ADVICE ON ACHIEVING NUTRIENT NEUTRALITY FOR NEW DEVELOPMENT IN THE SOLENT REGION

SECTION 1 INTRODUCTION

1.1 The water environment within the Solent region is one of the most important for wildlife in the United Kingdom. It is internationally important for its wildlife and is protected under the Water Environment Regulations[i] and the Conservation of Habitats and Species Regulations[ii] as well as national protection for many parts of the coastline and their sea.[iii] There are high levels of nitrogen and phosphorus input to this water environment with sound evidence that these nutrients are causing eutrophication at these designated sites. These nutrient inputs currently mostly come either from agricultural sources or from wastewater from existing housing and other development. The resulting dense mats of green algae and other effects on the marine ecology from an excessive presence of nutrients are impacting on the Solent's protected habitats and bird species.

1.2 There is uncertainty as to whether new growth will further deteriorate designated sites. This issue has been subject to detailed work commissioned by local planning authorities (LPAs) in association with Natural England, Environment Agency and water companies. This strategic work, which updates early studies, is on-going. Until this work is complete, the uncertainty remains and the potential for future housing developments across the Solent region to exacerbate these impacts creates a risk to their potential future conservation status.

1.3 One way to address this uncertainty is for new development to achieve nutrient neutrality. Nutrient neutrality is a means of ensuring that development does not add to existing nutrient burdens and this provides certainty that the whole of the scheme is deliverable in line with the requirements of the Conservation of Habitats and Species Regulations 2017 (as amended).

1.4 This report sets out a practical methodology to calculating how nutrient neutrality can be achieved. This methodology is based on best available scientific knowledge, and will be subject to revision as further evidence is obtained. It is our advice to local planning authorities to take a precautionary approach in line with existing legislation and case-law when addressing uncertainty and calculating nutrient budgets.

1.5 This report includes a brief summary of the planning and environmental context for this nutrient neutral approach, the detailed methodology and advice on mitigation. Further information and guidance is included in the annexes.

SECTION 2 PLANNING CONTEXT

2.1 The Partnership for Urban South Hampshire (PUSH), Natural England (NE), and Environment Agency (EA) have been jointly working to develop an Integrated Water Management Strategy (IWMS) since before 2008. This work examines the potential for the PUSH region to accommodate future housing growth without having a detrimental effect upon the water environment. A Water Quality Working Group has been set up to identify and analyse the existing evidence gaps and evaluate the need for strategic mitigation measures. A Water Quality Group including Natural England, Environment Agency and Chichester District Council have been working to identify solutions to water quality concerns in Chichester Harbour for at least 10 years. However, there is currently uncertainty as to whether there is sufficient capacity to accommodate the new housing growth.

2.2 Since March 2018, Natural England has been advising that one means of addressing this uncertainty for larger development (in excess of 200-300 houses), including all EIA development, is to calculate a nutrient budget and achieve nutrient neutrality.

2.3 During the summer of 2018, a review of the condition of designated sites water environment in the Solent harbours was undertaken (see next section). The best available up-to-date evidence has identified that some interest features at the designated sites, such as intertidal mudflat habitat and the wildlife they support are widely in unfavourable condition due to existing levels of nutrients and are therefore at risk from additional nutrient inputs.

2.4 It is Natural England’s view that there is a likely significant effect on several internationally designated sites (Special Protection Areas, Special Areas of Conservation and Ramsar sites) due to the increase in wastewater from the new developments coming forward.

2.5 The uncertainty about the impact of new development on designated sites needs to be recognised for all development proposals that are subject to new planning permissions and have inevitable wastewater implications. These implications, and all other matters capable of having a significant effect on designated sites in the Solent, must be addressed in line with Regulation 63 of the Conservation of Habitats and Species Regulations 2017.

2.6 LPAs and applicants will be aware of CJEU decisions regarding the assessment of elements of a proposal aimed toward mitigating adverse effects on designated sites and the need for certainty that mitigating measures will achieve their aims. The achievement of nutrient neutrality, if scientifically and practically effective, is a means of ensuring that development does not add to existing nutrient burdens.

2.7 The Water Quality Working Groups draw together expertise from local planning authorities, Environment Agency, Natural England and the water companies to examine this uncertainty further and develop an approach that ensures that development can progress in a timely manner whilst ensuring the requirements of the Habitats Regulations are met. Further information is included in Annex 1.

SECTION 3 ENVIRONMENTAL CONTEXT

3.1 In 2018 and 2019 Natural England undertook a number of condition assessments of the features of the designated international sites around the Solent (the Solent Maritime SAC, Chichester and Langstone Harbours SPA, Portsmouth Harbour SPA, Solent and Southampton Water SPA) as well as the nationally designated SSSIs that underpin these international designations. An account of the outcome of these assessments, together the evidence used to support the conclusions, is given in Annex 2 with a brief summary below. Annex 2 also includes information on the Solent and Dorset Coast SPA and the Solent and Isle of Wight Lagoons SAC.

Solent Maritime SAC

3.2 For the Solent Maritime SAC the condition assessments completed considered the SAC features across the site as a whole and found the condition of these features - estuary, mudflat & sandflats, sandbanks – to be unfavourable. The unfavourable assessment is based on a number of attributes failing, including the nutrient water quality attribute. Other attributes were also found to be failing, such as, for seagrasses, their extent, distribution, rhizome structure and reproduction as well as biomass, and for the intertidal mud and sand features their infaunal quality. These failures are considered to be in part due to impacts from elevated nutrients.

3.3 Currently the site condition assessment does not include the saltmarsh feature which has not yet been assessed. However preliminary analysis of data shows that there was a loss of extent of saltmarsh across the Solent between 2008 and 2016.

Special Protection Areas and Ramsar sites (Solent and Southampton Water, Portsmouth Harbour and Chichester and Langstone Harbours)

3.4 Condition assessment for the SPAs and Ramsar sites have yet to be undertaken, but a number of bird features are declining as highlighted by recent Wetland Bird Survey alerts. A comparison with regional and national trends indicates that several of the declines are likely to be due to site specific reasons rather than reflecting wider national or regional population trends. While the cause of these site specific declines in the Solent area are largely unknown there are possible links to the elevated nutrient loading.

Sites of Special Scientific Interest (SSSI)

3.5 During 2018 and 2019, Natural England revised and updated the SSSI assessments in the greater Solent area in relation to the influence of the water environment on the condition of estuarine SSSI interest features that underpin the SAC and SPAs. These assessments especially included littoral sediment habitat (mudflat and other tidally exposed sediment flats). The review of parts of the greater Solent area and some SSSI interest features is ongoing.

3.6 The SSSI interest feature assessments completed consider the concentrations of inorganic nitrogen status in each harbour and estuary, and evidence for ecological responses. Particular attention was given to records on phytoplankton abundance and the presence and abundance of opportunistic green macroalgae.

3.7 These SSSI assessments give a spatially more specific account of the condition of protected sites and details are given in Annex 2 with condition varying across different parts of the Solent. Overall some 81% of the total area assessed is in unfavourable condition. Breaking down this unfavourable area, 40% if it is classed as recovering condition, most of this being in Langstone Harbour but these units are considered 'at risk' of not recovering to a favourable situation as it is unclear whether the nutrient status will become adequate to substantially prevent the growth of dense macroalgae mats in parts of the Harbour.

3.8 In 2019 and 2020, a more detailed review of Chichester Harbour's intertidal features was undertaken of all the overlapping national and internationally designated features including saltmarsh, wintering and nesting birds. More than 3000 hectares of the harbour is in unfavourable declining condition. Reasons for feature declines are complex with many factors acting together, but water quality is one of the contributing causes to the observed declines.

SECTION 4 NUTRIENT NEUTRALITY APPROACH FOR NEW DEVELOPMENT

Introduction

4.1 Achieving nutrient neutrality is one way to address the existing uncertainty surrounding the impact of new development on designated sites. This practical methodology provides advice on how to calculate nutrient budgets and options for mitigation, should this be necessary.

4.2 There is evidence that inputs of both phosphorus and nitrogen influence eutrophication of the water environment. However, the principal nutrient that tends to drive eutrophication in the marine environment is nitrogen and this is supported by modelling and evidence. Please see Annex 2 for further details.

4.3 The best available evidence is for focus in the Solent harbours to be on nitrogen reduction, and reduction in both nitrogen and phosphorus in the Medina catchment. However, this approach may be refined if greater understanding of the eutrophication issue is gained by thorough new research or updated modelling.

4.4 The nutrient budget in this report calculates quantities of nitrogen (N) generated by development. This N comes in different forms and measured N concentrations vary according to exactly what is measured. These differences need to be recognised when calculating nutrient budgets. The key measurement is Total Nitrogen (TN), i.e. both organic and inorganic forms of nitrogen, because this is what is available for plant growth. TN is the sum of the inorganic forms - nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammoniacal - N - and organically bonded nitrogen.

4.5 For developments on the Isle of Wight that are impacting on the Medina estuary, both a phosphorus and nitrogen budget may be required. Natural England will work closely with the Isle of Wight Council and applicants to provide advice on a bespoke case-by-case basis.

Approach to calculating nutrient budgets

4.6 For those developments that wish to pursue neutrality, Natural England advises that a nitrogen budget is calculated for new developments that have the potential to result in increases of nitrogen entering the international sites. A nutrient budget calculated according to this methodology and demonstrating nutrient neutrality is, in our view, able to provide sufficient and reasonable certainty that the development does not adversely affect the integrity, by means of impacts from nutrients, on the relevant internationally designated sites. This approach must be tested through the 'appropriate assessment' stage of the Habitats Regulations Assessment. The information provided by the applicant on the nutrient budget and any mitigation proposed will be used by the local planning authority, as competent authority, to make an appropriate assessment of the implications of the plan or project on the designated sites in question. Further information of this process is available here.

4.7 The nutrient neutrality calculation includes key inputs and assumptions that are based on the best-available scientific evidence and research. It has been developed as a pragmatic tool. However, for each input there is a degree of uncertainty. For example, there is uncertainty associated with predicting occupancy levels and water use for each household in perpetuity. Also, identifying current land / farm types and the associated nutrient inputs is based on best-available evidence, research and professional judgement and is again subject to a degree of uncertainty.

4.8 It is our advice to local planning authorities to take a precautionary approach in line with existing legislation and case-law when addressing uncertainty and calculating nutrient budgets. This should be achieved by ensuring nutrient budget calculations apply precautionary rates to variables and adding a precautionary buffer to the TN calculated for developments. A precautionary approach to the calculations and solutions helps the local planning authority and applicants to demonstrate the certainty needed for their assessments.

4.9 By applying the nutrient neutrality methodology, with the precautionary buffer, to new development, the competent authority may be satisfied that, while margins of error will inevitably vary for each development, this approach will ensure that new development in combination will avoid significant increases of nitrogen load to enter the internationally designated sites.

Location of development

4.10 The nutrient neutrality approach only applies to developments where the treated effluent discharges into any Solent international sites (Solent Maritime SAC, Solent and Southampton Water SPA and Ramsar, Portsmouth Harbour SPA and Ramsar, Chichester and Langstone Harbours SPA and Ramsar), or any water body (surface or groundwater) that subsequently discharges into such a site. The catchment area is shown on Figure 1.

4.11 This approach may be refined if greater understanding of the eutrophication issue is gained by thorough new research or updated modelling.

Type of development

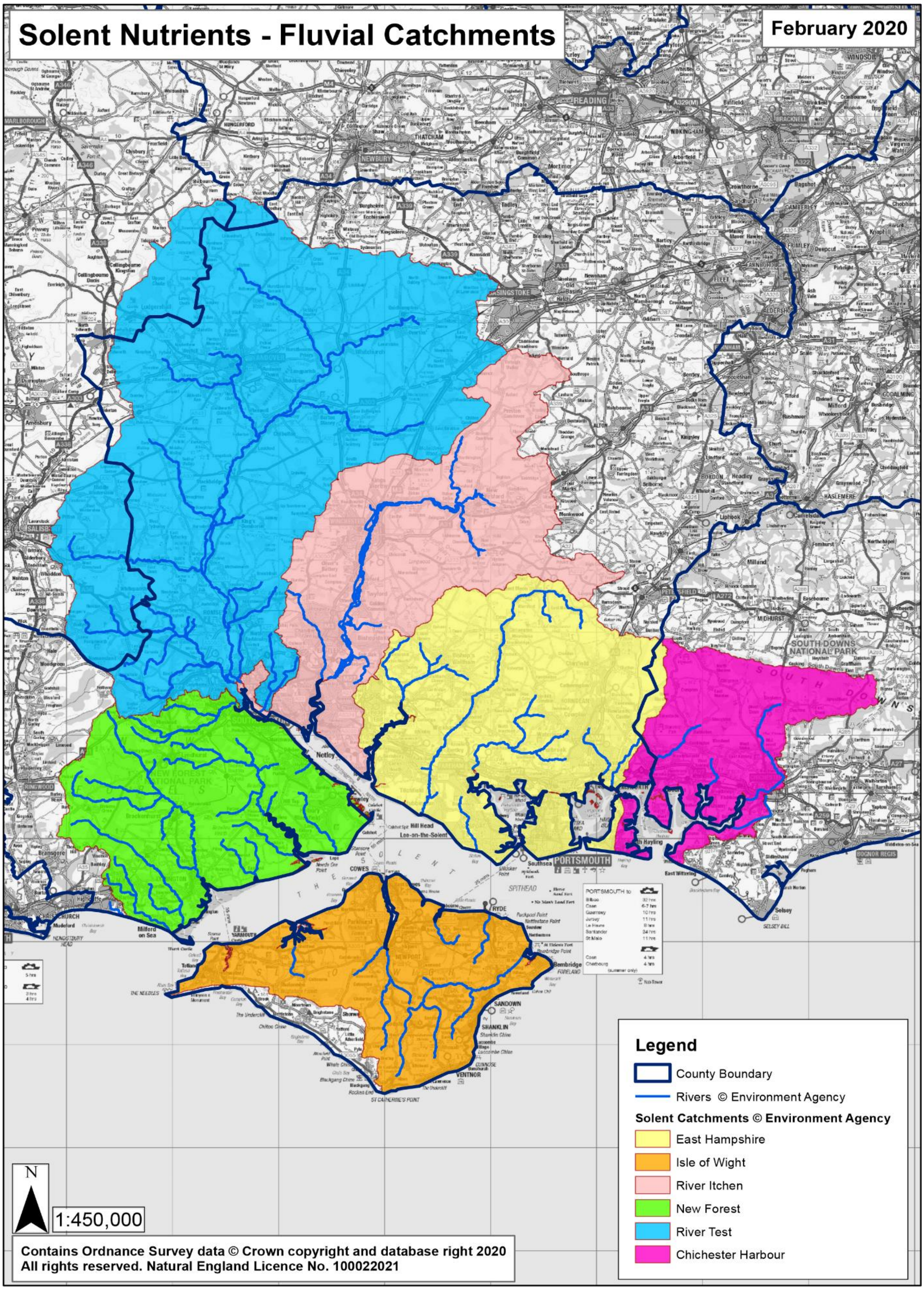
4.12 This methodology is for all types of development that would result in a net increase in population served by a wastewater system, including new homes, student accommodation, tourism attractions and tourist accommodation. This development will have inevitable wastewater implications.

4.13 Other commercial development not involving overnight accommodation will generally not be included. It is assumed that anyone living in the catchment also works and uses facilities in the catchment, and therefore wastewater generated by that person can be calculated using the population increase from new homes and other accommodation. This removes the potential for double counting of human wastewater arising from different planning uses.

