REPORT

Solutions Report

Phosphate Mitigation Solutions

Client: West Berkshire Council

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05	29.07.2024	Version 5 corrections to Table 4.1	C. Brodie and E. Harris	O. Bowers	I. Dennis

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Abbreviations

Abbreviation	Description
ADAS	Agricultural Development and Advisory Service
AMP	Asset Management Planning
BNG	Biodiversity Net Gain
CIRIA	Construction Industry Research and Information Association
CJEU	Courts of Justice of the European Union
CSF	Catchment Sensitive Farming
CSS	Countryside Stewardship Scheme
CW	Constructed Wetlands
DEFRA	Department for Environment Food and Rural Affairs
Dutch-N	Dutch Nitrogen Joint Cases
EIA	Environmental Impact Assessment
ELMS	Environmental Land Management Scheme
GIS	Geographic Information System
HRA	Habitats Regulations Assessment
ICW	Integrated Constructed Wetlands
LPA	Local Planning Authority
LURB	Levelling Up and Regeneration Bill
NN	Nutrient Neutrality
P	Phosphate
PTPs	Package Treatment Plants
PTWs	Portable Treatment Works
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
TAL	Technically Achievable Limit
TP	Total Phosphorus
WBC	West Berkshire Council
WFD	Water Framework Directive
WRC	Water Recycling Centre
WwTWs	Wastewater Treatment Works
WINEP	Water Industry National Environment Programme

Units of Measurement

Unit	Description
$g/m^2/yr$	Grams per metres squared per year
Kg	Kilogram
kg/yr	Kilograms per year
kg/ha/yr	Kilograms per hectare per year
kg TP/d	Kilogram of Phosphate per day
kg TP/yr	Kilogram of Phosphorus per year
km	Kilometre
ha	Hectare
m	Metres
m^2	Metres Squared
m^3	Metres cubed
Ml/d	Megalitres per day
mg/l	Milligrams per litre
mg TP/l	Milligrams of Phosphorus per litre
SRP/ha/yr	Orthophosphate per hectare per year
t/ha	Tonnes per hectare
t/yr	Tonnes per year
TP/yr	Total Phosphate per year
TP/ha/yr	Total Phosphate per hectare per year
Yr	Year
%	Percentage
£	Pound Sterling
£/ha	Pound Sterling per hectare
£/kg	Pound Sterling per kilogram
£/yr	Pound Sterling per year
£/kg/yr	Pounds sterling per kilogram per year

Executive Summary

Introduction and purpose of this report

Following the Dutch Nitrogen Joint Cases ('Dutch-N') in the Court of Justice of the European Union, which ruled that where a European important site, i.e., Special Areas of Conservation and Special Protection Areas, is failing to achieve condition due to pollution, the potential for a new development to add to the nutrient load is *necessarily limited*.

Similarly, internationally important wetland sites which are designated as Ramsar sites are also included in the judgement, as under national policy they are afforded the same protection as Special Areas of Conservation and Special Protection Areas. The Dutch-N case has informed the way in which Regulation 63 of the Conservation of Habitats and Species Regulations 2017 (as amended) ('the Habitats Regulations 2017') should apply to pollution related incidents and has resulted in greater scrutiny of proposed developments that are likely to increase nutrient loads to designated sites.

This report sets out short, medium and long-term mitigation options that could potentially be used to offset the additional nutrient load from a new development within the catchment of the River Lambourn Special Area of Conservation, including potential strategic options to manage nutrient (phosphate) inputs and allow further residential development to proceed. The range of potentially suitable and robust solutions considered within this report are subject to a comment with respect to Natural England's mitigation requirements. It was evident upon initial review that some solutions would be unviable and would not offer a sufficiently robust solution and as such were not included for consideration further within this report.

Potential nutrient mitigation options

Following a detailed review of scientific literature and best practice guidance, a range of different nutrient management solutions have been identified. The following types of solutions were identified as potentially viable for use in the River Lambourn catchment:

- Nature-based solutions: that would be implemented within a catchment to reduce diffuse-source phosphate loadings.
- Drainage and wastewater-based interventions: solutions that apply to wastewater and drainage and will require targeted interventions (excluding nature-based and wetland solutions) or specific local policies to be implemented.

The following solutions are considered in this report:

- Short-term solutions: taking land out of agricultural use; cessation of fertiliser and manure application; riparian buffer strips; wet woodlands; cover crops; bringing forward planned wastewater improvements; sustainable drainage systems; portable treatment works; alternative wastewater providers; retrofitting more water efficient fittings; package treatment plants; and cesspools.
- Medium-term solutions: constructed wetlands; beaver reintroduction; and retrofitting SuDS.
- Long-term solutions: use alternative wastewater treatment providers; rectifying misconnections within the sewer system; improvement of wastewater distribution infrastructure; and incentivising commercial water efficiency.

Housing projections

To understand the mitigation required to meet the upcoming housing requirements, a review of local plan documents and housing projections was undertaken.

Conclusions and next steps

The following sets out the next steps required to develop the solutions presented within this report to functioning nutrient mitigation solutions:

- A database or spreadsheet-based tracking tool to register and record the nutrient loading for each development and through what schemes this will be mitigated.
- A tracking tool could also be expanded to track ‘credits’ achieved through mitigation schemes that can be used for biodiversity net gain and carbon offsetting.
- Standardised legal agreements could be drawn up and used as a basis in future mitigation schemes. Conservation covenants are one option that should be explored.
- A Mitigation Plan should be created to formulate developer contributions. In establishing such a plan, the key solutions and timescales for expected delivery would set out in addition to the roles of relevant contributors and organisations relevant. This will allow for quantification of when and how many credits will be available.

Action Plan

The Action Plan expands on the recommended next steps listed above and aims to summarise solutions which are feasible and specific to the Lambourn catchment. Where possible, it summarises the likely costs, timescales, and delivery mechanisms. Emerging solutions which may be applicable to the Lambourn catchment are also summarised. These are potential solutions which are in the initial stages of data gathering and therefore lack information required to determine whether they fulfil the Habitat Regulations mitigation solutions criteria.

1 Introduction

1.1 Nutrient neutrality and the Dutch Nitrogen Case

A joint legal case was brought to the Court of Justice of the European Union (CJEU) regarding authorisations for schemes with respect to agricultural activities on sites protected by the *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and species* ('The Habitats Directive') and where nitrogen deposition levels already exceeded the critical load.

Following the Dutch Nitrogen Joint Cases (the 'Dutch-N') in the CJEU which ruled that where a European important site, i.e., Special Areas of Conservation (SACs) and/ or Special Protection Areas (SPAs), is failing to achieve condition due to pollution, the potential for a new development to add to the nutrient load is "*necessarily limited*". Similarly, internationally important wetland sites which are designated as Ramsar sites are also included in the judgement, as under national policy they are afforded the same protection as SACs and SPAs. The Dutch-N has informed the way in which Regulation 63 of the Habitats Regulations 2017 should apply to new projects that could potentially exacerbate existing pollutant loads.

The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 brought the Habitats Regulations 2017 into force from 1 January 2021. The Dutch-N ruling has resulted in greater scrutiny of proposed developments that are likely to increase nutrient loads to internationally important sites where a reason for unfavourable condition is an excess of a specific pollutant. The Dutch-N case applies to National Site Network sites which are already in an unfavourable condition due to high nutrient levels in combination with the importance of the designation. The types of developments which are impacted include:

- New residential units, student accommodation, care homes;
- Tourist attractions including campsites, glamping pods, and holiday lets;
- Commercial developments where overnight accommodation is provided;
- Agricultural development including additional barns, slurry stores; and
- Anaerobic Digesters.

In March 2022 Natural England published updated guidance on water quality and nutrient neutrality (NN) advice (NE785) which identified a further twenty protected sites that are adversely affected by nutrient pollution. The River Lambourn SAC was identified as being in an unfavourable condition due to excessive phosphorus (P) loading. As a result, West Berkshire Council (WBC) is not able to grant planning permission for new developments that provide overnight accommodation or result in increased phosphorous export loads within the catchment of the River Lambourn SAC unless it can be clearly demonstrated that they will not have a detrimental impact in terms of P loading to the designated protected area. Natural England has advised that this can be achieved by providing appropriate avoidance and mitigation measures that result in the development being nutrient neutral.

1.2 Purpose of this report

This report discusses potential solutions that could be used to offset increased P loadings and allow development in the catchments of the River Lambourn SAC to proceed whilst remaining nutrient neutral. **Section 2** of this report provides an overview of the River Lambourn SAC and its contributing catchments. Housing projections to identify the scale of likely mitigation requirements required within the River Lambourn SAC catchment and WBC area are also laid out in **Section 2**. Potential P management solutions are described in **Section 3**, and **Section 4.** provides a summary of the main findings of the report and recommendations for next steps.

Natural England has not reviewed this report, therefore the report has not received agreement or endorsement from Natural England.

2 Background

Natural England provide Conservation Objectives for Habitats Sites. These are referred to in the Habitats Regulations 2017 and provide a framework which informs the need for 'Habitats Regulations Assessments' (HRA) under Regulation 63 and Regulations 75 to 77.

2.1 River Lambourn SAC

Natural England's 2019 supplementary advice on the European Site Conservation Objectives relating to the River Lambourn SAC (site code: UK0030257) summarises the habitat as a classic example of a lowland chalk river. The River Lambourn is approximately 32.6 km long and has a catchment area of approximately 215 km^2. It has a moderate ecological status and is also designated as a Site of Special Scientific Interest (SSSI).

The River Lambourn rises 152 m above sea level north of Lambourn, flows through a rural chalk downland landscape for most of its length, and flows down to a confluence with the River Kennet east of Newbury. In its upper reaches, between the villages of Lambourn and Great Shefford, the Lambourn flows mainly through agriculturally improved pasture and arable fields. In its mid to lower reaches, south of Great Shefford to Bagnor it meanders through disused water meadow systems, wet pastures and woodlands. The river has a stable, gently meandering form, with a characteristic gravel rich substrate.

The river is fed by the chalk aquifer of the north Wessex Downs, which gives rise to highly calcareous water. Because the river is dominated by spring flow from the aquifer, the flow in the river is dependent on groundwater levels. In the upper river, the spring flows will cease entirely, and the river will dry up. This section of the river will only return once winter rains have filtered into the aquifer, and groundwater levels rise. These temporary reaches of chalk rivers are known as 'winterbourne', and they have developed their own unique ecology.

Additional habitats associated with the River Lambourn include areas of fringing reed swamp, tall fen and willow carr. The river has been modified in places by creating side channels to feed water meadows and mills, and there are a number of weirs and sluices. Despite these small modifications, the River Lambourn is regarded as one of the least-modified and least abstracted rivers in lowland England.

The qualifying features (habitats and species) with respect to the SAC designation are described as:

- H3260 Water courses of plain to montane levels with aquatic plants such as water crow-foot (*Ranunculion fluitantis* and *Callitricho-Batrachion)* vegetation;
- S1096 Brook lamprey (*Lampetra planeri); and,*
- S1163 Bullhead (*Cottus gobio).*

Figure 2.1 shows the River Lambourn surface water catchment:

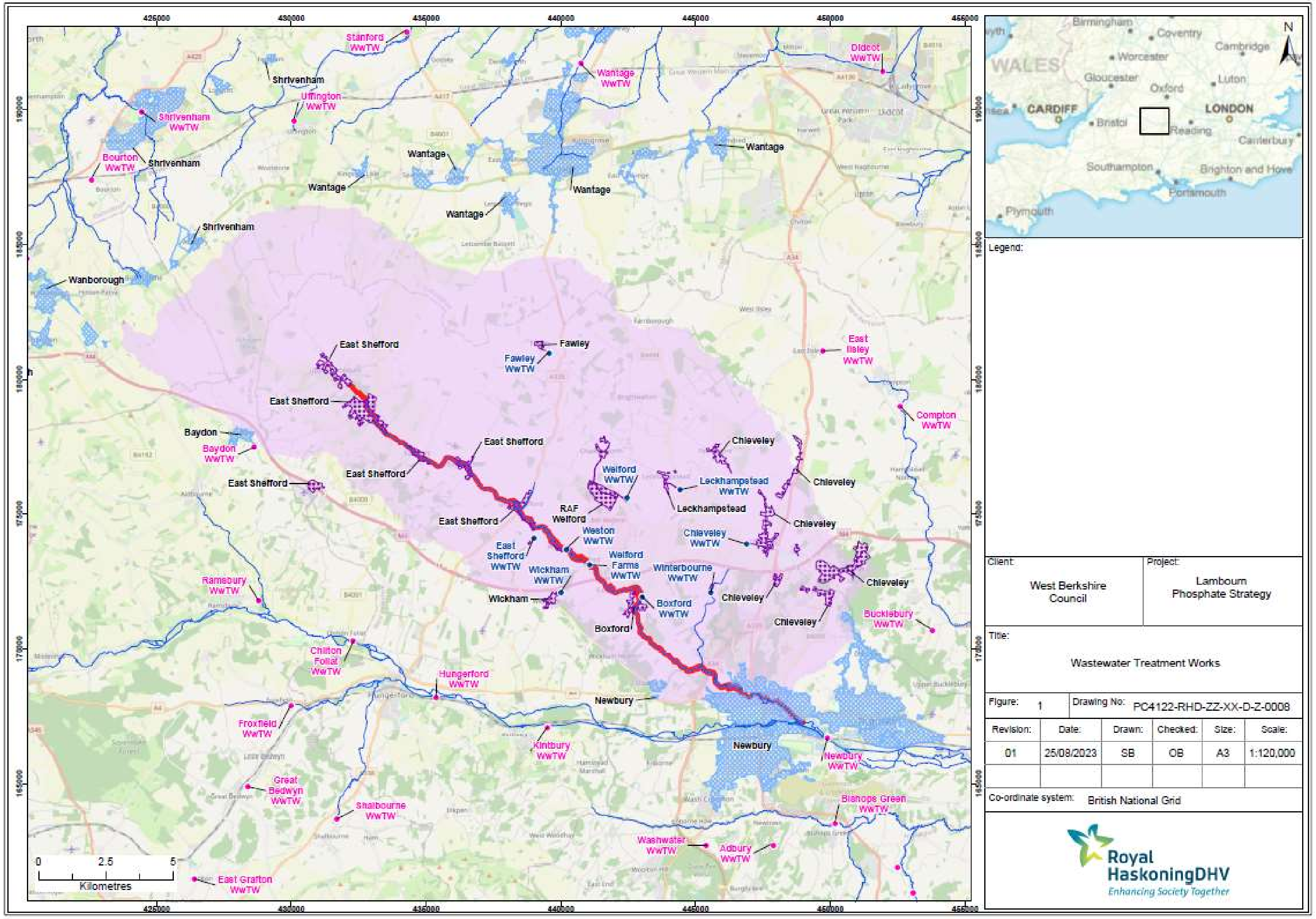

Figure 2.1: River Lambourn Catchment

2.2 Projected mitigation requirements

2.2.1 Methods and approaches

A review of the emerging local plan data and housing projections was undertaken to understand the mitigation required to meet the upcoming housing requirements. The additional P loading from the projected housing was calculated using the West Berkshire commissioned River Lambourn Phosphate Budget Calculator (The Calculator) (Royal HaskoningDHV, 2023). The parameters and values of The Calculator have been agreed upon following consultation with Natural England and replaces the previous version (Natural England 2022). Worst-case scenarios were assumed to ensure the P loading value is not understated and to provide the precautionary approach required by case law. For example, conservative assumptions were taken on future permit limits and land use types.

The following approach was used and assumptions were selected based on evidence:

- Local Planning Authorities (LPAs) are required by law to produce an annual report which demonstrates whether they have a deliverable supply of homes to meet their planned housing requirement over the next five years. Nutrient neutrality (NN) guidance has affected the delivery of new housing and therefore the five-year land supply. As such the delivery of housing is a key pressure, more so than other accommodation types, and is therefore the focus of this report;
- All new dwellings were assumed to be houses with an average occupancy of 2.38 persons per dwelling;
- It is assumed by Natural England that anyone living in the NN catchment also works and uses facilities in the catchment. Therefore, wastewater generated by commercial and industrial development is not considered, removing the potential for double counting of human wastewater arising from different planning uses;
- Other types of overnight accommodation, e.g., campsites, holiday homes, hotels, etc., that do not fall under the same use class as dwelling houses (Class C) are not considered, as there are no projections on the likelihood or number of these accommodation types being brought forward;
- The previous land use of the sites was derived from aerial imagery;
- Where the land use type was uncertain, it was assumed to be general arable which represents one of the dominant land use types in the catchment and has a runoff coefficient close to the average of all the land uses;
- The proposed land use following development was assumed to be medium-density urban;
- The soil drainage type was derived from Soilscapes (Cranfield Soil and AgriFood Institute, 2018)[1] and the dominant soil type was found to be freely draining in the upper Lambourn catchment and impeded drainage in the lower reaches of the catchment;
- The Wastewater Treatment Works (WwTWs) that a proposed development will drain to was estimated using Geographic Information System (GIS) data on the existing catchment;
- A 20% buffer was applied to the calculations in line with Natural England guidance on NN (Natural England, 2022);
- A water usage standard of 120 litres/person/day and an effluent concentration at 90% per permit are applied; and,

[1] *Soilscapes soil types viewer - Cranfield Environment Centre. Cranfield University (landis.org.uk)*

- The catchment that a development will contribute the P loading to was determined by the location of the WwTWs (also referred to as Water Recycling Centres (WRCs). Some developments will be located in one surface water catchment, but the wastewater (and majority of the nutrient contribution) will drain to a different catchment.

It was assumed that all developments currently held up would require nutrient mitigation by the end of 2025, and some developments are delayed to significant extent in which they require immediate mitigation solutions. This assumption ensures that mitigation requirements reflect the realistic demand for mitigation. The calculations consider reductions in permit limits that will take effect at the end of the Asset Management Planning (AMP) 7 Cycle (January 2025). Examples of WwTW with a reduction in the permit limit from January 2025 include Chieveley WwTW from 0.9 mg/l TP to 0.4 mg/l TP and East Shefford WwTW from 0.9 mg/l TP to 0.09 mg/l TP.

Furthermore, proposed 2030 permit limit reductions were also included following the Department for Levelling Up, Housing and Communities announcement (18th November 2022). It was assumed that only WwTWs with a current Population Equivalent (PE) of greater than 2,000 residents would be operating at Technically Achievable Limit (TAL) by 2030. The TAL for TP is 0.25 mg/l. It is assumed within the calculations that planned upgrades to WwTWs will be implemented by 2030 at the latest, however information on the target dates and scale of these improvements is pending confirmation from the water company and DEFRA (expected May 2024). It is noteworthy that some WwTWs may not achieve TAL, particularly smaller WwTWs and Chieveley is assumed to be operating at TAL.

2.2.2 Housing budget projections

The projected housing growth was derived from the Draft Local Plan (currently at Inquiry) and current planning applications.

A total of 872 dwellings are projected to be constructed across approximately 81.6 ha within the catchment. The total area was calculated by adding the area from each existing allocation, application and an area of 0.04 ha/dwelling (equivalent to 25 dwellings per hectare) was assumed for neighbourhood plans and Windfall. WBC advised a search had been undertaken on dwellings currently held up at Reserved Matters and Condition Discharge stages as well as current full and outline applications. A review of all planning applications submitted to the LPA within the Lambourn catchment since the 16th of March 2022 notification has been undertaken to determine the residential units currently held up due to nutrient neutrality requirements.

The number of dwellings associated with windfall was derived using values given within the Draft Local Plan. The plan notes the number of windfall dwellings is based on previous data and the number up for 2025-2041 is 140 dwellings per annum. The maps within the Draft Local Plan have been used to establish approximately 25% of 140 is relevant to the Lambourn SAC catchment and 35 dwellings per year is based on this.

Table 2.1 provides a breakdown of the number of dwellings and their status.

Table 2.1: Development status and number of dwellings in West Berkshire District

Status	No. of Proposed Dwellings across Plan Period	Source
Existing applications	133	Supplied by West Berkshire Council Planning Application Search
Allocations	154	West Berkshire Emerging Local Plan allocations including windfall
Windfall	560 (35 dwellings per year)	

Status	No. of Proposed Dwellings across Plan Period	Source
Five-year land supply (minus allocated sites)	25	West Berkshire Emerging Local Plan Five-Year Land Supply Position
Total	**872**	

The following equation was used to calculate the phosphorus loading requirements per development.

$$TP_{loading} = \left(\frac{D \times O \times W \times C}{1000000} \times 365.25\right) + \left(\left(A \times R_f\right) - \left(A \times R_c\right)\right) \times P$$

Where:

$TP_{loading}$ = The TP loading (kg/yr), D = No. of dwellings, O = occupancy rate (persons/dwelling), W = water usage (l/person/day), C = effluent concentration (mg/l), A = surface area of site (m2), R_f = future land use runoff coefficient (kg/ha/yr), R_c = current land use runoff coefficient (kg/ha/yr) and P = Precautionary buffer.

Equation 1: Phosphorus loading requirements per development

The expected excess P loading per year across the NN catchment area is provided in **Table 2.2** and the total amount of P required to be mitigated per year is represented visually in

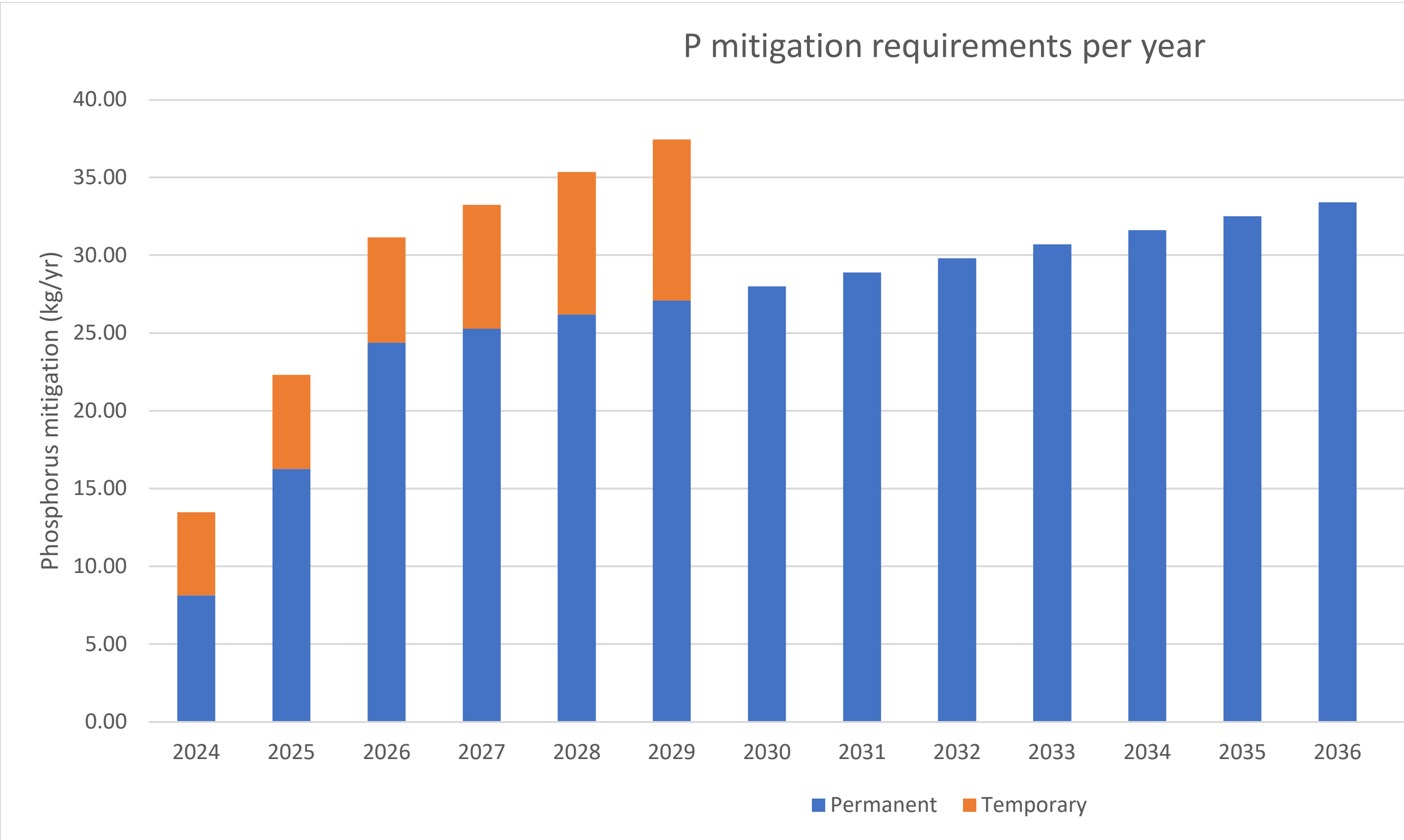

Figure 2.2. This includes both temporary mitigation (required until planned upgrades at wastewater treatment works are completed) and permanent mitigation (required for the duration of the development).

