NUTRIENT BUDGET CALCULATOR TECHNICAL REVIEW

A review of the approach to calculate phosphorus budget in the West Wales region

Report for: Carmarthenshire County Council

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Executive Summary

Carmarthenshire County Council (CCC), Ceredigion County Council (CeCC), and Pembrokeshire County Council (PCC) (West Wales) are facing barriers to consenting planning applications due to the implications of the Court of Justice of the European Union (CJEU) ruling known as the 'Dutch Case'[1]. In accordance with this ruling, new developments that are likely to affect European designated sites that are already under pressure from excessive nutrient loading must remove or offset the additional nutrient loading in order to be "nutrient neutral"[2] and comply with the Habitats Regulations[3]. Nutrient neutral development is necessary to comply with a Habitats Regulations Assessment (HRA) and show that new development will not result in adverse effects on site integrity in the Afonydd Cleddau / Cleddau Rivers Special Area of Conservation (SAC), Afon Tywi / River Tywi SAC, the Afon Teifi / River Teifi SAC and the Afon Gwy / River Wye SAC owing to increases in phosphorous loading through increases in wastewater generated by the new development. Evidencing nutrient neutrality for phosphorus in these areas comprises calculation of a phosphorous budget using the West Wales nutrient budget calculator. Assuming the phosphorus budget for a development shows that the development will result in a net increase in phosphorus loading to the European sites of concern, the developer will need to mitigate this additional phosphorus load.

This report comprises a technical review of a nutrient budget calculation methodology for use across three Local Planning Authorities (LPAs) that comprises West Wales. The original project was completed for CCC only and was subsequently expanded to include locally specific inputs for the three LPAs and to incorporate additional functionality. It aims to provide a robust framework and a set of inputs that can be used to determine a nutrient budget for any residential development draining to a European designated site that is in unfavourable condition or close to unfavourable condition due to phosphorus loading. The phosphorus budgets calculated using this methodology will form part of an HRA of new housing developments and thus needs to stand up to the scrutiny of the HRA tests. This means that the recommended inputs to the budget need to be based on best available evidence, be suitably precautionary and be valid in perpetuity (in practice for a duration of 80-125 years) in order to remove risks to site integrity beyond reasonable scientific doubt.

The overarching methodology detailed in this review follows a similar approach to that set out by Natural England, though it is specific to CCC, CeCC and PCC. The focus of the review was on defining input values that were specific to each LPA. The inputs have been grouped into four stages:

1. The increase in Phosphorous (P) loading to European sites that result from the increase in wastewater from a new development, which is based on population increase, water use, nutrient concentrations in discharges from wastewater treatment works (WwTW) and package treatment plants
2. The P export from the past/present land use of the development site.
3. The P export from the future mix of land use on the development site, e.g. urban land, greenspace, SuDS etc.
4. Calculation of the net change in nutrient loading to a designated site, the nutrient budget, which includes the addition of the 20% precautionary buffer.

The Stage 1 inputs were determined from secondary data and literature reviews. The concentration of P in effluent from package treatment plants (PTPs) and septic tanks (STs) is recommended to be taken from manufacturer specifications, if possible.

The review of the inputs to Stages 2 and 3 have been grouped as they comprise a set of export coefficients for different land uses. A Farmscoper modelling exercise was completed for the 3 West Wales LPAs administrative boundaries to determine locally relevant values for agricultural P export. Export coefficients for other landcovers have been identified through a targeted literature review. A simple rainfall runoff model was used to derive climate specific P export coefficients for built areas.

The inputs for Stages 1-3 all contain some uncertainty in their values. This review has assessed the uncertainty associated with the approach in each section. This uncertainty is accounted for in the Stage 4; the addition of a 20% precautionary buffer to estimates of a positive net change in nutrient loading. It is the recommendation

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

[2] Although the "Dutch Case" refers of nitrogenous nutrients, in the specified SACs the phosphorous is the nutrient of concern and the rivers are failing its target for phosphorous and not nitrogen.

[3] The Conservation of Habitats and Species Regulations 2017 (as amended)

of this review that whilst various of the inputs are locally specific to each LPA and are more precautionary, the 20% buffer is implemented to add additional precaution to the methodology, which also allows for the varying degrees of uncertainty associated with application of the methodology to individual developments.

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GLOSSARY

Abbreviation	Definition
CCC	Carmarthenshire County Council
CeCC	Ceredigion County Council
PCC	Pembrokeshire County Council
P	Phosphorus
TP	Total Phosphorus
SAC	Special Areas of Conservation
CJEU	Court of Justice of the European Union
LPA	Local Planning Authority
NRW	Natural Resources Wales
WwTW	Wastewater Treatment Works
PTP	Package Treatment Plants
ST	Septic Tank
HRA	Habitat Regulations Assessment
AA	Appropriate Assessment
LSE	Likely Significant Effects
WFD	Water Framework Directive
SuDS	Sustainable Urban Drainage Systems
HOST	Hydrology of Soil Types
MC	Management Catchment
RBD	River Basin District

1 THE REQUIREMENT FOR NUTRIENT NEUTRALITY

1.1 THE DUTCH CASE

The recent (2018) ruling in the European Court of Justice[4] referred to as 'The Dutch Case' or 'The Dutch Nitrogen Cases' resulted in a change to how the Habitat Regulations (as amended, 2017) are applied to plans or projects in the catchments of European Designated sites (hereafter, European sites) that are under pressure from pre-existing levels of nutrients.

The Dutch Case was concerned with the potential detrimental effects of nutrient loading from agricultural practices in the Netherlands on European Designated sites. However, the legal interpretation of The Dutch Case now requires local planning authorities to consider the impacts from new plans and projects that may generate additional nutrient inputs to European sites.

1.2 WHAT DOES THE DUTCH CASE MEAN?

Following the Dutch Case, Natural Resources Wales (NRW) issued interim planning advice in relation to new planning applications that have the potential to increase phosphorus (P) levels in rivers that are designated as SACs[5] *and* are under pressure from elevated nutrient concentrations. This interim advice has presented a significant barrier to CCC, CeCC, and PCC being able to determine new planning applications.

The administrative boundaries of these LPAs contain various SAC rivers and/or their catchments that are under pressure from high levels of existing nutrient inputs. The additional nutrient load from the increase in wastewater and/or the change in land use created by a new plan or project can create an 'impact pathway' that will exacerbate the problems related to nutrient loading that are currently seen in the SAC rivers with hydrological catchments in CCC, CeCC and PCC. This impact pathway is shown diagrammatically in Figure 1.

The existence of this impact pathway for nutrients from a new development will result in an HRA finding 'Likely Significant Effects' on the ecology of the European sites due to increased nutrient inputs. The two key nutrients that are output by new developments are nitrogen (N) and P. The SAC rivers of concern are under pressure from P.

An HRA comprises two key stages: Screening and Appropriate Assessment (AA). The Screening stage involves identifying whether a project or plan could infringe on the management objectives of a European site or significantly impact the quality of the site. Therefore, the existence of a nutrient impact pathway needs to be determined in this opening stage. The key factors to consider when assessing whether the nutrient neutrality approach is required for a new development are:

1. Whether the development is within a catchment that drains to an affected European site.
2. Whether the receiving Wastewater Treatment Works discharges to an affected European site.
3. Whether the development will lead to an increase in 'overnight stays'.
4. Whether the development will lead to an increase in the number of people coming into the catchment of the SAC river from outside of the catchment.

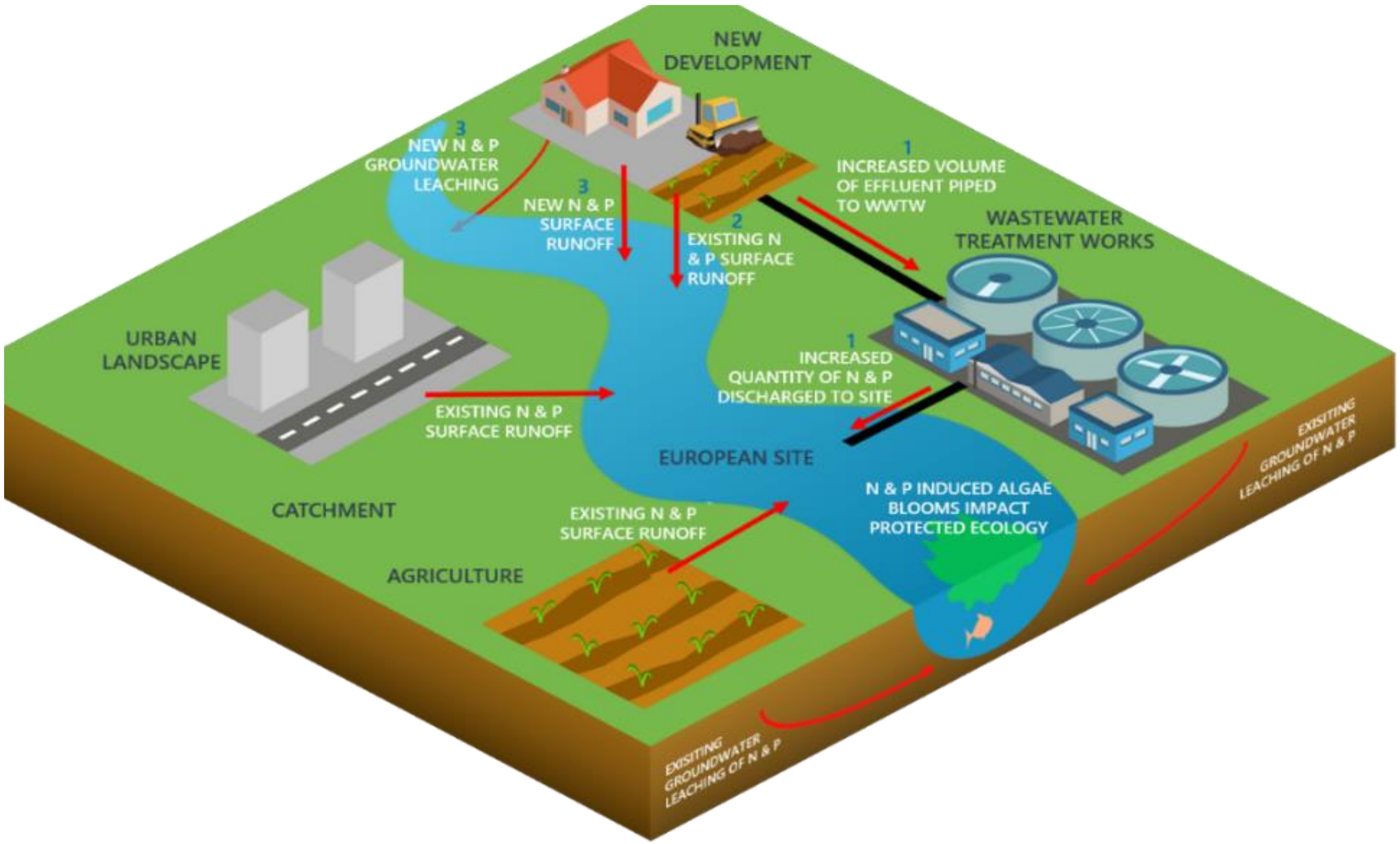
If the answer is yes to either 1, or the answer is yes to 2 *and* 3 or 2 *and* 4 as outlined above, a nutrient budget calculator will need to be completed in order to assess whether development will increase nutrient loading to a European site identified in Section 1.3. As such, an AA, will need to be completed. The first step in an AA that is applying nutrient neutrality is to understand whether a development will cause additional nutrient inputs to a European site. This requires calculation of the amount of nutrients a new residential development will create, otherwise known as a nutrient budget. Where a nutrient

[4] Joined Cases C-293/17 and C-294/17 *Coöperatie Mobilisation for the Environment UA and Others v College van gedeputeerde staten van Limburg and Other* (the Dutch Nitrogen cases)

[5] See NRW interim advice for planning applications that have the potential to increase phosphate levels in river Special Areas of Conservation (SACs), available here: https://cdn.cyfoethnaturiol.cymru/media/693022/interim-planning-advice-following-river-sac-compliance-report.pdf?mode=pad, accessed on: 06/04/2023

budget calculation shows that a development a plan or project will add additional nutrients to the European site, it will not be possible to conclude no ‘Adverse Effect on Site Integrity’ on the site if no mitigation is put in place. Thus, in order to conclude no ‘Adverse Effect on Site Integrity’ due to nutrient impacts, mitigation of nutrients to achieve ‘Nutrient Neutrality’ needs to be secured. The output from a nutrient budget will determine the annual amount of mitigation required to achieve Nutrient Neutrality for a plan or project.

Figure 1 Diagram showing potential nutrient impact pathways



1.3 EUROPEAN SITES IN CARMARTHENSHIRE COUNTY

The Afonydd Cleddau / Cleddau Rivers Special Area of Conservation (SAC), Afon Tywi / River Tywi SAC, the Afon Teifi / River Teifi SAC and the Afon Gwy / River Wye SAC are European sites that are in unfavourable condition or are close to unfavourable condition due to excessive P levels. Parts of the catchments of these European sites are within the CCC, CeCC and the PCC administrative boundaries. If a development is within one of these catchments, a P budget will need to be completed in order to consider if the developer will cause adverse effects on site integrity due to increased nutrient loading to the SAC rivers. As the LPA each county council must consider the affects to the SAC rivers when evaluating a plan or proposal as the competent authority. Figure 2 shows the location of these sites.

These rivers support a wide range of habitats and species between them, including:

- an abundance of water-crowfoots; white-flowered species which can be found as floating mats typically in the first half of summer.
- Fish species such as Brook Lamprey, Sea Lamprey, River Lamprey, Bullhead, Atlantic Salmon, Twaite Shad, and Allis Shad.
- White-clawed crayfish.
- Otters.
- Floating water plantain.

Increased levels of P entering aquatic environments via surface water and groundwater can severely threaten the sensitive habitats and species within each SAC. The elevated levels of nutrients can cause eutrophication, leading to algal blooms which disrupt normal ecosystem function and cause major changes in the aquatic community. These algal blooms can result in reduced levels of oxygen within the water, which in turn can lead to the death of many aquatic organisms including invertebrates and fish.