4.14 Tourism attractions and tourism accommodation are exceptions, as these land uses attract people into the catchment and generate additional wastewater and consequential nitrogen loading on the Solent. This includes self-service and serviced tourist accommodation such as hotels, guest houses, bed and breakfasts and self-catering holiday chalets and static caravan sites. Other applications will be considered on their individual merits, for example new cruise ship facilities etc.

4.15 There may be cases where planning applications for new commercial or industrial development or changes in agricultural practices could result in the release of additional nitrogen into the system. In these situations, a case-by-case approach will be adopted. Early discussions with Natural England via our chargeable services (DAS) are recommended.

Figure 1 Solent Catchment Area *Contains public sector information licensed under the Open Government Licence v3.0*



Methodology for nutrient budgets

4.16 The initial stage is to determine whether the development will drain to the mains network or to a non-mains facility e.g. an on-site package treatment plants.

4.17 The methodology for development that drains to the mains network is in Section A. Please go to Section B if the new development is not on the mains network.

<u>Section A</u>

Stage 1 Calculate Total Nitrogen (TN) in kilograms per annum derived from the development that would exit the Wastewater Treatment Works (WwTW) after treatment

Stage1 *Step 1 Calculate additional population*

4.18 New housing and overnight accommodation can increase the population as well as the housing stock within the catchment. This can cause an increase in nitrogen discharges. To determine the additional population that could arise from the proposed development, it is necessary that sufficiently evidenced occupancy rates are used. Natural England recommends that, as a starting point, local planning authorities should consider using the average national occupancy rate of 2.4, as calculated by the Office for National Statistics (ONS), as this can be consistently applied across all affected areas.

4.19 However competent authorities may choose to adopt bespoke calculations tailored to the area or scheme, rather than using national population or occupancy assumptions, where they are satisfied that there is sufficient evidence to support this approach. Conclusions that inform the use of a bespoke calculation need to be capable of removing all reasonable scientific doubt as to the effect of the proposed development on the international sites concerned, based on complete, precise and definitive findings. The competent authority will need to explain clearly why the approach taken is considered to be appropriate. Calculations for occupancy rates will need to be consistent with others used in relation to the scheme (e.g. for calculating open space requirements), unless there is a clear justification for them to differ.

Stage 1 *Step 2 Confirm water use*

4.20 Determine the water use / efficiency standard for the proposed development to be defined in the planning application and, where relevant, the Environmental Statement. The nitrogen load is calculated from the scale of water use and thus the highest water efficiency standards under the building regulations will minimise the increase in nitrogen from the development.

4.21 It is recommended that each Local Planning Authority impose a planning condition on all planning permissions for one or more net additional new dwellings requiring construction to the optional requirement[iv] under G2 of the Building Regulations 2010.

4.22 A model condition is set out below:

"*The dwellings shall not be occupied until the Building Regulations Optional requirement of a maximum water use of 110 litres per person per day has been complied with."*

4.23 The water use figure is a proxy for the amount of wastewater that is generated by a household. New residential development may be able to achieve tighter water use figures, with or without grey water recycling systems, and this approach is supported from a water resource perspective (for example in support of Southern Water's Target 100 litres per person per day). However, the key measurement is the amount of wastewater generated by the development that flows to the wastewater treatment works.

4.24 If tighter water use restrictions are used in the nutrient calculation – with or without grey water recycling systems – these restrictions should reflect the wastewater expected to be generated over the lifetime of the development. There is a risk that when kitchen and bathroom fittings are changed by occupants over the years, less water-efficient models could be installed. It is Natural England's view that it would be difficult to evidence and secure delivery of tighter restrictions at this time. However, if sound evidence can be provided, this will be considered on a case-by-case basis.

4.25 It is Natural England's view that while new developments should be required to meet the 100 litres per person a day standard, the risk of standards slipping over time and the uncertainty inherent in the relationship between water use and sewage volume should be addressed by the use in the calculation of 110 litres per person per day figure.

Stage 1 *Step 3 Confirm WwTW and permit level*

4.26 Identify the Wastewater treatment works (WwTW) that the development will drain to and whether it has a TN permit.

4.27 For most planning applications, the WwTW provider is not confirmed until after planning permission is granted. The nutrient calculation should be based on the permit levels of the most likely WwTW. In any cases where the WwTW changes, a reassessment of the nutrient calculation will be required to ensure the development is nutrient neutral.

WwTWs with TN permit

4.28 Identify the permit concentration limit for Total Nitrogen at the proposed WwTW. If the WwTW will have a tightened permit concentration limit for Total Nitrogen under the company's Water Industry Asset Management Plan by 2024 then use this tightened value. If a new WwTW is proposed, obtain a determination from the

Environment Agency on the permit limit for Total Nitrogen that would apply to the works and when they are likely to be built.

4.29 Where there is a permit limit for Total Nitrogen, the load calculation will use a worst case scenario that the WwTW operates at 90% of its permitted limit. A water company has the option of operating the works as close to the consent limit as practicable without breaching the consent limit. Natural England and the Environment Agency have agreed to take 90% of the consent concentration limit as the closest the water company can reasonably operate the works without risk of breaching the consent limit.

WwTWs without a TN permit

4.30 For developments that discharge to WwTWs with no TN permit limit, best available evidence must be used for the calculation. In the first instance, Southern Water or other wastewater provider should be contacted for details of the nitrogen effluent levels for the specific WwTW. Robust evidence may be available to derive a value for nitrogen in the wastewater stream based on the type of wastewater treatment at the works.

4.31 However, if this data is not available, a figure of 27mg/l can be used. This figure has been derived by Southern Water from nitrogen effluent concentrations at two WwTWs in the Solent area and this average figure may change if new evidence becomes available.

4.32 It is not possible to apply the 90% correction in these cases as these WwTWs are not regulated by a Total Nitrogen consent limit.

Relationship between TN and water use

4.33 For WwTWs with TN consents there is a direct relationship between TN and water use. For example, for WwTWs with a permit of 9 mg /l, it can be calculated that for each litre of water that passes through the works, 8.1mg (90% of 9 mg/l) of nitrogen could be released into the water environment. If a household uses 150 litres, this equates to 1215 mg of TN; if this is reduced to 100 litres, 810 mg of TN is released.

4.34 For WwTWs without a TN consent level, the relationship between water use and TN in the effluent is more complex, but applying the same methodology for nutrient neutrality is considered appropriate.

4.35 For these WwTWs, there is no guarantee that reductions in water use will lower TN discharges. These WwTWs are not regulated by the concentration of TN in each litre of effluent. Instead, the TN concentration could vary depending on the flow volume and concentration of TN coming into the WwTW. Growth in area will lead to more people which will increase the amount of nitrogen reaching a WwTWs and this could then change TN levels in the effluent. However, there is currently no clear correlation between the TN concentration of the WwTW discharge and size of population served. It is therefore not considered necessary to correct for this factor. The processes at WwTWs and how nitrogen changes its form during treatment are complex, especially the interaction between different levels of nitrogen and carbon in the wastewater. Any error due to marginal increases in TN concentration with increases in population served by a particular WwTW will be covered by the precautionary 20% buffer.

4.36 Please note that due to this uncertainty the use of measures designed to reduce water consumption as a means of reducing TN are not appropriate in areas served by WwTWs without an N permit. This is likely to affect authorities with WwTWs that drain into rivers, as many of these WwTWs do not have TN permit limits currently.

Stage 1 *Step 4 Calculate Total Nitrogen (TN) in Kg per annum that would exit the WwTW after treatment derived from the proposed development*

4.37 The TN load is calculated by multiplying the water use of the proposed development by the appropriate concentration of TN after treatment at the WwTW.

4.38 An element of the TN within the wastewater coming from a household is from the drinking water supplied to that household. However, this forms a relatively small proportion (<10%) of this total. This has been calculated by using a nitrate-N concentration in drinking water of 8mg/l and a TN generated per person of 3.5kg/yr.

4.39 Moreover, in order for favourable condition for the Solent sites to be achieved it is necessary for there to be substantial reductions in ground and river water nitrogen concentrations. Since drinking water comes from these same sources these reductions will in turn affect TN concentrations in drinking water. It is therefore not appropriate to calculate TN budgets over the lifetime of the development based on the current elevated TN levels in drinking water. To do so would lock in a higher TN discharge from development that would offset the required improvements in TN levels in drinking water from changes in agricultural practice over time.

4.40 Notwithstanding the above, it is our advice that it is appropriate to discount an amount of N that would be present in groundwater and river water if they were in a more natural condition. Peer review research indicates that the mean natural river concentration would have been below 0.45 mg/l nitrate-nitrogen[v]. Evidence also suggests that a nitrate concentration in rivers of c2 mg/l equates to the average concentrations in rivers before the 1960s, prior to the dramatic increase in N concentrations during the subsequent decades[vi]. This nitrate concentrations corresponds well with emerging evidence from the Poole Harbour catchment where it is considered that restoration to a favourable conservation status would require a nitrogen load below 1000 tonnes of TN per year landward input. To achieve this, average TN levels in river water in the Poole Harbour catchment would need to be <c2.75 mg/l TN.

4.41 The total annual nitrogen load reductions necessary to achieve a favourable conservation status for the international sites within the greater Solent area have yet to be determined. However, for the purpose of the methodology, a river and groundwater TN concentration of 2 mg/l is considered at this stage to be likely to meet the restoration objectives for the Solent international sites. We therefore recommend that a discounted figure of 2 mg/l is used to reflect the amount of N that would otherwise be present in river and groundwater.

4.42 Natural reductions in nitrogen concentrations, mainly through de-nitrification processes, also occur within watercourses. The scale of de-nitrification is complex and dependent on a number of variables, including the characteristics of the water channels, season, water flows, N concentrations, and uptake by plant communities, etc. Insufficient evidence is currently available to properly evaluate de-nitrification rates within the greater Solent catchments and therefore this factor has not been included within the current methodology. Nevertheless natural de-nitrification processes, particularly for discharges in the upper Solent catchment, provide an additional precautionary factor for the methodology.

Worked example of a nutrient budget calculation for discharge to a WwTW using methodology.

4.43 The following worked example calculates the Total Nitrogen load of a development of 1000 dwellings based on a WwTW with a consent limit for Total Nitrogen of 9 mg/l.

4.44 Where residential developments also include other overnight accommodation such as tourist accommodation and attractions, the associated water use from these additional land uses will need to be included in the calculation. These rates should be based on empirical evidence from similar developments or published literature and will be assessed on a case by case basis.

Table 1 – Calculating wastewater Total Nitrogen load from proposed development

STAGE 1 - WORKED EXAMPLE TO CALCULATE TOTAL NITROGEN (TN) LOAD FROM DEVELOPMENT WASTEWATER				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
Development proposal	Development types that would increase the population served by a wastewater system	1000	Residential dwellings	
Step 1	Additional population	2400	Persons	Uses an average household size of 2.4 x 1000 dwgs (greenfield site).
Step 2	Wastewater volume generated by development	264,000	litres/day	2400 persons (step 1) x 110 litres. Where relevant, deduct wastewater volume of population displaced by the proposed development.
Step 3	Receiving WwTW environmental TN permit limit. Assume discharge to be at 90% of consent limit.	8.1	mg/l TN	90% of the consent limit = 8.1 mg/l TN.
Step 4	Deduct acceptable TN loading (@ 2 mg/l TN) (as defined in paragraph 4.40)	6.1	mg/l TN	8.1 (step 3) – 2 mg/l TN
Step 5	TN discharged after WwTW treatment	1,610,400	mg/TN/day	264000 (step 2) x 6.1 (step 4) =1,610,400
Step 6	Convert mg/TN to kg/TN per day	1.6104	Kg/TN/day	Divide by 1,000,000
Step 7	Convert kg/TN per day to kg/TN per year	587.8	Kg/TN/yr	1.6104 x 365 days
Wastewater total nitrogen load	**587.8 kg/TN/yr**			

Stage 2 Adjust nitrogen load to account for existing nitrogen from current land use

4.45 This next stage is to calculate the existing nitrogen losses from the current land use within the redline boundary of the scheme. The nitrogen loss from the current land use will be removed and replaced by that from the proposed development land use. The net change in land use will need to be subtracted from or added to the wastewater Total Nitrogen load.

4.46 Nitrogen–nitrate loss from agricultural land can be modelled using the Farmscoper model. A study commissioned by Natural England from ADAS modelled this loss for different farm types across the river catchments that drain to the Solent (ADAS UK Ltd. 2015. Solent Harbours Nitrogen Management Investigation).

4.47 If the development area covers agricultural land that clearly falls within a particular farm type used by the Farmscoper model then the modelled average nitrate-nitrogen loss from this farm type should be used. The farm types used in the ADAS model are set out in Table 2, with the nitrate-nitrogen loss. Further details on farm classification are included in Appendix 1.

Table 2 Farm types and average nitrogen-nitrate loss

AVERAGE NITRATE-NITROGEN LOSS PER FARM TYPE IN THE SOLENT CATCHMENT AREA (kg/ha)	
Cereals	31.2
Dairy	36.2
General Cropping	25.4
Horticulture	29.2
Pig	70.4
Lowland Grazing	13.0
Mixed	28.3
Poultry	70.7
Average for catchment area	**26.9**

4.48 If the proposed development area covers several or indeterminate farm types then the average nitrate-nitrogen loss across all farmland may be more appropriate to use. The average figure is also included in Table 2.

4.49 The figures in the ADAS report are based on 2010 land use data and may be updated from time-to-time as land use and agricultural practice to control nitrate loss changes.

4.50 For maize farms, it is recommended that the general cropping nitrogen leaching rate is used in the calculation. For sites that are in use as allotments, it is recommended that the most appropriate farm type for allotments is the average rate of 26.9 kg/ha/yr. For sites that are currently in use as horse paddocks, it is recommended that the lowland grazing figure should be used in the calculation.

4.51 It is important that farm type classification is appropriately precautionary. It is recommended that evidence is provided of the farm type for the last 10 years and professional judgement is used as to what the land would revert to in the absence of a planning application. In many cases, the local planning authority, as competent authority, will have appropriate knowledge of existing land uses to help inform this process.

4.52 There may be areas of a greenfield development site that are not currently in agricultural use and have not been used as such for the last 10 years. In these areas as there is no agricultural input into the land a baseline nitrogen leaching value of 5 kg/ha should be used. This figure covers nitrogen loading from atmospheric deposition, pet waste and nitrogen fixing legumes.

4.53 Where development sites include wildlife areas, woodlands, hedgerows, ponds and lakes that are to be retained, these areas can either be excluded from the calculation as there will be no change in nitrogen input onto this land, or included with the same nitrogen leaching rate in stage 2 and 3. This approach assumes that if they are adopted as green infrastructure or a wildlife area in the new development, appropriate management can be secured with any planning permission (see next section) to restrict nitrogen loading.

4.54 A similar approach can also be taken for the redevelopment of urban land as the nitrogen leaching rate would be 14.3 kg/ha in stage 2 and 14.3 kg/ha in stage 3. If there is no change in site area, these areas can be excluded from the calculation.

4.55 For sites, where existing land use is not confirmed, it is Natural England’s advice to local planning authorities and applicants to take a precautionary approach in line with existing legislation and case-law.

4.56 Please note if evidence can be provided to support an alternative nitrogen figures for any existing land use, then this information will be reviewed by the local planning authority and Natural England.

