REPORT

Norfolk Nutrient Strategy

Mitigation Solutions

Client: Norfolk Local Authorities

Reference: PC3719-RHD-ZZ-XX-RP-Z-0002

Status: S1/P01.02

Date: 23 January 2023

Royal HaskoningDHV
Enhancing Society Together

Project related

HASKONINGDHV UK LTD.

Telecom House
125-135 Preston Road
Brighton
BN1 6AF
Industry & Buildings
VAT registration number: 792428892

+44 (0)1444 458551 **T**
info@uk.rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Norfolk Nutrient Strategy
Subtitle:	Mitigation Solutions
Reference:	PC3719-RHD-ZZ-XX-RP-Z-0002
Status:	P01.02/S1
Date:	23 January 2023
Project name:	Norfolk Nutrient Strategy
Project number:	PC3719
Author(s):	Royal HaskoningDHV
Drafted by:	RHDHV
Checked by:	RHDHV
Date:	19 January 2023
Approved by:	RHDHV
Date:	23 January 2023

Classification
Project related

Revision history

Revision	Date	Description	Prepared	Checked	Approved
00	14.10.2022	Draft version	RHDHV	RHDHV	RHDHV
01	30.11.2022	Second Draft - Revised following client review comments	RHDHV	RHDHV	RHDHV
02	23.01.2023	Third draft – Revised following second set of client review comments	RHDHV	RHDHV	RHDHV

Table of Contents

1 Introduction 1

1.1 Nutrient neutrality and the Dutch N Case 1

1.2 Purpose of this report 1

2 Background 2

2.1 Protected habitats in Norfolk 2

2.1.1 River Wensum SAC 2

2.1.2 Broads SAC, SPA and Ramsar 2

2.1.3 Contributing catchments 3

2.2 Projected mitigation requirements 6

3 Potential Nutrient Management Solutions 13

3.1 Types of nutrient management solution 13

3.2 Potential nutrient management solutions 13

3.2.1 Overview 13

3.2.2 Description of nutrient management solutions 15

3.2.3 Monitoring 17

3.3 Nature-based solutions 17

3.3.1 Silt traps 17

3.3.2 Riparian buffer strips 20

3.3.3 Wet woodlands 28

3.3.4 Willow buffers 32

3.3.5 Beetle banks 34

3.4 Runoff management solutions 35

3.4.1 Taking land out of agricultural use 35

3.4.2 Conversion of agricultural land to solar farms 43

3.4.3 Cessation of fertiliser and manure application 45

3.4.4 Cover crops 49

3.4.5 Installing Sustainable Drainage Systems (SuDS) in new developments 52

3.5 Wastewater Management Solutions 60

3.5.1 Expedite planned improvements to treatment works 60

3.5.2 Install portable treatment works 63

3.5.3 Install package treatment plants 66

3.5.4 Install cesspools and capture outputs from private sewage systems 70

3.6 Demand Management Solutions 72

3.6.1 Retrofit water saving measures in existing properties (local authority, registered providers, public buildings) 72

3.6.2 Retrofit water saving measures in existing properties (private housing, commercial and industrial premises) 76

3.6.3 Incentivise commercial water efficiency and treatment installation 77

4 4 Summary 80
4.1 Summary of potential solutions 80
4.2 Suitability of solutions 84
4.3 Next steps 84
5 5 References 86

Table of Tables

Table 2.1: Summary of the planned growth in Norfolk 7
Table 2.2: Total phosphorus loading per LPA District 7
Table 2.3: Total nitrogen loading per LPA District 8
Table 2.4: Mitigation required assuming permit limits are reduced to the TAL post 2030 8
Table 2.5 Phosphorus mitigation requirements per river catchment 10
Table 2.6: Nitrogen mitigation requirements per river catchment 10
Table 2.7: Mitigation required assuming permit limits are reduced to the TAL post 2030 10
Table 2.8: Phosphorus mitigation requirement breakdown per river catchment for each LPA District 11
Table 2.9: Nitrogen mitigation requirement breakdown per river catchment for each LPA District 12
Table 3.1 Potential nutrient management solutions 15
Table 3.2 Description of nutrient management solutions 16
Table 3.3 Estimated TP mitigation and associated costs in each sub-catchment 19
Table 3.4 Estimated TN mitigation and associated costs in each sub-catchment 20
Table 3.5 Silt traps 20
Table 3.6 Riparian buffer effectiveness depending on buffer width and soil type (edited from Zabronsky (2016)) 21
Table 3.7 Typical nitrogen removal rates 23
Table 3.8 Effectiveness of different types of buffer strip in removing TN (Edited from Mayer et al., 2005) 24
Table 3.9 Summary buffer strip costs (From Farmscoper Version 5 Costs tool). 26
Table 3.10 Annual Countryside Stewardship grants for riparian buffer strips 26
Table 3.11 Estimated TP mitigation and associated costs in each sub-catchment 27
Table 3.12 Estimated TN mitigation and associated costs in each sub-catchment 27
Table 3.13 Riparian buffer strips 27
Table 3.14 Nitrogen removal from wet woodland buffers 30
Table 3.15 Wet woodlands 31
Table 3.16 Willow buffers 33
Table 3.17: Beetle banks 35

Table 3.18 Typical rainfall and drainage characteristics of the Wensum, Yare and Bure catchments derived from the Norfolk Nutrient Budget Calculator. 36

Table 3.19 Typical agricultural nutrient runoff rates in the Wensum, Yare and Bure sub-catchments 37

Table 3.20 FBT rental rates (£/ha) for farming types in England (Source: Defra, 2022) 39

Table 3.21 FBT rental rates (£/ha) for FBT farms in the East of England (Source: Defra, 2021) 39

Table 3.22 Phosphorus mitigation and cost estimation for taking various agricultural land out of use 41

Table 3.23 Nitrogen mitigation and cost estimation for taking various agricultural land out of use 41

Table 3.24 Taking land out of agricultural use key considerations 42

Table 3.25 Conversion of agricultural land to solar farm key considerations 45

Table 3.26 Phosphorus removal from the temporary cessation of fertiliser and manure application 46

Table 3.27 Nitrogen removal from the temporary cessation of fertiliser and manure application 46

Table 3.28 Potential phosphorus mitigation and associated costs 47

Table 3.29 Potential nitrogen mitigation and associated costs 47

Table 3.30 Cessation of fertiliser / manure cost estimation 48

Table 3.31 Cessation of fertiliser and manure application 48

Table 3.32 Estimated TP mitigation and associated costs in each sub-catchment 50

Table 3.33 Estimated TN mitigation and associated costs in each sub-catchment 50

Table 3.34 Cover crops 51

Table 3.35 SuDS maintenance tasks 55

Table 3.36: Performance of SuDS components for phosphorus capture and removal (Edited from CIRIA C808 (2022)) 58

Table 3.37 SuDS costs for buffers, bunds and wetlands (edited from Vinten et al (2017)) 59

Table 3.38 Indicative capital costs for SuDS options (edited from Environment Agency (2015)) and relative performance edited from C808 CIRIA, (2022) 59

Table 3.39 SuDS key considerations 60

Table 3.40 Potential phosphorus reductions associated with upgrades to treatment works planned by 2025 61

Table 3.41: Potential nutrient reductions associated with upgrades to treatment works planned by 2030 61

Table 3.42 Expedite planned improvements to wastewater treatment works 63

Table 3.43: Potential phosphorus reductions associated with portable treatment works 64

Table 3.44 Portable treatment works 66

Table 3.45 Default performance values for PTPs and septic tanks (Natural England, 2022) 67

Table 3.46 Main PTP manufacturers phosphate removal rates 67

Table 3.47 Package Treatment Plants 69
Table 3.48 Cesspools key considerations 72
Table 3.49 Baseline (150 l/person/day) maximum water consumption values for appliances/fittings 73
Table 3.50 Cost estimation for installing appliances/fittings to meet the 110 l/person/day limit 75
Table 3.51 Retrofitting water efficient fittings (Local Authority, registered providers, public buildings) key considerations 75
Table 3.52 Retrofit water saving measures in existing properties (private housing, commercial and industrial premises) 77
Table 3.53 Incentivise commercial water efficiency and treatment installation key considerations 79
Table 4.1 Short-list solutions Summary 81
Table 4.2 Suitability of solutions 84

Table of Figures

Figure 3. 1 Silt trap installed in a stream (Source: IRD Duhallow, 2015) 17
Figure 3. 2 Silt fencing installed on agricultural fields (Source: HY-TEX, 2022) 18
Figure 3. 3 Buffer strip efficiency (Edited from Tsai et al. 2016) 22
Figure 3. 4 Relationship of nitrogen removal effectiveness and buffer width in for all vegetation types (From Mayer et al., 2005) 23
Figure 3. 5 Area of wet woodland created in Salford in 2016. The project led to the attenuation of pollutants by biodegradation (Natural Course, 2017) 28
Figure 3. 6 Traditional NFM structures, such as leaky barriers, can be used to enhance channel-floodplain connectivity to encourage nutrient deposition 29
Figure 3. 7 Example of a SuDS wetland (Source: Susdrain) 52
Figure 3. 8 Example of swales and conveyance channels (Source: Susdrain) 53
Figure 3. 9 Example of filter strips (Source: Susdrain) 53
Figure 3. 10 Example of a rain garden (Source: Welshwildlife.org) 54
Figure 3. 11 Example of a portable containerised wastewater treatment works (Source: Vikaspumps.com) 64

Abbreviations

Abbreviation	Description
CJEU	Courts of Justice of the European Union
CNA	Community Network Areas
CSMQ	Common Standards Monitoring Guidance
Dutch-N	Dutch Nitrogen Case
EQS	Environmental Quality Standards
HRA	Habitats Regulations Assessment
N	Nitrogen
NAVs	New Appointments and Variations
NFM	Natural Flood Management
NVZ	Nitrate Vulnerable Zone
P	Phosphorus
PE	Population Equivalent
PR19	Price Review 19
PTP	Package Treatment Plants
SAC	Special Area of Conservation
SAGIS	Source Apportionment Geographical Information System
SIMCAT	Simulated Catchment
SPA	Special Protection Area
SPD	Supplementary Planning Document
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
TP	Total Phosphorus
TN	Total Nitrogen
WFD	Water Framework Directive
WwTW	Waste water treatment works

Glossary

Name	Description
Diffuse	The movement of ions or molecules from an area of higher concentration to an area of lower concentration
Point Pollution	Any single identifiable source of pollution from which pollutants are discharged, such as a pipe

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EXECUTIVE SUMMARY

Introduction and purpose of this report

Following the Dutch Nitrogen Case (‘Dutch-N’) in the court of Justice of the European Union (CJEU), which ruled that where an internationally important site (i.e., Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar Sites) is failing to achieve condition due to pollution, the potential for a new development to add to the nutrient load is "necessarily limited". The Dutch-N case has informed the way in which regulation 63 of the Habitats Regulation 2017 should apply to pollution related incidents and has resulted in greater scrutiny of proposed developments that are likely to increase nutrient loads to designated sites.

This report sets out suitable short-term mitigation options that could potentially be used to offset the additional nutrient load from a new development within the catchment of the River Wensum SAC and/or the Broads SAC, including potential strategic options to manage nutrient inputs and allow further residential development to proceed.

Potential short-term nutrient mitigation options

Following a detailed review of scientific literature and best practice guidance, a range of different nutrient management solutions were identified. Following an initial screening exercise, in which the potential viability of solutions were evaluated, the following types of solutions were identified as potentially viable for use in the River Wensum and Broads catchment:

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

Short-term solutions include:

- Taking land out of agricultural use
- Cessation of fertiliser and manure application
- Riparian buffer strips
- Wet woodlands
- Cover crops
- Bringing forward planned wastewater improvements
- SuDS
- Portable treatment works
- Alternative wastewater providers
- Retrofitting more water efficient fittings
- Package treatment plants
- Cesspools

Housing projections

In order to understand the mitigation required to meet the upcoming housing requirements, a review of local plan documents and housing projections was undertaken. The additional nutrient loading from the projected housing was calculated using the Norfolk Nutrient Budget Calculator (2022).

The outcome of the study determined 41,287 dwellings require mitigation until the end of the plan periods in 2038. This is equivalent to 4,706kg/yr of phosphorus mitigation and 51,509kg/yr of nitrogen mitigation.

Conclusions and next steps

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

- Assessment of long-term nutrient mitigation solutions.
- Identification of the preferred solutions to be delivered and the likely costs, timescales, and delivery mechanisms. This will likely be undertaken by the creation of a mitigation plan in order to formulate developer contributions.
- A database or spreadsheet-based tracking tool to register and record the nutrient loading for each development and through what schemes this will be mitigated. This should include details of any agreements. The tool should be able to assign credits from various mitigation schemes at various stages of the development lifetime. The local authorities are already aware of the need for this tool and are proactively seeking a solution by working with developers and solution providers in order to bring forward nutrient neutral development.
- A tracking tool could also be expanded to track ‘credits’ achieved through mitigation schemes that can be used for biodiversity net gain, carbon offsetting and nitrogen mitigation. There are currently no published tools designed for this.
- Standardised legal agreements could be drawn up and used as a basis in future mitigation schemes. Conservation covenants are one option that should be explored. Conservation covenants can be applied to ecoservices which involve a legal obligation to be attached to land.
- A Mitigation Plan should be established which would set out the key solutions and timescales for expected delivery. This will allow for quantification of when and how many credits will be available.

1 Introduction

1.1 Nutrient neutrality and the Dutch N Case

Following the Dutch Nitrogen Case (the 'Dutch-N'), which ruled that where an internationally important site (i.e., Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar Sites) is failing to achieve condition due to pollution, the potential for a new development to add to the nutrient load is "necessarily limited". The Dutch-N has informed the way in which regulation 63 of the Habitats Regulation 2017 should apply to pollution related incidents. This has resulted in greater scrutiny of proposed developments that are likely to increase nutrient loads to internationally important sites where a reason for unfavourable condition is an excess of a specific pollutant.

As a result, Local Planning Authorities in Norfolk are not able to provide planning permission for new developments that provide overnight accommodation within the catchment of the River Wensum SAC and/or the Broads SAC unless it can be clearly demonstrated that they will not have a detrimental impact in terms of nutrient loading to the protected area.

1.2 Purpose of this report

This report discusses potential solutions that could be used to offset increased nutrient loadings and allow development in the catchments of the River Wensum and Broads SACs to proceed whilst remaining nutrient neutral.

Section 2 of this report provides an overview of the River Wensum and Broads SACs and their contributing catchments and uses housing projections to identify likely mitigation requirements in each catchment and local authority district. Potential nutrient management solutions are described in **Section 2.2**, and **Section 4** provides a summary of the main findings of the report and recommendations for next steps.

2 Background

2.1 Protected habitats in Norfolk

Norfolk is home to a number of internationally important ecologically protected habitats, including the River Wensum Special Area of Conservation (SAC) and the Broads SAC. Natural England provide Conservation Objectives for ecologically sensitive habitats. These are referred to in the Conservation of Habitats and Species Regulations 2017 (as amended), and provide a framework which informs the need for 'Habitats Regulations Assessments' (HRA).

2.1.1 River Wensum SAC

Natural England's 2019 supplementary advice about the European Site Conservation Objectives relating to the River Wensum SAC (site code: UK0012647) summarises the habitat as a low gradient, groundwater dominated river. The upper reaches are fed by springs that rise from the chalk and by run-off from calcareous soils rich in plant nutrients. It is also designated as a Site of Special Scientific Interest (SSSI) (Ref. 1001954). The river supports an abundant and diverse invertebrate flora and fauna in a relatively natural corridor.

The river flows over chalk, particularly in the upper reaches, and a complex sequence of superficial glacial drift deposits of sands and gravels which increase in thickness in the lower reaches. As the river is often separated from the chalk aquifer by these superficial glacial deposits, it does not exhibit some of the characteristics of "classic" chalk rivers. However, the chalk and run-off from calcareous soils gives rise to beds of submerged and emergent vegetation characteristic of a chalk stream.

Water management and artificial drainage significantly affect the levels of water and flow in the catchment. The once meandering river has been modified and managed historically and the channel has been straightened, dredged, diverted, impounded and embanked. Some reaches have been subject to excessive silt ingress, and/or lack natural riparian vegetation.

Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation; Rivers with floating vegetation often dominated by water-crowfoot is a qualifying habitat of Annex I of the (Conservation of Natural Habitats and of Wild Fauna and Flora) Habitats Directive (92/43/EEC). The qualifying features with respect to the SAC designation are described as:

- S1016 Desmoulin`s whorl snail (*Vertigo moulinsiana);*
- S1092 White-clawed (or Atlantic stream) crayfish (*Austropotamobius pallipes*);
- S1096 Brook lamprey (*Lampetra planeri*); and
- S1163 Bullhead (*Cottus gobio*).

2.1.2 Broads SAC, SPA and Ramsar

Natural England's 2019a supplementary advice about the European Site Conservation Objectives relating to The Broads SAC (site code UK0013577) summarises the habitat as an example of nutrient-rich lakes and contain several SSSIs. The Broadland Ramsar site and Broadland SPA overlies The Broads SAC. It is designated under article 4(4) of the Directive (92/43/EEC) as it hosts the following habitats listed in Annex I:

- H3140 Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. (Calcium-rich nutrient-poor lakes, lochs and pools);

- H3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation. (Naturally nutrient-rich lakes or lochs which are often dominated by pondweed);
- H6410 Molinia meadows on calcareous, peat or clay-silt soil (*Molinion caeruleae*).(Purple moor-grass meadows);
- H7140 Transition mires and quaking bogs, (very wet mires often identified by an unstable 'quaking' surface);
- H7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*.(Calcium-rich fen dominated by great fen sedge (saw sedge));
- H7230 Alkaline fens (Calcium-rich spring water-fed fens); and
- H91E0 Alluvial woods with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*). (Alder woodland on floodplains).

The site hosts the following species listed in Annex II:

- S1016 Desmoulin's whorl snail (*Vertigo moulinsiana);*
- S1355 Otter, (*Lutra lutra);*
- S1903 Fen orchid, (*Liparis loeselii); and*
- S4056 Little ram's-horn whirlpool snail (*Anisus vorticulus).*

The Broads is fed by three major river catchments; the River Wensum, the River Bure and the River Yare. The Broads catchment covers much of mid and east Norfolk, containing the city of Norwich as well as the towns of Dereham, Wymondham, Aylsham, Fakenham, North Walsham and Long Stratton.

2.1.3 Contributing catchments

Figure 2-1 presents a map of the River Wensum, River Bure and River Yare catchments, which could supply nutrients into the River Wensum SAC and the Broads SAC. This is based on surface hydrological catchments (i.e. the natural drainage network), as defined by the Environment Agency as part of the South East River Basin Management Plan (RBMP).

However, nutrient supply paths are complicated by the artificial wastewater catchments that cut across natural drainage patterns. This means that wastewater produced within a surface drainage catchment could potentially be collected, treated and discharged outside of that catchment. Conversely, the opposite could also apply, with wastewater produced outside a surface drainage catchment being discharged inside that catchment. The catchments shown in **Figure 2-1** have therefore been refined to reflect the foul water catchments and the locations at which they discharge. The Broads catchment is further sub-divided into four sub-catchments comprising the Bure, Ant Broad, Thurne Broad and Trinity Broad.

Mitigation must be delivered within the same catchment as the development. The discharge location of wastewater is used to determine where a development will have the greatest impact on nutrient concentrations. A development site may be located in one surface water (i.e. Wensum, Yare or Bure) catchment but the wastewater discharge will be within a different surface water catchment. Mitigation should also be provided upstream of the component SAC site in the Broads SAC catchment and upstream of the point of impact (i.e. wastewater discharge) in the Wensum.

The Yare Broads and Marshes SSSI (which is one of the designated sites within the Broads SAC subject to nutrient neutrality requirements) is located downstream within the Yare catchment. Any mitigation upstream of the Yare Broads and Marshes SSSI can provide mitigation for the River Yare catchment, including within the River Wensum catchment.

The River Wensum SSSI is only designated for phosphorus neutrality. However, the Wensum is a tributary of the Yare catchment which is subject to both phosphorus and nitrogen neutrality requirements. Therefore, any development in the Wensum catchment must provide phosphorus mitigation within the Wensum catchment and nitrogen mitigation within either the Wensum or Yare catchment.

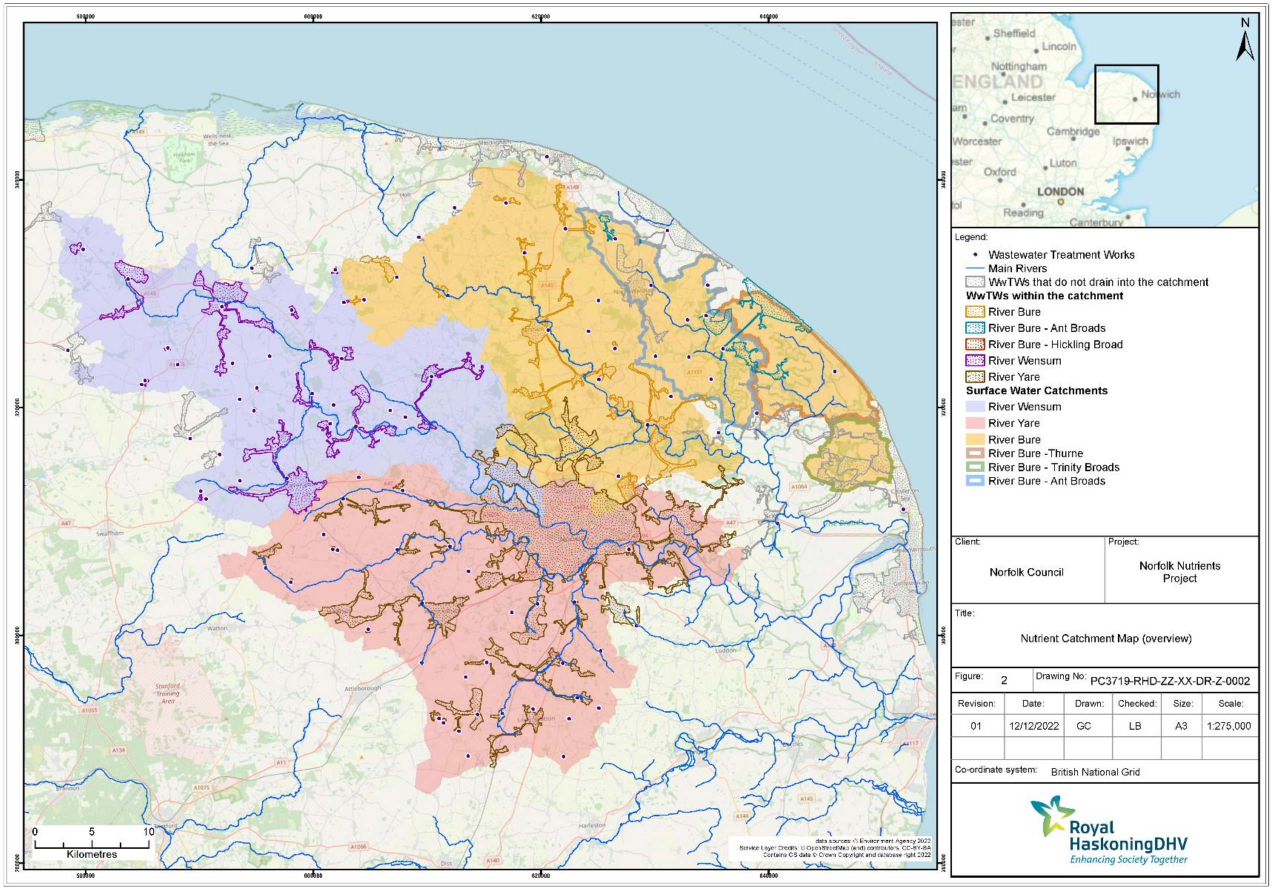

Figure 2-1: Norfolk nutrient catchment map

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2.2 Projected mitigation requirements

2.2.1.1 Methods and assumptions

In order to understand the mitigation required to meet the upcoming housing requirements, a review of local plan documents and housing projections was undertaken. The additional nutrient loading from the projected housing was calculated using the Norfolk Nutrient Budget Calculator (2022). Worst-case scenarios were assumed to ensure the nutrient loading value is not understated. For example, conservative assumptions were taken on future permit limits and land use types.