The total mitigation required up to 2041 is 48.28 kg/yr. In 2024 the total TP mitigation required is 13.48 kg/yr. The comparatively high mitigation requirements during this period reflects the immediate need for mitigation for the dwellings currently held up in the planning system and the higher effluent permit limits prior to planned technical upgrades and permit reductions post 2025. The TP loading per year in 2025 and 2026 is 8.83 kg/yr, between 2026-2029 is approximately 2.10 kg/yr for each year and between 2030-2041 is 0.90 kg/yr. These values were calculated using the available data set out in this section and equation 1. A value of 0.06 kg/yr/dwelling is calculated from dividing the budget total in Table 2.2 by the total number of dwellings in Table 2.1.

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Table 2.2: Total P loading and mitigation required across the West Berkshire District Plan period

<table>
<tr><th rowspan="2">Mitigation type</th><th colspan="19">Phosphorus loading over the Plan period (kg/yr) (per year)</th></tr>
<tr><th>2024</th><th>2025</th><th>2026</th><th>2027</th><th>2028</th><th>2029</th><th>2030</th><th>2031</th><th>2032</th><th>2033</th><th>2034</th><th>2035</th><th>2036</th><th>2037</th><th>2038</th><th>2039</th><th>2040</th><th>2041</th><th>Total</th></tr>
<tr><td>Permanent</td><td colspan="3">8.13</td><td colspan="15">0.90</td><td>37.92</td></tr>
<tr><td>Temporary</td><td>5.36</td><td colspan="2">0.70</td><td colspan="3">1.20</td><td colspan="12">0.00</td><td>10.36</td></tr>
<tr><td>Total</td><td>13.48</td><td colspan="2">17.66</td><td colspan="3">6.31</td><td colspan="12">10.83</td><td>48.28</td></tr>
</table>

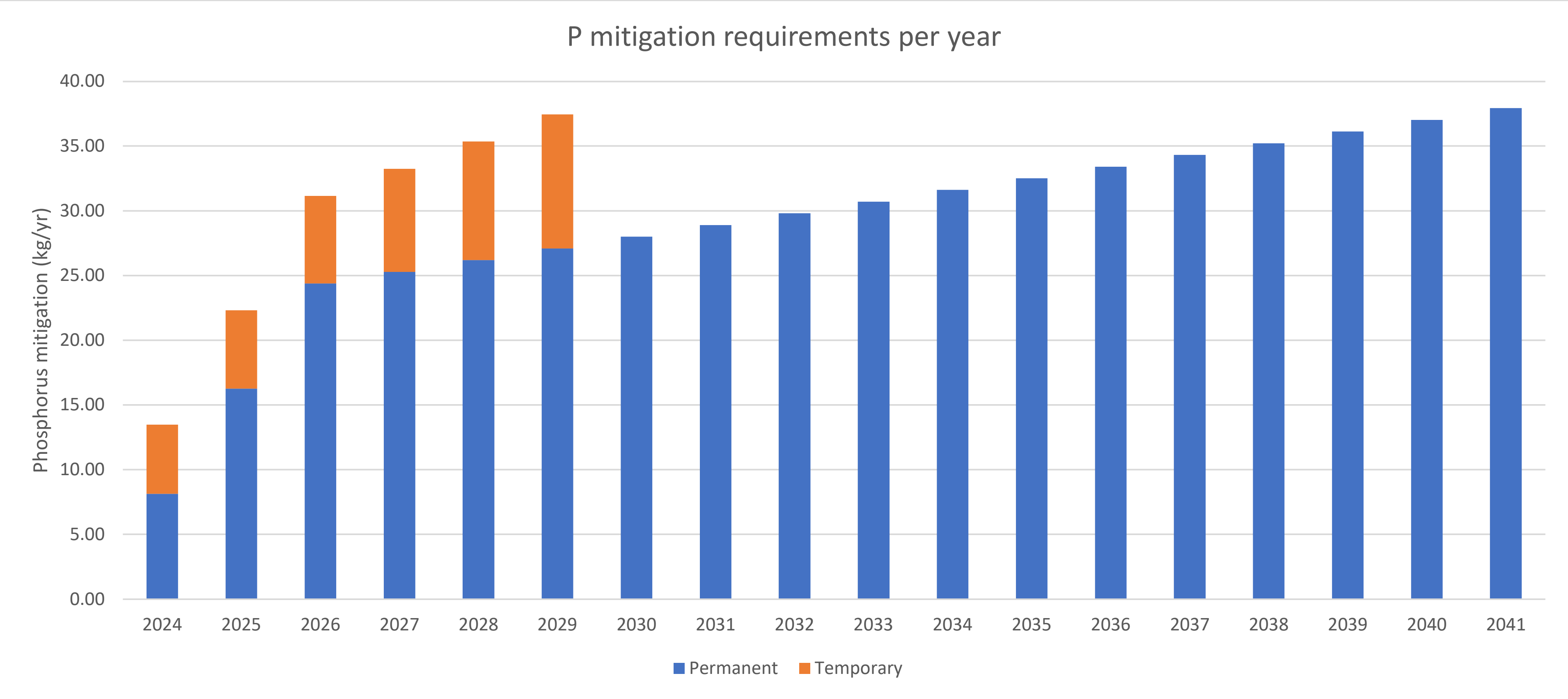

Figure 2.2: Total P mitigation required per year across the Plan period

3 Potential nutrient management solutions

The general characteristics of the Lambourn catchment are described in **Section 2.1**. The catchment characteristics are defined further:

- Upper Lambourn: typically freely draining soils, with an average rainfall of 700-900 mm/yr and comprising primarily arable land; and
- Lower Lambourn: typically slightly impeded soils, with an average rainfall of 600-700 mm/yr and comprising primarily arable land.

3.1 Types of nutrient management solution

This section outlines potential solutions that can be used to achieve P mitigation for the purpose of allowing planning applications to proceed by demonstrating nutrient neutrality. Solutions where there is the potential to comply with Natural England's HRA principles (such as using the best available objective and scientific information, proportionate, precautionary and securable in perpetuity) were assessed further (Natural England, 2023). The solutions have been classified into the four following categories:

- Nature-based solutions: solutions that aim to use natural processes (physical, chemical, and biological) to reduce diffuse- and point-sources of nutrients from within a catchment;
- Runoff management solutions: solutions that aim to reduce nutrient supply through the management of surface runoff and sediment supply (excluding nature-based solutions);
- Wastewater management solutions: solutions that aim to manage wastewater as a source of nutrients (excluding nature-based solutions); and
- Demand management solutions: solutions that aim to reduce nutrient loadings by reducing the production of wastewater at source, e.g., reduced water usage of residential properties.

Some established solutions for P management at a catchment-scale do not provide the certainty that is required for mitigating new developments and therefore have not been assessed. Examples of established solutions include:

- Methods adopted by Catchment Sensitive Farming (CSF) which is a government land management initiative (Natural England, 2022) that provides support such as:
  - farm advice; and
  - training and capital grants targeted at priority catchments to help reduce soil erosion and nutrient losses to water (air and soil).

The following section presents a brief overview of the potential short, medium and long-term nutrient management solutions that are considered and describes how they are appraised (**Section 3.2**). This is followed by a more detailed description and appraisal of Nature-based Solutions, which this report focusses on (**Section 3.3**), Runoff Management Solutions (**Section 3.3.2**), Wastewater Management Solutions (**Section 3.3.3**) and Demand Management Solutions (**Section 3.3.4**).

3.2 Overview of potential nutrient management solutions

The potential P management solutions that are considered are listed in **Table 3.1**. This overview table provides an indication of the timescales in which the solution could be delivered. A full description of each solution is provided in the subsequent sections of this report, as indicated by the cross references provided in **Table 3.1**. Natural England advice on mitigation principles which was issued to LPAs in March 2022 was used to assess the suitability of solutions and to facilitate the solutions in meeting the requirements of the Habitat Regulations.

Table 3.1: Potential nutrient management solutions

Type of Solution	Solution	Delivery Timescale	Further Information
Nature-based	Silt traps	Short-term	Section **Error! Reference source not found.**
	Riparian buffer strips	Short-term	Section 3.3.1.1
	Wet woodlands	Short-term	Section 3.3.1.3
	Constructed wetlands	Medium-term	Section 3.3.1.4
	Willow buffers	Short-term	Section 3.3.1.4
	Beetle banks	Short-term	Section 3.3.1.6
	Beaver reintroduction	Medium-term	Section 0
Run-off management	Taking land out of agricultural use	Short-term	Section 3.3.2.1
	Conversion of agricultural land to solar farms	Short-term	Section 3.3.2.2
	Cessation of fertiliser and manure application	Short-term	Section 3.3.2.3
	Cover crops	Short-term	Section 3.3.2.4
	Installation of SuDS in new developments	Short-term	Section 3.3.2.5
	Retro-installation of SuDS in existing developments	Medium-term	Section 3.3.2.6
	Paddock management	Short-term	Section 3.3.2.7
Wastewater management	Expedite planned improvements to treatment works	Short-term	Section 3.3.3.1
	Improvements to wastewater treatment works	Medium-term	Section 3.3.3.2
	Installation of cesspools and capture outputs from private sewage systems	Short-term	Section 3.3.3.3
	Replacement of package treatment plants / septic tanks	Short-term	Section 3.3.3.4
	Installation of portable treatment works	Short-term	Section 3.3.3.5
	Use alternative wastewater treatment providers	Long-term	Section 3.3.3.6
	Rectifying misconnections to combined systems	Long-term	Section 3.3.3.7
	Improve existing wastewater distribution infrastructure (reduce leakage from foul sewer network)	Long-term	Section **Error! Reference source not found.**
Demand management	Retrofit water saving measures in existing properties (local authority, registered providers, public buildings)	Short-term	Section 3.3.4.1
	Incentivise commercial water efficiency	Long-term	Section 3.3.4.2

3.2.1 Description of nutrient management solutions

The terminology used to describe the characteristics, performance and evidence base for each option in the subsequent sections is set out in **Table 3.2**.

Table 3.2: Description of nutrient management terminology

Descriptor	Definition
Description of solution	This section provides an overview of the P management solution and the activities required for its implementation.
Delivery timescale	Delivery timescales are classified as follows: ▪ Short: The solution could potentially be implemented in one year or less. Planning permission, policy changes and significant funding are not likely to be required, although it may be necessary to obtain third party consents and agreements. ▪ Medium: The solution could potentially be implemented over a period of one to five years. Planning permission, policy changes and/ or third-party funding are likely to be required, alongside other third-party consents and agreements. ▪ Long: It is likely to take more than five years to implement the solution. Environmental Impact Assessment (EIA), major policy changes and/ or significant funding are likely to be required, alongside other third-party consents and agreements.
Duration of operation	The longevity of the solution is classified as follows: ▪ Temporary: The solution is likely to remain in place for up to five years and could be secured through interim or temporary agreements with third parties. ▪ Impermanent: The solution is likely to remain in place for between five and 10 years, secured in agreement with third parties. ▪ Permanent: The solution is likely to remain in place for more than 10 years and could be secured in perpetuity through long term agreements with third parties.
Nutrient removal	This section provides a summary of the nutrient removal that the solution could potentially deliver.
Applicability	This section provides a high-level summary of the potential applicability of the solution in the catchment(s), including constraints posed by farm type, land use, etc.
Management and maintenance	This section describes the management and maintenance activities that are required to maintain the effectiveness of the solution.
Additional benefits	This section provides a description of any additional secondary benefits that could be delivered alongside the primary nutrient management aim of the solution.
Best available evidence	Sufficient reliable evidence which provides certainty that mitigation may be effective. It should be noted, with some types of mitigation there will be, (particularly with novel or complex mitigation), uncertainty as to the exact effectiveness the mitigation may deliver.
Wider environmental considerations	This section provides a description of any wider environmental constraints that could be associated with the solution. Potential unintended consequences are considered within this section.
Evidence of effectiveness	This section summarises any evidence available to demonstrate the effectiveness of the solution in managing nutrient supply.
Precautionary	The precautionary principle is an approach to ensure sufficient certainty via application of a precautionary an efficacy value based on the evidence can be applied, or provision of greater mitigation than required. For example, monitoring efficacy of a mitigation measure may provide evidence and therefore certainty which can be relied upon.
Securable in perpetuity	Natural England Nutrient Neutrality Principles guidance (Wood *et al.*, 2022) defines 'in perpetuity' timeframe between 80-125 years and 'securable' is defined as practical certainty that the mitigation measures will be implemented and in place at the relevant time.

Descriptor	Definition
	Mitigation measures which can be secured through legally binding obligations that are enforceable are understood to be securable in perpetuity. Likewise, a mitigation measure which can offer tax relief or a grant for example, although not legally enforceable, is considered to offer a degree of security.
Cost estimate	This section provides an outline estimate of the costs associated with implementing the solution. Costs are given over 80 years (the lifetime of the development) to allow for direct comparison with long-term solutions. Costs typically exclude administration and legal costs which are likely to apply to all solutions. Costs also exclude development of monitoring regimes to measure the effectiveness.

3.3 Short-term, medium-term & long-term solutions

3.3.1 Nature-based solutions

3.3.1.1 Silt traps

Silt traps can be installed on farms to intercept sediment bound phosphorus and prevent the nutrients from entering the surface drainage network. Error! Reference source not found. shows an example of a silt trap in situ and Error! Reference source not found. provides an overview of silt traps as a solution.

Figure 3.1: Silt trap installed in a stream (Source: IRD Duhallow, 2015)

Table 3.3: Key considerations of silt traps

Descriptor	Definition
Description of solution	Silt traps / engineered logjams can be installed on farms to catch sediment bound P. Silt traps are basins set upstream that capture sediments. Fine sediments to which P is bound become physically immobilised, i.e., deposited, behind a barrier due to a reduction in flow energy, decreasing the volume of sediment and therefore P within the watercourse. As a result of its early removal, there is also a reduced potential for P to become soluble further downstream and detrimentally impact water quality. The benefits of silt traps for water quality are well established.

Descriptor	Definition
Delivery timescale	Silt traps require limited infrastructure and, depending upon their location, may not require any environmental permits. They can therefore be delivered as a short-term solution.
Duration of operation	Silt traps are predominantly considered an impermanent solution due to the need for maintenance to remain effective (see Management and Maintenance below). Natural England’s framework for assessing engineered logjams (NECR545) (Lloyd et. al, 2024a) indicates that this solution cannot be as a permanent solution for phosphorus mitigation.
Nutrient removal	The P removal rate of silt traps is dependent on site-specific variables such as location, soil type, rainfall, frequency of de-silting and is likely to differ between locations. Silt trap schemes should not be reliant upon water supply from one single upstream surface water source as this does not provide sufficient certainty of the long-term nutrient removal. The Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS) guidance indicates that TP removal is regularly reported between 25-75% for well-designed and sited systems during design condition events. A conservative estimate of 25% can be used as a guide for predicting nutrient removal, however, cannot be relied upon for securing mitigation. Natural England’s framework indicates that a removal rate can only be determined through robust baseline and post0implementation monitoring.
Applicability	All farm typologies applicable, particularly farms which have a high risk of silt runoff.
Management and maintenance	Silt traps would need to be maintained periodically to remove accumulated fine sediments and ensure that they remain effective as sediment and nutrient traps. Fine sediments removed from the silt traps would need to be disposed of appropriately to prevent them becoming a new source of nutrients in the catchment.
Additional benefits	Silt traps are effective in improving the quality of water in the drainage network by reducing sediment supply to downstream watercourses. This can result in improved habitat quality for aquatic plants, invertebrates and fish.
Best available evidence	Although there is considerable evidence that supports the use of silt traps as effective measures to remove sediment from flowing water, e.g., Environment Agency (2011), there is limited evidence of their effectiveness in removing nutrients.
Wider environmental considerations	Periodic removal of the sediment containing nutrients and any other chemicals which have collected requires consideration with particular respect to re-use or waste disposal in addition to any environmental considerations related to removal and transport.
Evidence of effectiveness	This solution is effective beyond reasonable scientific doubt. Although there is evidence to indicate effective sediment capture, the effectiveness can vary considerably under different conditions, poor design and poor management. As such, there is currently uncertainty regarding nutrient removal rate.
Precautionary	Yes – with the assumption that the 25% is adopted a precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	Yes – management agreements will likely need to be put in place, especially where land is leased. Replacements will be required as the lifetime of the silt trap (approximately 30 years) is less than the developments.
Cost estimate	Capital costs are between £1,000-£4,000 with additional maintenance costs of £500 per annum.

3.3.1.2 Riparian buffer strips

Riparian buffer strips can be created around a watercourse to create separation between itself and an agricultural field. **Figure 3.2** shows an example riparian buffer strip, and **Table 3.4** provides an overview of them as a solution.

Figure 3.2: Aerial view of a riparian buffer strip (Source: Iowa State University Forestry Department, 2016)

The removal rates for the Lambourn for this type of solution have been calculated using a 29% removal rate as a precautionary value based on data provided in Natural England's framework for assessing riparian buffer strips (NECR541) (Lloyd *et. al*, 2024b).

Table 3.4: Key considerations of riparian buffer strips

Descriptor	Definition
Description of solution	Riparian buffer strips are zones of permanent grass and/ or woodland cover greater than 5 m wide that act as a separation barrier and filter between an agricultural field and a watercourse. They can also act as a filter between point sources of nutrients and the surface drainage network. Nutrient reductions are achieved through sedimentation of P-bound particles and uptake via vegetation. Vegetation within buffer strips increases surface roughness and reduces runoff rates, which in turn promotes infiltration (Hoffman *et al.,* 2009). Riparian buffer strips are typically located at field margins (less productive areas) and are, therefore, more likely to be adopted by farmers. This provides good certainty that the land use will be maintained and not revert back to agriculture. The upstream sources are important to maintaining the predicted removal rates from the buffer strips. If these sources are altered or removed, then the nutrient removal of the buffer could be adversely impacted. A minimal amount of monitoring will be required to confirm removal rates are consistent with the predicted rate. This is likely to comprise six months to yearly for approximately the first five years, then every 10 years for the lifetime of the scheme. Nutrient credits are earned by reducing nutrient outputs to below quota targets. The lower the nutrient output of a source, the greater number of quota targets are met, and credits earned. Therefore, should a riparian buffer strip outperform its predicted design capacity, this will be identified by the monitoring process and allow the additional nutrient removal to be used as nutrient credits. Key considerations of riparian buffer strips include the following: ▪ Where buffer strips are used as a long-term, in perpetuity solution, the long-term management of the adjacent fields presents a risk. Should the adjacent land be taken out of agricultural use or significant changes in agricultural practices, e.g., conversion to solar or wind farm, this could reduce the phosphorus sources and subsequent removal potential. ▪ Improper upkeep of buffer strip vegetation; fencing and excess silt could reduce the removal potential. ▪ Should overland flow not be maintained, and flow becomes channelised, the buffer strip will not operate at optimum removal rates.

<table>
<tr><th>Descriptor</th><th>Definition</th></tr>
<tr><td></td><td>Farmers may be unwilling to commit to 80-year agreements initially. Therefore, shorter agreements, e.g., 20-30 years, may be necessary to establish this solution, with the ability to renew agreements.</td></tr>
<tr><td>Delivery timescale</td><td>Buffer strips do not require extensive infrastructure or investment, although fencing may be necessary where used in livestock farming. They do not require planning or environmental permits and can therefore be delivered in the short term.</td></tr>
<tr><td>Duration of operation</td><td>Buffer strips are likely to be operational over long timescales, depending upon landowner agreements. However, because they do not require any specific infrastructure, they are considered impermanent and subject to changes in farming practices.</td></tr>
<tr><td>Nutrient removal</td><td>
P removal efficiency increases with buffer width, with 15-20 m buffers being the most effective (seen in Figure 3.3).
Buffer strips composed of woody material can store a significant amount of P biomass (Fortier et al., 2015), and are more effective at trapping sediment than grasses (Hoffmann et al., 2009; Anguiar et al., 2015).
Soil type may affect P removal efficiency, for example loam soils typically have lower P removal rates than silt soils when buffer strips consist of grass (Lee et al., 1998; Chaubey et al., 1995). Site-specific factors also play a role in controlling nutrient reductions from riparian buffer strips and should be considered when considering the most appropriate location for buffer strip placement. For example, the orientation of the buffers and the adjacent agricultural activity are both important considerations. Typically, riparian buffers adjacent to agricultural land used for cropping will achieve the greatest real-world reduction rates due to the potential to remove a high degree of phosphorus bound sediment in the runoff.
Natural England’s framework provides the following efficacy coefficients:
<table>
<tr><th>Riparian buffer strip width</th><th>TP reduction efficacy</th></tr>
<tr><td>10m+</td><td>0.22</td></tr>
<tr><td>12m+</td><td>0.25</td></tr>
<tr><td>15m+</td><td>0.29</td></tr>
<tr><td>18m+</td><td>0.32</td></tr>
<tr><td>20m+</td><td>0.34</td></tr>
<tr><td>24m+</td><td>0.38</td></tr>
<tr><td>25m+</td><td>0.39</td></tr>
<tr><td>30m+</td><td>0.43</td></tr>
</table>
The efficacy values presented above assume that a 2m buffer strip is already in place. This ensures that any buffer strip used for mitigation are consistent with the legal baseline.
The phosphorus removal rates for a 15m buffer are expected to be:

0.30 kg/ha/yr (range 0.09 – 0.63 kg/ha/yr) in the upper Lambourn catchment; and
1.27 kg/ha/yr (range 0.37 – 2.67 kg/ha/yr) lower Lambourn catchment.

It is noted that the greatest potential for riparian buffer strip uses exists within the upper catchment because this is where most of the arable land is located.
</td></tr>
</table>

Descriptor	Definition
Applicability	Can be applied to all agricultural land and farm typologies where land is suitable for riparian buffers to be grown.
Management and maintenance	Maintenance is predominantly limited to cutting vegetation and the removal of accumulated sediment. Woodland buffers, particularly those containing willow, have less onerous maintenance requirements than grassland buffers. Where input flows are too great to promote infiltration, ponds could be added to remove sediment and would also need to be de-silted. Monitoring of management practices and water quality will be required to establish both the baseline and the post-establishment functionality.
Additional benefits	▪ Riverbank stabilisation ▪ Improved water quality ▪ Erosion reduction ▪ Habitat creation ▪ Improved amenity value ▪ Biodiversity Net Gain (BNG) ▪ Carbon offsetting – potential for stacking ecosystem services credits carbon offsetting and BNG could provide an additional revenue stream, similar to the Countryside Stewardship payment scheme
Best available evidence	Riparian buffer strips are an established nature-based solution for pollution control within catchments and have been employed for multiple years.
Wider environmental considerations	Buffer strips may support sensitive species or communities and may need management to avoid damaging these. Fenced-off buffer strips may limit livestock access to a water source and wildlife throughways. Alternative water sources and fenced throughways may be required. Where groundworks are operating within a flood zone then it is important that the flood storage area is not reduced.
Evidence of effectiveness	This method is effective beyond reasonable scientific doubt.
Precautionary	Yes – a precautionary approach can be applied to this solution until and after site specific information becomes available. Using Natural England framework, a 2m buffer strip is already assumed.
Securable in perpetuity	Yes – management agreements may be needed where the solution is intended to provide medium/ long term solutions to ensure it does not revert to agricultural use and is maintained correctly. Conservation covenant agreements can be a mechanism for securing perpetuity.
Cost estimate	Typical annual costs are approximately £786/ha, with an approximate upfront cost of £183/ha (Farmscoper, 2023). This accounts for costs from loss of production, seasonal cutting and annual establishment, as well as cost savings from no crop management. This is fairly well constrained with annual Countryside Stewardship Grants that are paid at £440 - £512 ha/yr. It is not possible to stack Countryside Stewardship Grants with Nutrient Neutrality.