4.57 A worked example to calculate the nitrogen load from existing land use is set out in Table 3.

Table 3 Calculating nitrogen load from current land use

STAGE 2 - WORKED EXAMPLE TO CALCULATE NITROGEN LOAD FROM CURRENT LAND USE				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	Total area of existing agricultural land	40	Hectares	This is the area of agricultural land that will be lost due to development
2	Identify farm type and confirm nitrate loss.	26.9	Kg/ha/yr	The developable area covers several farm types therefore an average has been used. Reference Appendix 1 and Table 2
3	Multiply area by nitrate loss	1,076	Kg/N/yr	40 ha x 26.9 kg/N/yr
Nitrogen load from current land use	1,076 Kg/N/yr			

Stage 3 ***Adjust nitrogen load to account for land uses with the proposed development***

4.58 The last stage is to add in the nitrogen load that will result from the new development that is not received by a WwTW. This includes the nitrogen load from the new urban development and from the new open space including any Suitable Alternative Natural Greenspace (SANG), Nature Reserves, or Bird Refuge Areas as identified within the redline boundary of the scheme.

4.59 The calculation only includes the areas of the site where there will be a change in land use, for example from agricultural land to new urban development or agricultural land to Suitable Alternative Natural Greenspace (SANG) / open space. Where there is no proposed change to land use, this land should be excluded from the nitrogen budget as there will be no change to the nitrogen load from this area.

4.60 A worked example is shown in the table below. This is based on a developable area of 38 hectares covering land in a mix of farm types with the removal of 2 hectares of agricultural land to create SANG.

Urban development

4.61 The nitrogen load from the new urban development results from sewer overflows and from drainage that picks up nitrogen sources on the urban land. Urban development includes the built form, gardens, road verges and small areas of open space within the urban fabric. These nitrogen sources include atmospheric deposition, pet waste, fertilisation of lawns and gardens and inputs to surface water sewers. The nitrogen leaching from urban land equates to 14.3 kg/ha/yr[vii]. Appendix 2 sets out the scientific research and literature in relation to this figure.

Open Space and Green Infrastructure

4.62 Nitrogen loss draining from new designated open space or Suitable Alternative Natural Greenspace (SANG) should also be included. The nitrogen leaching from this land is likely to equate to 5 kg/ha/yr. Appendix 3 sets out the scientific research and literature in relation to this figure. This figure can also be used where new nature reserves or bird refuge areas are created and for new woodland planting areas.

4.63 The competent authority will need to be assured for that this open space will be managed as such and there will be no additional inputs of nutrients or fertilisers onto this land for the duration of the development. Appropriate conditions or other legal measures may be necessary to ensure it will not revert back to agricultural use, or change to alternative uses that affect nutrient inputs in the long term. It is therefore recommended that the 5 kg/ha/yr rate applies to areas of designated open space on-site of around 0.5 hectares and above. These sites will also need long term management to ensure the provision of dog bins and that these are regularly emptied.

4.64 Small areas of open space within the urban fabric, such as road verges, gardens, children's play areas and other small amenity areas, should not be included within this category. The urban development figure is appropriate for these land uses.

Community food growing provision

4.65 For any areas of the site that are proposed for community food growing provision such as allotments, it is recommended that the average farm type rate is used (26.9 kg/ha/yr).

Table 4 – Adjust nitrogen load to account for future land uses

STAGE 3 - WORKED EXAMPLE TO CALCULATE NITROGEN LOAD FROM FUTURE LAND USES				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	New urban area	38	Hectares	Area of development that will change from agricultural land to urban land use
2	Nitrogen load from future urban area	543.4	Kg/N/yr	38 ha x 14.3 Kg/N/yr
3	New SANG / open space	2	Hectares	Area of development that will change from agricultural land to SANG / open space
4	Nitrogen load from SANG / open space	10	Kg/N/yr	2 ha x 5.0 Kg/N/yr
5	Combine nitrogen load from future land uses	553.4	Kg/N/yr	543.4 Kg/N/yr + 10 Kg/N/yr
Nitrogen load - future land uses	553.4 Kg/N/yr			

Stage 4 ***Calculate the net change in the Total Nitrogen load that would result from the development***

4.66 The last stage is to calculate the net change in the Total Nitrogen load to the Solent catchment with the proposed development. This is derived by calculating the difference between the Total Nitrogen load calculated for the proposed development (wastewater, urban area, open space etc) and that for the existing land uses.

4.67 It is necessary to recognise that all the figures used in the calculation are based on scientific research, evidence and modelled catchments. These figures are the best available evidence but it is important that a precautionary buffer is used that recognises the uncertainty with these figures and in our view ensures the approach prevents, with reasonable certainty, that there will be no adverse effect on site integrity. Natural England therefore recommends that a 20% precautionary buffer is built into the calculation.

4.68 There may be instances where it is the view of the competent authority that an alternative precautionary buffer should be used on a site-specific basis where sufficient evidence allows the legal tests to be met.

4.69 Table 5 sets out a worked example.

Table 5 Nitrogen Load Budget

STAGE 4 - WORKED EXAMPLE TO CALCUATE THE NET CHANGE IN NITROGEN LOAD FROM THE DEVELOPMENT				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	Identify nitrogen load from wastewater (stage 1)	587.8	Kg/TN/yr	See Table 1
2	Calculate the net change in nitrogen from land use change - subtract existing land uses nitrogen load (stage 2) from future land uses nitrogen load (stage 3)	-522.6	Kg/TN/yr	553.4 (stage 3) - 1076 (stage 2) = -522.6 Kg/TN/yr
3	Determine nitrogen budget – the Total Nitrogen wastewater load for the proposed development plus the change in nitrogen load from land use change (the latter figure may be positive i.e. the change in land use will generate more nitrogen, or negative i.e. the change in land use will generate less Nitrogen)	65.2	Kg/TN/yr	587.8 (step 1) + -522.6 (step 2) = 65.2 Kg/TN/yr
4	Where TN budget is positive add 20% precautionary buffer	78.24	Kg/TN /yr	64.8 + 20% = 78.24
Total Nitrogen that needs to be neutralised	**78.24 Kg/TN /yr**			

Section B

Methodology for calculating TN budgets for package treatment plants (PTPs)

4.70 The Environment Agency has a presumption against private sewage treatment works in sewered areas and will always seek connection to the mains sewer where possible and practicable. A principle concern relates to the failure rates of PTPs and the lack of review and periodic upgrades via regulatory systems that apply to mains. There will be site specific factors (e.g. in proximity to watercourses, soil saturation levels, etc.) that would need to be considered when evaluating this risk.

4.71 Further advice from the Environmental Agency on the use of PTP may be found at - https://www.gov.uk/guidance/discharges-to-surface-water-and-groundwater-environmental-permits. Additional guidance may also be available via local planning authorities. For example, Chichester District Council has adopted a supplementary planning document for surface and foul drainage - https://www.chichester.gov.uk/article/29757/Supplementary-planning-documents-and-policy-guidance.

4.72 Where development are proposing to use package treatment plants, or similar, it is recommended that the TN level is calculated on a per person basis. On average each person produces sewage containing 0.0035 tonnes of nitrogen per year (3.5 kilograms)[viii].The TN prior to treatment = number of additional population x 3.5 Kg = Kg/TN/yr.

4.73 The percentage reduction of TN that may be applied as result of treatment will depend on the efficiency of the treatment processes employed and must be assessed on a case by case basis. NB The evidence supporting the efficiency of PTPs should include the test result documents from the lab (in English) and/or measured effluent concentrations from real world applications, not just the covering certificate. Information will also need to be provided on the long term monitoring and management of these installations and this will need to be secured.

4.74 Bespoke calculations of the TN load may be possible for larger PTPs in instances where robust evidence of the performance of the system in removing nitrogen is provided. In addition to the above, the evidence will need to include, as a minimum, a full year of operation and supporting information to ensure that the concentration of total nitrogen within the effluent can be reliably predicted. In these cases, early consultation with Natural England, through our charged advice service, and the competent authority is recommended.

4.75 Table 6 sets out a worked example for Stage 1. Stages 2, 3 and 4 of the above methodology can then be applied.

Table 6 Alternative Stage 1 methodology for package treatment plants (PTPs)

STAGE 1 - WORKED EXAMPLE TO CALCULATE TOTAL NITROGEN (TN) LOAD FROM DEVELOPMENT WASTEWATER WITH AN ONSITE PTP (prior to treatment)				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
Development proposal	Development types that would increase the population served by a wastewater system	100	Residential dwellings	
Step 1	Additional population	240	Persons	Based on average household size of 2.4
Step 2	TN prior to treatment Based on 3.5 Kg TN per person per year	840	Kg TN /yr	240 (step 1) x 3.5 Kg TN per person per yr
Step 3	Receiving PTP TN reduction efficiency	70	%	Efficiency of PTP used must be evidenced.
Step 4	TN discharged after PTP treatment	252	Kg TN /yr	30% of 840
Step 5	Acceptable N loading (as defined in paragraph 4.40) Based on 110 l per day per person	52,800	mg TN /day	Total waste water from development (110l x 240 persons) x Acceptable N loading of 2 mg/l
Step 6	Convert acceptable TN loading to TN Kg / Yr	19.3	Kg TN / Yr	Divide by 1000000 x by 365 days
Step 7	TN discharged - acceptable N loading (@ 2 mg/l)	232.7	Kg TN / Yr	252 (step 4) – 19.3 (step 6)
PTP Total Nitrogen Load	**232.7 Kg TN / Yr**			

SECTION 5 MITIGATION

Introduction

5.1 If there is a nitrogen surplus from the WwTW discharge (a positive figure), then mitigation is required to achieve nitrogen neutrality. If the calculation identifies a deficit (a negative figure), no mitigation is required. In the worked example set out in Table 5, the nitrogen budget with 20% buffer is 77.8 Kg/TN/yr. Nitrogen neutrality would therefore require appropriate mitigation measures that would remove a minimum of 77.8 Kg/TN/yr.

5.2 Mitigation can be 'direct' through upgrading sewage treatment works and through alternative measures, e.g. interceptor wetlands; or 'indirect' by taking land out of high nitrogen uses, e.g. crops or intensive livestock systems that result in an excess of nitrogen lost to the water environment.

5.3 The purpose of the mitigation measures is to avoid impacts to the designated sites, rather than compensating for the impacts once they have occurred. Avoiding impacts is achieved by neutralising the additional nutrient burden that will arise from the proposed development, achieving a net zero change at the designated sites in a timely manner.

5.4 To ensure it is effective mitigation, any scheme for neutralising nitrogen must be certain at the time of appropriate assessment so that no reasonable scientific doubt remains as to the effects of the development on the international sites. This will need consideration of the delivery of mitigation, its enforceability and the need for securing the adopted measures for the duration of the development's effects, generally 80-125 years.

5.5 Schemes that are being delivered by other sectors (for example water industry and agricultural sector) for the purpose of meeting the necessary conservation measures designed for the international sites and to take appropriate steps to avoid the deterioration of the international sites should not also be used as mitigation for plans and projects, as this would compromise the original purpose and would be unlikely to meet the legal tests of the Habitats Regulations.

5.6 Further information has been included in this section on recommended mitigation measures. Each mitigation scheme will be assessed on its own merits and on a case by case basis, based on the submitted evidence. We recommend applicants to discuss options with local planning authorities and Natural England through our charged advice service, at the earliest opportunity. However, it is ultimately the decision of the local planning authorities, as competent authorities, to determine the suitability of the proposed mitigation scheme in line with the legal tests in the Habitats Regulations.

Types of mitigation

Conversion of agricultural land for community and wildlife benefits

5.7 Permanent land use change by converting agricultural land with higher nitrogen loading to alternative uses with lower nitrogen loading, such as for local communities, wildlife, and under schemes for flood management or to deliver the UK Government's Net Zero greenhouse gas emissions target by 2050[ix], is one way of neutralising nutrient burdens from development. It is important to retain the best and most versatile agricultural land in food production, particularly food crop production. However, there are a number of reasons to support conversion of agricultural land where the land is less economic to farm. There may also be a wide range of incidental benefits for the local community and wildlife from this change, as well as delivery of wider planning policy objectives and climate emergency pledges.

On-site options

5.8 One option is to increase the size of the SANGs and Open Space provision for the development on agricultural land that reduces the nitrogen loss from this source. This can be secured as designated open space or by other legal mechanisms.

Off-site options

5.9 Another option is to acquire, or support others in acquiring, agricultural land elsewhere within an appropriate river catchment area. By changing the land use in perpetuity (e.g. to woodland, heathland, saltmarsh, wetland or conservation grassland), this reduces the nitrogen loss from this source.

5.10 Mitigation land should be appropriately secured to ensure that at the time of appropriate assessment it is certain that the benefits will be delivered in the long term. Natural England advises that this can be achieved through an appropriate change of ownership to a local planning authority or non-government organisation. However, it is recognised that there may be other legal mechanisms available to the competent authority to ensure deliverability and enforceability of a mitigation proposal. These can be considered on a case by case basis.

5.11 Small scale developments are encouraged to consider opportunities for providing local small scale mitigation measures that deliver multiple benefits. Possible options include the creation of local ponds, wetlands, local nature reserves, community orchards (without nitrogen inputs), or copse. Another example is to turn a strip (in excess of 10m width) of agricultural land immediately adjacent to a public footpath into a greenway. This could be demarcated by hedges or woodland planting for both public and wildlife benefits.

Woodland planting

5.12 Woodland planting on agricultural land is a means of securing permanent land use change without necessitating land purchase. It can be evidenced easily by aerial photography and site visits. The level of woodland planting required to achieve nutrient neutrality is 20% canopy cover at maturity. In very broad terms, this equates to 100 trees per hectare, although this is dependent on the type of trees planted and there are also options that this can be achieved by natural regeneration, especially if adjacent to existing native woodland. It is our preference that native broadleaf species are selected where possible, to secure wider biodiversity gains. A nitrogen leaching rate from woodland planting is likely to equate to 5 kg/ha/yr.

5.13 In a relatively short time, the woodland planting would require a felling licence and woodland removal would also be covered by the EIA Regulations where woodland is planted as mitigation for internationally designated sites. There are therefore a number of layers of security for the competent authorities to ensure this mitigation is being delivered effectively. Planted woodland does require management for the first decade in terms of plug fencing and maintenance until the canopy has reached above browsing height, thereafter management is relatively minimal though some thinning is preferable to enable mature trees to develop.

5.14 Woodland planting would secure carbon capture, biodiversity and recreational benefits. The established woodlands could also be used for wood fuel production or coppice timber production.

Wetlands

5.15 Wetlands receiving nitrogen-rich water can remove a proportion of this nitrogen through processes such as denitrification and sedimentation. Wetlands can be designed as part of a sustainable urban drainage (SUDs) system, taking urban runoff/stormwater; discharges from STWs can be routed through wetlands; or the flow, or part of the flow, of existing streams or rivers can be diverted through wetlands. Wetlands deliver incidental wildlife and biodiversity benefits, with possible drainage and flood defence benefits (by reducing risk of harm from natural hazards).

5.16 It is essential that wetlands and SUDs are maintained to provide ongoing nutrient removal. Provisions for resourcing the ongoing maintenance of SUDs will need to be secured with any planning permission. Further information on the potential for nitrogen mitigation using wetlands is included in Appendix 4.

Wastewater Treatment Work Upgrades

5.17 Mitigation options at WwTWs include the agreement with the wastewater treatment provider that they will maintain an increase in nitrogen removal at the WwTW. This may include either upgrades to infrastructure (long term), or where the existing WwTW infrastructure has capacity an agreement to operate the WwTW at a higher standard than required by the discharge consent. Natural England, Environment

Agency, Local Planning Authorities and water companies are working together to explore these options.