The following assumptions were made:

- All new dwellings were assumed to be houses with an average occupancy of 1.88 persons per dwelling;
- The previous land use of the sites was derived from aerial imagery.
- Where the land use type was uncertain, it was assumed to be general arable which represents one of the dominant land use types in the catchment and has a runoff coefficient close to the average of all the land uses;
- The proposed land use was assumed to be entirely urban;
- The soil drainage type was derived from Soilscapes and the dominant soil of the area was chosen;
- The wastewater treatment works that a proposed development will drain to was estimated using GIS data on the existing catchment of wastewater treatment works.
- Where onsite treatment plants are to be used, default values of 5mg/l TP and 25mg/l TN were used. These represent the likely effluent concentration from a typical package treatment plant but are still conservative estimates of what P-stripping package treatment plants can achieve.
- A 20% buffer was applied to the calculations in line with natural England guidance on nutrient neutrality (Natural England, 2020).
- The catchment that a development will contribute the nutrient loading to was determined by the location of the treatment works. Some developments will be located in one surface water catchment but the wastewater (and majority of the nutrient contribution) will drain to a different catchment.

The end dates of the Local Plans for the various local authorities did not align. In order to provide a standardised approach, the housing projections for North Norfolk, Breckland, West Norfolk and the Broads Authority were calculated up to 2036 and assumed to continue at the same rate up to 2038. The housing projections for Broadland, South Norfolk and Norwich were calculated up to 2038.

It was assumed that the affected projected development will be evenly spread across up to 2038 and within each year. The developments currently held up due to nutrient neutrality are as follows:

- Breckland - 668
- Broadland – 2,635
- Norwich – 2,257
- North Norfolk – 1,509
- South Norfolk – 3,887

Breckland developments currently held up only includes delayed developments. Permitted planning applications, unused allocations and windfall (143 per year) are evenly spread between 2023 and 2038.

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It was assumed that all development currently held up is in addition to the development projected in the various Local Plans to come forward between 2023 – 2038. It was also assumed that all development currently held up would require nutrient mitigation by the end of 2025.

The calculations consider reductions in permit limits that will take effect at the end of the AMP7 Cycle (December 2024). Furthermore, proposed April 2030 permit limit reductions were also included following the Department for Levelling Up, Housing and Communities announcement on the 18th November 2022. It was assumed that only wastewater treatment works with a current population equivalent of greater than 2000 would be operating at Technically Achievable Limit (TAL) by 2030. The TAL for TP and TN is 0.25mg/l and 10mg/l, respectively.

2.2.1.2 Projected housing growth per LPA district

The projected growth was derived from the respective Local Plans and previous housing data for each district and is presented in **Table 2.1**. A total of 41,287 dwellings are projected across the entire nutrient neutrality catchment.

Table 2.1: *Summary of the planned growth in Norfolk*

District	Dwellings	Source
North Norfolk	4,237 (1,509)	North Norfolk Local Plan allocations + windfall
Breckland	3,903 (668)	Breckland Local Plan (2019) + Delayed applications
West Norfolk	15	King's Lynn and West Norfolk Local Plan (2016)
Broads Authority	145	Local Plan for the Broads (2019)
Broadland	13,770 (2,635)	Greater Norwich Local Plan
South Norfolk	9,072 (3,887)	Greater Norwich Local Plan
Norwich	9,397 (2,257)	Greater Norwich Local Plan
Total	**41,287 (10,956)**	**-**

*value in brackets represents dwellings currently held up due to nutrient neutrality.

The expected phosphate and nitrate loading per year for each district is provided in **Table 2.2** and Table **2.3**. These tables show the amount of additional mitigation that is required each year within the defined period. The cumulative total for 2023 to 2038 is provided in the 'Total' column.

The total additional TP load is predicted to be 4,706kg/yr. In 2023 the required mitigation is 715kg/yr due to the number of dwellings currently held up. Following the improvements to treatment works in 2030, the TP loading per year will be 167kg/yr. Similarly, the TN loading is 51,509kg/yr, This is approximately 9,538kg/yr of loading per year until 2025, 3,276kg/yr for each year between 2026 and 2029 and 1,088kg/yr post 2030.

Table 2.2: *Total phosphorus loading per LPA District*

District	Phosphate loading per year (kg/yr)

	2023 - 2024	2025	2026 - 2029	2030 - 2038	Total
North Norfolk	89.15	88.76	26.42	15.00	**507.72**
Breckland	132.22	132.22	68.94	62.50	**1,234.94**
West Norfolk	0.08	0.08	0.08	0.08	**1.29**
Broads Authority	1.12	1.12	1.12	1.12	**12.22**
Broadland	219.63	216.15	93.59	59.35	**1,563.90**
South Norfolk	177.03	173.43	38.38	19.01	**852.06**
Norwich	96.74	96.74	37.60	10.36	**533.83**
Great Yarmouth	0.00	0.00	0.00	0.00	**0.00**
Total	**715.97**	**708.50**	**266.13**	**166.78**	**4,705.96**

Table 2.3: *Total nitrogen loading per LPA District*

District	Phosphate loading per year (kg/yr)			
	2023 - 2025	2026 - 2029	2030 - 2038	Total
North Norfolk	942.00	340.77	109.12	**5,171.15**
Breckland	664.52	289.49	155.88	**4,554.47**
West Norfolk	1.26	1.26	1.26	**20.09**
Broads Authority	17.52	17.52	3.05	**150.03**
Broadland	2180.46	1036.31	292.66	**13,320.58**
South Norfolk	2945.71	546.46	127.70	**12,172.28**
Norwich	2786.85	1044.00	398.20	**16,120.37**
Great Yarmouth	0.00	0.00	0.00	**0.00**
Total	**9,538.30**	**3,275.81**	**1,087.87**	**51,508.97**

Table 2.4 outlines the permanent and temporary mitigation required assuming permit limits are reduced to the TAL by 2030. **Figure 2.2** and **Figure 2.3** provide a visual representation of the permanent and temporary mitigation required.

A total of 1,378.85kg/yr of temporary TP mitigation is required up to 2030, which is approximately 29% of the total mitigation required. The temporary TN mitigation required is 29,446.75kg/yr and approximately 57% of the total mitigation required.

Table 2.4: *Mitigation required assuming permit limits are reduced to the TAL post 2030*

District	Total TP mitigation	Permanent TP mitigation	Temporary TP mitigation (up to 2030)	Total TN mitigation	Permanent TN mitigation	Temporary TN mitigation (up to 2030)
North Norfolk	507.72	332.58	175.15	5171.15	1745.91	**3425.24**
Breckland	1234.94	1174.78	60.16	4554.47	3234.29	**1320.17**
West Norfolk	1.29	1.29	0.00	20.09	20.09	**0.00**

District	Total TP mitigation	Permanent TP mitigation	Temporary TP mitigation (up to 2030)	Total TN mitigation	Permanent TN mitigation	Temporary TN mitigation (up to 2030)
Broads Authority	12.22	7.81	4.41	150.03	48.73	**101.30**
Broadland	1563.90	1182.95	380.96	13320.58	5063.73	**8256.85**
South Norfolk	852.06	422.39	429.67	12172.28	3615.91	**8556.37**
Norwich	533.83	205.33	328.51	16120.37	8333.56	**7786.81**
Great Yarmouth	0.00	0.00	0.00	0.00	0.00	**0.00**
Total	**4705.96**	**3327.11**	**1378.85**	**51508.97**	**22062.22**	**29446.75**

Figure 2.2: *Mitigation requirements for TP*

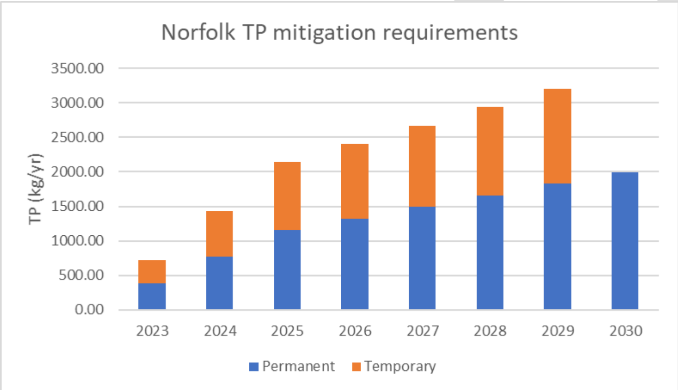
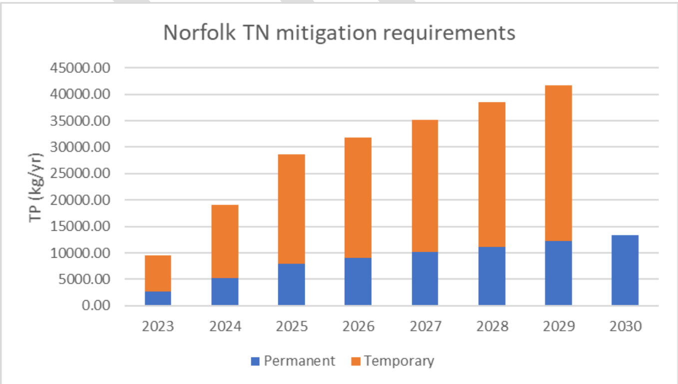


Figure 2.3: *Mitigation requirements for TN*



2.2.1.3 Projected housing growth per catchment

The projected nutrient loading from projected development has also been calculated for the Wensum, Yare and Bure catchments, as presented in **Table 2.5 and Table 2.6.** The majority of the nutrient mitigation is required within the River Yare catchment. This is primarily due to the discharge locations of wastewater treatment works within Norfolk, particularly Whitlingham treatment works which serves Norwich and surrounding areas.

Table 2.5 *Phosphorus mitigation requirements per river catchment*

District	Phosphorus loading (kg/yr)				
	2023 - 2024	2025	2026 - 2029	2030 - 2038	Total
Wensum	82.06	82.06	26.32	14.42	**481.21**
Yare	548.75	545.15	204.41	123.65	**3.257.13**
Bure sub-catchment	72.21	68.73	30.17	25.36	**562.04**
Ant sub-catchment	12.79	12.40	5.08	3.31	**88.07**
Thurne sub-catchment	0.15	0.15	0.15	0.05	**1.51**
Trinity sub-catchment	0	0	0	0	**0**
Total	**715.97**	**708.50**	**266.13**	**166.78**	**4,705.96**

Table 2.6: *Nitrogen mitigation requirements per river catchment*

District	Nitrogen loading (kg/yr)			
	2023 - 2025	2026 - 2029	2030 - 2038	Total
Wensum	1,014.21	369.56	72.23	**5,170.93**
Yare	7,752.38	2,479.84	734.91	**39.790.75**
Bure sub-catchment	638.96	364.67	252.64	**5,649.27**
Ant sub-catchment	130.01	58.99	27.83	**876.44**
Thurne sub-catchment	2.74	2.74	0.26	**21.59**
Trinity sub-catchment	0	0	0	**0**
Total	**9,538.30**	**3,275.81**	**1,087.87**	**51,508.97**

Table 2.7 outlines the permanent and temporary mitigation required assuming permit limits are reduced to the TAL by 2030.

Table 2.7: *Mitigation required assuming permit limits are reduced to the TAL post 2030*

District	Total TP mitigation	Permanent TP mitigation	Temporary TP mitigation (up to 2030)	Total TN mitigation	Permanent TN mitigation	Temporary TN mitigation (up to 2030)
Wensum	481.21	319.37	161.83	5170.93	1330.02	3840.91
Yare	3573.13	2446.21	1126.92	39790.75	15859.42	23931.33
Bure sub-catchment	562.04	498.84	63.19	5649.27	4423.33	1225.94
Ant sub-catchment	88.07	61.86	26.21	876.44	445.24	431.20
Thurne sub-catchment	1.51	0.82	0.69	21.59	4.22	17.37
Trinity sub-catchment	0.00	0.00	0.00	0.00	0.00	0.00

The expected TP and TN loading per year for each LPA district within the Wensum, Yare and Bure catchments are provided in **Table 2.8** and **Table 2.9**. The greatest TP mitigation is required in Breckland and Broadland. Despite Breckland having much lower development aspirations than Broadland, the lack of current and future phosphorus stripping at wastewater treatment works results in large TP loads. For example, a significant proportion of the development proposed in Breckland will drain to Shipdham water recycling centre which has a current population of 1,946. This is below the 2,000 threshold for mandatory TAL in 2030 which would make a significant difference to the permanent TP loading in the district.

The greatest TN mitigation requirements are in Norwich Broadland and Breckland. The modest proposed development within the nutrient neutrality catchments for West Norfolk and the Broads Authority results in low mitigation requirements.

Table 2.8: *Phosphorus mitigation requirement breakdown per river catchment for each LPA District*

District		Phosphorus loading (kg/yr)				
		2023 - 2024	2025	2026 - 2029	2030 - 2038	Total
North Norfolk	Wensum	57.10	57.10	10.69	4.38	**253.50**
	Bure	19.12	19.12	10.50	7.25	**164.64**
	Ant	12.79	12.40	5.08	3.31	**88.07**
	Thurne	0.15	0.15	0.15	0.05	**1.51**
Breckland	Wensum	23.78	23.78	14.44	9.553	**414.82**
	Yare	108.44	108.44	54.50	52.97	**1,020.12**
West Norfolk	Wensum	0.08	0.08	0.08	0.08	**1.29**
Broads Authority	Bure	0.14	0.14	0.14	0.03	**1.21**
	Yare	0.98	0.98	0.98	0.46	**11.00**
Broadland	Wensum	1.11	1.11	1/11	0.42	**11.60**
	Yare	165.56	165.56	72.94	40.85	**1,156.12**
	Bure	52.96	49.48	19.53	18.07	**296.19**

District		Phosphorus loading (kg/yr)				
		2023 - 2024	2025	2026 - 2029	2030 - 2038	Total
South Norfolk	Yare	177.03	173.43	3.38	19.01	**852.06**
Norwich	Yare	96.74	96.74	37.60	10.36	**533.83**
Great Yarmouth	Trinity	0.00	0.00	0.00	0.00	**0.00**
Total		**715.97**	**708.50**	**266.13**	**166.78**	**4,705.96**

***Table 2.9:** Nitrogen mitigation requirement breakdown per river catchment for each LPA District*

District		Nitrogen loading (kg/yr)			
		2023 - 2025	2026 - 2029	2030 - 2038	Total
North Norfolk	Wensum	640.52	181.32	31.90	**2933.93**
	Bure	168.73	97.71	49.13	**1339.19**
	Ant	130.01	58.99	27.83	**876.44**
	Thurne	2.74	2.74	0.26	**21.59**
Breckland	Wensum	346.60	161.15	31.42	**1967.21**
	Yare	317.92	128.34	124.46	**2587.25**
West Norfolk	Wensum	1.26	1.26	1.26	**20.09**
Broads Authority		3.23	3.23	1.16	**33.08**
	Yare	14.29	14.29	1.88	**116.96**
Broadland	Wensum	25.83	25.83	7.65	**249.70**
	Yare	1,687.62	746.76	82.67	**8793.89**
		467.00	263.72	202.34	**4276.99**
South Norfolk	Yare	2,945.71	546.46	127.70	**12172.28**
Norwich	Yare	2,786.85	1,044.00	398.20	**16120.37**
Great Yarmouth	Trinity	0.00	0.00	0.00	**0.00**
Total		**9,538.30**	**3,275.81**	**1,087.87**	**51,508.97**

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3 Potential Nutrient Management Solutions

3.1 Types of nutrient management solution

This report outlines solutions that can be used to achieve nutrient mitigation for the purpose of allowing planning applications to proceed. Some established solutions for nutrient management at a catchment-scale do not provide the certainty that is required for mitigating new developments and were not assessed here. Examples include methods adopted by catchment sensitive farming (CSF) is a government land management initiative (Natural England, 2022) that provides support such as farm advice, training and capital grants targeted at priority catchments to help reduce soil erosion and nutrient losses to water (air and soil).

Another example is compacted soil via tramline & wheeling disruption, Norfolk River Trust webpage summarises a study on the effect of tramline management (Cranfield, 2018) which indicates that wheelings and tramlines are a pathway for soil and nutrients as surface run-off within arable land.

Controlled traffic movements practice is described on the Soil Quality webpage as traffic control to confine soil compaction to smaller portions of a field, rather than random (uncontrolled) farm traffic patterns which create soil compaction across a wider field area. Controlled traffic movements can improve water infiltration and plant root growth.

Solutions where there is the potential to comply with Natural England's HRA tests (detailed below) were assessed further. The solutions have been classified into the following categories:

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

The following sections present a brief overview of the potential short-term nutrient management solutions that are considered and describes how they are appraised (**Section 3.2**). This is followed by a more detailed description and appraisal of Nature-based Solutions(**Section 3.3**), Runoff Management Solutions (**Section 3.4**), Wastewater Management Solutions (**Section 3.5**) and Demand Management Solutions (**Section 3.6**). Medium and long-term delivery timescale options have not been included at this stage of the project.

3.2 Potential nutrient management solutions

3.2.1 Overview

The potential nutrient management solutions that are considered in this report are listed in Error! Reference source not found.. This overview table provides an indication of the timescales in which the solution could be delivered. A full description of each solution is provided in the subsequent sections of this report, as indicated by the cross references provided in **Table 3.1.**

Natural England advice on mitigation principles which was issued to Local Planning Authorities in March 2022 was used to assess the suitability of solutions and to ensure solutions meet the requirements of the Habitat regulations.

Table 3.1 Potential nutrient management solutions

Type	Solution	Delivery timescale	Further information
Nature-based solutions	Silt traps	Short-term	Section 3.3.1
	Riparian buffer strips	Short-term	Section 3.3.2
	Constructed wetlands	Medium-term	Section X
	Wet woodlands	Short-term	Section 3.3.3
	Willow buffers	Short-term	Section 3.3.4
	Beetle banks	Short-term	Section 3.3.5
	Broadland restoration	Long-term	Section X
	Beaver reintroduction	Medium-term	Section X
Runoff management solutions	Taking land out of agricultural use	Short-term	Section 3.4.1
	Solar farms	Short-term	Section 3.4.2
	Cessation of Fertiliser and Manure Application	Short-term	Section 3.4.3
	Farm management measures	Medium-term	Section X
	Cover crops	Short-term	Section 3.4.4
	Installing Sustainable Drainage Systems in new developments	Short-term	Section 3.4.5
	Retrofitting Sustainable Drainage Systems in existing developments	Medium-term	Section X
Wastewater management solutions	Expedite planned improvements to treatment works	Short-term	Section 3.5.1
	Improve existing wastewater treatment infrastructure	Long-term	Section X
	Improve existing wastewater distribution infrastructure (reduce leakage from foul sewer network)	Long-term	Section X
	Install portable treatment works	Short-term	Section 3.5.1
	Remedying misconnections to combined systems	Long-term	Section X
	Incentivise disconnection from combined systems	Long-term	Section X
	Use alternative wastewater treatment providers	Medium-term	Section X
	Install package treatment plants	Short-term	Section 3.5.1
	Upgrade existing private sewage systems	Medium-term	Section X
	Install cesspools and capture outputs from private sewage systems	Short-term	Section 3.5.4
Demand management solutions	Retrofit water saving measures in existing properties (local authority, registered providers, public buildings)	Short-term	Section 3.6.1
	Retrofit water saving measures in existing properties (private housing, commercial and industrial premises)	Short-term	Section 3.6.2
	Incentivise commercial water efficiency	Short-term	Section 3.6.3

Commented [EH1]: Note: This report is focused upon short-term options. As such some medium and long term options have not been included at this stage of the project.

3.2.2 Description of nutrient management solutions

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

Table 3.2 Description of nutrient management solutions

Descriptor	Definition
Description of solution	This section provides an overview of the nutrient management solution and the activities required for its implementation.
Nutrient removal	This section provides a summary of the nutrient removal that the solution could potentially deliver.
Delivery timescale	Delivery timescales are classified as follows: • Short: The solution could potentially be implemented in 1 year or less. Planning permission, policy changes and significant funding are not likely to be required, although it may be necessary to obtain third party consents and agreements. • Medium: The solution could potentially be implemented over a period of 1 to 5 years. Planning permission, policy changes and/or third-party funding are likely to be required, alongside other third-party consents and agreements. • Long: It is likely to take more than 5 years to implement the solution. Environmental Impact Assessment (EIA), major policy changes and/or significant funding are likely to be required, alongside other third-party consents and agreements.
Duration of operation	The longevity of the solution is classified as follows: • Temporary: The solution is likely to remain in place for up to 5 years and could be secured through interim or temporary agreements with third parties. • Impermanent: The solution is likely to remain in place for between 5 and 10 years, secured in agreement with third parties. • Permanent: The solution is likely to remain in place for more than 10 years and could be secured in perpetuity through long term agreements with third parties.
Applicability	This section provides a high-level summary of the potential applicability of the solution in the catchment(s), including constraints posed by farm type, land use, etc.
Management and maintenance requirements	This section describes the management and maintenance activities that are required to maintain the effectiveness of the solution.
Additional benefits	This section provides a description of any additional secondary benefits that could be delivered alongside the primary nutrient management aim of the solution.
Best available evidence	Sufficient reliable evidence which provides certainty that mitigation may be effective. It should be noted, with some types of mitigation there will be, (particularly with novel or complex mitigation), uncertainty as to the exact effectiveness the mitigation may deliver.
Wider environmental considerations	This section provides a description of any wider environmental constraints that could be associated with the solution.
Evidence of effectiveness	This section summarises any evidence available to demonstrate the effectiveness of the solution in managing nutrient supply.
Precautionary	The precautionary principle is an approach to ensure sufficient certainty via application of a precautionary an efficacy value based on the evidence can be applied, or provision of greater mitigation than required. For example, monitoring efficacy of a mitigation measure may provide evidence and therefore certainty which can be relied upon.
Securable in perpetuity	Natural England Nutrient Neutrality Principles guidance (Wood *et al* 2022) defines 'in perpetuity' timeframe between 80-125 years and 'securable' is defined as practical certainty that the mitigation measures will be implemented and in place at the relevant time. Mitigation measures which can be secured through legally binding obligations that are enforceable are understood to be securable in perpetuity. Likewise, a mitigation measure which can offer tax relief or a grant for example, although not legally enforceable, is considered to offer a degree of security.
Cost estimate	This section provides an outline estimate of the costs associated with implementing the solution. Costs are given over 80 years (the lifetime of the development) to allow for direct comparison with long-term solutions. Costs typically exclude administration and legal costs which are likely to apply to all solutions. Costs also exclude development of monitoring regimes to measure the effectiveness.

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3.2.3 Monitoring

Baseline data has been obtained from various literature sources and other public domain data providers. The data compiled within this study has been relevant to the catchments and at this stage of the project sites have not been selected to have a mitigation solution installed. In the absence of a selected site(s), it is not possible to determine if baseline data is available or commence a monitoring programme to establish a baseline. Water company initiatives to reduce nutrient output from WwTWs may change the baseline in the near future at some Environment Agency monitoring points.

Cost estimates are included within some of the solutions described in the following sections such as riparian buffer strips, detailed in Section 3.3.2 where costs have been easily derived from Farmscoper. The varying parameters of monitoring requirements according to the solution (or combination of solutions), site-specific detail and available relevant data mean it is not possible to provide costs for monitoring effectiveness for solutions at this stage. However, as part of site selection for mitigation solutions it may be prudent to undertake site-specific baseline P soil and water measurements early on in the design and planning stage.

Monitoring typically would require 'wet weather' sampling over at least one year in order to recognise seasonal difference and include laboratory analysis of total P, dissolved P and orthophosphate.

3.3 Nature-based solutions

3.3.1 Silt traps

3.3.1.1 Description of solution

Table 3.5 shows key considerations associated with silt traps. Silt traps can be installed on farms to catch sediment bound phosphates that would be periodically removed. The benefits of silt traps on water quality are well established. Examples of different types of silt traps are presented in **Figure 3. 1** and **Figure 3. 2**.