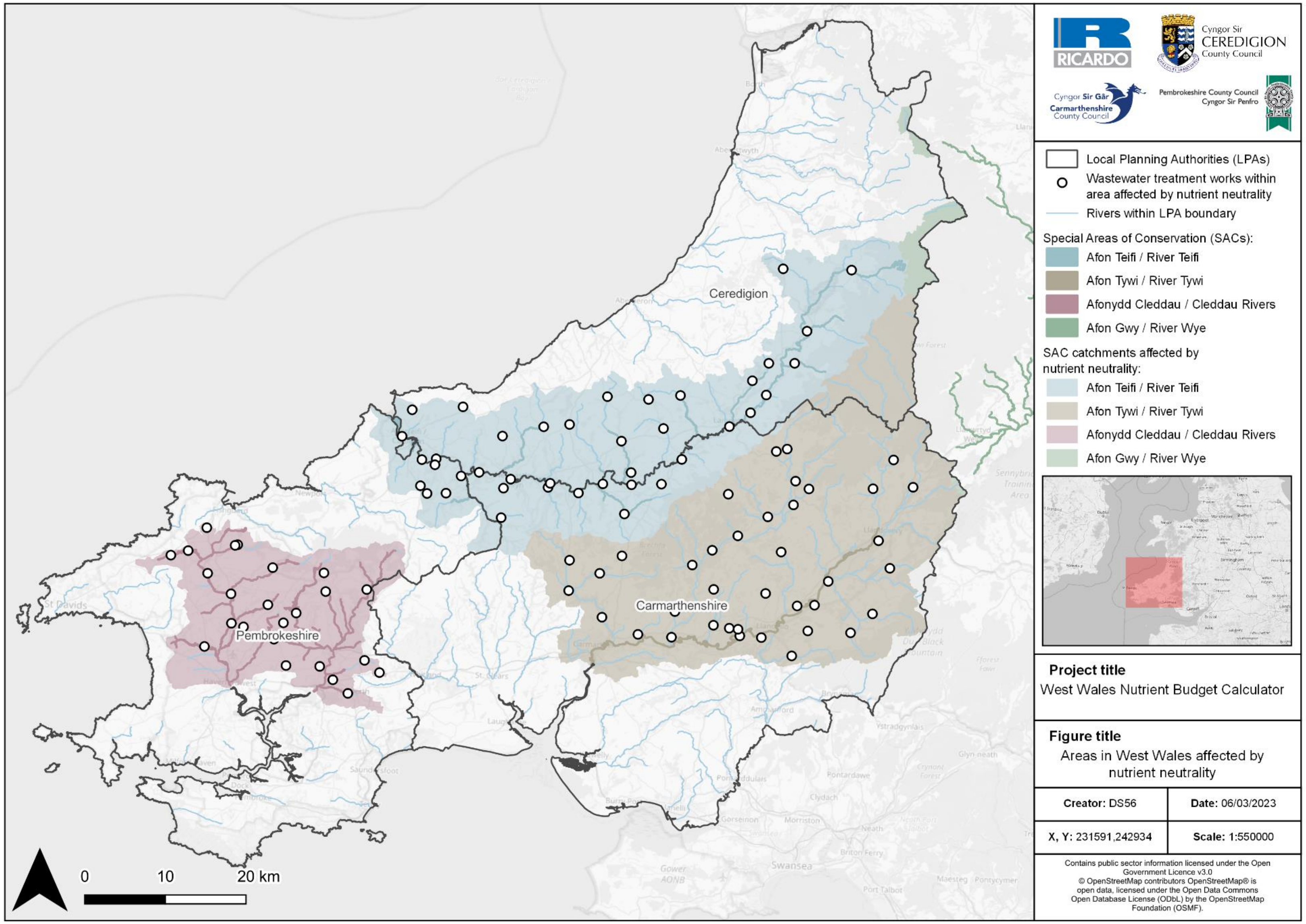
The habitats and species within these rivers that result in their respective designations as a SAC are referred to as 'qualifying features'. Not all of these qualifying features will be sensitive to changes in nutrients within these rivers. When completing an HRA involving nutrient neutrality, the LPA must identify and screen out qualifying features that are not sensitive to nutrients via an HRA. Developers will be asked to submit information to support this process.

More detailed information on the qualifying features of the SAC can be found in the following links:

- Afonydd Cleddau/ Cleddau Rivers[6]
- Afon Teifi/ River Teifi[7]
- Afon Tywi/ River Tywi[8]
- River Wye/ Afon Gwy[9]

[6] See Afonydd Cleddau/ Cleddau Rivers, available here: https://sac.jncc.gov.uk/site/UK0030074, accessed on: 06/04/2023
[7] See Afon Teifi/ River Teifi, available here: https://sac.jncc.gov.uk/site/UK0012670, accessed on: 06/04/2023
[8] See Afon Tywi/ River Tywi, available here: https://sac.jncc.gov.uk/site/UK0013010, accessed on: 06/04/2023
[9] See River Wye/ Afon Gwy, available here: https://sac.jncc.gov.uk/site/UK0012642, accessed on: 06/04/2023

Figure 2 *A map showing the 3 West Wales LPA administrative boundaries, the European Designated sites with nutrient issues and the areas that drain to the sites.*



1.4 PURPOSE OF THIS TECHNICAL REVIEW

This report comprises a technical review of an updated nutrient budget calculation methodology for use across CCC, CeCC, and PCC. It aims to provide a robust framework and a set of inputs that can be used to determine a nutrient budget for any residential development draining to a European site that is impacted by phosphorus. It details the rationale and evaluates the evidence that underpins the input values to provide confidence that the approach meets the requirements for the Habitat Regulations.

The phosphorus budgets calculated using this methodology will form part of an HRA of new housing developments and thus needs to stand up to the scrutiny of the HRA tests. This means that the recommended inputs to the budget need to be based on best available evidence, be suitably precautionary and be valid in perpetuity (in practice for a duration of 80-125 years) in order to remove risks to site integrity beyond reasonable scientific doubt.

This document will break the evidence down into two main sections. Section 2 details the approach used in the tool and the rationale that underpins it. It then discusses the different methods taken to determine each input. Section 3 analyses the inputs that were identified and/or generated, as well as detailing the reasoning behind the selection of each input. The following sections describe the considerations of uncertainties in the recommended input values have been made to inform a review of the precautionary buffer. These considerations are detailed in Section 3.4. The end of this section contains a summary table of the key inputs.

The nutrient budget methodology contains locally relevant input values where possible and used national values where necessary. This technical review systematically analyses the assumptions and uncertainties that underpin the inputs to these stages. Where default inputs cannot be determined, the approach to identifying robust local values for inputs will be provided.

2. APPROACH TO DETERMINING THE NUTRIENT BUDGET METHODOLOGY

The following sections highlights the key approaches to the methodology.

Section 2.1 describes the four key stages of the nutrient budget methodology. Each stage has various possible inputs that are fundamental for the calculation of a nutrient budget. This approach is utilised in England and is well documented in various publications by Natural England (Natural England, 2020a; Natural England 2020b). Ricardo has worked with Natural England extensively to assess and refine this methodology.

The first three stages aim to calculate the nutrient loading from an impact pathway associated with a development. The final stage quantifies the net nutrient loading with an uplift in accordance with the precautionary principle. This approach is both comprehensive and robust due to the inclusion of most major impact pathways, pre- and post-development, and maintains flexibility in its application through the use of local inputs. As such, it has been deemed appropriate to utilise, amend and upgrade this methodology for use in CCC, CeCC and PCC with modified functionality and locally relevant inputs to develop the West Wales calculator.

In addition to the updated inputs to the four main calculation stages, the West Wales nutrient budget calculator required the ability to select alterative development types to residential development (see **Section 2.2** and **Section 3.1** for details), as well as the ability to utilise data that is not available online. As such, a preliminary step was developed that allows the user to select other non-residential development types. Furthermore, a postcode search feature was built into the tool that returns key inputs to the calculator.

The rationale behind including non-residential development, and the approach to determining which types of development to include in the updated methodology is described in **Section 2.2. Sections 2.3-2.5** detail the approaches taken to determining the inputs to each stage of the nutrient budget methodology. The approach to determining the datasets to include in the postcode search function are detailed in **Section 2.6.**

2.1 THE STAGES OF THE NUTRIENT BUDGET METHODOLOGY

This nutrient budget methodology can be broken down into four key stages:

1. Calculate the increase in P loading to European sites that result from the increase in wastewater from a new development, which is based on population increase, water use and the nutrient concentrations in discharges from a WwTW, septic tanks or package treatment plants.
2. Calculate the P export from the current land use on the development site.
3. Calculate the P export from the future mix of land use on the development site, e.g. buildings, greenspace etc.
4. Calculation of the net change in nutrient loading to a designated site, the nutrient budget, which includes the addition of a precautionary buffer.

Each of these stages comprise a set of inputs. The keys stages of the nutrient budget methodology are shown in Figure 3 and Figure 4. An example of the key inputs required for calculating the nutrient budget of a residential development are shown in Figure 5. The following sections provide information on how these inputs were determined.

Figure 3 Diagram demonstrating the key stages of the nutrient budget calculator

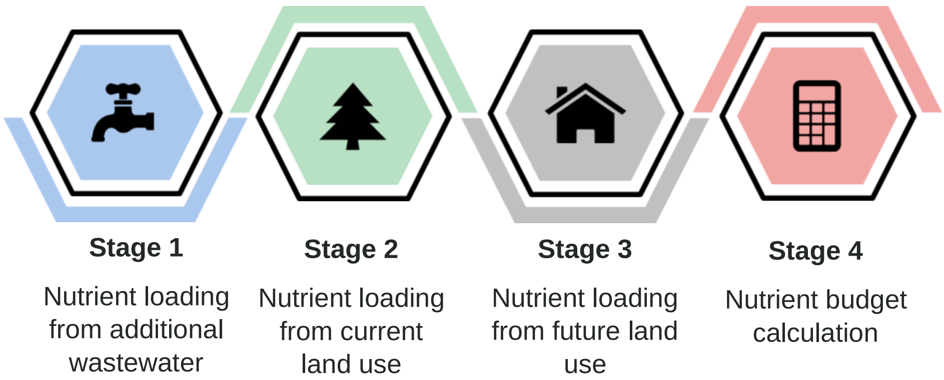


Figure 4 Diagram showing the overall equation used to calculate the phosphorus loading to a European site

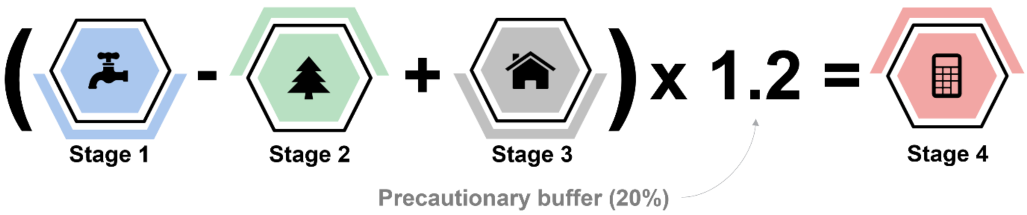
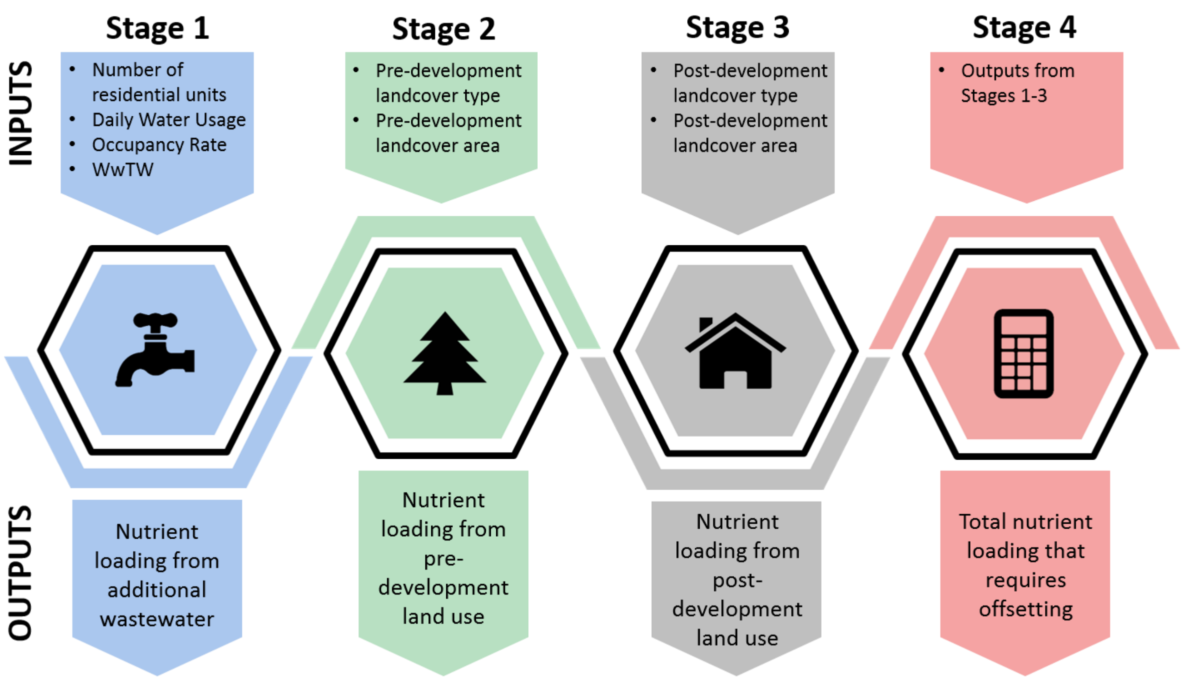


Figure 5 Diagram showing the inputs and outputs associated with each stage of the calculator for residential development (note: see Section 3.1 for other development types)



2.2 DETERMINATION OF APPROPRIATE DEVELOPMENT TYPES AND ADDITIONAL INPUTS

Through discussion with the steering group, it became clear that it was necessary to include additional types of development other than residential development within the calculator. This was in part due to the points NRW made on the initial nutrient budget methodology created for CCC. The original methodology assumed that all residential development increases the amount of 'overnight stays', resulting in additional population in the catchment and associated nutrient loading. However, it is possible that non-residential development can attract people from outside of the catchment leading to a temporary population increase, which may generate additional wastewater thereby increasing the nutrient loading. Non-residential development may also lead to a change in land use created by people coming into the hydrological catchment for other uses.

To determine the types of development to include within the updated calculator, a review of the 'Planning permission: use classes'[10] was completed. These use classes put the uses of land and buildings into categories. The way in which the type of development would change the inputs required in each stage of the methodology was determined by the review of use classes.

2.3 STAGE 1: DETERMINATION OF NUTRIENT LOADING FROM WASTEWATER

There are five inputs required for the first stage of the nutrient budget methodology. These are:

1. Occupancy rates for the new development (additional people per unit and percentage travelling from into the affected catchment for non-residential development).
2. Per capita water use figures.
3. Number of dwellings/units.
4. The WwTW that drain to European sites.
5. Nutrient concentrations in WwTW/private sewage treatment final effluent.