5.18 There may also be opportunities to progress a wetland at a WwTWs, at the final stage of the process, once the permit consents have been met. It is possible to discharge the WwTWs outfall through wetlands, prior to release into the wider environment. Further details of this option is included in Appendix 4.

Size of mitigation land

5.19 The mitigation land must be sufficient to ensure the legal tests in the Habitats Regulations can be met.

5.20 Larger schemes create more opportunities for other sources of funding. Land that is taken out of agriculture for nutrient mitigation could also qualify for additional funding for future management to meet other legislative and policy requirements. For example, with additional management and infrastructure, this land may qualify as Suitable Alternative Natural Greenspace to relieve recreational pressure on international designated sites or, alternatively, to deliver a strategic bird reserves in line with Solent Waders and Brent Goose Strategy. Furthermore, larger schemes have the potential to deliver wider community and biodiversity benefits and these options should be encouraged where possible.

5.21 Smaller schemes will also be acceptable where the legal tests in the Habitats Regulations are met so there is certainty around these measures, for example, their deliverability, enforceability and long term use

Location of mitigation

5.22 The location of the mitigation site will also influence the effectiveness of the measure. The appropriate location for mitigation land firstly depends on the catchment of the development and location of the WwTWs outfall. Consideration then needs to be given to site specific factors such as geology, hydrology and topography.

Identifying the catchment for mitigation land

5.23 The fluvial catchment for the Solent internationally designated sites is shown on Figure 1. Figures 2 – 7 show the catchment area at a larger scale[x].

5.24 A key objective is to ensure mitigation land is situated in the most effective location. In order to achieve this, it may be appropriate to establish mitigation land in a number of locations or catchments. For example, for some of the coastal WwTWs, there is a widespread distribution of output to a number of designated sites within the Solent. Therefore a number of catchments would be appropriate locations for mitigation land. This view is based on modelling that has been undertaken by the Environment Agency and analysed by water quality specialists within Natural England in relation to the internationally designated sites. The modelling identifies the relative contributions of all nitrogen sources within the harbours and estuaries of the Solent and is the best available scientific evidence available[xi].

5.25 The following recommendations can generally be applied to determine the suitability of the mitigation location. These recommendations are based on spatial principles and temporal principles

Spatial principles

5.26 It is Natural England's view that mitigation land within the same catchment as the development location is appropriate.

River catchments

5.27 For WwTWs that drain into the rivers, it is appropriate for the mitigation land to be within the same river catchment as the outfall location. This is the preferred solution in all cases. If this is not possible, mitigation in close alternative catchments would be appropriate in the following cases.

River Test and River Itchen

5.28 It is appropriate for the River Test and River Itchen catchment to be considered as one catchment. Therefore development located in the River Test catchment could be mitigated in the River Itchen catchment and *vice versa*.

Bartley Water

5.29 It is also appropriate for development within the Bartley Water catchment (New Forest) to be included with the Test and Itchen catchment. This is due to the close proximity of the outfalls within Southampton Water and the tidal flows between these estuaries.

New Forest Rivers

5.30 It is appropriate for the New Forest rivers that outfall to the southern coast of the New Forest to be considered as one catchment – River Beaulieu, River Lymington, Danes Stream, Dark Water, Sowley Stream and the coastal areas.

River Meon

5.31 For development that outfalls to the River Meon, it would be appropriate to mitigated within the River Hamble catchment and within the Portsmouth Harbour catchment.

River Hamble

5.32 For development that drains to ground within the River Hamble catchment or to a WwTWs that drains to the River Hamble, eg Bishops Waltham WwTW, mitigation land is limited to within the River Hamble catchment.

Isle of Wight Rivers

5.33 For development that drains to ground within the catchment of or direct to the each of the Isle of Wight rivers, eg Eastern Yar, mitigation land is limited to within the same river catchment.

Portsmouth Harbour, Langstone Harbour and Chichester Harbour

5.34 For the WwTWs that drains to each harbour (Portsmouth Harbour, Langstone Harbour and Chichester Harbour), priority locations for mitigation are the same river catchment as the WwTW outfall.

5.35 For example, the Bosham WwTW outfalls at the base of Bosham and Fishbourne Channels within Chichester Harbour. The most effective location for mitigation is within the same catchment as these arms of Chichester Harbour.

5.36 In some cases there may be opportunities to mitigate within other river catchments within the harbours. These will be examined on a case by case basis and we advise early consultation with Natural England and the local planning authority.

Coastal WwTWs

5.37 For development that drains to coastal WwTW (Portswood WwTW, Woolston WwTW, Millbrook WwTW) within the northern part of Southampton Water, mitigation is appropriate in the following catchments – River Test, River Itchen, Bartley Water.

5.38 For development that drains to other coastal WwTWs in Southampton Water eg Ashlett Creek WwTW, mitigation is appropriate in the following catchments - River Test, River Itchen, River Meon, River Hamble, eastern catchments of the New Forest.

5.39 For development that drains to Peel Common WwTW, mitigation is appropriate in the following catchments – River Meon, Portsmouth Harbour, Medina Estuary, Wootton Creek, Newtown Harbour, Langstone Harbour.

5.40 For development that drains to Budds Farm WwTW, mitigation is appropriate in the following catchments – River Meon, Portsmouth Harbour, Langstone Harbour, Chichester Harbour, Wootton Creek, Medina Estuary (and the estuaries in between).

5.41 For development that drains to Pennington WwTW, mitigation is appropriate in the following catchments, south coast of New Forest, Western Yar, Newtown Harbour

Drain to ground

5.42 For developments that drain to ground via a package treatment plant (PTP) or mains WwTWs, it is appropriate for mitigation land to be within the same catchment as the outfall location of the PTP or WwTW.

Temporal principles

5.43 Within chalk geology where the nitrogen discharge is to ground and remote from watercourses there is likely to be a considerable delay (it may take up to 1 year for ground water discharges to percolate through a meter of chalk) before the nitrogen discharged reaches the international designated sites. In such circumstances mitigation measures that take effect quickly may not need to be implemented immediately. We advise that these issues are examined on a case by case basis in consultation with the relevant local planning authority or authorities and Natural England.

Identifying optimal locations for mitigation

5.44 Any discharge from a development that is directed to a WwTW that outfalls to the estuaries and harbours has the potential to reach the designated sites in a matter of hours or tide cycle. It is therefore important for any mitigation sites to be located in the most optimal locations. Sites that are downstream of the WwTWs and upstream of the designated sites are ideally located to reduce the nutrient load reaching the designated sites.

5.45 It is our preference that mitigation sites are prioritised within the lower fluvial catchment and in close proximity to water courses that drain into the Solent estuaries and harbours. Sites that are located on tertiary geology or clay are preferred or sites that are located on the break of slope onto chalk bedrock. These sites reduce the time lag between the nutrient benefits of changes to land use within the catchment and the benefits to the designated sites.

5.46 For sites located on the upper fluvial catchment of the Solent on the chalk bedrock, without any water course in close proximity, there may be a time lag for consideration. It is our advice that the depth of the chalk groundwater is considered. For sites where the groundwater is more than 5m below ground level, then this land is unlikely to be appropriate for mitigation for short term development. Although it may be appropriate for development that is phased over more than 5 years, provided the mitigation land is delivered straightaway.

5.47 There may be sites where there is evidence of a short time lag between nutrient reduction at the mitigation site and the designated sites, or where the mitigation site is located on a geology or in an area that will result in additional benefits for nutrient removal, over and above the change in land use at the site itself. These options will be considered on a case by case basis.

Strategic Solutions

5.48 It is appreciated that achieving nutrient neutrality may be difficult for smaller developments, developments on brownfield land, or developments that are well-progressed in the planning system. Natural England is working closely with local planning authorities to progress Borough /District/ City/ Authority wide and more strategic options that achieve nutrient neutrality and enable this scale of development to come forward.

5.49 A number of options are coming forward. It is recommended that discussions are held with the relevant local planning authorities with regard to these options. Further information will be available on the Partnership for South Hampshire website and Chichester District Council website in due course.

5.50 Natural England can provide further advice on the methodology and mitigation options through our chargeable services (DAS).

[i] The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017

[ii] Conservation of Habitats and Species Regulations (England and Wales) Regulations 2017 (as amended)

[iii] Including Wildlife and countryside Act 1981 as amended, Countryside and Rights of Way Act 2000, Marine and Coastal Access Act 2009, Natural Environment and Rural Communities Act 2006

[iv] The optional requirement referred to in G2 requires installation and fittings and fixed appliances for the consumption of water at 110 litres per person per day.

[v] Desmit, X., Thieu, V., Billen, G., Campuzano, F., Dulière, V., Garnier, J., Lassaletta, L., Ménesguen, A., Neves, R., Pinto, L., Silvestre, M., Sobrinho, J.L., Lacroix, G., 2018. Reducing Marine Eutrophication May Require a Paradigmatic Change. Science of the Total Environment 635 (2018) 1444–1466

[vi] Crossley, Laura Helen (2019) Palaeoenvironmental reconstruction of Poole Harbour water quality and the implications for estuary management. *University of Southampton, Doctoral Thesis*, 331pp,

Howden, N.J.K., Burt, T.P., 2009. Statistical analysis of nitrate concentrations from the Rivers Frome and Piddle (Dorset, UK) for the period 1965–2007. Ecohydrology 2, 55–65. doi:10.1002/eco.39,

Howden, N. J. K., Burt, T. P., Worrall, F., Whelan, M. J., & Bieroza, M. (2010). Nitrate concentrations and fluxes in the River Thames over 140 years (1868-2008): Are increases irreversible? *Hydrological Processes*, **24**, 2657– 2662. https://doi.org/10.1002/hyp.7835

[vii] Supplementary Planning Document – Achieving Nitrogen Neutrality in Poole Harbour. 2017

[viii] Supplementary Planning Document – Achieving Nitrogen Neutrality in Poole Harbour, 2017

[ix] https://www.theccc.org.uk/publication/land-use-policies-for-a-net-zero-uk/

[x] These plans contain public sector information licensed under the Open Government Licence v3.0

[xi] Environment Agency – CPM modelling, SAGIS/SIMCAT and Telemac modelling for Water Framework Directive DIN and Ecological Impact Investigations, 2014

Figure 2

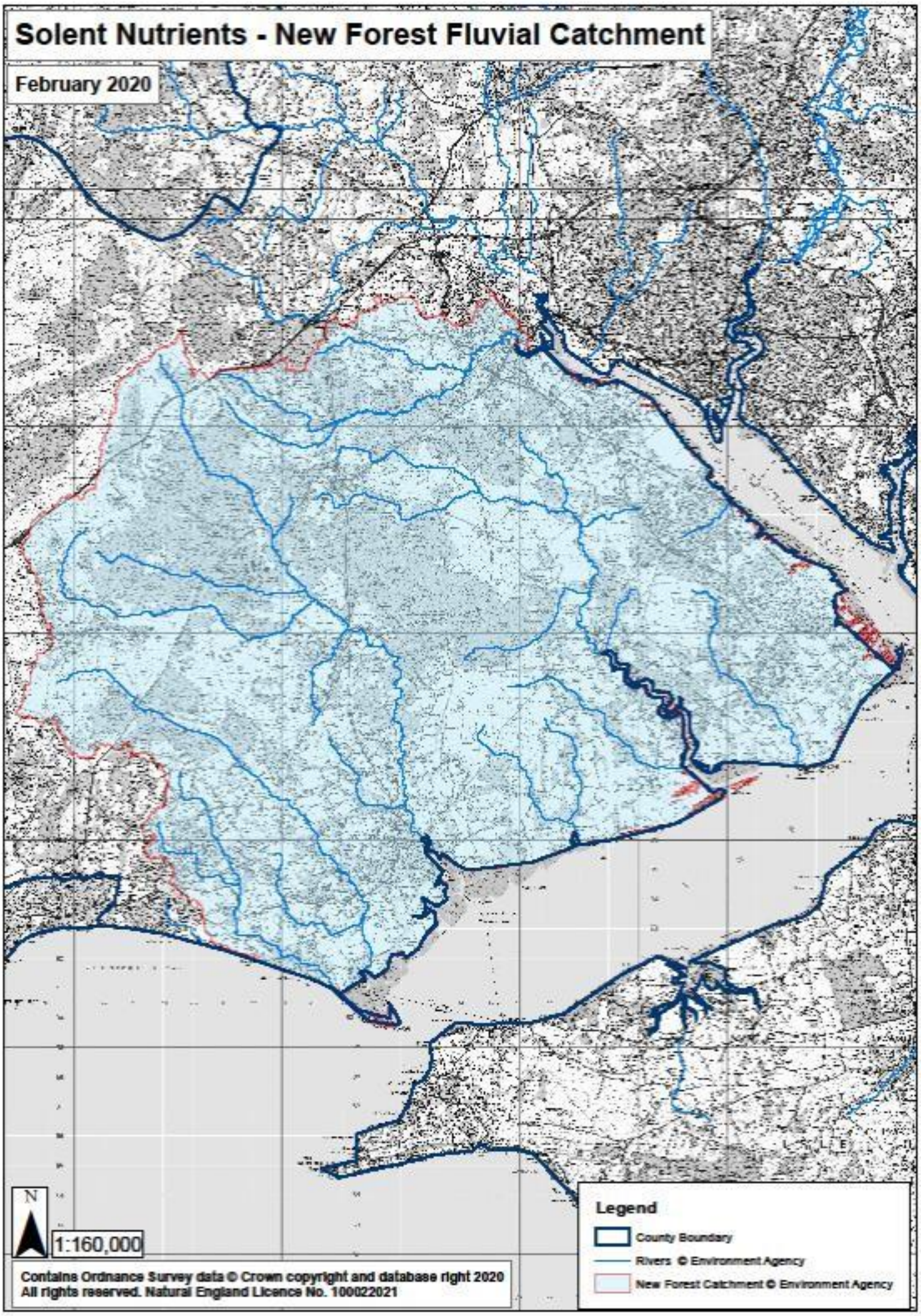

Solent Nutrients - New Forest Fluvial Catchment
February 2020
N
1:160,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
New Forest Catchment © Environment Agency

