Information on How to Deliver and Assess Riparian Buffer Strips for Nutrient Mitigation

Part 2 – Framework for Riparian Buffer Strips

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

This report was commissioned by Natural England to build knowledge and understanding on a range of nature-based solutions which potentially could be used to reduce nutrients. Ricardo was commissioned by Natural England to understand the mechanisms of nutrient removal for the different solutions, the factors which affect this and review the evidence on the scale of nutrient reductions that they could achieve. This report sets out a framework for the design, implementation, monitoring and maintenance and how (if it is possible) to determine any upfront scheme specific nutrient reduction for riparian buffer schemes that will provide sufficient scientific certainty in the assessment of nutrient neutrality mitigation schemes.

Executive summary

The objective of this project is to provide support to Natural England (NE) employees and those of other relevant organisations (such as Competent Authorities) to enable them to make informed judgements on riparian buffer strip proposals for nutrient mitigation. This report takes the form of a Framework, for the design, implementation, monitoring and maintenance and how to determine scheme specific nutrient reduction for riparian buffer strip schemes to achieve nutrient neutrality (NN). The project comprises three parts where:

- **Part 1** (the literature review) provides the evidence base on the effectiveness of four different NbS for nutrient mitigation including the methodology applied.
- **Part 2** (this document - The Framework) considers the design, implementation, monitoring and maintenance needs and how to determine a scheme specific nutrient reduction (where applicable). There are four framework documents, one for each of the four mitigation solutions considered in part 1.
- **Part 3** (the lookup tool – separate spreadsheet) comprises a user-friendly lookup tool with high-level practical information on a wider range of potential nutrient mitigation solutions.

This Framework specifically provides advice on achieving scientific certainty for riparian buffer strip schemes to achieve NN. This Framework sets out how to determine a scheme specific nutrient efficiency reduction considering the maximum values identified in **Part 1** (the literature review) which can then be applied to the baseline load to determine the number of upfront Nitrogen and / or Phosphorus credits which can be generated. The Framework follows the following structure to set out what information needs to be provided to evidence that the scheme is appropriate:

- Stage 1 – Design Objectives
- Stage 2 – Feasibility
- Stage 3 – Design Process
- Stage 4 – Implementation Process
- Stage 5 – Post-implementation Monitoring and Evaluation

This Framework also outlines how additional credits, above those that can be generated upfront can be determined for N and / or P through robust post-implementation monitoring.

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1. Introduction

The overall objective of this project is to provide support to Natural England (NE) employees and those of other relevant organisations (such as Competent Authorities) to enable them to make informed judgements on Nature-based Solutions (NbS) proposals for nutrient mitigation. The overall project comprises 3 parts where:

- **Part 1** (the literature review – separate report) provides the evidence base on the effectiveness of four different NbS for nutrient mitigation;

- **Part 2** (this report known from now on as the **Framework**) considers the design, implementation, monitoring and maintenance needs and how to determine an upfront scheme specific nutrient reduction (where applicable). There are four framework documents one for each of the four mitigation solutions considered in **Part 1** (the literature review).

- **Part 3** (the lookup tool – separate excel tool) comprises a user-friendly lookup tool with high-level practical information on a wider range of potential nutrient mitigation solutions.

1.1. Framework objectives and aims

Key Aims:

Support NE staff to identify NbS for Nutrient Neutrality (NN) mitigation that are:

- Compliant with habitat regulations assessment (HRA) requirements and;
- Can achieve improvements to water quality, specifically through the reduction of nitrogen (N) and / or phosphorus (P) loading and;
- Have robust design, implementation, and monitoring and maintenance plans.

Part 2 (this document) provides the FRAMEWORK for riparian buffer strips which can be used in conjunction with the efficacy values set out in **Part 1** and also feeds into **Part 3** (the lookup tool).

The mitigation measures in this project were determined in **Part 1** (the literature review – separate report) and comprise:

- River channel re-naturalisation and floodplain reconnection;
- Engineered logjams;
- Buffer strips; and
- Agroforestry

For each mitigation measure, there is a separate Framework document. This Framework document advises on riparian buffer strips and what is required to achieve scientific certainty for NN. It does not consider whether it is possible and how to achieve practical certainty that the measures can be secured.

This Framework sets out how to determine a scheme specific nutrient efficacy reduction through a combination of baseline and post-implementation monitoring to determine precautionary efficacy estimates. Stages 1 to 5 (explained in Figure 1:1) of the framework set out what information needs to be provided to evidence that the scheme is appropriate for the location and all factors in the design, implementation and maintenance of the scheme have been considered to ensure that there is confidence the scheme will achieve the required nutrient reductions. Checklists are provided at the end of each section to help the assessment of whether all the required information has been provided.

Although this framework focuses on riparian buffer strips in the context of NN mitigation, there can be potential synergies between different mitigation solutions. Implementing a system of multiple NbS to achieve NN will provide greater nutrient reduction benefits through floodplain reconnection, reduced velocities, and increased contact time between nutrient rich flows and sediments to which they can bind. Capitalising on the synergies between NbS to achieve NN will allow for reduced nutrient loads from each scheme to be stacked together to achieve more nutrient credits than any one scheme would mitigate. The load reduction benefits of synergistic interactions between NbS would need to be addressed on a case-by-case basis for realistic credit generation. In addition, NbS have the potential to provide many wider benefits. These wider benefits are also considered as part of the feasibility process which may support other biodiversity and societal net gain ambitions as part of the planning process.

Part 3 (the lookup tool) when used in conjunction with this Framework enables assessment of appropriateness alongside a wider range of potential mitigation measures for a given scenario

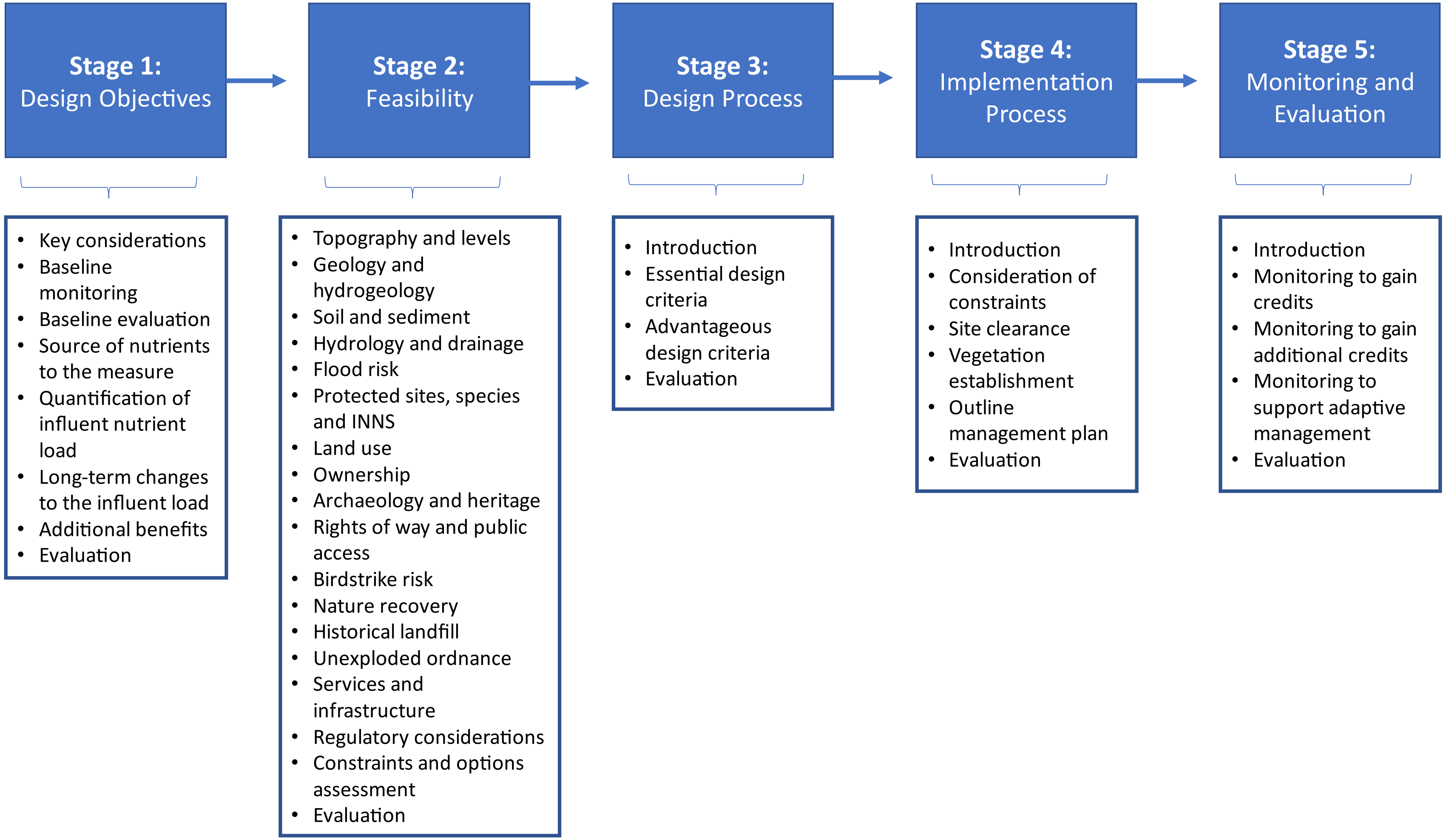

Figure 1:1 The outline structure or this framework

*Note: the level of detail and key information categories may vary between mitigation option. A version of this figure for that can be used by screen-reading software has been included on the following page.

Stage 1: Design Objectives	Stage 2: Feasibility	Stage 3: Design Process	Stage 4: Implementation Process	Stage 5: Monitoring and Evaluation
- Key Considerations - Baseline monitoring - Baseline evaluation - Source of nutrients to measure - Quantification of influent nutrient load - Long-term changes to the influent load - Additional benefits - Evaluation	- Topography and levels - Geology and hydrogeology - Soil and sediment - Hydrology and drainage - Flood risk - Protected sites, species and INNS - Land use - Ownership - Archaeology and heritage - Rights of way and public access - Birdstrike risk - Nature recovery - Historical landfill - Unexploded ordnance - Services and infrastructure - Regulatory considerations - Constraints and options assessment - Evaluation	- Introduction - Essential design criteria - Advantageous design criteria - Evaluation	- Introduction - Consideration of constraints - Site clearance - Vegetation establishment - Outline management plan - Evaluation	- Introduction - Monitoring to gain credits - Monitoring to gain additional credits - Monitoring to support adaptive management - Evaluation

1.2. Limitations to this framework

This Framework focusses on the key considerations required for a NbS proposal to achieve suitable mitigation solutions. There are, however, limitations to its use as outlined below.

This framework relies on expert judgement related to mitigation applicability: Certainty of the efficacy of a solution beyond reasonable scientific doubt is essential even though absolute certainty is not required for a solution to be deemed suitable. Therefore, judgement over the efficacy needs to be based on a combination of the level of confidence in the data, the design, and the consistent use of precautionary input values. Judgement on a site-specific basis will be required since only a generic overview of the requirements for each mitigation scheme is provided in this Framework.

Uncertainty in quantity of nutrient mitigation for a given solution: This applies to solutions whereby percentage removal efficiencies cannot be applied to estimate nutrient load reductions before implementation. Some mitigation measures need to be deployed and monitored since predictions cannot be made in advance regarding the quantity of nutrient pollution reduction they will achieve. This limits their applicability as nutrient credits will only be provided once sufficient baseline and post-implementation monitoring has taken place.

Prescriptive monitoring: Given the uncertainties highlighted above, and potential variation of geological conditions and locations, any monitoring will need to be bespoke (based around specific criteria) and dependent on incoming nutrient loads. This Framework, therefore, emphasises the importance of showing the principles of a robust approach, without limiting the options of the provider.

