Advice on Nutrient Neutrality for New Development in the Stour Valley Catchment in Relation to Stodmarsh Designated Sites - For Local Planning Authorities

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Selected extracts relevant to NFDC interim phosphate budget calculator

4.44 The phosphorous load from the new urban development results from sewer overflows and from drainage that picks up nutrient 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 nutrient sources include atmospheric deposition, pet waste, fertilisation of lawns and gardens and inputs to surface water sewers. The phosphorous leaching from urban land has been estimated to equate to 0.83 kg/ha/ yr[1]. These figures are proxy figures from best available data however if locally robust catchment specific data is available this can and should be used. Appendix 3 sets out some of the scientific research and literature in relation to these figures.

Open Space and Green Infrastructure

4.45 Nutrient loss draining from new designated open space or Suitable Alternative Natural Greenspace (SANG) should also be included. The phosphorous leaching from SANGS land has been estimated to equate to 0.14 kg/ha/yr. Appendix 4 sets out some of the scientific research and literature in relation to these figures. These figures can also be used where new nature reserves or bird refuge areas are created to address disturbance issues from development.

4.46 The competent authority will need to be assured for perpetuity that this open space will be managed as such and there will be no additional inputs of nutrients or fertilisers onto this land. Appropriate planning and legal measures will 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 0.14 kg/ha/yr for Phosphorous rate applies to areas of designated open space on-site of around

[1] From relevant Water framework directive export coefficient for urban and suburban land 2006 Final Report: Updating the estimate of the sources of phosphorus in UK waters

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.

4.47 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 as they are already taken account in the figures chosen.

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4.57 Further information on the potential phosphorous mitigation using wetlands is included in Appendix 5. Information has been provided on stormwater wetlands, constructed wetlands taking discharges from WwTW and wetlands associated with streams and rivers. Natural England will update this advice when a current research contract to collate guidance on the use of wetlands to reduced nutrients is published.

Appendix 3 – Leaching of phosphorous from urban areas

No Stodmarsh/ Stour management catchment specific information was found for urban land and Farmscoper does not cover urban land. Therefore the urban/suburban export coefficient was taken from White and Hammond 2006 (0.83kg/ha/yr.) This is the coefficient used for calculating the relative source apportionment in the first river basin cycle to UK river Basin Districts (RBD). Stodmarsh sits in the South East RBD and this was shown to have the highest relative contribution of phosphorous from households (both effluent and urban diffuse) compared to other sectors, with agriculture only contributing 21.8% of the South East RBD phosphorous load during the first river basin cycle (White and Hammond 2006).

Though this export coefficient is from an older study, more recent studies have used values of a similar range for example Bryan (2015) uses 0.7kg of P per hectare for urban areas in the River Avon Nutrient Management Plan modelling though this figure was based on studies mainly in Scotland. Duan *et al* (2012) found small urban catchments exported values of between 0.245 to 0.837 kg/ha/yr compared with much lower values from forested and very low density residential catchments (0.028 to 0.031 kg/ha/yr). The large range in Duan *et al* was explained by the relative density of roads and built structures in the existing catchments. The importance of housing and roads density but also proportion of impermeable surface in urban land was also reflected in a study by HR Wallingford commissioned by Natural England that looked at impacts of urban run-off of designated wetlands using a range of models (Natural England 2018). For new developments using the approach taken in this study the urban land is separated from SANGS and parks so the use of the higher end of these urban coefficients is relevant due to the relative density, though density in the Duan *et al* study were lower the average UK value even in the higher density urban catchments.

Phosphorus is made available in solution through a combination of physicochemical (adsorption/desorption and precipitation/dissolution) and biological/biochemical (mineralization/immobilization) processes. Geology is important in influencing the movement of nutrients through groundwater as it influences the minerals, pH (acidity/alkalinity) and the oxygen content of the waterbody. For example in chalk aquifers, a large proportion of the soluble reactive phosphorus (SRP) is removed from groundwater (as well as most other forms of P from agricultural sources) following a chemical reaction that results in the precipitation of phosphorus in the form calcium phosphate and adsorption (adhesion) to the rock matrix requiring regular soil testing (e.g. Mclaughlin *et al* 2011). Similar processes occur with phosphorus reacting with other minerals such as magnesium and iron. These reactions can be reversed with phosphorus moving back in to solution where the mineral content of groundwater and pH change in urban development. However recent evidence from China suggests the original soil type is still critical in urban phosphorous leaching (e.g. Wei *et al.,* 2019) provided sufficient permeable surface remains.

