CUMBRIA NUTRIENT MITIGATION SOLUTIONS

An assessment of the nutrient mitigation requirement and restoration opportunities in the catchments of four Habitats Sites in the Cumbria region

Report for: Lake District National Park Authority

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CONTENTS

GLOSSARY

Abbreviation	Definition
AA	Appropriate Assessment
BNG	Biodiversity Net Gain
CJEU	Court of Justice of the European Union
CC	Cumberland Council
DLUHC	Department for Levelling Up, Housing and Communities
DCC	Durham County Council
DWF	Dry Weather Flow
EA	Environmental Agency
HRA	Habitat Regulations Assessment
HOST	Hydrology of Soil Types
LDNP	Lake District National Park
LDNPA	Lake District National Park Authority
LURA	Levelling Up and Regeneration Act
LURB	Levelling Up and Regeneration Bill
LSE	Likely Significant Effects
LPA	Local Planning Authority
NE	Natural England
NbS	Nature-based Solutions
N	Nitrogen
NCC	Northumberland County Council
NNPA	Northumberland National Park Authority
NN	Nutrient Neutrality
OP	Orthophosphate
PTP	Package Treatment Plant
P	Phosphorus
PE	Population Equivalent
RBD	River Basin District
ST	Septic Tank
SSSI	Site of Special Scientific Interest
SAC	Special Area of Conservation
SuDS	Sustainable Urban Drainage Systems
TAL	Technical Achievable Limit
TP	Total Phosphorus

Abbreviation	Definition
WFD	Water Framework Directive
WFC	Westmorland & Furness Council
WSM	Weighted sum model
WwTWs	Waste Water Treatment Works
YDNPA	Yorkshire Dales National Park Authority

EXECUTIVE SUMMARY

PROJECT RATIONALE

This report has been commissioned by the Lake District National Park Authority (LDNPA) in order to identify the nutrient mitigation requirement in the four catchments affected by Natural England's (NE) nutrient neutrality (NN) advice in the Cumbria region. The River Kent Special Area of Conservation (SAC), the River Eden SAC, the River Derwent & Bassenthwaite Lake SAC, and the Esthwaite Water Ramsar (referred to as 'Habitats Sites') are in unfavourable condition or are close to unfavourable condition due to excessive phosphorus (P) levels. Thus, in accordance with the European Court of Justice (CJEU) 'Dutch Nitrogen' case ruling in 2018[1], new developments that increase the nutrient loading to these Habitats Sites without appropriate mitigation in place will no longer be compliant with the Habitat Regulations.

As such, new development within these river catchments need to:

a) ascertain if development will result in 'Adverse Effects on Site Integrity' due to causing a net increase in nutrient loading to the Habitats Site;
b) provide mitigation of any net increase in P loading to the river, in order to achieve NN and show compliance with the Habitat Regulations Assessment (HRA).

A new development that results in an increase in 'overnight stays' or encourages migration into the hydrological catchments of the Habitats Sites may result in additional nutrient loading from the increase in wastewater and/or the change in land use. This 'impact pathway' will exacerbate the problems related to nutrient loading that are currently seen in the Habitats Sites. Elevated levels of nutrients can lead to eutrophication and algal blooms. The algae blooms deplete the oxygen levels which detrimentally impacts the normal ecosystem functionality.

NE's NN advice has presented a significant barrier to development in the Local Planning Authorities (LPAs) that contain parts of the hydrological catchments that drain to failing units of these Habitats Sites. Developments in these areas, or developments that connect to a wastewater treatment works (WwTW) that discharges to these areas, will need to be assessed for 'Adverse Effects on Site Integrity'. Where an adverse effect on the site's integrity cannot be ruled out, mitigation measures to provide NN are required. Determining adverse effects can be completed using NE's nutrient budget calculators. Should a nutrient budget for a development demonstrate that the development will result in a net increase in nutrient loading to the Habitats Site, this additional nutrient load will need to be mitigated.

Consequently, applications for residential and tourism developments in these areas have become stalled because the LPAs cannot issue planning consents without the implementation of appropriate nutrient mitigation solutions within the affected catchments. This has major implications on homeowners, developers and LPAs whilst compromising the objectives of the respective Local Plans.

The LPAs affected by the advice are as follows:

- Cumberland Council (CC)
- Lake District National Park Authority (LDNPA)
- Northumberland County Council (NCC)
- Northumberland National Park Authority (NNPA)
- Westmorland & Furness Council (WFC)[2]
- Yorkshire Dales National Park Authority (YDNPA)

Although these LPAs are responsible for planning applications in their respective areas, it is paramount to consider a synergistic approach between the LPAs to implement strategic mitigation solutions for each of the affected Habitats Sites. Successfully achieving this requires a consistent methodology to ensure all LPAs are assessing nutrient loading in the same manner and the application of the same assumptions to mitigation solutions that adhere

[1] Joined Cases C-293/17 and C-294/17 Coöperatie Mobilisation for the Environment UA and Others v College van gedeputeerde staten van Limburg and Other

[2] Westmorland & Furness Council (WFC) area also contains parts of the catchment to the Teesmouth and Cleveland Special Protection Area (SPA), outlined in the NE Evidence Pack. However, this catchment is not considered within this report, as no stalled or future development have been identified that would drain into this catchment from the WFD area.

to the precautionary principle. This holistic and interconnected strategy enables further opportunity to not only prove NN and offset the additional load from development, but to restore the site to favourable condition.

A significant mitigation strategy is needed to reduce the P loading to the Habitats Sites. Furthermore, the Local Nutrient Mitigation Fund, first announced in the Spring Budget 2023 with a further £110 million announced in the Autumn Budget 2023[3], presents an opportunity for LPAs to accelerate the delivery of nutrient mitigation schemes through grant funding.

KEY REPORT AIMS

The original specification of this programme of work was submitted at the end of 2022 and subsequently commenced in late Spring 2023 following data collection and collation at that stage and discussion with the Lake District National Park Authority. As such the data that supports the current documentation outlined here does not necessarily contain all data available at the end of 2023 and therefore outputs should be seen as a high-level support document related to identification of issues. The documentation and the outputs (including associated GIS analysis) has been developed so it can be updated to encompass new data and policy as necessary at a later stage.

The key requirement of the proposal was to prepare a mitigation solutions report that:

- Identifies the development aspirations of local authorities within the catchments of The River Eden SAC, the River Derwent and Lake Bassenthwaite SAC, parts of the River Kent SAC, and the Esthwaite Water Ramsar (type, amount, location and nutrient outputs);
- Provides analysis of the phosphorus baseline of the affected catchments (sources, amounts, locations, and movements);
- Proposes mitigation solutions (type, amount, location and cost) which are sufficient to secure NN and accommodate development, and;
- Propose solutions (type, amount, location and cost) which are sufficient to reduce the nutrient concentrations in the water courses beyond the nutrient neutrality requirement.[4]

The key aims therefore include:

- Provision of the background to each of the Habitats Sites and detail of the current nutrient concentrations and respective conditions in order to set the context of the report and understand the scales of nutrient reductions that would be needed to voluntarily restore the site.
- Impact assessment of development within the LPAs and calculate nutrient budgets for the purposes of informing strategic mitigation plans (type of developments, number of developments, location of developments and the associated nutrient outputs).
- Assessment of the current point and diffuse P sources and their respective impact pathways within the hydrological catchments of the Habitats Sites.
- Identification of a suite of mitigation solutions that could be used to deliver NN for the development aspirations within each LPA affected by NE's guidance (note: this is to provide a discussion point rather than details at this stage). These solutions are referred to as *"mitigation solutions"* that aim to meet the legal requirements of nutrient neutrality.
- Identification of Nature Based (mitigation) Solutions[5] (NbS) that could be voluntarily implemented by the LPAs to restore the Habitats Sites back to favourable condition and deliver 'nutrient negativity' (i.e., potentially more than NN). These solutions are referred to as *"restoration solutions"* that aim to identify any addition opportunity to restore Habitat Sites to favourable condition, which goes above and beyond regulatory nutrient neutrality requirements.

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[3] See: Autumn Statement 2023: On the day briefing, available here: https://www.local.gov.uk/parliament/briefings-and-responses/autumn-statement-2023-day-briefing?trk=public_post_comment-text

[4] It is recognised that there are other plans such as Diffuse Water Pollution and the Water Industry National Environment Programme (WINEP) schemes that will detail precise targets and what is required related to targeted protection of habitat sites – as such this additional request within the original scope of the work is a high level assessment to understand if any of the Nutrient Neutrality sites may have additional benefits; as such it must be read in the context of other initiatives.

[5] Nature-based Solutions are defined by the International Union for Conservation of Nature (IUCN) as "Actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously benefitting people and nature". Definition available here: https://www.iucn.org/our-work/nature-based-solutions

- Exploration of the interconnection between the recommended mitigation solutions and other regulatory drivers / frameworks to maximise the associated benefits for required nutrient mitigation solutions and voluntary restoration solutions.

KEY CAVEATS RELATED TO CURRENT REPORTING

This report is based on a desk-based study only and aimed to utilise the most up-to-date data available. Therefore, this report comes with following caveats:

- The scope of the report is to quantify the mitigation requirement and identify strategic solutions. Therefore, it does not provide a detailed design of individual mitigation measures. Any further feasibility assessments of the mitigation solutions presented will need to be completed outside of this report (i.e. flood risk assessments, soil drainage assessments etc.).
- No monitoring of the Habitats Sites or the SSSI units that legally underpin them was undertaken during this study. All water quality data is sourced from the Environment Agency's (EA) Water Quality Archive or the NE NN evidence packs.
- All data on both stalled and future development was provided by the LPAs, or extracted from the Local Development Plans, between April - May 2023 and is therefore only representative of development up to that date. Furthermore, in accordance with NE's advice, only Residential and Tourism development was assessed as these development types can lead to an increase in overnight stays.
- Individual nutrient budgets were not calculated. Instead, nutrient budgets were estimated using two approaches to serve as a comparison: one approach estimated the budgets based on the nearest WwTW and the associated permits as of July 2023 and the second approach assumed the 'worst-case scenario' i.e. a probable load and a maximum load. The 'worst-case scenario' is suitably precautionary in order to reduce the impact of underestimating the mitigation requirement. As such, planning mitigation for this scenario will very likely need to take in account mitigation requirement resulting from windfall development and commercial development. The impact/benefit of this is likely to be extremely difficult to accurately estimate over the in-perpetuity period.
- Any changing permits that were not confirmed at the time of the analysis of the first chapter (completed during March – June 2023 and submitted August 2023) are not included. Therefore, PR24 WINEP upgrades and the 2030 Technical Achievable Limit (TAL) upgrades have not been included in this assessment (the list of WwTW subject to TAL will not be published until 26/01/24). The requirement for the TAL upgrades was confirmed when the Levelling Up and Regeneration Bill (LURB) received Royal Ascension and became an Act on the 26/10/2023.
- Nature-based solutions are prioritised. It is not within the scope of this report to identify WwTW process upgrades. Furthermore, any quick-to-implement solutions with a high degree of certainty that can be used to achieve NN have been included.
- The suite of solutions recommended for site restoration could be used instead of the recommended mitigation measures. However, the measures recommended for restoration are either less certain or require more land take.
- The timescales of implementation are not included as these would be dependent on the design of the solution, the feasibility assessment as well as the construction timescales, all of which are not in the scope of this report.
- For any solutions that target diffuse P and involve land use change, such as riparian buffers or catchment woodland creation, it is assumed that semi-natural woodland is created in place of agriculture, which could be inclusive of both arable farming and livestock grazing. These solutions are assessed at the catchment scale. It is not within the scope of this report to assess specific agricultural landcovers and associated land cover change scenarios.
- Where possible local data has been used:
    - The site features and objectives are reported at the Habitats Site scale. The nutrient concentrations are reported at the SSSI unit scale.
    - Stalled development is mapped at the postcode scale. Future development is mapped at either the postcode scale or at the settlement scale, depending on the data availability within each LPA.
    - Agricultural nutrient loads are reported at the WFD waterbody catchment scale. Point sources are reported at the discharge location scale. Maps showing sediment erosion risk use data that has a spatial resolution of 10 metres (each cell is 10 x 10 metres).
    - National datasets that contain locally specific data are used to identify suitable locations for mitigation solutions.

SUMMARY FINDINGS

Note: This report and its findings provide for a baseline of information and assessment with the aim of developing a summary of issues and opportunities for NN mitigation across the relevant affected catchments. Due to the timeframe of this work it does not necessarily include all the most up to date data at any given time but rather is based on that provided at the time of writing and outlined in the caveat above.

It therefore provides for a discussion document related to mitigation opportunities together with the associated maps and data that contain a detailed summary and assessment of the current condition of Habitat Sites, nutrient loading and P baseline together with potential mitigation solutions for NN and, where appropriate, other environmental regulatory drivers.

It is recommended that this is seen as a living document together with the supporting data, analysis and mapping provided separately that can be updated as new evidence and policy becomes relevant.

Note: *The sites identified are based on a desk-top survey only and based on the evidence provided. Any sites short listed will need to be agreed with key stakeholders including for example United Utilities and landowners etc. Each potential site would need further discussion and a detailed feasibility study. Sites are for discussion only.*

A methodology was developed to understand the condition and objectives of the Habitat Sites, identify catchment hotspots in terms of nutrient loading, identify mitigation opportunities spatially and in addition identify any Habitat restoration opportunities that could be linked in the context of Biodiversity Net Gain (BNG) as requested by the LDNPA. A series of activities were completed with associated outputs as summarised below.

Activity 1 – Background to condition and objectives of Habitats Sites (see section 3 of main report for details)

It is estimated that the following TP load reductions would be required to voluntarily restore the Habitats Sites back to favourable condition:

- Esthwaite Water Ramsar – 274 kg TP/year
- River Derwent and Lake Bassenthwaite (East) – 1853 kg TP/year
- River Derwent and Lake Bassenthwaite (West) – 551 kg TP/year
- River Eden – 22432 kg TP/year
- River Kent (East) – 217 kg TP/year
- River Kent (West) – 99 kg TP/year

Activity 2 – Nutrient Loading from development (see section 4 of main report for details)

The assessments in this activity were split into stalled and future development. Based on the assessment outlined in the methodology, the estimated and worst-case scenarios of the P mitigation required for the effected catchments (as of May 2023) include:

For stalled developments:

- Esthwaite Water Ramsar | no stalled developments | N/A
- River Derwent and Lake Bassenthwaite (East) noting that one residential and one tourism development may require 1.39 - 2.5 kg TP/year of mitigation.
- River Derwent and Lake Bassenthwaite (West) noting that four residential and 24 tourism development may require 30.35 - 35 kg TP/year of mitigation.
- River Eden - 3601 residential and 195 tourism development may require 2237.63 - 4745 kg TP/year of mitigation.
- River Kent | no stalled developments | N/A

For future development:

- Esthwaite Water Ramsar noting that four dwellings per year may require an additional 5 kg TP/year of mitigation.

- River Derwent and Lake Bassenthwaite (East) noting that 46 dwellings per year may require an additional 57.5 kg TP/year of mitigation.
- River Derwent and Lake Bassenthwaite (West) noting that three dwellings per year may require an additional 3.75 kg TP/year of mitigation.
- River Eden noting that 735 dwellings per year may require an additional 918.75 kg TP/year of mitigation.
- River Eden (St Cuthbert's Garden Village) noting that 333 dwellings per year may require 198.47 kg TP/year.
- River Kent (West) noting that 13 dwellings per year may require an additional 16.25 kg TP/year of mitigation.

Activity 3 – Identification of catchment 'hotspots' (contributions) of P (see section 5 of main report for details)

According to a pre-existing source apportionment dataset developed within Source Apportionment Geographical Information System (SAGIS) modelling, the P load to the four Habitat Sites totals 218,756 kg P per year. A breakdown of the load to each Habitat Site is shown in **Table 1**, with the largest load contribution attributed to livestock farming. The P loads were also calculated through alternative approaches using and mapping loads from agriculture for comparison the results of which suggested a load of more than 277000 kg TP/year as indicated in **Table 2**.

Table 1 Source apportionment of P contributions to Habitats Sites modelled with SAGIS (kg phosphate/year)

Catchment name	Mains sewage	CSO	Industry	Grazing	Arable	Roads	Urban	Private sewage	Lakes	Total
Esthwaite	22	4	0	142	62	0	0	8	1	**238**
Derwent & Bassenthwaite - West	942	12	276	3938	746	5	5	38	0	**5962**
Derwent & Bassenthwaite -- East	2066	32	127	6681	3377	104	64	147	185	**12783**
Eden	34657	1582	992	137169	18748	509	775	2281	184	**196897**
Kent - east	98	1	0	1492	310	3	2	37	0	**1942**
Kent - west	25	0	0	666	225	0	6	11	1	**934**

Table 2 Estimates of source contributions calculated throughout report (kg TP/year)

Catchment name	Agriculture	Mains sewerage	Private sewage	Urban	Total
Esthwaite	810	134	20	86	**1050**
Derwent & Bassenthwaite - West	7560	1253	69	45	**8927**
Derwent & Bassenthwaite -- East	24970	1921	792	947	**28630**
Eden	170300	50524	2016	9681	**232521**
Kent - east	3480	0	100	0	**3580**
Kent - west	2100	0	73	133	**2306**

Activity 4 – Mitigation solutions to achieve NN (see section 6 of main report for details)

In order to ensure accurate estimates of P removal that could be calculated, mitigation solutions with a high degree of certainty were selected for unlocking development that could potentially remove P. Furthermore, options that could be implemented relatively quickly and could remove a large amount of P with relatively low land take were selected. As such, the following list was considered as mitigation to provide NN noting in this reports caveats that identifying WwTW process upgrades was not the focus of this work.

- Wetlands at WwTW
- Riparian Buffer strips
- Private sewerage system upgrades

This report aims to quantify a high-level estimate of the potential P load reduction to Habitat Sites from implementing mitigation and restoration measures to meet nutrient neutrality and to support additional habitat restoration requirements that may be feasibility over and above regulatory Nutrient Neutrality only (noting this assessment is not intended to take the place of other plans such as Diffuse Water Pollution and the Water Industry National Environment Programme (WINEP) schemes that at aimed at detailing precise habitat site targets. The feasibility of each solution has not been investigated at specific sites, as this is not within the scope of this report. Further site specific pre-feasibility assessments are required to determine the suitability of solutions at specific sites (for example, treatment wetlands at WwTWs).

Across the four Habitat Sites and corresponding LPA's a total of 2,269 kg TP / year was determined to be the probable mitigation required to meet NN legislation and prevent further deterioration of habitat condition from stalled developments across the LPA's (as of May 2023). Mitigation measures have been split between stalled and future developments as summarised below.

Stalled developments

The following mitigation measures are recommended for the worst-case scenario of the P mitigation requirement which totals 4783 kg TP/year between the four catchments.

- Esthwaite Water Ramsar noting no stalled developments
- River Derwent and Lake Bassenthwaite (East) where **one private sewerage upgrade** could mitigate **28 kg TP/year**
- River Derwent and Lake Bassenthwaite (West)) where **one private sewerage upgrade** could mitigate **61 kg TP/year**
- River Eden where:
    - **Wetlands at six WwTW** could provide remove **1938 kg TP/year** (mitigation provided in kg TP/year): Dalston WwTW (849), Brough WwTW (371), Warcop Camp WwTW (314), Pooley Bridge East WwTW (235), Glenridding WwTW (101), Dufton Village STW (67)
    - **Upgrading 11 private sewerage systems** throughout the catchment could remove **437 kg TP/year.**
    - **500 hectares of riparian buffers** (50 metres wide) in place of agriculture throughout the Dacre Beck (Lower) (253 ha) and the Caldew (Hesket Newmarket) (247 ha) WFD waterbody catchments could mitigate **3117 kg TP/year.** This equates to 1832 and 1285 kg TP/year mitigated in the Dacre Beck and the Caldew, respectively (land take would be 23% and 20% of total catchment areas, respectively).
- River Kent noting no stalled developments

Future developments:

It has been estimated that a combined 1200 kg TP/year of mitigation will be needed every year. The following mitigation measures are recommended for each catchment:

- Esthwaite Water Ramsar where **a wetland at Hawkshead STW** could remove **62 kg TP/year**
- River Derwent and Lake Bassenthwaite (East) where:
    - Upgrading the remaining (in addition to those specified for stalled development) **29 private sewerage systems** that discharge upstream of Bassenthwaite Lake could mitigate **366 kg TP/year**

    - In addition, there is the opportunity to create **535 hectares of riparian buffers** in the Glenderamackin u/s Troutbeck WFD waterbody to mitigate **973 kg TP/year**
- River Derwent and Lake Bassenthwaite (West) private sewerage system upgrades as recommended for stalled development are likely to provide enough mitigation for the future development aspirations. However, there is the opportunity to create up to **1007 hectares of riparian buffers** in the Marron WFD waterbody catchment to mitigate **2825 kg TP/year**
- River Eden:
    - **Wetlands at three WwTW** could provide remove **1705 kg TP/year** (mitigation provided in kg TP/year): Brampton WwTW (1022), Gilsland WwTW (616), Askham WwTW (67).
    - **670 hectares of riparian buffers** throughout the Moorland Beck (282 ha) and the Roe Beck (Upper) (388 ha) WFD waterbody catchments could mitigate **7704 kg TP/year.** This equates to 4075 and 3629 kg TP/year mitigated in the Moorland Beck and the Roe Beck, respectively (land take would be 16% and 15% of total catchment areas, respectively).
- River Kent where **one private sewerage upgrade** could mitigate **39 kg TP/year**

Note: For each of these mitigation measures associated costs of delivery were estimated. Full details are summarised in **Table 6.2** of the main report with costs provided per unit (£/Kg/TP (Total Phosphorus) and an estimate of cost for each solution.

Additional dwellings:

An additional 16,891 dwellings are outlined in the data provided in the Local Development Plans with a total *average* mitigation required for the Habitat Sites is 12,498 kg TP / year. The mitigation options shown in **Table 3** provides an *average* total mitigation potential of 12,325 kg TP / year. This represents 98.6% of the average mitigation requirements can be met through a combination of land use change and grey solutions across the four Habitat Sites. It should be noted that the measures could provide 100% of the mitigation required for Esthwaite Water Ramsar and River Derwent & Lake Bassenthwaite, and 98% of the mitigation required for River Kent SAC. However, the measures below only provide 67% of the River Eden SAC requirements.

Table 3 Summary of the average mitigation requirements (kg TP / year) and recommended measures with average potential mitigation (kg TP / year) to unlock development in Cumbria. See main report **Section 5.2** for a detailed breakdown of all measures, including locations.

Habitats Sites	No. of dwellings (where applicable)	Mitigation options	Average mitigation requirements in catchment total in kg TP/year)	Mitigation provided (kg TP/year)
Esthwaite Water Ramsar	4 (12 years)	Wetland	60	61
Sub total	***4***	**-**	***60***	***61***
River Derwent & Lake Bassenthwaite	2	Private sewerage upgrade	2	28
	28	Private sewerage upgrade	32	61
	4/year (12 years)	Private sewerage upgrades	60	55
	42/year (x12 years)	Option 1) Private sewerage upgrades	396	311
		Option 2) Riparian buffers (50 m wide)		973
	3/year (x6 years)	Riparian buffers (50 m wide)	23	2825
Sub total	***79***	**-**	***513***	***4253***
River Eden SAC	3795	Wetlands	419	366
		Private sewerage upgrades	192	72
		Riparian buffers (50 m wide)	5	1284
			19	1831

Habitats Sites	No. of dwellings (where applicable)	Mitigation options	Average mitigation requirements in catchment total in kg TP/year)	Mitigation provided (kg TP/year)
	13000	Wetlands	6,370	568
		Riparian buffers (50 m wide)	4883	3851
Sub total	***16795***		***11888***	***7972***
River Kent SAC	13/year (12 years) (surface runoff only)	Private sewerage upgrade	37	39
Sub total	***13***	**-**	***37***	***39***
Total	***16891***	**-**	***12498***	***12325***

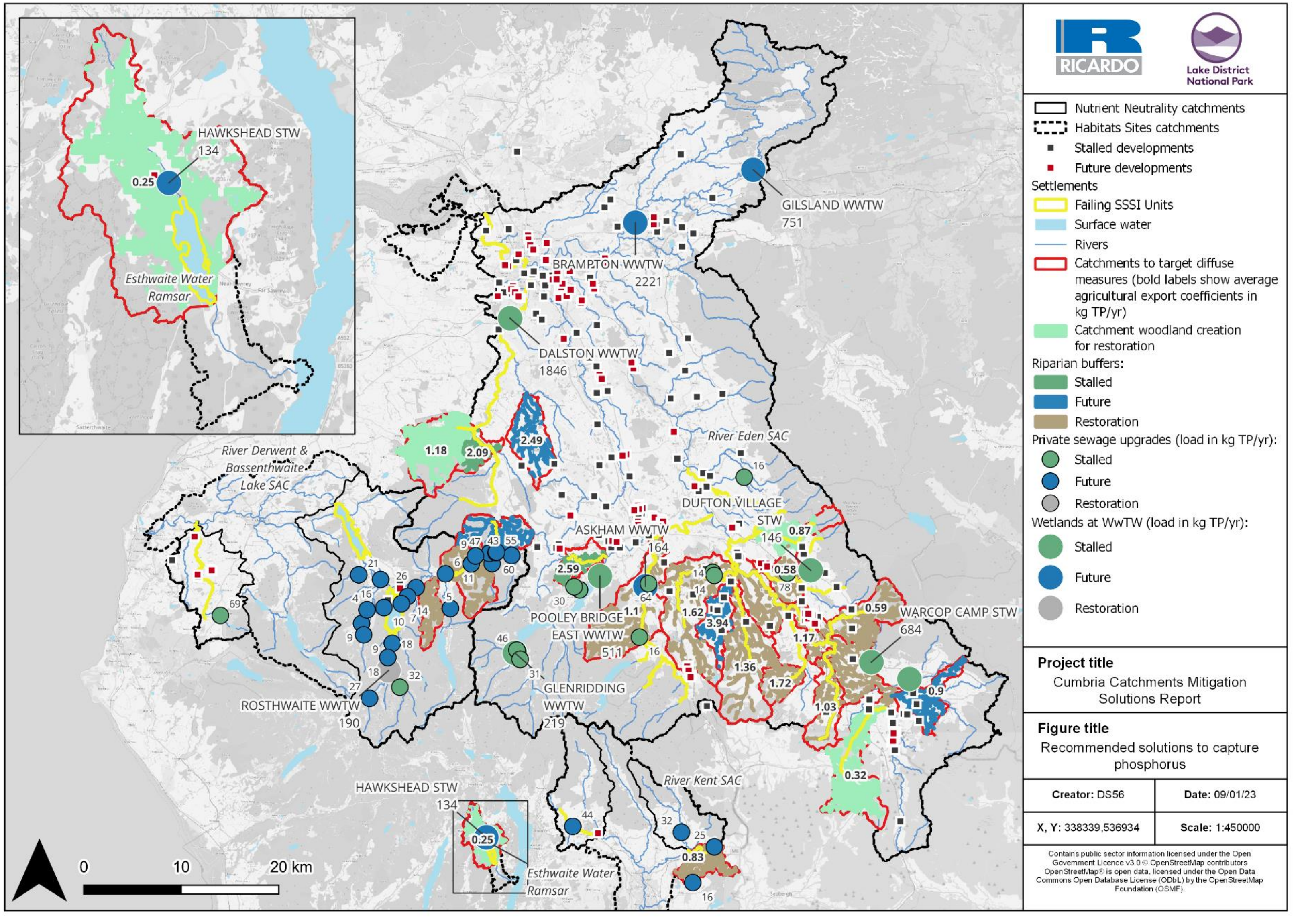
Activity 5 - Measures to restore habitat sites to favourable condition (see section 7 of main report for details)

Overall a range of restoration measures have been identified as potentially being able to achieve 93%, 36%, 97% and 100% of TP reduction required to respectively restore Esthwaite Water RAMSAR, River Derwent and Bassenthwaite Lake SAC, River Eden SAC and River Kent SAC to favourable condition. Should the mitigation measure recommended in Activity 4 be fully implemented, it is very likely that they would provide more P removal than the requirement for NN and so could also contribute to Habitat Site restoration. **Table 4** provides a summary of the measures proposed. Figure 1 shows all of the recommended mitigation and restoration measures.

Table 4 Summary of mitigation requirements (kg TP/ year) to restore Habitat Sites to favourable condition and the measures that can contribute to achieving this and the mitigation potential (kg TP / year).

Habitat Site	P removal required to restore sites (kg TP / year)	Measures	Mitigation potential (kg TP / year)
Esthwaite Water RAMSAR	274	Woodland creation	209
		Retrofitting SuDS	46
		Total	***255***
River Derwent and Bassenthwaite Lake SAC	3505	Wetland	87
		Riparian buffers	1170
		Total	***1257***
River Eden SAC	22000	Woodland creation	5823
		Riparian buffers	15292
		PTP upgrades	249
		Total	***21364***
River Kent SAC	217	Riparian buffers	359
		Floodplain reconnection	**N/A**
		Total	**359**

Figure 0-1 Map showing all stalled and future development and the recommended mitigation and restoration measures



Activity 6 - interconnection between nutrient mitigation and other regulatory drivers (see section 8 of main report for details)

The potential measures outlined in **Table 4** above have the potential not only to mitigate for nutrients and Habitats Site restoration, but can provide a range of co-benefits such as:

- Biodiversity & Habitat (including Biodiversity Net Gain (BNG) requirements)
- Climate Regulation (Carbon sequestration)
- Natural Hazard Regulation (Flooding)
- Water Purification
- Water Provisioning
- Recreation & Tourism (Including Health & well-being)
- Agriculture
- Air Quality – Air pollution removal
- Soil Erosion Reduction
- Material provisioning (e.g., wood)

As such opportunities as outlined in this report could be seen as part of wider environmental regulations and potentially provide for such planning requirements.

The mitigation measures recommended for both stalled and future development have for example been estimated to potentially provide the following BNG units:

- Esthwaite Water Ramsar: wetlands could create at least 2.2 BNG units
- River Derwent and Lake Bassenthwaite: riparian buffers could create nearly 13500 BNG units.
- River Eden: Wetlands could create at least 27 BNG units. Riparian buffers could create 10140 BNG units.

REPORT STRUCTURE

Further details of the above can be found in the main report, which is presented in the following structure:

- **Section 1**: Introduction to NN
- **Section 2**: Methodology
- **Section 3**: Current condition of the Habitats Sites (Activity 1)
- **Section 4:** Development aspirations and associated nutrient loading (Activity 2)
- **Section 5:** The P baseline (Activity 3)
- **Section 6:** Mitigation measures to achieve NN (Activity 4)
- **Section 7:** Mitigation measures to restore site to favourable condition (Activity 5)
- **Section 8:** Interconnection between nutrient migration solutions/regulatory drivers (Activity 6)
- **Section 9:** Summary and recommendations

In addition, there are four Appendices that should be read in conjunction with the relevant chapters, where stated, in the document.

Appendix A - Stalled Developments

Appendix B - Mitigation fact files

Appendix C - Details of measure and costs (as summarised in **Section 6.2**)

Appendix D - Wider benefits summary

1. INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

Nutrient neutrality (NN) as a concept is continually evolving. As such data and policies are regularly updated both locally and nationally. Because of these on going changes, it is recognised that this document has only assessed data provided as out lined in the **caveats** presented in the **Executive Summary** and only up to May 2023.

Overall, this document provides a comprehensive assessment of the nutrient mitigation requirement associated with new and stalled development that leads to additional overnight stays with each Habitat Site catchments to achieve NN.

It is recommended that as more data and information becomes available this document is updated to account for changes that may affect outcomes in particular for example any changing permits that were not confirmed at the time of the analysis of the first chapter (completed during March – June 2023 and submitted August 2023). (i.e. PR24 WINEP upgrades and the 2030 Technical Achievable Limit (TAL) upgrades are not currently included

This report and its findings provide for a detailed baseline of information and assessment with the aim of developing a summary of issues and opportunities for NN mitigation across the relevant affected catchments. Due to the timeframe of this work it does not necessarily include all the most up to date data at any given time but rather is based on that provided at the time of writing and outlined in the caveat above.

It therefore provides for a discussion document related to mitigation opportunities together with the associated maps and data that contain a detailed summary and assessment of the current condition of Habitat Sites, nutrient loading and P baseline together with potential mitigation solutions for NN and, where appropriate, other environmental regulatory drivers.

The original specification of this programme of worked was submitted at the end of 2022 and subsequently commenced in late Spring 2023 following data collection and collation at that stage and discussion with the Lake District National Park Authority. As such the data that supports the current documentation outlined here does not necessarily contain all data available at the end of 2023 and therefore outputs should be seen as a high level support document related to identification of issues. The documentation and the outputs (including associated GIS analysis) has been developed so it can be updated to encompass new data and policy as necessary at a later stage.

The key requirement of the proposal was to prepare a mitigation solutions report that:

- Identifies the development aspirations of local authorities within the catchments of The River Eden SAC, the River Derwent and Lake Bassenthwaite SAC, parts of the River Kent SAC, and the Esthwaite Water Ramsar (type, amount, location and nutrient outputs);
- Provides analysis the phosphate baseline of the affected catchments (sources, amounts, locations, and movements);
- Proposes mitigation solutions (type, amount, location and cost) which are sufficient to secure NN and accommodate development, and;
- Propose solutions (type, amount, location and cost) which are sufficient to restore the affected designated sites to favourable condition and remove nutrient neutrality (NN) requirements.

1.2 KEY AIMS

These include:

- Provision of the background to each of the Habitats Sites and detail of the current nutrient concentrations and respective conditions in order to set the context of the report and understand the scales of nutrient reductions that would be needed to voluntarily restore the site.

- Impact assessment of development within the LPAs and calculate nutrient budgets for the purposes of informing strategic mitigation plans (type of developments, number of developments, location of developments and the associated nutrient outputs).
- Assessment of the current point and diffuse P sources and their respective impact pathways within the hydrological catchments of the Habitats Sites.
- Identification of a suite of mitigation solutions that could be used to deliver NN for the development aspirations within each LPA affected by NE's guidance (note: this is to provide a discussion point rather than details at this stage).
- Identification of Nature Based (mitigation) Solutions[6] (NbS) that could be voluntarily implemented by the LPAs to restore the Habitats Sites back to favourable condition and deliver 'nutrient negativity' (i.e., potentially more than NN).
- Exploration of the interconnection between the recommended mitigation solutions and other regulatory drivers / frameworks to maximise the associated benefits for required nutrient mitigation solutions and voluntary restoration solutions.

REPORT STRUCTURE

The report has been structured as below to address the key aims of the project.

- **Section 1**: Introduction to NN
- **Section 2**: Methodology
- **Section 3**: Current condition of the Habitats Sites (Activity 1)
- **Section 4:** Development aspirations and associated nutrient loading (Activity 2)
- **Section 5:** The P baseline (Activity 3)
- **Section 6:** Mitigation measures to achieve NN (Activity 4)
- **Section 7:** Mitigation measures to restore site to favourable condition (Activity 5)
- **Section 8:** Interconnection between nutrient migration solutions/regulatory drivers (Activity 6)
- **Section 9:** Summary and recommendations

In addition, there are four Appendices that should be read in conjunction with the relevant chapters, where stated, in the document.

Appendix A - Stalled Developments

Appendix B - Mitigation fact files

Appendix C - Details of measure and costs (as summarised in **Section 6.2**)

Appendix D - Wider benefits summary

1.3 THE DUTCH CASE

In 2018 the European Court of Justice (CJEU) issued a significant judgement in two joined cases which related to the Habitats Directive, commonly referred to as 'The Dutch Case' or 'The Dutch Nitrogen Cases'[1]. This ruling led to changes in the application of the Habitat Regulations (amended in 2017) concerning plans or projects within the catchments of European Designated sites (hereafter Habitats Sites) that are already experiencing high nutrient levels.

The focus of The Dutch Case related to the potential damaging effect of agricultural nutrient loading practices on Habitats Sites. The CJEU ruled that increased atmospheric nitrogen deposition to Dutch European sites resulting from new projects and plans may pose a risk to "site integrity" due to the link between nutrient enrichment and eutrophication. Natural England (NE) now considers that the CJEU judgement applies to increased nutrient loading to European sites in England and therefore recommends an approach that considers the risk of significant

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[6] Nature-based Solutions are defined by the International Union for Conservation of Nature (IUCN) as "Actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously benefitting people and nature". Definition available here: https://www.iucn.org/our-work/nature-based-solutions

impacts that could arise from plans or projects that increase nutrient inputs to European sites. As such, the affected LPAs, as the Competent Authority, have incorporated NE's advice into their judgement of planning applications that concern developments which result in additional overnight stays.

1.4 INTERPRETATION OF THE DUTCH CASE

In response to The Dutch Case, NE updated their legal advice concerning new planning applications that could potentially raise nutrient levels in rivers designated as Special Areas of Conservation (SACs) and/or Ramsar sites already strained by high nutrient concentrations. This legal advice was presented as NN and was disseminated to Local Planning Authorities (LPAs) which contain areas that drain to units of these Habitats Sites. As the Competent Authority, the LPAs were presented with a significant obstacle to approving new planning applications.

The administrative boundaries of Cumberland Council (CC) LPA, Lake District National Park Authority (LDNPA) LPA, Northumberland County Council (NCC) LPA, Northumberland National Park Authority (NNPA) LPA, Westmorland & Furness Council (WFC) LPA and Yorkshire Dales National Park Authority (YDNPA) LPA contain part or all of the catchments of one Special Protection Area (SPA)[2], three SACs and one Ramsar and/or their catchment areas that are already experiencing elevated nutrient inputs[7]. The introduction of additional nutrients through increased wastewater discharge or alterations in land use resulting from new plans or projects can create an "impact pathway," exacerbating the existing nutrient loading issues observed in the Habitats Sites.

The existence of this impact pathway associated with nutrients from additional development will lead to a Habitat Regulations Assessment (HRA) indicating "Likely Significant Effects" (LSE) on the ecological conditions of the European sites within the three counties. Nitrogen (N) and phosphorus (P) are the two primary nutrients discharged by new developments, and the SAC rivers within these boundaries are specifically affected by P.

An HRA involves two principal phases: (i) Screening and (ii) Appropriate Assessment (AA). During the Screening phase, the objective is to determine whether a project or plan might infringe upon the management goals of a European site or significantly affect its quality. Hence, establishing the presence of a nutrient impact pathway is crucial during this initial stage. The key factors considered when evaluating the existence of this pathway include:

1. Whether the development is situated within a catchment that drains to a Habitats Site.
2. Whether the connecting Wastewater Treatment Works (WwTW) discharges to a Habitats Site.
3. Whether the development will lead to an increase in 'overnight stays.'

If the answer is yes for either 1, or for 2 and 3 as outlined above, the subsequent phase of the HRA process, the AA, must be carried out. In an AA, particularly when applying the concept of NN, the first step involves determining whether a development will introduce additional nutrient inputs to a Habitats Site. This necessitates calculating the quantity of nutrients that a new development that results in additional overnight stays will introduce, referred to as a nutrient budget.

Should the nutrient budget calculation reveal that a plan or project will indeed introduce additional nutrients to the Habitats Site, it becomes untenable to assert "No Adverse Effect on Site Integrity" without implementing mitigation measures. Consequently, in order to confirm the absence of adverse effects stemming from nutrient impacts, mitigation strategies to achieve "NN" must be secured by the developer and confirmed by CC, LDNPA, NCC, NNPA, WFC, and YDNPA through the assessment of the developers proposals. The outcome of a nutrient budget calculation dictates the annual mitigation amount required to achieve NN for a given plan or project.

1.5 HABITATS SITES OF CONCERN AND THE LPAS AFFECTED

The River Kent SAC, the River Eden SAC, the River Derwent & Bassenthwaite Lake SAC, and the Esthwaite Water Ramsar are all in unfavourable condition due to excessive P levels (**Section 2.1**). Elevated levels of P in aquatic environments through surface water and groundwater pathways can compromise the sensitive habitats and species supported within each Habitats Sites. Eutrophication and subsequent algal blooms can occur due to the higher levels of nutrients, in turn disrupting normal ecosystem function and initiating transformations in the aquatic community. Depletion of dissolved oxygen can occur alongside the algal blooms, which could contribute to the death of many aquatic organisms, including invertebrates and fish. The habitats and species that are a primary reason for the SAC and Ramsar designations are referred to as 'qualifying features'. It is unlikely that all

[7] Note: from the 1st April 2023 Allerdale Borough Council, Carlisle City Council, Copeland Borough Council, Eden District Council, and South Lakeland District Council, which previously acted as the LPA were reorganised into two new unitary authorities (CC and WFC).

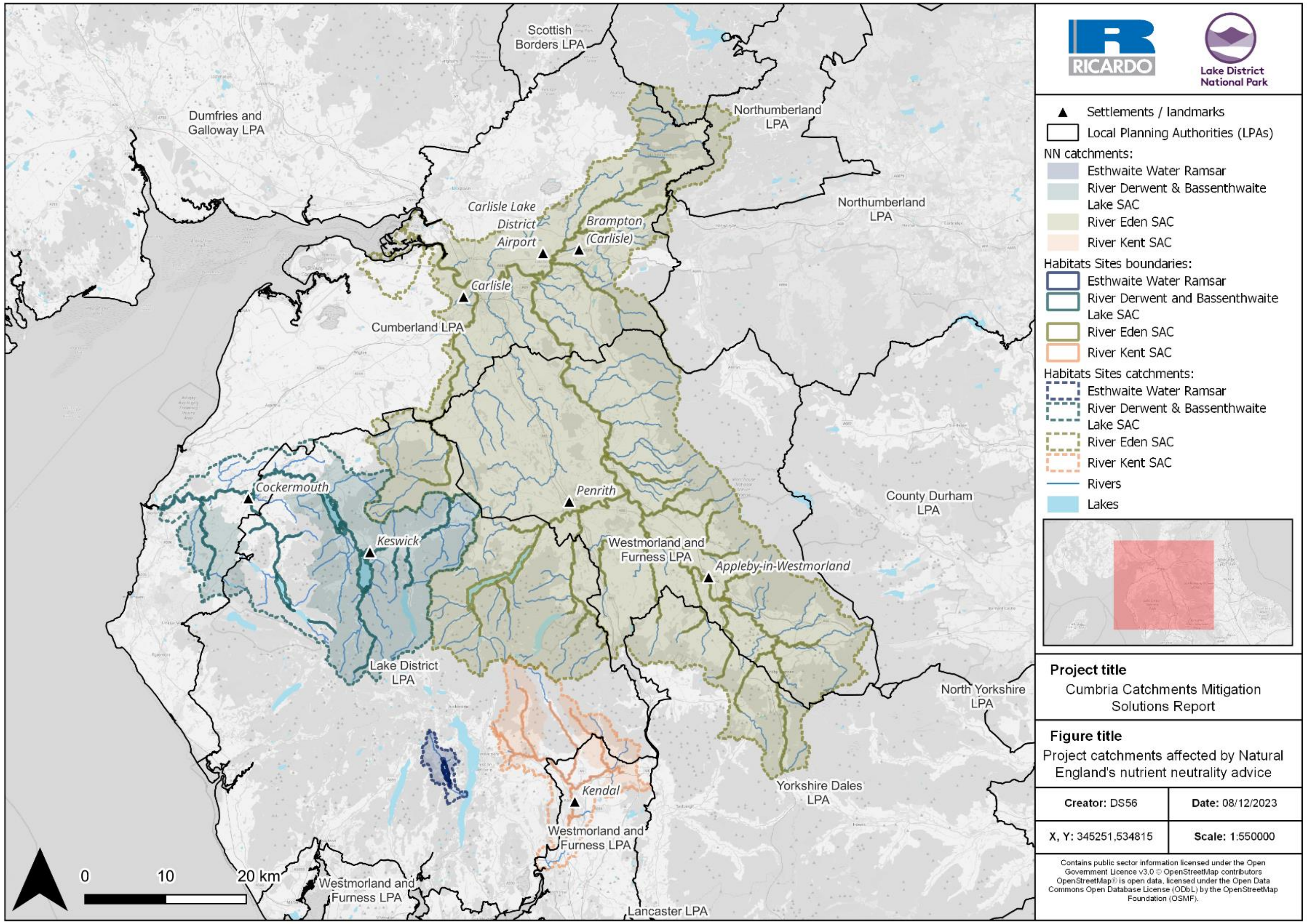
of these qualifying features will be detrimentally impacted by elevated nutrient levels and some receptors may therefore be screened out during an HRA.

There are a total of six LPAs affected by NE's NN advice as stated in **Section 1.4** that are within the scope of this report[2]. These LPAs as shown visually in **Figure1-1** whilst **Table 1-1** compares each LPA within the NN catchments.

Table 1-1 Table showing the area of each Habitats Site considered within the scope of this report, each LPA, and the percentage of each Habitats Site catchment within each LPA

Habitats Sites	Site area (km^2)	LPA	LPA area (km^2)	Percentage of site within LPA
Esthwaite Water Ramsar	16	LDNPA	2346	100
River Derwent & Bassenthwaite Lake SAC	427	CC	1978	13.2
River Derwent & Bassenthwaite Lake SAC	427	LDNPA	2346	86.7
River Derwent & Bassenthwaite Lake SAC	427	WFC	1892	0.1
River Eden SAC	2314	CC	1978	25
River Eden SAC	2314	LDNPA	2346	18.8
River Eden SAC	2314	NC	3981	0.9
River Eden SAC	2314	WFC	1892	45.9
River Eden SAC	2314	YDNPA	2185	8.2
River Eden SAC	2314	NNPA	1051	1.2
River Kent SAC	112	LDNPA	2346	75.2
River Kent SAC	112	WFC	1892	24.8

Figure1-1 Map of the catchments affected by Natural England's NN advice in the North West



2. METHODOLOGY

This report comprises six key activities, all of which are required to build a high-level scientific understanding of the catchment and identify the nutrient mitigation requirement to unlock development, and the optimal locations of a suite of nutrient mitigation solutions. In addition, two final activities are aimed at identifying opportunities for capturing nutrients for restoring the sites and identifying the co-benefits associated with nature-based solutions. The following sections describe the approaches used to complete this nutrient mitigation solutions report.

Each section describes the activity and the aims, the rationale, the sources of information required, the data collection techniques utilised and the overall method of the geospatial and data analysis is described.

Section 2.1 outlines the approach used to determine the current condition of the Habitats Sites as well as the status of the objectives.

Section 2.2 details the methods implemented to identify the development aspirations within each of the Habitats Sites hydrological catchments.

Section 2.3 provides information on how the P baseline was determined and how the hotspots within each catchment were identified.

Section 2.4 presents the approach used to identify the type, the amount, and the locations of nutrient mitigation solutions required for achieving NN for the development aspirations of each LPA within the Habitats Sites hydrological catchments.

Section 2.4.1 describes the methodology used to estimate the type, the amount, and the locations of nature-based solutions which could be implemented to restore the Habitats Sites back to favourable condition in the context of each Habitats Sites nutrient status and water quality objectives.