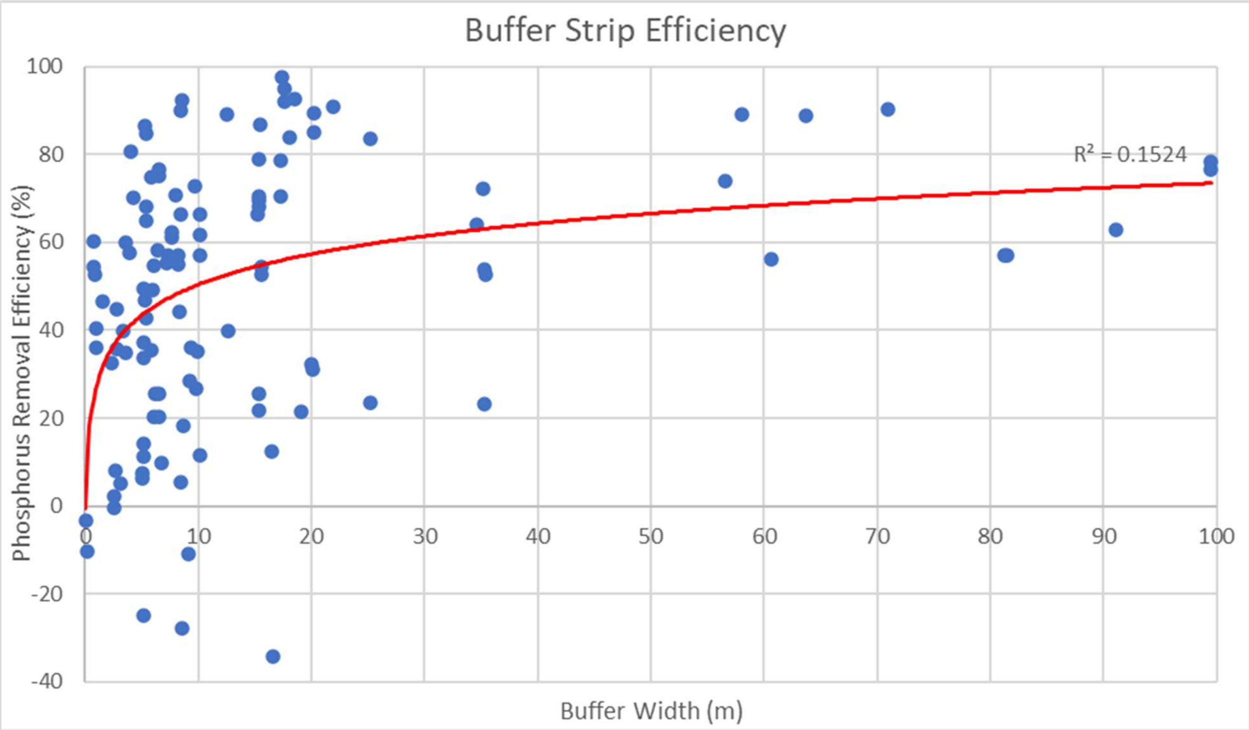

Figure 3.3: Buffer strip efficiency by width (edited from Tsai et al., 2016)

3.3.1.3 Wet woodlands

Wet (floodplain) woodlands can be created or restored on river floodplains and remove nutrients from the watercourse by enhancing sediment deposition and nutrient uptake by plants. **Figure 3.4** shows a created area of wet woodland, and

Table 3.5 provides an overview of wet woodlands as a solution.

Figure 3.4: Area of wet woodland created in Salford in 2016. The project led to the attenuation of pollutants by biodegradation (Source: Natural Course, 2017)

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Table 3.5: Key considerations of wet woodlands

Descriptor	Definition
Description of solution	Wet woodlands occur on soils that are permanently or seasonally wet. Wet woodlands increase hydraulic roughness, which slows flow velocities and allows sediment and particulate bound pollutants to fall out of suspension and enter storage on the floodplain, or in a designed wetland setting. Riparian woods reduce diffuse pollution by trapping fine sediment runoff generated by agricultural practices. Nutrient removal strategies involve either restoring existing floodplain woodland or creating new areas of planting. Natural Flood Management interventions can divert water out of the channel and into the floodplain wetland. Reversion of areas to floodplain woodland could deliver nutrient mitigation of land which is naturally wet, not only reducing the impact of runoff from the agricultural land, but also increasing the connectivity of the woodland. This would likely achieve greater nutrient reductions than purely the change of land use would predict.
Delivery timescale	Wet woodlands do not require extensive infrastructure, investment, planning or environmental permits, and can therefore be delivered in the short term. However, the relatively slow growth rate of trees means that it may take some time before they become fully effective.
Duration of operation	Wet woodlands are likely to be operational over long timescales, depending upon landowner agreements. Because of the long timescales required for them to become established, wet woodlands are considered to be permanent features.
Nutrient removal	TP removal potential: Uncertain – likely to be similar to riparian buffers (Median TP retention rates of 67%). Data on nutrient removal rates in wet woodlands is scarce. A study by Olde Venterink *et al.* (2006) analysed floodplain communities and their relative abilities to influence water quality through nutrient retention, though this does not consider key elements such as sediment trapping and associated standing water. Due to the lack of reliable literature, TP removal rates are assumed to have some similarities to riparian buffer strips. The phosphorus removal rates are expected to be: ▪ 0.57 kg/ha/yr (range 0.17 – 1.20 kg/ha/yr) in the upper Lambourn catchment; and ▪ 2.42 kg/ha/yr (range 0.70 - 5.06 kg/ha/yr) lower Lambourn catchment.
Applicability	Wet woodlands can be created on riparian land holdings that are likely to be inundated regularly, e.g., within the functional floodplain and/ or Flood Zone 3, as defined by the Environment Agency.
Management and maintenance	Wet woodlands by their nature thrive on non-intervention and limited to no management. Light management includes: ▪ Coppicing some areas to create a more diverse woodland structure with some clearings; ▪ Allowing woodland edges to grade upwards from grass, through scrub, to woodland; ▪ Coppicing to provide wood fuel; ▪ Managing areas of willow and scrub to maintain some open areas and wet scrub; ▪ Controlling invasive species, e.g., Himalayan balsam (*Impatiens glandulifera*).
Additional benefits	▪ Recreation ▪ Carbon sequestration ▪ Biodiversity conservation ▪ Air pollution reduction ▪ Flood risk reduction ▪ Short rotation coppice utilised as biofuel
Best available evidence	No – there is doubt over removal rates due to lack of research and data.

Descriptor	Definition
Wider environmental considerations	Once established, wet woodland could potentially support sensitive species and as such may need careful management to avoid adversely affecting these species. Care should be taken to ensure that the creation of wet woodlands does not contribute to the spreading of invasive species.
Evidence of effectiveness	There is limited scientific evidence to demonstrate with certainty that wet woodlands are effective at mitigating TP. As such, there is currently uncertainty regarding nutrient removal rate and monitoring is likely to be required.
Precautionary	Yes – a precautionary approach can be applied to this solution via using the minimum (<35%) removal rate, as per the approach taken with riparian buffer strips in Section 3.3.1.2 until and after site specific information becomes available.
Securable in perpetuity	Yes – it is anticipated that this solution will be suitable for the lifetime of the development. Land that is suited to wet woodland is very unlikely to revert to any other land use.
Cost estimate	Bare root stock suitable for tree planting programmes for typical wetland species are in the range of £2-£3 per tree, which may be reduced to <£1 if ordered in bulk from suppliers. Bulk order tree guards are a similar price. For broadleaved trees, planting density is recommended 1,600 to 2,500 trees per hectare (Creating Tomorrow's Forests, 2021). However, these figures are for general woodland creation, not floodplain wet woods where additional space may be needed for wetland landscaping, e.g., pools and scrapes. Typical planting costs (trees + guard) may be ~£5,000 per ha. Grants of up to £10,000/ ha could be available through the government's England Woodland Creation Offer (Gov.uk, 2022) and nutrient mitigation credits may need to match this figure. Total costs: up to £10,000/ha.

3.3.1.4 Constructed wetlands

Constructed wetlands (CW) have been used for nutrient removal and water treatment since the 1950s for improving water quality from industrial and agricultural water sources (Vymazal, 2010). CWs are designed to facilitate natural processes that can remove nutrients from the influent water source(s) to a wetland (Vymazal, 2010). Key considerations of constructed wetlands are presented in **Table 3.6**.

Table 3.6: Key considerations of Constructed Wetlands

Descriptor	Definition
Description of solution	Nutrient removal occurs through natural process such as physical, biogeochemical, and biological. ICW have proven to be the most effective in removing nutrients such as P.
Delivery timescale	CWs require engineering design and construction and may require planning permission, an environmental permit and an impounding licence. Depending on the watercourse, it is likely that a flood defence consent and a flood risk activity permit may also be needed. The River Lambourn catchment is characterised by a groundwater driven flow regime from the underlying chalk bedrock aquifer, overlaid by alluvial deposits offers viable opportunity for effective CW systems. The gentle gradient and meandering planform of the river together with the LiDAR mapping, ground truthing and historical evidence of a past braided river system underscore the connectivity of water levels between floodplains, tributaries, and the main channel, suggesting suitability for implementing effective nutrient removing CW. It is estimated that a CW scheme for nutrient removal will take between one to two years to complete.
Duration of operation	With an appropriate management and maintenance plan, it is likely CWs will be able to provide nutrient mitigation in perpetuity.
Nutrient removal	TP retention in wetlands occurs through physical processes such as soil/ sediment accretion, sediment adsorption, chemical precipitation, and burial of organic P (Vymazal, 2007). Biological processes include microbial and plant uptake convert P into forms that are available for biological uptake. It should be noted that P does not cycle to gaseous forms and thus is retained within wetlands, rather than being permanently removed.

Descriptor	Definition
	Various studies have shown that even with minimal intervention, CWs have maintained a high percentage removal efficiency for P (Cooper *et al.,* 2020). Nutrient removal rates are highly variable and should be derived following advice published in the Constructed Wetlands Framework (Johnson, 2022).
Applicability	Intensively farmed catchments with likely sources of agricultural runoff would result in a large nutrient source and be suitable for deployment of agricultural wetlands
Management and maintenance	Wetlands require periodic maintenance to remove sediment built up approximately every five to ten years. Vegetation will need to be replaced at a timescale appropriate to the lifecycle of the vegetation the wetland is planted with. Natural England's wetlands framework provides details of the aspects of a management and maintenance plan that will be needed for CW for nutrient removal (2022).
Additional benefits	A well designed and located ICW can provide: ▪ Biodiversity improvements, ▪ Water quantity and quality (additional to nutrients) management, ▪ Flood hazard management, ▪ Carbon offsetting, and ▪ Amenity and landscape aesthetic benefits (Harrington & McInnes, 2009)
Best available evidence	Yes – Although monitoring will be required to determine site specific nutrient removal the Framework Approach for Responding to Wetland Mitigation Proposal prepared for Natural England by The Rivers Trust and Constructed Wetlands Association (Johnson et al., 2022) provides evidence and notes nutrient removal accords to confidence in design.
Wider environmental considerations	Environmental considerations should include: ▪ Relatively flat topography ▪ Soils (including nutrient content), geology and hydrogeology (including groundwater level change) ▪ Hydrology and flood risk ▪ Infrastructure ▪ Nature, landscape, and archaeological conservation
Evidence of effectiveness	There is a large body of literature that provides evidence of the effectiveness of CWs for nutrient removal, which is supported by the recently release of Natural England's wetlands framework which is expressly aimed at supporting the development of wetlands for nutrient mitigation.
Precautionary	A feasibility assessment may show that a proposed wetland is not deliverable due to one or more of the environmental conditions not being met, i.e., topography does not support a wetland draining under gravity and/or flood risk.
Securable in perpetuity	It is anticipated that this solution will be suitable for the lifetime of the development. Land that is suited to wetlands is very unlikely to revert to any other land use.
Cost estimate	Cooper *et al*.,(2020): Capital costs for a 1.1ha wetland reported as: ▪ Planning, design & management £15,000 ▪ Construction £161,000 ▪ Wetland planting £18,000 ▪ Total cost £194,000 Total cost of the scheme suggested to be £500,000, which is assumed to include maintenance and monitoring Cooper *et al*., (2020): Capital costs for a 0.3ha wetland reported as: ▪ Planning, design & management £1,305 ▪ Construction £21,712 ▪ Wetland planting £7,004 ▪ Total cost £30,021 Note that the land for this site was donated

Descriptor	Definition
	Through consultation with various stakeholders and Local Authorities delivering similar schemes, a value of £300,000/ha is a reasonable cost for wetlands. This accounts for land purchase, design & permitting fees, construction, monitoring, ongoing maintenance, administration and contingency.

There are various types of CW, which are described in **Table 3.7**. However, Integrated Constructed Wetlands (ICW) can deliver the greatest number of additional benefits compared with other wetland types (Harrington & McInnes, 2009). In line with Natural England wetland framework (Johnson *et al*., 2022), wetlands should be appropriately designed and maintained.

Land et al., (2016) summarised the results of 93 studies of 203 wetlands predominantly treating agricultural sources of water. They concluded CWs have moderate removal efficiencies for TP at 46% (95% confidence interval of 37-55%).

A review of wetlands treating effluent from Water Recycling Centres (WRC) in Ireland concluded that ICWs performed best out of all types of CWs and where ICWs were well designed under rigorous guidance, they outperformed mechanical treatment for P (Hickey *et al*., 2018). A follow up study assessing the performance of the Glaslough wetland for Total Phosphate (TP) removal after four-years of operation showed a TP removal efficiency of 93.5% (Dzakpasu *et al*., 2015).

Well designed CWs that continue to receive high nutrient input loads can sustain high nutrient removal efficiencies. A study of 12 ICWs treating livestock wastewater found that these wetlands averaged soluble reactive phosphorus (SRP) removal efficiencies of > 80% over and eight-year period, with 11 of the 12 averaging removal efficiencies > 90%.

Recent studies have also been published for ICWs treating final effluent from two Anglian Water Services (AWS) WRCs in Norfolk, both of which are in Norfolk. In 2014, the Norfolk Rivers Trust (NRT) deployed an ICW to treat final effluent discharge from the Northrepps WRC. Analysis of monitoring data from the first 18 months of operation at this wetland reported high nutrient removal efficiencies, with TP concentrations reduced by 78%.

Table 3.7: Types of constructed wetland used for the treatment of polluted water sources (after Dotro et al., 2017; Hickey et al., 2018)

Type	Description
Horizontal Subsurface Flow (HF)	▪ Influent water flows horizontally through a sand- or gravel-based filter ▪ Water is kept below the wetlands surface ▪ Plants (emergent macrophytes[2]) grow in the filter media[3] and help to promote nutrient removal processes ▪ Filter media is mainly saturated, with anaerobic (oxygen-free) conditions dominating nutrient removal processes
Vertical Subsurface Flow (VF)	▪ Influent water is pumped intermittently onto a filter and percolates vertically through the filter ▪ Between pumping of water, air re-enters the filter and aerobic (oxygen-rich) conditions dominate ▪ Emergent macrophytes are grown at the surface of the wetland
Hybrid wetlands	▪ Combine HF and VF wetland types

[2] *A plant that has adapted to live in an aquatic (water) environment, both freshwater and saltwater. The term macrophyte is used to distinguish them from algae and other microphytes.*
[3] *A type of filter that uses a bed of sand, peat of man-made materials such as tyres, foam, crushed glass, or geotextile membranes to filter water for drinking aquaculture or other purposes to improve water quality.*

Type	Description
	▪ Most commonly a VF compartment is followed by an HF compartment
Free water surface (FWS)	▪ Resemble natural wetlands, with shallow water and emergent macrophytes ▪ FWS can either be engineered rectangular waterbodies or can be designed to fit in with landscape and termed ICWs ▪ Water is retained for longer in FWS (longer hydraulic residence time (HRT)) than in other types of wetlands

3.3.1.5 Willow buffers

Willow buffers consist of short-rotation willow coppice irrigated with wastewater from a development and removes a significant amount of P from the wastewater before it enters the watercourse. **Table 3.8** provides an overview of willow buffers as a solution.

Table 3.8: Key considerations of willow buffers

Descriptor	Definition
Description of solution	Short-rotation willow coppice can be used to treat wastewater by providing vegetation filter strips irrigated with wastewater to remove P from the wastewater, whilst producing woody biomass for energy purposes through a coppicing cycle (2-5 years, though commonly every 3 years). The irrigation system will not completely eliminate wastewater pollution as some wastewater by run off or percolate into groundwater. As a result, timing and irrigation rates must be considered. Evapotranspirative willow systems have zero discharge and are an alternative to irrigated systems and are typically used to treat domestic wastewater from small settlements or individual households. All influent wastewater and precipitation are evapotranspired on an annual basis with proper design. They do not require skilled personnel for operation or maintenance.
Delivery timescale	Willow buffers are unlikely to require extensive infrastructure, planning permission or environmental permits, and can therefore be delivered in the short term. The rapid growth rate of willows means that a functional solution could be delivered more rapidly than a traditional wet woodland.
Duration of operation	Willow buffers could potentially be operational over long timescales. Because they need to be regularly managed to maintain effectiveness and trees need to be periodically replaced, willow buffers are considered impermanent features.
Nutrient removal	TP removal potential: 70% long-term. Short-rotation willow coppice filter strips achieve TP removal rates of 67-74% (Larsson *et al.*, 2003; Perttu, 1994), although initial reduction rates are often closer to 95%. Lachapelle *et al.*, (2019) suggested a significant increase in available P in the soil, suggesting the soil can become saturated over time. For evapotranspirative willow systems, wastewater is constantly applied and stored as an elevated water level. P accumulation results in a P rich substrate which can be reused as fertiliser. More P is stored in the soil, roots, and leaves of the willows than in the woody biomass (Istenic and Bozic, 2021). The recommended TP application to prevent saturation of soils is 24 kg/ha/yr (Caslin *et al.*, 2015), which is typically a lesser volume than that applied directly from domestic wastewater. This solution could be used as a form of secondary treatment after domestic PTPs.
Applicability	Willow buffers are applicable to the Lambourn catchment as the rural land which dominates the landscape allows this to be a feasible option.
Management and maintenance	Harvesting of willow would be required every three to five years and replanting every 20-25 years. This solution typically sees a 30% increase in biomass yield (Buonocore *et al.*, 2012).
Additional benefits	There are additional benefits of improved water quality and a BNG due to improved habitat.

Descriptor	Definition
Best available evidence	No – monitoring will be required to determine nutrient removal.
Wider environmental considerations	The transport of biomass to energy production plants, and implications of waste disposal from the energy plant output must be considered as this may have adverse impacts on the wider environment.
Evidence of effectiveness	No - there is limited evidence to determine the efficacy of such a scheme. Although the solution is likely to be effective beyond reasonable scientific doubt. There is the potential for P saturation within soils and monitoring should be used to evidence the effectiveness.
Precautionary	Yes – a precautionary approach can be applied to this solution until and after site specific information becomes available.
Securable in perpetuity	Yes – it is anticipated that this solution will be suitable for the lifetime of the development, though the harvest cycle may lead to variance in uptake.
Cost estimate	The cost for establishment is typically £2,500/ha. Operational costs including ploughing and cultivation and are likely to £200 - £300/ha/yr. Potential returns vary hugely depending on many variables including price received for crop and drying requirements. Rising energy costs of oil and gas may provide greater future opportunities for willow chips as a fuel source.

3.3.1.6 Beetle banks

Beetle banks are densely grassed mound constructed on agricultural land to control runoff. **Figure 3.5** depicts an example beetle bank, and **Table 3.9** provides an overview of them as a solution.

Figure 3.5: Photograph of a beetle bank (Source: Walsh, 2016)

Table 3.9: Key considerations of beetle banks

Descriptor	Definition
Description of solution	A beetle bank is a densely grassed mound approximately 3m to 5m wide and a least 0.4 m high constructed on agricultural land to control runoff.

Descriptor	Definition
	Beetle banks can be planted across slopes or along natural drainage ways to minimise runoff and soil erosion. They present a similar scenario to a riparian buffer strip (**Section 3.3.1.1**). There is also unlikely to be a high uptake amongst farmers because they need to be positioned in more productive areas in the centre of fields rather than in the margins.
Delivery timescale	Beetle banks do not require extensive infrastructure, planning permission or environmental permits, and can therefore be delivered in the short term.
Duration of operation	Once installed and established beetle banks are anticipated to be a permanent feature.
Nutrient removal	Nutrient removal rates are unknown, but likely to be similar to Riparian Buffer strips. Calculations have not been undertaken to determine the level of P removal. An assumption is made that P is removed via both the removal of small areas of farmland which would ordinarily be subject to application of P containing fertilisers, and the uptake of P via the tussock grass on the bank.
Applicability	The agricultural nature of the catchment means this could offer plausible, although possibly small-scale, solutions. The location of beetle bank installation may be limited by parameters such as soil type, which should be suitable to form a free-draining raised bank.
Management and maintenance	The earth ridge size, measuring between 3m to 5m wide and at least 0.4m high, should be maintained. The grass should be cut several times in the first year to help it establish. Once a tussocky grass mixture has been established (1 year post construction) annual grass cutting should occur. This should take place after 1st August to protect nesting invertebrates and control woody growth and suckering species. The upper bank area should be dry and therefore constructed of free-draining soils to allow insects to hibernate securely.
Additional benefits	Beetle banks provide a BNG in the form of nesting and foraging habitats for pollinators, small mammals, some farmland birds and beneficial insects which feed on crop pests. To achieve wider environmental benefits beetle banks do not require the application of fertilisers, manured and/ or lime and pesticides (except herbicides used to weed-wipe or spot-treat control of injurious weeds, invasive non-natives, nettles or bracken). Beetle banks can help to slow down, reduce or stop soil erosion.
Best available evidence	No - As there have been no calculations to determine the level of P removal, evidence cannot be drawn upon.
Wider environmental considerations	Earthworks and associated machinery fuel and transport must be considered as they may have detrimental environmental impacts. Grass cut during maintenance must be removed from the area to remove nutrients, likely incurring fuel and carbon usage. Best practice beetle bank construction is designed in order to achieve wider environmental benefits.
Evidence of effectiveness	No - Significant monitoring is likely to be required as there is a high level of uncertainty as to the P removal rates.
Precautionary	Not possible to determine at this stage.
Securable in perpetuity	There are many site-specific location parameters required to deliver a successful beetle bank scheme. There is a high level of uncertainty of success. Monitoring for Countryside Stewardship grant could act as a mechanism for securing obligations; however, this is not a firm legally binding enforceable agreement. Therefore, the scheme is not currently securable in perpetuity.
Cost estimate	Costs are assumed to be as provided for riparian buffer strips.

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3.3.1.7 Beaver reintroduction

The Eurasian beaver (*Castor fiber*) was once common in UK riverscapes but has been largely extirpated across the UK and Europe. Beavers are recognised as ecosystem engineers and 'keystone species' that can have a disproportionate impact on the hydrology, geomorphology, water quality and aquatic ecology of rivers (**Figure 3.6**) (Brazier *et al*., 2021). As such, there is now an increased interest in conservation strategies that include beaver reintroduction as part of wider river restoration and catchment management strategies.

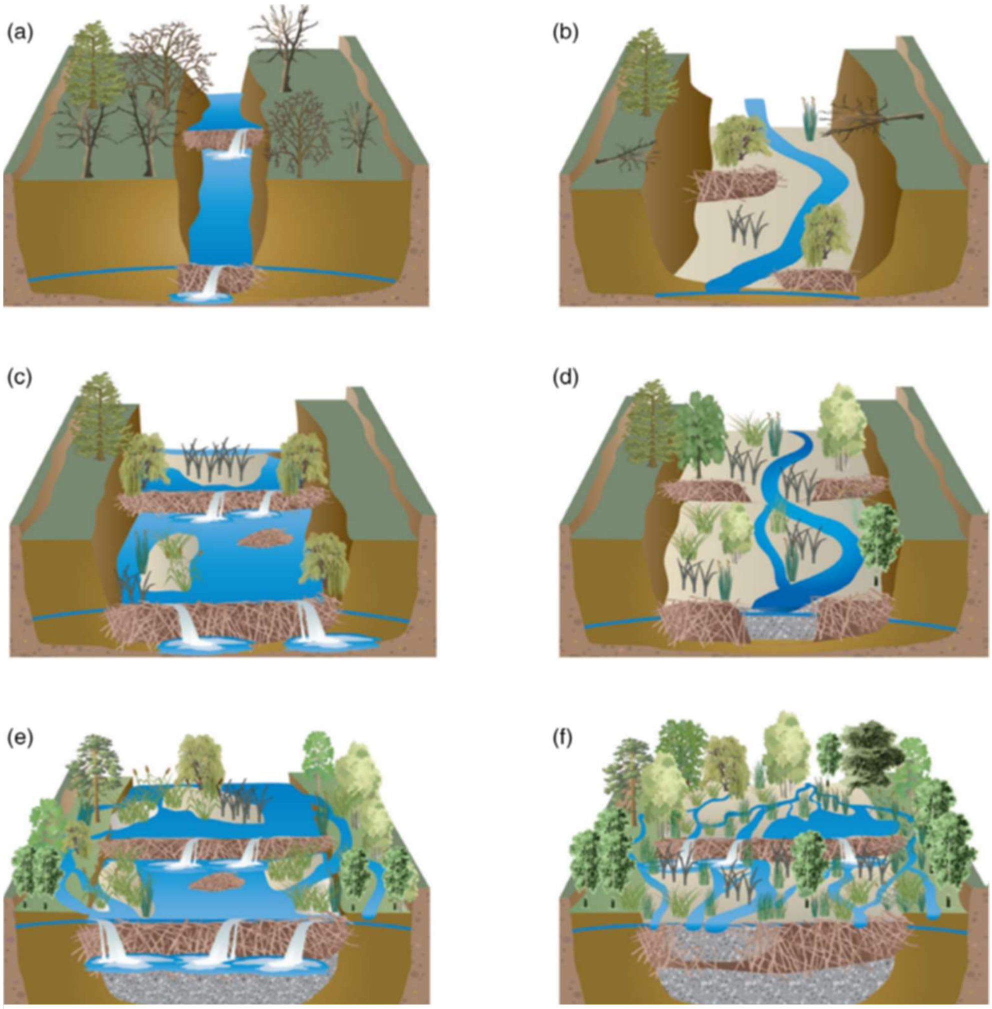

Figure 3.6 Conceptualisation of the geomorphic changes beaver damming can have on incised streams:

a) beavers dam an over-deep and straightened river channel;

b) channel widening and greater sediment mobilisation reconfigures the channel with vegetation establishment within new marginal channel areas;

c) a wider channel reduced high flow peaks, enabling more stable dams to be built;

d) vegetation establishment and sediment accumulation combined with small dam 'blowout' establishes a system of ponds;

e) process repeated with more dam building, channel widening resulting in an increase in water table height that reconnects the river to its floodplain;

f) further establishment of vegetation communities and sediment deposition results in a multi-thread channel with an increase in pond areas and areas of reduced flow that provide wetlands habitats. (Source: Brazier et al., 2021).

