions for boats, designated pathways and swimming areas and the installation of angling platforms to minimise the percentage of the shoreline taken up by angling pegs. Any compromise between recreation pressure and the restoration of natural shorelines should be discussed and documented within the lake management plan to give a transparent record of the decision making process.

3.6 Aeration and Mixing

Phosphorus may be released from anoxic sediments and large scale fish mortalities may occur if oxygen levels become depleted. An intense algal bloom may lead to the water column becoming super-saturated with oxygen due to algal photosynthesis during daylight hours. At night the algae then go into a state of net respiration and therefore become consumers of oxygen from the water. This may lead to fish mortalities occurring in the early hours of the morning. When algal cells die, they sink to the lake bed where they decompose, further depleting the dissolved oxygen concentrations within the water body and releasing nutrients back to the water column.

Systems which move oxygen rich surface waters and allow mixing with deeper oxygen depleted waters can be used to mitigate unnaturally large diurnal oxygen fluctuations. Such systems also have the capacity to alter algal communities by affecting their ability to stay in the upper zones where there is sufficient light for photosynthesis. There are many different systems on the market including fountains, pumps, floating aerators and bubble curtains. These systems are often most effective in deeper lakes that stratify and develop a deoxygenated, nutrient rich hypolimnion. All mechanical mixing and aeration equipment requires a power source to operate the associated pumps, impellers and compressors. In addition it will also require maintenance and possibly security to discourage vandalism. The installation and running costs of this type of equipment is often high and is, at best, a treatment for the symptoms of poor water quality, rather than a long-term restoration option. However, this type of equipment may provide a rapid response to developing water quality problems and may assist in reducing the impacts of internal nutrient cycling in deeper lakes. In a shallow water body careful selection and siting of aeration equipment is required to avoid the mobilisation and entrainment of sediment from the lake bed. This management technique addresses the symptoms rather than the source of the problem.

3.7 Barley Straw

In the 1980s it was noted that the addition of barley straw to a lake had the potential to reduce blue-green algal biomass in lakes, sometimes providing good levels of control. Evidence for the effectiveness of barley straw remained anecdotal for a period of time before numerous research projects were initiated and led to a refinement of the application process. While there remains some controversy over the effectiveness of barley straw, largely due to its relatively unpredictable success, the mechanism of action is thought to relate to decomposition products from the straw leading to the formation of hydrogen peroxide in the water.

To maximise the effectiveness of barley straw the method of application is critical. The mode of action is thought to inhibit algal growth more effectively than treating an established bloom, therefore, the straw should be applied during the spring and autumn. It is estimated that the straw will become active within approximately one month of application, dependant on the prevailing weather conditions. To allow the straw to decompose effectively the surface area in contact with the water should be maximised. This can be easily achieved using 'Christmas tree' bags containing broken up straw bales. The bags should be strung across the inlet to the lake allowing the algal control agents to be fully dispersed within the water body. Ideally the bags should be constructed from a biodegradable material, however, due to the requirement for the use of buoyant ropes linking the bags, these ropes are likely to be constructed from polypropylene and should be removed from the site when not directly used for tethering bags. For a detailed description of barley straw methods, please refer to *Information Sheet 1: Control of Algae With Barley Straw (2004).*

If deployed correctly there have been no reports of harmful effects on fish or invertebrates, in some instances the straw may promote invertebrate biomass by providing habitat and cover from predators.

In addition to barley straw deployment, there are commercially produced, concentrated extracts of breakdown products from barley straw decomposition marketed under such names as 'Excalibar'. In recent years it has been agreed that these compounds should be registered under the biocides regulations and regulated by the Health and Safety Executive if they are to be used in open waters. Anecdotal evidence indicates the successful use of such products. They are now licenced for use in the wider environment and manufactured in bulk quantities, however, the cost of deploying sufficient quantities of the product may prove prohibitive for many lakes. In addition, the mode of action is only likely to give short term algal control.