Figure 3. 1 Silt trap installed in a stream (Source: IRD Duhallow, 2015)

Figure 3. 2 Silt fencing installed on agricultural fields (Source: HY-TEX, 2022)

3.3.1.2 Nutrient removal

Evidence is available in respect of the silt capture rate, however, currently there a large degree of uncertainty specifically regarding the nutrient removal rate, which is dependent on multiple variables (e.g., location, soil type, rainfall, frequency of de-silting) and is likely to differ between locations. Design of silt trap installation and collection of quantitative nutrient data is required according to site-specific variables to seek optimal locations and pilot trials are considered necessary to determine the number of traps in a series of silt traps.

Reducing sediment runoff should be a matter of farming good practice where there is a serious risk of fine-grained sediment pollution. Therefore, mitigation schemes should not promote soil erosion or be installed at locations where ongoing soil erosion is currently taking place as locations such as these should be managed in line with farming good practice. Furthermore, a silt trap scheme should not be reliant upon water supply from one single upstream surface water source as this does not provide sufficient certainty of the long term nutrient removal.

The Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS) indicates that TP removal is regularly reported between 25-75% for well designed and sites sydtems during design condition events. TN removal is typically reported to remove less than 25%.

3.3.1.3 Delivery timescale

Silt traps require limited infrastructure and, depending upon their location, may not require any environmental permits. They can therefore be delivered in the short term.

3.3.1.4 Duration of operation

Silt traps are considered to be impermanent but long-term solutions, provided that they are adequately maintained throughout their lifetime.

3.3.1.5 Applicability

Typically, this nature-based solution is applicable for all farm typologies.

3.3.1.6 Management and maintenance requirements

Maintenance costs dependent on the loading rate and location but periodic clearance every 2 – 5 years. Maintenance costs are likely to be £500 per year. Returning the silt to land as a replacement for fertiliser may lead to overall financial savings for farmers. There is a possibility that in the future this solution would also be covered as part of countryside stewardship agreements that could provide additional financial benefits.

3.3.1.7 Additional benefits

Silt traps are effective in improving the quality of water in the drainage network by reducing sediment supply to downstream watercourses. This can result in improved habitat quality for aquatic plants, invertebrates and fish, particularly those that are sensitive to high turbidity or require coarse substrates for part of their life cycle.

3.3.1.8 Wider environmental considerations

Periodic removal of the sediment containing nutrients and any other chemicals which have collected requires consideration, with particular respect to re-use or waste disposal in addition to any environmental considerations related to removal and transport.

3.3.1.9 Evidence of effectiveness

Although there is considerable evidence that supports the use of silt traps as effective measures to remove sediment from flowing water (e.g., Environment Agency, 2011), there is limited evidence of their effectiveness in removing nutrients.

Although the solution is likely to have some effectiveness in the removal of sediment-associated nutrients, it is less likely to be effective at removing nutrients transported in the dissolved phase. The solution is therefore likely to be more effective in removing P than N, although there is a large uncertainty regarding its effectiveness. As such, monitoring and potentially pilot trials would be required to provide representative data which measures nutrient removal rate potential.

3.3.1.10 Deliverability and certainty

There is a large amount of uncertainty regarding removal rate which is dependent. This is dependent upon a number of parameters which determine variable success, for example water flow rates and storm events.

3.3.1.11 Cost estimate

Capital costs are between £1,000-£4,000 with additional maintenance costs of £500 per annum.

Table 3.3 and **Table 3.4** provide an indication of the likely mitigation that could be delivered and associated costs in each sub-catchment. This assumes a silt trap removes 25% of the TP and TN load from a 1 cereal field and the costs outlined above. This assumes that 100% of the flow is treated by a series of silt traps.

Table 3.3 Estimated TP mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£/ha)	£/kg TP/yr for each year	£/dwelling for each year	£/kg TP/yr over 80 years	£/dwelling over 80 years
Wensum	0.18	3	500	2740	186	219178	14868
Yare	0.09	1	500	5882	399	470588	31923
Bure	0.02	0	500	33333	2261	2666667	180895

Table 3.4 Estimated TN mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£/ha)	£/kg TN/yr for each year	£/dwelling for each year	£/kg TN/yr over 80 years	£/dwelling over 80 years
Wensum	5.94	3	500	84	159	6737	12694
Yare	4.81	3	500	104	196	8320	15678
Bure	6.44	3	500	78	146	6214	11708

3.3.1.12 Summary

Table 3.5 Silt traps

Key considerations	
Delivery timescale	Short-term
Duration timescale	Impermanent
P removal potential	Large uncertainty
Farm Typologies applicable	All applicable
Management / Maintenance requirements	Regular de-silting will be required
Additional benefits	Water quality
Based on best available evidence?	No
Effective beyond reasonable scientific doubt?	Yes – although there is evidence to indicate effective sediment capture, the effectiveness can vary considerably under different conditions, poor design and poor management. As such, there is currently uncertainty regarding nutrient removal rate.
Precautionary?	Yes
Securable in perpetuity?	Yes – management agreements will likely need to be put in place, especially where land in leased. Replacements may be required if the lifetime is less than the developments.
Cost estimation	Capital costs: £1,000 - £4,000. Maintenance costs: £500/yr.

3.3.2 Riparian buffer strips

3.3.2.1 Description of solution

Riparian buffer zones are strips from 5m wide composed of permanent grass and/or woodland cover that act as a separation between the agricultural field and a watercourse. They can also act as a filter between point sources of nutrients and the surface drainage network. Phosphorus reductions are achieved through sedimentation of phosphate-bound particles and uptake via vegetation.

3.3.2.2 Nutrient removal

Vegetation within buffer strips increases surface roughness and reduces runoff rates, which in turn promotes infiltration (Hoffman *et al*., 2009).

Riparian buffer strips are typically located at field margins and are, therefore, more likely to be adopted by farmers. **Table 3.6** shows a summary of recent published research on phosphorus removal using buffer strips. Buffer strips composed of woody material as opposed to herbaceous material can store significant amounts of biomass phosphorus (Fortier *et al*., 2015), whilst woody buffers are more effective at trapping sediment than grasses (Hoffmann *et al*., 2009, Anguiar *et al*., 2015). Woodland buffers, particularly those containing willow, also have less onerous maintenance requirements than grassland buffers. The phosphorus removal rate is greatest during the first few metres of the buffer strip. However, the highest total removal rates are typically only achieved in buffer strips 15m to 20m wide. Vought *et al* (1994) found that in grass buffer strips the phosphorus removal in the first eight metres was 66%, and by 16m, 95% removal was achieved. To obtain maximum nutrient retention a buffer width of 10m to 20m is needed, alongside a density of vegetation (Vought *et al*., 1994). Wide buffer strips can also allow for the restoration of wetlands in wet lying areas and the creation of small scrapes alongside tree planting.

Table 3.6 outlines the phosphorus removal efficiency achieved by riparian buffer strips depending on their soil types and width (Zabronsky, 2016). The major soil type does not appear to have a strong control over removal efficiency.

Table 3.6 Riparian buffer effectiveness depending on buffer width and soil type (edited from Zabronsky (2016))

Study	Vegetation cover	Buffer width	Phosphorus removal efficiency (%)	Major soil type
Chaubey *et al*., 1995	Grass	3.1	39.6	Silt
	Grass	6.1	58.4	Silt
	Grass	9.2	74.0	Silt
	Grass	15.2	86.8	Silt
	Grass	21.4	91.2	Silt
Meals, 1996	Grass	Unknown	86	Clay
Lee *et al*., 1998	Grass	3	39.5	Loam
	Grass	3	35.2	Loam
	Grass	6	55.2	Loam
	Grass	6	49.4	Loam
Lim *et al*., 1998	Grass	6.1	76.1	Silt
	Grass	12.2	90.1	Silt
	Grass	18.3	93.6	Silt
Dillaha *et al.*, 1989	Grass	9.1	79	Silt loam
	Grass	4.6	61	Silt loam

Figure 3. 3 confirms that removal efficiency increases with buffer width and that buffer widths of 15m to 20m are most favourable. Beyond 20m the removal efficiency does not dramatically increase, and it may not be viable for the agricultural land take required.

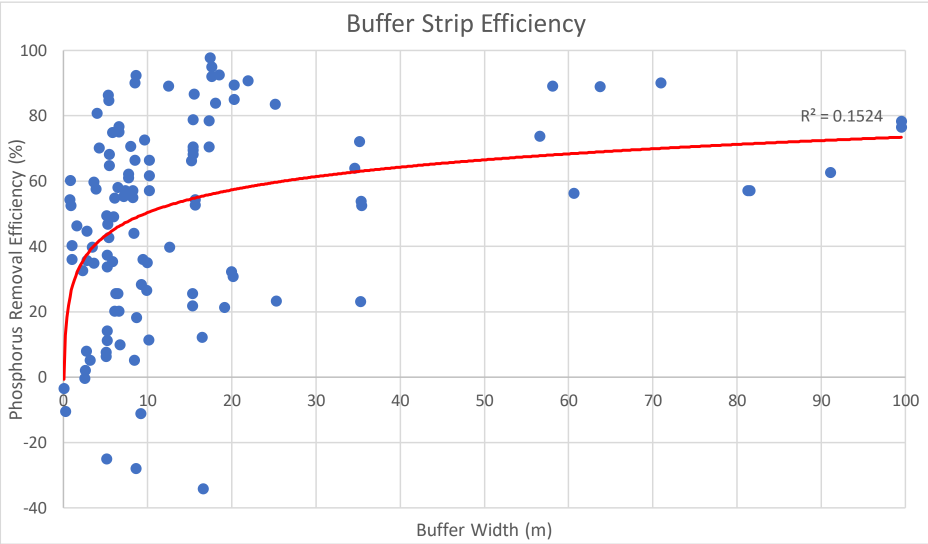

Figure 3. 3 Buffer strip efficiency (Edited from Tsai et al. 2016)

Site-specific factors also play a role in controlling nutrient reductions from riparian buffer strips and should be considered when considering the most appropriate location for buffer strip placement. For example, the orientation of the buffers and the adjacent agricultural activity are both important considerations. Typically, riparian buffers adjacent to agricultural land used for cropping will achieve the greatest real-world reduction rates due to the potential to remove a high degree of phosphate bound sediment in the runoff.

There is considerable evidence within the scientific literature regarding the effectiveness of buffer strips as solutions for nutrient removal. **Figure 3. 4** shows the relationship between riparian buffer width and nitrogen removal for all studies.

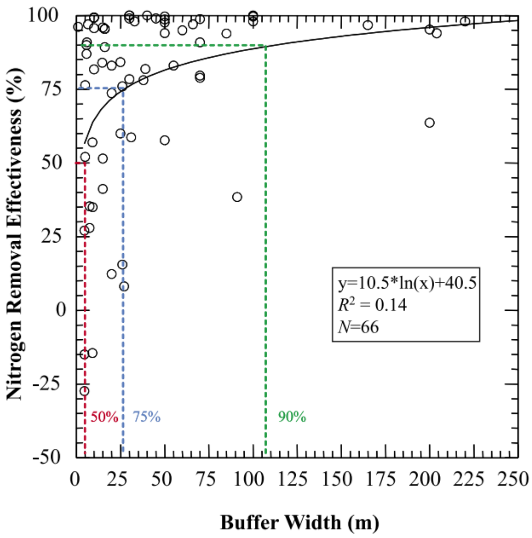

Figure 3. 4 Relationship of nitrogen removal effectiveness and buffer width in for all vegetation types (From Mayer et al., 2005)

Lv & Wu (2021) found that beyond widths of 15m, nitrogen reductions within buffers did not substantially change. Assuming an optimum buffer width of 15m, **Figure 3.4** predicts an average removal rate approximately 65%. **Table 3.7** presents some of the typical removal rates observed within the literature.

Table 3.7 Typical nitrogen removal rates

Study	Vegetation cover	Buffer width (m)	Nitrogen removal efficiency (%)	Major soil type
Mayer *et al.*, 2005	All	3	50	-
	All	28	75	-
	All	112	90	-
Lee *et al.*, 1998	Grass	3	28	Loam
	Grass	6	46	Loam
Lv & Wu, 2021	Poplar	15	65.06	-
	Poplar	30	65.02	-
	Poplar	40	66.01	-
Dillaha *et al.*, 1989	Grass	9.1	73	Silt loam
	Grass	4.6	54	Silt loam

Mayer *et al*. (2007) conducted a substantial review of riparian buffer strip literature with a variety of vegetation types and locations. The results identified that nitrogen removal is positively correlated with the width of the buffer, but other factors affected the effectiveness. Their non-linear regression model indicated that TN removal efficiencies of all vegetation types (grass, forest, grass/forest, wetland, forest/wetland) of 50%, 75% and 90% would be achieved at widths of 3m, 28m and 112m. The results also indicated that grass and forest buffers were more effective than only grass buffers. **Table 3.8** suggests that a 20m grass/forest buffer would achieve an average removal efficiency of 75%.

Table 3.8 Effectiveness of different types of buffer strip in removing TN (Edited from Mayer et al., 2005)

Buffer vegetation	Mean TN removal effectiveness (%)	Approximate buffer width by predicted effectiveness		
		50%	75%	90%
All vegetation types	74.2	3	28	112
Grass	53.3	16	47	90
Grass/forest	80.5	5	20	47

3.3.2.3 Delivery timescale

Buffer strips do not require extensive infrastructure or investment, although fencing may be necessary where used in livestock farming. They do not require any planning or environmental permits and can therefore be delivered in the short term.

3.3.2.4 Duration of operation

Buffer strips are likely to be operational over long timescales, depending upon landowner agreements. However, because they do not require any specific infrastructure, they are considered to be impermanent and subject to changes in farming practices.

3.3.2.5 Applicability

This is applicable to the catchments as a proportion is located within agricultural land where riparian buffers could be grown.

3.3.2.6 Management and maintenance requirements

Riparian buffer zones need continued maintenance to ensure they achieve the desired loading rates – maintenance is mainly limited to cutting vegetation and removal of accumulated sediment. This is an important process to prevent the area from becoming a nutrient source rather than a sink. Where input flows are too great to promote infiltration, ponds could be added to remove sediment and would also need to be de-silted. Monitoring of management practises and water quality may be required following establishment to determine functionality. Riparian buffer strips could be implemented as a short-term bridging solution or as a longer-term solution.

3.3.2.7 Additional benefits

Riparian buffer strips also have the added benefit of stabilising riverbanks and reducing erosion. This is achieved by dissipating energy in river flows and through stabilisation of soils by roots (Cooper *et al*., 1990). This will also lead to a reduction in particulate bound nutrients entering rivers, although quantification of the reduction is difficult to predict. Buffer strips also provide important habitats for wildlife.

3.3.2.8 Wider environmental considerations

The establishment of buffer strips will not require planning permission or any environmental permits. Buffer strips could potentially support sensitive species or ecological communities, and as such may need to be managed carefully to avoid damaging these communities. In addition, the establishment of fenced-off buffer strips may limit access to a water source by grazing livestock. It may therefore be necessary to provide an alternative source and/or defined drinking points.

Furthermore, new woodland in parts of the Broads are not welcomed by the sailing community due to wind shadow. Therefore, consideration on the impact to such stakeholders would need to be considered during the screening of suitable locations.

3.3.2.9 Evidence of effectiveness

Riparian buffer strips are an established nature-based solution for pollution control within catchments and have been employed for multiple years. Section 3.3.2.2 provides literature evidence of the expected nutrient removal rates which are based of multiple examples in differing locations, soil types and vegetation types.

3.3.2.10 Deliverability and certainty

Riparian buffer strips are likely to involve tree planting and fencing off from existing fields. This provides good certainty that the land use will be maintained and not revert back to agriculture. Furthermore, riparian land is typically on the less productive margins of fields. Long-term management of the land as a riparian buffer can be secured through legal agreements to provide further certainty.

The upstream sources are important to maintaining the predicted removal rates from the buffer strips. If these sources or altered or removed then the nutrient removal of the buffer could be adversely impacted. A minimal amount of monitoring will be required to confirm removal rates are consistent with the predicted rate. This is likely to comprise 6 months to yearly for the approximately the first 5 years, then every 10 years for the lifetime of the scheme. Should the riparian buffer be performing better than predicted then the monitoring process will also unlock these nutrient credits. The monitoring will also identify if the maintenance of the buffer is ensuring nutrient removal is maintained.

There are few consents which will be required for riparian buffer creation. Where groundworks are operating with a flood zone then it is important that the flood storage area is not reduced.

Key risks associated with riparian buffer strips include the following:

- Where buffer strips are used as a long-term, in perpetuity solution, the long-term management of the adjacent fields presents a risk. Should the adjacent land be taken out of agricultural use or significant changes in agricultural practises (e.g., conversion to solar or wind farm) this could reduce the phosphate sources and subsequent removal potential.
- Improper upkeep of buffer strip vegetation, fencing and silt could reduce the removal potential.
- Should overland flow not be maintained, and flow becomes channelised, the buffer strip will not operate at optimum removal rates.
- Farmers may be unwilling to commit to 80-year agreements initially. Therefore, shorter agreements (e.g., 20-30 years) may be necessary to establish this solution, with the ability to renew agreements.

Management agreements or a conservation covenant agreement could offer a route to securing this solution. A conservation covenant agreement is described as a private and voluntary agreement made between the landowner and responsible body and is legally binging executed as a deed and registered on the local land charges register.

A conservation covenant agreement must offer benefit to the public in some way in addition to having a conservation purpose, although provision of public access does not need to be a feature of such an agreement. Part of the agreement could include an obligation to make sure that money is available to cover maintenance costs.

To be considered as meeting securable in perpetuity goal for landowners who have a freehold title or a leaseholder with >80 years remaining on the lease. The duration of a conservation covenant can be considered as indefinitely if a timescale is not expressly set out in the agreement. A responsible body can be a public body or charity or private sector organisation where the main function relates to conservation or a Local Authority, and it is their responsibility to submit an annual return. DEFRA guidance for how to apply to become a responsible body should be available from early 2023.

3.3.2.11 Cost estimate

Costs were derived from Farmscoper Version 5 (updated in January 2022) which is an industry good practise tool for assessing mitigation solutions. Typical costs for establishing new buffer strips are shown in **Table 3.9**.

Table 3.9 Summary buffer strip costs (From Farmscoper Version 5 Costs tool).

Measure	Upfront costs (£/ha)	Annual cost (£/ha)
Loss of production		889
Seasonal cutting of buffer strip		200 (estimate made from 0.02 p per m)
No crop management		-383
Establishment of buffer strip	163	40
Soil testing (for analytical laboratory cost only and exclusive of sample collection costs)	20	10 to 40 (cost varies between grassland and arable land and based on minimum of 7 tests per)
Total	183	786

Additionally, **Table 3.10** outlines the rates received by farmers under the current Countryside Stewardship Grants.

Table 3.10 Annual Countryside Stewardship grants for riparian buffer strips

Option	Description	£/ha/yr	£/ha/80yr
SW11 Riparian Management Strip	Riparian buffer up to 12m in width. Prohibits application of fertiliser and pesticides and use of permanent fencing to exclude livestock	440	35,200
SW4 12 to 24m buffer on cultivated land	12 to 24m buffer strip excluding vehicles or stock and prohibiting fertiliser and pesticides.	512	40,960

Where riparian buffer strips are already present within the catchment, through stewardship and environmental land management schemes, nutrient 'credits' cannot be achieved as this is likely to represent double counting. However, typically buffer strips under stewardship and environmental land management schemes are typically up to 10m in width whereas the optimum width for buffer strips for nutrient mitigation are 15-20m. Therefore, riparian buffers for land management schemes could be extended to those for nutrient mitigation. A credit-based approach which utilises elements of the existing model could be established for new buffer strips. Riparian buffer strip grants are available under Mid-tier and Higher tier Countryside Stewardship Schemes. These grants have a typical term of 5 years, after which point new grants can be applied or from 2024 the Environment Land Management (ELMS) scheme will be in place. At the end of agreements, existing riparian buffers could be improved and extended for nutrient mitigation instead of payment schemes. This would reduce the need for significant areas of new riparian buffer strips.

Table 3.11 and **Table 3.12** provide an indication of the likely mitigation that could be delivered and associated costs in each sub-catchment. This assumes a 1ha buffer strip that is adjacent to a cereal farm and the costs outlined in **Table 3.9**.

Table 3.11 Estimated TP mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation (kg/ha/yr)	Housing equivalent	Cost estimation (£/ha)	£/kg TP/yr for each year	£/dwelling for each year	£/kg TP/yr over 80 years	£/dwelling over 80 years
Wensum	4.35	64	786	181	12	14452	982
Yare	2.03	30	786	388	26	31028	2107
Bure	0.36	5	786	2198	149	175815	11928

Table 3.12 Estimated TN mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation (kg/ha/yr)	Housing equivalent	Cost estimation (£/ha)	£/kg TN/yr for each year	£/dwelling for each year	£/kg TN/yr over 80 years	£/dwelling over 80 years
Wensum	167.31	89	786	5	9	382	710
Yare	135.47	72	786	6	11	470	877
Bure	152.63	81	786	5	10	418	778

3.3.2.12 Summary

Key considerations are summarised in **Table 3.13**.

Table 3.13 Riparian buffer strips

Key considerations	
Delivery timescale	Short-term
Duration timescales	Impermanent
TP removal potential	Median TP retention rates of 67% (Hoffmann *et al*., 2009)
TN removal potential	65% removal for a 15m buffer (Mayer *et al.*, 2005)
Farm typologies applicable	All applicable
Management / maintenance requirements	Cutting/vegetation removal
Additional benefits	Stabilised river banks. Water quality. Reduced erosion. Habitat creation. Improved amenity value. Biodiversity net gain (BNG) Carbon offsetting – potential for stacking ecosystem services credits carbon offsetting and BNG could provide an additional revenue stream, similar to the Countryside Stewardship payment scheme.
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes – management agreements may be needed where the solution is intended to provide medium / long term solutions to ensure it does not revert back to agricultural use and is maintained correctly. Conservation covenant agreement can be a mechanism for securing perpetuity.

Key considerations	
Cost estimation[1]	Typical costs are £786/ha. This is fairly well constrained with annual Countryside Stewardship Grants that are paid at £440 - £512 ha/yr. A conservation covenant agreement can be used to secure income and funding for conservation activities. Costs per dwelling are provided in Table 3.9 and Table 3.10

3.3.3 Wet woodlands

3.3.3.1 Description of solution

Wet (floodplain) woodlands occur on soils that are permanently or seasonally wet, either because of flooding, or because of the landforms and soil type. They are found on river floodplains, in peaty hollows and at the margins of fens, bogs and mires (Woodland Trust, 2022). Nutrient removal strategies utilising wet woodlands involve working with either restoring existing floodplain woodland or creating new areas of planting **(Figure 3. 5**). Natural flood management (NFM) interventions can also be used to divert water out of the channel and into the floodplain wetland (**Figure 3. 6**) to enhance sediment and nutrient deposition. The role of wet woodlands in water quality management is to increase hydraulic roughness, which slows flow velocities and allows sediment and particulate bound pollutants to fall out of suspension and enter storage on the floodplain, or in a designed wetland setting. Riparian woods reduce diffuse pollution by trapping fine sediment runoff generated by agricultural practices (Cooper *et al*., 2021).

Figure 3. 5 Area of wet woodland created in Salford in 2016. The project led to the attenuation of pollutants by biodegradation (Natural Course, 2017)

[1] *Environment Agency. 2015. Cost estimation for land use and run-off – summary of evidence (Report –SC080039/R12). (https://assets.publishing.service.gov.uk/media/6034eefdd3bf7f264e517436/Cost_estimation_for_land_use_and_run-off.pdf)*

Figure 3. 6 Traditional NFM structures, such as leaky barriers, can be used to enhance channel-floodplain connectivity to encourage nutrient deposition

Reversion of areas to floodplain woodland could deliver nutrient mitigation of land which is naturally wet. This would not only reduce the impact of runoff from the agricultural land but would also increase the connectivity of the woodland, which would likely achieve greater nutrient reductions than purely the change of land use would predict.

Similar gains (for managing diffuse pollution and flood risk) can be expected from extending fingers of riparian woodland into upstream source areas and intermittent flow/run-off pathways, although few data are available to quantify impacts at a catchment scale (Nisbett *et al*., 2011).