Figure 3

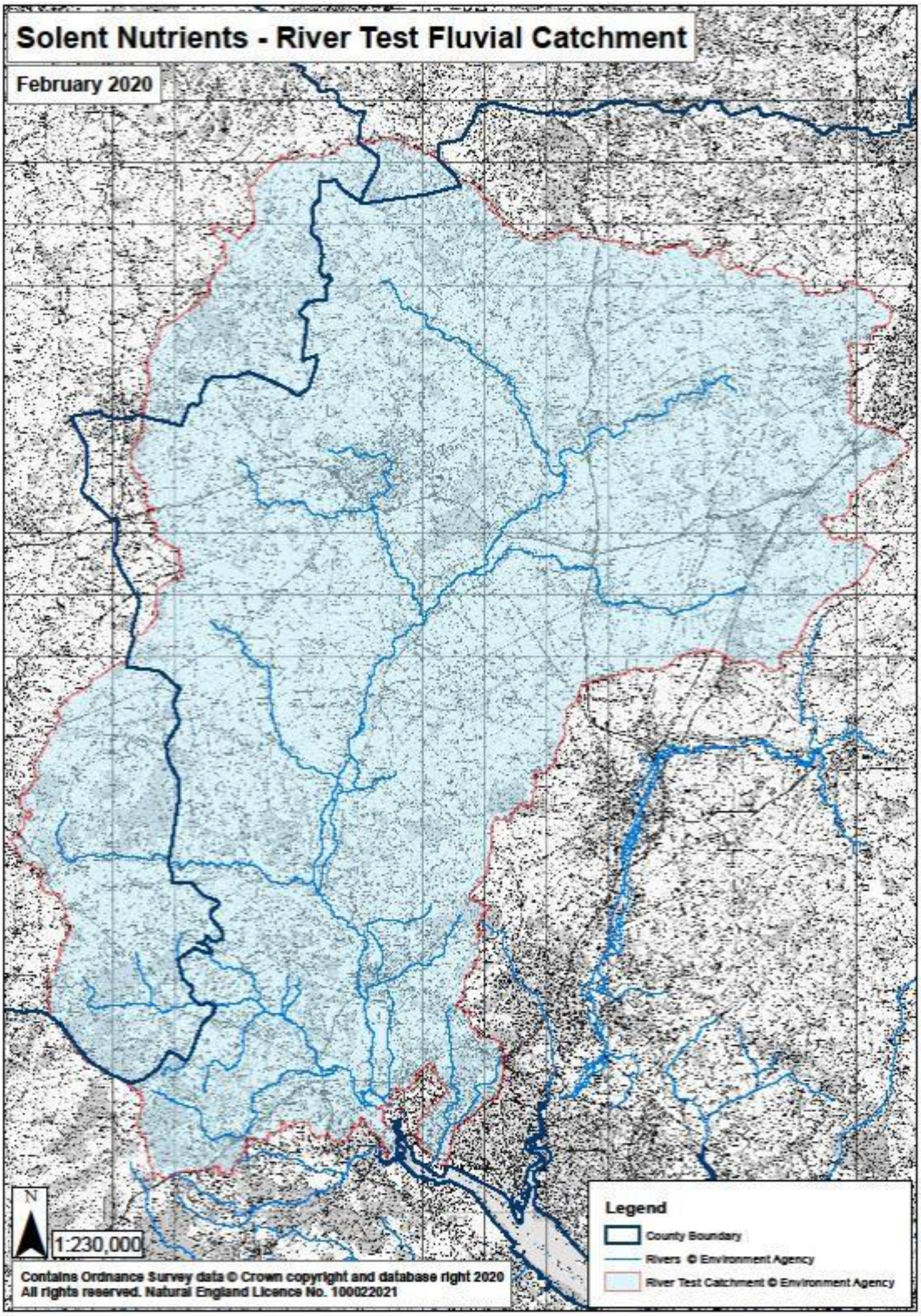

Solent Nutrients - River Test Fluvial Catchment
February 2020
N
1:230,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
River Test Catchment © Environment Agency

Figure 4

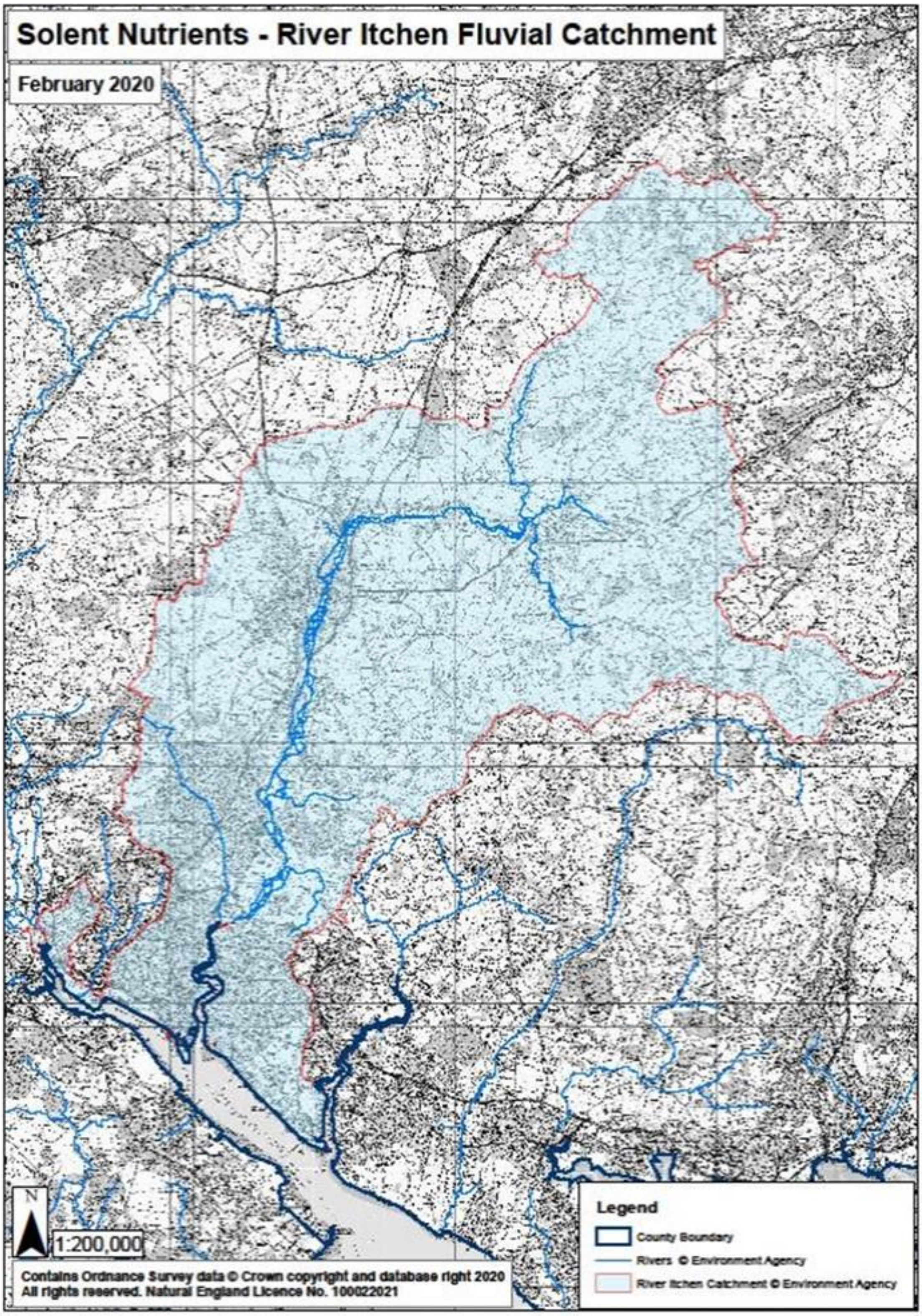
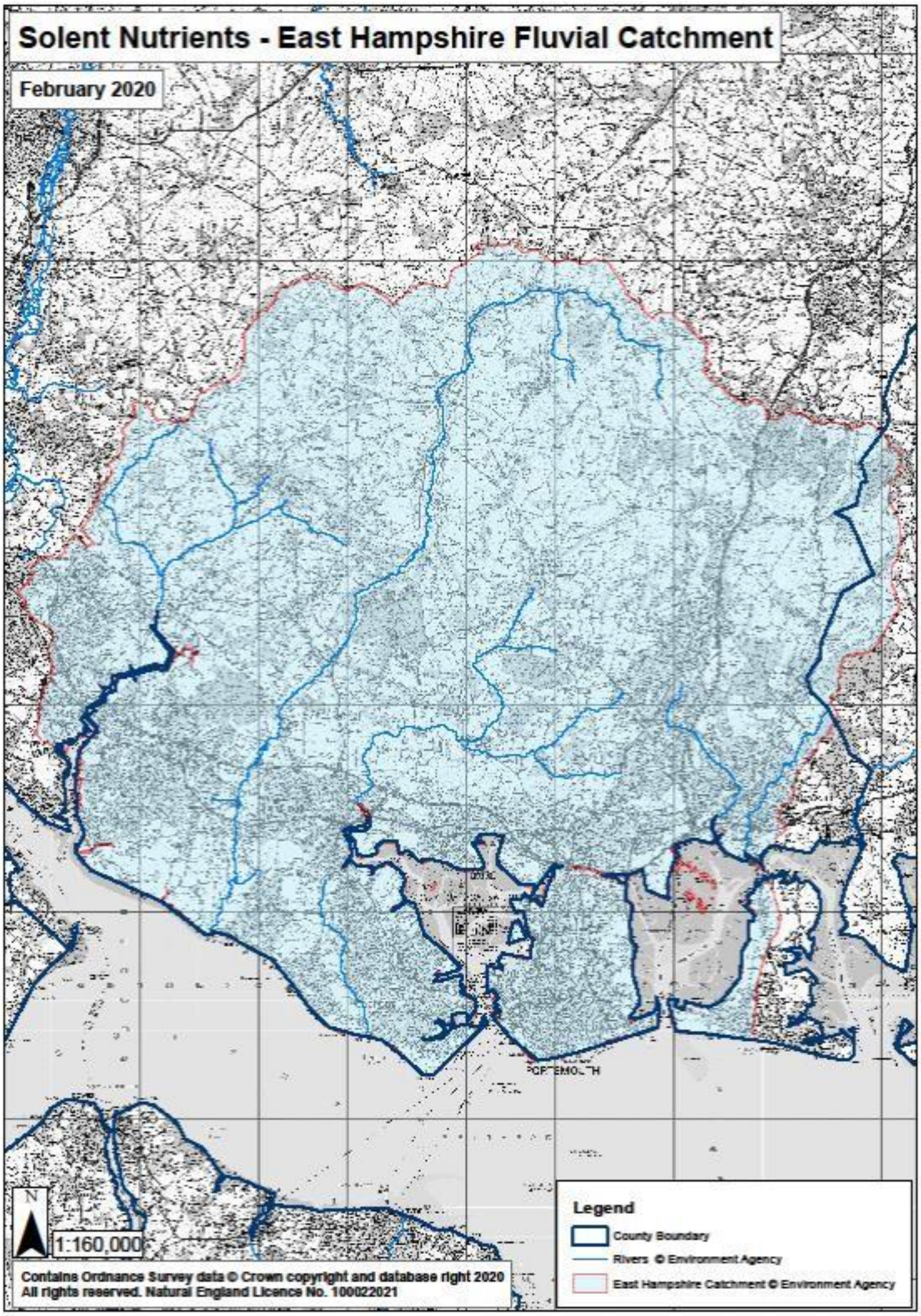

Solent Nutrients - River Itchen Fluvial Catchment
February 2020
N
1:200,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
River Itchen Catchment © Environment Agency

Figure 5



Solent Nutrients - East Hampshire Fluvial Catchment
February 2020
PORTSMOUTH
N
1:160,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
East Hampshire Catchment © Environment Agency

Figure 6

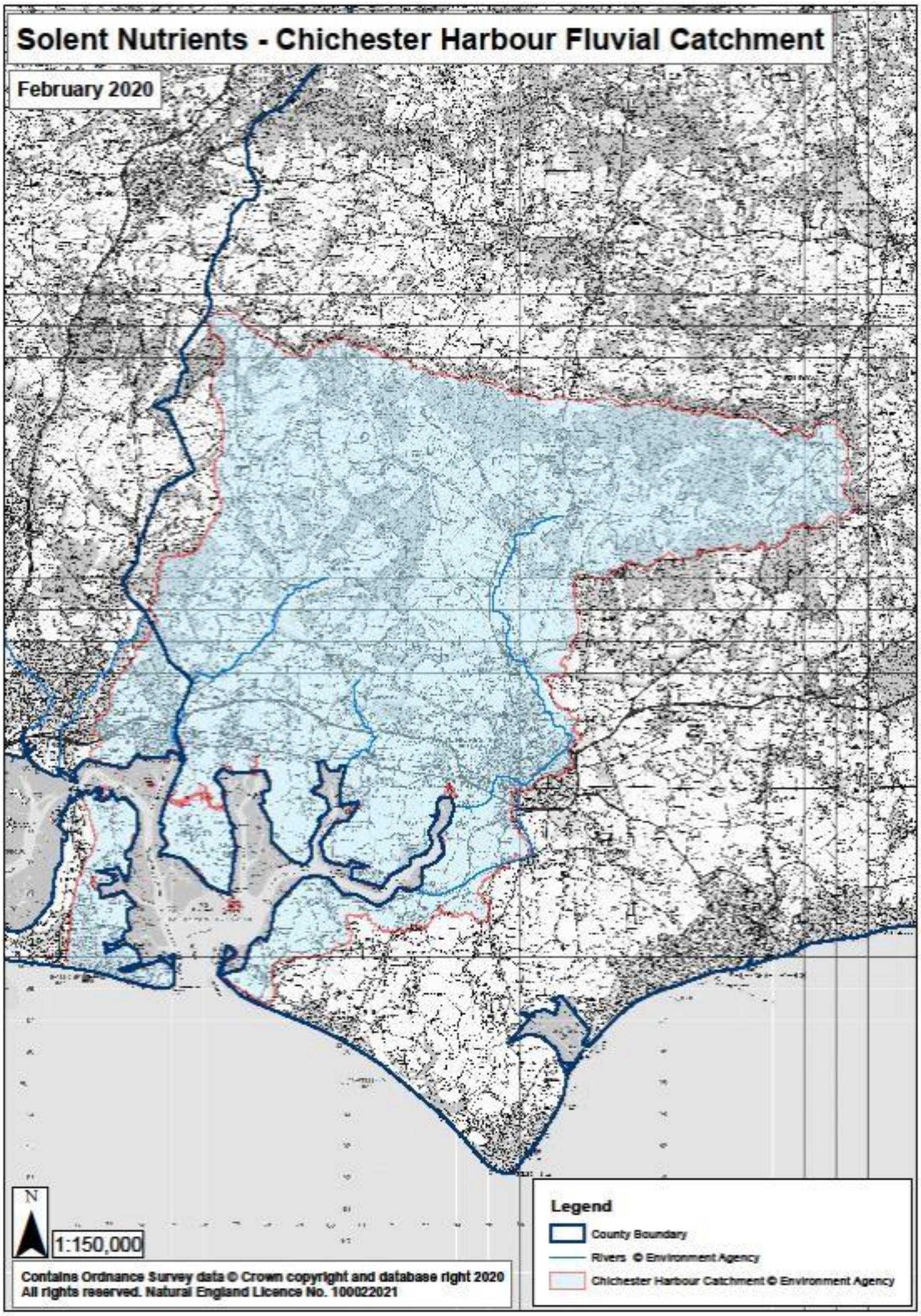
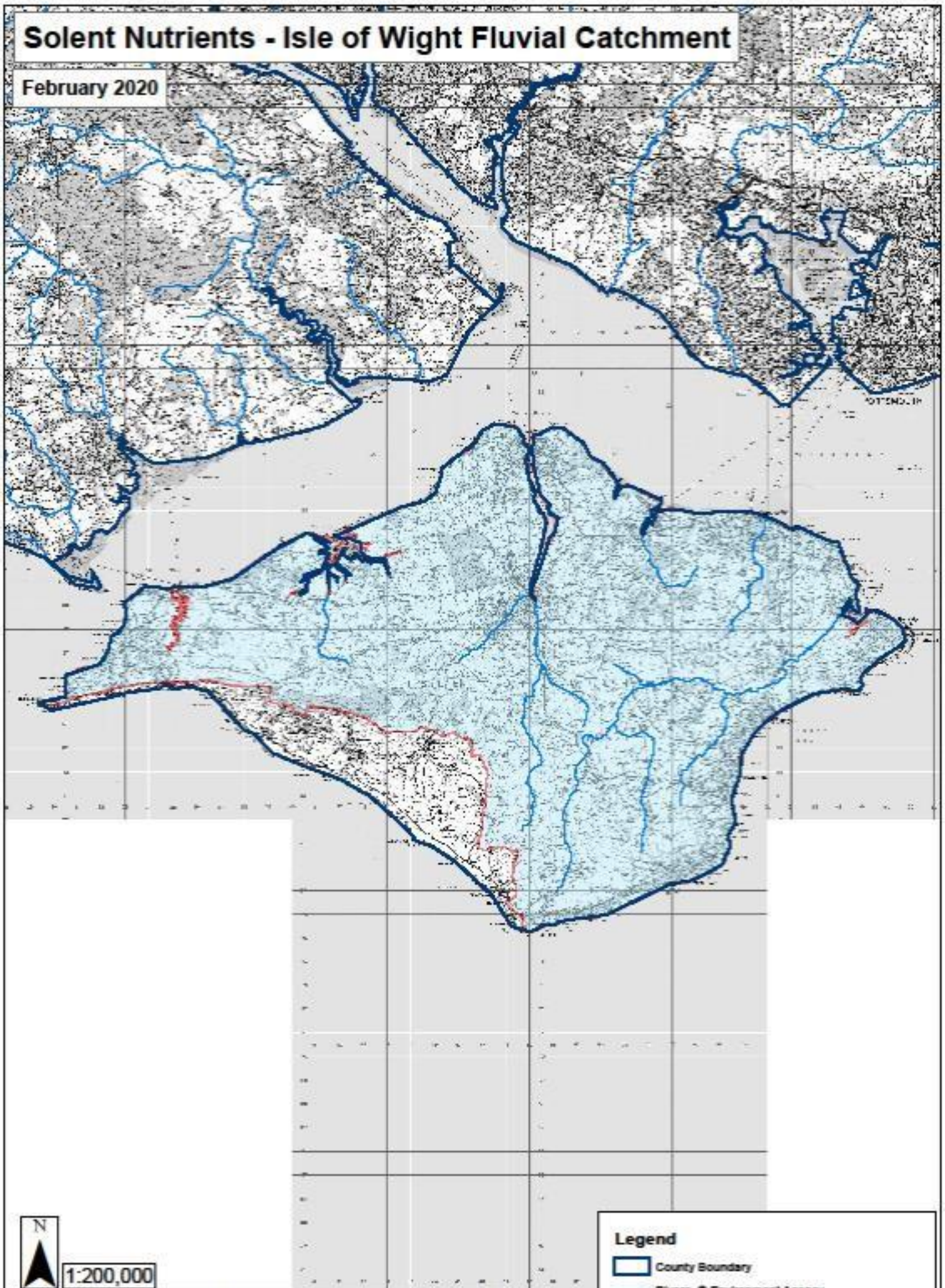