Detailed engineering design: This Framework is limited to the use of riparian buffer strips for nutrient mitigation and considering at a high level the key design, implementation, monitoring and maintenance requirements of any scheme to ensure there is confidence any scheme will provide the proposed efficacy reduction relative to baseline environmental conditions. This Framework is not intended to provide detailed engineering advice on how to implement a NbS. This will need to be sought separately although this guidance provides the list of expected outputs.

2. Determining scheme specific efficacy

This section sets out how to determine a scheme specific efficacy using the maximum nutrient efficacy values from **Part 1** (the literature review) and undertaking a confidence assessment looking at key design criteria and the calculation of the baseline load.

2.1. Maximum efficacy reductions

A review of studies was conducted on the efficacy of riparian buffer strip schemes within **Part 1** (the literature review). The precautionary maximum estimates of nitrate and total phosphorus (TP) removal efficiencies for riparian buffers have been derived by EnTrade and ARUP and set out in the Interim Nutrient Reduction Standard (ARUP and EnTrade, 2022b). Nitrate and TP have been chosen as the nutrient types to be examined to remain consistent with Farmscoper which will likely be used to calculate the baseline loads. As nitrate is a portion of total nitrogen (TN), the reductions will also be precautionary. EnTrade's assessment of nutrient retention in buffer strips suggests a 10m minimum width, with nutrient retention increasing when the buffer width increases (See Table 2:1[1]). The overall nutrient reduction therefore depends on the width chosen for the buffer strip. These figures were derived based on data on nutrient reduction against buffer width and the regression equations (for P y=39.5x0.24and for N y=1.30x + 43.2) presented by Schoumans and others (2011) which uses data from Collins and others (2009) on riparian buffers. The reduction calculated for the first 2m (using these regression equations) was deducted for each width band, to take account of the fact that a 1m (and is some cases up to 2m) buffer is already required through existing agricultural regulations. Although the regression equations are not particularly precautionary the deduction of the first 2m reduction which will be more than is currently required in many cases (i.e. 1m) ensures that the final reduction efficacy values are suitably precautionary.

Table 2:1 Efficacy coefficients of riparian buffer strips, dependent upon their width

Additional interceptor width (metres)	TP reduction efficacy (leading 2m impact deducted)	Nitrate reduction efficacy (leading 2m impact deducted)
10+	0.22	0.10
12+	0.25	0.13

[1] Table 2:1 represents EnTrade's efficacy coefficients for buffer strips, using the best available information as of 13/01/2023

Additional interceptor width (metres)	TP reduction efficacy (leading 2m impact deducted)	Nitrate reduction efficacy (leading 2m impact deducted)
15+	0.29	0.17
18+	0.32	0.21
20+	0.34	0.23
24+	0.38	0.29
25+	0.39	0.30
30+	0.43	0.36

2.2. Calculating the baseline load

A good baseline of key environmental variables is needed to robustly calculate the baseline load. This is especially important related to NN, in the context of demonstrating beyond reasonable scientific doubt that the reductions will be achieved in perpetuity in line with the Habitats Regulations requirements. Without a robust baseline it will be difficult to demonstrate upfront the benefits that a scheme provides.

Three variables need careful consideration when calculating the scheme baseline nutrient loading as indicated in Figure 2:1. With a strong understanding of these and a robust baseline monitoring or modelling method, the baseline nutrient load can be calculated.

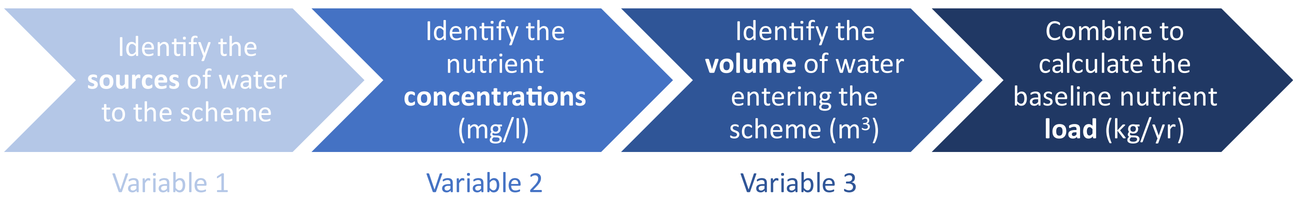

Figure 2:1 Key variables requiring consideration to when defining appropriate design objectives

To fully understand the three variables outlined above, a robust baseline assessment method is required. Baseline assessment characterises the nutrient load within the receiving environment prior to implementation of the riparian buffer strip. This provides the loading value to which the nutrient removal efficiency percentages can be applied to demonstrate credit generation. This can be done via scheme specific monitoring, using secondary datasets (i.e. data that has been collected for another purpose), or modelling (see more detail in Section 3.2.2). The means by which nutrient loads are characterised and the confidence the approach will have will differ between each scheme, however the broad requirements are uniform. These are as follows for generating upfront credits:

- Quantification of the water quality and quantity that will enter the mitigation scheme. This must account for groundwater, subsurface and surface flow pathways, where required.
- *If undertaking scheme specific monitoring:* Review of evidence in **Part 1** (the literature review) indicates that a minimum of a year's baseline monitoring is necessary to confidently quantify credits that can be gained from the mitigation scheme to provide a strong understanding of nutrient cycling in the system. The length of the dataset needs to be long and frequent enough to cover the full range of likely flow and water quality conditions, which could vary spatially and temporally. The programme should aim to capture nutrient loads in the receiving environment following different magnitude rainfall / flow events. This may require a reactive sampling programme. The monitoring must account for the time lag between events that mobilise nutrients and the point at which they can be monitored in flows. The location(s) of the sampling point(s) needs to be representative of what will enter the mitigation scheme and therefore needs to be upstream and ideally close to the scheme or at least where there will be no significant additional inputs (flow or concentration) before the scheme. Whether one or multiple locations need to be monitored will depend on the type of scheme and the likely spatial variability of the flows / concentrations into the scheme. To calculate the baseline load, take a mean of the values of the flow and concentration to estimate the load of nutrients in kg / year. This approach is the minimum required.
- *If using secondary datasets (i.e. monitoring data that was collected for another purpose):* If a robust dataset already exists that can be used to quantify the baseline nutrient load entering a mitigation scheme based on the requirements detailed above, this can be used. Where secondary datasets are used, they should meet the same requirements as set out above for scheme specific monitoring on the length and frequency of the dataset, range of flow conditions and location of sampling. The use of secondary datasets will require justification to ensure that is it robust and adequately representative for determining the load into the mitigation scheme as well as documentation that details the sampling methodology, location, frequency, and duration of the sampling programme. The baseline load should be calculated in the same way as set out above for scheme specific monitoring.
- *If modelling:* Depending on the scheme, modelling might be applicable to establish the baseline loading to mitigation scheme. Modelling must account for all sources of water and nutrients to the scheme and must be embedded with precautionary assumptions. The specifics are scheme-dependent, therefore will be further outlined in the relevant appendices.

To potentially gain additional credits post implementation*:* Monitoring would be required to determine the baseline and at least two survey points are required one upstream and one downstream. Perform a trend analysis (graphical analysis of flow, concentration, and potential time lags) using the most applicable statistical test based on extent of data. Using this approach increases understanding of the local variation and help to explain any outliers for example that may be negatively skewing the mean data statistics resulting in less credits. This approach increases the robustness of the monitoring method, increasing the likelihood that additional credits can be claimed.

Further details on baseline monitoring requirements can be found in section 3.2.2

2.3. Confidence assessment

A specific scheme load reduction can be determined through applying a percentage nutrient efficacy reduction to the calculated baseline load. The confidence in the load reduction calculated is dependent on the scheme being designed robustly and the baseline load being accurate. Overestimation of the baseline load will lead to an overestimation of the likely load reduction the scheme will achieve. Table 2:2 summarises the key elements from the rest of the framework which influence the confidence that the scheme will achieve the maximum efficacy reduction upfront. The table enables a confidence assessment to be undertaken on each of the key elements which will determine whether or not any upfront nutrient credits can be generated and if so, what percentage of the maximum efficacy can be used to calculate the scheme specific load reduction. It also can be applied to understand the confidence in the baseline load used to calculate any additional nutrient reduction post implementation.

Whilst filling out this table it should be noted that:

- The result (high, medium, or low) of each question's answer will help to determine an appropriately precautionary percentage removal efficiency that can be applied to the load.
- Based on the criteria specified for each question, the relevant boxes should be ticked.

The key questions need to be considered at the scheme idea stage to provide upfront clarity of the requirements and to encourage consideration at an early stage of the percentage efficiency values that can be claimed.

Table 3:1 must also be filled in to enable a confidence assessment of the scheme's design. The result of each question will impact the overall confidence rating of the scheme as the results inform the answers to Table 2:2.

Table 2:2 Confidence assessment

	High	Medium	Low
Have you accounted for all sources of water / nutrients in your monitoring or, modelling approach to calculating baseline loads?	Yes, all sources – groundwater, surface water, rainfall, point sources, etc. No – but the way it is considered is more precautionary in the context it is used	Most of the sources considered – those not considered are likely to be minor.	Only some sources considered and not considered some which could be significant source OR don't know as insufficient information has been presented.
Has the baseline load entering the scheme been accurately determined?	Yes all aspects have been considered including: Any flow bypassing the scheme has been removed. For schemes which have spatially diffuse inflow (rather than one single inflow) this has been robustly characterised. If using monitoring data, the location of any monitoring points are representative of the flow and concentration entering the scheme.	The vast majority of load has been accounted for. Any flow bypassing the scheme has been removed. If using monitoring data the location of any monitoring points means that any load inputs that not accounted for are likely to be minor. If using modelling, then precautionary assumptions have not always been used. Where this is the case they don't have a significant effect on the predicted load.	No there is significant uncertainty in how it has been determined including: No consideration as to whether any flow bypasses the scheme OR If using monitoring data, there are additional significant load inputs that have not taken into account due to the location of monitoring points. OR

	High	Medium	Low
	If using modelling, then precautionary assumptions / values have been used.		If using modelling, precautionary assumptions and values have not been used.
Does the baseline load calculation take account of the temporal variability including seasonality?	There is a robust estimate of temporal variability both seasonally and annually. If using monitoring data: data is for over a year, at a frequency which captures seasonality and different magnitude rainfall / flow events. If using modelling: the modelling take account of seasonal/annual variability and precautionary assumptions have been used.	Not all temporal variability is accounted for, however evidence is provided that the methodology takes account of the majority of the seasonal and annual variability and takes into account the worst-case situations[2].	There has been no consideration of seasonal or annual variability in flow or concentration or precautionary modelling assumptions have not been used.

[2] In this context, worst-case refers to scenarios where the conditions support low nutrient removal compared to the year-round average. It is not acceptable to look only at the data showing the best-case scenario for nutrient credit generation.

	High	Medium	Low
Have you taken account of any known anticipated future long term changes in baseline load e.g. due to climate change or existing planned development / activities?	Yes – everything relevant considered and the assessment has been undertaken in a robust way applying precautionary assumptions.	Some long-term changes have been considered but not all OR precautionary assumptions have not been used.	There has been no consideration of known anticipated future long-term changes.
Are the appropriate forms of N and / or P considered[3]?	Yes OR No – but the form considered is more precautionary in the context it is used.	N/A	No and the form considered is less precautionary in the context it is used.
Is the baseline assessment method	Yes – monitoring or modelling carried out in line with the requirements in Section 3.2.2.	N/A	No – approach used is unjustified with insufficient information. For example, an unjustified modelling approach is used, or monitoring

[3] To claim credits using this Framework's efficacy reductions, nitrate and TP must be used to remain consistent with Farmscoper's approach.