Section 2.5 details the additional benefits which were considered in the context of the stacking and bundling legalisation and describes the way in which the additional benefits provided by the identified mitigation solutions were assessed.

2.1 UNDERSTANDING THE CURRENT CONDITIONS AND OBJECTIVES OF THE HABITATS SITES

The ***activity aim*** is to provide underlying context to the mitigation solutions report. Developing a deeper understanding of the Habitats Sites objectives and determine the current status of these objectives will inform the mitigation and restoration recommendations related to opportunities related to nutrients over and above regulatory NN.

The Joint Nature Conservation Committee (JNCC) has a webpage[8] for the River Eden SAC, the River Derwent and Bassenthwaite Lake SAC, and the River Kent SAC. These webpages were reviewed in order to ascertain the site character and the primary reasons for the selection of the sites.

NE produced an evidence pack for each of the Habitats Sites affected by NN advice. These evidence packs detail Site of Special Scientific Interest (SSSI) units which legally underpin the site, the monitored concentrations of nutrients within each SSSI unit and contain maps of the hydrological catchments affected by NN. Therefore, the NE evidence packs[9] were reviewed to identify which SSSI units were failing and the concentration of P within each of these units. The latest water quality data for each of the monitoring points detailed in the evidence packs was downloaded from the water quality archive[10] to assess the most recent evidence.

[8] https://sac.jncc.gov.uk/

[9] The catchment evidence packs provided by Natural England are available here: https://www.lakedistrict.gov.uk/planning/planning-for-nature-recovery/nutrient-neutrality

[10] The water quality data was downloaded in July 2023 from: https://environment.data.gov.uk/water-quality/view/landing

The SSSI Units geographical information systems (GIS) dataset[11] was used to map the location of each SSSI Unit in unfavourable condition and create a GIS layer of each catchment. The catchments were created using the Water Framework Directive (WFD) Waterbody Catchments (Cycle 3) and through a catchment delineation using elevation data – a 30-metre resolution digital terrain model (DTM) was used[12].

The catchment area and the mean flow data for every flow gauging station within the study area was acquired[13] in order to estimate the flow for each SSSI unit failing to meet the water quality objective due to the P concentrations to the water quality. Flow was estimated using the watershed-area approach (Gianfagna, Johnson, Chandler, & Hofmann, 2015) – the area of the ungauged catchment for each SSSI unit was divided by the area of the gauged catchment and multiplied by the mean flow for every gauge. The average of the mean flow estimates was selected for use. The mean flow estimates for each failing SSSI unit was multiplied by the concentration reduction required to meet the target in order to determine the amount of P that would need to be captured to restore the sites.

2.2 IDENTIFYING DEVELOPMENT ASPIRATIONS

The aim of the approach outlined in this section is to support the understanding of the development ambitions in each LPA and assess where any development is likely to increase. This approach provides an estimate of the demand for mitigation within these catchments which will inform the assessment of mitigation solutions. Data on the stalled development and future development projections within each LPA was used to estimate the likely nutrient load. The output of the calculations informs a geospatial assessment of the potential mitigation options that could be deployed within the catchments.

To understand the estimated scale of nutrient mitigation required within these LPA areas, an assessment of the extent of development and locations of forthcoming developments was first required, as described in the sections below. This activity utilised data collected from the local and unitary authorities and local development plan from which the estimated demand for P mitigation has been calculated. The time periods considered for this assessment are as follows:

- Current planning applications for developments that lead to an increase in overnight stays (Residential and Tourism development) and are stalled by NN[14]. **(Section 2.2.1)**
- An annual projection of housing supply affected by NN **(Section 2.2.2).** Tourism developments were not included in this analysis due to the unpredictable nature of where tourism development may be located. Non-residential development was not included due to the unpredictable nature of this type of development, as well as the fact that the NE methodology applies the 'overnight stays' approach to determining whether a nutrient budget is required.

There are a six LPAs which contain parts of the catchments affected by NN, noting there were more LPAs before the government reform on the 01/04/2023 as highlighted in Section 1.2[7]. The projections of future housing requirements were made before this date which meant some inconsistencies were identified between the LPAs and even those LPAs that merged into new unitary authorities. As such, separate approaches were employed based on the former LPAs. The LPAs (some of which are now within Unitary Authorities) include:

- Allerdale Borough Council (now CC)
- Carlisle City Council (now CC)
- Copeland Borough Council (now CC)
- Eden District Council (now WFC)
- LDNPA

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[11] The Sites of Special Scientific Interest Units (England) dataset is available here: https://www.data.gov.uk/dataset/c52ead19-47c2-473b-b087-0842157e00b6/sites-of-special-scientific-interest-units-england

[12] The Shuttle Radar Topography Mission (SRTM) data is available for download using this webpage: https://www.earthdata.nasa.gov/sensors/srtm

[13] The mean flow data was identified using the National River Flow Archive, available here: https://nrfa.ceh.ac.uk/

[14] Certain LPAs are not accepting planning applications and so the actual number of stalled developments may be higher.

- NCC
- NNPA
- South Lakeland District Council (now WFC)
- YDNPA

2.2.1 Understanding the quantity of applications currently stalled by NN

Data was acquired from each LPA[15] detailing residential and tourism development applications which are currently stalled due to NN within each LPA area[14]. To confirm that the development sites provided were both within the NN catchments and the LPA areas, geospatial data such as the address, postcode or coordinates were used to plot all sites on a map. All stalled developments located within NN catchments were identified and those not affected by NN were rejected. As the data was provided at an LPA scale and not a catchment scale, the outlines of each NN catchment were plotted to enable simple analysis of which developments were stalled within each of the four NN catchments. To understand the estimated scale of nutrient mitigation required on a catchment scale, the number of currently stalled dwellings per catchment was calculated.

To avoid including developments which will not increase the number of overnight stays within a catchment, any development involving the demolition of one dwelling to build a new replacement dwelling were rejected from the lists.

2.2.2 Understanding the annual projection of housing supply affected by NN

Following a data request to each LPA regarding residential development aspirations within the NN catchments, a review of all provided data was carried out to understand what data was missing, if any. Where data was not provided, the available data was supplemented with information from the relevant LDPs. Where some of the following LPAs now fall within Unitary Authorities, data was acquired from contacts from the former LPA or from the former LPA's LDP. See **Table 2-1** for a summary of the data collected on stalled developments and future development projections within each LPA boundary. Please note that the current undersupply (if any) has not been included in this analysis because this data was not provided.

2.2.2.1 Carlisle City Council Method

No data on future development was provided by Carlisle City Council, therefore allocated sites data sourced from the LDP was utilised to understand the likely spatial distribution of future residential development. The LDP suggests that 9606 dwellings are to be built in the 2013 – 2030 plan period, equating to 565 dwellings per year[16]. The total number of dwellings proposed at allocated sites is 4188.

To adhere to the precautionary principle and ensure that the correct scale of mitigation is proposed in future tasks, the number of dwellings proposed at allocated sites was multiplied by 2.29 to match the LDP's proposed 9606 dwellings over the plan period. This is in lieu of any official data representing the likely spatial distribution of development. Additionally, without an understanding of the quantity of developments built since 2013, it has been assumed that an equal distribution of 9606 dwellings will be developed annually between 2013 and 2030 in an attempt to define a representative value that is neither an overestimate nor an underestimate.

The allocated sites outlined in the LDP were identified using opensource street maps and satellite imagery and plotted on QGIS alongside a NN catchment boundaries layer to allow for easy identification of whether or not the future developments require mitigation. Of the 4188 proposed dwellings at allocated sites 3178 dwellings are located within the Eden Catchment. As previously mentioned, this value was multiplied by 2.29 and subsequently divided by 15 to represent the likely number of dwellings to be developed within the NN catchment on an annual basis.

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[15] The data was collected over a two-month period between April - May 2023.

[16] Although the Local Plan states that 626 net new homes are planned for the 2020-2030 period (adjusted to have regard to delivery in the 2013-2020 period), the goal of creating land to accommodate 9606 net new homes between 2013 and 2030 was assumed to be split equally between the 17-year planning period as the number of developments built in this period was unknown.

There are plans for 10,000 homes to be built as part of the St. Cuthbert's Garden Village between 2020-2050[17]. This equates to 333 homes per year over a 30-year period. Although the Local Plan states that 626 houses will be built between 2020-2030, St Cuthbert's Garden Village has been treated as separate to this figure for the purposes of this report as the design statement suggests it will cover the 2020-2050 period, it is uncertain whether it is included in the Local Plan figures, and the aim of this report is to facilitate strategic mitigation planning. Due to the sheer size of the garden village development it is likely that this site will need a bespoke nutrient mitigation solution. Therefore, the plan has within this document been considered separately as it is not clear whether these values and development contributes towards the LDP figure specifically.

2.2.2.2 LDNPA Method

LDNPA provided a spreadsheet of allocation sites for future residential development which is planned within the 15-year local plan period. As this data resembles the data acquired from the Carlisle City Council LDP, a similar approach was used to provide a nutrient budget estimate for predicted residential development.

The LDP outlines a target of 80 new dwellings per year which equates to 1200 during the local plan period, whilst the allocated sites provide site specific data for only 219 dwellings. To adhere to the precautionary principle and ensure that the correct scale of mitigation is proposed in future tasks, this value was multiplied by 5.48 to match the LDP's proposed 1200 dwellings over the plan period (2020-2035). As such, the locations of the allocated sites are used to provide an indication of where all future development is likely to occur. This is in lieu of any official data representing the specific locations of all future development.

2.2.2.3 South Lakeland District Council Method

No data was provided regarding future development within South Lakeland, therefore a similar method as discussed for Carlisle City Council was used to provide a nutrient budget estimate for predicted development. The allocated sites and number of dwellings proposed per site were acquired from the LDP and plotted on QGIS to enable visual identification of whether the allocated sites fall within the NN catchment boundaries or not. This process clarified that no allocated sites were affected by NN, therefore in lieu of any data suggesting otherwise, it has been assumed that no residential development is planned within the parts of the River Kent NN Catchment within South Lakeland District Council for the plan period. This assumption is based on the fact that not data has been provided to the contrary and there is no built up urban areas[18] within the former South Lakeland LPA NN catchments.

2.2.2.4 Eden District Council Method

Windfall and allocations data was provided to be used for future projections. In addition, the proposed housing distribution projections detailed in Eden District Council's LDP, coupled with the GIS data of housing allocations and future growth sites, were used to be more geographically specific and more precautionary (i.e. higher values). The LDP outlines the development targets of each major settlement as well as for each tier of the settlement hierarchy. Using open-source street maps as well as Ricardo's NN catchment boundaries to identify which settlements require mitigation, the settlements not affected by NN were subtracted from the total value of 4356 to be developed within the 18-year LDP period (2014-2032). The final annual development aspiration affected by NN equates to 227 dwellings per year within the plan period.

Where settlement names were not listed, the subcategory of 'villages and hamlets' for example, it was assumed that 100% of villages and hamlets are affected by NN. This is to adhere to the precautionary principle and ensure that the scale of mitigation is not underestimated.

2.2.2.5 Allerdale Borough Council Method

Allerdale Borough Council outlined that there are no allocated sites within the affected parts of the LPA area, however NN does affect a number of rural villages that are listed within the settlement hierarchy.

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[17] The St. Cuthbert's Garden Village Masterplan is available here: https://www.stcuthbertsgv.co.uk/MASTER-PLAN/Masterplan-Stage-1

[18] https://geoportal.statistics.gov.uk/maps/built-up-areas-2022-gb-bgg

To provide clarity on these villages, Allerdale Borough Council provided a GIS layer for all settlements with a settlement limit. This layer was mapped alongside an outline map of the NN catchments to enable identification of which settlements are subject to NN restrictions. Any settlements located on the NN catchment boundary were assumed to be affected if greater than half of the settlement area fell within the NN catchment. This task returned three limited growth villages located within River Derwent and Bassenthwaite Lake NN catchment.

Data from Allerdale Borough Council's LDP regarding future planned residential development was collected to supplement the data provided by Allerdale Borough Council. The LDP outlines that 5471 dwellings are expected to be built within the 18-year plan period, which equates to 304 dwellings per year. The LDP also outlines the percentage of residential development allocated to each tier of the settlement hierarchy. Up to 6% of 304 dwellings per year is allocated to limited growth villages, of which there are 21 within the LPA area. Based on an assumption of equal growth between each village, it has been estimated that 1 new dwelling (rounded from 0.86) will be established within each limited growth village per year during the plan period.

2.2.2.6 YDNPA Method

Data regarding future development aspirations and past trends was provided by YDNPA. The data outlined that over the last 3 years average completions in the River Eden SAC catchment have been 6 dwellings per year. Due to the rural nature of the area and the small crossover between YDNPA, this value was deemed appropriate and has been utilised to understand the quantity of residential development planned on an annual basis which will require mitigation.

2.2.2.7 Durham County Council (DCC) Method

No calculations were carried out for DCC due to the area of intersect between the NN catchments and the Council boundary being too small to evaluate. It has therefore been assumed that no development within the NN catchment is planned.

2.2.2.8 Copeland Borough Council, NCC, and NNPA Method

No calculations were carried out for Copeland Borough Council, NCC or NNPA as the Councils confirmed that no development is planned within the NN catchments.

Table 2-1 Summary table of outputs from **Section 2.2.2**

Council	New Authority	LDP Timeline	No. of residential plots/dwellings currently stalled by NN	No. of tourism plots/dwellings currently stalled by NN	Estimated no. dwellings requiring mitigation to be built per year
Carlisle City Council	CC	2020-2050 (St Cuthbert's)	0	0	333
		2015 – 2030	2689	47	485
LDNPA		2020 – 2035	5	16	80
South Lakeland District Council	WFC	2003 – 2025	0	0	0
Eden District Council	WFC	2014 – 2032	905	130	227

Council	New Authority	LDP Timeline	No. of residential plots/dwellings currently stalled by NN	No. of tourism plots/dwellings currently stalled by NN	Estimated no. dwellings requiring mitigation to be built per year
Allerdale Borough Council	CC	2014 – 2029	4	24	3
YDNPA		2023 – 2040	3	3	6
DCC		2020 – 2035	0	0	0
Copeland Borough Council	CC	2021 – 2038	0	0	0
NCC		2016 – 2036	0	0	0
NNPA		2017 – 2037	0	0	0
Total:			3606	220	

2.2.3 Calculating nutrient budgets for stalled and future residential developments

Permit limits of connecting WwTW are one of the variables with the largest impact on a development's nutrient budget. To determine the nutrient load associated with development, two approaches were applied:

For both stalled development and future development, a precautionary approach was applied which assumed the 'worst-case' scenario that all development would connect to a non-permit limited Waste Water Treatment Works (WwTWs) in order to identify the maximum amount of mitigation that may be required. As per the NE nutrient budget methodology, these WwTWs are assumed to discharge final effluent with a concentration of 8 mg TP/litre (TP/l). Furthermore, the loading from landcovers was estimated using the River Eden Nutrient Budget Calculator[19] and the assumptions that each dwelling was 0.1 hectares in size (assuming a large land take for precautionary purposes) and being converted from lowland grazing to residential land within the Eden Lower catchment experiencing 1,100-1,200 mm of rainfall per annum on slightly impeded soils. Furthermore, it is assumed that the developments will use the default calculator inputs of 2.4 people per dwelling, as this is the national average occupancy rate, and 120 litres per person per day of water used/wastewater produced. Inputting these values into the River Eden Nutrient Budget Calculator results in an estimated final nutrient budget of 1.25 kg total phosphorus (TP) / year per dwelling. This approach assumes the worst-case scenario and is therefore suitably pre-cautionary in line with an HRA. This value has been allocated to nutrient budgets for stalled and future developments. It should be noted that these values have been estimated adhering to the precautionary approach to ensure that the nutrient mitigation requirement is not underestimated, and a suitable amount of mitigation is planned. The nutrient budgets for each site may be lower than what has been reported. Any mitigation solution that generates additional credits compared to the requirement for stalled development could be used to unlock future development.

Another approach, which was only applied to stalled developments due to the data provided showing a precise location, assumed the 'probable' scenario and utilised the wastewater asset data, as provided by

[19] See the 'River Eden – NN budget calculator (13.7.22: Excel), available here: https://www.lakedistrict.gov.uk/planning/planning-for-nature-recovery/river-eden

United Utilities[20], to develop WwTWs catchments in GIS (assuming a buffer of 200 metres from the sewerage network). These catchments were then used to identify which developments are likely to connect to each WwTWs. If the site was not within a WwTW catchment (whether the point for the development was in the catchment polygon or not in catchment polygon), it was assumed to have the default Package Treatment Plant (PTP) value. This enabled more accurate (and smaller) nutrient budgets to be calculated which incorporated the P permits at each works and identify the probable, or most-likely amount of mitigation required. The same landcover, occupancy and water usage assumptions used in the worst-case method were applied in lieu of any specific site information.

For tourism developments, the maximum amount of mitigation was calculated by multiplying 1.25 kg TP/year by the number of units, in accordance with the precautionary approach detailed above. Whereas the 'probable' mitigation incorporated the permit limit of the connecting WwTW if applicable (or PTP) and assumed 80 litres of water is used per person[21].

For St Cuthbert's Garden Village, the estimated load from the 333 homes was calculated assuming the development would connect to Carlisle WwTW (and that the WwTW had capacity) and assuming the area per dwelling will be the site area (1323 hectares) divided by the number of dwellings units planned (10000). The same landcover assumptions were made as above.

2.3 IDENTIFYING THE CATCHMENT HOTSPOTS

The ***activity aim*** is the development of a robust understanding of the P sources, amounts, locations, and movements in the catchment. The assessment of source apportionment data (**Section 2.3.1**), assessment of agricultural TP export (**Section 2.3.2**), runoff erosion risk (**Section 2.3.3**) and the consented discharge register (**Section 2.3.4**) enables the identification of key catchment hotspots to target for nutrient mitigation plans (i.e., baseline solutions), which are outlined more detail in **Section 2.4** and **Section 2.4.1**, and to identify major sources which could be targeted for restoration opportunities.

2.3.1 Sector contributions of phosphate

Identifying the current sources of P within the catchment is essential for careful and effective catchment mitigation planning. Source apportionment of annual nutrient contributions to rivers has previously been completed for England and Wales through the Source Apportionment-GIS (SAGIS) modelling framework[22] and using the Sector Pollutant Apportionment for the Aquatic Environment (SEPARATE) framework[23]. Between the two source apportionment datasets the total P loads from the following sources are estimated:

- Agricultural land with mitigation measures applied. *Note: An alternative option is to assume that the agricultural land has no mitigation measures applied. However, this is unlikely to be representative of the potentially significant variation throughout the catchment and over the in-perpetuity period.*
- Sediment erosion
- Urban diffuse
- Sewer treatment works
- Storm Tanks
- Septic Tanks (STs)
- Combined sewer overflows

[20] United Utilities provided Ricardo with confidential wastewater asset data on the 08/06/2023.

[21] See the British Water loadings for Sewage Treatment Systems, available here: https://cdn.ymaws.com/www.britishwater.co.uk/resource/resmgr/publications/codes_of_practice/flows_and_loads___bw_cop_18..pdf

[22] See the Source apportionment of nutrient contributions to rivers in England and Wales modelled with SAGIS, available here: https://www.data.gov.uk/dataset/9e97da97-3607-4048-a781-a1e98296dc26/source-apportionment-of-nutrient-contributions-to-rivers-in-england-and-wales-modelled-with-sagis

[23] The Source apportionment of annual nutrient and sediment loads to rivers in England and Wales, from the SEPARATE framework is available here: https://www.data.gov.uk/dataset/3e698568-8492-4dfd-aa11-3439d77cd71a/source-apportionment-of-annual-nutrient-and-sediment-loads-to-rivers-in-england-and-wales-from-the-separate-framework

- Direct Deposition
- Industrial discharges

The SAGIS dataset is provided as points along each river. Each downstream datapoint contains cumulative loads of the upstream area and thus represents the 'outlet' at each point. The frequency of these data points combined with the cumulative calculations allows for the identification of total phosphate loads from each source for specific catchments. Therefore, this dataset was used to estimate the percentage contributions from each source for each specific NN catchment (see **Section 5.1)**.

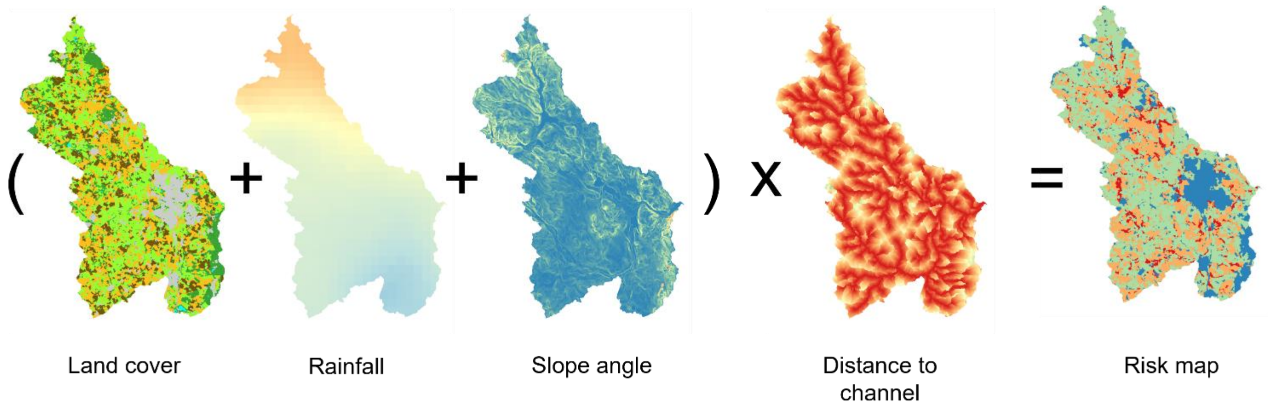
2.3.2 Agricultural export

The SEPARATE source apportionment dataset provides estimates of TP loading at the local WFD waterbody scale. As such, this dataset was used to map the TP load from diffuse agricultural sources and agricultural export coefficients were generated by dividing the agricultural load reported in the by the area of the non-agricultural landcovers from the WFD waterbody catchments (surface water, urban areas, public greenspace). These export coefficients were then added as attributes to the WFD Waterbody catchments geospatial layer to facilitate the visual identification and representation of catchments with high P loading per hectare.

2.3.3 Sediment erosion risk

Sediment-bound P is typically mobilised through sediment erosion. Mapping the sediment erosion risk can provide useful insights on the key nutrient pathways and potential sources of legacy P. The sediment runoff risk was modelled using a weighted-sum model (WSM) approach that considers land cover data, rainfall data, slope, and soil erodibility. The landcover dataset was created by 'stacking' a variety of open source landcover datasets and was utilised in other sections of this report. The results of this WSM were multiplied by the hydrological connectivity of the land, determined through hydrological analysis of a DTM. The outputs of this sediment runoff risk model were reclassified into classes through the application of the empirical rule (which utilises the mean and the standard deviation of the data) into areas of very low risk of sediment erosion, low risk, moderate risk, high risk and very high risk. A diagram of this modelling approach can be seen in **Figure 2-1.**

Figure 2-1 Diagram showing the approach to calculating the sediment erosion risk.



2.3.4 TAL Point source baseline

It is important to locate the wastewater point sources within the catchment at a higher spatial resolution than the WFD waterbody scale due to the high load they are likely to contribute at a specific point. The Consented Discharges Register[24] was assessed to locate the WwTWs within the hydrological catchments of the Habitats Sites. The conditions of the permit were analysed to extract the dry weather flow (DWF) permits and the P concentrations in the final effluent. Furthermore, the Price Review 2019 (PR19) Water

[24] See the 'Consented Discharges to Controlled Waters with Conditions', available here: https://www.data.gov.uk/dataset/55b8eaa8-60df-48a8-929a-060891b7a109/consented-discharges-to-controlled-waters-with-conditions

Industry National Environment Programme (WINEP) dataset[25] was assessed to extract any changing permits.

It is important to note that the PR24 WINEP dataset is due to be published soon which will contain further permit changes, as well as the incoming Technical Achievable Limits (TAL) as part of the Levelling UP and Regeneration Act (LURA). The TAL have not been included in this methodology as this project was procured before the amendments which detailed TAL within the Levelling Up and Regeneration Bill (LURB) on the 21/11/22, and the Bill, including the TAL amendments, did not receive Royal Ascension until the 26/10/23. The full list of works affected by TAL has not been released at the time of writing.

The P load from each WwTWs was estimated by multiplying the DWF permitted discharge limits by the permitted limits of P concentrations in the final effluent, or the default concentration as used in the NE nutrient budget calculators (8 mg TP/l). It should be noted that the TAL requirement under the LURA is 0.25 mg TP/l, though it is not known which works will be required to reach this concentration as some works will be exempt and the list has not yet been released at the time of writing.

This exercise was then completed for private sewerage systems. However, the concentration of TP in the final effluent was assumed to be 9.7 mg TP/l, in accordance with the values used in NE's nutrient budget calculators. At the time of writing NE has not released documentation specifying where all of the inputs to the nutrient budget calculation methodology are sourced from. However, Ricardo is aware that the default value is based on the average value of 9.7 mg TP/l reported in a study of PTP effluents (May & Woods, 2016). Other point sources, such as combined sewage overflows (CSOs), were not mapped due to the extreme variability in the frequency of discharges and the concentrations of P in the effluent. This variability makes predictions of the load very inaccurate and complex.

2.4 IDENTIFYING THE MITIGATION OPPORTUNITIES FOR DEVELOPMENT

The ***activity aim*** is the develop a list of recommended mitigation solutions which can be used to achieve NN. This section details the methodology used to identify the type of mitigation measures that will best deliver mitigation, the amount of mitigation measures to target, the locations of the mitigation measures, and the indicative costs associated with achieving NN for the development aspirations identified in **Section 2.3**.

2.4.1 Type of mitigation measures

2.4.1.1 Long-list identification

Drawing on our expert knowledge and numerous technical reviews of P mitigation measures undertaken previously, an 'extensive' list of the types of potential P mitigation measures was identified **Table 2-2.**

Table 2-2 Extensive list of P mitigation measures

Mitigation Solution	Applicability	Level of certainty
Private sewerage with drainage field (see **Table B-1** in **Appendix B**)	Yes	High
Private sewerage system upgrades (see **Table B-2** in **Appendix B**)	Yes	High
Retrofitting SuDS (see **Table B-3** in **Appendix B**)	Yes	High
Wetlands (constructed wetlands at WwTW) (see **Table B-4** in **Appendix B**)	Yes	High
Riparian buffer strips (see **Table B-5** in **Appendix B**)	Yes	High
Agricultural land use change / woodland creation (includes agricultural cessation) (see **Table B-6** in **Appendix B**)	Yes	High

[25] See the ' Water Industry National Environment Programme', available here: https://www.data.gov.uk/dataset/a1b25bcb-9d42-4227-9b3a-34782763f0c0/water-industry-national-environment-programme

Mitigation Solution	Applicability	Level of certainty
River channel re-naturalisation / engineered logjams (see **Table B-7** in **Appendix B**)	Yes	Low
Drainage Ditch Blocking (see **Table B-8** in **Appendix B**)	Yes	Low
Terrestrial sediment Traps (see **Table B-9** in **Appendix B**)	Yes	Low
Aquacultural cessation / Discharge permit removal (see **Table B-10** in **Appendix B**)	Yes	Low
Water efficiency measures (see **Table B-11** in **Appendix B**)	Yes	Low
Transporting excess phosphorous from dairy farms to arable farms	No	Low
Regulatory controls on agricultural phosphorus	No	Low
Reduce leakage from the foul sewage network	No	Low
Reduce leakage from potable water supply	No	Low
Increased treatment of effluent	No	Low
Diverting surface water flows away from the sewage network	No	Low
Addressing misconnections	No	Low

An initial high-level review of these P mitigation measures was undertaken to narrow down this extensive list to establish a long-list of measures appropriate for the hydrological catchment of the Habitats Sites and the respective LPAs. The review of the extensive list of measures (**Table 2-2**) assessed the applicability of the measures and the certainty of a measures ability to remove phosphorus. A fact file was created for each mitigation measure that was seen as applicable ('Yes') to the scope of the project based on the original proposal that was submitted. Furthermore, any measures that are within the remit of water companies or government legislation are not considered because they are the responsibility of those organisations and are therefore not feasible in practice in the timescales needed to unlock housing. In addition, any measures that would require data collection that is out of the scope of this project are not included, i.e., identifying specific types of farm and determining their individual contributions is not within the scope of this project.

Each fact file was created with information including: a summary description of the option, maintenance and monitoring requirements, potential additional benefits, scale of development in which it could be implemented to mitigate P, spatial scale, P removal method and efficiency, factors affecting efficacy, time to effectiveness, design requirements, input sources, longevity, certainty, cost, constraints, wider environmental considerations, and stakeholders for engagement. The fact files for each mitigation solution can be found in **Appendix B.** The detail and reliability of this information was dependent on the best available evidence and data at the time of review.

Due to the uncertainty of P reduction potential of some measures it can be difficult to understand and thus provide P load reduction potential estimates with a high degree of certainty. A suitably precautionary approach was therefore taken, alongside consideration of their removal rates in perpetuity (in practice for a duration of 80-125 years) in order to remove risks to the sites integrity beyond reasonable scientific doubt. As a result, many of the long-listed measures (i.e., those with fact files) were considered to have low certainty and were not short-listed for further analysis. Criteria for low certainty included consistency across literature around removal rates and design of systems.

2.4.1.2 Short-list identification

A shortlist of measures was selected that were considered appropriate for the hydrological catchment based on the P hotspots identified in **Section 5** and had a high degree of certainty associated (i.e. the incoming loads are able to be estimated in a desk-based study and there is a wide range of literature that details observed removal rates of TP) with them (see **Table 2-2**) were selected and further analysed to quantify their P mitigation potential. Technical treatment upgrades at WwTWs were not considered as these are not NbS and within the scope of this report. Technical upgrades at WwTWs are upgrades are the responsibility of the water company and require permitting agreements between the water company and the environmental and industry regulators. Agricultural land use change / agricultural cessation has not been included in the shortlist because this should be seen as a 'last resort' to sustain food production systems and local business. PTPs with drainage fields should be considered for implementation on a site-by-site basis when designing the drainage for a development and so have not been included in the shortlist. Retrofitting SuDS has not been included in the shortlist in lieu of detailed information on the surface water drainage configuration in each settlement. The short-list of measures for which the P load reduction was quantified included:

- Wetlands (constructed wetlands at WwTW)
- Riparian buffer strips (over 30 metres wide)
- Private sewerage system upgrades[26]

These measures were selected due to the high level of mitigation that can be achieved from treatment wetlands and riparian buffers, and the simplicity and time-saving element of upgrading sewerage systems.

2.4.2 Amount of mitigation measures

The work completed in **Section 4** quantified the amount of annual P load that needs to be mitigated within each Habitats Site catchment in order to achieve NN, assuming that all stalled applications proceed with development (see **Section 4.1.1**), and that all future development is delivered (see **Section 4.1.2**). Here, the load to each SSSI unit that is failing was determined by the location of the development within the Habitat site, and associated loads (per dwelling). The load from stalled development as well as the load from future development was assessed in the context of the load from the catchment hotspots (**Section 5**) and the P removal efficiency of the shortlist of mitigation solutions to identify which solutions are likely to provide a desired level of mitigation. The efficacy of mitigation measures, and therefore the amount of P they will mitigate, is uncertain due to the large number of variables that may affect the performance. As such, the precautionary P removal rates that were sourced from literature and detailed in the fact files created in **Section 2.4.1.1** were applied.

When determining the amount of mitigation required, it was acknowledged that the mitigation benefits of measures can propagate downstream of the measure. This means that mitigative measures implemented upstream within a catchment can unlock development in both the upper and lower sections within the catchment. Benefits are thus cumulative as you move downstream within a catchment, and not just localised to the area surrounding the mitigation measure.

2.4.3 Locations of mitigation measures

Building upon work completed in **Section 2.4.2,** locations for the short-listed mitigation measures (**Section 2.4.1.2**) were assessed by identifying areas with a high baseline loading of P that are key opportunity areas to implement measures. Furthermore, the position of the mitigation opportunities was assessed in order to identify sources that affect the most SSSI units that are failing. This involved utilising outputs from **Section 2.1 -** which provided the amount of P that needs to be mitigated to achieve NN as well as determine the distribution of the additional P loading, and **Section 2.3.1-** which provided information on sector contributions of P, agricultural exports, sediment erosion risks, and point source baselines within the LPAs/Habitat sites. It should be noted that WwTW that were subject to WINEP obligations were not included within our analysis due to this constraint. In addition, at the time of writing WwTW subject to Technically Achievable Limits (TAL) upgrades under the LURB were not published and therefore, this consideration was not taken into account within the methods.

For each short-listed mitigation measure, the following information was used to identify key locations:

- **Wetlands (constructed wetlands at WwTW).** Data on the P load from the WwTW and the position in the catchment (which utilised SSSI units) was used to create a list of WwTWs that are

[26] It is assumed that when upgrading private sewerage systems for nutrient mitigation the replacement system has a manufacturer certified concentration of TP in the final effluent.

recommended as targets for the construction of a treatment wetland. For the Eden, the WwTWs were ranked due to the large number in the catchment.

- **Private sewerage system upgrades.** Information on private sewerage loads identified in **Section 2.3.4** was used to identify private sewerage systems which with upgrades could have the potential to offer high reduction in P. The information used in this assessment included the estimated age of the system identified through the effective permit data, the position, and the load (see **Section 2.4**)
- **Riparian buffer strips (over 30 metres).** The agricultural export coefficients for the WFD waterbody catchments were used to target catchments for riparian buffers. The locations of woodland riparian buffers were identified using a riparian woodland dataset which identify areas of potential riparian woodland planting that are not currently wooded[27].

Geographical variables and locations have been considered, to ensure for example, that a WwTW is positioned in a strategic place within the catchment, with sufficient space for construction, and will have sufficient nutrient loads entering the mitigation measure to provide the most benefit for the Habitats Sites. A high-level assessment of feasibility was also undertaken which identified locations for wetlands using a variety of data sets including: elevation, slope, landcover, designated sites (e.g. Ancient woodlands, Parks and gardens, registered battlefields, scheduled monuments, NNR, Ramsar, SSSI, SAC, SPA) and flood zones.

The key output of this exercise are geospatial datasets[28] that will help catchment planners make decisions on where to place mitigation options. Worked case studies for the site selection of wetlands and buffer strips were also undertaken in order to apply the rationale that underpins locating mitigation opportunity areas. It is important to note that this exercise did not comprise a detailed design of exactly where mitigation options should be located, but an indication of opportunity areas (**Section 6**).

2.4.4 Costing of mitigation measures

A literature review was completed of academic sources, grey literature, and other case studies to identify the indicative costs of the mitigation measures proposed. This literature review identified cost per unit size of a solution and the cost per unit of P mitigated. Results of this review can be found in the fact files for the long-list of measures (**Appendix B**). These costs were then multiplied by the size of the mitigation measure, or the amount of P mitigated. For wetlands, the costs are indicative of construction costs only. For riparian buffers, the costs are inclusive of land cost and woodland planting/woodland management. The costs of upgrading PTPs was inclusive of purchasing the system and cost of installing the system.

Searches for academic literature were made using the Google Scholar academic search engine by entering keywords and phrases associated with the topic. Searches for grey literature were undertaken using the Google search engine as well as following leads within the reference list of any acquired literature. Articles were initially screened by examining the relevance of the abstract, with articles with details relevant to P mitigation in their abstracts retained for a full review.

2.4.5 Key considerations for implementing nutrient mitigation solutions

A number of key considerations for planning nutrient mitigation measures were identified during the literature review in **Section 2.4.1.1**. These were considered relevant for all mitigative measures considered appropriate for the hydrological catchment (i.e., the long-list).

[27] See: WWNP Riparian Woodland Potential, available here: https://www.data.gov.uk/dataset/517b89ab-7209-4b71-b888https://www.data.gov.uk/dataset/517b89ab-7209-4b71-b888-2af956a7a1bc/wwnp-riparian-woodland-potential2af956a7a1bc/wwnp-riparian-woodland-potential
[28] Geospatial dataset cannot be published (internal use only)

2.5 IDENTIFYING ADDITIONAL MEAUSURES BEYOND NUTRIENT NEUTRALITY

This activity aims to identify a suite of restoration measures that could be used to restore the Habitats Sites back to favourable condition. The methodologies used to determine the types of solutions is presented, including the amount required, the locations of the solutions and the estimated cost of the suite of solutions. Restoration measures aim to improve the condition of habitats and whilst not subject to the legal nutrient mitigation requirements of NN this document has, as part of the requested work, looked to identify opportunities where it may be feasible to go above and beyond NN regulatory requirements. This activity does not aim to usurp other plans that have been developed to detail how restoration could be carried out on protected sites[4].

2.5.1 Type of solutions

The longlist of solutions relevant to the Habitats Sites catchments, determined in **Section 2.4.1.1**, is assessed with a focus on certainty and timescales. The type of solutions recommended are split into two lists: a shortlist of solutions with a high degree of certainty from **Section 2.4.1.2** and a long list of solutions with less certainty but are considered to be good practice as part of the catchment based approach.

The full list of restoration measures is as follows:

- Wetlands
- Buffer strips
- Private sewerage upgrades
- Agricultural land use change
- Retrofitting SuDS
- River channel re-naturalisation / Engineered logjams
- Aquacultural cessation / discharge permit removal
- Sediment Traps
- Drainage Ditch Blocking

2.5.2 Amount of restoration solutions

The outputs from **Section 2.1** were assessed to identify the amount of nutrient removal required to restore each of the Habitats Sites. The amount of nutrient removal a solution could provide was considered in the context of the load from the catchment hotspots (**Section 2.3**), and the P removal efficiency of the shortlist of nutrient removal solutions (mitigation solutions if considering for NN), in order to identify which solutions are likely to provide a desired level of restoration.

2.5.3 Locations of restoration solutions

The locations of the suite of restoration measures (related to opportunities to go above and beyond regulatory NN) were identified using the work completed in **Section 2.5.1** and **2.5.2**, as well as the catchment hotspots identified using methods outline in **Section 2.3.** A strategic approach was implemented which considered how the water quality benefits propagate downstream - restoration solutions that benefit the most SSSI units that are failing were favoured. The recommended locations exclude those identified in **Section 2.4**.

The locations of the shortlist of restoration solutions were identified using the approaches detailed in **Section 2.4.3**. For each long-listed measure, the following information was used to identify key locations:

- **Retrofitting Sustainable Drainage Systems (SuDS).** The Built Up Areas[29] dataset was used to identify urban areas with the potential for retrofitting SuDS. The mean rainfall for each built up urban area was identified using rainfall data for the period between 1990-2019[30]. The percentage rainfall runoff was calculated using the Rational runoff method (Kellagher, 1981). This runoff was then multiplied by the multiplied by the open urban event mean concentration of 0.22 mg TP/l as

[29] See: Built Up Areas, available here: https://geoportal.statistics.gov.uk/datasets/ons::built-up-areas-2022-gb-bgg/about

[30] The standard annual average rainfall between 1990-2019 was created using Gridded estimates of daily and monthly areal rainfall for the United Kingdom (1890-2019), available here: https://catalogue.ceh.ac.uk/documents/dbf13dd5-90cd-457a-a986-f2f9dd97e93c

reported in (Mitchell, 2005) to determine the load from the urban landcovers. Although this data does not provide information on existing SuDS features, it enables calculations of the estimated load from an urban area to be calculated. Applying a SuDS removal rate identified in literature enables estimates of the nutrient removal to be calculated. This dataset was then used in combination with opensource WWNP datasets to identify potential locations for a number of SuDS measures. These datasets included attenuation features datasets[31,32] which show locations of high surface water runoff accumulation across the land surface,

- **Agricultural land use change.** Involved identifying existing agricultural land use within catchment with high export coefficients (**Section 2.3**). The WWNP Wider Catchment Woodland Potential[33] dataset was used to identify specific areas in the catchment suitable for woodland planting.
- **River channel renaturalisation / engineered logjams.** The WWNP Floodplain Reconnection Potential[34] and the WWNP Floodplain Woodland Potential[35] datasets was used to identify areas suitable for flooding that were upstream or along the reach of failing SSSI units.
- **Aquacultural cessation (**i.e., fish farms). A search of fish farms in the hydrological catchment of the Habitats Sites was completed using the Consented Discharges register[24] as most fish farms require consents to discharge to rivers. The P load from fish farms can only be calculated if there are nutrient permits or if there is monitoring of the inlet and outlet. One load estimate were calculated because there was only one permitted discharge with TP conditions. Monitoring of the inlet and outlet concentrations is not within the scope of this project.
- **Sediment traps / drainage ditch blocking**. A range of datasets, coupled with the catchment hotspots identified in **Section 2.3** (using data on diffuse pollution and sediment erosion risk) was used to target suitable areas for deploying certain types of catchment management solutions for P removal. Opensource WWNP datasets[31,32] were used to identify locations of high surface water runoff accumulation across the land surface that could be targeted as locations for features that promote sediment deposition.

2.5.4 Costing of restoration measures

Costing of restoration measures proposed in each catchment to restore the site will be calculated using methods outlined in **Section 2.4.4.**

2.6 IDENTIFYING THE ADDITIONAL OPPORTUNITIES

2.6.1 Using the Potential Biodiversity Opportunity Tool to identify BNG opportunity

2.6.1.1 The Potential Biodiversity Opportunity Tool

To aid in identifying additional opportunities the Potential Biodiversity Opportunity (PBO) tool has been used to identify areas that are suitable for offering functioning biodiversity. The PBO tool, which was developed by Ricardo, uses a scoring system of specific criteria to identify a sites potential to offer functioning biodiversity. The tool is underpinned by a large range of nationally available open-source datasets (**Table 2-3**), as well as local data to include non-statutory and statutory designations, strategically significant sites and land ownership where available. Non-statutory and statutory designations (such as SSSI and SAC) were not removed from the model but instead buffered to assess an areas proximity to these features to prioritise habitat connectivity, in line with the Lawton principles.

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[31] See: WWNP Runoff Attenuation Features 1% AEP, available here: https://www.data.gov.uk/dataset/0b21fa23-6cd9-4d9e-9299-92c7d981616e/wwnp-runoff-attenuation-features-1-aep

[32] See: WWNP Runoff Attenuation Features 3.3% AEP, available here: https://www.data.gov.uk/dataset/a491c6aa-5742-4c1a-beb2-da163c3997a9/wwnp-runoff-attenuation-features-3-3-aep

[33] See: WWNP Wider Catchment Woodland Potential, available here: https://www.data.gov.uk/dataset/abe0c86f-4088-4d3a-8517-c6e70e2a57a3/wwnp-wider-catchment-woodland-potential

[34] See: WWNP Floodplain reconnection potential here: https://www.data.gov.uk/dataset/11873c69-d971-44ce-a648-872da9be847f/wwnp-floodplain-reconnection-potential

[35] See: WWNP Floodplain Woodland Potential, available here: https://www.data.gov.uk/dataset/717bffc4-b165-4deb-b761-a12a7d58af58/wwnp-floodplain-woodland-potential

Areas where mitigation cannot take place such as urban areas, roads and water bodies were identified as constraining areas and removed. Each site was assigned a score based on multiple criteria to indicate their suitability for functioning biodiversity (**Table 2-4**). Scores for each site were totalled to produce the final scoring of the site's suitability. The higher the scores the more positive criteria the site is meeting, and therefore the site is more suitable for offering biodiversity benefits.

Table 2-3 All datasets used to calculate specific scores

Datasets	Link
SSSI's (England)	https://www.data.gov.uk/dataset/5b632bd7-9838-4ef2-9101-ea9384421b0d/sites-of-special-scientific-interest-england
SPAs (England)	https://www.data.gov.uk/dataset/174f4e23-acb6-4305-9365-1e33c8d0e455/special-protection-areas-england
Ramsar (England	https://www.data.gov.uk/dataset/67b4ef48-d0b2-4b6f-b659-4efa33469889/ramsar-england
National Nature Reserves (England)	https://www.data.gov.uk/dataset/726484b0-d14e-44a3-9621-29e79fc47bfc/national-nature-reserves-england
Special Areas of Conservation (England)	https://www.data.gov.uk/dataset/a85e64d9-d0f1-4500-9080-b0e29b81fbc8/special-areas-of-conservation-england
Common Land (England)	https://www.data.gov.uk/dataset/05c61ecc-efa9-4b7f-8fe6-9911afb44e1a/database-of-registered-common-land-in-england
Priority Habitat Inventory (England)	https://www.data.gov.uk/dataset/4b6ddab7-6c0f-4407-946e-d6499f19fcde/priority-habitats-inventory-england
Ancient Woodland (England)	https://www.data.gov.uk/dataset/9461f463-c363-4309-ae77-fdcd7e9df7d3/ancient-woodland-england
Living England	https://www.data.gov.uk/dataset/e207e1b3-72e2-4b6a-8aec-0c7b8bb9998c/living-england-habitat-map-phase-4
CORINE Land Cover 2018	https://land.copernicus.eu/en/products/corine-land-cover
OS Open Roads	https://www.data.gov.uk/dataset/65bf62c8-eae0-4475-9c16-a2e81afcbdb0/os-open-roads
OS Vector Map District (railway track)	https://osdatahub.os.uk/downloads/open/VectorMapDistrict
Cumbria Local Nature Recovery Strategy (LNRS) Habitat Network	https://www.cbdc.org.uk/about-us/projects/clnrn_story_map/

Table 2-4 Scoring Criteria

Score	0	1	2	3
Size of site		<1ha	1-3ha	>5ha
On common land	Yes			No

Score	0	1	2	3
Proximity to statutory sites		>5km	2-5km	<2km
Sites within LNRS, recreation/restoration zones	No			Yes
On priority habitats		No		Yes
Proximity to ancient woodland*		>1km	300m-1km	<300m

*Only relevant for woodland broad habitat opportunity areas

2.6.1.2 Interoperating outputs

The PBO tool outputs are in the form of vector and raster data as Tif and shapefiles respectively and are able to be used on a Geographic Information System (GIS) platform. Each parcel of land has a score assigned to it with each score showing a different colour. The criteria underpinning the scores and the scores themselves can be viewed and analysed by interacting with the individual polygons within the shapefile. A further excel file is produced which contains all the criteria and scoring information for each site.

As well as the overall PBO scores for the whole study area, further shapefiles are produced which relate to the five broad habitat types fell, grassland, peat, wetland and woodland. These broad habitat types have the specific restoration/creation zone dataset based on the LNRS habitats that fall into each category. These files identify and score areas based on their suitability to provide biodiversity relating to the habitat type. ***Note:*** the lowest and highest score differ per broad habitat type however are generally within a range of 6 - 18 due to the minimum score an area of land can score is 6 but the highest range can differ.

The outputs from the grassland, wetland and woodland outputs proved most beneficial to this project in terms of looking at the wider biodiversity benefits. However, the fell and peatland outputs could be used to inform agricultural abandonment schemes and therefore have been included in the assessment.