In the UK, the most suitable trees for creating wet woodlands are native species best suited to boggy ground. For the main canopy this includes alder (*Alnus glutinosa*), crack willow (*Salix fragilis*), white willow (*Salix alba*), and downy birch (*Betula pubescens*). Understory species may typically include grey willow (*Salix cinerea),* osier (*Salix viminalis*) and a range of grasses (e.g., purple moor grass (*Molinia caerulea*)) (Woodland Trust, 2022). It is uncertain how these species cycle and potentially uptake floodplain nutrients.

3.3.3.2 Nutrient removal

Data on nutrient removal rates in wet woodlands are scarce. Olde Venterink (2006) analysed various floodplain communities in terms of their relative abilities to influence water quality through nutrient retention and denitrification. The results showed that productivity and nutrient uptake were high in reedbeds, intermediate in agricultural grasslands, ponds, and semi-natural grasslands, and very low in woodlands (only understorey). Furthermore, rehabilitation of agricultural grasslands into ponds or reedbeds is likely to be more beneficial for downstream water quality than into woodlands or semi-natural grasslands. Note that this study refers to woodland, not wet woodland, so comparisons are uncertain and do not necessarily reflect UK soils or climate. This study does not consider more effective sediment trapping in wet woodlands and associated standing water. Removal rates may have some similarities to riparian buffer strips.

Nitrogen removal rates are highly variable in wet woodlands, ranging from 12-80% of surface water nitrogen (Yates and Sheridan 1983; Brusch and Nilsson, 1993). Greater reductions can occur in the groundwater (Burns and Nguyen, 2002). **Table 3.14** presents examples of nitrate removal from wet woodlands (Mayer *et al*., 2005).

Table 3.14 Nitrogen removal from wet woodland buffers

Flow path	Buffer width (m)	Nitrogen removal (%)	Soil type	Source
Surface	-	81	Sand	Yates and Sheridan, 1983
Subsurface	31	59	Sand	Hanson *et al*., 1994
Subsurface	38	78	Sandy loam	Vellidis *et al*., 2003
Subsurface	14.6	84	Sandy mix	Simmons *et al*., 1992
Subsurface	5.8	87	Sandy mix	Simmons *et al*., 1992
Subsurface	5.8	90	Sandy mix	Simmons *et al*., 1992
Subsurface	6.6	97	Sandy mix	Simmons *et al*., 1992
Subsurface	30	100	Loamy mix	Pinay *et al*., 1993
Surface	20	12	Clay loam	Brusch and Nilsson, 1993
Surface	20	74	Peat/sand	Brusch and Nilsson, 1993
Subsurface	5	76	Stony silt loam	Clausen *et al*., 2000
Subsurface	5	52	Stony silt loam	Clausen *et al*., 2000
Subsurface	1	96	Clay loam/clay	Burns and Nguyen, 2002
Subsurface	200	95	Silt/sand/gravel	Fustec *et al*., 1991
Subsurface	40	100	Fine to coarse sand	Puckett *et al*., 2002

3.3.3.3 Delivery timescale

Wet woodlands do not require extensive infrastructure or investment. They do not require any planning or environmental permits and can therefore be delivered in the short term. However, the relatively slow growth rate of trees means that it may take some time before they become fully effective.

3.3.3.4 Duration of operation

Wet woodlands are likely to be operational over long timescales, depending upon landowner agreements. Because of the long timescales required for them to become established, wet woodlands are considered to be permanent features.

3.3.3.5 Applicability

Wet woodlands can be created on riparian land holdings that are likely to be inundated regularly (e.g. within the functional floodplain and/or Flood Zone 3, as defined by the Environment Agency).

3.3.3.6 Management and maintenance requirements

Wet woodlands by their nature thrive on non-intervention and limited to no management. Light management includes:

- Coppicing some areas to create a more diverse woodland structure with some clearings.
- Allowing woodland edges to grade upwards from grass, through scrub, to woodland.
- Coppicing to provide wood fuel.
- Managing areas of willow and scrub to maintain some open areas and wet scrub.
- Controlling invasive species (e.g., Himalayan balsam *Impatiens glandulifera*).

3.3.3.7 Additional benefits

Wet woodland creation, or expansion of existing riparian woodland, has several co-benefits, such as: carbon sequestration, flow regulation and flood risk management, biodiversity conservation, landscape and amenity, air pollution reduction and reduced flood risk (Nisbett *et al*., 2011). One of the major potential benefits of using woodland to improve water quality is the opportunity to supplement farm income by utilising short rotation coppice for biofuel (Mackenzie and McIlwraith, 2013).

3.3.3.8 Wider environmental considerations

Planting wet woodland will not require planning permission or any environmental permits. Once established, wet woodland could potentially support sensitive species and as such may need to be managed carefully to avoid adversely affecting these species.

3.3.3.9 Evidence of effectiveness

There is limited scientific evidence to demonstrate with certainty that wet woodlands are effective at mitigating phosphates. Evidence summarised in **Table 3.13** demonstrates that although wet woodlands can be effective in the removal of nitrogen, removal rates vary considerably (possibly reflecting local conditions).

3.3.3.10 Deliverability and certainty

It is anticipated that this solution will be suitable for the lifetime of the development.

3.3.3.11 Cost estimate

Bare root stock suitable for tree planting programmes for typical wetland species are in the range of £2-3 per tree. Typically, bulk orders from suppliers reduce these unit costs to less than £1. Bulk order tree guards are a similar price. For broadleaved trees, planting density is recommended 1600 to 2500 trees per hectare respectively (Creating Tomorrow's Forests, 2021). However, these figures are for general woodland creation, not floodplain wet woods where additional space may be needed for wetland landscaping (e.g., pools and scrapes). Typical planting costs (trees + guard) may be ~£5,000 per ha. Grants of up to £10,000 per ha could be available through the government's England Woodland Creation Offer (Gov.uk, 2022) and nutrient mitigation credits may need to match this figure.

3.3.3.12 Summary

Table 3.15 presents a range of considerations for using wet woodlands for nutrient offsetting.

Table 3.15 Wet woodlands

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
TP removal potential	Uncertain – likely to be similar to riparian buffers
TN removal potential	Uncertain – likely to be similar to riparian buffers
Farm typologies applicable	Riparian land holdings (withing FZ3)
Management / maintenance requirements	Minimal – some coppicing to encourage understory growth; removal on invasive species (e.g., Himalayan balsam)
Additional benefits	Recreation carbon sequestration Biodiversity conservation Air pollution reduction Flood risk reduction Biofuel

Key considerations	
Based on best available evidence?	No – there is doubt over removal rates (lack of research and data)
Effective beyond reasonable scientific doubt?	Yes - although there is evidence to indicate effectiveness, the effectiveness can vary considerably under different conditions. As such, there is currently uncertainty regarding nutrient removal rate and monitoring is likely to be required.
Precautionary?	Yes
Securable in perpetuity?	Yes – land suited to wet woodland is very unlikely to revert to any other land use
Cost estimation	Up to £10,000 per hectare

3.3.4 Willow buffers

3.3.4.1 Description of solution

Short-rotation willow coppice can be used to treat wastewater whilst producing woody biomass for energy purposes. The solutions can be used to treat domestic and industrial wastewater. The solutions comprise vegetation filter strips of short-rotation willow coppice irrigated with wastewater. The willow is harvested on a two-to-five-year cycle, although most commonly every three years. The irrigation system will not completely eliminate wastewater pollution as some wastewater by run off or percolate into groundwater. As a result, timing and irrigation rates must be considered. Evapotranspirative willow systems have zero discharge and are an alternative to irrigated systems and are typically used to treat domestic wastewater from small settlements or individual households. When designed properly, all influent wastewater and precipitation are evapotranspired on an annual basis. They provide efficient wastewater treatment and do not require skilled personnel for operation and maintenance.

3.3.4.2 Nutrient removal

Short-rotation willow coppice filter strips achieve phosphate removal rates of 67-74% (Larsson *et al*., 2003; Perttu, 1994), although initial reduction rates are often closer to 95%. Lachapelle *et al*. (2019) suggested a significant increase in available phosphate in the soil, suggesting the soil can become saturated over time. In the case of evapotranspirative willow systems, wastewater is constantly applied and stored as an elevated water level. Phosphate accumulation is expected and results in a phosphate rich substrate which can be reused as fertiliser. Initial studies suggest that phosphate stored in woody biomass is between 31 – 45% of the influent, whereas phosphate stored in soil, roots and leaves is between 55 – 69% (Istenic and Bozic, 2021). The recommend phosphate application to prevent saturation of soils is 24 k/ha/yr (Caslin *et al*., 2015), which is typically lower than what is applied directly from domestic wastewater. This solution could be used as a form of secondary treatment after domestic package treatment plants.

3.3.4.3 Delivery timescale

Willow buffers are unlikely to require extensive infrastructure, planning permission or environmental permits, and can therefore be delivered in the short term. The rapid growth rate of willows means that a functional solution could be delivered more rapidly than a traditional wet woodland.

3.3.4.4 Duration of operation

Willow buffers could potentially be operational over long timescales. Because they need to be regularly managed to maintain effectiveness and trees need to be periodically replaced, willow buffers are considered to be impermanent features.

3.3.4.5 Applicability

Willow buffers are applicable to the catchments as the rural land which dominates the landscape allows this to be a feasible option. Further detail can be sought to the location of biomass energy plants to better determine how relevant this could be, however initial indications suggest that biomass energy plants are operational within Norfolk.

3.3.4.6 Management and maintenance requirements

Harvesting of willow would be required every 3-5 years and replanting every 20-25 years. This solution typically sees a 30% increase in biomass yield (Buonocore *et al*., 2012).

3.3.4.7 Additional benefits

There are additional benefits of improved water quality and a gain in biodiversity due to improved habitat.

3.3.4.8 Wider environmental considerations

Transport of biomass to energy production plants should be considered and implications of waste disposal from the energy plant output.

3.3.4.9 Evidence of effectiveness

There is the potential for phosphate saturation within soils and limited evidence to determine the efficacy of such a scheme.

3.3.4.10 Deliverability and certainty

A level of uncertainty is associated with the success of planting and growth. The harvest cycle may lead to variance in uptake. It is likely that a phase of 'trial and error' with respect the successful growth of particular willow species.

3.3.4.11 Cost estimate

The cost for establishment is typically £2,500 per hectare. Operational costs including ploughing and cultivation and are likely to £200 - £300 per ha per year. Potential returns vary hugely depending on many variables including price received for crop and drying requirements. Rising energy costs of oil and gas may provide greater future opportunities for willow chips as a fuel source.

3.3.4.12 Summary

Table 3.16 presents the key considerations for the use of willow buffers for nutrient reduction and/or offsetting.

Table 3.16 Willow buffers

Key considerations	
Delivery timescale	Short term
Duration timescale	Impermanent
TP removal potential	70% long-term
Management / Maintenance requirements	Harvesting every 2-3 years.
Additional benefits	Water quality Biodiversity
Based on best available evidence?	No – monitoring will be required to determine nutrient removal
Effective beyond reasonable scientific doubt?	Yes – there is the potential for phosphate saturation within soils
Precautionary?	Yes
Securable in perpetuity?	Yes
Cost estimation	Capital costs: £2,500 per hectare, operational costs £200 - £300 per ha per year.

3.3.5 Beetle banks

3.3.5.1 Description of solution

A beetle bank is a densely grassed mound approximately 3.0 m to 5.0 m wide and a least 0.40 m high constructed on agricultural land to control runoff. They can be planted across long or steep slopes or along natural drainage ways to minimise runoff and soil erosion. Beetle banks present a similar scenario to a riparian buffer (cf. **Section 3.3.2**).

3.3.5.2 Nutrient removal

Calculations have not been undertaken to determine the level of nutrient removal. An assumption is made the nutrients are removed via both the removal of small areas of farmland which would ordinarily be subject to application of nutrient containing fertilisers and the uptake of nutrients via the tussock grass on the bank. Nutrient removal rates are likely to be similar to Riparian Buffer strips.

3.3.5.3 Delivery timescale

Beetle banks do not require extensive infrastructure, planning permission or environmental permits, and can therefore be delivered in the short term.

3.3.5.4 Duration of operation

Once installed and established they are anticipated to be a permanent feature.

3.3.5.5 Applicability

The agricultural nature of the catchment means this could offer plausible although possibly small-scale solutions. The location of beetle bank installation may be limited by parameters such as soil type, which should be suitable to form a free-draining raised bank.

3.3.5.6 Management and maintenance requirements

Best practice beetle bank construction is designed in order to achieve wider environmental benefits. The earth ridge size (measuring between 3.0 m to 5.0 m wide and at least 0.4m high) should be maintained and once a tussocky grass mixture has been established after the first year of construction, following grass cutting several times in the first year to help grass establish. Annual grass cutting to be undertaken after 1 August (to protect nesting invertebrates) and control woody growth and suckering species. The upper bank area should be dry and therefore constructed of free-draining soils to allow insects to hibernate securely.

3.3.5.7 Additional benefits

Beetle banks provide increased biodiversity in the form of nesting and foraging habitats for pollinators, small mammals, some farmland birds and beneficial insects which feed on crop pests. In order to achieve wider environmental benefits beetle banks do not require, and indeed the Countryside Stewardship grant funding prohibits application of fertilisers, manured and/or lime and pesticides (excepting herbicides used to weed-wipe or spot-treat control of injurious weeds, invasive non-natives, nettles or bracken). Beetle banks can help to slow down or stop soil erosion.

3.3.5.8 Wider environmental considerations

Earthworks and associated machinery fuel and transport requirements will be required. Grass cut from the annual maintenance would need to be removed from the beetle bank area to remove nutrients, which has transport costs in terms of fuel and carbon to be considered.

3.3.5.9 Evidence of effectiveness

Significant monitoring is likely to be required and there is a high level of uncertainty. There is also unlikely to be a high uptake amongst farmers because they need to be positioned in more productive areas in the centre of fields rather than in the margins.

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3.3.5.10 Deliverability and certainty

There are many site-specific location parameters required to deliver a successful beetle bank scheme, in addition to maintenance (of size structure of the beetle bank and grass cutting activities) and monitoring. There is a high level of uncertainty of success. Monitoring for Countryside Stewardship grant could act as a mechanism for securing obligations, however this is not a firm legally binding enforceable agreement.

3.3.5.11 Cost estimate

There is government incentive scheme via a Countryside Stewardship Grant which could be used to supplement the cost for this option if the selected site is on current arable or temporary grassland. In order to take advantage of a government grant scheme, declarations are required to confirm the prohibited activities (fertiliser and pesticide application for example) have not been applied on the beetle bank and record evidence to demonstrate delivery of the scheme.

3.3.5.12 Summary

Significant monitoring is likely to be required and there is a high level of uncertainty. There is also unlikely to be a high uptake amongst farmers because the location recommendations advise that beetle banks should be positioned in open landscape in larger fields, which is possibly the more productive areas in the centre of fields rather than in the non-productive margins.

Table 3.17: Beetle banks

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
Nutrient removal potential	Unknown at this stage
Management / Maintenance requirements	Annual grass cutting
Additional benefits	Biodiversity net gain potential Soil erosion
Based on best available evidence?	No
Effective beyond reasonable scientific doubt?	Not possible to determine at this stage
Precautionary?	Not possible to determine at this stage
Securable in perpetuity?	No
Cost estimation	Costs are assumed to be as provided for Riparian buffer strips (Section 3.3.2)

3.4 Runoff management solutions

3.4.1 Taking land out of agricultural use

3.4.1.1 Description of solution

Taking land out of agricultural use involves replacing high nutrient exporting agricultural land with low exporting land such as semi-natural grassland, woodland, or energy crops (e.g., willow or *Miscanthus*). Soil erosion which can lead to nutrient mobilisation is also likely to decrease with time as soil is stabilised by more continuous vegetation cover. Reversion of previously agricultural land to a more natural state will eventually reduce phosphorus and nitrogen leaching to natural background rates.

In addition, measures can be imposed which actively uptake nutrients and limit the impact of legacy phosphates. One method is to propose uptake by vegetation, which will also reduce the risk of soil erosion. Vegetation may include using the site for woodland, energy crops or cover crops. Other methods include blocking drains on drained land (or alternatively installing a field-wetland). Sharpley (2003) and Dodd *et al* (2014) suggested that ploughing to reduce nutrient stratification and redistribute and dilute enriched topsoil can decrease concentrations by half leading to reduced surface runoff losses. Monitoring may also be able to demonstrate that nutrient loading is returning to background levels.

Woodland planting is one mechanism of accelerating the transition to background nutrient concentrations. Natural England advice suggests that woodland planting is a viable mitigation method that can be easily implemented. There is a minimum requirement for 20% canopy cover at maturity, which is equivalent to approximately 100 trees per hectare. Maintenance of woodland is easy to verify and well established. Woodland planting may be secured without land purchase. Native tree species would also be the preferred choice, although it may be necessary to consider climate resilience and the use of non-native species to account for long-term climate change effects. Nutrient reductions would be calculated using the Norfolk Nutrient Budget Calculator (2022) and assuming a runoff coefficient of 0.02kg TP /ha/yr and 3 kg TN / ha/yr.

Energy crops such as *Miscanthus* (silvergrass / elephant grass) are generally considered to have a higher soluble nutrient uptake than woodland and should be considered. Miscanthus is also ideally suited to marginal land that provide little value for generating income (Miscanthus can be grown for biofuel). There is also the possibility to harvest the *Miscanthus* after 5 – 10 years. However, this would have a lower biodiversity benefit and would be unable to retrieve as much income through potential monetised biodiversity schemes as more natural planting would.

3.4.1.2 Nutrient removal

The nutrient reduction calculations assume that farms will be operating according to best practice and not polluting. This is to ensure that potential pollution from agriculture is not traded to another sector, which would then discharge this load back in the catchment in the form of new housing. This will also ensure that mitigation schemes do not compromise the ability to deliver long term WFD targets.

The Norfolk Nutrient Budget Calculator (2022) can be used to determine the nutrient mitigation achieved. Alternatively, Defra's Farmscoper Tool can be used to calculate nutrient reductions and the associated cost. Farmscoper was developed by ADAS (Agricultural Development and Advisory Service) for Defra to enable the assessment of the cost and effect of one or more diffuse pollution mitigation methods at the farm scale. The tool estimates baseline emissions of a suite of different pollutants and predicts the mitigation potential against these pollutants and quantifies potential benefits for biodiversity. The tool can be set up to model most basic farm types by changing livestock numbers, crop areas, fertiliser rates, soil type and climate. In this way the effects of taking land out of production or changing land use can be assessed. The typical catchment characteristics for the River Wensum, Yare and Bure sub-catchments are presented in **Table 3.18**.

Table 3.18 Typical rainfall and drainage characteristics of the Wensum, Yare and Bure catchments derived from the Norfolk Nutrient Budget Calculator.

Sub-catchment	Rainfall (mm/yr)	Drainage type	Nitrate Vulnerable Zone (NVZ)?
Wensum	700-750	Slightly Impeded	Yes
Yare	650-675	Slightly Impeded	Yes
Bure	675-700	Freely draining	Yes

Assuming the catchment characteristics outlined in **Table 3.18**, the typical agricultural nutrient runoff rates for each catchment are presented in **Table 3.19**.

Table 3.19 Typical agricultural nutrient runoff rates in the Wensum, Yare and Bure sub-catchments

Land Use	Phosphorus runoff coefficient (Kg TP/ha/yr)			Nitrogen runoff coefficient (Kg TN/ha/yr)		
	Wensum	Yare	Bure	Wensum	Yare	Bure
Dairy	0.41	0.27	0.14	17.17	22.72	35.87
Lowland grazing	0.22	0.15	0.10	13.66	11.24	18.15
Mixed livestock	0.60	0.29	0.09	24.06	20.94	34.60
Poultry	0.70	0.39	0.16	177.92	158.74	228.65
Pig	0.72	0.35	0.08	73.20	64.59	89.80
Horticulture	0.66	0.31	0.05	19.08	15.39	22.63
Cereals	0.73	0.34	0.06	23.75	19.23	25.75
General arable	0.64	0.29	0.05	21.72	17.41	27.73

The east of England is dominated by cereal farms, which account for 51% of the total farmed area and general cropping farms which account for 33% of the farmed area (Defra, 2021).

The River Wensum sub-catchment results have the greatest phosphorus runoff coefficients within the Norfolk nutrient neutrality catchment as a result of the higher annual rainfall. A cereal farm within the Wensum catchment has a runoff coefficient of 0.73 kg TP/ha/yr compared to a comparable farm in the Bure catchment with a runoff coefficient of 0.05 kg TP/ha/yr.

Nitrogen runoff rates are greatest in the Bure sub-catchment due to the freely draining nature of the soil. Cereal farms within this sub-catchment have a runoff rate of 25.75 kg TN/ha/yr.

The difference between the agricultural land runoff rate (typically 0.06 – 0.73 kg TP/ha/yr and 19.23 – 25.75 kg TN/ha/yr) and the future runoff rate (which would be 0.02kg TP/ha/yr and 3 kg TN/ha/yr) is generally small which results in a large amount of land required to offset developments. However, cereal farms and general arable farms typically have some of the highest nutrient runoff rates for both phosphorus and nitrogen.

There are some conditions where nutrient loading rates from agricultural land are higher, and the land take is not as significant. This would be applicable pig and poultry farming for nitrogen removal. However, there is likely to be limited availability of taking these lands out of use within the catchment due to a relative lack of abundance within the areas impacted by nutrient neutrality.

Due to the significant land take that would be required to deliver this solution as a long-term measure, it is unlikely that at a strategic scale this would provide anything more than a short-term solution to bridge the gap until more efficient and effective longer-term solutions can be developed. There is the potential for land to be leased on short term solutions without the need for purchase. Management agreements are likely to be needed to ensure the land remains out of agricultural use.

3.4.1.3 Delivery timescale

Taking agricultural land out of use can be implemented over short-term timescales. Identification of suitable land, willing landowners and agreeing terms are likely to be the most time-consuming tasks in the implementation process of this solution.

3.4.1.4 Duration of operation

This solution could potentially be implemented over a variety of timescales. It could be used as a temporary measure, with land taken out of production but otherwise unchanged. Alternatively, it could also be used as a longer-term (impermanent) reversion from agriculture, or as a permanent solution that could be maintained in perpetuity if the land is used for non-agricultural purposes.

3.4.1.5 Applicability

Unlikely to be applicable to indoor pig or poultry farms, but applicable to most other farm types.

3.4.1.6 Management and maintenance requirements

Miscanthus needs no additional fertiliser for growing until it is established and less needs to be applied than most farming practices. Harvesting needs to be completed every 2-4 years. Energy Crop Schemes are available.

3.4.1.7 Additional benefits

Energy crops can be used for coppice and provide fuel for renewable energy and therefore carbon offsetting. Schemes will provide carbon sequestration and will qualify for biodiversity net gain as well as nutrient neutrality credits.

3.4.1.8 Wider environmental considerations

Implementation of this option is unlikely to be significantly constrained by wider environmental factors. Should the solution be used to provide a significant amount of long-term mitigation or used to provide a substantial amount of short-term mitigation then this could impact on regional food production in Norfolk. Removing agricultural land which will achieve minimal nutrient reductions (e.g. some agricultural land in the Bure catchment) should be considered against the impact of food supply and maintaining the agricultural characteristic of the County.

There is the potential for long term inflated agricultural land prices if this solution requires land to be out of agricultural use for more than 1-2 years (i.e., it is used as a long-term solution). This could be further exacerbated when coupled with the impact of mandatory biodiversity net gain which is expected to be adopted in November 2023 through the Environment Bill.

3.4.1.9 Evidence of effectiveness

However, repeated applications of fertilizers and animal waste results in the build-up of phosphorus in soil (commonly known as 'legacy P'). Nitrogen build up in soil can still occur, but nitrogen is typically more mobile and does not present such a long term problem. Long-term field experiments have shown that a large proportion (> 70%) of the surplus phosphorus added via fertilisers remains in the soil, some in forms not readily available to crops (Pavinto *et al*., 2020).