The damming of streams by beavers results in the creation of ponds behind the dams that allow for increased sediment deposition. These ponds can facilitate a set of linked processes that together can remove or retain P within the beaver pond complexes. Because the nutrient removal processes that are associated with beaver impacts on rivers require beavers to construct and maintain large dam and pond complexes, they cannot be relied upon to deliver nutrient removal in perpetuity.

Engineered logjams have the potential to support the same set of processes that remove nutrients as in beaver dam and pond complexes but are not supported by a large body of academic research for water quality impact as most research focusses on flood risk management. Because engineered logjams have a greater ability to be managed and maintained in the long-term, the sections below will consider them as an alternative practical solution to beaver reintroduction as a nutrient mitigation option.

Key considerations for beaver reintroduction are summarised in **Table 3.10**.

Table 3.10: Key considerations of beaver reintroduction

Descriptor	Definition
Description of solution	The Eurasian beaver was once common in UK and are recognised as ecosystem engineers and a ‘keystone species’ that can have a disproportionate impact on the hydrology, geomorphology, water quality and aquatic ecology of rivers. Their damming of streams results in the creation of ponds behind the dams, which can remove or retain P due to physical and chemical processes. As such, there is now an increased interest in conservation strategies that include beaver reintroduction as part of wider river restoration and catchment management strategies.
Delivery timescale	For beaver reintroduction schemes, likely between 4.5-6 years. Logjam schemes could be delivered in six to nine months
Duration of operation	Beaver reintroduction schemes are unlikely to last in perpetuity. Logjams with appropriate maintenance may provide long-term, in perpetuity nutrient mitigation
Nutrient removal	TP removal potential: Variable, with some studies reporting P sources from beaver ponds while UK and European studies reporting P removal efficiencies between 20%-80%. Most studies also report SRP and not TP UK and European studies reporting P removal efficiencies between 4%-60%.
Applicability	NA
Management and maintenance	Beaver reintroduction requires little management and maintenance. Logjams require maintenance to repair dams should they become damaged by high flows
Additional benefits	NFM, biodiversity and amenity benefits
Best available evidence	Yes, but evidence is more limited for UK applications
Wider environmental considerations	The following environmental considerations and assessments may be required for deploying beaver/ logjam schemes: ▪ FRA – for flood risk; ▪ WFD – for potential impacts on WFD status of a protected water body; ▪ HRA – for potential impacts on Habitats Sites; and ▪ Engagement with landowners and managers to tackle perception issues
Evidence of effectiveness	Yes, but only if assuming very precautionary estimates of N and P removal
Precautionary	Yes
Securable in perpetuity	Beaver reintroductions – no, engineered logjams – yes
Cost estimation	No reliable estimate for beaver reintroduction

Descriptor	Definition
	Engineered logjams in the range of £5,000-25,000, not including land purchase if required

Nutrient removal

Recent reviews of the impact of beavers on river systems presents contrasting evidence on the impact of beaver impacts on P removal. In a meta-analysis of studies from across North America and Eurasia, Ecke *et al*., (2017) suggest that beaver have a little impact on P removal in streams.

Brazier *et al*., (2021) detail how beaver impacts cause changes to hydrology and geomorphology that are linked to nutrient removal. They cite numerous studies that have provided evidence of P removal in rivers because of beaver activities and discuss the concept of 'beaver meadows': an end state of beaver damming where infilling of beaver ponds by sediment and then progressive vegetation growth results in an altered landscape akin to that shown in **Figure 3.6**. Progression to beaver meadows is likely to result in more sustained P removal.

The processes that retain P within beaver dam and pond complexes are predominantly related to P deposition that is attached to sediments. Some adsorption of P to sediments occurs in beaver ponds due to exchange of surface water with subsurface flow pathways in pond sediments, however where subsurface flow pathways encounter anaerobic conditions, this can also result in the release of P that is bound to sediments and has been hypothesised as the reason for inconsistent results for SRP removal by beaver activities (Larsen *et al*., 2021).

Table 3.11 collates key information from relevant studies and highlights that each study recorded P reductions resulting from beaver activities, with a wide range of reductions recorded across the different study sites.

Table 3.11: Results from studies of beaver impacts on phosphorous in rivers in the UK and Europe

Study	Location	Study length	*Upstream to downstream Nutrient concentration reductions - P*	Accounted for seasonality?
Puttock *et al*., (2017)	Devon, UK	1 year	80% PO_4 reduction	Yes
Law *et al*., (2016)	Blairgowrie, Scotland	1 year	25% PO_4 reduction	Yes
Smith *et al*., (2020)	Brandenburg, Germany	1 year	46% PO_4 reduction and 13% TP reduction	Yes
Čiuldiene *et al*., (2020)	Northwest Lithuania	< 1 year	20% TP reduction	No

Research has shown that beaver impacts on streams can result in the removal of P, including in a UK context, but this removal is not always consistent and removal efficiencies may not be that high.

It is noted that there is very limited research on the impact of logjams on nutrient dynamics in rivers. However, if a series of logjams was designed that created a similar ponding effect to that created by beavers where they dam rivers, the same nutrient removal processes could potentially be created at similar removal efficiencies.

Engineered logjams can be deployed in a complex of dams in one go, which may help a logjam scheme to reach peak nutrient removal efficiency faster than a beaver reintroduction scheme. It is likely that a logjam scheme would take six to nine months to deliver, allowing for site assessments, surveys, design, land acquisition and deployment.

3.3.2 Runoff management systems

3.3.2.1 Taking land out of agricultural use

Taking land out of agricultural use involves replacing high nutrient exporting agricultural land with low nutrient exporting land. **Table 3.12** provides an overview of taking land out of agricultural use as a solution.

Table 3.12: Key considerations of taking land out of agricultural use

Descriptor	Definition
Description of solution	Land taken out of agricultural use is replaced with low exporting land such as semi-natural grassland, woodland, or energy crops, e.g., willow or *Miscanthus*. Vegetation such as this actively uptakes nutrients and limits the impact of legacy P (build-up of P in soil caused by repeated applications of fertilizers and animal waste). Reversion of previously agricultural land to a more natural state will eventually reduce P leaching to natural background rates. Woodland planting can accelerate the transition to background P concentrations. Natural England suggest that woodland planting is a viable mitigation method that can be easily implemented. There is a minimum requirement for 20% canopy cover at maturity, which is equivalent to approximately 100 trees/ha. Maintenance of woodland is easy to verify and well established. Native tree species would be the preferred choice, although climate resilience may require the use of non-native species to account for long-term climate change effects. Though most P is sediment bound, it is worth noting energy crops (e.g., *Miscanthus* and willow) are considered to have a higher soluble nutrient uptake than woodland. *Miscanthus* is also ideally suited to marginal land that provides little value for generating income, as it can be grown for biofuel. However, energy crops provide a lower biodiversity benefit and would be unable to retrieve as much income through potential monetised biodiversity schemes as more natural planting would. Other measures to accelerate the transition to P background levels include the ploughing of previously agricultural land, suggested by Sharpley (2003) and Dodd *et al*., (2014) to decrease nutrient concentrations by half and therefore reduce P surface runoff losses.
Delivery timescale	Taking agricultural land out of use can be implemented over short-term timescales. Identification of suitable land, willing landowners and agreeing terms are likely to be the most time-consuming tasks in the implementation process of this solution.
Duration of operation	This solution could potentially be implemented over a temporary, impermanent and permanent timescale. ▪ Temporary: Land taken out of production but otherwise unchanged ▪ Impermanent: A longer-term reversion from agriculture ▪ Permanent: It could be maintained in perpetuity if the land use is changed so that it is used for non-agricultural purposes (i.e., woodland, *Miscanthus* etc.)
Nutrient removal	The P reduction calculations assume that farms will be operating according to best practice and not polluting. This will also ensure that mitigation schemes do not compromise the ability to deliver long term Water Framework Directive (WFD) targets. Average TP removal potential: Upper Lambourn: 0.07 kg/ha/yr Lower Lambourn: 0.36 kg/ha/yr Nutrient removal rates for all land use types as provided in Table 3.13.
Applicability	Unlikely to be applicable to indoor pig or poultry farms - other methods of calculating nutrient removal
Management and maintenance	For Miscanthus, fertiliser application is not needed to be added until it is established (after one to two years) and less needs to be applied than most farming practices. Harvesting needs to be completed every two to four years.

Descriptor	Definition
Additional benefits	▪ Energy crops can be used for coppice ▪ BNG potential ▪ Soil erosion which can lead to nutrient mobilisation is also likely to decrease with time as soil is stabilised by more continuous vegetation cover.
Best available evidence	This solution uses the best available scientific evidence. However, some doubt may remain over legacy P concentrations and may require further research or monitoring to gain a better understanding.
Wider environmental considerations	There is the potential for long term inflated agricultural land prices if this solution requires land to be out of agricultural use for more than one to two years.
Deliverability & certainty	Certainty regarding cessation of arable farming can be easily secured and verified using aerial imagery and site visits. Where grazing land is taken out of use, in order for there to be an actual reduction in nutrient loads, then it is assumed that livestock numbers would also need to be decreased and the livestock/ hectare rate maintained. However, it is assumed that farms typically operate close to optimal stocking densities and livestock reductions would be needed to maintain this. Where this solution is used as a temporary measure, livestock can be temporarily located outside of the catchment. However, changes to grazing practices and stocking densities are more difficult to monitor and enforce in comparison to arable reversion to woodland or energy crops, and therefore provide a lower degree of certainty. Furthermore, consideration would need to be given where potentially polluting agricultural activity is moved to another location where the land parcel is smaller and could increase the pollution risk.
Evidence of effectiveness	Yes – beyond reasonable scientific doubt. Taking land out of agricultural use has an immediate impact on its P output, as the desisting of fertiliser application reduces surface water P levels following rainfall events. However, some legacy P will be maintained in the soil. The time taken for soils to reduce to agronomic targets and background concentrations varies depending on soil types and P concentrations (Dodd *et al*., 2012). A study by McCollum (1991) indicated that P levels may not be reduced to background concentrations for at least 17 years, based on fine sandy loamy soils in arable production in the United States. Much of the soil surrounding the Lambourn is loamy. Gatiboni *et al.,* (2021) found that the median time to reach agronomic targets was <1 year but could take as long as 11 years. However, the time taken to reach environmental targets purely by cessation of phosphorus fertiliser would be 26 – 55 years.
Precautionary	Yes – a precautionary approach can be applied to this solution until and after site specific information becomes available.
Securable in perpetuity	Yes – However, it is unlikely this solution would be used in the long term. Plantations may need to prove they can be in place for the lifetime of the development or offer a fallback option with an equivalent P removal.
Cost estimate	The average Farm Business Tenancy (FBT) rental price in the southeast of England for farms in 2021 was £217/ha The average purchase price in the Berkshire of England for arable farms is £25,550/ha and for livestock farms is £19,163/ha (Farmers Weekly, 2024). Energy Crop Schemes that provide establishment grants for approved energy crops are available.

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Table 3.13: TP mitigation per land use type

Original farm type	New land use type	Phosphorus mitigation (Kg TP/ha/yr)	
		Upper Lambourn	Lower Lambourn
Dairy	Meadows or Woodland or Grassland or Orchards	0.11	0.75
Lowland grazing		0.05	0.06
Mixed livestock		0.09	0.49
Poultry		0.11	0.27
Pig		0.10	0.57
Horticulture		0.08	0.44
Cereals		0.10	0.30
General arable		0.07	0.36
Allotment		0.38	0.18

3.3.2.2 Conversion of agricultural land to solar farms

Converting agricultural land to solar farms works in a similar way to taking land out of agricultural use, in that high nutrient exporting land use is replaced with low nutrient exporting land use. Land converted to solar farms may need light maintenance (**Figure 3.7**).

Table 3.14 provides an overview of converting agricultural land to solar farms as a solution.

Figure 3.7: Land that has been converted to a solar farm being maintained (Source: Tugwellcontracting.com)

Table 3.14: Key considerations of the conversion of agricultural land to solar farms

Descriptor	Definition
Description of solution	A solar farm is a renewable energy installation with many solar panels which generate electricity. Solar farm installation can reduce the P export of the land by: ▪ a reduction in number of grazing livestock and therefore P manure in livestock output by either reducing the density of grazing animal or removal of livestock from agricultural land; and ▪ removal of agricultural land usage and therefore removal of nutrient inputs from fertiliser or waste applied to land from agricultural benefit to enhance crop growth. Land can be taken completely out of agricultural use and replaced with solar farms, or agricultural use can mostly cease, both agricultural land and solar farm usage with reduced livestock density continuing to manage vegetation and continue to provide some cost benefit.
Delivery timescale	An estimated timeframe of less than five years is required to gain approval and install a solar farm. Solar farms are a less intensive land use than typical agricultural operations and produce significantly fewer nutrients. Therefore, solar farms have a lower environmental and nutrient impact, meaning existing or imminent solar farms could be used for nutrient mitigation in the short-term.
Duration of operation	A solar farm is estimated to operate for approx. 40 years, and the change of land use is therefore considered to be permanent. However, it is important to note that operation and maintenance costs could potentially exceed the cost for renewal of the solar farm after 40 years. As such, the solution may not reach the threshold to be classified as 'securable in perpetuity' (80-125 years) unless a longer-term agreement between the operator and landowner is in place, e.g., to replace photovoltaic cells with new infrastructure at the end of their economic lifespan.
Nutrient removal	P is removed or reduced according to the cessation of usage of land as agricultural land or reduction correlated with reduction of grazing animal density. The Calculator has been used to estimate the effectiveness of this solution. These calculations would need to be refined using Farmscoper Tool and site-specific information input related to fertiliser type and/ or manure application. The initial calculations undertaken provide the following ranges: ▪ Upper Lambourn: 0.05 – 0.38 kg/ha/yr ▪ Lower Lambourn: 0.06 – 0.75 kg/ha/yr
Applicability	Solar farm installation is applicable to areas of West Berkshire where there is available agricultural land which can be used, available connections to the National Grid and planning applications have been received for such schemes within West Berkshire. Some key considerations when proposing a solar farm installation in West Berkshire are that some areas are heavily designated and protected, such as the North Wessex Downs Area of Outstanding Natural Beauty, and primarily include visual impacts on the landscape and/ or character of the area, and heritage assets. A farm would need to be located and designed so it does not have an unacceptable impact on these receptors.
Management and maintenance	Once land is no longer in agricultural use, further land management and maintenance is not anticipated. Should land be retained as both agricultural land and solar farm usage with reduced livestock density, it will be necessary to monitor livestock numbers. It may be necessary to determine a threshold number for specific grazing animal species and monitor in order to keep the number below the threshold. If the land is not kept in agricultural use, occasional cutting of vegetation may be necessary to avoid shading of the solar panels. The solar arrays will also require maintenance to ensure that they remain operational and are working efficiency.
Additional benefits	▪ Renewable energy provision ▪ BNG potential ▪ Water quality ▪ Affordable and feasible

Descriptor	Definition
Deliverability & certainty	To be considered as a viable solution and follow distinctions made in the 'Dutch N' case, nutrient neutrality must be one of the key aims of the solar farm. Natural England's position is that if the primary purpose of scheme is for power generation for example, with the unintended consequence of providing mitigation, the scheme may not be considered as acceptable nutrient mitigation. Additionally, a proposed solar farm will require planning permission. Any proposed development identified at the planning stage to potentially have adverse effects on the integrity of a site's habitat (e.g., the proposed mitigation is not specifically for the purpose of nutrient mitigation) may not be considered acceptable 'in principle' as a mitigation measure compliant with the Habitats Regulations 2017.
Best available evidence	This solution uses the best available scientific evidence. However, some doubt may remain over legacy P concentrations and may require further research or monitoring to gain a better understanding.
Wider environmental considerations	The construction cost of the solar farm infrastructure can cause pollution, environmental degradation and pressure on natural resources in other areas or countries. Solar farms should ideally be installed on brownfield land, which can be difficult to repurpose.
Evidence of effectiveness	Indicative calculations which have not been subject to review have been undertaken using The Calculator using available data and the evidence indicates this can be an effective solution. The effectiveness of removing land from agricultural production is provided in **Section 3.3.2.1**.
Precautionary	Yes – a precautionary approach can be applied to this solution until and after site specific information becomes available.
Securable in perpetuity	Yes - the lifetime of such a scheme can be estimated as approximately 40 years. Complete conversion from agricultural land to solar farm is the most viable and certain solution. There is potential for the lease and planning permission as a mechanism to secure a legally enforceable scheme.
Cost estimate	Land rental or lease costs and construction costs can be offset against energy sale price.

3.3.2.3 Cessation of fertiliser and manure application

Where full land abandonment is not available, a change of farming practices or cessation of fertiliser application may be applicable. **Table 3.15** provides an overview of cessation of fertiliser and manure application as a solution.

Table 3.15: Key considerations of the cessation of fertiliser and manure application

Descriptor	Definition
Description of solution	A change of farming practices or cessation of fertiliser will have an immediate short-term impact by reducing the small amount of soluble P runoff lost following application, particularly during rainfall events. There will also be a longer-term impact on particulate P loss should the solution be implemented for consecutive years due to a reduction in soil P reserves. Particulate forms of P are typically lost through soil erosion when P is bound to soil. Legacy P could potentially be a source of fertiliser for use on crops and could decrease the dependence on external fertilisers. An alternative option to ceasing fertiliser application would be to apply the correct level of fertiliser, rather than applying a constant amount. However, the P removal is more variable, and the release of credits would only be available following soil sampling.
Delivery timescale	This solution does not require any investment in infrastructure, planning permission or environmental permits. It can therefore be implemented in very short timescales. This solution will go above and beyond the requirements for catchments within nitrate vulnerable zones.
Duration of operation	This solution is envisaged as a temporary measure for use while longer-term solutions are developed and implemented. Prolonged cessation of fertiliser application may produce similar results as taking land out of agricultural use (**Section 3.3.2.1**).
Nutrient removal	Cessation of fertiliser allows land to continue to be farmed whilst still providing P reductions, with the loss of productivity from the lack of fertilisation balanced by income from nutrient mitigation.

Descriptor	Definition
	P levels can be reduced through cutting for silage without fertiliser which would prevent the application of approximately 30 kg/ha of P (Agriculture and Horticulture Development Board, 2022). Particulate P runoff reductions from the cessation of 100% of fertiliser application is estimated to be 50% (Newell Price *et al.*, 2011). White and Hammond (2009) found that particulate P accounts for 40% of the TP loss from improved grassland. However, on arable land particulate forms of phosphorus typically have more of an influence than on grassland areas, due to the lack of dense vegetation preventing particulate loss. Neal *et al.*, (2010) found that particulate P in agricultural and rural settings in the UK made up 50% TP. TP mitigation rates (Kg/ha/yr) are provided in **Table 3.16.**
Applicability	This solution is applicable to all types of arable agriculture where natural or synthetic fertilisers are applied.
Management and maintenance	Monitoring will be required to ensure that estimated nutrient removal rates are achieved and validate that fertiliser/ manure application has ceased. This is likely to comprise initially of one to two visits per year, including an initial round of sampling to establish the baseline conditions.
Additional benefits	Land could be selected strategically to help buffer from other pollution sources, e.g., suspended sediment.
Best available evidence	Yes – monitoring likely to be needed to confirm.
Wider environmental considerations	If the solution is widely implemented, then the reduced yield could result in food supply issues, but to a lesser degree than taking land out of agricultural use.
Evidence of effectiveness	Yes – beyond reasonable scientific doubt. The cessation of fertiliser and manure has an immediate impact on the land's P output, reducing surface water P levels following rainfall events. As with the taking land out of agricultural use solution, some legacy P will be maintained in the soil. McCollum (1991) indicated that P levels may not be reduced to background concentrations for at least 17 years.
Precautionary	Yes – a precautionary approach can be applied to this solution until and after site specific information becomes available.
Securable in perpetuity	No – likely to be utilised as a bridging solution. Cessation of fertiliser allows land to continue to be farmed whilst still providing P reductions, with the loss of productivity from the lack of fertilisation balanced by income from nutrient mitigation. This could be secured as a short-term bridging solution by planning conditions. Legal agreements to cease fertiliser application for a set area and duration will be required and spot checks undertaken to monitor farming practices and nutrient concentrations in runoff.
Cost estimate	Cessation of fertiliser application to arable land is estimated to have a 50% reduction in yield on the affected area. Similarly, cessation to grassland is assumed to have a reduction of 30% to an average yield of 8 t/ha (Newell Price *et al.*, 2011). The actual costs per farm are likely to differ due to the variety of variables, such as fertilisation rates, soil types, crop types, etc. An estimated cost breakdown is provided in **Table 3.17**.

Table 3.16: Cessation of fertiliser mitigation rates

Farm type	Phosphorus mitigation (Kg TP/ha/yr)	
	Upper Lambourn	Lower Lambourn
Dairy	0.03	0.19
Lowland grazing	0.02	0.02
Mixed livestock	0.03	0.13
Poultry	0.03	0.07

Farm type	Phosphorus mitigation (Kg TP/ha/yr)	
	Upper Lambourn	Lower Lambourn
Pig	0.03	0.15
Horticulture	0.03	0.12
Cereals	0.03	0.08
General arable	0.02	0.10
Allotment	0.10	0.05

Table 3.17: Cessation of fertiliser/ manure cost estimation

Description	Cost (£/ha/yr)	
	Arable	Grassland
Saving in fertiliser	-100.82	-35.96
Reduced use of fertiliser spreaders	-6.65	-6.65
Reduced yield / forage replacement	781.86	311.12
Soil testing	600	600
Total	**1,274.39**	**868.51**

3.3.2.4 Cover crops

Cover crops can be implemented on bare soils, particularly steeper slopes, to intercept and uptake P present in surface water runoff before it reaches the watercourse. **Table 3.18** provides an overview of cover crops as a solution.

Table 3.18: Key considerations of cover crops

Descriptor	Definition
Description of solution	Surface runoff and erosion represents a principal mechanism for nutrient loss from many agricultural systems. The risk of runoff is primarily controlled by timing, rate and method or fertiliser or manure application, as well as post-application rainfall. Natural factors such as slope, surface roughness, infiltration capacity and magnitude of erosion also have a strong control. Bare soils are very prone to erosion and cover crops help maintain soil cover during the autumn and winter or any time of the year including drier months and cover crops can also be sown in springtime. They are especially useful to mitigate erosion on high-risk sloping land. Cover crops act to encourage infiltration and reduce overland flow velocity. They are best employed when land would otherwise be left bare during the crop rotation process. They are typically used either prior to main production cycle, e.g., potatoes, sugar beet, or post-harvest, e.g., cereals. Validation of cover crops can be achieved through satellite imagery, photographs, and drive by visits. Due to some uncertainty in removal values, soil sampling and monitoring may be required to establish the baseline and P reduction.
Delivery timescale	This solution does not require any investment in infrastructure, planning permission or environmental permits. It can therefore be implemented in short timescales.
Duration of operation	This solution is envisaged as a long-term change in agricultural land management practices. However, in the absence of any significant infrastructure, long term investment, or mechanisms for binding agreements with landowners, it is considered to be impermanent.

Descriptor	Definition
Nutrient removal	Published P reduction rates are variable within the literature. Novotny and Olem (1994) suggest significant P removal rates of 30-50%, with others (Sharpley and Smith,1991) finding an average reduction of 77% across four studies. However, another investigation concluded that changes to P losses were not significant (Kleinman *et al.*, 2005). Similarly, Cooper *et al.* (2017) found that oilseed radish crops had no effect on P losses. Overall, there is a vast amount of uncertainty and removal rates are assumed to be ~30%, which equates to winter cover cropping removal rates: ▪ Upper Lambourn: 0.07 kg/ha/yr; and ▪ Lower Lambourn: 0.36 kg/ha/yr. There is also the possibility to use summer cover cropping for further nutrient removal.
Applicability	This solution is applicable to all types of arable agriculture, particularly where fields are left bare and thus vulnerable to surface water runoff and erosion after the harvest of the main crop.
Management and maintenance	There will be annual maintenance requirements associated with preparation, planting, destruction, and cultivation of cover crops.
Additional benefits	▪ Reduced soil erosion ▪ Improved water quality ▪ BNG due to habitat creation and winter cover provides habitat for birds, mammals, and insects.
Best available evidence	No – P reduction estimates are highly variable and may require further research.
Wider environmental considerations	Implementation of this option is unlikely to be significantly constrained by wider environmental factors.
Evidence of effectiveness	Although there is scientific evidence to suggest that cover crops are effective in reducing the supply of P from agricultural land, estimates show considerable variation. There is therefore a degree of uncertainty associated with the effectiveness of this solution. It is expected that a conservative removal rate of 30% could be applied for cover crops. Monitoring would then be required to access ‘credits’ for removal rates above 30%.
Precautionary	Yes, a conservative, precautionary estimated P removal rate of 30% is assumed.
Securable in perpetuity	This solution is securable in perpetuity through management agreements, particularly where land in leased.
Cost estimate	Annual maintenance costs estimated to be £150/ha/yr (AHDB, 2020)

3.3.2.5 Installation of SuDS in new developments

SuDS are efficient sediment traps that reduce the amount of runoff entering a watercourse. There are a variety of SuDS that can be installed with new developments, such as SuDS wetlands, swales and conveyance channels, filter strips and rain gardens. The different SuDS types are explored in **Table 3.19**, which provides an overview of installing SuDS in new developments as a solution.