3.8 Aquatic Dyes

In recent years investigations have been carried out into the use of dyes to block light transmission through the water column and therefore limit photosynthesis. Although **not considered a lake restoration technique**, dye use/misuse is discussed here to avoid continued confusion over their suitability for the restoration of a naturally functioning lake ecosystem.

Aquatic dyes are generally liquid or powder food colourings with very low mammalian and invertebrate toxicities. Refinements have been made to the dyes in an attempt to block specific light wavelengths associated with plant and algal photosynthesis. It is likely that dyes have proved effective at reducing both algae and higher plants in a number of locations; however, there are a number of factors that render them **unsuitable** for use in lake restoration programmes.

Dyes are not considered a biocide in the legal context and products marketed for aquatic use are likely to have extremely low toxicity to aquatic organisms, however, their use has been contentious with regulatory authorities. Technically the application of dye to a surface water could be considered a pollution offence under the Environmental Permitting (England and Wales) Regulations 2010 as it could be defined as a discharge of poisonous, noxious or polluting matter into an inland freshwater, however, due to their potential use for algal or macrophyte control in waters of low ecological value, such as fire ponds or winter storage lagoons, use is reviewed on a case by case basis with some level of pragmatism involved.

Dye works by blocking light transmission through the water column, therefore, a number of factors render them unsuitable for use in waters of high ecological value:

- Limitation of photosynthesis may block oxygen production while maintaining the plants in a state of net respiration, further reducing dissolved oxygen in the water column. If the dye was sufficient to maintain this situation for a prolonged period the plants will eventually die and consume even more dissolved oxygen during decomposition.

- Dye has the potential to damage the whole submerged plant community and may disproportionately impact rarer primary colonisers in deeper water.
- Dye may actively select for blue-green algae as many species have a competitive advantage due the ability to control their buoyancy, facilitating or reinforcing a forward switch to an algal dominated community.
- Dye is not effective once macrophytes have become established on or near the water surface, potentially selecting for the more vigorously growing plant species with lower conservation value.
- Dyes are liable to be most effective if applied early in the season to stop a blue green bloom developing. This correlates with the main macrophyte growing season.
- For dyes to remain effective, flushing rates should be reduced. This may lead to a build-up of nutrients if inlets and outlets are closed or diverted. The dyes are broken down by photo-degradation over several months. This may result in repeat applications being required later in the season.

Due to the inherent ecological and water quality impacts associated with the use of dyes, their use is incompatible with the objectives of designated sites.

3.9 Choosing the Most Suitable Restoration Measures

Once it is decided that the LRP 'remedy' or 'mechanism' is required and the restoration measures available are fully understood, it is vital that measures are sequenced with other 'remedies' to increase the likelihood of a successful restoration plan. However, there will be no regrets, low risk actions that can be taken early in the planning process to deliver benefits to the lake habitat.

Required restoration measures will be specific to a particular lake, however, there are some general guidelines which can give those planning lake restoration an idea of how to sequence the techniques for certain situations (see Figure 2).

The key underlying principle to all successful lake restoration is an understanding of nutrient dynamics. As nutrient enrichment is often the main cause for unfavourable condition, it is critical to ensure that the external sources of excess nutrients are controlled prior to expensive within-lake work to rectify the symptoms, otherwise restoration is unlikely to prove sustainable. Even where nutrient enrichment is not the cause for unfavourable condition, investigation of water quality will still often be required to verify this. However, in many situations there will be a number of pressures that can be addressed by low risk actions as opportunities arise through a lake restoration project. These actions should be undertaken at the earliest opportunity and should not be delayed until all detailed investigations are complete. Examples include agreeing fishery visions, catchment walkovers and marginal plant management which can be progressed at any stage of the project, irrespective of nutrients management investigations.

Figure 2. Flow chart to help decide which lake restoration technique is likely to be needed (based on Jeppesen & Sammalkorpi, 2002, Skeate & Perrow, 2007, and Spears *et al.* 2011). TP = Total Phosphorus; Chl a = Chlorophyll a; N-limitation = nitrogen limitation.