The time taken for soils to reduce to agronomic targets and background concentrations varies depending on soil types and nutrient concentrations (Dodd *et al*., 2012). A study by McCollum (1991) indicated that soil concentration may not be reduced to background concentrations for at least 17 years, based on fine sandy loamy soils in arable production in the United States. Loamy soils in arable production are typical of the characteristics seen in large parts of the Bure catchment. Gatiboni *et al* (2021) found that the median time to reach agronomic targets was <1 year but as high as 11 years. However, the time taken to reach environmental targets purely by cessation of phosphorus fertiliser would be 26 – 55 years. This is consistent with Dodd *et al* (2012) which estimated that following cessation of phosphorus application to grassland, the time taken for surface runoff to reduce to acceptable levels is 23 – 44 years.

3.4.1.10 Deliverability and certainty

Certainty regarding cessation of arable farming can be easily secured and verified using aerial imagery and site visits. Where grazing land is taken out of use, in order for there to be an actual reduction in nutrient loads, then it is assumed that livestock numbers would also need to be decreased and the livestock/hectare rate maintained. However, it is assumed that farms typically operate close to optimal stocking densities and livestock reductions would be needed to maintain this. Where this solution is used as a temporary measure, livestock can be temporarily located outside of the catchment. However, changes to grazing practices and stocking densities are more difficult to monitor and enforce in comparison to arable reversion to woodland or energy crops, and therefore provide a lower degree of certainty with regards to their effectiveness. Furthermore, consideration would need to be given where potentially polluting agricultural activity is moved to another location where the land parcel is smaller and could increase the pollution risk.

Norfolk is a major food producer for the UK and this may impact the actual uptake of this solution by landowners. As a result, financial incentives will need to be attractive and agreements likely to be temporary or impermanent.

3.4.1.11 Cost estimate

There are two main types of agricultural tenancies:

- Full agricultural tenancies, which are subject to the Agricultural Holdings Act 1986.
- Farm business tenancies, which are subject to the Agricultural Tenancies Act 1995.

Most tenancy agreements made after 1 September 1995 are subject to the Agricultural Tenancies Act 1995 and are commonly known as Farm Business Tenancies. **Table 3.20** presents the rental rates for farming types across England for 2019 and 2020 (the latest data available at the time of writing). Note that there is a degree of fluctuation in prices between the different years.

Table 3.20 FBT rental rates (£/ha) for farming types in England (Source: Defra, 2022)

Farm Type	Rental price (£/ha)	
	2019	2020
Cereal	263	261
General cropping	298	367
Dairy	271	283
Grazing livestock	79	81
Lowland grazing	128	166
All Farms	222	239

The average rental price in the East of England during 2019 is £231/ha. The average removal potential is approximately 0.5kg/ha/yr. It is expected that a short-term price inflation of agricultural land will increase the rental price above the baseline figures presented in **Table 3.21**.

Table 3.21 FBT rental rates (£/ha) for FBT farms in the East of England (Source: Defra, 2021)

Farm Type	Rental price (£/ha)	
	2019	2020
East of England FBT	281	314
England	222	239

The East of England average value of all arable land types is estimated to be £24,500/ha in 2022 (Savills, 2022).

Farmscoper Version 5 Cost tool was used to identify the likely cost from loss of production. A cost of £506 per ha is assumed which is derived from a loss of production (£889) offset against the saving from no crop / field management (£383).

Agricultural land may qualify for agricultural tax relief and it is likely that taking land out of agricultural production long term could have a tax implication which may cause this to be economically unviable and a barrier to delivery. Some solutions may cease to be eligible for agricultural relief and may qualify for financial benefits via the Countryside Stewardship Scheme (CSS).

Other capital costs associated with woodland planting, grass conversion and planting cover crops may result in a short-term negative cash flow. Maintenance costs (e.g., harvesting, cutting) are expected to be minimal and offset by sales of products.

3.4.1.12 Mitigation potential

Table 3.22 and **Table 3.23** present an example of the mitigation achieved and equivalent housing for taking land out of agricultural use. This assuming that land is taken out of a cereal use and put into woodland / semi-natural grassland use. The housing equivalent assumes a phosphorus permit limit of 1 mg/l and a nitrogen limit of 25 mg/l. The cost estimate assumes that land is purchased and also accounts for loss of production. No monitoring costs are assumed as this may only be necessary for some applications.

The number of houses mitigated / cost of mitigation is provided for both P and N. The cost estimate indicates that a solution provides more N than P. As such, the more expensive P cost estimate is the most relevant costs estimation to review regarding this solution because a development has to mitigate both P and N. A solution that achieves P mitigation will likely deliver an excess of N mitigation and therefore not be considered to achieve nutrient neutrality balance.

Table 3.22 Phosphorus mitigation and cost estimation for taking various agricultural land out of use

Sub-catchment	Area (ha)	Mitigation (kg TP/yr)	Housing equivalent	Cost estimation (£)	£/kg TP/yr over 80 years	£/dwelling over 80 years
Wensum	1	0.71	10	25,006	35,220	2,389
	5	3.55	52	125,030		
	10	7.1	105	250,060		
	25	17.75	262	625,150		
Yare	1	0.32	5	25,006	78,144	5,301
	5	1.6	24	125,030		
	10	3.2	47	250,060		
	25	8	118	625,150		
Bure	1	0.04	1	25,006	625,150	42,407
	5	0.2	3	125,030		
	10	0.4	6	250,060		
	25	1	15	625,150		

Table 3.23 Nitrogen mitigation and cost estimation for taking various agricultural land out of use

Sub-catchment	Area (ha)	Mitigation (kg TN/yr)	Housing equivalent	Cost estimation (£)	£/kg TN/yr over 80 years	£/dwelling over 80 years
Wensum	1	20.75	11	25,006	1,205	2,272
	5	103.75	55	125,030		
	10	207.5	110	250,060		
	25	518.75	275	625,150		
Yare	1	16.23	9	25,006	1,541	2,903
	5	81.15	43	125,030		
	10	162.3	86	250,060		
	25	405.75	215	625,150		
Bure	1	22.75	12	25,006	1,099	2,071
	5	113.75	60	125,030		
	10	227.5	121	250,060		
	25	568.75	302	625,150		

Table 3.22 highlights the difference the location can have on the amount of phosphorus mitigation that can be achieved by taking agricultural land out of use. Approximately 17x more mitigation can be achieved in the Wensum sub-catchment compared to the Bure sub-catchment, which leads to a marked difference in the cost. **Table 3.23** indicates that nitrogen removal rates are consistent across the sub-catchments and typically have a lower £/dwelling cost compared to phosphorus mitigation. In order to be 'nutrient neutral', a

development must satisfy both the excess phosphorus and nitrogen. Therefore, the costs to achieve phosphorus neutrality as more representative of the likely costs incurred from a development to achieve nutrient neutrality.

3.4.1.13 Summary

Table 3.24 presents a range of considerations when taking land out of agricultural use for nutrient offsetting.

Table 3.24 Taking land out of agricultural use key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Temporary, impermanent, permanent
TP removal potential	Average mitigation removal rate of 0.04 – 0.71 kg TP/ha/yr
TN removal potential	Average mitigation removal rate of 16.23 – 22.75 kg TN/ha/yr
Farm typologies applicable	Unlikely to be applicable to indoor pig or poultry farms, but applicable to other farm types
Management / maintenance requirements	For miscanthus growing – no fertiliser needs to be added until it is established and less needs to be applied than most farming practises. Harvesting needs to be completed every 2-4 years. Energy Crop Schemes are available.
Additional benefits	Energy crops can be used for coppice Biodiversity net gain potential
Based on best available evidence?	Yes – Although some doubt may remain over legacy phosphates and may require further research or monitoring to gain a better understanding.
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes - However, it is unlikely this solution would be used for long term solutions. Plantations may need to prove they can be in place for the lifetime of the development or offer a fallback option with an equivalent nutrient removal
Cost estimation	The average rental price in the East of England for farms is £314/ha. The average purchase price in the East of England for farms is £24,500/ha The cost from the loss of production is estimated to be £506/ha The cost estimate per dwelling is approximately £2,389, £5,301 and £42,407 for the Wensum, Yare ad Bure catchments, respectively.

3.4.2 Conversion of agricultural land to solar farms

3.4.2.1 Description of solution

A solar farm is a renewable energy installation with a large number of solar panels which are set up in order to generate electricity. Solar farm installation can reduce phosphate input by:

- a reduction in number of grazing livestock and therefore phosphate manure in livestock output by either reducing the density of grazing animal or removal of livestock from agricultural land.
- removal of agricultural land usage and therefore removal of nutrient inputs from fertiliser or waste applied to land from agricultural benefit to enhance crop growth.

A solar farm installation can also be used for provision of nutrient credits. The lifetime of such a scheme can be estimated as approximately 40 years.

3.4.2.1.1 Planning developments 'autonomous measure' position

Nutrient neutrality principles may be met with schemes such as conversion of agricultural land to solar farms. However, in respect of compliance with the Habitats Regulations, should any proposed development come forward through planning which might have adverse effects on the integrity of a Habitats site, regardless i.e. not specifically for the purpose of nutrient mitigation, may not be agreed that 'in principle' as a mitigation measure complaint with the Habitats Regulations.

The 'Dutch N' case made the following distinctions:

- an 'autonomous measure' is such that, unless solar farms are installed for the singular reason of nutrient mitigation. i.e., those which are likely to come forward regardless of any proposed development which might have adverse effects on the integrity of a Habitats site.
- 'bespoke' – a mitigation measure which is developed specifically to mitigate impacts of a proposed development. i.e., a scheme which are being delivered in combination and through a related proposed development (a residential development for example) to mitigate the nutrients from the primary proposed development.

Natural England may be able to comment upon a scheme and the supporting justification and/or evidence. However, the position is that if the primary purpose of scheme is for power generation for example, with the unintended consequence of providing mitigation, and the primary intent is not to provide nutrient mitigation, the scheme may not be considered as acceptable nutrient mitigation.

3.4.2.2 Nutrient removal

P is removed or reduced according to the cessation of usage of land as agricultural land or reduction correlated with reduction of grazing animal density. The Norfolk Nutrient Budget Calculator has been used to estimate the effectiveness of this solution. These calculations would need to be refined using Farmscoper and site-specific information input related to fertiliser type and/or manure application. The initial calculations undertaken provide the following ranges:

- Total P Average mitigation removal rate of 0.04 – 0.71 kg TP/ha/yr; and
- Total N removal potential Average mitigation removal rate of 16.23 – 22.75 kg TN/ha/yr.

3.4.2.3 Delivery timescale

A medium estimated timeframe of <5 years is estimated to gain approval and install a solar farm. However, should existing solar farms have recently come forward or will be doing so in the near future, these could be used for nutrient mitigation in the short-term.

3.4.2.4 Duration of operation

Once agricultural land has been taken out of use as a solar farm or other, it is considered to be permanent. A solar farm is estimated to operate for approximately 40 years, which is >10 years classification for permanent duration of operation. Operation and maintenance costs may exceed the cost for renewal after 40 years, which although less than the 80-125 years 'securable in perpetuity' range is relevant to indicate a solar farm as a permanent installation and is therefore considered to be permanent. This is not without noting the complexities over combined solar farm and grazing fields.

3.4.2.5 Applicability

Solar farm installation is applicable to Norfolk where there is available agricultural land which can be used, available connections to the national grid and planning applications have been received for such schemes within Norfolk.

3.4.2.6 Management and maintenance requirements

Once land is no longer agricultural use no further management and maintenance is anticipated. Should land be retained as both agricultural land and solar farm usage with reduced livestock density, maintenance will be required in monitoring of livestock numbers. It may be necessary to determine a threshold number for specific grazing animal species and monitor in order to keep the number below the threshold.

3.4.2.7 Additional benefits

Renewable energy can be provided in addition to nutrient mitigation. This may offer carbon offsetting benefit and offer opportunity for biodiversity net gain by changing land use from a grass monocrop. Solar farms can be affordable and feasible to install, may reduce rainfall, and therefore nutrient leachate from soils and provide shade which may reduce soil desiccation in drought conditions.

3.4.2.8 Wider environmental considerations

Available sunlight in the United Kingdom is a limiting factor on investment in solar farms may outweigh the returns on the purpose for energy production. The construction cost of the solar farm infrastructure can cause pollution, environmental degradation and pressure on natural resources in other areas or countries. Priority sites for installation of solar farms should ideally be brownfield land, which can be challenging to repurpose. Providing incentive to develop solar farm on agricultural land could disincentivise installation and therefore usage of brownfield land.

3.4.2.9 Evidence of effectiveness

Indicative calculations which have not been subject to review have been undertaken using the nutrient calculator using available data and the evidence indicates this can be an effective solution. Further information on the effectiveness or removing land from agricultural production is provided in **Section 3.4.1**.

3.4.2.10 Deliverability and certainty

P and N over time stocking density controls in reduction. Only viable if complete conversion from agricultural land to solar farm. There is potential the lease and planning permission for change in use is the mechanism to secure a legally enforceable scheme.

3.4.2.11 Cost estimate

Land rental or lease costs and construction costs can be offset against energy sale price per watt. Reference should be made to the cost estimate in **Section 3.4.1.11**.

3.4.2.12 Summary

Table 3.25 presents the key considerations for the option to convert agricultural land to solar farms.

Table 3.25 Conversion of agricultural land to solar farm key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
Nutrient removal potential	Total P between 15 and 24 kg/ha/yr: and Total N between 783 and 1,279 kg//ha/yr
Management / Maintenance requirements	Livestock number monitoring
Additional benefits	Renewable energy Biodiversity net gain potential Water quality
Based on best available evidence?	No
Effective beyond reasonable scientific doubt?	Yes, when using the evidence presented in Section 3.4.1 Taking land out of agricultural use as a proxy
Precautionary?	Yes - Precautionary principles can be adopted
Securable in perpetuity?	Yes
Cost estimation	Costs are variable between landowners

3.4.3 Cessation of fertiliser and manure application

3.4.3.1 Description of solution

Where full land abandonment is not available, a change of farming practices or cessation of fertiliser application may be applicable. Stopping fertiliser or manure application will have an immediate short-term impact by reducing the amount of soluble nutrient runoff that is usually lost following application, particularly during rainfall events. There will also be a longer-term impact on particulate phosphate loss should the solution be implemented for consecutive years due to a reduction in soil phosphate reserves. Particulate forms of phosphorus are typically lost through soil erosion when phosphorus is bound to soil.

In a study of long-term (45 years) land use, cropping without fertilisation reduced legacy phosphorus significantly (Zhang *et al*., 2020). This was also confirmed in Zhang *et al* (2020) where after 11 years of cultivation, in which the yield and phosphorus uptake by maize-soybean crops was not affected by withdrawal of phosphate fertilizer down to the critical level, legacy phosphorus was significantly reduced. The study also found that reliance on legacy phosphorus improved farmers' economic margins and reduced the soil test phosphorus levels to safe levels for surrounding catchments. Legacy phosphorus does serve as a potential source for crop use and could potentially decrease the dependence on external fertilisers.

An alternative option to ceasing fertiliser application would be to apply the correct amount of fertiliser that is required rather than applying a constant amount. However, the nutrient removal is more variable and the release of credits would only be available following soil sampling. Nutrient mitigation achieved is also likely to be less than ceasing fertiliser application all together. This solution would only be applicable to farmers who currently apply at constant rates. This solution could be employed as a temporary solution and validated through monitoring of soils.

3.4.3.2 Nutrient removal

Cessation of fertiliser allows land to still be farmed whilst also providing nutrient reductions, with the loss of productivity from the lack of fertilisation balanced by income from nutrient mitigation. This could be secured as a short-term bridging solution by planning conditions. Legal agreements to cease fertiliser application for a set area and duration will be required and spot checks undertaken to monitor farming practises and nutrient concentrations in runoff. Monitoring will be required to ensure that estimated nutrient removal rates are achieved and validate that fertiliser / manure application has ceased. This is likely to comprise 3-4 visits per year, including an initial round of sampling to establish the baseline conditions.

This solution would be best implemented on farms in arable use as removing a biomass will reduce legacy phosphorus values. However, it could also be extended to farms with grazing and mixed livestock. This method would have a significant impact on crop yields, with the greatest impact on responsive crops such as potatoes and some vegetables, which may increase the cost of this solution for these farming types. Where implemented on livestock farms, the soils should have P indices of 2. Phosphorus levels can be farmed down through cutting for silage without fertiliser application which will quickly reduce excess phosphorus. This would prevent approximately 30 kg/ha of P application that would normally be added after each cut (Agriculture and Horticulture Development Board, 2022).

Particulate phosphorus runoff reductions from the cessation of 100% of fertiliser application is estimated to be 50% (Newell Price *et al*., 2011). White and Hammond (2009) found that particulate phosphorus accounts for 40% of the total phosphorus loss from improved grassland. However, on arable land particulate forms of phosphorus typically have more of an influence than on grassland areas, due to the lack of dense vegetation preventing particulate loss. Neal *et al*. (2010) studied the relationship between soluble and particulate phosphorus in nine major UK Rivers and found that particulate phosphorus in agricultural and rural setting made up 50% of the Total Phosphorus. As such, it was assumed that particulate phosphorus makes up 50% of Total Phosphorus. Therefore, the total phosphorus removal values for cessation of fertiliser and manure application is assumed to be 25%. Newell Price *et al*. (2011) estimates that nitrate losses would be approximately 90% from the cessation of fertiliser.

The phosphorus and nitrogen removal that can be achieved for each farming typology is presented in **Table 3.26** and **Table 3.27**.

Table 3.26 Phosphorus removal from the temporary cessation of fertiliser and manure application

Farm type	Phosphorus removal from cessation of fertiliser / manure application (kg TP/ha/yr)		
	Wensum	Yare	Bure
Dairy	0.10	0.07	0.04
Lowland grazing	0.06	0.04	0.03
Mixed livestock	0.15	0.07	0.02
Poultry	0.18	0.10	0.04
Pig	0.18	0.09	0.02
Horticulture	0.17	0.08	0.01
Cereals	0.18	0.09	0.02
General arable	0.16	0.07	0.01

Table 3.27 Nitrogen removal from the temporary cessation of fertiliser and manure application

Farm type	Nitrogen removal from cessation of fertiliser / manure application (kg TN/ha/yr)		
	Wensum	Yare	Bure
Dairy	15.45	20.45	32.28
Lowland grazing	12.29	10.12	16.34

Farm type	Nitrogen removal from cessation of fertiliser / manure application (kg TN/ha/yr)		
	Wensum	Yare	Bure
Mixed livestock	21.65	18.85	31.14
Poultry	160.13	142.87	205.79
Pig	65.88	58.13	80.82
Horticulture	17.17	13.85	20.37
Cereals	21.38	17.31	23.18
General arable	19.55	15.67	24.96

The impact of legacy phosphates limits the phosphorus reduction potential that can be achieved through stopping fertiliser application. However, much greater amounts of nitrogen can be removed and make the solution much more viable. **Table 3.28** and **Table 3.29** provide an indication of the likely mitigation that could be delivered and associated costs in each sub-catchment. This assumes a 10ha cereal farm would cease fertiliser application and the costs outlined in **Table 3.30**

Table 3.28 Potential phosphorus mitigation and associated costs

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£)	£/kg TP/yr for each year	£/dwelling for each year	£/kg TP/yr over 80 years	£/dwelling over 80 years
Wensum	1.83	27	12,744	6,983	474	558,637	37,896
Yare	0.85	13	12,744	14,993	1,017	1,199,426	81,364
Bure	0.15	2	12,744	84,959	5,763	6,796,747	461,062

Table 3.29 Potential nitrogen mitigation and associated costs

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£)	£/kg TN/yr for each year	£/dwelling for each year	£/kg TN/yr over 80 years	£/dwelling over 80 years
Wensum	213.75	113	12,744	60	112	4,770	8,988
Yare	173.07	92	12,744	74	139	5,891	11,100
Bure	231.75	123	12,744	55	104	4,399	8,290

The nitrogen mitigation that can be achieved through the cessation of fertiliser application is likely to cost more than taking agricultural land out of use completely. However, allowing crop production to continue could be more appealing to farmers and will not have as detrimental of an impact on food supplies. The phosphorus mitigation is limited and leads to significant costs for mitigation.

3.4.3.3 Delivery timescale

This solution does not require any investment in infrastructure, planning permission or environmental permits. It can therefore be implemented in very short timescales.

3.4.3.4 Duration of operation

This solution is envisaged as a temporary measure for use while longer-term solutions are developed and implemented. Prolonged cessation of fertiliser application may be akin to taking land out of agricultural use (cf. **Section 3.4.1**).

3.4.3.5 Applicability

This solution is applicable to all types of arable agriculture where natural or synthetic fertilisers are applied.

3.4.3.6 Management and maintenance requirements

No maintenance required.

3.4.3.7 Additional benefits

Land could be selected strategically to help buffer from other pollution sources (e.g., suspended sediment).

3.4.3.8 Wider environmental considerations

Implementation of this option is unlikely to be significantly constrained by wider environmental factors. If the solution is over-used then the reduced yield could result in localised food supply issues. However, this would not have the same impact as taking land out of agricultural use.

3.4.3.9 Evidence of effectiveness

Information on the effectiveness or removing land from agricultural production is provided in **Section 3.4.1**.

3.4.3.10 Deliverability and certainty

Certainty that fertiliser application has ceased can be provided through soil sampling which could be conducted in Spring (following typical spring application) for each year the solution is in place.

3.4.3.11 Cost estimate

Table 3.30 outlines the likely costs associated with this solution, both for arable and grassland farming. Cessation of fertiliser application to arable land is estimated to have a 50% reduction in yield on the affected area. Similarly, cessation to grassland is assumed to have a reduction of 30% to an average yield of 8t/ha (Newell Price *et al*., 2011). The actual costs per farm are likely to differ due to the variety of variables, such as fertilisation rates, soil types, crop types, etc.

Table 3.30 Cessation of fertiliser / manure cost estimation

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

3.4.3.12 Summary

Table 3.31 presents a range of considerations for cessation of fertiliser / manure application for phosphate offsetting.

Table 3.31 Cessation of fertiliser and manure application

Key considerations	
Delivery timescale	Short-term
Duration timescale	Temporary
TP removal potential	0.02 – 0.18 kg/ha/yr
TN removal potential	17.31 – 21.38 kg/ha/yr

Key considerations	
Farm typologies applicable	Arable and Grassland
Management / maintenance requirements	None
Additional benefits	Positioning of farms could be strategic to help buffer from other pollution sources (e.g. suspended sediment)
Based on best available evidence?	Yes – monitoring likely to be needed to confirm
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	No – likely to be utilised as a bridging solution
Cost estimation	Arable: £1,274.39 ha/yr

3.4.4 Cover crops

3.4.4.1 Description of solution

Surface runoff and erosion represents a principal mechanism for nutrient loss from many agricultural systems. The risk of runoff is primarily controlled by timing, rate and method or fertiliser or manure application, as well as post-application rainfall. Natural factors such as slope, surface roughness, infiltration capacity and magnitude of erosion also have a strong control. Bare soils are very prone to erosion and cover crops help maintain soil cover during the autumn and winter or any time of the year including drier months and cover crops can also be sown in Springtime. They are especially useful to mitigate erosion on high-risk sloping land. Cover crops act to encourage infiltration and reduce overland flow velocity. They are best employed when land would otherwise be left bare during the crop rotation process. They are typically used either prior to main production cycle (e.g., potatoes, sugar beet) or post-harvest (e.g., cereals).

Numerous studies have demonstrated that cover crops' uptake of nitrogen lowers the possibility of nitrate losses due to leaching over the winter. Having less soil runoff also means having less phosphate linked to soil particles to lose.

A study conducted by The New Farming Systems Project (NFS) with a view to explore ways of improving the sustainability, stability and output of conventional arable farming systems started in 2007 with additional study in 2011 on a sandy loan soil at Morley in Norfolk. Research has shown advantages in terms of improved soil properties, favourable yield responses, and increases in financial margins over fertiliser input related with the employment of particular cover crop systems.

A study conducted by NFS over two seasons on Origins^{TM} in sites in Leicestershire have revealed mean N leaching reductions of approximately 43% (mean values for 2015 and 2016 were approximately 40% and 46%, respectively, or 38 kg/ha and 25 kg/ha, respectively, of N). The results of other studies in this field are consistent with this. To help crops and the larger soil system, this N will be kept in the soil. For this use, a variety of fast-growing cover crops are appropriate (Stobart, 2016).