Any potential locations of mitigation opportunities that were identified using methods detailed in in **Section 2.5.3** and **Section 2.4.3** were assessed for BNG opportunity. Firstly, the PBO tool scores were assessed at each location. Next, the BNG units for the habitat being created were assessed. Subsequently, the landcover dataset created in **Section 2.3.3** was used to map the baseline BNG score for the recommended locations. Finally, the potential uplift in BNG score was estimated by subtracting the baseline score from the estimated score of the mitigation solution (**Table D-1 in Appendix D**)

2.6.2 Taking a Natural Capital approach

At the beginning of 2023 the Government released its Environmental Improvement Plan 2023[36] in which there are 10 goals. These goals included enabling thriving plants and wildlife, using resources from nature sustainably and mitigating and adapting to climate change. There are a number of frameworks and ideas which exist to help achieve these goals, for example, mandatory BNG, the LNRS, the Natural Capital Approach, and the Natural Flood Management (NFM) plan. To achieve these goals and reach the 2030, 2042 and 2050[37] targets as set out by the UK Government, it is important to consider the wider benefits that can be achieved by the nutrient mitigation solutions and how they can help contribute to these frameworks. Considering these wider benefits is vital as they can offer significant monetary and non-monetary benefits which improve human well-being and biodiversity, mitigate against flooding, and

[36] Defra (2023) 'Environmental Improvement Plan 2023: Executive summary'. https://www.gov.uk/government/publications/environmental-improvement-plan/environmental-improvement-plan-2023-executive-summary. *Last accessed 11/10/23.*

[37] Defra, Environment Agency, Natural England (2022) 'New legally binding environment targets set out'. https://www.gov.uk/government/news/new-legally-binding-environment-targets-set-out. *Last accessed 11/10/23.*

reduce species decline. These wider benefits can be assessed through the delivery of ecosystem services, which in this case are delivered by the nutrient mitigation solution itself.

A high-level review of the potential wider ecosystem services delivered by the three short-listed nutrient mitigation solutions (see **Section 2.4.1.2 and**) and the five restoration measures (see **Section 2.5.1**) was undertaken. The following ecosystem services were chosen based upon ENCA[38], and WINEP[39] guidance:

- Biodiversity & Habitat
- Climate regulation (Carbon sequestration)
- Natural Hazard Regulation (Flooding)
- Water Purification
- Water Provisioning
- Recreation & Tourism (including Health and Well-being)
- Agriculture
- Air Quality – Air Pollution removal
- Soil Erosion Reduction
- Material Provisioning
- Natural Flood Management

The mitigation measures were analysed based upon the number of ecosystem services which each can potentially deliver, presented in **Section 8.1** (**Figure 8-1**). These ecosystem services potentially delivered are directly related to the type of habitat created by the nutrient mitigation solution. For this assessment the habitat type for each solution was selected based on UK HAB classification system[40] (**See Table D-1 Appendix D**).

2.7 LIMITATIONS

The following limitations constrain the methods and result of this report:

- TAL upgrades of WwTW under the LURB were not published at the time of writing, therefore these WwTW were included in our analysis as potential opportunities for P mitigation.
- The report aims to provide a high-level assessment of nutrient mitigation opportunities and does not consider in-depth feasibility of solutions at individual locations (notably, wetland design, land acquisition, land agreements and stakeholder engagement).
- Due to the developments and changes to NN legislation potential solutions identified in our recommendations may become ineligible for NN mitigation measures, and therefore these recommendations should be considered alongside the most up to date information.
- The efficacy of mitigation measures, and therefore the amount of P they will mitigate, is uncertain due to the large number of variables that may affect the performance. As such, the precautionary P removal rates that were sourced from literature and detailed in the fact files created in **Section 2.4.1.1** were applied. This report aims to provide a high level overview of P load reduction, further feasibility and detailed analysis of the preferred mitigation measures is required.

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[38] ENCA, Enabling a Natural Capital Approach Guidance. See: https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance

[39] Defra (2022) 'Water industry national environment programme methodology'. https://www.gov.uk/government/publications/developing-the-environmental-resilience-and-flood-risk-actions-for-the-price-review-2024/water-industry-national-environment-programme-winep-methodology. *Last accessed 11/10/23.*

[40] The UK Habitat Classification Working Group (2018) 'The UK Habitat Classification. Habitat Definitions Version 1.0'. https://ecountability.co.uk/wp-content/uploads/2018/05/UK-Habitat-Classification-Habitat-Definitions-V1.0-May-2018-1.pdf. *Last accessed 11/10/23*

3. ACTIVITY 1 - CONDITIONS AND OBJECTIVES OF HABITAT SITES

Esthwaite Water Ramsar, the River Derwent and Bassenthwaite Lake SAC, the River Eden SAC and the River Kent SAC are all in unfavourable condition due to elevated P concentrations. These sites are legally underpinned by various SSSIs. A map of these locations is highlighted in **Figure 3-1**. The NE evidence packs[9] contain key information about each Habitats Site, the current concentrations of P within in each unit and thus, whether that SSSI unit is meeting the required P target. This information is summarised below, alongside more recent monitoring data of P where applicable. Estimates of the load reduction required to reduce the P concentrations below the target are also presented to inform estimates of the amount of restoration measures that could be implemented to restore the site. **Sections 3.1**, **3.2**, **3.3** and **3.4** provide further information on the current conditions of the Esthwaite Water Ramsar Site, the River Derwent and Bassenthwaite Lake SAC, the River Eden SAC and the River Kent SAC, respectively.

3.1 ESTHWAITE WATER RAMSAR

3.1.1 Site description

Esthwaite Water Ramsar is a natural (and highly eutrophic) lake located in a glacial valley in the Lake District, north-west England. It is situated between Lake Windermere and Coniston Water. The site includes the open water lake and surrounding fen and grassland communities.

The lake is approximately 65 metres above sea level with an area of one km^2. It has a maximum depth of 15.5 m and an average retention time is 90 days. It has a catchment area of 17.1 km^2 mainly composed agricultural land and forestry.

Reasons for designation:

- Mesotrophic Lake
- Slender naiad *Najas flexilis*
- Wetland invertebrate assemblage
- Wetland plant assemblage

Esthwaite water qualifies as a Ramsar Site under Criterion 1a because it is a particularly good example of a mesotrophic lake and under Criterion 2a because it contains nationally rare plant and other restricted species. The nutrient pressure for which Esthwaite Water is unfavourable is P, with recent water quality measurements showing it to be exceeding the targets for TP.

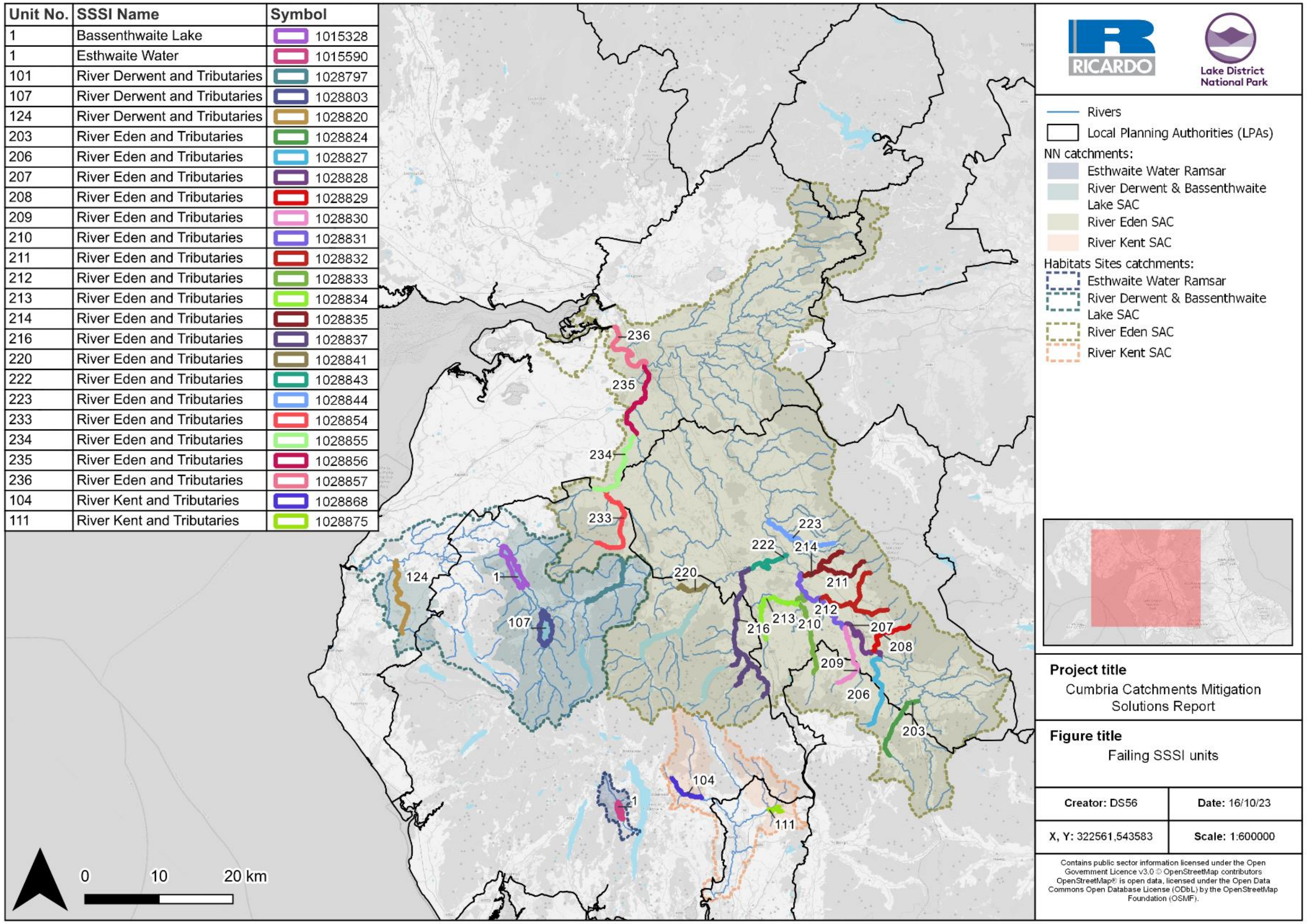
3.1.2 Assessment of the restoration goals for SSSI Units affected by NN guidance

Esthwaite Water Ramsar is legally underpinned by the SSSI Esthwaite Water, SSSI Unit number 1. As shown in **Figure 3-1**, the SSSI unit is currently failing to meet the P target and a 48% reduction in TP is required. This equates to a concentration reduction of 14 ug TP/l. The estimated mean flow for the site is 0.62 m^3/s. The P concentrations and flow suggest a load of at least 274 kg TP / year needs to be captured to reach the target concentration. The most recent water quality data from the EA WIMS water quality database indicates that the water quality for the site is improving. The monitored TP concentration from one sample in June 2023 was 21 ug TP/l. This could mean that approximately 117 kg TP needs to be mitigated[41]. However, when assessing the condition of a site, NE do not use one-off measurements and generally assume an average of the last five years and therefore, this result should not be used as evidence of a downward trend. Furthermore, a recent unpublished report, Lakes Tour 2021, suggested that the water quality of the Esthwaite Water has been deteriorating and the concentration of P is actually closer to 35 ug P/l (Mackay, et al., 2023). The locations of the failing SSSI units can be seen in **Figure 3-1** (note: the NE NN evidence review can be referred to in order to identify the name of the water body

[41] The concentrations of TP for each of the SSSI units detailed in the Natural England evidence packs are based on a longer period of monitoring data and therefore more evidence of consistently lower monitored concentrations is required to determine any clear trends.

that corresponds to the SSSI unit. Furthermore, the length of the WFD waterbodies within each length of SSSI unit is detailed in **Table C-1 in Appendix C).**

Figure 3-1 Map showing the Catchments affected by Natural England's NN advice and the locations of the failing SSSI units that underpin each Habitats Site



Unit No.	SSSI Name	Symbol
1	Bassenthwaite Lake	1015328
1	Esthwaite Water	1015590
101	River Derwent and Tributaries	1028797
107	River Derwent and Tributaries	1028803
124	River Derwent and Tributaries	1028820
203	River Eden and Tributaries	1028824
206	River Eden and Tributaries	1028827
207	River Eden and Tributaries	1028828
208	River Eden and Tributaries	1028829
209	River Eden and Tributaries	1028830
210	River Eden and Tributaries	1028831
211	River Eden and Tributaries	1028832
212	River Eden and Tributaries	1028833
213	River Eden and Tributaries	1028834
214	River Eden and Tributaries	1028835
216	River Eden and Tributaries	1028837
220	River Eden and Tributaries	1028841
222	River Eden and Tributaries	1028843
223	River Eden and Tributaries	1028844
233	River Eden and Tributaries	1028854
234	River Eden and Tributaries	1028855
235	River Eden and Tributaries	1028856
236	River Eden and Tributaries	1028857
104	River Kent and Tributaries	1028868
111	River Kent and Tributaries	1028875

Table 3-1 Table showing the water quality summary statistics of failing SSSI units in the Esthwaite Ramsar Habitats Site

Habitats site	SSSI ID	SSSI Unit	Sample ID	Target (ug/l)	Unit	Evidence Pack concentration (ug/l)	Units	Percentage reduction	WIMS updated concentration (ug/l)	WIMS Data Date	Estimated mean flow (m^3/s)	Catchment area (km^2)	Load reduction (kg P / unit)	Trend
Esthwaite Ramsar	1015590	1	NW-88004551	15	TP	29	TP	48	21	Jun 23 only	0.62	16.41	273.92	Down

3.2 RIVER DERWENT AND BASSENTHWAITE LAKE SAC

3.2.1 Site description

The Derwent is a river system in Cumbria, within the West Cumbria Coastal Plain National Area and the Cumbria High Fells National Character Area. The River Derwent flows through two lakes: Derwent Water with a nutrient poor status (oligotrophic/mesotrophic), and Bassenthwaite with a moderate nutrient status (mesotrophic). The River Marron catchment flows into the River Derwent d/s of both lakes.

Reasons for European Site Designation:

- H3130 Oligotrophic to mesotrophic standing water with vegetation
- H3260 Water courses of plain to montane levels with *R. fluitantis*
- S1065 Marsh fritillary, *Eurodryas aurinia*
- S1095 Sea lamprey, *Petromyzon marinus*
- S1096 Brook lamprey, *Lampetra planeri*
- S1099 River lamprey, *Lampetra fluviatilis*
- S1106 Atlantic salmon, *Salmo salar*
- S1355 Otter, *Lutra*
- S1831 Floating water-plantain, *Luronium natans*

The nutrient pressure for which the Bassenthwaite and Marron catchment is unfavourable is P. Recent water quality measurements show that Bassenthwaite Lake, and Derwent Water to be exceeding the targets for TP, and the River Marron is exceeding the target set for Soluble Reactive Phosphate (SRP) concentrations.

3.2.2 Assessment of the restoration goals for SSSI Units affected by NN guidance

The River Derwent and Bassenthwaite Lake SAC is legally underpinned by the Bassenthwaite Lake SSSI, Buttermere SSSI and the River Derwent and Tributaries SSSI. This site is comprised of a total of 40 SSSI units, of which four are failing to meet the designated targets. **Figure 3-1** shows that the catchments affected by NN are on separate sides of the wider catchment. **Table 3-2** shows that the Bassenthwaite Lake SSSI unit 1 requires a reduction of 4.3 ug TP/l (30%). Furthermore, the River Derwent and Tributaries SSSI units 101, 107 and 104 require reductions of 50.5, 9 and 15% of the monitored P concentrations, respectively. Applying the estimated mean flow for each SSSI unit to the P reduction requirements equates to a total of 1853 kg TP of restoration required within the catchment of Bassenthwaite Lake and 551 kg orthophosphate (OP) may need capturing to ensure that the western part of the Habitats site catchment is meeting the water quality objective. Restoration implemented upstream of Bassenthwaite Lake is likely to provide the most benefit if targeted in the catchment of an upstream failing SSSI unit. The most recent WIMS water quality data demonstrates a current decreasing trend in P concentrations relative the those reported in the NE evidence packs[41].

Table 3-2 Table showing the water quality summary statistics of failing SSSI units in the River Derwent and Bassenthwaite Habitats site

Habitats site	SSSI ID	SSSI Unit	Sample ID	Target (ug/l)	Unit	Evidence Pack concentration (ug/l)	Units	Percentage reduction	WIMS updated concentration (ug/l)	WIMS Data Date	Estimated mean flow (m^3/s)	Catchment area (km^2)	Load reduction (kg P / unit)	Trend
River Derwent and Bassenthwaite	1015328	1	NW-88010015	10	TP	14.3	TP	30	13.8	Nov 22 - Mar 23	13.65	360.44	1852.60	Down
River Derwent and Bassenthwaite	1028803	107	NW-88010014	8	TP	8.8	TP	9	N/A	N/A	3.25	85.62	81.98	N/A
River Derwent and Bassenthwaite	1028797	101	NW-88022117	10	SRP	20.2	OP	50.5	N/A	N/A	2.52	66.34	809.81	N/A
River Derwent and Bassenthwaite	1028820	124	NW-88005728	40	SRP	46.9	OP	15	44	Apr 23 – Aug 23	2.53	66.75	551.16	Down

3.3 RIVER EDEN SAC

3.3.1 Site description

The Eden SAC is situated within multiple National Character Areas (NCA) including, Cumbria High Fells, Orton Fells, North Pennines, Solway Basin, Border Moors and Forests, Tyne Gap and Hadrian's Wall, and the Yorkshire Dales, where it flows north to discharge into the Solway Estuary. The nutrient status gradually changes along the Eden's length as nutrient loadings naturally increase in the lower reaches.

Reasons for European Designation:

- H3130 Oligotrophic to mesotrophic standing water with vegetation
- H3260 Water courses of plain to montane levels with *R. fluitantis*
- H91E0 Alluvial woods with *A. glutinosa, F. excelsior*
- S1092 Freshwater crayfish, *Austropotamobius pallipes*
- S1095 Sea lamprey, *Petromyzon marinus*
- S1096 Brook lamprey, *Lampetra planeri*
- S1099 River lamprey, *Lampetra fluviatilis*
- S1106 Atlantic salmon, *Salmo salar*
- S1163 Bullhead, *Cottus gobio*
- S1355 Otter, *Lutra*

The nutrient pressure for which the River Eden SAC is unfavourable is P. Recent water quality monitoring data shows that the site is failing its water quality targets at a number of river units within the catchment although Ullswater lake is passing its nutrient targets.

3.3.2 Assessment of the restoration goals for SSSI Units affected by NN guidance

The River Eden SAC is legally underpinned by 40 different SSSI units which comprise the River Eden and Tributaries SSSI. **Table 3-3** shows that 18 distinct SSSI units are exceeding due to elevated OP concentrations. The Table presents all water quality monitoring points and as such, some SSSI units have multiple water quality monitoring points. For the purposes of determining the restoration requirement, it is suggested that the highest value of OP is considered. The SSSI unit 236 is the most downstream SSSI unit and requires a 17% reduction in OP concentrations. This equates to 22432 kg OP that requires restoration in order to meet the water quality objective for P. If P restoration was to be implemented for this downstream SSSI unit, the upstream failing SSSI units could be targeted to deliver benefits throughout the catchment. Of the SSSI units with more recent WIMS water quality monitoring data, the majority of the monitored OP concentrations are trending downwards, bar SSSI unit 220 to the north of Ullswater[41].

Table 3-3 Table showing the water quality summary statistics of failing SSSI units in the River Eden Habitats Site

Habitats site	SSSI ID	SSSI Unit	Sample ID	Target (ug/l)	Unit	Evidence Pack concentration (ug/l)	Units	Percentage reduction	WIMS updated concentration (ug/l)	WIMS Data Date	Estimated mean flow (m^3/s)	Catchment area (km^2)	Load reduction (kg P / unit)	Trend
River Eden	1028824	203	NW-88006163	7	SRP	15.8	OP	56	N/A	N/A	1.51	39.71	418.16	N/A
River Eden	1028824	203	NW-88006452	7	SRP	10.1	OP	31	N/A	N/A	1.51	39.71	147.31	N/A
River Eden	1028827	206	NW-88006181	15	SRP	22.5	OP	33	N/A	N/A	0.88	23.21	208.31	N/A
River Eden	1028828	207	NW-88010151	15	SRP	25.3	OP	41	N/A	N/A	13.93	367.25	4527.04	N/A
River Eden	1028829	208	NW-88006185	7	SRP	12	OP	42	N/A	N/A	1.03	27.10	162.14	N/A
River Eden	1028830	209	NW-88006190	15	SRP	20.5	OP	27	N/A	N/A	1.77	46.58	306.57	N/A
River Eden	1028831	210	NW-88006186	15	SRP	19.1	OP	21	15.8	Jun 22 - Aug 23	23.83	628.38	3083.33	Down
River Eden	1028831	210	NW-88006220	15	SRP	21.7	OP	31	19.6	Jun 22 - Jul 23	23.83	628.38	5038.62	Down
River Eden	1028832	211	NW-8800619	7	SRP	12.1	OP	42	N/A	N/A	2.72	71.68	437.49	N/A
River Eden	1028832	211	NW-88006197	15	SRP	29.7	OP	49	N/A	N/A	2.72	71.68	1260.99	N/A
River Eden	1028833	212	NW-88006212	15	SRP	24.2	OP	38	N/A	N/A	4.93	129.93	1430.58	N/A
River Eden	1028834	213	NW-88021261	25	SRP	33.2	OP	25	N/A	N/A	2.28	60.13	590.00	N/A
River Eden	1028834	213	NW-88006202	25	SRP	35.5	OP	30	N/A	N/A	2.28	60.13	755.49	N/A

Habitats site	SSSI ID	SSSI Unit	Sample ID	Target (ug/l)	Unit	Evidence Pack concentration (ug/l)	Units	Percentage reduction	WIMS updated concentration (ug/l)	WIMS Data Date	Estimated mean flow (m^3/s)	Catchment area (km^2)	Load reduction (kg P / unit)	Trend
River Eden	1028834	213	NW-RSN0095	25	SRP	26.1	OP	4	23.2	Jun 22 – Dec 22	2.28	60.13	79.15	Down
River Eden	1028835	214	NW-88006203	15	SRP	28.3	OP	47	N/A	N/A	1.72	45.30	721.07	N/A
River Eden	1028835	214	NW-88019870	15	SRP	22.4	OP	33	N/A	N/A	1.72	45.30	401.20	N/A
River Eden	1028837	216	NW-88006244	25	SRP	36.2	OP	31	N/A	N/A	5.94	156.53	2098.16	N/A
River Eden	1028841	220	NW-88006238	15	SRP	29.1	OP	48	N/A	N/A	1.44	38.02	641.64	N/A
River Eden	1028841	220	NW-88022212	15	SRP	37	OP	59	46	Jun 2022 - Aug 2023	1.44	38.02	1001.14	Up
River Eden	1028841	220	NW-88024204	15	SRP	32.7	OP	54	47	Jun 22 – Jul 23	1.44	38.02	805.46	Up
River Eden	1028843	222	NW-8800626	10	SRP	11.2	OP	11	10	Apr 23 - Jun 23	15.49	408.37	586.48	Down
River Eden	1028843	222	NW-RSN0607	10	SRP	12.3	OP	19	N/A	N/A	15.49	408.37	1124.08	N/A
River Eden	1028844	223	NW-88006266	25	SRP	62.8	OP	60	N/A	N/A	1.49	39.16	1771.48	N/A
River Eden	1028854	233	NW-88020889	10	SRP	14.5	OP	31	N/A	N/A	3.22	85.04	457.96	N/A
River Eden	1028855	234	NW-88006393	15	SRP	15.2	OP	1.3	N/A	N/A	6.88	181.52	43.45	N/A
River Eden	1028856	235	NW-88006424	30	SRP	41.4	OP	28	N/A	N/A	10.01	263.91	3600.64	N/A
River Eden	1028857	236	NW-88021071	40	SRP	48.1	OP	17	36.5	Apr 23– July 23	87.76	2314.05	22432.06	Down

3.4 RIVER KENT SAC

3.4.1 Site description

The River Kent SAC is situated in Cumbria, with its main tributaries having their catchments in the south-eastern Lake District fells.

Reasons for European Designation:

- H3260 Water courses of plain to montane levels with *R. fluitantis*
- S1029 Freshwater pearl mussel, *Margaritifera*
- S1092 Freshwater crayfish, *Austropotamobius pallipes*
- S1163 Bullhead, *Cottus gobio*

The nutrient pressure for which the River Kent SAC is unfavourable is P. Recent water quality monitoring data shows that SSSI unit 104 (River Gowan) and SSSI unit 111 (River Grayrigg) are failing their targets.

3.4.2 Assessment of the restoration goals for SSSI Units affected by NN guidance

The River Kent SAC is legally underpinned by the River Kent and Tributaries SAC. There are 14 SSSI units that comprise this site, of which two are failing to meet the designated soluble reactive phosphorus (SRP) targets. Two of these SSSI units, 104 to the west and 111 to the east, require reductions in SRP concentrations of 26 and 56%, respectively. **Table 3-4** shows the summary statistics for these two units. It is estimated that 99 kg SRP need removing from the western SSSI unit (104) to meet the water quality targets, and 217 kg SRP in the eastern SSSI units. However, the evidence packs produced by NE suggest that a larger catchment than what has been calculated drains to these SSSI units, potentially due to the boundary for each SSSI unit being different in practice compared the GIS layer. Therefore, it is possible that this estimate is a much lower than the actual restoration requirement.

Table 3-4 Table showing the water quality summary statistics of the failing SSSI units in the River Kent Habitats Site

Habitats site	SSSI ID	SSSI Unit	Sample ID	Target (ug/l)	Unit	Evidence Pack concentration (ug/l)	Units	Percentage reduction	WIMS updated concentration (ug/l)	WIMS Data Date	Estimated mean flow (m^3/s)	Catchment area (km^2)	Load reduction (kg P / unit)	Trend
River Kent	1028875	111	NW-88004390	10	SRP	22.6	OP	56	N/A	N/A	0.55	14.39	216.95	N/A
River Kent	1028868	104	NW-88004369	15	SRP	20.3	OP	26	N/A	N/A	0.59	15.55	98.65	N/A

4. ACTIVITY 2 – NUTRIENT LOADING FROM DEVELOPMENT

This section details the estimates of nutrient loading for each LPA and each Habitats Sites catchment and refers to **Figure 4-1** and **Figure 4-2** and **Figure 4-3**.

4.1.1 Nutrient budgets for applications currently stalled by NN

This section outlines the quantity of nutrient mitigation that will be required within the LPAs, assuming that all the stalled residential applications have been recorded and will proceed with development. This data was collected in April 2023, it should be noted that the number of developments may be different after this date. To provide an overview of the quantity of nutrient mitigation that might be required, **Table 4-1** outlines the demand for nutrient mitigation based on the NN Catchment each stalled development site is located within. The maximum mitigation demand is estimated based on an estimated load per dwelling of 1.25 kg TP/year. This is based on the default national average occupancy rate of 2.4 people per dwelling/unit. The probable mitigation demand is based on an assessment of the WwTW to which the developments are most likely to connect, or assuming private sewerage if there is no works near (see **Appendix B, Table B-1**). For tourism developments, the maximum mitigation applies the figure of 1.25 kg/TP per unit to the number of units, whereas the probable mitigation assesses the permit limit of the connecting WwTW if applicable (or PTP) and assumes 80 litres of water is used per person[21]. This results in a nutrient load of 1.06 kg TP/year per unit if the default value for a non-permit limited WwTW is assumed. **Figure 4-1** and **Figure 4-2** display this information visually as maps.

Table 4-1 Nutrient mitigation demand for stalled residential applications by NN catchment.

Catchment	Stalled residential developments (dwellings)	Stalled tourism development (units)	Maximum mitigation demand (residential + tourism kg TP/year)	Probable mitigation demand (residential + tourism kg/year)
Esthwaite Water Ramsar	0	0	0	0
River Derwent and Bassenthwaite Lake SAC	5	25	6.25 + 31.25 = **37.50**	5.33 + 26.41 = **31.74**
River Eden SAC	3601	195	4501.25 + 243.75 = **4745**	2046.07 + 191.56 = **2237.63**
River Kent SAC	0	0	0	0

Table 4-2 presents the same information as in **Table 4-1** (above), however the demand for mitigation is categorised by LPA, as opposed to NN catchment. This overview outlines exactly how much each LPA is impacted by NN and how much mitigation must be invested in. The stalled tourism development was provided by the LPAs, as detailed in **Section 2.2**.

Table 4-2 Nutrient mitigation demand for stalled applications by LPA.

LPA	LPA (former name)	Stalled residential development (dwellings)	Stalled tourism development (units)	Maximum mitigation demand (kg TP/year)	Probable mitigation demand (kg TP/year)
CC	Allerdale Borough Council	4	24	35	30.35
	Carlisle City Council	2689	47	3420	1557.41
	Copeland Borough Council	0	0	0	0
LDNPA	LDNPA	5	16	26.25	19.1
WFC	South Lakeland District Council	Assuming 0 as no data	0	Assuming 0 as no data	0
	Eden District Council	905	130	1293.75	658
NCC	NCC	0	0	0	0
NNPA	NNPA	0	0	0	0
YDNPA	YDNPA	3	3	7.5	4.51
DCC	DCC	0	0	0	0
Totals		**3606**	**220**	**4782.5**	**2269.37**

Figure 4-1 below shows the spatial distribution of the stalled developments within the LPA authority areas based on submitted planning applications that are located within catchments affected by NN authority areas, as provided by the LPAs. This may underestimate the total number of stalled applications because the data does not capture those developments that have either been refused due to NN or those that are waiting to submit until nutrient mitigation is available. The data that underpins the values displayed in **Figure 4-1** and the total loads presented in **Table 4-1** and **Table 4-2** can be viewed in **Appendix A**. This provides an idea of where mitigation might be required following the development of these sites.

Figure 4-1 Map showing the locations of stalled and future development within each Habitats Site NN catchment. The black labels within the nutrient neutrality catchments show stalled residential development, the blue labels show stalled tourism development, and the red labels show future developments.

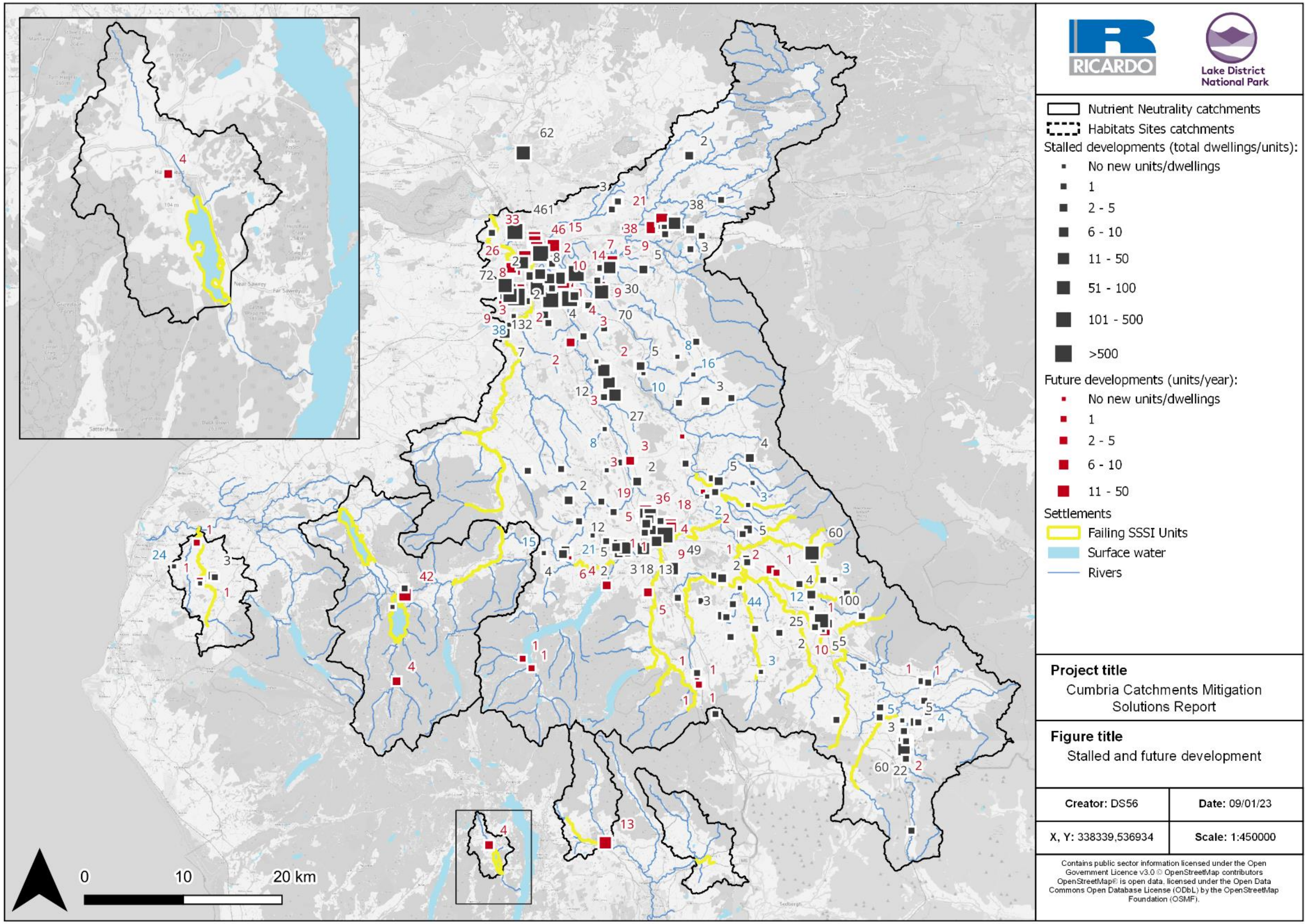


Figure 4-2 Map showing revised estimates of mitigation requirement in kg/year for stalled development

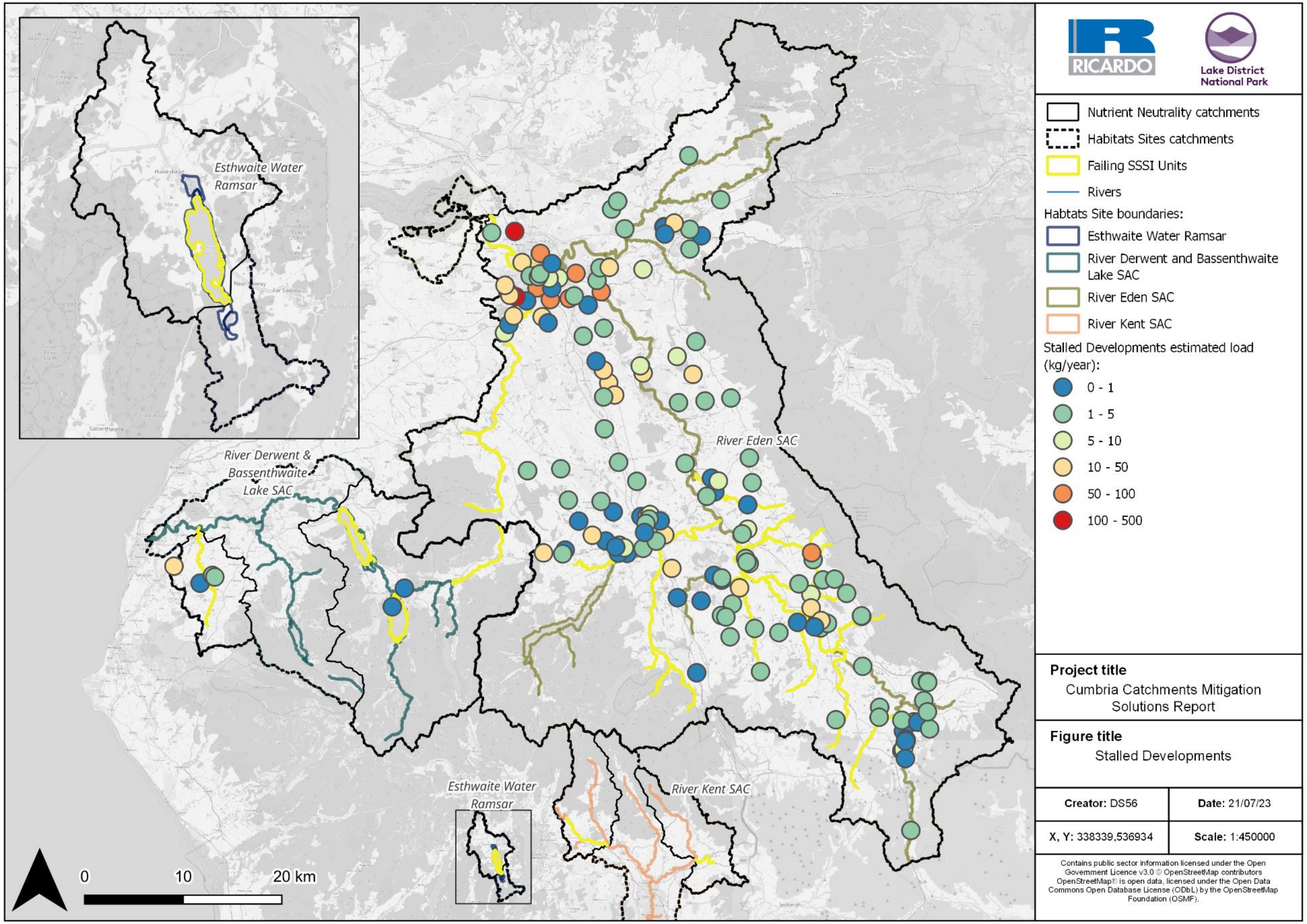
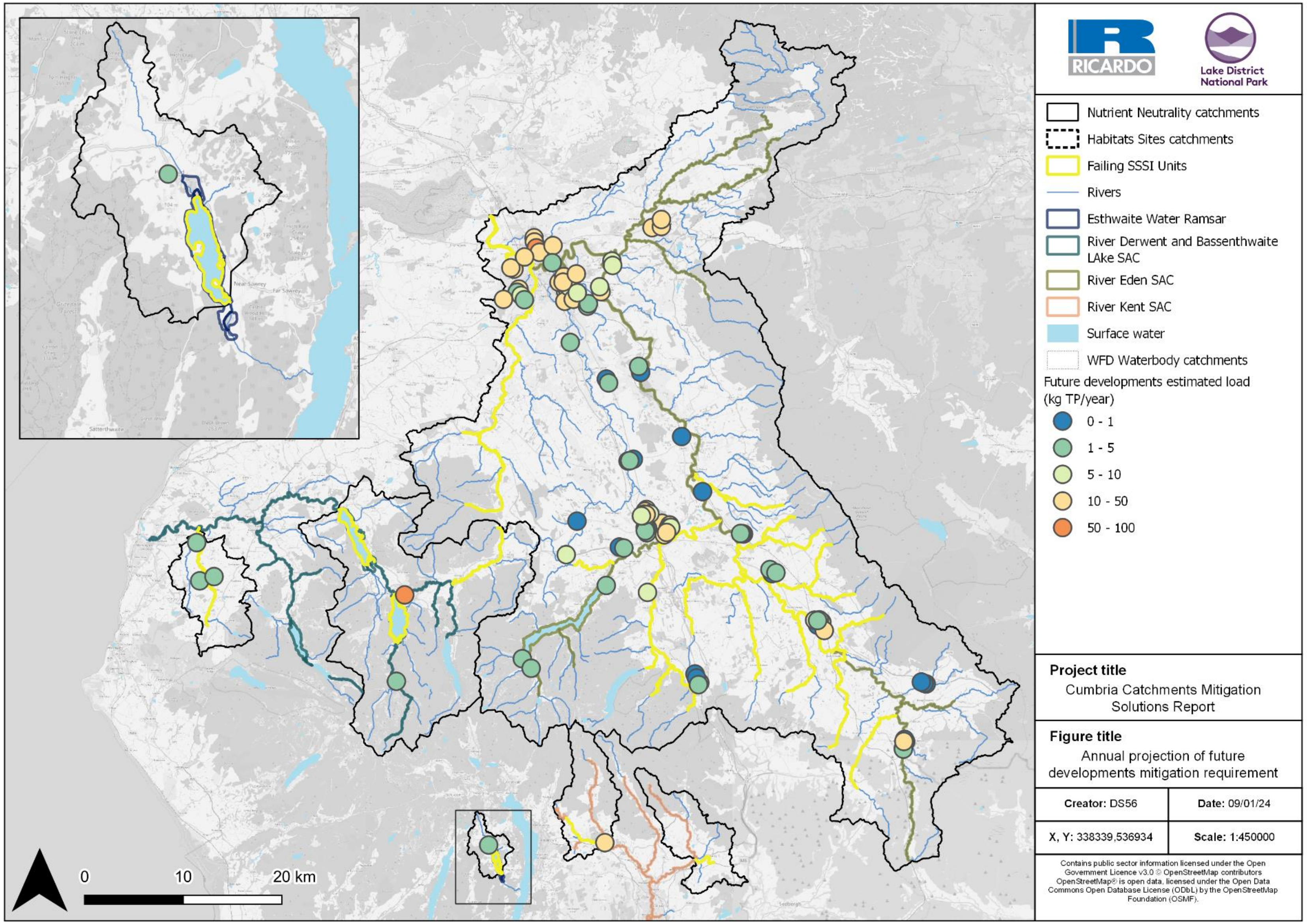


Figure 4-3 Map showing estimates of mitigation requirement in kg/year for future development



4.1.2 Nutrient budgets for the annual projection of housing supply affected by NN

This section outlines the quantity of nutrient mitigation that will be required to mitigate against the development aspirations of the LPAs on an annual basis. Note that this data is based on estimates provided by the LPAs and is supplemented by data within the LDPs, where necessary (see **Section 2.2**). It should be noted that this does not consider any windfall allowances identified in the Local Plan, with a focus only on stalled and allocated developments. As such, these estimates are subject to change as development aspirations are re-evaluated and more up to date data comes to light. This section provides an estimate of the required annual mitigation based on the assumptions detailed in the method (see **Section 2.2**). **Table 4-3** shows the results of the P budgets calculated for the housing projections, subdivided by catchment.

Table 4-3 Nutrient mitigation demand for the annual projection of housing supply affected by NN, by catchment.

Catchment	Expected no. dwellings / year	Mitigation demand (kg TP/year)
Esthwaite Water Ramsar	4	5
River Derwent and Bassenthwaite Lake SAC	49	61.25
River Eden SAC*	735	918.75
	333	198.47
River Kent SAC	13	16.25
Totals	1135	1199.72

**River Eden SAD split into two expected number of dwellings. 735 dwelling are planned each year. An additional 333 dwellings have been included in the assessment with the assumption that housing develop plans at St Cuthbert's Garden Village will be connected to Carlisle WwTWs. 2.2.3*

The results offer an understanding of the likely range of nutrient mitigation that will be required within the catchment annually. **Table 4-4** however, outlines the nutrient budgets for future development aspirations, subdivided by LPA as opposed to NN catchment. This offers an understanding of the impact that NN will have on each LPA with regard to the quantity of mitigation required.

Table 4-4 Nutrient mitigation demand for the annual projection of housing supply affected by NN, by LPA

	LPA	Expected no. dwellings / year	Mitigation demand (kg TP/year)
CC	Allerdale Borough Council	3	3.75
	Carlisle City Council	485	606.25
		333	198.47 *
	Copeland Borough Council	0	0
LDNPA	LDNPA	80	100
WFC	South Lakeland District Council	0	0
	Eden District Council	227	283.75
NCC	NCC	0	0

	LPA	Expected no. dwellings / year	Mitigation demand (kg TP/year)
NNPA	NNPA	0	0
YDNPA	YDNPA	6	7.5
DCC	DCC	0	0
Totals		1135	1999.72

*(Load for St Cuthbert's Garden Village calculated assuming a connection to Carlisle WwTW).

Figure 4-1 shows the spatial distribution of the estimated annual housing supply based on data provided by the LPAs, supplemented by LDP data where necessary. This provides an idea of where mitigation might be required following the development of these sites.

5. ACTIVITY 3 – IDENTIFYING CATCHMENT HOTSPOTS OF P

Creating a conceptual model of the current sources (baseline) of P within the catchments facilitates the identification of 'hotspots'. Hotspots are defined here as diffuse and point sources of P that contribute high loads relative to the catchment. Quantifying and mapping the P contribution from the hotspots informs understanding of the reasons behind the exceedance of P concentration targets. Furthermore, the assessment of catchment hotspots highlights catchment opportunities for a variety of mitigation or restoration solutions. For example, a WwTW which serves a large population and currently discharges hundreds of kilograms of P may present an opportunity for the implementation of a constructed wetland. There are a variety of approaches which can be used to identify catchment hotspots, including source apportionment datasets, catchment modelling of farm emissions, mapping WwTW and private sewerage systems, sampling soils for P analysis and monitoring river water quality. To determine the key sources of P in the catchment analysis of a source apportionment dataset was completed to ascertain what the key sector sources of phosphate are within each NN catchment (**Section 5.1**). Next, the loads of TP from agriculture were mapped using another apportionment dataset (**Section 5.2**). This dataset was also used to calculate agricultural export coefficients for each WFD waterbody catchment were calculated to facilitate comparison to be made between target catchments. In **Section 5.3** the sediment runoff risk across the NN catchments is presented, alongside data on the average slope in each waterbody catchment. Finally, the locations of point sources are mapped using a national database of consented discharges and the loads of P which are discharged to the environment calculated **(Section 5.4)**. This was completed for both WwTW and private sewerage systems.

5.1 SECTOR CONTRIBUTIONS OF PHOSPHATE

This section provides a summary of the key sources of phosphate and the relative contributions according to the source apportionment dataset modelled with SAGIS[22]. The sector sources considered are: WwTWs; intermittent discharges (CSOs); industrial discharges; livestock farming; arable farming; highways; urban runoff; atmospheric deposition; soils; on-site wastewater treatment; and lakes[42]. Where the catchments affected by NN are disconnected, each distinct catchment is assessed. The sector contributions of phosphate are shown in **Table 5-1** and **Table 5-2.** It is recognised that there may be other sources of P to these sites, such as internal sediment loading, although if these sources are not detailed in the datasets used then they are not considered.

5.1.1 Esthwaite Water Ramsar

The estimated total load of phosphate entering the lake is approximately 238 kg/year. The two primary sources of phosphate are agriculture (85.6%) and mains sewage (9.4%). The phosphate load associated with private sewerage systems is around third of the load from mains sewerage.

5.1.2 River Derwent and Lake Bassenthwaite SAC

The estimated total load of phosphate entering the NN catchment to the west is approximately 5962 kg/year. The three primary sources of phosphate are livestock farming (66.1%), mains sewage (15.8%), and arable farming (12.5%). Industry comprises 4.7% of the total phosphate load. The loading to the NN catchment in the east of the River Derwent catchment is approximately 12783 kg/year. This is over double the load entering the western catchment. The three primary sources of phosphate are livestock farming (52.3%), arable farming (26.4%) and mains sewage (16.2%).

5.1.3 River Eden SAC

The estimated total load of phosphate entering the River Eden is approximately 196897 kg/year. The three primary sources of phosphate are livestock farming (69.7%), mains sewage (17.6%) and arable farming (9.5%).