The default occupancy rates, additional people per unit and water usage values were identified through a targeted review of academic literature, independent reports and government publications. The number of dwellings/units is an input that is unique to each development and therefore does not require a default value.

WwTW that discharge to a European Site, to a tributary upstream of a European Site or discharge to ground can affect the nutrient concentrations of that site. These WwTW that could have an impact on the site need to be identified, as well as any permit limits on nutrient levels in the final effluent. The WwTW were identified using the dataset Consented Discharges to Controlled Waters with Conditions[11]. The catchments for the SACs with nutrient issues were identified using a Geographical Information System (GIS) to analyse the SAC geospatial dataset[12] and the Water Framework Directive (WFD) River Waterbody Catchments Cycle 2[13]. Where a catchment was larger than the SAC boundary, a catchment delineation exercise was completed on the Shuttle Rader Topography Mission elevation data[14].

The suggested inputs for nutrient concentrations of the final effluent in WwTW or PTP final effluent were determined using a review of the consented discharges register and expert judgement based on knowledge of the water industry. The low amount of permit limited WwTW in the affected areas of the LPAs meant a suitable default average value for the concentration of P in the final effluent needed to

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[10] See Planning permission: use classes (change of use), available here: https://www.gov.wales/planning-permission-use-classes-change-use, accessed on: 06/04/2023

[11] See Consented Discharges to Controlled Water with Conditions, available here: https://www.data.gov.uk/dataset/7f371d30-fc18-4750-91ca-ea8649d16d38/consented-discharges-to-controlled-waters-with-conditions, accessed on: 06/04/2023

[12] See Special Areas of Conservation (SAC),available here: https://datamap.gov.wales/layers/inspire-nrw:NRW_SAC

[13] See Water Framework Directive (WFD) River Waterbody Catchments Cycle 2, available here: https://datamap.gov.wales/layers/geonode:nrw_wfd_river_waterbody_catchments_c2, accessed on: 06/04/2023

[14] See: Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global, available here: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-shuttle-radar-topography-mission-srtm-1?qt-science_center_objects=0#qt-science_center_objects, accessed on: 06/04/2023

be established. A review of nutrient neutrality literature in England was completed to assess the previous approaches used to establish a default average value for WwTW without permit limits. This review made it clear that there is a general lack of nutrient monitoring at non-permit limited works. Therefore, the value reported in nutrient budget methodologies published by Natural England were used; the values documented in the English nutrient budget calculators adhere to the precautionary principle (Natural England 2020a).

2.4 STAGES 2 & 3: DETERMINATION OF NUTRIENT LOADING FROM DEVELOPMENT SITE LAND USES

Stages 2 and 3 of the nutrient budget methodology are used to calculate the nutrient export from the land use(s) / landcovers on the pre- and post-development site, respectively. Stages 2 and 3 are distinct, but they use the same approach to calculate nutrient export from land use. Both stages apply export coefficients that describe the amount of P exported from a given land use on a kg per hectare basis. Where a landcover may be present on a development site pre- and post-development, these landcover share the same values for the same landcovers. Users of the nutrient budget calculator provide the areal extent of the land use(s) / landcovers on their pre- and post-development site, with this area multiplied by the export coefficients in order determine the total phosphorus export from these land uses. As such, the review of how inputs for different land uses were derived is treated together in this report, though it is noted that agricultural land use export coefficients are only relevant to Stage 2 of the nutrient budget calculations. In the guidance document that accompanies this technical review, Stages 2 and 3 are treated separately. Descriptions of the land uses that are available to select in Stages 2 and 3 of the nutrient budget calculator are provided in Appendix 1.

2.4.1 Determination of agricultural land use export coefficients

The first step in identifying agricultural export coefficients for use in the calculator is identifying a suitable method for the generation of these values. Farmscoper V5 was deemed to be the most appropriate method for modelling agricultural export coefficients. Other models were considered such as the Phosphorus Indicator Tool (PIT) (Heathwaite et al, 2003) or the PSYCHIC model (Davison et al, 2008), though it became apparent these models would need extensive parametrisation exercises that would be too expensive and too onerous for developers to apply themselves. Ricardo have previously worked with Natural England to determine approaches to calculate agricultural export coefficients in England and found that Farmscoper was the optimal method to model diffuse pollution for the purposes of nutrient budget calculations. There are simpler approaches that employ a scaling approach of pre-defined export coefficients, though these values are often without the level of evidence required for an HRA.

Farmscoper is a decision support tool that can be used to estimate diffuse agricultural pollution at various scales. Farmscoper contains a set of tools that can be used to model diffuse pollution at the field scale or catchment scale using bespoke inputs or pre-defined June Agricultural Survey (JAS) data, respectively. It utilises a model called PSYCHIC to estimate P export (Strömqvist et al, 2008; Davis et al, 2008; Gooday & Anthony, 2010). The Farmscoper Upscale tool is used to model agricultural pollution at different catchment scales per combination of farm type, soil type, climate type and nitrate vulnerable zone (NVZ). It comes pre-loaded with the 2019 JAS data and a variety of physical environment data to produce estimates of diffuse pollution from different farm types for English catchments. This means that Farmscoper Upscale can be run to generate agricultural export coefficients for a catchment without the need for additional data collection.

The initial run of Farmscoper Upscale provides baseline diffuse pollutant loadings, including P export coefficients. These baseline export coefficients assume no mitigation measures have been used on-farm to reduce diffuse P pollution. These initial model outputs can then be run through mitigation scenarios which amends the baseline pollutant loadings based on a list of mitigation measures. The default mitigation settings are based on the average application of each measure across England as of 2019. The Upscale tool was previously used in England by Natural England at the Operational Catchment (OC) scale because this provides the highest spatial resolution of pre-populated data whilst including detailed landcover types. The various pre-loaded datasets required to run Farmscoper

Upscale are not available for Welsh catchments. Therefore, it was necessary to identify an approach to using Farmscoper that was suitable for CCC, CeCC and PCC. Ricardo and CCC discussed the possibility of directing developers to model P losses at the field-scale based on site-specific information that users of the nutrient budget calculator would input to Farmscoper. However, this was determined to be too onerous for users of the calculator[15].

To determine the best way to use Farmscoper to model agricultural nutrient export, the functionality of the tool was assessed. Farmscoper uses underlying data on physical variables such as soil types and chemical parameters, connectivity of fields to watercourses, slope and climate to drive models that take JAS data as inputs. The JAS data describes the farming practices that add nutrients to the environment, with the physical environment variables being used to drive the physical processes that determine the fate of nutrients in the environment. Some of this data is hidden to the user and therefore cannot be amended. There are a variety of pre-set assumptions within Farmscoper Upscale regarding fertiliser usage, proportions of landcover type within each farm type, and the degree to which agricultural mitigation measures are set. Therefore, using a prepopulated English catchment with similar physical characteristics to the affected areas as a 'donor' catchment was identified as a suitable alternative approach, assuming agricultural data inputs were available.

Through discussion with the steering group[15], it was decided that Farmscoper Upscale would be used to model a donor catchment with agricultural data specific to each LPA. High level analysis was completed on catchments in England that assessed the topography, agricultural data, soil drainage characteristics, and climate information to identify a suitable donor catchment. A dataset titled 'Agricultural small area statistics' was identified as an appropriate source of the agricultural data inputs used to model the three respective LPAs. This dataset breaks down agricultural statistics for the counties in Wales and contains results from the June Survey of Agriculture and Horticulture at the regional and subregional level. It contains information on the populations of livestock and the hectarage of grassland, woodland, and cropland. Where the dataset was not detailed enough to map onto the required input categories for Farmscoper Upscale, the agricultural data were split proportionally across the more detailed categories required to parameterise the model. The total number of farms in each farm type at the regional level within the respective LPA were also split equally across the soil drainage types and rainfall inputs available within Farmscoper. This process is explained in further detail in Section 3.2.1.1. The implementation of mitigation measures was assumed to be the same as the standard in England. This approach modelled the whole county, as opposed to hydrological catchments.

A review of this modelling exercise was completed to addresses uncertainties. The P export coefficients generated using this modelling exercise for were compared to three English catchments run using the standard Farmscoper Upscale tool in order to assess the potential impacts of the assumptions used to generate the agricultural export coefficients.

2.4.2 Determination of built-environment export coefficients

A targeted literature review was conducted to identify approaches for calculating urban nutrient export coefficients. This literature review identified a method that calculates urban export coefficients by multiplying the annual urban or built environment runoff by an event mean concentration (EMC) for total phosphorus (TP) in urban runoff, following Zhang et al (2014). The EMCs, shown in Table 2.1, are derived from a review of 160 studies of urban runoff (Mitchell, 2005), including 71 UK catchments. The inclusion of a large number of UK catchments in this study helped to increase the applicability of this approach to Wales. The EMCs detailed in Table 2-1 are the best available evidence for this approach. However, it is noted that these values are averages and there will be local variability in EMCs that cannot be accounted for with this approach.

[15] This was originally discussed as part of the CCC Nutrient Budget Calculator project on the 15/12/21. The approach was then ratified by the steering group on the 15/12/22.

Table 2-1: Event mean concentrations for nutrient runoff from different urban/built environment land uses.

Land use	Phosphorus event mean concentration (mg P/l)
Residential	0.41
Commercial/industrial	0.30
Open urban land	0.22

To calculate urban/built environment runoff, the HR Wallingford Modified Rational Method (DoE, 1981) should be used (*Equation 1*). This approach has recently been applied in the Improvement Programme for England's Natura 2000 Sites (IPENS) project WQ0223 on pollutant source apportionment of diffuse pollution[16].

Equation 1

$$L = R * Pr$$

Where:

L = annual average runoff (mm)

R = annual average rainfall (mm)

Pr = percentage runoff (%)

$$Pr = 0.829 * PIMP + 0.078 * U - 20.7$$

$PIMP$ = the percentage of land that is impervious (whole number)

U = catchment wetness index. Calculated by (use 41 if rainfall over 760 mm):

$$U = -129.5 + (0.424 * R) - (2.28 * 10^{-4} * R^2) - (4.56 * 10^{-8} * R^3)$$

The PIMP is recommended to be set at 80%, as this has been suggested as the proportion of impervious surfaces once urban creep (the paving over of pervious surfaces) reaches a maximum (Gorton, Kellagher, & Udale-Clarke, 2017). The use of an 80% PIMP value, while high, accounts for the potential increases in impervious surfaces that may occur over the lifetime of a development. Research has also suggested that non-paved gardens account for between 19-27% of an entire urban area (Perry & Nawaz, 2008). As gardens are the primary type of permeable surface within residential areas, the use of an 80% PIMP value is considered to be precautionary for P as an area with 19% coverage by non-paved gardens would indicate that around 80% of the remaining urban residential area would be impermeable surfaces. This means that P loading from urban areas considers the P derived from runoff generated by the 80% of surfaces in an urban area that are likely to be impermeable, thus neglecting fluxes of P along subsurface pathways, which could result in an underestimate of P loading from urban areas. Given the high retention rate of P in soils, it is likely that the magnitude of this underestimate is negligible.

[16] See: IPENS008a edition 1 - Application of a cross sector pollutant source apportionment modelling framework to protected sites, available here: http://publications.naturalengland.org.uk/publication/6226121240608768, accessed on: 06/04/2023

2.4.3 Determination of greenspace and community food growing export coefficients

A review of literature relating to P inputs and export coefficients was completed to determine values for both natural and urban greenspace. A lack of clarity on loadings to and from greenspace meant that a value had to be selected from the literature that had limited evidence behind it, other than expert judgement. An approach that considered pet waste inputs to greenspace according to those reported in literature was rejected on the assumption that pet waste, one of the key inputs of nutrients in urban greenspace, is likely to be incorporated in the estimate of P in urban runoff due to the way in which urban runoff water samples are collected (see Section 3.3.1). A hectare of woodland was modelled using Farmscoper at the field scale in order to serve as a comparison to the values identified in literature.

There is a lack of studies that quantify the nutrient loading from allotments or community food growing areas. Therefore, it was decided that an approach that utilises export coefficients modelled in Farmscoper would provide the best estimations of these losses. A community food growing farm type is not available in Farmscoper so a suitable substitute that included a specific combination of farm type, soil drainage type, and rainfall volume needed to be determined. The 'General' farm type available in Farmscoper was selected because it includes a mix of different agricultural landcovers likely to be present in a small-scale farming area, such as cereals, vegetables and horticulture. A freely draining soil type was assumed because it is unlikely that community food growing areas will have drainage considering the small scales on which they operate. The rainfall volume is assumed to be that which is input buy the user.

2.5 STAGE 4: DETERMINATION OF THE PRECAUTIONARY BUFFER

For each of the values proposed in this methodology, an estimate of uncertainty was provided. Where possible, this estimate was quantitative. However, it is recognised that for values derived from the literature or taken from secondary data sources without estimates of uncertainty, the understanding of the potential variability of an input value will be more limited.

2.6 POSTCODE SEARCH FUNCITON

A postcode search function was built in order to improve the user experience of the calculator and to provide access to datasets unavailable online. This postcode search function made use of the following datasets:

- Ordnance Survey (OS) Code-Point Open[17] postcode dataset
- WwTW catchments provided by each LPA
- Consented Discharges to Controlled Waters with Conditions
- CEH-GEAR: 1 Km resolution daily and monthly areal rainfall estimates for the UK was used to create a 1990-2019 standard annual average rainfall (SAAR) dataset
- SAC catchments
- Local Planning Authority boundaries

A GIS was used to extract the data at each postcode point. Where the postcode was not within a WwTW catchment, the closest WwTW was identified for each postcode point. This dataset was then used to build a reference table and a postcode lookup function in the calculator

[17] See OS Code-Point Open, available here: https://www.ordnancesurvey.co.uk/business-government/products/code-point-open, accessed on: 06/04/2023

3. INPUTS TO THE GENERIC NUTRIENT BUDGET METHODOLOGY

The following sections detail the inputs selected for the phosphorus budget calculator and the rationale that underpins their selection. A summary table is provided at the end of each stage detailing the chosen value and some notes on the rationale or key considerations behind each value.

3.1 DEVELOPMENT TYPES TO INCLUDE IN THE CALCUALTOR

An assessment of the development use classes[10] allowed for the identification of five main development types: residential, commercial, leisure, public service infrastructure and tourism. The use classes which are included within each category are shown in Table 3-1.