Another study was conducted on a 143-ha commercial arable farm in Norfolk, UK, to determine the effectiveness of cover crops in reducing farm-scale nutrient losses with a cover crop of winter oilseed radish (*Raphanus sativus*), various observations were made from the year 2012 to 2015 and according to the results, oilseed radish had no effect on phosphate (P) losses but reduced nitrate (NO3-N) leaching losses in soil water by 75-97% in comparison to the fallow land (Cooper *et al*., 2017).

Published phosphorus reduction rates are variable within the literature. Some studies suggest significant phosphorus removal can be achieved, such a study by Novotny and Olem (1994) which suggested phosphorus removal of 30-50% and Sharpley and Smith (1991) which found an average reduction of 77% from four different studies. However, other investigation concluded that changes to phosphorus losses were not significant (e.g., Kleinman *et al*, 2005).

Published nitrogen reductions values are also variable within the literature. Kaspar and Singer (2011) studied nitrate reductions from cover crops for 16 studies and found that the reduction in leaching losses ranged from 6 to 94%. Spier *et al*., 2022 found that cover crops consistently reduced tile drain nitrate loss by 27-72%. Similarly, Hanrahn *et al*., (2018) measured median nitrate savings of 69-90% compared to fields without cover crops during winter/spring. Kaspar *et al*., (2012) observed nitrate reductions of 48% over 5 years using rye winter crop.

Validation of cover crops can be achieved through satellite imagery, photographs, and drive by visits. Due to the uncertainty in removal values, monitoring may be required to establish the baseline and phosphate reduction.

3.4.4.2 Nutrient removal

Table 3.32 and **Table 3.33** provide an indication of the likely mitigation that could be delivered and associated costs in each sub-catchment. This assumes 1ha of cover crops on cereal land and that payments are equivalent to £124 per hectare.

Table 3.32 Estimated TP mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£)	£/kg TP/yr for each year	£/dwelling for each year	£/kg TP/yr over 80 years	£/dwelling over 80 years
Wensum	0.22	3	124	566	38	45,297	3,073
Yare	0.10	2	124	1,216	82	97,255	6,597
Bure	0.02	0	124	6,889	467	551,111	37,385

Table 3.33 Estimated TN mitigation and associated costs in each sub-catchment

Sub-catchment	Mitigation	Housing equivalent	Cost estimation (£)	£/kg TN/yr for each year	£/dwelling for each year	£/kg TN/yr over 80 years	£/dwelling over 80 years
Wensum	7.13	4	124	17	33	1,392	2,624
Yare	5.77	3	124	21	41	1,720	3,240
Bure	7.73	4	124	16	30	1,284	2,420

3.4.4.3 Delivery timescale

This solution does not require any investment in infrastructure, planning permission or environmental permits. It can therefore be implemented in very short timescales.

3.4.4.4 Duration of operation

This solution is envisaged as a long-term change in agricultural land management practices. However, in the absence of any significant infrastructure, long term investment or mechanisms for binding agreements with landowners, it is considered to be impermanent.

3.4.4.5 Applicability

This solution is applicable to all types of arable agriculture, particularly where fields are left bare and thus vulnerable to surface water runoff and erosion after the harvest of the main crop.

3.4.4.6 Management and maintenance requirements

There will be annual maintenance requirements associated with preparation, planting, destruction and cultivation of cover crops.

3.4.4.7 Additional benefits

Reduces soil erosion, improves water quality and increases biodiversity due to habitat creation. Cover crops also provide winter cover and habitat for birds, mammals, and insects.

3.4.4.8 Wider environmental considerations

Implementation of this option is unlikely to be significantly constrained by wider environmental factors.

3.4.4.9 Evidence of effectiveness

Although there is scientific evidence to suggest that cover crops are effective in reducing the supply of phosphorus and nitrogen from agricultural land, estimates show considerable variation (cf. **Section 3.4.4.1**). There is therefore a degree of uncertainty associated with the effectiveness of this solution.

It is expected that a conservative removal rate of 30% could be applied for cover crops. Monitoring would then be required to access 'credits' for removal rates above 30%.

3.4.4.10 Deliverability and certainty

Certainty that the solution has been delivered and will continue to be delivered can be provided through site visits, aerial imagery and submission of photos from landowners. Monitoring of local watercourses can be conducted to confirm the predicted removal rates are achieved.

3.4.4.11 Cost estimate

Annual maintenance costs estimated to be £150/ha/yr (AHDB, 2020) £124 per hectare.

3.4.4.12 Summary

Table 3.34 presents a range of considerations for using cover crops for nutrient offsetting.

Table 3.34 Cover crops

Key considerations	
Delivery timescale	Short-term
Duration timescale	Impermanent
TP removal potential	Large uncertainty - Assumed to be 30% removal.
TN removal potential	Large uncertainty - Assumed to be 30% removal.
Farm Typologies applicable	Arable farms (particularly cereals)
Management / Maintenance requirements	Time and money costs associated with preparation, planting, destruction and cultivation.
Additional benefits	Water quality Habitat creation
Based on best available evidence?	No – Phosphate reductions estimates highly variable
Effective beyond reasonable scientific doubt?	Yes

Key considerations	
Precautionary?	Yes
Securable in perpetuity?	Yes – management agreements will likely need to be put in place, especially where land in leased.
Cost estimation	Maintenance costs: £150/ha/yr (AHDB, 2020) £124 per hectare

3.4.5 Installing Sustainable Drainage Systems (SuDS) in new developments

3.4.5.1 Description of solution

SuDS are efficient sediment traps and reduce the amount of runoff entering watercourses. The fundamental principles of SuDS are to slow flow and promote infiltration, allowing rainfall to enter the groundwater where it falls. Examples include basins and ponds, filter strips and swales, constructed wetlands, soakaways, infiltration basins, gravelled areas, and porous paving. SuDS systems require design specific to a development site and the phosphate reduction efficacy can vary between options.

3.4.5.2 SuDS typologies

SuDS systems that promote infiltration of water and settlement of sediment will have the greatest benefit for phosphorus removal. Similarly, SuDS that provide an environment for vegetation to uptake phosphorus will achieve good phosphorus removal rates. SuDS used in combination and that are linked in a treatment train, often culminating in a SuDS wetland, represent the most favourable scenario.

SuDS wetlands should typically comprise of an initial sediment fallout pond, a variety of deeper zones and shallow macrophyte zones (**Figure 3. 7**). The wetlands should also be able to accommodate additional volume for excess rain. Regular wetland maintenance is also essential to ensure that removal rates are maintained and to ensure that an accumulation of phosphorus enriched sediment does not become a source rather than a sink. Indicative cost estimates are presented in **Section 3.4.5.12**.

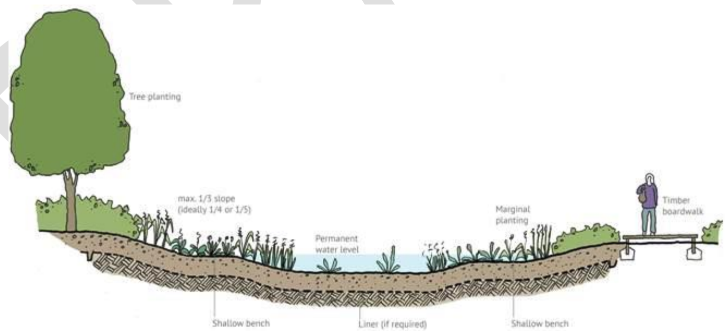

Figure 3. 7 Example of a SuDS wetland (Source: Susdrain)

Swales are shallow, relatively wide, and vegetated depressions that are designed to store and convey runoff and remove pollutants. They can also be used as conveyance structures to transfer runoff into the next stage of the SuDS treatment process. They are fairly easy to incorporate, with low capital costs and simple maintenance. They are best suited to low gradients on both sides and can be enhanced by placing check dams across the swale to reduce flow rate (**Figure 3. 8**).

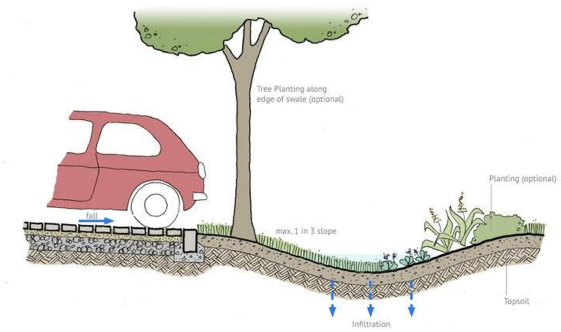

Figure 3. 8 Example of swales and conveyance channels (Source: Susdrain)

Filter strips are gently sloping, vegetated strips of land that slow conveyance and promote infiltration. They typically lie between hard-surfaces and a receiving stream / surface water collection (**Figure 3. 9**). Runoff is primarily by overland sheet flow. They are easy to construct and have low capital costs. They are unsuitable where the slope gradients are too steep.

Figure 3. 9 Example of filter strips (Source: Susdrain)

Bioretention areas are landscaped depressions which use enhanced vegetation and filtration to remove pollution and reduce runoff (**Figure 3. 10**). They are aimed at managing and treating runoff from frequent rainfall events. They are very effective at removing pollutants and flexible to install into the landscape.

Figure 3. 10 Example of a rain garden (Source: Welshwildlife.org)

Source control is also a key method in reducing runoff. Permeable paving can attenuate flow and increase infiltration. Green roofs also provide interception storage and treat some of the more frequent but smaller, polluting rainfall events.

The latest advice provided by Natural England suggests that they may be able to give more details on how SuDS should be incorporated into the calculator and the mitigation potential this may have. Further details to this solution will be given following the guidance from Natural England.

SuDS can be best incorporated into new developments where they can be designed from an early stage to achieve the greatest impact. The use of SuDS should be encouraged as this will treat excess phosphorus on site. Furthermore, the Norfolk County Council (as Lead Local Flood Authority) drainage design standards for highways[2] indicate Norfolk County Council seeks to reduce the rate of surface water run-off through the use of SuDS and the Norfolk Local Flood Risk Management Strategy (2015) encourages SuDS approaches in new developments and considers retrofitting SuDS within existing settlements. The strategy takes information from Authorities respective Surface Water Management Plans (SWMP)[3] some of which identify SuDS to be used where appropriate. This is likely to be most applicable larger urban areas such as Dereham, Wymondham, Aylsham and Norwich where the SuDS manual (CIRIA, 2015) sets out further design approaches. Other areas such as Poringland in South Norfolk may not be appropriate for SuDS as the use of infiltration methods could create new or aggravate existing local groundwater flooding problems by increasing the rate at which rainwater enters the ground.

Urban retrofitting can be used to install SuDS. To accommodate surface water run-off from existing developments and built-up areas Strategic driven retrofitting can achieve phosphorus reductions and can be combined with the need for urban regeneration and flood reduction.

[2] https://www.norfolk.gov.uk/rubbish-recycling-and-planning/planning-applications/highway-guidance-for-development/drainage

[3] https://www.norfolk.gov.uk/what-we-do-and-how-we-work/policy-performance-and-partnerships/policies-and-strategies/environment-and-planning-policies/flood-and-water-management-policies/surface-water-management-plans

3.4.5.3 Nutrient removal

Many of the components of a SuDS design do not have a strong evidence base to determine removal efficiencies. Lucke *et al*. (2014) reported total phosphorus removal of 20 - 23% under runoff simulation. Lucke *et al*. (2014) reviewed a range of other published data and found slightly higher mean TP reduction of 48%. Moderate phosphorus reductions associated with swales suggest they would be best used alongside a suite of other measures to achieve a greater cumulative impact and achieve neutrality (e.g., as a part of SuDS schemes used in new housing developments). As such, it is the expectation that CIRIA guidance (to be published December 2022) on SuDS will provide more information on the likely TP and TN reduction rates. SuDS are well-established and familiar to many developers and are likely to be an attractive method for achieving on-site mitigation.

3.4.5.4 Delivery timescale

A requirement to implement SuDS as part of all new developments can be established in the short term.

3.4.5.5 Duration of operation

Once installed, SuDS are assumed to be permanent drainage and nutrient management solutions.

3.4.5.6 Applicability

This solution is applicable to all new dwellings in the catchment and should be designed from an early stage. The size of the site will control the design and nutrient removal potential. Retrofitting of SuDS is more location specific to ensure the greatest return.

3.4.5.7 Management and maintenance requirements

The long-term performance of SuDS would also need to be secured through maintenance agreements (e.g., via Section 106 rather than planning conditions given the required duration of these commitments). Key maintenance tasks are outlined in **Table 3.35**. Sedimentation will eventually compromise some aspects of the SuDS function and rejuvenation measures will be necessary (Kadlec and Wallace, 2009).

Table 3.35 SuDS maintenance tasks

Activity	Indicative frequency	Typical tasks
Routine/regular maintenance	Monthly (for normal care of SuDS)	• litter picking; • grass cutting; and • inspection of inlets, outlets and control structures.
Occasional maintenance	Annually (dependent on the design)	• silt control around components; • vegetation management around components; • suction sweeping of permeable paving; and • silt removal from catchpits, soakaways and cellular storage.
Remedial maintenance	As required (tasks to repair problems due to damage or vandalism)	• inlet/outlet repair; • erosion repairs; • reinstatement of edgings; • reinstatement following pollution; and • removal of silt build up.

3.4.5.8 Additional benefits

SuDS can provide multiple benefits other than phosphorus removal. They mimic natural drainage process and reduce the quantity of runoff from developments as well as providing amenity, improved quality of water, habitat creation and biodiversity benefits. Where appropriately designed and used, a SuDS treatment train will reduce runoff and storm flow, which can lead to a reduction in combined sewage overflows.

3.4.5.9 Wider environmental considerations

The use of SuDS in new developments is unlikely to be significantly constrained by wider environmental factors.

3.4.5.10 Evidence of effectiveness

As discussed in **Section 3.4.5.3**, there is currently limited evidence to demonstrate the efficiency of SuDS measures in the removal of nutrients from runoff. However, parallels could potentially be drawn with the evidence base for their effectiveness in attenuating flows and reducing sediment supply.

3.4.5.11 Deliverability and certainty

SuDS are often permanent features which are designed for the lifetime of developments. SuDS will typically provide additional benefits other than nutrient removal which are fundamental to the functionality of the development (e,g, surface water attenuation).

3.4.5.11.1 Summary of Draft CIRIA C808 'Using SuDS to reduce phosphorus in surface water runoff' schedule

The CIRIA C808 (Bradley *et al.,* 2022) document; 'Using SuDS to reduce phosphorus in surface water runoff' has been informally issued and is summarised in this section. The document was prepared following agreement of the schedule with Natural England. It works towards definitive recommendations for the use of SuDS for P removal. The document sets out SuDS deployment via 'treatment trains' to achieve good practice P removal which are expected to be set out at outline and full planning applications stages. A precautionary reduction in the runoff rate of P from new developments can be achieved for developments that secure the good practice SuDS set out in the document.

For the design of an effective SuDS management train, varying site characteristics need to be understood, these include:

1. Soil characteristics – soil type, permeability, pre-existing nutrient content and infiltration of surface water capacity.
2. Groundwater level and seasonal changes.
3. Vulnerability of underlying groundwater.
4. Receiving watercourse characteristics – type, location, flow rate and size of receiving watercourse.

The principles of P capture and removal with respect to residential developments are set out as:

1. Ground infiltration of water from residential developments where conditions allow without a risk of groundwater pollution should be the first step of P pollution control.
2. Sediment capture via SuDS can remove a proportion of P in run off for sites where conditions are such that runoff infiltration cannot work. A SuDS can also protect further treatment device from sediment accumulation.
3. Vegetation within a treatment device captures dissolved phase P and supports P associated with particulates to be captured.
4. The treatment train hierarchy starts with: infiltration, sedimentation, reduction of suspended solids, and plants to take up dissolved phase P.
5. Enhancement of such devices can be made with the inclusion of P specific treatment media.

The documents lists 16 site-specific factors to be considered with respect to design and monitoring effectiveness of SuDS which ranges from establishing 'legacy' P in respect of previous land use and consideration of sustainability of construction materials.

The document also lists an order of SuDS components/devices:

1 Primary components comprise: source control such as permeable paving, spillage control (such as oil/water interceptors), sedimentation devices, such as vortex grit separators. Rain and stormwater capture and reuse system installation in properties and landscaped areas. Capture and reuse systems reduce flow into SuDS (and form part of other solutions for Norfolk Authorities described in Demand Management Solutions (Section 3.6).

2 Secondary components comprise: additional removal of suspended solids and dissolved P from ponds, basins, wetlands, floating wetlands and willow beds.

3 Tertiary components comprise: downstream of sedimentation devices, stormwater filters and granular treatment media beds. Treatment is more effective via this component when the runoff water has been subject to some degree of 'cleaning' prior to this point.

4 All-in-one devices components are described as bio-retention zones (which are typically shallow landscaped in-ground depressions) and tree pits.

The document includes a flow chart with suggested good practice design methodology. The quantity calculation set out in the following steps in key:

Step 1 – P in the runoff each year.

Step 2 – runoff that can be infiltrated to ground using SuDS.

Step 3 – remaining P that can be removed using SuDS.

Step 4 – P contained in runoff which bypasses the SuDS without treatment in heavy rain events.

Step 5 - P to be mitigated offsite (that remaining at the end of Step 3 and 4).

The document provides information for the detailed design of individual components of SuDS, such as wetlands, ponds, bioretention zones/ rain gardens and other examples include:

- Swales which are linear in-ground depressions.
- Detention basins and retention basins which capture runoff during rain events and detain water using a flow control device and release after the rainfall event. Detention basics are generally dry and retention basins have standing water in between rain events.
- Tree pits are constructed depressions similar to bioretention zones.
- Floating wetlands are constructed on permanent water bodies, the roots grow into the water and remove P and ca also offer sediment removal via root growth.
- Filter strips which are formed by a grassy strip with a gentle downward include to allow flow towards another SuDS device.
- Filter drains, which are granular coarse stone-filled trenches which capture sediment from water runoff in the void spaces.

The document provide a modelling statement which describes the methodology used for modelling pollutant efficiencies of different SuDS trains. It also summarises the relative performance of SuDS components for P capture and removal which is noted as highly variable. Where SuDS promote infiltration, it is assumed that 100% of the TP is removed. The TP removal from conveyed flows which are not infiltrated are presented in **Table 3.36**.

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Table 3.36: *Performance of SuDS components for phosphorus capture and removal (Edited from CIRIA C808 (2022))*

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

3.4.5.12 Cost estimate

Table 3.37 and **Table 3.38** present outline cost estimates for various SuDS types.

Table 3.37 SuDS costs for buffers, bunds and wetlands (edited from Vinten et al (2017))

Measure	Recurrent costs	Capital costs
8m buffer	£495 ha/yr for 6m buffer	Nil
20m buffer	£495 ha/yr for 18m buffer	Nil
Detention bund	Nil	£7m bund £10.50m^2 excavation £5.50m^2 perimeter fence

Table 3.38 Indicative capital costs for SuDS options (edited from Environment Agency (2015)) and relative performance edited from C808 CIRIA, (2022)

SuDS Option	Cost estimation	Source
Green roofs	£80/m^2 - £90/m^2	Bamfield, 2005
Rainwater harvesting (water butts)	£100 - £243 per property	Stovin & Swan, 2007
Advanced rainwater harvesting	£2,100 - £3,700 per residential property £45/m^2 for residential properties	Environment Agency, 2007 RainCycle, 2005
Greywater re-use	£3,000 per residential property	Environment Agency, 2007
Permeable paving	£30/m^2 - £54/m^2	CIRIA, 2007 Environment Agency, 2007
Filter drains / perforated pipes	£120/m^2 £100/m^3 - £140/m^3	Environment Agency, 2007 CIRIA, 2007
Swales	£10/m^2 – £15/m^2	Environment Agency, 2007 CIRIA, 2007
Infiltration basin	£10/m^3 – £15/m^3 stored volume	CIRIA, 2007
Soakaways	£450 - £550 per soakaway	Stovin & Swan, 2007
Infiltration trench	£60/m^2 £55/m^3 - £65/m^3 stored volume	Environment Agency, 2007 CIRIA, 2007
Filter strip	£2/m^2 - £4/m^2	CIRIA, 2007
Constructed wetland	£25/m^3 - £30/m^3 stored volume	CIRIA, 2007
Retention pond	£16/m^3 pond £25/m^3 - £30/m^3 stored volume	SNIFFER, 2006 CIRIA,2007
Detention basin	£15/m^3 - £55/m^3 stored volume	CIRIA, 2007 Stovin & Swan, 2007

SuDS Option	Cost estimation	Source
Onsite attenuation and storage	£449/m^3 - £518/m^3 for reinforced concrete storage tank	Stovin & Swan, 2007

3.4.5.13 Summary

Table 3.39 presents the key considerations for the use of SuDS for nutrient offsetting or reduction.

Table 3.39 SuDS key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
TP removal potential	Highly variable and will likely need site specific calculations. The CIRIA C808 (2022) 'Using SuDS to reduce phosphorus in surface water runoff' document summarises the varying sediment capture capability (which ranges from 22 to 44%) and dissolved P capture/removal (which ranges from nil to 100%).
TN removal potential	Highly variable and will likely need site specific calculations.
Management / maintenance requirements	The long-term performance of SuDS would also need to be secured through maintenance agreements. Maintenance works would include desilting of swales, wetlands, and basins to maintain their efficiency. Vegetation management of buffers would be necessary to maintain the optimum roughness/composition and sediment trapping efficiency.
Additional benefits	Water quality Reduced erosion Habitat creation Improved amenity value
Based on best available evidence?	No – monitoring may be required to determine the efficacy of specific schemes
Effective beyond reasonable scientific doubt?	No
Precautionary?	Yes
Securable in perpetuity?	Yes – maintenance agreements may be required
Cost estimation	See Error! Reference source not found. and Error! Reference source not found..

3.5 Wastewater Management Solutions

3.5.1 Expedite planned improvements to treatment works

3.5.1.1 Description of solution

Bringing forward scheduled improvements to treatment works which are scheduled to be online by 2025 or 2030, will lead to increased phosphate reductions above and beyond what was originally planned. This would require Anglian Water to complete the upgrades in advance of the deadline, but would not operate at the reduced permit limit until required in order to save operational costs.

Upgrades are planned to Aylsham, Southrepps and Swardeston at the end of the current AMP cycle (i.e. by 2025).

3.5.1.2 Nutrient removal

The potential savings that could be achieved by bringing forward upgrades planned to be in place by 2025 are presented in **Table 3.40**. Contributions to cover the operational costs could achieve 1,407.94kg/yr of short-term mitigation that could be utilised until December 2024. The largest reductions can be achieved at Swardeston treatment works which is currently unpermitted and therefore assumed to have an effluent concentration of 6mg/l. The large population served by Aylsham also results in significant TP mitigation opportunities. Swardeston would provide mitigation in the Yare catchment (which has the largest mitigation burden) whereas Alysham and Southrepps would provide mitigation in the Bure catchment. Total nitrogen reductions are uncertain and may vary between wastewater treatment works.

Table 3.40 *Potential phosphorus reductions associated with upgrades to treatment works planned by 2025*

Treatment works	TP loading under current permit limits (kg/yr)	TP loading under future permit limits (kg/yr)	TP Mitigation from bringing forward improvements (kg/yr)
Aylsham	359.53	215.72	143.81
Southrepps	115.42	22.78	92.64
Swardeston	1246.27	74.78	1171.50
Total	**1721.22**	**313.27**	**1,407.94**

Contributions to cover the operational costs could achieve 1,407.94kg/yr of short-term mitigation that could be utilised until December 2024. The largest reductions can be achieved at Swardeston treatment works which is currently unpermitted and therefore assumed to have an effluent concentration of 6mg/l. The large population served by Aylsham also results in significant TP mitigation opportunities.

Swardeston would provide mitigation in the Yare catchment (which has the largest mitigation burden) whereas Alysham and Southrepps would provide mitigation in the Bure and Ant catchments, respectively.