Phosphorous is thought to be highly conserved in natural catchments (e.g. Verry and Timmons 1982, May *et al* 1996) but urban catchments have less phosphorous retention with the rate of retention being linked to the permeability of the urban environment and soil type (e.g. Duan *et al* 2012, Natural England 2018).

Atmospheric deposition including from vehicles, leaching roads, fertilising gardens and parks including pet urine and waste have all been shown to be a significant source of P in urban catchments (e.g. Hobbie e*t al* 2017). Bryan, 2015 quotes several studies which examined levels of P in urban runoff in terms of Event Mean Concentrations (EMCs) as part of a wider project to develop a screening tool for Scotland and Northern Ireland to identify and characterise diffuse pollution pressures. The use of pulsed concentrations is relevant to urban land as the areas of impermeable surfaces tend to result in higher concentrations during rainfall events. Ockenden *et al* (2017) looks at the efficacy of different models including those that use export coefficients on predicting run-off of TP. This study found that temporal resolution of the underpinning rainfall data used in models was critical because “storm” events are so central to phosphorous transport. Few if any urban catchments have this level of temporal resolution of data and therefore these models cannot be derived with any accuracy for the Stour catchment at this time.

Conclusion on urban P

Based on the information above there is insufficient evidence to move away from 0.83 kg/ha for urban P leaching. Even though soils in the Stour valley are likely to show a high degree of P retention much export from urban land is from the impermeable surfaces and during high flow events therefore urban run-off has very little attenuation by soils so export coefficients towards the upper end of those observed are justified. Should evidence of a more appropriate value be provided or derived Natural England will update this figure.

Built Design to reduce phosphorous export from urban land

Most studies have noted that the export of N and P from urban systems differ. Most P appears to export through high flows via surface drainage. Planning applications to reduce phosphorous should be designed to:

- Maximise permeable surfaces
- Implement Sustainable urban drainage schemes extensively based on larger wetlands (not ponds or detention basins) (see Appendix 5)

- Minimise composting of garden waste direct to catchment surfaces (though composting in structures should be encouraged)
- Maximise pet waste collection though this does nothing to address pet urine

Appendix 4 - Estimating the leaching of total nitrogen (TN) and Phosphorous (TP_ from natural greenspace (SANG).

The value used in this methodology is based on work from the Solent Nutrient Neutral methodology and is set out below, APIS values for the Stodmarsh area have been used for the N deposition value which is the only change from the Solent methodology. However if locally specific data on SANGS is available and evidenced this figure can be replaced by a locally derived figure, provided it is sufficiently well evidenced.

A number of assumptions must be made about the management of the SANG to allow an estimate of TN/TP 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 and P retention. It matters most because of the differences in the rate of atmospheric N and to a much lesser extent P deposition between the two habitats.
- The grassland would be permanent (ploughing will release large amounts of N/P) 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 and to a much lesser extent P 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 be 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.

Phosphorous

Export coefficients for phosphorous for different land cover classes were assessed and compiled by White and Hammond (2006) for the first River Basin Cycle source apportionment. They note the extremely low coefficient from natural land use such as woodland and unfertilised grassland; both habitats are given an export coefficient of 0.02 kg/ha/yr based on the rough grazing value of Johnes 1996. Similar low phosphorous from natural habitats have been recorded from many other studies including more recent studies in the USA (e.g. Hobbie et al 2017, Duan *et al* 2012).