	High	Medium	Low
appropriate to the scheme type?			does not meet the requirements of Section 3.2.2.
Have the key design criteria been met in Table 3:1?	Yes – all minimum design criteria have been met	N/A	No – not all of the minimum design criteria have been met
Is there is robust maintenance plan?	Yes, there is a detailed maintenance plan covering all maintenance requirements for the lifetime of the scheme.	N/A	No – schemes should not be agreed without detailed maintenance plans.

After answering all questions in Table 2:2, the following criteria must be considered to provide a percentage of the total efficacy value which can be applied to the baseline nutrient load.

- If **any** answer low, the scheme is not robust enough to be able to generate any credits upfront
- If **any** answers medium, the scheme can claim 50% of the maximum efficacy value
- If **all** high, the scheme can claim 100% of the maximum efficacy value

Considering how any scheme will deliver against the confidence assessment throughout its development and particularly at the start, will ensure it can be designed in a way to maximise or optimise the upfront credits that can be claimed or any additional credits that may be generates post implementation verses the costs and taking account of any constraints.

It should be noted that if credits can be claimed upfront, although post implementation monitoring is not required to evidence the validity of the credits claimed upfront, monitoring should always be included as part of an adaptive management regime that will support the mitigation scheme to continue providing nutrient mitigation in perpetuity (or if using as a temporary measure for as long as the scheme is required). Adaptive management monitoring should focus on scheme function.

2.4. Calculating scheme specific load reductions

After answering all questions in Table 2:2 to come up with a percentage of the maximum efficacy reduction which can be claimed upfront, the user of this Framework must then use Table 2:1 to establish the maximum efficacy reduction with reference to the buffer strip's width. After reducing the maximum efficacy value by the relevant percentage (100%, 50%, or 0%), the resultant efficacy reduction can be applied to the baseline nutrient load and credits claimed upfront.

See below for a worked example:

Worked Example: Calculating the scheme specific load reductions of a buffer strip proposal

1. Complete questions within Table 2:2
2. Establish whether the scheme can claim 100%, 50% or 0% of the maximum efficacy value for the given width
    - For example, some answers from Table 2:2 are medium, therefore 50% of the maximum efficacy value can be claimed
3. The user is able to claim 50% of the maximum efficacy values for the given width (See Table 2:1)
    - For example, if the buffer is 30m
    - TP: 50% of 43 = 21.5%
    - TN: 50% of 36 = 18%

Output: The user can claim a 21.5% reduction of the influent TP baseline loads and a 18% reduction of the influent TN baseline loads to the buffer strip upfront.

After calculating the nutrient credits which can be claimed upfront, if the user of this Framework believes there is potential for the scheme to mitigate nutrients to a greater standard, post-implementation monitoring can be carried out to gain additional credits. This is only applicable where the scheme is mitigating more nutrients than the upfront credits assume.

3. Framework for Riparian Buffer Strips

3.1. Key considerations

Buffer strips can either be located within a field, at field margins or along the riparian corridor. From a nutrient removal perspective, the overall chemical and physical removal processes active in these systems remain similar regardless of their location, though the overall effectiveness is dependent upon a range of local environmental conditions and their spatial scale. As evidenced in **Part 1** (the literature review), most of the literature on nutrient pollution control focusses on riparian buffers as the direct effect on local waterbodies is easier to monitor, hence this Framework focuses on riparian buffers. Although grass buffers can also reduce nutrient losses, any riparian buffer for nutrient neutrality purposes needs to be predominately wooded. This is to ensure there is certainty that the nutrient reductions are achieved and maintained in perpetuity as the presence of trees ensures it is easy to monitor and enforce that nutrients will not be added.

Mitigation schemes may not be suitable for deployment in all locations within a given catchment and there are certain key considerations that might indicate proposed options are not viable. A summary of the key upfront considerations that should be considered in the first stages of planning for riparian buffer schemes is provided in the checklist below.

Key Headline Messages:

- The implementation of riparian buffer strips to achieve NN may not be suitable for deployment in all locations.
- Key considerations can help identify where a proposal may not be viable and / or needs more investigation to increase confidence of success noting that evidence is required to demonstrate a favourable NN outcome.
- If sufficient evidence related to the point above is not provided, further information will need to be requested and reviewed.

A checklist for these points is provided below.

Key Considerations Checklist

Key considerations	Evidence to be provided	Evidence provided (Y/N)
The Local Planning Authority has confirmed	A nutrient mitigation scheme needs to have practical certainty that can be secured and will provide the mitigation for the lifetime of the development or if being used as a temporary	

Key considerations	Evidence to be provided	Evidence provided (Y/N)
that it is possible to secure the mitigation.	measure for the length of time that the mitigation is required. It may not be possible in all cases to adequately secure that the mitigation will continue to provide the reduction for the required length of time. Mitigation proposals should demonstrate engagement with the Local Planning Authority to ensure schemes can be sufficiently secured and there is certainty that they will provide the required reductions for the length of time the mitigation is required.	
That the proposed buffer strip will not have an adverse impact on or hinder restoration of any protected sites or species or negatively affect existing habitats, or the ability to achieve other environmental objectives.	An evidence statement will be required. If adverse impacts are identified, the scheme will need to be reviewed / changed noting that all buffer strip schemes will be subject to ecological survey prior to implementation.	
The soils and hydrology at the deployment location won't compromise the efficacy of the riparian buffer.	The proposal should clearly show how the soils and hydrology at a deployment location will impact the nutrient removal processes active in a riparian buffer. For example, heavy clay soils will reduce infiltration rates and limit the P removal capacity of a buffer, or for N removal the water table needs to be at least in the root zone.	
The local hydrogeology means that the source of nutrients won't bypass the buffer.	The proposal should consider and ensure that the local hydrogeological conditions means that the source of nutrients doesn't bypass the buffer. For example, nutrient rich groundwater might pass underneath the buffer, and the presence of subsurface drains can limit the contact between the nutrient source and riparian	

Key considerations	Evidence to be provided	Evidence provided (Y/N)
	soils. If this is the case, then drains may need to be disrupted.	
That it is not within 8m of a main water course where is it deemed inappropriate by the EA or where it would pose an access barrier to flood risk.	Early discussion with the EA will ensure that the riparian buffer is not deemed inappropriate in the location. Evidence that this has been discussed with the EA should be provided.	
That the buffer is not required through another legal obligation for example an existing grant scheme or other public or private funding.	The requirements of any grants or other agreements on the land should be provided. If the riparian buffer is required through another legal obligation, then it can't also be used as NN mitigation.	
For maximum effectiveness the riparian buffer strip to area of run off contributing area should be 1:50 or less.	To ensure that the riparian buffer is not overloaded the catchment area feeding the buffer should not be too large compared to the size of the buffer. Therefore, the size of the catchment feeding the buffer and size of the buffer should be calculated to determine the ratio.	
The Local Planning Authority been engaged to ensure the mitigation will serve developments impacted by NN,	Nutrient mitigation schemes must remove at least the equivalent quantity of nutrients, if not more than what will be added by new development before impact on a Habitats site waterbody takes effect. The mitigation measure will need to be upstream of the location where the development site run off and wastewater input will have its effect on the Habitats site. This means if the wastewater/run off is direct to	

Key considerations	Evidence to be provided	Evidence provided (Y/N)
	(i.e. within) the Habitats site boundary the measures will need to be upstream of this location. If the discharge is indirect i.e. upstream in the catchment of the Habitat site, then the mitigation measures can be up or downstream within the catchment, as long as it will provide the offsetting before the point at which the development impacts the Habitat site. Mitigation proposals should demonstrate engagement with the Local Planning Authority to ensure schemes will provide sufficient NN.	
There are no insurmountable reasons why any required permissions or consents would not be granted.	Proposal should show that the relevant competent authorities (e.g. Environment Agency) have been consulted from an early stage to ensure there are no evident or insurmountable concerns early on. This approach can also mitigate any potential risks regarding consents and permissions.	

3.2. Stage 1 – Design Objectives

3.2.1. Introduction and objective setting

Implementing a riparian buffer strip aims to increase the rates and extents to which denitrification and P sorption to sediments and soils occur. Increasing the heterogeneity of the strip enhances these primary N and P removal processes, whilst encouraging the return to a more natural state to support ecological restoration. A review of studies was conducted on the effectiveness of the implementation of riparian buffer strips within **Part 1** (the literature review).

To provide confidence that a riparian buffer will deliver the allocated nutrient removal capacity, clearly defined design objectives are required. These should make clear that the scheme has been proposed in a way that will allow application of these percentage nutrient removal efficiencies, which will in turn show the quantity of nutrient removal the scheme will achieve. Setting the design objectives should lead to an understanding of the source of nutrients that will enter a buffer. This is pivotal to applying the percentage reduction efficiencies, since without a robust estimate of the nutrient input to a buffer, further uncertainty will be added to the estimated nutrient removal that the scheme will deliver. A robust estimate for the amount of nutrient removal a buffer scheme will deliver is important for meeting the requirement for *reasonable scientific certainty* under the Habitat Regulations.

Key Headline Messages:

Defining appropriate objectives to support NN requires initial understanding key factors including:

- Knowledge of the sources of water entering the scheme;
- Knowledge of the concentration of nutrients in the inflowing water;
- The overall quantity of water flowing into the mitigation scheme;
- Predicting how concentrations and flows might fluctuate over time; and
- The level of confidence there is in the understanding of these factors.

For the design objectives to be robust enough to meet the Habitat Regulations requirements, sufficient evidence and information needs to be provided for each of the above.

The following sections 3.2.2 - 3.2.7 need to be evaluated in this context.

3.2.2. Has a robust baseline monitoring method been employed to inform scheme efficacy?

Key questions

- **Why is baseline monitoring / modelling required?** To fully understand the three variables outlined in figure 2:1, a robust baseline monitoring method is required. The output provides the baseline loading value to which the nutrient removal efficiency percentage can be applied for N and P to demonstrate upfront credit generation. Regardless of the method, choice of parameters must be TN and TP or a parameter which is more precautionary (e.g. looking at the scheme reduction as nitrate which makes up only part of TN, will under estimate the TN reduction and therefore would be precautionary). This can be done via physical monitoring or modelling.

- **What is baseline monitoring / modelling?** Baseline monitoring / modelling characterises the nutrient load within the receiving environment prior to implementation to provide a baseline against which the maximum percentage removal efficiencies can be applied. Understanding nutrient concentrations and flow rates into the riparian buffer strip and sediment movement is essential as a minimum. This can be carried out via monitoring, which is likely to be highly expensive, therefore it is recommended that a modelling approach is used. Putting in robust monitoring to take account of any spatial and temporal variability of the inputs into the buffer is likely to be challenging. This is because the nutrients inputs are diffuse i.e they do not enter the buffer at one location, rather they enter across the length of the buffer and the nutrient load entering at any one point will be variable. In addition, nutrients can potentially enter the buffer through multiple pathways (surface, subsurface and groundwater). Therefore, the use of modelling, using precautionary assumptions, is considered an appropriate approach for determining the baseline nutrient loads for riparian buffer schemes. This is also consistent with the approach for determining nutrient losses from taking agricultural land out of production. However, if additional credits over and above those allocated up front want to be claimed then monitoring would need to be undertaken.
- **What should happen to the monitoring data?** If monitoring is undertaken this should be decided and agreed at the beginning of the monitoring programme including approaches to assess data. It is likely to be of interest to LPAs, NE and other third-party stakeholders (e.g. local catchment groups and academics). Building a supporting open-source database including the efficacy rates will be highly beneficial for future programmes.
- **Have suitably precautionary values from the data been used?** The collected data or any modelling must be considered holistically, with specific reference to the most precautionary scenarios which have been characterised. It is not acceptable to look only at the data or model inputs/scenarios which represent the best-case for nutrient credit generation.