Table 3-1 Table showing how the planning permission use classes fit into the development types selected for use in this methodology

Development type	Description
Residential	C2 Residential institutions; C2A Secure Residential Institution; C3 Dwellinghouses, used as sole or main residences; C4 Houses in multiple occupation; C5 Dwellinghouses, used otherwise than as sole or main residences; C6 Short term
Commercial	A1 Shops; A2 Financial and professional services; A3 Food and drink; B1 Business; B2 General industrial; B8 Storage or distribution
Leisure	D2 Assembly and leisure
Public service infrastructure	D1 Non-residential institutions
Tourism	C1 Hotels

In the calculator the development type was set to 'Residential' as a default. These development types specifically relate to the permanent change of land use compared to temporary uses of land, such as festivals. Changing the development type changes the functionality in 'Stage 1' of the calculator:

- If 'Residential' is selected, the user is prompted to confirm the use of the average occupancy rate upon selecting the appropriate LPA.
- If 'Commercial', 'Leisure', or 'Public service infrastructure' is selected the user of the calculator is provided with a cell to enter the estimated total number of customers/users and a cell to enter the number of employees required for commercial uses. Below each cell the user of the calculator is prompted to enter the percentage of people who are commuting from outside of the catchment.
- If 'Tourism' is selected the user is provided with an area to enter the average number of tourists per unit, which could also be considered as the tourism occupancy rate. The user is also provided with an area to enter the percentage of time that the dwellings/units will be populated. The user is also provided with a cell to enter the number of employees required, the percentage commuting from outside of the catchment, and the water usage per employee and per tourist.

The percentage of customers/users and employees commuting from outside of the catchment, and the percentage of time the average tourist occupancy rate applies, is set to 100% as a default in lieu of any evidence to suggest otherwise. However, it is improbable that 100% of customers/users and employees will commute or travel from outside of the catchment, or that tourists will occupy tourism units for 100% of the time. If a bespoke value is used, it will be up to the user to identify a suitable and appropriately precautionary rate that will need to be agreed by the appropriate LPA. It may be possible to estimate the amount of people travelling from outside of the catchment based on the location and type of the development and analysing census data such as 'Distance travelled to work by occupation'[18] or conducting surveying of similar facilities/industries.

3.2 STAGE 1: NUTRIENT LOADING FROM WASTEWATER

The Nutrient Budget Calculator methodology calculates the additional nutrient load due to wastewater from a new development as the product of the number of dwellings and average occupancy rate of dwellings in the new development, average water use per person and the concentration of P in final effluent from treated wastewater generated by the new development. These three inputs to the nutrient budget cover the key components of the process that results in additional nutrient loading from wastewater. The sections below present the results of the review of the input values to Stage 1 that are specific to Carmarthenshire.

3.2.1 Occupancy rates for new dwellings

The 2021 Census data contains the most recent data on occupancy rates, or persons per household. Analysis of the Population and household estimates, Wales: Census 2021[19] was conducted to identify an average occupancy rate for each LPA. The average for CCC, CeCC and PCC was 2.3, 2.31 and 2.22 people per dwelling, respectively. Therefore, these values are considered appropriate unless a more recent, locally relevant occupancy rate is known and can be supported with sufficient evidence. If a specific development is being built which has known occupancy rates, such as a care home or student halls, then a bespoke value suitable for this type of development should be used. In these situations, the onus is on the developer to prove that this information is correct and accurate in perpetuity.

3.2.2 Water use per person in new dwellings

The Building Regulations 2010 Amendments to Approved Document G[20] details the water efficiency requirements for new dwellings. New erected dwellings must be built with an estimated maximum water usage of 110 litres/person/day. Dwellings formed by a material change to a building must adhere to 125 litres/person/day. A water efficiency calculation should be completed to estimate the water usage based on the fittings and fixtures at the time of construction, or a fittings approach is used where the fittings used need to conform to specified flow rates.

The Building Regulations water efficiency targets are recommended for use in the calculator, with an additional 10 litres/person/day added to account for any variation from the estimate and to account for potential changes to fittings by homeowners over the lifetime of a development (assumed to be 80-125 years). The average water usage for Dŵr Cymru's customers between 2020-2021 is reported to be 163 litres/person/day – the highest of any water company in the UK[21]. This highlights the real possibility of water consumption to drift from a higher water efficiency standard, even if it is secured with a planning condition, and thus justifies the use of 120 litres/person/day for the water use input (or 135 litres/person/day where a dwelling is formed by a material change to a building). Where appropriate, a more development-specific water usage can be applied, though the onus is on the developer to provide sufficient evidence this value can be supported for the lifetime of the development.

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[18] See Distance travelled to work by occupation, available here: https://www.ons.gov.uk/datasets/RM016/editions/2021/versions/1, accessed on: 06/04/2023

[19] See: Population and household estimates, Wales: Census 2021, available here: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationandhouseholdestimateswalescensus2021, accessed on: 06/04/2023

[20] See: Amendments to Approved Document G, available here: https://gov.wales/sites/default/files/publications/2019-05/building-regulations-guidance-part-g-sanitation-hot-water-safety-and-water-efficiency-amendments.pdf, accessed on: 06/04/2023

[21] See Discover Water company comparison Apr 2020 – Mar 2021, available here: https://discoverwater.co.uk/amount-we-use, accessed on 06/04/2023

3.2.3 Nutrient concentrations in wastewater

Where feasible, the wastewater from a new development will discharge to a mains sewer for subsequent treatment at a WwTW. New developments in more rural areas without mains sewerage connections will need to be connected to a package treatment plant (PTP) or septic tank. Whatever treatment the additional wastewater receives, the concentration of P in its final effluent is required for the nutrient budget calculation.

3.2.3.1 Identification of wastewater treatment works that drain to protected sites

The Consented Discharges to Controlled Waters with Conditions[11] dataset provides permit details of discharges in Wales as required under the Environmental Permit Regulations. This dataset contains information on all permit holders as well as details on the substances that are controlled by each permit.

The Consented Discharges dataset was first filtered in order obtain all WwTW. All combined sewage overflows (CSOs), sewage pumping stations (SPS) and private sewerage discharges were removed because they cannot treat a new development's wastewater. The remaining WwTW were mapped using the national grid reference (NGR). Any WwTW that discharged to waterbodies that do not flow to the affected European sites within Carmarthenshire were removed. See Figure 2 for the WwTW locations, and Appendix 2 for the names of the WwTW.

Only three of the WwTW identified in the LPAs had P permits: Clynderwen STW, Llandewi Brefi WwTW and Maenclochog STW had TP permits ranging from 1-2 mg TP/l. For all other WwTWs, an average value of the P concentration in the final effluent for all WwTW that was based on the best available evidence needed to be identified

3.2.3.2 Identification of an average concentration of P in the final effluent of non-permit limited wastewater treatment works

Dŵr Cymru does not routinely monitor P concentrations in final effluent unless they have a requirement to evidence compliance with permitted P limits. This makes it difficult to determine an accurate value for the P concentration in the final effluent. It was considered whether P concentrations in treated final effluent could be determined based on the type of treatment used at a WwTW. Typically, WwTW without dedicated P stripping use either activated sludge processes or biological filtration (or combinations of both) to lower the concentrations of pollutants in influent sewage. A literature review on the efficacy of these treatment processes to remove P has highlighted variation between specific processes as well as the importance of the influent nutrient concentration and the chemical conditions within the bio-reactors (Gao, Xie, Zhang, Yu, & Yang, 2016; Kocadagistan, Kocadagistan, E., & Demircioğlu, 2005; Li, et al., 2020; Li, Yuan, Zhan, & Liu, 2014; Wang, Li, Li, & Wang, 2021). This limits the ability to confidently estimate the P concentration based on the treatment process alone.

The Stodmarsh advice note on nutrient neutrality (Natural England, 2020b) noted that Southern Water estimated the upper figure of 8 mg/l TP for non-permit limited WwTW. This value is based on monitoring datasets from water companies at non-permit limited works. In Herefordshire a value of 5 mg/l TP is used, based on a dataset for works in Herefordshire provided by Dŵr Cymru. However, Ricardo has seen a larger dataset for non-permit limited works in an area of Southern England[22] and these data show an average concentration of around 8 mg/l. In a meeting with CCC nutrient neutrality stakeholders, it was mentioned that Dŵr Cymru use 5 mg/l TP in their modelling (08/02/2022 – SAC Rivers Planning Sub-Group meeting). However, it was not clear what monitoring data the value of 5 mg/l TP was based on. A data request from CeCC for TP monitoring data at WwTW was submitted to Dŵr Cymru on the 14 October 2022 but was not fulfilled. Due to the lack of data available on the P concentration of treated wastewater in CC, it is recommended that 8 mg/l TP is used as the estimate as this adheres to the precautionary principle.

3.2.3.3 Private Sewerage Treatment Systems

In situations where a development cannot feasibly connect to mains sewerage, a private wastewater system will be required. Typically, the two treatment options are a septic tank or a package treatment

[22] We do not have permission publish further details of these data.

plant (PTP). Package treatment plants (PTP) generally treat effluent to a higher standard than a septic tank and therefore can discharge directly to a river or stream, whereas a septic tank infiltrates to the ground and cannot discharge directly to surface water without further treatment[23]. Although widely regarded to be more effective at treating wastewater, many PTPs have not been designed to remove phosphorus and therefore do not necessarily provide additional phosphorus removal over a septic tank, though there are some available that are designed for this purpose. A drainage field will provide additional P removal for both systems. Where a cesspool is being proposed, which should only be when no other option is feasible, then these should be treated as if they go to mains, as the effluent should be emptied and taken to a nearby WwTW which can accept this waste.

Research on the P concentrations of the final effluent from PTPs indicates that flow rates and concentrations from package treatment plants are not constant (May & Woods, 2016) and deriving a daily estimate of load based on effluent flow rate and P concentration is therefore prone to large uncertainties. However, on an annual basis it is reasonable to assume that differences in daily loads due to fluctuating flow rates and nutrient concentrations will average out and therefore load can be calculated using the 120 litres/person/day water use figure (see Section 3.2.2) and the TP concentration guaranteed by the manufacturer where provided.

If the manufacturer of a PTP guarantees a TP concentration of the final effluent this should be multiplied by the wastewater generated by the development. For example, all of the BioKube products, which vary in sizes from 5-10000 population equivalent (PE, can produce effluent with < 1.2 mg TP/litre according to their own research[24]. Moreover, some PTP manufacturers claim effluent TP concentrations of <1 mg TP/l. For example, some of the GRAF UK products claim the final effluent has been tested to be 0.4 mg TP/l[25].

If a system does not provide a specified TP concentration of the final effluent, an alternative method to estimate the loading should be used. One approach involves using the annual TP load in the wastewater from a PTP based on the annual TP production per person from human excreta and detergent use and an estimated TP removal rate of the system. The human loading is estimated to be between 0.91-0.97 kg/yr following the values reported in May et al. (2015). A review of P emissions factors for human excreta and detergents from various studies by Naden et al (2016) suggested TP emissions per person of 0.69-1.16 kg P/year. However, the potential for human P emissions to change due to behavioural and diet changes add uncertainty to this method (Naden et al., 2016; Forber et al., 2020). There is also the option to multiply the annual wastewater volume by the concentration of TP in the final effluent of private sewerage systems reported in literature. The average of reported mean values of TP in PTP and septic tank effluent was calculated as 9.7 mg TP/l (May & Woods, 2016) and 11.6 mg TP/l (O'Keeffe, et al., 2015) from 59 samples of six PTPs and a review that collated data from studies assessing 17 septic tank systems, respectively.

PTPs or septic tanks that discharge to ground are likely to achieve further reductions in P export from a development, as a large proportion of P is retained in soil. Even better retention of P in drainage fields can be achieved through the use of filter media with high P sorption capacity. Soils and filter media will eventually become saturated with P, leading to a migratory effluent plume; effluent plumes originating from septic tanks have been recorded moving at 1 metre per year (Robertson, 2003).

However, there is a requirement for suitable drainage field management plans to be put in place in order to secure the reduction in P export in perpetuity. If evidence can be provided that shows the reductions in P that are likely to be achieved by a drainage field, along with a suitable maintenance plan to ensure P reductions are maintained for the lifetime of a development, it is likely that mitigation requirements could be reduced significantly. The level of P reductions that a drainage field can achieve should be dealt with on a case-by-case basis as it depends on a variety of local characteristics such as the soil conditions and the choice of filter media if one is used. It should also be noted that owing to the strong

[23] See: Water discharges and septic tanks, available here: https://naturalresources.wales/permits-and-permissions/water-discharges-and-septic-tanks/register-your-septic-tank-or-small-sewage-treatment-plant/?lang=en, accessed on 06/04/2023

[24] See: Cleaning results for al 3800 BioKube systems in Denmark, January 2021, available from: https://www.biokube.com/download/biokube-technical-library/, accessed on: 06/04/2023

[25] See: Catalogue Wastewater Treatment Solutions, available here: https://www.graf.info/en/wastewater-treatment.html, accessed on: 06/04/2023

retention of P in soils, septic tanks discharging to a drainage field are likely to result in less mitigation being required than PTPs that discharge directly to a watercourse.

3.2.4 Summary of recommended input values to Stage 1

Table 3-2 provides a summary of the recommended inputs to Stage 1, including brief notes on the key recommendations around each input.

Table 3-2: Summary of the recommended inputs to Stage 1 of the nutrient budget calculator.

Input	Phosphorous	Notes
Occupancy rates:	CCC: 2.3 CeCC: 2.31 PCC: 2.22	• Taken from 2021 UK census data
Per person water usage	120 litres/person/day (135 litres/person/day)	• Based on the Buildings Regulations with an uplift of 10 litres to account changes over time. • the 135-litre value is only relevant where a dwelling is formed from a material change to a building.
WwTW effluent concentration with permit	Ranges from 1-2 mg TP/l	• Taken from the consented discharges register
Non-permit limited WwTW effluent concentration	8 mg/l TP	• Further research recommended to determine more robust values. • Value subject to change based on future availability of monitoring data from Dŵr Cymru.
Package treatment plant (PTP) effluent concentration	9.7 mg/l TP or user defined	• This is the recommended value to use in the methodology. • User defined inputs can be determined based on verifiable manufacturer specifications.
Septic tank effluent concentration	11.6 mg/l TP or user defined	• This is the recommended value to use in the methodology. • User defined inputs can be determined based on verifiable manufacturer specifications.

3.3 STAGES 2 & 3: NUTRIENT LOADING FROM PRE- AND POST-DEVELOPMENT LAND USES

The following sections provide descriptions of the approaches to determining the nutrient export coefficients from different land uses, as well as the evidence base that underpins these export coefficients.