Table 3.19: Key considerations of the installation of SuDS in new developments

Descriptor	Definition
Description of solution	The fundamental principles of SuDS are to slow flow and promote infiltration, allowing rainfall to enter the groundwater where it falls. SuDS that promote the infiltration of water and settlement of sediment will have the greatest benefit for P removal.

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Descriptor	Definition
	Similarly, SuDS that provide an environment for vegetation to uptake P will achieve good removal rates. SuDS used in combination and that are linked in a treatment train, often culminating in a SuDS wetland, represent the most favourable scenario. Examples of different SuDS and their benefits are outlined below.
Delivery timescale	A requirement to implement SuDS as part of all new developments can be established in the short term.
Duration of operation	Once installed, SuDS are assumed to be permanent drainage and nutrient management solutions.
Nutrient removal	The CIRIA C808 (Bradley *et al*., 2022) document; 'Using SuDS to reduce phosphorus in surface water runoff' works towards definitive recommendations for the use of SuDS for P removal. The document sets out SuDS deployment via 'treatment trains' to achieve good practice P removal which are expected to be set out at full planning applications stages. A precautionary reduction in the runoff rate of P from new developments can be achieved for developments that secure the good practice SuDS set out in the document. The document summarises the relative performance of SuDS components for P capture and removal which is noted as highly variable. Where SuDS promote infiltration, it is assumed that 100% of the TP is removed if certain criteria have been met: ▪ The SuDS installation is not subjected to significant flooding (no in flood risk zone 2 or 3) ▪ The SuDS installation is in an area where the high-water table groundwater depths is at least 1m below the the base of the proposed solution. ▪ The total pollution risk score for the SuDs installation is less than 180, calculated using Highways England (2020) and Table 26.6 of Woods Ballard *et al* (2015). It is noted that the full removal rates can only be claimed for the first drainage asset in the drainage management train and only 50% for each asset thereafter. **The TP removal from conveyed flows which are not infiltrated are presented in Table 3.20**.
Applicability	This solution is applicable to all new dwellings in the catchment and should be designed from an early stage. The size of the site will control the design and P removal potential.
Management and maintenance	The long-term performance of SuDS would also need to be secured through maintenance agreements, e.g., via Section 106 rather than planning conditions given the required duration of these commitments. There will be routine/ regular, occasional, and remedial maintenance (e.g. de-silting).
Additional benefits	▪ Improved water quality ▪ Reduced erosion ▪ Habitat creation / BNG ▪ Improved amenity value
Best available evidence	Yes – P removal rates derived from CIRIA.
Wider environmental considerations	The use of SuDS in new developments is unlikely to be significantly constrained by wider environmental factors.
Evidence of effectiveness	There is currently limited evidence to demonstrate the efficiency of SuDS measures in the removal of nutrients from runoff. However, parallels could potentially be drawn with the evidence base for their effectiveness in attenuating flows and reducing sediment supply.
Precautionary	A precautionary approach can be adopted when implementing this solution.
Securable in perpetuity	Yes, though maintenance agreements (such as Section 106 agreement) may be required.
Cost estimate	Costs are highly variable and site specific. Likely to be £20/m^2 – £40/m^2

Table 3.20: Performance of SuDS components for phosphorus capture and removal (Edited from CIRIA C808 (2022))

Relative performance	Swale	Detention basin	Retention basin	Pond	Floating wetland	Bioretention zone	Tree pit	Filter strip	Filter drain	Willow beds	Permeable pavement	Vortex grit separator	Oil water separator	Stormwater filter	Granular treatment media	Rainwater and stormwater capture
Sediment capture capability	28%	28%	28%	38%	38% settled in pond	44%	44%	22%	22%	100%	38%	28% based on 50% Total Suspended Solids (TSS) removal	28% based on 50% TSS removal	44% if sediment removal device included upstream	44% if sediment removal device included upstream	N/A
Dissolved phosphorus capture / removal	Nil	12%	50%	50%	Test results provided by manufacturer	Nil	Nil	Nil	Nil	100%	Nil	Nil	Nil	Up to 90% if the media selected specifically for P capture		N/A
TP removal	15.4%	20.8%	37.9%	43.4%	20.9%	24.2%	24.2%	12.1%	12.1%	100%	20.9%	15.4%	15.4%	64.7%	64.7%	N/A

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3.3.2.6 Retrofitting SuDS in existing developments

Retrofitting SuDS into existing developments will provide efficient sediment traps and a reduction in the amount of runoff entering watercourses. **Table 3.21** presents the key considerations for the use of retrofitting SuDS for nutrient offsetting or reduction.

Table 3.21: Key considerations for retrofitting SuDS

Key considerations	
Description of solution	Retrofitting SuDS into existing developments will provide efficient sediment traps and a reduction in the amount of runoff entering watercourses.
Delivery timescale	Medium-term
Duration of operation	Permanent
Nutrient removal	Highly variable and will likely need specific calculations. The best SuDS for retrofitting are likely to include swales, bioretention areas, filter drains, tree pits and porous paving.
Management and maintenance	The long-term performance of SuDS would also need to be secured through maintenance agreements. Maintenance works would include desilting of swales, wetlands, and basins to maintain their efficiency. Vegetation management of buffers would be necessary to maintain the optimum roughness/ composition and sediment trapping efficiency.
Applicability	Location specific
Additional benefits	▪ Improved water quality ▪ Reduced erosion ▪ Habitat creation ▪ Improved amenity value
Best available evidence	No - Monitoring may be required to determine the efficacy of specific schemes.
Wider environmental considerations	The use of SuDS in new developments is unlikely to be significantly constrained by wider environmental factors
Evidence of effectiveness	Yes - P removal rates derived from CIRIA
Precautionary	Yes
Securable in perpetuity	Yes - maintenance agreements may be required
Cost estimation	See **Table 3.19**.

3.3.2.7 Paddock management

Paddock management can be effective if good equine pasture management is undertaken and is based on the concept that off-site removal of manure entails removal out of catchment. Information has been taken from a recent Technical Note for Donnington Veterinary Hospital by Ardent (2023) and combined with other relevant information in **Table 3.22**.

Table 3.22: Key considerations for paddock management

Descriptor	Definition
Description of solution	All manure wastes are regularly collected and removed from the application site by a licenced waste carrier and disposed of at a licenced or otherwise approved facility outside the Lambourn catchment. Similarly, liquid wastes are drained from the stables and yards and collected in a lagoon/tank where it is regularly emptied by tanker.
Delivery timescale	Short-term
Duration of operation	Temporary in the absence of a legally binding method of securing adherence to a Land Management Plan. Permanent if a planning obligation Section 106 agreement is made. This solution is included on the basis that it can only be considered with a legally binding agreement.
Nutrient removal	All phosphorus sources from the site would be removed, therefore achieving 100% TP removal.
Applicability	Applicable to equine paddocks and commercial veterinary centres
Management and maintenance	At least twice weekly removal of manure from pasture is required to be effective according to the British Horse Society
Additional benefits	Reuse of manure off-site can reduce pressure on resources
Best available evidence	Yes – legacy P may require future research on a site-specific basis
Wider environmental considerations	Removal of manure out of the catchment is likely to require fuel for transport and machinery, therefore incur carbon emission. Furthermore, the waste could be transported to an adjacent catchment where it will increase nutrient loading, albeit to a less protected catchment.
Evidence of effectiveness	Yes – as detailed within Ardent's 2023 Donnington Veterinary 2104391-03 nutrient neutrality technical note which indicates 100% TP removal is possible.
Precautionary	Yes
Securable in perpetuity	Yes – via a Section 106 agreement and adherence to a Land Management Plan
Cost estimate	Research required into cost of manure as potential product and cost to remove. Cost for disposal also needs consideration if sale as a product is not possible.

3.3.3 Wastewater management solutions

3.3.3.1 Expedite planned improvements to treatment works

Bringing forward scheduled improvements to treatment works which are planned to be online by 2025 or 2030 will reduce the temporary mitigation burden. In addition, it may be possible for both permitted and unpermitted WwTWs to use innovative new technologies that use microbes and aquatic plant growth in greenhouses to uptake nutrients and contaminants from the wastewater into plant biomass, as described in **Section 3.3.3.6** (alternative wastewater treatment providers).

Table 3.23 provides an overview of expediting planned improvements to treatment works as a solution.

Table 3.23: Key considerations of expediting planned improvements to treatment works

Descriptor	Definition
Description of solution	In many cases, water companies will complete infrastructure upgrades to WRCs in advance of AMP deadlines but would not operate at the future permit limit until required to do so to save on operational costs. Operating these WRCs at the permit limit in advance of original deadline reduces the amount of temporary

Descriptor	Definition
	mitigation that needs to be delivered. Agreements would need to be in place between the water company, environment agency and Ofwat.
Delivery timescale	The delivery timescales are dependent on the level of existing infrastructure in place and how quickly the effluent concentrations could reach the target concentration.
Duration of operation	This is a short-term intervention that would be operational between the agreed expedited date and the original planned improvement date.
Nutrient removal	TP removal potential: Unknown at this stage, it would dependant on how many schemes could be delivered. Chieveley is scheduled to operate at a permit limit of 0.45mg/l by 2025 and 0.25mg/l by 2030. Bringing forward the 2030 improvement would reduce the temporary mitigation burden by 0.56 kg/yr for each year.
Applicability	WRCs planned for upgrades in 2025 and 2030 – primarily Chieveley.
Management and maintenance	Nothing in addition to the regular maintenance and monitoring requirements fulfilled by the water company.
Additional benefits	This solution is unlikely to deliver any wider environmental benefits.
Best available evidence	This solution used the best available evidence.
Wider environmental considerations	Achieving low TP effluent concentrations may require extensive chemical dosing, which is typically imported, e.g., from China, and may be associated with carbon dioxide emissions.
Evidence of effectiveness	The WRC upgrades will employ industry best practise in order to achieve the desired TP effluent concentrations. Mandatory monitoring of effluent quality can be used to verify the intended reductions have been achieved.
Precautionary	Precautionary measures can be implemented.
Securable in perpetuity	Yes - the schemes would go beyond what was originally planned.
Cost estimate	Thames Water may be willing to bring forward these improvements following pressure from the Environment Agency. Alternatively, funding could be provided by developer contributions. Costs are uncertain and would need to be provided by Thames Water. The likely costs associated with expediting improvements will be the operational and management costs, e.g., phosphorus dosing and energy costs to operate to a lower permit limit.

3.3.3.2 Improvements to treatment works

An overview of improving the effluent concentration at unpermitted wastewater treatment works within the catchment is provided in **Table 3.24.**

Table 3.24: Key considerations of improving treatment works

Descriptor	Definition
Description of solution	Much of the additional nutrient load from new residential development comes from the increase in wastewater production that results from the additional population occupying new developments. Raw sewage entering a municipal Wastewater treatment works is highly enriched in phosphorus. Most WwTWs have primary and secondary treatment of wastewater, which uses settlement of sediments and biological removal processes to remove organic pollution and some dissolved nutrients (Rout *et al*., 2021). However, secondary treatment does not remove a significant amount of nutrients from wastewater and tertiary treatment systems are needed to provide large reductions in P concentration and load in the final treated effluent discharged by a WwTWs (Kang *et al*., 2008). Tertiary treatment to remove nutrients at WRCs is often termed ‘nutrient stripping.’ Installation of nutrient stripping technologies at WRCs requires significant capital expenditure by the water company and as such, a relatively small number of WwTWs have tertiary treatment to remove nutrients.

Descriptor	Definition
	The Levelling Up and Regeneration Bill (LURB) is proposing a mandate for all WRCs that serve more than 2,000 people (> 2,000 PE) to be upgraded to TAL by 2030. TAL concentrations for P in treated wastewater is 0.25 mg TP/L. Furthermore, some WwTWs will be required to improve their effluent concentration through the Water Industry National Environment Programme (WINEP). Any WwTWs not requiring upgrades through the LURB and WINEP could deliver phosphorus mitigation. This is likely to apply to Fawley, Wickham and Winterbourne.
Delivery timescale	The delivery timescales are dependent on the level of existing infrastructure in place and how quickly the effluent concentrations could reach the target concentration.
Duration of operation	This solution is a permanent solution that would deliver mitigation in perpetuity.
Nutrient removal	TP removal potential, assuming a final effluent concentration of 2 mg/l, are as follows: ▪ Fawley: 16.07 kg/yr ▪ Wickham: 37.61 kg/yr ▪ Winterbourne: 12.86 kg/yr
Applicability	Unpermitted WRCs in the catchment.
Management and maintenance	Nothing in addition to the regular maintenance and monitoring requirements fulfilled by the water company.
Additional benefits	This solution is unlikely to deliver any wider environmental benefits.
Best available evidence	This solution used the best available evidence.
Wider environmental considerations	Achieving low TP effluent concentrations may require extensive chemical dosing, which is typically imported, e.g., from China, and may be associated with carbon dioxide emissions.
Evidence of effectiveness	The WRC upgrades will employ industry best practise in order to achieve the desired TP effluent concentrations. Monitoring of effluent quality can be used to verify the intended reductions have been achieved.
Precautionary	Precautionary measures can be implemented.
Securable in perpetuity	Yes - the schemes would go beyond what was originally planned.
Cost estimate	It is anticipated that nutrient credits would be used to pay for, or contribute partly towards, upgrades of some of the WRCs. Costs are uncertain and would need to be provided by Thames Water, however, information from WBC indicates Thames water have recently estimated in order to achieve TAL in the WwTW's at Fawley, Wickham and Winterbourne £3.5 million each capital costs plus an additional £165,000 per annum revenue costs.

3.3.3.3 Installation of cesspools and capture outputs from private sewage systems

Cesspools and capture outputs from private sewerage systems offer the possibility of tankering waste from dwellings within the catchment to registered waste facilities outside of the catchment. **Table 3.25** provides an overview of installing cesspools and capture outputs from private sewage systems as a solution.

Table 3.25: Key considerations of installing cesspools and capture outputs from private sewage systems

Descriptor	Definition
Description of solution	Closed cesspool systems offer the possibility of tankering waste from dwellings within the catchment to registered waste facilities outside of the catchment. As a result, there would be no increase in wastewater loading to the River Lambourn SAC from developments that use this approach. There are some locations towards the edge of the catchment where the distance waste would be carried is minimal. There is some risk of overflow and leak causing nutrients to be released into the environment, however we assume compliance with the associated planning conditions, building regulations, and the Environment Agency's General Binding Rules.
Delivery timescale	The implementation of this solution will require the installation of new infrastructure and would require planning permission. The solution is assumed to be achievable in the short-term.
Duration of Operation	Cesspools would require regular maintenance to maintain their effectiveness and are an impermanent solution that could be used until a permanent solution can be implemented.
Nutrient removal	Nutrient removal rates will be dependent on the number of dwellings. The use of cesspools will temporarily remove the entire wastewater contribution from catchment. This could be coupled with a well-designed SuDS scheme which could remove P contributions from surface water runoff and therefore achieve nutrient neutrality.
Applicability	This option could potentially be applicable to new or existing developments that cannot currently be connected to the foul drainage network.
Management and maintenance	Cesspools would need to be emptied regularly and the owner would be responsible to ensure they do not leak or overflow. Where a cesspool causes pollution, it would break the law and the Environment Agency could take legal action under the Water Resource Act 1991, which can carry a fine of up to £20,000 and three-months imprisonment. Similarly, the Environment Agency and Local Authority can enforce repairs or replacements of cesspools in poor condition.
Additional benefits	There are no additional benefits associated with cesspools.
Best available evidence	This mitigation solution is based on the best available evidence.
Wider environmental considerations	Cesspools could cause a significant increase in carbon production. If water company infrastructure allows for mains connection in the future, water companies would be obliged to connect and wastewater would then be contributing to loads into the catchment, requiring further mitigation. This solution involves moving the nutrient loads from one catchment to another, which could lead to increased nutrient concentrations in these river catchments.
Evidence of effectiveness	This solution is reliant on treatment of wastewater at a dedicated WRC therefore it is assumed to be highly effective.
Precautionary	A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	Yes – management agreements will likely need to be put in place, especially where land is leased. Replacements may be required if the lifetime is less than the developments.
Cost estimate	Capital costs: approx. £3,000 - £6,000. Operational costs: £3,200 - £5,600 per year.

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3.3.3.4 Replacement of package treatment plants and septic tanks

Older package treatment plants and septic tanks are typically poorly performing and often have high phosphorus effluent concentrations. Replacing these poorly performing onsite treatment plants with new treatment plants can provide significant nutrient mitigation. **Table 3.26** provides an overview of replacing onsite treatment plants as a solution, and **Table 3.27** provides approximate P removal rates for the main PTP manufacturers.

Table 3.26: Key considerations of installing PTPs

Descriptor	Definition
Description of solution	Correctly operated and well-maintained PTPs produce a higher quality effluent which may be able to be discharged to a soakaway, surface water or groundwater in some circumstances, as well as to drainage fields. Septic Tanks (STs) are an alternative type of basic onsite wastewater treatment along with PTPs. Alterations to existing PTPs and ST or installing new tanks to provide additional dosing could achieve significant nutrient reductions. Typically, older PTPs (especially those without P dosing) will be discharging effluent at a much higher concentration than new PTPs. An assumption is made that a default ST will have an effluent concentration of 11.6 mg/l TP. A default PTP will have an effluent concentration of 9.7 mg/l TP. It is assumed that a future PTP would have an effluent concentration of 1.6 mg/l TP. Assuming general parameters on occupancy and flow rates the likely mitigation yield per PTP replacement is 0.77 kg/year.
Delivery timescale	PTPs typically take three months to deliver and set up; they can therefore be implemented over short timescales. An environmental permit is likely to be required for any discharges from the PTP.
Duration of operation	PTPs are considered a permanent solution. It is assumed that the PTP would be replaced with a model that has at least the same P removal in the future.
Nutrient removal	Assuming a default PTP is replaced with a new PTP with a TP effluent concentration of 2 mg/l, approximately 0.97 kg/yr of mitigation would be created. The replacement would have an estimated additional cost of approximately £15,000.
Applicability	PTPs could potentially be applicable to all residential developments that cannot currently be connected to the existing foul sewer network.
Management and maintenance	Some maintenance of the PTP would be required. Where additional P stripping is used, this should be applied in accordance with the design instructions. It is noted that Natural England do not currently accept the use of PTP's that require chemical dosing as the dosing cannot be satisfactorily monitored and therefore has a large degree of risk and uncertainty.
Additional benefits	This solution is unlikely to deliver any additional or wider environmental benefits.
Best available evidence	This solution uses the best available evidence from the available data.
Wider environmental considerations	The use of package treatment plants could potentially have implications for the local population, including visual impact, noise, and odour. Energy use may also be an important consideration.
Evidence of effectiveness	The manufacturers of PTPs have undertaken detailed testing of their performance and can provide certainty regarding the level of nutrient removal that can be achieved (**Table 3.27**). An advice note jointly published by Somerset Authorities in consultation with Environment Agency and Natural England in September 2022 states that all new ST and PTPs must undergo independent third-party testing to meet British Standards (BS EN 12566) with certification setting out the mean concentration of the effluent from that system.

Descriptor	Definition
Precautionary	A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	No – management agreements will likely need to be put in place, especially where land is leased. Replacements may be required if the lifetime is less than the developments. Natural England have advised that PTPs provide limited biological treatment without additional phosphorus dosing into the system, causing unreliable TP removal rates, and subsequently should not be accepted as a viable mitigation solution. However, treatment plants typically achieve the lowest effluent concentrations. Management agreements could be put in place to provide additional certainty regarding management of the PTPs but this will incur additional costs and administration. Alternatively, PTPs which do not require additional dosing could be selected (typical effluent concentration of 2mg/l) and would represent a much simpler option meet the requirements of the habitat regulations. A filter media could also be used to further reduce effluent concentrations and would not require as much management and maintenance as chemical dosing.
Cost estimate	Capital expenses will depend on plant size. The upper range will be approximately £10,000 - £15,000 for purchasing and installation. Additional costs are from administration (£5,000), Legal fees (£5,000), technical sign off (£2,500) and contingency (£5,000). As such, the estimated cost per plant is £30,000

Table 3.27: Main PTP manufacturers P removal rates

System	Removal rate / concentration	Source
Graf One2clean plus	95.1% / 1.6 mg/l	https://www.graf.info/fileadmin/media/Catalogue_Wastewater_Treatment_Solutions.pdf
Kingspan Klargester BioDisc	2 mg/l	Klargester Biodisc Sewage Treatment System | Kingspan | Great Britain
WPL HIPAF	3 - 6 mg/l	WPL HiPAF® Sewage System - WPL | WCS EE Division (wplinternational.com)

3.3.3.5 Installation of Portable Treatment Works

Portable Treatment Works (PTWs) are typically used by water companies during upgrades and can be used as a secondary treatment system designed specifically for P removal. **Figure 3.8** provides an example of a PTW and **Table 3.28** provides an overview of installing PTWs as a solution.

Figure 3.8: Example of a portable containerised wastewater treatment works (Source: Vikaspumps.com)

Table 3.28: Key considerations of portable treatment works (PTWs)

Descriptor	Definition
Description of solution	PTWs can be used as short-term solutions whilst other mitigations options are designed and developed. Other examples of portable treatment works include portable vertical flow wetlands. The portable treatment works typically have a small footprint of <0.2ha.
Delivery timescale	PTWs typically take three months to deliver and set up; they can therefore be implemented over short timescales. They are typically built inside standard 20 ft shipping containers making them easy to install and move to another site (**Figure 3.8**). An Environmental Permit is likely to be required for any direct discharges from the PTWs.
Duration of operation	This solution is envisaged to be a temporary solution that would be used until permanent solutions can be implemented. However, there is the potential for PTWs to be used over longer timescales as an impermanent solution, although costs may be proportionately high.
Nutrient removal	TP removal potential: Effluent to 0.5 mg/l can be achieved. This can apply to all existing houses served by the WwTWs. Installing a PTWs to an unpermitted WRC would achieve the following phosphorus estimated reductions: ▪ Fawley – 22.10 kg/yr ▪ Wickham – 51.71 kg/yr ▪ Winterbourne – 17.68 kg/yr
Applicability	This solution is most likely to be applicable for use in a WwTWs alongside existing treatment equipment.
Management and maintenance	Some maintenance on the system is required, equivalent to a few hours a week, likely to be carried out by staff from the rental company.
Additional benefits	Potential for water quality improvements.
Best available evidence	A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.

Descriptor	Definition
Wider environmental considerations	Potential implications such as including visual impact, noise, and odour on the local population. Energy use may also be an important consideration. Disposal of waste produced by the portable works may need to be removed and handled appropriately. There is the potential for the waste to be applied as a replacement to imported fertiliser.
Evidence of effectiveness	The manufacturers of PTWs have undertaken detailed testing of their performance and are able to provide certainty regarding the level of nutrient removal that can be achieved.
Precautionary	A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	Yes – management agreements will likely need to be put in place, especially where land is leased. Replacements may be required if the lifetime is less than the developments.
Cost estimate	Capital costs £10,000 - £100,000 depending on size. Maintenance costs £1,000/yr - £5,000/yr.

3.3.3.6 Use alternative wastewater treatment providers

Alternative WRC providers will treat foul water from new developments by designing, consenting and building an alternative treatment works. There is significant cost of laying pipework and therefore such schemes are feasible for developments with a large number (over 500) of dwellings. It may be possible for multiple customers to corroborate to make a feasible number of adjoining sites.

Although full details are not currently available, alternative and current wastewater treatment providers could use new and innovative technologies such as those provided by Organica Water[4]. This technology allows wastewater to flow through 'reactors' approximately 5-6m deep within greenhouses. Aquatic plants and microbes within the reactor's digest/uptake nutrients and other contaminants into the biomass of the plant. There appears to be potential to use this type of 'Food Chain Reactor' technology as a standalone method or part of the process in addition to pre-existing facilities. This mitigation option is not detailed further because it has not been possible to obtain further detail, specific data on nutrient removal, or determine if the UK climate inhibits this as an option.

Table 3.29 provides an overview of the use of alternative wastewater treatment providers.