5.1.4 River Kent SAC

The estimated total load of phosphate entering the eastern NN catchment is approximately 1942 kg/year. The three primary sources of phosphate are livestock farming (76.8%), arable farming (16%), and mains sewage (5.1%). The western NN catchment 934 kg/year. This is less than half the load entering the eastern catchment.

[42] See full breakdown of categories from SAGIS modelling, available here: Source apportionment of nutrient contributions to rivers in England and Wales modelled with SAGIS - EIDC (ceh.ac.uk)

The three primary sources of phosphate are livestock farming (71.3%), arable farming (24.1%) and mains sewage (2.7%).

Table 5-1 Table showing the modelled load of phosphate (kg/year) from diffuse and point sources in each NN catchment (values from SAGIS[22] modelling and as such may not be representative of reality)

Catchment name	Mains sewage	CSO	Industry	Livestock	Arable	Roads	Urban	Private sewerage	Lakes	Total
Esthwaite	22	4	0	142	62*	0	0	8	1	**238**
Derwent & Bassenthwaite - West	942	12	276	3938	746	5	5	38	0	**5962**
Derwent & Bassenthwaite -- East	2066	32	127	6681	3377	104	64	147	185	**12783**
Eden	34657	1582	992	137169	18748	509	775	2281	184	**196897**
Kent - east	98	1	0	1492	310	3	2	37	0	**1942**
Kent - west	25	0	0	666	225	0	6	11	1	**934**

Table 5-2 Table showing the relative contributions (%) from diffuse and point sources in each NN catchment (values from SAGIS[22] modelling and as such may not be representative of reality)

Name	Mains sewage	CSO	Industry	Livestock	Arable	Roads	Urban	Private sewerage	Lakes
Esthwaite	9.4	1.5	0.0	59.5	26.1	0.0	0.0	3.2	0.3
Derwent & Bassenthwaite - West	15.8	0.2	4.6	66.1	12.5	0.1	0.1	0.6	0.0
Derwent & Bassenthwaite -- East	16.2	0.3	1.0	52.3	26.4	0.8	0.5	1.1	1.4
Eden	17.6	0.8	0.5	69.7	9.5	0.3	0.4	1.2	0.1
Kent - east	5.1	0.0	0.0	76.8	16.0	0.1	0.1	1.9	0.0
Kent - west	2.7	0.0	0.0	71.3	24.1	0.0	0.6	1.2	0.1

5.2 AGRICULTURAL EXPORT

This section provides estimates of the annual agricultural P export for each Habitats Site. Annual average TP export coefficients are presented at the WFD waterbody scale as shown in **Figure 5-1.** Catchments with high export coefficients present potential opportunities for the implementation of mitigation solutions that target diffuse P. At the field scale there may be individual farms that export different levels of TP compared to the catchment average.

5.2.1 Esthwaite Water Ramsar

The map in **Figure 5-1** shows that this Habitats Site has one WFD waterbody catchment with a relatively low annual agricultural export coefficient of 0.42 kg TP/ha/year. The source apportionment dataset which uses the SEPARATE framework suggests the total agricultural load in this catchment is 810 kg TP/year. This value is over triple the estimate of phosphate loading shown in **Table 5-1**. This suggests that inorganic P comprises a large portion of TP in this catchment. Furthermore, the SEPRATE methodology details the inclusion of woodland in the agricultural modelling, although the SAGIS source apportionment data does not. Therefore, the differences in modelled values are likely to arise from both factors.

5.2.2 River Derwent and Bassenthwaite Lake SAC

The map in **Figure 5-1** shows this Habitats Site has 16 WFD waterbody catchment affected by NN. The majority of these catchments have a low amount of agricultural P per hectare. The six catchments with moderate export coefficients are the Lostrigg Beck (WFD waterbody ID: GB112075070550), the Derwent DS Bassenthwaite Lake (GB112075073562), the Glenderamackin u/s Troutbeck (GB112075070490), the Naddle Beck (GB112075070420), the Trout Beck (Derwent NW) (GB112075070450), the Marron (GB112075070540), Glenderamackin (Greta) (GB112075070460) and the Derwent US Bassenthwaite Lake (GB112075073561) which export 1.61, 1.43, 1.14, 1.09, 1.05, 1.03, 1.00 and 0.78 kg TP/ha/year, respectively. The two WFD waterbody catchments to the west contribute a total of 7560 kg P/year to the Habitats Site, compared to the 14 to the east that contribute an estimated 24970 kg P/year. These values differ markedly compared to the phosphate estimates shown in **Table 5-1** and suggest a high portion of organic P.

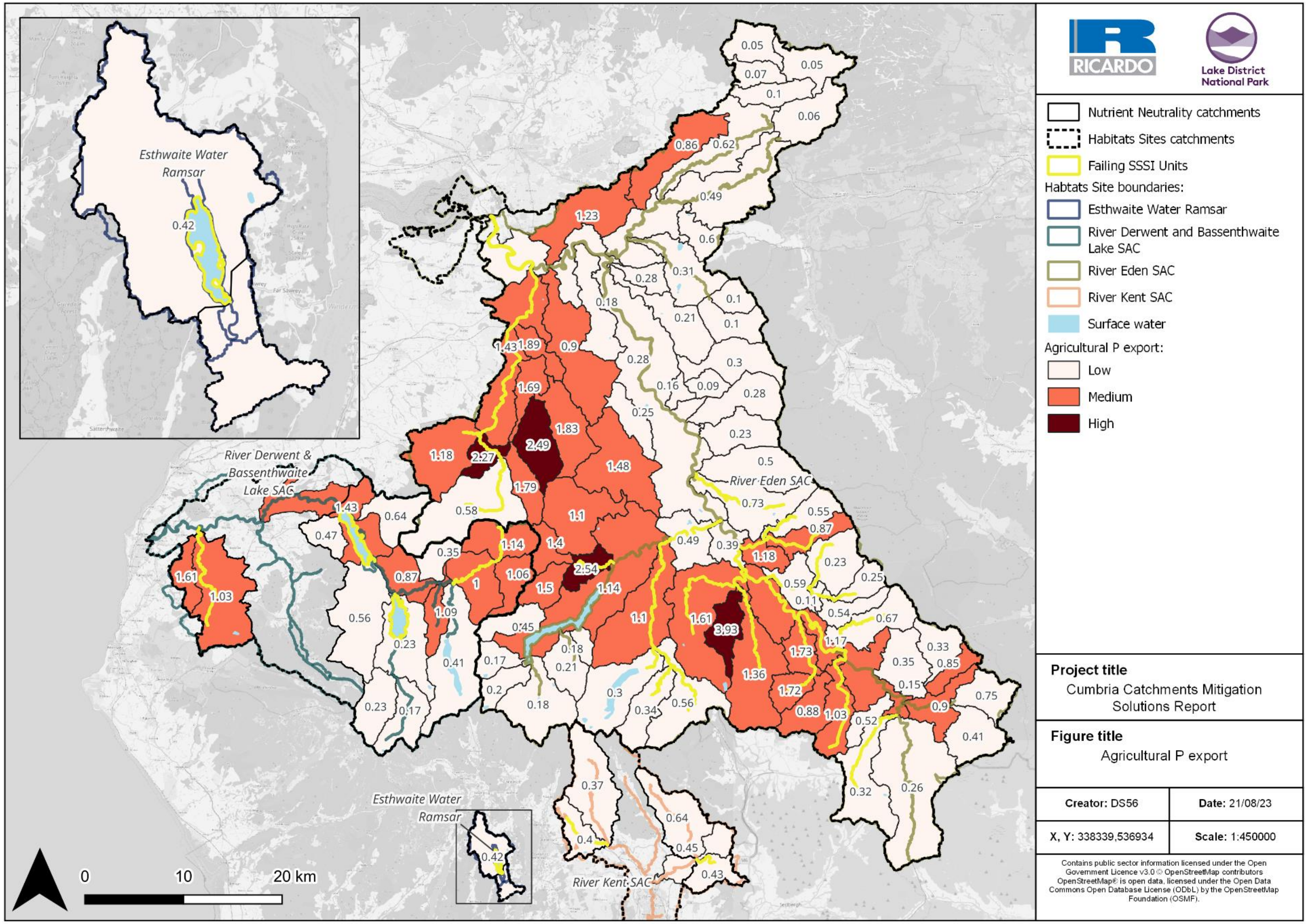
5.2.3 River Eden SAC

The map in **Figure 5-1** shows this Habitats Site has 81 WFD waterbody catchments affected by NN. Over a third (26 catchments) are estimated to export a moderate level of TP between 0.75-1.89 kg TP/year. The top 4 highest export coefficients of 3.93, 2.54, 2.49, and 2.27 kg TP/ha/year are found in the catchments of the Morland Beck (GB102076070830), the Dacre Beck (Lower) (GB102076070940), the Roe Beck (Upper_ (GB102076073750), and the Caldew (Upper) (GB102076073710), respectively. These four catchments contribute an estimated 18950 kg TP/ha/year. The total P from agricultural sources is estimated to be 170300 kg TP/ha/year. This total load is around 10% more than the phosphate values shown in **Table 5-1,** which may suggest a lower portion of organic P in the TP.

5.2.4 River Kent SAC

The map in **Figure 5-1** shows this Habitats Site has five WFD waterbody catchment affected by NN. The majority of these catchments contribute a relatively low amount of agricultural P per hectare. The Mint – Upper (GB112073074640) has the highest TP export coefficient at 0.64 kg P/ha/year. The two WFD waterbody catchments to the west contribute a total of 2100 kg TP/year to the Habitats Site, compared to the three to the east that contribute an estimated 3480 kg TP/year. The difference between the phosphate values reported in **Table 5-1** suggests a high portion of organic P within the TP.

Figure 5-1 Map showing the agricultural P export coefficients in kg/year for the WFD waterbody catchments affected by NN



5.3 SEDIMENT EROSION RISK

This section presents the results of the sediment risk modelling and refers to **Figure 5-2, Figure 5-3** and **Table 5-3**. The model incorporates slope, landcover, rainfall, soil erodibility and hydrological connectivity to identify the runoff risk for areas that are 10 metres by 10 metres. The outputs of the modelling are classed into areas of very low risk of sediment erosion, low risk, moderate risk, high risk and very high risk. The results are discussed according to the WFD waterbody catchments. The outputs of the modelling can be used to identify area that are high risk of sediment erosion and are therefore target areas for diffuse P mitigation measures.

5.3.1 Esthwaite Water Ramsar

The map in **Figure 5-2** shows the main areas of high risk of sediment erosion in the Esthwaite Water catchment are in the upper catchment of the Black Beck, the watercourse which drains the Lake. **Table 5-3** shows nearly 17% of this catchment is at high risk of sediment erosion. The slope-aspect map in **Figure 5-3** demonstrates the correlation between the runoff risk and the gradient of the slope.

5.3.2 River Derwent and Bassenthwaite Lake SAC

The main areas of high risk of sediment erosion are in the eastern catchment around the source of the River Derwent and upstream of Derwent Water, Thirlmere and Lake Bassenthwaite. **Table 5-3** shows that 27.8% of this catchment is classified as high and very high risk of sediment erosion with 11381 hectares of land in these classes. This catchment has the highest percentage of land in the very high risk class.

5.3.3 River Eden SAC

The main areas of high risk of sediment erosion are in the south-west of the catchment upstream of Ullswater and Haweswater Reservoir. There are also pockets of high and very high sediment risk spread throughout the catchment on the arable farmland. **Table 5-3** shows that only 10% of this catchment is classified as high and very high risk of sediment erosion due to the grouping of both the eastern and western NN catchments. However, over 22300 hectares of land is in these classes, of which 22% of land is in the highest risk category.

5.3.4 River Kent SAC

The main areas of high risk of sediment erosion are to the north of the upper catchments. **Table 5-3** shows that only 34.5% of this catchment is classified as high and very high risk of sediment. Furthermore, these N catchments shave the least amount of land in the very low and low risk classes. This suggests that runoff risk is generally high throughout the catchment.

Table 5-3 Table showing the breakdown of the area of each sediment runoff risk class within each NN catchment

Habitats Site	Sediment runoff risk				
	Very low	Low	Moderate	High	Very high
Esthwaite Water Ramsar area (ha)	0.4	188.3	1053.2	243.3	9.1
Esthwaite Water Ramsar area (%)	0.0	12.6	70.5	16.3	0.6
River Derwent and Lake Bassenthwaite SAC area (ha)	151.0	2171.5	27147.7	8138.0	3243.2
River Derwent and Lake Bassenthwaite SAC area (%)	0.4	5.3	66.5	19.9	7.9
River Eden SAC area (ha)	8371.2	30973.9	163528.9	17471.3	4859.1
River Eden SAC area (%)	3.7	13.8	72.6	7.8	2.2
River Kent SAC area (ha)	1.1	109.9	7127.2	3374.8	429.0
River Kent SAC area (%)	0.0	1.0	64.5	30.6	3.9

Figure 5-2 Map showing the sediment runoff risk across in the catchments of the Habitats Sites affected by NN

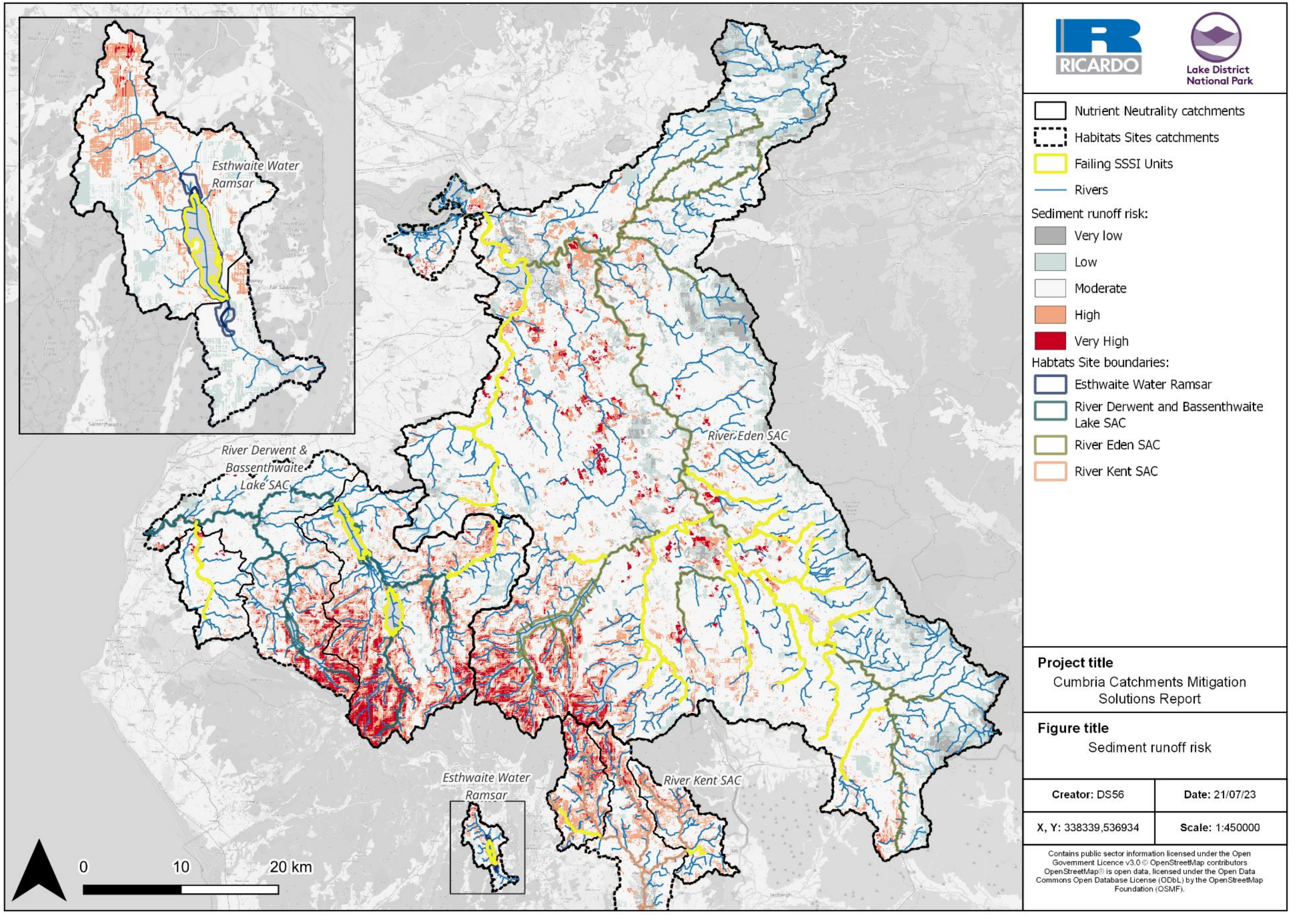
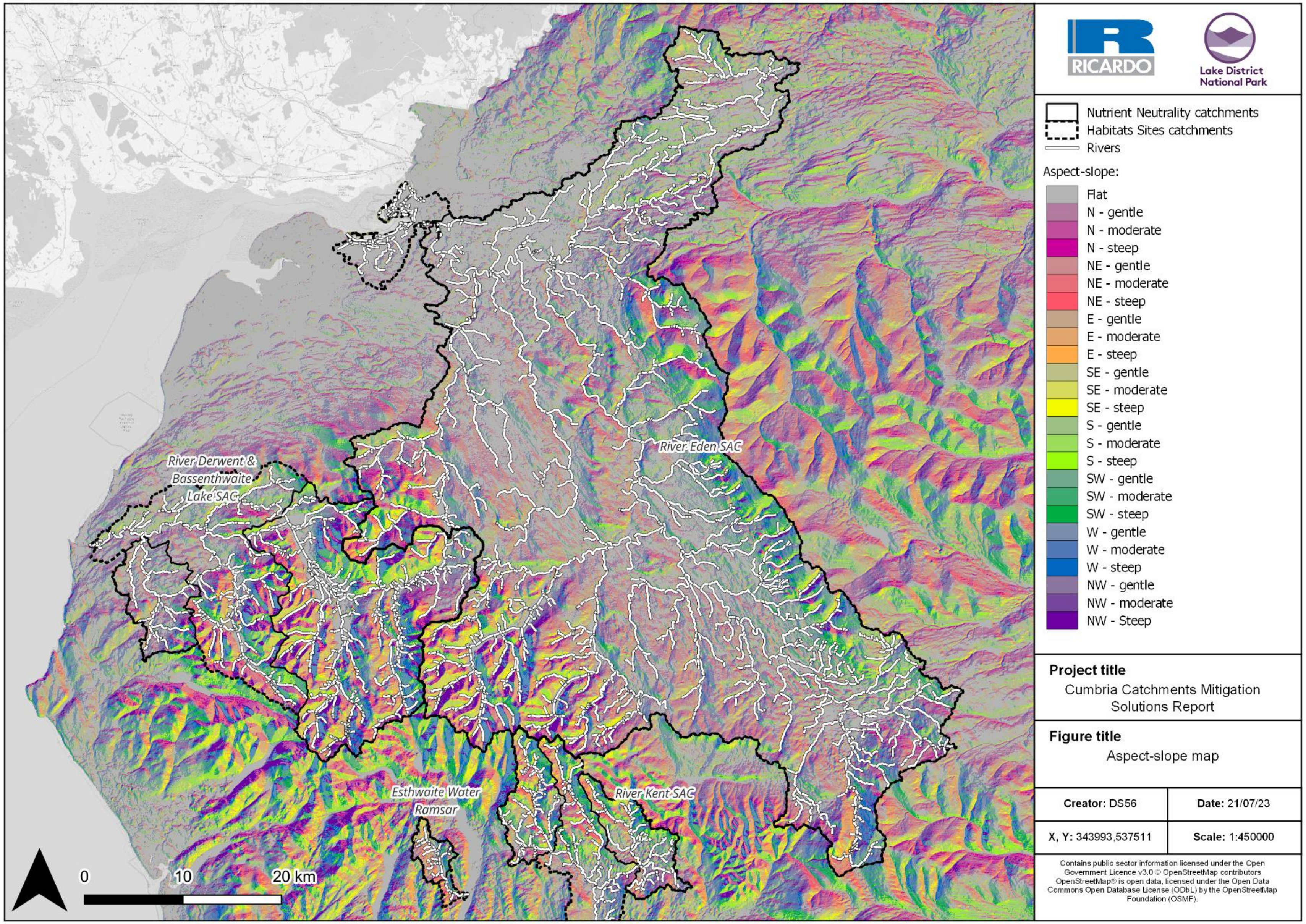


Figure 5-3 A map showing the aspect and slope for the catchments of the Habitats Sites affected by NN



5.4 POINT SOURCE BASELINE

This section discusses the point sources in each NN catchment referring to **Figure 5-4**[43] and **Figure 5-5**. The point sources detailed are WwTW and private sewerage systems. The private sewerage systems will mainly comprise STs and PTPs. The loads associated with each source are estimates that have been calculated using DWF permits and the consented TP limits associated with the permit or using the default concentrations of TP for non-permit limited systems. Only those private sewerage systems with a DWF of over 2 or 5 m^3, depending on whether the system is discharging to the ground or surface water respectively[44], have been included all of which require permits. Estimates of the load could not be completed where a point source does not have a DWF permit. The WwTW hotspots present opportunities for wetlands as this solution is considered an effective NbS for reducing nutrient loads and WwTW are typically located in areas surrounded by suitable land. Furthermore, the likely significant nutrient reductions are likely to offset the cost of implementation. Alternatively, the private sewerage hotspots present opportunities for upgrading/replacing the systems as it is unlikely that small residential settlements will implement wetlands due to the requirement for suitable land, associated costs and the complexity in designing, constructing and managing a wetland.

5.4.1 Esthwaite Water Ramsar

5.4.1.1 WwTW

The map in **Figure 5-4** shows two-point sources in the Esthwaite Water Ramsar catchment. One of the WwTW does not have a DWF permit detailed in the consented discharge register and is adjacent to the outlet of the lake. As such, this is not considered in the analysis. Alternatively, the other WwTW in the catchment, Hawkshead Sewage Treatment Works (STW), is estimated to contribute 134 kg TP/year and is likely to be the largest point source. This WwTW has permitted discharge concentration of 1 mg TP/l and a DWF permit of 368 m^3/day.

5.4.1.2 Private sewerage

The map in **Figure 5-5** shows three private sewerage point sources in the NN catchment which contribute a combined 20 kg TP/year. The highest load of 11 kg TP/year is from a system over 10 years old at time of writing.

5.4.2 River Derwent and Bassenthwaite Lake SAC

5.4.2.1 WwTW

The map in **Figure 5-4** shows there are 22 WwTW in the NN catchment, of which 12 have DWF permits and contribute an estimated 3173.8 kg TP/year. In the western catchment Bassenthwaite STW and Little Clifton STW contribute an estimated 660 and 573 kg TP/year, respectively. The top five key sources in the eastern catchment which contribute over 100 kg TP/year each are Keswick WwTW, Embleton WwTW, Rosthwaite WwTW, Bassenthwaite WwTW, and Grange-in-Barrowdale STW. These WwTWs contribute 1068, 210, 190, 161, 117 kg TP/year, respectively. All of the WwTW bar Keswick WwTW are non-permit limited works and so the default concentration of TP in the final effluent has been assumed (8 mg TP/l); Keswick WwTW has a permit limit of 0.8 mg TP/l.

5.4.2.2 Private sewerage

The map in **Figure 5-5** shows there are 43 private sewerage systems in the NN catchments which contribute an estimated 861 kg TP/year. The western catchment contains two of these sources. The largest hotspot in the west contributes an estimated 69 kg TP/year. This consented discharge became effective on the 01/10/2018. There are 41 private sewerage systems in the eastern catchment. The largest source of TP of 11614 kg is extremely likely to be an anomalous value due to an incorrect daily flow (DF) permit in the consented discharge register and so has been discounted from this analysis. The point sources contribute a total of 791.8 kg TP/year with the top ten private point sources contribute a combined 583 kg TP/year and 80% are comprised of tourism units (caravan sites, campsites etc.).

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[43] The labels for the River Eden shown in the map (Figure 5.4) show two numbers. The first number shows the rank, used in the analysis in Activities 4 and 5. The second number shows the load in kg TP/year. For all other catchments the labels show the load in kg TP/year.

[44] The thresholds for permit applications for STs and sewage treatment plants can be viewed here: https://www.gov.uk/permits-you-need-for-septic-tanks/apply-for-a-permit

5.4.3 River Eden SAC

5.4.3.1 WwTW

The map in **Figure 5-4** shows there are 88 WwTWs in the Eden catchment which contribute an estimated 50524 kg TP/year. The loads of TP have been estimated for 58 of the WwTW. The top five WwTW with highest estimated TP loads are Carlisle WwTW, Brampton (Carlisle) WwTW, Penrith WwTW, Dalston WwTW and Wetheral and Great Corby WwTW. These five WwTWs comprise 70% of the WwTW load and discharge an estimated 28078, 2221, 2042, 1846 and 1338 kg TP/year, respectively. The top ten are shown in **Table 5-4** All of these WwTW bar Penrith, are positioned in the lower catchment and discharge to the most downstream failing SSSI units. The remaining 53 WwTW are spread throughout the catchment and discharge TP loads ranging from 14 – 862 kg TP/year (Wreay WwTW and Appleby WwTW, respectively). Over 80% of the WwTWs with DWF permits are estimated to discharge over 100 kg TP/year. There are 11 WwTW upstream of Penrith which contribute a load of 1090 kg TP/year to the River Eamont. Furthermore, there are 26 WwTW upstream of the confluence between the River Eamont and the River Eden that contribute an estimated total of 5537 kg TP/year.

Table 5-4 Top ten WwTW that are estimated to contribute the highest load of TP in the River Eden catchment

WwTW Name	Permit Reference	Dry Weather Flow (m^3/d)	Daily Flow (m^3/d)	Permit limit (mg TP/l)	Estimated load (kg TP/year)	X coordinate of discharge point	Y coordinate of discharge point
Carlisle WwTW	17670049	30749	104976	2.5	28077.7	-2.96107	54.8996
Brampton (Carlisle) WwTW	17670206	1520		4	2220.7	-2.76955	54.94105
Penrith WwTW	17670084	6989	14043	0.8	2042.2	-2.69523	54.65922
Dalston WwTW	17670115	1011	2383	5	1846.3	-2.96787	54.85147
Wetheral And Great Corby WwTW	17670075	458	2810	8	1338.3	-2.83208	54.89202
Appleby WwTW	17670001	1180	2566	2	862	-2.50391	54.58315
Brough WwTW	17670004	276	370	8	806.5	-2.32719	54.52247
Kirkoswald STW	17670065	265	638	8	774.3	-2.70541	54.76368
Gilsland WwTW	17670091	257	840	8	751	-2.58137	54.9908
Warcop Camp STW	17670162	234		8	683.7	-2.38759	54.53775

5.4.3.2 Private sewerage

Figure 5-5 shows the distribution of private sewerage systems in the River Eden catchment. There are a total of 179 private systems in operation of which 104 have daily flow permits and contribute an estimated load of 2106 kg TP/year. The top three private sewerage systems contribute 407 kg TP/year, nearly 20% of the total load from private systems. Of the 20 systems that are estimated to discharge over 25 kg TP/year, 17 are tourism and leisure units and over 85% are over 10 years old. There are 32 private sewerage systems upstream of Penrith which contribute a total load of 608 kg TP/year to the River Eamont. Furthermore, there are 34 private sewerage systems upstream of the confluence between the River Eamont and the River Eden that contribute a combined 367 kg TP/year.

5.4.4 River Kent SAC

5.4.4.1 WwTW

The map in **Figure 5-4** shows there is one WwTW in the catchment affected by NN, Grayrigg STW. This WwTW does not have a DWF permit and so an estimate of the TP load has not been made.

5.4.4.2 Private sewerage

The map in **Figure 5-5** shows that there are 13 private sewage systems in the catchments affected by NN which contribute an estimated 173 kg TP/year. The four consented discharges in the western catchment with DWF permits contribute 73 kg TP/year. The private sewerage systems in the eastern catchment contribute 100 kg TP/year. The top three sources in the west contribute 44, 11 and 11 kg TP/year are 3, 5 and over 10 years old at the time of writing. The top three sources in the eastern catchment contribute 32, 25 and 16 kg TP/year and are over 10 years old at the time of writing.

Figure 5-4 Map showing the estimated TP load from WwTW in the NN catchments

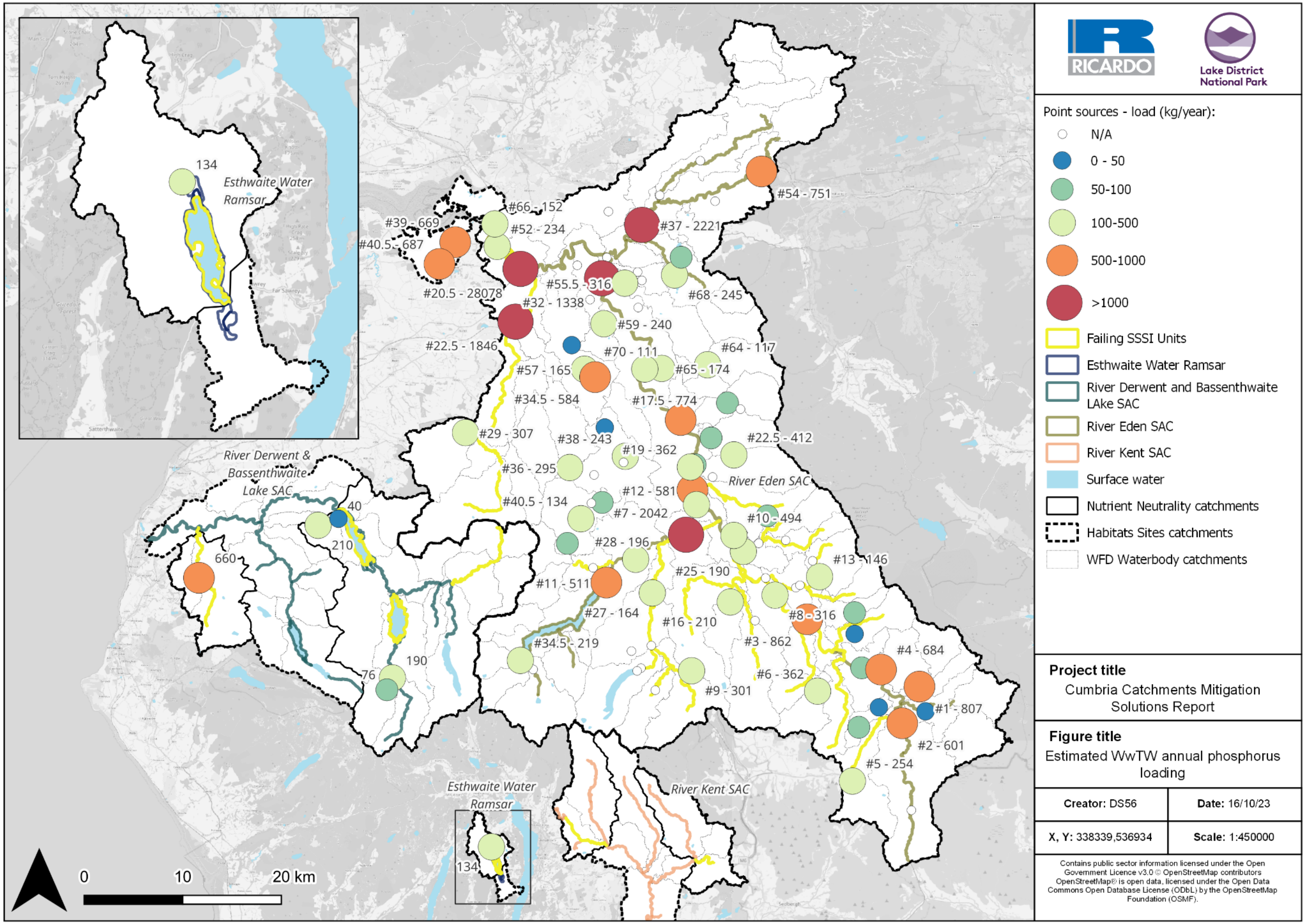
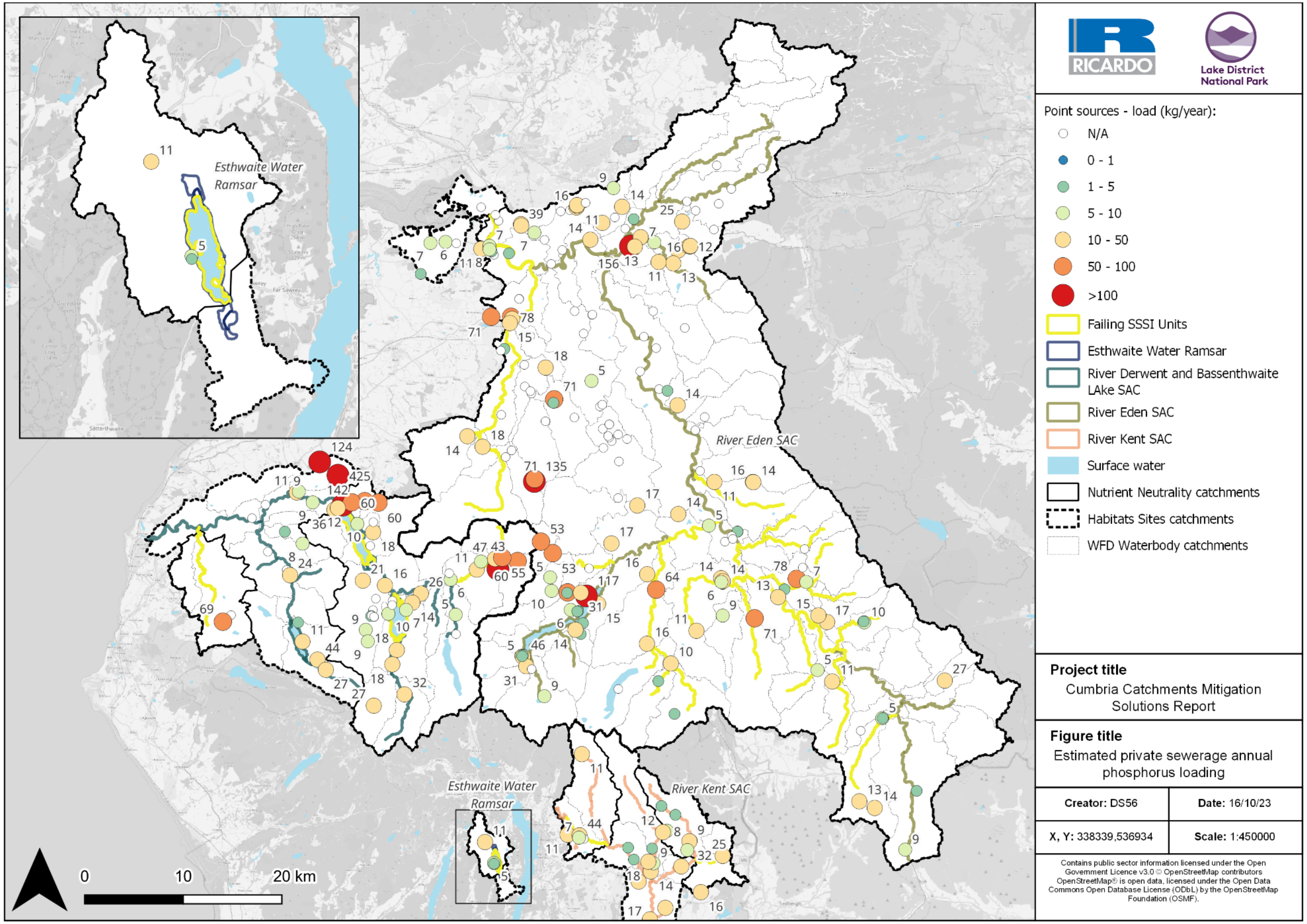


Figure 5-5 Map showing the estimated TP load from private sewerage systems in the NN catchments



6. ACTIVITY 4 – MITIGATION SOLUTIONS TO ACHIEVE NEUTRALITY

This section provides an overview of the recommended mitigation measures to implement to achieve NN for immediately stalled developments and continually each year for future developments[45]. These recommendations are made for each Habitat Site catchment as per SSSI unit that is failing. It should be noted that these recommendations have been made to identify solutions that have the least land take and are quick to implement. There are further restorative measures detailed in **Section 7** which could be used instead of the recommendations listed below. Furthermore, datasets have been provided which detail the estimated nutrient removal (and estimated cost) provided through planting woodland on agricultural land. However, these have not been recommended here due to the extent of the land take required, as well as the impact to local business and food supplies.

Section 6.1 provides a high-level summary of the issues and the recommended mitigation measures for each catchment.

Table 6-1 provides a summary of the mitigation extent, locations and costs etc.

NOTE:

This section should be read in conjunction with:

Appendix B which provides further detail on how the option functions and the mechanisms of P mitigation.

Appendix C which provides the detailed assessment related to mitigation amount needed; location of measure and high level costs of measures

Key considerations sections of this document related to mitigation implementation in **Section 2.4.1.1** and the shortlist of mitigation solutions which provide a high level of certainty for nutrient removal as presented **Section 2.4.1.2.**

6.1 TYPE OF MITIGATON MEASURES

6.1.1 Esthwaite Water Ramsar

6.1.1.1 Stalled development

There is no stalled development within the Esthwaite Water catchment. As such, no mitigation solutions are recommended.

6.1.1.2 Future development

There is an estimate of four dwellings per annum to be constructed in the Esthwaite Water catchment with an estimated contribution of 5 kg TP/year (see **Table 4-3**). However, it is very likely that development will connect to Hawkshead STW which has a TP permitted discharge limit of 1 mg TP/l and as such the load is likely to be lower. The load of P agriculture that contributes is estimated to be relatively low at 0.42 kg TP/ha/year (see **Section 5.2.1**). The proportion of the catchment at risk of sediment erosion is low at 17% (see **Section 5.3.1**). This suggests that catchment management measures which target diffuse agricultural pollution, such as riparian buffers and sediment traps, may not offer the most mitigation opportunity. There are three private sewerage systems with consented discharge permits which have been estimated to contribute a total of 20 kg TP/year (see **Section 5.4.1.2**). Furthermore, Hawkshead STW is estimated to contribute 134 kg TP/year (**Section 5.4.1.1**).

[45] Although the TAL upgrades made under the LURA by 2030 may begin to improve and restore some of the failing SSSI units, it is assumed that nutrient mitigation requirement will continue for planned future development. It should be notes that the TAL upgrades will only cover the largest WwTW and hence will only benefit some of the failing units.

6.1.1.3 Recommendation(s)

Future development: A *treatment wetland* at Hawkshead STW as this is the largest point source of TP in the Esthwaite Water catchment (contributing 134 kg TP/year). Therefore, this offers the largest potential for TP mitigation via a treatment wetland (48 dwellings over 12 years). It should be noted that further investigation into wetland feasibility and licencing is required. See Appendix C, Section C.1.1 for further details.

6.1.2 River Derwent and Bassenthwaite Lake SAC

6.1.2.1 Stalled development

There are four residential dwellings and 24 tourism units stalled in the western River Derwent and Bassenthwaite catchments with an estimated range of 30.35 – 35.00 kg TP/year of mitigation needed. There is one residential and one tourism development stalled in the eastern catchments that require an estimated range of 1.39 – 2.5 kg TP/year of mitigation. Agriculture contributes a relatively high amount of P with the top three catchments contributing 1.61, 1.43 and 1.14 kg P/ha (a combined 10990 kg TP) and the proportion of the catchments at risk of sediment erosion is high at 27.8%. This suggests that catchment management measures which target diffuse agricultural pollution, such as riparian buffers, have the potential to be an effective mitigation solution.

In the western catchment, Bassenthwaite STW contributes an estimated 660 kg TP/year but, discharges halfway along the River Marron and therefore does not contribute to any poor water quality upstream of this discharge point. The next largest point source of TP in the western catchment is Little Clifton STW (573 kg TP/year) though this works is also too far downstream to provide mitigation throughout the catchment. In the eastern catchments Keswick WwTW contributes 1068 kg TP/year, however the permit of 0.8 mg TP/l is very low and unlikely to benefit from a wetland. Alternatively, Rosthwaite WwTW contributes an estimated 190 kg TP/year and is well paced in the catchment for any mitigation provided here to propagate downstream. There is one private sewerage system that contributes 69 kg TP/year that is in the upper western catchment. To the east there are many private sewerage systems spread throughout the catchment - the top ten private point sources contribute an estimated 583 kg TP/year and 80% are located at tourism sites (caravan sites, campsites etc.).

6.1.2.2 Future development

There are three additional residential dwellings predicted per year in the western River Derwent and Bassenthwaite catchments with an estimated 3.75 kg TP/year of mitigation needed. An additional 46 residential developments may be built per year in the eastern catchments which may require 57.5 kg TP/year. However, it is likely that 42 of these developments may connect to Keswick WwTW which has a TP permitted discharge limit of 0.8 mg TP/l and, as such, the mitigation required for these future developments may be closer to 13.9 kg TP/year or less.

The summary of the sources in **Section 5.4.2** suggests that there may not a suitable amount of TP loading from point sources upstream of the predicted locations of the future development (**Figure 4-1**) to provide the mitigation opportunities required over the planning periods in the western and eastern catchments, respectively.

6.1.2.3 Recommendation(s):

Stalled development: *Private sewerage upgrades* should be targeted in both the eastern and western catchments to unlock stalled development due to the low amount of mitigation required in the east, and the moderate amount required in the west. Private sewage upgrades have been identified as the priority recommendation for stalled developments as these are a quick to implement solution and will provide more mitigation then is required from the stalled developments. See Appendix C, Section C.1.2 for further details.

Future development:

1) *Riparian buffers* should be implemented in the upper catchment so the water quality benefits are provided upstream of the discharge. We have recommended 50 m wide buffers.

2) Private sewerage upgrades (see **Section 5.4.2.2)** whilst carefully quantifying the mitigation provided may provide more immediate mitigation since there will be a time lag from when buffers are implemented to being fully effective.

See Appendix C, Section C.1.2 for further details.

6.1.3 River Eden SAC

6.1.3.1 Stalled development

There are 3601 residential dwellings and 195 tourism units with an estimated range of 2237.63 – 4745 kg TP/year of mitigation needed (as shown in **Table 4-1**).. The top five WwTWs discharge an estimated 28078, 2221, 2042, 1846 and 1338 kg TP/year, respectively (70% of total WwTW load). Private sewerage systems contribute a combined 2106 kg TP/year. Agriculture contributes a high amount of P with the top four catchments contributing 3.93, 2.54, 2.49 and 2.27 kg P/ha (a combined 18950 kg TP) and the majority of the catchment is at moderate risk of sediment erosion at 72.6%.

6.1.3.2 Future development

There is an estimated 735 dwellings that will be constructed each year. The estimated mitigation demand associated with these households is 918.75 kg TP/year. In addition, there are plans to build 10000 additional dwellings/units as part of St Cuthbert's Garden Village (see **Section 2.2.3**), south of Carlisle. It has been estimated that 333 dwellings will be built each year requiring 198.47 kg TP/year of mitigation.

6.1.3.3 Recommendation(s)

Stalled development: *Treatment wetlands at WwTWs, private sewerage upgrades, and riparian buffers* should be targeted to provide mitigation. Treatment wetlands adjacent to WwTWs have been recommended over wetlands elsewhere in the catchment as this solution offers opportunity to mitigate TP point sources within the catchment. This opportunity can be monitored over the long-term at the WwTW discharge point and the wetland outflow point to ascertain treatment efficiency. It should be noted that additional wetland feasibility at the WwTWs is required. Further detail including ranked WwTW and associated TP loading is provided in Appendix C, Section C.1.3. It should be noted that further investigation into wetland feasibility at each WwTW is required.

Future Development: *Treatment wetlands at WwTWs, private sewerage upgrades, and riparian buffers* should be targeted to provide mitigation. Treatment wetlands adjacent to WwTWs have been recommended over wetlands elsewhere in the catchment as this solution offers opportunity to mitigate TP point sources within the catchment. This opportunity can be monitored over the long-term at the WwTW discharge point and the wetland outflow point to ascertain treatment efficiency. It should be noted that additional wetland feasibility at the WwTWs is required. Further detail including ranked WwTW and associated TP loading is provided in Appendix C, Section C.1.3. It should be noted that further investigation into wetland feasibility at each WwTW is required.

6.1.4 River Kent SAC

6.1.4.1 Stalled development

There is no stalled development within the River Kent catchment. As such, no mitigation solutions are recommended.

6.1.4.2 Future development

There is an estimate 13 dwellings per annum to be constructed in Staveley, in the western River Kent catchment and are estimated to contribute a total of 16 kg TP/year. The load of P agriculture contributes is estimated to be relatively low on a per hectare basis. The proportion of the catchment at high and very high risk of sediment erosion is the most out of any catchment at 34.5%, with the western catchment the most at risk. There are no WwTW within the catchments affected by NN for which a nutrient load can be calculated. There are 13 private sewerage systems with consented discharge permits which have been estimated to contribute a total of 173 kg TP/year.

6.1.4.3 Recommendation (s)

Future Development: *Private sewerage upgrades* should be targeted to provide mitigation for future development in the context of the sources of TP.

Private sewage upgrades have been recommended over land-use change as this solution is quicker and simpler to implement and offers larger mitigation potential. See Appendix C, Section C.1.4. for further detail.

6.2 SUMMARY OF MITIGATION MEASURES

Table 6.1 provides a summary of the above recommendations proposed, including location, mitigation requirements and potential and associated costs. To add clarity, the names and the length of the centre lines of the WFD waterbodies (as lines) that are within the SSSI unit polygons were extracted. **Table C-1** in **Appendix C** shows the names of each WFD Waterbody that is 'within' each SSSI unit polygon.