3.3.1 Agricultural land use export coefficients

3.3.1.1 Alternative approaches to Farmscoper

Alternatives to Farmscoper were reviewed in order to assess their applicability in the nutrient budget calculator.

A literature review identified alternative models and methods that could be used. The James Hutton institute developed the Phosphorus Land Use and Slope model in the 1990’s for source apportionment in Scotland. This model is based in GIS and scales pre-defined export coefficients from different land uses based on slope. The pre-defined export coefficients used in this tool were developed based on expert judgement on agricultural diffuse pollution in Scotland by the Macaulay Land Use Research Institute with the Forth River Purification Board (Donnelly et al, 2011). The study does not reference a body of academic research or provide empirical evidence to explain how these values were created. The potential regional limitations and the lack of evidence behind the values adds a lot of uncertainty and limits their application. The Phosphorus Indicators Tool (PIT) generates catchment-scale diffuse pollution estimates but requires extensive data inputs, such as livestock numbers, Hydrology of Soil Types (HOST) class, soil characteristics (including texture and plant available phosphorus) and fertilizer inputs (Heathwaite et al, 2003). The original PSYCHIC model that Farmscoper utilises for P losses could be used to estimate agricultural export coefficients but parameterising the model would require large amounts of site-specific information, as well as the ability to run the model. Based on this review of alternative approaches to estimate agricultural P export, it was determined that although Farmscoper Upscale is not available for Wales, it is still the best available approach to generate agricultural export coefficients. Farmscoper V5 was used to model agricultural export coefficients for each LPA.

3.3.1.2 Approach to generating agricultural export coefficients using English donor catchments

A previous Farmscoper model of Welsh agricultural pollutant losses used JAS data, LPIS data and the 1st and 2nd Welsh Farm Practice Surveys[26]. In a report for the Welsh government, Cao et al (2019) also used JAS data. Therefore, a data request was made for the JAS data, LPIS data, and Welsh Farm Practice Surveys. This request was not fulfilled.

In lieu of the required JAS, LPIS and Welsh Farm Practice Survey data, the 'Agricultural Small Area Statistics' dataset[27] was used in a Farmscoper modelling exercise that aimed at replicating some of the key characteristics of different farm types used in Farmscoper. The Agricultural Small Area Statistics dataset is mainly based on the June Welsh Agricultural Survey. However, it is noted that supporting documentation for this dataset states it is not a definitive record on agricultural practices in Wales. The survey responses are a sample of the total farm population; in 2019 there were just under 4,000 responses from a total population of 24,000 farms[28]. This sample survey is adequate to produce a wide range of estimates although these estimated figures mean that there is a level of uncertainty attached. These estimates are not at the farm scale but are aggregated across the 36, 23 and 24 subregions of CCC, CeCC, and PCC, respectively. The cattle population data present within the Agricultural Small Area Statistics for Wales are taken from the Cattle Tracing System (CTS) which is an administrative source, rather than survey estimates. Thus, the cattle data is more accurate than for other livestock populations and arable areal extents.

The Agricultural Small Area Statistics dataset contains data from 2002 to 2020. The data is reported for a whole LPA and for each subregion. However, the statistics for the small areas (subregions) do not match the reported region totals. For most categories this will not be a major issue as the differences are small. However, the sums of the small areas for Wheat, Maise, Pigs and Poultry are very different to the reported regional totals. For example, the calculated total of Poultry units in Ceredigion subregions in 90,601 less than the reported total for Ceredigion. Table 3-3 shows the differences in the dataset.

[26] See: Regulatory Impact Assessment Doc 17 available here: https://gov.wales/sites/default/files/publications/2021-03/atisn14824doc9.pdf, accessed on: 06/04/2023

[27] See: Agricultural small area statistics: 2002 to 2020, available here: https://gov.wales/agricultural-small-area-statistics-2002-2020, accessed on: 06/04/2023

[28] The size of the survey was confirmed in email correspondence between CCC and the Welsh Government during December 2021.

Table 3-3 Table showing the difference between the reported total of category and the calculated total of the subregions

Date	Area	Wheat (ha)	Maize (ha)	Pigs	Poultry
2019	Ceredigion	-209	-255	-498	-90,601
2019	Pembrokeshire	-1,360	-1,329	-324	-246,133
2019	Carmarthenshire	-246	-1,356	-1,154	-89,743

The 2019 data showing the reported totals of each farm category was selected as this year was the most recent survey with the most complete record - the dataset is based on a self-reported sample survey and can contain gaps. The dataset breaks down the livestock populations into various categories based on demographics and the arable data is broken down into areas of each crop. However, Farmscoper uses different, more detailed categories to break down the JAS in English catchments. In order to split the Agricultural Small Area Statistics data into the more specific categories, a proportional approach was used to split the less detailed regional data into the required categories. For example, in Farmscoper Upscale for English catchments, the total number of cattle is split into different categories, whereas the Agricultural Small Area Statistics data for Wales just provides the number of cattle across a smaller number of categories. It was assumed that the split of, for example, total cattle into the required sub-categories is unlikely to vary markedly between catchments and so the totals for each category were disaggregated based on the percentage of the total for each sub-category in the donor catchment JAS data. An example of this approach is shown in Box 1.

The agricultural data was input to an English donor catchment with similar physical characteristics to each LPA. The PSYCHIC model was evaluated to identify the key physical environment data that is used to parameterise the model; areas of major crops, livestock populations, slope, soil characteristics and climatic data are some of the key data inputs to PSYCHIC model. High-level visual analysis of the JAS data in Farmscoper for English catchments, the Agricultural Small Area Statistics data, the Soilscapes dataset, elevation data and the standard annual average rainfall in the UK showed that the Tamar Management Catchment (MC) in Southwest England, the South Devon MC, and the North Devon MC were found to be the most similar to CCC, CeCC and PCC, respectively. In order to assess the approach to splitting agricultural input data to generate the export coefficients, the results were compared against the Tamar MC and viewed in the context of other export coefficients generated from English catchments.

Farmscoper also estimates what proportion of the catchment-wide totals of landcovers would be represented in a farm based on predefined but editable weightings. The weightings are used to apportion the total agricultural data within a catchment data between farm types. For this modelling exercise the default weightings were maintained because there was no evidence on which to base any amendments.

Due to a lack of information on the number of different farm types, the total number of each farm type in the catchment also needed to be estimated based on a proportional approach. For example, if 10% of farms in the donor catchment were Cereals, then 10% of the total number of farms in the LPA were assumed to be Cereal farms. Analysis of the CEH-GEAR rainfall dataset enabled the identification of the proportion of each LPA that received rainfall within a specific rainfall band. These area-rainfall proportions were used to split the farm types into specific rainfall bands using a similar proportional split approach. However, amount of farm with each soil drainage type were split equally based on the estimated total number of farm types because it was not possible to identify which combination would be more or less likely with the data used. If the farm value was greater than 0 but less than 1 it was assumed that one whole farm had this specific combination of physical characteristics. An example of this approach is shown in Box 1.

Box 1: Example of the Farmscoper proportional approach.

Agricultural Small Area Statistics data for cattle in CCC:

Dairy cows (CTS)	Beef cows (CTS)	Calves (CTS)	Other cattle (CTS)
73199	24633	48927	44285

Proportional approach splitting the cattle data for CCC Farmscoper categories using the Tamar Management Catchment (MC):

Dataset	Total Cattle	Dairy Cows and Heifers	Dairy Heifers in Calf (2 years +)	Dairy Heifers in Calf (< 2 years)	Bulls (2 years +)	Beef Cows and Heifers	Beef Heifers in Calf (2 years +)	Beef Heifers in Calf (< 2 years)	Other Cattle (2 years +)	Other Cattle (1 - 2 years)	Other Cattle (< 1 year) & Calves
Tamar MC data	159585	32,884	4,309	7,232	1,463	22,492	7,294	14,914	5,854	17,581	45,563
Tamar % of total cattle	100	20.6	2.7	4.5	0.9	14.1	4.6	9.3	3.7	11.0	28.6
CCC estimated data (% * total population)	191044	39366	5158	8657	1752	26925	8732	17854	7008	21047	54544

The farm types in the Tamar MC were split proportionally:

Catchment	Farm type	Total	Percentage
Tamar MC	Cereals	78	3.7
Tamar MC	General cropping	412	19.6
Tamar MC	Horticulture	52	2.5
Tamar MC	Indoor pig farming	16	0.8
Tamar MC	Poultry	35	1.7
Tamar MC	Dairy	185	8.8
Tamar MC	LFA grazing	534	25.4
Tamar MC	Lowland grazing	631	30.0
Tamar MC	Mixed	150	7.1
Tamar MC	Outdoor pig farming	6	0.3
	Total	**2099**	**100.0**

Analysis of the percentage area of each LPA that received a rainfall within a Farmscoper rainfall band was completed:

Farmscoper rainfall band (mm)	Km^2 that received rainfall within each band	Percent
700-900	0	0%
900-1200	90	4%
1200-1500	986	42%
>1500	1285	54%

The proportions of different farm types in the Tamar MC were applied to total number of farms in the Carmarthenshire data, with each total number of farms per farm type then split equally across the Farmscoper combinations of rainfall volume and soil drainage type:

Catchment	Farm type	Farm Count	900 – 1200 mm			1200 - 1500 mm			>1500 mm		
			Free Draining	Drained for Arable	Drained for Arable & Grass	Free Draining	Drained for Arable	Drained for Arable & Grass	Free Draining	Drained for Arable	Drained for Arable & Grass
CCC	Cereals	150	2	2	2	21	21	21	27	27	27
CCC	General cropping	789	10	10	10	110	110	110	143	143	143
CCC	Horticulture	99	1	1	1	14	14	14	18	18	18
CCC	Indoor pig farming	33	1	1	1	4	4	4	6	6	6
CCC	Poultry	66	1	1	1	9	9	9	12	12	12
CCC	Dairy	354	5	5	5	49	49	49	64	64	64
CCC	LFA grazing	1026	13	13	13	143	143	143	186	186	186
CCC	Lowland grazing	1212	15	15	15	169	169	169	220	220	220
CCC	Mixed	288	4	4	4	40	40	40	52	52	52
CCC	Outdoor pig farming	15	1	1	1	2	2	2	2	2	2
	Total	**4032**	**53**	**53**	**53**	**561**	**561**	**561**	**730**	**730**	**730**

3.3.1.3 Analysis of Carmarthenshire County Farmscoper results compared to English catchments

The full results of the modelling exercise are shown in Appendix 3. The modelled export coefficients for the LPAs, using the 2019 Agricultural Small Area Statistics and the respective donor catchments are typically lower than those generated for the original Tamar MC. Table 3-4 shows the difference between the export coefficients for the various combinations of farm types and the Tamar MC. The results show that the PCC export coefficients are most similar to the Tamar MC. The export coefficients are consistently lower for all farm types in each LPA bar poultry and indoor pig farming.

Table 3-4: The export coefficients for each LPA have been compared to the Tamar MC. Note if the percentage value is lower than 100 then the export coefficient if lower than the Tamar MC and vice versa.

Farm type	CCC export coefficient % of Tamar MC coefficients	CeCC export coefficient % of Tamar MC coefficients	PCC export coefficient % of Tamar MC coefficients
Cereals	54	61	95
General cropping	67	68	94
Horticulture	79	78	87
Indoor pig farming	113	110	116
Poultry	141	150	103
Dairy	74	68	108
Less Favoured Area grazing	91	80	93
Lowland grazing	90	85	94
Mixed	67	64	94
Outdoor pig farming	91	86	86

Farmscoper produces output files for each specific combination of farm type, soil type, and rainfall volume. Analysis of these files showed that the disparity between the LPA export coefficients and the original Tamar MC data may arise from the pre-populated weightings of each farm type, differences in livestock populations and the high proportion of pastures and woodland relative to arable land in CC. For example, the cereals landcover is weighted to include small areas of pastures, fallow land, rotational grassland, woodland, vegetables and large areas of cereals. Furthermore, the CCC, CeCC and PCC export coefficients for the combination of a cereal farm, over 1500 mm of rainfall and soil that is drained for arable was 1.11, 1.30, and 2.29 kg/ha/year compared to 2.46 kg/ha/year for the Tamar MC. Analysis of the datasheets that underpin the model showed that for this combination in the CCC data, 11.9% of the total 'cereals' farm area was modelled as cereal crops, with the remaining 88.1% being modelled as grassland and woodland, despite this being considered a cereals area. In comparison, 43.6% of the area was modelled as cereals for this specific combination in the Tamar MC. In addition, analysis of the same combination of the cereals farm type for PCC showed that 41.9% of the area was treated as cereal crops. As such, this is likely to explain the differences between the modelled values; modelled fertiliser inputs to the cereals farms within CCC and CeCC are much lower than the Tamar MC.

It is recognised that the modelled farm systems in the three LPAs are not a true reflection of real-world stocking densities and nutrient inputs to the farms and that actual inputs may be more similar to those in England. It is also recognised that the values are generally lower than the typical variation of the modelling results for the English catchments. These issues notwithstanding, the generated Farmscoper outputs are recommended for use as they are based on the best available data for generating agricultural export coefficients at the LPA scale. It should also be noted the agricultural P export is relatively small proportion of the majority of nutrient budgets and thus the impact of the inaccuracies in the export coefficients will have a relatively minor impact on inaccuracies in nutrient budget outputs. Furthermore, the general trend of modelled values being lower than other English catchments adds a layer of precaution to the approach, as a low value equates to a smaller offset in P loading from existing land use. Furthermore, although there maybe a size difference between the modelled export coefficients and those for the English catchments may be different in relative terms, the differences are still small in absolute terms; the modelled export coefficients are not erroneously high or low (see Appendix 3 for a comparison between the export coefficients for the different modelled catchments).

3.3.1.4 Identifying export coefficients for development sites

The nutrient export coefficients output by Farmscoper are split into combinations of farm type, soil drainage type and rainfall volume. The user of the methodology will need to select the export coefficient for the relevant combination of farm type, rainfall and soil drainage that describes their development site. This will require the following further information to be gathered:

- The most relevant farm type should be determined by the developer or LPA through consultation with the farmer / landowner of a proposed development site.
- The soil drainage type for the development can be identified using the Cranfield Soil and Agrifood Institute Soilscapes map[29]. The soil drainage type on this website is not the same as the Farmscoper soil drainage type. However, the HOST class corresponding to Farmscoper soil types were documented in Collins & Zhang (2015). High-level analysis of the Soilscapes dataset and the HOST data[30] allowed for a soil drainage conversion table to be created which can be used to find the associated Farmscoper definition. This is shown in Table 3-5.
- The site-specific rainfall volume can be identified using the postcode lookup or the National River Flow Archive[31] (NRFA) to identify the average annual rainfall for the development site. Every flow gauge station page contains a map of the average annual rainfall for the UK for the period between 1961-1990. This map is within the 'Catchment info' tab on a gauging station's web page. A conversion table for the rainfall bands used in the NRFA map and the Farmscoper rainfall bands can be seen in Table 3-6.