Solent Nutrients - Chichester Harbour Fluvial Catchment
February 2020
N
1:150,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
Chichester Harbour Catchment © Environment Agency

Figure 7


Solent Nutrients - Isle of Wight Fluvial Catchment
February 2020
N
1:200,000
Contains Ordnance Survey data © Crown copyright and database right 2020
All rights reserved. Natural England Licence No. 100022021
Legend
County Boundary
Rivers © Environment Agency
Isle of Wight Catchment © Environment Agency

ANNEX 1 PLANNING CONTEXT

A1.1 In 2016, an Integrated Water Management Study (IWMS) for South Hampshire was commissioned by the Partnership for Urban South Hampshire (PUSH) Authorities, with the Environment Agency and Natural England. This examined the delivery of development growth in relation to legislative and government policy requirements for designated sites and wider biodiversity. It updated an earlier study in 2008. Similar studies have also been undertaken for Chichester Harbour and growth in Sussex (2018) though this study was largely for Water Framework Directive assessments.

A1.2 The IWMS for South Hampshire was completed in March 2018 and identified that there is currently uncertainty as to whether new housing growth can be accommodated without having a detrimental effect upon the water environment.

A1.3 The updated IWMS report in March 2018 concluded that there is uncertainty about the impact of local plan growth on the designated sites, especially after 2020. There was uncertainty about the efficacy of catchment measures to deliver the required reductions in nitrogen levels, and/or whether the upgrades to wastewater treatment works will be sufficient to accommodate the quantity of new housing proposed.

A1.4 To examine this issue further, local planning authorities set up a Water Quality Working Group in South Hampshire to add to the one already in existence for Chichester with the Environment Agency, Natural England and water companies. The objectives of these groups include identifying and analysing the existing evidence gaps and evaluating the need for strategic mitigation measures. The primary focus of this work is to address the uncertainty associated with strategic local plan growth.

A1.5 Natural England is working closely with local planning authorities to address this wider issue and progress options that achieve nutrient neutrality. It is appreciated that this may be difficult for smaller developments, developments on brownfield land or developments that are well-progressed in the planning system.

A1.6 Natural England has advised affected local planning authorities to set up Borough-wide, or strategic approaches that developments can contribute to thereby ensuring that this uncertainty is fully addressed by all applications and is working closely with affected local planning authorities to help address this issue.

ANNEX 2 ENVIRONMENTAL CONTEXT

Designated sites review

Solent Maritime SAC and SPAs

A2.1 In 2018, condition assessments of the estuary, mudflat & sandflats, and sandbanks features of the Solent Maritime SAC were undertaken. The condition assessments completed considered the SAC features across the site as a whole and found the condition of these features assessed to be unfavourable. The unfavourable assessment is based on a number of attributes failing, including the nutrient water quality attribute. Other attributes were also found to be failing, such as the extent, distribution, rhizome structure and reproduction, and biomass of seagrasses, as well as the infaunal quality of the intertidal mud and sand features. These failures are likely to be in part due to impacts from nutrients. Currently the site condition assessment does not include the saltmarsh feature which has not yet been assessed. However preliminary analysis of data shows that there was a loss of extent of saltmarsh across the Solent between 2008 and 2016. The cause of this loss it is not known but elevated nutrients can contribute towards the susceptibility of saltmarsh to erosion through effects on plant root growth and the cohesion of mud around the roots. In 2019/20 the intertidal areas of the Chichester Harbour estuary were examined in detail including the saltmarsh feature. The saltmarsh feature of this part of the SAC is in unfavourable declining condition due to the poor quality of the remaining marsh and ongoing net loss. Chichester Harbour contained half the saltmarsh feature area at designation of the SAC. Water quality impacts (macroalgal mats rotting and living) were recorded on all the saltmarsh surveyed.

A2.2 A full SPA condition assessment has yet to be undertaken, however the 2019/20 assessment of Chichester Harbour included assessment of the Chichester and Langstone Harbours SPA as well as the SSSI birds. This showed that shelduck populations on the SSSI and the SPA are showing a 71% decline in the long term that appears to be tracking that of the region although not the British trend. The declining proportion of the regional numbers supported by this site suggest that site-specific pressures are affecting this species. While the cause of these site specific declines in Chichester Harbour and the Solent area more widely are yet to be confirmed, research has found that the foraging ability of shelduck can be affected by algal mats. The wintering bird assemblage in general across Chichester Harbour is in unfavourable no change condition.

Solent and Dorset Coast Special Protection Area

A2.3 The Solent and Dorset Coast Special Protection Area (SPA) protects important foraging areas at sea used by qualifying interest features from colonies within adjacent SPAs, namely the Solent and Southampton Water SPA and the Chichester and Langstone Harbours SPA. These qualifying interest features are the foraging and nesting of three species of tern: common tern, Sandwich tern and little tern. This site was designated in 2020. Given the relationship between the designated sites for the foraging areas and the colonies, the threats and condition of each these interrelated designated sites should be considered in combination as part of the Habitat Regulations Assessment. The SPA has not yet been fully condition assessed but the Chichester Harbour review of 2020 looked at not only breeding numbers of the three tern species in but also the productivity (how many chicks survived). The terns in Chichester Harbour, which are also a feature of the SSSI, are considered to be overall in unfavourable declining condition. The relationship of the tern breeding and foraging populations to water quality impacts in the Solent is not currently known, although it is not thought to be the primary reason for declining numbers of poor productivity in Chichester Harbour.

Solent and Isle of Wight Lagoons Special Area of Conservation

A2.4 The Solent encompasses a series of coastal lagoons, including percolation, isolated and sluiced lagoons. The site includes a number of lagoons in the marshes in the Keyhaven – Pennington area, at Farlington Marshes in Langstone Harbour, behind the sea-wall at Bembridge Harbour and at Gilkicker, near Gosport.

A2.5 The water quality target for the coastal lagoon features is to maintain nutrient levels at which biological indicators of eutrophication (opportunistic macroalgal and phytoplankton blooms) do not affect the integrity of the site and features, avoiding deterioration from existing levels. Surveys in 2013, noted several lagoons had high pH levels likely due to photosynthetic activity, however there were no records of opportunistic macroalgae or phytoplankton blooms and most lagoons (except for Butts Lagoon and Shut Lake) continue to support good lagoonal communities. The sediment in Butts Lagoon has remained anoxic in surveys in 2013, although this represents similar conditions to that present in baseline surveys. Therefore, available evidence does not indicate that eutrophication is affecting site integrity at any of the lagoons within the SAC, except for Butts Lagoon.

SSSI

A2.6 During 2018 and 2019, Natural England revised and updated the SSSI assessments in the greater Solent area in relation to the influence of the water environment on the condition of estuarine SSSI interest features that underpin the SAC and SPAs. These assessments especially included littoral sediment habitat (mudflat and other tidally exposed sediment flats). The review of parts of the greater Solent area and some SSSI interest features is ongoing.

A2.7 The SSSI interest feature assessments completed consider the concentrations of inorganic nitrogen status in each harbour and estuary, and evidence for ecological responses. Particular attention was given to records on phytoplankton abundance and the presence and abundance of opportunistic green macroalgae. Other responses to elevated nutrients may also occur, such as effects on phytoplankton composition and seagrass and saltmarsh extent and composition. These have not yet been assessed.

A2.8 Where there is sufficient information to show that the water environment causes interest features to be in unfavourable condition, this has been recorded within the completed assessments. In addition, in cases where there is significant uncertainty that elevated nutrient levels are affecting the condition of interest features, a provisional assessment of borderline favourable condition is recorded, along with a potential threat that unfavourable condition may become apparent with more evidence. In cases where there is currently inadequate information to come to a conclusion the SSSI assessment has remained unchanged. Some parts of the greater Solent area are also recorded to be in unfavourable condition for SSSI interest features for reasons other than the water environment, such as coastal squeeze and disturbance. A brief summary of the condition classes in relation to the water environment for interest feature condition follows.

Unfavourable Declining Condition

A2.9 The 2018 assessment did not assign units to this condition as this condition requires demonstration of significant deterioration or declines in populations above threshold numbers for birds or loss of habitat for features or demonstrable and consistent worsening of attributes over time.

A2.10 The more detailed, follow-on assessment, to review trends in the interest features of Chichester Harbour in 2019/20 has determined that the Chichester Harbour condition is declining due to the continued net loss of the saltmarsh feature, poor condition of the remaining marsh, declining numbers of some species of terns and low or zero productivity of nesting terns in the Harbour. Overall the wintering bird assemblage was unfavourable no change not because the birds populations were stable but because on average the declines in populations were not sufficient to trigger a declining status. Trends varied with species, with those species that can switch to other foraging methods and habitats away from the intertidal in general showing lesser declines or even increases. The other features assessed (littoral sediment, eelgrass were all given unfavourable status but with low confidence and Natural England were unable to discern a trend due to insufficient data. The units were assigned to the features in the worst condition where the data was of high confidence so overall the intertidal habitats in Chichester Harbour in unfavourable declining condition.

Unfavourable no change

A2.11 This work identified that there are sections of the designated sites in the Solent that are unfavourable for the interest features on the weight of evidence of elevated levels of inorganic nitrogen and biological indication of eutrophication shown by the abundance of macroalgae. Where sites are recorded as unfavourable, opportunistic green macroalgae is recorded to reach >75% cover, or a biomass of $1kg/m^2$ or more. In these cases there is also little or no evidence of any reduction in nutrient status that would be adequate to substantially prevent the growth of dense macroalgae mats.

A2.12 There are unfavourable (no change) assessment on units within the following estuaries and harbours in Hampshire: Southampton Water, Hamble estuary, Portsmouth Harbour, Chichester Harbour and on the Isle of Wight: Yar estuary, Newtown Harbour, Medina estuary, Wootton Creek and Bembridge Harbour.

Unfavourable recovering (at risk)

A2.13 The review identified that there are parts of Langstone Harbour where the water environment of a unit is assessed as unfavourable for the interest features on the weight of evidence on inorganic nitrogen concentrations and biological indications of eutrophication, shown by the abundance of macroalgae (>75% cover density or a biomass of ≥ 1kg/m^2), but recovering on the basis of a large reduction in nutrient inputs through diversion of wastewater. These units are considered 'at risk' of not recovering to a favourable situation on the water environment as it is unclear whether the nutrient status will become adequate to substantially prevent the growth of dense macroalgae mats in parts of the Harbour. Also other potential ecological responses to elevated nutrient concentrations that could affect the condition of the designated features, such as impacts on saltmarsh and seagrass, have not been assessed.

A2.14 The 2018 assessments did not identify any Unfavourable (recovering) units where there is a littoral sediment feature in any of the other estuaries and harbours.

Favourable – high threat

A2.15 Some sections of the designated sites in the Solent are provisionally assessed as borderline favourable for the interest features. Here there is elevated levels of inorganic nitrogen but, at a local unit scale, the data that is available only demonstrates slight biological indication of eutrophication shown by some presence of macroalgae (<75% cover density, or a biomass of <1kg/m^2). These are provisional assessments with a high threat that the nutrient status is inadequate to substantially prevent detrimental ecological effects on designated features, particularly if there is change in environmental conditions. The high threat assessment also reflects the fact that other potential ecological responses to elevated nutrient concentrations that could affect the condition of the designated features, such as impacts on saltmarsh and seagrass, have not yet been assessed.

A2.16 There are favourable (high threat) units within the following estuaries and harbours in Hampshire: Lymington estuary, Solent and Itchen Estuary, Test Estuary, Southampton Water, Portsmouth Harbour, Chichester Harbour, Langstone Harbour, and on the Isle of Wight: Newtown Harbour and Bay and Bembridge Harbour.

Catchment work

A2.17 The high levels of nitrogen and phosphorus input to the water environment is currently caused by agricultural sources and wastewater from existing housing.

There are a number of mechanisms already in place to reduce the amount of nutrient inputs within our rivers and coastal waterbodies.

A2.18 Within the river catchments; Defra's Catchment Sensitive Farming (CSF) programme works with agriculture to reduce diffuse sources of pollution such as fertiliser and slurry run-off. One of the aims of this work is to deliver environmental benefits from reducing diffuse water pollution. To achieve these goals CSF delivers practical solutions and targeted support which should enable farmers and land managers to take voluntary action to reduce diffuse water pollution from agriculture to protect water bodies and the environment.

A2.19 In addition, Southern Water is upgrading their wastewater treatment works to reduce the amount of phosphorus inputs from human sewage. There are agreed improvements to phosphorus permits on four Southern Water Services on the River Test and phosphorus upgrades at two wastewater treatment works on the River Itchen.