Table 6-1 Summary of mitigation measures and associated costs recommended to unlock development in Cumbria

Habitats Sites	Type	No. of dwellings and/or tourist units (where applicable)	Mitigation options	Location name	Cost per unit (£/kg TP)	Total cost of the mitigation solution (£)	Mitigation requirements in catchment total in kg TP/year)	Mitigation provided (kg TP/year)
Esthwaite Water Ramsar	Stalled	No stalled developments	-	-	-	-	-	-
	Future	4	Wetland	Hawkshead STW	[redacted]	[redacted]	5 kg TP/year over 12 years = 60	61.64
River Derwent & Lake Bassenthwaite	Stalled	2 (1 residential and 1 tourism)	Private sewerage upgrade	[redacted] (East, upstream of Derwent Water)	[redacted]	[redacted]	1.39 – 2.5	28.28
		28 (4 residential and 24 tourism)	Private sewerage upgrade	[redacted] (West)	[redacted]	[redacted]	30.35– 35	61.18
	Future	4/year (x12 years)	Private sewerage upgrades	Three remaining private sewerage systems upstream of Derwent Water	[redacted]	[redacted]	5 kg TP/year over 12 years = 60	55.86 (plus remaining load from private sewerage upgrades)
		42/year (x12 years)	**Option 1)** Private sewerage upgrades	All private sewerage systems in Eastern catchments	[redacted]	[redacted]	13.49 (assuming connection to Keswick WwTW) - 52.5 kg TP/year over 12 years = 161.88 – 630	311.1
			Option 2) Riparian buffers (50 m wide)	Glenderamackin u/s Troutbeck waterbody catchment (East) - **535 ha**	[redacted]	[redacted]		973
		3/year (x6 years)	Riparian buffers	Marron waterbody catchment (West) - **1007 ha**	[redacted]	[redacted]	3.75 kg TP/year over 6 years = 22.5	2825

Habitats Sites	Type	No. of dwellings and/or tourist units (where applicable)	Mitigation options	Location name	Cost per unit (£/kg TP)	Total cost of the mitigation solution (£)	Mitigation requirements in catchment total in kg TP/year)	Mitigation provided (kg TP/year)
River Eden SAC	Stalled	3796 (3601 residential + 195 tourism)	Wetlands	Brough WwTW and (SSSI Unit 1028828)	[redacted]	[redacted]	126.14 - 318.75	371.22
				Warcop Camp WwTW (SSSI Unit 1028828)	[redacted]	[redacted]	126.14 - 318.75	314.5
				Dufton Village STW (SSSI Unit 1028832)	[redacted]	[redacted]	117.33 - 110	67
				Pooley Bridge East WwTW (SSSI Unit 1028843)	[redacted]	[redacted]	154.54 – 526.25	235.24
				Glenridding WwTW (SSSI Unit 1028843)	[redacted]	[redacted]	154.54 – 526.25	100.74
				Dalston WwTW (SSSI Unit 1028855 / 1028856)	[redacted]	[redacted]	774.8 - 1795	849
			Private sewerage upgrades	[redacted] (SSSI Unit 1028832)	[redacted]	[redacted]	110	69.2
				SSSI Unit 1028843	[redacted]	[redacted]	154.54 – 526.25	199.5
				Private sewerage system (SSSI Unit 1028833)	[redacted]	[redacted]	57.69 – 67.5	62.9
				Private sewerage system (SSSI Unit 1028834)	[redacted]	[redacted]	3.33 - 12.5	24.8
				[redacted] (SSSI Unit 1028837)	[redacted]	[redacted]	16.21 – 61.25	65.6
				SSSI Unit 1028844	[redacted]	[redacted]	10.66 – 12.5	14.2
			Bespoke solution	SSSI Unit 1028827	-	-	-	-

Habitats Sites	Type	No. of dwellings and/or tourist units (where applicable)	Mitigation options	Location name	Cost per unit (£/kg TP)	Total cost of the mitigation solution (£)	Mitigation requirements in catchment total in kg TP/year)	Mitigation provided (kg TP/year)
			Riparian buffers	Caldew (Hesket Newmarket) (SSSI Unit 1028854) – **247 ha**	[redacted]	[redacted]	5	1284.92
				Dacre Beck WFD waterbody catchment (SSSI Unit 1028841) – **253 ha**	[redacted]	[redacted]	15.84 - 18.75	1831.91
	Future	13000	Wetlands	Askham WwTW (SSSI unit 1028837)	[redacted]	[redacted]	71.25	67.17
				Gilsland WwTW (SSSI unit 1028857)	[redacted]	[redacted]	9520	616
				Brampton WwTW (SSSI unit 1028857)	[redacted]	[redacted]	9520	1022
			Riparian buffers	Morland Beck (SSSI unit 1028833) – **282 ha**	[redacted]	[redacted]	9520	4074.94
				Roe Beck (Upper) (SSSI unit 1028856) – **388 ha**	[redacted]	[redacted]	245	3628.71
River Kent SAC	Stalled	No stalled developments	-	-	[redacted]	[redacted]	-	-
	Future	13/year (x12 years) (surface runoff only)	Private sewerage upgrade	[redacted]	[redacted]	[redacted]	3.12 over 12 years = 37.44	39

6.3 KEY CONSIDERATIONS FOR PLANNING NUTRIENT MITIGATION MEASURES

Following the some of the principles of the work Ricardo has recently completed for NE (not yet published) the section below identifies the key high-level considerations related to planning related to a mitigation level. The level of detail required will be dependent on the type of measure. As such the following provides a list only of the considerations that can support the detailed design and future assessment of the measures.

This summary section should be read in conjunction with **Appendix B** (Fact files of different mitigation solutions).

6.3.1 Pre-implementation requirements

Prior to developing a mitigation scheme there is a need to answer questions about the baseline of the site to understand potential risks and the extent of the opportunity as part of a pre-feasibility assessment. This will require a mixture of analysis of 3rd party data and potentially some on site data collection to support analysis and any modelling required. The key areas include:

- *Consult local and nature recovery plans* to establish if there is any opportunity to combine outputs. to establish if the nutrient mitigation.
- *Confirming the baseline load*: Monitoring influent and effluent TP load from input sources (likely to be for a minimum of a year with monthly measurements taken) to calculate loads from the system prior to any land use change.
- *Determine the TP output from a site* prior to land use change: model input sources to generate export coefficients.
- *Identify if there are any Invasive Non-Native Species (INNS)* present in the area to establish if mitigation solution with have a negative impact in terms of potential spread to other locations in the catchment.
- *Ecological surveys* to determine if proposed mitigation solution could have negative impact on protected habitats or species.
- *Physical process surveys to help inform feasibility assessment and understand flow pathways:* e.g. Soil analysis, hydrogeological assessments (inputs and outputs, and seasonality), flood risk, and topography at proposed site, current land use. survey at proposed site.
- *Determine functional area* via application of appropriate design models and equations
- Environmental regulatory considerations:
  - Environmental permits
  - Flood risk assessment
  - Flood defence consent from Environmental Agency (EA) regarding works within 8m of a main river
  - Archaeology and pathway assessment
  - Wildlife licences
  - Planning permission
- Wetland feasibility assessments at each WwTW are required to assess land availability and suitability. Following this, considerations for land acquisition (or non-owned agreements or negotiations) will need to be appraised.

6.3.2 Monitoring (post-delivery)

- *Robust design and maintenance and monitoring plan* – this requires regular, long-term monitoring programmes (e.g., of inlet and outlet) to determine TP removal efficiency, with the results from sampling programmes being fed into an adaptive management system. The post project monitoring relies on the pre-feasibility monitoring for a baseline.
- *Monitoring programmes* should be conducted for as long as required for the system to reach equilibrium, whereby the fluctuations in load reductions show steady patterns of change on repeating cycle, or simply stabilise around a long-term average

- *Pre- and post- implementation monitoring* of influent and effluent, soil dynamics, hydrogeology, flood risk, topography, ecology etc. to determine reduction in concentrations
- *Regular visual inspections* to support early identification of requirements for adaptive management
- A monitoring method with an appropriate experimental design which collects enough data to be confident in characterising the surface and subsurface flows and nutrient concentrations across the site.

6.3.3 Wider environmental considerations

Whilst the focus of schemes is benefits for NN, nature-based solutions as flagged in this report can also have benefits for BNG, carbon sequestration and potentially wider environmental and societal benefits. To achieve this will require an assessment of the habitats condition and extent/present to provide a baseline against which wider benefits can be considered. More details of what is needed to assess these criteria are highlighted in **Section 8.1.**

6.3.4 Key Constraints

- *How large is your mitigation?* If large-scale alterations are likely to require earthworks the detailed design will require construction and environmental management plans, as well as potentially requiring planning permission and permits.
- *Are there any public rights of way which could be affected*? What permissions are required?
- *Is the land available?* Land constraints can cause significant delays to deploying solutions. An example of this is landowner agreement. Agreement should be sought with the landowner as well as any other nearby landowners who might experience impacts of the scheme.
- *Is there mitigation demand in the area?* A mitigation scheme should be located in an area where credits are required and therefore should be located in an area able to serve developments impacted by NN. This is to ensure that nutrient offsetting is provided before the point at which the development has an impact on a Habitats Site.
- *Is the scheme able to provide mitigation in perpetuity?* A scheme must have practical certainty that it can achieve the calculated quantity of nutrient mitigation for the lifetime of the development unless, it is a temporary measure. Legal agreements might be required to confirm with landowners that the land will be managed in such a way so as to provide long term mitigation.
- *Is the scheme being implemented for NN specifically?* For a mitigation scheme to be eligible to provide mitigation to local developments, it must be designed and implemented for the primary purpose of achieving NN. The scheme cannot provide credits if it is required under a different legal obligation, for example.
- *Is the physical environment at the site suited to the mitigation measure?* For nature-based solutions, the proposal should consider physical conditions to understand whether they might compromise or improve the efficacy of a scheme. Considerations should include but should not be limited to soil type, hydrology, geology, topography, flood risk, protected sites and species, land-use and site history.

7. ACTIVITY 5 – MEASURES TO RESTORE HABITAT SITES TO FAVOURABLE CONDITION

Notes:

- Getting to the stage of restoring the sites back to favourable condition is later down in the process, relative to unlocking stalled and future development.
- Quantifying the amount of restoration measures that will be needed is uncertain at this state.
- This section identifies areas within each Habitats Site that could be targeted to restore the sites.
- Because of the estimated large load reductions required, at this early stage section solutions have been identified at the WFD waterbody catchment scale that target diffuse pollution.
- The measures listed for restoration can also be used for mitigation.

In this section example maps are provided which form part of a large GIS spatial data set and associated interpretation.

All datasets used, including any tools or the outputs of any tools, have been provided to the client as a data package (**NN_Ric_data_v01**). It is highly recommended that the datasets are investigated in conjunction with this section.

This section discusses the potential restoration measures that could be implemented to ameliorate the P concentrations in each of the failing SSSI units to restore each of the Habitats Sites back to favourable condition. Restoration measures are similar to mitigation measures, though they are aimed to restore a site to combat contemporary and legacy P, as opposed to NN which focuses on mitigating future nutrient discharges.

A variety of opensource datasets were used to assess the suite of potential restoration measures for each of the Habitats Sites catchments, as discussed in **Section 2.4.3** and **Section 2.5.3**. This includes:

Note:

- Restoration measures are not required as part of NN legislation, and have therefore been distinguished from mitigation measures, although both restoration measures and mitigation measures both aim to reduce P loading to Habitat Sites.

A description of these datasets and key information about attributes is provided, along with instructions on how these datasets can be used to inform decision making and a worked example demonstrating the utility of each dataset is presented through a set of maps, one for each longlisted mitigation measure (**See section 7.1**)

Key recommendations are made which highlight the suite of restoration solutions that could be implemented to restore the sites back to favourable condition. To add clarity, a summary of the current condition of each failing SSSI unit is presented using the information in **Section 3**. This subsection considers the recommendations for unlocking stalled and future development, detailed in **Section 6**, and incorporates any 'remaining' nutrient credits associated with these measures that could be considered for NN objectives.

Please note that the following restorative measures could also be used for nutrient mitigation, though they are either too uncertain or require a vast land take and therefore may be extremely costly. As such, any mitigation measures recommended in **Section 6** that are not selected could be replaced with any of the restorative measures.

An overview of the potential restoration measures available in the catchment to each SSSI unit is presented where only significant opportunities are presented that fit the context of the catchments.

Finally, a set of recommendations is made for each failing SSSI unit within each of the Habitats Sites.

7.1 DATASETS USED TO IDENTIFY MITIGATION MEASURES

7.1.1 Overview of datasets

As detailed in **Section 2.4.3** and **Section 2.5.3**, a set of opensource datasets were used to assess the mitigation opportunities available in each catchment. The datasets were amended to add more attributes in order to enhance their utility in planning and increase the applicability to each catchment. Initially the datasets were clipped to the NN catchments.

Then, for all of the restoration measures which tackle diffuse pollution, the WFD waterbody catchment was added to each dataset - understanding which WFD waterbody catchments comprise the failing SSSI unit catchments and their respective Habitats Sites is useful for strategic planning.

In addition, the following attributes were added:

- Average annual export coefficient for the catchment,
- Sum of the combined area of all potential areas per WFD waterbody catchment,
- Estimated load reduction associated with implementing that mitigation solution (if applicable),
- Cost of implementing the measure on a credit basis (if applicable),
- BNG baseline score (score per hectare),
- Scores from the outputs of Ricardo's in house PBO tool for all habitats, grassland, peatland, woodland, and wetland.

For the point source restoration opportunities, such as WwTW, private sewerage upgrade opportunities, aquaculture and commercial discharges, the estimated load was calculated and conditions of each permit superfluous to NN were removed. For WwTWs in the Eden catchment, a rank was given to each point source in relation the catchment which was based on the proximity to a failing SSSI units, the distance from the catchment outlet and the load.

An accompanying tool has developed in Microsoft Excel which allows the user to enter the load removed through mitigation / restoration solutions at each site. The loads entered are automatically removed from each of the downstream SSSI units in order to be confident in the load reduction accounting.

7.1.2 WwTW point source dataset

7.1.2.1 What is it?

This dataset is entitled "NN_Ric_WwTW_V01". It utilises the Consented Discharges to Controlled Waters with Conditions dataset[24] as described in **Section 132.3.4**. It contains additional data on the estimated load from the discharge, the WFD waterbody catchment and the failing SSSI unit catchment each point is situated within, if the site has been recommended as mitigation for stalled development, and if the site is recommended for future development.

7.1.2.2 How can it be used?

This dataset can be used to identify WwTW point sources that have an opportunity to provide mitigation/restoration through the implementation of a treatment wetland, as the dataset details the potential TP load discharged from the WwTWs. Assessing the field parcels that surround a site and determining physical characteristics of the surrounding land, such as slope, may facilitate the identification of a suitable and affordable site for a wetland. This dataset does not include information on the surrounding landcovers, constraints or topography. An example of how this dataset can be used is shown in **Figure 7-1**

7.1.3 Riparian buffer dataset

7.1.3.1 What is it?

This dataset is titled "NN_Ric_Buffer_V01". It utilises the WWNP Riparian Woodland Potential dataset[27] which is an estimate of the locations where woodland creation may be possible 50 metres either side of watercourses close to flow pathways. It was created to pinpoint areas for flood attenuation that are not already wooded. However, it can also be used to map potential areas for riparian buffers that target P because intercepting and slowing surface runoff encourages P deposition for subsequent uptake by the vegetation. Additional attributes were added to the data as described in **Section 7.1.1**. It should be noted that non-wooded buffers can also be used for restoration measures, however these may have reduced P and biodiversity benefits.

7.1.3.2 How can it be used?

This dataset can be used to identify individual sites for establishing riparian buffers or to quantify the load reduction associated with creating wooded riparian buffers on all of the potential areas in a catchment. However, these opportunities may be constrained by costs of land acquisition, implementation and maintenance. An example of the information within this dataset is presented in **Figure 7-2**

7.1.4 Floodplain reconnection potential

7.1.4.1 What is it?

This dataset is titled "NN_Ric_Flood_V01". It utilises the WWNP Floodplain Reconnection Potential[34] which shows rivers and the natural floodplains can be reconnected to capture river sediment, essentially creating natural wetlands. It uses flood risk maps areas near the river that have no homes or key services. Additional attributes were added to the data as described in **Section 7.1.1.**

7.1.4.2 How can it be used?

This dataset can be used to identify individual sites that can be targeted for floodplain reconnection through river channel renaturalisation or engineered logjams. This dataset does not account for P, therefore agricultural export coefficients have been added from the SEPRATE dataset. This data covers the entire catchment extent. Ideally, the river would be reconnected to the floodplain throughout the entire catchment. However, this would be extremely difficult to achieve in practice. As such, it is recommended that this dataset is used to assess restoration plans, and to target river restoration measures, such as the introduction of engineered log jams (see also large woody debris), in areas that have low agricultural export coefficients, in order to minimise the risk of remobilising legacy P. An example is presented in **Figure 7-3.**

7.1.5 Wider catchment woodland potential

7.1.5.1 What is it?

This dataset is titled "NN_Ric_Catchment_Wood_V01". It utilises the WWNP Wider Catchment Woodland Potential dataset[35] which is an estimate of the locations that are not currently wooded and have slowly permeable soils. Additional attributes were added to the data as described in **Section 7.1.1.**

7.1.5.2 How can it be used?

This dataset can be used to identify individual WFD waterbody catchments that can be targeted for woodland creation. The load associated with creating woodland in the potential areas per WFD catchment can be ascertained. An example of the information within this dataset is presented in **Figure 7-4**.

Figure 7-1 Map showing the utility of the WwTW point source dataset

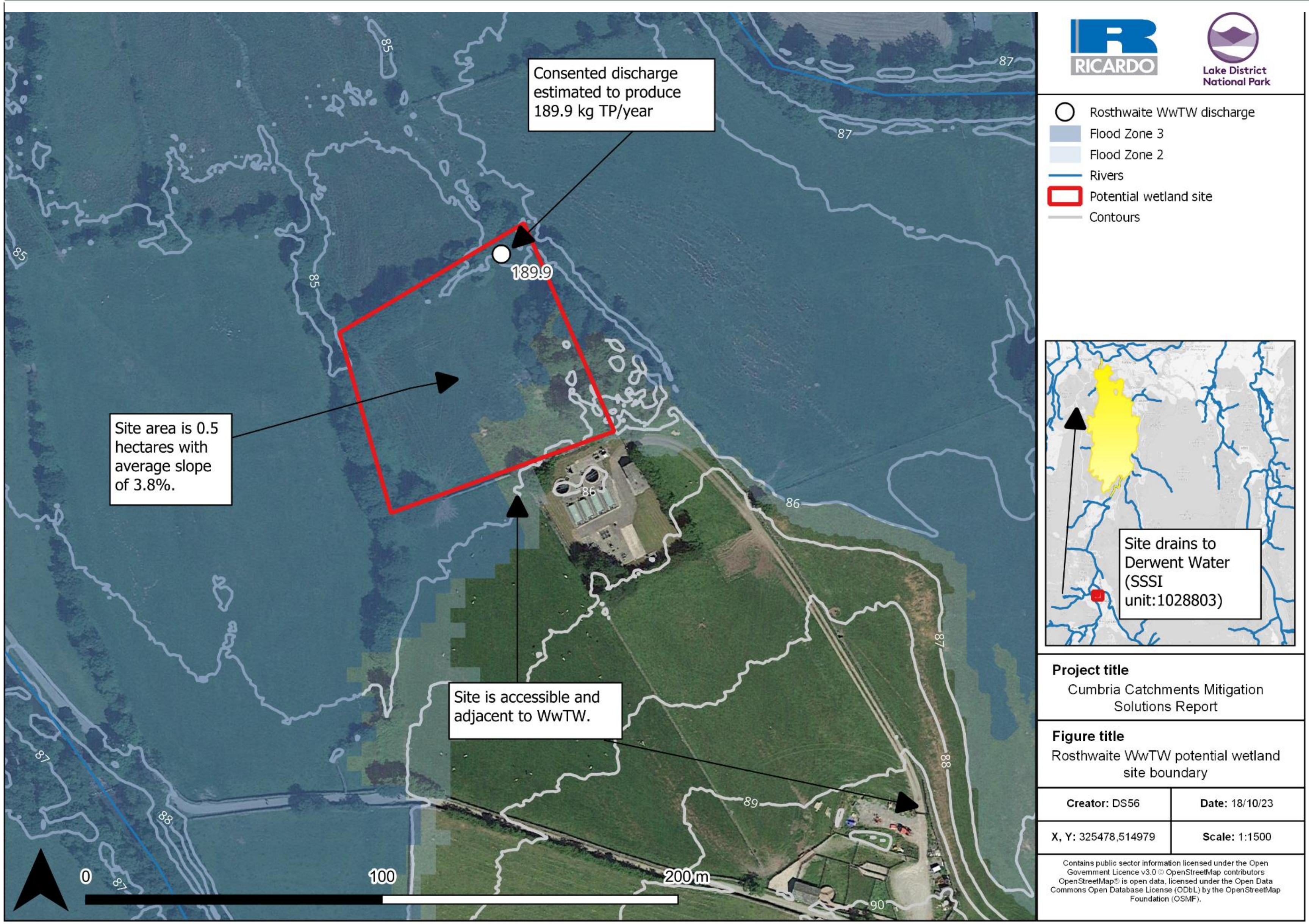


Figure 7-2 Map showing the utility of the 50 m riparian buffer dataset

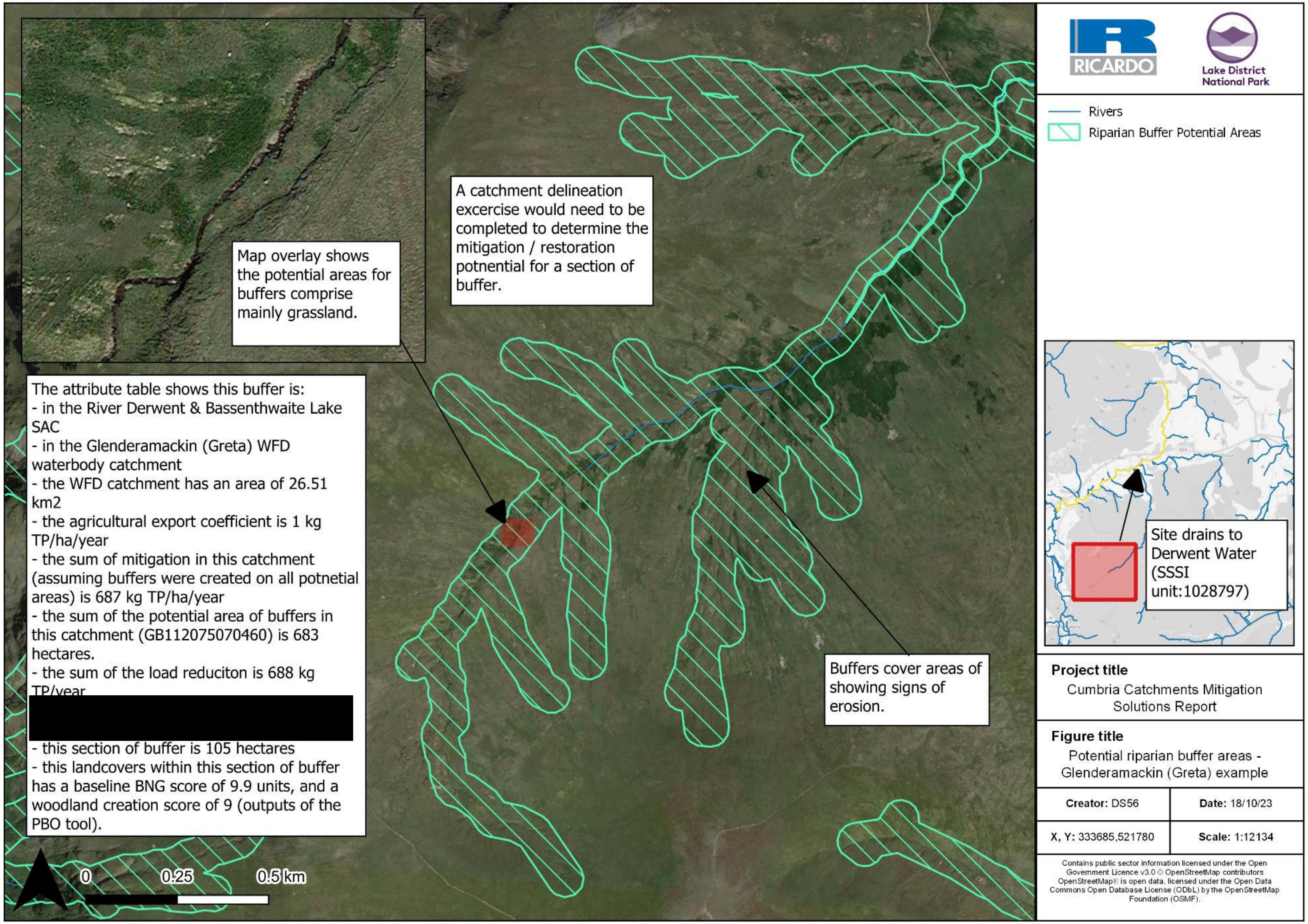


Figure 7-3 Map showing the utility of the floodplain reconnection potential dataset

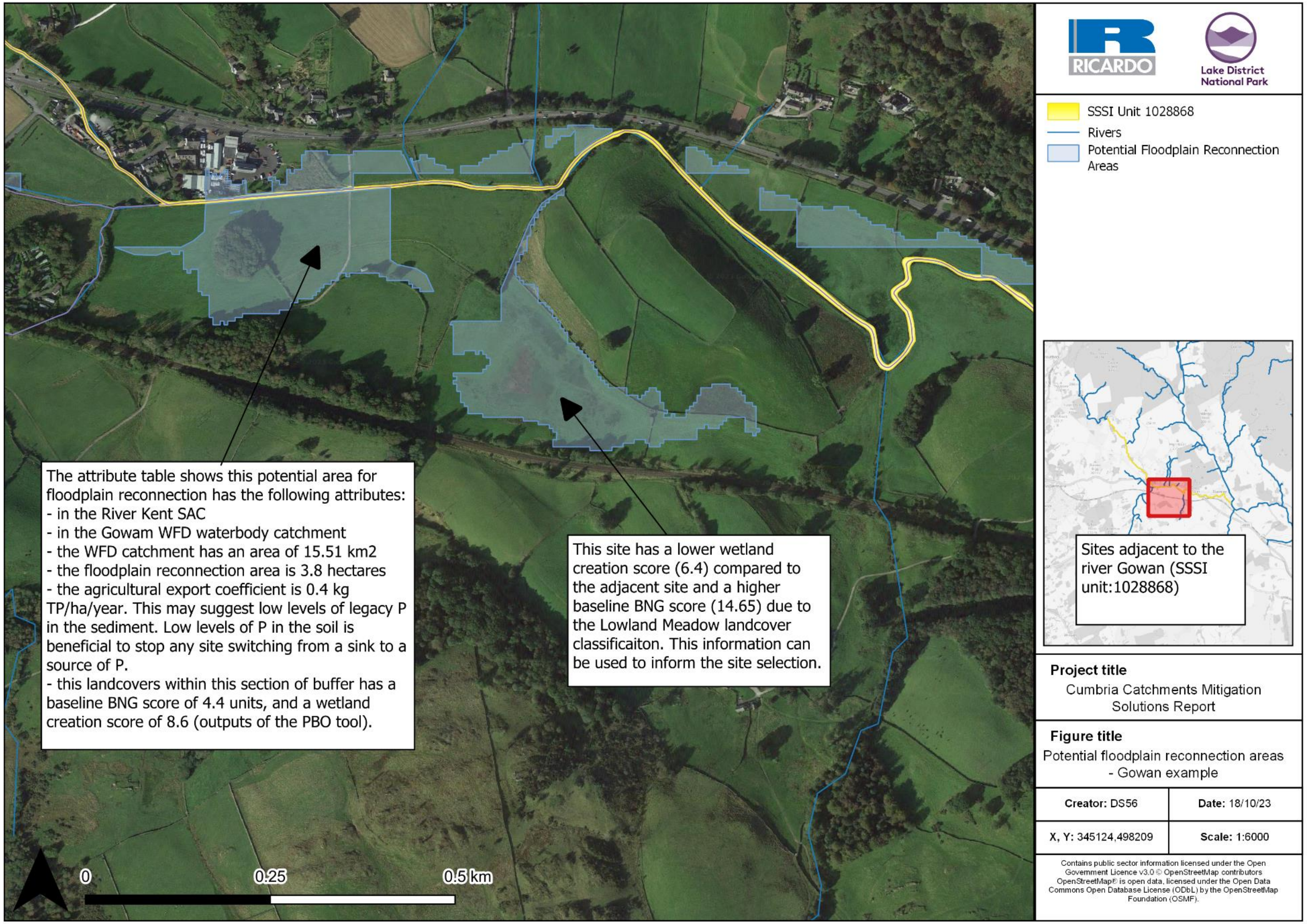
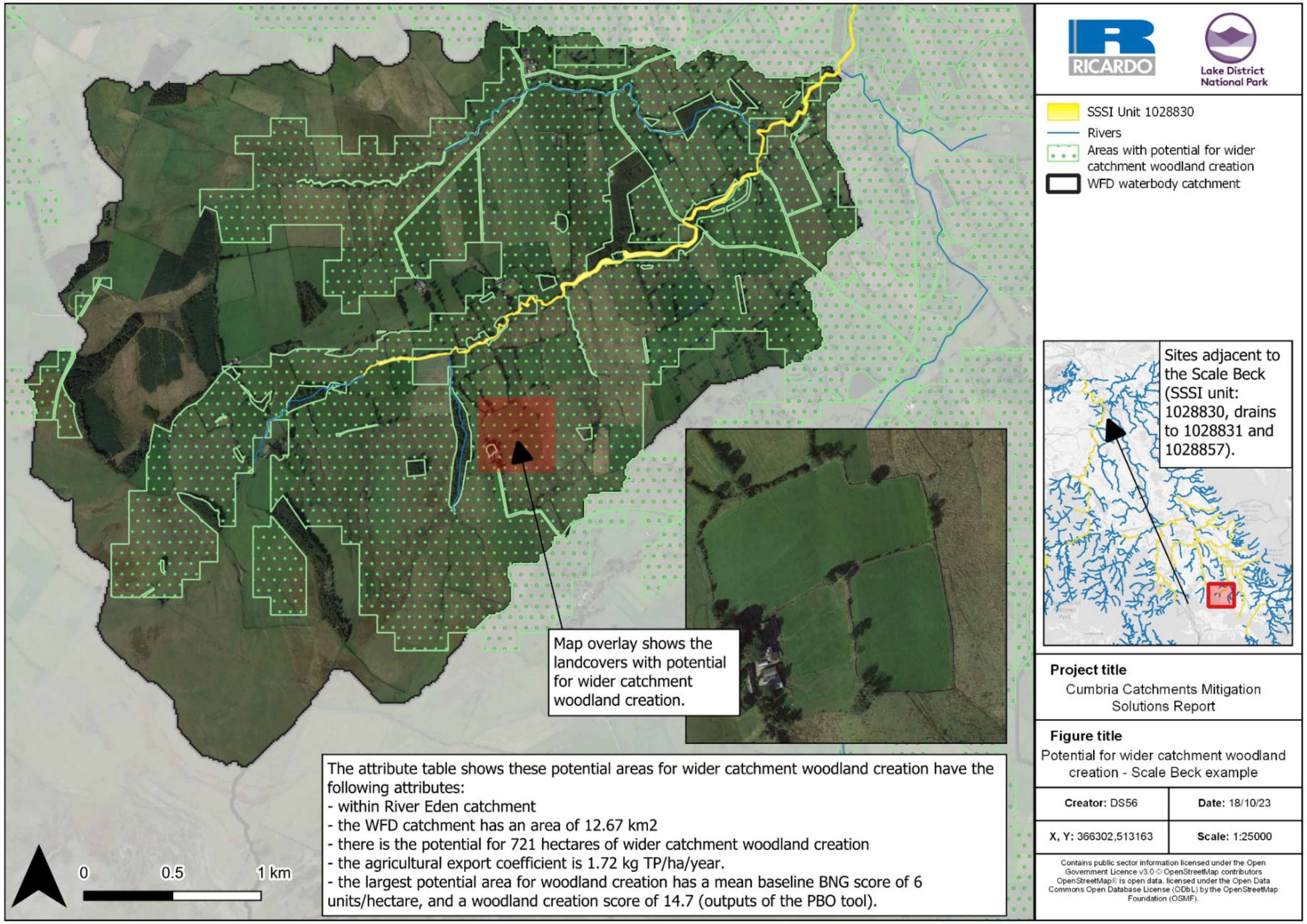


Figure 7-4 Map showing the utility of the potential areas for wider catchment woodland creation



7.1.6 Private sewerage point source dataset

7.1.6.1 What is it?

This dataset is titled "NN_Ric_UA_V01". It utilises the Consented Discharges to Controlled Waters with Conditions dataset[24] as described in **Section 132.3.4**. It contains additional data on the estimated load from the discharge, age of the permit (from time of writing) the WFD waterbody catchment and the failing SSSI unit catchment each point is situated within, if the site has been recommended as mitigation for stalled development, and if the site is recommended for future development.

7.1.6.2 How can it be used?

This dataset can be used to identify private sewerage system point sources that have an opportunity to provide mitigation/restoration through upgrading the system.

7.1.7 Aquaculture / trade discharge point source dataset

7.1.7.1 What is it?

This dataset is titled "NN_Ric_TA_V01". It utilises the Consented Discharges to Controlled Waters with Conditions dataset[24] as described in **Section 132.3.4**. It contains additional data on the estimated load from the discharge, age of the permit (from time of writing) the WFD waterbody catchment and the failing SSSI unit catchment each point is situated within.

7.1.7.2 How can it be used?

This dataset can be used to identify consented discharges that could be taken out of production in order to reduce any P loading associated with that discharge.

7.1.8 Retrofitting SuDS

7.1.8.1 What is it?

This dataset is titled "NN_Ric_BUA_V01". It utilises the Built-Up Urban Areas[29] which shows the locations of urban areas across the Great Britain. The dataset has been modified to include the rainfall for the site, and the TP load has been estimated for the area.

7.1.8.2 How can it be used?

This dataset can be used to identify urban areas which could be targeted for retrofitting SuDS. However, the dataset does not include any information on the current locations of SuDS.

7.2 ESTHWAITE WATER RAMSAR

7.2.1 Summary of the current condition of each failing SSSI unit

There is one failing SSSI unit in the Esthwaite Wate catchment. The SSSI ID for this unit is 1015590. The analysis detailed in **Section 3.1.2** suggests a load of 274 kg P/year may need mitigation.

The mitigation recommended to unlock development, detailed in **Table 6-1**, is estimated to match the mitigation required and therefore there is unlikely to be any nutrient credits (mitigation surplus) to be counted towards the site restoration.

7.2.2 Recommendations

Woodland planting could be targeted throughout the entire catchment to potentially remove 209 kg TP/year. However, the cost of riparian buffers is likely to be at least [redacted] per kilogram of TP mitigation due to the low agricultural export coefficients. Creating 544 hectares of woodland is likely to cost at least [redacted] for the purchase of the land.

SuDS could be retrofitted to Hawkshead urban area, which is estimated to export 46 kg TP. Assuming SuDS could mitigate 50% of the urban load, the recommended measures may leave a nutrient mitigation deficit of around 40 kg TP/year. should the recommended measures not restore the site, it may be necessary to implement further measures.

7.3 RIVER DERWENT AND LAKE BASSENTHWAITE SAC

7.3.1 Summary of the current condition of each failing SSSI unit

There are four failing SSSI units in the River Derwent and Lake Bassenthwaite catchment. The SSSI ID's for these units are 1015328, 1028803, 1028797, and 1028820. The analysis detailed in **Section 3.2.2** suggests a load of 1852.60, 81.98, 809.81, 551.16 kg P/year may require mitigation, respectively. SSSI unit 1028820 is in the western catchment. SSSI units 1028803 (Derwent Water) and 1028797 (River Glenderamackin) are upstream of Bassenthwaite Lake (1015328).

The mitigation detailed in **Table 6-1** would likely result in a mitigation surplus (additional credits) of 680 kg TP/year in the eastern catchments and 2825 kg TP/year in the western catchments. As such, the riparian buffers recommended for the Marron are likely to restore 1028820 back to favourable condition by removing over 2,250 kg TP/year more than the requirement. Furthermore, the riparian buffers recommended for the Glenderamackin u/s Troutbeck should restore 1028797 and halve the requirement for 1015328. The updated load reductions required to restore the site would be 1173 kg TP/year and 81.96 kg TP/year for SSSI units 1015328 and 1028803. SSSI unit 1028803 drains to 1015328.

7.3.2 Recommendations

Due to the low agricultural export upstream of Derwent Water, it is recommended that Rossthwaite WwTW is targeted for a wetland. A wetland at this site has the potential to mitigate 87 kg TP/year which may be sufficient to restore the site (SSSI unit 1028803) back to favourable condition. A wetland here is estimated to cost [redacted]

To restore SSSI unit 1028820, it is recommended that riparian buffers are targeted in GB112075070460 and GB112075070420. These solutions should capture 687 and 451 kg TP/year for a total of 1170 kg TP/year, thus restoring the site back to favourable condition. Implementing buffers at locations GB112075070460 and GB112075070420 is estimated to cost [redacted].

7.4 RIVER EDEN SAC

7.4.1 Summary of the current condition of each failing SSSI unit

There are 18 failing SSSI units in the River Eden catchment. The full list of failing SSSI ID's is as follows (load reduction in kg P/year in brackets): **1028824** (418.16), **1028827** (208.31), **1028828** (4527.04), **1028829** (162.14), **1028830** (306.57), **1028831** (5038.62), **1028832** (1260.99), **1028833** (1430.58), **1028834** (755.49), **1028835** (721.07), **1028837** (2098.16), **1028841** (1001.14), **1028843** (1124.08), **1028844** (1771.48), **1028854** (457.96), **1028855** (43.45), **1028856** (3600.64) and **1028857** (22432.06). The analysis is detailed in **Section 3.3.2** SSSI unit 1028857 is the most downstream failing SSSI unit and therefore suggest that throughout the whole catchment over 22 tonnes of TP needs mitigation.

7.4.2 Recommendations

SSSI unit 1028824 / 1028835 / 1028844 / 1028855
It is recommended that the Scandel Beck (GB102076070600), the Milburn Beck (GB102076071000), and the Whelpo (Cald) Beck are targeted for **woodland creation** since creating woodland on the potential areas may reduce the nutrient load by 641, 742, 1730, and 2710 kg TP/year.

SSSI unit 1028827 / 1028828 / 1028829 / 1028830 / 1029932 /1028833 / 1028834 / 1028837
It is recommended that **riparian buffers** are implemented in the Helm Beck catchment (GB102076070710), Eden - Scandal Beck to Lyvennet (GB102076070880), Hilton Beck (GB102076070770), Scale Beck (GB102076070640), Trout Beck (GB102076070930), Lyvennet (GB102076070840), Leith (GB102076070900), and the Lowther (GB102076071010) to remove 997, 4089, 997, 1008, 551 4596, 3054 and 1973 kg TP/year.

In addition there are **two commercial discharges with TP permits** that may be useful to target in the River Eden catchment:

- [redacted] is responsible for the discharge named [redacted]. This discharge has a permitted daily flow of 22000 m^3/day and a TP permit of 0.06 mg/l. The potential TP load from this facility is 482 kg TP/year. This site is located by [redacted] and discharges to SSSI unit 1028837. Taking this licence out of production may provide some restoration if needed for the SSSI unit 1028837. However, this site may already be subject to improvements / licence condition updates and so may not be feasible for use as a restorative measure.

- [redacted] is responsible for [redacted]. This tourism site is associated with three discharges in total. One of the discharges is considered in the analysis of point sources as it is primarily a sewage discharge and is estimated to discharge 53 kg TP/year. Another commercial discharge has a daily flow permit of 65 m^3/day and a TP permit of 2 mg. Therefore, it is estimated to discharge a load of 47 kg per year (effective date of 2006). These discharge to the SSSI unit 1028841. Furthermore, there is another discharge (2012 effective date) with no TP limit , DF of 42 – straight to ground infiltration system. Estimated load of 149 kg. Therefore these discharges may contribute a total of 249 kg. Therefore, upgrading these wastewater treatment facilities or taking them out of production could restore SSSI Unit 1028841.

7.5 RIVER KENT SAC

7.5.1 Summary of the current condition of each failing SSSI unit

There are two failing SSSI units in the River Kent catchment. The SSSI ID's for these units are 1028868 and 1028875. The analysis detailed in **Section 3.4.2** suggests a load of 98.65 and 216.95 kg P/year may require mitigation, respectively. SSSI unit 1028868 (River Gowan) is in the western catchment, whereas 1028875 (Flodder Beck) is in the east.

7.5.2 Recommendations

It is recommended that **floodplain reconnection** measures are implemented along the Flodder Beck and the River Gowan. Furthermore, in the Flodder Beck WFD waterbody catchment it is recommended that riparian buffers are established to restore the site (359 kg TP/year mitigated). The load reduction is low for the River Gowan. Therefore, river restoration measures might be enough.

8. ACTIVITY 6 – INTERCONNECTION BETWEEN NUTRIENT MITIGATION AND OTHER REGULATORY DRIVERS

8.1 WIDER BENEFITS

Results from the high-level review of the potential wider ecosystem services benefits delivered by the 3 short-listed nutrient mitigation solutions (i.e. Wetlands, buffer strips and private sewerage treatment upgrade (see list in **Section 2.4.1.2**) and other measures that could be used to restore the Habitats Sites back to favourable condition (**see Section 2.5**) revealed variation in the number of ecosystem services benefits which could be delivered.

The nine ecosystem services benefits are included here in this high level assessment. These include carbon sequestration, natural hazard regulation (flooding), water purification, water provisioning, recreation & tourism, agricultural services (food provision), air pollution removal, soil erosion reduction and material provisioning such as wood. These key ecosystem services have been identified as being the key benefits identified in the UK Enabling Natural Capital Approach (ENCA)[46] with provisioning services identified as relates a key service for woodland related agriculture.

Ecosystem services are provided by nature. Habitat extent and condition, which is assumed to be improved by the mitigation measures discussed in **Section 6**, will have direct influence on the ecosystem services benefits that those habitats are able to provide. The quality of services provided should be considered rather than just the quantity. For a number of wider benefits there are several assumptions which need to be considered. For example, the woodland extent will have direct influence on the carbon sequestration by woodland and therefore the benefit or monetary value of the ecosystem service; the recreation and tourism service for example is dependent on the accessibility of the habitat/nutrient mitigation solution e.g., access to riparian buffers and wetlands at WwTWs.

As show in **Figure 8-1** the measures which would provide the highest number of wider benefits are river channel restoration (nine benefits), followed by Wetland at WwTWs (surface flow wetland, sub-surface flow – horizontal flow, and sub-surface flow – vertical flow), grassland buffer strips, SuDS, short rotation coppice, converting agricultural land to woodland, and aquacultural cessation of which all have the potential to provide up to eight wider ecosystem services.

Solutions which offer the lowest number of additional wider benefits are permanent farmyard/barn removal and conversion to residential housing, which delivered no wider benefits; whilst PTP upgrades and permanent farmyard/barn removal would provide only two wider benefits. A matrix showing the nutrient mitigation solutions, the ecosystem services used to analyse their wider benefits, and the number of ecosystem services potentially delivered by each solution, can be found in **Appendix C**.

There is therefore significant potential for these nutrient mitigation solutions identified to offer a wide range of ecosystem services. However, further work is required to fully analyse the monetary and non-monetary benefits of which these services can potentially offer and the quantity of benefits as this related to the size and location of the mitigation measure (see **Section 8.1.1**).

In addition to the number of ecosystem services benefits delivered by each nutrient mitigation solutions, the habitat unit value was also identified for each solution using the BNG Metric tool[47]. This value was based on the habitat type created by each nutrient mitigation solution. This ranged from 0 habitat units for the solution of ‘Agricultural land use change: Permanent farmyard/barn removal and conversion to residential housing’ (‘Urban – Developed land; sealed surface) to 13.2 for the solutions ‘Wetlands at WwTWs: Surface flow wetland’ (‘Wetland – Reedbed’ habitat). However, the BNG Metric tool was run based on hypothetical scenarios of the habitats created by the nutrient mitigation solutions (see **Table D-1** in **Appendix D**). In order to accurately determine the biodiversity benefit i.e., the biodiversity net gain value for each solution, an assessment (metric) would need to be run with the known baseline and created habitats and their areas. The full habitat creation scores and estimated baseline BNG units for the site can be seen in the associated datasets that contain the

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[46] Enabling a Natural Capital Approach (ENCA) - GOV.UK (www.gov.uk)

[47] Natural England (2022). The Biodiversity Metric 4.0. https://publications.naturalengland.org.uk/publication/6049804846366720#:~:text=Biodiversity%20Metric%204.0%20is%20a%20biodiversity%20accounting%20tool,the%20previously%20published%20biodiversity%20metric%203.1%20%28April%202022%29. *Last accessed 11/10/23.*

locations of the mitigation measures (see **Section 7.1**)[48]. Estimates of the BNG units created for each mitigation solution recommended in **Section 6.2** can be seen in **Table 8-1.**

To ensure the full value of the services are understood, the exact type of nutrient mitigation solution and the location of nutrient mitigation solution implemented to achieve the wider ecosystem service benefit must be analysed. This is further discussed in the following section.

[48] Ricardo will provide the client with a set of datasets that demonstrate the locations of recommended mitigation measures and contain further information on the BNG potential, if applicable.