If modelling:

- **What is a modelling-based approach to calculating influent nutrient loads?** One approach to calculating the baseline nutrient loading into a riparian buffer scheme is outlined in EnTrade's Interim Nutrient Reduction Standard (ARUP and EnTrade, 2022b). Various agricultural pollution models can be applied, assuming they are supported by an appropriate body of research, however it is suggested that FarmScoper can be used. This would be consistent with how nutrient losses from agricultural land use is calculated in determining the scale of nutrient load reduction and therefore mitigation required by a development. See the Interim Nutrient Reduction Standard for a worked example of a suggested modelling approach. The high-level stages involved in the process are outlined below:

1. Delineation of the catchment area that drains to the buffer using topographic data[4]. For smaller catchment areas, higher spatial resolution data may be more suitable whereas lower spatial resolution may be better for larger catchments (ARUP and EnTrade, 2022a)[5].
2. Classification of the areas of land uses within the delineated catchment of the buffer.
3. Calculation of the baseline nutrient load exported by these land uses to the buffer, making sure to exclude any loads which are likely to bypass the buffer via groundwater, for example. This could use export coefficients for different types of agriculture generated by the Farmscoper model[6].

If monitoring

- **What is a monitoring-based approach to calculating influent nutrient load?** Monitoring-based approaches collect real-world data that can be used to calculate the influent nutrient load to a riparian buffer. Monitoring is required where the user of this Framework is looking to gain additional credits, above the precautionary figures.

  There is no standard monitoring method to collect data on influent nutrient loads to a riparian buffer. However, a monitoring programme to collect data on influent nutrient loads should adhere to the following principles:

  1. A monitoring design should be specified that shows how data on influent concentration and flow rate will be collected – these variables are combined to calculate nutrient load[7].
  2. Concentration and flow rates data should be captured for both surface, subsurface, and groundwater flow pathways.
  3. Because the source of nutrients is mainly driven by rainfall, monitoring should capture the influent load generated by different magnitude rainfall events across all four seasons. This will require a reactive sampling programme to accurately understand the effect of different flow conditions

[4] Potential open-source topographic data for this purpose include the EA Lidar digital elevation model (DEM; high spatial resolution), the Copernicus European EU-DEM (medium spatial resolution) or the Shuttle Radar Topography Mission Global DEM (medium spatial resolution).

[5] As per NE's guidance, ARUP and EnTrade's Solent Nutrient Market Design outlines the maximum suggested catchment size to be 1000ha. Robust justification and monitoring required for larger catchment sizes.

[6] Farmscoper v5 is an agricultural pollution model that generates nutrient export coefficients and was used to generate data on nutrient export from agriculture for use in the Natural England Nutrient Budget Calculators.

[7] By multiplying concentration with flow rate, the influent nutrient load is expressed as a mass per unit time, which are the required units for calculating nutrient removal using the percentage reduction efficiencies.

and impacts on nutrient transport[8]. A minimum of both monthly sampling and some rainfall event sampling is required if monitoring is taking place to gain additional credits. Where reactive sampling is not possible, the user will not be able to claim additional credits.

4. The number of monitoring points should increase with the length of the buffer strip to reduce the risk of missing local variations in hydrology and water quality that will impact the influent nutrient load. The location of the monitoring points should look to account for any variations in soil type, hydrology, topography etc which may affect the efficacy of the buffer.

Note*:* Due to the complexity of monitoring buffer strips, this methodology is likely to be expensive, therefore model-based approaches are recommended if the user is not looking to claim additional credits. If implementing a monitoring approach, however, it must have a degree of reactiveness to account for seasonality and changes in weather conditions.

- **Where should baseline monitoring take place?** The aim of baseline monitoring is to robustly characterise the nutrient dynamics within the system. If baseline monition is just being done to generate upfront credits then only the inflow will need to be characterised, however if additional credits post implementation are to be determined then monitoring the inflow and outflow will be required. To successfully do this, the locations at which inflowing and outflowing measurements should take place need to be identified on a project-specific basis. There are, however, guidelines which must be followed. One monitoring point must be located the field-side of the buffer strip, as close to the buffer itself as possible such that it is below any features which are likely to impact nutrient concentrations. Similarly, the second monitoring point should be on the river-side of the buffer strip, as close to the strip itself as possible. These monitoring points must account for overland, subsurface, and groundwater flows. Based on these requirements, it is up to the individual to identify the best locations for monitoring to characterise the nutrient removal potential of the scheme.

Key information required

- A modelling methodology using precautionary input values and assumptions. If undertaking baseline monitoring, then a baseline monitoring plan detailing monitoring methods, sampling locations, monitoring frequency and the duration of the monitoring programme is required. This may take the form of documentation supporting an existing monitoring programme using for example The River Restoration Centre Monitoring Planner[9].

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[8] I.e., sampling at a non-standardised frequency in response to different size rainfall events.

[9] See: [Monitoring Planner | The RRC]

- Clear methodology explaining how the assessments have been completed. The method must provide confidence of assessment and demonstrate it has considered the hydrogeology especially in the context of ground water versus surface water catchments. Refer to open-source information first and present this with justification of the sources used.
- **Optional:** A plan detailing how any data from baseline monitoring will be made available to stakeholders.

3.2.3. Has the source of nutrients to the measure been clearly defined

Key questions

- **Do you have a strong understanding of the number of sources and pathways of water to the buffer?** Riparian buffer strips treat diffuse nutrient pollution from terrestrial sources. They are mostly deployed in rural settings, where the main nutrient sources are from agricultural runoff that may reach the buffer via surface, subsurface drainage or groundwater pathways.
- **Do you have a clear picture of where the nutrients will be entering the buffer?** This is important to understand as it will directly determine potential project location, width, and success (e.g. are nutrients carried in surface water flows likely to infiltrate soils before, or during the buffer, or is the groundwater too deep or there are drains which means the water bypasses under the buffer).
- **What if the source of water to a buffer is not well defined?** If the source of water has not been characterised robustly, the overall design process could be undermined.
- **What is the concentration of nutrients in the influent water?** The concentration of nutrients will influence the location of the proposed scheme but may not greatly impact the design. Nutrient removal processes generally operate better at higher concentrations and buffer schemes should be targeted in areas with higher nutrient concentrations. However, in relation to riparian buffers it is also important that the buffer is not overloaded with nutrients which will reduce the efficacy of the buffer in removing nutrients. Hence it is important that there is good soil and crop management in upslope fields (i.e. compliance with agricultural regulations as minimum).
- **Is a buffer being proposed in an urban area?** Buffers for nutrient removal can theoretically be deployed in urban areas, but the alterations to natural surface and subsurface drainage pathways will have to be considered when defining the source of water to a buffer.
- **Why do I need to show the source and pathway of water to a buffer?** Understanding the source and pathway of nutrients to a buffer is important for predicting the potential nutrient input (hereafter referred to as nutrient loading) to the buffer.

Key information required

- The source(s) of water and nutrients to be treated by the buffer strip needs to be clearly defined and described

- The catchment of the buffer and pathway(s) that the water carrying the nutrients will take to reach the buffer strip should be clearly defined.

3.2.4. Has any allowance been made for long-term changes to the influent nutrient load

Key questions

- **Has climate change impact been considered in terms of the potential impacts on influent nutrient loads?** This could have a future impact on the efficiency of buffer strip for achieving mitigating nutrient pollution in the future. At this stage it is recommended that key open-source data is reviewed to ascertain long term local predicted trends[10].
- **Have planned infrastructure changes within the catchment been considered in terms of the potential impacts on influent nutrient loads?** Already planned improvements at WwTW for example, could have a future impact on the efficiency of a buffer strip at mitigating nutrient pollution due to decreased loading into the scheme. A HRA would only require an allowance for changes that are known at the time of the assessment, therefore all improvements that have been secured at this stage need to be considered.
- **Are there any known site-specific land use changes that may affect long-term nutrient impacts?** An evidence log is required to understand if any currently planned changes will result in either increasing or decreasing loads.
- **How should long-term changes in influent nutrient loads be acknowledged?** Mitigation proposals will need to incorporate known long-term increases or decreases in influent nutrient loads e.g. due to climate change or already planned land use change, and the impact this might have on the amount of nutrient mitigation a buffer will deliver in perpetuity.

Key information required

- Summary statement outlining all planned improvements within the catchment, with reference to likely impacts.
- Account for climate change that is evidenced.
- Statement of any known land use changes and potential effect (positive and negative).

[10] To account for climate change, see: Product Selection - UKCP (metoffice.gov.uk). Search for the relevant area to determine the environmental impact of climate change on rainfall, and therefore influent nutrient concentrations. Use this to support research.

3.2.5. How are credits calculated?

Key questions

- **When can credits be calculated?** Once robust modelling has been carried out or following the required minimum of a year of baseline monitoring to account for all seasonal variability, the quantity of N and P credits available from the buffer strip can be calculated.
- **How is the generation of credits calculated?**

If modelling:

- Following the modelling exercise to calculate the influent nutrient load, there are two stages required to understand the credit generation.
    1. Using the baseline width of the buffer strip, the relevant maximum nutrient removal efficiency can be identified from Table 2:1. Applying the confidence assessment will then determine the scheme specific nutrient reduction efficiency.
    2. Apply the relevant scheme specific percentage reduction efficacy value to the modelled baseline load to acquire the reduction (kg TP / year or kg TN / year).

If monitoring:

- Following the required baseline monitoring for a minimum of a year, nutrient credits can be calculated via a nutrient concentration and flow trend analysis to provide a strong understanding of nutrient cycling in the system. The trend analysis will need to take account of time lags between nutrient mobilisation and the point at which the nutrients can be monitored within the channel. To achieve this will require monitoring / modelling of a range of flow / concentration conditions with the aim of characterising nutrient trends. The scheme specific nutrient percentage removal efficiencies (determined using the confidence assessment and the maximum nutrient reduction efficacy values in Table 2:1 as set out in section 2.1 can then be applied to the loading value, to provide an estimate of the quantity (in kg TN and / or TP / year) of nutrients which can be mitigated against through the implementation of a riparian buffer strip. This can be calculated as set out in Section 2.4.

Key information required

- Evidence of a sound methodology including the calculations and justifications for the method used.
- The load of TN and / or TP in kg / year which can be mitigated against by the scheme.

3.2.6. What additional benefits can be delivered through the design objectives?[11]

Key questions

- **Have wider benefits to the environment and society been considered?** Riparian buffer strips can provide benefits over and above water quality (e.g. habitat resilience under flood and drought conditions for a range of species, enhance human health and wellbeing, recreation, air quality, carbon sequestration and local economic benefits etc). Outside of the scope of NN, these benefits are often simplistically restricted to a small subset of values such as biodiversity net gain, natural flood management and carbon sequestration. Every scheme provides the opportunity for wider benefits via the encouragement of ecosystem services.
- **Have wider benefits been considered in the context of biodiversity net gain, natural and societal capital?** Whilst mitigation should firstly focus on NN benefits and meeting the needs of Habitat Regulation, understanding how any mitigation can support wider development requirements to support regulatory biodiversity net gain (BNG) and associated Natural Capital parameter is valuable. This understanding will help to establish how different ways of packaging multiple ecosystem goods and services can incentivise conservation-based funding support for the proposed mitigation (i.e. support stacking and bundling concepts) and avoid undervaluing nature.

Key information required

- Consideration should be given to the potential for mitigation schemes to provide wider benefits to the local, and wider, community such as amenity value, pollination, job creation, food supply, local climate regulation and timber production.
- An ecosystem services assessment of the available wider benefits can be carried out to support the proposal. This should seek to link the benefits to the beneficiaries, focussing predominantly on wider values at this stage. A simple assessment based on a high-level RAG assessment would be acceptable at this stage.