Table 3.29: Key considerations for use of alternative wastewater treatment providers

Descriptor	Definition
Description of solution	New Appointments and Variations (NAV) provide sewerage services in an area which is currently or previously provided by the incumbent monopoly provider. Companies that are not defined by region and that can operate anywhere in England could potentially provide alternative wastewater solutions. Using alternative wastewater providers would be most applicable where a development is currently proposed to connect to a WRC with no or limited nutrient stripping currently or in the future. Alternative providers would be able to build bespoke treatment works which can achieve the desired effluent concentrations and outperform the proposed WRC.
Delivery timescale	Setting up an alternative wastewater provider typically takes up to three years to deliver and set up; they can be implemented over a long timescale. The WRC would need to comply with permits and ensure that environmental impacts, such as visual and odour impacts are limited.

[4] https://www.organicawater.com/

Descriptor	Definition
Duration of operation	This solution is considered to be a permanent long-term solution.
Nutrient removal	The alternative WRC providers build bespoke plant for developments which includes nutrient stripping. Assuming this solution is used on a housing development of approximately 500 dwellings, effluent from a WRC can achieve 0.5mg/l, this could deliver a P loading of 10 kg/yr, which would be 8 kg/yr lower than if the development was to drain to Newbury WwTW under current permit limits. However, this solution is a viable solution up to 2030. It is not considered to be a solution beyond 2030 because the effluent concentrations at Newbury would be lower following the amendments to the LURA
Applicability	This solution would not completely mitigate excess nutrient loading from developments and mitigation would still be required through other solutions. However, it could significantly reduce the mitigation required which could potentially be addressed through on-site measures such as Sustainable Drainage Systems (SuDS).
Management and maintenance	The management and maintenance will be provided by the local operator. The maintenance of this system is paid through foul drainage bills.
Additional benefits	Can be integrated with SuDS to deliver flood risk benefits and amenity space.
Best available evidence	Yes.
Wider environmental considerations	Implementing this scheme is unlikely be significantly constrained by the wider environment.
Evidence of effectiveness	Yes - P effluent concentrations of 0.5 mg/l are achievable, which is very close to industry best removal rates. The evidence of effectiveness for the removal of TN cannot be calculated as the wastewater providers did not provide the TN effluent concentrations.
Precautionary	Yes - A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	Yes – management agreements will likely need to be put in place, especially where land is leased. Replacements may be required if the lifetime is less than the developments.
Cost estimate	Capital Expenses will depend on the plant size, ranging from approximately £1.9 Million to £3.8 Million.

3.3.3.7 Rectifying misconnections to combined systems

Misconnections occur at a local property level when household wastewater is connected to a surface water drain instead of the local sewer network. **Table 3.30** provides an overview of rectifying misconnections to combined systems.

Table 3.30: Key considerations for rectifying misconnections to combined systems

Descriptor	Definition
Description of solution	Misconnections can cause pollution to the local environment and cause problems for bathing waters. The solution for this is to identify the misconnections and rectifying them so that the household wastewater is connected to the local sewer network. Examples of misconnections include washing machines and dishwashers which typically have a high P content.
Delivery timescale	Rectifying a misconnection to a surface water drain can be established in the short term. However, the process for identification of misconnections and subsequent connection is subject to a long-term timescale.
Duration of operation	Once the misconnection has been remediated, it is assumed to be a permanent drainage and nutrient management solution.
Nutrient removal	Highly variable and specific calculations would need to be established.

Descriptor	Definition
	In order to quantify the nutrient saving from rectifying misconnections, assumptions would need to be made on concentrations of the appliances/ fitting that were misconnected. Wastewater volumes could be estimated using the Part G calculator[5]. It is unlikely that there will be many opportunities for monitoring misconnections to retrieve meaningful data on the nutrient reductions.
Applicability	This solution could be applied to existing properties in order to provide mitigation for new dwellings.
Management and maintenance	Correction of the misconnection is the duty of the property owner. The local water company will ensure the correction is performed satisfactorily. Maintenance is likely to be minimal once correction completed.
Additional benefits	The rectification of misconnected surface water drainage networks will reduce the volume of pollutants entering the catchment and therefore benefit water quality.
Best available evidence	Yes.
Wider environmental considerations	The rectification of misconnections is unlikely to be significantly constrained by wider environmental factors.
Evidence of effectiveness	There is currently limited evidence to demonstrate the efficiency of rectifying misconnections to surface water drainage networks in the removal of nutrients from the catchment. Monitoring opportunities are likely to be limited. Therefore, generic concentrations would likely need to be applied with a conservative approach taken.
Precautionary	A precautionary approach can be taken with this method through assuming precautionary removal rates and the possible addition of precautionary buffers within the calculations.
Securable in perpetuity	Yes – management agreements will likely need to be put in place, especially where land is leased. Replacements may be required if the lifetime is less than the developments.
Cost estimate	The costs may differ due to the level of construction work associated with rectifying misconnections. Cost estimates are unknown.

3.3.3.8 Improve existing wastewater distribution infrastructure (reduce leakage from foul sewer network)

The water distribution networks in the UK are subject to leakage from sewer and (drinking) water mains are a potential source of groundwater nutrient pollution (Reynolds & Barrett, 2003). Water leaks from water distribution networks follows subsurface flow pathways to reach surface waters quickly as throughflow, or flow through superficial geological deposits and deep aquifers to enter surface waters as baseflow. Nutrient enrichment of wastewater and drinking water in water distribution networks means leaks can create sources of P to designated sites. Key considerations for improvement of existing wastewater infrastructure via reduction of leakage from the foul sewer and mains water network are summarised in **Table 3.31**.

Table 3.31: Key considerations to improve existing wastewater distribution infrastructure

Descriptor	Definition
Description of solution	Nutrient enrichment of wastewater and drinking water in water distribution networks means leaks can create sources of nutrient pollution. Raw sewage entering a municipal WRC is highly enriched in P.
Delivery timescale	Completion of infrastructure works <1 year. However, water industry AMP expenditure cycles may impact delivery timescales. Lag times due to hydrogeological flow parameters may mean impact from mitigation scheme is not seen for years to decades.
Duration of operation	Materials used in the improvement of infrastructure may provide an operational timescale in excess of 80 years. This duration can be achieved with the assumption that the system is managed and maintained, and other factors such as pipe failures and ground movements do not adversely impact it.

[5] https://wrcpartgcalculator.co.uk/

Descriptor	Definition
Nutrient removal	TP removal potential: 365 kg P/yr and 4,380 kg P/yr from reducing 1 Ml/d of leakage from drinking water and sewer mains, respectively. This is based on published concentrations of P in drinking water and raw sewage and does not account for attenuation.
Applicability	The greater density of water distribution networks in urban areas concentrates potential nutrient pollution associated with leakage in these areas (Ascott *et al*., 2016). As such, reducing leakage from sewers and water mains will be best targeted in towns and cities within the affected catchment areas. Much of the Lambourn catchment is within a rural setting, and this may reduce the applicability of this mitigation option.
Management and maintenance	Management and maintenance required by skilled professionals from the water and sewerage company. Pressure testing for pipe defects should be used to help detect problems. Early detection of pipe defects and rectification may result in inhibiting repaired pipes bursting. This may help increase duration timescale that may result in fixed pipes bursting again.
Additional benefits	Reductions in water pollution from other contaminants, e.g., from microbiological pollutants, and therefore benefit water quality.
Best available evidence	Yes.
Wider environmental considerations	Improvement works are unlikely to be significantly constrained by wider environmental factors. Consideration should be given to managing construction works which may be required as part of improvement works to minimise environmental impacts by using a CEMP for example.
Evidence of effectiveness	Yes - There is a significant range in the potential reductions in nutrient load that will occur along subsurface flow pathways, with studies citing P removal efficiencies from 0.4% to 99% for different types of soil and sediment (Penn *et al*., 2017).
Precautionary	Yes - Assuming allowance for attenuation of P on subsurface flow pathways.
Securable in perpetuity	Yes - Assuming appropriate robust management and maintenance plans.
Cost estimate	This is variable depending on the size of a scheme, and meaningful information on costs for fixing sewer leaks has not been possible to obtain. An estimated ~£1 million to reduce 365 kg P/yr from leaking water mains, assuming no attenuation of P on subsurface flow pathways.

3.3.4 Demand management solutions

3.3.4.1 Retrofit water saving measures in existing properties (Local Authority, Registered Providers, public buildings)

When water saving measures are retrofitted into existing properties (such as buildings that belong to Local Authority (LA), Registered Providers, and Public Buildings), the water usage saved from the retrofitted properties will be replaced by the additional water demand from new dwellings. Key considerations are summarised in **Table 3.32**.

Table 3.32: Key considerations of retrofitting water saving measures (LA, Registered Providers, and Public Buildings)

Descriptor	Definition
Description of solution	When retrofitting water saving appliances the volume of water entering the treatment works will stay the same and providing the treatment works operates to a permit limit, the effluent discharge concentration remains the same. There is a greater potential for reducing P loading associated with older rather than more recently constructed dwellings. This solution is only applicable to existing dwellings where an organisation has control over fittings and any upgrade works. Requirement G2 and Regulations 36 and 37 of the Building Regulations (2015) introduce a minimum water efficiency standard for new dwellings of no more than 125 l/person/day. The UK Government also

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Descriptor	Definition
	introduced an optional requirement of 110 l/person/day for new dwellings (excluding properties owned by Local Authorities and Registered Providers), which Local Planning Authorities must adhere to in future Local Plans. As a result, these two figures were used as targets when retrofitting water efficient appliances and fittings. This solution is not applicable to WwTWs without a permit limit.
Delivery timescale	Short-term
Duration of operation	Permanent – The fittings will be in place for the lifetime of the development and any replacements required will be to the same efficiency or better.
Nutrient removal	Wastewater achievable reductions of 40 litre/ person/ day. Approximately three existing dwellings will need to be retrofitted for every single new dwelling.
Applicability	Applicable to Housing and buildings owned by Local Authorities or Registered Providers
Management and maintenance	Replacement parts of the same or better efficiency must be used. Monitoring compliance checks required.
Additional benefits	▪ Sustainability ▪ Water resources ▪ Reduced water bills for residents and/or organisations
Best available evidence	Yes – UK government published calculator would be used for calculating water usage for appliances.
Wider environmental considerations	This option may reduce water use in the south of England, an area of the UK, which is under water stress, saving water as a valuable resource.
Evidence of effectiveness	Yes - UK government published calculator would be used for calculating water usage for appliances.
Precautionary	Yes – precautionary assumptions can be applied to the water saving calculations.
Securable in perpetuity	Yes – Where a Local Authority or Registered Provider have ownership and control of dwellings that are due to be retrofitted with more water efficient fittings. Registered providers may need to evidence water savings through water bills pre and post improvements. Where a scheme is proposed by private housing, commercial and industrial premises then this solution is unlikely to have sufficient certainty in perpetuity. In these cases, there is a greater risk that replacement fittings would not meet the required water efficiency.
Cost estimate	£4,000 per new dwelling for a full retrofit (taps, toilets, showers, bath).

3.3.4.2 Incentivise commercial water efficiency

Operators of a consent to discharge trade effluent would install treatment facilities ahead of discharge to the sewerage network. The installation of which would be enforced via the consent provided by the water company. Key considerations are summarised in **Table 3.33**.

Table 3.33: Key considerations of incentivising commercial water efficiency

Descriptor	Description
Description of solution	For reasons of commercial confidentiality and/ or competition law it is considered necessary that this option would be led by a party other than the local sewerage undertaker (water company). A water company is the regulator of trade effluent discharge licence consents into the foul sewer network and the Environment Agency regulates effluent discharge into the surface water catchment (and groundwater). Operators of a consent to discharge trade effluent would install treatment facilities ahead of discharge to the sewerage network, the installation of which would be enforced via the consent provided by the water company.
Delivery timescale	Long-term
Duration of operation	Permanent – This would require the installation of a permanent treatment facility on site.
Nutrient removal	The nutrient removal calculations have not been undertaken and this option would require specific discharge output detail to develop an understanding of the plausible removal potential. However, the concept of this option is considered to remove nutrient from the catchment at a point upstream of the point of discharge to surface water (or groundwater).
Applicability	The incentivisation of water efficiency is applicable to businesses which discharge into the catchment either via WRCs, which are regulated by the Water Industry Act 1991 as amended, and the Environmental Permitting Regulations 2016 as amended, and direct to surface water or groundwater, as regulated by the Environment Permitting Regulations 2016 as amended.
Management and maintenance	The treatment facilities will require regular management and maintenance to maintain effective operation. Waste removal of solids in the form of 'filter cake' or similar is anticipated. Regulators of a discharge consent would review monitoring data for compliance and undertake site inspections.
Additional benefits	Other potentially harmful substances within the discharge could also be captured via on site treatment facilities, therefore benefitting water quality.
Best available evidence	Industry best practise methods and site-specific data can be used when determining the nutrient removal.
Wider environmental considerations	Construction work to install on-site treatment facilities, and operation of a treatment facility, could potentially present wider environmental implications, for example: ▪ potential loss of habitat for new developments on greenfield sites; or, ▪ potential for pollution resulting from construction activities if good environmental management practices are not adopted, e.g., non-compliance with oil and fuel storage regulations.
Evidence of effectiveness	The treatment processes installed will be effective beyond reasonable scientific doubt.
Precautionary	Yes – precautionary principles can be adopted when calculating the nutrient removal.
Securable in perpetuity	Yes
Cost estimate	Costs are unknown and will be very site specific.

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4 Summary

4.1 Summary of potential solutions

Table 4.1 provides an overview of the required land / units and associated costs required for the implementation of some of the mitigation solutions outlined in **Section 3**. Riparian buffer strips and constructed wetlands offer the greatest nutrient removal for the cost required. Replacing existing private sewer systems also provide a cost effective and implementable mitigation option. Cover cropping represents an efficient temporary solution when compared to other temporary solutions such as taking agricultural land out of use. The calculations for some mitigation solutions, such as retrofitting of water saving devices, rely upon assumptions, such as assumptions which are based on the type of proprietary technology used and the precise amount of water that can be saved. As such, the data is generic and not as robust as for those for the solutions listed in the table below. The solutions listed are also considered to be the more relevant of the solutions discussed in this document.

Table 4.1 Nutrient and cost budget summary of deliverable solutions

Solution	Removal Rate Coefficient (kg/ha/yr)	Costs used in Estimation (£)	Total Area (Ha) / Units	Estimated cost (£)	£/kg/yr	£/dwelling
Silt traps	0.095	40,000 (£500/ha per annum maintenance)	508.2	£20,329,848	£421,053	£23,314
Riparian buffer strips (Lower Lambourn)	1.27	62,880 (£786/ha/yr)	37.9	£2,383,434	£49,363	£2,733
Constructed wetlands	12	300,000	3.9	£1,170,034	£24,233	£1,342
Taking agricultural land out of use (**Upper Lambourn)	0.07	25,550 (assumes land purchase prices)	689.8	£17,623,437	£365,000	£20,210
Cessation of fertiliser	0.095	101,951	508.2	£51,816,309	£1,073,171	£59,422
Cover crops	0.114	9,920	423.5	£4,201,502	£87,018	£4,818
Upgrade existing private sewer systems	0.77 kg/yr as per Table 3.26	42,025	62.3*	£2,618,196	£54,226	£3,003

Note: * Units refer to a PTP or septic tank unit in this context as area is not relevant for these solutions.
** the Upper Lambourn is selected because it is considered to be of more relevance with respect to agricultural land use (see further explanation in Section 5).

A range of techniques can be used in the river catchments, and these are mainly aimed at slowing runoff and trapping sediment-bound pollutants. Wastewater management and demand management solutions provide an opportunity to deliver mitigation in restively short timescales. These solutions typically have greater certainty than runoff and nature-based solutions and issues with land purchase/ rental may be possible to avoid.

Table 4.2 summarises potential nature-based solutions for the Lambourn and **Table 4.3** summarises potential wastewater management solutions.

Table 4.2: Potential nature-based management solutions summary

Solution	Delivery timescale	Duration of operation	Estimated P removal potential	Management / maintenance requirements	Additional benefits	Best available evidence	Evidence of effectiveness?	Precautionary	Securable in perpetuity?	Approximate cost estimate	Further information
Silt traps	Short-term	Impermanent	25-75%	Regular de-silting	Water quality	No	Yes	Yes	Yes	Capital costs £1,000-£4,000. Maintenance costs £500/yr.	Section **Error! Reference source not found.**
Riparian buffer strips	Short-term	Impermanent	0.79 kg/ha/yr to 5.72 kg/ha/yr in the upper Lambourn; and 0.70 kg/ha/yr to 5.06 kg/ha/yr lower Lambourn catchment	Vegetation cutting / management	Riverbank stabilisation Water quality Erosion reduction Habitat creation Amenity value BNG Carbon offset	Yes	Yes	Yes	Yes	Capital costs £183/ha Maintenance costs £786/ha.	Section 3.3.1.1
Wet woodlands	Short-term	Permanent	0.79 kg/ha/yr to 5.72 kg/ha/yr in the upper Lambourn; and 0.70 kg/ha/yr to 5.06 kg/ha/yr lower Lambourn catchment	Minimal to none	Recreation Carbon sequestration Biodiversity conservation Air pollution reduction Flood risk reduction Biofuel	No	No	Yes	Yes	£10,000/ha. Maintenance costs N/A as minimal.	Section 3.3.1.3
Constructed wetlands	Medium-term	Permanent	Variable	Periodic maintenance to vegetation and de-silting	Biodiversity improvement Water quality and quantity Flood hazard management Carbon offsetting Amenity	Yes	Yes – if following Constructed Wetlands Framework	Yes – if following Constructed Wetlands Framework	Yes – if following Constructed Wetlands Framework	Approximately £300,000/ha.	Section 3.3.1.4
Willow buffers	Short-term	Impermanent	67-74%	Harvest every 3-5 years Replant every 20-25 years	Water quality BNG	No	No	Yes	Yes	Capital costs £2,500/ha. Maintenance costs £200 - £300/ha/yr.	Section 3.3.1.4
Beetle banks	Short-term	Permanent	Unknown and possibly similar to riparian buffer strips	Regular cutting	BNG Soil erosion reduction	No	No	Not known at this stage	No	Unknown – possibly similar to riparian buffer strips.	Section 3.3.1.6
Beaver reintroduction	Medium-term	Beaver – impermanent Logjams - permanent	Variable – 20-80%.	Beaver – little maintenance Logjams – repair if damaged	Flood management Biodiversity Amenity	Yes	Yes	Yes	Beaver – no Logjams - Yes	Beaver – no reliable estimate. Logjams - £5,000 - £25,000.	Section 0
Taking land out of agricultural use	Short-term	Temporary Impermanent Permanent	Upper Lambourn: 0.07 kg/ha/yr Lower Lambourn: 0.36 kg/ha/yr	Harvest every 2-4 years	Energy crop BNG Soil erosion reduction	Yes	Yes	Yes	Yes	£25,550/ha land purchase for average arable land	Section 3.3.2.1

Solution	Delivery timescale	Duration of operation	Estimated P removal potential	Management / maintenance requirements	Additional benefits	Best available evidence	Evidence of effectiveness?	Precautionary	Securable in perpetuity?	Approximate cost estimate	Further information
Conversion of agricultural land to solar farms	Short-term	Permanent	Upper Lambourn 0.05 – 0.38 kg/ha/yr Lower Lambourn: 0.06 – 0.75 kg/ha/yr	Livestock number monitoring	Renewable energy provision BNG Water quality	No	Yes	Yes	Yes	Unknown.	Section 3.3.2.2
Cessation of fertiliser / manure application	Short-term	Temporary	0.02 – 0.19 kg/ha/yr	None	Suspended sediment buffer via strategic land selection	Yes	Yes	Yes	No	£1,274.37/ha/yr.	Section 3.3.2.3
Cover crops	Short-term	Impermanent	uncertainty and assumed to be ~30%, equates to 0.07 – 0.36 kg/ha/yr	Regular maintenance with preparation, planting, destruction, and cultivation of cover crops	Soil erosion reduction Water quality BNG	No	No	Yes	Yes	£150/ha/yr.	Section 3.3.2.4
Installation of SuDS in new developments	Short-term	Permanent	20-100%	Regular maintenance including de-silting	Soil erosion reduction Water quality Habitat creation Improved amenity value	Yes	Yes	Yes	Yes	Unknown and variable according to bespoke design at any particular site.	Section 3.3.2.5
Retro-installation of SuDS in existing developments	Medium-term	Permanent	20-100%	Regular maintenance including de-silting	Soil erosion reduction Water quality Habitat creation Improved amenity value	Yes	Yes	Yes	Yes	Unknown and variable according to bespoke design at any particular site.	Section 3.3.2.6
Paddock management	Short-term	Permanent	100% of input	Regular removal and cleaning	Reuse of manure reducing pressure on resources	Yes	Yes	Yes	Yes	Unknown at this stage.	Section 3.3.2.7

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Table 4.3: Summary of wastewater management solutions summary

Solution	Delivery timescale	Duration of operation	Estimated P removal potential	Management / maintenance requirements	Additional benefits	Best available evidence	Evidence of effectiveness?	Precautionary	Securable in perpetuity?	Approximate cost estimate	Further information
Expedite planned improvements to treatment works	Short-term	Temporary	0.56 kg/yr for each year	Nothing in addition to the usual water company maintenance	None	Yes	Yes	Yes	Yes	Unknown and bespoke to any specific scheme undertaken by Thames Water.	Section 3.3.3.1
Improvements to wastewater treatment works	Medium-term	Permanent	12.86 – 37.61 kg/yr	Nothing in addition to the usual water company maintenance	None	Yes	Yes	Yes	Yes	Thames Water estimate £3.5M/ WwTW. Operational costs: £165,000 per year/WwTW.	Section 3.3.3.2
Installation of cesspools and capture outputs from private sewage systems	Short-term	Impermanent	100% temporarily	Regular emptying and inspection	None	Yes	Yes	Yes	Yes	Capital costs: £3,000 to £6,000. Operational costs: £3,200 to £5,600 per year.	Section 3.3.3.3
Improvements to package treatment plants / septic tanks	Short-term	Permanent	0.97 kg/yr	Regular maintenance	None	Yes	Yes	Yes	No	Capital costs: bespoke to plant size, up to £10,000 - £15,000. Additional costs likely to take total cost to £30,00/plant	Section 3.3.3.4
Installation of portable treatment works	Short-term	Temporary	0.5 mg/l	Regular maintenance	Water quality	Yes	Yes	Yes	Yes	Capital costs £10,000 to £100,000 (depending on size). Maintenance costs £1,000 to £5,000 per year.	Section 3.3.3.5
Use alternative wastewater treatment providers	Long-term	Permanent	10 kg/yr	Regular maintenance	May be integrated with SuDS to deliver flood risk benefits and amenity space	Yes	Yes	Yes	Yes	£1.9 Million to £3.8 Million dependent on the plant size.	Section 3.3.3.6
Rectifying misconnections to combined systems	Long-term	Permanent	Calculations not available to determine and removal potential unknown	Minimal maintenance once misconnection corrected.	Water quality	Yes	No	Yes	Yes	unknown	Section 3.3.3.7
Improve existing wastewater distribution infrastructure (reduce leakage from foul sewer network)	Long-term	Permanent	365kg P/yr from reducing leaks from drinking water pipes 4,380kg P/yr from reducing leaks from sewer system	Regular maintenance	Water quality	Yes	Yes	Yes	Yes	~£1 million to reduce 365 kg P/yr from leaking water mains. Sewer system costs unknown.	Section 3.3.3.8
Retrofit water saving measures in existing properties (local authority, registered	Short-term	Permanent	Approximately 40 l/person/day removal	Maintenance and compliance monitoring	Sustainability Water resources	Yes	Yes	Yes	Yes	£4,000 full retrofit.	Section 3.3.4.1

Solution	Delivery timescale	Duration of operation	Estimated P removal potential	Management / maintenance requirements	Additional benefits	Best available evidence	Evidence of effectiveness?	Precautionary	Securable in perpetuity?	Approximate cost estimate	Further information
providers, public buildings)											
Incentivise commercial water efficiency	Long-term	Permanent	Unknown	Regular maintenance	Water quality	Yes	Yes	Yes	Yes	unknown	Section 3.3.4.2

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4.2 Next steps

The following sets out the next steps required to develop the solutions presented within this report to functioning nutrient mitigation solutions:

- Identification of the preferred solutions to be delivered and the likely costs, timescales, and delivery mechanisms.
- A database or spreadsheet-based tracking tool to register and record the nutrient loading for each development and through what schemes this will be mitigated.
- A tracking tool could also be expanded to track ‘credits’ achieved through mitigation schemes that can be used for biodiversity net gain and carbon offsetting.
- Standardised legal agreements could be drawn up and used as a basis in future mitigation schemes. Conservation covenants are one option that should be explored.
- A Mitigation Plan should be created to formulate developer contributions. In establishing such a plan, the key solutions and timescales for expected delivery would set out in addition to the roles of relevant contributors and organisations. This will allow for quantification of when and how many credits will be available.