Figure 8-1 Total no potential wider benefits delivered by each nutrient mitigation solution

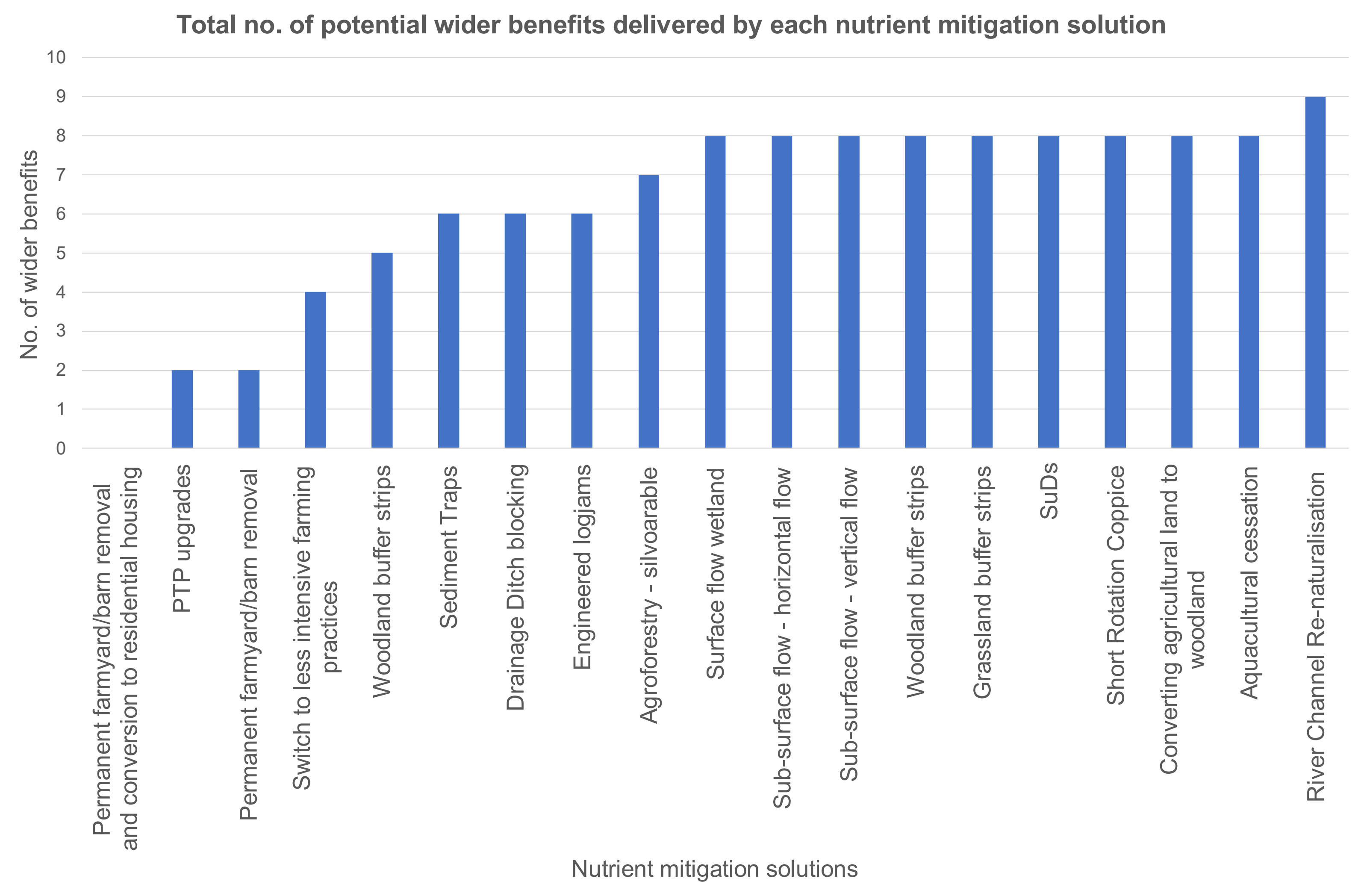

Table 8-1 Table showing the estimated BNG units created for each mitigation solution recommended in **Section 6.2**

Habitats Sites	Mitigation options	Location name	Estimated area of solution (ha)	BNG credits created	Habitat created	BNG units for habitats created
Esthwaite Water Ramsar	Wetland	Hawkshead STW	0.25	2.2	Wetland - Reedbeds	13.2
River Derwent & Lake Bassenthwaite	Riparian buffers	Glenderamackin u/s Troutbeck waterbody catchment (East)	535	4669.3	Woodland and forest - Other woodland; broadleaved	8.8
		Marron waterbody catchment (West)	1007	8822.9	Woodland and forest - Other woodland; broadleaved	8.8
River Eden SAC	Wetlands	Brough WwTW and (SSSI Unit 1028828)	0.18	1.6	Wetland - Reedbeds	13.2
		Warcop Camp WwTW (SSSI Unit 1028828)	0.16	1.4	Wetland - Reedbeds	13.2
		Dufton Village STW (SSSI Unit 1028832)	0.03	0.3	Wetland - Reedbeds	13.2
		Pooley Bridge East WwTW (SSSI Unit 1028843)	0.12	1	Wetland - Reedbeds	13.2
		Glenridding WwTW (SSSI Unit 1028843)	0.05	0.4	Wetland - Reedbeds	13.2
		Dalston WwTW (SSSI Unit 1028855 / 1028856)	0.67	5.9	Wetland - Reedbeds	13.2
		Askham WwTW (SSSI unit 1028837)	0.04	0.5	Wetland - Reedbeds	13.2
		Gilsland WwTW (SSSI unit 1028857)	0.17	2.3	Wetland - Reedbeds	13.2
		Brampton WwTW (SSSI unit 1028857)	1.01	13.4	Wetland - Reedbeds	13.2
	Riparian buffers	Caldew (Hesket Newmarket) (SSSI Unit 1028854)	247	2134.9	Woodland and forest - Other woodland; broadleaved	8.8
		Dacre Beck WFD waterbody catchment (SSSI Unit 1028841)	253	2187.7	Woodland and forest - Other woodland; broadleaved	8.8

		Morland Beck (SSSI unit 1028833)	282	2442.9	Woodland and forest - Other woodland; broadleaved	8.8
		Roe Beck (Upper) (SSSI unit 1028856)	388	3375.7	Woodland and forest - Other woodland; broadleaved	8.8

8.1.1 Next steps

The aim of this assessment is to provide a high-level review of the wider potential ecosystem services benefits which the mitigation measures could provide. As noted above, the benefits were not quantified in either monetary or non-monetary value but rather gave an estimate of the number of benefits that could potentially be reached by each mitigation solution.

To assess the benefits of ecosystem services, often an ecosystems accounting approach following the System of Environmental-Economic Accounting (SEEA)[49] and ENCA are applied. These approaches and ecosystem services accounting are underpinned by understanding the condition and the extents of these habitats associated with the specific location and time of mitigation. In ecosystems accounting specifically, ecosystem services can be accounted for in purely physical terms, or they are combined with monetary terms to be comparable with conventional economic accounts. This can be done by comparing an opening and closing value to a target value, or by comparing a variable to a reference value (e.g. past, present, future ecosystem condition) to measure the relative change over time. In ecosystems accounting, the principle of exchange methods is followed where ecosystem services and assets are "valued at a price which they are exchanged or would be exchanged if markets were present"[50]. It should be noted here that the monetary values do not reflect the value of nature but rather indicate the relative economic significance of each ecosystem service.

Values may be expressed as annual estimates (pound per year) or as capitalised, 'asset value' estimates that reflect an expected flow over many years (e.g. 70 or 100 years depending on the assumed lifetime of the mitigation solution) with a discount rate applied to future values. For example, the value of parks within a local authority area may be expressed in annual flow terms as providing say £50 million of services per year; or as asset value of say £700 million.

Table 8-2 provides an example of how the net present benefit value over 70 years could look depending on the different ecosystem services benefits, shown as scenarios, provided by a wetland and buffer strips. The monetary value of solutions depends on a combination of values from accounting rates (e.g. Carbon sequestration, the air pollutant removal and accessibility to the site etc).

A Natural Capital Accounting analysis would therefore quantify the benefits of the specific solution and enable LPAs to implement the solution which would enable the greatest environmental gain, rather than implementing the solution which had the highest number of perceived benefits.

To fully understand where the greatest wider benefits for additional financial ecosystem services benefits a Natural Capital Account analysis would need to be completed for each option when the location (or approximate location) is known. Once the location is known the precise units of BNG present can be identified as a baseline against which a Natural Capital Account can be derived for the same baseline and benefits assessed against the option.

Table 8-2 Example of potential ecosystem services benefits scenarios of a wetland and buffer strip asset value

Scenarios with different ecosystem services provisioning	**Net present benefit Asset value over 70 years (£2023) – *example only and will vary on scale and solution***	
	Mitigation solution: Wetland	Mitigation solution: Buffer strips
Scenario 1: Carbon sequestration, Air quality benefits	££	£
Scenario 2: Carbon sequestration, Air quality, Recreation & Tourism benefit	£££	£
Scenario 3: Carbon sequestration, Air quality, Natural hazard regulation (flooding) etc	£££	££

49 seea_ea_white_cover_final.pdf (un.org)
50 https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_white_cover_final.pdf (Page 7, section 1.29).

9. SUMMARY AND RECOMMENDATIONS

This report has detailed a set of mitigation options that may be appropriate for mitigating P in Cumbria. The report has sought to provide recommendations for the amount and locations of mitigation solutions to unlock stalled and future development. Furthermore, a high-level mitigation strategy was presented which detailed the scale of mitigation that would be required to restore the sites back to favourable condition. Finally, the wider benefits and ecosystem services provided by the potential mitigation solutions were presented.

The report commences with a succinct recap of the fundamental concepts of NN. The background to NN is revisited, emphasizing the drivers and requirements of the NN approach. The four Habitats Sites under investigation are presented:

- Esthwaite Water Ramsar
- The River Derwent and Lake Bassenthwaite SAC
- The River Eden SAC
- The River Kent SAC

The methodology employed throughout the report has been described. The methods used to identify the nutrient mitigation requirement to restore the Habitats Sites have been outlined and the approaches implemented to calculate the load reduction for stalled and future development defined, including the bespoke set of assumptions applied to each LPA.

An initial longlist of mitigation options have been selected based on previous reviews of nutrient mitigation solutions. From this longlist, a shortlist of options have been selected based on an analysis of whether a mitigation option is applicable to the study area, and whether the evidence-base provided enough certainty that the solution would deliver P mitigation in perpetuity.

This shortlist includes mitigation options that have the confidence level to apply average removal rates to the P inputs in order to quantify load reductions, but where monitoring may be required to quantify the amount of P mitigation the option can provide. The methods used to locate mitigation solutions were presented and the tools and approaches utilised to elucidate ancillary benefits were summarised.

The current condition of the Habitat Sites was presented. This section includes a review of the P concentrations for each SSSI unit that legally underpin the Habitats Sites. The load required to restore the sites has been calculated, based on the review of P concentrations and the estimated of flow in each unit, to understand what would be required to restore these sites to their favourable condition.

The development aspirations and associated nutrient loading have been determined. These calculations are crucial for identifying the extent and location of nutrient mitigation needed. For stalled development the maximum and probable nutrient load has been calculated for each catchment and a set of assumptions have been applied to the future development aspirations, identified through a review of the LDPs for the respective LPAs, to estimate the potential load from future development plans.

An assessment of the P baseline was completed and this section emphasised the major sources of P within each catchment. This was then used in the following sections to identify the mitigation opportunities in each catchment. The P loads from key point sources, such as WwTW and private sewerage systems were then calculated together with an assessment of previous source apportionment modelling which has been completed to highlight the impact of agricultural diffuse sources and map agricultural export coefficients in each catchment. Understanding these sources has been identified as essential for informed decision-making in nutrient management.

9.1 KEY RECOMMENDATIONS

The recommendations made throughout this document have been presented to guide stakeholders in implementing effective nutrient mitigation measures. Recommendations have been made on where to implement nutrient mitigation solutions within each catchment to unlock development with the development projections and nutrient sources revisited to highlight the types, quantities, locations, and associated costs of mitigation solutions required to unlock development.

Building on the nutrient mitigation solutions required to unlock development, recommendations for restoring sites back to favourable condition were presented. The recommended solutions mainly comprise catchment woodland planting to capture agricultural diffuse pollution due to the scale of the nutrient loads that need mitigation and the dearth of point sources for which nutrient loads can be calculated that were not recommended for unlocking development.

The interconnections between nutrient mitigation solutions and regulatory drivers were explored to underscore the broader environmental benefits and compliance with regulations that such solutions can offer. An overview of the potential BNG units provided by implementing the recommended mitigation solutions was presented.

The next steps recommended to realise nutrient mitigation in each catchment to unlock development and achieve NN are as follows:

- Compile a database of the nutrient budgets for each planning application. This should comprise a standard form for all LPAs across the Cumbria catchments and should include key information on the development, coordinates, as well as inputs and outputs of each of the nutrient budget calculations. This record keeping should provide clarity on the locations and requirement for each development and should facilitate connecting developments to available nutrient mitigation schemes.
- Complete a pre-feasibility assessment for the recommended mitigation solutions.
- Should the pre-feasibility assessment demonstrate a sites potential, complete a full feasibility assessment and an outline design of the mitigation solution
- Maintain a database on the nutrient mitigation schemes available, including credits provided, credits available, construction costs, timelines, and details on areas unlocked by the mitigation.

The above steps should be implemented as soon as possible, or even expedited, especially on the measures identified in this report, in order to implement solutions. These solutions should then be monitored the to gain the understanding of these measures in practice and to demonstrate that they are acting effectively to deliver required mitigation (e.g. Reducing river nutrients – Herefordshire Council which is being assessed jointly with Welsh Water and Ricardo). Such approaches to monitoring and assessment are already being completed in other part of the country, which key monitoring protocol developed (e.g. Luston). Initially, implementing solutions will require land acquisition or partnership with landowners. As such, it is recommended that a ‘call for sites’ is announced to find delivery partners. Furthermore, in order to connect developers to suitable mitigation, it is recommended that draft **Section 106** and **Section 33** agreements are drawn up, or responsible authorities that can enter conservation covenants are identified. Setting up these templates and identifying stakeholders as early as possible will speed up the process.

Throughout the development of this report, more data has become available and legislative changes such as the Royal Ascension of the LURB has meant that some of the analysis may be based on outdated figures or is not representative of the quantity of mitigation provided in perpetuity. Once the list of WwTW that are due to receive TAL upgrades is published the recommendations in this report should be re-assessed. Specifically, the mitigation requirement for development and mitigation provision through wetlands at WwTW should be re-assessed when this data becomes available. Furthermore, the estimates of future development plans are indicative of the general distribution and quantum of development; hence the figures provide in the LDP should be treated with caution and edited to incorporate any additional data as this become available.

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Built Up Areas (2022) GB BGG | Built Up Areas (2022) GB BGG | Open Geography Portal (statistics.gov.uk). Source: Office for National Statistics licensed under the Open Government Licence v.3.0. Contains OS data © Crown copyright and database right 2023.

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APPENDICES

APPENDIX A – STALLED DEVELOPMENT LIST

Table A-1 Stalled Developments. The max load has been calculated assuming a development requires 1.25 kg TP/year of mitigation. The probable load has been calculated assuming the development connects to the WwTW that is within catchment. If the development is not within a WwTW catchment, it is assumed that a package treatment plant (PTP) will be used (assuming the NE average concentration of 9.7 mg TP/l). It is estimated that the change in land cover will result in a net 0.2 kg TP/year of mitigation needed per dwelling. The occupancy rates are assumed to be the national average of 2.4. For tourism, it is assumed that the wastewater consumption is 80 litres/person/day.

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
FUL/2023/0065 & LBC/2023/0013	[redacted]	[redacted]	0	0	Allerdale	CC	River Derwent & Bassenthwaite Lake SAC	Commercial	BRANTHWAITE STW	8		
FUL/2022/0124	[redacted]	[redacted]	0	0	Allerdale	CC	River Derwent & Bassenthwaite Lake SAC	Commercial	BRANTHWAITE STW	8		
VAR/2023/0001	[redacted]	[redacted]	0	24	Allerdale	CC	River Derwent & Bassenthwaite Lake SAC	Tourism	PTP	9.7	30	25.35
CON/2022/0027	[redacted]	[redacted]	1	0	Allerdale	CC	River Derwent & Bassenthwaite Lake SAC	Residential	BRANTHWAITE STW	8	1.25	1.25
VAR/2022/0006	[redacted]	[redacted]	3	0	Allerdale	CC	River Derwent & Bassenthwaite Lake SAC	Residential	BRANTHWAITE STW	8	3.75	3.75
7/2022/2297	[redacted]	[redacted]	0	1	LDNPA	LDNPA	River Derwent & Bassenthwaite Lake SAC	Tourism	PTP	9.7	1.25	1.06
7/2022/2296	[redacted]	[redacted]	1	0	LDNPA	LDNPA	River Derwent & Bassenthwaite Lake SAC	Residential	KESWICK STW	0.8	1.25	0.33
22/0240	[redacted]	[redacted]	0	1	Carlisle	CC	River Eden SAC	Tourism	DALSTON WWTW	5	1.25	0.62
22/0233	[redacted]	[redacted]	0	8	Carlisle	CC	River Eden SAC	Tourism	PTP	9.7	10	8.45
22/0364	[redacted]	[redacted]	0	38	Carlisle	CC	River Eden SAC	Tourism	PTP	9.7	47.5	40.14

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
22/0574	[redacted]	[redacted]	0		Carlisle	CC	River Eden SAC	Tourism	BRAMPTON (CARLISLE) WWTW	4	0	0.00
21/0743	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	1.25	0.69
22/0002/ COU	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	1.25	0.69
22/0118	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52
22/0182	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0241	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52
22/0291	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	LAVERSDALE STW	8	1.25	1.25
22/0318	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0435	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0450	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	WETHERAL AND GREAT CORBY WWTW WETHE	8	1.25	1.25
22/0538	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52
22/0751	[redacted]	[redacted]	1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
22/0903	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	1.25	0.69
22/0405	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52
22/0431	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0581	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	COTEHILL WWTW	8	1.25	1.25
22/0934	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	WARWICK BRIDGE STW	8	1.25	1.25
23/0091	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
23/0093	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	1.25	0.52
23/0235	[redacted]		1		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	1.25	0.69
21/0682	[redacted]		1		Carlisle		River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0011	[redacted]		2		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	2.5	1.05
22/0837	[redacted]		2		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	2.5	2.93
22/0866	[redacted]		2		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	2.5	1.05
22/0001/ COU	[redacted]		3		Carlisle	CC	River Eden SAC	Residential	PTP	9.7	3.75	4.39
22/0737	[redacted]		3		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	3.75	2.08

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
21/0878	[redacted]		4		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	5	2.10
23/0231			5		Carlisle	CC	River Eden SAC	Residential	THE HOW STW	8	6.25	6.25
21/1091			7		Carlisle	CC	River Eden SAC	Residential	DALSTON WWTW	5	8.75	5.66
22/0626			8		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	10	4.19
22/0391			10		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	12.5	5.24
21/0325			12		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	15	6.29
20/0623			21		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	26.25	11.00
23/0266			30		Carlisle	CC	River Eden SAC	Residential	WARWICK BRIDGE STW	8	37.5	37.50
20/0797			33		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	41.25	17.29
23/0204			38		Carlisle	CC	River Eden SAC	Residential	BRAMPTON (CARLISLE) WWTW	4	47.5	26.39
21/0655			70		Carlisle	CC	River Eden SAC	Residential	WETHERAL AND GREAT CORBY WWTW WETHE	8	87.5	87.49
22/0128			72		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	90	37.73
23/0148			90		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	112.5	47.16

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
21/0744	[redacted]	[redacted]	92		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	115	48.21
22/0297	[redacted]	[redacted]	101		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	126.25	52.93
21/1068	[redacted]	[redacted]	112		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	140	58.69
20/0015	[redacted]	[redacted]	132		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	165	69.17
21/0623	[redacted]	[redacted]	157		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	196.25	82.27
21/1109	[redacted]	[redacted]	461		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	576.25	241.57
17/0883	[redacted]	[redacted]	480		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	600	251.53
21/0351	[redacted]	[redacted]	722		Carlisle	CC	River Eden SAC	Residential	CARLISLE WWTW	2.5	902.5	378.34
22/0927	[redacted]	[redacted]	0	1	Eden	WFC	River Eden SAC	Tourism	LANGWATHBY WWTW	4	1.25	0.54
22/0082	[redacted]	[redacted]	0	1	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	1.25	1.06
22/0622	[redacted]	[redacted]	0	2	Eden	WFC	River Eden SAC	Tourism	LANGWATHBY WWTW	4	2.5	1.09
20/0143	[redacted]	[redacted]	0	3	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	3.75	3.17
22/0049	[redacted]	[redacted]	0	3	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	3.75	3.17
23/0005	[redacted]	[redacted]	0	4	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	5	4.23

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
22/0402	[redacted]	[redacted]	0	5	Eden	WFC	River Eden SAC	Tourism	KIRKBY STEPHEN WWTW	1.5	6.25	1.77
22/0664	[redacted]	[redacted]	0	8	Eden	WFC	River Eden SAC	Tourism	CALTHWAITE WWTW	1.7	10	2.95
23/0090	[redacted]	[redacted]	0	10	Eden	WFC	River Eden SAC	Tourism	ARMATHWAITE WWTW	8	12.5	9.13
22/0178	[redacted]	[redacted]	0	12	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	15	12.68
21/1087	[redacted]	[redacted]	0	16	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	20	16.90
21/0961	[redacted]	[redacted]	0	21	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	26.25	22.18
22/0199	[redacted]	[redacted]	0	44	Eden	WFC	River Eden SAC	Tourism	PTP	9.7	55	46.48
22/0914	[redacted]	[redacted]	0		Eden	WFC	River Eden SAC	Agricultural	PTP	9.7		
21/0721	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	1.25	0.47
21/1086	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	GREYSTOKE WWTW	2	1.25	0.47
22/0034	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	1.25	0.47
22/0131	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0236	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0409	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0815	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
22/0821	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0934	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	LANGWATHBY WWTW	4	1.25	0.69
22/0985	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
23/0048	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	DUFTON VILLAGE STW	8	1.25	1.25
23/0133	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
21/0341	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0063	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	BROUGH WWTW	8	1.25	1.25
22/0537	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	TEMPLE SOWERBY WWTW	8	1.25	1.25
22/0538	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
23/0197	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
21/0521	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
21/0700	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	TEMPLE SOWERBY WWTW	8	1.25	1.25
21/0849	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
21/0934	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	BROUGH WWTW	8	1.25	1.25
21/1001	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	MORLAND WASTEWATER TREATMENT WORKS	8	1.25	1.25
21/1099	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
22/0257	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0341	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0529	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0536	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	CULGAITH STW	8	1.25	1.25
23/0103	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	LANGWATHBY WWTW	4	1.25	0.69
17/0375	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
21/0458	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	SHAP STW	1	1.25	0.35
21/0519	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0331	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	TEMPLE SOWERBY WWTW	8	1.25	1.25
22/0474	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0505	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
21/0125	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	1.25	0.47
21/1101	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	BROUGH WWTW	8	1.25	1.25
22/0186	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0203	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
22/0219	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	SANDFORD VILLAGE WWTW	8	1.25	1.25
22/0384	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	LONG MARTON EAST STW	8	1.25	1.25
22/0980	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
23/0074	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	KABER WASTEWATER TREATMENT WORKS	8	1.25	1.25
21/0872	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0762	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	GREAT SALKELD WWTW GRSAL	8	1.25	1.25
22/0792	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	RENWICK STW	8	1.25	1.25
22/0997	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
23/0040	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	WWTW OPPOSITE FOWRASS FARM	8	1.25	1.25
21/0963	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0067	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0272	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0274	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0276	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0318	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0466	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0564	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0564	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
22/0783	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PTP	9.7	1.25	1.46
23/0004	[redacted]	[redacted]	1		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	1.25	0.33
22/0224	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	PTP	9.7	2.5	2.93
23/0144	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	PTP	9.7	2.5	2.93
21/0922	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	2.5	0.93
21/1006	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	2.5	0.66
21/1095	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	2.5	0.66

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
22/0022	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	2.5	0.66
21/0886	[redacted]	[redacted]	2		Eden	WFC	River Eden SAC	Residential	MOTHERBY WASTEWATER TREATMENT WORKS	2	2.5	0.93
20/0665	[redacted]	[redacted]	3		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	3.75	1.23
22/0021	[redacted]	[redacted]	3		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	3.75	0.99
22/0042	[redacted]	[redacted]	3		Eden	WFC	River Eden SAC	Residential	PTP	9.7	3.75	4.39
22/0086	[redacted]	[redacted]	3		Eden	WFC	River Eden SAC	Residential	PTP	9.7	3.75	4.39
22/0221	[redacted]	[redacted]	4		Eden	WFC	River Eden SAC	Residential	PTP	9.7	5	5.86
22/0348	[redacted]	[redacted]	4		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	5	1.64
21/0204	[redacted]	[redacted]	4		Eden	WFC	River Eden SAC	Residential	MELMERBY STW	8	5	5.00
22/0612	[redacted]	[redacted]	4		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	5	1.32
22/0524	[redacted]	[redacted]	4		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	5	1.32
22/0635	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	6.25	2.05

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
21/0847	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	6.25	2.34
22/0626	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	6.25	2.34
22/0362	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	CULGAITH STW	8	6.25	6.25
21/0287	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	6.25	1.65
22/0055	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	HUNSONBY STW	8	6.25	6.25
23/0064	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	6.25	1.65
22/0672	[redacted]	[redacted]	5		Eden	WFC	River Eden SAC	Residential	ARMATHWAITE WWTW	8	6.25	6.25
22/0477	[redacted]	[redacted]	6		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	7.5	1.99
22/0943	[redacted]	[redacted]	7		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	8.75	2.32
19/0343	[redacted]	[redacted]	12		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	15	3.97
22/0383	[redacted]	[redacted]	12		Eden	WFC	River Eden SAC	Residential	LOW HESKET STW	8	15	15.00
21/0792	[redacted]	[redacted]	13		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	16.25	4.30
22/0995	[redacted]	[redacted]	18		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	22.5	5.96

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
23/0032	[redacted]		18		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	22.5	5.96
20/0211			22		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	27.5	9.03
22/0507			25		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	31.25	11.68
22/0570			27		Eden	WFC	River Eden SAC	Residential	LOW HESKET STW	8	33.75	33.75
22/0336			33		Eden	WFC	River Eden SAC	Residential	LOW HESKET STW	8	41.25	41.24
21/0953			49		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	61.25	16.21
20/0561			60		Eden	WFC	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	75	24.62
22/0951			60		Eden	WFC	River Eden SAC	Residential	PTP	9.7	75	87.87
21/1029			100		Eden	WFC	River Eden SAC	Residential	APPLEBY WWTW	2	125	46.72
19/0840			105		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	131.25	34.74
22/0256			194		Eden	WFC	River Eden SAC	Residential	PENRITH WWTW (PENRT)	0.8	242.5	64.19
22/0093					Eden	WFC	River Eden SAC	Agricultural	PTP	2.5		
7/2023/3045			0	15	LDNPA	LDNPA	River Eden SAC	Tourism	PTP	9.7	18.75	15.84
7/2023/3032			4	0	LDNPA	LDNPA	River Eden SAC	Residential	MOTHERBY WASTEWATER	2	5	1.87

Application reference	Y coordinate (longitude) (WGS84)	X coordinate (latitude) (WGS84)	Number residential	Number tourism	LPA Former	LPA Current	Habitats Site	Type	WwTW Name	WwTW TP Permit	Max load	Probable load
									TREATMENT WORKS			
E/03/65C	[redacted]	[redacted]	0	3	Yorkshire Dales	YDNPA	River Eden SAC	Tourism	APPLEBY WWTW	2	3.75	1.17
E/09/9	[redacted]	[redacted]	1	0	Yorkshire Dales	YDNPA	River Eden SAC	Residential	KIRKBY STEPHEN WWTW	1.5	1.25	0.41
E/01/55 & E/01/55A/LB	[redacted]	[redacted]	1	0	Yorkshire Dales	YDNPA	River Eden SAC	Residential	PTP	9.7	1.25	1.46
E/07/19	[redacted]	[redacted]	1	0	Yorkshire Dales	YDNPA	River Eden SAC	Residential	PTP	9.7	1.25	1.46

APPENDIX B – MITIGATION FACTFILES

FACTFILES FOR EACH MITIGATION MEASURE CONSIDERED

Table B-1 Private Sewerage with Field Drainage

Key Option Considerations	
Summary description of option	• A small PTP or ST used to treat wastewater from properties which cannot connect to a mains sewer • Biological PTP/STs treat wastewater by promoting biological processes to remove nutrients; whilst chemical PTP/STs treat wastewater using chemical dosing to promote nutrient removal. Chemical and biological PTPs can be combined to increase nutrient removal • The effluent of a private sewerage system e.g., PTP/STs, is diverted to a drainage field. A drainage field is a network of discharge pipes laid in trenches under the ground surface so that effluent can be discharged to the ground • Orchards (fruit or coppicing) can also be planted where small PTP/STs discharge to the ground. They act as a mitigation solution through harvesting as nutrients are removed from the system via plant matter and yields • Treated effluent from private sewerage systems can also be diverted through a wetland to remove P
Maintenance and monitoring requirements	• Interannual/annual servicing e.g., pipe blockages • Interannual/annual desludging of PTP/ST and associated (specific) disposal requirements • Chemical dosing (if applicable) • Monthly checks of drainage field for water logging • Annual monitoring of influent and effluent to make assumptions about TP loading to the drainage field • A detailed sampling strategy incl. testing of filter material to determine max P saturation • Replacement of filter material once max P saturation is reached • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and existing the drainage field • Robust design and maintenance and monitoring to ensure correct dosing in perpetuity • Pre- and post-implementation monitoring outputs to gain credits for P (only for PTP/ST orchards)
Potential additional benefits	• PTP/ST could deliver water purification benefits, amenity value, carbon sequestration, hazard reduction, biodiversity benefits, reduced soil degradation, and improved nutrient cycling through mycorrhizal associations (if applicable) • Profits from orchards and SRC can be increased with the potential for stable returns from tree crops within 5 years (crop dependant) • Orchards and SRC could provide community-level benefits if energy crops are used to provide combined neighbourhood energy and NN schemes
Development scale	• All development sizes (which can range from minor to major developments[51])

[51] See: Pre-application Community Consultation: Best Practice Guidance for Developers, available here: https://gov.wales/planning-major-developments-guidance-pre-application-consultation , accessed on: 05/05/2023

Key Option Considerations	
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) or medium (0.5-2 ha of land required) for deployment (often within boundary of a PTP/ST) • The orchard system is scalable, and can deliver more mitigation from larger schemes
P removal method and efficiency	• The main process of P removal is the settlement of organic matter via gravity as solid waste is settled out within the system. If chemical dosing is used in a PTP/ST, chemical precipitation of P will be the main removal process • The percolation of effluent through the soil (within the drainage field/orchard) immobilises any sediment bound P • Sorption of soluble P onto the surface of sediments and soil particles • High efficiency (67-100%)
Factors affecting efficacy	• Type of PTP. Chemical PTPs have higher P removal capacities; whilst biological PTPs have lower P removal capacities • Soil type. Average P retention of 97% in non-calcareous sediments and 69% in calcareous (Robertson, 2019) • Hydraulic conductivity (i.e., the ability to drain water) of the soil. Smaller particles e.g., sandy soils decrease HC and increase saturation of soils and overland flow of effluent that had not undergone P removal • Manufacturers, types of systems, sizes, population served, treatment processes, and maintenance regimes • Filter media for drainage field - Polonite (with grains of 2-5 mm diameter) can have a 90% TP reduction over a two-year monitoring period (Renman and Renman, 2010). Gravels, sands, and soils generally have a low sorption capacity (< 0.5 grams of TP per kg). Fine (< 1 mm) blast furnace slag, fly ash, and Polonite have high phosphorous sorption capacities (over 1 gram of TP per kg) (Cucarella & Renman, 2009). Lightweight expanded clay aggregates (LWAs) have a high P sorption capacity and a potential to be recycled • Age of PTP/ST. Depending on the material used, the system may begin to deteriorate over time and leak untreated effluent with plastic, fibre glass, and concrete lasting longer than steel (May et al, 2015). • The volume of settled organic matter (sludge). The greater the volume of settled sludge, the greater the decrease in sludge removal
Time to effectiveness	• Between 1 - 3 years
Design Requirements	• Water must flow through the scheme and not bypass it via groundwater • Drainage fields should comprise a network of perforated pipes laid in a uniform gradient (trenches should not be steeper than 1:200) • The drainage field/orchard should be downslope of groundwater sources, away from water supply pipes and away from any roads or paved surfaces • Located in areas with verifiably high influent nutrient concentrations otherwise they are unlikely to provide any benefit • Orchards require land with a nutrient source from a PTP/ST
Input sources	• New development sites
Longevity	• The lifecycle is estimated to be between 10-40 years. Systems over 30 years old are 12 times more likely to cause water pollution issues than systems less than 10 years old (May et al, 2015). This figure is highly dependent on the materials used, the manufacturer guidelines, and the maintenance regime

Key Option Considerations	
	• A drainage field is assumed to have a 10 to 20-year lifespan. Assuming the private sewerage system and a drainage field would last 20 years, it may be necessary to replace and relocate a drainage field at least four times during the lifetime of a development to ensure P removal in perpetuity
Certainty	• Predictable performance in reductions of TP
Cost	• Cost of the PTP/ST, installation and ongoing maintenance means PTP/STs are ranked as medium cost relative to other mitigation options
Constraints	• Drainage fields eventually become saturated with P and cease to function effectively or potentially become a source of P to the environment (May, et al., 2015) • PTP/STs should only be used where it is not reasonable for development to connect to a public foul sewer • PTP/STs must be able to connect to an electricity supply • The drainage field/orchard must be at least 10 m from any watercourse or permeable drain, 50 m from boreholes or abstraction points, 15 m from buildings, sufficient distance from other drainage fields, and not in a Zone 1 groundwater protection zone • The water table must not come within 2 metres of the ground surface at any time • The soil should have suitable permeability in accordance with planning conditions and building regulations
Wider environmental considerations	• If using a drainage field, consider climate change impacts on nutrient removal processes • If a chemical PTP/ST, aluminium treatment should not be used due to the likelihood of detrimental impacts on the surrounding environment/ecology • If a biological PTP/ST, it must be ensured the residents in dwellings linking to the private sewerage system being upgraded are not using chemicals or detergents which have the potential to negatively impact treatment • If possible, the previous land use on a proposed site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the PTP/ST drainage field • An orchard proposal may need to consider long-term inputs of the nutrients to the system, including the availability of "legacy" nutrients for removal by the trees
Stakeholders for Engagement	• NE • EA • Water companies • Landowners • LPAs

Table B- 2 Private Sewerage Upgrade

Key Option Considerations	
Summary description of option	• Aging private sewerage systems, such as a PTP or ST, are replaced or upgraded with a modern private sewerage system with certified TP removal rates
Maintenance and monitoring requirements	• Interannual/annual servicing e.g., pipe blockages • Interannual/annual desludging of sewerage treatment system and associated (specific) disposal requirements • Chemical dosing (if applicable) • Monthly checks of drainage field for water logging • Annual monitoring of influent and effluent to make assumptions about TP loading to the drainage field • A detailed sampling strategy incl. testing of filter material to determine max P saturation (if applicable) • Replacement of filter material once max P saturation is reached (if applicable) • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and existing the PTP/ST • Robust design and maintenance and monitoring plan. Credits can be calculated upfront but maintenance required to ensure efficacy in perpetuity
Potential additional benefits	• PTPs could deliver water purification, amenity value, carbon sequestration, hazard reduction and biodiversity enhancement benefits
Development scale	• All development sizes (which can range from minor to major developments[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) / medium (0.5-2 ha of land required) for deployment (often within boundary of PTP/ST)
P removal method and efficiency	• The main process of P removal is the settlement of organic matter via gravity as solid waste is settled out within the system. If chemical dosing is used in a PTP/ST, chemical precipitation of P will be the main removal process • High efficiency (67-100%)
Factors affecting efficacy	• Type of PTP/ST. Chemical PTP/STs have higher P removal capacities; whilst biological PTP/STs have lower P removal capacities • Manufacturers, types of systems, sizes, population served, treatment processes, and maintenance regimes • The volume of settled organic matter (sludge). The greater the volume of settled sludge, the greater the decrease in sludge removal • The type of system and nutrient removal technology being used to replace a treatment system • Filter media for drainage field - Polonite (with grains of 2-5 mm diameter) can have a 90% TP reduction over a two-year monitoring period (Renman and Renman, 2010). Gravels, sands, and soils generally have a low sorption capacity (< 0.5 grams of TP per kg). Fine (< 1 mm) blast furnace slag, fly ash, and Polonite have high phosphorous sorption capacities (over 1 gram of TP per kg) (Cucarella & Renman, 2009). Lightweight expanded clay aggregates (LWAs) have a high P sorption capacity and a potential to be recycled

Key Option Considerations	
Time to effectiveness	• < 1 - 3 years
Design Requirements	• Water must flow through the scheme and not bypass it via groundwater • There is a positive correlation between the mitigation capacity of a drainage field and the discharge concentration of TP from a private sewerage system, thus a drainage field is therefore best placed at the discharge site of a PTP/ST with high effluent TP concentrations • PTP/ST with high daily flow permits to maximise mitigation
Input sources	• Urban areas
Longevity	• It should be assumed that it can continue to function effectively without requiring maintenance towards the lower end of the range (<10 years)
Certainty	• Predictable performance in reductions of TP
Cost	• PTP / ST upgrades are significant capital infrastructure projects with a medium cost relative to other mitigation options • [redacted]
Constraints	• PTP/STs that discharge to ground should only be replaced by units that also discharge to ground, where ground conditions are appropriate for drainage • PTP/STs which meet the P thresholds for small scale discharges may not be used to generate credits
Wider environmental considerations	• If using a drainage field, an upgrade proposal may need to consider climate change impacts on nutrient removal processes • If upgrading a chemical PTP/ST, aluminium treatment should not be used due to the likelihood of detrimental impacts on the surrounding environment/ecology • If upgrading a biological PTP/ST, it must be ensured the residents in dwellings linking to the private sewerage system being upgraded are not using chemicals or detergents which have the potential to negatively impact treatment
Stakeholders for Engagement	• NE • EA • Water companies • Landowners • LPAs
	•

Table B- 3 SuDS

Key option considerations	
Summary description of option	• SuDS is a general term for a variety of different mitigation measures that capture urban runoff and mimic natural drainage processes in urban environments. These measures can include wetlands, bioretention systems, swales, permeable pavements, soakaways, filter drains, raingardens or filter strips, or greens roofs and living walls. When implemented together, SuDS features can be referred to as a treatment 'train' • SuDS reduce flow velocities and facilitate infiltration and bio-filtration • 100% infiltration SuDS provide drainage in urban environments, infiltrating runoff though subsoil and removing nutrients and other pollutants in the process
Maintenance and monitoring requirements	• Certain SuDS features may need desilting and cleaning. Appropriate disposal of sediments should be conducted in order to reduce the risk of recirculating sediment-bound P within the same river catchment • Seasonal grass cutting, vegetation replacement and removal (incl. weeds) • Monthly/seasonal green waste and debris removal • Annual visual inspections and reporting of the vegetation, water quality, water depth, and bed level water should be completed regularly • Sampling programmes to capture the variability of urban surface water runoff pollution • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and existing the measure • Robust design and maintenance and monitoring plan to gain P credits
Potential additional benefits	• SuDS are traditionally used for flood management although they can contribute to significant water quality improvements • Wetlands features of SuDS manage rainfall and run off in developments but also control pollution, recharge groundwater, control flooding, and often provide landscape and environmental enhancement (Woods Ballard et al., 2015) • Biodiversity enhancement, amenity value, hazard reduction, water purification, carbon sequestration, and additional pollutant removal benefits
Development scale	• All sizes (which can range from minor to major developments[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) / medium (0.5-2 ha of land required) • The scheme is usually buried and thus does not require much land
P removal method and efficiency	• Sorption of soluble P onto the surface of sediments and soil particles when water infiltrates or is bio-filtered • Vegetative uptake of P i.e., biomass storage (during growing period). Plant roots uptake P and incorporate it within their structure • Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment • High efficiency (67-100%)
Factors affecting efficacy	• Type of SuDS. Each have their own P removal efficiency. A treatment 'train' i.e., SuDS combinations can further enhance performance • Inflow hydraulics • Soil type. Freely draining soils e.g., clay which encourage infiltration will increase the likelihood of P removal

Key option considerations	
	• Silt/sediment accumulation. Reduces P removal and remobilise sediment-bound P • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998) • For wetland measures see fact file 'Wetlands'
Time to effectiveness	• <1 years
Design requirements	• The concentration of TP in urban runoff often peaks during the early stages of a rainfall event in what is termed the 'first flush'. It is essential that SuDS are designed to capture and retain at least the water volume associated with the first flush • SuDS should be designed to be able to treat the runoff volume generated from the catchment that drains to them without becoming over saturated • Water must flow through the scheme and not bypass it via groundwater • Located on freely draining soils in urban areas • Located where measures can be implemented in combination • The design must comply to CIRCA guidance[52]
Input sources	• Urban Areas • New development sites
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• Some uncertainty in the reductions in TP it can deliver (as dependant on SuDS measure)
Cost	• Effectiveness of solution too variable and site specific to calculate costs
Constraints	• Consideration needs to be given to the local geology and possible presence of Source Protection Zones where the rules and requirements are likely to be more stringent • Owing to land constraints, they are most likely to be implemented on new development sites however can be retrofitted to pre-existing developments • Surrounding land-take
Wider environmental considerations	• 100% infiltration SuDS and treatment train SuDS may need to consider long-term changes to influent nutrient loads • Treatment train SuDS may also need to consider long-term climate change impacts on nutrient removal processes • If possible, the previous land use on a proposed site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the site
Stakeholders for Engagement	• NE • EA • Water companies

[52] CIRIA guidance (susdrain.org)

Key option considerations	
	• Landowners • LPAs

Table B- 4 Wetlands

Key option considerations	
Summary description of option	• Wastewater, surface runoff, or streamflow is discharged to a constrained area that is saturated or permanently inundated i.e., a wetland. Wetlands are traditionally configured so water flows through from an inlet to an outlet. They can comprise a singular wetland 'cell' or a chain of connected cells. Typically, TP concentrations will decrease along the flow path through a wetland. There are many different wetlands configurations that are categorised based on the water source, the type of flow through the wetland, and the vegetation used • In most cases there will be some percolation of flow through wetland beds although liners and low permeability substrates are often used to limit infiltration • Treatment wetlands are either natural or constructed systems managed in a specific manner to treat a source of water through a variety of physical, chemical, and biological processes. They have a fixed or closed water source, the likely inflow rates rate, variability of water quality and hydraulic retention time can be well defined and there is a low risk of uncontrolled water levels • Treatment Wetlands comprise natural or constructed wetlands that are designed and managed to improve the water quality of a known inflow rate and quality to a desired standard. These systems are referred to as 'closed' because the characteristics of the inflow are tightly controlled by the source of water to the wetland. Wetlands removing TP from the final effluent at STWs are examples of 'closed', wetland systems because the characteristics of the water entering the system (the influent) are known and will not vary markedly over time • Wetland systems treating non-controlled sources of water such as agricultural runoff can be referred to as 'Other Wetlands'. These systems are typically designed and managed to receive and treat influent with more dynamic water volumes and more variable water quality parameters, e.g., surface runoff or stream flow • Both Treatment and 'Other Wetlands' also have a various sub-categories based on their specific design • There are two main sub-categories of wetland include: surface flow wetlands and subsurface flow wetlands. Free water surface (FWS) wetlands are the most common surface flow wetland. These comprise areas of open water and are most similar to a natural wetland. FWS wetlands can be further split according to the mix of emergent plants, submerged plants and floating vegetation that are planted in the wetland. They are often used as tertiary treatment of domestic wastewater, urban runoff, and agricultural runoff • There are two main types of subsurface wetlands, horizontal subsurface flow (HSSF) wetlands and vertical flow (VF) wetlands. HSSF wetlands are designed so water flows laterally through a planted bed from the inlet to the outlet. Treatment occurs as water moves horizontally through the bed of the wetland. In comparison, VF wetlands discharge water over a permeable substrate planted with vegetation. Water treatment occurs through percolation through the root zone. Both subsurface flow wetlands can be used for the primary treatment of wastewater. It is possible to treat raw sewage with specific configurations of VF systems • Non-treatment wetlands differ from treatment wetlands as their hydrology is more dynamic and the ability to manage and control water inflows and water levels is considerably more challenging. However, these wetlands can be designed, created, or restored as part of an overall strategy for managing nutrients in the aquatic environment
Maintenance and monitoring requirements	• Desilting/desludging to prevent remobilisation and infilling (timescales dependent on wetland type, design, and management practices). 10 - 15 years depending on the sedimentation rates (Ellis et al, 2003). Or when the main pool volume is reduced by 20% and could be carried out every 25-50 years with effective pre-treatment (Woods-Ballard et al, 2015)

Key option considerations	
	• Seasonal trimming and removal of vegetation to remove P stored in vegetation from the wetland system • Annual visual inspections e.g., to assess the bed level and plan a sediment removal regime accordingly • An adaptive monitoring regime may be possible whereby frequency of monitoring can be reduced from a higher to lower frequency if the monitoring data shows that changes in TP removal efficiency occur with a predictable temporal pattern, e.g., seasonal changes • Replacement of bed material that is saturated with P (if using an artificial bed material is used for the purposes of removing P) • Due to the difficulty of characterising flows and loads, post-implementation monitoring is required to calculate credits, however evidencing the full nutrient removal potential may take longer than 1-3 years • VF wetlands require more frequent maintenance than an HSSF wetland • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and existing the wetland • Robust design and maintenance and monitoring plan
Potential additional benefits	• Subsurface flow wetlands can provide carbon sequestration and additional pollutant removal • FSW wetlands provide the most ancillary benefits due to the provision of biodiversity enhancement and amenity value • More natural wetlands with an open body of water can provide NFM, biodiversity enhancement, hazard reduction, water purification, amenity value, carbon sequestration, and additional pollutant removal
Development scale	• Medium / large (which is equivalent to a major development[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) / medium (0.5-2 ha of land required) • HSSF wetlands typically require a larger area than VF • Dependant on the volume of run-off entering wetland i.e., flow rate and concentration of nutrients. A higher flow rate and low P concentration = larger wetland required • Non-treatment wetland can be deployed with minimal land take
P removal method and efficiency	• Sorption of soluble P onto the surface of sediments and soil particles • Vegetative uptake of P i.e., biomass storage (during growing period). Plant roots uptake P and incorporate it within their structure • Sediment-bound P is deposited within the wetland as surface flow velocities are reduced – this immobilises P in the local environment (Mainstone & Parr, 2002; Kadlec & Wallace; 2009) • Medium efficiency (33-67%)
Factors affecting efficacy	• Type of wetland - subsurface flow (HSSF & VF) have higher TP removal (70%) compared to FWS (50%). TP removal performance of HSSF wetlands, like most wetlands, is variable and has been found to reduce overtime as sorption capacities of the substrate are reached • Hydraulic loading rate (HLR). The longer the water is held in the system, the greater time for P removal processes • Influent TP concentration is positively correlated with TP removal efficiency (whilst keeping HLR as low as possible) • Nutrient input source (see input sources) • Wetland shape. Wetlands shaped to encourage slow flow through a central area from inlet to outlet, minimise HLR, and increase residence time of water within the wetland.