3.2.7. Overall evaluation of design objectives

For the design objectives to be robust enough to meet the requirements of the Habitat Regulations, the key evidence and information required must be provided for each of the above categories. If any information is missing or the information provided is not

[11] Whilst wider benefits assessment is out of the direct scope of NN it is highly recommended that this assessment is included since planning does require assessment of biodiversity net gain and wider net zero opportunities (e.g. carbon sequestration) whilst opportunities for natural flood and drought management and resilience can support local ambitions.

commensurate with the obligations of the Habitat Regulations, the objectives must be re-considered to meet the mandatory criterion for NN mitigation.

The series of questions within the confidence assessment outline the stages required to be able to evidence that the design objectives and baseline monitoring method for a riparian buffer strip scheme are robust (Section 2.3). Table 2:2 and Table 3:1 should be completed to provide verification that likely nutrient loads entering the riparian buffer strip have been robustly estimated. The result (high, medium, or low) of each answer is associated with a score which when combined will correspond to a percentage value. The percentage acquired is the proportion of the width's maximum efficacy value for nitrate and / or TP which can be claimed.

To establish the strength of the design, the tables below can be used in conjunction with Table 2:2 and Table 3:1. Some cells have been left blank.

Report Section	Comment	All information has been provided in the relevant format (mapped, tabular, or summary)	There are gaps in the information provided
3.2.2	Baseline monitoring method		
3.2.3	Source of nutrients to the measure		
3.2.4	Allowance for long-term changes		
3.2.5	Credit calculation		
3.2.6	Additional benefits		

	Response statements
If ALL green (noting that 3.2.6 is optional)	This is a well-structured feasibility assessment that maximises the likelihood that this riparian buffer strip scheme will be a sustainable natural asset within this catchment.

	Response statements
If SOME red	The application is missing mandatory feasibility information, as shown by the rows populating the red column. Please provide this information so that the feasibility assessment can be evaluated.

3.3. Stage 2 – Feasibility

3.3.1. Introduction

Before a riparian buffer strip is designed, a proposal should consider the feasibility of the scheme. The sub-sections below detail the key factors that will impact of the feasibility of a riparian buffer strip scheme. For most of these factors, there will be options to mitigate potential constraints on feasibility. A riparian buffer strip proposal will need to show how constraints on feasibility have been mitigated. There are some circumstances where evidence to show feasibility is not required but is strongly recommended. These areas are highlighted in the text alongside areas where optional information should be incorporated where possible. Including optional information to support scheme feasibility will help to reduce the risk of unforeseen problems in delivering the scheme.

3.3.2. Topography and levels

Key questions

- **Will nutrient rich water flow through the buffer?** The topography of the site needs to be considered such that the water will flow through the buffer under gravity. This is less of an issue for riparian buffers due to their position at the terminus of hillslopes, i.e. where hillslopes meet river channels. Where agricultural tile drain systems are present, these might need to be broken to increase retention time and support the effectiveness of the buffer zone.
- **Can a buffer zone be too steep?** The gradient of the riparian buffer needs to be considered. If a buffer is too steep there is a risk that surface water runoff will pass over the buffer with minimal infiltration. This will likely be site-specific as a maximum gradient for buffer effectiveness will be related to local soil and vegetation characteristics. However, buffer strips between 8-15m strips can be effective up to a slope of <10% gradient (Cole, Stockan, & Helliwell, 2020).
- **Can local topography impact effectiveness?** The local topography of the riparian buffer surface needs to be assessed to show that it will not concentrate surface flows into a braided channel pattern which can cause local scouring. A buffer should have a relatively even surface that will support laminar sheet flow, which is optimal for infiltration and nutrient removal. Where topography causes convergent flows and / or higher loadings then wider buffers are needed to ensure that the buffer does not become saturated. Variable width buffers depending on local topography are recommended to achieve this.

- **What is the catchment to buffer area size ratio?** For maximum effectiveness of a vegetated buffer strip the ratio of the buffer strip to the area of runoff contributing area should be 1:50 or less (Cranfield University, 2006).

Key information required

- A map showing the gradient of the proposed buffer strip, showing that it is less than 10% gradient, and that water will flow through it under gravity.
- Map of the catchment area, to show that the buffer to catchment area ration is 1:50 or less.
- An assessment of the topography, and / or design features, to show that overland flows will be evenly distributed across the buffer to allow for maximum infiltration, reduce the risk of scour and ensure the width of the buffer is tailored to ensure that the buffer is not being overwhelmed.

3.3.3. Geology and hydrogeology

Key questions

- **What is the site geology?** This is important because it provides the parent material for the soil and determines the vulnerability of any associated groundwater impacts related to water quality. Parent materials which equip subsequently derived soils with characteristics such as high P sorption capacity and permeability are favourable. The local geology will also affect the hydrogeology of the buffer's catchment, which will in turn impact how subsurface flows reach the buffer.
- **Can hydrogeology impact the efficacy of a buffer?** There is a potential risk that nutrient rich groundwater might flow underneath a buffer. It is also possible that flows are directed away from the buffer due to groundwater gradients that do not follow surface topography.
- **Are any aquifers present which may result in upward discharge?** If there is an aquifer below a buffer, it could cause upward discharge into the buffer's soils. This could either dilute the concentration of nutrients within the buffer strip, reducing the efficacy of the scheme, or provide an additional source of nutrients to the scheme, making it more effective. Groundwater water sources to the buffer will also need to be accounted for to specify a robust monitoring plan (see Stage 5 – monitoring and management).

Key information required

- A map of the expected geology beneath and in close proximity to the mitigation site. This is likely to be highly indicative at this stage and based on open-source data.
- An assessment of the potential issues that may be caused by the catchment hydrogeology.

3.3.4. Soil and sediment[12]

Key questions

- **What is the composition?** This will affect the nutrient removal capacity of a buffer strip particularly for P. Soils should support a balance between infiltration capacity and other chemical and structural properties (e.g. P sorption capacity) that may limit infiltration capacity but increase nutrient removal capacity. Sandy soils, for example, have a high infiltration capacity but a much lower P removal potential than clay soils, which have higher nutrient removal potential but very low infiltration capacities.
- **Will soil type preclude locations for buffer deployment?** The implications of soil type will be site-specific and can vary within the location in which a buffer strip is planted. It is advised that buffers are placed in areas with less porous soils where groundwater movement is slow to encourage nutrient removal processes. Buffers deployed in locations with sub-optimal soil conditions may still provide nutrient mitigation, though it may be lower than in locations with more optimal soils (See Section 3.3.8 for more information regarding pre-existing nutrient contents of soils).

Key information required

- An assessment of the expected soil type(s) at the buffer deployment location which considers the impact of the soil type on the nutrient removal potential.
- **Optional:** A site investigation identifying the local soil type along with an estimate of the hydraulic conductivity[13]. This will help to support the assessment of the impact of soil type on nutrient removal.

3.3.5. Hydrology and drainage

Key questions

- **What are the optimal drainage conditions for a buffer strip?** Ideally, nutrient-rich runoff will enter a buffer via overland, subsurface, and shallow groundwater flows. Overland flows should mainly be infiltrated into the soil within the width of the buffer, with little overland flow exiting the buffer. This is especially important for riparian buffers where overland flow exiting a buffer will directly enter a river channel with little nutrient removal.

[12] See the Nutrient Reduction Standard and the Woodland Creation Project Development Guidance for more information regarding soil type.

[13] Soils are preferable where hydraulic conductivity supports a longer residence time of water in the soil without resulting in the soil becoming waterlogged and generating overland flow.

- **How shallow does the water table need to be?** For denitrification (a key N removal process) to occur, oxic and anoxic conditions are required[14]. If the water table is too high, anoxic conditions dominate, whereas if the water table is too low, oxic conditions dominate. Both scenarios limit denitrification potential. It is favourable for the water table (i.e. groundwater) in a buffer strip to be at a similar depth to the rooting depth of vegetation (which is easier to achieve in riparian buffers where the water table will be higher than buffers further from river channels).
- **Can subsurface flows be too deep?** If runoff infiltrates into groundwater and flows underneath a buffer strip (i.e. below the root zone), the nutrients will be transported beneath the buffer, rendering it ineffective.
- **What is the effect of any field drainage?** Field drains which transport water and the associated nutrients under the buffer direct to the watercourse will bypass the nutrient removal potential of the buffer. Therefore, any field drains should be disrupted to ensure the water flows through the buffer rather than bypassing it.
- **What effect does catchment area have?** To ensure that the riparian buffer is not overloaded the catchment area feeding the buffer should not be too large compared to the size of the buffer. For maximum effectiveness the riparian buffer strip to area of run off contributing area should be 1:50[15] or less.

Key information required

- An assessment should characterise flow paths of overland and subsurface flows, as well as the water table height within the width of the buffer.
- The size of the catchment versus the buffer area should be calculated.

3.3.6. Flood risk

Key questions

- **Can the scheme increase flood risk?** Changing the path of flood flows or reducing the storage capacity of a floodplain may increase flood risk and is not permitted in Flood Zones 2 and 3 without a flood risk assessment (FRA).
- **Can flooding reduce nutrient removal?** Flooding of a buffer strip is possible (and inevitable for riparian buffers). The scheme must be designed with this in mind, with careful consideration of the potential implications of flooding on nutrient re-mobilisation and the requirement for flood resilience.

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[14]. The primary forms of N from agriculture are nitrate and ammonium. Oxic conditions are required to nitrifiy ammonium to nitrate). Denitrification (the process of cycling nitrate into gaseous forms of N) requires anoxic conditions. If only oxic conditions are available, denitrification is limited to the supply of nitrate.

[15] Defra Project PE0205 – Appendix B – A review of the literature on the strategic placement and design of buffering features for sediment and P in the landscape. Cranfield Uni.

- **Have flood risk benefits been identified?** If the buffer strip is connected to the floodplain there might be benefits regarding reduced flood risk as the retention time of water within the buffer strip is increased. This subsequently is likely to increase the nutrient removal capacity of the scheme.

Key information required

- A map to show if the buffer deployment location is in a flood zone. If it is in Flood zone 2 or 3, it will require a flood risk assessment.
- A map showing current flood risk extent based on the Environment Agencies flood risk mapping will support this understanding including downstream to any key infrastructure[16].
- Note: if areas of risk are identified they should be flagged to determine if any localised flood mitigation strategy is necessary/can be implemented.

3.3.7. Protected sites, species, and Invasive Non-Native Species (INNS)

Key questions

- **Will the riparian buffer strip impact a protected site?** If the deployment location for the proposed mitigation is within, or near, a protected site, either its implementation or operation phases may impact the site. The following authorisations might be required:
    - As the owner or occupier of a SSSI, notice must be given, and NE's permission (consent) is required before a planned activity is carried out on the site. This only applies to owners of land within the SSSI itself.
    - Public bodies must give notice and get NE's agreement (assent) before carrying out a planned activity that's likely to damage a SSSI or land near the site's boundary.
    - For proposals within European sites and Ramsar sites, a competent authority must undertake a HRA for any plan or project which is not necessary for management of the site.
- **Will the buffer strip impact protected species?** If protected species are present at or near the deployment location and could be impacted by the scheme. This will require a conversation with NE to gain consent.
- **Are there any known INNS at the site?** There may be INNS at the deployment location, which would require an INNS risk assessment to show how these species will be removed and disposed of to remove the risk of spreading INNS to other locations in the catchment.

[16] See: Check the long term flood risk for an area in England - GOV.UK (www.gov.uk) and Flood Risk Maps for Rivers and Sea in England - December 2019 (arcgis.com)

- **Have beavers been introduced into the area?** A presence of beaver can reduce or remove tree management requirements and enhance the functioning of the riparian buffer for nitrogen removal subject to their being adequate habitat space to support beaver activity.
- **Will the buffer strip impact other natural habitats or environmental objectives?** The scheme should not compromise the restoration of other natural habitats or cause a negative impact on existing natural habitats. It should also not negatively the ability to achieve other environmental objectives.