A2.20 Natural England has recently published a review of the effectiveness of catchment sensitive farming approaches in the report "Catchment Sensitive Farming Evaluation Report – Water Quality Phases 1 to 4 (2006-2018) (NE731)". Work is on-going to evaluate the effectiveness of such work in reducing existing inputs into the Solent's water environment. Nationally, the results in this report state that water quality is estimated to have improved, due to reduced pollutant loadings, by between 1.2 and 6.5 per cent across water bodies associated with Phase 1 CSF Target Areas.

Type of nutrient inputs to designated sites

A2.21 There is evidence that inputs of both phosphorus and nitrogen influence eutrophication of the water environment. However, the principal nutrient that tends to drive eutrophication in the marine environment is nitrogen and this is supported by modelling and evidence.

A2.22 A modelling assessment has been undertaken by the Environment Agency to understand the importance of nitrogen in causing the growth of macroalgae and phytoplankton within estuaries in the Solent. This work used the Combined Phytoplankton and Macroalgae model developed by Cefas and was assessed at a water body scale. This scale provides an overview and may mask conditions that are unfavourable for designated interest features at a more local scale. The modelling suggests that in one estuary, the Medina, both nitrogen and phosphorus availability may control macroalgae growth (e.g. Rees-Jones et al 2014 and Udal *et al* 2014).

A2.23 The best available evidence is for focus in the Solent harbours to be on nitrogen reduction, and reduction in both nitrogen and phosphorus in the Medina catchment. However, this approach may be refined if greater understanding of the eutrophication issue is gained by thorough new research or updated modelling.

A2.24 The nutrient budget in this report calculates quantities of nitrogen (N) generated by development. This N comes in different forms and measured N concentrations vary according to exactly what is measured. These differences need to be recognised when calculating nutrient budgets. The key measurement is Total Nitrogen (TN), i.e. both organic and inorganic forms of nitrogen, because this is what is available for plant growth. TN is the sum of the inorganic forms - nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO2-N), ammoniacal-N - and organically bonded nitrogen.

A2.25 Total Nitrogen is measured by WwTW where there is a permit with a TN limit consent. However, for WwTWs without permits, measurements could be inorganic nitrogen (nitrate + nitrite + ammoniacal N) or TN or a mix. Most river quality monitoring by EA only records the inorganic N forms. The Farmscoper report measures nitrate-nitrogen not TN. Nitrate is normally the largest component of TN but quantities of organic N are significant. In the Test catchment dissolved organic nitrogen has been found to comprise 7% of the potential biologically available nitrogen in the river and 13% of that in the estuary (Purdie, 2005). Thus, the land use change element of this methodology will underestimate TN leaching. We therefore advise that this uncertainty is recognised as one of the several factors taken into account by the recommended precautionary buffer approach adopted by this methodology.

A2.26 For developments on the Isle of Wight that are impacting on the Medina estuary, both a phosphorus and nitrogen budget may be required. Natural England will work closely with the Isle of Wight Council and applicants to provide advice on a bespoke case-by-case basis.

A2.27 This approach is also supported by scientific literature which confirms that whilst both nitrogen and phosphorus should be reduced to tackle estuarine eutrophication, primarily the focus should be on nitrogen. Phosphorus reduction alone does not address the mechanisms caused by elevated nitrogen that affect sea-grass health and the structural stability, extent and plant species diversity of saltmarsh. In addition, most land use measures to reduce nitrogen are also likely to reduce phosphorus concurrently.

References

Bamber, R., McLaverty, C., Robbins, R. and Perez-Dominguez, R. 2014. Solent and Isle of Wight Monnitoring Survey Report 2013, Natural England.

Udal I., Rees-Jones S. and Robinson K., (2014) Chichester Harbour Water Framework Directive DIN and Ecological Impact Investigations 2007 to 2012. Environment Agency.
Rees-Jones S., Robinson K. and Udal I. (2014) Medina Water Framework Directive DIN and Ecological Impact Investigations 2007 to 2012. Environment Agency

Purdie, D., Shaw, P., Gooday, A. and Homewood, J. (2005) Dissolved Organic Nitrogen in the River Test and Estuary, University of Southampton

E.g. Jones B.L and Unsworth R..F. (2016) The perilous state of seagrass in the British Isles. *R. Soc. open sci.* **3**: 150596.

Turner R.E. Beneath the saltmarsh canopy: Loss of soil strength with increasing nutrient loads. Estuaries and Coasts (2011) 34:1084

Cole S., Codling I.D., Parr W. and Zabel T. 1999 Guidelines for managing water quality impacts within UK European marine sites. UK Marine SAC Project

Scott C.R, K. L. Hemingway, Elliot. M, de Honge V.N, Penthick J.S., Malcolm S. and Wilkinson M. Impact of Nutrients in Estuaries – Phase 2 Environment Agency 1999

Appendix 1 – Farm Types

The UK system is based on weighting the contributions of each enterprise in terms of their associated outputs. The weights used (known as 'Standard Outputs' or SOs) are calculated per hectare of crops and per head of livestock and used to calculate the total standard output associated with each part of the Farm Business.

Cereals

Holdings on which cereals, combinable crops and set-aside account for more than two thirds of the total SO and (pre-2007) where set-aside alone did not account for more than two thirds of the total SO. (Holdings where set-aside accounted for more than two thirds of total SO were classified as specialist set aside and were included in "other" below.)

General cropping

Holdings on which arable crops (including field scale vegetables) account for more than two thirds of the total SO, excluding holdings classified as *cereals;* holdings on which a mixture of arable and horticultural crops account for more than two thirds of their total SO excluding holdings classified as *horticulture* and holdings on which arable crops account for more than one third of their total SO and no other grouping accounts for more than one third.

Horticulture

Holdings on which fruit (including vineyards), hardy nursery stock, glasshouse flowers and vegetables, market garden scale vegetables, outdoor bulbs and flowers, and mushrooms account for more than two thirds of their total SO.

Specialist Pigs

Holdings on which pigs account for more than two thirds of their total SO.

Specialist Poultry

Holdings on which Poultry account for more than two thirds of their total SO.

Dairy

Holdings on which dairy cows account for more than two thirds of their total SO.

Lowland Grazing Livestock

Holdings on which cattle, sheep and other grazing livestock account for more than two thirds of their total SO except holdings classified as *dairy.* A holding is classified as lowland if less than 50 per cent of its total area is in the Less Favoured Area (LFA).

Mixed

Holdings for which none of the above categories accounts for more than 2/3 of total SO. This category includes mixed pigs and poultry farms as well as farms with a mixture of crops and livestock (where neither accounts for more than 2/3 of SOs).
http://farmbusinesssurvey.co.uk/DataBuilder/UK_Farm_Classification_2014_Final.pdf

Appendix 2 – Leaching of nitrogen from urban areas

The average total nitrogen leaching rate from an urban area (14.3kg/ha/yr) comes from values for hydrologically effective rainfall (478mm - precipitation minus losses from evapo-transpiration) and the nitrogen concentration of leachate (3mg/l) given in Bryan et al (2013) the latter figure derived from an AMEC report. The value for nitrogen concentration is similar to one quoted in House et al (1993) who give a mean event concentration of 3.2mg/l for total nitrogen (with this value derived from other sources) with a range of 0.4-20mg/l. Thus although it is not specified by Bryan et al (2013), it is probably reasonable to take the 3mg/l to be total nitrogen especially since the organic component of N from urban areas is likely to be relatively small.

Mitchell (2001) gives the following event mean concentrations in mg/l total N from urban areas; Urban Open 1.68; Ind/Comm 1.52; Residential 2.85; Main roads 2.37.
It is recognised that the datasets that produced these figures are not large (n = 14 in this case), a good deal of uncertainty remains and that further sampling is needed to validate models of pollutant effects from urban runoff (Leverett et al 2013).

Typical nutrient concentrations in urban stormwater runoff in the U.S. are 2.0 mg/l for total N (TN) (Schueler 2003). Population densities seem to be less in the most studied urban catchments (eg Groffman et al 2004 in Baltimore, Hobbie et all 2017 in Minnesota) than those in the UK but this does not necessarily lead to an increase in the rate of nitrogen leaching from the catchment for the factors affecting this value are complex. Thus although there will clearly be variation between different urban areas, there is insufficient knowledge to be able to predict N leaching from the different characteristics of these areas. And for practical purposes an overall N leaching figure is needed; nothing found in the literature indicates that another value would be more representative than 3mg/l.

An N leaching figure can also be derived by using the relationship between mean stream and river flow rate and catchment area. The ratio for the gauging station on the River Meon at Mislingford is $0.014m^3/sec/km^2$ and, with a TN concentration of 3mg/l, this equates to a TN leaching rate of 13.2mg/l, similar to the value obtained when hydrologically effective rainfall is used.

Comparison can also be made with direct measurements of TN urban outputs from studies in the USA (Hobbie et al 2017, Groffman 2004). The values in the Hobbie paper for urban catchments in Minnesota varied from 12.5-27.2 kg/ha/yr with a mean of 17.3 kg/ha/yr. The outputs measured by Groffman (2004) were smaller (between 5.5 and 8.6kg/ha/yr) but these were less urbanised catchments, several including areas of old growth forest where nitrogen retention was very high. Thus these values are broadly of the same order as the 14.3 kg/ha/yr leaching figure initially calculated.

Nitrogen inputs in these studies come predominantly from three sources - atmospheric deposition, pet waste and lawn fertilisation. N deposition was slightly lower in both Baltimore and Minnesota than values from APIS in the around the Solent (23.8kg/ha/yr for hedgerows or woodland, 14.7kg/ha/yr for grassland). No UK studies have been found to compare with the US ones for N inputs in urban areas from pet waste or from lawn fertilisation.

References

Bryan, G, Kite, D, Money, R, Jonas, P and Barden R. 2013. Strategy for managing nitrogen in the Poole Harbour catchment to 2035. Environment Agency report.

Ellis JB and Mitchell G. 2006 Urban diffuse pollution: key data information approaches for the Water Framework Directive. Water and Environment Journal **20** (2006) 19–26.

Groffman, P.M., Law, N.L., Belt, K.T., Band, L.E., Fisher, G.T., 2004. Nitrogen fluxes and retention in urban watershed ecosystems. Ecosystems 7, 393e403.

Hobbie Sarah E, Jacques C. Finlay, Benjamin D. Janke, Daniel A. Nidzgorski, Dylan B. Millet, and Lawrence A. Baker (2017). Contrasting nitrogen and phosphorus budgets in urban watersheds and implications for managing urban water pollution PNAS April 18, 2017 114 (16) 4177-4182.

House, M.A., Ellis, J.B., Herricks, E.E., Hvitved-Jacobsen, T.,Seager, J., Lijklema, L., Aalderink, H. and Clifforde, I.T. (1993) Urban Drainage: Impacts on Receiving Water Quality. Water Sci. Techol., 27 (12), 117–158.

Leverett Dean, John Batty, Dawn Maycock (2013) Assessing the scale and impact of urban run-off on water quality. Report to DEFRA from WCA Environment Ltd.
Mitchell G. 2001. The Quality of urban stormwater in Britain & Europe: Database & recommended values for strategic planning models. School of Geography, University of Leeds.

Schueler, T., 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No 1. Center for Watershed Protection, Ellicot City, MD.

Appendix 3 - Estimating the leaching of total nitrogen (TN) from natural greenspace (SANG).

A number of assumptions must be made about the management of the SANG to allow an estimate of TN leaching to be made. These are as follows:

- The vegetation of the SANG would be predominantly permanent grassland but with an element of tree and scrub cover (this will of course vary for different SANGS but a 20% average figure is used here). The degree of tree and scrub cover will not greatly affect the result as both permanent grassland and woodland/scrub exhibit a high degree of N retention. It matters most because of the differences in the rate of atmospheric N deposition between the two habitats.
- The grassland would be permanent (ploughing will release large amounts of N) and is not fertilised either with artificial fertiliser or manures. It may be ungrazed or grazed very lightly (<0.1LU/ha/yr) with no supplementary feeding (even without supplementary feeding, grazing can increase N leaching because N retention is lower when N is delivered in the form of cattle urine and dung [Wachendorf et al 2005]).
- The grassland may be cut with the cutting regime dependent on other factors. Cuttings may be left or removed from site as the case may be but should not gathered and composted in heaps on site. Any gorse within the scrub should be controlled so it is no more than rare across the mitigation area since a significant amount of nitrogen fixation occurs within gorse stands.

A generic leaching value for N concentration from AMEC for ‘rough grazing’, quoted in Bryan et al (2013), is 2mg/l. Using this concentration together with a value of 478mm for the hydrologically effective rainfall (HER) gives a leaching value for N of 9.6 kg/ha/yr. A similar value (8.8kg/ha/yr) is obtained if the relationship between mean stream flow and catchment area (0.014 cumecs/km^2 which is the ratio for the gauging station on the nearby River Meon at Mislingford) is used instead, keeping the same N concentration of 2mg/l. It is not clear whether these AMEC concentrations are for total nitrogen or for inorganic nitrogen.

The particular grassland management regime for which the 2mg/l N concentration applied is not known. However, even though studies of N leaching from natural unfertilised grasslands are rare in the literature (most are of agricultural grasslands with fertiliser inputs of some sort) it seems likely that this value is higher than might be expected from a natural grassland with no fertiliser inputs such as a SANG. Thus for example TN leachate concentrations were between 0.44 and 0.67 mg/l in an extensively managed montane grassland (that still had one slurry application per year) and the equivalent mean TN loss was 1.0, 2.6 and 3.1 kg/ha/yr for three different areas (Fu et al 2017).

Adjusting for a SANG with 20% woodland/scrub, using the AMEC woodland generic leaching value of 0.5mg/l (Bryan et al 2013) for the woodland/scrub component, results in an N output of 8.1 kg/ha/yr.

The 0.5mg/l value is also much higher than the very low nitrate concentrations in streams from purely forested catchments (Groffman 2004) and from those reported by for a large sample of forested streams by Mulholland et al 2008 where the mean nitrate-N concentrations were <0.1mg/l. All but a few of the samples from an unfertilised suburban lawn had nitrate-N concentrations below the detectable limit of 0.2mg/l (Gold et al 1990). The same was true for a forest plot and the average nitrate-N losses from both home lawn and the forest plots averaged 1.35 kg/ha/yr over 2 years. These studies of both grassland and woodland nutrient cycling suggest that the AMEC generic leachate concentration of 3mg/l, resulting in an N output of 9.6kg/ha/yr, is too high when applied to a SANG.

Despite there being no direct N fertiliser inputs on a SANG, N inputs will still occur from three main sources. These are atmospheric deposition, pet waste and N fixation from legumes and estimating the contribution of each of these sources, together with the proportion of N retained, is an alternative method of working out the N contribution from a SANG.

N deposition

The following are typical values taken from APIS for TN deposition in the Solent area. .

Improved grassland 14.7 kgN/ha/yr; Arable horticultural 14.7 kgN/ha/yr; Neutral grassland 14.7 kgN/ha/yr

Hedgerows 23.8 Kg N/ha/year; Broadleaved, Mixed and Yew Woodland 23.8 Kg N/ha/year

Using the value for hedgerows and woodland for the 20% scrub component of the hypothetical SANG and the neutral grassland value for the rest results in a deposition rate of 11.76 + 4.76 = 16.5 kg/ha/yr.

Pet waste

SANGs are specifically designed to attract increased levels of public access particularly dog walkers so the potential inputs of N from dog waste are likely to be significant.

Hobbie et al (2017) give a figures for TN inputs from this source for entire urban areas and these vary between 3.56 and 21.2kg/ha/yr for 7 urban catchments with a median of 6.9kg/ha/yr. A figure of 17kg/ha/yr can be gleaned from Baker 2001 which was worked out using information on pet numbers, nutritional needs, pet weights etc; 76% of this was from dogs.