Key option considerations	
	• Wetland length and width. Increasing flow route length increases water residence times and thus P removal (Woods-Ballard, et al., 2015). A flow route length to width ratio of at least 3:1. • Wetland depth. Depth should not exceed 2m to facilitate oxygen circulation to the wetland bed and thus P removal processes. Generally, shallower wetlands promote greater oxygen circulation and thus nutrient removal • Flow pattern and hydraulic efficiency. The distribution of water tends to be more uniform at low velocities. Low velocities avoid resuspension of sediments. <0.2 m/s is optimal; however, this depends on the dominant sediment size. No greater than 0.03 m/s for large wetlands • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998) • Redistribution of P stores within a wetland that affect its availability and mobility • Water residence time. A FWS of <0.001 m/s for optimal P removal • Sediment / soil type. Soils with greater hydraulic conductivity increase P removal • Vegetation type and coverage. Seasonal die-off of vegetation can bury nutrients within the wetland; however, decomposition of vegetation can result in the remobilisation of nutrients previously stored in vegetation. Species with high P removal capacity but are native to area where a wetland is being deployed. Phragmites species are common reeds that are often used to plant wetlands, especially subsurface flow wetlands (Kadlec & Wallace, 2009)
Time to effectiveness	• 1-3 years
Design Requirements	• Water must flow through the scheme and not bypass it via groundwater • Must be a treatment wetland with influent P concentrations > 0.1 mg/l and N concentrations > 4 - 5 mg/l to gain credits upfront • Slope of the surrounding land should prevent surface runoff draining into the wetland • Where wetlands are being located on permeable soils, wetlands may need to be lined with impermeable material such as clay • Ideally a wetland should be sited where topography allows a wetland to be gravity fed, as this will typically require less maintenance than a pumped system and will be cheaper to operate • Design requirements should meet NE's Wetland Framework to ensure proposals are adequate for NN[53]
Input sources	• Agricultural Diffuse Source (non-treatment wetland) • Agricultural Point source (non-treatment wetland) • Flowing Waterbodies (lotic) • Aquaculture • Urban areas • Other Industrial/Urban Point Sources • New development sites • Wastewater Treatment Works

[53] See: Framework Approach for Responding to Wetland Mitigation Proposals, available here: Natural_England_Framework_FINAL_REV7.3.pdf (ago-item-storage.s3.amazonaws.com)

Key option considerations	
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• This distinction between wetland types based on the source of the influent has a significant impact on the ability to predict the quantity of TP a wetland will remove • Variable inflow rates and water quality make it very difficult to predict how much TP ‘Other Wetlands’ can remove • Treatment Wetlands with known inflow rates and inflow water quality allow for much more accurate prediction of TP removal capacity based on appropriate design • Assumed consistent inflow of nutrient enriched water • The wetland design process should incorporate suitable allowances for uncertainty that means predicted TP removal estimates from a wetland are suitably precautionary
Cost	• Constructing wetlands at WwTW discharge sites [redacted]) • [redacted]
Constraints	• Sorption and biomass storage have limited retention capacity and can become saturated (although secondary processes, such as sedimentation, can remove saturated components) • Flood defence consents may be required from the EA if the works are to be carried out within 8m of a main river • Permitting constraints in catchments of rivers with water availability issues • The requirement for abstraction licences must also be considered and engagement with the relevant regulator should be evidenced for each permit or licence required • Possible increased flood risk of nearby infrastructure or agricultural land • If a wetland is in Flood Zone 2 or 3 then a flood risk assessment should be completed • Consideration should be given to whether a proposed wetland has any environmental designations, e.g., SSSI, National Nature Reserve etc. Developing wetlands on sites designated for historical and/or archaeological importance should also be considered and avoided where possible
Wider environmental considerations	• Peatland soils should be avoided due to their higher environmental and ecological value • Hydrogeological assessments should consider groundwater vulnerability to remove the risk of a wetland causing pollution to any aquifers that may impact water resources • A treatment wetland proposal may need to consider long-term changes in influent nutrient concentrations, long-term changes in inflow rates, climate change impacts on wetland efficacy • If a wetland is being created to have biodiversity and social amenity co-benefits, vegetation communities should be selected carefully and managed to maximise TP removal and other co-benefits • If possible, the previous land use on a proposed wetland site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the wetland • As wetlands can attract birds this maybe be an issue if the site is near an airfield. This is especially an issue for large wetland birds such as geese and swans and also large flocks of birds such as starlings. An evaluation of risk needs to be within the context of the type of airport. Airports may have their own bird strike risk management programmes or plans. These should be consulted, and any mitigation of bird strike risk should be derived through consultation and the development of a mutually agreed strategy.

Key option considerations	
Stakeholders for Engagement	• NE • EA • Water companies • Environmental NGOs • Landowners • LPAs

Table B- 5 Buffer Strips

Key option considerations	
Summary description of option	• Thin, vegetated land parcels (including trees) that intercept surface runoff and sub-surface flow pathways • Buffer strips can either be located within fields, at field margins away from watercourses (often referred to as windbreaks or shelterbelts), or at field margins along watercourses (often referred to as riparian buffers) • Buffer strips aims to decrease surface runoff velocities, increase infiltration, and maximise resident time of water in the subsurface. By reducing overland flow velocities, riparian planting/forested buffers prevent soil erosion and stabilise riverbanks, resulting in less bank erosion and the associated input of sediment-bound nutrients to rivers • Buffer strip vegetation can be established through planting or through natural colonisation • Due to the presence of both subsurface flows and the infiltration of surface water, the majority of nutrient removal processes occur within the soil matrix (Valkama et al., 2019)
Maintenance and monitoring requirements	• Periodic vegetation management (review annually) to increase light reaching understory vegetation • Fencing maintenance (if applicable) • Harvesting vegetation and removal of biomass to prevent decomposition and remobilisation of nutrients to the local environment, and increase the longevity with which buffers can continue to remove P (Stutter and others, 2020) • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and existing the buffer • Robust design and maintenance and monitoring plan to gain credits for P upfront
Potential additional benefits	• NFM, biodiversity enhancement, carbon sequestration, water purification, hazard reduction, amenity value, air quality regulation, human health and wellbeing enhancement, local economic benefits, and additional pollutant removal
Development scale	• Small (which is equivalent to a minor development) / medium (which is equivalent to a major development[1])
Spatial scale	• Medium (0.5-2 ha of land required)
P removal method and efficiency	• The main mechanism of P removal is via sorption of soluble P onto the surface of sediments and soil particles – occurring to the greatest extent at the field-side edge of the riparian buffer • Vegetative uptake of P i.e., biomass storage (during growing period). Plant roots uptake P and incorporate it within their structure • Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment (Mainstone & Parr, 2002)

Key option considerations	
	• Medium efficiency (33-67%)
Factors affecting efficacy	• Soil type. P binding more readily to clayey soils with high specific surface area and thus more sites for P sorption (Stutter et al., 2020). However, clay soils also have poor drainage and thus will limit infiltration capacity. Ideally a balance will be met to allow for optimal drainage as well as P sorption capacity, which is likely to be seen in loamy soils that are mix of sand, silt, and clay particles • Sediment size. Coarse sediment is generally trapped as overland flow enters a buffer, whilst finer sediment requires longer distances and significantly decreased velocities to come out of suspension (Stutter et al. 2020) • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998) • Proximity to watercourses. Riparian buffers i.e., next to watercourses, are more likely to intercept greater amounts of surface runoff and subsurface flows, resulting in greater amounts of nutrient removal than shelterbelts • Presence, quantity, and variation of vegetation present affects nutrient attenuation capacity (Cole, Stockan, & Helliwell, 2020). Nutrient assimilation rates are greater in mixed species stands when compared to monocultures (Richards et al. 2010). Native vegetation is also important for nutrient assimilation and to increase surface roughness to promote sedimentation • Increased surface roughness caused by variations in vegetation types -particularly larger woody vegetation. This increases channel complexity, reduces surface flow velocities, and further increases nutrient uptake by reducing energy available for sediment transport • Species type. Poplar and willow will assimilate nutrients into biomass more quickly during their early stages of growth. This immobilises the nutrients into the woody part of the trees • Density of tree planting. Reduced density helps to prevent shading of understory vegetation • Root structure and size. The more complex root structures of larger plants increase hydraulic residence times of water the soils of buffers, increasing the time chemical nutrient removal processes have to occur (Johnston & Dawson, 2005). Deep rooted trees, such as willow, are also beneficial as they support bank stabilisation, reducing flood risk whilst recovering nutrients and preventing P bound sediment from falling into watercourse • Rainfall intensity influences sediment trapping efficiency • Buffer width. For dissolved P, greater buffer widths are required for the P to come out of solution and be deposited (Haycock, 1997). A wider buffer provides more soil for P to sorb to and allows more time for P penetration into soil particles to occur, completing the process of adsorption • Slope. Buffer strips between 8-15m strips can be effective up to a slope of <10% gradient (Cole, Stockan, & Helliwell, 2020). Steeper gradients are likely to limit infiltration and increase soil erosion • Size. Generally, larger schemes have greater nutrient removal potential
Time to effectiveness	• <1 year
Design Requirements	• Water must flow through the scheme and not bypass it via groundwater • Buffers should be minimum 10m width and wider where there are converging flows/increased loads (i.e., water needs to flow through the buffer and not bypass it) • The catchment area feeding the buffer/run-off contributing area should not be too large compared to the size of the buffer (a catchment size: strip size ratio of 50:1 or less) (Cranfield University, 2006)

Key option considerations	
	• A width of 10m (Nutrient Reduction Standard) is a precautionary estimate of the minimum width for nutrient credits (ARUP and Entrade, 2022) • Flat sites and on freely-draining soils e.g., clayey soils – to increase residency times • Upstream of the location where the development site run off and wastewater input will have its effect
Input sources	• Agricultural diffuse source
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• Some uncertainty in the reductions in TP it can deliver • There is little clarity as to what the ideal residence time is for water in a buffer
Cost	[redacted]
Constraints	• There is potential for P sorption sites in soils to become saturated, preventing sediments from mitigating any further nutrient pollution. Under these circumstances it is possible for P to start leaching from soils, temporarily rendering the buffer strip as a source of P (rather than sink) • Consents and permissions incl. landowner agreement and consultation from relevant competent authorities (e.g., EA) • Sediment deposition of P may only be temporary, as resuspension can occur if surface runoff events are sufficient to cause soil erosion and re-suspend sediment bound P for transport into rivers • Changing the path of flood flows or reducing the storage capacity of a floodplain may increase flood risk and is not permitted in Flood Zones 2 and 3 without a flood risk assessment (FRA) • The requirements of any grants or other agreements on the land should be provided. If the riparian buffer is required through another legal obligation, then it can't also be used as NN mitigation • Planting trees and vegetation has the potential to disrupt landscape character and heritage features. This will need to be checked with landowners and relevant bodies e.g., English Heritage
Wider environmental considerations	• Long-term changes in influent nutrient loads and flow rate (due to climate change and planned infrastructure/land use changes) • Climate change impacts on nutrient removal efficacy • Long-term erosion risks • Good soil and crop management in upslope fields (i.e., compliance with agricultural regulations as minimum) • If possible, the previous land use on a proposed site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the buffer • Groundwater gradients may not follow surface topography leading to flows directed away from buffer • It should also be noted that river channel re-naturalisation and buffer strips are complementary measures and river channel re-naturalisation could help to increase the success of a riparian buffer strip if bank reprofiling can help to facilitate connectivity between groundwater and the rhizosphere in riparian buffers

Key option considerations	
Stakeholders for Engagement	• NE • EA • Landowners • Environmental NGOs • LPAs

Table B- 6 Agricultural Land Use Change

Key option considerations	
Summary description of option	• Agricultural land use change can either involve the cessation of agricultural practices on previously agricultural land or a change to the way agricultural land is managed while still remaining in agriculture. This can comprise of agroforestry, short rotation coppice (SRC), converting agricultural land to woodland, permanent farmyard / barn removal, or a switch to less intensive farming practice • Agroforestry is a farming system where trees are planted within the areas used for arable food or livestock production and these two types of agroforestry are often termed silvo-pasture, i.e., the incorporation of trees within areas of livestock pastures, and silvo-arable farming, i.e., the incorporation of trees within areas of arable agriculture • Short-rotation coppice (SRC) is an example of an agroforestry system that involves growing trees in order to harvest energy crops such as poplar and willow. The aim of this measure is to reduce the P inputs to agricultural land and reduce mobilisation of sediment through more natural land management systems or growing and harvesting specific plants and trees to remove P stored in soil • Permanent farmyard / barn removal removes a discharge of nutrients to ground and surface water in uncovered areas that are regularly used by livestock. The scheme requires the farmyard to be demolished and the site to be appropriately restored (or converted or rebuilt into residential housing) • Where agriculture is ceased and previous agricultural land is allowed to rewild or is planted with woodland, vegetation communities will generally return to a more natural state and agricultural nutrient pollution is removed
Maintenance and monitoring requirements	• Seasonal/interannual vegetation management • Plan and programme for tree planting and pruning (silvo-arable/silvo-pasture) • Harvesting of plants/trees (silvo-arable/silvo-pasture). A plan is required to show how disposal of the vegetation will not result in re-circulation of the stored nutrients within the same catchment, as this would reduce the efficacy of the scheme • Fencing/casings or use of non-toxic deterrents to prevent grazing by livestock (silvo-arable/silvo-pasture) • Implement an adaptive management plan that is more rigorous initially to target the removal of invasive species with the aim of quickly depleting the legacy P reserves • If a precautionary nutrient removal percentage is established prior to implementation, monitoring will likely be required to check compliance • Once mature, agroforestry is designed to be a relatively self-sustaining ecosystem

Key option considerations	
	• Monitoring effectiveness of soil erosion reduction techniques, such as sediment fences or bunds, cover crops and drainage ditch blocking implemented to reduce P legacy lag time • Pre- and post-implementation monitoring outputs to gain credits for P (silvo-pasture) • Robust design and maintenance and monitoring plan to gain P credits (silvo-arable) • Monitoring to provide evidence that the land will remain in semi-natural state in perpetuity
Potential additional benefits	• NFM, biodiversity enhancement, water purification, amenity value, hazard reduction, carbon sequestration, additional pollutant removal, livestock health and reduced stress, reduced soil degradation, and improved nutrient cycling through mycorrhizal associations • Fast-growing crops providing food, biomass fuel, and other sustainable wood products (SRC) • Agroforestry is a highly customisable solution with flexibility to suit the needs of landowners/land managers • Depending on the tree choices, profits can be increased with the potential for stable returns from tree crops within 5 years • Similar levels of arable and livestock productivity are maintained whilst additional products such as wood fuel, timber, and other crops, e.g., fruit and nuts, are produced for sale, providing additional income • Community-level benefits is energy crops are used to provide combined neighbourhood energy and NN schemes • Reduction in N and P fertilisers needed
Development scale	• Small (which is equivalent to a minor development) / medium (which is equivalent to a major development[1]) / large (2+ ha of land required)
Spatial scale	• Silvo-arable/silvo-pasture farming requires a significant area of arable land for tree planting; however, the area will remain in agricultural production and current yields can be maintained • Permanent farmyard / barn removal requires a small amount of land for machinery required for removal process
P removal method and efficiency	• Vegetative uptake of P (during growing period) - particularly the presence of phreatophitic trees that can access previously inaccessible nutrients - is a key mechanism by which P is removed from the soil system in land managed as agroforestry. Plant roots uptake P and incorporate it within their structure • SRC removes P via the export of harvested coppice (biomass) containing P • Low efficiency (<33%) in silvo-arable/silvo-pasture schemes • High efficiency (67-100%) in schemes taking agricultural land out of production
Factors affecting efficacy	• Soil type. Permeable soils e.g., clay soils provide more sites for P sorption (silvo-pasture/silvo-arable) • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998) • Intensity of P inputs from current agricultural land use. The future nutrient inputs to the field through fertiliser or manure for example, must remain equal to or less than the current agricultural nutrient inputs to retain P removal efficiency • Presence of rewilded / planted woodland. They intercept surface and sub-surface flow pathways (decreasing surface water runoff and reducing flow velocities). This reduces soil erosion and transportation, and increases the uptake of P by vegetation • The plant tree species, leafing period, rooting depth, species combination, growth rate, and the time taken to become established. An endemic mixture of plants and trees should be grown with deep rooted trees that can utilise the nutrients in the permanently saturated phreatic zone. Any sort of incompatibility has the potential to compromise the productivity of the system and hence will affect the likely nutrient uptake

Key option considerations	
	• Tree density. 80-120 trees/ha is recommended as the best bio-physical density for crop and tree growth. Too little distance and the canopy can close, causing crops to fail • Alley width must always be greater than the tree height • Light availability. North to South orientation will optimise the light available to crops and tree stands, minimising shade within the system and thus crop failure • Topography. A relatively even surface/low slope that will support laminar sheet flow (by promoting lower flow velocities), which is optimal for infiltration and thus P removal • Maturity of the system. As trees age, they tend to be more effective at taking up water and reducing run-off (George & Marschner, 1996)
Time to effectiveness	• <1 year (permanent farmyard / barn removal and taking agricultural land out of production) • 1-3 years (silvo-arable/silvo-pasture)
Design Requirements	• The design should account for the type of access that will be required and whether vehicular access will be necessary • Located on farms with the highest TP export coefficients
Input sources	• Agricultural Diffuse Source • Agricultural Point source
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• Predictable performance in reductions of TP • It is relatively easy to evidence the scale of P reduction through the use of agricultural export coefficients
Cost	• Taking agricultural land out of production can be potential costly [redacted] • Taking agricultural land out of productio[redacted] • Taking agricultural land out of production has a low cost of implementation as there are minimal costs associated with converting the land back to a semi-natural state due to low design requirements, for example • Agroforestry - effectiveness too variable and site specific to calculate costs • Permanent farmyard / barn removal costs based on size of barn and machinery required
Constraints	• Agroforestry schemes can only be deployed where agricultural practices are present • Landowner engagement and agreements • If the land is currently under an agri-environment scheme, payments may be lost through the deployment of an agroforestry scheme • Farmyards on chalk where significant delays are expected before the affected watercourse benefitted are not acceptable • The farmyard must currently be legally compliant; this will require an independent agricultural consultant appraisal or confirmation from the EA
Wider environmental considerations	• Taking agricultural land out of production/silvo-pasture schemes may need to consider the long-term climate change impacts • Calculations of TP loading reductions from agricultural land use change schemes should account for legacy P by assuming a lag time of 20 years unless monitoring can prove otherwise

Key option considerations	
	• Farmyard / barn removal may need to consider the impact of legacy nutrients in the soil, the geology of the site with reference to lag times, and climate change impacts on surface water runoff volumes
Stakeholders for Engagement	• NE • Landowners • LPAs

Table B- 7 River Channel Re-naturalisation

Key option considerations	
Summary description of option	• River channel re-naturalisation seeks to reinstate natural processes to anthropogenically modified river channels through the reestablishment of natural channel forms and habitats, which in turn promotes natural nutrient removal processes • River restoration techniques are varied and may involve reconnection of a river to the floodplain (or alternatively wetlands, unused tributary channels, or oxbow lakes), re-meandering a channelised section, creating berms and riffle-pool systems, bank stabilisation, engineered logjams, and marginal vegetation planting • These techniques promote processes that remove P from river water by increasing sediment deposition and increasing the contact time of water with riverbed and bank sediments
Maintenance and monitoring requirements	• Develop adaptive management regime depending on location and degree of re-naturalisation • Pre- and post-implementation monitoring outputs to gain credits for P • Flow measurements and water quality samples (measuring TP) should be taken upstream and downstream of a restored river reach • Annual visual inspections of the periodicity of lateral inundation, vegetation, INNS • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering the river • Pre- and post-implementation monitoring outputs to gain credits for P
Potential additional benefits	• NFM, biodiversity enhancement, amenity value, hazard reduction, water purification, carbon sequestration, and additional pollutant removal
Development scale	• Medium (which is equivalent to a major development[1])
Spatial scale	• Medium (0.5-2 ha of land required) • Re-naturalisation can take place entirely within the existing footprint of a river channel • Larger schemes involving floodplain reconnection will require more land
P removal method and efficiency	• Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment (Mainstone & Parr, 2002) • P sorption onto the surface of bank sediments and soil particles is the primary process of P removal within the waterbody • Vegetative uptake of P i.e., biomass storage (during growing period). Plant roots uptake P and incorporate it within their structure • Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment
Factors affecting efficacy	• Vegetation density. In-channel and marginal vegetation densities assimilate P by biomass and increase habitat heterogeneity. Most vegetation in rivers is short lived and assimilated nutrients are likely to be remobilised when vegetation dies and decomposes. Increased vegetation densities in rivers will also reduce velocities, increase residence times, increase hyporheic exchange between benthic and riparian sediments, and increase abundance of organic debris. These processes result in greater deposition of sediment and associated P and absorption rates of P • Presence of woody debris in areas of high P concentrations increases P absorption • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998)

Key option considerations	
	• High flow events. Remobilisation of sediment-bound P likely under high flow events due to bed and bank erosion • Floodplain connectivity i.e., connectivity of river flow with the floodplain during flood events. Higher connectivity promotes sediment deposition and P removal, though this P store can also be remobilised during high flow events (Sharpley, et al., 2013) • Initial TP concentrations. Should be greater than 0.3 µg/l for optimal P removal (Harper et al., 1999) • Slope. Gently sloping floodplain topography will be most beneficial for sedimentation and associated P removal during flood events • Sediment type. Greater number of absorption sites (such as Fe- and Ai-oxides) and thus greater p sorption
Time to effectiveness	• 1-3+ years
Design Requirements	• Floodplain reconnection should aim to understand the current and previous land use around the river to ascertain if legacy P stored with soils may be remobilised when a restored river floods • River and flood re-naturalisation schemes are likely to have the greatest benefit for nutrient removal if the main source of nutrient pollution enters the river upstream rather than at some point along the restored reach • Water must flow through the scheme and not bypass it via groundwater • Downstream of river reaches with high TP concentrations (and thus higher rate of TP removal) • Sufficient influent nutrient concentrations as well as hyporheic exchange capacity within benthic, riparian, and floodplain soils
Input sources	• Flowing Waterbodies (lotic)
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• Unpredictable reductions in TP (however highly reliant on design)
Cost	• Effectiveness of solution too variable and site specific to calculate costs
Constraints	• Flood risk to nearby infrastructure or agricultural land if a scheme involves re-connecting to floodplains • Any alterations to a river channel will require engagement and permissions from relevant body e.g., NE/EA • Landowner/manager engagement and agreement • As it is likely re-naturalisation scheme will be carried out within a designated sites (e.g., a SAC river) or supporting habitat for a SAC river, there will also be a requirement to consider any potential risks to the protected features of the designated site • Woody debris can be washed away in storm events and degrade if left in-situ, so offer only temporary storage of P through absorption (if applicable)
Wider environmental considerations	• A channel re-naturalisation proposal may need to consider long-term changes to nutrient concentrations and river flows, and climate change impacts on nutrient removal processes • It should also be noted that river channel re-naturalisation and buffer strips are complementary measures and river channel re-naturalisation could help to increase the success of a riparian buffer strip if bank reprofiling can help to facilitate connectivity between groundwater and the rhizosphere in riparian buffers
Stakeholders for Engagement	• NE • EA

Key option considerations	
	• Landowners • Environmental NGOs • LPAs

B. 8 Drainage Ditch Blocking

Key option considerations	
Summary description of option	• Drainage ditches (typically in agricultural environments) are blocked by a barrier, trapping agricultural runoff behind the barrier, increasing water table heights, and promoting various nutrient immobilisation and cycling processes that remove nutrients • This involves creating an impermeable/water-tight dam (or similar) made of for example, peat turf, plastic pilling, plywood, wooden plank, corrugated Perspex, heather bale, straw bales, sheep wool in Hessian, or combinations (Ramchunder et al, 2009; Armstrong et al., 2010) • Dam materials to create a drainage ditch block include turf, plastic pilling, plywood, wooden plank, corrugated Perspex, heather bales, and straw bales or any combination (Ramchunder, et al., 2009; Armstrong, et al., 2010).
Maintenance and monitoring requirements	• Visual inspections periodically (dependant on dam material) during rainfall events. Non-natural materials such as Perspex sheets will require fewer inspections • Vegetation removal or replanting (based on visual inspections) • De-sedimentation/siltation behind dams • Desilting of ditch (depending on location) to prevent lateral inundation – particularly if surrounding land is agricultural • Low frequency repairs if a scheme is well designed. Wooden dams may need repair as they are subject to bowing and distortion of the wood • Sampling programme will need to be reactive to rainfall events in order to sample runoff entering and exiting a blocked ditch • If livestock have access to a drainage ditch, they may cause soil erosion on ditch banks which will mobilise nutrients. In this case livestock should always be excluded from the drainage ditch • Robust design and maintenance and monitoring plan to gain credits for N and P upfront
Potential additional benefits	• NFM, biodiversity enhancement, hazard reduction (subject to location), carbon sequestration, water purification, amenity value, and additional pollutant removal
Development scale	• Small (which is equivalent to a minor development) / medium (which is equivalent to a major development[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) • Schemes require a relatively small allowance for some land around a ditch to be inundated
P removal method and efficiency	• Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment (Mainstone & Parr, 2002). • P sorption onto the surface of bank sediments and soil particles. Increased surface roughness, reduced flow velocities, and increased transient storage enhances P sorption through increased contact time with particulate material • Plant uptake of P (during growing period). Due to short life-span of plants this method can be short-lived as P is remobilised upon decomposition (Yoon, Noh, Han, Lee, & Son, 2014). • Low efficiency (<33%)
Factors affecting efficacy	• Vegetation presence around blocked drains increases hydrological heterogeneity and surface roughness of the sediment • Tree-stand density. Increased wood vegetation will increase nutrient retention (Koskinen et al., 2017)

Key option considerations	
	• P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998) • Block material. Plywood is better suited to very wet peatlands compared to heather bale • Peat source used for dam construction. Deeper peat creates better cohesion thus lengthening the life-span of the dam (Armstrong and others, 2009). • Location, number and spacing of block. Blocking downstream ditches first is recommended • Width and angle of block • Notch presence • Soil type. Soils with high specific surface areas and more P sorption sites e.g., clay. Within restored peatlands, sites with high Fe/P ratios result in greater P retention due to P adsorption by reduced Fe (Koskinen et al., 2017) • Width of channel • The height of the dam will impact whether or not flows are likely to bypass the drainage ditch block during rainfall events. The dam must be watertight and at least the same height as the ditch to optimise efficacy and prevent flows from finding a route around the dam • Peat height • Pool depth and width. Drainage ditches that create shallower wider pools upstream of the ditch block create conditions that allow for increased contact time of water with sediments, which will generally promote greater P removal (Armstrong, et al., 2010). Shallow, wider pools are preferrable for vegetation growth due to light penetration, which will further increase P removal. • Slope. Ditches that are perpendicular to local slope direction will capture the greatest amount of water, which will improve the nutrient removal potential
Time to effectiveness	• <1 – 3 years
Design Requirements	• Creation of pools with favourable conditions for plant growth to facilitate revegetation (Armstrong, et al., 2010) • Ditch geometry and materials suitable for blocking the ditch • Materials considers hydrology to reduce risk of dam being washed away after heavy rainfall events • Water must flow through the scheme and not bypass it via groundwater • Located in semi-natural habitats – particularly peatlands
Input sources	• Agricultural Diffuse Source • Agricultural Point source
Longevity	• Can continue to function effectively without requiring maintenance for 50+ years
Certainty	• Unpredictable reductions in TP
Cost	• Effectiveness of solution too variable and site specific to calculate costs
Constraints	• Flooding impacts should be considered, especially where the land is agricultural, or infrastructure is nearby • Engagement with landowners / land managers to ensure they will not object to the loss of land during wet weather

Key option considerations	
Wider environmental considerations	• A drainage ditch blocking proposal may need to consider long-term changes influent nutrient loads, climate change impacts on nutrient removal processes • Despite the benefits of multiple ditch blocking measures, it is important to consider that methane fluxes are likely to increase with greater number of drain blocks due to the enhanced production under waterlogged conditions (Holden, 2009) • Peatland recovery lags hydrological recovery. Consequently, in the short-term (i.e., < 5-year post-restoration) average water tables, and thus nutrient levels, remain the same • If possible, the previous land use on a proposed site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the site
Stakeholders for Engagement	• NE • EA • Landowners • Environmental NGOs • LPAs

B. 9 Terrestrial Sediment Traps

Key option considerations	
Summary description of option	• There are two main types of sediment traps: sediment fences, and detention ponds • Sediment fences (also known as a filter fence or silt fence) are temporary or permanent barriers made of permeable geotextiles or other permeable materials that allow water through but trap sediment. They are constructed downslope of a farm at a field boundary and at the location of known surface water runoff pathway. This blocks the flow pathway and water is forced through the permeable fence, slowing flow to cause sedimentation, and essentially acting as a filter to trap sediment and the associated P load (Vinten et al, 2014). Sediment accumulated in the traps is left to stabilise or is removed thus immobilising and removing a source of P pollution to rivers. They can be moved to different locations once accumulated sediment has been removed. It is also possible to leave them in a location and allow them to become buried. They are typically used on arable farms and in construction sites • Temporary detention ponds are depressions that capture surface water runoff during rainfall events, forming ephemeral wetland features. A detention pond will slow surface water runoff flows and drain slowly, allowing time for sediment to be trapped in the pond. Detention ponds are typically used as a SuDS feature, though they can also be deployed in the rural environment to intercept eroded soils. Urban detention ponds are typically more engineered than rural detention ponds in order to reduce the risk of localised flooding if the pond overtops. Rural detention ponds can utilise natural depressions by routing flow to these features
Maintenance and monitoring requirements	• Sediment fences require little maintenance if left to be buried by accumulated sediment (provided there are no rips or breaks in the geotextile used) • Sediment removal and cleaning of sediment fences • Urban detention ponds require regular maintenance in a similar manner to SuDS wetland features including sediment removal, unblocking/desilting of outlet pipes, and visual monitoring to assess accumulation rates • Appropriate disposal of sediments should be conducted in order to reduce the risk of recirculating sediment-bound P at the site • Monthly (or more regularly) monitoring of inlet and outlet water quality – to calculate TP removal efficiency • Pre- and post-implementation monitoring outputs to gain credits for P
Potential additional benefits	• Additional pollutant removal, water purification, carbon sequestration, amenity value, hazard reduction, and biodiversity enhancement
Development scale	• Medium (which is equivalent to a major development[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) • Silt traps require little land to be deployed in the terrestrial landscape and no land if being deployed in a fluvial environment
P removal method and efficiency	• Sediment-bound P is deposited as surface flow velocities are reduced – this immobilises P in the local environment i.e., in the trap (Mainstone & Parr, 2002) • Sorption of soluble P onto the surface of deposited sediments and soil particles is encouraged by increased contact time with particulate material behind dam • Medium efficiency (33-67%)

Key option considerations	
Factors affecting efficacy	• Sediment fence location. This dictates how much surface water passes through and sediment trapped – which influences P removal • Sediment accumulation and storage capacity of the pond. Full ponds will reduce sediment deposition and thus P removal • Flow velocities. High flow velocities could cause damage and negatively impact P removal • P sorption can be inhibited by the organic matter content of soil. Organic matter competes for sorption sites and can also alter sorption sites, both of which prevent the sorption of P to soils while also potentially causing P release (Reddy, et al., 1998)
Time to effectiveness	• < 1 – 3 years
Design Requirements	• Rural detention ponds are typically designed with an outlet that allows water out when it is near ground level, rather than being positioned at the base of a pond, in order to avoid accumulated sediment blocking the outlet (Fiener et al, 2005) • High risk areas. Steep slopes, exposed soils, high connectivity with river channels • Located on surface flow pathways downslope of an agricultural field
Input sources	• Agricultural Diffuse Source
Longevity	• Can continue to function effectively without requiring maintenance between a range of 0-50 years
Certainty	• Unpredictable reductions in TP
Cost	• Sediment fences can be constructed cheaply
Constraints	• Silt traps should not be built in areas of high velocities which are likely to cause damage and impact nutrient removal via remobilisation of sediments
Wider environmental considerations	• A silt trap proposal may need to consider long-term changes in influent nutrient loads • If possible, the previous land use on a proposed site should be determined to assess the likelihood of ground contamination and legacy P causing problems with water quality of water discharged from the site
Stakeholders for Engagement	• NE • EA • Landowners • LPAs

B. 10 Agricultural Cessation / Discharge Permit Removal

Key option considerations	
Summary description of option	• Removal of treatment works discharge permits • This also includes aquacultural offsetting – which permanently removes an aquaculture operation and the associated nutrient pollution from activities like fish farming. The river reach is returned to a semi-natural state, as it likely would have been prior to the commencement of fish farming, for example
Maintenance and monitoring requirements	• See 'Applicable to all section'
Potential additional benefits	• Aquaculture offsetting could deliver amenity value, biodiversity enhancement, carbon sequestration, water purification, and hazard reduction
Development scale	• All development sizes (which can range from minor to major developments[1])
Spatial scale	• Small (0-0.5 ha or applicable at the household scale) / medium (0.5-2 ha of land required) • Aquacultural operations do not require large land areas, but larger farms will likely deliver more mitigation
P removal method and efficiency	• Reduction in nutrients discharged by treatment works/ aquaculture • High efficiency (67-100%)
Factors affecting efficacy	• Abstraction and discharge rates • Inflow hydrology • Nutrient concentrations • Post-implementation land use • Decommissioning process
Time to effectiveness	• <1 year
Design Requirements	• No design requirements
Input sources	• Aquaculture/fish farms • Urban Areas • New Development sites
Longevity	• Can continue to function effectively without requiring maintenance for as long as the permit is in place/the aquaculture remains out of operation
Certainty	• Predictable performance of P removal
Cost	• Decommissioning costs

Key option considerations	
Constraints	• Aquaculture schemes are limited to existing aquaculture sites • Discharge permit removal schemes are limited to existing PTP/ST sites • They require high effluent concentrations and volumes to be viable for offsetting. Hence, it can be difficult to find a viable scheme as many aquaculture practices act as N and P sinks • Landowner engagement and permission
Wider environmental considerations	• An aquaculture offsetting proposal may need to consider future management and / or revoking of abstraction licenses
Stakeholders for Engagement	• NE • EA • Landowners • Environmental NGOs • LPAs

B. 11 Water Efficiency Measures

Key option considerations	
Summary description of option	• Water efficiency measures reduce the amount of water entering the sewer system, which in turn reduces the amount of nutrient rich sewage discharge from a treatment works • Can be implemented at any PTP/STs – particularly those with overspill and reaching max treatment capacity
Maintenance and monitoring requirements	• Minimal intervention post-installation • Requires evidence that water efficiency measures cannot be undone
Pre-implementation requirements	• n/a
Potential additional benefits	• NFM, hazard reduction, amenity value through reduced abstraction, water purification and provision, and carbon sequestration
Development scale	• All development sizes (which can range from minor to major developments[1])
Spatial scale	• Implementing water efficiency measures does not require any additional land take
P removal method and efficiency	• Reduction in volume of influent and discharge and associated P from treatment works • P removal via methods in PTP/STs • Low efficiency (<33%)
Factors affecting efficacy	• Dependant on type of water efficiency measure
Time to effectiveness	• <1 year
Design Requirements	• No design requirements
Input sources	• Urban Areas • New Development Sites
Longevity	• Dependant on type of water efficiency measure
Certainty	• Dependant on type of water efficiency measure
Cost	• Purchase of fixtures and fittings
Constraints	• Securing the water efficiencies measures in perpetuity of treatment works without TP permit, if using them as a long-term solution • Access to properties for retrofitting

Key option considerations	
Wider environmental considerations	• Water efficiency proposals may need to consider future changes to STWs nutrient removal permit
Stakeholders for Engagement	• NE • Water Companies • Landowners • LPAs

APPENDIX C – DETAIL OF MEASURES AND COSTS

The following provides the detail of the information that is summarised in **Table 6-1.** The following sections discuss the locations of nutrient mitigation opportunities in the context of the SSSI unit catchment that the opportunities are located within. To add clarity, the names and the length of the centre lines of the WFD waterbodies (as lines) that are within the SSSI unit polygons were extracted. The table below (**Table C-1**) shows the names of each WFD Waterbody that is 'within' each SSSI unit polygon.

C - 1 Table showing the lengths of WFD waterbody centre lines within each failing SSSI unit. Recommended for use in conjunction with Figure 3-1.

Habitats site name	SSSI Name	SSSI Unit No.	SSSI Unit ID	WFD Waterbody ID	Waterbody name	Length of WFD river in failing SSSI unit
Esthwaite Water Ramsar	Esthwaite Water	1	1015590	GB112073071400	Cunsey Beck/Black Beck	2734
River Derwent and Lake Bassenthwaite SAC	Bassenthwaite Lake	1	1015328	GB112075070530	Dash Beck	209
River Derwent and Lake Bassenthwaite SAC	Bassenthwaite Lake	1	1015328	GB112075070500	Wythop Beck	667
River Derwent and Lake Bassenthwaite SAC	Bassenthwaite Lake	1	1015328	GB112075073561	Derwent US Bassenthwaite Lake	809
River Derwent and Lake Bassenthwaite SAC	Bassenthwaite Lake	1	1015328	GB112075070440	Newlands Beck	992
River Derwent and Lake Bassenthwaite SAC	Bassenthwaite Lake	1	1015328	GB112075073562	Derwent DS Bassenthwaite Lake	6087
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	101	1028797	GB112075070450	Trout Beck (Derwent NW)	8
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	101	1028797	GB112075070490	Glenderamackin u/s Troutbeck	4412
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	101	1028797	GB112075070460	Glenderamackin (Greta)	6586
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	107	1028803	GB112075070410	Derwent - Stonethwaite Beck to conf Greta	7530
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	124	1028820	GB112075070550	Lostrigg Beck	7
River Derwent and Lake Bassenthwaite SAC	River Derwent and Tributaries	124	1028820	GB112075070540	Marron	14257
River Eden SAC	River Eden and Tributaries	203	1028824	GB102076070600	Scandal Beck	11131

Habitats site name	SSSI Name	SSSI Unit No.	SSSI Unit ID	WFD Waterbody ID	Waterbody name	Length of WFD river in failing SSSI unit
River Eden SAC	River Eden and Tributaries	206	1028827	GB102076070710	Helm Beck	12634
River Eden SAC	River Eden and Tributaries	207	1028828	GB102076070770	Hilton Beck	18
River Eden SAC	River Eden and Tributaries	207	1028828	GB102076070710	Helm Beck	13
River Eden SAC	River Eden and Tributaries	207	1028828	GB102076070880	Eden - Scandal Beck to Lyvennet	10927
River Eden SAC	River Eden and Tributaries	208	1028829	GB102076070770	Hilton Beck	7828
River Eden SAC	River Eden and Tributaries	209	1028830	GB102076070630	Hoff Beck (upper)	4
River Eden SAC	River Eden and Tributaries	209	1028830	GB102076070640	Scale Beck	3478
River Eden SAC	River Eden and Tributaries	209	1028830	GB102076070820	Hoff Beck (lower)	7349
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070980	Eden Lyvennet to Eamont	3204
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070950	Crowdundle Beck - Lower	28
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070930	Trout Beck	15
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070820	Hoff Beck (lower)	21
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070900	Leith	31

Habitats site name	SSSI Name	SSSI Unit No.	SSSI Unit ID	WFD Waterbody ID	Waterbody name	Length of WFD river in failing SSSI unit
River Eden SAC	River Eden and Tributaries	210	1028831	GB102076070880	Eden - Scandal Beck to Lyvennet	10562
River Eden SAC	River Eden and Tributaries	211	1028832	GB102076070860	Trout Beck (Kirkby Thore)	2076
River Eden SAC	River Eden and Tributaries	211	1028832	GB102076070910	Burthwaite Beck	4598
River Eden SAC	River Eden and Tributaries	211	1028832	GB102076070930	Trout Beck	6120
River Eden SAC	River Eden and Tributaries	211	1028832	GB102076070960	Swindale Beck nr Dufton	6897
River Eden SAC	River Eden and Tributaries	212	1028833	GB102076070830	Morland Beck	5
River Eden SAC	River Eden and Tributaries	212	1028833	GB102076070840	Lyvennet	12012
River Eden SAC	River Eden and Tributaries	212	1028833	GB102076070900	Leith	3617
River Eden SAC	River Eden and Tributaries	213	1028834	GB102076070900	Leith	12263
River Eden SAC	River Eden and Tributaries	214	1028835	GB102076070950	Crowdundle Beck - Lower	3406
River Eden SAC	River Eden and Tributaries	214	1028835	GB102076073790	Crowdundle Beck - Upper	5687
River Eden SAC	River Eden and Tributaries	214	1028835	GB102076071000	Milburn Beck	9162
River Eden SAC	River Eden and Tributaries	216	1028837	GB102076070720	Haweswater Beck	3215

Habitats site name	SSSI Name	SSSI Unit No.	SSSI Unit ID	WFD Waterbody ID	Waterbody name	Length of WFD river in failing SSSI unit
River Eden SAC	River Eden and Tributaries	216	1028837	GB102076070670	Swindale Beck (Lowther)	5685
River Eden SAC	River Eden and Tributaries	216	1028837	GB102076070690	Lowther (Upper)	10509
River Eden SAC	River Eden and Tributaries	216	1028837	GB102076071010	Lowther (Lower)	15626
River Eden SAC	River Eden and Tributaries	220	1028841	GB102076070940	Dacre Beck (Lower)	5570
River Eden SAC	River Eden and Tributaries	222	1028843	GB102076071020	Eamont (Upper)	101
River Eden SAC	River Eden and Tributaries	222	1028843	GB102076070990	Eamont (Lower)	8571
River Eden SAC	River Eden and Tributaries	222	1028843	GB102076071010	Lowther (Lower)	118
River Eden SAC	River Eden and Tributaries	223	1028844	GB102076073800	Briggle Beck	12730
River Eden SAC	River Eden and Tributaries	233	1028854	GB102076073720	Gillcambon Beck	3
River Eden SAC	River Eden and Tributaries	233	1028854	GB102076073730	Caldew (Hesket Newmarket)	4397
River Eden SAC	River Eden and Tributaries	233	1028854	GB102076073710	Caldew (upper)	11619
River Eden SAC	River Eden and Tributaries	234	1028855	GB102076073740	Whelpo (Cald) Beck	2211
River Eden SAC	River Eden and Tributaries	234	1028855	GB102076073730	Caldew (Hesket Newmarket)	416

Habitats site name	SSSI Name	SSSI Unit No.	SSSI Unit ID	WFD Waterbody ID	Waterbody name	Length of WFD river in failing SSSI unit
River Eden SAC	River Eden and Tributaries	234	1028855	GB102076073880	Caldew d/s Caldbeck	11206
River Eden SAC	River Eden and Tributaries	235	1028856	GB102076073770	Roe Beck (Lower)	17
River Eden SAC	River Eden and Tributaries	235	1028856	GB102076073780	Pow Beck (Eden and Esk)	35
River Eden SAC	River Eden and Tributaries	235	1028856	GB102076073880	Caldew d/s Caldbeck	13332
River Eden SAC	River Eden and Tributaries	236	1028857	GB102076073940	Eden - Eamont to tidal	9275
River Eden SAC	River Eden and Tributaries	236	1028857	GB102076073880	Caldew d/s Caldbeck	74
River Kent SAC	River Kent and Tributaries	104	1028868	GB112073071410	Gowan	6629
River Kent SAC	River Kent and Tributaries	111	1028875	GB112073071340	Flodder Beck	3292

C.2 MITIGATION MEASURES - AMOUNT NEEDED TO UNLOCK DEVELOPMENT

C.2.1 Esthwaite Water Ramsar

C.2.1.1 Stalled development

There is no stalled development within the Esthwaite Water catchment. As such, no mitigation solutions are recommended.

C.2.1.2 Future development

A systematic review of the efficacy of wetlands for nutrient removal which included analysis of the results of over 200 wetlands found a median removal rate of 46% for all sources of water, 68% for secondary wastewater, and 48% for tertiary wetlands (Land, et al., 2016). Applying the lowest rate to the load of 134 kg TP/year (see **Section 5.4.1.1**) would result in a reduction of 61.64 kg TP/year, assuming all DWF is treated (368 m^3/s).

Using the development estimate of 4 units/dwellings built per annum, and assuming this would equate to 5 kg TP/year (see **Table 4-3**) that would need mitigation, a wetland at this site could unlock 48 dwellings/units over a 12-year period[54].

Note: Removal rates should not be used to design a wetland[55]. These rates are simply used as an indication of median removal rates and are dependent on a plethora of factors, such as hydraulic retention time, hydraulic loading rate, inlet concentrations, treatment area, depth, type of wetland, flow rate etc.

C.2.2 River Derwent and Bassenthwaite Lake SAC

C.2.2.1 Stalled development

The overall recommendation identified as private sewerage upgrades, should be implemented in both the eastern and western catchments noting that some manufacturers of private sewerage systems guarantee the concentration of TP in the final effluent[56]. On this assumption and that:

- The pre-existing private sewerage systems discharge the full quantity of the permitted daily flow of effluent;
- The effluent has TP concentrations of 9.7 mg TP/l (see **Section 2.3.4**);
- The systems are replaced with an up to date Private Treatment Plants that can achieve concentrations of 1.1 mg TP/l;

Upgrading all of the systems could reduce the nutrient load by 89%.

Key opportunities wetlands (western catchment)

- There is one **private sewerage system** in the western catchment which is estimated to contribute 69 kg TP/year to a tributary upstream of the River Marron. Applying the assumptions detailed above, this site could provide 61.18 kg TP/year of mitigation in the western catchment.

Note: This is nearly double the maximum potential mitigation needed of 30.35- 35 kg TP/year (see **Section 6.1.2.1**). Furthermore, if the tourism development to the north-west of the catchment on Winscales Road used a PTP that could achieve concentrations of 1.1 mg TP/l, the mitigation requirement would be even less.

Solution: Upgrading the private sewerage system in the western catchment is likely to provide more mitigation than is needed to unlock the stalled development.

Key opportunities wetlands (eastern catchment)

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[54] At the time of writing, 12 years would mark the end of the LDNPA LDP (2020-2035).

[55] See the Constructed Wetlands Hub for further information on wetland design, available here: https://storymaps.arcgis.com/collections/6543a2f8de0348f683187ff268a79687?item=1

[56] For example, systems made by BioKube, which manufacture systems from 5-10000 population equivalent (PE), can produce effluent with 1.1 mg TP/litre according to their own research[56]. Furthermore, some PTP manufacturers claim effluent TP concentrations of <1 mg TP/l. For example, some of the GRAF UK products claim the final effluent has been tested to be 0.4 mg TP/l[56].

- In the eastern catchment 1.39 – 2.5 kg TP/year of mitigation is needed. There are **nine private sewerage systems upstream of Keswick**, the majority of which drain to River Glenderamackin (SSSI ID 1028797), which have been estimated to contribute 261.8 kg TP/year. Furthermore, there are **seven private sewerage systems in the south** which have been estimated to contribute 124.8 kg TP/year upstream of Derwent Water (SSSI ID 1028803). All of these systems are on average over 10 years old.

Solution: By replacing the systems outlined above with newer systems that achieve TP concentrations of 1.1 mg TP/l in the final effluent (assuming all systems currently discharge 9.7 mg TP/l and discharge the full quantity of the daily flow permit) there is a potential to mitigate 342.76 kg TP/year.

C.2.2.2 Future development

The projections of three new developments that may be constructed per year in the western catchments are sourced from the Allerdale LDP which extends until 2029. Therefore, over the next six-year period a total of 18 developments may be constructed equating to 22.5 kg TP/year of mitigation required. For the eastern catchments, 46 new dwellings per year over the next 12-year period (LDNPA LDP continues until 2035) results in an additional 552 dwellings / units may require mitigation. These future developments may require up to 690 kg TP/year of mitigation. However, applying the lower estimate of 18.49 kg TP/year (see **Section 6.1.2.2**) that will need mitigating results in a total load reduction of 221.88 kg/year TP over the planning period.

The mitigation provided by private sewerage upgrades described in **Section C.2.2.1** likely to provide enough mitigation for the future development in the western catchments and the eastern catchment, provided the lower estimate is applied. However, the actual discharge volumes and concentrations of TP in the final effluent is very uncertain. Therefore, it is recommended that riparian buffers are targeted as a precautionary measure in addition the private sewerage upgrades described.

Key opportunities - riparian buffers in the western catchments

There are 4228 hectares of agricultural land[57] in the Marron (GB112075070540) WFD waterbody catchment to the west of the Habitats Site (**Figure 5-1**). Assuming these areas are used for livestock grazing, multiplying the catchment average agricultural export coefficient of 1.03 kg TP/ha/year to the area of modified grassland could contribute 4354.84 kg TP/year. Furthermore, a relatively large proportion of this modified grassland is considered at moderate risk of sediment erosion.