These export coefficients take account of atmospheric deposition but are for natural habitats unlike SANGS which, although ecologically functioning as natural habitats, are designed to be used for informal recreation including dog walking. It is therefore reasonable to assume that pet waste and urine *into* SANGs will be equivalent to urban areas. Hobbie *et al* 2017 found that household nutrient inputs from pet (dog) waste contributed up to 76% of total P inputs in American catchments due to high pet ownership in urban environments - values of inputs for Phosphorous in Hobbie *et al* for dog waste were from 2.7 kg/ha/yr to 0.46 kg/ha/yr with a mean of 1.21 kg/ha/yr. However P *output* from SANGS is likely to be significantly less as phosphorous is highly conserved in the natural land uses and the high contribution of pet waste to export coefficients of urban systems is partly due to the relative lack of permeability of the surfaces onto which the pet urine and waste are frequently deposited. In addition (as explained in Appendix 3) phosphorous is highly conserved on the types of soils found in the Stour valley. Using the mean rate of dog waste from Hobbie *et al* 2017 to be precautionary but assuming a high retention in any SANGS in the Stour valley of 90% gives a value as follows:

Mean TP loading from pet waste to urban sites - 1.21 Kg/ha/year
Mean Catchment retention TP = 90%
= TP 0.12 kg/ha/Yr

+0.02 Kg/ha/year - natural land export coefficient from Johnes 1996

= 0.14 kg TP/ha/yr

Conclusion for phosphorous
Based on best available evidence SANGS value for Stour catchment of 0.14 kg TP/ha/yr has been estimated.

Appendix 5– Potential for Nutrient (N&P) mitigation using wetlands

Where N and or P budget calculations indicate that N and/ or P outputs from proposed developments are greater than pre development conditions, the use of new constructed wetlands to retain some of the N and P 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 provided this does not adversely alter the ecological status of the river and does not increase flood risk. Environment Agency advice should always be sought in design of any wetland creation scheme.

Wetlands receiving nutrient-rich water can remove a proportion of this nutrient through processes sedimentation, absorbing nutrients to the sediment, plant growth and processes such as denitrification some of which were reviewed in Fisher and Acreman (2004) and 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 TN and 1.2 g/m^2/yr TP (or just under a tonne/ha/year TN and 12 kg/ha/yr TP). The proportion of N removed is termed the efficiency and the median efficiency of wetlands TN removal included in the Land review was 37%. Median remail efficiency for TP in the same review was 46 % with a 95 % confidence interval of 37–55 %.

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

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

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 offsetting 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/ flood wetlands

These are what is termed event-driven precipitation wetlands with intermittent flows. There will normally be baseflow and stormwater / flood water 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 and P (Newman *et al* 2015) than shallow free water surface constructed wetlands (FWS wetlands) so the emphasis here should be on the latter although a small initial sedimentation basin is desirable since this 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 and will not add to the water resource issues of the relevant catchment. Initial flush of Phosphorous from soils on former intensively agricultural land was noted in the Land study and this may reduce the short and potentially even long term efficacy of such restored wetlands. Release of phosphorus associated with iron complexes under anaerobic conditions can also contribute to low or negative removal rates, as suggested by Healy and Cawley 2002 as an explanation for the observed low TP removal rates.

Wetlands need to be appropriately sized taking into account the HLR and N or P loading rates. To give a general idea of the areas involved, a wetland 1ha in area would serve a development area of about 50 ha for Nitrogen but given the increased importance of area a larger area would be required for TP reduction from the same development. The Land *et al* review noted the inconsistency of TP reduction was particularly acute at wetlands below 2 hectares in size with wetlands below this size more likely to be net exporters of TP especially if they were created on former intensively farmed agricultural land.

Calculating the potential N or P retention in such wetlands involves first determining the proportion of the hydraulic load that will pass through the wetland because a percentage of the water carrying N and P 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 and using 37% is also reasonable for P due to the larger variation of P retention shown in the Land study and this is the bottom end (and therefore precautionary) of the 95% confidence interval for TP retention.

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). Phosphorus uptake and amount partitioned to roots and shoots differs between different wetlands species but as a general rule tall rapidly growing emergent species are the most likely to retain P in vegetation with *Juncus effusus* having the highest percentage of retained P in the leaf litter of 5 tall emergent species in a comparative study (Kao *et al* 2003).

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 a*l (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 and P 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 and very high P concentration the potential for N and P retention in such wetlands is also high. The concentration of N and P in the outflow will be variable but the purpose of such wetlands is to retain N and P 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 and P 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 and this may have implications for the ecological status – any such proposals should always be discussed in detail with the Environment Agency.