Key information required

- Maps of international (SAC, SPA, Ramsar) and national (SSSI) protected sites for nature conservation.
- Maps of locally protected nature / environment sites (local nature reserves, local wildlife sites and local geological sites) and other protected areas (National Parks, AONBs) that may have requirements which need consideration when deploying a buffer strip scheme.
- Maps of priority habitats and areas that are currently under habitat restoration.
- Map of INNS locations using any local observations and the NBN Atlas[17] with INNS statement on pathways and impacts.
- Depending on the interaction of the scheme with the above designations, a full ecological assessment may be required to provide confidence there will be no impacts on these designations due to the scheme.

3.3.8. Land use

Key questions

- **Can land use of the fields upslope of the buffer effect the efficacy of the buffer strip?** The management of the upslope field will impact on the nutrient loads entering the buffer. In order to ensure that the buffer is not overloaded and therefore enabling the riparian buffer to function effectively it is important that there is good soil and crop management in upslope fields (i.e. compliance with agricultural regulations as minimum).
- **Can previous land use impact the efficacy of a riparian buffer strip?** The current and previous land use at a buffer deployment location needs to be considered in order to ascertain the risk of legacy nutrients being remobilised. This is more of a problem for P than N, as N is less readily stored in soils and is most

[17] See: NBN Atlas - UK's largest collection of biodiversity information

likely to occur during implementation. It may be necessary to test soil nutrient levels to determine potential legacy risk from land use.

The Framework Approach for Responding to Wetland Mitigation Proposals specifies the following limits to prevent remobilisation of nutrients:

- Soils with TN content: < 1000 mg / kg
- Soils with TP < 80 mg / kg.

If the soil is P saturated prior to implementation, it will still be beneficial to deploy a buffer strip scheme and harvest the vegetation earlier than typically suggested in order to reduce P levels. As such, high P levels are unlikely to prevent a buffer strip scheme from being implemented, however it will influence the vegetation and maintenance requirements.

- **Are there interactions with other land management schemes?** If the land is currently under an agri-environment scheme, payments may be lost through the deployment of a buffer scheme.

Key information required

- Map of current land use and explanation of any previous land uses that might cause an elevated risk of pollution during the implementation of a buffer strip. Where there is risk of high P levels in the soils, soil testing should be undertaken to inform the maintenance requirements.
- Map of active agri-environment schemes.
- No evidence of non-compliance with agricultural regulations for upslope fields in the catchment and/or commitment that there will be compliance going forward.

3.3.9. Ownership

Key questions

- **Has the landowner, and any surrounding landowner, agreed to the mitigation in principle?** A project can only be delivered with the agreement of the landowner and following discussion with any other landowner where they may be a direct effect. A legal agreement should also be confirmed with the landowner that the land used for the buffer strip will remain in place in perpetuity (practically this is 80+ years).

Key information required

- Evidence of engagement with the landowner regarding the deployment of the buffer scheme.
- Outline details of any in principle, legal or management agreements to secure the land required for the buffer strip in perpetuity.

3.3.10. Landscapes and heritage

Key questions

- **How might a buffer strip impact landscapes and heritage?** Planting trees and vegetation has the potential to disrupt landscape character and heritage features. This will need to be checked with landowners and bodies such as English Heritage.
- **How can this disruption be accounted for?** The loss of landscape and heritage features can be mitigated through early identification of possible disruptions and the uses of suitable mitigation measures.

Key information required

- Heritage value risk assessment and landscape character assessment based on advice from the Local Authority.
- Map of scheduled monuments.

3.3.11. Rights of way and public access

Key questions

- **What if a public right of way is affected by the proposed measure?** Public rights of way cannot be closed or diverted, even temporarily, without permission from the local authority. Implementing a buffer strip has the potential to cause changes in the landscape which could affect public rights of way.
- **Are there wider benefits associated with public access?** Public access to the buffer strip will improve the scheme's amenity value, with the potential to provide education and public awareness of nutrient pollution issues. However, it may also increase the risk of degradation that might reduce nutrient removal efficiencies.

Key information required

- Map of the nearest public rights of way and any plans for any required mitigation.
- Demonstration that the local authority has been engaged regarding changes to public rights of way, if required.
- If possible / relevant, consider opportunities available for education and raising public awareness while minimising risks to degradation of the scheme.

3.3.12. Birdstrike risk

Key questions

- **Is the proposed buffer strip near an airfield?** Buffer strips can attract birds which may be an issue if the site is near an airfield. This is especially an issue for large flocks of birds such as starlings. The risk of bird strike will depend on the type of airport and its associated usage by planes. An evaluation of risk needs to be within the context of the type of airport.

- **Will a bespoke birdstrike risk assessment be needed?** Airports may have their own birdstrike risk management programmes or plans. These should be consulted and any mitigation of birdstrike risk should be derived through consultation and the development of a mutually agreed strategy.

Key information required

- Map showing the nearest airfields and the type of airfield (commercial, military etc) along with any proposed mitigation strategy.

3.3.13. Nature recovery

Key questions

- **Does the buffer strip have the potential to be part of a habitat network or natural recovery area etc?** It will be beneficial to look at local plans that support nature recovery plans to establish if the nutrient mitigation provides any opportunity to combine outputs. This should be considered in the context of the most beneficial placement of the nutrient mitigation solution.
- Does **the proposed plan intersect with other plans identified for alternative nature recovery requirements?** There may be locations in which the NN proposal could displace more valuable habitat nature recovery opportunities.

Key information required

- Map identifying that the proposed deployment location is suitable for buffer strips. In time the Local Nature Recovery Strategy (LNRS) should be used to minimise the risk that a buffer strip will compromise a local habitat network.

3.3.14. Historical landfill, coal mining and contaminated ground

NOTE: This is unlikely to be an issue for buffer strips unless earthworks are required. It is recommended that this is checked to determine any potential risk.

3.3.15. Unexploded ordnance

NOTE: This is unlikely to be an issue for buffer strip installation. Expert judgement will be required to determine if an assessment is needed (e.g. movement of plant to remote site for installation).

3.3.16. Services and infrastructure

Key questions

- **Has an assessment of services both underground and overhead (water, gas, and electricity) been conducted?** Moving services is expensive and time-consuming and requires the involvement of the service provider. Projects that require earthworks have potential to impact underground and overhead services such as water, gas, and electricity. The above services may impact the ability to deliver the project during to constraints of plant access the site.

Key information required

- A full search and a map of all local services, if any. The services should be plotted alongside the proposed buffer location to show their relative locations.
- A mitigation strategy for any services identified.

3.3.17. Regulatory considerations

Key questions

- **Does the implementation of a riparian buffer strip require any environmental permits or permissions?** The regulatory requirements might include, but are not limited to, the following:
    - Environmental permits
    - Flood risk assessment
    - Flood defence consent from EA regarding works within 8m of a main river
    - Archaeology and pathway assessment
    - Wildlife licences
    - Planning permission

Key information required

- A list of the permits and licences required along with an assessment of the likelihood that they will be granted
- A narrative on each permit identifying any engagement with the relevant regulator and advice already received would be useful as supporting information is available.

3.3.18. Constraints and options assessment

Key questions

- **Is the proposed riparian buffer strip scheme a suitable nutrient mitigation option?** The feasibility assessment may have identified a range of constraints. It is important to consider these constraints and any knowledge gaps that the feasibility assessment has found. This will help to provide a justification that the riparian buffer strip is a suitable option as it has been proposed. It will be useful to condense the key information identified in the feasibility assessment into a summary which, in a successful proposal, will highlight that the proposed deployment location is well suited to the scheme, and that the scheme is the best option available.

  Although this step is not mandatory, it will show that the proposal given significant thought to the feasibility of the mitigation scheme.

Key information required

- **Optional:** a summary table of the constraints associated with the scheme.

- **Optional:** a description of the scheme's suitability in the proposed location, based on the feasibility assessment.

3.3.19. Evaluation of feasibility assessment

For a buffer scheme to pass the feasibility assessment, it must include all required pieces of information from Stage 2 related to topics 3.3.2 - 3.3.18. Providing evidence for each key piece of information shows that the risks have been considered, with plans in place for management and mitigation.

To establish the strength of the feasibility assessment, the tables below can be used. Mapped information is required where possible except for regulatory considerations which should be provided as a statement. Cells in the following table have been left deliberately blank to provide a template for users when measuring the strength of a feasibility assessment.

Report Section	Comment	All information has been provided in the relevant format (mapped, tabular, or summary)	There are gaps in the information provided
3.3.2	Topography & Levels		
3.3.3	Geology & hydrogeology		
3.3.4	Soil and sediment		
3.3.5	Hydrology & drainage		
3.3.6	Flood risk		
3.3.7	Protected sites & species		
3.3.8	Land use		
3.3.9	Ownership		
3.3.10	Landscapes and heritage		
3.3.11	Rights of way and public access		
3.3.12	Birdstrike risk		

Report Section	Comment	All information has been provided in the relevant format (mapped, tabular, or summary)	There are gaps in the information provided
3.3.13	Nature recovery		
3.3.14	Historic landfill, coal mining and contaminated ground		
3.3.15	Unexploded ordnance		
3.3.16	Services & infrastructure		
3.3.17	Regulatory considerations		
3.3.18	Constraints and options assessment		

	Response statements
If ALL green (noting that 3.3.18 is optional)	This is a well-structured feasibility assessment that maximises the likelihood that the buffer strip will provide nutrient removal at the stated level of efficacy.
If SOME red	The application is missing mandatory feasibility information. Please provide the information under the feasibility factors highlighted in the red column so that the feasibility assessment can be evaluated.

3.4. Stage 3 – Design Process

3.4.1. Introduction

The sections below show provides further details on the design criteria deemed to be essential to achieving the percentage nutrient removal efficiencies as well as essential practical considerations. Further optional design criteria are provided that will help to increase the certainty with which the scheme will deliver these percentage nutrient removal efficiencies. The design will ideally incorporate details on how the buffer strip will realise additional environmental benefits

This document does not cover the detailed design requirements for on-the-ground delivery of a riparian buffer strip.

Design processes outlined in this document are related to key requirements to support the understanding of the confidence in the scheme being used as NN mitigation in the context of riparian buffer strips.

A design engineer will be required to take this forward using supporting information provided in the feasibility stage.

Note: There are different design requirements for N and P.

3.4.2. Essential design criteria

Table 3:1 provides a summary of the minimum design criteria which must be met to claim credits upfront from a riparian buffer strip scheme. Not all of the requirements for N and P are the same, so where a buffer is looking to reduce both nutrients, any buffer will need to be particularly well designed so that the requirements for both are present within the buffer. The evidence required from Table 3:1 must be provided. Additionally, Table 3:2 provides a summary list of documentation that should be covered as part of the detailed design. It should be used as a 'tick list' and to check key statements related to success. Where not completed, a justification will be needed. This will be used to provide details of on-the-ground design criteria at a level that can be used by a contractor. Confidence factors of success for riparian buffer strip schemes and NN should be included based on physical, water quality and ecological parameters. Any uncertainties should be flagged using RAG risk register.