Glossary

Term	Definition
Avian botulism	A strain of botulism that affects bird populations, particularly waterfowl, caused by the toxin produced by the bacterium *Clostridium botulinum*. *C. botulinum* may rapidly multiply in anoxic substrates associated with lakes suffering from eutrophication effects.
Asset Management Plan (AMP)	A tactical plan for managing an organisation's infrastructure and other assets to deliver an agreed standard of service taking a system approach to co-dependent assets which are required to work together to deliver an agreed standard of service over a defined period. UK Water companies follow an AMP methodology to drive continuous improvement, and reduce their Operating Expenses. The current period (2018) is AMP6.
Biodiversity 2020: A strategy for England's wildlife and ecosystem services	A national strategy for England's wildlife and ecosystem services, published in summer 2011. It provides a vision of how England is implementing international and EU commitments and sets out the strategic direction for biodiversity policy for the following decade.
Biomanipulation	To restructure the biological community to achieve a desired response.
Catchment Sensitive Farming (CSF)	A project run by Natural England in partnership with the Environment Agency and Defra. CSF raises awareness of diffuse pollution from agriculture by giving free training and advice to farmers in selected areas in England.
CMSi	Conservation Management System International is the database system that supports Natural England's designated site management work.
Common Standards Monitoring (CSM)	Covers the basic standards related to the monitoring of nature conservation on statutory sites and ensures consistency throughout the UK. In England the standards apply to Sites of Special Scientific Interest (SSSIs), Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Ramsar sites.
Diffuse Water Pollution Plans (DWPP)	Are detailed, evidenced and spatially specific catchment based plans to tackle diffuse water pollution issues on designated sites. They enable targeting of measures, track progress against measures and allow engagement with catchment partnerships.
Countryside Stewardship	A land management scheme managed by Natural England. It provides financial incentives for farmers and land managers to maintain wildlife habitat, deliver flood risk management, manage woodland, reduce water pollution, maintain the character of the countryside, preserve historical features and encourage access.
Eutrophication	The enrichment of waters by inorganic plant nutrients resulting in undesirable changes such as increased production of algae and/or other aquatic plants, poor water quality and disturbance of biotic assemblages. These changes may interfere with human water use.
Favourable Condition	A set of attributes selected for a habitat or species to enable an assessment of condition to be made. The specific attributes are defined in Favourable Condition Tables. Favourable condition indicates that conservation objectives are being met.

Term	Definition
Favourable Conservation Status (FCS)	A combination of components used to assess the conservation status of a species and includes population dynamics, species range and habitat extent and quality to be assessed. Favourable conservation status indicates that species components are being met.
Good Ecological Potential (GEP)	Classification within the EU Water Framework Directive 2000/60/EC. The values of the relevant quality elements reflect, with only slight changes, those associated with the closest comparable surface water body type, given the physical conditions which result from the artificial or heavily modified characteristics of the water body.
Good Ecological Status (GES)	Classification within the EU Water Framework Directive 2000/60/EC. The values of the quality elements for a surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.
Grant in Aid (GIA)	A payment by a government to finance all or part of the costs of the body in receipt of the grant in aid. Grant in aid is paid where the government has decided that the recipient body should operate at arm's length.
Guanotrophy	The addition of excess nutrients to a water body attributed to the deposition of faeces from bird populations.
Habitats and Species Directive	The Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. It aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. It forms Europe's nature conservation policy with the Birds Directive and establishes the EU wide Natura 2000 ecological network of protected areas.
Hydromorphology	The interaction of hydrologic processes, including both surface and ground water, with landforms and features such as lakes.
Hydrosere	The successional sequence which develops at the margins of aquatic environments such as lakes and ponds, transitioning the macrophyte community of a water body from aquatic to terrestrial.
Hypolimnion	The cold, dense, basal layer of water, lying below the thermocline in a thermally-stratified lake.
Limits of liability	An approach to managing multiple pressures on freshwater environments, allowing a structured decision making process to protect and restore freshwater habitats.
Limnetic zone	The open surface waters of a lake away from the shore where light penetrates to the lake bed and enables submerged aquatic macrophyte growth.
Littoral zone	The near shore area, incorporating seasonal drawdown zones, where sunlight penetrates to the lake bed and allows aquatic macrophytes to grow.
Mechanism	Refers to the process linked to a remedy (cf) to deliver favourable condition or the continued work required to maintain recovering condition. A mechanism is the enabling structure used to implement an action. For example to address eutrophication of a lake, the action would be to reduce nutrient inputs to the catchment and this would be implemented using one or more mechanisms, including CSF (cf)