The heavy use of SANGS by dogs suggests that N inputs would most likely be higher than these figures averaged over the whole urban area. Nevertheless, inputs to the SANG from this waste means that it is not deposited elsewhere in the urban area where N may anyway end up in the same receiving water.

TN retention in grasslands will also be higher than the average over other parts of the urban area but the characteristics of the inputs from dogs is likely to lower the amount of TN retained because the concentrated patchy nature of the input will reduce the proportion of TN retained compared with more evenly spread inputs, as mentioned above.

Picking up dog faeces will obviously reduce the input from but not remove inputs from urine. Dog urine has a high N content.

In these circumstances there is clearly uncertainty about the level of input from this source the highest figure from Hobbie et al (21.2kg/ha/yr) has been used but adjusted downwards because not all of this will be from dogs resulting in an overall value of 16.1 kg/ha/yr.

This has also been done on the basis that funding, together with a binding commitment, is provided for in perpetuity collection of dog waste and enforcement of pick up rather than relying on direct LA resources which could stop at any time.

TN fixation

Hobbie et al (2017) give a value for this of 17.5kg/ha/yr from direct investigation of unfertilised urban parks and this is the value used. Fixation would only be in the grassland part of the SANG which reduces the figure to 14 kg/ha/yr.

TN retention

A number of studies have shown high TN retention in urban areas (eg 80% Hobbie et al 2017) thought to be mainly attributable to TN retention in urban grasslands and lawns which may be in turn related to high carbon within organic matter in the soils. The release of large quantities of N when permanent grassland is ploughed illustrates the capacity of these grassland for N storage (eg Howden et al 2011).

Direct measurements of total N outputs from urban grasslands in the Groffman et al (2009) studies in Baltimore also show high N retention in urban grassland but there are difficulties in applying these results directly to SANGs partly because the plots were either quite heavily fertilised or may have had unmeasured N inputs from neighbouring land. Nitrate-N losses from an unfertilised home lawn averaged 1.35 kg/ha/yr over 2 years (Gold et al 1990). Generally the complex processes and uncertainties about how the management of these grasslands might affect the degree of TN retention and TN output makes estimation of the proportion retained difficult. Nevertheless a value of 90% given in Groffman et al (2009), and supported by a number of references given there, would seem reasonable considering also that overwatering and over fertilising, neither of which would happen on a SANG, seem to be factors that lead to more leaching.

Woodland and scrub. N retention measured in forest plots in Baltimore was very high (95%) Groffman (2004). N percolation losses measured by Gold et al 1990 in forest plots were low and similar to those in unfertilised lawn. However, it is probably not valid to equate a scrub/woodland part of a SANG with the forest plots measured in the Groffman studies in Baltimore for these were old growth well established forests. Nevertheless there is still likely to be high N retention in these areas even if not as much as 95%.

Given all of the above, a 90% TN retention rate over the SANG as a whole has been used in the calculation below**Inputs**

N Deposition (APIS) = 16.5 kg/ha/yr
Pet waste 16.1 kg/ha/yr
N fixation 14 kg/ha/yr

Total = 46.6 kg/yr

Watershed retention of TN 90%

Total TN output = 4.66 kgN/ha/yr

Conclusion

The question of estimating TN outputs from a SANG has been approached from different angles. These investigations all indicate that the value used so far – 13 kg/ha/yr is too high. Instead an TN output of 5 kg/ha/yr is considered to be close to the true value but still sufficiently precautionary.

References

Baker LA, Hope D, Xu Y, Edmonds J, Lauver L. 2001. Nitrogen balance for the central Arizona–Phoenix (CAP) ecosystem. Ecosystems 4:582–602.

Bryan, G, Kite, D, Money, R, Jonas, P and Barden R. 2013. Strategy for managing nitrogen in the Poole Harbour catchment to 2035. Environment Agency report.

Carey Richard O., George J. Hochmuth, Christopher J. Martinez, Treavor H. Boyer, Michael D. Dukes, Gurpal S. Toor, John L. Cisar (2012) Evaluating nutrient impacts in urban watersheds: Challenges and research opportunities. Environmental Pollution 173 (2013) 138-149.

Fu, Jin, Rainer Gasche, Na Wang, Haiyan Lu, Klaus Butterbach-Bahl, Ralf Kiese (2017) Impacts of climate and management on water balance and nitrogen leaching from montane grassland soils of S-Germany. Environmental Pollution 229 (2017) 119-13.

Gold, A.J., W.R. DeRagon, W.M. Sullivan, and J.L. LeMunyon. 1990. Nitrate nitrogen losses to groundwater from rural and suburban land uses. J. Soil Water Conserv. 45:305–310.

Groffman, P.M., Law, N.L., Belt, K.T., Band, L.E., Fisher, G.T., 2004. Nitrogen fluxes and retention in urban watershed ecosystems. Ecosystems 7, 393-403.

Groffman, P.M., Williams, C.O., Pouyat, R.V., Band, L.E., Yesilonis, I.D., 2009. Nitrate leaching and nitrous oxide flux in urban forests and grasslands. Journal of Environmental Quality 38, 1848-1860.

Hobbie Sarah E, Jacques C. Finlay, Benjamin D. Janke, Daniel A. Nidzgorski, Dylan B. Millet, and Lawrence A. Baker (2017). Contrasting nitrogen and phosphorus budgets in urban watersheds and implications for managing urban water pollution PNAS April 18, 2017 114 (16) 4177-4182.

Howden N J K, T.P. Burt, S.A. Mathias, F. Worrall, M.J. Whelan (2011) Modelling long-term diffuse nitrate pollution at the catchment-scale: Data, parameter and epistemic uncertainty. Journal of Hydrology 403 (2011) 337–351

Magesan Guna N., Hailong Wang and Peter W. Clinton 2011 Nitrogen cycling in gorse-dominated ecosystems in New Zealand. New Zealand Journal of Ecology (2012) 36(1): 21-28

Mulholland P J and 30 others (2008) Stream denitrification across biomes and its response to anthropogenic nitrate loading. Nature 452, 202-206

Wachendorf Christine, Friedhelm Taube and Michael Wachendorf (2005) Nitrogen leaching from ^{15}N labelled cow urine and dung applied to grassland on a sandy soil. Nutrient Cycling in Agroecosystems (2005) 73:89–100

Appendix 4 – Potential for N mitigation using wetlands

Where N budget calculations indicate that N outputs from proposed developments are greater than pre development conditions, the use of new constructed wetlands to retain some of the N output is one mitigation option.

There are a number of possibilities for different types of constructed wetland. Wetlands can be designed as part of a sustainable urban drainage (SUDs) system, taking urban runoff/stormwater; discharges from STWs can be routed through wetlands; or the flow, or part of the flow, of existing streams or rivers can be diverted through wetlands.

Wetlands receiving nitrogen-rich water can remove a proportion of this nitrogen through processes such as denitrification and sedimentation. This has been demonstrated in numerous studies; a recent systematic review of the effectiveness of wetlands for N (and P) removal (Land et al 2016) used data from 203 wetlands worldwide of which the majority were free water surface (FWS) wetlands (similar in appearance and function to natural marshes with areas of open water, floating vegetation and emergent plants). The median removal rate for wetlands that were included in this review was 93g/m^2/yr (or just under a tonne/ha/year). The proportion of N removed is termed the efficiency and the median efficiency of wetlands included in the Land review was 37%.

Many factors influence the rate of N removal in a wetland the most important being hydraulic loading (HLR - a function of the inlet flow rate and the wetland size), inlet N concentration and temperature. Together inlet N concentration and flow rate determine the amount of N that flows through the wetland which ultimately limits the amount of N saving that can be achieved.

The rate of removal can also be expressed in terms of the amount of N removed per unit wetland area. This removal rate will typically increase as the inlet N concentration increases, at least within the normal range of inlet N concentrations. Thus wetlands that treat the N rich discharges, for example from STWs, or water in rivers where the N concentrations are high, will remove more N per unit area than say, wetlands treating water in a stream where water quality is very good and the N concentration is low. Thus if space is at a premium, and the goal is to remove as much N as possible, it makes sense to site wetlands where N concentrations are high.

For wetlands to work well, specialist design input based on sound environmental information will be necessary. There will be a need for consultation with relevant statutory bodies. These processes are likely to be easier where wetlands are an integral part of a larger development. Wetlands do offer additional benefits above offering neutrality but will also require ongoing monitoring, maintenance and adjustments beyond any particular developments completion. Consideration of the long term security of facilities and their adoption at an early stage is advisable.

There are a number of publications which advise about constructed wetlands. For example, Kadlec and Wallace (2009) is a comprehensive source of information covering all stages related to the implementation of different types of constructed wetland. The many papers relating the results from detailed monitoring over many years of the performance of two constructed wetlands in Ohio, USA are also instructive (eg Mitsch et al 2005, 2006, 2014).

Stormwater wetlands

These are what is termed event-driven precipitation wetlands with intermittent flows. There will normally be baseflow and stormwater components to the inputs.

For such wetlands Kadlec and Wallace state that:-

'*A typical configuration consists of a sedimentation basin as a forebay followed by some combination of marshes and deeper pools'*

However, ponds are usually less effective at removing N (Newman et al 2015) than shallow FWS wetlands so the emphasis here should be on the latter although a small initial sedimentation basin is desirable since is likely to reduce the maintenance requirement for sediment removal in the FWS wetland. One advantage of this type of wetland is that it can be designed as an integral part of SUDs for the development and therefore is subject to fewer constraints.

Some wetlands with intermittent flows are prone to drying out and may need provisions for a supplemental water source. In some circumstances, this may be possible through positioning the wetland bottom so that there is some connection to groundwater. However many varieties of wetland vegetation can withstand drying out although there may be a small reduction in water quality improvement (Kadlec and Wallace 2009). Nevertheless base and stormwater flows to each wetland should be worked out to ensure that it is viable.

Wetlands need to be appropriately sized taking into account the HLR and N loading rates. To give a general idea of the areas involved, a wetland 1ha in area would serve a development area of about 50ha.

Calculating the potential N retention in such wetlands involves first determining the proportion of the HER that will pass through the wetland because a percentage of the water carrying N will go directly into groundwater, bypassing storm drains and SUDs and the constructed wetlands. This percentage will depend on such factors as the proportion of hard surface within the development and the geology. Then, assuming the inlet TN concentration is 3mg/l, a proportionate reduction of 37% can be used to work out the amount of N retained.

Provision is needed to control tree and scrub invasion, for wetlands with emergent vegetation medium height such as Typha and reed had higher rates of denitrification than those dominated by trees and woody shrubs (Alldred and Baines 2016).

Other critical aspects of design are the water control structures - inflow and outflow arrangements with water level control – and the need or otherwise for a liner. This last issue is related to soil permeability. A variety of emergent wetland plants, not only reed, can be effective within wetlands. Wetlands with a number of different plant species, rather than monocultures, are desirable both for biodiversity reasons and because they are more resilient against changes in environmental conditions; different species will have different tolerances. Guidance concerning planting can be found in Kadlec and Wallace (2009); allowance should be made in planting ratios and densities for different rates of expansion of different species. Another approach is to use material containing wetland plant seeds from a nearby wetland with a species composition similar to the one preferred. However, unless the donor site is carefully monitored, this would obviously increase the risk of importing unwanted alien plants.

Sedimentation will eventually compromise some aspects of the wetland's function and rejuvenation measures will be necessary (Kadlec and Wallace 2009). The same authors indicate a sediment accretion rate in the order of 1 or 2cm/yr and give examples of rejuvenation after 15 and 18 years but other wetlands have not needed any significant restoration in similar timespans. Various different options for the management of sediment accumulation are given by Qualls and Heyvaert (2017). There of course needs to be provisions to ensure that appropriate maintenance and restoration measures, guided by monitoring, are periodically carried out.

Other sources of information about stormwater wetlands include Wong et al (1999, available on line). The papers about a stormwater wetland in the Lake Tahoe Basin in California are also useful (Heyvaert et al 2006, Qualls and Heyvaert 2017).

Constructed wetlands taking discharges from STW

Many of the considerations discussed above for stormwater wetlands apply equally here. There will obviously be constraints on the location and size of such a wetland because of land availability in the area of the STW. The flow from the STW together with the N concentration in the discharge are needed to determine the approximate size of a wetland. We would recommend a wetland area that gives an N loading of about 500 $g/m^2/yr$ or lower. Because many of the discharges from STW have a high N concentration the potential for N retention in such wetlands is also high. The concentration of N in the outflow will be variable but the purpose of such wetlands is to retain N overall rather than to provide a specific constant standard of water quality in the outflow.

Wetlands associated with streams and rivers

Diverting part of the flow of a stream or river through a wetland, with the outflow returning to the watercourse, provides another opportunity for N saving. For obvious reasons such wetlands would mostly need to be located on the river floodplain. The inlet flow rate can be controlled so it is appropriate for the size of the wetland created and so that the ecology of the watercourse is not compromised in the section affected.

There can be other concerns in relation to the potential effects on the stream or river. An abstraction licence will almost certainly be required.

References

Alldred, M and Baines, S B (2016). Effects of wetland plants on denitrification rates: a met-analysis. Ecological Applications 26(3) 2016, 676-685.

Heyvaert, Alan C., John E. Reuter, Charles R. Goldman (2006). Subalpine, Cold Climate, Stormwater Treatment with a Constructed Surface Flow Wetland. Journal American Water Resources Association 42:1 45-54

Kadlec R H, and S D Wallace (2009). *Treatment Wetlands*. 2nd ed. CRC press, Taylor & Francis Group.

Land M, Graneli W, Grimvall A, Hoffmann CC, Mitsch WJ, Tonderski KS, Verhoeven JTA (2016) How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. Environmental Evidence 5:9

Mitsch, William J., Li Zhang, Christopher J. Anderson, Anne E. Altor, Maria E. Hernandez (2005). Creating riverine wetlands: Ecological succession, nutrient retention, and pulsing effects. Ecological Engineering 25 (2005) 510–527.

Mitsch, William J., John W. Day Jr (2006) Restoration of wetlands in the Mississippi–Ohio–Missouri (MOM) River Basin: Experience and needed research. Ecological Engineering 26 (2006) 55–69

Mitsch, William J., Li Zhang, Evan Waletzko, Blanca Bernal (2014) Validation of the ecosystem services of created wetlands: Two decades of plant succession, nutrient retention, and carbon sequestration in experimental riverine marshes. Ecological Engineering 72 (2014) 11–24

Newman, Jonathan R., Manuel A Duenas-Lopez, Mike C. Acreman, Elizabeth J. Palmer-Felgate, Jos T. A. Verhoeven, Miklas Scholz, Edward Maltby (2015) Do on-farm natural, restored, managed and constructed wetlands mitigate agricultural pollution in Great Britain and Ireland? A Systematic Review. CEH report to DEFRA.

Qualls, Robert G. and Alan C. Heyvaert, (2017). Accretion of Nutrients and Sediment by a Constructed Stormwater Treatment Wetland in the Lake Tahoe Basin. Journal of the American Water Resources Association (JAWRA) 1-18. https://doi.org/10.1111/1752-1688.12595

Wong Tony H F, Peter F Breen, Nicholas L G Somes and Sara D Lloyd (1999*). Managing Urban Stormwater Using Constructed Wetlands*. Cooperative Research Centre (CRC) for Catchment Hydrology and Department of Civil Engineering, Monash University: Clayton, Victoria, Australia.