Table 3:1 Minimum design requirements

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
Surface micro-topography	Uneven, 'lumpy bumpy', with complex, impeded drainage pathways and numerous small-scale depressions that significantly increase a wetted surface area with organic matter and retain and detain surface water runoff that aids water infiltration into the buffer soils. Absence or removal of spoil banks or levees not required for flood defence purposes.	Uneven, 'lumpy bumpy', with complex drainage pathways and numerous depressions that capture and retain sediment transported by surface water runoff and aid water infiltration into well-draining buffer soils. Absence or removal of spoil banks or levees not required for flood defence purposes. Use low bunds, lips or other sediment trapping measures to the leading (landward) edge of the buffer as a first line to trap sediment (and associated P) but avoid directing run-off to focussed drainage pathways through the buffer.	Justification for the chosen site with reference to the surface micro-topography and the site's suitability for a buffer strip scheme. Must meet both sets of requirements if deploying a buffer strip to achieve both N and P credits.
Vegetation type	Predominantly a wooded but open tree and scrub canopy in which there is a mix of wetland vegetation types that provide abundant surface dead wood and organic matter, and shallow to deep roots that penetrate below the water table throughout the year e.g. willows, tall herbaceous fen species and other wetland trees and scrub.	Zoned such that there is a high density of vegetation at the ground surface that intercepts and slows surface run-off to capture water borne phosphorus and sediment laden phosphorus. At leading (landward) side, there must be a zone of dense, low growing vegetation that retains an up- standing structure during winter e.g coarse grass and tall woody stemmed herbs. Beyond, predominately a	A mapped vegetation plan including any seeding or planting of the buffer strip to promote nutrient removal, accounting for the minimum requirements outlined for N and/or for P.

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
		wooded but open tree and scrub canopy in which there is a densely vegetated understory.	Clear justification of the species chosen. Evidence of a comprehensive vegetation management plan to ensure a mix of tree canopy and open sunlit ground year-round.
Vegetation cover	Minimum of 100 trees per hectare at maturity, irregularly spaced to provide an intricate mix of tree canopy and open sunlit ground. Trees should be 100% native and climate/future proofed.	Minimum of 100 trees per hectare at maturity, irregularly spaced to provide an intricate mix of tree canopy and open sunlit ground. Tree planting density should be sufficiently low to allow establishment of ground storey vegetation thus increasing hydraulic roughness and therefore effectiveness. Ensure there is little bare ground (less than 5% as a mix within the vegetation) in grass and herb swards both along the leading edge of the buffer and in open canopy areas to ensure effective trapping of P. Trees should be 100% native and climate/future proofed.	
Buffer management	Remove tree guards once growth is substantially free from browsing pressure. Periodically thin / coppice tree and scrub growth to maintain an open wooded canopy which will also aid permanent removal of nitrogen. Ensure any	Remove tree guards once growth is substantially free from browsing pressure. Periodically thin/coppice tree and scrub growth to maintain an open wooded canopy and remove phosphorus taken up by the trees/scrub.	Detailed management plan with stakeholder responsibilities clearly identified. The management plan should show consideration towards possible needs for

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
	vegetation removed is removed from the catchment.	Targeted periodic cutting along the leading (landward) side to remove any establishment of scrub cover and maintain dense vegetation close to the ground surface. Also, regular harvesting of vegetation from the leading edge to both maintain dense vegetation close to the ground surface and remove phosphorus taken up by the vegetation. Ensure any vegetation removed is removed from the catchment. Regularly remove sediment captured by bunds, lips. Ensure management is done at a time, frequency and method which minimises nutrient losses.	supplementary planting and vegetation removal.
Width	Minimum 10m at narrowest point but should be larger where there are converging flows or higher loads. Deploying buffers that are as wide as possible given constraints on land availability will increase the confidence in the design.	Minimum 10m at narrowest point but should be larger where there are converging flows, higher loads or where soil has fine particles which will travel further (e.g. clay soils). Deploying buffers that are as wide as possible given constraints on land availability will increase the confidence in the design.	Detailed design evidencing the width of the buffer along its whole length, as may vary along its length depending on relative risk, but always minimum of 10m.

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
Livestock within buffer	No Livestock	No livestock.	Evidence that no livestock will have access to the buffer. If livestock are present in adjacent fields then fencing will need to be implemented.
Fertiliser / manure / slurry or any other application	None	None	Evidence that no fertiliser, manure, slurry, or any other application will be applied to the buffer.
Hydrology of the buffer	Water table needs to be sufficiently close to the ground surface to support a dominance of wetland vegetation and at least within the deeper tree and scrub root zone through the warmer part of the year to promote denitrification. Ensure flows don't bypass the buffer – e.g. through gravelly sub-soil, underdrainage, field drains or ditches. Field drainage if present need to be blocked and disrupted to ensure this.	Freely draining surface soils that enable infiltration of waterborne P. Ensure flows don't bypass the buffer – e.g. through underdrainage, field drains or ditches. Field drainage if present need to be blocked and disrupted to ensure this.	Characterisation of flow paths of overland and subsurface flows, as well as the water table height within the width of the buffer and consideration as to how these will impact the nutrient removal processes active in the riparian buffer.

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
Field and adjoining land management	Good soil and crop management in upslope fields (i.e. compliance with agricultural regulations as minimum). Break up any lines of surface drainage that directs and concentrates run-off to focal points at the buffer e.g. a low field corner. No trafficking routes or turning circles within the buffer.	Good soil and crop management in upslope fields (i.e. compliance with agricultural regulations as minimum). Break up any lines of surface drainage that directs and concentrates run-off to focal points at the buffer e.g. a low field corner. No trafficking routes or turning circles within the buffer. Depending on size of leading-edge grass / tall woody herb zone, the buffer may need to be fenced.	Evidence that current agricultural practices are compliant with agricultural regulations.
Slope	Less than 10%[18]	Less than 10%	A map showing the gradient of the proposed buffer strip, showing that it is less than 10% gradient.
Soil characteristics	Soils are preferable where hydraulic conductivity supports a long residence	Soils should support a balance between sufficient infiltration capacity and high P sorption capacity. Soils are preferable	An assessment of the expected soil type(s) at the buffer deployment location

[18] For gentle slopes, less than 10% gradient, widths of 8-15m are typically adequate (Cole et al, 2020)

Design criteria	Requirements for N reductions	Requirements for P reductions	Evidence required
	time of water moving slowly through the buffer.	where hydraulic conductivity supports residence time of water in the soil without the soil becoming waterlogged, de-oxygenated and generating a dominance of overland flow. Soils with higher P sorption capacities (e.g. from calcium and iron) will be able to store greater amounts of P without it leaching.	which considers the impact of the soil type on the nutrient removal potential.
Future maintenance requirements	It is important to understand what sort of maintenance and monitoring the scheme will require and allow for access to conduct this maintenance where necessary. The design should account for the type of access that will be required and whether vehicular access be necessary.		Evidence that the design accounts for the required access for maintenance and monitoring.

Table 3:2 Key information to include using data from Stage 2

Key information to include (using data from Stage 2)	*Why*
Land access statement	Identify risks, required mitigation to avoid damage and permits.
Method Statement	Planned construction with associated maps. This should include information on slope, cross section dimensions, requirements to remove current trees or other infrastructure, requirements for pre-construction surveys, materials, specific design features and proposed timing relative to environmental considerations.

Key information to include (using data from Stage 2)	*Why*
Construction Design and Management (CDM) statement[19]	To support health and safety.
Bill of quantities	To support construction. This should include volumes of required excavation of materials, construction, silt removals[20], import of material to support cost estimation and how this links to land access. Reference should also be made to what is going to be done with any excavated materials. This information supports future cost estimations for material and labour.
Monitoring plan[21]	To demonstrate success in the context of NN and determine any future maintenance requirements. Upstream and downstream monitoring can support the precautionary approach to avoid overly favourable estimates from being calculated. See also Stage 5 (Section 3.6).

[19] See: The Construction (Design and Management) Regulations 2015 (legislation.gov.uk)

[20] See Section 3.3.4 for more information regarding sediment removal during construction.

[21] Using a planner to support your monitoring may help. See: Monitoring Planner | The RRC

3.4.3. Advantageous design criteria for optimisation

Key questions

- **How can tree species be chosen to support the efficacy of the buffer?** Faster growing species, such as poplar and willow will assimilate nutrients into biomass more quickly during their early stages of growth. This immobilises the nutrients into the woody part of the trees.

  Deep rooted trees, such as willow, are also beneficial as they support bank stabilisation, reducing flood risk whilst recovering nutrients and preventing P bound sediment from falling into watercourses.

  When planting trees it must be ensured that the density of tree planting immediately adjacent to the watercourse will not provide too much shade so as to not suppress the growth of aquatic plants.
- **Will vegetation impact the efficacy of the buffer?** As is outlined in Table 3:1, it is essential to consider the vegetation type when planting a buffer strip. There are also advantageous design criteria which should be considered:
  - Native vegetation is important for nutrient assimilation, organic matter production to fuel denitrifying bacteria, and to increase surface roughness to promote sedimentation.
  - The longevity of vegetation is important. Woody vegetation and perennials are preferable for N as they store nutrients in their biomass for longer than annual plants which can re-release stored nutrients when they die and decay. For P, however, grasses are more efficient at removing nutrients from the system. To optimise nutrient uptake, consideration should be given to the combination of species planted as well as their independent longevities.
  - Research suggests that mixed species stands promote greater nutrient assimilation rates than monocultures. Having a range of native species will also provide greater benefit the ecosystem in terms of biodiversity, drought resistance and resistance to disease and pests.
  - Implementing a short rotation coppice (SRC) scheme should be considered to encourage nutrient uptake and ensure that nutrients are removed from the system regularly. These systems must be managed on a rotational approach to ensure that the nutrient removal is consistent year-round[22].
- **Are there any other advantageous design criteria?** A riparian buffer can restore degraded areas of riverbank. These areas of riverbank may be prone to erosion during high flow events. It may be necessary to include temporary bank stabilisation

[22] Year-round coppicing can provide economic benefits to the land-owner as the harvested biomass can be sold for profit.

using natural materials while vegetation establishes. Once vegetation, trees, and / or SRC systems have established, they will stabilise the riverbank and provide flood resilience. This is dependent upon suitable management and maintenance.

Key recommended information

- **Optional:** If bank stabilisation is required, a design will be required to show the materials to be used and how it will be installed.
- **Optional:** If the deployment location for the buffer is an area of degraded riverbank, a plan for any temporary bank stabilisation may be needed.

3.4.4. Evaluation of the design process

For a scheme to be conducted with reasonable scientific certainty that it will reduce nutrient loading downstream, the design must consider and provide the necessary information explained in Stage 3 (Section 3.4). This process aims to minimise the uncertainty associated with the mitigation scheme whilst mitigating any possible risks. The below table should be filled in at this stage to ascertain firstly if the scheme is suitable, and if relevant, where further information needs to be provided. Some cells have been left blank.

Report section	Comments	All information has been provided	There are gaps in the information provided
3.4.2	Essential design criteria		
3.4.3	Advantageous design criteria for optimisation		

	Response statements
If ALL green (noting that 3.4.3 is recommended, not required)	The information provided regarding the design detail is appropriate and sufficient.
If 3.4.2 is red	Not enough information has been provided regarding the essential design criteria for the scheme. Additional information is required to fully evaluate the scheme design

3.5. Stage 4 – Implementation Process

3.5.1. Introduction

The design of a riparian buffer strip will need to be supported by an implementation plan outlining the stages and issues which need to be addressed before the scheme is deployed. These are discussed below and aim to support the eligibility of the proposal. For the plan to progress, consideration also needs to be given to the management and maintenance requirements of the scheme. These too are outlined below to aid the formulation of a plan to assess the requirements for operating and maintaining a robust and effective mitigation scheme in perpetuity.

Headline Messages:

Riparian buffer strip schemes must be supported with an implementation plan. This plan must outline the following subsections:

- Constraints
- Site clearance
- Vegetation establishment and management
- Management plan

A checklist for these points is provided below.

3.5.2. Consideration of constraints

Key questions

- **Have any constraints been identified in the feasibility assessment?** There may have been constraints on the deployment of a riparian buffer strip that were identified during Stage 2 – Feasibility and / or Stage 3 – Design Process. The implementation plan should consider how these constraints will impact the implementation of the buffer strip.