Solutions:

- There is an estimated 1006.53 hectares of riparian woodland planting potential on the modified grassland within this catchment. Converting these areas from agricultural production (1.03 kg TP/ha/year) to woodland (0.02 kg TP/ha/year) will remove P in the order of 1.01 kg TP/year.
- Strategically targeting riparian buffers (50 metres wide) on all of the modified grassland would remove an estimated 1016.6 kg TP/year through the landcover change. In addition to this load removed through agricultural land use change, riparian buffers can remove P from the agricultural runoff they intercept[58]. If the specified amount of modified grassland is converted to riparian buffers, 3221.68 hectares of modified grassland remains.

Note: Applying the catchment average export coefficient, this area is likely to contribute 3318.33 kg TP/year to the Habitats Site. Assuming this load is delivered as surface runoff which can be intercepted by the riparian buffers and the buffers remove 54.5% of TP, the riparian buffers could capture a total of 1808.49 kg TP/year. Therefore, riparian buffers have the potential to remove a total of 2825.09 kg TP/year through landcover change and surface runoff interception in the western catchments. This is far greater than the requirement. Therefore, the recommendation is to target specific areas as opposed to implementing buffers along the whole catchment.

Key opportunities- riparian buffers in the eastern catchments

There are 1137 hectares of agricultural land in the Glenderamackin u/s Troutbeck (GB112075070490) WFD waterbody catchment to the east of the Habitats Site (See **Figure 5-1).** Applying the same assumptions as detailed above and using the catchment average export coefficient of 1.14 kg TP/ha/year, modified grassland

[57] For the purposes of this analysis landcovers defined as modified grassland and crops are assumed to be agricultural land. Any other grasslands and heathlands are excluded.
[58] A meta-analysis of 36 peer-reviewed articles found average P removal rates of 54.5% (Tsai, Zabronsky, Zia, & Beckage, 2022).

may contribute 4247.72 kg TP/year. Furthermore, a relatively large proportion of this modified grassland is considered at high risk of sediment erosion and so this load may be even higher in times of high surface flow.

Solution:
There is an estimated 535 hectares of riparian woodland planting potential on the modified grassland within this catchment. Strategically targeting riparian buffers (50 metres wide) on all of the modified grassland and converting these areas out of agricultural production (1.14 kg TP/ha/year) to woodland (0.02 kg TP/ha/year) could remove an estimated 599.2 kg TP/year through the landcover change alone. In addition to this load removed through landcover change that occurs through creating the buffer, further TP is removed through the surface runoff intercepted by the buffer.

Note: Assuming the catchment area for the buffers equals 602 hectares, the remaining area of modified grassland in the catchment, the load associated with the surface runoff may total 686.28 kg TP/year. As such, a riparian buffer with a removal rate of 54.5 %, a riparian buffer planted with woodland might remove 374 kg TP/year. Therefore, riparian buffers have the potential to remove 973.22 kg TP/year in total. This is far greater than the requirement for future development in the eastern catchments. Therefore, the recommendation is to target specific areas as opposed to implementing buffers along the whole catchment.

C.2.3 River Eden SAC

C.2.3.1 Stalled development

Assessing the amount of mitigation required in a catchment as large as the Eden is complex. There are many stalled developments spread throughout the catchment and so discussing the amount of mitigation required for the whole catchment can obfuscate where the mitigation is needed. Therefore, the catchment has been split up into the catchments of failing SSSI units (**Table C-1**) In addition, **Table C-2** shows the WwTW that discharges the highest load to each SSSI failing unit, as well as the WwTW which discharges the highest load upstream of the catchment. In addition to splitting up the Eden catchment, each WwTW was ranked based on the load and position in the catchment (the higher the better). The top 25 highest ranking WwTW can be seen in **Table C-3.**

Table C-1 Summary statistics showing the failing SSSI unit to which the stalled development will drain.

Failing SSSI Unit ID	U/S failing SSSI units (#)	D/S failing SSSI units (#)	Residential development (#)	Tourism development (#)	Maximum load (kg TP/ year)	Probable load (kg TP/ year)
1028827	1	1	1	0	1.25	1.46
1028828	4	2	246	9	318.75	126.14
1028830	4	2	1	0	1.25	0.47
1028831	4	2	1	0	1.25	1.25
1028832	4	2	73	15	110	117.33
1028833	1	2	7	47	67.5	57.69
1028834	0	3	10	0	12.5	3.33
1028835	1	2	3	0	3.75	3.75
1028837	1	2	49	0	61.25	16.21
1028841	1	2	0	15	18.75	15.84
1028843	3	1	400	21	526.25	154.54
1028844	3	1	6	4	12.5	10.66
1028854	3	1	4	0	5	5.86
1028855	3	1	1397	39	1795	774.80
1028856	3	1	2	0	2.5	2.93
1028857	16	0	1401	45	1807.5	945.38

Table C-2 WwTW with highest load of TP in the catchments to the failing SSSI units

SSSI ID	WwTW with highest TP load in catchment	Load (kg TP/year)	WwTW with highest load in upstream catchment	Load (kg TP/year)
1028828	Appleby WwTW	862	Ravenstonedale STW	254.2
1028857	Carlisle WwTW	28077.7	Penrith WwTW	2042.2
1028855	Dalston WwTW	1846.3	N/A	N/A
1028830	Great Asby WwTW	362.3	N/A	N/A
1028843	Penrith WwTW	2042.2	Askham WwTW	163.6
1028832	Dufton Village STW	146.1	N/A	N/A
1028833	Shap STW	301.3	N/A	N/A
1028835	Temple Sowerby WwTW	189.9	N/A	N/A
1028844	Blencarn WwTW	96.4	N/A	N/A
1028831	Culgaith STW	493.8	Appleby WwTW	862
1028837	Askham WwTW	163.6	N/A	N/A
1028854	N/A	N/A	N/A	N/A
1028856	Skelton STW	295.1	Dalston WwTW	1846.3
1028827	N/A	N/A	N/A	N/A
1028841	Outhgill STW	N/A	N/A	N/A

Key opportunities:

The following list summarises the mitigation requirement in each catchment and the opportunities available:

- SSSI Unit 1028828 - The five WwTW with the most opportunity for a **treatment wetland** are: Brough WwTW, Kirkby Stephen WwTW, Appleby WwTW, Warcop Camp, and Bolton Penrith WwTW.

Note: these WwTW are estimated to discharge a combined 3268.3 kg TP/year with Appleby WwTW and Bolton Penrith WwTW directly discharge to the failing SSSI unit whereas the other are upstream. Upstream works should be prioritised for mitigation.

Note: There are many WwTW wetland opportunities available as shown in **Table C-2**

- SSSI Unit 1028857 - Brampton WwTW and Weatherall WwTW discharge 2221 and 1338 kg TP/year may be viable sites to implement a **wetland** noting that this is the most downstream SSSI unit that is failing and hence is the reason for the whole catchment being affected by NN. Therefore, **any mitigation solutions in catchments upstream** can be used for offsetting this development.

Note: Even though there are many stalled developments in this catchment, it may not be necessary to implement mitigation solutions in this catchment. .

- SSSI Unit - 1028854 – Two large **private sewerage systems** with estimated TP loads of 71 and 135 kg TP/year.

Note: The upper Caldew catchment has a very high average export coefficient of 2.27 kg TP/ha/year and 207 hectares of riparian buffer planting opportunities.

- SSSI Unit 1028855 / 1028856 – Dalstown WwTW and Caldbeck WwTW are the two largest point sources in the catchments discharging 1846 and 307 kg TP/year and could be suitable targets for a treatment **wetland**. In addition, there are seven key **private sewerage sources** of TP that could be upgraded and contribute a combined 292.4 kg TP/year. **Riparian buffers** should also be considered due to the high diffuse agricultural loading (see note below).

Note: For the purposes of this analysis the opportunities in the catchments to these failing SSSI units are considered together due the WFD waterbody catchments not aligning with the SSSI unit extents. The diffuse agricultural TP loading in these catchments is high with the WFD waterbody catchments export coefficients ranging from 1.18-2.49 kg TP/ha/year.

- SSSI Unit 1028830 - Great Asby WwTW could be targeted as a **wetland** as is the largest point source of TP.
- SSSI Unit 1028843 – **Pooley Bridge WwTw provides for a wetland** opportunity for unlocking development as is the most upstream in the catchment. There are also **23 private sewerage systems** that could be targeted for upgrades.

Note: This catchment contains the Penrith urban area and has many point sources of TP. The WwTW that discharge the highest TP loads are Penrith WwTW, Pooley Bridge WwTW, Glenridding WwTW, Sockbridge and Tirril WwTW. These works contribute 2042, 511, 219, 196 kg TP/year, respectively. The private sewerage systems collectively contribute 420.2 kg TP/year.

- SSSI Unit1028832 – There are a combination of options that could be considered including **6 private sewerage systems including** [redacted] **(where the later could contribute to restoring the site to favourable condition) 5 WwTw wetlands** and **monitoring** (see details below)

Note: This catchment comprises mainly point source mitigation opportunities. The five WwTW are estimated to discharge 213.3 kg TP/year whilst the 6 private sewerage systems (including one at [redacted]) site are estimated to discharge 183 kg TP/year (with the later contributing 78kg TP/year). There is also a large development of 60 dwellings/units that is likely to discharge to Knock STW which does not have a permitted limit of TP and would therefore require monitoring to determine if this presents a mitigation opportunity.

- SSSI Unit 1028833 –**Riparian buffers** in this catchment are likely to capture a large load of agricultural P. The largest point sources are Morland WwTW which contributes 210 kg TP/year and a **private sewerage system** which discharges an estimated 71 kg TP/year. This is because catchment contains the WFD waterbody catchment which has the highest export coefficient in the catchment at 3.93 kg TP/ha/year.
- SSSI Unit 1028834 – This catchment contains Leith WFD waterbody catchment which has an agricultural export coefficient of 1.61 kg TP/ha/year. Shap STW contributes 301 kg TP/year but has a very low TP permit and therefore does not present a good opportunity for a **wetland**. There are **three private sewerage systems** that could be upgraded that contribute 39 kg TP/year.
- SSSI Unit 1028835 - The key mitigation opportunity in this catchment is **riparian buffers on** the Milburn Beck WFD waterbody catchment which has an export coefficient of 0.87 kg TP/year.
- SSSI Unit 1028844 – The three point sources in this catchment discharge a relatively low amount of TP. The key opportunities include a **wetland at Blencarn WwTW** which discharges a load of 96.4 kg TP/year and **two private sewerage system** that discharge 14 and 16 kg TP/year.
- SSSI Unit 1028831 – The key opportunity in this catchment is a **wetland at Culgaith WwTW**. This works has been estimated to contribute 494 kg TP/year.
- SSSI Unit 1028837 – [redacted] **private sewerage system**, presents the best opportunity for mitigation which discharges 64 kg TP/year.

Note: There are six WwTW in the catchment but only Askham WwTW could have a TP load calculated. This WwTW discharges164 kg TP/year. The three private sewerage systems with the highest load contribute 64, 16 and 10 kg TP/year. The are 49 developments near the outlet of this catchment although they are likely to connect to Penrith WwTW, outside of the catchment. Therefore, the only TP loading is likely to be from surface runoff..

- SSS Unit 1028827 – The key mitigation opportunity in this catchment is **intercepting diffuse agricultural pollution** as there is only one private sewerage system that discharges 11 kg TP/year. The agricultural export coefficient is 1.03 kg TP/ha/year.
- SSSI Unit 1028841 **– Riparian buffers** on account of the high diffuse agricultural loading of 2.54 kg TP/ha/year within Dacre Beck (GB102076070940) and two **private sewerage systems** which have been estimated to discharge 53 kg TP/year.

[redacted]

Table C-3 List of the top 25 ranked WwTW to target in the River Eden catchment

WwTW Name	Permit reference	DWF (m^3 / day)	TP permit (mg TP/l)	TP load (kg TP / year)	Rank	Upstream failing SSSI units (#)	Failing SSSI Unit ID	First D/S failing SSSI Unit ID	Second D/S failing SSSI Unit ID	Third D/S failing SSSI Unit ID
Brough WwTW	17670004	276	8	806.5	1	4	1028828	1028831	1028857	
Kirkby Stephen WwTW	17670013	1096	1.5	600.5	2	4	1028828	1028831	1028857	
Appleby WwTW	17670001	1180	2	862	3	4	1028828	1028831	1028857	
Warcop Camp STW	17670162	234	8	683.7	4	4	1028828	1028831	1028857	
Ravenstonedale STW	17670024	87	8	254.2	5	1	1028824	1028828	1028831	1028857
Great Asby WwTW	17680364	124	8	362.3	6	1	1028830	1028831	1028857	
Penrith WwTW	17670084	6989	0.8	2042.2	7	3	1028843	1028857		
Bolton Penrith WwTW	17670002	108	8	315.6	8	4	1028828	1028831	1028857	
Shap STW	17670025	825	1	301.3	9	1	1028833	1028831	1028857	
Culgaith STW	17670167	169	8	493.8	10	8	1028831	1028857		
Pooley Bridge East WwTW	17670085	175	8	511.4	11	3	1028843	1028857		
Langwathby WwTW	17670066	397.4	4	580.6	12	16	1028857			
Dufton Village STW	17670010	50	8	146.1	13	1	1028832	1028831	1028857	
Sandford Village WwTW	17680300	32	8	93.5	14	4	1028828	1028831	1028857	
Crosby Garret WwTW	17670005	20	8	58.4	15	4	1028828	1028831	1028857	
Morland WwTW	17670019	72	8	210.4	16	1	1028833	1028831	1028857	
Kirkoswald STW	17670065	265	8	774.3	17.5	16	1028857			
Soulby WwTW	17680876	10	8	29.2	17.5	4	1028828	1028831	1028857	
Great Salkeld WwTW	17670061	124	8	362.3	19	16	1028857			

WwTW Name	Permit reference	DWF (m^3 / day)	TP permit (mg TP/l)	TP load (kg TP / year)	Rank	Upstream failing SSSI units (#)	Failing SSSI Unit ID	First D/S failing SSSI Unit ID	Second D/S failing SSSI Unit ID	Third D/S failing SSSI Unit ID
Carlisle WwTW	17670049	30749	2.5	28077.7	20.5	16	1028857			
Kaber WwTW	17670011	13	8	38	20.5	4	1028828	1028831	1028857	
Dalston WwTW	17670115	1011	5	1846.3	22.5	2	1028855	1028856	1028857	
Melmerby STW	17670068	141	8	412	22.5	16	1028857			
Murton WwTW	17680532	23	8	67.2	24	1	1028832	1028831	1028857	
Temple Sowerby WwTW	17670042	65	8	189.9	25	1	1028835	1028857		

C.2.3.2 Future development

The future development within the Eden catchment is estimated to require 5194.85 kg TP/year. In addition, the 10000 dwellings to be built by 2030 as part of St Cuthbert's village may require and additional St Cuthbert's Garden Village 5700 kg TP/year. The estimated mitigation requirement for future development within each failing SSSI unit is as follows:

- SSSI Unit 1028857 requires 9427.5 kg TP/year
- SSSI Unit 1028843 requires 98.55 kg TP/year
- SSSI Unit 1028837 requires 71.25 kg TP/year
- SSSI Unit 1028841 requires 93.15 kg TP/year
- SSSI Unit 1028844 requires 245 kg TP/year
- SSSI Unit 1028855 requires 197.25 kg TP/year

The ***key mitigation opportunities*** are the same as those summarised in **Section 6.1.3.1.**

C.2.4 River Kent SAC

C.2.4.1 Stalled development

There is no stalled development within the River Kent catchment. As such, no mitigation solutions are recommended.

C.2.4.2 Future development

The 13 developments estimated to be built in Staveley each year equates to 156 developments over the LDNPA LDP (2020-2035). These 156 developments are estimated to contribute a total load of 195 kg TP/year, using the high estimate of 1.25 kg TP/year. However, it is also extremely likely that these developments will connect to Staveley WwTW, which is outside of the NN catchment. As such, it is likely that only the nutrient load associated with the landcover component requires mitigation. Applying the same assumptions as detailed in **Section 2.2.3** but nullifying the nutrient load associated with the wastewater component results in a nutrient load of 0.24 kg TP/year that requires mitigation per development. Therefore, the total load from 156 developments is likely to be 37.44 kg TP/year.

Solution: Assuming that the pre-existing private sewerage systems discharge effluent with TP concentrations of 9.7 mg TP/l (see **Section 2.3.4**), and that they are replaced with a system that discharges effluent with a maximum concentration of 1.1 mg TP/l, upgrading all of the systems could reduce the nutrient load by over 88%. Therefore, replacing the system that contributes an estimated 44 kg TP/year could remove 39 kg TP/year, providing enough mitigation for the future development for the remainder of the planning period.

C.3 LOCATION OF MITIGATION MEASURES

The key locations are highlighted in bold in the following text.

C.3.1 Esthwaite Water Ramsar

C.3.1.1 Stalled development

There is no stalled development within the Esthwaite Water catchment. As such, no locations of mitigation solutions are recommended.

C.3.1.2 Future development

Solution

A **wetland at Hawkshead STW** is recommended as this works is the largest point source at 134 kg TP/year.

This opportunity has been presented as a case study and hence is in more detail than other options.

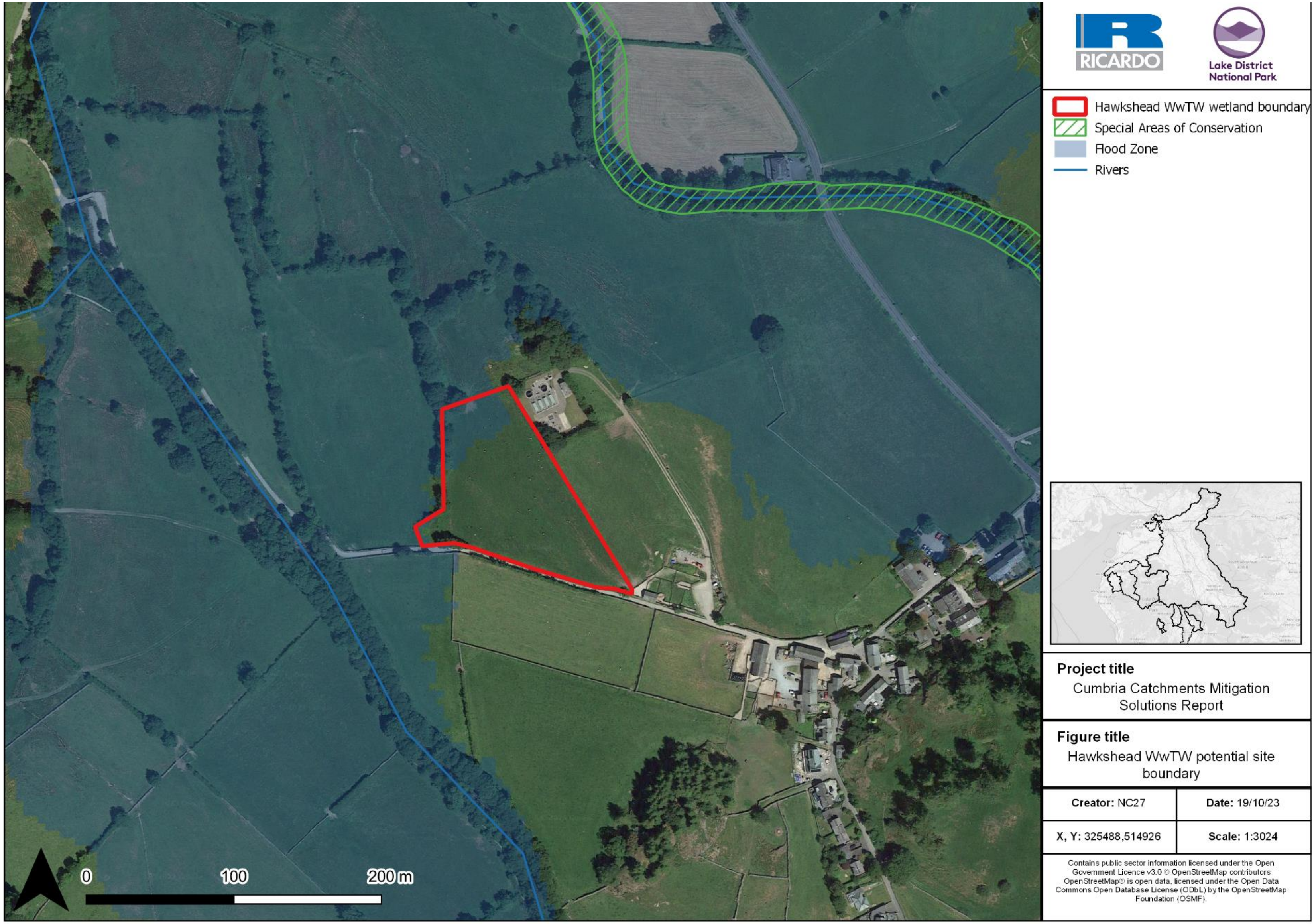
Note: This load has been estimated from the DWF permit of 368 m^3/day and the permitted concentration limit of TP in the final effluent of 1 mg TP/l. The inlet concentration is relatively low and will influence the TP removal rate (Land et al, 2016). Prior to selecting a set of possible sites to situate a wetland, it is first important to consider the best practices of wetland design - the following criteria are proposed by the Constructed Wetland Association and the Rivers Trust[41].

- An optimal water depth should range from 0.1-0.3 metres and is typically 0.15 metres, though deeper zones can be designed and should not exceed 1.5 metres.
- Width to length ratios of the active area should be between 1:2 to 1:3.
- There should be at least 2 cells within a system; the number of cells typically ranges from 2-5. The hydraulic retention time, calculated in its simplest form by dividing the storage capacity by the influent volume (assuming no evapotranspiration or groundwater losses), should be a minimum of 8 hours and typically ranges between 12-24 hours.
- Influent concentrations should be at least 0.1 mg TP/l and the substrate should have a maximum of 80 mg TP/kg
- Flow velocities should not exceed 0.04 m/s.

The map in **Figure C-1** shows Hawkshead STW. The land parcel to the west of the WwTW is 1.4 hectares and comprises modified grassland. Assuming an internal buffer of 5 metres to this parcel for curtilage, this site has 1.2 hectares of usable area. The cells could be designed in a way in which the width to length ratios is achieved. Assuming a mean depth of 0.15m, a wetland here could store 1800m^3. Assuming no other losses, the maximum hydraulic retention time could be 117 hours. The hydraulic loading rate would be a minimum of 0.03 m/day. An assessment of the mean slope of the site using 1-metre LiDAR data found the site has a mean slope of 2.15% and in line with the 2-5% recommended (Kadlec & Wallace, 2009). This field parcel is not in Flood Zone 2 or Flood Zone 3. There are no environmental or historic designated sites within the site boundary. It is therefore recommended that a further investigation into constructing a wetland at this site is completed.

This high-level example is useful to understand the potential mitigation a wetland system could provide. However, it is strongly recommended that when designing a wetland the inflow quality and quantity have been clearly defined, that industry standard calculations are applied to estimate nutrient removal, such as the P-K-C* approach, and the confidence level of the evidence used to inform decisions has been incorporated into the predictions of the performance. Furthermore, the calculation of the nutrient removal and wetland area must consider the water balance, hydraulic loading rates, hydraulic retention rates, hydraulic control and management, and the sediment loads and accumulation rate.

Figure C-1 Hawkshead potential wetland



C.3.2 River Derwent and Bassenthwaite Lake SAC

C.3.2.1 Stalled development

Western Catchment

In the western catchment it is recommended that the private sewerage system that discharges an estimated 69 kg TP/year is targeted.

This system is [redacted] [59]. It has a daily flow of 19.5 m^3/day and an effective permit date of 01/10/2018. The package treatment plant locations that are recommended for upgrades can be seen **Table 6-1**. Therefore, it may be a newer system that is certified to discharge a low concentration of TP in the final effluent. However, it is also possible that the system is a septic tank (ST) with poor TP removal performance.

Solutions

It is recommended that the above system is targeted for upgrades, albeit with preliminary monitoring of the effluent, and replaced with a system with certified concentrations of TP in the final effluent, such as those manufactured by BioKube or GRAF. In addition, it is strongly recommended that the tourism development of 24 units uses a private sewerage system with a low concentration of TP in the final effluent.

Eastern Catchment

In the eastern catchment, it is recommended that upgrading private sewerage sources with the oldest effective permit dates and that have the highest dry flow permit is the priority. It is also important to consider the description of the system to understand if the type of system used in known or if the number of connecting houses is known.

The recommended target is the private sewerage system at [redacted]. This is estimated to discharge a load of 31.9 kg TP/year and has a daily flow permit of 9 m^3/day. It is owned by the National Trust and has an effective permit date of 30/11/2020. Therefore, it is unlikely to have the most current phosphorus removal technology. Upgrading his system could mitigate 28.28 kg TP/year.

C.2.2.2 Future development

The list of private sewerage systems that are recommended as targets for upgrades can be seen in **Table 6-1**. Recommended locations for riparian buffers can be seen in **Figure 7-2**. These targets are in the catchments of the **Marron (GB112075070540**) and the **Glenderamackin u/s Troutbeck (GB112075070490**) WFD waterbody catchments.

Solutions

Riparian buffer creation should begin in the upper catchments to ensure the maximum river length receives the water quality benefit. The site selection process should consider the catchment area for the length of buffer being implemented and sources of TP in the surface runoff.

An assessment of the landcovers and farm types will allow for more detailed estimates of the TP load that is being intercepted. Any agricultural drainage networks within the buffer catchment should be identified in order to determine whether they bypass the buffer.

C.3.3 River Eden SAC

C.3.3.1 Stalled development

The following list details the catchments and mitigation solutions recommended within each catchment to the failing SSSI units:

- SSSI Unit 1028828 – It is recommended that wetlands are constructed at **Brough WwTW**, which discharges 806.5 kg TP/year and **Warcop Camp STW** which discharges 683.7 kg TP/year. These WwTW will unlock development that drains/discharges to the SSSI unit and will provide mitigation opportunities downstream. Applying a removal rate of 0.46 suggests wetland at these locations could

[59] Permit references can be searched here: https://environment.data.gov.uk/public-register/view/search-water-discharge-consents

provide 685.5 kg TP/year of mitigation. A maximum of 318.75 kg TP/year is needed to unlock development. As such there is a mitigation surplus of 367 kg TP/year.

- SSSI Unit 1028827 – There is only one development stalled in this catchment, and as such a *bespoke mitigation solution is recommended*. For example, creating a small section of riparian buffers upstream of the development to intercept agricultural runoff from a small field should be sufficient. Especially if a private sewerage system is used that can achieve TP concentration of less than 1.1 mg TP/l.
- SSSI Unit 1028832 – ***It is recommended that a wetland is targeted at Dufton Village STW*** which discharges 146 kg TP/year. A wetland here could remove 67 kg TP/year. Furthermore, it is suggested that [redacted] is targeted for **private sewerage upgrades**. This system has an effective permit date of 01/08/2005 and is estimated to discharge 78 kg/year from a daily flow of 22 m^3/day. Upgrading the works to a system with a TP permit of 1.1 mg TP/l could mitigate 69.2 kg TP/year. The combined mitigation of 136.2 kg TP/year would deliver the 110 kg TP/year requirement with a surplus of 26 kg TP/year.
- SSSI Unit 1028833 - ***It is recommended that a private sewerage system*** which is estimated to discharge 71 kg TP/year [redacted] is targeted for private sewerage upgrades. This effective permit date of 30/06/2017. Upgrading this system could provide 62.9 kg TP/year of mitigation per year. This mitigation provided is 4.6 kg TP/year lower than the maximum requirement. However, it also recommended that the tourism development of 44 units/dwellings (application reference 22/0199) is required to implement a high specification PTP.
- SSSI Unit 1028834 - There are **two private sewerage systems** that both discharge 14 kg TP/year [redacted]. Both systems were effective as of 2012 and so are unlikely to have the most up to date TP removal technology. *Upgrading these two systems could provide 24.8 kg TP/year.* This would provide mitigation for the maximum requirement of 12.5 kg TP/year.
- SSSI Unit 1028843 – There is a load of 526 kg TP/year that requires mitigation in this catchment. ***It is recommended that two WwTW are targeted for wetlands, Pooley Bridge East WwTW and Glenridding WwTW.*** These WwTW discharge 511 and 219 kg TP/year, respectively. Assuming a removal rate of 46%, these wetlands could mitigate 336 kg TP/year. In addition, it is recommended that **four private sewerage systems** are upgraded that discharge 117, 46, 31 and 31 kg TP/year ([redacted]. Upgrading these systems could mitigate 199.5 kg TP/year. In total the mitigation solutions outlined exceed the maximum requirement of 526.25 kg TP/year by 9 kg TP/year.
- SSSI Unit 1028837 – The stalled developments in this catchment require 61 kg TP/year of mitigation. This can be achieved through ***upgrading the private sewerage systems*** that discharge an estimated 64 and 10 ([redacted]). The mitigation secured through these upgrades is estimated to be 65.6 kg TP/year, 4 kg TP/year over the maximum requirement in this catchment.
- SSSI Unit 1028841 – **Riparian buffers on Dacre Beck WFD waterbody catchment (GB102076070940**). The agricultural export coefficient for this catchment is 2.54 kg TP/year. This catchment has 1116 hectares of modified grassland, on which there is 253 hectares of riparian buffer planting opportunity. Through the landcover change from agriculture to natural woodland, and the interception of surface runoff, planting buffers in this catchment is estimated to capture 1832 kg TP/year. This is a surplus of 1813.16 kg TP/year over the catchment requirement for stalled development of 18.75 kg TP/year. As such, this mitigation can be utilised in downstream catchments.
- SSSI Unit 1028844 – ***It is recommended that the private sewerage system (***[redacted]) which discharges 16 kg TP/year is upgraded to provide mitigation in this catchment. Upgrades could remove 14.2 kg TP/year. This is 1.6 kg TP/year over the requirement.
- SSSI Unit 1028854 – **Riparian buffers within the Caldew (Hesket Newmarket) WFD waterbody catchment (GB102076073730).** The agricultural export coefficient for this catchment is 2.27 kg TP/year. This catchment has 247 hectares of riparian buffer planting opportunity on modified grassland (836.62 hectares total). The estimated load removed through planting riparian buffers throughout the catchment is 1285 kg TP/year. This results in a mitigation surplus of 1280 kg TP/year over the catchment requirement for stalled development of 5 kg TP/year. As such, this mitigation can be utilised in downstream catchments.
- SSSI Unit 1028855 / 1028856 – The SSSI unit 1028855 is upstream of 1028856 but for the purposes of this analysis the catchments to the units are considered collectively. There are no developments that will discharge to 1028855, the upstream failing SSSI unit. However, there is a maximum mitigation requirement of 1795 kg TP/year for the SSSI unit 1028856. Due to the large load (1846 kg TP/year)

and the strategic position, it is recommended that **Dalston WwTW it targeted for a wetland**. This WwTW has a permitted TP limit of 5 mg TP/l. It is assumed that a wetland at this site will remove 849 kg TP/year. This does not meet the maximum required load of 1795 kg TP/year by 945 kg TP/year. However, the riparian buffers recommended for SSSI Unit 1028854 can be used as mitigation for the developments within these catchments as the water quality benefit provided by mitigation is upstream of the discharge. As such, the mitigation surplus of 1280 kg TP/year detailed above can be reduced to a **mitigation surplus of 335 kg TP/year.**

- SSSI Unit 1028857 –The above recommendations suggest that there would remain a surplus of 2515 kg TP/year (335 + 1813 + 367) upstream of this catchment. However, there would remain a requirement of 1806.25 kg TP/year in this catchment. Therefore, the **mitigation surplus would provide mitigation upstream of these developments.** The final estimation of the mitigation surplus is 708.75 kg TP/year. Although this is a lot more than what is currently required in the catchment, it could be used to unlock future development. Alternatively, the designs of the mitigation solutions could be tweaked to unlock stalled development exactly.

C.3.3.2 Future development

Future development is mainly distributed in SSSI unit 1028857, with plans to build nearly 13000 new developments within the planning periods (including St Cuthbert's Garden Village) with a total estimate of 9520 kg TP/year of mitigation needed to unlock this development. Furthermore, there is a total of 196 dwellings planned (245 kg TP/year) that may be discharge to SSSI unit 1028856. Additionally, there may be a total of 71.25 and 98.55 kg TP/year required in the catchment to the SSSI units 1028837 and 1028843, respectively.

SSSI unit 1028837 - To unlock the future development planned in 1028837, it is recommended that **a wetland is targeted at Askham WwTW,** which discharges an estimated load of 146 kg TP/year. Following the TP removal assumptions applied throughout, a wetland could remove 67.17 kg TP/year. This is just under the requirement so it is recommended that **private sewerage system upgrades are implemented as and when needed.**

SSSI unit 1028843 – It was recommended in **Section** that riparian buffers should be targeted in the Dacre Beck WFD waterbody catchment (GB102076070940). This is upstream of the catchment. Therefore, the **remaining mitigation from the Dacre Beck riparian buffer solution should be used** to unlock this development. However, it is very important to keep clear evidence on and accounting on where mitigation is being applied and what development is being used for to avoid double counting credits. Removing the requirement of 98.55 kg from the remaining surplus leftover from the mitigation for the stalled development (see **Section C.3.3.1**) results in a remaining surplus of 610.2 kg TP/year.

SSSI Unit 1028828 & 1028831 – There are an estimated 48 dwellings per year required scattered around Kirkby Stephen, Appleby-in-Westmorland and Kirkby Thore. This equates to around 430 developments over the planning period requiring 537.5 kg TP/year. The mitigation surplus of 367 kg TP/year that could result from implementing wetlands at Brough WwTW and Warcop Camp to unlock stalled development could provide 68% of this mitigation. As such, it is recommended that these wetlands are used to unlock future development in these areas. If further mitigation is required diffuse measures are recommended in the Belah (lower) WFD waterbody catchment, which has an average agricultural export coefficient of 0.9 kg TP/ha/year.

SSSI units 1028856 and 1028857 – For the purposes of this analysis, these two failing SSSI units are treated together. Part of the reason for this is that the plans for St Cuthbert's Garden Village appear to straddle the catchment. Therefore, it is unclear what units will be affected. Furthermore, 1028856 is upstream of 1028857 and so any mitigation applied in this catchment may benefit 1028857, provided all of the nutrient credits are not used up. Initially, it is recommended that **riparian buffers are established in the WFD waterbody catchment Morland Beck (GB102076070830)**. This catchment has a very high export coefficient of 3.93 kg TP/ha/year and there is 1669.8 hectares of modified grassland in this catchment. In addition, there is a potential to create over 278 hectares of riparian woodland. Applying the same assumptions used throughout, riparian buffers in this catchment could remove 4074.94 kg TP/year through landcover conversion and through capturing diffuse P in agricultural runoff. It is also recommended that **riparian buffers are established in the Roe Beck (upper) (GB102076073750) WFD waterbody catchment**. This catchment has an agricultural export coefficient of 2.49 kg TP/ha/year. Similarly, riparian buffers here could mitigate 3628.71 kg TP/year.

Another key recommendation is to target **wetlands at Gilsland WwTW and Brampton WwTW,** which discharge an estimated 1338 and 2221 kg TP/year. Wetlands at these locations could remove 616 and 1022 kg TP/year.

The total load removed from these solutions is 9408.82 kg TP/year. However, there was also an additional mitigation surplus leftover from the stalled development of 708.75 kg TP/year. Therefore, the mitigation solution detailed will provide 10117.57 kg TP/year. The mitigation requirement for future development is 9,690 kg TP/year. Therefore, a mitigation surplus of 427.57 kg TP/year may be leftover for site restoration.

C.3.4 River Kent SAC

C.3.4.1 Stalled development

There is no stalled development within the River Kent catchment. As such, no mitigation solutions can be recommended.

C.3.4.2 Future development

It is recommended the private sewerage sources with the oldest effective permit dates that have the highest dry flow permit. The private sewerage system which contributes an estimated 44 kg TP/year ([redacted]). has a dry flow permit of 12.5 m^3/day and an effective permit beginning at the start of 2020. Therefore, it may be a newer system that is certified to discharge a low concentration of TP in the final effluent. However, it is also possible that the system is a ST with poor TP removal performance. Nonetheless, it is recommended that this system is targeted for upgrades, albeit with preliminary monitoring of the effluent, and replaced with a system with certified concentrations of TP in the final effluent, such as those manufactured by BioKube or GRAF.

There is no development planned in the eastern catchments. However, it is recommended that the following private sewerage systems are upgraded should development arise in these catchments:

- [redacted] contributes an estimated 31.9 kg TP/year and became effective in 2012;
- [redacted] contributes an estimated 24.8 kg TP/year and became effective in 2011;
- [redacted] contributes an estimated 15.9 kg TP/year and became effective in 2012.

C.4 COST OF MITIGATION MEASURES [redacted]

C.4.1 Esthwaite Water Ramsar

C.4.1.1 Stalled development

There is no stalled development within the Esthwaite Water catchment. As such, no mitigation solutions can be recommended.

C.4.1.2 Future development [redacted]

Agricultural land is £26,000 per hectare in Cumbria[60]. Previous estimates of the costs of water storage capacity range from £1-£30/m^3 [61]. Two examples of wetlands built in Norfolk that both receive treated effluent ranged from £6/m^2 of wetland area to £18/m^2 (the range per entire site area was £3-£6/m^2), with an additional cost of monitoring of £2000/year-£5000/year (higher estimate included planting) (Wake, et al., 2022).

[redacted]

Applying the costs of the case studies detailed in Wake et. Al (2022), and assuming the wetland is 0.15 metres deep and only needs to be able to store the DWF, the cost of constructing the active wetland area (2453m^2) is likely to range between [redacted] The total cost, with the price of the land assuming these estimates ranges from [redacted]he average of the four estimates of the total cost is [redacted].

[60] See: Land value estimates for policy appraisal 2019, available here: https://www.gov.uk/government/publications/land-value-estimates-for-policy-appraisal-2019

[61] See: Cost estimation for land use and run-off –summary of evidence, available here: https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/long-term-costing-tool-for-flood-and-coastal-risk-management

[redacted] although this estimate does not include the costs of design, monitoring, additional administrative costs associated with connecting a development to a nutrient mitigation solution.

C.4.2 River Derwent and Bassenthwaite Lake SAC

C.4.2.1 Stalled development

An eight-person sewage system may cost over £3,500 with an installation cost of [redacted]. This equates to [redacted] per person [redacted] has a DWF permit of 19.5 m^3/day. According to the British flows a person uses 150 litres of water per day. Therefore, this system is likely to have the capacity to serve 130 people.

Applying the cost estimates for an eight person system, an upgrade could cost between [redacted]

Although the costs increases are very unlikely to be linear with system size, this estimate can be used to calculate cost per credit. Assuming 61.18 kg TP/year (see **Section C.2.2)** is mitigated through the upgrade, the TP credits could cost [redacted] per kg TP mitigated.

Multiplying these costs per credit to the potential load of 28.28 kg TP/year (see **Section C.3.2.1)** removed through an upgrade at [redacted]

The total cost of this measure is between [redacted]

C.4.2.2 Future development

The mitigation for stalled development in the western catchment is likely to be adequate for mitigating future developments in the western catchment. Therefore, the costs are the same. The potential mitigation achieved through upgrading private sewerage systems in the eastern catchment is 311.1 kg TP/year (see **Section C.2.2.1**). Assuming all of these upgrades were made, unlocking all future development through private sewerage upgrades could cost [redacted] However, as discussed in **Section C.2.2.2** the maximum potential mitigation may be higher than can be delivered with private sewerage upgrades.

Alternatively, there is the potential to create up to 1007 hectares of riparian buffers in the Marron (GB112075070540) WFD waterbody catchment to mitigate an estimated 2825 kg TP/year (see **Section C.2.2.2**). This equates to 2.8 kg TP/year per hectare. Furthermore, there is the option to create 535 hectares in the Glenderamackin u/s Troutbeck (GB112075070490) WFD waterbody catchment to provide 973 kg TP/year of mitigation. The kilo per hectare removal rate is 1.82 kg TP/year.

Evidence suggests woodland planting may cos[redacted] Over a 100 year in perpetuity period the maintenance cost would be [redacted] Furthermore, agricultural land in Cumbria is likely to cost £26,000 per hectare.

The total cost per hectare of riparian buffer planting is likely to be [redacted].

[redacted]

C.4.3 River Eden SAC

C.4.3.1 Stalled development

This section applied the cost estimates and assumptions detailed in **Section C.4.1** and **Section C.4.2** [redacted]

[redacted]

The cost of the wetlands is assumed to be [redacted] In total, the wetlands are likely to remove 1937.7 kg TP/year.

Summary of costs for key wetland and riparian areas are:

- Wetlands at these sites is likely to cost [redacted]
- Riparian buffers in the Caldew (Hesket Newmarket) WFD waterbody catchment (GB102076073730) are estimated to cost [redacted] for 1285 kg TP/year or [redacted].
- Riparian buffers in the Dacre Beck WFD waterbody catchment (GB102076070940) are estimated to cost a total of [redacted] for 1832 kg TP/year ([redacted].

Note: these cost estimates include the purchasing of the land which may not be required.

C.4.3.2 Future development

This section applied the cost estimates and assumptions detailed in **Section C.4.1** and **Section C.4.2** Assuming costs per credit for wetlands is [redacted] per kg TP mitigated (credit), in total, the wetlands are likely to remove 1704.31 kg TP/year. [redacted]

The riparian buffers and costs are as follows:

- [redacted]
- [redacted]

Note: These cost estimates include the purchasing of the land which may not be required.

C.4.4 River Kent SAC

C.4.4.1 Stalled development

There is no stalled development within the River Kent catchment. As such, no mitigation solutions can be recommended.

C.4.4.2 Future development

[redacted]

APPENDIX D – WIDER BENEFITS SUMMARY

WIDER BENEFITS AND ECOSYSTEM SERVICES TABLES

The table shows the wider benefits i.e. ecosystem services which could be potentially delivered by each of the nutrient mitigation solutions. Each solution which could potentially deliver a service was marked as ‘x’, and those which would not deliver the service with a ‘-‘. The habitat unit value (where appropriate) was also noted in the below table.

It should be noted that as to avoid double-counting, the ecosystem service ‘Recreation and Tourism’ included the services ‘Health and Wellbeing’ as these services are delivered together.

Table D-1 Matrix of nutrient mitigation solutions and potential ecosystem services delivered.

Type of measure	Natural Capital benefits (Ecosystem services)											Total
	Biodiversity & Habitat	Climate Regulation (Carbon sequestration)	Natural Hazard Regulation (Flooding)	Water Purification	Water Provisioning	Recreation & Tourism (Including Health & well-being)	Agriculture	Air Quality - Air pollution removal	Soil Erosion Reduction	Material provisioning (e.g., wood)	NFM	
Wetlands at WwTWs: Surface flow wetland	x	x	x	x	x	x	-	x	-	-	x	8
Wetlands at WwTWs: Sub surface flow - horizontal flow	x	x	x	x	x	x	-	x	-		x	8
Wetlands at WwTWs: Sub surface flow - vertical flow	x	x	x	x	x	x	-	x	-		x	8
Buffer strips: Woodland; Broadleaved	x	x	x	x	-	-	-	x	x	x	x	8
Buffer strips: Woodland; Coniferous		x	x	x				x	x			5

Type of measure	Natural Capital benefits (Ecosystem services)											Total
	Biodiversity & Habitat	**Climate Regulation (Carbon sequestration)**	**Natural Hazard Regulation (Flooding)**	**Water Purification**	**Water Provisioning**	**Recreation & Tourism (Including Health & well-being)**	**Agriculture**	**Air Quality - Air pollution removal**	**Soil Erosion Reduction**	**Material provisioning (e.g., wood)**	**NFM**	
Buffer strips: Grassland	x	x	x	x	-	x	-	x	x	-	x	8
SuDs	x	x	x	x	x	x	-	x	-	-	x	8
PTP upgrades	-	-	-	x	x	-	-	-	-	-	-	2
Agricultural land use change: Agroforestry – silvo-arable	x	x	x	x	-	-	x	x	x	x	-	7
Agricultural land use change: Short Rotation Coppice	x	x	x	x	-	-	x	x	x	x	-	8
Converting agricultural land to woodland	x	x	x	x	-	x	-	x	x	x	-	8
Agricultural land use change: Permanent farmyard/barn removal	-	x	x	-	-	-	-	-	-	-	-	2
Agricultural land use change: Permanent farmyard/barn removal and conversion to	-	-	-	-	-	-	-	-	-	-	-	0

Type of measure	Natural Capital benefits (Ecosystem services)											Total
	Biodiversity & Habitat	Climate Regulation (Carbon sequestration)	Natural Hazard Regulation (Flooding)	Water Purification	Water Provisioning	Recreation & Tourism (Including Health & well-being)	Agriculture	Air Quality - Air pollution removal	Soil Erosion Reduction	Material provisioning (e.g., wood)	NFM	
residential housing												
Agricultural land use change: Switch to less intensive farming practices	x	x	x	-	-	-	-	-	-	x	-	4
Aquacultural cessation	x	x	x	x	x	x	-	x	-	-	x	8
Sediment Traps	x	-	x	x	x	-	-	-	x	-	x	6
Drainage Ditch blocking	x	-	x	x	x	-	-	-	x	-	x	6
Engineered logjams	x	-	x	x	x	-	-	-	x	-	x	6
River Channel Re-naturalisation	x	x	x	x	x	x	-	x	x	-	x	9

Table D-2 Type of nutrient mitigation solution, habitat created (UK Habitat classification), and BNG Habitat Unit value.

Type of nutrient mitigation solution	Habitat created (UK Habitat Classification)	BNG Habitat Units (per ha)
Wetlands at WwTWs: Surface flow wetland	Wetland - Reedbeds	13.2
Wetlands at WwTWs: Sub surface flow - horizontal flow	Urban - Sustainable drainage system	4.4
Wetlands at WwTWs: Sub surface flow - vertical flow	Urban - Sustainable drainage system	4.4
Buffer strips: Woodland; Broadleaved	Woodland and forest - Other woodland; broadleaved	8.8
Buffer strips: Woodland; Coniferous	Woodland and forest - Other coniferous woodland	4.4
Buffer strips: Grassland	Grassland - Modified grassland	4.4
SuDs	Urban - Sustainable drainage system	4.4
PTP upgrades	No significant change	-
Agricultural land use change: Agroforestry – silvo-arable	Cropland - Non-cereal crops	2.2
Agricultural land use change: Short Rotation Coppice	Cropland - Non-cereal crops	2.2
Converting agricultural land to woodland	Woodland and forest - Other woodland; mixed	8.8
Agricultural land use change: Permanent farmyard/barn removal	Grassland - Modified grassland	4.4
Agricultural land use change: Permanent farmyard/barn removal and conversion to residential housing	Urban - Developed land; sealed surface	0
Agricultural land use change: Switch to less intensive farming practices	Grassland - Modified grassland	4.4
Aquacultural cessation	Pond (non-priority)	8.8
Sediment Traps	No significant change	Dependant on baseline habitat
Drainage Ditch blocking	No significant change	Dependant on baseline habitat
Engineered logjams	No significant change	Dependant on baseline habitat
River Channel Re-naturalisation	No significant change	13.2

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