Once this information has been found, the user will be able find the development specific combination of farm type, soil drainage type and rainfall band in the Farmscoper results and select this export coefficient. These datasets have been confirmed as suitable for the purpose of determining the correct agricultural export coefficient from Farmscoper through consultation with Natural England and ADAS Ltd. (who developed Farmscoper). Detailed instructions on how to find the required data are provided in the accompanying guidance document. The rainfall data used to select the agricultural export coefficients will also be used to calculate/select nutrient export coefficients for urban land use (see Section 3.3.2) and community food growing (see Section 3.3.4).

Table 3-5: Soil drainage type conversion table showing Soilscape drainage definition and the relative Farmscoper terminology

Soilscape drainage term	Farmscoper term	Definition
Freely draining	FreeDrain	Free Draining
Slightly impeded drainage	DrainedAr	Drained for arable
Impeded drainage	DrainedArGr	Drained for arable and grassland
Variable	DrainedAr	Drained for arable
Surface Wetness	DrainedAr	Drained for arable
Naturally wet	DrainedAr	Drained for arable

[29] See: Soilscapes map, available from: http://www.landis.org.uk/soilscapes/, accessed on: 06/04/2023
[30] A developer of Farmscoper confirmed the suitability of this approach on a previous project (email dated 10/03/2021)
[31] See: National River Flow Archive data search page, available from: https://nrfa.ceh.ac.uk/data/search, accessed on: 06/04/2023

Table 3-6: Rainfall band conversion table showing National River Flow Archive rainfall band and the relative Farmscoper band.

NRFA rainfall band (mm)	Farmscoper rainfall band (mm)	NRFA rainfall band (mm)	Farmscoper rainfall band (mm)	NRFA rainfall band (mm)	Farmscoper rainfall band (mm)
508 - 525	Under600	700.1 - 750	700to900	1,200.1 - 1,400	1200to1500
525.1 - 550	Under600	750.1 - 800	700to900	1,400.1 - 1,600	1200to1500
550.1 - 575	Under600	800.1 - 850	700to900	1,600.1 - 2,000	Over1500
575.1 - 600	Under600	850.1 - 900	700to900	2,000.1 - 2,400	Over1500
600.1 - 625	600to700	900.1 - 950	900to1200	2,400.1 - 3,000	Over1500
625.1 - 650	600to700	950.1 - 1,000	900to1200	3,000.1 - 4,000	Over1500
650.1 - 675	600to700	1,000.1 - 1,100	900to1200	4,000.1 - 5,500	Over1500
675.1 - 700	600to700	1,100.1 - 1,200	900to1200		

3.3.2 Built environment land use export coefficients

The annual average rainfall for the development site is used in Equation 1 (see above) to calculate the surface runoff volume for the urban area of a development site, with the assumption that 80% of land is impermeable (see Section 2.3.2). The calculation that generates the surface runoff value for a site will be completed for the rainfall associated with the postcode entered, or the rainfall band selected by the user of the calculator based on the NRFA rainfall map (see Section 3.3.1.4 for the approach to find this value). The surface runoff volume is multiplied by the relevant EMC found in Table 2-1 above. An example of these calculations can be seen in Box 2. For calculating the export coefficients as input to Stage 2 on brownfield development sites, the relevant EMC should be selected for each area of the site classified as residential, industrial/commercial or open land within the built environment. If the pre-development site is covered by a single type of urban land, e.g., it is entirely residential, then only this EMC is required in the calculations for Stage 2. For the Stage 3 calculations, it is recommended that the residential EMC value is used to calculate P export from the built environment on the post-development site unless a development incorporates areas of industrial/commercial land use or open land within the built environment that is not classified as a type of greenspace.

The resulting export coefficients for the built environment land uses are relatively high compared to agricultural values, though these values would be more similar to a farm with under drainage and grazing animals. This is likely a reflection of the contribution of P from pet waste inputs and the assumption of a high percentage of impermeable land. It is recommended that the residential land types include green areas with unmanaged pet waste such as gardens, grass verges and swales due to the potential for pet waste inputs; De Frenne et al (2022) found the fertilisation rates from dogs to be 5 kg P per hectare per year (predominantly from faeces) in urban ecosystems. These high values provide added incentive to incorporate well-designed SuDS systems within new developments; SuDS wetlands tend to be the SuDS component that can achieve the greatest reductions in P (Strecker, Kersnor, Driscoll, & Horner, 1992; Shatwell & Cordery, 1999; Land, et al., 2016).

Box 2: Example of residential built environment runoff calculations

A theoretical development has been identified as receiving an annual average rainfall of 2,000.1 – 2,400 mm based on the approach of identifying rainfall in Section 3.3.1.4. Using Equation 1.

- $PIMP = 80\%$ (Section 2.4.2)
- $U = 41$ (based on Zhang et al's (2014) recommendation with rainfall volumes over 760 mm)

$$Pr = 0.829 * 80 + 0.078 * 41 - 20.7$$

Therefore, Pr = 48.818%

- $R = 2{,}200.05$ mm (median value between 2,000.1 – 2,400 mm)
- Pr = 48.818%

$$L = 2{,}200 * 0.48818$$

Therefore, $L = 1{,}073.996$ mm runoff ≡ 1,074 litres / m^2 ≡ 10,740,000 litres / ha

- Residential EMC = 0.41 mg/l

Therefore, residential export coefficient = 0.41 * 10,740,000 = 4,403,400 mg /ha ≡ **4.40 kg/ha**

3.3.3 Greenspace export coefficients

The term greenspace is used to refer to natural and semi-natural outdoor spaces provided for recreational use where fertilisers will not be applied and dog waste is managed, e.g. semi-natural parks. This does not include gardens and sports fields, as these are included in the 'residential land' and 'open land within the built environment categories', respectively (See Appendix 1).

A background export of 0.02 kg/ha/year P from natural land uses has previously been used for catchment-scale nutrient load modelling (Johnes et al, 1996). This value is relatively low, considering pet waste inputs could be a significant source of P in natural and semi natural environments (Hobbie et al, 2017; De Frenne et al, 2020), although there are also higher rates of nutrient cycling which in turn would retain P in the system, and higher permeability, which is likely to reduce surface flows and therefore reduce sediment-bound P mobility. Modelling of a single farm using Farmscoper V5 with no fertiliser inputs, one hectare of woodland and with an annual average rainfall volume of <900, 900-1,200, 1,200 – 1,500, and <1,500 mm produced a P export of 0, 0.01, 0.02, and 0.06 kg P/ha/year, respectively. Considering the spread of Farmscoper generated P export coefficients around the value reported in Johnes et al (1996), and noting that the annual average rainfall in CCC, CeCC and PCC is 1536, 1422, and 1283 mm, respectively, it is recommended that the greenspace P export coefficient used is 0.02 kg/ha/year due to the consistency between the literature and Farmscoper modelling.

The EMC used to calculate the P export from residential land (0.41 mg P/l) is considerably higher than the EMCs for commercial/industrial (0.30 mg P/l) and open urban land (0.22 mg P/l). In residential areas the key sources of P are from detergent use, garden fertiliser and pet waste inputs. The EMCs suggested for use are the averages of 160 studies of urban stormwater quality, including 71 UK catchments detailed in Mitchell (2005). This is an unpublished database, therefore the sampling strategy for the collection of urban stormwater is unknown. Surface runoff is typically sampled by collecting water in surface drains or through a dedicated surface runoff collection experimental design. As pet waste inputs are not restricted to greenspaces within an urban area, it is assumed that the pet waste inputs associated with housing and population are, at least in part, captured in estimates of P export calculated from the EMCs for residential urban land use (see Sections 2.3.2 and 3.3.2). This in turn may partially explain why the export coefficients for urban environments are higher than those used in the original Natural England nutrient budget methodology and also provides further justification for using a low greenspace export coefficient.

3.3.4 Community food growing export coefficients

There is a potential for developments to contain community food growing areas, e.g. allotments. A literature search found no usable research on P leaching from allotments. It is therefore suggested that a suitable farm type export coefficient is used to approximate the P leaching associated with community food growing. It is recommended the general cropping farm type is likely to best represent the type of mixed cultivation seen in community food growing. Community food growing is assumed to have no under drainage, so the free draining soil type is the most applicable. The rainfall volume, inputted by the user in Stage 2, will be combined with the General Cropping farm type and freely draining soil to select the relevant Farmscoper export coefficient.

3.3.5 Summary of recommended input values to Stages 2 & 3

Table 3-7 provides a summary of the recommended inputs to Stages 2 & 3, including brief notes on the key recommendations around each input.

Table 3-7: Summary of the recommended inputs to Stages 2 & 3 of the generic nutrient budget methodology.

Input	**Value** (TP (kg/ha/year)	Notes
Agricultural nutrient export	Can be viewed in Appendix 3	• Values derived using Farmscoper to model each LPA using the Agricultural Small Area Statistics dataset and assumptions on the proportions to which the agricultural data is broken down into smaller categories • Site-specific inputs of rainfall and soil drainage acquired from open-source datasets.
Greenspace nutrient export	0.02	• Values revised down by removal of pet waste inputs and incorporation of pet waste in urban residential export coefficients.
Community food growing nutrient export	Dynamic	• Based on local values of P export from General Cropping farm types using local rainfall and free draining soil.
Urban nutrient export	Dynamic	• Calculated using event mean concentrations of P in urban runoff and urban runoff rates based on local rainfall used within the modified rational runoff method.

3.4 STAGE 4: THE PRECAUTIONARY BUFFER

The inputs detailed in Sections 3.1 and 3.2 contain a degree of inherent uncertainty. There are also other variables, such as combined storm overflows (CSOs) and wastewater pipe leakage, which will impact nutrient budgets but that cannot be quantified with any degree of accuracy. In the Natural England's Solent and Stodmarsh advice notes, uncertainty in input values and the issue of unquantifiable variables was accounted for by the addition of a 20% buffer to the net change in N or P loading calculated by the nutrient budget. Natural England's rationale behind setting the precautionary buffer at 20% was provided to Ricardo as part of a review of the nutrient budget methodology that set the generic approach to calculating nutrient budgets that is now used in England. This rationale considered the scale of the uncertainties associated with both the quantified and unquantified variables that will determine a nutrient budget. Natural England deemed the 20% increase in the nutrient budget as suitable to account for uncertainties in the methodology, whilst not unduly increasing the final output of the nutrient budget and the associated mitigation requirements. Ricardo's review of the nutrient budget methodology and the recommended changes to the methodology resulted in a set of inputs that had reduced uncertainty relative to the original Natural England approach (Ricardo, 2021). However, Natural England opted to retain the original 20% buffer to add additional precaution to the nutrient budget outputs.

Following the approach taken in Ricardo (2021), the sub-sections below assess the uncertainties inherent in the inputs to the nutrient budget methodology estimated using a semi-quantitative scale that ranges from 0 to 1. Values of 0 suggest very little uncertainty and 1 indicates a very high level of uncertainty. Uncertainty values closer to 1 are more reliant on a large precautionary buffer in order to avoid the danger of underestimating nutrient loading.

3.4.1 Uncertainties in the inputs to Stage 1

3.4.1.1 National average occupancy rate – estimated uncertainty = 0.1

The input is based on the most recent census data and Office for National Statistics estimates for 2020 values[32]. The average household size has not varied significantly for three decades; the average household size in CCC, CeCC and PCC was 2.5, 2.41 and 2.53 in 1991[32,] respectively. The average occupancy rates are also likely to trend downwards or remain stable in the future (Holmans, 2005). However, there will be natural variation within occupancy rates and rates will be different depending on the development type. Therefore, the calculator has included functionality to amend this value based on development specific data, provided this figure is evidenced in perpetuity. This flexible approach reduces the probability of uncertainty and need for a precautionary approach.

3.4.1.2 Water use per person – estimated uncertainty = 0.25

The water usage per capita recommended is nearly 25% lower than the Dŵr Cymru average (120 l/person/day vs 163 l/person/day). The value is based on the Building Regulations requirement with an additional 10 litres per day added. The 120 litres/person/day figure recognises these water efficiency standards are unlikely to be maintained in all cases. Water usage is likely to decrease with the UK government aim of reducing water use per person per day to 110 litres by 2050[33]. Therefore, the recommended value has some uncertainty at the time of writing but is likely to be an overestimate in perpetuity if the 2050 goal is reached.

3.4.1.3 Nutrient concentrations for non-permit limited WwTW – estimated uncertainty = 0.8

P concentrations in WwTW without limits on P concentration in the final effluent remain uncertain and currently the best available evidence are averages from small samples. The use of the more precautionary 8 mg TP/l does not reduce uncertainty but does reduce the risk of underestimating. Although the default input value can be revised down based on new local evidence, accuracy of the data is dependent of the size of the dataset and the temporal and geographical coverage. This review suggests that the combination of a limited evidence base with the potential for underestimates of the nutrient budget if P concentrations in treated wastewater are underestimated means that this input contributes to needing a larger precautionary buffer.

3.4.1.4 Verifiable P concentration in PTP/septic tank effluent – estimated uncertainty = 0.4

Where P concentrations in PTP/septic tank effluent are provided with manufacturer specifications for the system *and* the concentrations are verified adequately, this input is assessed as being relatively robust, assuming the PTP/septic tank is maintained effectively. However, the uncertainty is presumed to be moderate due to the potential for an increase in P concentrations that can arise from poor maintenance and a variety of manufacturing and environmental factors.