Term	Definition
	initiatives to reduce or remove diffuse water pollution and action on point source pollution such as sewage treatment works.
Natura 2000 (N2K) sites	A network of core sites for rare species and natural habitat types across EU countries. The aim of the network is to ensure the long-term survival of threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.
No Deterioration	A Water Framework Directive definition requiring Member States to implement measures to prevent deterioration of the status class of each water body.
Notified feature	Relates to a habitat or species which has been selected as being of special interest by Natural England and worthy of special protection within a SSSI under the Wildlife and Countryside Act 1981 (as amended).
Price Review	A financial review led by the water industry's regulator (Ofwat). The review determines the price limits that water companies can increase or decrease the prices charged to customers over a period of time, currently 5 years. The price limits are set to enable water companies to deliver the services required of them, including capital maintenance, security of supply and environmental quality standards. See AMP.
Phoslock	A trade name for commercial product designed to remove phosphate from water and cap phosphate rich sediments. It is comprised of bentonite clay and lanthanum and binds soluble phosphate into an insoluble form.
Protected Areas	Defined by the Water Framework Directive are areas that require special protection under other EC Directives and includes areas designated for the abstraction of water for human consumption (Drinking Water Protected Areas); areas designated for the protection of economically significant aquatic species (Freshwater Fish and Shellfish); bodies of water designated as recreational waters, including areas designated as Bathing Waters; nutrient-sensitive areas, including areas identified as Nitrate Vulnerable Zones under the Nitrates Directive or areas designated as sensitive under Urban Waste Water Treatment Directive (UWWTD); areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection including relevant Natura 2000 sites.
Ramsar sites .	Wetland sites designated of international importance under the Ramsar Convention. The Convention on Wetlands, known as the Ramsar Convention, is an intergovernmental environmental treaty established in 1971 and came into force in 1975
Reference conditions	Are described within the Water Framework Directive as the conditions that represent the stable state of an ecosystem in the absence of significant human disturbance.
Remedy	A Remedy is information entered in CMSi which identifies what is needed to bring an SSSI into recovering and eventually favourable condition. Remedies are not just a statement of the actions required, but consist of three things: i) what mechanism is needed to deliver favourable or recovering condition; ii) who is responsible ie the organisation which will put the mechanism in place; and iii) when ie a date for implementation.

Term	Definition
Rural Development Programme For England (RDPE) -	Provides funding for projects to improve agriculture, the environment and rural life. It is administered by Defra and funded by the EU.
Sites of Special Scientific Interest (SSSI)	Notified under the Wildlife and Countryside Act 1981 are a suite of sites providing statutory protection for the best examples of the UK's flora, fauna, or geological or physiographical features.
Special Areas of Conservation (SAC) -	Areas designated under the EC Habitats Directive which have been identified as best representing the range and variety within the European Union of habitats and (non-bird) species listed on Annexes I and II to the Directive.
Special Protection Areas (SPA) -	Classified by the UK Government under the EC Birds Directive. SPAs are areas of the most important habitat for rare (listed on Annex I to the Directive) and migratory birds within the European Union.
Stratification (thermal)	Refers to a distinct change in the temperature within the water column of a lake, signified by the thermocline, and is due to the change in water's density with temperature. The upper layers of the water column may become effectively isolated from deeper areas by the thermocline.
Water Framework Directive (WFD)	2000/60/EC - is an EU directive which commits European Union member states to achieve good ecological status or potential within defined water bodies by prescribed dates.

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