Total nitrogen reductions are uncertain and may vary between wastewater treatment works.

The potential savings that could be achieved by bringing forward upgrades planned to be in place by 2030 are presented in **Table 3.41**. This demonstrates that considerable reductions in nutrient loading could be achieved (14,244 kg/yr P and 289,139 kg/yr N). The greatest benefit in reductions of both P and N would be achieved by bringing forward proposed upgrades to Whitlingham WRC, reflecting the large population served by this asset. Improvements at Dereham, Forncett, Hempnall, Mattinghall and Saxlingham could also deliver significant benefits for P concentrations, while the greatest reductions in N concentrations could be realised through the improvement of the WRCs at Dereham, Fakenham, Wymondham and Aylsham.

Table 3.41: *Potential nutrient reductions associated with upgrades to treatment works planned by 2030*

Treatment works	Phosphorus			Nitrogen		
	TP loading under current or 2025 permit limits (kg/yr)	TP loading under proposed 2030 permit limits (kg/yr)	TP Mitigation from bringing forward improvements (kg/yr)	TN loading under current or 2025 permit limits (kg/yr)	TN loading under proposed 2030 permit limits (kg/yr)	TN Mitigation from bringing forward improvements (kg/yr)
Aylsham	221	92	129	10,231	3,683	6,548
Belaugh	388	83	305	9,234	3,328	5,916
Briston	78	26	52	2,818	1,015	1,804
Bylaugh-Near Church	255	30	225	3,378	1,216	2,162
Dereham-Rushmeadow	773	229	544	25,413	9,149	16,264
Fakenham	604	151	453	16,791	6,045	10,746

Forncett	744	28	716	3,102	1,117	1,985
Hempnall-Fritton	663	25	638	2,762	994	1,768
Long Stratton	193	59	134	6,505	2,342	4,163
Mattishall	897	34	864	3,740	1,346	2,393
Reepham	157	43	115	4,740	1,706	3,034
Saxlingham	610	23	587	2,541	15	1,626
Stalham	295	77	218	5,876	3,087	2,789
Swardeston	76	47	28	5,256	1,892	3,364
Whitlingham	11,893	2,973	8,920	330,364	118,9100	211,454
Wymondham	500	185	216	20,505	7,382	13,123
Total	**18,346**	**4,104**	**14,244**	**453,265**	**164,127**	**289,139**

3.5.1.3 Delivery timescale

The delivery timescales is dependent on the level of existing infrastructure in place and how quickly the effluent concentrations could reach the target concentration.

3.5.1.4 Duration of operation

This solution is envisaged to be a temporary solution that would provide mitigation up to the end of the AMP cycle (assumed to be online by December 2024).

3.5.1.5 Applicability

This solution is only applicable to wastewater treatment works planned for upgrades in 2025.

3.5.1.6 Management and maintenance requirements

Normal maintenance and monitoring requirements would be fulfilled by the water company.

3.5.1.7 Additional benefits

This solution is unlikely to deliver any wider environmental benefits.

3.5.1.8 Wider environmental considerations

Achieving low TP effluent concentrations may require extensive chemical dosing which is typically imported.

3.5.1.9 Evidence of effectiveness

The manufacturers of portable treatment plants have undertaken detailed testing of their performance and as such are able to provide certainty regarding the level of nutrient removal that can be achieved.

3.5.1.10 Deliverability and certainty

Agreements with water companies will be required in order to implement this solution. These agreements will provide the certainty that the solution will be implemented and the intended timescales.

3.5.1.11 Cost estimate

Costs are uncertain and would need to be provided by Anglian Water. It is anticipated that nutrient credits would be used to pay for, or contribute partly towards, upgrades of some of the WwTWs. The likely costs associated with expediting improvements will be the operational and management costs (e.g. phosphorus dosing & energy costs) to operate to a lower permit limit.

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3.5.1.12 Summary

Table 3.42 presents the key considerations for the expedition of planned improvements to wastewater treatment works in the catchment.

Table 3.42 Expedite planned improvements to wastewater treatment works

Key considerations	
Delivery timescale	Short-term
Duration timescale	Temporary – up to 2025
TP removal potential	1,407.94 kg/yr of mitigation could be delivered assuming all three schemes come forward.
Management / maintenance requirements	Normal maintenance carried out by water company
Additional benefits	Potential nitrogen reductions
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	No - because although brought forward, it would not go beyond what was originally planned
Cost estimation	Costs are uncertain as they are bespoke to each scheme and would need to be provided by Anglian Water

3.5.2 Install portable treatment works

3.5.2.1 Description of solution

Portable treatment works that can be used as a secondary treatment specifically for nutrient removal (**Table 3.42**). They are typically used by water companies during upgrades. One container can typically serve up to 20,000 population equivalent (PE). The containers are modular so can be used in parallel to handle any flow. They are typically built inside standard shipping containers making them easy to install and move to another site (**Figure 3. 11**). They could be used as short-term solutions whilst other mitigations options and designed and developed. Other examples include portable vertical flow wetlands. The portable works typically have a small footprint of <0.2ha.

Figure 3. 11 Example of a portable containerised wastewater treatment works (Source: Vikaspumps.com)

Technically, the treatment works can be used for treating river water. However, there may be some difficulties in preventing plants, fish, and invasive species from entering the system and pre-treatment would be needed. In this case, the systems could be used on proposed wetland creation sites during the design and construction phase to deliver short-term phosphate mitigation.

Agreement with Anglian Water is likely to be required in order to link the current effluent to the portable treatment works. Adjacent land rental may also be required.

3.5.2.2 Nutrient removal

Using portable treatment works in place of mains WwTWs could reduce phosphorus effluent to 0.5mg/l. This would represent a large decrease from unpermitted sites which are assumed to operate at 6mg/l. For example, using portable treatment works at Swardeston could achieve a short-term phosphorus reduction of 1,156kg/yr TP, equivalent to 17,046 new dwellings draining to Whitlingham. Assuming the solution is in place for 3 years, the total cost of the treatment works, maintenance and land rental would likely be £115,000. This solution could therefore deliver phosphorus mitigation at a cost of £101 per kg/yr of mitigation per year or £7 per dwelling per year. Over 80 years this is equivalent to £8,053 per kg/yr mitigation £546 per dwelling.

The greatest phosphorus reductions will be achieved through installing portable treatment works to treatment works without phosphorus stripping and those which are serving a large population. Examples are included in **Table 3.43**.

***Table 3.43**: Potential phosphorus reductions associated with portable treatment works*

Treatment works	TP loading under current permit limits (kg/yr)	TP loading portable treatment works (kg/yr)	TP Mitigation (kg/yr)	Housing equivalent
Swardeston	1,261.49	105.12	1156.37	17,047
Shipdham	469.11	39.09	430.02	6,339
Stoke Holy cross	382.09	31.84	350.25	5,163
Saxlingham	609.89	50.82	559.07	8,242
Total	2722.58	226.87	2495.71	36,791

The upgrades are likely to have some impact on nitrogen effluent concentrations. However, there is greater uncertainty of the final effluent concentrations.

3.5.2.3 Delivery timescale

Portable treatment works typically take 3 months to deliver and set up; they can therefore be implemented over short timescales. An environmental permit is likely to be required for any discharges from the portable treatment works.

3.5.2.4 Duration of operation

This solution is envisaged to be a temporary solution that would be used until permanent solutions can be implemented. However, there is potential for portable treatment works to be used over longer timescales as an impermanent solution, although costs may be proportionately high.

3.5.2.5 Applicability

This solution is most likely to be applicable for use in a WwTW alongside existing treatment equipment.

3.5.2.6 Management and maintenance requirements

Review of limited monitoring data may be required with some maintenance on the system required to an equivalent of a few hours a week.

3.5.2.7 Additional benefits

This solution is unlikely to deliver any wider environmental benefits.

3.5.2.8 Wider environmental considerations

The use of portable treatment works could potentially have implications for the local population, including visual impact, noise and odour. Energy use may also be an important consideration.

Disposal of waste produced by the portable works may need to be removed and handled appropriately

3.5.2.9 Evidence of effectiveness

The manufacturers of portable treatment plants have undertaken detailed testing of their performance and as such are able to provide certainty regarding the level of nutrient removal that can be achieved.

3.5.2.10 Deliverability and certainty

Agreements with water companies will be required in order to implement this solution. These agreements will provide the certainty that the solution will be implemented and the intended timescales.

Consultation would also be required with the Environment Agency who are the regulatory body overseeing the permit limits of wastewater treatment works. Permitting timetables are expected to be 3-6 months.

3.5.2.11 Cost estimate

Given the bespoke nature of the systems for nutrient removal, it is likely that the systems would need to be purchased. Rental is available for standard systems, but it unlikely to be available for bespoke systems. Capital costs vary depending on the size of the treatment plant. Costs are expected to range from between £10,000 for treatment at small WwTWs and £100,000 for treatment at the larger WwTWs. Maintenance costs of £1,000 - £5,000 per year are expected but vary depending on the size / number of plants.

3.5.2.12 Summary

Table 3.44 presents the key considerations for the installation of portable treatment works for nutrient reduction.

Table 3.44 Portable treatment works

Key considerations	
Delivery timescale	Short-term
Duration timescale	Temporary
TP removal potential	Effluent to 0.5mg/l can be achieved. This can apply to all existing houses served by the treatment works.
Management / maintenance requirements	Review of limited monitoring data may be required. Some maintenance on the system is required, equivalent to a few hours a week.
Additional benefits	Water quality improvements
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes
Cost estimation	Capital costs £10,000 - £50,000 depending on size. Maintenance costs £1,000 - £2,000 a year.

3.5.3 Install package treatment plants

3.5.3.1 Description of solution

Package treatment plants (PTPs) can be used to treat wastewater onsite and are normally used where connection to mains sewerage system is not possible. Septic tanks are an alternative type of basic onsite wastewater treatment. However, phosphate reductions are typically low (O'Keeffe *et al.*, 2015) and effluent may require further treatment (e.g., by a soakaway). Correctly operated and well-maintained package treatment plants produce a higher quality effluent which may be able to be discharged to surface water or groundwater, as well as to drainage fields (May & Woods, 2015).

Alterations to existing PTPs and septic tanks or installing new tanks to provide additional dosing could achieve significant nutrient reductions. Typically, older treatment works (especially those without P dosing) will be discharging effluent at a much higher concentration than new treatment works. **Table 3.45** outlines the default values that PTPs and STs are assumed to operate at.

The Natural England significance of septic tanks around freshwater SSSIs (May et al., 2016) report indicates that small sewage discharges (SSDs), mainly septic tank systems but also package treatment plants, potentially pose a significant environmental risk to freshwater habitats.

An assumption is made that a default septic tank will have an effluent concentration of 11.6 mg/l TP and 96.3mg/l TN. A default package treatment plant will have an effluent concentration of 9.7 mg/l TP and 72.9 mg/l TN.

The effluent quality of a new PTP is variable, but typically around 2-3mg/l TP and 25-50 mg/l TP for PTP without P stripping and as low as 0.4-0.5 mg/l TP for a PTP with additional P stripping.

Therefore, replacing one default septic tank serving one property with a PTP with P stripping will deliver 0.84 kg/yr TP and 3.48 kg/yr TN. This is a best case scenario calculation to provide an indication.

Information indicates there are over 1,500 PTPs or septic tanks at high risk of pollution in the Yare and Wensum catchment combined (out of an expected 9,250 unsewered properties) (May et al., 2016). The mitigation that can be achieved is very good and the costs are relatively low (up to £10k to replace with the addition of management and maintenance costs). The management and maintenance of these new PTPs would need to be guaranteed in order to achieve credits.

There is the potential for this solution to be delivered on a scale greater than individual proprieties; a village or block of houses which are unsewered could be brought on the on to the main sewerage network. This could be particularly effective where the mains connection to a treatment plant with P and N stripping.

It may be possible to identify unsewered properties via a request for information to the water company to review water bills. Alternatively, a private company may be able to provide this data for a fee. A challenge may be encountered with engagement of the public and incentivising people to proceed with such a scheme.

Table 3.45 Default performance values for PTPs and septic tanks (Natural England, 2022)

Treatment plant	Default TP effluent concentration (mg/l)	Default TN effluent concentration (mg/l)
Package treatment plant	9.7	72.9
Septic tank	11.6	96.3

PTPs with additional phosphate stripping are capable of achieving effluent concentrations as low as 0.4mg/l. **Table 3.46** outlines some of the reductions available through leading brands. Nitrogen effluent concentrations are assumed to be 55mg/l for PTPs.

Table 3.46 Main PTP manufacturers phosphate removal rates

System	Removal rate / concentration	Source
Graf One2clean plus	95.1% / 1.6mg/l	https://www.graf.info/fileadmin/media/Catalogue_Wastewater_Treatment_Solutions.pdf
Graf Klaro E Professional KL24plus	94.5% / 0.4mg/l	https://www.graf.info/fileadmin/media/Catalogue_Wastewater_Treatment_Solutions.pdf
Kingspan Klargester BioDisc	2 mg/l	Klargester Biodisc Sewage Treatment System | Kingspan | Great Britain
WPL HIPAF	3-6 mg/l	WPL HiPAF® Sewage System - WPL | WCS EE Division (wplinternational.com)

Reed beds or wetland treatment systems can be used to provide secondary or tertiary treatment of effluent from package treatment plants. The systems purify the effluent as it moves through the gravel bed and is taken up by the roots. Both horizontal flow and vertical flow systems are suitable.

In order to achieve the highest rates of phosphorus removal, a package treatment plant that has additional phosphate stripping could be used. However, this required additional maintenance that would need to be secured via maintenance agreements.

Building regulations require foul drainage to be connected to a public sewer or where this is not feasible (in terms of cost and/or practicality), to package treatment plants or Septic Tanks (Document H, Building Regulations 2010). The package treatment plant or septic tank must comply with the general binding rules

(Environment Agency, 2021) or a permit will be required. It may be possible for package treatment plants to be discharged to surface water, whereas septic tanks must not discharge effluent to surface water.

Package treatment plants or septic tanks that drain to a field must be compliant with the Building Regulations in order to be used as mitigation. Part H2 of the Building Regulations 2010 requires that they are located:

- A minimum of 10m from watercourses;
- 50m from a point of abstraction of any groundwater supply;
- Not in any Zone 1 groundwater Source Protection Zone;
- At least 15m from any building; and
- Sufficiently far from any other drainage fields.

In order for the solutions to be achievable in perpetuity, maintenance would need to be in places for the lifetime of the development. Maintenance and regular emptying of package treatment plants and septic tanks is required under rules 11 and 12 of the General Binding Rules (Environment Agency, 2021). The waste biproducts of PTPs are likely to be classified as sewage sludge and would need to be disposed according to requirements of the Environment Agency.

3.5.3.2 Nutrient removal

Assuming a default PTP is replaced with a new PTP with a TP effluent concentration of 2mg/l, approximately 0.68kg/yr could be saved. The replacement would have an estimated additional cost of approximately £32,000. This is equivalent to £3,239 per kg/yr reduction.

3.5.3.3 Delivery timescale

Package treatment plants typically take 3 months to deliver and set up; they can therefore be implemented over short timescales. An environmental permit is likely to be required for any discharges from the PTP.

3.5.3.4 Duration of operation

PTPs are envisaged to be a permanent solutions for developments that cannot currently be connected to the foul sewer network.

3.5.3.5 Applicability

PTPs could potentially be applicable to all residential developments that cannot currently be connected to the existing foul sewer network.

3.5.3.6 Management and maintenance requirements

Review of limited monitoring data may be required with some maintenance on the system required to an equivalent of a few hours a week.

3.5.3.7 Additional benefits

This solution is unlikely to deliver any wider environmental benefits.

3.5.3.8 Wider environmental considerations

The use of portable treatment works could potentially have implications for the local population, including visual impact, noise and odour. Energy use may also be an important consideration.

3.5.3.9 Evidence of effectiveness

The manufacturers of PTPs have undertaken detailed testing of their performance and as such are able to provide certainty regarding the level of nutrient removal that can be achieved. Furthermore, an advice note jointly published by Somerset Authorities in consultation with Environment Agency and Natural England in September 2022 states that all septic tanks and PTPs undergo independent third-party testing to meet British Standards (BS EN 12566) with certification setting out the mean concentration of the effluent from that system.

Testing for total nitrogen (TN) and total phosphorus (TP) is not mandatory requirement by the British Standard for PTPs and as such not all PTP will have undergone these tests. However, where a certificate (or test results from a separate independent test, if one was conducted but not included on the certificate) can be provided, this serves as sufficient proof of the concentrations the effluent will reach. There is no need to obtain any additional monitoring evidence in these cases. Recommended PTPs have accredited certification and bear CE/UKCA marking.

In July 2022, the Herefordshire district council granted planning permission to a private development (Canon Frome Court) to install Package Treatment Plant (Otto Graf KLARO E - sequencing batch reactor with phosphorous precipitant).

This development is converting two out buildings into three new buildings with approval for all of the foul water created by existing residential occupation of Canon Frome Court and additional flows created by the development to discharge through connection to a new shared PTP, with a final direct outfall into the River Frome in compliance with the Habitats Regulations and the Herefordshire Local Plan core strategies.

3.5.3.10 Deliverability and certainty

Confirmation on the number of package treatment plant installations can be provided via reports from contractors.

It can be assumed that once installed, the PTP would be in operation for its lifetime, and would be replaced by a PTP or mains sewerage that has at least the same effluent quality.

3.5.3.11 Cost estimate

PTP cost varies according to the size required and PTPs with additional P stripping typically cost more than standard models. Upfront costs are typically £2,000 to £2,500 for plants serving 4/5 persons and up to £5,000 for plants serving 15/20 persons. Installation costs may vary but are likely to be £thousands. Average annual costs for PTPs with additional phosphate stripping for operating and maintenance (including emptying) are typically £400 - £600

3.5.3.12 Summary

Table 3.47 presents the key considerations for the use of Package Treatment Plants for nutrient offsetting.

Table 3.47 Package Treatment Plants

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
TP removal potential	Variable (e.g., 0.4 – 2 mg/l)
TN removal potential	Variable (e.g., 55 mg/l)
Management / maintenance requirements	Annual cleaning required in most cases. Phosphate dosing may be required
Additional benefits	Additional water quality benefits Flood risk Habitat creation Amenity space when combined with SuDS / Wetlands

Key considerations	
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes
Cost estimation	Capital costs: approx. £5,000 Operational costs: £100 - £200 per annum

3.5.4 Install cesspools and capture outputs from private sewage systems

3.5.4.1 Description of solution

Closed cesspool systems offer the possibility of tankering waste from dwellings within the catchment to registered waste facilities outside of the catchment. As a result, there would be no increase in wastewater loading from developments that use this approach.

Cesspools are an unsustainable solution that would have a significant carbon increase associated, particularly for dwellings in the centre of the catchment where the distance from registered waste facilities will be the greatest. However, there are some locations towards the edge of the catchment where the distance waste would be carried is minimal. Furthermore, if water company infrastructure allows for mains connection in the future, the water companies would be obliged to connect and wastewater would then be contributing to loads into the catchment, requiring further mitigation. Maintenance of the cesspools would need to be written as a planning condition as well as into the deeds of the dwelling.

3.5.4.2 Nutrient removal

Nutrient removal rates will be dependant on the number of dwellings. The use of cesspools will temporarily remove the entire wastewater contribution from catchment. This could be coupled with a well deigned SuDS scheme which could remove phosphorus contributions from surface water runoff and therefore achieve phosphorus neutrality.

3.5.4.3 Delivery timescale

The implementation of this solution will require the installation of new infrastructure and would require planning permission. However, there may be the option to achieve credits through solar farms which are recently operational or close to operation. This option is therefore considered to be a short-term solution.

3.5.4.4 Duration of operation

Cesspools would require regular maintenance to maintain their effectiveness, and are considered to be an impermanent solution that could be used until a permanent solution can be implemented.

3.5.4.5 Applicability

This option could potentially be applicable to new or existing developments that cannot currently be connected to the foul drainage network.

3.5.4.6 Management and maintenance requirements

Multiple criteria would need to be met in order for cesspools to be viable:

- Waste would need to be transferred by a registered waste carrier
- Waste would need to be transferred to a registered facility outside of the catchment

- Ensure it has a minimum capacity of 18,000 litres per 2 users (plus another 6,800 litres per each extra user)
- Planning permission would be required

The cesspool would need building regulations approval, which includes the following:

- Cesspools should only be considered where mains drainage is not practicable
- Sited at least 7m from any habitable parts of buildings
- Sited within 30m of vehicle access
- No opening except for the inlet
- Cesspools should be inspected fortnightly for overflow and emptied as required

Cesspools would need to be emptied regularly and the owner would be responsible to ensure they do not leak or overflow. Where a cesspool causes pollution, it would break the law and the Environment Agency could take legal action under the Water Resource Act 1991, which can carry a fine of up to £20,000- and 3-months imprisonment. Similarly, the Environment Agency and local council can enforce repairs or replacements of cesspools in poor condition.

3.5.4.7 Additional benefits

There are no additional benefits associated with cesspools.

3.5.4.8 Wider environmental considerations

Cesspools are an unsustainable solution that would have a significant carbon increase associated, particularly for dwellings in the centre of the catchment where the distance from registered waste facilities will be the greatest. However, there are some locations towards the edge of the catchment where the distance waste would be carried is minimal. Furthermore, if water company infrastructure allows for mains connection in the future, the water companies would be obliged to connect and wastewater would then be contributing to loads into the catchment, requiring further mitigation. Maintenance of the cesspools would need to be written as a planning condition as well as into the deeds of the dwelling.

Where cesspools are used as a short-term bridging solution until longer term, more sustainable, solutions are in place, then details of these longer-term solution would be required at the time of granting permission. The removal of the cesspool would also need to be included in any planning conditions / obligations.

3.5.4.9 Evidence of effectiveness

Because this solution is reliant on treatment of wastewater at a dedicated WwTW, it is assumed to be highly effective.

3.5.4.10 Deliverability and certainty

Confirmation on the installation of cesspools can be provided via contractors. Confirmation of waste removal and treatment location can be provided via sludge handling company.

3.5.4.11 Cost estimate

Cesspool costs and installation vary depending on size but are likely to be between £3000 - £6000. Emptying requirements are dependent on the capacity of the pit and the average waste amount of the household. On average, emptying would be required every 1 - 2 months with a cost of £400 - £700 depending on location. This is likely to result in annual costs of £3,200 - £5,600, which over 80 years equates to 256,000 - £448,000 per property.

3.5.4.12 Summary

Table 3.48 presents the key considerations for the use of cesspools for nutrient reduction and/or offsetting.

Table 3.48 Cesspools key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Impermanent
TP removal potential	100% of wastewater
TN removal potential	100% of wastewater
Management / maintenance requirements	Emptying every 1 – 2 months Regular inspection
Additional benefits	None
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes
Cost estimation	Capital costs: approx. £3,000 - £6,000 Operational costs: £3,200 - £5,600 per year

3.6 Demand Management Solutions

3.6.1 Retrofit water saving measures in existing properties (local authority, registered providers, public buildings)

3.6.1.1 Description of solution

When retrofitting water saving appliances, the water usage saved from the retrofitted properties will be replaced by the additional water from new dwellings. As a result, the volume of water entering the treatment works will stay the same and providing the treatment works operates to a permit limit, the effluent discharge concentration remains the same. This solution is not applicable to WwTWs without a permit limit. Similarly, WwTWs should be operating at close to capacity with little headroom, which is not the case in all of the treatment works in the catchment. The Whitlingham treatment works typically operates close to its permit limit and therefore would be suitable. Older houses generally have higher water usages per person and therefore have a greater potential for reducing nutrient loading.

Certainty over the efficacy of this method is difficult to achieve due to the limited ability to measure reductions. This solution is unlikely to pass the in-perpetuity test for private properties where there is no control over homeowners changing fittings in the future. Therefore, this solution is only applicable to existing dwellings where an organisation has control over fittings and any upgrade works. This is likely to include housing owned by local authorities or Registered Providers, and public buildings. It is likely that wastewater reductions from new water efficient appliances could be achieved during planned refurbishment of such properties. The greater water saving is typically achieved through upgrades to bathrooms as opposed to kitchens, with improvements to toilets and showers providing the greatest reductions.