Key information required

- A description of how constraints identified at the feasibility stage will be mitigated in order to reduce risks to the implementation of the buffer strip.

3.5.3. Site clearance and earthworks

Key questions

- **Will the location for deployment of the riparian buffer strip require preparation?** Depending on the vegetation present at the deployment location and the planting plan for the site, clearance of existing vegetation may be required. This will be highly dependent on the design and what vegetation is currently present at the site. Also, if watercourse dredged spoil such as heaps and levees, redundant flood banks and raised ground that reduce hydrological connectivity with the watercourse are present then these should be removed. It is recommended that the design is reviewed, and key related elements checked.

Key information required

- An environmental management plan must be provided. This must ensure that:
  - Existing biodiversity is protected;
  - Trees and vegetation are not detrimentally impacted unless they need to be cleared to plant replacement vegetation;
  - Soil compaction is prevented;
  - Soil erosion and sediment pollution is mitigated;
  - Buried services are protected; and,
  - Topsoil and subsoil are handled separately, and the disposal of surplus soil is suitably managed.
- There must also be an indication of what site clearance and earthworks procedures are likely during the implementation phase.
- Information regarding incident management and waste management, if relevant, should be provided.
- This should be completed as part of the design criteria: review recommended.
- Evidence that the requirements of the Solent Woodland Project Development Guidance have been reviewed and included.

3.5.4. Vegetation establishment and management

Key questions

- **Is the riparian buffer strip going to be planted?** Buffer strip vegetation can be established through planting or through natural colonisation. Planting a buffer strip will allow for faster colonisation than if the system is left to colonise naturally and will likely increase the speed with which the buffer reaches peak nutrient removal efficacy. For those elements which need planting, details should be provided on how the planting will be implemented, including the mix of species that will be planted in the buffer.
- **Will vegetation require management?** Nutrient removal via assimilation by vegetation can be temporary unless suitable vegetation management plans are in place to remove vegetation from the buffer. It is recommended that mowing of grass / herbaceous vegetation zones occurs annually, doing this at the end of the growing season can help prevent decomposition remobilising nutrients. Mowing however will decrease the density and structural complexity thereby decreasing the buffer efficiency so careful consideration as to how and when this is undertaken is required. Trees must also be actively managed to encourage increased growth and therefore nutrient immobilisation in the wood of the tree, this may not be required as

often as annually and should be done in rotation. Thinning or harvesting the trees can damage the soil and impact on pollution trapping however impacts can be minimised by good management practices (e.g. by phasing or zoning harvesting work) or appropriate design of the buffer (e.g. having a narrow strip of permanent trees immediately adjacent to the watercourse). If vegetation is being removed from a buffer strip, a plan is required to show how disposal of the vegetation will not result in re-circulation of the stored nutrients within the same catchment, as this would reduce the efficacy of the buffer strip.

- **Do soils and vegetation need any protection?** Vegetation should be protected during its establishment phase. Saplings need to be protected from browsing by rabbits, hares, and deer, this can be achieved by appropriate fencing or individual tree protection. Planting vegetation may result in soil exposure, which can be mobilised along with associated nutrients during rainfall events. The implementation plan should look to minimise the risk of soil erosion following vegetation planting.

Key information required

- A planting plan is required. This plan should show the locations and planting densities of the species to be planted in the buffer.
- The implementation plan should detail protection measures, such as fencing, to stop plants being eaten or damaged following colonisation and measures to mitigate soil erosion risks during planting.
- Plants may die because of disease, consumption, or damage. It is recommended that buffer strip proposals provide a supplementary planting plan detailing checks on vegetation and further planting where required.
- A vegetation management plan is required to show how vegetation will be managed to maximise efficacy of the buffer.

3.5.5. Outline management plan

Key questions

- **Why is an outline management plan required?** For a buffer strip to provide effective treatment in perpetuity, a robust management and maintenance plan must be formulated prior to implementation. Any routine operation and maintenance requirements must be identified and there must be certainty that these will take place. The maintenance plan is highly dependent upon the observations gained from the monitoring described in Section 3.6.3.
- **What aspects of a buffer strip might need long-term management?** As detailed above, vegetation management may be required to support the long-term efficacy of a riparian buffer for nutrient removal. To assist with the establishment and maintenance of vegetation in a riparian buffer, fencing may be required. This fencing will require maintenance. It may be necessary to manage bank erosion that if left unchecked could erode the buffer and remove it as a nutrient mitigation option. However, it is noted that well-vegetated buffers particularly those with trees along the riverbank should stabilise riverbanks against erosion.

Key information required

- Stakeholder responsibilities should be clearly identified and outlined within the management plan, covering the key roles and responsibilities related to the scheme. Contact information for stakeholders should be provided.
- A monitoring plan that is appropriate for adaptive management that ensures continuation of processes necessary to achieve NN. Key assessment should include:
    - Bank maintenance: Regular maintenance checks are required for riparian buffer strip schemes to ensure the stability of riparian banks. If any issues associated with riverbanks arise, appropriate remedial work must be actioned.
    - Vegetation management: As detailed above, the management plan should consider possible needs for supplementary planting and vegetation removal.
    - If fencing is required, maintenance of fencing may be needed to protect vegetation.
- Emergency maintenance may be required if bank failure occurs at a riparian buffer strip scheme. The management plan should account for emergency maintenance requirement. Emergency contact information should be included within the plan.

3.5.6. Evaluation of the implementation process

For the proposal to progress, all pieces of information outlined above in Stage 4 (Section 3.5) must be provided to show evidence that all possible risks associated with implementation have been reduced as much as possible and that any remaining risks will be mitigated against. If necessary, the tables below can be used to identify which pieces of information are missing and the applicable response statement will outline exactly what steps are necessary to complete this stage. Some cells have been left blank.

Report section	Comments	All information has been provided in the relevant format (mapped, tabular, or summary)	There are gaps in the information provided
3.5.2	Consideration of constraints		
3.5.3	Site clearance and buffer implementation works		
3.5.4	Vegetation establishment and management		

Report section	Comments	All information has been provided in the relevant format (mapped, tabular, or summary)	There are gaps in the information provided
3.5.5	Outline management plan		

	Response statements
If ALL green	This provides comprehensive information regarding the implementation process for the buffer strip and maximises the likelihood that this buffer strip will be constructed appropriately and managed effectively.
If SOME red	The application is missing mandatory information. Please provide the relevant missing information so that the implementation process assessment can be evaluated.

3.6. Stage 5 – Post-implementation Monitoring and Evaluation

3.6.1. Introduction

Either modelling or monitoring is required to estimate the baseline nutrient load that will enter the riparian buffer strip. The nutrient reduction that can be claimed upfront can then be calculated using the schemes specific efficacy value generated from the maximum

Monitoring requires a plan that is bespoke to the individual scheme, therefore the following subsections must be considered alongside the site-specific environment.

These sections **MUST** be included, regardless of the desired credit outcome:

- Baseline monitoring / modelling.
- Post-implementation monitoring to support adaptive management focusing on scheme function.

Buffer strip schemes have the option to carry out the following:

- Monitoring to gain additional credits.

nutrient efficacy values applied to the baseline load (see section 2). The maximum nutrient efficacy values are precautionary, therefore post-implementation monitoring may prove the scheme to be more effective than the designated nutrient removal efficiencies. This would allow further nutrient credits to be claimed by the buffer strip scheme. Monitoring, although not required to evidence the validity of the credits claimed upfront, must be used as part of an adaptive management regime that will support the buffer strip to continue providing nutrient mitigation in perpetuity. Adaptive management monitoring should focus on scheme function.

3.6.2. Monitoring to gain additional N and / or P credits

Key questions

- **What is monitoring to gain additional credits?** Post-implementation monitoring is required in scenarios where an individual wants to claim additional credits, above those calculated in the precautionary estimates. Unless the user wishes to claim additional credits, post-implementation water quality monitoring is not required to verify the nutrient removal potential of the scheme[23].
- **When should monitoring to gain additional credits be employed?** Baseline monitoring does not need to have been undertaken to gain additional credits from post implementation monitoring. The expense and complexity of monitoring the water quality impacts of buffer strips, may make undertaking post implementation monitoring to gain additional credits costly and therefore not cost effective. If post-implementation monitoring to gain further credits is being done, however, the following sections outline the minimum requirements.
- **How should monitoring to gain additional credits be carried out?** Post-implementation monitoring to gain additional credits should be carried out using the same monitoring design as suggested for baseline monitoring.
- **How long is monitoring to gain additional credits required for?** To gain additional credits, post-implementation monitoring should be conducted for a minimum of three years to capture seasonal variation in nutrient removal efficacy at inter-annual timescales to claim additional credits. It should continue until the system can be shown to have reached a quasi-equilibrium whereby its nutrient removal efficacy is approximately stable over time. More frequent monitoring particularly in the initial few years may make it quicker to identify when stabilisation has occurred.
- **What should happen to the monitoring data?** This should be decided and agreed at the beginning of the monitoring programme including approaches to assess data. It is likely to be of interest to LPAs, NE and other third-party stakeholders (e.g. local catchment groups and academics). Building a supporting

[23] The percentage efficiency figures are suitably precautionary, therefore post-implementation water quality monitoring is not required for schemes which do not wish to gain additional credits.

open-source database including of the efficacy rates, will be highly beneficial for future programmes.

Key information required

- For additional nutrient credits to be quantified, an evidence base of consistent monitoring is required. The nutrient credits should be calculated from a monitoring plan that demonstrates at least a minimum of three years of water quality and flow data beyond the baseline Consistent monitoring will be required to prove that an equilibrium has been reached.

3.6.3. Post-implementation monitoring to support adaptive management

Key questions

- **What is monitoring to support adaptive management?** Post-implementation monitoring is not required to confirm the calculated nutrient loads are accurate (due to the precautionary pre-determined efficacy values), however it should still be implemented with a focus on the scheme's function. Regular visual inspections and repeat photography will support early identification of any requirements for adaptive management and may help to highlight conditions whereby the nutrient removal being delivered could start to reduce; for example, problems related to vegetation or bank erosion. The monitoring data should be used in an adaptive management regime that can highlight when different aspects of the management plan detailed in Section 3.5.5 may be required to be implemented.
- **What are the requirements of monitoring to support adaptive management?** Visual inspections and repeat photography should begin once the scheme has been implemented. The period and regularity of inspections will depend on the scheme, location, and if other schemes are likely to be implemented. The scheme must be reviewed for at least 3 years annually and then the future required monitoring plan and timelines should be determined. This plan should ensure the scheme's in-perpetuity benefits.

Key information required

- A post implementation monitoring plan to support adaptive management. The monitoring plan does not need to specify water quality monitoring unless it is required to instigate maintenance. It should include consistent visual inspections and repeat photography to support adaptive maintenance and ensure long term nutrient removal function and efficacy of the riparian buffer.

3.6.4. Summary evaluation

The required information outlined above in Stage 5 (Section 3.6) should be provided to evidence that the proposed riparian buffer strip scheme has accounted for the need to monitor its performance and use this monitoring to guide management of the scheme. If necessary, the tables below can be used to identify which pieces of information are missing and the applicable response statement will outline exactly what steps are necessary to complete this stage. Some cells have been left blank.

Report section	Comments	All information has been provided (where relevant)	There are gaps in the information provided
3.6.2	Monitoring to gain additional N and / or P credits		
3.6.3	Post-implementation monitoring to support adaptive management		

	Response statements
If ALL green (where relevant)	The application provides comprehensive information regarding the monitoring and evaluation process for the buffer strip scheme and maximises the likelihood that this buffer strip will be designed appropriately, function as intended and be managed effectively.
If SOME red	The application is missing mandatory information from Stage 5 – Implementation Process. Please provide this information so that the implementation process assessment can be evaluated.

4. References

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