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[32] See Average household size (persons) by local authority and year, available at: https://statswales.gov.wales/Catalogue/Housing/Households/Estimates/AverageHouseholdSize-by-LocalAuthority-Year, accessed on: 06/04/2023

[33] See: Meeting our future water needs: a national framework for water resources – accessible summary, available here: https://www.gov.uk/government/publications/meeting-our-future-water-needs-a-national-framework-for-water-resources/meeting-our-future-water-needs-a-national-framework-for-water-resources-accessible-summary, accessed on 06/04/2023

3.4.1.5 Non-verifiable P concentration in PTP/septic tank effluent – estimated uncertainty = 0.7

Where PTP/septic tank effluent concentrations are not provided, averages from studies of P loads associated with a range of septic tanks and PTPs are recommended as the input value. Developers could install PTPs/septic tanks that discharge P concentrations that are greater than the recommended averages, though it is also possible that developers could install systems that do not provide a maximum P concentration in the final effluent but that still perform better than the average recommended by this review. The average of reported mean values of TP in PTP and septic tank effluent was calculated as 9.7 mg TP/l (May & Woods, 2016) and 11.6 mg TP/l (O'Keeffe, et al., 2015) from 59 samples of six PTPs and review that collated data from studies assessing 17 septic tank systems, respectively. An analysis of the variability of P concentrations showed that the mean concentration from these studies was 11.6 mg P/l, with a standard deviation of 6.1 mg P/l. This suggests that the mean is not being particularly skewed by outliers and thus within a sample of septic tanks, the majority will perform around 53% better or worse than average. A similar analysis of the values used to determine the average P concentration for PTPs indicates that the concentrations may vary, on average, by approximately ± 90%. This analysis suggested that a high uncertainty value is needed to account for the variability in the datasets used to calculate average P concentrations from PTPs and septic tanks. Although uncertain, the use of the average values should help to account for both high and low values. A 20% buffer is likely to be sufficient to account for the uncertainty associated with non-verifiable TP concentrations from PTPs/septic tanks.

3.4.2 Uncertainties in the inputs to Stage 2

3.4.2.1 Export coefficients from agricultural land – estimated uncertainty = 0.6

The Farmscoper model was populated using agricultural statistics from 2019 and further data predictions based on that of a similar English catchment. The lack of detailed agricultural and physical environment datasets specific to each LPA meant that a lot of assumptions were required for the generation of these inputs. This will in turn will increase uncertainty of these inputs. The models of P dynamics that generate the export coefficients result in inherent uncertainty as these models cannot fully replicate the complex processes that determine P export from farming. However, the use of specific combinations of farm type, soil type and rainfall type help to at least bring a degree of site specificity to this input. The export coefficients were mostly lower than the Tamar MC which was modelled with actual data. As such, these inputs have a low risk of overestimating P loading from prior land use on a development site. Overestimates of P loading from pre-development land use risk causing underestimates in the P budget and so although there is high uncertainty in the export coefficients generated for each LPA, the fact that the export coefficients are low compared to English analogues suggest these inputs are precautionary and hence a moderate uncertainty value has been suggested.

3.4.2.2 Built environment land use export coefficients – estimated uncertainty: 0.4

Estimates of runoff rates are based on simple models for generating runoff, however those models are likely to perform fairly well in most urban environments where runoff generating surfaces tend to perform in ways that are hydraulically well understood. The event mean concentrations that are combined with the runoff values to generate export coefficients are averages and will therefore include a degree of variance. However, the linear increase in P export coefficients with increased rainfall may not be exactly characteristic of P mobilisation in urban environments. Without a suitably simple alternative, this approach has been utilised for precautionary purposes. This potential simplification of urban P dynamics, coupled with the use of average P concentrations, reduces the need for a large precautionary buffer.

3.4.2.3 Greenspace P export – estimated uncertainty: 0.5

The greenspace export coefficient is low. A literature review on determining this input returned very little robust research. Alongside estimates of high P fertilisation from pet waste inputs to greenspaces located in the rural-urban fringe (De Frenne et al 2022), it is possible this value is an underestimate. However, the notably high built environment export coefficients should account for the use of this lower value and reduce the need for a particularly precautionary input. The Farmscoper modelling exercise conducted for woodland provided further evidence that this value may be an accurate representation of P leaching from greenspace, reducing the uncertainty.

3.4.2.4 P export from community food growing – estimated uncertainty: 0.6

There is very limited evidence on P leaching from community food growing. The recommendation for deriving this input uses Farmscoper modelling. Therefore, these values have the same uncertainty as the agricultural land export coefficients outlined in Section 3.3.2.1.

3.4.3 Recommendation for the precautionary buffer

The above analysis reviewed the uncertainty associated with each input to the calculator. The average uncertainty score was 0.48. The use of averages where appropriate, which are inclusive of all monitored values, and the scientific and statistical principles on which the inputs are derived reduce the likelihood of underestimation. A precautionary buffer serves to protect against underestimation and is not necessarily proportional to the estimated uncertainty. Thus, the use of a 20% precautionary buffer is deemed appropriate to mitigate for the uncertainty outlined above. This precautionary buffer is the same as that used in England. This buffer may also add an additional layer of protection for unforeseen nutrient inputs such as CSO spills that could be affected by an increase in population within the counties.

4. SUMMARY

This technical review has described the approaches taken to generate inputs to a nutrient budget calculation methodology for use in CCC, CeCC, and PCC. This nutrient budget approach has been developed for the purposes of determining the net P loading from a new development to a European site affected by nutrient issues. The same overall approach used to calculate a nutrient budget in England has been applied with the inclusion of inputs specific to each LPA. A breakdown of the methods used to determine the input values has been provided. The input values have been identified, assessed and the uncertainty surrounding the values has been analysed.

The inputs to Stage 1 of this methodology are either provided by the user, e.g. number of dwellings/units in a development, or have been derived from freely available data / information sources and a literature review. Inputs for household occupancy were taken from Census data and surveys by the Office for National Statistics. Per person water use was adapted from the required set by the Building Regulations in order to provide a precautionary estimate that accounts for potential changes in water use of time. Inputs describing the concentration of P in treated wastewater were taken from a limited datasets for non-permit limited WwTW and from a literature review for default values for PTPs and septic tanks.

Inputs that describe the P input for different land uses are required for Stages 2 and 3 of the nutrient budget methodology. These inputs are based on an export coefficient approach, where the P export from the different land uses is described on a kg P/ha/year basis. For agricultural land uses, Farmscoper is the industry standard tool for determining P export coefficients. However, the modules of Farmscoper that can be used to generate export coefficients without significant user inputs are not available for Wales. A method for using Farmscoper to generate P export coefficients for the LPAs was devised based on available sources of agricultural input data. This method was based on a range of assumptions but based on analysis of the export coefficients relative to English catchments, it seems the that modelled P export coefficients for each LPA are suitably precautionary and do not risk underestimating the nutrient budget output.

The inputs describing P export from urban land were derived using an approach that combined a simple surface runoff model with average P concentrations in urban runoff. Both of these elements of P export from urban land were derived from analysis of literature. The surface runoff model requires only an input of annual average rainfall, which users of the nutrient budget calculators enter to generate the required urban P export coefficients. Values for the P export from greenspace use a value taken from the literature, while the P export from community food growing (i.e. allotments) is based on modelled agricultural values in lieu of any research to provide specific values for this land use.

In order to account for the uncertainties in the various inputs used in the calculation of a nutrient budget and certain unquantifiable factors that could result in an increase in P loading due to new development, a 20% precautionary buffer is added to net change in P loading calculated in Stage 4 of the nutrient budget calculation. This 20% buffer was originally proposed for the English approach to calculating nutrient budgets, which the approach has been based on. An analysis of the suitability of the 20% buffer found that the changes made to nutrient budget approach to make is locally applicable to each LPA context has not resulted in a need to increase or reduce the 20% buffer.

This review has also identified areas where data limitations could be addressed in order to improve the accuracy of this methodology. As a result, the following recommendations for further research have been made:

1. Determine a more accurate P concentration input for non-permit limited WwTW:

The concentration of P in final effluent non-permit limited WwTW is not known for all WwTW within the affected catchments. A monitoring campaign to collect data on WwTW final effluent from non-permit limited works would help to reduce uncertainty associated with these inputs. This monitoring campaign should also include measurements of flow data where they are not routinely taken, which would serve a dual purpose of helping with the design of P mitigation wetlands.

2. Development or application of more accurate models of P export from urban land uses.

The urban export coefficients are based on the received rainfall and an EMC of P in urban runoff. The HR Wallingford Modified Rational Method (DoE, 1981) used to estimate the surface runoff is an empirically derived regression equation. Therefore, the dataset used to develop it may have contained anomalous results or may not be representative of modern precipitation patterns. The percentage of impermeable landcover is assumed to be 80% which may not be indicative of the landcovers present within each LPA. More recent data specific to each LPA could be collected to improve on this method for estimating surface runoff, or another method could be used. The EMCs reported in Mitchell (2005) include the results of over 160 different studies. A monitoring campaign to derive more locally relevant EMCs in the CCC, CeCC and PCC would help to provide more accurate and locally specific results for P export from urban environments.

3. Development or application of more accurate models of P export from agricultural land uses.

The accuracy of the modelled agricultural P export coefficients is uncertain, as they were generated based on a large set of assumptions. Monitoring of P losses from a variety of farms could be completed to compare to the modelled data. Considering the agricultural data used in Farmscoper is based on a survey and had to be modified and input to an English catchment due to a lack of the required physical environment data, it is also likely that more accurate data could be used to populate Farmscoper and build each catchment. It would be beneficial for the Farmscoper Upscale module that is available for England to be extended to Wales.

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Afon Tywi / River Tywi

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APPENDICES

APPENDIX 1 STAGE 2 & 3 LANDCOVER TYPES USED IN THE TOOL

The table below shows the descriptions of the landcover types available in the tool. The table can be used to classify the landcovers present on the site into classes available in the tool. Further information on the robust farm types that are used in Farmscoper and this tool are available in the Farmscoper documentation and online[34].

Table 5-1 Table detailing the landcover types available for use in the tool.

Land use types used in the calculator tool	Description
Cereals	Agricultural areas on which cereals, combinable crops and set aside are farmed.
General	Agricultural areas on which arable crops (including field scale vegetables) are farmed.
Horticulture	Agricultural areas on which fruit (including vineyards), hardy nursery stock, glasshouse flowers and vegetables, market garden scale vegetables, outdoor bulbs and flowers, and mushrooms are farmed.
Indoor Pig farming	Agricultural areas on which pigs farmed indoors.
Outdoor Pig farming	Agricultural areas on which pigs farmed outdoors.
Poultry	Agricultural areas on which poultry are farmed.
Dairy	Agricultural areas on which dairy cows are farmed.
Less Favoured Area (LFA) grazing	Agricultural areas on which cattle, sheep and other grazing livestock are farmed in locations where agricultural production is difficult. An area is classified as an LFA holding if 50 per cent or more of its total area is classed as LFA.
Lowland grazing	Agricultural areas on which cattle, sheep and other grazing livestock are farmed. A holding is classified as lowland if less than 50 per cent of its total area is in the LFA.
Mixed	Agricultural areas in which none of the above categories are farmed or where it is too difficult to select a single category to describe the farm type.
Greenspace	Natural and semi-natural outdoor spaces provided for recreational use where fertilisers will not be applied and dog waste is managed, e.g. semi-natural parks. This does not include green infrastructure within the built urban environment, such as gardens, or grass verges, as these are included in the residential urban land category.
Woodland	Natural and semi-natural outdoor wooded areas.
Shrub	Natural and semi-natural outdoor shrubland area.
Water	Areas of surface water that remain inundated all year round, including rivers, ponds, permanently inundated SuDS features and lakes.
Residential land	Areas of houses and associated infrastructure. This is inclusive of residential roads, driveways, grass verges, gardens and blue-green SuDS infrastructure[35].

[34] To view the specific definitions of the robust farm types, see: Farm Classification in the United Kingdom. Available here: http://farmbusinesssurvey.co.uk/DataBuilder/UK_Farm_Classification_2014_Final.pdf, accessed on: 06/04/2023

[35] Following the precautionary principle blue-green SuDS are incorporated into the Residential land type as they are likely to have similar nutrient inputs as the surrounding residential land.

Land use types used in the calculator tool	Description
Commercial / industrial land	Areas that are used for industry. These are businesses that typically manufacture, process or otherwise generate products. Included in the definition of industrial land are factories and storage facilities as well as mining and shipping operations.
Open land within the built environment	Area of land in urban areas used for various purposes, e.g. main roads, built facilities such as schools, sports centres, areas used for leisure and recreation - this may include open land, e.g. caravan sites, camping sites, sports fields, playgrounds, public squares.
Community food growing	Areas that are used for local food production, such as allotments.

Appendix 2 Table of Wastewater Treatment Works

WwTW name	WwTW name	WwTW name
Abercych WwTW	Cynghordy WwTW	Mathry STW
Abergorlech WwTW	Cynwyl Elfed WwTW	Myddfai WwTW
Adpar WwTW	Danrhelyg STW	Narberth West STW
Alltwalis STW	Drefach/Velindre WwTW	Newchapel STW
Ambleston STW	Farmers STW	Olmarch STW
Bethlehem STW	Felingwm WwTW	Panteg STW
Beulah WwTW	Ffairfach STW	Pencader STW
Boncath STW	Ffostrasol STW	Pentrecwrt STW
Brechfa WwTW	Glanyrafon STW	Pont-Ar-Gothi & Nantgaredig WwTW
Bro Dolau STW	Golden Grove WwTW	Pontrhydfendigaid WwTW
Bro Nant STW	Gorsgoch STW	Pontrhydyceirt STW
Broad Oak WwTW	Gwynfe STW	Pumpsaint STW
Bronant STW	Henllan STW	Puncheston WwTW
Bronwydd STW	Heol Timothy STW	Rhandirmwyn STW
Bryndulais STW	Lampeter STW	Rhoshill STW
Bryngwyn WwTW	Letterston West STW	Rhosygadair Newydd Blaenannerch
Caio STW	Llanddewi Velfrey STW	Rhydlewis STW
Camrose WwTW	Llandewi Brefi WwTW	Rhydowen STW
Capel Dewi STW	Llandovery WwTW	Rnad Trecwm STW
Capel Iwan STW	Llandysul WwTW	Robeston Wathen Housing Act Works
Cardigan WwTW	Llanfair Clydogau WwTW	Rosebush WwTW
Castlemorris WwTW	Llanfihangel-Ar-Arth STW	Salem STW
Cellan WwTW	Llanfynydd STW	Spittal WwTW
Cenarth WwTW	Llangadog STW	Talgarreg WwTW
Cilgerran STW	Llangathen STW	Talley WwTW
Cilycwm WwTW	Llangolman STW	Trapp STW
Clarbeston WwTW	Llangybi STW	Trecwn Valley Haverfordwest
Clynderwen STW	Llanpumpsaint WwTW	Treffgarne STW
Cribyn WwTW	Llansawel WwTW	Tregaron WwTW
Crugybar STW	Llanybydder WwTW	Twynllanan STW
Cwm Ifor WwTW	Llawhaden STW	Verwig STW
Cwmduad STW	Llechryd STW	Walton East STW
Cwrt Henri STW	Llys Y Fran WwTW	Wiston STW
Cwrtnewydd STW	Maenclochog STW	Wolfscastle STW

Appendix 3 Analysis of the Farmscoper modelling results for each LPA and three Catchments in England

The table below shows the outputs of the Farmscoper modelling results for CCC, CeCC and PCC along with the export coefficients for the Tamar MC (MC), the Eden and Esk MC, the Southeast River Basin District (RBD), as well as the results for each LPA against the Tamar MC. Each row of data shows the values and statistics associated with the phosphorus export coefficients for a specific combination of the farm type, rainfall volume and soil drainage. The first column shows the possible combinations of the farm type, rainfall volume and soil drainage type that may be present within the LPAs. The second to seventh columns show the CCC, CeCC, PCC, Southeast RBD, Eden and Esk MC, and the Tamar MC, respectively. The eighth to the tenth columns show the LPA export coefficients as a percentage of the Tamar MC

There is low variation between the English catchments export coefficients for the specific combination of farm type, rainfall volume and soil drainage type for all farm types bar poultry farms. The low sample size of the modelled English Catchments limits the ability to draw statistically significant conclusions about the influence of the physical environment on the modelled P export coefficients. However, the available data suggests that the differences in the physical environment have a low impact in the final export coefficients.