5 Action Plan

An action plan in the catchment can be devised by weighting the feasible mitigation solutions presented in **Section 3**. The feasibility of selected options emphasises standalone application while considering the potential for broader, integrated impacts when combined. Mitigation solutions were tailored to the distinct land-use characteristics and geological conditions of the upper and lower catchments, delineated by their unique agricultural features and wastewater capacities. Preferred solutions included agricultural/land-based options for the upper catchment, known for its arable grasslands, and equine paddock management alongside retrofitting water-saving devices in both catchments to address similar wastewater treatment needs. Constructed wetlands receiving water from rivers / streams and other options such as beaver reintroduction was excluded based on unsuitability or ineffectiveness within the specific catchment contexts.

It is worth noting that emerging solutions can offer plausible mitigation and floating in-channel wetlands have not currently been considered as a feasible option until more research is conducted; these potential future mitigation solutions are detailed in **Section 5.5**.

5.1.1 Habitat Regulations Assessment requirements for a mitigation solution

The Habitat Regulations require mitigation solutions to meet the following criteria:

- The solutions should be based on the best available evidence.
- The solutions should be effective beyond reasonable scientific doubt.
- The solutions should apply the precautionary principle.
- The solutions should be secured in perpetuity (i.e., 80 years).

The mitigation provider will be responsible for ensuring that the mitigation solutions are compliant with the above criteria. The solutions must be in place and operational prior to occupation. Short-term bridging solutions can be used as temporary measures until long-term solutions are identified and established. However, in order for West Berkshire Council to be able to approve planning applications with a short-term solution that will transition into a long-term solution, details (such as the location and likely amount of phosphate removal) and certainty of delivery on the long-term solution will be required – that will need monitoring confirmation from Natural England.

To comply with The Habitat Regulations (particularly the in-perpetuity test), monitoring and maintenance will be required for most of the solutions. Maintenance obligations will vary depending on the mitigation solution. However, mitigation providers will be able to pass maintenance responsibilities to third parties via legal and financial agreements to ensure that the solution is maintained in perpetuity. In this case, a financial transaction for the mitigation measure could occur directly between the third-party and the mitigation provider. Where mitigation providers are buying into a privately run off-site mitigation scheme, these schemes would again be owned and managed by a third-party or the mitigation provider.

5.2 Identification of preferred solutions

Various mitigation solutions were considered, and preferred options were shortlisted based on the Lambourn catchment's land use features, equine paddocks, and location of associated facilities. These options were split into the upper and lower catchment areas based on the different characteristics highlighted in **Section 3** and elevation data based on the different catchments within West Berkshire and effluent output by the Winterbourne STW and Chieveley STW (**Figure 5.1**). The elevation data is presented from yellow (high elevation) to green (low elevation). Sewage Treat Work (STW) catchment areas are shown in blue.

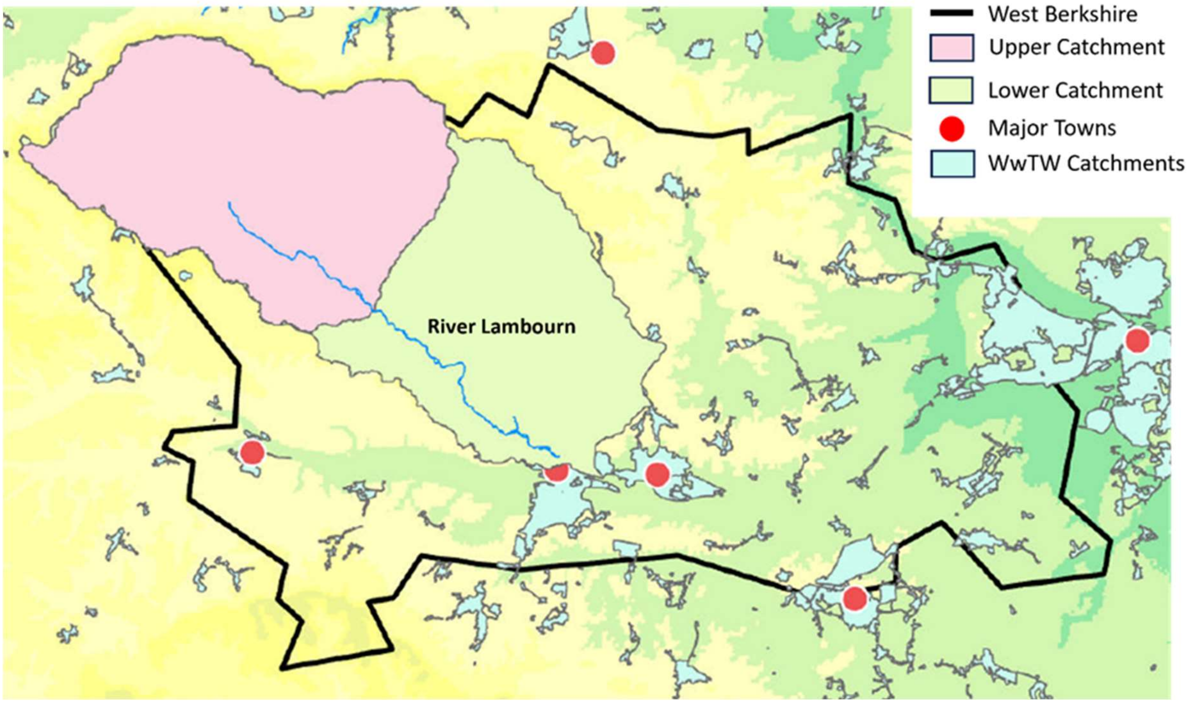

Figure 5.1 Upper and Lower catchment areas of the River Lambourn

Table 5.2 and **Table 5.3** outline preferred mitigation solutions related to nature-based strategies and wastewater management. These solutions are evaluated using a Red, Amber, and Green (RAG) scoring system, distinctly categorised to reflect their applicability within the upper and lower catchment areas. Within each catchment the RAG score is based on three key criteria: costs (capital and/or maintenance), estimated phosphorus-removal amounts, and Habitat Regulations Assessment (HRA) feasibility within the specific environmental setting. Land use data divided by the catchment area was used to determine a high level analysis of the available space for mitigation solutions. The RAG colour for each of these categories are shown in **Table 5.1**, nature-based solutions and waste water solutions were assessed separately for the cost and p-removal RAG score. Within this ranking system environmental feasibility is ranked as the most important because it is imperative for the implementation of a solution. The foundational data for the cost and P-removal evaluations is derived from **Table 4.3** and the nutrient calculator developed by West Berkshire, tailored to local land use. Each mitigation solution is quantitatively and qualitatively assigned an overall score reflecting its suitability as either a temporary (short-term) or permanent (long-term) solution, based on an aggregate of its RAG scores across both catchment areas.

The assessment of the cost, p-removal and environmental feasibility categories are a top-level assessment to provide an indicator of the suitability of some of the solutions as standalone options, the RAG assessment for these options would change if some options were used in combination.

Table 5.1 RAG score classification for the upper and lower catchment categories

Categories	Red	Amber	Green
Cost	Estimated upper quartile cost of the median maintenance and capital costs.	Estimated cost between the upper and lower quartile of the median maintenance and capital costs.	Estimated cost within lower quartile of the median maintenance and capital costs.

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Categories	Red	Amber	Green
P-removal	Estimated phosphorous removal of less than 40% of the median phosphorous removal rate.	Estimated phosphorous removal of 40%-59% of the median phosphorous removal rate.	Estimated phosphorous removal of 60% or more of the median phosphorous removal rate.
Environmental feasibility	Does not pass the HRA suitability test on more than one category and/or is not feasible because the area or solution is not viable.	Passes the HRA suitability but fails one of the HRA criteria such as perpetuity. And/ or can only be implemented in very small-scale areas.	Passes the HRA suitability criteria and is feasible option for the environmental setting.

For these preferred solutions, constructed wetlands have not been considered due to extensive groundwater flooding across the catchment and chalk and peat compositions within the Lambourn catchment being not suitable for wetland construction. In addition, other options have been removed if they are not applicable to the Lambourn area, this includes reintroduction of beavers and engineered logjams (see **Table 3.10**), removal of agricultural land (see **Table 3.12**), use of alternate waste water treatment providers, and improving existing water distribution (see **Table 3.31**).

Within the upper catchment areas, there is a higher percentage of arable grassland in comparison to the lower catchment areas. This has resulted in agricultural/ land-based solutions being more feasible in the upper catchment than the lower. In addition, options like the silt traps would be more cost effective within the upper catchments, where the silt traps could decrease the nutrients entering from multiple tributaries that will encompass a larger surface area of agriculture runoff compared to just using silt traps lower on the main river. Riparian buffer strips are a plausible solution in both the upper and lower catchments; however, it is possible much of the Lambourn has riparian buffer strips already and there may not be space to add more. West Berkshire Council has provided recent examples of Natural England accepting equine paddock management and is provided as a potential standalone solution in **Table 5.2**.

Regarding waste management solutions, the upper and lower catchment areas have similar waste water treatment areas, with slightly higher populations and lower water capacity within the upper catchment. Retrofitting water-saving devices in properties, due to similar wastewater treatment capacity in both catchments, could be complementary, aiming at sustainability and reducing overall water demand.

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Table 5.2: Proposed nature-based solutions RAG score for the Lambourn upper and lower catchment areas, reasons behind the RAG score have been highlighted in the feasibility comments column

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
Silt traps	Cost	£500 yr and capital costs of £1,000- £4,000 per installation.	Cost	£500 yr and capital costs of £1,000- £4,000 per installation.		
	P removal	*0.025kg/ha/yr (25% has been used as a conservative assumption of the total available arable land)*	P removal	*0.095kg/ha/yr (25% has been used as a conservative assumption of the total available arable land)*		
	Feasibility of environmental setting	*Suitable for arable grassland areas in the upper catchment areas. Would not pass all HRA requirements – most notably he in-perpetuity test.*	Feasibility of environmental setting	*Fewer feasible areas within the lower catchment. Less prevalent arable areas close to Lambourn River and would not pass all HRA requirements – most notably he in-perpetuity test.*		
Riparian buffer strips and Willow Buffer strips	Cost	*£1186 ha/yr and capital costs £183/ha*	Cost	*£1186 ha/yr and capital costs £183/ha*		
	P removal	*0.30 kg/ha/yr (29% removal rate for 15m buffer))*	P removal	*1.27kg/ha/yr (29% removal rate for 15m buffer)*		
	Feasibility of environmental setting	*There are already riparian buffer strips in place, meaning the number of hectares available are reduced. Would meet the HRA requirements. There must be a 12-24m wide area of water-dependent habitat between the land and the water's edge of*	Feasibility of environmental setting	*The lower catchment has more available land and appropriate soil types that can be utilised as buffer strips in comparison to upper catchment areas. Would meet the HRA requirements. There must be a 12-24m wide area of water-dependent habitat*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
		rivers and streams (riparian habitats) and lakes and ponds.		*between the land and the water's edge of rivers and streams (riparian habitats) and lakes and ponds.*		
Wet woodlands	Cost	*£1186/ha/yr and capital costs £10,000/ha ~*	Cost	*£1186/ha/yr and capital costs £10,000/ha ~*		
	P removal	*0.30 kg/ha/yr (29% removal rate for 15m buffer)*	P removal	*1.27 kg/ha/yr (29% removal rate for 15m buffer)*		
	Feasibility of environmental setting	*Feasible locations in the upper catchment and would meet the HRA requirements.*	Feasibility of environmental setting	*Feasible locations in the lower catchment and would meet the HRA requirements.*		
Beetle banks	Cost	*Estimated £764 ha/yr and capital costs £183/ha*	Cost	*Estimated £764 ha/yr and capital costs £183/ha*		*The farming community would be unlikely to adopt this solution long term.*
	P removal	*0.029 kg/ha/yr (29% has been used as a conservative assumption of the total available arable land)*	P removal	*0.029 kg/ha/yr (29% has been used as a conservative assumption of the total available arable land)*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	Feasibility of environmental setting	*Can be used in areas with arable land. Applicable in multiple areas with raised areas and suitable soil types. It is only a short-term solution so would not meet perpetuity aspect of the HRA requirements but would meet all other aspects.*	Feasibility of environmental setting	*Can be used in areas with arable land. Applicable in multiple areas with raised areas and suitable soil types. It is only a short-term solution so would not meet perpetuity aspect of the HRA requirements but would meet all other aspects.*		
Conversion of agricultural land to solar farms	Cost	*Unknown*	Cost	*Unknown*		*Until an accurate account of the costs can be calculated this cannot be considered a long-term option. It is also only feasible in the upper catchment area.*
	P removal	*0.05 – 0.38 kg/ha/yr (10%- 90% removal based on the total agricultural land available)*	P removal	*0.06 – 0.75 kg/ha/yr (10%- 90% removal based on the total agricultural land available)*		
	Feasibility of environmental setting	*A feasible option for the upper catchment. It may only have small-scale impacts and must not impact designated sites.*	Feasibility of environmental setting	*Not a feasible option for the lower catchment- less feasible environmental areas that would also pass HRA requirements in the lower catchment.*		
Taking agricultural land out of use	Cost	*£326 ha/yr*	Cost	*£326 ha/yr*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	P removal	*0.07 kg/ha/yr ~ (The effectiveness of this conversion in terms of phosphorus removal can vary widely, depending on factors such as soil type and existing levels of phosphorus, types of grasses planted)*	P removal	*0.36 kg/ha/yr ~ (The effectiveness of this conversion in terms of phosphorus removal can vary widely, depending on factors such as soil type and existing levels of phosphorus, types of grasses planted)*		
	Feasibility of environmental setting	*This solution would pass the HRA requirements for perpetuity but would require stakeholder agreements.*	Feasibility of environmental setting	*This solution would pass the HRA requirements for perpetuity but would require stakeholder agreements.*		
Cessation of fertiliser / manure application	Cost	*£1,274.37/ha/yr*	Cost	*£1,274.37/ha/yr*		
	P removal	*0.02 – 0.19 kg/ha/yr*	P removal	*0.02 – 0.19 kg/ha/yr*		
	Feasibility of environmental setting	*The total cessation poses practical and economic challenges for active agricultural operations, potentially affecting productivity and livelihoods. It is a temporary solution and would not pass all HRA requirements.*	Feasibility of environmental setting	*The total cessation poses practical and economic challenges for active agricultural operations, potentially affecting productivity and livelihoods. It is a temporary solution and would not pass all HRA requirements.*		
Cover crops	Cost	*£150/ha/yr.*	Cost	*£150/ha/yr.*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	P removal	*0.027kg/ha/yr (~30% removed based on the total arable land available)*	P removal	*0.114kg/ha/yr (~30% removed based on the total arable land available)*		
	Feasibility of environmental setting	*Highly suitable for arable grassland areas, aiding in reducing runoff and hence nutrient leaching. Is not a potential long-term solution so would not pass all HRA requirements.*	Feasibility of environmental setting	*Highly suitable for arable grassland areas, aiding in reducing runoff and hence nutrient leaching. Is not a potential long-term solution so would not pass all HRA requirements.*		
Highway drainage (SuDS)	Cost	*Estimated capital costs of £20/m^2 – £40/m^2 (would require 1 year monitoring survey)*	Cost	*Estimated capital costs of £20/m^2 – £40/m^2 (would require 1 year monitoring survey)*	*Dependent on P removal statistics*	*Dependent on P removal statistics*
	P removal	*No available data*	P removal	*No available data*		
	Feasibility of environmental setting	*This solution would be feasible based off the HRA requirements and is a long-term solution. Feasibility of establishing is dependent on the water company.*	Feasibility of environmental setting	*This solution would be feasible based off the HRA requirements and is a long-term solution. Feasibility of establishing is dependent on the water company.*		
Installation of SuDS in new developments	Cost	*Estimated capital costs of £20/m^2 – £40/m^2 (New developments will already have SuDS installation costed in)*	Cost	*Estimated capital costs of £20/m^2 – £40/m^2 (New developments will already have SuDS installation costed in)*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	P removal	*20-100% removed of total P from new developments.*	P removal	*20-100% removed of total P from new developments.*		
	Feasibility of environmental setting	*Feasible in all new development areas and meets HRA requirements.*	Feasibility of environmental setting	*Feasible in all new development areas and meets HRA requirements.*		
Retro-installation of SuDS in existing developments / urban areas	Cost	*Estimated capital costs of £20/m² – £40/m²*	Cost	*Estimated capital costs of £20/m² – £40/m²*	*Potentially an option that is already in use*	
	P removal	*20-100% removed of total P from existing developments.*	P removal	*20-100% removed of total P from existing developments.*		
	Feasibility of environmental setting	*Feasible in all new development areas, would meet HRA requirements.*	Feasibility of environmental setting	*Feasible in all new development areas, would meet HRA requirements.*		
Paddock management	Cost	*Estimated £150/ha/yr.*	Cost	*Estimated £150/ha/yr.*	*Short to medium term solution.*	*Would only provide reduced long-term benefits to the wider catchment.*
	P removal	*0.07kg/ha/py (upper limit for lowland grazing)*	P removal	*0.08kg/ha/py (upper limit for lowland grazing)*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	Feasibility of environmental setting	*Feasible for only equine paddocks, which there are fewer hectares of land of across West Berkshire compared to the available land for other solutions.*	Feasibility of environmental setting	*Feasible for only equine paddocks, which there are fewer hectares of land of across West Berkshire compared to the available land for other solutions.*		

Table 5.3 Proposed waste water solutions RAG score for the Lambourn upper and lower catchment areas, reasons behind the RAG score have been highlighted in the feasibility comments column

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
Expedite planned improvements to treatment works	Cost	*No immediate costs, but Thames Water will expect reimbursement that can be sought via a further agreement.*	Cost	*No immediate costs, but Thames Water will expect reimbursement that can be sought via a further agreement. There are planned upgrades already due to take place in WRC of Chieveley within the lower catchment area*		
	P removal	*Expedite improvements scheduled for 2024. Approximate temporary mitigation achieved for each year improvements are expedited.* *East Shefford: 272.84 kg/yr*	P removal	*Expedite improvements scheduled for 2024. Approximate temporary mitigation achieved for each year improvements are expedited.* *Boxford: 110.81kg/yr* *Chieveley: 211.99 kg/yr* *East Shefford: 272.84 kg/yr*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	Feasibility of environmental setting	*Feasibility will depend on Thames water. Would not meet the perpetuity aspect of the HRA.*	Feasibility of environmental setting	*Feasibility will depend on Thames water. Would not meet the perpetuity aspect of the HRA.*		
Improvements to wastewater treatment works	Cost	*Thames Water estimate capital costs of £3.5M/ WwTW. Operational costs: £165,000 per year/WwTW.* *Although, this option is likely to be funded by nutrient credits.*	Cost	*Thames Water estimate capital costs of £3.5M/ WwTW. Operational costs: £165,000 per year/WwTW.* *Although, this option is likely to be funded by nutrient credits.*		
	P removal	*Fawley: 21 kg/yr for an effluent concentration of 2mg/l*	P removal	*Winterbourne: 17 kg/yr for an effluent concentration of 2mg/l*		
	Feasibility of environmental setting	*Feasible WwTW locations in the upper catchment and would meet the HRA requirements. Only applicable to treatment works not requiring improvements under TAL or WINEP. However, water companies are unlikely to commit to improvements to treatment works for nutrient benefits if the Environment Agency will force compliance for other determinants. Furthermore, water companies have no mechanism under the current OFWAT rules for*	Feasibility of environmental setting	*Feasible WwTW locations in the upper catchment and would meet the HRA requirements. Only applicable to treatment works not requiring improvements under TAL or WINEP. However, water companies are unlikely to commit to improvements to treatment works for nutrient benefits if the Environment Agency will force compliance for other determinants. Furthermore, water companies have no mechanism under the current OFWAT rules for*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
		accepting developer contributions for improvements..		*accepting developer contributions for improvements.*		
Installation of cesspools and capture outputs from private sewage systems	Cost	*Capital costs: £3,000 to £6,000.* *Operational costs: £3,200 to £5,600 per year.*	Cost	*Capital costs: £3,000 to £6,000.* *Operational costs: £3,200 to £5,600 per year.*		
	P removal	*100% of private systems output*	P removal	*100% of private systems output*		
	Feasibility of environmental setting	*Would not be an option to bring in across a wide scale of the catchment and would only provide small amounts of P removal benefits in total. Meets the HRA requirements, but would likely only be used as a short-term solution.*	Feasibility of environmental setting	*Would not be an option to bring in across a wide scale of the catchment and would only provide small amounts of P removal benefits in total. Meets the HRA requirements but would likely only be used as a short-term solution.*		
Improvements to package treatment plants / septic tanks	Cost	*Capital costs: bespoke to plant size, up to £10,000 - £15,000.* *Maintenance costs of £400 to £600 per year.*	Cost	*Capital costs: bespoke to plant size, up to £10,000 - £15,000.* *Maintenance costs of £400 to £600 per year.*		
	P removal	*0.97 kg/yr*	P removal	*0.97 kg/yr*		
	Feasibility of environmental setting	*In order for the solution to pass the in-perpetuity test, there must be sufficient certainty that the system will*	Feasibility of environmental setting	*In order for the solution to pass the in-perpetuity test, there must be sufficient certainty that the system will be in place for the*		

Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
		be in place for the duration of the development it is mitigating (i.e. 80 years) and that if it needs to be replaced at the end of its lifetime (e.g. 40 years), the future system is to the same effluent concentration or better. This will often require agreements to be made with mortgage lenders.		*duration of the development it is mitigating (i.e. 80 years) and that if it needs to be replaced at the end of its lifetime (e.g. 40 years), the future system is to the same effluent concentration or better. This will often require agreements to be made with mortgage lenders.*		
Installation of portable treatment works	Cost	*Capital costs £10,000 to £100,000 (depending on size).* *Maintenance costs £1,000 to £5,000 per year.*	Cost	*Capital costs £10,000 to £100,000 (depending on size).* *Maintenance costs £1,000 to £5,000 per year.*		
	P removal	*0.5mg/l – depending on the area serviced this could be a small or significant removal.*	P removal	*0.5mg/l – depending on the area serviced this could be a small or significant removal.*		
	Feasibility of environmental setting	*The solution will not pass the in-perpetuity test. It is therefore a short-term solution with varying environmental feasibility depending on location.*	Feasibility of environmental setting	*The solution will not pass the in-perpetuity test. It is therefore a short-term solution with varying environmental feasibility depending on location.*		
Rectifying misconnections to combined systems	Cost	*£1.9 Million to £3.8 Million dependent on the plant size.*	Cost	*£1.9 Million to £3.8 Million dependent on the plant size.*		
	P removal	*10 kg/yr – varies based on the number of misconnections.*	P removal	*10 kg/yr– varies based on the number of misconnections.*		

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Solution	Upper Catchment RAG	Upper Catchment Comment	Lower Catchment RAG	Lower Catchment Comment	Overall Ranking as a Temporary solution	Overall Ranking as a Permanent solution
	Feasibility of environmental setting	*Does not meet all the HRA requirements of feasibility, specifically that there is no evidence of the P-removal impacts. It is also difficult to identify location of misconnections and opportunities are only likely to be identified on an ad-hoc basis. A full survey of potential properties would be prohibitively expensive.*	Feasibility of environmental setting	*Does not meet all the HRA requirements of feasibility, specifically that there is no evidence of the P-removal impacts. It is also difficult to identify location of misconnections and opportunities are only likely to be identified on an ad-hoc basis. A full survey of potential properties would be prohibitively expensive.*		
Retrofit water saving measures in existing properties (local authority, registered providers, public buildings)	Cost	*£4000 per instalment*	Cost	*£4000 per instalment*		
	P removal	*Approximately 40l/person/day removal (Approximately 3 existing dwellings to every 1 new dwelling)*	P removal	*Approximately 40 l/person/day removal (Approximately 3 existing dwellings to every 1 new dwelling)*		
	Feasibility of environmental setting	*Feasible only at certain existing properties and dwellings, passes all HRA requirements.*	Feasibility of environmental setting	*Feasible only at certain existing properties and dwellings, passes all HRA requirements.*		
Incentivise commercial water efficiency	Cost	*Unknown*	Cost	*Unknown*		
	P removal	*No available data*	P removal	*No available data*		
	Feasibility of environmental setting	*Feasibility is dependent on the water company*	Feasibility of environmental setting	*Feasibility is dependent on the water company*		

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5.3 West Berkshire preferred mitigation solution stages and timescales

Natural England has developed different stages of the life cycle of a mitigation solutions implementation. These five stages include; a feasibility assessment, technical development and initial consultation, design and consenting, construction and post-construction monitoring. Each of these stages have varying time scales that need to be considered before options are chosen.

Table 5.4 sets out the stages and timescales for mitigation solutions (from **Table 5.2** and **Table 5.3)** that scored a green or amber RAG score for an overall temporary or permanent solution. For Table 5.4 the mitigation options for nature-based solutions that were excluded include; Beetle banks, conversion of agricultural land to solar and cessation of fertiliser. For waste water solutions the excluded solutions included; Expedited planned WwTW improvements, improvements to WwTWs, installation of cesspools from private sewers, and retrofitting water saving efforts.