An average volume of water usage of around 150 l/person/day can be assumed for existing dwellings in the catchment. The WRc water efficiency calculator (WRc, 2021) has been used to approximate the water usage per appliance / fitting for usage of 150 l/person/day. The findings are presented in **Table 3.49**.

Table 3.49 Baseline (150 l/person/day) maximum water consumption values for appliances/fittings

Fitting / Appliance	Maximum Consumption
Toilet	8 litres
Shower	12 l/min
Bath	200 litres maximum capacity
Basin taps	9 l/min
Sink taps	10.5 l/min
Dishwasher	1.25 l/place setting
Washing machine	8.17 l/kilogram

Requirement G2 and Regulations 36 and 37 of the Building Regulations (2015) introduce a minimum water efficiency standard for new homes of no more than 125 l/person/day. The Government also introduced an optional requirement of 110 l/person/day for new residential developments (excluding properties owned by local authorities and Registered Providers), which should be implemented through local policy where there is a clear evidence need. As a result, these two figures were used as targets when retrofitting water efficient appliances and fittings.

Retrofitting water saving measures is applicable to treatment works served by the following wastewater treatment works:

- Aldborough
- Aylsham
- Belaugh
- Bylaugh
- Coltishall
- Dereham
- Foulsham
- Long Stratton
- Rackheath
- Reepham
- Stalham
- Wymondham

3.6.1.2 Nutrient removal

Actual nutrient reductions will be dependent on the population served and the permit limit of the WwTWs. However, a water saving of 40 l/person/day can be achieved from retrofitting a single house with an existing water efficiency of 150 l/person/day to an upgraded efficiency of 110 l/person/day. This would require 2.75 retrofitted dwelling for every new dwelling draining to Whitlingham. This is equivalent to 0.09 kg/yr TP and 2.49kg/yr TN. The expected cost is £3,988 per new dwelling. Implementing further water saving measures beyond 110 l/person/day for new dwellings in the catchment would reduce the increased load from wastewater for that new dwelling.

Efficiencies could be drawn from greywater harvesting, which involves the use of recycling systems to collect used water from sinks, dishwashers, showers, and baths, and then clean it up and plumb it straight back into your toilet, washing machine and outside tap. Greywater typically makes up between 50% - 80% of a household's wastewater – recycled greywater can save approximately 70 l/person/day, equivalent to 0.055kg/yr, in domestic households. Alongside retrofitting water efficient appliances, greywater harvesting could significantly reduce household consumption and loadings transferred for treatment. A new greywater system may cost £2,000 - £3,000 per dwelling, although it is hard to calculate the payback because it is dependent on current water usage, and what kind of system is installed.

3.6.1.3 Delivery timescale

It is anticipated that this solution could be implemented in the short term in housing stock that is under the control of the local authority, for example as part of ongoing programmes to upgrade residential properties.

3.6.1.4 Duration of operation

This solution is considered to be an impermanent solution, given that householders or contractors could potentially change water-efficient fittings with less efficient alternatives in case of failure or if they undertake their own refurbishment.

3.6.1.5 Applicability

This solution is only applicable to housing owned by local authorities or Registered Providers.

3.6.1.6 Management and maintenance requirements

For this option be effective over longer timescales, it will be necessary to ensure that any future refurbishment works or emergency works are undertaken using fittings that meet the appropriate water efficiency standards.

3.6.1.7 Additional benefits

This option will provide the added benefit of reducing the required water consumption from new development mitigated through this scheme (i.e. the water consumption will not increase as a result of new development). This is an important benefit in an area of water stress. Secondly, water bills will also be reduced for existing dwellings.

3.6.1.8 Wider environmental considerations

This option is unlikely to be subject to any significant environmental constraints.

3.6.1.9 Evidence of effectiveness

A reduction in water usage in a residential property will lead to a corresponding reduction in wastewater loading. This in turn will mean that there is a reduction in nutrient loading in the discharge from the WwTW to which the property drains. It was necessary for Registered Providers (RPs) in a different Local Authority to undertake a provide historical water bills to demonstrate past consumption and future consumption in addition to an audit of all properties within their jurisdiction, which has the positional to be significant expense.

3.6.1.10 Deliverability and certainty

Retrofitting water efficient fittings to dwellings where this is control on the fittings provides sufficient certainty that the water consumption will be maintained. Should fittings need replacing in the future they will be to the required water consumption or better.

Anglian Water are also supportive of proposed upgrades and their advice has given further confidence on the long-term water usage of appliances. It is considered unlikely that people will make significant changes to fittings that reduce water usage and subsequently reduce water bills.

Details on the exact number of retrofits and details of fittings can be provided from contractors.

A comparison of water bills pre and post retrofit could also be used to verify water reductions.

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3.6.1.11 Cost estimate

Table 3.50 provides an approximate cost estimate for installing new appliances / fittings that are likely to meet the 110 l/person/day limit. The costs presented below include fitting and are consistent with the costs quoted by existing organisations carrying out works for Local Authorities win Norfolk.

Table 3.50 Cost estimation for installing appliances/fittings to meet the 110 l/person/day limit

Fitting / Appliance	Approximate cost	Source
Toilet	£200 - £300 for a new dual flush toilet including labour. Retrofitting a traditional toilet with a dual flush mechanism may cost as little as £15.	https://www.thegreenage.co.uk/tech/water-saving-toilet/
Shower	£25 - £50	Water Efficient Showers | How To Save Water (how-to-save-water.co.uk)
Bath	£250	How Much Does a Bathroom Renovation Cost in 2021? | Checkatrade
Basin Taps	£100	How Much Does a Bathroom Renovation Cost in 2021? | Checkatrade
Sink Taps	£100	How Much Does a Bathroom Renovation Cost in 2021? | Checkatrade
Dishwasher	£300	Best dishwashers to buy 2021 - BBC Good Food
Washing Machine	£350	Top 5 Energy Efficient Washing Machines - Appliance City
Total	**£1,450 per property**	

3.6.1.12 Summary

Table 3.51 shows key considerations associated with restricting water usage to reduce the wastewater loading.

Table 3.51 Retrofitting water efficient fittings (Local Authority, registered providers, public buildings) key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Impermanent
TP removal potential	Wastewater reductions of 40 l/person/day achievable.
TN removal potential	Wastewater reductions of 40 l/person/day achievable.
Management / maintenance requirements	Replacement parts of the same or better efficiency must be used. Monitoring compliance checks required.
Additional benefits	Sustainability Water resources
Based on best available evidence?	Yes – The government published calculator would be used for calculating water usage for appliances.
Effective beyond reasonable scientific doubt?	Yes
Precautionary?	Yes
Securable in perpetuity?	Yes – It is unlikely this solution could be achieved in perpetuity unless the local authority or Registered Provider have ownership and control of dwellings that are due to be retrofitted with more water efficient fittings.

3.6.2 Retrofit water saving measures in existing properties (private housing, commercial and industrial premises)

3.6.2.1 Description of solution

In addition to retrofitting water efficient appliances to housing stock under the control of a local authority or Registered Providers (**Section 3.6.1**), it may also be possible to encourage a similar programme for private housing, commercial and industrial premises. This is likely to require an incentive scheme (e.g. operated by the water undertaker and/or local authorities) to encourage uptake.

3.6.2.2 Nutrient removal

Actual nutrient reductions will be dependent on the population served and the permit limit of the WwTWs. An estimate of 2.75 – 3 existing to 1 new dwelling is likely.

3.6.2.3 Delivery timescale

It is likely that wastewater reductions from new water efficient appliances could be achieved during planned refurbishment of such properties. The greater water saving is typically achieved through upgrades to bathrooms as opposed to kitchens, with improvements to toilets and showers providing the greatest reductions. There is no known project or scheme where this has been undertaken on private properties to obtain a timescale deliver estimate.

3.6.2.4 Duration of operation

The driver for duration is dependent upon property owners or tenants adhering to the retrofitted installation. If there is no interference it could offer a permanent duration timescale. However, in the absence of a robust mechanism to ensure that water-efficient fittings remain in place, this is considered to be a temporary measure.

3.6.2.5 Applicability

This option is applicable to discharges into the catchment via intercept of input ahead of input into WwTWs. It could potentially be applicable to all properties in the catchment.

3.6.2.6 Management and maintenance requirements

Compliance is likely to be difficult to monitor, and although planning conditions on developers could provide some security, spot checks may be required to prevent homeowners changing approved fittings in the future.

3.6.2.7 Additional benefits

This option is unlikely to deliver any additional environmental benefits.

3.6.2.8 Wider environmental considerations

This option is unlikely to be subject to any significant environmental constraints.

3.6.2.9 Evidence of effectiveness

Certainty over the effectiveness of this method is difficult to achieve due to the limited ability to measure reductions. This solution is unlikely to pass the in-perpetuity test for private properties where there is no control over homeowners changing fittings in the future.

3.6.2.10 Deliverability and certainty

Certainty over the efficacy of this method is difficult to achieve due to the limited ability to measure reductions. Smart meters could be used for tracking loading but is unlikely that developments will have these fitted in high enough numbers to obtain sufficient data. This solution is also unlikely to pass the in-perpetuity test for private properties where there is no control over homeowners changing fittings in the future.

3.6.2.11 Cost estimate

Cost estimates for this solution are presented in **Section 3.6.1.11**.

3.6.2.12 Summary

Table 3.52 Retrofit water saving measures in existing properties (private housing, commercial and industrial premises)

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
Nutrient removal potential	2.75 – 3 existing dwellings to every 1 new dwelling. Nutrient reductions dependant on population served and permit limit of WwTWs.
Management / Maintenance requirements	Replacement parts of the same or better efficiency must be used. Monitoring compliance checks required.
Additional benefits	Sustainability Water resources
Based on best available evidence?	Yes
Effective beyond reasonable scientific doubt?	Yes – The government published calculator would be used for calculating water usage for appliances
Precautionary?	Yes
Securable in perpetuity?	No - It is unlikely this solution could be achieved in perpetuity unless the Local Authority or Registered Provider have ownership and control of dwellings that are due to be retrofitted with more water efficient fittings.
Cost estimation	Capital costs: Approximately £1,450 per property

3.6.3 Incentivise commercial water efficiency and treatment installation

3.6.3.1 Description of solution

For reasons of commercial confidentiality and/or competition law it is considered necessary that this option would be led by a party other than the local sewerage undertaker (water company).

A water company is the regulator of trade effluent discharge licence consents into the foul sewer network and the Environment Agency regulates effluent discharge into the surface water catchment (and groundwater). Operators of a consent to discharge trade effluent would install treatment facilities ahead of discharge to the sewerage network the installation of which would be enforced via the consent provided by the water company.

3.6.3.2 Nutrient removal

The nutrient removal calculations have not been undertaken and this option would require specific discharge output detail to develop an understanding of the plausible removal potential. However, the concept of this option is considered to remove nutrient from the catchment at a point upstream of the WwTW and upstream of the point of discharge to surface water (or groundwater).

3.6.3.3 Delivery timescale

Delivery timescale is subject to a change in consent regulation and the requisite consultation process ahead of such change in addition to change enforcement. Operators are also required to install on-site treatment facilities, which may be subject to planning permission. Ahead of this, a feasibility study and possible monitoring programme would be required to prioritise operations which would have an effective result in nutrient removal.

In addition, the current Asset Management Planning period (AMP7, 2020-2025) which water companies operate capital investment via does not include additional measures to address phosphate supply from WwTWs and they are likely to be considered in the next Price Review in 2024.

On this basis the delivery time is considered to be <1 year and therefore short-term.

3.6.3.4 Duration of operation

Durability is considered to be permanent as it would require the installation of a permanent treatment facility on site.

3.6.3.5 Applicability

It is applicable to discharges into the catchment via intercept of input ahead of input into WwTWs (under water company regulation) and direct to surface water or groundwater (under Environment Agency regulation).

3.6.3.6 Management and maintenance requirements

The treatment facilities will require regular management and maintenance in order to maintain effective operation. Waste removal of solids in the form of ‘filter cake’ or similar is anticipated. Regulators of a discharge consent would review monitoring data for compliance and undertake site inspections.

3.6.3.7 Additional benefits

Other potentially harmful substances within the discharge could also be captured via on site treatment facilities.

3.6.3.8 Wider environmental considerations

Construction work to install on-site treatment facilities and operation of a treatment facility presents wider environmental implications related to potential loss of habitat from construction of infrastructure can cause pollution, environmental degradation and pressure on natural resources in other areas or countries.

3.6.3.9 Evidence of effectiveness

Available scientific evidence in relation to the effectiveness is not available at this stage and is required to be catchment and discharge point specific. It is also not possible to apply a precautionary efficacy value in the absence of evidence.

3.6.3.10 Deliverability and certainty

A discharge consent is a legal agreement and can be enforced and provides a control mechanism, improvement notices and/or enforcement action can be served which in turn provides certainty and securable in perpetuity (between 80-125 years). Temporary trade effluent discharges which include heating system flushing and groundwater remediation practices also offer less certainty due to the unpredictable and temporary nature.

3.6.3.11 Cost estimate

It is not possible to estimate the cost at this stage of options appraisal. A feasibility study is likely to be required to determine and estimate.

3.6.3.12 Summary

Table 3.53 presents the key considerations for the option to incentivise commercial water efficiency.

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Table 3.53 Incentivise commercial water efficiency and treatment installation key considerations

Key considerations	
Delivery timescale	Short-term
Duration timescale	Permanent
Nutrient removal potential	Unknown
Management / Maintenance requirements	Operation of the treatment facility and associated waste disposal works
Additional benefits	Water quality
Based on best available evidence?	No
Effective beyond reasonable scientific doubt?	Not possible to determine at this stage
Precautionary?	Not possible to determine at this stage
Securable in perpetuity?	Yes
Cost estimation	Capital costs: £unknown per ha, operational costs £unknown per ha per year

4 4 Summary

4.1 Summary of potential solutions

Table 4.1 provides a summary of short-listed solutions that could be used mitigate and offset additional nutrients arising from new developments that could adversely affect the River Wensum and Norfolk Broads SACs.

It is likely that a combination of measures will be most effective in nutrient offsetting. For example, incorporating SuDS into new developments, whilst constructing riparian buffer strips to lower the nutrient burden. A range of techniques can be used in the river catchments, and these are mainly aimed at slowing runoff and trapping sediment-bound pollutants.

Wastewater management and demand management solutions provide an opportunity to deliver mitigation in restively short timescales. These solutions typically have greater certainty than runoff and nature-based solutions and if most cases can avoid issues with land purchase / rental.

Table 4.1 Short-list solutions Summary

Solution	Delivery timescale	Duration timescale	Nutrient removal potential	Farm type	Management /Maintenance requirements	Additional benefits	Best available evidence?	Effective beyond reasonable scientific doubt?	Precautionary?	Securable in perpetuity?	Cost estimation
Nature based solutions											
Silt traps	Short-term	Impermanent	25% - 75% TP <25% TN	All	Regular de-silting will be required	Water quality	No	Yes	Yes	Yes	Capital costs: £1,000 - £4,000. Maintenance costs: £500/yr.
Riparian buffer strips	Short-term	Impermanent	67% TP 65% TN	All	Cutting/Vegetation management	Stabilised riverbanks. Water quality. Reduced erosion. Habitat creation. Improved amenity value. Biodiversity net gain (BNG). Carbon offsetting	Yes	Yes	Yes	Yes	Typical costs of £786/ha. Wensum: £128 /kg/yr Yare: £275 /kg/yr Bure: £1,503 /kg/yr
Wet woodlands	Short-term	Permanent	Uncertain - Similar to riparian buffer strips	Riparian land holdings (withing FZ3)	Minimal	Recreation carbon sequestration Biodiversity conservation Air pollution reduction Flood risk reduction Biofuel	No	Yes	Yes	Yes	Up to £10,000 per hectare
Willow buffers	Short-term	Impermanent	70% long-term	All	Harvesting every 2-3 years.	Water quality Biodiversity	No	Yes	Yes	Yes	Capital costs: £2,500 per hectare, operational costs £200 - £300 per ha per year.
Beetle banks	Short-term	Permanent	Unknown	All	Annual grass cutting	Biodiversity net gain potential Soil erosion	No	Not possible to determine at this stage	Not possible to determine at this stage	No	Assumed to be similar to riparian buffer strips Wensum: £128 /kg/yr Yare: £275 /kg/yr Bure: £1,503 /kg/yr
Runoff management solutions											
Taking land out of agricultural use	Short-term	Temporary, impermanent, permanent	0.04 – 0.71 kg TP/ha/yr 16.23 – 22.75 kg TN/ha/yr	Not indoor pig or poultry	For miscanthus growing – no fertiliser needs to be added until it is established and less needs to be applied than most farming practises. Harvesting every 2-4 years Energy Crop Schemes are available.	Energy crops Biodiversity net gain potential	Yes	Yes	Yes	Yes	The average rental price in the East of England for farms is £314/ha. The average purchase price in the East of England for farms is £24,500/ha £506/ha from loss of production. Wensum: £35,220 /kg/yr Yare: £78,144 /kg/yr Bure: £625,150/kg/yr

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Solution	Delivery timescale	Duration timescale	Nutrient removal potential	Farm type	Management /Maintenance requirements	Additional benefits	Best available evidence?	Effective beyond reasonable scientific doubt?	Precautionary?	Securable in perpetuity?	Cost estimation
Conversion of agricultural land to solar farms	Short-term	Permanent	Total P between 15 and 24 kg/yr: and Total N between 783 and 1,279 kg/yr	Arable and pastoral	Livestock number monitoring	Renewable energy Biodiversity net gain potential Water quality	No	Yes	Yes	Yes	unknown
Cessation of fertiliser / manure application	Short-term	Temporary	0.02 – 0.18 TP kg/ha/yr 17.31 – 21.38 TN kg/ha/yr	Arable and Grassland	None	Suspended solids buffer	Yes	Yes	Yes	No	Arable: £1,274.39 ha/yr
Cover crops	Short-term	Impermanent	Large uncertainty – Assumed to be 30% removal.	Arable farms	Preparation, planting, destruction, cultivation	Water quality Habitat creation	No	Yes	Yes	Yes	Maintenance costs: £150/ha/yr (AHDB, 2020) £124 per hectare
Installing SuDS in new developments	Short-term	Permanent	Highly variable and will likely need site specific calculations.	n/a	The long-term performance of SuDS would also need to be secured through maintenance agreements. Maintenance works would include desilting of swales, wetlands, and basins to maintain their efficiency. Vegetation management of buffers would be necessary to maintain the optimum roughness/composition and sediment trapping efficiency.	Water quality Reduced erosion Habitats Improved amenity value	No	No	Yes	Yes	Cost are variable and bespoke to each site. The scale of the SuDS will have a large control on costs.
Wastewater management solutions											
Expedite planned improvements to treatment works	Short-term	Temporary	1,407.94 kg/yr of mitigation could be delivered assuming all three schemes come forward.	n/a	Normal maintenance carried out by water company	Potential nitrogen reductions	Yes	Yes	Yes	No – because although brought forward, it would not go beyond what was originally planned.	Costs are bespoke to each scheme and would need to be provided by Anglian Water
Portable treatment works	Short-term	Temporary	Up to 0.5 mg/l	n/a	Review of limited monitoring data may be required. Some maintenance on the system is required, equivalent to a few hours a week.	Water quality	Yes	Yes	Yes	Yes	Capital costs £10,000 - £50,000 depending on size. Maintenance costs £1,000 - £2,000 a year.
PTPs	Short-term	Permanent	TP removal is variable (e.g., 0.4 – 2 mg/l) TN removal is variable (e.g., 55 mg/l)	n/a	Annual cleaning Phosphate dosing may be required	Additional water quality benefits Flood risk Habitat creation Amenity space when combined with SuDS / Wetlands.	Yes	Yes	Yes	Yes	Capital costs: approx. £5,000 Operational costs: £100 - £200 per annum
Cesspools and capture private sewage system outputs	Short-term	Impermanent	100% of wastewater	n/a	Emptying every 1 – 2 months. Regular inspection.	None	Yes	Yes	Yes	Yes	Capital costs: approx. £3,000 - £6,000 Operational costs: £3,200 - £5,600 per year

Solution	Delivery timescale	Duration timescale	Nutrient removal potential	Farm type	Management /Maintenance requirements	Additional benefits	Best available evidence?	Effective beyond reasonable scientific doubt?	Precautionary?	Securable in perpetuity?	Cost estimation
Demand management solutions											
Retrofit water efficient fittings (Local Authority, registered providers, public buildings)	Short-term	Impermanent	Wastewater reductions of 40 l/person/day achievable.	n/a	Replacement parts of the same or better efficiency must be used. Monitoring compliance checks required.	Sustainability Water resources	Yes	Yes	Yes	Yes	Capital costs: Approximately £1,450 per property
Retrofit water efficient fittings (private housing, commercial and industrial premises)	Short-term	Permanent	2.75 – 3 existing dwellings to every 1 new dwelling. Nutrient reductions dependant on population served and permit limit of WwTWs.	n/a	Replacement parts of the same or better efficiency must be used. Monitoring compliance checks required.	Sustainability Water resources	Yes	Yes	Yes	No	Capital costs: Approximately £1,450 per property
Incentivise commercial water efficiency and treatment installation	Short-term	Permanent	Unknown	n/a	Operation of the treatment facility and associated waste disposal works	Water quality	No	Not possible to determine at this stage	Not possible to determine at this stage	Yes	unknown

4.2 Suitability of solutions

Table 4.2 outlines the short-listed solutions that are likely to be the most suitable for each Local Authority to adopt.

Table 4.2 Suitability of solutions

Solution	Broadland and South Norfolk	Norwich City	Breckland	North Norfolk	Broads Authority	Kings Lynn and West Norfolk
Silt traps	✓		✓	✓	✓	✓
Riparian buffer strips	✓		✓	✓	✓	✓
Wet woodlands	✓		✓	✓	✓	✓
Willow buffers	✓		✓	✓	✓	✓
Beetle banks	✓		✓	✓	✓	✓
Taking land out of agricultural use	✓		✓	✓	✓	✓
Conversion of agricultural land to solar farms	✓	✓	✓	✓	✓	✓
Cessation of fertilizer and manure application	✓		✓	✓	✓	✓
Cover crops	✓		✓	✓	✓	✓
Installing SuDS	✓	✓	✓	✓	✓	✓
Expedite planned improvements to treatment works	✓	✓	✓	✓	✓	✓
Portable treatment works	✓	✓	✓	✓	✓	✓
Package treatment plants	✓		✓	✓	✓	✓
Cesspools	✓		✓	✓	✓	✓
Retrofit water saving measures (public)		✓				
Retrofit water saving measures (private)						
Incentivise commercial water efficiency	✓		✓	✓	✓	✓

4.3 Next steps

The following sets out the next steps of what is required in order to develop the solutions presented within this report to functioning phosphate mitigation solutions.

- Assessment of long-term nutrient mitigation solutions.
- Identification of the preferred solutions to be delivered and the likely costs, timescales and delivery mechanisms. This will likely be undertaken by the creation of a mitigation plan in order to formulate developer contributions.

- Further engagement with Anglian Water over the preferred schemes and what / how much of the wastewater and demand management solutions can be implemented.
- A mapping exercise of land in the ownership of the Local Planning Authorities to test the suitability for short-term solutions.
- A database or spreadsheet-based tracking tool to register and record the nutrient loading for each development and through what schemes this will be mitigated. This should include details of any agreements. The tool should be able to assign credits from various mitigation schemes at various stages of the development lifetime. The local authorities are already aware of the need for this tool and are proactively seeking a solution by working with developers and solution providers in order to bring forward nutrient neutral development.
- A tracking tool could also be expanded to track 'credits' achieved through mitigation schemes that can be used for biodiversity net gain, carbon offsetting and nitrogen mitigation. There are currently no published tools designed for this.
- Standardised legal agreements could be drawn up and used as a basis in future mitigation schemes. Conservation covenants are one option that should be explored. Conservation covenants can be applied to ecoservices which involve a legal obligation to be attached to land.
- A Mitigation Plan should be established which would set out the key solutions and timescales for expected delivery. This will allow for quantification of when and how many credits will be available.

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