Combination of farm type, rainfall volume and drainage type	CC P export (kg/ha/year)	CeCC TP (kg/ha)	PCC TP (kg/ha)	South East RBD TP export (kg/ha/year)	Eden MC P export (kg/ha/year)	Tamar MC P export (kg/ha/year)	CCC as % of Tamar MC	CeCC as % of Tamar MC	PCC as % of Tamar MC
Cereals700to900FreeDrain		0.09	0.14	0.15	0.16				
Cereals700to900DrainedAr		0.32	0.58	0.73	0.68				
Cereals700to900DrainedArGr		0.61	0.87	1.00	0.99				
Cereals900to1200FreeDrain	0.15	0.16	0.24	0.26	0.28	0.25			
Cereals900to1200DrainedAr	0.51	0.61	1.09	1.37		1.16	59.4	65.0	98.0
Cereals900to1200DrainedArGr	0.90	1.04	1.43	1.63	1.62	1.51	44.1	52.0	93.4
Cereals1200to1500FreeDrain	0.22	0.24	0.36		0.42	0.37	59.5	68.8	94.6
Cereals1200to1500DrainedAr	0.83	0.98	1.77			1.90	59.7	64.9	97.9
Cereals1200to1500DrainedArGr	1.33	1.54	2.07		2.34	2.19	43.8	51.6	93.3
CerealsOver1500FreeDrain	0.39	0.43	0.67	0.71		0.68	60.9	70.2	94.7
CerealsOver1500DrainedAr	1.11	1.30	2.29	2.88		2.46	57.5	62.5	97.8
CerealsOver1500DrainedArGr	2.35	2.72	3.89				45.2	53.1	93.1
General700to900FreeDrain		0.07	0.10	0.11	0.11				
General700to900DrainedAr		0.20	0.33	0.47	0.36				
General700to900DrainedArGr		0.48	0.61	0.73	0.66				
General900to1200FreeDrain	0.13	0.13	0.18	0.20	0.20	0.18			
General900to1200DrainedAr	0.37	0.37	0.62	0.89	0.69	0.68	72.6	72.8	97.3
General900to1200DrainedArGr	0.81	0.86	1.04	1.23	1.13	1.11	55.2	54.4	91.3
General1200to1500FreeDrain	0.20	0.20	0.27		0.30	0.28	72.9	77.0	93.7
General1200to1500DrainedAr	0.62	0.61	1.02			1.11	73.0	72.8	97.3
General1200to1500DrainedArGr	1.23	1.31	1.56		1.69	1.66	55.4	54.5	91.4
GeneralOver1500FreeDrain	0.35	0.34	0.47	0.53	0.53	0.49	74.3	78.7	93.9
GeneralOver1500DrainedAr	0.82	0.80	1.33	1.89	1.48	1.46	71.1	70.1	97.2
GeneralOver1500DrainedArGr	2.12	2.23	2.79	3.37	3.04	2.98	56.1	55.2	91.3
Hortic700to900FreeDrain		0.09	0.10	0.11	0.12		71.1	74.6	93.4
Hortic700to900DrainedAr		0.34	0.39	0.52	0.48				

Combination of farm type, rainfall volume and drainage type	CC P export (kg/ha/year)	CeCC TP (kg/ha)	PCC TP (kg/ha)	South East RBD TP export (kg/ha/year)	Eden MC P export (kg/ha/year)	Tamar MC P export (kg/ha/year)	CCC as % of Tamar MC	CeCC as % of Tamar MC	PCC as % of Tamar MC
Hortic700to900DrainedArGr		0.61	0.64	0.76	0.77				
Hortic900to1200FreeDrain	0.17	0.16	0.18	0.20	0.22	0.20	82.0	79.7	90.4
Hortic900to1200DrainedAr	0.65	0.63	0.73	0.99		0.87	74.9	72.1	84.0
Hortic900to1200DrainedArGr	1.01	1.04	1.06	1.24	1.28	1.22	82.5	84.8	86.7
Hortic1200to1500FreeDrain	0.25	0.25	0.28		0.34	0.31	82.2	79.7	90.5
Hortic1200to1500DrainedAr	1.07	1.03	1.20			1.43	74.8	71.9	84.0
Hortic1200to1500DrainedArGr	1.49	1.54	1.56			1.80	83.0	85.7	86.9
HorticOver1500FreeDrain	0.46	0.44	0.51			0.56	81.4	77.9	90.5
HorticOver1500DrainedAr	1.40	1.34	1.57		1.91	1.86	74.8	72.0	84.1
HorticOver1500DrainedArGr	2.71	2.76	2.88						
InPig700to900FreeDrain		0.15	0.17	0.16					
InPig700to900DrainedAr		0.74	0.74	0.66	0.62				
InPig700to900DrainedArGr		1.03	1.03	1.12	1.19				
InPig900to1200FreeDrain	0.28	0.26	0.29	0.26	0.31	0.27	103.7	97.6	108.0
InPig900to1200DrainedAr	1.37	1.36	1.37	1.20					
InPig900to1200DrainedArGr	1.64	1.64	1.64	1.74	1.82				
InPig1200to1500FreeDrain	0.42	0.40	0.44			0.38	109.8	103.7	114.3
InPig1200to1500DrainedAr	2.22	2.21	2.22			1.53	145.1	144.6	145.3
InPig1200to1500DrainedArGr	2.35	2.35	2.36		2.55	2.56	92.1	91.7	92.1
InPigOver1500FreeDrain	0.77	0.73	0.81			0.66	116.6	109.9	121.6
InPigOver1500DrainedAr	2.87	2.85	2.87						
InPigOver1500DrainedArGr	4.50	4.48	4.50		4.34				
Poultry700to900FreeDrain		0.17	0.15	0.16	0.29				
Poultry700to900DrainedAr		0.72	0.38	0.51	0.53				
Poultry700to900DrainedArGr		1.07	0.84	0.92	1.49				
Poultry900to1200FreeDrain	0.28	0.28	0.24	0.26	0.42	0.24	120.4	120.7	101.8
Poultry900to1200DrainedAr	1.15	1.30	0.66	0.92	0.88	0.61	190.5	214.8	109.7
Poultry900to1200DrainedArGr	1.60	1.69	1.35	1.50	2.26	1.42	113.2	119.1	95.3
Poultry1200to1500FreeDrain	0.40	0.41	0.33		0.53	0.32	125.9	127.1	102.9
Poultry1200to1500DrainedAr	1.83	2.07	1.04			0.95	191.7	216.9	109.4
Poultry1200to1500DrainedArGr	2.28	2.40	1.94		3.10	2.03	112.3	117.9	95.4
PoultryOver1500FreeDrain	0.73	0.74	0.57			0.54	134.1	136.6	104.5
PoultryOver1500DrainedAr	2.38	2.68	1.37						
PoultryOver1500DrainedArGr	4.12	4.41	3.22		4.72				
Dairy700to900FreeDrain		0.14	0.21	0.18	0.20				
Dairy700to900DrainedAr		0.18	0.33	0.39	0.29				
Dairy700to900DrainedArGr		1.03	1.46	1.36	1.29				
Dairy900to1200FreeDrain	0.22	0.20	0.30	0.27	0.28	0.27	80.9	73.1	110.1
Dairy900to1200DrainedAr	0.30	0.27	0.53	0.68	0.46	0.49	61.4	55.1	108.3
Dairy900to1200DrainedArGr	1.73	1.62	2.21	2.08	1.99	2.10	82.3	77.2	105.3
Dairy1200to1500FreeDrain	0.29	0.26	0.39		0.37	0.35	81.1	74.2	109.2

Combination of farm type, rainfall volume and drainage type	CC P export (kg/ha/year)	CeCC TP (kg/ha)	PCC TP (kg/ha)	South East RBD TP export (kg/ha/year)	Eden MC P export (kg/ha/year)	Tamar MC P export (kg/ha/year)	CCC as % of Tamar MC	CeCC as % of Tamar MC	PCC as % of Tamar MC
Dairy1200to1500DrainedAr	0.46	0.41	0.81			0.75	60.5	54.6	107.6
Dairy1200to1500DrainedArGr	2.41	2.28	3.03		2.75	2.89	83.3	78.7	104.7
DairyOver1500FreeDrain	0.42	0.39	0.58		0.54	0.53	79.8	73.4	108.5
DairyOver1500DrainedAr	0.57	0.52	1.02			0.95	59.5	54.2	107.1
DairyOver1500DrainedArGr	3.44	3.27	4.38	4.37	3.97				
LFA700to900FreeDrain		0.08	0.10		0.10				
LFA700to900DrainedAr		0.09	0.11		0.11				
LFA700to900DrainedArGr		0.49	0.57		0.53				
LFA900to1200FreeDrain	0.15	0.13	0.16		0.16	0.16	89.8	81.5	95.7
LFA900to1200DrainedAr	0.17	0.15	0.18		0.17	0.19	90.3	78.2	94.0
LFA900to1200DrainedArGr	0.98	0.82	0.96		0.89	1.09	89.3	75.1	88.2
LFA1200to1500FreeDrain	0.21	0.19	0.22		0.22	0.23	91.5	84.2	96.9
LFA1200to1500DrainedAr	0.27	0.24	0.28			0.30	91.9	80.7	95.1
LFA1200to1500DrainedArGr	1.44	1.20	1.43		1.32	1.60	89.8	75.1	88.9
LFAOver1500FreeDrain	0.32	0.30	0.34		0.35	0.35	93.0	87.1	98.1
LFAOver1500DrainedAr	0.36	0.32	0.37		0.37	0.39	93.0	83.1	96.1
LFAOver1500DrainedArGr	2.15	1.79	2.13		1.97	2.37	90.6	75.4	89.6
Lowland700to900FreeDrain		0.11	0.13	0.10	0.13				
Lowland700to900DrainedAr		0.16	0.18	0.17	0.18				
Lowland700to900DrainedArGr		0.74	0.77	0.67	0.76				
Lowland900to1200FreeDrain	0.18	0.16	0.19	0.16	0.20	0.20	87.9	82.7	95.8
Lowland900to1200DrainedAr	0.30	0.26	0.30	0.30	0.30	0.32	91.7	82.2	93.0
Lowland900to1200DrainedArGr	1.22	1.22	1.27	1.12	1.25	1.39	88.0	87.8	91.4
Lowland1200to1500FreeDrain	0.24	0.23	0.26		0.27	0.27	89.7	84.7	96.6
Lowland1200to1500DrainedAr	0.46	0.42	0.47			0.50	92.9	83.4	93.4
Lowland1200to1500DrainedArGr	1.77	1.76	1.84		1.82	2.00	88.7	88.1	92.0
LowlandOver1500FreeDrain	0.38	0.36	0.41	0.36	0.42	0.42	91.2	86.0	97.3
LowlandOver1500DrainedAr	0.61	0.55	0.61	0.64	0.61	0.65	93.8	84.3	93.8
LowlandOver1500DrainedArGr	2.69	2.64	2.77		2.73				
Mixed700to900FreeDrain		0.11	0.15	0.14	0.15				
Mixed700to900DrainedAr		0.21	0.38	0.53	0.42				
Mixed700to900DrainedArGr		0.81	0.93	0.95	0.99				
Mixed900to1200FreeDrain	0.18	0.17	0.23	0.23	0.25	0.24	75.6	70.9	98.3
Mixed900to1200DrainedAr	0.38	0.36	0.68	0.99	0.77	0.74	51.3	49.0	92.0
Mixed900to1200DrainedArGr	1.31	1.32	1.52	1.56	1.60	1.66	79.1	79.5	91.9
Mixed1200to1500FreeDrain	0.25	0.24	0.33		0.36	0.34	74.6	70.7	98.2
Mixed1200to1500DrainedAr	0.60	0.58	1.09			1.19	50.7	48.8	91.9
Mixed1200to1500DrainedArGr	1.89	1.89	2.19		2.29	2.36	79.7	80.1	92.4
MixedOver1500FreeDrain	0.40	0.38	0.56		0.62	0.57	70.8	67.5	97.8
MixedOver1500DrainedAr	0.79	0.76	1.43			1.56	50.5	48.8	91.9
MixedOver1500DrainedArGr	2.91	2.92	3.59		3.81				

Combination of farm type, rainfall volume and drainage type	CC P export (kg/ha/year)	CeCC TP (kg/ha)	PCC TP (kg/ha)	South East RBD TP export (kg/ha/year)	Eden MC P export (kg/ha/year)	Tamar MC P export (kg/ha/year)	CCC as % of Tamar MC	CeCC as % of Tamar MC	PCC as % of Tamar MC
OutPig700to900FreeDrain		0.20	0.20	0.23	0.24				
OutPig700to900DrainedAr		1.19	0.98	1.56	1.41				
OutPig700to900DrainedArGr		1.61	1.29	2.19	1.96				
OutPig900to1200FreeDrain	0.37	0.35	0.36	0.39	0.42				
OutPig900to1200DrainedAr	2.13	2.13	1.85	2.61					
OutPig900to1200DrainedArGr	2.45	2.45	2.08	3.12	2.83				
OutPig1200to1500FreeDrain	0.55	0.52	0.53			0.62	88.2	82.9	85.3
OutPig1200to1500DrainedAr	3.39	3.36	3.02						
OutPig1200to1500DrainedArGr	3.40	3.40	2.97		3.82				
OutPigOver1500FreeDrain	1.03	0.96	1.00			1.14	90.3	84.3	87.3
OutPigOver1500DrainedAr	4.27	4.24	3.86						
OutPigOver1500DrainedArGr	6.42	6.36	5.78		6.81	6.81			

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