The time scales for each of the stages have been estimated based on previous case studies and estimations on similar solutions. For example, wet woodlands and willow buffer strips have similar requirements to that of the riparian buffer strips, and thus the timescales have been estimated using the riparian buffer strip time scales as a baseline. For specific mitigation solutions where the P-removal data is needed to be monitored for Natural England to develop an accurate understanding of the nutrient removal a solution is having a baseline monitoring survey must be conducted. Natural England “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 use of SuDS for highway drainage is one such solution that will require this baseline survey.

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Table 5.4 Breakdown of tasks and timescales required to deliver preferred solutions for West Berkshire

Solution	Stage	Tasks	Timescales
Nature based mitigation solutions			
Riparian buffer strips and Willow Buffers	Initial Feasibility	1. The screening of the catchment for suitable areas where buffer strips could be implemented within West Berkshire. This will use existing mapping. 2. Evaluation of suitable areas to identify highest priority land parcels. Areas are identified using the following criteria: a. Nutrient removal potential. b. Topography. c. Geology and Hydrology. d. Soil and sediment types. e. Hydrology and drainage. f. Flood risks. g. Protected sites and Invasive species. h. Current land use. i. Ownerships. j. Landscape and heritage. k. Public access and bird strike risk. l. Regulatory considerations and infrastructure.	~ 4-6 weeks
	Technical development & initial consultation	3. Engagement with landowners to gauge interest and willingness to participate in the scheme. 4. Detailed feasibility and refine the nutrient calculations based on site specific information. 5. Consultation with Natural England regarding proposed nutrient removal methodology which should be in line with the Riparian buffer strip framework.	~ 8-11 weeks
	Design & consenting	6. Design stage, likely to include: a. Site plans including; surface topography, vegetation type and cover, slope, soil type, livestock. b. Planting schedule. c. Construction methods statement (expect that they would not need planning consent). d. Maintenance schedule. Note: There is a potential for high level surveys (e.g., Phase 1 Ecology Survey) to be needed at this stage, which may need to be undertaken in survey season (May-September). 7. In tandem with 6: Enter legal agreements with landowner regarding:	~ 20-25 weeks* *This timescale assumes no planning permission is required

Solution	Stage	Tasks	Timescales
		a. Leasing land identified as suitable for implementing buffer strips. b. Arrangements regarding future management and maintenance. 8. Gain approval by Natural England, likely to include the submission of the following documents: a. Technical documents (i.e., technical reference sheet) for each site. b. Site plans. 9. Consult with Natural England regarding Riparian Buffer framework and award % of the maximum efficacy value that can be claimed. 10. Identification of delivery partner. Using a "familiar face" in the catchment may be aid a good relationship with landowners. Note: if undertaking scheme specific monitoring instead of modelling, a minimum of a year's baseline monitoring is necessary to quantify the nutrient credits that can be achieved.	
	Construction	11. Implementation/ construction of riparian buffer strips in agreed locations. 12. Validation of works carried out from council to Natural England (this could involve photographic evidence). After works have been validated, upfront Nutrient Credits can be released.	~ 10-13 weeks
	Post-construction monitoring	13. Post-implementation monitoring will be required to gain additional credits. Two surveys points are required (one upstream and one downstream) and a trend analysis required on concentrations, flow and potential time lags. Note: post-implementation monitoring can only achieve additional credits if baseline monitoring was also carried out.	N/A
Wet Woodlands	Initial feasibility	1. Screening of catchment for suitable areas where buffer strips could be implemented within West Berkshire. This will use existing mapping. 2. Evaluation of suitable areas to identify highest priority land parcels. Areas are identified using the following criteria: a. Nutrient removal potential. b. Topography. c. Geology and Hydrology. d. Soil and sediment types. e. Hydrology and drainage. f. Flood risks. g. Protected sites and Invasive species. h. Current land use. i. Ownerships.	~ 4-6 weeks

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Solution	Stage	Tasks	Timescales
		j. Landscape and heritage. k. Public access and bird strike risk. l. Regulatory considerations and infrastructure.	
	Technical development & initial consultation	3. Engagement with landowners to gauge interest and willingness to participate in the scheme. 4. Detailed feasibility and refine the nutrient calculations based on site specific information. 5. Consultation with Natural England regarding proposed nutrient removal methodology which should be in line with the Riparian buffer strip framework.	~ 8-11 weeks
	Design & consenting	6. Design stage, likely to include: a. Site plans including; surface topography, vegetation type and cover, slope, soil type, livestock. b. Planting schedule. c. Construction methods statement (expect that they would not need planning consent). d. Maintenance schedule. Note: There is a potential for high level surveys (e.g., Phase 1 Ecology Survey) to be needed at this stage, which may need to be undertaken in survey season (May-September). 7. In tandem with 6: Enter legal agreements with landowner regarding: a. Leasing land identified as suitable for implementing buffer strips. b. Arrangements regarding future management and maintenance. 8. Gain approval by Natural England, likely to include the submission of the following documents: a. Technical documents (i.e., technical reference sheet) for each site. b. Site plans. 9. Consult with Natural England regarding Riparian Buffer framework and award % of the maximum efficacy value that can be claimed. 10. Identification of delivery partner. Using a "familiar face" in the catchment may be aid a good relationship with landowners. Note: if undertaking scheme specific monitoring instead of modelling, a minimum of a year's baseline monitoring is necessary to quantify the nutrient credits that can be achieved.	~ 20-25 weeks* *This timescale assumes no planning permission is required
	Construction	11. Implementation/ construction of riparian buffer strips in agreed locations.	~ 10-13 weeks

Solution	Stage	Tasks	Timescales
		12. Validation of works carried out from council to Natural England (this could involve photographic evidence). After works have been validated, upfront Nutrient Credits can be released.	
	Post-construction monitoring	13. Post-implementation monitoring will be required to gain additional credits. Two surveys points are required (one upstream and one downstream) and a trend analysis required on concentrations, flow and potential time lags. Note: post-implementation monitoring can only achieve additional credits if baseline monitoring was also carried out.	N/A
Reverting agricultural land to grassland or semi-wooded areas.	Initial feasibility	1. Screening of catchment for suitable areas where arable land could be reverted to low fertiliser input grassland. 2. Evaluation of suitable areas to identify highest priority land parcels. Areas are identified according to the following criteria: a. Nutrient removal potential. b. Environmental constraints. c. Size of arable land package. d. Protected sites.	~ 4-6 weeks
	Technical development & initial consultation	3. Evaluation of initial feasibility to find priority areas where schemes can be implemented, must be on arable areas that have either had the land cultivated for at least 2 years and is identified on the Farm Environment Record (FER) is at risk of soil erosion or surface run off, or is an important site for buffering sensitive habitats. 4. Implementation strategy defined (e.g., using local authority enforcement or volunteers). 5. Legal agreements and Natural England approval of scheme.	~ 8-11 weeks
	Design & consenting	6. Design requirements are likely to include: a. Site plans. b. Planting schedule. c. Maintenance schedule. 7. In tandem with 6: Enter legal agreements with landowner regarding: a. Leasing land identified as suitable to revert and identifying the grass species to sow. b. Arrangements regarding future management and maintenance this includes ensuring that the following activities are not carried out:	~ 20-25 weeks* *This timescale assumes no planning permission is required

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Solution	Stage	Tasks	Timescales
		▪ Use of pesticides, except for herbicides to weed wipe or spot treat injurious weeds, invasive non-native species, nettles, or bracken; ▪ Application of any manure or fertiliser between 15 August and 1 February; ▪ Application of any livestock manures with more than 100 kg of total nitrogen per ha per year, or, no more than 50kg per ha of total nitrogen per year (where there is no use of livestock manures); and, ▪ Supplementation of livestock feed except for mineral blocks (non-energy based). 8. Gain approval by Natural England. This is likely to require the submission of the following documents: a. Technical documents (i.e., technical reference sheet) for each land area. b. Site plans for each arable land owner.	
	Construction	9. Implementation (planting). 10. Validation of the works carried out from the Council to Natural England (this could involve photographic evidence). After the works have been validated Nutrient Credits can be released.	~ 10-13 weeks
	Post-construction monitoring	11. It is assumed there will be no requirement for post-construction monitoring.	N/A
Cover Crops	Initial feasibility	1. Screening of catchment for suitable areas where cover crops could be implemented. This will use existing mapping. 2. Evaluation of suitable areas to identify highest priority land parcels. Areas are identified using the following criteria: a. Nutrient removal potential and current nutrient uptake by soil. b. Environmental constraint. c. Current land use. d. Root depth and soil structure.	~4-6 weeks
	Technical development & initial consultation	3. Evaluation of initial feasibility to find priority areas where schemes can be implemented. 4. Implementation strategy defined (e.g., using Local Authority enforcement or volunteers). 5. Legal agreements and Natural England approval of scheme.	~ 8-11 weeks

Solution	Stage	Tasks	Timescales
	Design & consenting	6. Design requirements are likely to include: a. Site/ farm plans. b. Planting windows and rotation planning schedule. c. Selection of a cover crop species for optimal growth and removal. 7. In tandem with 6: Enter legal agreements with landowner regarding: a. Leasing land identified as suitable for growth of cover crops. b. Arrangements regarding future crop rotation. 8. Gain approval by Natural England, likely to include the submission of the following documents: a. Technical documents (i.e., technical reference sheet) for each site. b. Site/farm/crop plans.	~ 20-25 weeks* Includes a baseline survey to be carried out in tandem with legal documentation. *This timescale assumes no planning permission is required
	Construction	9. Cover crops should be planted ahead of the wetter months (Autumn) and planting planned according to the designated crop rotation schedule. 10. Validation of works carried out from the Council to Natural England (this could involve photographic evidence). After works have been validated Nutrient Credits can be released.	~2- 3 weeks* *Depending on the size of the field and weather conditions
	Post-construction monitoring	11. There is a likelihood that water quality monitoring will be required by Natural England.	Min 52 weeks
Paddock Management	Initial feasibility	1. Finding suitable areas within catchment – mapping exercise and landowner conversations to establish who owns an equine paddock in West Berkshire, where they are located and how to contact them. 2. Feasibility assessment to identify shortlist sites, including analysing: a. Nutrient removal potential. b. Topography. c. Appropriate environmental setting d. Initial approval from landowners/ paddock owners.	~ 8-10 weeks
	Technical development & initial consultation	3. Evaluation of feasibility to identify priority sites/ paddocks for P removal. 4. Initial consultation with Natural England.	~ 4-6 weeks
	Design & consenting	5. Design stage, likely to include: a. Site plans. b. Maintenance schedule. 6. In tandem with 6: Enter legal agreements with landowner regarding: a. Leasing equine paddocks identified as suitable.	~ 15-20 weeks

Solution	Stage	Tasks	Timescales
		b. Arrangements regarding future management and maintenance. 7. Gain approval by Natural England, likely to include the submission of the following documents: a. Technical documents (i.e., technical reference sheet) for each site. b. Site plans.	
	Construction	8. Paddock management plans undertaken. 9. Validation of works carried out from council to Natural England – could involve photographic evidence. After works have been validated Nutrient Credits can be released.	~ 1-2 weeks
	Post-construction monitoring	10. It is assumed there will be no requirement for post-construction monitoring.	N/A
Waste water mitigation solutions			
Upgrading or replacing existing private sewage package treatment plants	Initial Feasibility	1. Call for sites to identify potential homeowners in the catchment (this may include utilising social media, websites, letter drops). This stage involves: a. Liaison with the Environment Agency and water companies to identify hotspot areas for upgrades or replacement of PTPs. b. Review of the consented discharges list with Environment Agency.	~ 8-12 weeks
	Technical development & initial consultation	2. Screening potential sites that have come forward against the small-scale discharge thresholds. 3. Shortlisting and evaluation of sites. This step involves evaluating which sites are likely to provide the greatest nutrient removal and ease of implementation. 4. Identify delivery partner. This will likely be an external contractor and therefore an agreement on the type of works to be carried out and specific PTP models to be installed should be outlined.	~ 25-30 weeks* *timescales may vary subject to the council's subcontractor procurement process (task 7)
	Design & consenting	5. Legal agreements and Natural England approval gained. At this stage there is still some uncertainty regarding agreements, and the current understanding is that security with mortgage lenders would be needed. 6. Development of design plans, including home visits (likely performed by an external contractor), ordering of PTPs, and supply of PTPs.	~ 8-20 weeks per task* *timescales assume PTPs cannot be implemented using Environment Agency's general binding rules
	Construction	7. Implementation of upgrades/ replacements of PTPs in agreed locations. 8. Validation of works carried out from the Council to Natural England (this could involve photographic evidence). After works have been validated Nutrient Credits can be released.	~ 10-14 weeks

Solution	Stage	Tasks	Timescales
	Post-construction monitoring	9. It is assumed there will be no need for monitoring post-construction, but post-construction observations will be carried out to ensure maintenance is carried out according to the manufacturer's requirements across the engineering life time (80 years).	N/A
Highways drainage/ Sustainable drainage systems	Initial feasibility	1. Finding suitable areas within catchment – mapping exercise to identify suitable areas. This should consider high erosion risk areas, known problem areas and an understanding of existing infrastructure. 2. Feasibility assessment to identify shortlist sites, including analysing: a. Nutrient removal potential. b. Existing SuDS. c. Flow volumes. d. Upstream sources of nutrients.	~ 8-10 weeks
	Technical development & initial consultation	3. Evaluation of feasibility to identify priority sites. 4. Initial consultation with Natural England.	~ 4-6 weeks
	Design & consenting	5. Development of design plans and management & maintenance plans. These will require Natural England approval. 6. Finalisation and evaluation of designs.	~ 15-20 weeks
	Construction	7. Construction of SuDS. 8. Validation of works carried out from the Council to Natural England – could involve photographic evidence. After works have been validated Nutrient Credits can be released.	~ 15-20 weeks
	Post-construction monitoring	9. There is a likelihood that water quality monitoring will be required by Natural England.	min 52 weeks
Retro-installation of SuDS in existing developments	Initial feasibility	1. Screening of existing developments for existing drainage structures and availability for retro-installation of SuDS. 2. Feasibility assessment to identify shortlist sites, including analysing: a. Nutrient removal potential. b. Flow volumes. c. Existing SuDS and features (swales, rain gardens, detention basins). d. Upstream nutrients for baseline water quality. e. Site topography.	~8 -10 weeks

Solution	Stage	Tasks	Timescales
	Technical development & initial consultation	3. Evaluation of feasibility to identify priority sites. 4. Initial consultation with Natural England. 5. Initial consultation with Thames Water and development stakeholders.	~4-6 weeks
	Design & consenting	6. Development of conceptual SuDS design plans and management & maintenance plans. These will require Natural England approval. This is likely to include. f. Selecting appropriate components to form treatment trains. g. Consider integrating SuDS into the landscape or urban fabric for multifunctional benefits. h. Public stakeholder engagements. i. Maintenance schedule. 7. Determination of nutrient removal potential, using the CIRIA SuDS guidance for phosphorus removal. 8. Finalisation and evaluation of designs.	~15-20 weeks
	Construction	9. Construction of SuDS in accordance with best-practise.	~ 5 - 30 weeks* *Depending on the number of available retro-installations available.
	Post-construction monitoring	It is assumed there will be no requirement for post-construction monitoring.	N/A

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5.4 Delivery of preferred mitigation solutions

Each mitigation solution can be led by the same or a different authority. This section sets out the different options of mitigation solution delivery and the aspects that need to be considered for their delivery by each authority.

5.4.1 Developer led mitigation

Under this option, developers would be solely responsible for delivering the mitigation needed to offset the proposed development. On-site measures, e.g., SuDS, are likely to be primarily delivered by developers who would identify, finance, and deliver the mitigation solutions. Off-site measures could either be delivered by developers (as for on-site mitigation) or through purchasing established mitigation credits from other landowners.

The mitigation measures must comply with the Habitats Regulations, and developers and/or landowners should be guided by the Solutions Report which presents and assesses suitable mitigation options. Some of the solutions suggested (e.g., SuDS for highway run off management and nature-based solutions such as riparian buffer strips) could be delivered by private developers and landowners.

Developer led mitigation is likely to be more suitable for larger developments (i.e. >50 dwellings) that have the financial resources, space and capabilities for delivery. Identifying suitable off-site mitigation land is also likely to require relationships with landowners across the catchment areas.

Additionally, identifying and implementing specific solutions will require capital expenditure for design and consultancy fees and land purchase/rent. Smaller developments (i.e. <50 dwellings) and particularly windfall developments are unlikely to have the space to deliver on-site mitigation nor the ability to deliver off-site mitigation. To overcome this, smaller developers could work in partnership to deliver mitigation by pooling resources and funding.

In order to minimise the risks associated with developer-led mitigation, developers could partner with organisations that have experience in delivering and maintaining schemes. These organisations include private consultancies, non-governmental organisations (e.g., Wildlife Trust, Rivers Trusts) or private entities such as water companies.

There is also the option to include ‘step-in rights’, where the Council or another third-party (e.g. Environment Agency) may acquire the scheme if it is not maintained appropriately. An appropriately designed ‘step-in’ arrangement would be needed which should ensure there are enough funds to maintain the solution in perpetuity.

The Local Authority, or a body acting on their behalf, is likely to have a role to play in this option by validating and securing proposed schemes and carrying out associated monitoring on an ongoing basis. Costs for this should be retrieved during the planning process.

Developers may find difficulty in the administration of nutrient credits, particularly if selling excess nutrient credits to other developers. There also comes a risk that if a singular scheme does not perform, it cannot be underwritten by a portfolio of other solutions.

5.4.2 Local Authority mitigation

A Local Authority strategic scheme would allow developers to purchase mitigation credits in a wider mitigation scheme. The mitigation scheme would be primarily developed by the Local Authority and would utilise off-site mitigation solutions. Combining financial contributions would allow the Local Authority to deliver ‘strategic’ scale mitigation measures.

As mitigation solutions tend to have fixed costs in terms of design and consent mechanisms, it is often cheaper to deliver one larger ‘strategic’ solution rather than multiple smaller solutions. The Local Authority could also look to partner with third-party organisations to implement and manage the schemes on their behalf.

A Local Authority led scheme will provide a strategic mechanism for small developments to achieve mitigation which would otherwise be unviable based on their resources and capabilities; much of West Berkshire are more rural than urban. This option would acquire financial contributions through a credit-based scheme and the purchase of credits would be used to secure these offsite mitigation schemes. This method has been utilised in other catchments with nutrient neutrality issues.

One advantage of a Local Authority-led scheme over a developer-led scheme is that it would give the Local Authority direct oversight of the functioning and maintenance of the mitigation scheme, and therefore further certainty regarding the delivery. A Local Authority scheme can also be underwritten by a portfolio of solutions to ensure that someone takes responsibility for addressing any future shortfalls in credits delivered. However, a precautionary approach should be taken by underestimating phosphate removal rates for solutions, to ensure that at the very least, the required mitigation is delivered.

Should the demand for credits outweigh supply, there is the potential that credits could be locked up in projects that are not able to progress upon receiving the credits. This could occur where a development needs credits assigned to progress through the planning process but is not likely to be built out for some time. This could result in some developments which are more advanced in the planning process and in a position to construct, failing to acquire credits and causing delay. A Local Authority led scheme can have greater control over this than any of the other options presented. Limiting forward buying will help to reduce price volatility from short-term demand and supply and allow credits to be allocated to projects where there is an immediate requirement. Therefore, it would be useful to incorporate a mechanism into the strategic schemes to ensure that the credits obtained are used to immediately unlock development rather than being banked for the future. This could potentially include a time limit for their use, after which the credits must be returned so that they are available for use by other developers.

A Local Authority scheme would also be able to impose conditions that mitigation credits can only be acquired once all on-site mitigation options (e.g., SuDS) have been explored and exhausted. This will prevent developers relying purely on off-site mitigation options.

It is anticipated that any payments to landowners for delivering mitigation schemes would be paid in lump sums over a pre-defined timescale. Upfront payments will be required to cover capital expenditure, with the remaining monies paid at a later date (e.g., at 5 year intervals).

In the case that a development will be completed in stages, then credits could be secured over multiple years, as opposed to all-in-one year. However, it is likely to be necessary to ensure that any scheme includes a mechanism to provide developers with assurances in managing risks and securing the credits they require for the whole multi-phase development at a reasonable price. Further measures which could be implemented, include establishing viability checks of developments to ensure credits are not unnecessarily locked up. A Local Authority led strategic scheme will also have greater control on any price volatility should there be a high demand for credits.

5.4.3 Third-party schemes

A third-party credit scheme would work in a similar way to a Local Authority scheme but would be delivered and managed by a single, private entity. A third-party scheme would not offer the same level of certainty over the deliverability of mitigation measures as a Local Authority scheme and there would be limited control over releasing credits to the developments most in need. It is also likely that there would be greater price volatility. At present and third-party entity operating in West Berkshire would have to be identified.

5.4.4 Local Authority nutrient trading

A Local Authority controlled nutrient trading platform would involve establishing an exchange market in which credits are tradeable between private mitigation schemes and developers. The platform would create mechanisms for landowners and developers to engage with each other. The Local Authority would act as the market operator and once the platform has been established, they would have minimal input other than validating schemes and securing mitigation. During the initial trading rounds, more support from the Local Authority would be required to ensure market rules are met and legal agreements are appropriate.

As the Local Authority would be the market operator, this would allow some control over who can receive credits and over price volatility through market rules. Similarly, the trading platform would give the Local Authority oversight of the functionality and maintenance of the mitigation scheme, and therefore have further certainty regarding the delivery.

There are limited examples of established local authority trading platforms in other catchments with nutrient neutrality issues. Many of the trading platform available are either at the development or pilot stage and rely heavily on third-party input (see below). As a result, there is likely to be a large financial burden on the Local Authority to establish a scheme which would then also be likely to take many years to become fully operational.

To be successful, a trading platform will need input from the following:

- Market operator – to oversee the entire trading platform;
- Landowner engagers – ideally with experience and contacts within the upper and lower catchment;
- Management system designer – to establish the management system and test the platform;
- Economic and policy team - to design the market settlement process; and
- Communications team - to support market information and communications.

5.4.5 Third-party nutrient trading

A third-party trading platform would operate in a similar way to a Local Authority trading platform but would be controlled and managed by a private entity (or consortium) that would act as the market operator. Example schemes include the Wessex Water Entrade Somerset Levels and Moors trading platform and the Solent nutrient trading pilot study. The Solent pilot study is also exploring how additional environmental benefits may be delivered, such as carbon pollution reduction, or biodiversity gains.

Whilst a third-party trading platform would work closely with Local Authorities, Natural England and the Environment Agency, it would not offer the same level of security on the deliverability of mitigation measures as a Local Authority scheme would.

There are currently no private entities or consortiums operating a nutrient trading platform in the West Berkshire catchment areas. However, should the Solent nutrient trading pilot be successful, there is the potential that this could be established in other catchments.

5.5 Potential future options

Emerging future options are potential solutions which are in the initial stages of data gathering and therefore lack information required to determine whether they fulfil the Habitat Regulations mitigation solutions criteria. The non-exhaustive list of potential future options is based on the Natural flood management measures guide from the Eden rivers trust (2018) that lays out potential management methods using three levels of interventions that are based on complexity, consultation requirements, and costs. Level 1 interventions are generally simple, low-cost measures that can be easily implemented without significant consultation. Level 2 interventions require more planning and possibly consent, involving medium-cost measures. Level 3 interventions are the most complex and costly, targeting specific locations within a catchment and usually requiring design, planning permission, and specialized contractors. West Berkshire could explore a range of innovative interventions to further enhance nutrient mitigation strategies and provide additional flood resilience in the region. These include the following;

Potential Level 1 Interventions

- Cross slope tree planting is a method of woodland creation that could be considered in combination with woodland and willow creation which is discussed in **Table 5.2**. The cross-slope design strengthens stream banks and reduces erosion and siltation, increasing the amount of pollution draining into water courses.

Potential Level 2 Interventions

- Bunds are low earth mounds that are built following the contour of the slope. Water is held in a detention basin by the bund and allowed to disperse through a combination of infiltration into the soil, evaporation, and slow release (for example through a small pipe or filter material). This in turn reduces the amount of groundwater run off entering the catchment and reduces agricultural pollution entering water systems.
- Wooded dams, ponds and shallow scrapes are additional nature-based methods of preventing runoff entering water systems. They also provide potential areas of resistance during flood events and drought periods to the land. These methods however do slowly drain back into the water systems so do not provide a 100% removal solution and just slow down the nutrient supply rather than removing nutrients.

Potential Level 3 Interventions

- Stabilising and revegetation blanket bogs stores high amounts of carbon and can act as a sponge to water runoff, decrease erosion and store away phosphorus and nitrogen pollution. They also provide a biodiversity benefit for moorland species. However, they can only be implemented in areas with appropriate bog areas.
- Water companies utilise reverse osmosis via salinity solutions. Trial periods are currently underway in Somerset and the solution may emerge as a viable temporary solution.

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